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Secondary Emission Detectors for Fixed Target Experiments at Fermilab

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SECONDARY EMISSION DETECTORS FOR FIXED TARGET EXPERIMENTS AT FERMILAB

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Abstract. A description of a Secondary Emission Electron Detector (SEED) is given. The SEEDs provide accurate profiles and positions at small wire spacing (125-500 μm) in a high energy, high rate environment that exceeds the capabilities of traditional segmented wire ion chambers (SWICs). This device has been designed and constructed to monitor beam position and profile of two fixed target beamlines, namely, KTeV (FNAL E-799, E-832) with an average beam sigma at target of 0.22 mm and NuTeV (FNAL E-815) with a sigma = 0.6 mm. KTeV took beam at an intensity of up to 5E12 800 GeV protons over a 20 sec spill and NuTeV received 1E13 800 GeV protons in five pings/spill.

I. INTRODUCTION

Secondary emission detectors have been used at Fermilab and at other laboratories for measuring beam intensity, position and profile for many years [1,2]. Two of Fermilab's fixed target beamlines that took 800 GeV proton beam in 1996-1997 are KTeV and NuTeV. The SEEDs were built to measure precisely the beam position and profile and can display beam intensity by adding an intensity section. Figure 1 shows the main detector. In designing the detector we considered the past experience obtained in building and testing the TSEM [3] which was used in the PBAR source.

II. EXPERIMENTAL REQUIREMENTS

The beam parameters and design requirements were quite different for KTeV and NuTeV but resources only allowed for one detector design, so the SEEDs were kept as modular as possible. The NuTeV beam was measured at two stations before the target. At the upstream (US) station the beam had a FWHM of 2.6 mm horizontal and 1.9 mm vertical, and at the downstream (DS) station 0.7 mm horizontal and 2.4 mm vertical. The beam was delivered in 4 msec "pings". The 5 pings each had an intensity of 2E12/ping. The KTeV beam was also measured at two stations. At the upstream station the beam had a FWHM of 0.9 mm horizontal and vertical. At the DS (target) station 0.56 mm horizontal and 0.47 mm vertical. The beam intensity averaged about 3E12.

III. REFERENCE AND ALIGNMENT

The detector, Fig 1, can be mounted in a stationary position or inside a vacuum vessel to allow the detector to be moved in/out of the beam. Because of the different specification parameters, stainless steel vessels were made for KTeV and aluminum for E-815. In order to meet the requirements for absolute position and angle referencing on the SEED was done with CMMs (accuracy = ±3 μm) and alignment was done with a laser tracking interferometer (accuracy = ±30 μm distance, ±1 arcsecond for both angles). Since the SEED wires were not visible after assembly (even with the vacuum window off) referencing from the inside out was required during the assembly process. All the ceramic boards on which the wire planes were attached had two precision mounting holes, see Figure 2. One hole was circular to define the x,y position of the board and the other hole was slotted to allow for heat expansion and fix rotation. Because the vendor was unable to meet the tolerance required, it was necessary to map the location and angle of a reference wire with respect to the holes for each board. This was done with a CMM using an optical probe. Wire spacing was also verified with this procedure. Only the ends of the locating pins are visible after the board and foil assembly are mounted in the vacuum chamber, making it necessary to fabricate and fasten the mounting plate and pin assembly such that the pins are mounted perpendicular to a precision machined "fiducial" surface on the outside. The pins and surface were then mapped using a CMM with a touch probe and referenced to the outside fiducials. The fiducials are precision 1/4" holes drilled into the stainless steel collar located above the vacuum chamber. Laser tracker sphere mount pins fit into these holes and hold the retroreflecting sphere on the flat surface of the collar. The SEED could now be accurately aligned under vacuum

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after being installed into the beamline using a laser tracking interferometer or rough aligned with conventional survey instruments using special adapters which fit onto the sphere mounts.

IV. PROFILE SECTION

The profile section contains x and y signal planes located between three bias foils. In order to satisfy the beamline requirements, two types of ceramic boards have been designed. A single sided board with a wire pitch of 0.500 mm and a double sided board with a pitch of 0.250 mm and 0.125 mm offset between the front and back sides. Fig. 2 shows a layout of a 0.125 mm ceramic board. A description of how the wires were soldered to the ceramic substrate was already given [4].

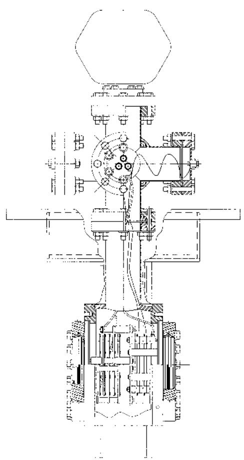

FIGURE 1. Detector Assembly

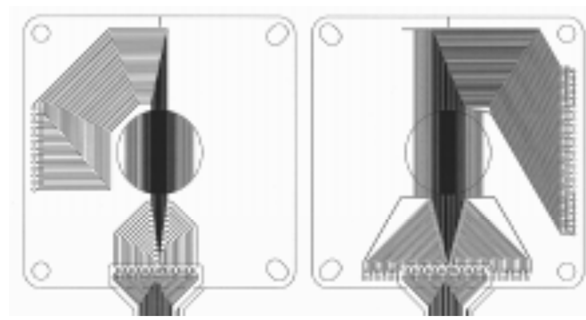

FIGURE 2. 125 µm Signal Board

V. RESULTS

E-815: The detectors were placed in the beam only about 3% of the total run time, or about 1E17 protons. The estimated resolution is 3.5 microns for the 125 µm boards, 7 microns for the 250 um boards, and 14 µm for the 500 µm boards. The measured secondary electron efficiency is (4.0 +/- 0.5)% as compared to a current transformer. This is the number of electrons liberated per proton that hits a wire. Figures 3 and 4 show a comparison between the SEED (solid lines) and nearby SWICs (dashed lines) at the downstream station in the NuTeV beam. The SWIC profiles contain large tails which the SEED show are not actually present in the beam.

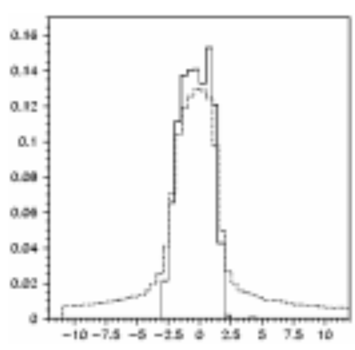

FIGURE 3. Horizontal Beam Profile

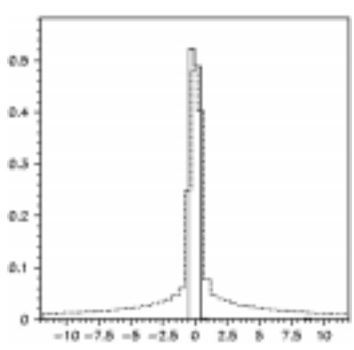

FIGURE 4. Vertical Beam Profile

KTeV: The KTeV target SEED was tested for signal degradation since it had the highest integrated flux density and the beam was focused on the same spot for the entire run. The signal strength was tested by moving the beam to various locations on the wire and comparing the integrated signal. The result was a 20% drop in signal strength for a 1 year run of ~3E12 ppp and a beam sigma of 220 µm. This was not a problem since this SEED was not used for intensity monitoring. Figure 5 illustrates the resolution of the KTeV target SEED. In order to test the resolution, the beam was moved up and down an equal amount by changing a magnet current. This was done on alternating spills to eliminate any effects of beam drift. Each point represents the average beam position of 9 samples during an 18 second spill interval with random readout noise subtracted. The plot shows that at each of the two magnet settings, the beam and SEED are stable within about 10 µm over the period tested with an estimated 2 µm beam drift.

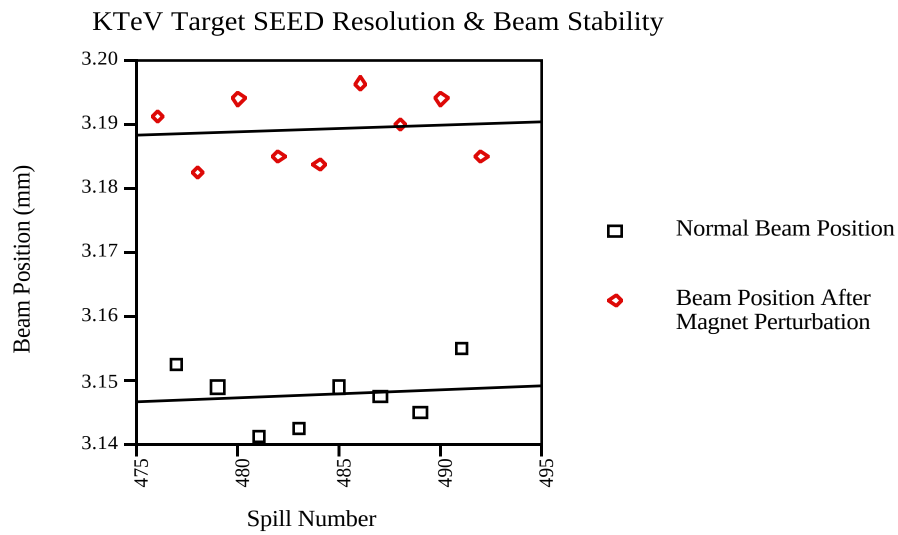

FIGURE 5. KTeV Target SEED Resolution & Beam Stability

VI. DISCUSSION

Of the four detectors built and tested, three worked very well and one had some outgassing that necessitated replacement of the ion pump. The plan is to investigate the source of this outgassing during shutdown. The pretarget KTeV SEED was left in the beam at all times and took an accumulated intensity of about 1E18 protons. None of the wires failed. For the next run, we plan to upgrade the ceramic boards by adding vias to allow soldering the wires to the pads without having to epoxy the wires to the boards. We also plan to upgrade the flex tapes that take the signals from the ceramic boards to the vacuum feedthroughs. Finally, we expect to upgrade the electronics. The hardware will consist of a multiprocessor system with a master CPU and multiple data collection slaves. The sequencer will manage the integration and storage of up to 16 scans that can be recalled at will. The communication between the CPU and the slaves will be done via ARCNET. Ethernet will provide communication between the VME crate and the computers. The software will also be upgraded .

VII. ACKNOWLEDGMENTS

We would like to thank the numerous people that helped in all the facets of this project: the engineering, mechanical, electrical and the alignment groups.

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