DOE Cover Page

- The project title: **Superconducting RF electron gun**
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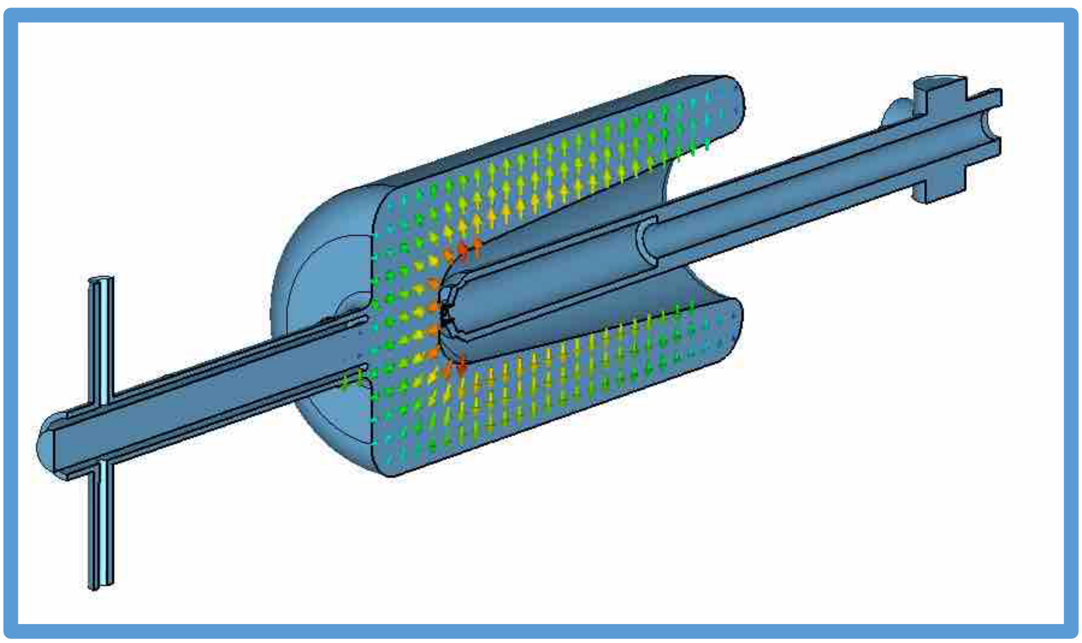
- Funding Opportunity Announcement (FOA) Number: **LAB 20-2310**
- DOE/SC Program Office: **Nuclear Physics**
- DOE/SC Program Office Technical Contact: **Dr. Manouchehr Farkhondeh**, Manouchehr.Farkhondeh@science.doe.gov
- Research Areas:

Transformative accelerator R&D in next generation ion and electron sources
Transformative accelerator R&D in SRF technology for restoring cryomodule performance at SRF-based accelerator facilities



COVER PAGE SUPPLEMENT FOR COLLABORATION

Collaborating institutions

Stony Brook University (SBU): Lead PI Prof. V. N. Litvinenko, vladimir.litvinenko@stonybrook.edu
Brookhaven National Laboratory (BNL): Co-PI Dr. Y. Jing, yjing@bnl.gov
Fermi National Accelerator Laboratory (FNAL): Co-PI Dr. V. Yakovlev, yakovlev@fnal.gov
Thomas Jefferson National Accelerator Facility (TJNAF): Co-PI Dr. M. Poelker, poelker@jlab.org

Leadership structure

The lead PI will coordinate activities of four collaborating institutions, develop the overall schedule, organize procurement of key equipment and components, and correlate programmatic needs and travel. Coordination will be organized via regular by-weekly web-meeting of the lead PI, co-PIs, and key personnel. The co-PIs will be responsible for timely execution of the assigned portion of activates in their institutions and facilities and will provide written quarterly progress report to the lead PI. In particular, SBU will be responsible for defining and coordinating the SRF gun experimental program; computer simulations of the SRF gun; and supervision of a graduate student. BNL will be responsible for operation of the CeC SRF accelerator (including the SRF gun), beam dynamics simulation, upgrades to various systems, and development and production of photocathodes and cathode transfer systems. FNAL will lead development of a 100 kW fundamental power coupler (FPC) for the SRF gun, the key component of the phase II of the project; will be responsible for full-scale simulation, design and assembly of plasma processing system for the SRF gun; and will advise the collaboration on SRF physics and technology issues. TJNAF will design and manufacture beam polarimeter; participate in installation and commissioning the polarimeter at BNL and measurements of beam polarization; will advise the BNL team on development of polarized beam photocathodes. The lead PI will be the point of contact for the combined research activity and will use the information provided by co-PIs for quarterly progress reports to Dr. M. Farkhondeh at the DOE/SC Office of Nuclear Physics. Modification of the schedule or major changes in approaches will be decided jointly by the lead PI and co-PIs.

Facilities, equipment and resources at collaborating institutions

SBU: The project will utilize purchasing department and machine shop at SBU for manufacturing key components for the SRF gun upgrade. A Research Scientists and one graduate student will be made available at the Department of Physics and Astronomy.

BNL: Facilities, equipment and resources of the Coherent electron Cooling (CeC) group and Accelerator Division of the Collider-Accelerator Department (C-AD), and the BNL's Instrumentation Division will be made available to the collaboration. C-AD facilities – including the CeC SRF accelerator, RHIC cryogenic and control systems – are the main ingredients of the proposed research.

FNAL: The project will be supported by facilities, equipment and resources at the SRF Development and SRF Measurements & Research Departments of the Applied Physics and Superconducting Technology Division (APS-TD). Contemporary 3D computer simulation and modeling tools (e.g., Microwave Studio, ANSYS, NX) will be utilized for developing a 100 kW FPC for the BNL SRF gun. An existing plasma processing facility at APS-TD will provide a baseline for design and assembly of the new plasma processing system for the SRF gun.

TJNAF: The project will use facilities, equipment and resources available at the Center for Injectors & Sources at TJNAF to design and manufacture the beam polarimeter.

Collaboration budget

	Name	Institution	Year 1 Budget	Year 2 Budget	Total Budget
Lead PI	V. N. Litvinenko	SBU	$372k	$526k	$898k
Co-PI	Yichao Jing	BNL	$216k	$227k	$443k
Co-PI	V. Yakovlev	FNAL	$149k	$151k	$300k
Co-PI	Matt Poelker	TJNAF	$209k	$47k	$256k
		Proposal total	**$946k**	**$951k**	**$1,897k**

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Project Narrative
Superconducting RF electron gun

Abstract. High-current low-emittance CW electron beams are of great importance for existing and future DOE facilities, medical, industrial and homeland security applications, and beyond. Such beams are indispensable for nuclear and high-energy physics fixed target and collider experiments, cooling high energy hadron beams, generating CW beams of monoenergetic X-rays (in FELs) and γ-rays (in Compton sources), high-power EUV beams for manufacturing the next generation of microchips, border cargo inspection, to mention just a few. Polarization of electrons in these beams provides extra value by opening a new set of observables and frequently improving the data quality by boosting signal to background ratio.

The CW super-conducting radiofrequency (SRF) electron gun is one of the most advanced, but also one of the most challenging, technologies promising to deliver such beams. While SRF technology is paving the way for the future accelerators, the compatibility of advanced SRF technology with complex photocathodes remains on the forefront of the modern accelerator science, and many important questions remain unanswered.

SRF cavities that operate at cryogenic temperatures naturally work as a powerful cryo-pump to provide the ultra-high vacuum environment for photocathodes by freezing harmful gas species. Still, multiple effects – for example avalanche multipacting or ion back-bombardment – can affect efficiency and even survival of high quantum efficiency (QE) multi-alkali (CsK_2Sb and others) and polarized GaAs photocathodes. Furthermore, the necessity to keep the photocathodes at room temperature while being surrounded by cryogenic temperature of the SRF cavity creates additional complexity for SRF gun design and operation. Finally, complex and volatile chemical compounds used for photocathodes could contaminate surfaces of the SRF cavity. Such high QE compounds (for example Cs) could create centers for cold electron emission which degrades performance of the SRF gun. Such a circumstance would require development of the in-situ processing techniques for restoring the SRF cavity performance.

We propose to upgrade the unique and fully functional CW SRF facility installed at RHIC facility (BNL) by adding high-current and polarized beam capabilities. Our 1.25 MeV SRF gun, built as part of the Coherent electron Cooling (CeC) project, has demonstrated sustained CW operation with CsK_2Sb photocathodes generating electron bunches with record-low transverse emittances and record-high bunch charge exceeding 10 nC. The cathodes survive many months of continuous operation. Nevertheless, the average beam current, determined by the needs of the CeC project, is limited to about 100 microamperes. We propose to extend the capabilities of this system to high average current of 100 milliampere in two steps: increasing the current 30-fold at each step. The goal of this R&D is to demonstrate reliable long-term operation of the high-current low-emittance CW SRF guns. We also propose to test polarized GaAs photocathodes in the ultra-high vacuum (UHV) environment of the SRF gun – which has never been successfully demonstrated in RF accelerators. The upgrades include the cathode preparation and UHV cathode transfer system, and a polarimeter to measure polarization of the generated electron beam.

Finally, we propose to optimize in-situ processing, including both He treatment and plasma processing, for restoring and improving performance of our gun's quarter-wave SRF cavity.

Our proposed research will significantly advance state-of-the art accelerator capabilities relevant to existing and next-generation nuclear physics facilities and it will address areas of special interest: (1) Transformative accelerator R&D in next generation ion and electron sources, and (2) Transformative accelerator R&D in SRF technology for restoring cryomodule performance at SRF-based accelerator facilities. One example is R&D to establish practical and reproducible in-situ plasma processing techniques. A collaboration of experts in the SRF technology and high brightness electron guns – both unpolarized and polarized - from Stony Brook (SBU)), Brookhaven National Laboratory (BNL), Fermi National Accelerator Laboratory (FNAL) and Thomas Jefferson National Accelerator Facility (JLab) is uniquely able to address the DOE need for novel CW sources of polarized and unpolarized electron beams. Each of the collaborating

institutions brings unique skills critical for the overall success of the proposed research program. Finally, the use of an existing and operational $20M SRF facility at BNL makes this proposal very cost effective.

I. Background Information.

Multiple DOE accelerator-based present and future facilities are rapidly moving towards operation in CW mode, which frequently require high-quality, high-current CW polarized and unpolarized electron beams. Applications of these beams include, but are not limited to, coolers for hadron beams [1-6], and future electron-hadron and electron-positron colliders [7-15], intense γ-ray sources [16-19] that can be used for isotope production and high-power X-ray and extreme ultraviolet (EUV) continuous wave (CW) free electron lasers (FELs) [20-29] for scientific and industrial uses.

Superconducting radio-frequency (SRF) electron guns are frequently considered to be the favorite pathway for generating CW electron beams with quality comparable to the best state-of-the-art pulsed SRF guns. First, and most importantly, SRF guns operate at cryogenic temperatures and naturally provide the ultra-high vacuum (UHV) environment critical for achieving long lifetime of high quantum efficiency (QE) photocathodes (CsK_2Sb and similar) and photocathodes used for production of polarized beams (GaAs). Second, in contrast to DC and room temperature RF guns, SRF guns provide higher accelerating gradient and high beam energy – the ingredients critical for generation of low-emittance high brightness electron beam. It is well known [30] that the value of the electric field at the surface of the photocathode, E_{em}, defines the maximum charge density of the generated electron bunches[1]:

$$\sigma = \frac{E_{em}}{4\pi} \tag{1}$$

and, therefore, the best attainable normalized emittance [31-39] of the generated electron beam. Since the space charge forces responsible for emittance degradation are falling with the cube of the beam energy, E, (e.g. as γ^3, where $\gamma = E/mc^2$ is relativistic factor of the beam) – the value of the gun energy is critical for preserving high brightness of the generated beam.

The best DC electron guns [40-45], while demonstrating delivery of high-current electron beams, are typically limited to about 0.25-0.4 MV in gun voltage (i.e., the kinetic beam energy at the gun exit). Multiple well-funded attempts to increase DC gun voltages to 0.5-0.75 MV and above have not resulted in sustainable, operational photoinjectors. The main reasons are dark current (which is continuous) and electrical break-down. The resulting limitations in gun voltage result in accelerating gradients at the photocathode, E_{em}, below 10 MV/m. Another challenge for DC guns is photocathode bombardment by ions generated by the electron beam scattering from residual gas: the ions naturally travel back to the cathode in the DC electric field. This problem can be partially mitigated by off-axis generation of the electron beam.

In contrast with DC guns, CW RF guns can accelerate beams to high kinetic energies and generate accelerating gradients well above 10 MV/m at the photocathode surface. In addition, dark current in RF guns is low (because it is generated only at the peaks of RF cycles) and ions exhibit very different behavior in RF fields [56] and could be less harmful than in DC guns.

Currently there are two kinds of CW RF guns: room-temperature normal conducting (NC RF) and superconducting (SRF). While NC RF photoemission guns have made significant progress in recent years, they require enormous amounts of power and presently are delivering maximum accelerating voltage of 0.75 MV [57-59]. In contrast, CW SRF guns [46-55] have been operating with MeV-scale accelerating voltages for many years and are capable of producing accelerating gradients of 25 MV/m and above [60-62]. Furthermore, as mentioned above, SRF guns provide the UHV environment required for long lifetime photocathodes.

The great potential of SRF guns was recognized as early as 1988 and several successful experiments have been carried out since 2002 [46-55]. A brief summary of the main experimental results in the

[1] We use Gaussian units in equations and practical units in descriptions of devices and equipment.

performance of the currently operating (CeC, HZDR, HZB) and previously (NPS, UW) operational CW SRF photoinjectors is shown in Table I.

Table 1. The main experimental results for five operational CW SRF photoinjectors [50].

Parameter	Units	**CeC [50]**	HZDR[45]	HZB [64]	NPS [48]	UW [49]
Cavity type	-	**QWR[a]**	Elliptical	Elliptical	QWR	QWR
Number of cells	-	**1**	3.5	1.4	1	1
RF frequency	MHz	**113**	1300	1300	500	200
Temperature	K	**4**	2	2	4	4
E_{max}	MV/m	**18**	12	7	6.5	12
Gun energy	MeV	**1.25[b] – 1.7**	3.3	1.8	1.2	1.1
Max bunch charge	nC	**10.7**	0.3	0.08	0.08	0.05
CW beam current	μA	**140**	18	0.005	<0.0001	<0.1
Dark current	nA	**< 1**	30	100	<20,000	<0.001
Photocathode		**CsK_2Sb**	Cs2Te	Cu	Nb	Cu
Laser wavelength	μm	**532**	266	266	266	266
QE	%	**1 - 5**	~ 1	<0.01	<0.01	<0.01
Projected emittance [c]	μm rad	**0.3 – 0.57[d]**	2	0.5	4.9	1
at bunch charge	pC	**100 - 600**	200	77	43	200

[a] QW - Quarter Wave Resonator; [b] Currently used for CeC operations; [c] Normalized emittance;
[d] Larger emittance for larger charge per bunch

While for many years SRF electron guns were considered the favorite pathway towards achieving the high brightness high average current CW electron beams, practical experience had been, to state it mildly, disappointing. High QE photocathodes did not last long and beam parameters were inferior to other state-of-the-art guns. Experts in the field were even questioning compatibility of SRF accelerators and high QE photocathodes.

A real breakthrough that clearly demonstrates the superiority of SRF CW photoinjectors came from BNL's SRF gun built for the Coherent electron Cooling (CeC) experiment [53,63]. The CeC SRF gun demonstrated CW electron beam using high QE photocathodes that survive for many months while generating record high charge per bunch and record low emittances [50]. The demonstrated success of the CeC SRF gun, when compared to competitors, is a result of its unique design including the low frequency QW Nb cavity with adjustable coaxial fundamental power coupler (FPC) and high QE photocathode system at the room-temperature (inside 4K cryogenic enclosure) with controllable cathode recess to control beam optics.

It is well known in the theory of photo-emission RF guns that emittance extracted bunch depends on the value of the electric field at the cathode at the moment of emission, E_{em}, and the bunch shape [65, 66]. For a flat (pancake shape) bunch it can be expressed as [31, 38, 67-72]:

$$\varepsilon_n \propto \sqrt{q\frac{E_{MTE}}{E_{em}}} \tag{2}$$

where q is the bunch charge, and E_{MTE} is the mean transverse energy of the photoelectrons at the cathode. For long (cigar shape) bunches[1] scaling also depends on the bunch duration Δt [66]:

$$\varepsilon_n \propto \frac{\sqrt{E_{MTE}}}{E_{em}}\left(\frac{q}{\Delta t}\right)^{2/3}. \tag{3}$$

In all cases, the achievable beam emittance reduces with increasing E_{em}. The accelerating gradient at the moment of beam emission depends not only on the maximum electric field attainable at the cathode surface, E_{max}, but also on the phase of emission, ϕ, with $E_{em} = E_{max} \cdot \sin(\phi)$ [38], which is selected to maximize the beam energy gain. It depends on the geometry of the RF cavity, accelerating gradient E_{acc}, the RF frequency $\omega = 2\pi f_{RF}$, and it is well described by a dimensionless parameter α [72]:

$$\alpha = \frac{eE_{acc}}{2mc\omega}. \tag{4}$$

The value of α indicates the relativism of the particle exiting the cavity [22, 28], and determines the optimum phase of the emission: at $\alpha < 1$, ϕ is close to zero, and for $\alpha >> 1$ it is close to the crest at 90°. One can see that the choice of the geometry and operational frequency of a gun plays an important role. For example, the HZDR SRF gun operates at significantly higher frequency compared to the CeC photoinjector. The maximum attainable electric field in the HZDR gun is E_{max} ~20 MV/m with $\alpha = 0.7$, which results in the optimum emission phase of 12.5 degrees. Because of its low frequency and quarter-wave (QW) cavity, the CeC SRF gun operates with much higher E_{em} than the 1.3 GHz HZDR and HZB guns. This fact significantly limits E_{em} to $(0.2-0.25)\cdot E_{max}$. The CeC SRF gun operates at the same accelerating gradient, however the choice of the frequency results in $\alpha = 8.34$ with the optimum emission phase of 78.5 degrees, which leads to significantly higher electric field at the cathode at the moment of emission: $E_{em} \approx 0.98 \cdot E_{max}$. As the result, the CeC SRF gun has much better beam quality.

The Naval Postgraduate School (NPS [48]) and the University of Wisconsin (UW, [49]) SRF guns share QW geometry (and actually the same manufacturer- Niowave Inc.), but they were lacking the dedicated photocathode system of the CeC SRF gun - including the room temperature cathode stalk (controlled by circulating water) and high QE UHV storage and transfer components. As the result, they were using metal cathodes with very low QE resulting in the middle-of-the-road performance.

Therefore, the CeC SRF photo-emission gun offers a cost-effective path for exploring performance of CW SRF guns to full extent.

II. Goals of the proposal

The overarching goal of this proposal is to fully explore the unique capabilities of the CeC SRF gun by extending its operations to high average current CW unpolarized electron source, generation of polarized electron beam and establishing reliable in-situ processing techniques to remedy possible contamination of Nb surfaces. Because we were focused on supporting the CeC experiment, the CeC SRF gun and its RF system were designed to operate with bunch rep-rate of 78 kHz (i.e., equal to the RHIC beams revolution frequency). This repetition rate resulted in relatively low average current ~ 150 μA. To continue to push the state-of-the-art, we propose to upgrade the gun to demonstrate high average current operation in two phases: 1 -3 mA in the Phase I (current proposal) and 30 -100 mA in the future Phase II. Further, we propose to verify that Cs_2Te coated GaAs can successfully generate polarized electron beam in an SRF gun. Finally, we propose to define useful techniques of restoring performance of SRF guns in a case of possible contamination, e.g. in-situ repairing technique to maintain such valuable investments.

The proposed research is divided into three distinct tracks:

Track 1, High current SRF electron gun: The focus of this research direction is to increase average current of unpolarized electron beam to 1 mA (maximum 3mA – ultimate goal) in the first two years (Phase I) of the project, and to 30 mA (maximum 100 mA -ultimate goal) during follow-up Phase II of the project. Demonstration of 1 to 3 mA of average current will use existing hardware (the SRF gun, 4 kW RF FPC and PA, transport, beam dump, controls, MPS, etc.) of the CeC SRF accelerator (see section IV) and will require only a modest modification of the drive-laser. In addition, the goals of the Phase I are:

(a) Build the laser driver necessary for 100 mA CeC SRF gun operation;
(b) Upgrade the cathode manipulator and transport system for 100 mA current capabilities;
(c) Develop 100 kW SRF system for Phase II: design 100 kW SRF gun FPC, transmission line and circulator, and identify supplier of 100 kW 113 MHz transmitter;
(d) Identify an appropriate 1 MW beam dump for 100 mA 1 MeV beam.

The Phase I developments are critical for speedy success of the Phase II. We expect that our research would provide critical information on ultimate capabilities of the SRF photoemission guns, the lifetime of high

QE (CsK_2Sb, NaKSb, etc.) photocathodes in extreme conditions and, overall, applicability of this promising technology for DOE and societal applications.

Track 2, Polarized SRF electron gun: In contrast with Track I, this is completely new and untested direction in polarized electron gun R&D. All successful polarized electron guns are based on UHV and XHV (i.e., vacuum well below 10^{-11} torr) DC guns. GaAs cathodes have previously been tested in RF guns and survived at best for only a few seconds due to multipacting, ion back-bombardment, over-heating of the GaAs wafer, or chemical poisoning due to inferior vacuum conditions - see for example BNL test of GaAs photocathode in a 1.3 GHz half-cell SRF gun [73]. There are two reasons we propose to attempt a successful test as part of this project: the extremely good vacuum conditions in our SRF gun and recent progress to extend the lifetime of GaAs photocathode coated with a layer of Cs_2Te [74,75]. The track 2 goal is two-fold: (a) to demonstrate sufficient lifetime of Cs_2Te-coated GaAs photocathode in the CeC SRF gun using existing 532 nm (green) laser; (b) generate polarized electron beam using 780 nm IR laser and measure beam polarization using a polarimeter. The first goal, planned for the first year of Track 2, could be achieved with a modest investment in the cathode preparation and transport systems. The second goals, allocated for Year 2 of Track 2, involves construction of a new IR laser and laser beam transport for circular polarized light, as well as design, construction and commissioning. In the Phase II of this track we plan to explore the performance of the superlattice GaAs photocathodes.

Track 3, SRF electron gun performance restoration techniques: As any other SRF system, the SRF gun performance can degrade, for example from contamination or aging processes. There are two processes which are currently used for performance restoration: He processing and plasma treatment. Helium processing is done by operating the SRF cavity at nominal cryogenic temperatures (in our case, 4 K) by filling the gun with pure He gas at pressure ranging from 10^{-6} to 10^{-5} torr. Then by applying short high voltage RF pulses, one creates He ions in proximity of the dark current field emitters, to effectively burn them out. We successfully applied this technique to the CeC SRF gun in the past and propose to accurately evaluate its effectiveness during the Phase I of the project. In-situ plasma treatment of the SRF cavities, currently tested by the FNAL team for 1.3 GHz LCLS II SRF cavities, is performed at room temperature and involves filling the cavity with a mixture of noble gases and oxygen, and exciting an RF discharge. This process removes and/or oxidizes contaminants of the Nb surfaces. As part of Phase I, we propose to simulate, design and build plasma processing system suitable for our 113 MHz QW gun geometry. These Phase I developments would be critical for the Phase II, when we plan to explore this technique to full extent.

Successful completion of this project would result in establishing a reliable high-brightness high-current source of CW electron beams, which includes long-life time, high QE photocathodes and dependable treatment techniques in the case of degrading gun performance. Generation of polarized electron beam from such SRF gun could result in major technological breakthroughs, for example in reduction in the ion back-bombardment and a longer cathode lifetime.

III. Collaboration structure, key personnel and their roles

This proposal is a collaboration between four institutions: Stony Brook University (SBU), Brookhaven National Laboratory (BNL), FERMI National Accelerator Laboratory (FNAL) and Thomas Jefferson National Accelerator Facility (TJNAL or Jlab). SBU serves as the lead institution and will coordinate the collaboration activities, develop schedules, procure the majority of the equipment, and coordinate travel based on the programmatic needs of the project. Formal structure of the collaborations with the key personnel is shown in Figure 1. Coordination will be organized via regular by-weekly web-meetings of the PI, the Co-PIs and, when necessary, selected key personnel. Co-PIs will be responsible for timely execution of the assigned portion of activities in their institutions and facilities and will provide written quarterly progress report to the PI. The PI will use this information for quarterly progress reports to Dr. Manouchehr Farkhondeh at NP DOE office.

Collaboration includes well-established leaders in all critical aspects of SRF, polarized and unpolarized guns, photocathodes and beam dynamics including Sergey Belomestnykh (Chief Technology Officer and head of Applied Physics and Superconducting Technology Division (APS-TD), FNAL), Wolfram Fischer

(Head of C-AD Accelerator Division), Joe Grames and Riad Suleiman (Polarimetry experts, Jlab), Yichao Jing (Beam dynamics expert, BNL), Vladimir Litvinenko (CASE director at SBU, Director of CeC project at BNL), Martina Martinello (Deputy Head of SRF Measurements and Research Department, FNAL), Irina Petrushina (SRF gun expert, SBU), Matt Poelker (Head of the Center for Injectors & Sources, TJNAF), Erdong Wang (Lead Scientist, Electron Source Development, BNL), Vyacheslav Yakovlev (Head of SRF Development Department, APS-TD, FNAL). The project relies on a panoply of facilities and vast engineering and technical expertise of the collaborating institutions.

Each collaborating institution and each key person has a specific role and project responsibilities.

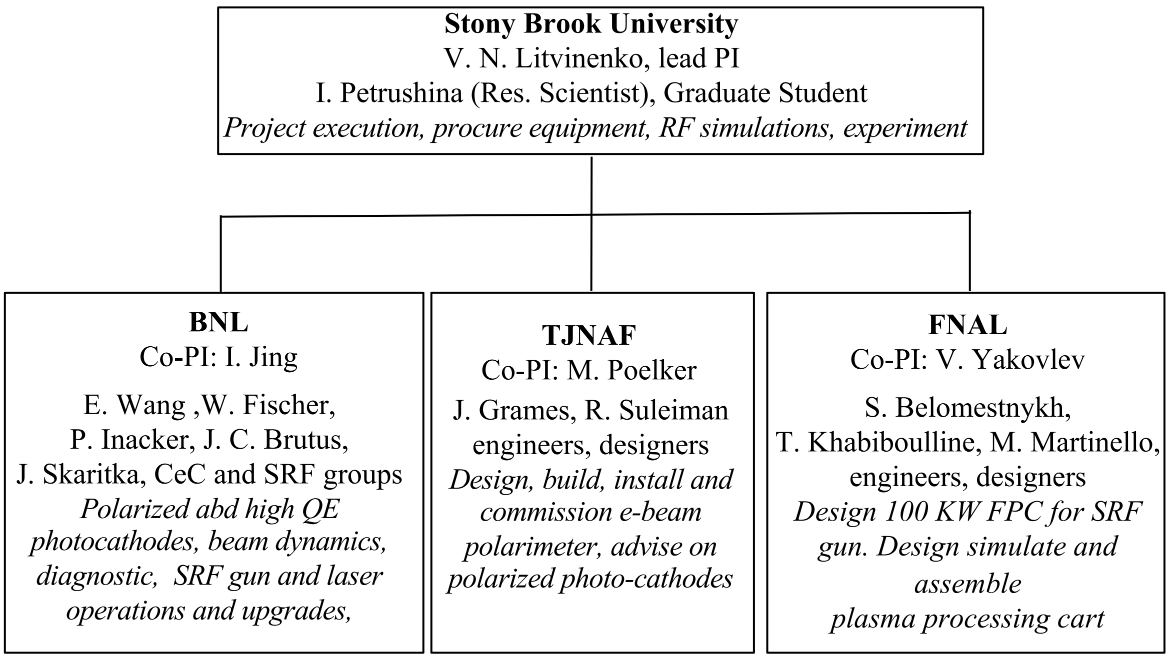


Figure 1. Structure of the proposal collaboration including abbreviated lists of key personnel and project responsibilities.

SBU team includes Prof. Vladimir Litvinenko (the lead PI), Dr. Irina Petrushina (Research Scientist) and one graduate student. The PI will define and coordinate, in collaboration with Dr. W. Fisher, the SRF gun experimental program with RHIC and CeC operation schedules. Dr. Petrushina, expert in SRF guns simulations and operations, will lead the E&M and beam dynamics simulations of the gun, and co-supervise the graduate student with the PI. Project will utilize purchasing department and machine shop at SBU for manufacturing key components for the SRF gun upgrade.

BNL team key investigators are Drs. Yichao Jing (co-PI), Wolfram Fischer (Head of C-AD Accelerator Division), Erdong Wang (photocathodes), laser expert Patrick Inacker and two mechanical engineers: John Skaritka and Jean Clifford Brutus. In addition, the team will use support of the CeC group (J. Ma, I. Pinayev, G. Wang) and the engineering and technical support from the C-AD Accelerator Division and BNL's Instrumentation Division. BNL team will be responsible for operation of the SRF accelerator (including the SRF gun), beam dynamics simulation for the system and implementing upgrades to the systems. Dr. Jing will coordinate overall BNL activities, beam dynamics simulations and data analysis. Dr. Fischer will supervise and coordinate project activities carried out by the C-AD Accelerator Division, including upgrades to the SRF accelerator systems, which will involve the CEC system designer, J.C. Brutus. Mr. P. Inacker will develop, build-up and commission laser system for the SRF gun. Dr. E. Wang, in collaboration with J. Skaritka and the Instrumentation Division, will lead the development and production of photocathodes and cathode transfer systems. C-AD facilities – including the CeC SRF accelerator, RHIC cryogenic and control systems are are an essential part of the proposed research.

FNAL team includes Dr. Vyacheslav Yakovlev (co-PI)), Dr. Sergey Belomestnykh, Mr. Timergali Khabiboulline (Head of RF design and Test Group, APS-TD) and Dr. Martina Martinello (expert in SRF plasma processing techniques). Dr. Yakovlev and Mr. Khabiboulline will be responsible for the design and delivering production drawings of the 100 kW RF system for CeC SRF gun – the key component of phase II of the project. Design of the coaxial 100 kW FPC will be their main deliverable. Dr. Martinello will be responsible for full-scale simulation, design and assembly of plasma processing system for the BNL SRF gun. Dr. Belomestnykh will provide overall supervision of the project activities in the APS-TD Division and provide advice to the collaboration on SRF physics and technology issues. Dr. Belomestnykh led the design and the commissioning of the CeC RF systems and his expertise is critical for success of this project. **TJNAF team** includes Drs. Matt Poelker (co-PI, Head of the Center for Injectors & Sources), Joe Grames and Riad Suleiman, (experts in polarized beam and polarimeters). The team will use JLab recourses to design and manufacture the beam polarimeter of the proposed experiment. In Year 2 of the project, the team will participate in installation and commissioning the polarimeter at BNL, and measurements of beam polarization. Dr. Poelker will also advise the collaboration on the development of polarized beam photocathodes and generation of polarized beam.

IV. Status of the CeC CW SRF electron gun at BNL

The proposed research takes full advantage of the CeC accelerator system and its 113 MHz SRF photoelectron gun, that was designed, built and commissioned at BNL. The SRF gun, see Figures 2 and 3, is unique because it operates at very low frequency which provides the beneficial condition for photoelectrons to be generated at the peak of the accelerating field (10-20 MV/m electric field at the photocathode surface).

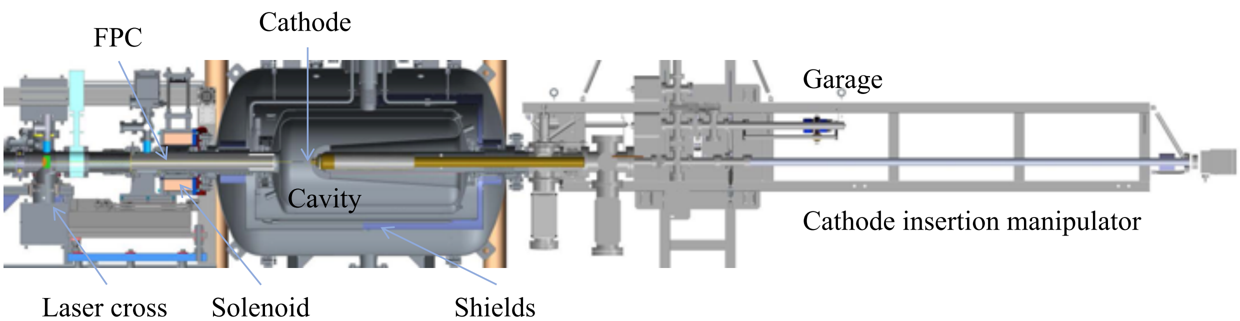


Fig. 2. Cross-section view of the 113 MHz SRF photo-emission electron gun showing the cathode exchange/manipulator and cathode storage (“garage”) system. The CsK_2Sb photocathode is maintained at room temperature within the cryogenic (4K) SRF quarter-wave cavity. Laser pulses are delivered to the photocathode through the in-vacuum laser cross, with light passing through the hollow fundamental power coupler (FPC).

The SRF gun functioned exceptionally well using high CsK2Sb photocathodes: our in-depth studies of multipacting and its elimination, resulted in months-long lifetime of high QE CsK2Sb photocathodes [76]. The CeC SRF easily generates electron bunches with charge of more than 10 nC and world-record low normalized transverse emittances [50]. After the commissioning, we were completely satisfied that the gun can reliably operate and generate high quality electron beam.

Our proposed research will utilize the significant infrastructure of the SRF CeC accelerator shown in Fig. 4 below: RF controls, laser, cryogenic, vacuum, power, water, magnets, power supplies, diagnostics, beam dumps, etc. The CeC SRF accelerator is located in the RHIC tunnel, it uses liquid He supplied by RHIC He refrigerator and, therefore, it operates during RHIC runs, which are typically scheduled from December to June. The CeC SRF accelerator is fully commissioned and was successfully used to demonstrate beam parameters required for the Coherent electron Cooling experiment. Full power beam was generated, accelerated, propagated through the 30-m long system and delivered to the high-power beam dump. This system – together with the high brilliance SRF photo-electron gun – is ready for our proposed research.

For Track 1 of the proposed research, we will deliver electron beam from the SRF gun to the water-cooled high power beam dump capable of absorbing up to 8.5 kW. The 500 MHz cavities, the 704 MHz SRF linac and 1.4 GHz transverse cavity would be turned off and detuned. This means the present system RF transmitter, the FPC, the gun, the transport system and the beam dump will be capable of supporting CW beam up to 3 mA. The main modification to the present CeC SRF accelerator is the increase in the rep-rate of the drive laser system.

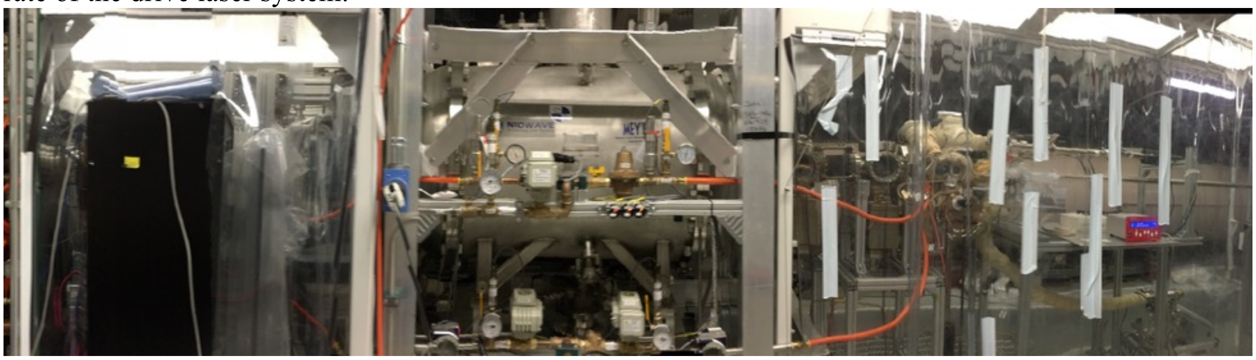


Fig. 3. Photographs of the SRF gun system from the cathode manipulator (right) to laser delivery box (on the left) and the SRF gun cryostat in the middle.

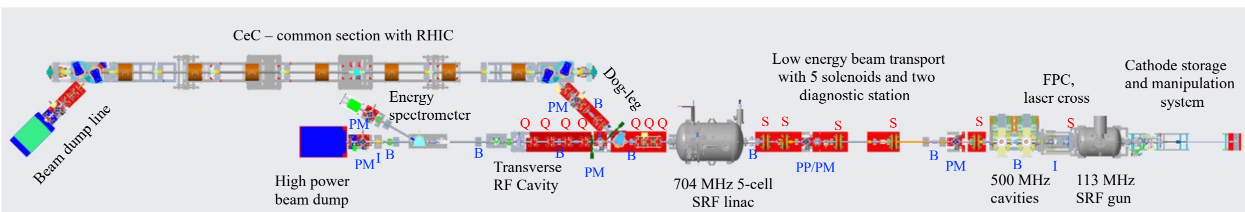
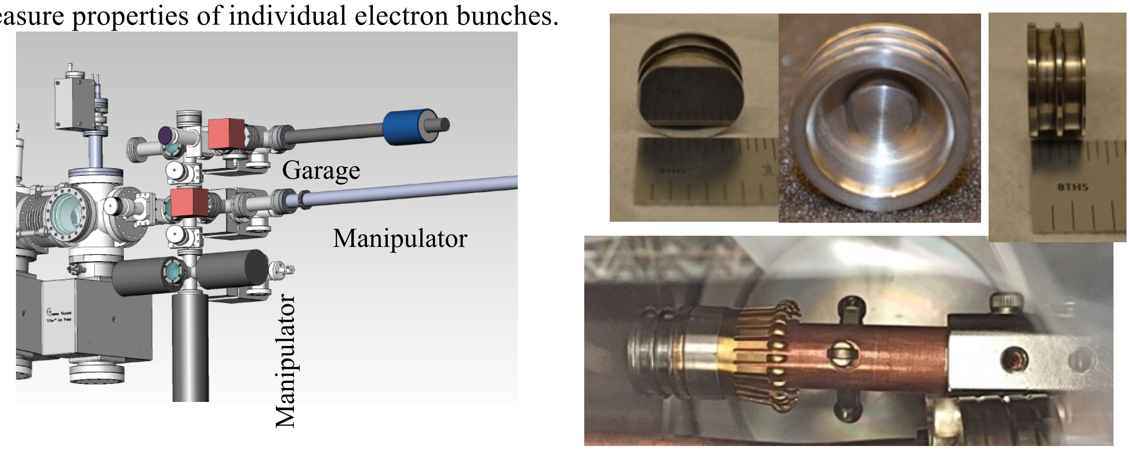


Fig. 4. Layout of the CeC SRF accelerator at IP2 with key components that will be used for proposed research, from the SRF gun to the high-power beam dump. Legend for key components: I – ICT (beam current monitors), B – BPMs, PM – insertable YAG profile monitors, PP/PM – PM with a "pepper-pot", S – solenoids Q – quadrupoles with bipolar supplies. The beamlines are equipped with a full set of dipole steering magnets and radiation loss monitors (not shown). The 500 MHz cavities and 1.4 GHz transverse cavity can be occasionally used (either alone or in combination with dog-leg and energy spectrometer) to measure properties of individual electron bunches.



(a) (b)

Fig. 5. (a) Close-up view of the cathode storage and UHV manipulator system with regular ion pumps and TSP pumps (red). (b) Top: Front, back and side views of Mo pucks: a front-polished surface is used for deposition of CsK_2Sb photocathodes, 20 mm in diameter. Bottom: photograph of the photocathode puck

attached to the manipulator (with RF fingers and three spring rollers) during initial stage of transfer into the gun: viewed through the large glass window above the ion pump in Fig. 5 (a).

Cathodes are prepared a few km from the RHIC and transported in a UHV vacuum suite ("garage" holds 3 cathodes), which then attaches to the cathode transfer system of the SRF gun (see Fig. 5). While vacuum in this system is sufficient for CsK_2Sb photocathodes, we need to improve it further for testing GaAs cathodes during Track 2 of the prosed research. Some of the features of the CeC SRF accelerator are summarized in Table 2.

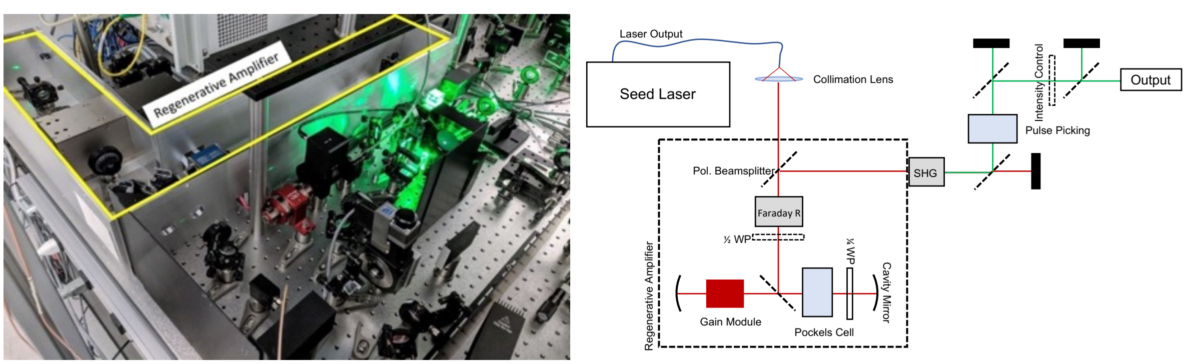
Table 2: Typical operating parameters of the 113 MHZ SRF gun system.

Parameter	**Units**	**Value**	**Parameter**	**Units**	**Value**
Gun voltage	MV	1.25	RF amplifier, power	kW	4
Laser rep-rate	kHz	78	FPC design, power limit	kW	5
Laser power at the cathode	mW	30	Charge per bunch	nC	1-2
Laser wavelength	nm	532	Average current	mA	<0.15
CsK_2Sb cathode QE	%	1 to 5			

V. Track I – High beam current from the CW SRF electron gun

Generating higher current from the SRF gun requires following components: a high rep-rate laser, a high QE photocathodes, a low loss beam transport to the high-power beam dump and the RF system supplying power to the beam. The existing CeC laser system (Fig. 6) is located in a trailer outside the RHIC tunnel, which is shared with a large laser used for LEReC. Laser beams delivered to the SRF and LEReC guns pass through long evacuated pipes, with some of the laser transport system shared by both lasers. The laser beams are separated at an optical table inside the RHIC tunnel.

The CeC laser system (Fig. 6), which is a Nd:YAG Master Oscillator Power Amplifier (MOPA) system using a commercial, arbitrary pulse generator to generate 125-750ps pulses and an in-house designed, solid state, regenerative amplifier will be upgraded to generate beam currents up to 10 mA by increasing the repetition rate from 78 kHz to a few MHz. This is achieved by exchanging the existing commercial seed laser for one that runs at high repetition rates, as well as upgrading the amplifier with a high repetition rate Pockels Cell enabling repetition rates up to 5MHz. This modification will allow to switch between different repetition rates and pulse durations remotely. Similar performance of a regenerative amplifier has already been demonstrated using a system developed for the future EIC DC high voltage polarized electron gun at Stony Brook University.



(a) (b)

Fig. 6. Photograph (b) and schematic (b) of the present drive laser for the CeC SRF gun.

With these modifications, included in the SBU equipment budget, the laser system will be capable of generating electron beam we plan for Phase 1 – details are in Table. 3. We also include in the budget the plan to upgrade the laser system for Phase II beam parameters. We are pursuing two possible options. The first option is to modify the existing LEReC laser, retrofitting it with a new seed laser and to remove the current temporal shaping stage. This modification is subject to departmental approval, as the LEReC laser may be needed for further studies, after the LEReC project finishes. The second option is a further upgrade of the CeC laser. Due to rep. rate limitations the regenerative amplifier will be replaced by a fiber pre-amplifier and a solid state multipass main amplifier to generate ~30W of IR power @ 80MHz with tunable longitudinal flat-top pulses. The Seed laser, as well as most parts of the regenerative amplifier can be reused for this upgrade. Both options have similar costs, which is included in the SBU equipment budget. By the end of the Phase I we will have a laser system with following parameters:

Table 3: Parameters of the upgraded CeC laser

Parameter	**Units**	**Value**	**Parameter**	**Units**	**Value**
Laser rep-rate, range	MHz	1 to 5	CsK_2Sb cathode QE	%	2 to 5
Laser wavelengths	nm	1064/532	Pulse profile		Beer- can
Pulse (flattop)	psec	50- 750	Jitter, RMS	psec	6
Pulse energy	nJ	1 -700	Charge per bunch	nC	1 - 2
Average power	W	6	Maximum average current	mA	≥10

Table 4: Laser system parameters for the high current operation of the SRF gun

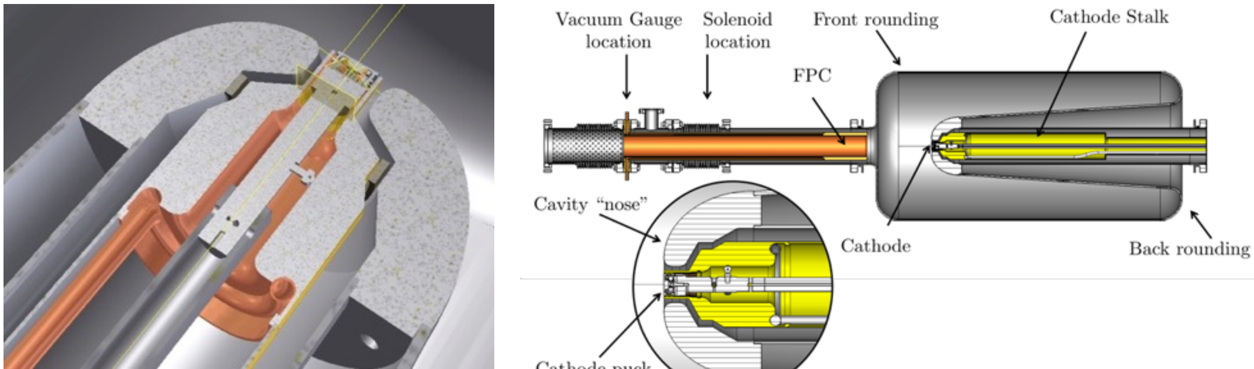
Parameter	**Units**	**Value**	**Parameter**	**Units**	**Value**
Laser rep-rate, range	MHz	56.5	CsK_2Sb cathode QE	%	2 to 5
Pulse (flattop)	psec	50- 750	Jitter, RMS	psec	6
Pulse energy	nJ	600	Charge per bunch	nC	up to 2
Average power at cathode	W	12	Maximum average current	mA	100

The existing beamline laser transport system will be used to deliver light to the photocathode located at the tip of the stalk inside the SRF gun. The room temperature hollow Cu-coated stainless-steel stalk is inserted into the 4K superconducting gun cavity. The stalk has an impedance transformer and serves as a half-wave choke shorted outside the cryostat. The cathode magnetic manipulator system has three UHV arms to transport the cathode pucks from a storage tank (called a "garage" with up to 3 pucks stored inside) into the gun cavity (Fig.7a). The long arm delivers the cathode to the end of the stalk (Fig. 7a), where it is grounded to the stalk by RF fingers. Controlling the depth of the stalk insertion with respect to the cavity nose allow us to control focusing strength near the cathode surface, and thereby control the beam quality from this SRF gun.

The CsK_2Sb photocathode material is deposited onto the polished surface of Mo puck using a dedicated cathode deposition system located in the Instrumentation Division building (see Fig. 8). The garage, equipped with mobile UHV ion and sublimation pumps, can be attached to this system via a load-lock, and accepts up to three photocathodes. When it is detached, the garage is transported to RHIC IP, where it is connected to the gun's load-lock. After a brief bake-out, the cathodes can be transferred to the gun. The cathode exchange between the gun and the garage takes about 30 minutes.

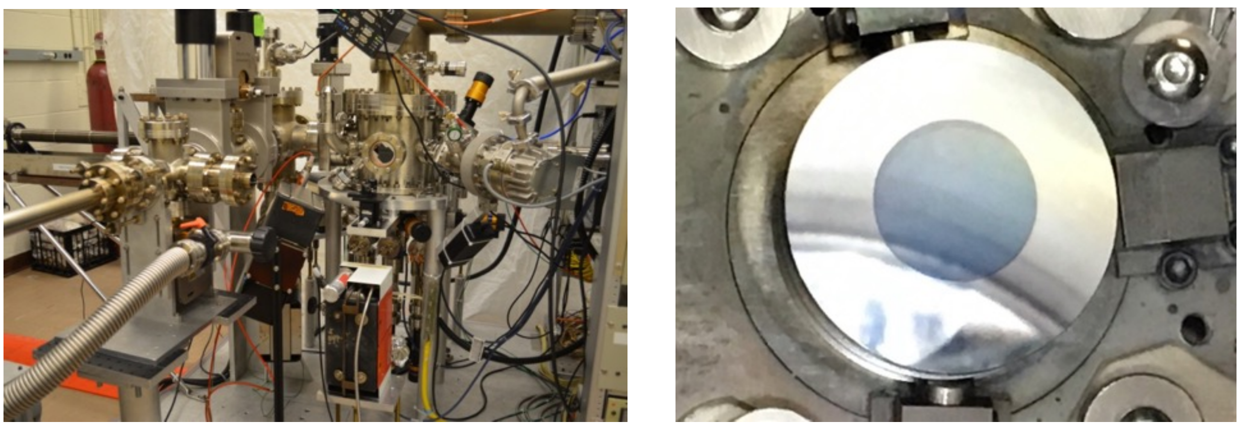
We plan to upgrade the cathode stalk and the cathode transfer system both to improve the vacuum during transfers (see details in next section) and to improve heat transfer from the photocathode's puck to cooling water. The latter will be important for Phase II, when a significant portion of 12 W average laser power will dissipate in the photocathode. We plan to build a real size in-vacuum model of critical components and to verify effectiveness of the heat transfer.

We experimentally proved that the combination SRF gun with room temperature CsK_2Sb photocathode has numerous advantages. The most important are that room temperature provides for high photocathodes QE, while the cathode lifetime benefits from super ultra-high vacuum inside the 4K SRF cavity. Our SRF gun demonstrated generation of electron bunches with charge above 10 nC and extremely low emittance [50]. Furthermore, we found a way of overcoming multipacting [10], which was problematic during initial tests of our gun, and demonstrated that high-QE K_2CsSb photocathode can operate for at least two months in our CW SRF gun without any measurable QE degradation [76] (see Fig. 9a).



(a) (b)

Fig. 7. Details of the room-temperature stalk and photocathode system of our SRF gun: (a) Details of the SRF cavity nose (at 4K) and gold-coated stalk with inserted cathode at room temperature controlled by the water running in the channel; (b) a room temperature hollow Cu quarter-wave stalk with water channel, used for both cooling and heating, is inserted inside the SRF gun cavity nose (at 4K); (c) Details of the CeC SRF gun design.

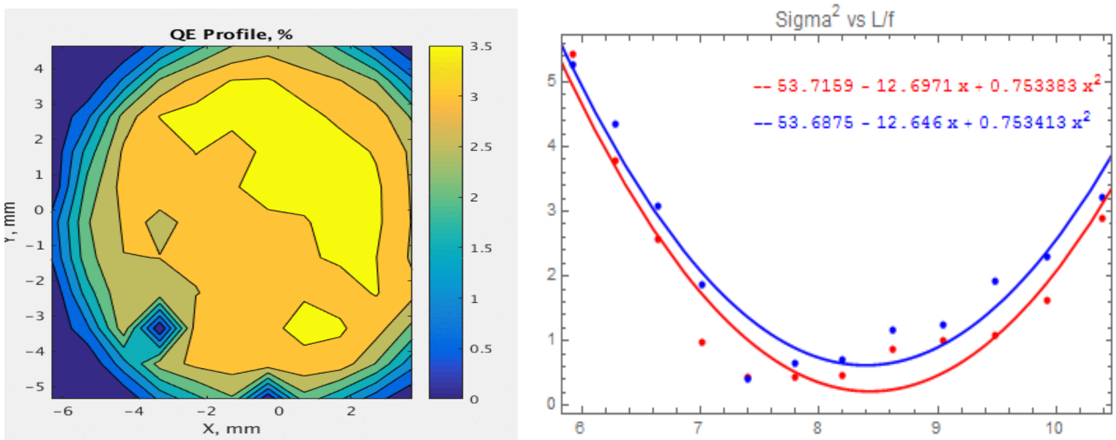


(a) (b)

Fig. 8. (a) Cathode deposition system (located in Instrumentation Division) and (b) 10 mm diameter K_2CsSb photocathode material (bluish) deposited onto the polished surface of Mo puck (20 mm in diameter).

In fact, the operational QE of photocathodes was higher than its initial value when it was inserted the gun. We attribute these QE improvements to a gentle cleaning of the photocathode surface by soft X-rays and removal of possible contamination accumulated during the cathode transport and storage in the garage. According to our measurements [50], the CeC SRF gun generates the highest experimentally demonstrated transverse brightness for bunched beams: normalized projected emittance of 0.35 mm mrad for 0.5 nC change per bunch (see Fig.9b).

The beam diagnostics of the CeC SRF accelerator includes, but not limited to, three profile monitors and three beam position monitors to measure beam profile and positions; two integrated current transformers at the exit of the gun and at the exit of the beamline to measure electron beam current; a pepper pot system in between profile monitors to measure beam emittances and a Faraday cup at the end of beamline (also used as a beam dump) for measuring the bunch charge. The present version of the time-resolved diagnostic beam-line (see Fig. 4, funded by the C-AD CeC experiment project funds) will allow us to measure slice emittance of the generated beam as part of the proposed research.



(a) (b)

Fig. 9 (a) Quantum efficiency (QE) of K_2CsSb after 2 month of continuous operation in 113 MHz SRF gun [11]; (b) Solenoidal scan for 0.5 nC bunch generated from our SRF gun indicating vertical normalized emittance of 0.35 mm mrad [12].

The SRF gun can generate bunches with rep-rate up to its operational frequency of 113 MHz or its sub-harmonic. Hence, our SRF gun can be easily and inexpensively upgraded for generating milliamps of average beam current, limited only by its 4 kW RF transmitter and current FPC. This mode will be used for initial demonstration of 1 to 3 mA average beam current in Phase 1 of the project.

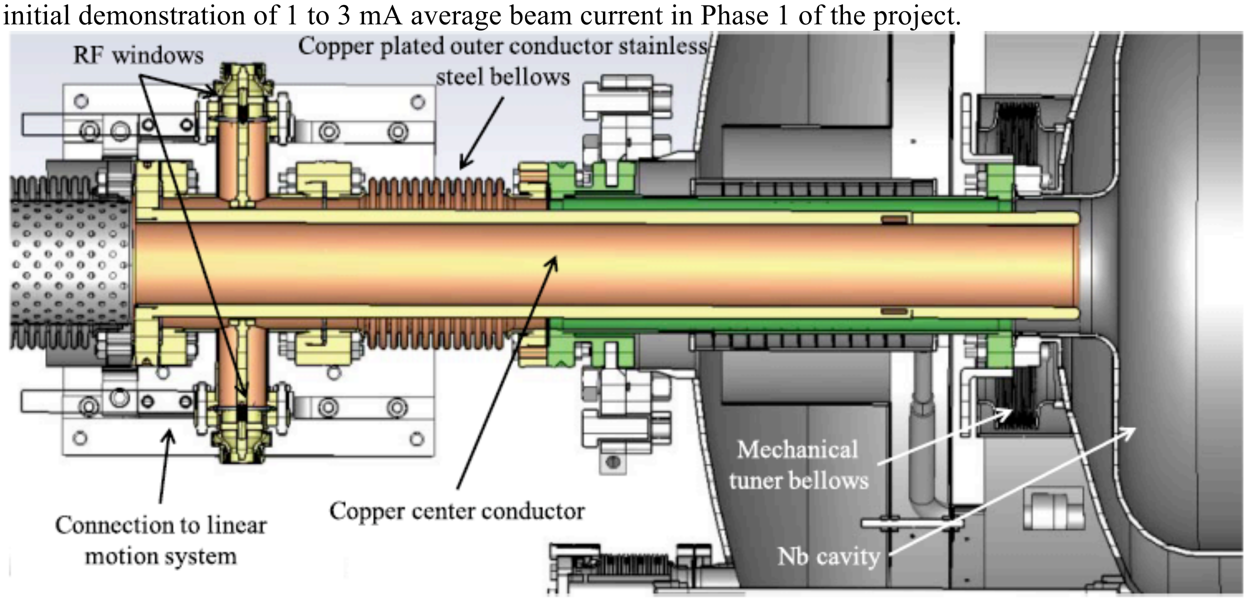


Fig. 10. Cross section of the current FPC attached to the beam-exit port [77].

For the next phase, we will design the 113 MHz 100 kW RF system including all necessary components: the amplifier, the circulator and the transmission line (to be procured from commercial vendors) and the gun's FPC – which is the most complicated part of the system. The new FPC will retain the coaxial structure of the present FPC (see Fig. 10) but will have stronger coupling (i.e., it will be inserted deeper inside the cavity) and four RF feedthroughs designed to operate at up to 50 kW each. This will make the gun capable of operating with 100 kW of transmitter power and with plenty of engineering margin. The coupler must have hollow to allow laser light and electron beam propagation and because of high operating power (100 kW) the FPC must be cooled. Multipactoring is very probable in a coaxial coupler at this power level so there must be some means for multipactor suppression. Since magnetic fields cannot be applied to the coupler of a superconducting cavity, the only way to suppress multipactoring is to use a high voltage bias.

This means that antenna must to be isolated from ground and the RF sources must be protected from the high voltage of bias. In the present configuration the antenna penetration can be changed, which permits the coupling value and cavity frequency to be adjusted. The combination of all these features makes the design of the new coupler challenging but feasible. The FNAL team, in collaboration with Dr. Petrushina, will be responsible for this critically important task. The FNAL team has vast experience in design and testing of main couplers for accelerating cavities, normal conductive and superconductive. Several types of main couplers were designed and successfully tested within PIP-II project: 162.5 MHz, 80 kW, CW couplers for normal conductive RFQ cavity; 325MHz, 20kW, CW couplers for superconductive single spoke cavity and 650 MHz, 50kW, CW couplers for superconductive elliptical cavities. All couplers have some similar features: single room temperature coaxial ceramic windows, air cooling of antennas, ability to apply high voltage bias to suppress multipactoring. Layout of the 650 MHz, 50 kW coupler is presented in Figure 11. The power of the proposed 113 MHz coupler is higher, but the frequency is lower and specific thermal depositions and thermal stresses are expected to be close to the ones of designed and tested FNAL couplers. The main task is to modify FNAL designs to fit the existing CeC SRF cavity and configuration.

Based on the technical requirements mentioned above, we suggest designing the coupler having the following parameters and features:

- Operating power and frequency 100 kW and 113 MHz.
- Single, room temperature ceramic coaxial window with ceramic diameter ≥ 4 inch
- Antenna and window cooled by air.
- High voltage bias applied to the coupler to suppress multipactoring.
- Special device (DC block, see Fig. 12) used to protect RF sources from high voltage bias.
- Antenna - hollow for laser light and electron beam propagation.
- Antenna - movable to adjust cavity frequency and/or coupling.
- The coupler should provide acceptable static and dynamic cryo-losses.

The CeC program will be completed in two years (e.g. in Summer of 2022), providing the opportunity to upgrade the SRF gun for Phase II operations, to generate currents up to 100 mA.

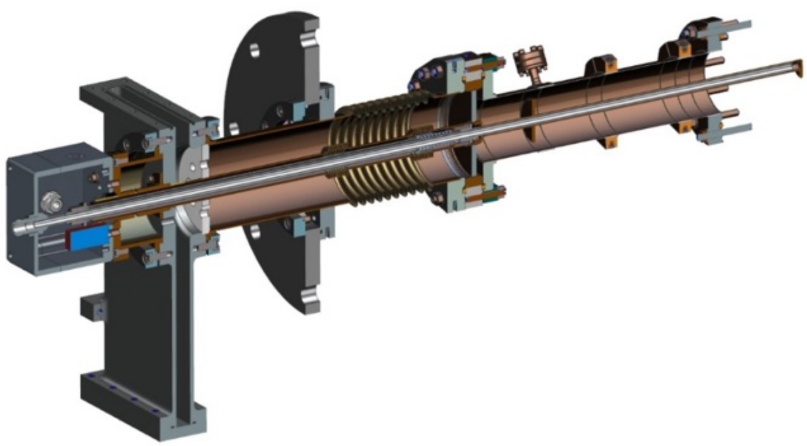


Fig. 11. Layout of FNAL 650 MHz, 50 kW couplers for PIP II having similar features: a single room-temperature coaxial ceramic windows, air cooling of antennas, ability to apply high voltage bias to suppress multipactoring.

Understanding beam dynamics is critically important for the proposed research. Dr. Jing and the CeC group at BNL developed a large number of off-line and online tools to predict beam dynamics of space-charge dominated beams [5,50,78-81]. As part of the proposed research the team will evaluate and optimize normalized beam emittance generated from the SRF gun, design a low-loss lattice for the beam transport and evaluate beam hallo generated by the SRF gun.

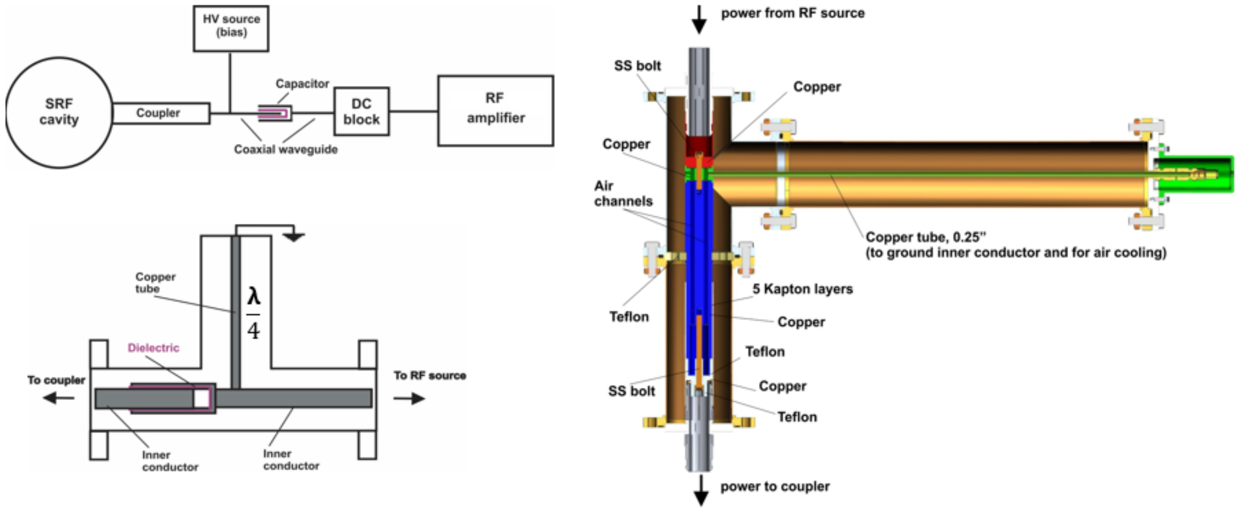


Fig. 12. DC block protecting the RF amplifier from the DC bias voltage. A similar device must be designed for the 113 MHz, 100 kW coupler.

After the electron beam exits the SRF gun, it passes through a beam line consisting of multiple RF cavities and solenoids for beam quality control and phase space manipulation. For the CeC SRF accelerator, many computer codes were used to calculate a variety of effects, e.g., ECHO/ABCI for wake-fields, SUPERFISH/CST/ACE3P for RF fields, etc. The fields simulated from these codes were then imported into IMPACT-T, which is a 3D particle-in-cell code, to simulate the beam 6D phase space evolution along the beamline. The simulated beam sizes agree very well with the measurements – sees Fig. 13 below.

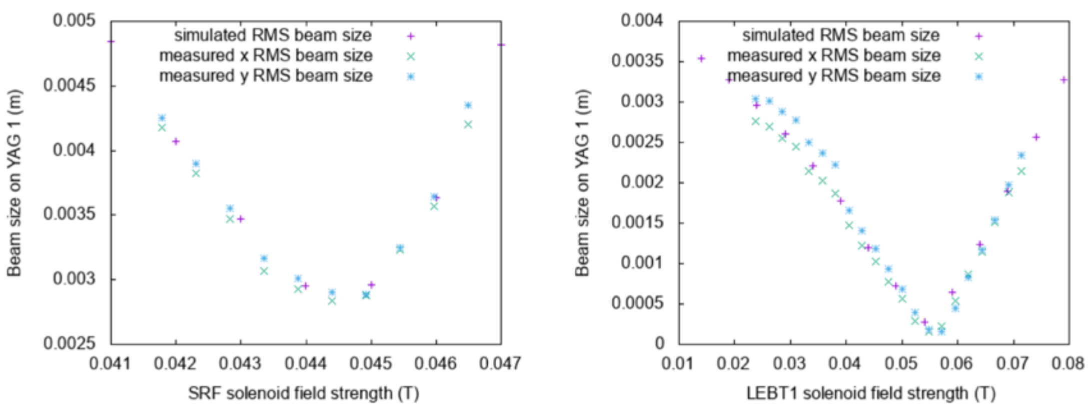


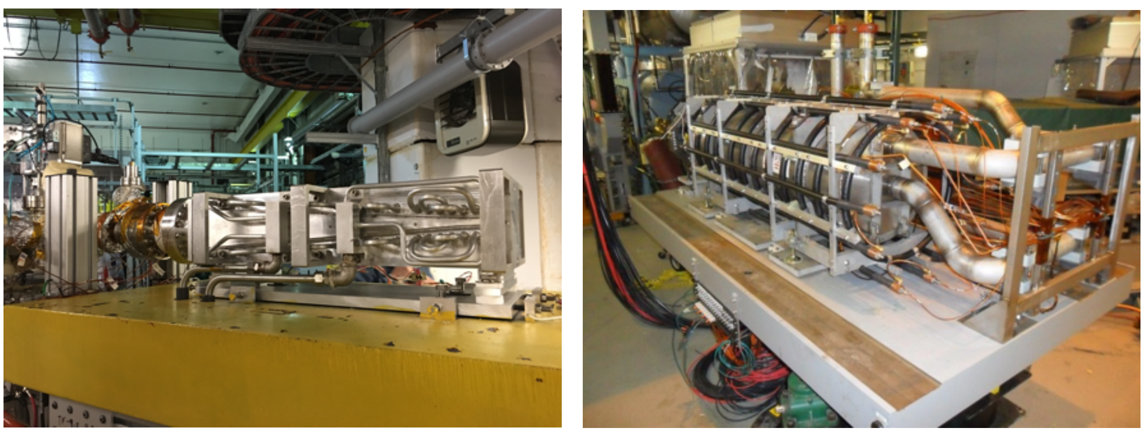
Figure 13. Simulated beam sizes agree well with experimental measurements in CeC SRF accelerator.

The simulation results were also benchmarked with others beam dynamics codes, such as GPT/ASTRA/PARMELA and show good agreement in both transverse/longitudinal phase spaces, projected emittances and peak beam current. We will apply the expertise developed during CeC operation to the SRF gun upgrade proposal, to preserve the bright beam properties from the gun to the high power dump. We also developed a user-friendly online GUI (using Matlab) to evaluate the beam parameters (the envelope, emittance, energy, bunch length, etc.) using real-time control setting of the accelerator. Such a GUI helped us evaluate the beam qualities using current machine settings and greatly speed-up tuning of the accelerator – Fig. 14 shows one of the GUI windows with envelope of the electron beam.

The last, but not least, important component of the beam line is the high-power beam dump. While the existing beam dump (Fig. 15 (a)) can support operations up to 6 mA, we plan to replace it with a beam dump capable of absorbing up to 1 MW of 2 MeV electron beam (Fig. 15 (b)). Such a beam dump is currently used at the LEReC accelerator and will become available for Phase II of the project.

Figure 14. An online modelling of beam envelope from the gun to the high-power beam dump.

We will use the existing control and machine protection system of the CeC accelerator with some modest modifications for the proposed research. Modification will include two DCCT (DC current transformer) units and tuning of LLRF system for high beam loading.



(a) (b)

Fig. 15. (a) Existing 8.5 kW water-cooled high-power dump with removed shielding; (b) A 1 MW beam dump for low energy (~ 1-3 MeV) electron beam during transport from BNL R&D ERL to LEReC.

We have tested many CsK_2Sb and Na_2KSb photocathodes in both SRF and DC high voltage guns. Highlights include:

1. Photocathodes with 8~10% QE were routinely produced for operation in the 113 MHz SRF Quarter Wave Resonator gun of the CeC experiment. The dark lifetime in the transfer chamber was more than half a year. In this gun, the CsK_2Sb cathode produced large bunch charges (between 1 nC and 10 nC) in the CW RF operation. In 2017, the cathode operated at an average current of 150μA with a QE of 4% continuously during 3 months of operation [92,93].
2. BNL produced multiple CsK_2Sb and Na_2KSb cathodes for the 400 keV DC gun for Low Energy RHIC electron Cooling (LEReC), demonstrating 9% QE with 30 mA average current with one week lifetime

during gun commissioning. Recently, during 24/7 operation at 20 mA, cathode lifetime was more than a month [9]. This is the first routine operation of a high current gun.

When compared with the DC gun, the SRF gun offers better vacuum and significantly lower ion back bombardment. Hence, SRF guns with CsK_2Sb cathode could generate high current and low emittance beam. By rearranging the cathode growth chamber for GaAs cathode activation, we also will be able to grow CsK_2Sb by sequential deposition which in principle can make much larger crystals. We will test such large crystal CsK_2Sb cathode in SRF gun and compare to the cathode deposited by sequential method.

The proposed research will ascertain the capabilities of SRF photoemission guns, the lifetime and the charge capacity of high QE photocathodes. The high QE CsK_2Sb photocathode portion of the proposed research will be an important of part of Track I. Alkali antimonide cathodes show great promise towards meeting the goals of high QE and good lifetime. High QE performance in the gun is obtained by fabricating the cathode on a clean substrate in an ultra-high vacuum (UHV) environment and transporting it to the injector through a UHV load-lock system. With conventional vacuum practices, vacuum levels in the range of 10^{-11} Torr are obtained routinely. A QE of around 10% at 532 nm has been obtained at BNL routinely. For nuclear physics applications, the primary focus in recent years has been on improving the lifetime of the cathode in high current, high charge operation. The CsK_2Sb has small intrinsic thermal emittance due to small excessive energy. The operational lifetime of a CsK_2Sb photocathode is dictated by contamination of the surface, changes in the stoichiometric composition due to laser heating of the cathode, and/or ion back-bombardment of the cathode in the gun environment [91,92]. CsK_2Sb cathode studies have been carried out at BNL for more than 10 years, including cathode recipe optimization, gun tests and growth optimization with in-situ X-ray analysis

VI. Track II – Polarized electron beam from the CW SRF gun

Using GaAs photocathodes in the SRF gun is completely untested direction and, therefore, represents the "high risk high impact" part of our proposal. The encouraging signs that this portion of our proposal could be successful is the superb UHV vacuum in the SRF gun and absence of significant ion back-bombardment - resulting in long lifetime of photocathodes - and recent success in reduced sensitivity of GaAs photocathode to pressure of residual gas when it is coated and activated by a robust CsTe layer.

We consider that there are significant advantages of the SRF gun mitigating cathode degradation mechanisms. The degradation of the QE and subsequent short lifetime of photocathodes may be attributed primarily to three mechanisms:

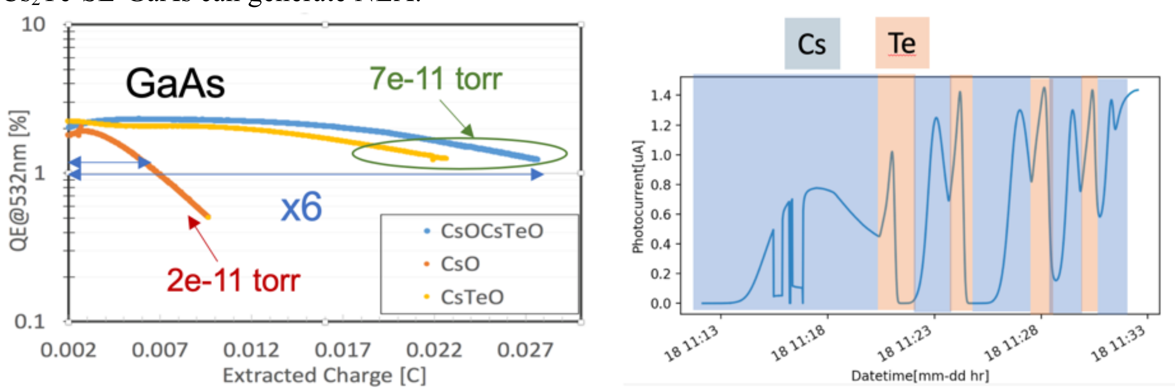
- Chemical poisoning: Residual gas in the gun could react with the cathode material, generating an oxidized surface leading to increased electron affinity. Experiments have shown that O_2, H_2O, CO, CO_2, and N_2 can readily contaminate the cathode [82,83]. The residual gas could be generated by beam loss on the vacuum chamber, multipacting in the RF gun. This contaminating layer could increase the electron affinity of the cathode. The SRF gun cavity wall can absorb and freeze the residual gases due to large area of cryo-pumping, resulting in extremely good vacuum.
- Dissociation due to heating: It has been experimentally demonstrated that the QE of K_2CsSb and KNa_2Sb will degrade at temperatures above 80° C or 120° C, respectively [84]. The Cs or K dissociates from the cathode at high temperature, inducing a stoichiometry change correlating to the increase in the electron affinity. Such degradation can be recovered partially by the addition of alkali metal. In order to accomplish this recovery, gun operation has to be suspended for a short period, the cathode retracted to a deposition section, alkali metal re-evaporated and the cathode reinserted into the gun. Such a process will impede the routine operation of the photoinjector. The SRF gun operated at 4 K provides a cold environment. Meanwhile, the cooling channel at back of cathode provide the way to maintain the temperature for cathode operate at ideal temperature.
- Ion back bombardment: The high energy ions produced by the ionization of residual gas in the system will bombard the cathode material and may damage the lattice, especially in a DC gun where the cathode bias remains negative all the time [85,86]. In addition to lattice damage, the low energy ions will attach to the cathode surface and increase the electron affinity. Since the ion current is proportional to the electron current, this effect increases as electron beam current is increased.

Ion back bombardment is the dominant mechanism for GaAs photocathode QE degradation. However, in recent experiments at BNL with multi-alkali cathodes in an SRF gun operating at 70 μA, ion back bombardment did not appear to be the dominant lifetime-limiting mechanism directly. However, the ion back bombardment can cause the HV-DC gun to trip and result in QE degradation. In SRF gun, the ion back bombardment will be significantly eliminated due to the RF potential barrier close to the cathode.

These considerations indicate that the SRF gun is likely the best candidate for long lifetime time operation with photocathodes.

Second indication comes from properties of novel GaAs photocathodes activated by robust CsTe layer. Polarized electron sources have been used in particle and nuclear physics experiments around the world. The most efficient way to generate short pulse polarized electron bunches is using strained superlattice GaAs (SL-GaAs) in a high voltage DC gun. The SL-GaAs photocathodes can provide electron beams with a polarization of up to 92 %, with QE of 1% approximately at IR laser illumination. In recent years, SVT in collaboration with JLab developed a 6.4% of QE with 84% polarization from "Distributed Bragg Reflector (DBR)" GaAs [87].

At KEK, Cornell, and BNL, use of a Cs_2Te layer (instead of the conventional Cs-NF_3(O) layer) has shown a factor of 5-8 improvement in the charge lifetime when illuminated by a green laser [88]. Figure 16 (a) shows the lifetime comparison between the conversional O-Cs layer and the innovated Cs_2Te layer which growth by the "yoyo" process shown in Figure 16 (b). In principle, heavy n-doped heterojunction of Cs_2Te-SL-GaAs can generate NEA.



(a) (b)

Figure 16. (a): The lifetime comparison of conventional O-Cs activation GaAs and novel CsTeO activation GaAs. Our experiments show that the lifetime has increased 6-8 times by CsTeO coating. (b): A typical yoyo process of Cs_2Te coating on SL- GaAs photocathode.

However, in previous studies, the QE of Cs_2Te-SL-GaAs was lower when compared to CsO-SL-GaAs. Typically, the GaAs photocathodes are heavily doped by either B or Zn and hence are also p-type [89]. With a thin layer of n-type doped protection material, the heterojunction structure is able to reduce the work function. The typical electron-phonon mean free path at room temperature is 3-8 nm, which is comparable to, or thicker than, the protection layer, causing negligible electron-phonon scattering. Besides enhancing the QE and prolonging the lifetime, the surface layer may also provide a mechanism to reduce the thermal emittance. It can act as a transverse momentum filter. The momentum acceptance of the surface layer can limit the emission of the large transverse momentum excited photoelectrons from the cathode. At BNL, we developed a new recipe that can obtain 5% QE of bulk GaAs with illuminated by 780 nm laser. It is comparable to conventional O-Cs-GaAs. And we are ready to test this robust cathode in SRF gun.

We propose to test the GaAs photocathodes in the CeC SRF gun, and we expect success because the Cs_2Te-coated GaAs will survive with high QE if the gun exhibits multipactoring during the ramp to high RF voltage. Furthermore, the CeC group developed a technique eliminate multipacting inside the SRF gun by rapid (msec) ramp of the RF voltage.

We developed a method to incorporate the GaAs cathode into the 113MHz SRF gun cathode puck and the transport arm holder. Only the activated emitting surface will be exposed to the RF field to eliminate the unnecessary RF heat dissipations. The RF shielding will be applied to the cathode holder to prevent the RF power leak into the cathode stalk. We designed a new cathode puck that can accommodate GaAs without changing the gun insertion structure. The puck design can be used with the same cathode transfer system. The puck design is shown in Fig. 17.

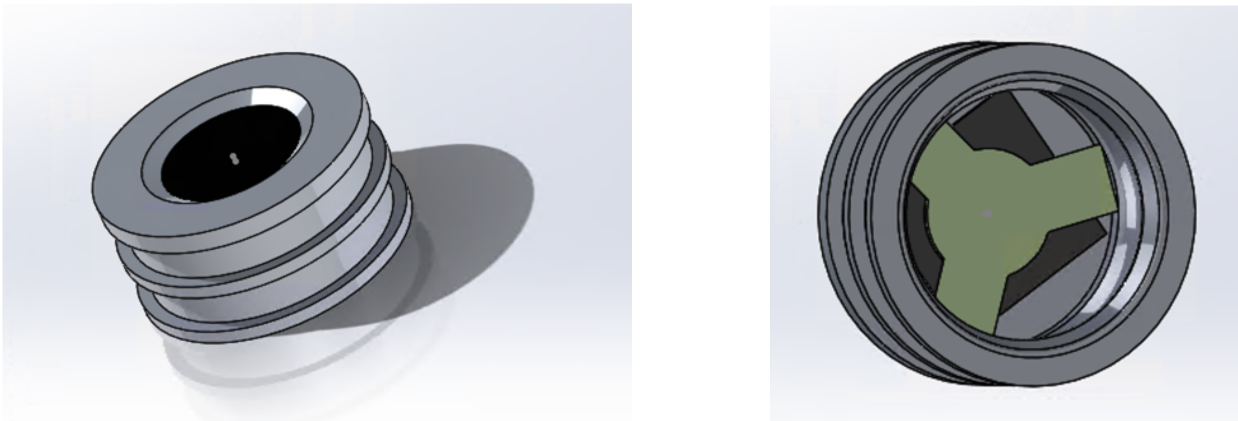


Figure 17. The design of SRF gun puck can accommodate a GaAs cathode. The back of the GaAs is a sprint plate to hold the cathode in place. It can fully match the insertion system cooling figure.

As the first step, we will measure the lifetime of the photocathode with a green laser. We will test if the average current ~ 1 mA can be reached in such a test. The impact of multipacting and ion back bombardment will be studied experimentally through beam tests as well.

Another issue that prevented tests of GaAs in CeC SRF gun is related to the cathode transfer system. The O-Cs coated GaAs did not survive the baking of the intervening load-lock section, which caused the transfer chamber vacuum to increase 5-10 times. Our CsTe-coated GaAs can survive in low 10^{-10} torr vacuum for days without obvious decay and can survive in low 10^{-9} torr for 3 hours. This is comparable to the typical K_2CsSb lifetime and indicates with the improvement of the transfer system can keep the GaAs at high QE.

The present cathode deposition and transfer systems only can make and deliver CsK_2Sb photocathodes and a significant upgrade is needed to grow GaAs cathode with CsTe coating:

1. *Hydrogen cleaning system*: The CsK_2Sb cathode substrate preheating cleanup system only can reach temperature of 400 ^oC, while GaAs requires heating temperature of 580 ^oC. We also propose to add a hydrogen cracker system to generate H atoms to clean the GaAs surface at 350 ^oC.
2. *Source system:* The current CsK_2Sb cathode is growth by sequential deposition. However, we found the CsTe activation layer must be prepared by co-deposition. Rearranging the source system and adding an extra Te source is included in this upgrade.
3. *Cathode transport system:* The *in-situ* QE measurement system causes a vacuum bursts due outgassing of the copper anode. To reduce the outgassing, we propose to use single Mo/Ti crystal for the anode material. We also plan to increase the pumping speed by adding a 400 l/s pump. This will improve vacuum in the cathode transfer system to about 2 10^{-11} torr, which is sufficient to keeping active GaAs cathode for weeks. All the cathode transfer system will be fired to 900 ^oC and post bake at 500 ^oC for 2 days to reduce the H_2 outgassing.
4. Avoiding the vibration during the cathode transfer and opening the load-lock assembly is also important part of vacuum hygiene. We have developed and plan to implement improvements of the transfer chamber handling system, including slow motorized activation of the manipulators.

While the existing CeC green laser will be sufficient to test the survivability of GaAs cathodes in the SRF gun, we need 780nm light to generate a polarized electron beam. To achieve this the CeC green laser using the regenerative amplifier can be run at low repetition rates (10 - 100kHz), generating high energy green laser pulses 100 – 700µJ, which in turn can be converted to 780nm light using an optical parametric conversion stage and a low power seed source. This upgrade is low cost and provides both, green and 780nm light for the proposed studies with GaAs cathodes..

Table 5: IR Laser system for generating polarized electron beam from the CeC SRF gun.

Parameter	**Units**	**Value**	**Parameter**	**Units**	**Value**
Laser rep-rate, range	kHz	10-100	Expected cathode QE	%	0.1 to 1
Laser wavelengths	nm	780	Pulse profile		Beer-can
Pulse (flattop)	psec	50- 750	Jitter, RMS	psec	6
Pulse energy	µJ	30	Charge per bunch	nC	1
Average power at cathode	W	0.6	Maximum average current	mA	0.1 to 1

Polarization of the electron beam will be measured using a Compton Transmission Polarimeter [92] provided by JLab. Although Mott polarimeters provide larger measured asymmetries, the Compton Transmission polarimeter is relatively inexpensive and easy to build, it works best with electron beam energies in the few MeV range which is perfectly suited for the CeC accelerator, and importantly, it measures longitudinal spin polarization which means the CeC beamline does not need to be modified to include a spin manipulator required by Mott scattering which is only sensitive to transverse polarization.

When longitudinally polarized electrons strike a target, like the beam dump at the end of the CeC beamline linac, circularly polarized Bremsstrahlung photons are produced. The degree of circular polarization is proportional to the magnitude of the electron beam polarization, and the circular polarization flips right/left circular when the electron spin direction is flipped parallel/antiparallel to the beam motion. These polarized Bremsstrahlung photons are directed onto a magnetized iron target, where the photons Compton-scatter from the longitudinally polarized electrons in the magnetized iron. The degree of transmission through the iron depends on the orientation of the circular polarization of the Bremsstrahlung photons (i.e., left/right circular) and the direction of the magnetization of the iron target (parallel/antiparallel to the beam direction). The technique is shown schematically at the top of Figure 18, together with photographs of a Compton Transmission polarimeter installed at the CEBAF photoinjector, behind the beam dump of the 5 MeV Mott polarimeter [93].

Polarization of the electron beam, P_b , is given by:

$$P_b = \frac{Asym}{P_T \times A}$$

where P_t is the polarization of the magnetized iron, A is the analyzing power of the polarimeter which depends on the electron beam/photon energy, and $Asym$ is the measured photon transmission asymmetry for the two spin states of the electron beam obtained using the calorimeter/PMT. Alternatively, the electron beam polarization can be maintained constant and the direction of the magnetization of the iron target can be flipped by reversing the direction of the magnetizing field. A magnetometer installed within the solenoid magnet used to magnetize the iron target provides confirmation that the iron is saturated (i.e., sets the solenoid current), and a relatively simple TOSCA model predicts the magnetization, typically of the order 8% [3]. Established formulas can be used to provide a value for the analyzing power, based on the electron beam and photon energy [4, 5], or as we propose, the analyzing power can be measured empirically via cross calibration with the precise CEBAF 5 MeV Mott polarimeter [2]. Such an exercise was performed [6]: electron polarization measured using the 5 MeV Mott polarimeter indicated 86% polarization, which provided photon transmission asymmetries of the order 2%. This means for the apparatus used at CEBAF, the analyzing power integrated over all photon energies was ~ 28%, which is consistent with measurements using similar devices [7 - 9]. There is a tradeoff between photon yield at the detector and analyzing power. Lower energy photons provide smaller analyzing power and vice versa. By choosing a thick iron target, one obtains a higher analyzing power but at the expense of photon flux delivered to the detector.

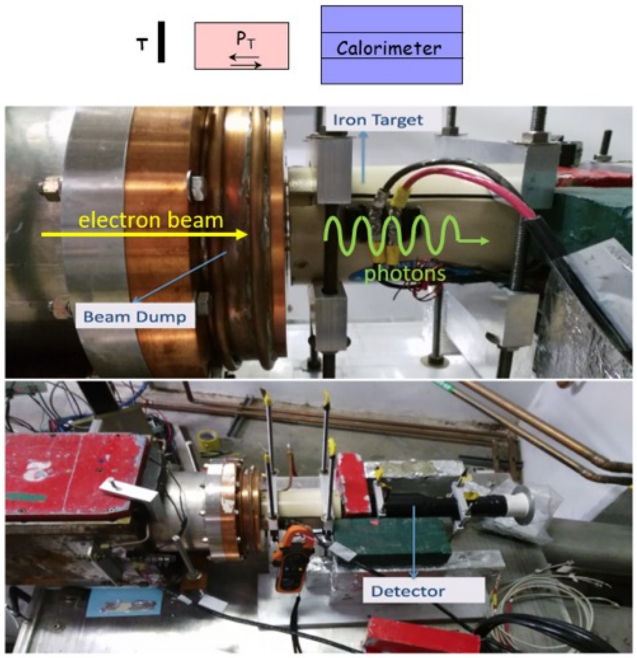


Figure 18. The Compton Transmission polarimeter is composed of a target for the electron beam from which Bremsstrahlung photons are produced. The photons then pass through a magnetized iron target and the transmission through the iron target depends on the polarization of the photons, and hence the electron beam. The Bremsstrahlung photon transmission asymmetry is measured using a calorimeter/PMT. The photos show a Compton Transmission polarimeter at the CEBAF photoinjector.

We propose to build a Compton Transmission polarimeter composed of solenoid and iron target, with internal magnetometer and evaluate it at the CEBAF 5 MeV injector before shipping it to BNL for installation behind the CeC accelerator linac beam dump. Since the geometry of the beam dump influences the Bremsstrahlung photon fluence and energy spectrum, we will build a similar dump for CEBAF or propose modifications to the dump used at CeC so that test conditions used at CEBAF are similar to those used at BNL, to ensure the analyzing power determined at CEBAF will be similar to that at BNL. We will provide the collimator that will define the Bremsstrahlung photons that pass the iron target and reach the calorimeter/PMT and the data acquisition system used to measure the Bremsstrahlung transmission asymmetry. The IR laser used to drive the CeC SRF photo-gun will provide two circular polarization states. For this, Jefferson Lab can provide the helicity control card that will provide a synchronization signal to the data acquisition system.

Besides providing a calibrated Compton Transmission polarimeter with all necessary hardware to operate it, we propose funding a graduate student to simulate the polarimeter: radiator, iron target, collimator, and detector response using Geant4.

A Compton Transmission polarimeter is accurate to 5-10% but with the cross comparison provided by the CEBAF 5 MeV Mott polarimeter, we should be able to claim accuracy of a few percent. The caveat is that the beam at BNL and CEBAF be identical.

Progress with generating polarized electrons during Phase I will determine our plans for Phase II of this project. We preliminary plan to extend our studies in Phase to super-lattice GaAS photocathode famous for producing electron beams with extremely high polarization.

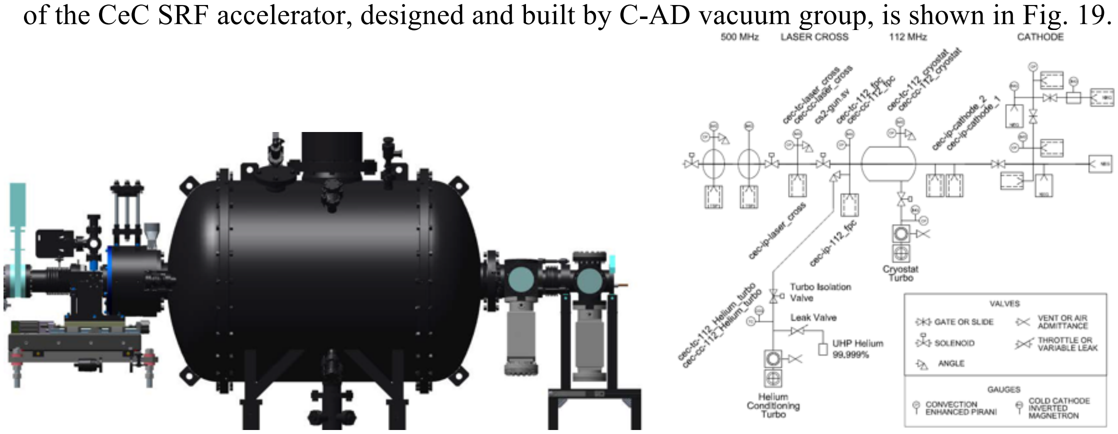
VII. Track III – In-situ processing of the CW SRF gun

Compatibility of photocathodes and SRF guns is a two-way street – while the SRF gun can damage the cathode, the cathode can harm the SRF cavity by depositing volatile or highly emissive compounds (such as Cs, Na, K, etc.) on the Nb surfaces. Harm to the SRF gun can come in form of creation of new emission centers and increased dark current or/and in enhanced multipacting strength. Both of these negative effects had been observed in operational SRF guns [45,76].

Dark current – caused by low work-function of highly emissive compounds – can reach cavity walls and in addition to generating increased X-ray radiation field, it would result in increased consumption of liquid He – or even in gun quenching. As result, the gun could be forced to operate at reduced accelerating voltage and with reduced beam quality, Similarly, multipacting can prevent SRF gun from reaching operational voltage and, most importantly, will destroy photocathodes by electron bombardment, or poison them by generating pressure spikes by inducing outgassing of otherwise deep-frozen gases on Nb surfaces. Again, such a result can be devastating if there is no existing and reliable remedies to restore SRF gun operation.

There can be also other sources of SRF gun cavity contamination, including particulates generated by inserting and removing cathodes or those migrating from other parts of the vacuum system, which can result either in reduced performance of the SRF gun or even in loss of valuable piece of equipment. In short, developing methods of restoring performance of SRF guns is important part of the R&D. In practice, such method- especially in important details – strongly depend on the frequency and geometry of the cavity.

One of successful methods we have implemented for improving performance of our SRF gun is RF conditioning using clean He gas with pressure ranging from 10^{-6} to 10^{-5} torr. A system for He conditioning of the CeC SRF accelerator, designed and built by C-AD vacuum group, is shown in Fig. 19.



(a) (b)

Figure 19: (a) Detailed view of the SRF gun cryostat with critical vacuum components; (b) Schematic of clean He gas delivery for the CeC SRF cavities conditioning.

He conditioning is performed under operational (cryogenic) conditions – hence use of He gas - with short pulses of RF power creating electric field at the dark current emitters above the critical level. According to experts, the He conditioning works as follows: when high electric field is applied to the emitter of the dark current, the emitted burst of electrons ionize surrounding He gas, and He ion bombard the source and, frequently, destroy such emitters. In some cases we observe a flash of light from such an event, but usually the process is rather slow and tedious. During six years of operation we used He conditioning twice: during initial commissioning and on January 21, 2020, when we observed that He consumption - which was gradually growing – reached critical level at nominal operational voltage of 1.25 MeV. Figure 20 illustrates the conditioning process: after the SRF cavity was filled with He at pressure in the mid 10^{-6} torr range, the cavity was operated in phase-locked mode with short RF pulses applied on the top of the CW voltage.

The process is rather delicate and sudden increases of the applied power could result in interruption by the cavity MPS system. Only a few people learned how to do this and it was always a try-and-sometime-succeed process. As one can see from Fig.20, both the liquid helium consumption and the X-ray radiation are gradually improving while the level of CW and peak voltages are slowly increasing. When done properly, the results are rather remarkable – after four hours of processing on January 21, liquid He consumption and X-ray radiation were reduced by factor two at operational RF voltage of 1.25 MV. We propose to improve and properly characterize this method in Phase I of this project.

Another important in-situ restoration method for improving performance of contaminated SRF systems is plasma processing – the method actively pursued at FNAL and elsewhere [103-105]. In contrast with He conditioning, this method is applied to SRF cavities at room temperature. Plasma processing uses a mix of noble gases (such neon or argon) at pressure between 70-200 mTorr to ignite and sustain the glow discharge in the cavity. A low percentage of oxygen is added to react with the hydrocarbons adsorbed on the cavity surface.

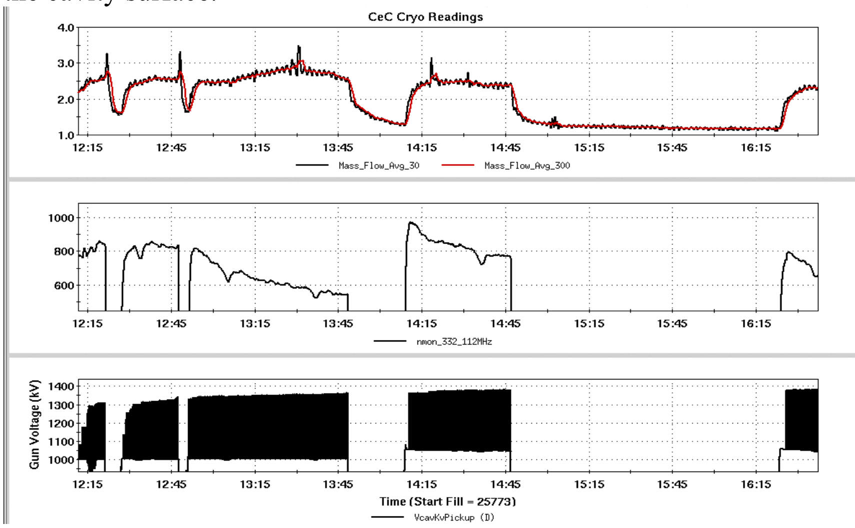
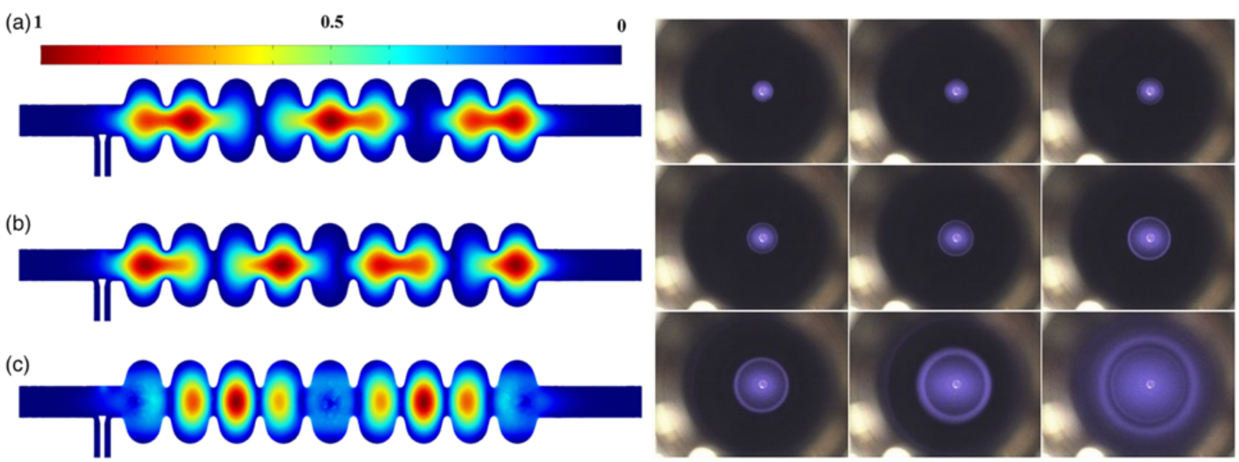


Fig. 20. Evolution of ligiid He consumption by SRF gun cavity (top graph, in g/sec), and level of X-ray radiation near the cavity (middle graph, in mRad/h) while short RF pulses were applied on the top of the constant voltage (bottom graph, in kV)

The volatile byproducts are pumped out of the cavity and monitored with a Residual Gas Analyzer (RGA). Neon and oxygen are mixed before reaching the cavity and their ratio is controlled with the RGA. The in-situ plasma processing technique was developed mostly to mitigate hydrocarbon related field emission [106]. Starting from SNS experience [107,108] and using the new ignition method, plasma processing has been applied to multiple 1.3 GHz cavities at FNAL and extended to using HOM (Higher Order Modes) couplers to ignite the glow discharge with only a few watts or RF power required [109, 110]. In multi-cell cavities, the plasma can be ignited one cell at a time using a superposition of HOMs – see Fig.21.



(a) (b)

Fig. 21. (a) Normalized electric field distribution on the X-Z plane of all modes used for plasma transfer between cells: 1-3 (a), 1-4 (b), and 2-2 (c); (b) Ar plasma in each cells (9 to 1) of a LCLS-II cavity, fundamental power coupler side view. Illustrations taken from ref. [104].

Similarly, in the QW SRF gun this technique can be used to move active plasma into various regions of the cavity including rounded corners and the FPC where multipacting is most prominent [76]. We plan to simulate this process for the CeC SRF gun, and design and build the dedicated plasma processing system suited for our purposes.

It is important to note, that in addition to the removal of organic contaminations this process allows the addition of oxygen into the mix of noble gasses which could oxidize and remove highly emissive compounds (such as Cs, Na, K, etc.). We will identify the recipe in terms of pressure, duration, plasma density and O_2 percentage suited for treating our QW SRF cavity. We expect that such treatment will result in similar improvement for our SRF gun cavity, e.g. in reduced field emission and enable us to operate at higher RF gun voltage. It is known that hydrocarbons ($C_x H_y$), similar to highly emissive compounds, have lower the work function when attached to Nb surface and can result in increasing field emission. Plasma processing is one of the most promising methods of removing such contaminations.

FNAL team will design and assemble plasma processing system, e.g. to create system similar to that shown in Fig. 22, but tuned for the CeC SRF cavity need by the end of the Phase 1 - funds for this equipment are included in the SBU equipment budget. It will allow us to investigate effect of plasma cleaning on SRF gun performance in the Phase II of this project.

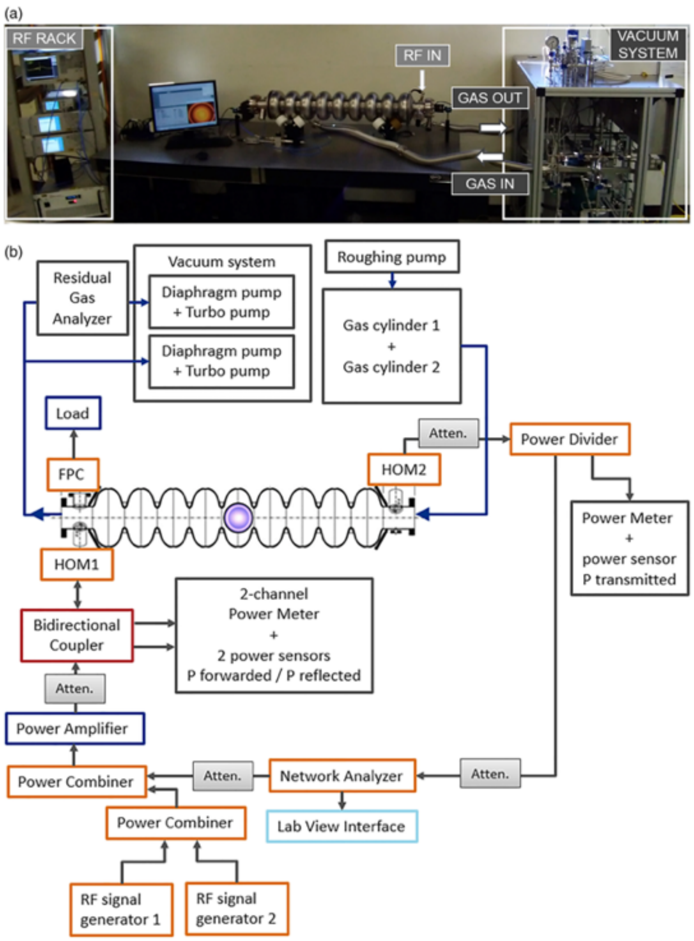


Fig. 22. Plasma cleaning experimental setup: (a) picture of RF and vacuum systems connected to a 9-cell LCLS-II cavity and (b) RF and vacuum connections schematic, including all major components. The plasma is represented in (b) by the purple circle: processing of cell 5. FPC identifies the fundamental power coupler, and HOM1 and HOM2 refer to the high order model couplers on the cavity. Illustration is taken from ref.

VIII. Schedule, milestones and deliverables

As we described above, we proposed to explore the full range of potential of the very promising CeC SRF photoelectron gun in two phases. Phase I, which will continue for two years, is the core of this proposal comprises of three tracks: high current operation of the SRF gun, generation of polarized electron beam and developing techniques to further the SRF gun parameters. Limited in time and funds, it does not allow us to reach all of our ultimate goals, but it paves clear path to demonstrating them in Phase II, which may extend this research for additional two-three years. This schedule is also technically driven and takes into account realistic assessment of RHIC and CeC schedules, as well as the availability of the equipment and personnel. Below we summarize our proposed milestones and deliverables for both Phase I and Phase II. It is clear that Phase II plans are tentative and could be modified by our findings during phase one, but we do not expect them to change significantly.

Phase I, YR 1 milestones

Track 1 *Complete simulations of beam dynamic*
Propagate beam from the gun to the high-power dump
Evaluate beam quality for 2nC bunches
Complete simulations of 100 kW RF system

Track 2 *Upgrade cathode deposition and transport systems for GaAs*
Introduce GaAs cathode in the SRF gun
Design and build electron beam polarimeter

Track 3 *Develop and test reliable He condition technique*
Complete simulations and design of plasma processing system for CeC SRF gun

Phase I, YR 2milestones

Track 1 *Design and procure laser for Phase II 30-100 mA operations*
Optimize gun setting for generating maximum beam current
Complete design of the 100 kW RF system

Track 2 *Commission 780 nm circular polarized laser*
Install and commission Compton polarizer at CeC accelerator
Measure electron beam polarization

Track 3 *Complete studies of He condition technique*
Assemble the plasma processing system for the CeC SRF gun

Phase II milestones

Track 1 *Procure and install 100 kW RF system, Install high power beam dump with capacity of 100 kW and Upgrade of beam diagnostics*

Track 2 *Produce Super-Lattice GaAs with CsTe coating*, *test performance of these cathodes in the SRF gun and measure beam polarization*

Track 3 *Evaluate performance of the plasma processing system for CeC SRF gun*

Phase I, YR 1 deliverables

Track 1 *1 mA average electron beam current*
Data on lifetime and charge capacity of CsK_2Sb *photocathodes*
Upgraded laser system

Track 2 *Data on lifetime of CsTe coated GaAs photocathodes*
Compton polarimeter

Track 3 *Initial data on effectiveness of He conditioning*
Design of plasma processing system for CeC SRF gun

Phase I, YR 2 deliverables

Track 1 *3 mA average electron beam current*
Data on lifetime and charge capacity of CsK_2Sb *photocathodes*
Completed laser system
Design of 100 kW RF system

Track 2 *Polarized electron beam from SRF gum*
Electron beam polarization measurements

Track 3 *Complete data on effectiveness of He conditioning*
Plasma processing system for CeC SRF gun

Phase II, deliverables

Track 1 *30 to 100 mA average electron beam current*, *100 kW SRF gun system*
Data on lifetime and charge capacity of CsK_2Sb *photocathodes*

Track 2 *Polarized electron beam from SRF gum using super-lattice GaAS*
Electron beam polarization measurements

Track 3 *Data on effectiveness of plasma processing system for CeC SRF gun*

APPENDIX 1: BIOGRAPHICAL SKETCHES

Biographical Sketch for **Vladimir N. Litvinenko**

Education **Novosibirsk State University**, Russia, BS 1975
Novosibirsk State University, Russia, MS/Ph.D. in Physics, 1977
Institute for Nuclear Physics, **Novosibirsk**, Ph.D. in Physics and Mathematics, 1989

Appointments

Department of Physics and Astronomy, **Stony Brook University,** Stony Brook, NY,
Professor of Physics (2013-present)
Brookhaven Professor of Physics (2011-2013)
Adjunct Professor of Physics (2003 – 2011)
Center for Accelerator Science and Education, Director, (2008-present)

Brookhaven National Laboratory, Upton, NY (2003 –2013)
Senior Physicist (tenured in 2004), Collider-Accelerator Department
eRHIC Scientific Advisor the Chair, Collider-Accelerator Department (since 2016)
Leader of eRHIC design (2007-2016)
Deputy Head, Accelerator R&D Division (2009-2016), Collider-Accelerator Department
Head of Accelerator Physics Group (2004-2013), Collider-Accelerator Department
Deputy Director, NSLS II Accelerator Division (2006 – 2007)

Duke University, Physics Department, Durham, NC (1991- 2006),
Professor (Adjunct, 2004-2006), Associate Professor (1994-2004, tenured in 1999)
Assoc. Res. Professor (1991-1994)
Associate Director, Duke FEL Laboratory (1999- 2003)
Institute for Nuclear Physics, Novosibirsk, Russia (1975-1991)
Senior Scientist, Scientist, Research Associate, (1975-1991);
Project Leader, the OK-4/VEPP-3 storage ring UV FEL (1985-1991);

One hindered thirty refereed and hundreds of conference publications. Relevant publications:

- ✓ *High brightness CW electron beams from Superconducting RF photoemission gun, I. Petrushina, V.N. Litvinenko, Y. Jing, J. Ma, I. Pinayevet al., accepted for PRL*
- ✓ *Vladimir N. Litvinenko, Thomas Roser, Maria Chamizo-Llatas, High-energy high-luminosity e+e− collider using energy-recovery linacs, Phys. Lett. B Volume 804, 135394, (2020)*
- ✓ *Experimental Demonstration of Hadron Beam Cooling Using Radio-Frequency Accelerated Electron Bunches, A. V. Fedotov, Z. Altinbas, S. Belomestnykh, I. Ben-Zvi, …, V. Litvinenko, et al., Physical Review Letters* ***124****, 084801 (2020*
- ✓ *Precision control of gamma-ray polarization using a crossed helical undulator free-electron laser, J. Yan, J. M. Mueller, M. W. Ahmed, H. Hao, S. Huang, J. Li, Vladimir N. Litvinenko, P. Liu, S. F. Mikhailov, V. G. Popov, M. H. Sikora, N. A. Vinokurov, and Y.K. Wu, Nature Photonics, 2019*
- ✓ *Simulation studies of modulator for coherent electron cooling, J. Ma, X. Wang, G. Wang, Kwangmin Yu, R. Samulyak, and V. Litvinenko, Phys. Rev. Accel. Beams 21, 111001 (2018) https://journals.aps.org/prab/pdf/10.1103/PhysRevAccelBeams.21.111001*
- ✓ *Simulations of Coherent Electron Cooling with Two Types of Amplifiers, J. Ma, Gang Wang, V. Litvinenko,International Journal of Modern Physics A (IJMPA), Vol. 34 (2019) 1942029*
- ✓ *Mitigation of multipacting in 113 MHz superconducting RF photo-injector, I. Petrushina, V.N. Litvinenko, I. Pinayev, K. Smith, G. Narayan, F. Severino, Phys. Rev. Accel. Beams 21, 082001, 2018, https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.21.082001*
- ✓ *Design of a high-bunch-charge 112-MHz superconducting RF photoemission electron source, T. Xin, J. C. Brutus, Sergey A. Belomestnykh, I. Ben-Zvi, C.. Vladimir N. Litvinenko, et al.,, Review of*

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- ✓ *Experimental observation of suppressing CSR-Induced beam energy spread with shielding plates, V. Yakimenko, M. Fedurin, V. Litvinenko, A. Fedotov, D. Kayran, P. Muggli, Physical Review Letters **109**, 164802 (2012)*
- ✓ *Coherent Electron Cooling, Vladimir N. Litvinenko, Yaroslav S. Derbenev, Physical Review Letters 102, 114801 (2009) 4 pages, March 20, 2009, http://link.aps.org/abstract/PRL/v102/e114801*
- ✓ *Potential uses of ERL-based γ-ray sources*, V. N. Litvinenko, I. Ben-Zvi, D. Kayran, I. Pogorelsky, E. Pozdeyev, T. Roser, V. Yakimenko, IEEE Transactions on Plasma Science, Volume: 36, Issue: 4 , Part: 4, 2008, 1799 http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4599040
- ✓ *Parity Measurements of Nuclear Levels Using a Free-Electron-Laser generated γ-Ray Beam, N. Pietralla, Z. Berant, V.N. Litvinenkoet al.,, Physical Review Letters **88** (2002) 012502, http://prl.aps.org/pdf/PRL/v88/i1/e012502*
- ✓ *Gamma-ray Production in a Storage Ring Free Electron Laser, V.N. Litvinenko et al., Physical Review Letters, **78**, 24 (1997) 4569-4572, http://prl.aps.org/pdf/PRL/v78/i24/p4569_1*

Invited Talks - About one hundred eighty colloquia, invited talks and lectures

Synergistic Activities

- Chair, 2013 International Free Electron Laser Conference
- Chair, 2011 Particle Accelerator Conference, Scientific Program Committee
- Chair, 2000 International Free Electron Laser Conference
- Member, 2010, 2011 and 2012 IPACs, Organizing and Scientific Program Committees
- Reviewer for Physical Review Letters, Phys. Rev. B, PR AB, Proc. of the Royal Society, Journal of Physics, OIP, NIM A, IEEE Journal of Quantum Electronics and others.
- Reviewer for National Science Foundation and Department of Energy

Awards and Honors

- Brookhaven Science and Technology Award, 2011
- International FEL Prize, 2004
- Fellow of American Physical Society, 2003
- Academy of Science Award for Outstanding Contribution to FEL Science, Russia, 1989
- The Academy of Science Award and Golden Medal for best graduate research in Physics, 1977
- FEL Research Awards, Ministere de la Recherche et de la Technologie, France, 1991, 1993

Collaborators & Other Affiliations

- Member of CeC, eRHIC, LHeC, EuPRAXIA and FCC collaborations.
- Profs. T.Hemmick, A. Deshpande, P. Grannis (SBU), Drs. I. Ben-Zvi, I. Pinayev, T. Roser (BNL)
- Graduate advisors & postdoctoral sponsors: Profs. E. Perevedentsev and N.A. Vinokurov, Budker Institute of Nuclear Physics, Novosibirsk, Russia
- *Advisor for graduate students & postgraduate-scholars*: B.Burnham (University of Tennessee, Memphis, TN), K. Chalut (Oxford University, UK) A. Elizarov (Bank of America), L. Hammons, (BNL) Y. Hao (MSU), Y. Jing, D. Kayran (BNL), E. Longhi (Diamond Light Source, UK), K. Mihara (Sumimoto Heavy Ind, Japan), S.H. Park, (KAERI, Korea)), Irina Petrushina (SBU), I. Pinayev (BNL), V. Popik (BINP. Novosibirsk, Russia), S. Roychowdry (Boston Universtiry), T. Shaftan

(BNL), S. Webb, (Tech X copr. Boulder, Co), G. Wang (BNL), Y.K.Wu (Duke University

- *Currently is supervising three PhD students*: Nikhil Bachhawat, Kai Shih, and Yuan-Hui Wu.

Yichao Jing

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EDUCATION

Doctorate of Philosophy, Physics, August 2011
Indiana University Bloomington (IUB), Bloomington, IN
Advisor: Prof. Shyh-Yuan Lee

Bachelor of Science, Physics, Sept 2006
University of Science and Technology of China, Hefei, Anhui, China

RELATED RESEARCH EXPERIENCE

Physicist, Collider Accelerator Department, Brookhaven National Lab

- Design of an ultimate storage ring with natural emittance less than 10 picometer for future light source. Dynamic aperture (DA) optimization is carried out with nonlinear elements.
- Design of a Zigzag type bunch compressor with Coherent Synchrotron Radiation (CSR) compensation scheme, which reduces the emittance growth induced by CSR effect by an order of magnitude comparing to a traditional C-type bunch compressor.
- Study and propose various possible FEL operation modes based on the future eRHIC ERL and start-to-end simulation demonstrates good preservation of beam quality and high performance soft- and hard X-ray FELs.
- Study and simulate the evolution and saturation of the Green function in FEL for different wavelengths ranging from IR to X-ray.

RELATED PUBLICATIONS

- **Y. Jing**, Y. Hao, V.N. Litvinenko, "Bunch compressor design for potential FEL operation at eRHIC", Proceedings of IPAC 12 (2012)
- **Y. Jing**, V. N. Litvinenko, "Beam dynamics and performance of ERL-driven X-ray FEL", Proceedings of FEL 2012, (2012)
- **Y. Jing**, V. N. Litvinenko, "Bunch compressor design for CSR compensation", contributed talk, Future light source workshop 2012, VA
- **Y. Jing**, Y. Hao, V.N. Litvinenko, "Compensating Effect of the Coherent Synchrotron Radiation in Bunch Compressors", PRST-AB (2013)
- **Y. Jing**, V.N. Litvinenko, G. Wang, Y. Hao, "Simulation studies of FEL Green function and its saturation", contributed talk, FEL 2013, NY
- **Y. Jing**, V.N. Litvinenko, "ERL as FEL Driver", contributed talk, ERL 2015, Stony Brook, NY

SYNERGISTIC ACTIVITIES

- Design the bunch compressors for proposed ATF project upgrade.
- Participate in the commission of deflecting cavity at ATF beam line. Participate in an online

GUI development using ELEGANT at ATF.

- Design a zigzag chicane to compress electron bunch at ATF beamlines to reach sub-kA peak current beam operation.

COLLABORATORS

- Vladimir N. Litvinenko, Stony Brook University/Brookhaven National Lab.
- Igor Pinayev, Brookhaven National Lab
- Ji Qiang, Lawrence Berkley National Lab
- Gang Wang, Brookhaven National Lab

COMMITTEE SERVICES

Referee for journals: PRSTAB, NIMA, AOP, JQE
Reviewer for SBIR/STTR for FY2015, FY2016, FY2017, FY2018

MENTORING ACTIVITIES

Adjunct assistant professor at Stony Brook University physics department

Biographical Sketch for **Vyacheslav Yakovlev**

Education

Novosibirsk State University, Russia, BS/MS 1977
Institute for Nuclear Physics, **Novosibirsk**, Ph.D. in Physics and Mathematics, 1988

Appointments

Fermi National Accelerator Laboratory, Batavia, Il.

- Department Head, Senior Scientist(2012-present)
- Group leader, Senior Scientist (2009-2012)
- Senior scientist (2007 – 2009)

Facility for Rare Isotope Beams, Michigan State University, Lansing, USA

- Adjunct Professor of Accelerator Science (2017- present)

Omega-P, Inc., New Haven, CT, USA/Department of Physics, Yale University, New Haven, CT, USA

- Senior *Research Scientist (*1996 – 2007)

Budker Institute for Nuclear Physics (BINP), Novosibirsk, Russia

- Senior Scientist, Group leader (1992-1996)
- Senior Scientist, Scientist, Research Associate, (1977-1992).

Novosibirsk State Technical University

- Associate Professor (1994-1996)

Thirty five refereed papers; three hundred fifty conference publications; five patents, and tens of conference and workshop presentations including invited talks. Relevant publications:

✓ *P.N. Ostroumov, C. Contreras, A.S. Plastun, J. Rathke, T. Schultheiss, A. Taylor, J. Wei, M. Xu, T. Xu, Q. Zhao, I.V. Gonin,T. Khabiboulline, Y. Pischalnikov, V.P. Yakovlev, "Elliptical superconducting RF cavities for FRIB energy upgrade," Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 888, 21 April 2018, Pages 53–63.*

✓ *M.H. Awida, D. Passarelli, P. Berrutti, I. Gonin, S. Kazakov, T. Khabiboulline, J. Holzabauer, Th. Nicol, J. Ozelis, M. Parise, Y. Pischalnikov, O. Pronitchev, L. Ristori, G. Romanov, A. Rowe, W. Schappert, D. Sergatskov, N. Solyak, A. Sukanov, and V.P. Yakovlev, "Development of Low β Single-Spoke Resonators for the Front End of the Proton Improvement Plan-II at Fermilab," IEEE Transactions on Nuclear Science, Vol. 64, No. 9, September 2017, pp. 2450-2464.*

✓ *Ch. Densham, Frank Gerigh, J. Grillenberger, A. Lundmark, M. Seidel, M. Wohlmuther, V.P. Yakovlev, " The Energy Efficiency of Proton Driver Accelerators, " Editor Series on Accelerator Science, vol. XLIII, Inst. Of Electronic Systems, Warsaw 2017, ISBN 978-83-7814-615-5*

✓ *G. Kazakevich, V. Lebedev, V. Yakovlev, V. Pavlov, "**An Efficient Magnetron Transmitter for Superconducting Accelerators," Nucl. Instrum. Meth. A839 (2016) 43-51,** (2016-12-11)*

✓ *Karl Bane, Christopher Nantista, Chris Adolphsen, Tor Raubenheimer, Arun Saini, Nikolay Solyak, Vyacheslav Yakovlev, "Distribution of Heating from Untrapped HOM Radiation in the LCLS-II Cryomodules," Physics Procedia, Volume 79, 2015, Pages 13–20.*

✓ *A.Vostrikov, A. Sukhanov' V. Yakovlev, and N. Solyak, "Cumulative HOM Excitation and Transition Effects in LCLS-II," Physics Procedia, Volume 79, 2015, Pages 46–53.*

- ✓ *A. Lunin, I. Gonin, M. Awida, T. Khabiboulline, V. Yakovlev, A. Zholents, "Design of a Quasi-waveguide Multicell Deflecting Cavity for the Advanced Photon Source, "Physics Procedia, Volume 79, 2015, Pages 54-62.*

Synergistic Activities

- Chair, 2014, ICFA Workshop on High Order Modes in Superconducting Cavities
- Member, 2012-present, Program Committee of ICFA Workshop on High Order Modes in Superconducting Cavities
- Member, 2014-present, Program Committee of International Linear Accelerator Conference.
- Reviewer for PRST-AB, NIM, JAP, JPS, Int. Journal of Antenna and Propagation, and others.
- Reviewer for National Science Foundation and Department of Energy
- Member, 2009 – present, FNAL PhD Committee
- Chair, 2012-2016, FNAL PhD Committee
- Member, 2017-2019, Peoples Fellowship Committee.

Awards and Honors

- 1980 Award of BINP Scientific Council for the best graduate.
- 1994 International Science Foundation (ISF) Grant meant for the development of the high precision methods and computer codes for evaluation of SC RF cavities with high lossy HOM dumpers (ISF awards grants to the winner of a highly competitive selection to support extraordinary research in the former Soviet Union).

Collaborators & Other Affiliations

- Member of ILC, LHC, PIP II, LCLS II collaborations.
- Graduate advisors & postdoctoral sponsors: Prof. M.M. Karliner, Budker Institute of Nuclear Physics, Novosibirsk, Russia

Advisor for graduate students & postgraduate-scholars:

- D. Myakishev, M. Tiuniov, N. Mityanina (BINP), O. Danilov (Atomiton, Inc), A. Sokulin (GE), A. Grudiev (CERN), S. Schelkunov (Yale), A. Saini (FNAL).

Currently is supervising the PhD student:

- C. Cantreras-Martinez (MSU).

DR. MATTHEW POELKER

Dr. Matthew Poelker is the group leader of the Center for Injectors and Sources at Jefferson Lab where he has worked since 1994, with key responsibility being the maintenance and upgrade of the CEBAF spin polarized electron source. Areas of research interest include photoguns, spin polarized electron and positron beams, photocathodes, high voltage, drive lasers and vacuum. Recent focus has been the construction of a compact 10 MeV spin polarized accelerator for testing the HDIce polarized target, and development of high current electron guns that make magnetized beam. Before working at Jefferson Lab, Dr. Poelker was a post-doctoral assistant in the Medium Energy Physics group at Argonne National Lab where he worked on a laser-driven target of polarized hydrogen and deuterium gas.

Education and Training:

1992 Ph.D. Electrical Engineering, Northwestern University, Evanston, IL
1988 M.S., Electrical Engineering, Northwestern University, Evanston, IL
1983 B.S., Engineering Physics, University of Illinois, Champaign/Urbana, IL

Professional Experience:

1994 - present Senior Staff Scientist and Group Leader Center for Injectors and Sources, Thomas Jefferson National Accelerator Facility
1992 – 1994 Postdoctoral research associate, Physics Division, Argonne National Lab

Selected Publications:

1- C. Hernandez-Garcia, B. Bullard, J. Benesch, J. Grames, J. Gubeli, F. Hannon, J. Hansknecht, J. Jordan, R. Kazimi, G. A. Krafft, M. A. Mamun, M. Poelker, M. L. Stutzman, R. Suleiman, M. Tiefenback, Y. Wang, and S. Zhang ;A. Valerio Lizarraga ; R. Montoya Soto ;A. Canales Ramos ;G. Palacios-Serrano, S. Wijethunga, J. T. Yoskowitz *Compact −300kV dc inverted insulator photogun with biased anode and alkali-antimonide photocathode*", Phys. Rev. Accel. Beams **22**, 113401 (2019)
2- Xincun Peng, Zhidong Wang, Yun Liu, Dennis M. Manos, Matt Poelker, Marcy Stutzman, Bin Tang, Shukui Zhang, and Jijun Zou, "*Optical-Resonance-Enhanced Photoemission from Nanostructured GaAs Photocathodes*", Phys. Rev. Applied **12**, 064002 (2019)
3- Marcy L. Stutzman, Philip A. Adderley, Md. Abdullah A. Mamun, and Matt Poelker, "*Nonevaporable getter coating chambers for extreme high vacuum,*" J. Vac. Sci. Technol. A **36**, 031603 (2018)
4- M.A. Mamun, M. R. Hernandez-Flores, E. Morales, C. Hernandez-Garcia, and M. Poelker, "*Temperature Dependence of Alkali-Antimonide Photocathodes: Evaluation at Cryogenic Temperatures,*" Phys. Rev. Accel. Beams **20**, 103403 (2017)
5- Wei Liu, Matt Poelker, Xincun Peng, Shukui Zhang, and Marcy Stutzman, "*A comprehensive evaluation of factors that influence the spin polarization of electrons emitted from bulk GaAs photocathodes*", J. Appl. Phys., **122**, 035703 (2017)
6- Wei Liu, Yiqiao Chen, Wentao Lu, Aaron Moy, Matt Poelker, Marcy Stutzman, and Shukui Zhang, "*Record-level quantum efficiency from a high polarization strained GaAs/GaAsP superlattice photocathode with distributed Bragg reflector*", Appl. Phys. Lett. **109**, 252104 (2016)
7- D. Abbott, P. Adderley, A. Adeyemi, P. Aguilera, et,al. "*Production of Highly Polarized Positrons Using Polarized Electrons at MeV Energies*", Phys. Rev. Lett., 116, 214801 (2016)
8- C. Hernandez-Garcia, M. Poelker, and J. Hansknecht, "*High Voltage Studies of Inverted-geometry Ceramic Insulators for a 350 kV dc Polarized Electron Gun*", IEEE Transactions on Dielectrics and Electrical Insulation, Vol. **23**, No. 1; February 2016
9- M. BastaniNejad, A.A. Elmustafa, E. Forman, J. Clark, S. Covert, J. Grames, J. Hansknecht, C. Hernandez-Garcia, M. Poelker, and R. Suleiman, *"Improving the performance of stainless-steel DC*

high voltage photoelectron gun cathode electrodes via gas conditioning with helium or krypton." Nucl. Instr. And Meth. A **762**, (2014), pp.135-141

10- Md. Abdullah A. Mamun, Abdelmageed A. Elmustafa, Marcy L. Stutzman, Philip A. Adderley, Matthew Poelker, *"Effect of heat treatment and coatings on the outgassing rate of stainless steel chambers."* Journal of Vacuum Science and Technology A **32(2)**, (2014), pp.021604, 1-8

Awards, Honors, and Acknowledgement

- APS Fellowship, 2015 (nominated by the Division of Physics of Beams)
- E. O. Lawrence Award Recipient, 2011
- Member BNL C-AD R&D Machine Advisory Committee since 2015
- Member Super KEKB Accelerator Review Committee since 2014
- Member University of Chicago "Godparent" review committee, large area photodetector project managed by Prof. Henry Frisch
- Member of the International Spin Physics Committee since 2012

Collaborations

(i) Elmustafa, Abdelmageed and Baumgart, Helmut, Old Dominion University (student projects)
Gay, Tim, University of Nebraska-Lincoln (polarimetry, vortex beams)
Smedley, John, Brookhaven National Laboratory (photocathodes)
Bubble Chamber Collaboration, Medium Energy Physics Dept., Argonne National Lab (astrophysics measurements)
HDIce polarized target group at Jefferson Lab
Cultrera, Luca, Cornell University (photocathodes)
Paschke, Kent, University of Virginia and other parity violation experimenters
Rai Weiss and LIGO collaboration on vacuum topics
Ring EDM collaboration at COSY/Juelich (high voltage electrodes)
Numerous small businesses via the SBIR/STTR program

(ii) Graduate Advisors and Postdoctoral Sponsors (Total # of Advisors: 2)
Advisor: Prof. Prem Kumar, Northwestern University, Evanston, IL
Post-doctoral Advisor: Roy Holt, Argonne National Lab, IL

(iii) Dissertation Advisor (Total # of Students: 4)
James McCarter, Mahzad BastaniNejad, Abdullah A. Mamun, Wei Lui

BIOGRAPHICAL SKETCH

Sergey Belomestnykh
FNAL, PO Box 316, MS 316, Batavia, IL 60510-5011, (630) 840-5015, sbelomes@fnal.gov

Education and Training

Ph.D. Engineering Sciences, Budker Institute of Nuclear Physics, Novosibirsk, Russia, 1998.
M.S. Engineering Electrophysics, Novosibirsk State Technical University, Novosibirsk, Russia, 1981.

Research and Professional Experience

Fermi National Accelerator Laboratory (FNAL)

Chief Technology Officer (2015 – present)
Head of Applied Physics and Superconducting Technology Division, Fermilab

Stony Brook University, Department of Physics and Astronomy

Adjunct Professor of Physics (2011 – 2015, 2020 – present)
Brookhaven Professor of Physics (2015 – 2019)

Brookhaven National Laboratory

Physicist (2010 – 2015)
Head of SRF Group)2010 – 2015)

Cornell University, Laboratory for Elementary Particle Physics

Senior Research Associate (2000 – 2011)
CESR RF Group Leader (2000 – 2011)
Research Associate (1995 – 2000)

Budker Institute of Nuclear Physics

Various positions (Scientist, Engineer, Intern) (1981 – 1995)

Publications most closely related to the proposed project

1. S. Belomestnykh, "Superconducting radio-frequency systems for high-β particle accelerators," *Reviews of Accelerator Science and Technology* **5** (2012) 147-184.
2. S. Belomestnykh, "Survey of SRF guns," *Proc. 15th International Conference of RF Superconductivity*, Chicago, IL, July 25-29, 2011, pp. 23-26.
3. T. Xin, J. C. Brutus, S. Belomestnykh, I. Ben-Zvi, C. H. Boulware, T. L. Grimm, T. Hayes, V. N. Litvinenko, K. Mernick, G. Narayan, P. Orfin, I. Pinayev, T. Rao, F. Severino, J. Skaritka, K. Smith, R. Than, J. Tuozzolo, E. Wang, B. Xiao, H. Xie, A. Zaltsman, "Design of a high-bunch-charge 112-MHz superconducting RF photoemission electron source," *Review of Scientific Instruments* **87**, 093303 (2016).
4. S. Belomestnykh and J. Kirchgessner, "Superconducting single cell cavities," in *Handbook of Accelerator Physics and Engineering* (2nd Edition), World Scientific (2013) pp. 683-687.
5. S. Belomestnykh and H. Padamsee, "Cavities for Accelerators," in *Applied Superconductivity. Handbook on Devices and Applications*, edited by P. Seidel, Wiley-VCH, Berlin (2015).
6. V. D. Shemelin and S. A. Belomestnykh, *Multipactor in accelerating cavities,* Springer (2020), in press.
7. S. Belomestnykh and V. Shemelin, "Multipacting-free transitions between cavities and beam-pipes," *Nuclear Instruments and Methods in Physics Research A* **595**, pp. 293-298 (2008).
8. A. Fedotov, Z. Altinbas, S. Belomestnykh, et al., "Experimental demonstration of hadron beam cooling using radio-frequency accelerated electron bunches," *Phys. Rev. Let.* **124**, 084801 (2020).
9. S. Belomestnykh, I. Bazarov, V. Shemelin, J. Sikora, K. Smolenski, and V. Veshcherevich, "Deflecting cavity for beam diagnostics at Cornell ERL injector," *Nuclear Instruments and Methods in Physics Research A* **614** pp. 179-183 (2010).

10. I. Pinayev, V. N. Litvinenko, J. Tuozzolo, J. C. Brutus, S. Belomestnykh, et al., "High-gradient high-charge CW superconducting RF gun with CsK_2Sb photocathode," arXiv:1511.05595 [physics.acc-ph] (2015).

Honors and Awards:

Fellow, American Physical Society, 2015

2015 *IEEE NPSS Particle Accelerator Science and Technology Award* "for achievements in the science and technology of RF and SRF for particle accelerators."

Senior Member, IEEE, 2014.

Synergistic Activities:

- Teaching at Stony Brook University, including a graduate-level course "RF Superconductivity for Accelerators" (2011) and courses on RF superconductivity at USPAS (2009, 2011, 2013, 2017).
- Chair, The 56th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs (ERL2015).
- Member of the Tesla Technology Collaboration (TTC) Executive Committee and Collaboration Board, 2015 – present.
- Member of the APS/DPB Wilson Prize Selection Committee (2018-2019), and APS/DPB Fellowship Committee (2017-2018).
- Member of numerous organizing, program, advisory and review committees.

<u>Identification of Potential Conflicts of Interest or Bias in Selection of Reviewers</u>

Collaborators and Co-editors:

E. Aschenauer[2], M. Awida[13], M. Bai[2], I. Bazarov[5], I. Ben-Zvi[2], M. Blaskiewicz[2], C.H. Boulware[7], J. M. Brennan[2], J. C. Brutus[2], A. Burill[14], R. Calaga[8], O. Capatina[8], B. Dunham[14], R. Ehrlich[5], A. Fedotov[2], J.L. Fernández-Hernando[4], D. Frolov[13], D. Gassner[2], A. Grassellino[13], T. L. Grimm[7], C. Gulliford[5], Y. Hao[2,9], H. Hayano[15], D. Holmes[2], E. Jensen[8], R. Kaplan[5], D. Kayran[2], M. Kelly[6], Y. Li[5], Z. Li[14], V. N. Litvinenko[2,11], X. Liu[5], P. McIntosh[4], G. McIntyre[2], K. Mernick[2], S. Michizono[15], M. Minty[2], G. Narayan[2], A. Neumann[13], P. Orfin[2], H. Padamsee[5], C. Pai[2], B. Parker[2], S. Pattalwar[4], I. Petrushina[11], R. Pilipenko[13], I. Pinayev[2], S. Posen[13], T. Rao[2], A. Romanenko[13], T. Roser[2], P. Quigley[5], J. Sears[5], F. Severino[2], V. Shemelin[5], J. Skaritka[2], K. Smith[2], R. Than[2], M. Tigner[5], R. Todd[2], D. Trbojevic[2], E. Tsentalovich[10], N. Tsoupas[2], J. Tuozzolo[2], S. Verdu-Andres[2], V. Veshcherevich[5], E. Wang[2], A. Wheelhouse[4], Q. Wu[2], Y. Yamamoto[15], S. Xiao[2], H. Xie[2], T. Xin[2], W. Xu[2], A. Zaltsman[2], Z. Zhao[2], S. Zorzetti[13].

1 – AES, 2 – BNL, 3 – TRIUMF, 4 – ASTeC, 5 – Cornell University, 6 – ANL, 7 – Niowave, 8 – CERN, 9 – FRIB, 10 – MIT-Bates, 11 – Stony Brook University, 12 – JLAB, 13 – FNAL, 14 – SLAC, 15 – KEK.

Graduate and Postdoctoral Advisors: None.

Graduate and Postdoctoral Advisees: *C. Marques, BNL, NY – M.S. from Stony Brook in 2014*.

Dr. Joseph Grames (JLab)

Dr. Joseph Grames is a Senior Staff Scientist in the Accelerator Division and Deputy Group Leader of the Center for Injectors and Sources. He received his PhD in 2000 from the University of Illinois at Urbana-Champaign for work performed at Jefferson Lab to characterize a sensitivity of the electron beam polarization to the optics of the CEBAF accelerator. After earning his PhD he joined the Electron Gun Group, where his work over the past 19 years has focused on extending the capabilities of polarized electron photo-guns and precision polarimetry. He serves as project leader, manager or supervisor for programs aimed at improving the capabilities or performance of accelerator operations. In these roles he routinely communicates and leads efforts requiring broad functional knowledge of accelerator operations, beam dynamics and accelerator systems. He presently manages the polarized electron injector at CEBAF, to ensure the simultaneous beams delivered to the Experimental Halls meet the requirements necessary to successfully complete the Nuclear Physics program. His recent research activities have focused on developing new beam sources, such as the generation of spin polarized positron beams and the development of a vortex electron beam that carries both spin and orbital angular momentum. He enjoys collaborating with other laboratories and working with students.

Education and training:
2015 DOE Strategic Laboratory Leadership, Booth School of Business, University of Chicago
2002 USPAS, R. Davidson "*High Intensity Beams*", Univ. of California Los Angeles
2000 Ph.D. Physics, University of Illinois Urbana-Champaign
1997 USPAS, S.Y. Lee "*Accelerator Physics*", University of California Berkeley
1994 M.S. Physics, University of Illinois Urbana-Champaign
1994 USPAS, H. Wiedemann "*Accelerator Physics*", University of Indiana
1992 DOE Student Intern, I. Ben-Zvi, Brookhaven National Laboratory, NY
1992 B.S. Physics and Minor Mathematics, Stevens Institute of Technology, NJ

Professional Experience:
2017 – present Senior Staff Scientist, Accelerator Division, Jefferson Laboratory
2016 – present Adjunct Research Faculty, Department of Physics, Old Dominion University
2008 – 2017 Staff Scientist III, Accelerator Division, Jefferson Laboratory
2004 – present Deputy Group Leader, Center for Injectors & Sources, Jefferson Laboratory
2003 – 2008 Staff Scientist II, Accelerator Division , Jefferson Laboratory
1999 – 2003 Staff Scientist I, Accelerator Division, Jefferson Laboratory

Selected Publications:
[1] D. Abbott et al., "Production of Highly Polarized Positrons Using Polarized Electrons at MeV Energies", Phys. Rev. Lett., 116, 214801 (2016).

[2] B. Roberts, F. Hammon, M. M. Ali, E. Forman, J. Grames, R. Kazimi, W. Moore, M. Pablo, M. Poelker, A. Sanchez, and D. Speirs, "Harmonically resonant cavity as a bunch-length monitor", Phys. Rev. ST Accel. Beams, **19**, 052801 (2016).

[3] R. Mammei, R. Suleiman, J. Feingold, P. A. Adderley, J. Clark, S. Covert, J. Grames, J. Hansknecht, D. Machie, M. Poelker, T. Rao, J. Smedley, J. Walsh, J. McCarter, *M. Ruiz-Osés, "Charge Lifetime Measurements at High Average Current Using a K2CsSb Photocathode inside a DC High Voltage Photogun", Phys. Rev. ST Accel. Beams, **16**, 033401 (2013).

[4] J. Grames, R. Suleiman, P. A. Adderley, J. Clark, J. Hansknecht, D. Machie, M. Poelker, and M. L. Stutzman, "Charge and fluence lifetime measurements of a DC high voltage GaAs photogun at high average current", Phys. Rev. ST Accel. Beams **14**, 043501 (2011).

[5] P. A. Adderley, J. Clark, J. Grames, J. Hansknecht, K. Surles-Law, D. Machie, M. Poelker, M. L. Stutzman, and R. Suleiman, "Load-locked dc high voltage GaAs photogun with an inverted-geometry ceramics insulator", Phys. Rev. ST Accel. Beams **13**, 010101 (2010).

Synergistic Activities:
2017 Chair, International Workshop on Physics with Positrons at Jefferson Lab
2015 Convener, Workshop on Intense Electron Beams, Cornell University
2013 – present Journal Referee, Physical Review Accelerators and Beams
2009 – present Reviewer, Department of Energy SBIR/STTR Program
2008 Organizer, Polarized Electron Sources & Polarimeters, Jefferson Laboratory

Collaborators and co-editors:
D. Dutta (Louisiana State University), T. Gay (University of Nebraska), C. Hyde (Old Dominion University), R. P. Johnson (Muons, Inc., Batavia, IL), A. Kawasuso (National Institutes for Quantum and Radiological Science and Technology, Japan), B. McMorran (University of Oregon), B. Roberts (University of New Mexico), Y. Taira (National Institute of Advanced Industrial Science and Technology, Japan), F. Selim (Bowling Green State University), R. Talman (Cornell University), E. Voutier (National Institute of Nuclear and Particle Physics, France), K. Paschke (University of Virginia), K. Aulenbacher (Johannes-Gutenberg Universität Mainz), M. Fukuda (High Energy Accelerator Research Organization, Tsukuba, Japan), M. Kuriki (Hiroshima University, Higashiiroshima, Japan), C. Hernandez-Garcia, B. Bullard, J. Benesch, J. Gubeli, F. Hannon, J. Hansknecht, J. Jordan, R. Kazimi, G. A. Krafft, M. A. Mamun, M. Poelker, M. L. Stutzman, R. Suleiman, M. Tiefenback, Y. Wang, S. Zhang, (Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA); A. Valerio Lizarraga (Facultad de Ciencias Físico-matemáticas Universidad Autónoma de Sinaloa, Culiacán 80010, Mexico); R. Montoya Soto (Departamento de Física, Universidad de Guanajuato, León 37150, Mexico); A. Canales Ramos (Universidad Nacional Autónoma de Mexico, Mexico City 04510, Mexico)

Graduate and Postdoctoral Advisors and Advisees:
Mr. J. Yoskowitz, Old Dominion University, USA (advisee: PhD expected 2021)
Mr. G. Palacios, Old Dominion University, USA (advisee: PhD expected 2020)
Dr. M. J. McHugh, George Washington University (advisee: PhD awarded 2016)
Dr. A. Adeyemi, Hampton University, USA (advisee: PhD awarded 2016)
Dr. J. Dumas, Joseph Fourier University, France (advisee: PhD awarded 20111)
Dr. D. H. Beck, University of Illinois at Urbana-Champaign, USA, (graduate advisor)
Dr. C. K. Sinclair, Thomas Jefferson National Accelerator Facility, USA, (graduate advisor)

Dr. Riad Suleiman (JLab)

EMPLOYMENT

- *JEFFERSON LABORATORY:*
  2018 - present: Senior Staff Scientist, Accelerator Division.
  2012 - 2018: Staff Scientist III, Accelerator Division.
  2007 - 2012: Staff Scientist II, Accelerator Division.
- *VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY:*
  2005 - 2007: Research Scientist.
  2004 - 2005: Postdoctoral Research Associate.
- *MASSACHUSETTS INSTITUTE OF TECHNOLOGY:*
  2002 - 2004: Senior Postdoctoral Research Assoc. at the Laboratory for Nuclear Science.
  1999 - 2002: Postdoctoral Research Associate at the Laboratory for Nuclear Science.

EDUCATION and TRAINING

- *KENT STATE UNIVERSITY:* September 1993 - October 1999. Ph.D. student at the Center for Nuclear Research of the Physics Department. Doctor of Philosophy degree in Physics awarded in December 1999. Thesis project (Adviser: Professor Makis Petratos): "Measurement of the Electric and Magnetic Elastic Structure Functions of the Deuteron at Large Momentum Transfers".
- *YARMOUK UNIVERSITY, JORDAN:* February 1990 - May 1993. Bachelor of Science degree in Physics, 1993.

MAJOR RESEARCH ACTIVITES

- Technical Liaison of Accelerator Division to MOLLER Project. Responsible for polarized beam delivery and representing Accelerator Division in Jefferson Lab Director and Office of Science (Department of Energy) project reviews.
- Project Manager of Laboratory Directed Research and Development (LDRD, 2016-2018) funded proposal ($1M) on the "Generation and Characterization of Magnetized Bunched Electron Beam from DC Photogun for JLEIC Cooler".
- Co-spokeperson of a proposal approved by Jefferson Lab Program Advisory Committee: Measurement of $^{16}O(\gamma,\alpha)^{12}C$ with a bubble chamber and Bremsstrahlung beam.
- Contact person of a proposal approved by Jefferson Lab Program Advisory Committee to search for evidence of two-photon exchange: Measurement of Recoil Polarizations in Elastic Electron-Proton Scattering.

PATENTS

- Jefferson Lab Inventor Disclosure (April 2017): "Non-invasive RF Cavity to Measure Beam Magnetization".

SYNERGISTIC ACTIVITIES

- 2019 - present: Adjunct Professor at Old Dominion University.
- 2019 - present: Division Conferences and Publications Committee, Jefferson Laboratory.
- 2018 - present: Journal Referee, Physical Review Accelerators and Beams.
- 2018: Paper Reviewer, 9th International Particle Accelerator Conference (IPAC'18), Vancouver, British Columbia, Canada.
- 2013 - present: Reviewer, Department of Energy's SBIR/STTR Program.

Recent Publications in Peer-Reviewed Journals:

- *Compact -300 kV dc inverted insulator photogun with biased anode and alkali-antimonide photo-cathode.* C. Hernandez-Garcia *et al.*, Phys. Rev. Accel. Beams 22, 113401, (2019).
- *Comparing proton momentum distributions in A=2 and 3 nuclei via* ^{2}H, ^{3}H *and* $^{3}He(e,e'p)$ *measurements.* R. Cruz-Torres *et al.*, Phys. Lett. B 797, 134890 (2019).
- *Precision measurement of the weak charge of the proton.* D. Androi´c *et al.*, Nature 557, 207 (2018).
- *JLab Measurements of the* ^{3}He *Form Factors at Large Momentum Transfers.* A. Camsonne *et al.*, Phys. Rev. Lett. 119, 162501 (2017).
- *Production of Highly Polarized Positrons Using Polarized Electrons at MeV Energies.* D. Abbott *et al.*, Phys. Rev. Lett. 116, 214801 (2016).
- *The Qweak experimental apparatus.* T. Allison *et al.*, Nucl. Instr. and Meth. A 781, 105 (2015).

Collaborators and co-authors

C. Hernandez-Garcia, B. Bullard, J. Benesch, J. Grames, J. Gubeli, F. Hannon, J. Hansknecht, J. Jordan, R. Kazimi, G. A. Krafft, M. A. Mamun, M. Poelker, M. L. Stutzman, R. Suleiman, M. Tiefenback, Y. Wang, and S. Zhang (Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA); A. Valerio Lizarraga (Facultad de Ciencias Físico-matemáticas Universidad Autónoma de Sinaloa, Culiacán 80010, Mexico); R. Montoya Soto (Departamento de Física, Universidad de Guanajuato, León 37150, Mexico); A. Canales Ramos (Universidad Nacional Autónoma de Mexico, Mexico City 04510, Mexico)

Graduate and Postdoctoral Advisors and Advisees:

Dr. M. Petratos, Kent State University, USA, (graduate advisor)
Dr. M. Pitt, Virginia Tech, USA, (postdoctoral advisor)
Dr. S. Kowalski, Massachusetts Institute of Technology, USA, (postdoctoral advisor)
Ms. S. Wijethunga, Old Dominion University, USA (advisee: Ph.D. expected 2021)

Erdong Wang
Brookhaven National Laboratory

Education and Training:

Peking University, Ph. D. in nuclear technology and application, 2012

Research and Professional Experience:

2019-present:	Scientist, Electron source development lead scientist Collider Accelerator Department (C-AD), BNL, Upton
2017-2019:	Associate Scientist, Electron source development lead scientist Collider Accelerator Department (C-AD), BNL, Upton
2015-2017:	Assistant Scientist, C-AD, BNL, Upton
2013-2015:	Goldhaber Distinguished Fellow, C-AD, BNL, Upton
2012-2013:	Research Assistant, C-AD, BNL, Upton

Publications (Selected 10 papers):

1. Rahman, O., **Wang, E.D. ,** Ben-Zvi, I., Biswas, J., Skaritka, J. Increasing charge lifetime in dc polarized electron guns by offsetting the anode. *Physical Review Accelerators and Beams* 22 (8), 083401 (2019).
2. Liu, W., **Wang, E.D. ,** Monte Carlo modeling of thing GaAs photocathodes. *Journal of Applied Physics* 126 (7), 075706 (2019).
3. A. V. Fedotov, Z. Altinbas, S. Belomestnykh, I. Ben-Zvi, M. Blaskiewicz, M. Brennan, D. Bruno, C. Brutus, M. Costanzo, A. Drees, W. Fischer, J. Fite, M. Gaowei, D. Gassner, X. Gu, J. Halinski, K. Hamdi, L. Hammons, M. Harvey, T. Hayes, R. Hulsart, P. Inacker, J. Jamilkowski, Y. Jing, J. Kewisch, P. Kankiya, D. Kayran, R. Lehn, C. J. Liaw, V. Litvinenko, C. Liu, J. Ma, G. Mahler, M. Mapes, A. Marusic, K. Mernick, C. Mi, R. Michnoff, T. Miller, M. Minty, G. Narayan, S. Nayak, L. Nguyen, M. Paniccia, I. Pinayev, S. Polizzo, V. Ptitsyn, T. Rao, G. Robert-Demolaize, T. Roser, J. Sandberg, V. Schoefer, C. Schultheiss, S. Seletskiy, F. Severino, T. Shrey, L. Smart, K. Smith, H. Song, A. Sukhanov, R. Than, P. Thieberger, S. Trabocchi, J. Tuozzolo, P. Wanderer, **E. Wang**, G. Wang, D. Weiss, B. Xiao, T. Xin, W. Xu, A. Zaltsman, H. Zhao, and Z. Zhao Experimental Demonstration of Hadron Beam Cooling Using Radio-Frequency Accelerated Electron Bunches *Phys. Rev. Lett.* 124, 084801(2020).
4. Wang, E., Ben-Zvi. I., Chang, X., Wu, Q., Rao, T., Smedley, J., Kewisch, J., Xin, T. Systematic study of hydrogenation in a diamond amplifier. *Physical Review Special Topics Accelerators and Beams 14,* 061302 (2011).
5. Wang, E., Ben-Zvi, I., Rao, T., Dimitrov, D.A., Chang, X., Wu, Q., Xin, T. Secondary-electron emission from hydrogen terminated diamond: Experiments and model. *Physical Review. Special Topics Accelerator and Beams* 14, 111301 (2011).
6. Wang, E., Rao, T., Ben-Zvi, I. Enhancement of photoemission and post processing of K_2CsSb photocathode using excimer laser. *Physical Review Special Topics: Accelerators & Beams*, 17, 023402 (2014).
7. Dimitrov, D.A., Smithe, D., Cary, J.R., Ben-Zvi, I., Rao, T., Smedley, J., Wang, E. Modeling electron emission and surface effects from diamond cathodes. *Journal of Applied Physics* 117, 055708 (2015).
8. Xie, H., Ben-Zvi, I., Rao, T., **Wang, E.** Experimental Measurements and Theoretical model of the cryogenic performance of bi-alkali photocathode and Characterization with Monte Carlo Simulation *Physical Review Special Topics: Accelerators & Beams* 19, 103401 (2016).
9. Xin, T., Brutus, J. C., Belomestnykh, S.A., Ben-Zvi, I., Boulware, C. H., Grimm, T. L., Hayes, T., Litvinenko, V.N., Mernick, K., Narayan, G., Orfin, P., Pinayev, I., Rao, T., Severino, F., Skaritka, J., Smith, K., Than, R., Tuozzolo, J. , **Wang, E.,** Xiao, B., Xie, H., and Zaltsman, A. Design of a

High bunch charge 112MHz Superconducting RF photoemission electron source *Rev. Sci. Instrum.* 87, 093303 (2016).

10. Tian, Y., Gu, G., Johnson, P., Rao, T., Tsang, T., **Wang, E.** Topological insulator for the generation of electron beams *Appl. Phys. Lett.* 113, 233504 (2018).

Synergistic Activities:

- PI on BNL LDRD proposal surface charge limit on super lattice GaAs
- Co-PI on polarized electron source project at FOA 17
- Co-PI Diamond amplify for lasertron STTR
- Co-PI RF sputtering coating of electron transparent materials for photocathode encapsulation BES SBIR phase I
- DOE NP & BES SBIR program reviewer; BES FOA program reviewer; HP SBIR & accelerator stewardship program reviewer
- Journal reviewer for Chemistry of Materials, Journal of Applied Physics, AIP Advances, Results in Physics, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
- Energy Recovery Linac (ERL) 2017 and 2019: Scientific program committee, Injection section convener
- EIC ecooling 2019 workshop: Organization committee and Scientific program committee, EIC ecooling 19 workshop, High brightness, low noise electron beams for cooling, section Convener, Session Chair
- 2019-present IEEE/PASS student thesis award committee
- 2019 NSLS-II UED/UEM development review committee
- 2013 The Local Organization student award committee of FEL

Honors and Awards:

- Goldhaber Distinguished Fellowship Award, 4/2013 – 11/2015. Brookhaven National Laboratory, Collider-Accelerator Department
- Doctoral Student Award, 2011, IEEE NPSS 2011 Accelerator Science and Technology

Identification of Potential Conflicts of Interest or Bias in Selection of Reviewers:

Collaborators and Co-editors:

Dr. Dimitre Dimitrov, Tech-X

Dr. John Smedley, LANL

Graduate and Postdoctoral Advisors and Advisees:

PI's Postdoctoral advisor: Dr. Ilan Ben-Zvi, Stony Brook University/Brookhaven National Laboratory

PI serving as Ph.D dissertation advisor committee: Dr. Zihao Ding

Igor Pinayev

EDUCATION

- Doctor of Philosophy in Physics (1987), Moscow Institute of Physics and Technology, Russia.
- Master of Science in Physics (1984), Moscow Institute of Physics and Technology, Russia.

PROFESSINAL EXPERIENCE

- Collider-Accelerator Division, Brookhaven National Laboratory, Physicist (since Nov 2011)
- NSLS-II Project, Brookhaven National Laboratory, Physicist (Nov 2006 – Dec 2011)
- NSLS, Brookhaven National Laboratory, Physicist (May 2004 – Nov 2006)
- Free Electron Laser Laboratory, Physics Department, Duke University (June 1998 – May 2004)
  1. Assistant Research Professor (September 2002 – May 2004)
  2. Sr. Research Scientist (June 1999 – August 2002)
  3. Research Scientist (June 1997 - June 1999)
- Budker Institute of Nuclear Physics, Novosibirsk, Russia (April 1988 - June 1997)
  1. Senior Research Scientist (1992 – 1998)
  2. Research Scientist (1990 – 1992)
  3. Junior Research Scientist (1988 – 1990)

PROFESSIONAL SERVICES

- Reviewer for PR-AB and Nuclear Instruments and Methods (A)
- Member of Local Organizing Committee for National Synchrotron Radiation Conferences, Budker Institute of Nuclear Physics, Novosibirsk, Russia, 1988, 1994
- Secretary of the 2nd Asian Symposium on Free Electron Lasers (AFEL'95), Novosibirsk, Russia, 1995
- Member of Local Organizing Committee of the 22nd Free Electron Laser Conference (FEL2000), Durham, NC, USA, 2000
- Member of the Program Committee of the Synchrotron Radiation Instrumentation Conference, Synchrotron Radiation Center, Madison, Wisconsin, 2001

HONORS

- The USSR Academy of Sciences Award for pioneering research in the area of free electron lasers (1989).

INVITED TALKS

- "Coherent Electron Cooling Diagnostics: Design Principles and Demonstrated Performance", IBIC'18
- "High Charge High Current Beam from BNL 113 MHz Gun", ERL'17
- "Status of Proof-of-principle of Coherent Electron cooling Experiment at BNL", COOL'17
- "Using ERLs for Coherent Electron Cooling", ERL'15
- "Beam Current Monitoring with ICT and BPM Electronics", ERL'15
- "Coherent Electron Cooling PoP Experiment", EIC'14

Biographical Sketch for
Irina Petrushina, Research Scientist

Education **The State University of New York at Stony Brook,** NY, USA, PhD in Physics, 2019.
NRNU Moscow Engineering-Physics Institute (MEPhI), Russia, MS in Physics, 2013.

Internships **Fermi National Accelerator Laboratory,** IL, USA, Intern, 2013.
DESY, Germany, Summer Student, 2012.

Appointments

Stony Brook University, Stony Brook, NY
Research Scientist (2019-present).
NRNU Moscow Engineering-Physics Institute (MEPhI), Moscow, Russia
RF engineer (2010-2014).

Scholarships and grants

Student grant to attend the 8th International Particle Accelerator Conference, 2017.
President of Russian Federation Scholarship for Education Abroad, 2012.
O.A. Valdner Scholarship for educational excellency, 2012.

Products

- ✓ *Plasma-Cascade Instability—theory, simulations and experiment, V.N. Litvinenko, G. Wang, Y. Jing, D. Kayran, J. Ma, I. Petrushina, et.al. In preparation for publication Phys. Rev. Let., arXiv preprint arXiv:1902.10846.* https://arxiv.org/pdf/1902.10846.pdf
- ✓ *Solenoid – Universal Tool for Measuring Beam Parameters, I. Pinayev, Y. Jing, D. Kayran, V.N. Litvinenko, K. Mihara, I. Petrushina, K. Shih, G. Wang In preparation for publication Phys. Rev. Accel. Beams, arXiv preprint arXiv:1902.09619.* https://arxiv.org/abs/1902.09619.pdf
- ✓ *High brightness CW electron beams from Superconducting RF photoemission gun, I. Petrushina, V.N. Litvinenko, I. Pinayev, K. Mihara, Y. Jing, D. Kayran, J. Ma, et.al. In preparation for publication Phys. Rev. Let., arXiv preprint arXiv:2003.05920.* https://arxiv.org/pdf/2003.05920.pdf
- ✓ *Mitigation of multipacting in 113 MHz superconducting RF photo-injector, I.Petrushina, V.N. Litvinenko, I. Pinayev, K. Smith, G. Narayan, F. Severino Phys. Rev. Accel. Beams 21, 082001 – Published 13 August 2018.* https://journals.aps.org/prab/pdf/10.1103/PhysRevAccelBeams.21.082001
- ✓ *Comparison of HOM damping techniques for 800 MHz single cell superconducting cavities, Ya.V. Shashkov, N.P. Sobenin, I. Petrushina, M. Zobov Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, vol. 767, pp. 271–280, Elsevier, 2014.* https://www.sciencedirect.com/science/article/pii/S0168900214010079

Talks

- ✓ *High Brightness CW Electron Beams from Superconducting RF Photoinjector*. Center for Bright Beams seminar at NIU, Chicago, IL, USA, 2020.
- ✓ *The Chilling Recount of an Unexpected Discovery: First Observations of the Plasma-Cascade Instability in the Coherent Electron Cooling Experiment*. Meeting of the Division of Particles & Fields of the APS, Boston, MA, USA, 2019.
- ✓ *High Brightness CW Electron Beams from Superconducting RF Photoinjector*. North American Particle Accelerator Conference, Lansing, MI, USA, 2019.

- ✓ *The Chilling Recount of an Unexpected Discovery: First Observations of the Plasma-Cascade Instability in the Coherent Electron Cooling Experiment*. Early Career Research Symposium, BNL, Upton, NY, USA, 2019.
- ✓ *The Chilling Recount of an Unexpected Discovery: First Observations of the Plasma-Cascade Instability in the Coherent Electron Cooling Experiment*. Women in STEM Research Showcase, Stony Brook, NY, USA, 2019.

Collaborators & Other Affiliations

1) *Member of the CeC collaboration and Laser-Wakefield Acceleration collaboration at Stony Brook University.*

Martina Martinello, PhD

Education and Training:

- Illinois Institute of Technology: PhD, Physics, 2016
- University of Padua: Post-lauream 1st level master, Surface Treatment for Industrial Applications, 2014
- University of Padua: Master Degree, Material Science, 2013
- University of Padua: Bachelor Degree, Material Science, 2011

Research and Professional Experience:

- Peoples Fellow, Associate Scientist (Aug 2017 – current position) – FNAL
  - Managerial activities: Deputy head of SRF Measurement and Research department, Leader of the Material Analysis group
  - Project activities: Deputy CAM for LCLS-II HE, responsible of Cavity Processing and Testing for PIP-II 650 MHz cavities
  - Main R&D activities: Leading the effort to develop a plasma processing for suppressing the field emission in-situ in LCLS-II cryomodules, N-doping optimization in HB and LB 650 MHz cavities, microscopic investigation of flux trapping sites in Niobium cavities
- Research Associate (Jan 2017 – Aug 2017) – FNAL
  - Study of the field dependent surface resistance contributions as a function of the cavity resonance frequency. Extension of the nitrogen doping and other state-of-the-art treatments on 650 MHz, 2.6 GHz and 3.9 GHz cavities
  - Leading the effort to develop a plasma processing for suppressing the field emission in-situ in LCLS-II cryomodules
- Research Assistantship (Sep 2014 – Dec 2016) – FNAL
  - Research on Q-factor maximization of SRF cavities. Detailed study on i) magnetic flux expulsion during the superconducting transition in vertical and horizontal test and ii) surface resistance contributions analysis on cavities with different surface treatments.
- Post-lauream 1st Level Master Thesis Internship (Jan 2014 – Sep 2014) – LNL-INFN
  - Research on the minimization of the Kapitza resistance between niobium and copper in thin film Nb/Cu 6 GHz accelerating cavities
- Master's degree Thesis Internship (Mar 2013 – Dec 2013) – LNL-INFN
  - Research on the improvement of the SRF properties of Nb/Cu thin film 6 GHz accelerating cavities
- CERN Summer Student (May 2013 – Sep 2013)- CERN
  - Research on the SRF properties of niobium thin film sputtered on copper Quarter Wave Resonators for the HIE-ISOLDE project

Awards:

- IEEE PAST Doctoral Student Award (2019) "For contributions to physical understanding of limiting factors in SRF cavities"

Publications:

- B. Giaccone, P. Berrutti, A. Grassellino, **M. Martinello**, D. Gonnella, G. Lanza, M. Ross Plasma processing to reduce field emission in lcls-II 1.3 GHz SRF cavities, Proc. Of SRF 2019, Dresden, Germany https://doi.org/10.18429/JACoW-SRF2019-FRCAB7

- P. Berrutti , B. Giaccone , **M. Martinello** , A. Grassellino, T. Khabiboulline, M. Doleans , S. Kim, D. Gonnella, G. Lanza, and M. Ross "Plasma ignition and detection for in-situ cleaning of 1.3 GHz 9-cell cavities", J. Appl. Phys. 126, 023302 (2019); https://doi.org/10.1063/1.5092235
- P. Berrutti, A. Grassellino, T. Khabiboulline, **M. Martinello**, M. Doleans, S. Kim, K. Tippey, D. Gonnella, G. Lanza, M. Roset al., "Update on Plasma Processing R&D for LCLS-II", Proc. Of IPAC 2018, Vancouver, Canada https://accelconf.web.cern.ch/ipac2018/papers/wepmk012.pdf
- K.E. Tippey, R. Afanador, M. Doleans, S. Kim, J.D. Mammosser, C. McMaha, **M. Martinello** "Improving the work function of nitrogen-doped niobium surfaces for srf cavities by plasma processing", Proc. of IPAC 2018, Vancouver, BC, Canada https://doi.org/10.18429/JACoW-IPAC2018-THPAL065
- **M. Martinello**, M. Checchin, A. Romanenko, A. Grassellino, S. Aderhold, S. K. Chandrasekeran, O. Melnychuk, S. Posen, and D. A. Sergatskov "Field-Enhanced Superconductivity in High-Frequency Niobium Accelerating Cavities", Phys. Rev. Lett. 121, 224801 (2018) https://doi.org/10.1103/PhysRevLett.121.224801
- A. Grassellino, A. Romanenko, Y. Trenikhina, M. Checchin, **M. Martinello**, O.S. Melnychuk, S. Chandrasekaran, D.A. Sergatskov, S. Posen, A.C. Crawford, S. Aderhold, D. Bice "Unprecedented quality factors at accelerating gradients up to 45 MVm−1 in niobium superconducting resonators via low temperature nitrogen infusion", Supercond. Sci. Technol. 30, 094004 (2017) https://iopscience.iop.org/article/10.1088/1361-6668/aa7afe/meta
- M. Checchin, **M. Martinello**, A. Grassellino, A. Romanenko, J. Zasadzinski "Frequency dependence of trapped flux sensitivity in SRF cavities", Supercond. Sci. Technol. 30, 034003 (2017) https://doi.org/10.1063/1.5016525
- **M. Martinello**, A. Grassellino, M. Checchin, A. Romanenko, O. Melnychuk, D.A. Sergatskov, S. Posen, J. Zasadzinski "Effect of interstitial impurities on the field dependent microwave surface resistance of niobium", App. Phys. Lett. 109, 6 (2016) https://doi.org/10.1063/1.4960801
- M. Checchin, **M. Martinello**, A. Romanenko, A. Grassellino, D.A Sergatskov, S. Posen, O. Melnychuk "Quench-Induced Degradation of the Quality Factor in Superconducting Resonators", Phys. Rev. Applied 5, 044019 (2016) https://doi.org/10.1103/PhysRevApplied.5.044019
- **M. Martinello**, M. Checchin, A. Grassellino, A.C. Crawford, O. Melnychuk, A. Romanenko, D.A. Sergatskov "Magnetic flux studies in horizontally cooled elliptical superconducting cavities", J. App. Phys. 118, 5 (2015) https://doi.org/10.1063/1.4927519

Synergistic Activities:

- Co-convener of the: "Accelerator Science and Technology" working group, all-scientist retreat, Fermilab (2018), "Surface resistance and non-equilibrium" session, topical TTC Meeting, Fermilab (Dec 2017), "Cold test diagnostics and novel processing methods" working group, TTC Meeting, Vancouver (Jan 2019);
- Reviewer for: Accelerator Stewardship of DOE HEP, SBIR-STTN, Physical Review Accelerator and Beams, Journal of Applied Physics;
- Student mentorship: Bianca Giaccone (Italian Summer Student Program, 2017; Master Thesis Internship, 2018; PhD student 2019-present), Chiara Marcora (Helen Edward Student Internship, 2019);
- Early-career executive committee member of the APS-DPB (01/2019-12/2020) and co-editor of APS-DPB newsletter (01/2019-12/2020);
- Young Professional Member-at-Large of the IEEE NPSS PAST (01/2019-12/2020).

Biographical Sketch for **Sergey Kazakov**

Education **Novosibirsk State University**, Russia, BS 1978
Novosibirsk State University, Russia, MS in Physics, 1980
Graduate University for Advanced Studies, SOKENDAI, Japan, Ph.D. in Physics, 2003.

Appointments

Fermi National Accelerator Laboratory, Batavia, IL,
Senior Engineering Physicist (2010-present)

High Energy Accelerator Research Organization, KEK, Tsukuba, Japan,
Associate Professor, (2005-2010)
Foreign Visiting Scientist (2002-2005)

Brunch of Budker Institute of Nuclear Physics, Protvino, Russia,
Senior Research Scientist, head of group (1995-2002)
Senior Research Scientist, (1990-1995)

Budker Institute of Nuclear Physics, Novosibirsk, Russia,
Research Scientist, (1988-1990)
Junior Research Scientist, (1986-1988)
Engineer, (1984-1988)
Senior Laboratory Assistance, (1982-1984)
Graduated Employee, (1980-1982)

More than hundred of conference publications. Relevant publications:

- ✓ *S. Kazakov, "New Possible Configuration of 3.9 GHz Coupler ",17th International Conference on RF Superconductivity, Whistler, September 13-18, 2015.*
- ✓ *S. Kazakov, et al, "Testing of 325 MHz Couplers at Test Stand in Resonance Mode",17th International Conference on RF Superconductivity, Whistler, September 13-18, 2015.*
- ✓ *S. Kazakov, et al, "Status of 325 MHz Main Couplers for PXIE", LINAC2014, Geneva, Switzerland*
- ✓ *S. Kazakov, et al, "Design of 162.5 MHz CW Main Coupler for RFQ", LINAC2014, Geneva, Switzerland.*
- ✓ *S. Kazakov, et al, "Test Stand for 325 MHz Power Couplers", LINAC2014, Geneva, Switzerland.*
- ✓ *Terechkine, M. Chen, I.V. Gonin, S. Kazakov, T.N. Khabiboulline, L. Ristori, G.V. Romanov, "CW Room Temperature Re-buncher for the PIP-II Linac Front End", IPAC2014, Dresden, Germany,*
- ✓ *P.V. Avrakhov, A. Kanareykin, R.A. Kostin, Y. Xie , S. Kazakov, N. Solyak, V.P. Yakovlev, "Design of 3-Cell Travelling Wave Cavity for High Gradient Test", SRF2013, Paris, France*
- ✓ *S. Kazakov, et al, " Multipactor Simulation in SC Elliptical Shape Cavities", IPAC2012, New Orleans, Louisiana, USA*
- ✓ *S. Kazakov, et al, "How to Eliminate a Copper Coating and to Increase an Average Power of Main Coupler", SRF2011, Chicago, IL USA*
- ✓ *S. Kazakov, et al, "High Power Couplers for the Project X Linac", SRF2011, Chicago, IL USA*

Synergistic Activities

- Design and testing high power couplers for SC accelerators.
- Design and testing high power multiplication systems for accelerators.
- Design and testing high-power RF vacuum windows.
- Design and testing high power vacuum amplifiers.

Timergali N Khabiboulline
Fermi National Laboratory, Batavia, IL 60510, USA

Education and Training

Moscow Institute of Physics and Technology	Engineering Physics	M.S.	1985

Research and Professional Experience

2012 – Pres. Head of Group of RF Develpment and Tests, SRF Department, Technical Division, Engineer IV, Fermi National Laboratory, Batavia, IL, USA

2001 – 2012 Guest Engineer, Engineer II, Engineeer III, Group of RF Develpment and Tests, SRF Department, Technical Division, Fermi National Laboratory, Batavia, IL, USA

1993 - 2001 Visiting Scientist at DESY, Hamburg, Germany.

1985 - 2001 Research Scientist, INR, Moscow, Russia

Publications

1. N. Solyak, E. Cullerton, E. Harms, B. Hartsell, J. Holzbauer, J. Einstein-Curtis, T. Khabiboulline, A. Lunin, O.Napoly, Y. Pischalnikov, R. Stanek, G. Wu, "Performance of the First LCLS-II Cryomodules. Issues and Solutions". IPAC2018, Vancouver, BC, Canada
2. A. Solopova, D. Forehand, A. Palczewski, Jefferson Lab, 23608, T. Khabiboulline, "LCLS-II Cavity Higher Order Modes Coupler Tuning Optimization and Challenges at Jefferson Lab", LINAC2018, Beijing, China.
3. D. Gonnella, S. Aderhold, A. Burrill, E. Daly, K. Davis, A. Grassellino, C. Grimm, T. Khabiboulline, F. Marhauser, O. Melnychuk, A. Palczewski, S. Posen, M. Ross, D. Sergatskov, and K. Wilson, "RF Performance of Nitrogen-Doped Production SRF Cavities for LCLS-II", IPAC2017, Copenhagen, Denmark
4. R. Kephart, B. Chase, I. Gonin, A. Grassellino, S. Kazakov, T. Khabiboulline, S. Nagaitsev, R. Pasquinelli, S. Posen, O. Pronitchev, A. Romanenko, V. Yakovlev, S. Biedron, S. Milton, N. Sipahi, S. Chattopadhyay and P. Piot, "Compact Accelerators for Industry & Society", SRF2015, Whistler, BC, Canada
5. T.N. Khabiboulline , I.V. Gonin, C.J. Grimm, A. Lunin, T.H. Nicol, V.P. Yakovlev, "Mechanical Optimization of High Beta 650 MHz Cavity for Pulse and CW Operation of PIP-II Project," 17th International Conference on RF Superconductivity, Whistler, September 13-18, 2015.
6. G. Romanov, P. Berrutti, T.N. Khabiboulline, "Simulation of Multipacting in SC Low Beta Cavities at FNAL," IPAC 2015, May 3-8, Richmond, VA, USA.
7. A. Lunin, T.N. Khabiboulline, N. Solyak, V.P. Yakovlev, "Development of a Button BPM for the LCLS-II project," IBIC2014, Monterey, CA, USA.
8. I. Gonin, T. Khabiboulline, A. Lunin, O. Prokofiev, N. Solyak, V. Yakovlev, "TTF-III Coupler Modification for CW Operation," LINAC2014, Geneva, Switzerland.
9. I. Terechkine, T.N. Khabiboulline, D.A. Sergatskov, "Performance Degradation of a Superconducting Cavity Quenching in Magnetic Field," SRF2013, Paris, France.
10. T.N. Khabiboulline, P. Berrutti, V.A. Lebedev, A. Lunin, T.H. Nicol, J.-F. Ostiguy, T.J. Peterson, L. Ristori, A. Saini, N. Solyak, V.P. Yakovlev, ","IPAC2013, Shanghai, China.

Identification of Potential Conflicts of Interest or Bias in Selection of Review

Collaborators and Co-Editors – Z. Conway, M. Kelly, J. Kerby, A. Nassiri, P. Ostroumov, A. Zholents (ANL); D. Li, L. Doolittle, J. Byrd, J. Staples (LBL); C. Adolphsen, C.D. Nantista, S. Tantawi, V. Dolgashov, M. Ross (SLAC); M. Champion (SNS); W-D. Moeller, D. Kostin (DESY); C. Reece, E. Daly, F. Marhauser (JLAB); J. Delaen (ODU); M. Liepe, G.H. Hoffstaetter, (Cornell University); C.H. Boulware, T. Grimm; A. Kanareykin (Euclid LLC).

Jun Ma
Email: jma1@bnl.gov
Tel: (631)344-2628
Brookhaven National Laboratory
Collider-Acceleator Department, Bldg. 911B
Upton, NY 11973

Education

Doctor of Philosophy, **Stony Brook University**, Stony Brook, NY
Major: Applied Mathematics and Statistics

Bachelor of Science, **Fudan University**;
Major: Information and Computing Science

Experience

Assistant Scientist, **Brookhaven National Laboratory**
Nov. 2019 – Present

- Participate in the operations of the Coherent electron Cooling experiments. Develop various operation tool-kits for the experiment.
- Simulate the newly discovered plasma cascade instability, and explore the usage of the instability as the amplifier for Coherent electron Cooling. Perform detailed simulation study of the plasma cascade amplifier.
- Take shifts in the Low Energy RHIC electron Cooling project, and contribute to the demonstration of ion cooling with bunched electron beam.

Research Associate, **Brookhaven National Laboratory**
Oct. 2017 – Nov. 2019

- Build numerical models for Coherent electron Cooling experiments. Design and develop software to simulate particles' interactions to assist the academic research.
- Analyze simulation results with appropriate statistical methods. Create reports based on the data analysis of simulation results to better understand physical phenomena.
- Coordinate with Collider Accelerator Department scientists, provide predictions for experiments, suggest ways of improvement.

Post-Doctoral Associate, **Stony Brook University**
Jun. 2017 – Sep. 2017

- Perform particle-in-cell simulations for the modulator and kicker sections of coherent electron cooling, conduct free electron laser simulations using software GENESIS for the amplifier section simulation.
- Calculate the beam dynamics and the particle trajectories in the coherent electron cooling experiments.
- Develop software to control the beam's orbit during the RHIC Run-17.

Research Assistant, **Stony Brook University**
Jan. 2014 - May 2017

- Observe and analyze trends of charged particles' motions in electromagnetic fields through modeling to better assist academic research.
- Estimate and compare possible circumstances in solving electromagnetic fields and electrostatic fields numerically and improve code to ensure the accuracy and effectiveness for various experiments.

- Periodically report to advisor about simulations results of beam dynamics in electromagnetic fields and electrostatic fields. Suggest ways of applications, including coherent electron cooling.

Publications

- J. Ma, X. Wang, G. Wang, K. Yu, R. Samulyak, and V. Litvinenko. "Simulation studies of modulator for coherent electron cooling." Physical Review Accelerators and Beams 21. 11 (2018): 111001.
- V.N. Litvinenko, G. Wang, D. Kayran, Y. Jing, J. Ma, and I. Pinayev. "Plasma-cascade micro-bunching amplifier and coherent electron cooling of a hadron beams." arXiv preprint arXiv:1802.08677 (2018).
- V.N. Litvinenko, G. Wang, Y. Jing, D. Kayran, J. Ma, I. Petrushina, I. Pinayev, and K. Shih. "Plasma-Cascade Instability-theory, simulations and experiment." arXiv preprint arXiv:1902.10846 (2019).
- J. Ma, G. Wang, and V. Litvinenko. "Simulations of coherent electron cooling with two types of amplifiers." International Journal of Modern Physics A (2019): 1942029.

Patrick Inacker

9 Eastview Drive, 11789 Sound beach, NY USA

Education and Training:

Bachelor of Science, Physics (2014) at RWTH-Aachen University, Germany

Thesis: "Studies on point-selective ablation used for form correction of fused silica with CO2 laser radiation"

Master of Science, Physics (2016) at RWTH-Aachen University, Germany

Thesis at Townes laser Institute, CREOL, Orlando, FL USA

"Investigation of the effects of system noise on the performance of the first optical parametric amplification stage of the HERACLES laser system"

Research and Professional Experience:

Staff (Optical) Engineer (Jul.2016 – today)

- Responsible for the EIC Large Area Cathode gun drive laser design and construction at Stony Brook University (2018 – today)
- 24/7 Operational support throughout the Accelerator run (2016-today)
- Responsible for design, construction of the CeC experiment drive laser (2017)
- Responsible for the LEReC and CeC free space laser transport systems, part of the original design team (2016- today)

Laser Group Deputy Leader, Instrumentation Division, Collider-Accelerator Department (oct. 2018 – today)

Publications:

"Design of the 2-stage laser transport for the Low Energy RHIC electron Cooling (LEReC) DC Photogun", NAPAC2019; P. Inacker-Mix†, L. Nguyen, S. Bellavia, A. Curcio, A.V. Fedotov, W. Fischer, D. Gassner, J. Jamilkowski, P. Kankiya, D. Kayran, R. Lehn, R. Meier, T. Miller, M. Minty, S. Nayak, L. Smart, C. Spataro, B. Streckenbach, A. Sukhanov, J. Tuozzolo, Z. Zhao Brookhaven National Laboratory, 11973 Upton, NY, USA

Synergistic Activities:

none

Identification of Potential Conflicts of Interest or Bias in Selection of Reviewers:

Collaborators and Co-editors: NA

Graduate and Postdoctoral Advisors and Advisees:

none

Gang Wang, PI

Education:

Ph.D. Physics 2008
State University of New York at Stony Brook,
Stony Brook, NY (USA)
Research Advisor: Ilan Ben-Zvi
Thesis Title: "Coherent Electron Cooling and Two Stream Instabilities due to Electron Cooling"

M.A. Physics 2001
Peking University, Beijing, P.R. China
Research Advisor: Ze-Sen Yang

B.S. Physics 1998
Sichuan University, Chengdu
Sichuan Province, P.R. China

Research and Professional Experience:

Staff Physicist 2010 – Present
Collider-Accelerator Department
Brookhaven National Laboratory, Upton, NY

Postdoctoral-Research Associate 2008-2010
Collider-Accelerator Department
Brookhaven National Laboratory, Upton, NY

Teaching

Adjunct Associate Professor 2016-present
Department of Physics and Astronomy, Stony Brook University, New York

Publications.

1. G. Wang and M. Blaskiewicz, 'The dynamics of ion shielding in an anisotropic electron plasma', Physical Review E, 78 (2008) 026413
2. S. Webb, G. Wang and V.N. Litvinenko, 'Three-dimensional model of small signal free electron lasers', Physical Review Special Topics: Accelerators and Beams, 14 (2011) 051003
3. S. Webb, G. Wang and V.N. Litvinenko, 'Free-electron laser growing modes and their bandwidths', Physical Review Special Topics: Accelerators and Beams, 15 (2012), 080701
4. G. Wang, V.N. Litvinenko and S. Webb, 'Counting 1D free electron laser growing modes in the presence of space charge', Physical Review Special Topics: Accelerators and Beams, 15 (2012) 120701

5. G. Wang, M. Blaskiewicz and V.N. Litvinenko, ‘Influence of longitudinal space charge fields on the modulation process of coherent electron cooling’, Physical Review Special Topics: Accelerators and Beams, 17 (2014) 101004

6. V.N. Litvinenko and G. Wang, ‘Compensating tune spread induced by space charge in bunched beams’, Physical Review Special Topics: Accelerators and Beams, 17 (2014) 114401

7. J. Ma, X. Wang, G. Wang, K. Yu, R. Samulyak, V. Litvinenko, ‘Simulation studies of modulator for coherent electron cooling’, Physical Review Accelerators and Beams, 21 (2018) 111001

8. V.N. Litvinenko, G. Wang, D. Kayran, Y. Jing, J. Ma, I. Pinayev, ‘Plasma-Cascade micro-bunching Amplifier and Coherent electron Cooling of a Hadron Beams’, arXiv preprint arXiv:1802.08677, (2018).

9. J. Ma, G. Wang and V.N. Litvinenko, ‘Simulation of coherent electron cooling with two types of amplifiers’, International Journal of Modern Physics A, 34 (2019) 194209

10. G. Wang, ‘Evolution of ion bunch profile in the presence of longitudinal coherent electron cooling’, Physical Review Accelerators and Beams, 22 (2019) 111002

Synergistic Activities:

1. I served as Scientific Committee Chair for ICFA mini-workshop CeC 2019 and as Convener for EIC Hadron Cooling Workshop 2019.

2. Since 2008, I have been a regular reviewer for peer-reviewed journals such as PRAB and NIM (Nuclear Instruments and Methods). I also reviewed a couple of SBIR proposals for DOE.

3. I have been invited to give talks at multiple conferences:

‘Influence of e-beam Parameters on Coherent electron Cooling’, invited at the 3rd International Particle Accelerator Conference (IPAC’12) (2012).

‘Advanced Theoretical Aspects of CeC’, invited at International Workshop on Accelerator Science and Technology for Electron-Ion Collider (EIC’14) (2014)

‘Developing Analytical and Simulation Tools for a Coherent Electron Cooling System’, invited at the 11th International Workshop on Beam Cooling and Related Topics (COOL’17) (2017)

‘CeC Theory and 3D Simulations’, invited at EIC Hadron Cooling Workshop (2019)

APPENDIX 2: CURRENT AND PENDING SUPPORT

Vladimir N Litvinenko

Current Support:

Grant, NSF, PHY-1415252, Principle Investigator
Title "Center for Accelerator Science and Education at Stony Brook University"
Funding Source: National Science Foundation
Location: Stony Brook University
Duration: FY 2014-2017
Total funds requested: $700,000
Person-Mos. per year committed: 1 month

Abstract. We propose to establish an unique NSF-supported advanced accelerator physics research and education program at Stony Brook University, New York. The proposed 3-year program will be carried at the Center for Accelerator Science and Education. We propose to systematically attack an unique challenge in modern accelerator: physics of enhanced electron cooling in circular high-energy hadron- and lepton-colliders.

DOE (HEP) Award DE-SC0014043
Funding Source: Dept. of Energy (Office of Science, High Energy Physics Program)
Title: CO_2-laser-driven GeV wakefield accelerators
Total Amount Requested: $1,100,000
Award Period: 6/1/2019-5/31/2022
Person-Mos. per year committed: one month (summer)

Abstract. Modern laser wake-field accelerators have achieved GeV-scale electron beams with very low transverse emittance. But they produced "accelerating bubbles" with prohibitively small sizes (~ 30 μm, e.g. a width of a human hair) unsuitable for external injection and difficult to characterize and control. Proposed research will consist of the following inter-related elements: (a) the ATF CO_2 laser, one of the world's most powerful CO_2 lasers, will drive bubble-regime wakes in a stable, repeatable plasma that will be custom-built for the research; (b) we will implement advanced holographic and tomographic plasma diagnostic techniques to visualize the internal structure and evolution of the bubble on each shot (c) we will generate electron bunches from the ATF linear accelerator suitable for injecting in such "accelerating bubbles".

Pending: DOE (HEP)

Funding Source: Dept. of Energy (Office of Science, High Energy Physics Program)
Title: **Compressing FACET-II e-beam to hundreds of kA (this proposal)**
Total Amount Requested: **$848,733**
Award Period: 6/1/2020-5/31/2023
Person-Mos. per year committed: 1 months
Abstract: The goal of this research will be a development of a novel bunch compressor for FACET-II capable of compressing electron bunches to 200 kA peak current (and beyond) while preserving beam quality. We propose to use already designed FACET-II compressor to test predicting power of our simulations for extreme beam compression. The proposed work will yield the comprehensive design of bunch compressor for FACET-II operation with low emittance beams having hundreds of kA peak current. The design will be supported by experimentally bench-marked simulation and possible application of generated beams. There is no significant overlap with this proposal

Funding Source: Dept. of Energy (Office of Science, High Energy Physics Program)
Title: Application Title: **High transformer ratio CW dielectric wakefield accelerator**
Total Amount Requested: $690,312
Award Period: 6/1/2020-5/31/2023
Person-Mos. per year committed: 1 months
Abstract: The goal of this research is demonstration of a high transformer ratio wakefield acceleration and experimental study of the dielectric wakefield accelerating structure operating at CW regime. This will include, but will not be limited, to beam dynamics study, heat load control and charging mitigation of DWA structures at high repetition rate. The driver for the DWA will be an SFR accelerator previously used for Coherent Electron Cooling experiments. There is no significant overlap with this proposal

CURRENT AND PENDING SUPPORT
DR. Matthew Poelker (JLAB)

Dr. Matthew Poelker is supported by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177, currently at 1 FTE

CURRENT AND PENDING SUPPORT
Yichao Jing

Support: ☒ Funded ☐ Pending
Sponsor or Source of Funding: Department of Energy-Office of Nuclear Physics
Award Number or Identifying Number: KB0202011
Title of the award or activity: RHIC Collider-Accelerator Operations
Award period (either actual or expected): FY2020 and Ongoing
The number of person-months per year to be devoted to the project: 12

Pending: DOE (HEP), Principle investigator

Funding Source: Dept. of Energy (Office of Science, High Energy Physics Program)
Title: **Compressing FACET-II e-beam to hundreds of kA**
Total Amount Requested: **$848,733**
Award Period: 6/1/2020-5/31/2023
Person-Mos. per year committed: 1 months
Abstract: The goal of this research will be a development of a novel bunch compressor for FACET-II capable of compressing electron bunches to 200 kA peak current (and beyond) while preserving beam quality. We propose to use already designed FACET-II compressor to test predicting power of our simulations for extreme beam compression. The proposed work will yield the comprehensive design of bunch compressor for FACET-II operation with low emittance beams having hundreds of kA peak current. The design will be supported by experimentally bench-marked simulation and possible application of generated beams. There is no significant overlap with this proposal

CURRENT AND PENDING SUPPORT
Dr. Vyacheslav Yakovlev (Fermilab)

Dr. Vyacheslav Yakovlev is supported by Fermi Research Alliance (FRA) , LLC under U.S. DOE Contract No DE-AC02-07CH11359, currently at 1 FTE

Investigator: Martina Martinello
Support: ☒ Funded ☐ Pending
Sponsor or Source of Funding: Department of Energy-Office of High Energy Physics
Award Number or Identifying Number: LAB 19-2069
Title of the award or activity: Development of High Performance Medium Velocity Superconducting Elliptical Cavities for Hadron Linacs
Award period (either actual or expected): FY2019
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $85K
The number of person-months per year to be devoted to the project: 1/2
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research: identify any overlaps and synergies with the proposed research: Optimize processing parameters for medium-beta elliptical 644 MHz 5-cell cavities (for potential FRIB upgrades) in order to maximize performance in terms of Q-factor and accelerating gradient.

Investigator: Martina Martinello
Support: ☐ Funded ☒ Pending
Sponsor or Source of Funding: Department of Energy-Office of Nuclear Physics
Award Number or Identifying Number: LAB 20-2310
Title of the award or activity: Development of in-situ plasma treatment for 650 MHz cryomodules
Award period (either actual or expected): FY2021 and 2022
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $877,339
The number of person-months per year to be devoted to the project: 2.5
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research: identify any overlaps and synergies with the proposed research: Optimize processing parameters for medium-beta elliptical 644 MHz 5-cell cavities (for potential FRIB upgrades) in order to maximize performance in terms of Q-factor and accelerating gradient.

Investigator: Robert Kephart, Charles Thangaraj
Support: ☒ Funded ☐ Pending
Sponsor or Source of Funding: ERDC
Award Number or Identifying Number:

Title of the award or activity: Improved Pavement Processes using Compact Superconducting Radio-Frequency (SRF) Electron Accelerators
Award period (either actual or expected): FY2017 – FY2020
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $2,000,000
The number of person-months per year to be devoted to the project: 12
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research:

Investigator: Thomas Kroc
Support: ☒ Funded ☐ Pending
Sponsor or Source of Funding: DOE-NNSA
Award Number or Identifying Number:
Title of the award or activity: Technology Roadmap for High-power X-ray source for Medical Device Sterilization
Award period (either actual or expected): FY2019 – FY2020
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $500,000
The number of person-months per year to be devoted to the project: 12
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research:

Investigator: Ram Dhuley
Support: ☒ Funded ☐ Pending
Sponsor or Source of Funding: DOE-HEP Stewardship
Award Number or Identifying Number:
Title of the award or activity: Design and demonstration of an economical SRF structure for Continuous Wave (CW), high-energy, Megawatt-class beams
Award period (either actual or expected): FY2019 – FY2021
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $370,000
The number of person-months per year to be devoted to the project: 12
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research:

CURRENT AND PENDING SUPPORT
Sergey Belomestnykh

Dr. Belomestnykh's salary is supported by Fermi National Accelerator Laboratory, where Dr. Belomestnykh serves as Chief Technology Officer and Head of Applied Physics and Superconducting Technology Division.

Support: **X** Current | Pending | Submission Planned in Near Future | Transfer of Support

Project/Proposal Title: **ADVANCED ACCELERATOR TECHNOLOGY**
Source of Support: **DEPARTMENT OF ENERGY**
Total Award Amount: **$60,000** Total Award Period Covered: **01-Jun-2019 to 31-May-2020**
Location of Project: **FNAL**
Person-Months Per Year Committed to the Project. Cal: 0 Acad: Sumr:

Abstract

The superconducting radio-frequency (SRF) acceleration technology together with high precision acceleration field control technology, high precision orbit measurement and control technology, are the key technologies for future next generation of accelerators for High Energy Physics and has extended to other areas: Nuclear Physics, Basic Energy Sciences, etc. This research program covers all these important technologies to be used in an advanced accelerator.

Support: **X** Current | Pending | Submission Planned in Near Future | Transfer of Support

Project/Proposal Title: **EARNEST COURANT TRAINEESHIP IN ACCELERATOR SCIENCE & ENGINEERING**
Source of Support: **DEPARTMENT OF ENERGY**
Total Award Amount: **$88,114** Total Award Period Covered: **01-Sep-2019 to 31-Aug-2024**
Location of Project: **FNAL**
Person-Months Per Year Committed to the Project. Cal: 0 Acad: Sumr:

Abstract

This proposal is submitted by a consortium of Stony Brook (SBU) and Cornell Universities (CU) in collaboration with Brookhaven National Laboratory (BNL) and Fermi National Accelerator Laboratory (FNAL). We propose to establish a workforce development program in Accelerator Science and Engineering on basis of already well-established educational centers – the Center for Accelerator Science and Education (CASE) at SBU and the Cornell Laboratory for Accelerator-based Science and Education (CLASSE) – and their unprecedented access to large and medium accelerators, superconducting RF accelerators and related research, high power RF system engineering and large liquid helium cryogenic systems at BNL and FNAL.

Support: Current | **X** Pending | Submission Planned in Near Future | Transfer of Support

Project/Proposal Title: **ADVANCED ACCELERATOR TECHNOLOGY**
Source of Support: **DEPARTMENT OF ENERGY**
Total Award Amount: **$90,000** Total Award Period Covered: **01-Jun-2020 to 31-May-2021**
Location of Project: **FNAL**
Person-Months Per Year Committed to the Project. Cal: 0 Acad: Sumr:

Abstract

The superconducting radio-frequency (SRF) acceleration technology together with high precision acceleration field control technology, high precision orbit measurement and control technology, are the key technologies for future next generation of accelerators for High Energy Physics and has extended to other areas: Nuclear Physics, Basic Energy Sciences, etc. This research program covers all these important technologies to be used in an advanced accelerator.

Support: Current **X** Pending Submission Planned in Near Future Transfer of Support

Project/Proposal Title: **SUPERCONDUCTING RF ELECTRON GUN**

Source of Support: **DEPARTMENT OF ENERGY**

Total Award Amount: **$300,000** Total Award Period Covered: **01-Sep-2020 to 31-Aug-2022**

Location of Project: **FNAL**

Person-Months Per Year Committed to the Project. Cal: 0 Acad: Sumr:

Abstract

High-current low-emittance CW electron beams are of great importance both for existing and future DOE facilities, medical, industrial and home-land security applications, and beyond. Such beams are indispensable for nuclear and high-energy physics in fixed target and collider experiments, cooling high energy hadron beams, generating CW beams of monoenergetic X-rays (in FELs) and γ-rays (in Compton sources), high-power EUV beams for manufacturing the next generation of microchips, border cargo inspection, to mention few. Polarization of electrons in these beams provides extra value by opening new set of observables and frequently improving the data quality by boosting signal to background ratio. The CW super-conducting radiofrequency (SRF) electron gun is one of the most advanced, but also one of the most challenging, technologies promising to deliver such beams. We propose an upgrade to the unique operational CW SRF facility installed at RHIC facility (BNL) by adding the high-current and the polarized beam capabilities. Our 1.25 MeV SRF gun, built as part of the Coherent electron Cooling (CeC) project, had demonstrated sustained CW operation with CsK_2Sb photocathodes generating electron bunches with record low transverse emittances and record high charge per bunch exceeding 10 nC. The cathodes survive many months of continuous operation. Nevertheless, the average beam current, determined by the needs of the CeC project, is limited to about 100 microamperes. We propose to extend the capabilities of this system towards average current of 100 milliampere in two steps: increasing the current 30-fold at each step. The goal of this R&D is to demonstrate reliable long-term operation of the high-current low-emittance CW SRF guns.

CURRENT AND PENDING SUPPORT
Martina Martinello

Investigator: Martina Martinello
Support: ☒ Funded ☐ Pending
Sponsor or Source of Funding: Department of Energy-Office of High Energy Physics
Award Number or Identifying Number: LAB 19-2069
Title of the award or activity: Development of High Performance Medium Velocity Superconducting Elliptical Cavities for Hadron Linacs
Award period (either actual or expected): FY2019
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $85,000

The number of person-months per year to be devoted to the project: 1/2
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research: Optimize processing parameters for medium-beta elliptical 644 MHz 5-cell cavities (for potential FRIB upgrades) in order to maximize performance in terms of Q-factor and accelerating gradient. Identify any overlaps and synergies with the proposed research: No overlap with the proposed research.

Investigator: Martina Martinello
Support: ☐ Funded ☒ Pending
Sponsor or Source of Funding: Department of Energy-Office of Nuclear Physics
Award Number or Identifying Number: LAB 20-2310
Title of the award or activity: Development of in-situ plasma treatment for 650 MHz cryomodules
Award period (either actual or expected): FY2021 and 2022
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $877,339
The number of person-months per year to be devoted to the project: 2.5
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research: development of a plasma treatment capable to mitigate field emission in-situ in 650 MHz cryomodules. Identify any overlaps and synergies with the proposed research: No overlap with the proposed research.

Investigator: Anna Grassellino, Martina Martinello and others
Support: ☐ Funded ☒ Pending
Sponsor or Source of Funding: Department of Energy
Award Number or Identifying Number: DE-FOA-0002253
Title of the award or activity: NQI Center Proposal – Superconducting Quantum Materials and Systems Center (SQMS)
Award period (either actual or expected): FY2020 - FY2025
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $125,000,000
The number of person-months per year to be devoted to the project: 3
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research: development of a superconducting quantum materials and system center. Identify any overlaps and synergies with the proposed research: No overlap with the proposed research.

CURRENT AND PENDING SUPPORT

Erdong Wang, is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics (KB020201-1), in his role of supporting accelerator R&D and accelerator operations at BNL's RHIC complex. This is currently at .95 FTE.

Current and Pending Support
Investigator: Erdong Wang
Support: ☒ Funded ☐ Pending
The award period (start date – end date): 11/21/2019 – 4/20/2020
Sponsor or Source of Funding: STI Optronics, Inc
Award Number or Identifying Number: Army STTR 19.B Program, Solicitation No. A19B-T004 STTR
Title of the award or activity: Diamond Electron Amplifier
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $50K
The number of person-months per year to be devoted to the project: .6
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research: Study the diamond amplifier for high current electron source. There is no synergy to the proposed research

Current and Pending Support
Investigator: Erdong Wang
Support: ☒ Funded ☐ Pending
The award period (start date – end date): 2/28/2020 – 11/28/2020
Sponsor or Source of Funding: Euclid Techlabs, LLC
Award Number or Identifying Number: DOE DE-FOA-0002145
Title of the award or activity: RF sputtering coating of electron transparent materials for photocathode encapsulation
The total cost or value of the award or activity, including direct and indirect costs. For pending proposals, provide the total amount of requested funding: $50K
The number of person-months per year to be devoted to the project: .02
Briefly describe the research being performed and explicitly identify any overlaps or synergies with the proposed research: There is no synergy to the proposed research

CURRENT AND PENDING SUPPORT
DR. JOSEPH GRAMES (JLAB)

Current
Sponsor: U.S. Department of Energy (DOE) Office of High Energy Physics (HEP)
Award ID: LAB 19-2110
Title of award: U.S.-Japan Science and Technology Cooperation Program in High Energy Physics National Laboratory Announcement
Total value of sub-award for this work: $20k for technical staff and procurement
Award period: June 1, 2019 – May 31, 2020
Cal Months: 0.5 (technical staff)
Description of work: Jefferson Lab evaluates conditions required for polarized positron beam generation produced in a conventional pair production target using a spin polarized electron beam. A focus will be the means to improve the capability to reliably operate a GaAs photocathode in a very high voltage photo-gun (>400 kV) to produce the corresponding high bunch charge and peak currents needed for future lepton colliders.

Pending
Sponsor: U.S. Department of Energy (DOE) Office of Nuclear Physics (NP)
Award ID: LAB 19-1902
Title of award: Advancing the Science and Technology of Quantum Computing
Total value of sub-award for this work: $1,335,527
Award period: PENDING
Person-months of effort: 3.3 (JLab PI); no other overlap
Description of work: The objective of this work is to use a new positron probe to study the spin densities and defect distributions and characteristics in quantum computing candidate materials. Firstly, *slow* moderated positrons will be used to study the population and characteristics of nitrogen center (N_V) qubits in diamond, specifically their coherence time, to advance the design and fabrication of scalable networks of qubits using positron annihilation lifetime spectroscopy (PALS) and Doppler broadening spectroscopy. Secondly, *fast* ~1 MeV channel polarized positrons, with as yet unattainable polarized intensities of 10^{10} e+/sec, will be used for in-flight annihilation to study the local distributions and characteristics of spins in thin crystals in order to identify potential new qubits.

CURRENT AND PENDING SUPPORT
DR. RIAD SULEIMAN (JLAB)

Pending Support
Sponsor: U.S. Department of Energy (DOE) Office of Nuclear Physics (NP)
Award ID: LAB 20-2261
Title of award: Data, Artificial Intelligence, and Machine Learning at DOE Scientific User Facilities
Total value of sub-award for this work: $300,000
Award period: PENDING
Person-months of effort: 3.3
Description of work: Minimize radiation levels due to field emission in CEBAF SRF Linacs. Supervise two graduate students.

CURRENT AND PENDING SUPPORT
Patrick Inacker

Support: ☒ Funded ☐ Pending	
Sponsor or Source of Funding: Department of Energy-Office of Nuclear Physics	
Award Number or Identifying Number: KB0202011	
Title of the award or activity: RHIC Collider-Accelerator Operations	
Award period (either actual or expected): FY2020 and Ongoing	
The number of person-months per year to be devoted to the project: 12	

CURRENT AND PENDING SUPPORT

Dr. Irina Petrushina is currently supported by HEP DOE grant "CO_2-laser-driven GeV wakefield accelerators", currently at 1 FTE

Drs. Wolfram Fischer, Jun Ma, Igor Pinayev and Gang Wang, and Mr. John Skaritka and Jean Clifford Brutus are supported by Brookhaven Science Associates, currently at 1 FTE

APPENDIX 3: BIBLIOGRAPHY & REFERENCES CITED

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APPENDIX 4: FACILITIES & OTHER RESOURCES

Stony Brook University: Prof. Litvinenko will serve as the PI throughout the duration of the proposal. He will devote up-to 1 month of his effort per year towards this activity. In addition to his service as the PI, he also will be supervising graduate student. The Department of Physics and Astronomy (SBU) will support the Accelerator Physics effort by offering office- and laboratory-space as needed and will provide programmatic- and administrative-support for the proposed research program.
Machine & Electronics shops. The Department of Physics and Astronomy maintains a full-time professional machine shop and electronics shops, which will be available for manufacturing equipment and apparatuses for the proposed research.

BNL: The proposal will take advantage of unprecedented access to the accelerators at **Brookhaven National Laboratory**, and specifically to an SRF electron accelerator (built for CeC experiment) located at IP2 of RHIC at Collider-Accelerator Department, - an arrangement that will allow us to pursue our proposed advanced accelerator research very cost-effectively. Most of collaborating scientists from SBU,

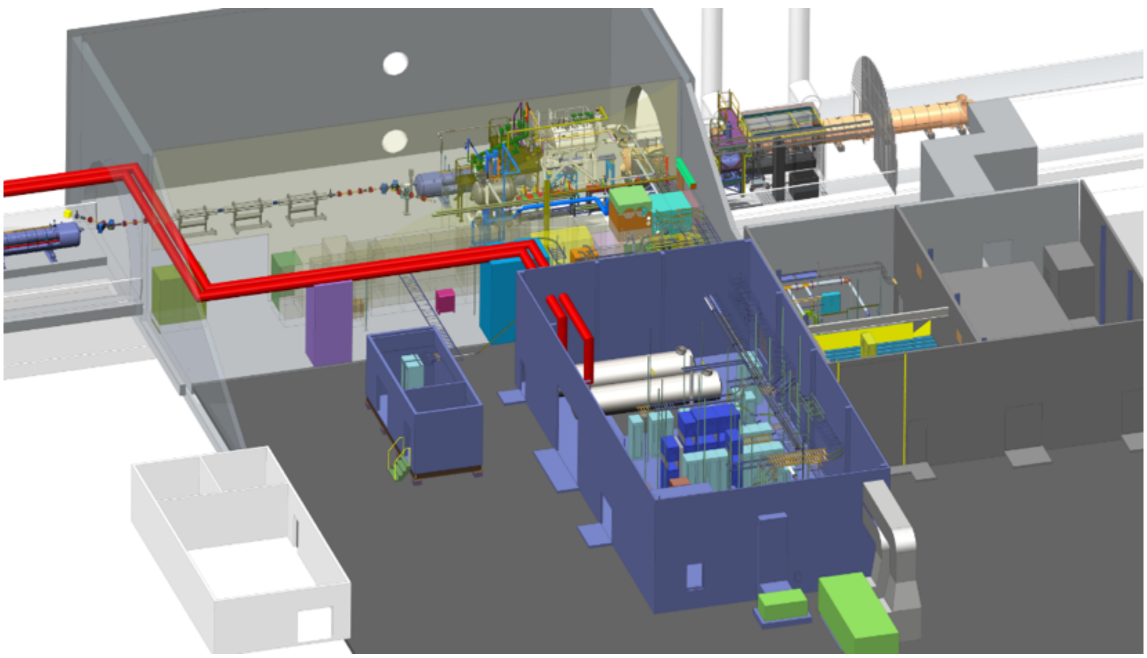
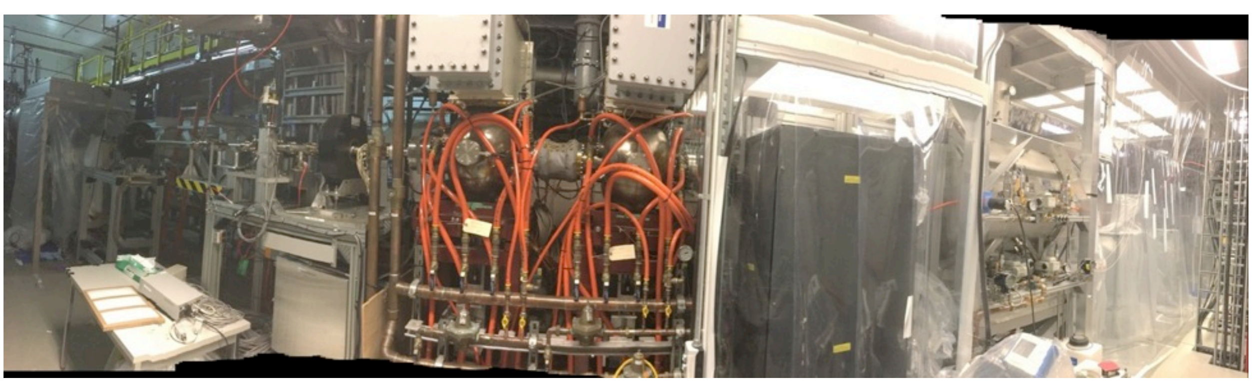


Fig. 4.1 A 3D rendering of the location of CeC SRF accelerator- the location for the proposed experiments.



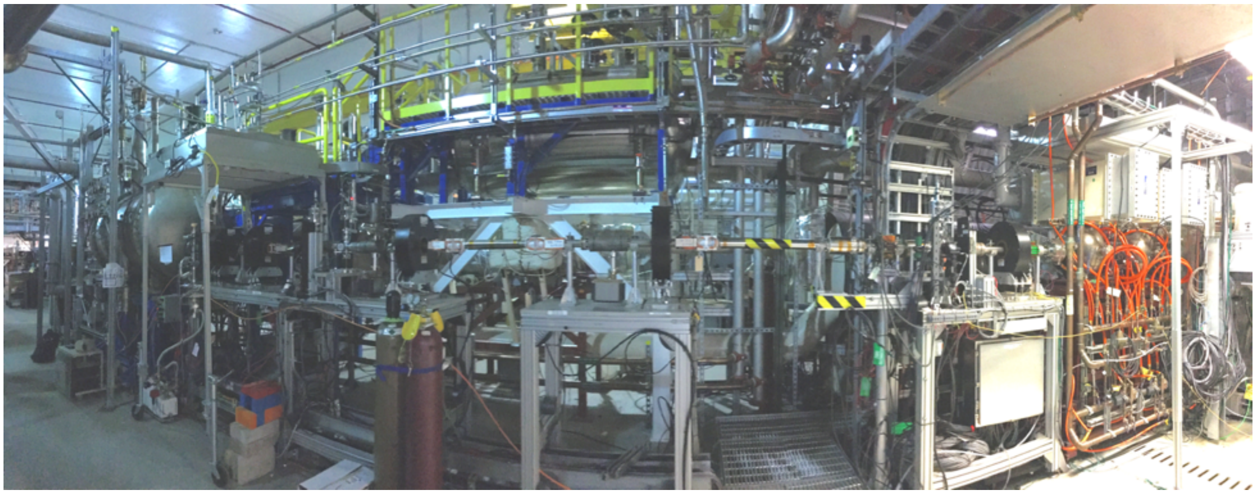


Fig. 4.2.Panoramic view of the CeC 15 MeV CW SRF accelerator: from the gun to the low energy beam transport(top) and from 500 MHz bunching cavities to the SRF linac. Electron are traveling from the right (1.25 MV SRF photo-electron gun) to the left (13.5 MeV STF linac).

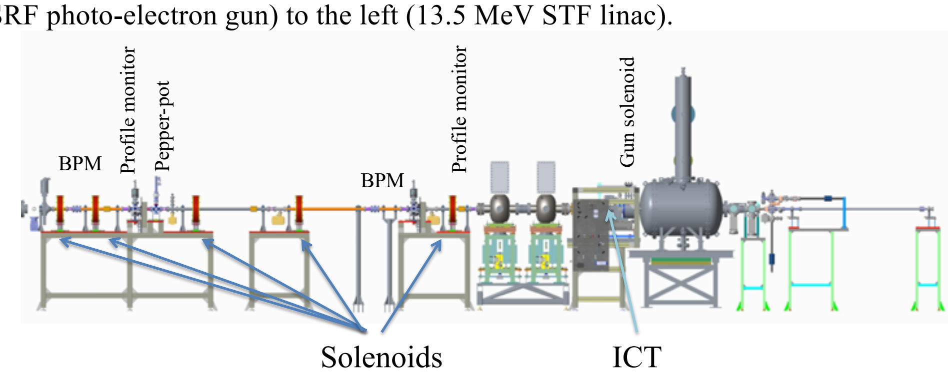


Fig. 4.3. Low energy beam transport (LEBT) line: beam from the SRF gun passes through the gun solenoid. ICT, two bunching 500 MHz cavities, compression line with five solenoids before arriving to the SRF linac.

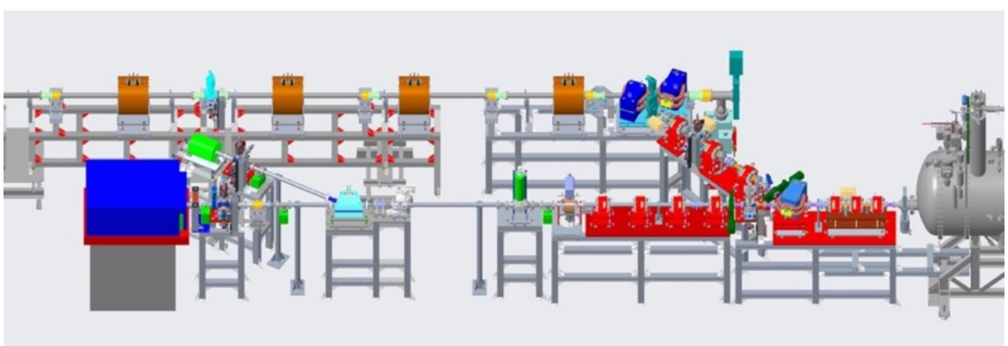
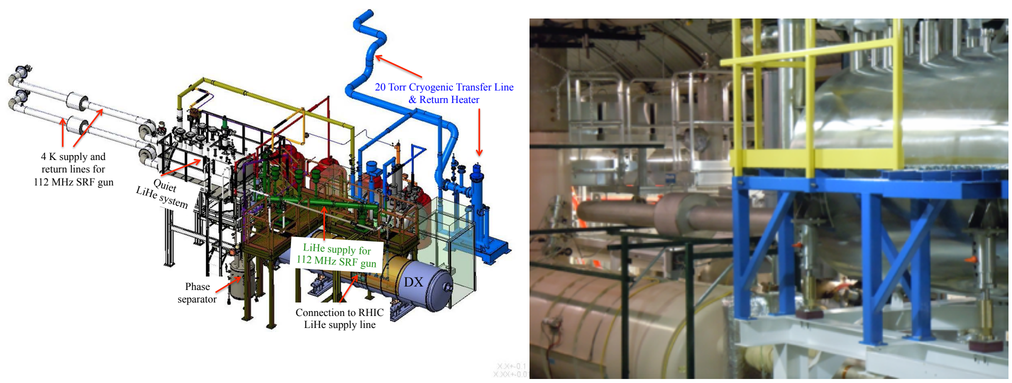


Fig. 4.4. CeC time-resolved diagnostic beam-line is downstream the SRF linac and a matching section with three quadrupoles (with the dog-leg with 45-degree dipole magnet off). It has four quadrupoles, transverse deflecting 1.4 GHz RF cavity and two diagnostics section with YAG screens and video-cameras – direct with 8.5 kW high power beam dump, and the 30-degree dispersion beam-line with a low power beam dumps. Both beam dumps serve as Faraday cups.
BNL, FNAL and Jlab will take part in the project activities.

We will conduct the proposed experimental research at BNL's CeC linear accelerator, at a well-known and well-regarded scientific user facility, RHIC. The CeC linear accelerator system is coming with all-important infrastructure, ranging from electrical, water-cooling, cryogenic (both 4 K and 2 K liquid He systems), three RF transmitters and a set of power supplies. The most important part of the CeC linear accelerator for this proposal is the state-of-the-art SRF gun – a record-breaking source of high-brightness electron beams - and LLRF system synchronizing laser with the RF systems for the proposed experiments.

We will use the CeC 1.25 MeV 112 MHz SRF gun to generate polarized and unpolarized electron beam. When necessary, we can used the 500 MHz bunching cavities for accurate control of the bunch shaping (via compressing or expanding the bunch train) and 704 MHz SRF linac for accelerating beams to 15 MeV.



(a) (b)

Fig. 4.5. (a) schematic of CeC LIHe system; (b) Partial view of the CeC's quite helium source (top-right) is installed at IP2 above RHIC magnets.

FNAL: This research capitalizes on the extensive and unique SRF facilities and expertise available at Fermilab. One of the most critical infrastructures for the High-Power RF couplers assembly is the cleanroom facility at the LAB2 shown in Figure 4.6. This is a Class 10 cleanroom having square of 75 m^2. The cleanroom is used for cavity string assembly for SSR1 cryomodule well as for SSR1 high-power coupler test stand clean part assembly, see Figure 4.7 Before assembly coupler part go through cleaning preparations when needed. 35 m^2 class 10 cleaning area with High Pressure Rinsing capability located next to assembly clean room shown in Figure A3.

Figure 4.6: The Lab2 cleanroom used for SRF cryo-module assembly.

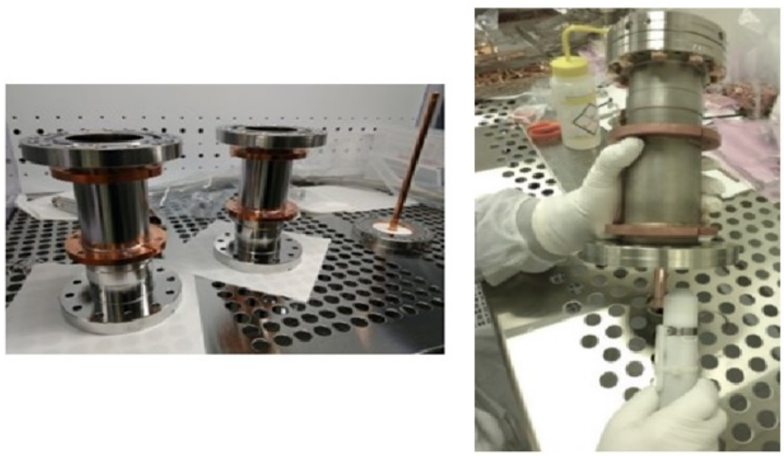


Figure 4.7 SSR1 coupler cold part in Lab 2 clean room.

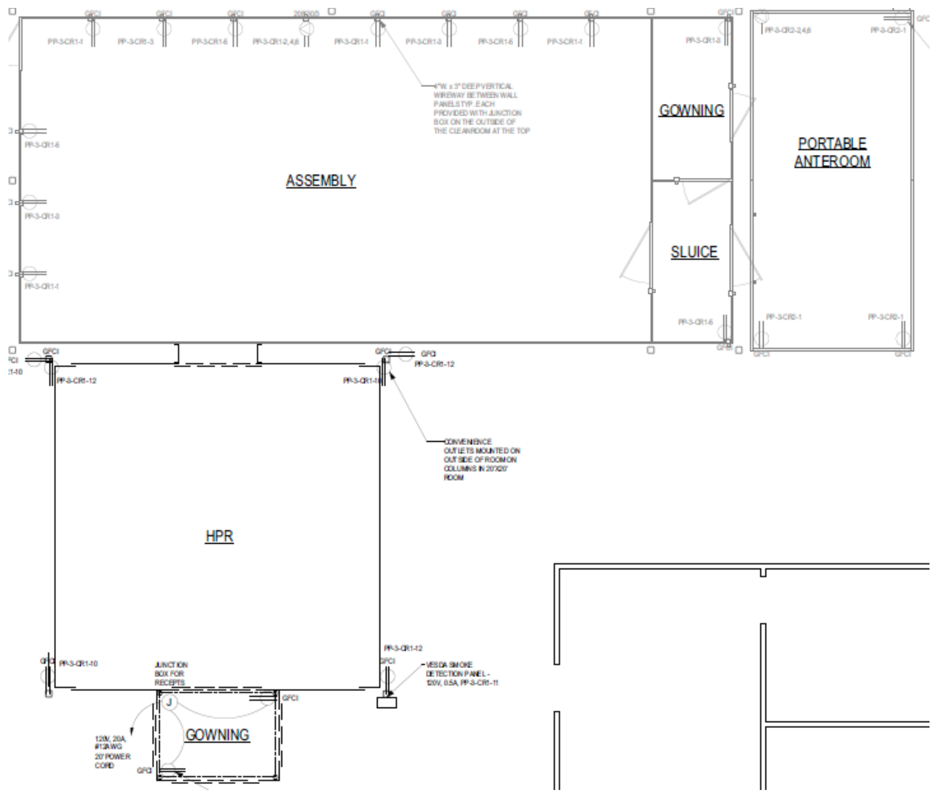


Figure 4.7: Lab 2 clean rooms, assembly and HPR.

Jlab: Jefferson Lab is a DOE basic-science research facility with several electron accelerators providing unique opportunities for nuclear science and technology. Cross-calibration of the Compton transmission polarimeter will take place at the CEBAF Injector using a very accurate 5 MeV Mott polarimeter. The Mott polarimeter layout is shown in Fig. 4.8. Like other national laboratories, JLab facilities include machine and electronics shops, and a magnet measurement lab.

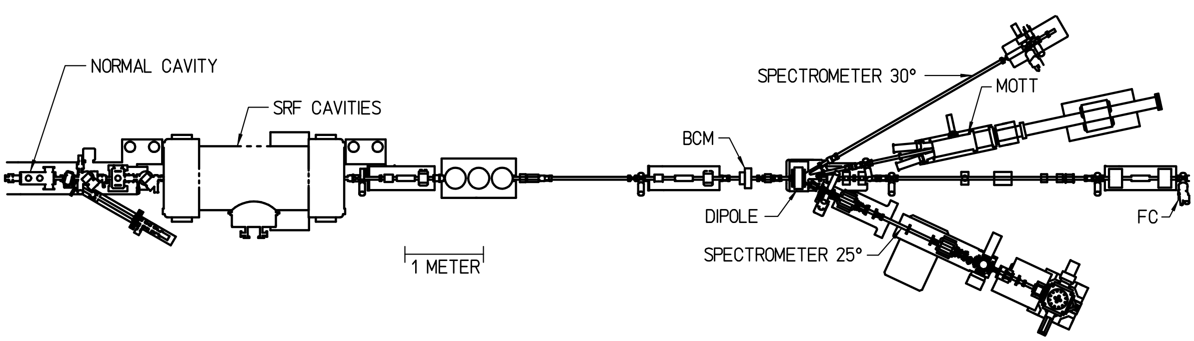


Figure 4.8. Plan view of the CEBAF injector showing the RF accelerating cavities, the 12.5° beam line through the Mott polarimeter, the spectrometer beam lines at -30° and 25°, and the straight beam line leading to the rest of the CEBAF injector including an RF cavity beam current monitor (BCM) and a Faraday cup (FC).

APPENDIX 5: EQUIPMENT

While no direct cost-sharing is offered from the participating institution, the project will utilize a very significant amount of equipment at SBU. BNL, FNAL and Jlab.

BNL

Fig.5.1 and 5.2 show two examples: a beam diagnostics and RF system of the CeC SRF accelerator that will be used for the proposed research.

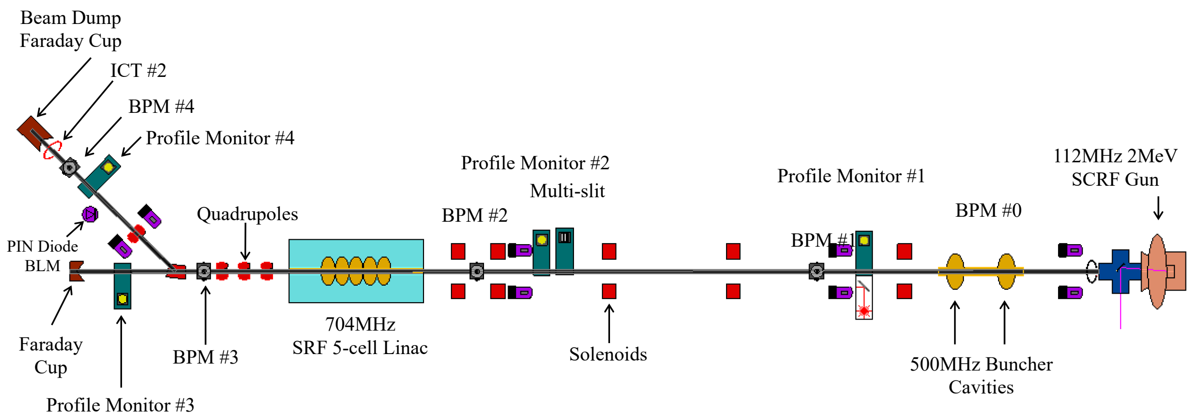


Fig.5.1. Part of the diagnostics on the operational CeC SRF accelerator diagnostics.

The CeC SRF accelerator system is fully operational with a full set of regular and beam-based controls.

(a) (b)

Fig.5.2. RF panels and local controls

In addition, a panoply of measurement and calibrations equipment will be used for commissioning and tuning the instruments we will develop for the proposed research. It includes but not limited to net-works analyzers, high speed digital scopes, laser calibration equipment : power, wavelength and polarization measurements, streak camera, etc.

JLab
JLab equipment of interest for this proposal includes the 5 MeV Mott polarimeter at the CEBAF injector, which will provide cross-calibration of the Compton Transmission polarimeter.

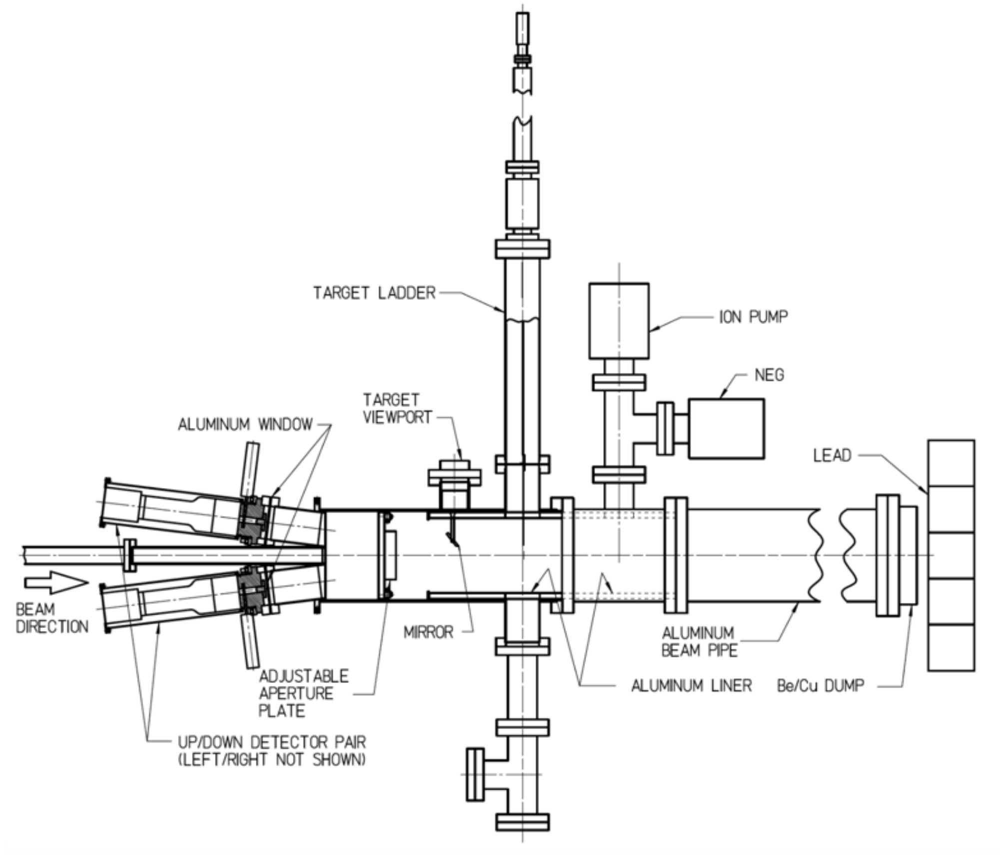


Figure 5.3. Elevation view of the Mott polarimeter

Fermilab
The proposed research plan takes advantage of the unique hardware and software complex build at Fermilab for a demanding multiphysics engineering analysis. The complex consists of the High Performance Computing (HPC) solutions and the broad suite of modern state-of-the art scientific and engineering tools for making 3-D professional engineering drawings (NX) and performing mechanical, thermal, fluid (ANSYS, COMSOL, CST) and electromagnetic simulations (HFSS, MAXWELL, ANALYST), as well as beam physics codes (CST, MICHELLE, TRACE-3D, ECHO-3D).
This software suite allows self-consistent simulations of a coupler, including electro-magnetic optimization, multipacting analysis, cooling schemes, thermal and stress regime optimization. The Fermilab team has a vast experience in multiple aspects of accelerator components engineering encompassing accelerator system mechanical design and reliable integrated technical solutions and establish a good contact with the vendor to get updates and consulting for the best practices. Besides, over the years Fermilab engineers created and tested set of custom scripts and programs for data acquisition and processing (LabVIEW, MATLAB, etc.).
The HPC solutions include the modern multicores high performance servers connected with fast speed interconnections to a redundant common network storage. Each server has a pre-installed standard engineering environment dedicated for a multiphysics calculations. Servers are available

by a remote access lab wide and provide sufficient computational power to support the coupler design, optimization and verification efforts.

This project capitalizes on the extensive and unique SRF and cryogenic facilities and expertise available at Fermilab. Plasma processing is a recently developed treatment that can be applied in-situ in cryomodules in order to reduce field emission in SRF cavities. The field emission reduction is given by the increasing of the work function of the inner surface of Niobium cavities once subjected to the plasma processing. The effect of plasma cleaning is given by the presence of Oxygen, becomes particularly reactive once excited into the plasma state, and easily reacts with hydrocarbons generating volatile species that can be pumped out. This process takes place under vacuum, at a pressure of about 100-200 mTorr, by using a mixture of Neon, an inert gas, and a very small amount of Oxygen (3-5 %), the reactive gas. A continuous flow of which gas in injected from one side of the cavity, and pumped out from the opposite side, is created in order to make sure the volatile species created during the reaction are efficiently pumped out instead of being redeposited on the cavity surface. A schematic of the process, and the equipment used during the plasma processing is shown in Fig. 5.4.

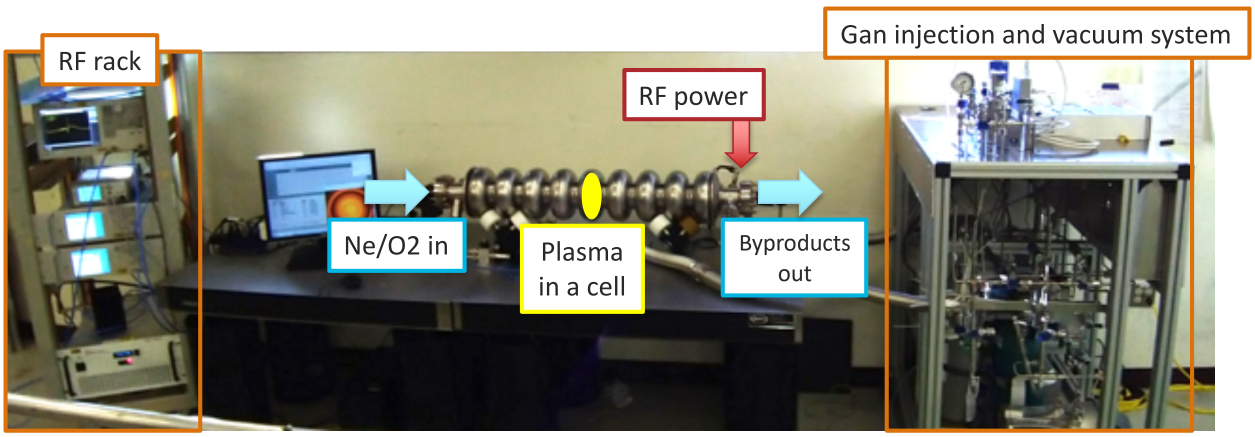


Figure 5.4. Picture of the equipment needed to plasma process an SRF cavity with a schematic representation of the process.

When plasma processing is applied in multi-cell cavities, the plasma is ignited on cell at a time, therefore it is important to cleverly mix the available modes in order to maximize the electric field amplitude in the desired cell. Only in this way the process is reliable and can be applied in-situ in cryomodule.

In case of SRF guns, the problem is partially simplified because no mixing of modes in needed in order to maximize the electric field amplitude. Also in this case, however, of particular importance is to select cleverly the proper mode for plasma ignition, and, subsequently, the proper mode for plasma cleaning. For plasma ignition it is indeed important to take into account that the process is implemented at room temperature, therefore the fundamental mode of the gun will be weakly coupled with the fundamental power coupler (FPC) used to excite the modes in the cavity. High order modes may be better coupled and therefore more suitable for plasma ignition on the SRF gun.

Combination of BNL and FNAL equipment:

RF measurements of the SRF gun at room temperature will identify the well-coupled mode and RF simulations will help to understand the nature of these modes and their electromagnetic distribution. These informations will help to understand which is the best mode that can be used to ignite plasma in the SRF gun. Once plasma ignition has been established, the research will be focused on defining the best mode that can be used to sustain plasma during the plasma cleaning process. To maximize the plasma cleaning efficiency, it is important that the plasma is localized in the high-electric field region of the cavity, therefore simulations of several high order mode will be used to identify the best modes that could be used at this purpose.

The effectiveness of the developed methodology will be then tested using part of the RF equipment already available at FNAL to carry out plasma processing studies. The gas injection and vacuum cart will be instead procured by BNL and assembled by FNAL during the first year of the project. This cart will be therefore used to carry out the plasma processing studies on the SRF gun.

The gas injection and vacuum cart will be a replica of the current gas cart in use at FNAL for plasma processing studies (Fig. 5.5). This cart is equipped with: a gas injection system that allows to mix up to three different gases at the same time, a vacuum system needed to keep the cavity under vacuum and to pump-out the byproducts during the processing, a residual gas analyzer (RGA) which analyze the gas species during the treatment, two mass flow controllers (MFC) that allow to operate the cart in a particle-free environment, and a series of gauges and valves that allow to respectively monitor and modify the pressure on the different areas of the cart.

Figure 5.5. Front picture of the gas injection and vacuum cart currently in use at FNAL for plasma processing studies.

APPENDIX 6: DATA MANAGEMENT PLAN

SBU, BNL, FNAL and Jlab adhere to the recently implemented policy of the DOE Office of Science:

http://science.energy.gov/funding-opportunities/digital-data-management/

The policy addresses four distinct aspects of digital data management

1) The policy on sharing and preservation of research data, specifically for the purposes of research validation.

2) Compliance with open availability of research data cited in publications.

3) The provisioning of data management resources

4) Issues of confidentiality, proprietary, intellectual property and national interest.

This DMP covers three classes of activity: research on legacy experimental data sets, the acquisition of new research data from experimental, observational and simulated sources, and research projects which are in the R&D phase.

The management of research data and resulting publications are the responsibility of the collaboration. The provisioning of data management resources is insured via agreements between the partners of the collaboration in agreement with the relevant funding agency and the relevant host laboratory. Collaborations have detailed Computing Models that describe the storage requirements and internal processes and details such as data content and format. Collaborations also have extensive internal review processes to validate scientific results prior to publication. The collaborations have computing models that complies with standard practice for data sharing, referencing and preservation for their respective domains.

In all cases of publications, data in the plots, charts and figures, and Digital Object Identifiers will be made available in accordance with policy at the time of publication by using mechanisms provided by the publisher, hosting by a collaborating institution, or services provide by INSPIRE. This includes publications resulting from research data from experiments, observation, simulation, and research and development projects such as large-scale detector prototype data.

Expected Data: The following data will be generated by collaboration and will be stored and maintained at CASE data systems:

a) The simulation data performed by the collaboration.

b) Experimental data recorded in the form of digital CCD screen-shots from electron diagnostics, the data will be saved in binary, ASCII, PDF and pictorial forms.

c) Published information will be available on the Center for Accelerator Science and Education website http://case.physics.stonybrook.edu/index.php/CASE:Courses without restrictions

When appropriate, we will also use Excel and MS word formats.

Data Storage and Preservation: Short-term protection against the loss of design documentation and test data will be accomplished by periodic – automated - local back up to secure storage in RHIC, Jlab and FNAL archival system, and later transferred to CASE archival storage located at Stony Brook. All logged data will be preserved in the RHIC, JLan and FNAL archive storages. The data will be also transferred to the central CASE data server, which will have an archiving program and a frequent back-up. The data will accessible to the project participants via password protected access.

Sharing and Access of Data: The collaboration retains the right for the first use of the data. All data created during the course of this project will be made freely available, subject to the policies of collaborating institutions. Data relating to patentable devices will be subject to review by the office of technology transfer before being released to share.

When analysis is completed, the data will be disseminated through publication in refereed, for example, Physical Review (Letters, A,B, PR ST-AB), Nature and Science, as well as in more dedicated journals and conference proceedings.

Published data will be available on the CASE website. Requests for the raw data should be directed to the CASE Director, Vladimir Litvinenko (vladimir.litvinenko@stonybrook.edu)

Period of Retention: Data will be retained for a minimum of three years after conclusion of the award or three years after public release (publication), whichever is later. Data related to a student's research work will be retained for at least three years after the degree is awarded. Data that support patents will be retained for the entire term of the patent.

Policy about Intellectual Property: The research results will be disseminated through the collaboration. The intellectual property developed under the proposed research may include patents and original papers. The authorship and the rights to the intellectual properties will be held or shared by the inventers or producers and their respective institutions according to the policies of Stony Brook University. The CASE's Executive Council will be responsible for solving any possible conflicts.

Data management details specific for BNL are listed below:

The main products of the proposed research will include:

- archival journal publications,
- conference presentations and proceedings,
- invention disclosures and patent applications,
- colloquia at universities, industry, and national/international laboratories.

The analyzed data will be published in archival journals. Data will be archived in curated repositories when appropriate and hard and soft copies will be provided to the government (DOE). This will be the venue we plan to use for making accessible data generated in the project. The participation at conferences by the PI, CO-PIs, research investigators, and early-career individuals will enable outreach to a broad-base of communities.

All C-AD engineering data is archived and backed up to tape. Archive servers provide real-time random access to almost 1 PB of data representing 20 years of C-AD operations. Tape backup is done by daily cron processes that send data over 10 GB links to the RHIC/Atlas Computing Facility (RACF) at BNL. Current run data is stored on an operations NAS, with redundant links, power, and RAID storage. Process servers also are configured for redundant power and RAID storage. All data used for published results will be store and archived on these systems. The RACF data repository is a curated long-term record. This availability of all raw data enables all results to be future validated. All published results and associated data will remain available as unclassified open research data.

User accounts on the C-AD systems are managed from BNL central authentication systems managed by the BNL Information Technology division. Only authorized C-AD users can have accounts on the C-AD systems.

Published results will follow the standard BNL process for open research publication and will be included in the OSTI systems. All data for publications will be preserved and available to the public, if requested. When possible, data used in publications will be included as supplementary information. Publications will include point of contact information (e.g., author email). The permanent repository of the data for this project will be kept by BNL, as described above. None of the data for this project will fall beyond standard and expected use for existing BNL systems.

No confidential, personal privacy, PII or other data of a sensitive nature will be part of this project.

Data management details specific for Fermilab are listed below:

Overview: Fermilab is the lead laboratory for many particle physics experiments. Some of those experiments leverage the lab's accelerator facility while others do not. No matter whether part of the Fermilab facility or not, these experiments all go through multiple phases in their lifecycle, from conceptual design to prototype detectors in test beams, to full blown operating experiments and ultimately final data analysis and ultimately data archival and knowledge preservation. While the needs for a data management plan vary in detail over the experiment lifecycle, they all have common themes with respect to digital data and how it is treated.

Fermilab is also the home to a number of facilities that provide support to the enterprise, perform accelerator and detector technology development.

A key deliverable of each experiment as well as the facility is a digital record of the data representing selected physics of interest whether that be a cosmic ray passing through a detector or a digital snapshot of the sky. Fermilab provides the experiments in which it is the lead laboratory as well as users of its various facilities the means to store, manage, access and share the raw data, simulation data as well as all of the research dependent reconstruction and calibration data.

Policy: It is the policy of the facility to provide long-term data storage and data access to all of the experiments and scientific programs associated with the facility in order to ensure the integrity, availability and safe keeping of the data products, associated conditions data, as well as relevant simulation data. How long the data is stored and subsequently archived is typically negotiated on a case-by-case basis, depending on the needs and uniqueness of the data being captured. However, the default is that Fermilab will keep the data active for a minimum of 5 years after it was collected. All experiments in which Fermilab is the lead laboratory will use Fermilab as its primary repository for the data. Other copies of the data may exist throughout the world depending on the experiments unique needs.

Resources Available: See Computing and Data Resources at Fermilab for an overall description of available resources. Each experiment will be provided a minimal "baseline" level of support for their data needs to get each experiment started. A yearly Portfolio Review is held and resource allocations for each experiment are made taking into account the facilities total demand for computing needs, budgets, and scientific priorities. Exceptional needs may require that additional funding be secured in order to satisfy them.

Data Validation: It is expected that each experiment and/or facility user will take "ownership" of the operation of its experiment – though will receive ample support from the laboratory. It is the researchers' responsibility for the integrity of all its public scientific research signed by the collaboration. A vigorous internal review process prior to its public presentation handles that validation.

Data availability and sharing: Fermilab provides the means for experiments' researchers to access data from anywhere in the world and to share data. There are a variety of systems available to meet wide ranging needs; the appropriate technology choice will be made consistent with a particular experiment's requirements.

Researcher Responsibilities: The decision as to who may have access to the data is the responsibility of the experiment to define. The default will be to only allow members of the collaboration to access it. Fermilab provides tools to implement the access decisions once it is informed.

Responsibility for Experiments: he Experiment must, in conjunction with the laboratory, define the long-term retention period for its data products consistent with the policy described in Computing and Data Resources at Fermilab. The overall retention length will be determined on a case-by-case basis depending on the scientific relevance of the data and the cost required to maintain it. Individual agreements will be established between each experiment and the facility to document these requirements.

It is expected that any experiment that wants something other than the default parameters must contact the head of Scientific Computing Division and CIO to establish a special Service Level Agreement (SLA) that all parties agree to.

Data management details specific for JLab are listed below:

Dissemination of research results is a critical part of modern research and development, Jefferson Lab supports the concept of data sharing and prolifically presenting research results at international conferences and regularly publishes research results in peer-review journals. However, any release of data is done in such a way to be compliant with any export control mandates and to protect intellectual property (IP) and proprietary information where appropriate. Jefferson Lab does not believe this technology contains any export controlled information, however, if it is determined to be so, we will conduct an export control review as appropriate.

Types of Data Produced

The data types generated by the research described in this project include:

- Design notes, calculations, algorithms and computer simulations
- Processes and controls
- Processed data (e.g., analyzed data, tables, graphs)
- Drawings and schematics
- Publications, talks and documents (e.g., papers in refereed journals, conferences and workshops, internal technical notes, competitive incentive proposals)

The data management system will offer the following minimum capabilities:

- Data capture and storage
- User-friendly graphical access to laboratory, industry and international collaborators
- Backup and archiving of data
- Compatibility with multiple formats (e.g., documents, spreadsheets, graphics, presentations)
- Access controls

Plans for archiving and preservation

The products of this research will published in the open literature. The main venues are:

- Physical Review Special Topics – Accelerators and Beams
- Proceedings of the International Particle Accelerator Conference
- Proceedings of the International Linear Accelerator Conference

All the electronic files generated for this project will be preserved according to Jefferson Lab's record management policy and DOE's Research and Development Records Schedule.

Policies for access and sharing, and provisions for appropriate protection/privacy

Documents generated and classified in the course of this project will be shared among collaborators from the start of the project, and will be continually upgraded and updated. E-mail will be the most common method to share information. Prior to making them available for wider distribution, such as through journal publications or conference presentations, applications for the protection of Intellectual Property would be filed, as agreed upon by all collaborators.

Electronic documents created during this project will be stored in a project folder on a network drive maintained and backed-up daily by Jefferson Lab's IT Division. Jefferson Lab has robust cyber security processes and policies in place which will ensure data integrity and prevent unauthorized access.

Policies and provisions for re-use re-distribution

Allocation of Intellectual Property rights will be in accordance with JSA's Prime Contract with the U.S. Department of Energy or under a separate CRADA between the Participants.

With the exception of items that have potential for Intellectual Property rights, data and expertise acquired during this program will be either published, presented at conferences, or both. Information will be made available to researchers elsewhere when the Intellectual Property rights are secured.

APPENDIX 7: OTHER ATTACHMENTS

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managed by Brookhaven Science Associates
for the U.S. Department of Energy

May 12, 2020

Prof. Vladimir Litvinenko
Department of Physics and Astronomy
Stony Brook University
Stony Brook, NY 11794-3800

Re: Letter of Support for "Superconducting RF electron gun" submission to DE-FOA-0002310

Dear Prof. Litvinenko,

It is a pleasure to strongly support the Accelerator R&D proposal "Superconducting RF electron gun" that you are submitting to DE-FOA-0002310 in collaboration with groups at BNL, JLab and FNAL.

Your proposal is building on the highly successful performance of the existing quarter-wave SRF electron gun that is part of the CeC set up at RHIC. The success of this SRF gun is particularly remarkable after the many years of much less successful developments of other SRF electron guns.

SRF electron guns are uniquely capable to provide bright CW electron beams because of the high voltage gradient they can sustain. The main difficulty has been to maintain a photocathode with high quantum efficiency inside a superconducting cavity. This has been solved in the CeC e gun producing reliably very bright and intense electron bunches. The next step is to increase the repetition rate to reach high currents, which is the focus of this proposal.

There are many potential applications of this next generation electron source: an ideal electron source for strong hadron cooling, an ideal electron source for high power CW FELs, an ideal electron source for ERL-based Compton gamma sources and ERL-based isotope production.

The collaboration, that you assembled, covers all the necessary expertise and forms the basis for a successful effort.

Sincerely,

Thomas Roser

Thomas Roser, Ph.D.
Deputy Associate Laboratory Director for Accelerators
Chair, Collider-Accelerator Department
Brookhaven National Laboratory