PROPOSAL FOR POSITRON PRODUCTION EFFICIENCY STUDY USING HIGH REPETITION RATE LINAC AT IAC

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Abstract

I propose to measure the positron production efficiency for a positron source that uses a quadrupole triplet system to collect positrons from a tungsten target that are produced when the target is impinged by electrons from the High Repetition Rate Linac (HRRL) at Idaho State University's (ISU) Idaho Accelerator Center (IAC). Positrons were observed in May of 2008 at the IAC without the use of a quadrupole triplet collection system. Positrons escaping from the downstream side of the tungsten target have a wide momentum spread of 0 to 2 MeV when using a 10 MeV electron beam and a large divergence of π rad. A second quad triplet collection system is used to focus the positron beam and as a result increase our positron collection efficiency. I will install the collection system and associated beam line components to measure the positron production efficiency using the HRRL.

1 Introduction

I propose to measure the positron production efficiency for a positron source that uses a quadrupole triplet system to collect positrons from a tungsten target that are produced when the target is impinged by electrons from the HRRL. A polarized positron source, as a new probe to explore nuclear and particle physics at Jefferson Lab, is being studied at the Continuous Electron Beam Accelerator Facility (CEBAF). While their main mission is to optimize polarization, ISU's, goal is to optimize positron production efficiency. On the other hand, positron beamline at ISU is also potential tool for more nuclear physics studies. 4 NaI detectors available for positron detection, and I have measured the emittance of the electron beam optimization. I will install the collection system and associated beam line components to measure the positron production efficiency using the HRRL.

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2 Previous Measurements

Earlier measurements were conducted at ISU's IAC in the May of 2008. The setup is shown in Fig. 1 and the beamline elements are described in Table 1. The accelerator was operated at a 300 Hz repetition rate and 10 MeV energy. The electron was bent by the first dipole, and sent to a 2 mm thick tungsten target. Positrons produced were focused using two quadrupoles and bent 45 degree by the second dipole which was set to transport 3 MeV positrons. Positrons were transported to the end of the linac where they annihilated in Ta target. 511 keV photons were observed in both HpGe and NaI detectors. Fig. 2 shows the spectrum was taken over 600 seconds.

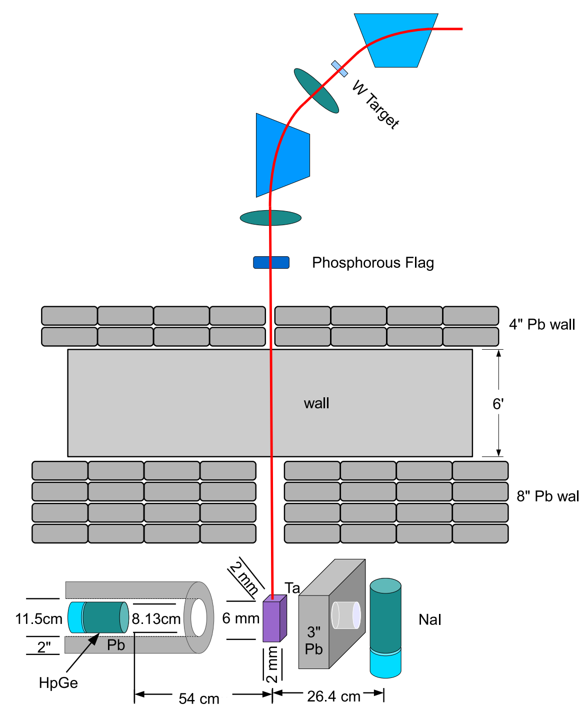

Figure 1: The HRRL beamline configured for positron production at IAC in 2008.

Table 1: Beamline elements for positron production at IAC in 2008.

Item	**Description**
Tantalum foil	6 mm thick 20 mm x 20 mm area
Tungsten foil	2 mm thick 20 mm x 20 mm area
Phosphorus flag	1 mil aluminum backing
HpGe detector	81.3mm Diameter, 55.5mm Length

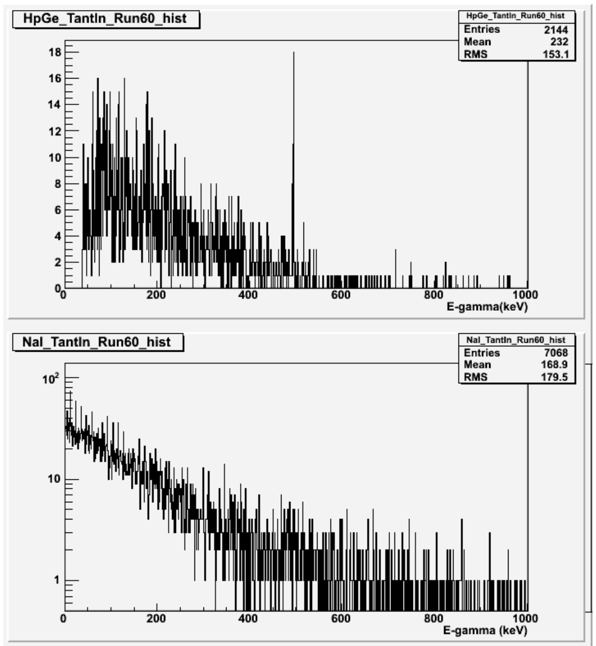

Figure 2: Spectrum from HpGe Detector and NaI detecotrs.

3 Proposed Beamline

I propose a measurement of the positron production efficiency using the HRRL. The HRRL can provide electron beams with energies between 3 MeV and 16 MeV, and a maximum repetition rate of 1 kHz. The HRRL beamline had recently been reconfigured to generate and collect positrons. More details about the HRRL are shown in Table 2.

The new beamline was first designed by Dr. G. Stancari, it uses quadrupole triplet system to collect positrons [1]. The design was further optimized by Dr. Y Kim. The final design of the beamline is shown in Fig. 3. The HRRL accelerator room is divided into two parts by an L-shaped cement wall. The accelerator cell houses the cavity and other elements needed to transport electrons to an experimental cell. The experimental cell is located in an adjacent room to the accelerator cell. The HRRL beamline was reconfigured into an achromat by moving the accelerator cavity to accommodate two dipoles and a system of quadrupole magnets optimized for collecting positrons.

Table 2: Operational Parameters of The HRRL Linac.

Parameter	Unit	Value
maximum electron beam energy E	MeV	16
electron beam peak current I_{peak}	mA	80
macro-pulse repetition rate	Hz	1000
macro-pulse pulse length (FWHM)	ns	250
rms energy spread	%	4.23

In the new beamline, shown in Fig. 3, the electron beam from the cavity passes first through a quadruple triplet that will focus the electron beam onto the positron target. Positrons produced from the positron target will be collected by the second quadruple triplet that will be optimized to collect positrons. The first dipole magnet bends the positrons/electrons, depending on the magnet polarity, by 45 degrees towards the second dipole magnet. The second dipole will bend the beam another 45 degrees, thus completes a 90 degree bend. A third quadruple triplet will focus the e-/e+ beam, as users desire. All beam elements are described in Table 3.

Table 3: The new HRRL positron beamline elements.

Item	Description
T1	Positron target
T2	Annihilation target
EnS	Energy Slit
FC1, FC2	Faraday Cups
Q1,...Q10	Quadrupoles
D1, D2	Dipoles
NaI	NaI Detecotrs
OTR	Optical Transition Radiaiton screen
YAG	Yttrium Aluminium Garnet screen

4 Preparation for the Positron Production Experiment

4.1 HRRL Emittance measurements

Emittance, a key parameter in accelerator physics, is used to quantify the quality of an electron beam produced by an accelerator. The beam size and divergence at any

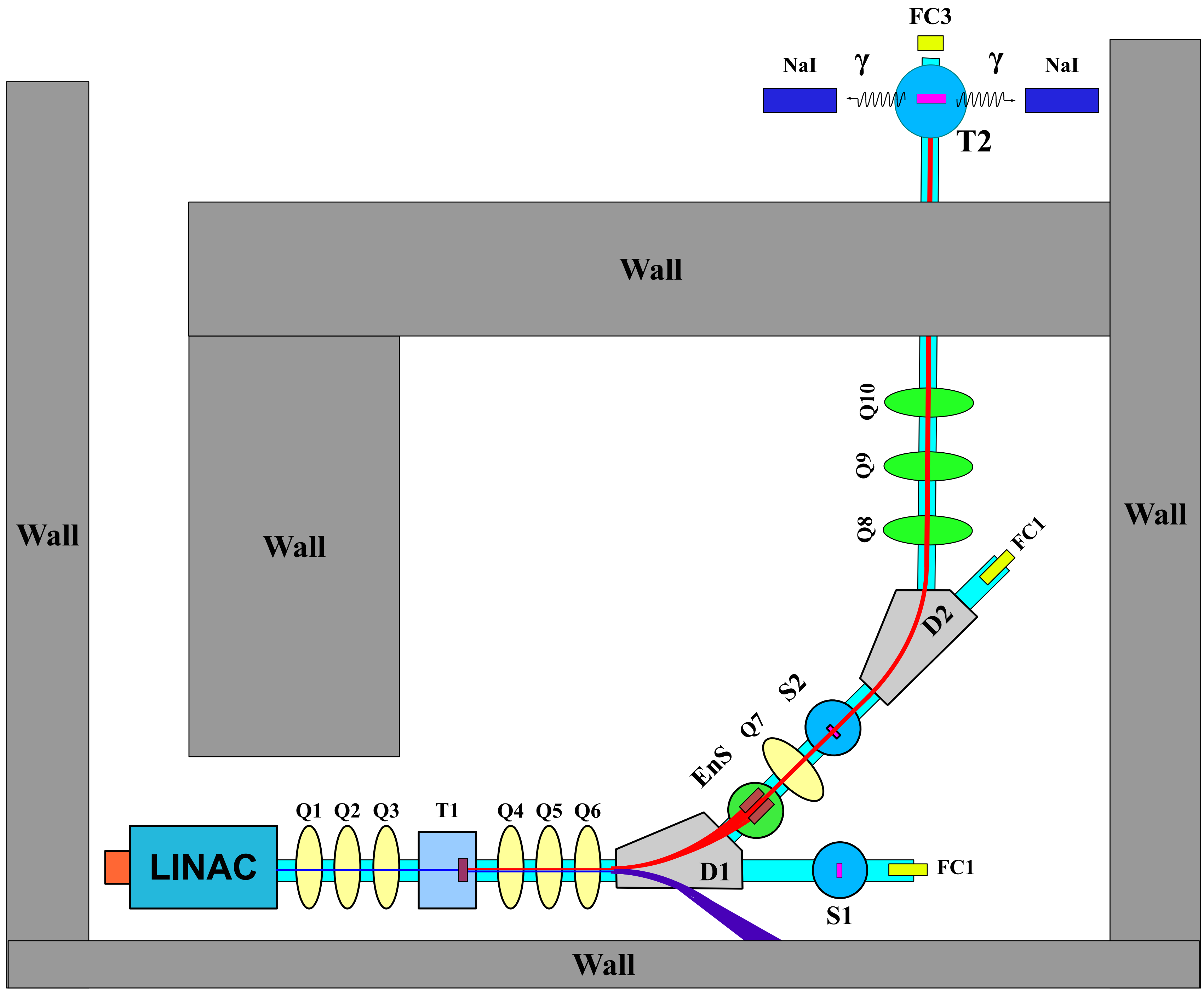

Figure 3: The new HRRL beamline cofiguration for positron generation.

point in the beamline can he obtained using emittance and Twiss parameters by simulation.

An Optical Transition Radiation (OTR) based viewer was installed to allow measurements at the high electron currents available using the HRRL. The visible light from the OTR based viewer is produced when a relativistic electron beam crosses the boundary of two mediums with different dielectric constants. Visible radiation is emitted at an angle of 90° with respect to the incident beam direction [2] when the electron beam intersects the OTR target at a 45° angle. These emitted photons are observed using a digital camera and can be used to measure the shape and intensity of the electron beam based on the OTR distribution.

The emittance of the HRRL was measured to be less than 0.4 μm as using the OTR based tool at an energy of 15 MeV. The details on this emittance measurement using quadrupole scanning method were described in the IPAC12 proceeding [3]. The results are summarized in table 4.

Table 4: Emittance Measurement Results.

Parameter	Unit	Value
projected emittance ϵ_x	μm	0.37 ± 0.02
projected emittance ϵ_y	μm	0.30 ± 0.04
β_x-function	m	1.40 ± 0.06
β_y-function	m	1.17 ± 0.13
α_x-function	rad	0.97 ± 0.06
α_y-function	rad	0.24 ± 0.07
micro-pulse charge	pC	11
micro-pulse length	ps	35
energy of the beam E	MeV	15 ± 1.6
relative energy spread $\Delta E/E$	%	10.4

4.2 Positron Detection using NaI crystals

For detecting positrons, an annihilation target will be placed at the end of the 90 degree beamline. I want to use NaI detectors to detect 511 keV photons. I acquired some NaI crystals from Idaho Accelerator Center (IAC). Since their own bases relied on slow post-amplification, I built new PMT bases. I modified the design of model PA-14 from Saint-Gobain Crystals & Detectors Ltd. These detectors are tested, calibrated, and ready to be used for the measurement. Fig. 4 shows the crystals and the bases I built. Fig. 5 shows the spectrum taken by the detector using button sources.

5 Future Plan

We want to produce positrons using the HRRL beam line. We can improve positron collection efficiency by

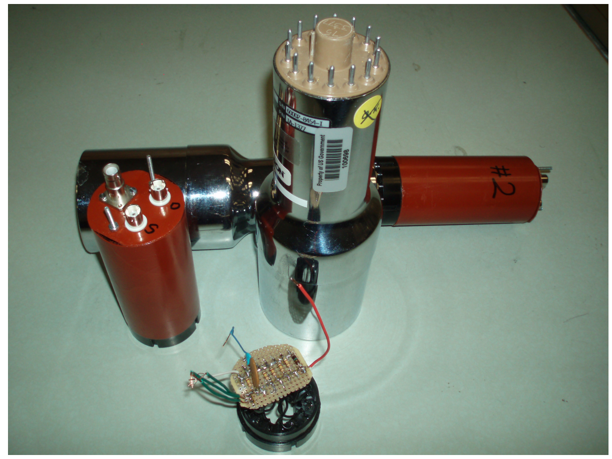

Figure 4: The NaI detector and base built.

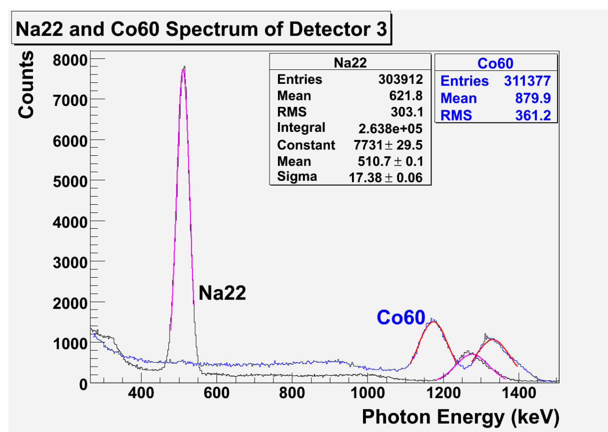

Figure 5: Detector 3 calibrated Spectrum.

applying following methods:

1. By using a quadrupole triplet before tungsten a target, we will have control over the beam size and divergence at the target.

2. Cryogenically cooled converter will be installed, and these targets will be able to take on more beam power and increase positron yield.

3. Positrons will be collected by the quadrupole triplet system, which will improve collection efficiency.

4. Simulations will optimize beam elements for positron collection.

References

[1] G. Stancari and T. Forest ”Design of a new beamline for electrons, positrons and photons at the HRRL lab”, Pocatello, ID, USA (2009).

[2] B. Gitter, Tech. Rep., Los Angeles, USA (1992).

[3] S. Setiniyaz, K. Chouffani, T. Forest, and Y. Kim, in $Proc. IPAC$2012, New Orleans, USA.