CEBAF INJECTOR MODEL FOR K-LONG BUNCH CHARGE AT 200 kV*

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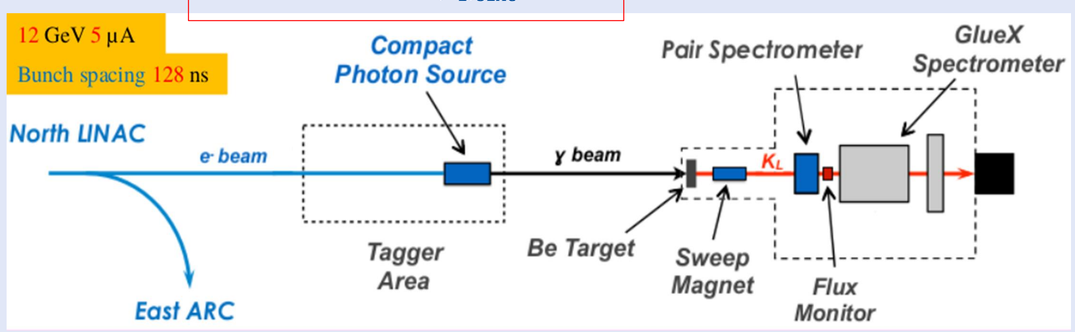
ABSTRACT

The upcoming Jefferson Lab K-Long experiment at Hall D will require unique beam conditions with much lower bunch repetition rates and atypically high bunch charge. To optimize the Continuous Electron Beam Accelerator Facility (CEBAF) injector for this experiment, we performed Multi-Objective Genetic Optimization (MGO) using General Particle Tracer (GPT) to determine the magnetic elements and RF setting necessary for the K-long bunch charge (0.64 pC) at 200 kV. We also investigated the transmission and beam characteristics for low to high charge per bunch electron beam through the CEBAF injector for simultaneous operations of four CEBAF Halls and characterized the transmission as a function of laser spot size and pulse length. Our findings provide valuable insights into optimizing the CEBAF injector for the Jefferson Lab K-Long experiment, as well as for other experiments with similar beam conditions.

INTRODUCTION

- The K-Long (beam of neutral kaons) experiment at JLab in Hall D, using the CEBAF with GlueX experimental setup for strange hadron spectroscopy.
- Measure differential cross section, polarizations of produced hyperons Λ, Σ, Ξ, Ω.
- New and unique data can be obtained with an intense K-Long beam aimed at LD2/LH2 target.

$$\frac{N(K_L)}{s} \approx 10^4, \quad \frac{N(K_L)_{JLab}}{N(K_L)_{SLAC}} \approx 10^3$$



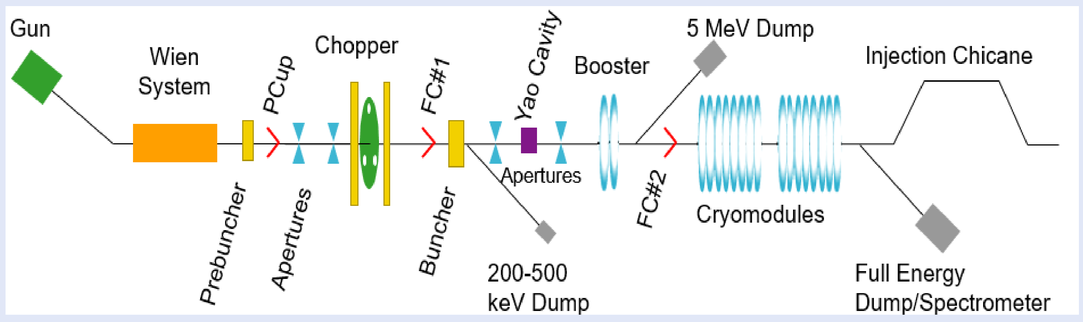
Schematic view of Jefferson Lab Hall D beamline on the way e → γ → K_L.

CEBAF injector bunch charges and repetition rates for K_L experiment

Current (μA)	Repetition Rate (MHz)	Sub-harmonic of 499 MHz	Bunch Charge (pC)	Equivalent 249.5 MHz current (μA)	
2.5	15.59	32nd	0.16	40	
2.5	7.80	64th	0.32	80	64 ns
5.0	15.59	32nd	0.32	80	64 ns
5.0	7.80	64th	0.64	160	128 ns

OPTIMIZATION AND SIMULATION

- Computer Modeling provides suitable settings to satisfy the different beam specifications for the simultaneous operation of CEBAF four Halls.
- This work is a continuation and expansion of the CEBAF Injector modeling activities.



Layout of the CEBAF Injector with upgraded beamline elements (solenoids, quads, correctors, etc. not shown).

- These all elements are incorporated into the General Particle Tracer (GPT) model.
- Used a straight beamline, 15°dipole, RF choppers, beam diagnostics, Wiens are OFF.
- The Gaussian beam with a transverse beam size of 0.55 mm, and a laser pulse length of 45 ps.
- The transverse emittance is given by, $\epsilon_{n,\perp} = \sigma_\perp \sqrt{\frac{MTE}{mc^2}}$, MTE = 30.691 meV.
- Performed multi-objective global optimization implemented in GPT for 250 macroparticles.
- The optimizations were performed for K-long bunch charge (0.64 pC), at 320 μA beam current at a laser frequency of 499 MHz for 200 keV beams.
- Simulations were performed for 10,000 macroparticles.

OUTLOOK AND FUTURE WORK

- The beam simulations and measurements conducted at the 130 kV gun successfully meet the beam requirements of 0.32 pC charge, indicating suitability for the K-Long Experiment.
- By employing Multi-objective Genetic Optimization (MGO), the optimized settings of magnetic elements and RF system were obtained for achieving a K-long bunch charge (0.64 pC) at 200 kV.
- Simulation results demonstrate that the simultaneous operation of K-Long (0.64 pC, 128 ns) and MOLLER (0.26 pC, 4 ns) experiments poses no issues in terms of beam characteristics.
- A beam test plan has been submitted to evaluate the performance of the injector using a 200 kV gun specifically for the K-Long experiment.
- An injector simulation with the spin rotator/Wien system ON is planned for the K-Long bunch charge for 200 keV beams.

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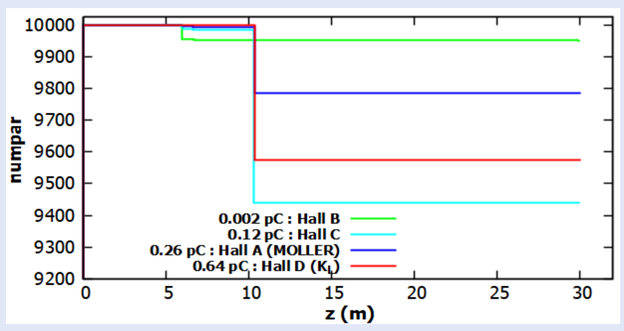
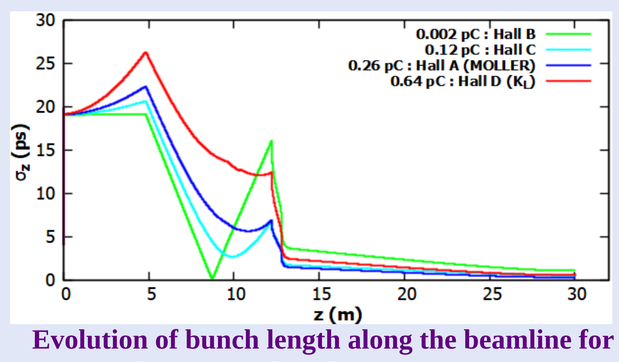
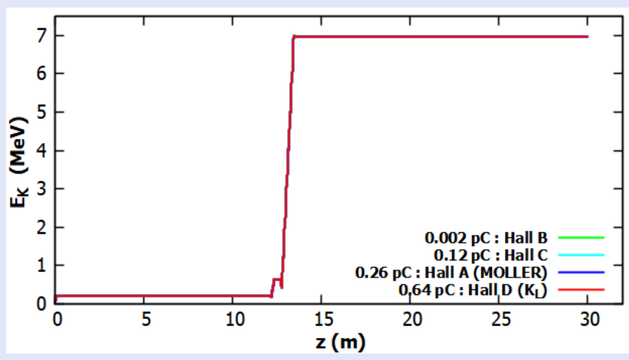
SIMULATED BEAM CHARACTERISTICS



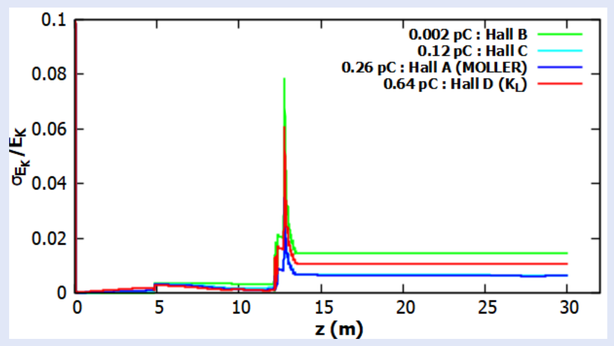
Transmission for various bunch charge specifications for the CEBAF four Halls.



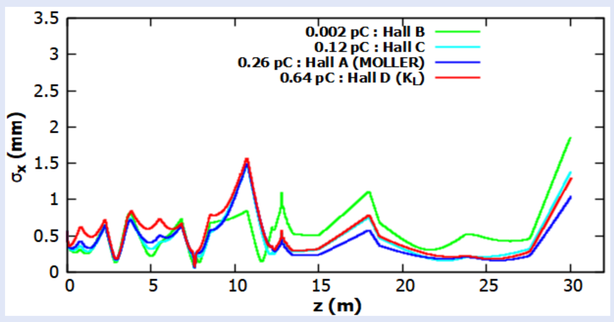
Evolution of bunch length along the beamline for various charges per bunch.



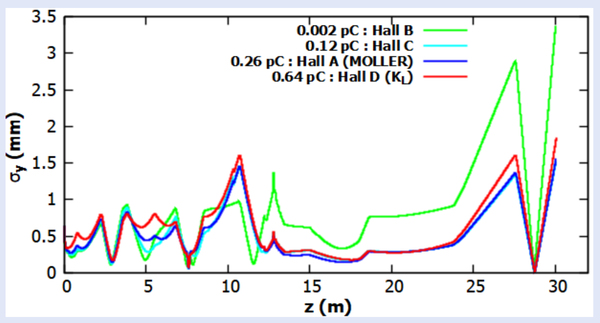
The average kinetic energy for different bunch charges, its value is around 6.98 MeV.



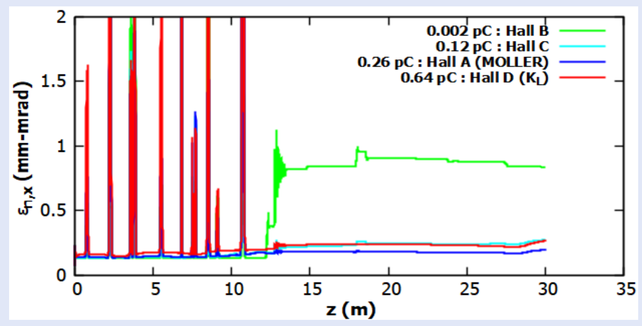
Energy spread for different charges per bunch.



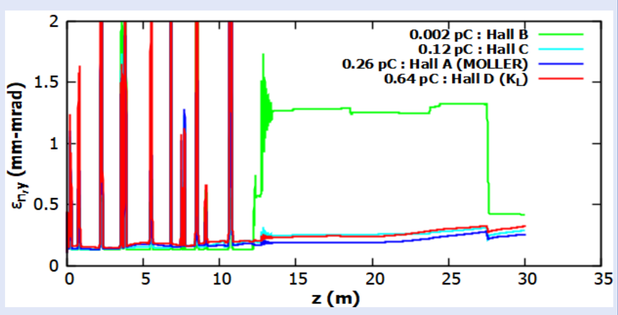
Transverse horizontal beam sizes for different bunch charges along the beamline.



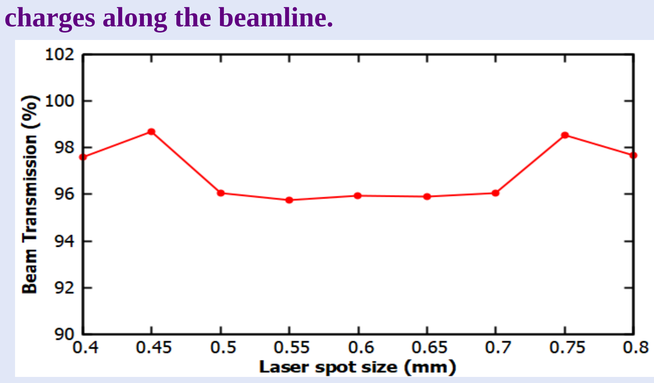
Transverse vertical beam sizes for different bunch charges along the beamline.



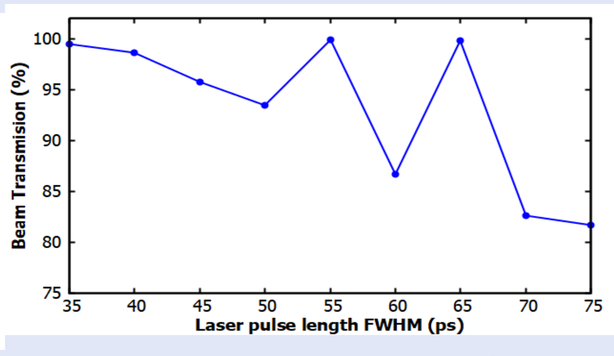
Normalized horizontal emittance for different bunch charges along the beamline.



Normalized vertical emittance for different bunch charges along the beamline.



Beam transmission vs. laser spot size at cathode for K-Long bunch charge (0.64 pC) in CEBAF Injector.



Beam transmission vs. laser pulse length for K-long bunch charge (0.64 pC) in CEBAF Injector.

REFERENCES

[1] M. Amaryan, et al. “Strange hadron spectroscopy with secondary KL beam in hall D“ arXiv:2008.08215v3 [nucl-ex] 4 Mar, (2021).
[2] S. Pokharel *et al.*, “CEBAF Injector for KL Beam Conditions", in 13th Int. Particle Acc. Conf., Thailand, Bangkok, Ju2ne 022, pp. 580 -583. doi:10.18429/JACoW-IPAC2022-MOPOTK052.
[3] A. Hofler *et al.*, “Modeling for the Phased CEBAF Injector Upgrade for 12 GeV CEBAF” presented at the 14th Int. Particle Accelerator Conf. (IPAC’23), Venice, Italy, May 2023, paper WEPL075.
[4] Pulsar Physics, General Particle Tracer, http://www.pulsar.nl/gpt/.
[5] S. B. Van Der Geer *et al.*, "3D space-charge model for GPT simulations of high brightness electron bunches”, Institute of Physics Conference Series. Vol. 175, (2005).
[6] I. V. Bazarov *et al.*, "Thermal emittance and response time measurements of negative electron affinity photocathodes", Journal of Applied Physics, 103(5), 054901 (2008).