Request for Parasitic Beam Test of GlueX Active Collimator Prototype

Richard Jones
University of Connecticut

Alexander Somov
Jefferson Lab
(Dated: October 18, 2010)

Permission is requested to install the GlueX prototype active collimator in the photon beam dump area of Hall B during the Primex run of Fall 2010. This run follows up on a prior successful beam test of this same device which was conducted in parasitic mode in Spring 2007. Results from that run are summarized. The readout of this device has now been upgraded to instrument 4 of the 8, which permits two complete opposing quadrants to be monitored continuously during scans across the beam. The readout cables have also been reconfigured to minimize spurious peaks that appeared in the earlier scans, believed to have been caused by showering in the readout cables. The device is to be mounted on top of the total absorption counter in the back of the Hall B alcove, as in the prior beam test. Goals of the run are to test the spatial resolution of the device in the absence of the narrow upstream collimator that was present in the 2007 test, and to determine the bandwidth limits of the position readout. Knowing the bandwidth is very important for this device because it is planned to use it to stabilize the photon beam position on the Hall D collimator using a controlled feed back loop to electron beam correctors upstream of the radiator.

A prototype of the active front-end of the photon beam collimator being built for Hall D has been assembled and bench-tested at the University of Connecticut [1–3]. The detector senses the position of the photon beam by measuring the current produced by knock-on electrons generated in the early stages of an electromagnetic shower. An segmented tungsten block partitioned in both radius and azimuth doubles as the shower material and the cathode. The tungsten wedges are positioned just upstream of the entrance face of the primary collimator, which serves as the anode of the detector circuit. A hole through the center of the tungsten plates allows the collimated photon beam to pass unattenuated. No bias voltage is applied to the detector; the current is driven by the shower energy when the beam is on. A difference between the measured currents in opposite sectors is the signal of beam misalignment.

According to Monte Carlo simulations, the currents in the inner sectors at full operating intensity in Hall D are on the order of 1 nA. However to be useful during initial running at reduced intensities it is essential that the device be sensitive to photon beam position at currents as low as 30 nA, where the expected currents are on the order of 10 pA. Using current-sensitive preamplifiers with a transimpedance gain of $10^{11}\,\Omega$, the device has been shown on the bench to be sensitive to currents on the order of 0.1 pA with a bandwidth of order 100 Hz.

The primary collimator prototype has been assembled and tested at the University of Connecticut with four opposing tungsten wedges installed. Four high-gain current preamplifiers have been interfaced to a PC using a PCI adc card and read out using the Labview data acquisition package. The proposal requests permission to install the detector and in the Hall B alcove and monitor the response of the detector to the Primex tagged bremsstrahlung beam in parasitic mode.

I. DETECTOR DESCRIPTION

The active collimator is a disk of 14.72 cm diameter 4.2 cm thick. There is a clearance hole of 5 mm diameter through the central axis for the passage of the central core of the photon beam. Normally the primary tungsten collimator would sit directly behind the detector, but that object does not currently exist. There is an aluminum casing around the active collimator elements that is sufficiently thick to provide the return path for the current loop, so the lack of additional material behind the detector to stop the knock-ons and return them through a low-impedance path to ground is not expected to make any observable difference.

For the beam test, the collimator will rest on its outer insulating case. The outer surface of the case has been machined to a cylinder with an axis on the center of the clearance hole to a precision of 125 microns. Four electronics channels are available for the readout. Two opposing sectors along the horizontal axis will be tested.

A photograph of the detector mounted in the alcove of Hall B is shown in Fig. 1. The detector is mounted on top of the TAC which serves as a horizontal translation stage which can be controlled remotely to scan the detector through the electron beam without interfering in any way with operation of the Primex experiment. The detector is held fixed on the translation stage by a pair of wedges under its base that prevent it from rolling.

FIG. 1: Photograph of the prototype active collimator installed on top of the total absorption counter in Hall B, as configured for the parasitic beam tests in April 2007. The detector was mounted so that its central hole is at the height of the electron beam while the TAC is in its parked position below the lead brick wall that shields it from the direct photon beam. It was then horizontally scanned across the beam by moving the TAC left and right.

II. RESULTS FROM THE 2007 TESTS

The primary goal of the 2007 parasitic beam test in Hall B was to demonstrate that the tungsten pin-cushion design with current-mode readout would work in a tagged photon beam, that the currents predicted in Monte Carlo were on the right order of magnitude, and that this device would work under realistic conditions in an experimental hall without excessive electronic pickup noise. The currents reported in Figs. 2-3 are a factor 3.5 larger than those predicted by the Geant3 simulation. This discrepancy is not altogether surprising because the Geant3 result was sensitive to the lower cutoff on the energy of shower particles and deltas in the simulation, and the photoelectric effect that dominates photon absorption at energies below 100 keV is a complex Z-dependent function of energy that is only described in an average way by Geant3.

What is more surprising about these results is the relatively large response seen on the inner wedges when the photon beam interacts in the outer wedges (peaks at 15.5 and 22.0 cm in Fig. 2). In the simulation this cross-talk effect was limited to less than 5% of the peak current seen when the photon beam directly strikes the wedge being read out, but in the beam test the effect was more like 25%. The same thing is seen in reverse in Fig. 3. It is difficult to imagine what might give rise to such a large cross-talk between sectors. They are physically separated by grounded conductors, so there is no direct path available for current to pass between the wedges. One possibility is that when the photon beam was directed onto the wedges that were not being read out, they were charging up to a high voltage and surface leakage currents were being created to drain the charge along the insulator surface to the nearest path to ground, which was through the adjacent wedges connected to the readout. If this hypothesis is correct, then repeating the test with all four wedges connected will result in much smaller cross-talk between the wedges. The presence of 25% inter-wedge cross-talk will not render the device unusable but it reduces the resolution somewhat, and in any case, it should be understood.

The other anomaly in these results is related to the middle peaks seen in Figs. 2-3 at positions 16.5 and 21.0 cm. These are interpreted as resulting from the readout cables hanging in front of the detector acting as a pre-shower. These cables can be seen in Fig. 1. The asymmetry between left and right comes from the fact the the cable on the

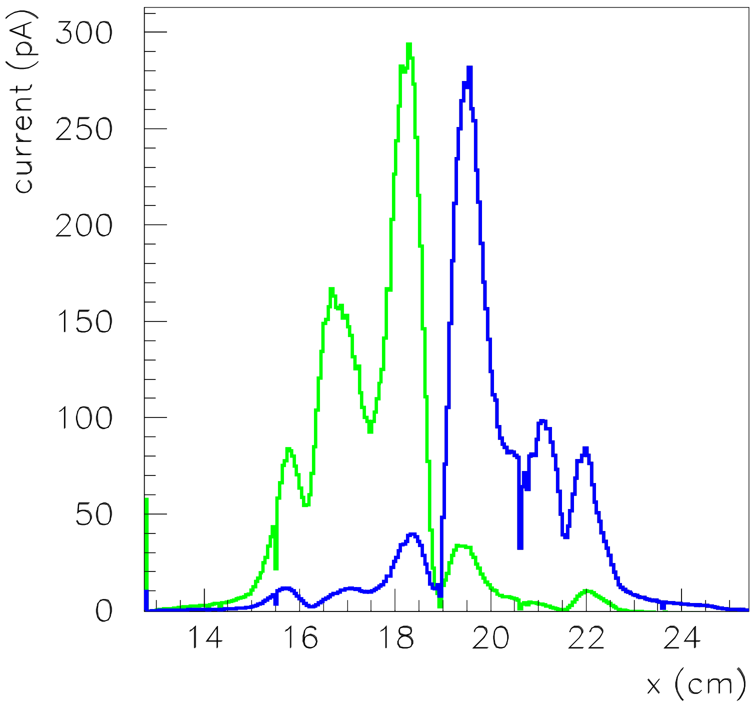

FIG. 2: Current measured on the two inner wedges of the active collimator as it was scanned horizontally through the beam. The green curve is the current measured from the left wedge and the blue from the right. The large inner peaks arise from the beam directly hitting the inner wedges, while the smaller peaks come from the beam interacting in other material and somehow producing current in the inner wedges.

left hangs down from above the beam height across the beam, whereas the one on the right starts out somewhat below the center of the photon beam and so interacts with a smaller fraction of the beam. The cable connections have now been replaced with right-angle elbows that direct the cable radially outward from the connector. If this explanation for the middle peaks is correct, they should be more or less eliminated by this change.

III. GOALS FOR 2010 TESTS

The first goal of the 2010 parasitic beam test is to confirm that the anomalies seen in the 2007 beam test described in the previous section were correctly diagnosed and that the remedies were successful. The second goal is to measure the signal noise vs. bandwidth of the detector signals. The currents plotted in Figs. 2-3 were averaged over 10-second intervals between steps in the scan. The readout is capable of sampling the input currents at 1 kHz or even higher, although the amplifiers have a bandwidth limit somewhat below this. In the Hall D photon beam line it is important that the active collimator have a bandwidth higher than 60 Hz in order to pick up the dominant frequency components of beam motion and send a cancellation signal to the corrector coils upstream on the electron beam line. In 2007 it was possible to see a large 60 Hz component on the current signals from the preamplifiers when viewed on an oscilloscope, but the data acquisition system used during that run did not save the waveforms, only the average values. During this run we will save the full sequence of sampled values at a frequency of 1 kHz and from that it will be possible to determine the bandwidth vs. sensitivity curve of the detector and readout system.

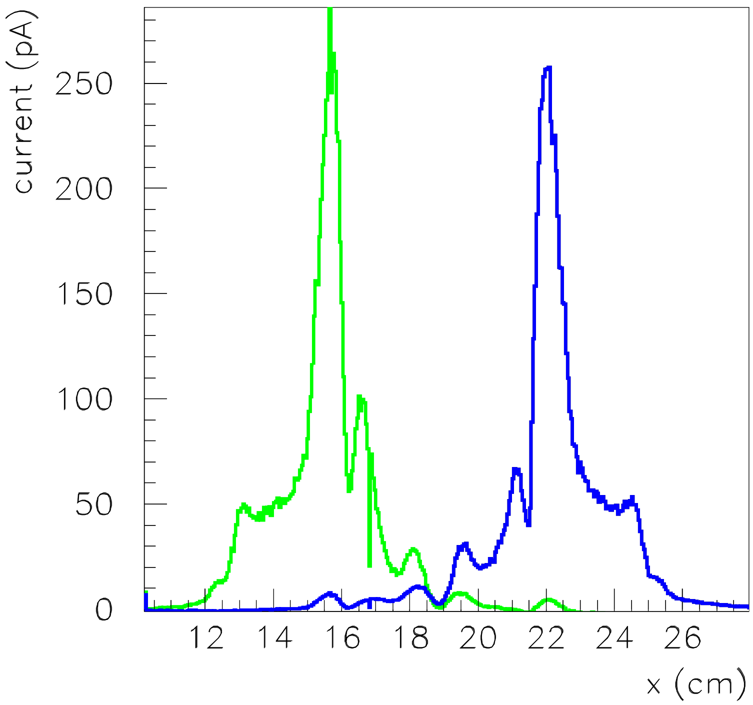

FIG. 3: Current measured on the two outer wedges of the active collimator as it was scanned horizontally through the beam. The green curve is the current measured from the left wedge and the blue from the right. The large outer peaks arise from the beam directly hitting the outer wedges, while the smaller peaks come from the beam interacting in other material and somehow producing current in the inner wedges.

IV. IMPACT ON PRIMEX

No modifications to the photon beamline or shielding are required for this test, other than the placement of the detector in the beam at the back of the hall. There are no outstanding safety issues with this device because it is entirely passive. Killing the power to the hall in case of an emergency would have no impact other than to abruptly shut down the PC. The internal detector tolerances allow for differential expansion within the temperature range -20° to +50°C. Control software for moving the TAC is already integrated into the slow controls for the Hall. A 24/7 telephone number will be available in the counting room in case questions arise regarding this apparatus.

During the 2007 test run, the active collimator was left installed on top of the TAC for the entire period from mid-March until the end of June. At the end of the run, the RadCon group surveyed the instrument and found no detectable activation was present. Thus we expect that no issues will arise with radiation safety when the time comes to remove it from the beam line in preparation for the TPE experiment.

[1] C. Gauthier and R.T. Jones, “Simulation of Shielding Options for an Active Collimator”, Gluex-doc-60, 2003.
[2] C. Gauthier and R.T. Jones, “Simulation of a Position-Sensitive Tungsten Pin-Cushion Detector for GlueX”, Gluex-doc-244, 2003.
[3] I. Senderovich and R.T. Jones, “Assembly and Bench Tests of an Active Collimator”, GlueX-doc-759, 2007.