The GlueX Start Counter Detector

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Abstract

The design, fabrication, calibration, and performance of the GlueX Start Counter detector is described. The GlueX experiment, staged in Hall D at the Thomas Jefferson National Accelerator Facility (TJNAF), primarily aims to study the rich spectrum of photo-produced mesons with unprecedented statistics. The coherent bremsstrahlung technique is implemented to produce a linearly polarized photon beam incident on a liquid H_2 target. A Start Counter detector was fabricated to properly identify the accelerator electron beam buckets and to provide accurate timing information. The Start Counter detector was designed to operate at photon intensities of up to $10^8\gamma$/s in the coherent peak and provides a timing resolution $<$ 300 ps thus providing successful identification of the electron beam buckets to within 99% accuracy. Furthermore, the Start Counter detector provides excellent solid angle coverage, $\sim$ 90% of 4π hermeticity, a high degree of segmentation for background rejection, and is utilized in the level 1 trigger for the experiment. It consists of a cylindrical array of 30 thin scintillators with pointed ends that bend towards the beam at the downstream end. Magnetic field insensitive silicon photomultiplier detectors were selected as the readout system.

Keywords: GlueX, Flash ADC, F1 TDC, Plastic Scintillator, Silicon Photomultiplier, Multi-Pixel Photon Counter, Time of Flight, Trigger, Particle Identification

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1. Design

1.1. Overview

The Start Counter (ST) detector, seen in figure 1, surrounds a 30 cm long super cooled liquid H_2 target while providing $\sim 90\%$ of 4π solid angle coverage relative to the target center. The primary

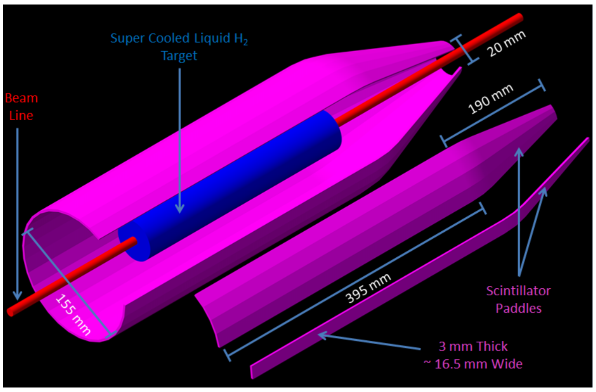

Figure 1: Start Counter geometry.

purpose of the ST detector is, in coincidence with the tagger, to properly identify the electron beam bucket associated with detected particles produced *via* linearly polarized photons incident on the target. It is designed to operate at tagged photon intensities of up to $10^8\,\gamma/s$ in the coherent peak. Moreover, the ST has a high degree of segmentation for background rejection, is utilized in particle identification, and is a primary component of the level 1 trigger of the GlueX experiment.

EJ-200 scintillator material from Eljen Technology, which provides a decay time on the order of 2 ns and a long attenuation length, was used to properly identify the beam buckets which are about 2 ns apart[1]. The ST detector consists of an array of 30 scintillators with pointed ends that bend towards the beam at the downstream end. The amount of support structure material was kept to an absolute minimum in the active region of the detector and is made up of low density Rohacell®. Silicon Photomultiplier (SiPM) detectors were selected as the readout system. The detectors are not affected by the high magnetic field produced by the superconducting solenoid magnet. Moreover, the SiPMs were placed as close as possible, *i.e.* $< 250\ \mu m$, to the upstream end of each scintillator element, thereby minimizing the loss of scintillation light[1].

1.2. Scintillator Paddles

Each individual paddle of the Start Counter was machined from a long, thin, polyvinyltoluene plastic EJ-200 scintillator bar that was diamond milled to be 600 mm in length, 3 mm thick, and 20 ± 2 mm wide, by Eljen Technology. Each scintillator was bent around a highly polished aluminum drum by applying localized infrared heating to the bend region. The bent scintillator bars were then sent to McNeal Enterprises Inc., a plastic fabrication company, where they were machined to the following desired geometry (see figure 2).

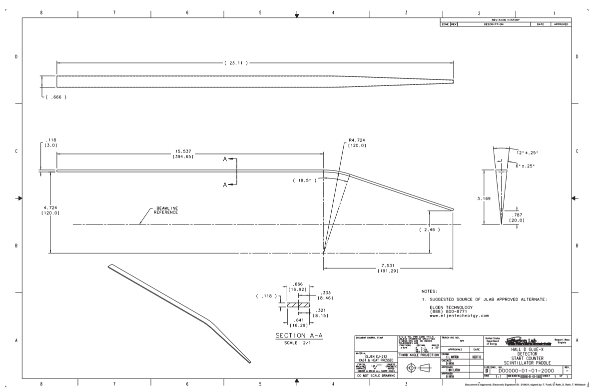

Figure 2: Start counter single paddle geometry.

The paddles consist of three sections and is described from the upstream to the downstream end of the target. The straight section is 394.65 mm in length and is parallel to the target cell. The bend region is a 18.5° arc of radius 120 cm and is downstream of the straight section. The tapered nose region is downstream of the target chamber and bends towards the beam line such that the tip of the nose is at a height of 2 cm above the beam line.

After the straight bar is bent to the desired geometry, the two flat surfaces that are oriented orthogonal to the wide, top and bottom, surfaces are cut at a 6° angle. During this process the width of the top and bottom surfaces are machined to be 16.92 mm and 16.29 mm wide respectively. Each of the 30 paddles may be rotated 12° with respect to the paddle that preceded it so that they form a cylindrical shape with a conical end. The geometry of the ST increases solid angle coverage while minimizing multiple scattering.

The 30 scintillator paddles are placed atop a Rohacell support structure which envelopes the target vacuum chamber seen in figure 3. Rohacell is a

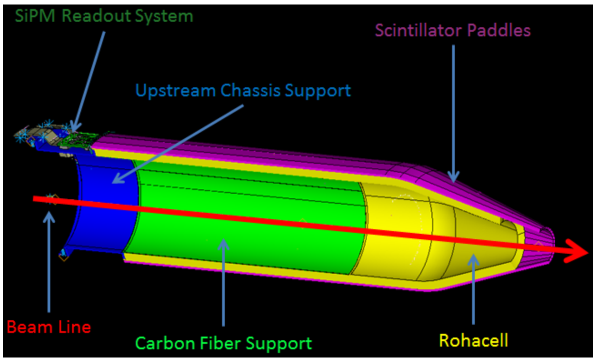

Figure 3: Cross section of the ST.

rigid, low density foam ($\rho = 0.075\ g/cm^3$). The Rohacell, which is 11 mm thick, is rigidly attached to the upstream support chassis and extends down the length of paddles however, not to include the end of the conical section. Glued to the inner diameter of the Rohacell support structure are 3 layers of carbon fiber ($\rho = 1.523\ g/cm^3$) which are 650μm thick. A cross section of the ST can be seen in figure 3 where the carbon fiber is visible. The carbon fiber serves as to provide additional support during the assembly process as well as long term rigidity.

The SiPM detectors are held in a fixed position while being attached to the lip of the upstream chassis *via* two screws. The scintillators are placed as close as possible to the active region of the SiPMs (see figure 4).

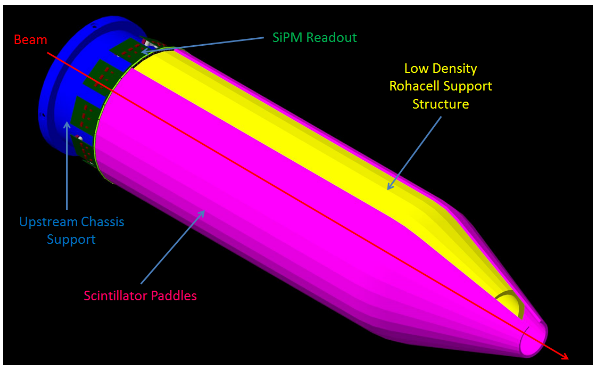

Figure 4: Partially assembled Start Counter.

The ST scintillators are coupled *via* an air gap ($< 250\mu m$) into groups of four SiPMs set in a circular arrangement. The individual SiPMs are single-cell SiPMs (Hamamatsu MPPC, S10931-50P) with a $3 \times 3\ mm^2$ active area. Four individual SiPMs, grouped together in a linear array, are arranged such that they are parallel to the end of the upstream end of a scintillator as seen in figure 5.

Four SiPMs, reading out one individual paddle,

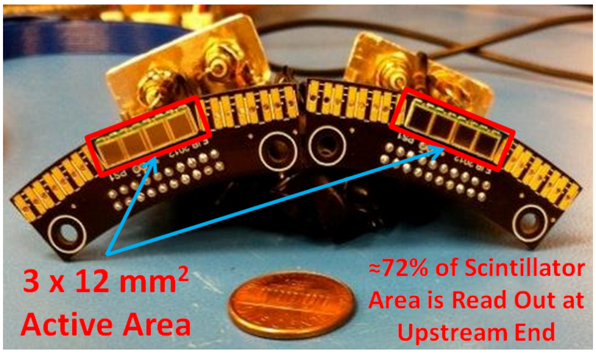

Figure 5: ST1 of SiPM.

are current summed prior to pre-amplification. The output of each preamp is then split, buffered for the Analog to Digital Converter (ADC) output, and amplified for the Time to Digital Converter (TDC) output by a factor five relative to the ADC. The ADC outputs are readout *via* flash ADCs (JLab 250 MHz Flash, fADC250), while the TDC outputs are input into leading edge discriminators (JLab LE discriminator), followed by a 32 channel flash TDC (TDC JLab F1-TDC). Furthermore, each group of four SiPMs utilizes a thermocouple for temperature monitoring. There are 120 SiPMs in total, for a total of 30 pre-amplifier channels as seen figure 6.

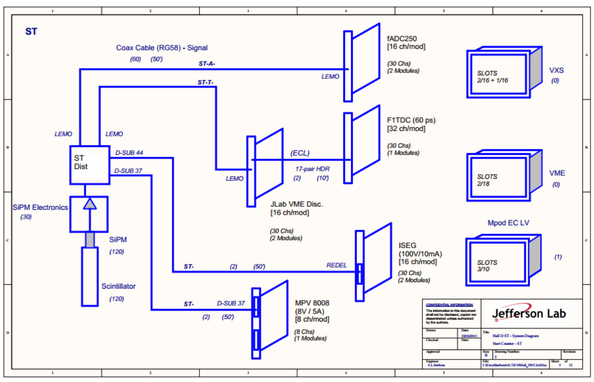

Figure 6: Start counter electronics.

There are three components that comprise the SiPM detector and readout system. The first component is the ST1 which holds 3 groups of 4 SiPMs. The SiPMs are housed in a ceramic case, while being rigidly attached to the ST1. In order to mimic the geometry of the 30 paddle design one group (of four SiPM's) is offset by 12° relative to the central group, while another group is offset by −12°. One ST1 unit will collect light from three paddles individually. The ST1 implements the current sum and bias distribution per group of 4 SiPMs. It also has a thermocouple for temperature monitoring.

The second component is the ST2 which is a Printed Circuit Board (PCB) that houses the electronics of the readout system. It has 3 channels of pre-amplifiers, 3 buffers, and 3 factor five amplifiers. Furthermore, it has 3 bias distribution channels with individual temperature compensation *via* thermistors. The ST2 is attached to the ST1 *via* 90° hermaphroditic connector.

The third component, the ST3, provides interface to the power and bias supplies. It also routes the 3 ADC, and 3 TDC outputs as well as the thermocouple output. The ST3 connects to the ST2 emphvia a signal cable assembly. The ST3 is installed in the upstream chassis upstream of the Start Counter and next to the beam pipe seen in figure 7.

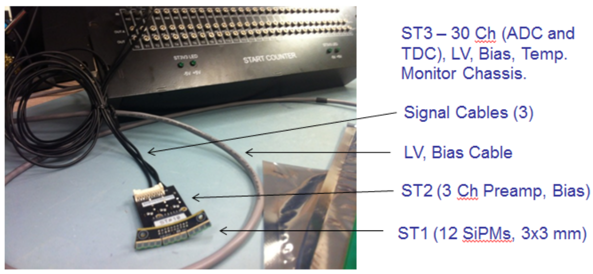

Figure 7: SiPM Readout System.

2. Fabrication

References

[1] E. Pooser, The GlueX start counter and beam asymmetry Σ in single π^0 photoproduction, Ph.D. thesis, Florida International University (2016).