LABORATORY DIRECTED RESEARCH AND DEVELOPMENT LETTER OF INTENT

TITLE: PRE-CONCEPTUAL DESIGN OF A CW POSITRON SOURCE FOR JLAB

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Abstract

There is recent and growing interest for positron beams for Nuclear Physics at Jefferson Lab. This proposal aims to explore the scope of physics motivated User beam requirements and to then produce a Pre-Conceptual Design Report for an accelerator driven positron source with respect to existing Jefferson Lab facilities (CEBAF/FEL). The design would be based on a powerful Multi-Object Genetic Algorithm (MOGA) approach which may efficiently optimize a challenging set of technical, engineering and economical parameters. Such a report would provide critical information and timely advice if a positron accelerator were further pursued at Jefferson Lab. The work itself would span the Accelerator, Engineering and ESH&Q Divisions, as well as attract and develop a new scientist at Jefferson Lab.

1.0 Summary of Proposal

1.1 Description of Project

The motivation for positron beams at Jefferson Lab has broad interest (see Table 1 and Refs. [1-8]), as evidenced by User Group members for positrons at CEBAF, inclusion of positron beam parameters in Electron Ion Collider documents, and recent proposals for a Dark Matter Search and Slow Positron Facility at the FEL. Any suitable positron source requires a careful understanding of the User-driven beam specifications and an integrated technical design which spans a demanding range of particle beam (positron production/collection/accelerator) and technological (thermal, radiation, vacuum) issues.

Table 1. Physics interest using positrons at JLab in recent years (see Refs. [1-8]).

PHYSICS INTEREST	POSITRON INTENSITY
Two Photon Exchange	10 – 50 nA
Positron Proton Elastic Scattering	20 – 40 pA
GPD's and DVCS with Positrons	8 – 40 nA
Inclusive Structure Functions	100 – 250 nA
U-Boson Dark Matter Search	20 nA
Positron-Ion Collider	1 – 10 μA
Slow Positron Facility	10 – 100 pA

The implementation of an accelerator driven positron source at Jefferson Lab would be a significant activity and likely benefit from and extend upon the CEBAF or FEL electron accelerators. In this context positron source schemes have been explored in recent years but arguably not in sufficient detail, for example, optimizing positron yields without full consideration to the management of electron beam power “footprint” (thermal loss, radioactivity, facility realities). We believe an optimum engineering solution of a positron production installation at JLab will necessarily include as a critical element the design of high power target(s), capable of absorbing and converting high energy electron beams with beam power of the order of hundreds of kilowatts. We propose to investigate possible engineering solutions that would satisfy thermal and radiological constraints of such designs. New designs based on the recent JLab patents [9-10] addressing such problems will be included in the consideration, and optimized solutions worked out for candidate scenarios of a positron source at Jefferson Lab.

We believe this proposal is well aligned to the Jefferson Lab Strategic Plan and highly compatible with LDRD funding criteria, by exploring an as yet unfunded potential avenue for future Nuclear Physics at Jefferson Lab.

1.2 Expected Results

The ultimate deliverable of this proposal is a technically well-developed Pre-Conceptual Design Report based upon physics-motivated User input, with alignment and feasibility to the existing CEBAF and FEL facilities, and including an optimization and technical review of candidate design schemes.

Physics Motivation (Year 1)

We would meet with interested Users to explore and document positron beam requirements for possible experiments with focus on Nuclear Physics at CEBAF, the FEL or a future Electron/Positron Ion Collider. The goal is to develop, for example, a version of Table 1 that identifies in detail a full set of parameter (intensity, energy, energy spread, emittance, polarization, time-structure). In addition, we would work with interested Users of slow positrons in order ascertain mutual synergy and benefits. This would take the form of a Workshop and of joint meetings with the Jefferson Lab User Group, the Electron Ion Collider study group, Division leadership and interested Collaborators. Specifically, we would identify beam requirements and specifications like that prepared for PAC proposals.

Candidate Scenarios and Optimization (Years 1-2)

We would develop candidate positron source scenarios based upon User beam specifications with existing (CEBAF/FEL) and proposed (EIC) facilities. *A critical feature not yet explored at Jefferson Lab is the integration of a high-power converter from electron drive beam to positron physics beam*. We believe such a real-world analysis is a critical link in order to evaluate a realistic implementation of a future positron source connecting to and capitalizing upon Jefferson Lab facilities.

We believe an important step is to explore the paths for either a single-target or double-target configuration, the latter of which functionally separates the bremsstrahlung radiator from the positron converter. We would use a Multi-Object Genetic Algorithm (MOGA) like that employed, for example, to achieve high brightness in a high-current electron photo-injector at Cornell University [11], to optimize luminosity in the International Linear Collider design [12] or similar to like-minded applications at Jefferson Lab [13]. Such a MOGA optimization would be a powerful tool to optimize over the challenging physics, engineering and beam specification requirements and constraints.

Specifically, the optimization would include:

- Electron drive beam (energy, intensity, radiation, polarization)
- Single- or Double-Target Bremsstrahlung and Pair Production Converter (target materials and design, heat dissipation properties and requirements, prompt radiation, pressure-stress fields, material lifetime, activation of components, maintenance and safety concerns)
- Electron Beam Power (radiation, activation, thermal management)
- Positron Collection (AMD, acceleration, optics)
- Positron Beam (emittance, damping, transport, acceleration)
- Positron Polarization - (unpolarized or polarized electron beam, positron source polarization, Sokolov-Ternov self-polarization)

Technical Review (Year 2)

We would hold a technical review in the second year where we would convey motivating physics, candidate scenarios and optimization results. The goal of the review would be to judge candidate solutions and prioritize, or down-select, a leading configuration. The remainder of the project would focus on developing a Pre-Conceptual Design Report for the selected candidate. Reviewers would be both internal and invited experts.

Pre-Conceptual Design Report (Year 2)

We would develop a conceptual design report for an accelerator based positron source at Jefferson Lab suitable for Nuclear Physics to include:

- Electron driver and facility integration
- Positron source systems
- Positron beam specifications and delivery to User
- Resource requirements, prototype engineering plan, resources
- Risk assessment, critical path R&D

At the end of the work proposed we would publish this Pre-Conceptual Design Report and discuss with leadership the merit and potential plans for extended, specific R&D engineering and/or prototyping of a suitable high power positron conversion target.

2.0 Proposal Narrative

The work is proposed as a 2-year project. The LDRD funds would support a full-time postdoctoral physicist for this term. Co-PI's Pavel Degtiarenko and Joseph Grames would each contribute 10% of their time to supervise the post-doc, organize workshop and technical review and participate in design studies. Mechanical Engineering support is proposed; 15% in the first year to begin thermal analysis and technical support, and then ~doubling to 33% in the second year to develop complete competitive analysis, prepare for the technical review and prepare the Pre-Conceptual Design Report. Work plan activities, people, computing, travel and meetings are summarized in Table 2.

Table 2. Work plan and some estimated costs for Years 1 and 2.

TASKS	YEAR 1	YEAR 2
Activities	• Collect beam specifications, design schemes, compatibilities with CEBAF/FEL • Identify and develop candidate scenarios based on conditions • Refine scenarios and start genetic algorithm based optimization	• Complete optimization of candidate scenarios • Iterate with ME for engineering analysis • Review candidate scenarios with down-select recommendation • Developed pre-conceptual design report with recommendations, resource

	• Begin ME thermal analysis of high power target solutions	and risk
People	• FTE Postdoc (new hire) • 0.15 FTE ENGII (ME) • 0.10 SS III (Degtiarenko) • 0.10 SS III (Grames)	• FTE Postdoc (new hire) • 0.33 FTE ENGII (ME) • 0.10 SS III (Degtiarenko) • 0.10 SS III (Grames)
Computing/ Software	• Free - FLUKA • Free – GEANT4 • Licensed - ANSYS • $1800 - GPT	• Free - FLUKA • Free - GEANT4 • Licensed ANSYS • Licensed GPT
Travel	• $5k for (3) domestic conference (1) international school	• $3k for (3) domestic conference
Meetings	• $3k for Workshop @ JLAB (2) domestic travel support	• $3k for • Technical Review @ JLAB • (3) domestic reviewers

In addition, we are presently soliciting interest for this proposal as detailed here:

- Externally funded scientist at LPSC to provide leadership and work effort in organizing Physics Interest for positrons for Nuclear Physics at Jefferson Lab,

- Externally funded graduate student or post-doc from Old Dominion University to participate in technical design and simulation studies of the optimization schemes,

- Synergy with MEIC R&D (physics Users and Accelerator study groups) to provide a Pre-Conceptual Design Report consistent with plausible positron option or capability to an MEIC.

3.0 Summary Budget

All budget numbers include estimated burden and overheads.

FUNDS USE	YEAR 1	YEAR 2 (IF REQUESTED)	YEAR 3 (IF REQUESTED)
Staff (FTE/$k)	1.4 FTE/$196.6k	1.5 FTE/$231.2k	___/___/

M&S ($k)			
Equipment ($k)			
Travel ($k)	12.0k	9.0k	
Services and Subcontracts			
Other (Computing Software)	2.7k		

Complete the table here (a very high level budget) and add a brief explanation if the relevant interpretation of the numbers isn't obvious.

The G&A rate calculation is an estimated 50% for all three years.

Staff: Year 1 will have 1 FTE Postdoc (new hire), .15 FTE Eng II (ME), .10 FTE SS III (Degtiarenko), .10 FTE SS III (Grames). Year 2 will have 1 FTE Postdoc (new hire), .33 FTE Eng II (ME), .10 FTE SS III (Degtiarenko), .10 FTE SS III (Grames).

M&S: N/A.

Equipment: N/A.

Travel: $12.0k in Year 1 for 5 domestic conference/workshop support trips & 1 international school. Plus $9k in Year 2 for 6 domestic conference/reviewer trips.

Services and Subcontracts: N/A.

Other: $2.7k in Year 1 for computing software – GPT.

The budget is $204.7k for Year 1 and $203.3k for Year 2. The total for both years is $408.0k.

References

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[13] A. Hofler, et al., Phys. Rev. ST Accel. Beams 16, 010101 (2013).