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The Development of a Positron Source for JLab at the IAC

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1 Project Description

1.1 Proposed Research & Methods of Accomplishment

We propose to develop a partnership between Jefferson Lab's (JLab) Continuous Electron Beam Accelerator Facility (CEBAF) in Newport News, VA and the Idaho Accelerator Center (IAC) at Idaho State University. The partnership will bring the experiences of both electron accelerator facilities together in a joint research and development project to construct a positron source for use by CEBAF. The research will focus on optimizing positron production efficiencies using existing electron accelerator facilities at incident electron energies which minimize radioactive waste. Electron accelerators have previously produced positron beams with intensities approaching $10^7 e^+$/sec [1] at 100 MeV energies that are at least an order of magnitude larger than traditional radioactive source based beams [2]. Positron beams have also been produced at GeV beam energies with intensities of $10^{10} e^+$/sec for use by the high energy physics community. The impact of a positron source on the physics program at JLab is described below in section 2

Two approaches will be used to determine the optimal source configuration appropriate for the CEBAF. The first approach will focus on measuring the maximum positron production rate possible when a finite energy range of positrons from Figure 1a are selected for transport to the CEBAF beam line. The second approach will measure slow positron productions rates using a positron moderator as described in Reference [3]. The goal will be to determine which method suffers from the least loss in positron intensity after being transported to the acceleration stage of the CEBAF. A simulation [4] predicts that one can produce at least a factor of 100 more high energy positrons than low energy ("slow") positrons using 20 MeV electrons when accelerator loss is ignored. The goal of this project will be to construct a positron production test beam facility at the IAC, determine a positron source configuration which can provide the highest intensity, be compatible with the CEBAF beam line, and minimize radioactive waste.

A Memorandum of Understanding (MOU) will be used to describe the general features of the CEBAF-IAC partnership for accelerator physics based education and research. The roles of each partner specific to this R&D project are given below.

- Arne Freyberger and a graduate student will design a beam line for the IAC to test the feasibility of a positron source for the first approach described above.
- CEBAF will provide the magnets needed to transport positrons into a shielded cell at the IAC.
- The IAC will provide a 20 MeV electron beam and beam pipe to enclose the primary and secondary beams.

- Both partners will provide manpower for the installation and operation of the research project.

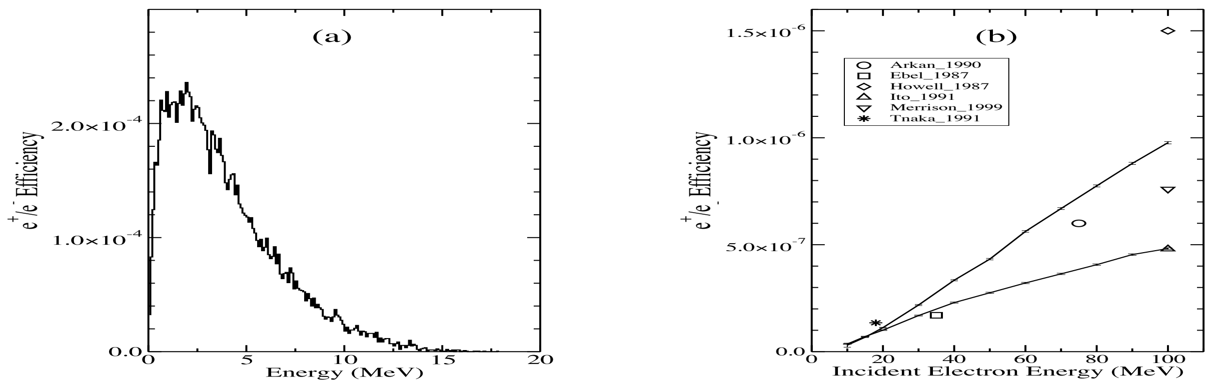

Figure 1: a.)The calculated energy distribution of positrons exiting the front surface of a tungsten converter [4]. The optimal tungsten converter thickness was 3.3 mm thick for 20 MeV electrons at normal incidence with the converter. b.) Slow Positron ($E \leq 600$ keV) production efficiency as a function of the incident electron energy. The lines represent the simulation from Reference [4] which has assumed 90% beam loss due to transport. Measurement from several groups [5] are shown.

2 Project's importance and Relevance to DOE's Mission

The Department of Energy has identified 5 strategic themes which its strategic goals have been formulated to promote in order to satisfy its mission. "Strengthening U.S. scientific discovery" and "Ensuring America's nuclear security" are two of the themes listed which resonate with both the CEBAF and the IAC. Both accelerator facilities have a record of DOE funding for the purpose of scientific discovery. The IAC also has a research program to image cargo containers with electron accelerator based probes for the purpose of improving homeland security against nuclear threats. By forming this partnership, CEBAF will expand its scientific discovery potential with the addition of a positron source and the IAC will acquire infrastructure to quantify beam properties which will open up new avenues of fundamental physics measurements. The work in this proposal will be the impetus for a program of education and training between both facilities that can enhance the mission of each as well as the DOE's overarching mission

The scientific program at Jefferson Lab can benefit in at least three areas. First, the use of charge symmetric probes is one of the most direct methods to evaluate two photon exchange processes. There is a current disagreement between electro-magnetic form factor measurements extracted from asymmetries measured using polarized beams and targets and experiments which rely on Rosenbluth separation with unpolarized beams and targets [7]. Two photon exchange has been blamed for this discrepancy and there are several proposals to measure the amplitudes. Secondly, e^+ and e^- charge asymmetry measurements may be used to measure the interference between Bethe-Heitler and Deeply Virtual Compton Scattering (DVCS) in order to extract DVCS amplitudes and access generalized parton distributions that are used to describe the non-perturbative aspects of a nucleon [8]. Thirdly, the search for a low energy U-boson is an area of scientific discovery which can be probed by the $e^+e^- \to U\gamma$ reaction and contribute information towards unraveling the mystery of the abundant 511 keV photons observed at the Galactic Center [9]. The availability of a positron source at JLab will result in the ability to investigate controversies which have come to light as a result of JLab's original form factor measurement mission as well as extend that mission into the area of generalized parton distributions and the search for a low energy U-boson.

The direct benefits of developing a positron source at the IAC are two fold. The extra instrumentation of the IAC beamline will allow the IAC to expand its experimental program to include absolute measurements of fundamental cross sections for use in their homeland security program. A second benefit is the continued use of a positron source proto-type at the IAC as a facility to probe for defects in materials. Metal fatigue has been identified as the dominant source of mechanical failures [10] which in 1982 was estimated to cost the U.S. economy $119 billion. In 2000, non-destructing testing equipment used to evaluate material defects was estimated to be a market larger than $800 million with even more spent on consulting services. The IAC has demonstrated the feasibility of defect measurements in the past [11] but it has not established a full time user facility. The development of an intense positron source will allow the IAC to reap the above benefits.

3 Methodology and Equipment Needs

Positrons are created when a target of high atomic number (Z), typically Tungsten, is bombarded with electrons of sufficient energy to generate a shower of secondary electrons, photons, and positrons. The primary positrons which exit the tungsten target (converter) have a broad energy distribution. An example of this energy distribution for an incident electron energy of 20 MeV using the optimal tungsten thickness for positron production is shown in Figure 1a. The IAC will provide a 25 MeV electron accelerator with an operating peak current range from 2 to 80 mAs that is capable of accelerating electrons in pulse lengths of 100 ns at a frequency of 120 Hz.

The equipment needed to complete this research project will consist of a magnet system, additional beam line, a positron converter, and a positron moderator. The CEBAF has designed a beam line and will provide the necessary additional magnets beyond what is currently available at the IAC. The IAC will machine and install the additional beamline to transport positrons into a shielded 12' x 12' room housing a positron detection system provided by JLab. The IAC will provide necessary cabling and rack space to data acquisition system. A tungsten converter is available but a positron moderator would be required to complete the "slow" positron component of the project. A beam profile monitor is requested to diagnose beam losses in order to minimize them for positron transport.

4 Anticipated Project Results

The project expects to establish a partnership between CEBAF and the IAC by developing a positron source which is compatible with the CEBAF at JLab. The primary result of this research project will be to determine the source configuration which will enable the highest positron intensity at the CEBAF. The successful completion of this project will demonstrate the effectiveness of the partnership and facilitate more R&D projects. We anticipate establishing the IAC as a training facility in accelerator science that can be leveraged by CEBAF and other facilities to enhance human resources to meet current and future needs.

5 Project Schedule

Project Schedule	
MASD*	Milestone
4	Complete positron Beam line design
8	Complete positron Beam line construction
12	complete MeV positron production efficiencies measurements
14	Complete positron moderator design
18	Complete positron moderator construction
24	Complete positron moderator installation
30	Complete slow positron production efficiencies measurements
36	Publish optimal positron source for CEBAF conclusions
*Months After Start Date	

6 Cost Share & Total Project Cost

The bulk of support in this proposal is devoted to manpower. A postdoctoral researcher at ISU is currently performing experiments which generate positrons to probe materials. A Van De Graff accelerator is being used to accelerate protons onto an Aluminum target for capture, ^{27}Al(p,γ)^{28}Si*). The Silicon decays by emitting two photons, one is used for timing and the other is used for e^+e^- pairs production in the target material being surveyed. The above experiment will conclude by September 2007 freeing up manpower to work on a positron source for JLab if this project is funded.

The remaining expenditures in the budget will be directed towards implementation. Support for one graduate student is requested as well as some support for a faculty advisor. The travel budget will allow at least 5 exchanges of personnel between JLab and the IAC per year for a duration of 2 weeks. Equipment designed to improve the beam diagnostic infrastructure of the IAC is requested in order to evaluate the quality of the positron beam. A harp scanner for $20,000 will be purchased to assess the beam profile in the first year, followed by a positron moderator at relatively the same cost in year 2. The travel budget for the final year will increase to $30,000, in order to sponsor a workshop on positron development designed to issue a white paper documenting the results of this work and recommending a specific design for a positron source at JLab. We request an annual budget of $140,000 from the DOE and $15,000 (10% cost share) from the IAC for a total annual budget of $155,000

Annual Project Budget	
Cost	Description
$80,000	Research Faculty
$30,000	grad student/summer faculty
$20,000	equipment
$10,000	travel
($15,000)	IAC Beam Time (10% cost share)

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