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 quad triplet collection system can 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. 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) injector. While their main mission is to measure and increase polarization, at ISU, we want to explore methods to increase positron production efficiency. On the other hand, positron beamline at ISU is also potential tool for more nuclear physics studies. I have 4 NaI detectors ready for positron test, and I have measured emittance of the electron beam for beamlien 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 Idaho Accelerator Center of ISU, May of 2008. Setup are shown in Fig. 1 and beamline elements are described in Table 1. The accelerator was operated at 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 by two quadrupoles and bent 45 degree by the second dipole which was set for 3 MeV positrons. Positrons then transported to the end of the linac where they were annihilated in the Ta target. 511 keV photons were observed in both HpGe and NaI detectors. In the Fig. 2, the spectrum was taken over 600 seconds.

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

2.1 Proposed Beamline

I propose a measurement of the positron production efficiency using the HRRL and is one the 15 small size linacs dedicated for nuclear application operated by the IAC. HRRL can provide electron beam with energies between 3 MeV and 16 MeV, and Maximum repetition rate of 1 kHz. HRRL beamline had recently been reconfigured to generate and collect positrons, while it still can provide electron beam with improved quality. More details about HRRL is shown in Table 2.

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, and J.Ellis. Beamline is to be constructed, as shown in Fig. 3, in the down stairs of Beam Lab. The room HRRL located is

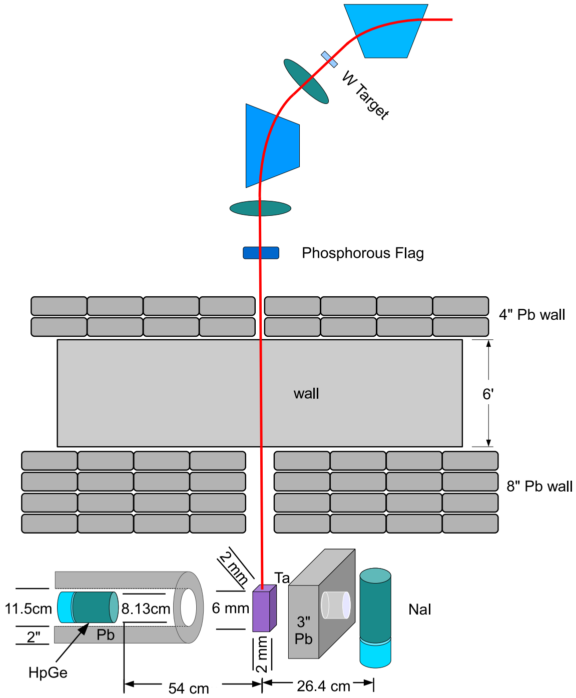

Figure 1: HRRL beamline configured for positron production at IAC in 2008.

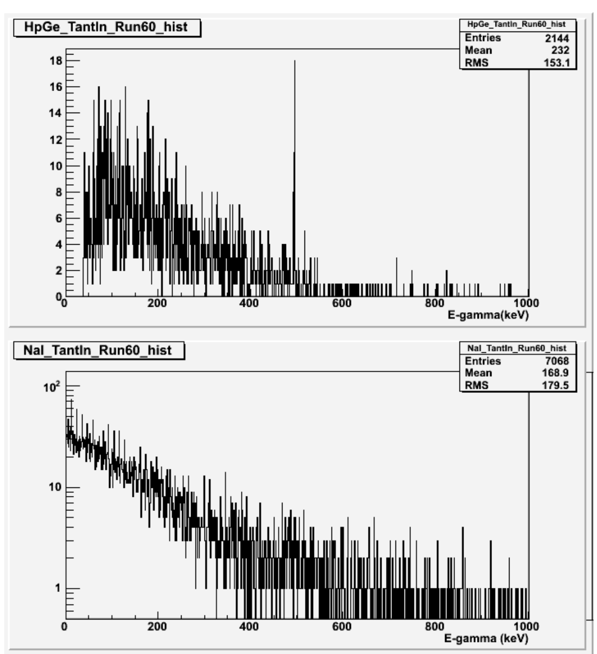

Figure 2: Spectrum from HpGe Detector and NaI detecotrs.

Table 2: Operational Parameters of 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

divided into two parts by a L-shaped cement wall. The accelerator cell houses the cavity and magntic 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.

In the new beamline, shown in Fig. 3, the electron beam from the cavity passes through first the set of quadruple triplet magnets which will be used to focus the electron beam onto the positron target. Positrons produced from the positron target will be collected by the second set of quadruple triplet that will be optimized to collect positrons. The first dipole magnet bends the positrons or electrons, depending on the polarity setting, 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 be used focus the e-/e+ beam, as users desire. All beam elements are described in Table 3.

Table 3: 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

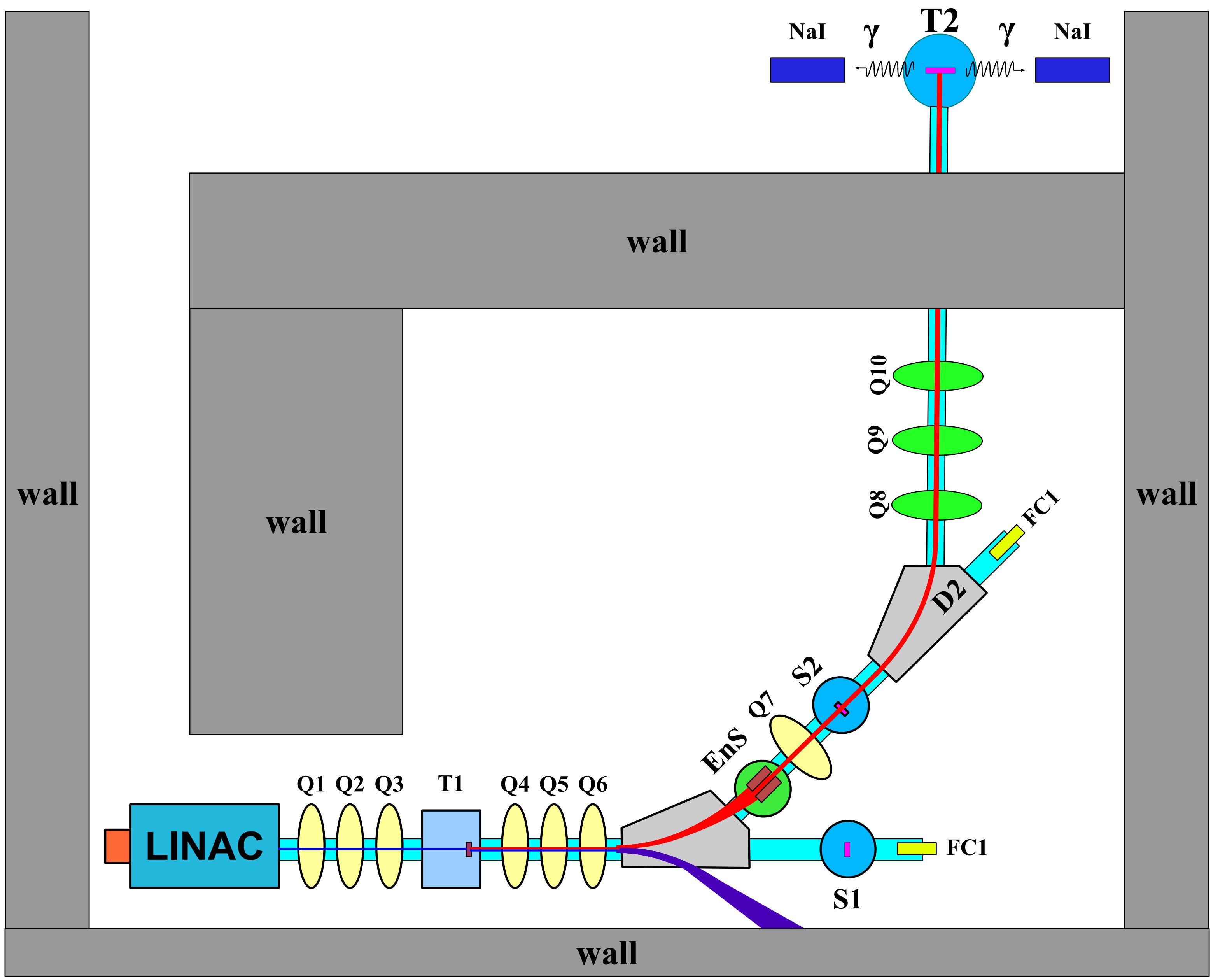

Figure 3: New HRRL beamline cofiguration for positron generation.

3 Preparation for the Positron Production Experiment

3.1 HRRL Emittance measurements

Emittance is a key parameter in accelerator physics that is used to quantify the quality of an electron beam produced by an accelerator. The beam size and divergence at any point in the beamline can he obtained by emittance and Twiss parameters by simulation. This will allow user to have better control over the beam. Energy spread was also measured by scanning the beam with a dipole.

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 projected emittance of the HRRL was measured to be less than 0.4 μm as measured by the OTR based tool at an energy of 15 MeV. Details on this emittance measurement with quadrupole scanning method were described in the IPAC12 proceeding [3]. 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

3.2 Positron Detection using NaI crystals

For detecting positrons, an annihilation target will be placed at the end of 90 degree beamline. I want to use NaI detectors to detect these 511 keV photons. I acquired some NaI crystals from Idaho Accelerator Center (IAC). Since their own bases were not working properly, I built new PMT bases. I modified the design of model PA-14 from Saint-Gobain Crystals & Detectors Ltd. Now these detectors are tested and 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. I expect by doing coincidence, the resolution of 511 keV peak in the spectrum will be improved.

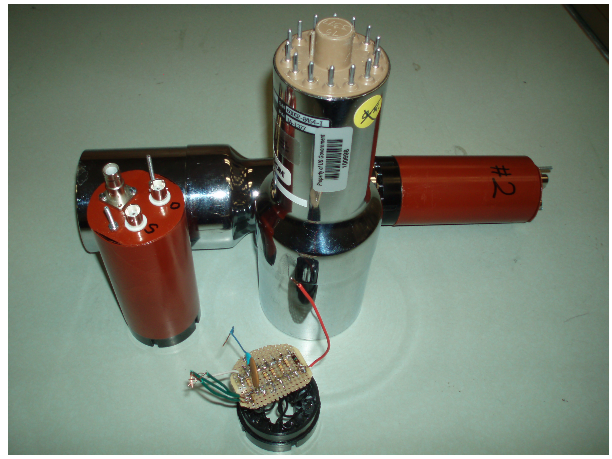

Figure 4: The NaI detector and base built.

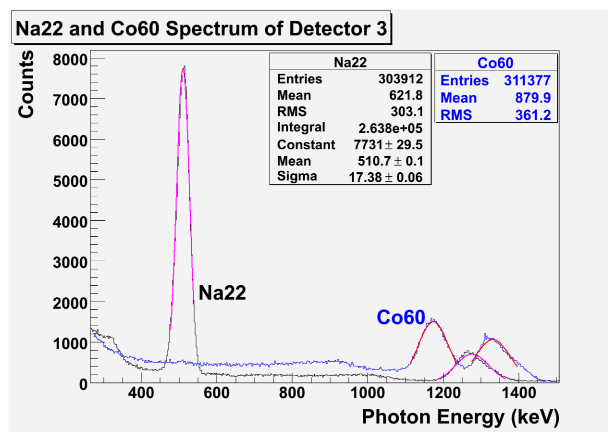

Figure 5: Detector 3 calibrated Spectrum.

3.3 Positron Target Installation

A step motor is ready to be installed once the vacuum chamber is ready. The step motor, shown in the Fig. 6, will hold 8 tungsten targets.

4 Future Plan

We want to produce positrons using HRRL beam line. We can improve positron collection efficiency by applying following methods:

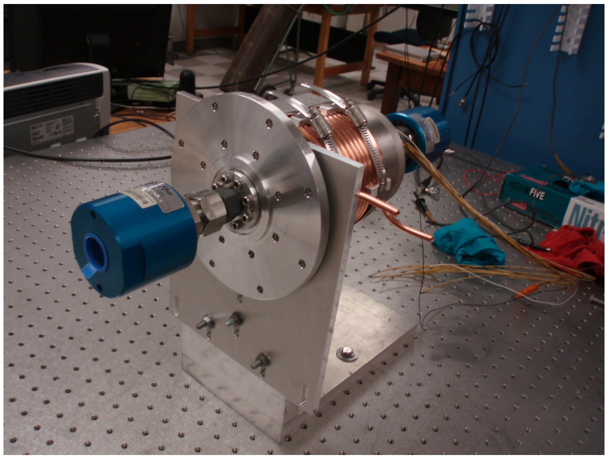

Figure 6: Step motor for holding W targets.

1. By applying a quadrupole triplet before tungsten 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 more beam power, 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.