

A FIBER PROFILE MONITOR FOR LOW BEAM INTENSITIES*

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Abstract

A scintillating Fiber Profile Monitor (FPM) has been prototyped, built and tested for the new low intensity Meson Test (M-Test) beamline at Fermilab. The beamline has the following beam parameters: E = 1-120 GeV, I from a few hundreds to 700,000 particles/spill, the spill length is 4.5 seconds with a cycle time of 1 minute. Segmented Wire Ion Chambers (SWICs) and Proportional Wire Chambers (PWCs) do not display the beam profile accurately below about 10,000 particles.

For the prototype FPM detector a modified SWIC vacuum can was used. An (x, y) array of fibers replaced the chamber containing windows, gas, and AuW wires soldered on a ceramic substrate. The fibers were purchased from Saint Gobain and are of the type BCF-12 MC, 420 nm wavelength. They have a diameter of 0.75 mm and are coated with black EMA for optical isolation. The 64 channel fibers are positioned and then epoxied in a vacuum feed-through “cookie” to match a Burle 64 channel multianode microchannel plate PMT of the type Planacon # 85011-501. The gain of the Planacon PMT is 800,000 at -2400 Volts. Unlike SWICs or PWCs, this device will allow for vacuum continuity. Comparative data with PWCs will be presented.

THE BEAMLINE

Meson Test is a Fixed Target beamline that takes a primary beam of 120 GeV from the Main Injector, through a section of the TeV tunnel and Switchyard before hitting a target station in MT4. Secondary beams of various energies and intensities are then produced and refocused to satisfy experimental requests. Figure 1 shows the location of the Meson Area.



Figure 1. Meson Area

M-Test has recently been re-designed. Various types of secondary beams are now produced. As the energy of the secondary beam is lowered beam scattering increases mainly because of the large amount of material in the beam due to many beamline windows. A fiber profile monitor was developed to allow experimenters to profile secondary beams below the threshold region of SWICs and PWCs.

PWC CHAMBERS

These profile monitors were originally designed and built by Howard Fenker [1] in 1983 and are still in use in a few low intensity, fixed target, secondary beamlines. An X and Y sense plane, made using 10 μm diameter AuW wire is installed between three high voltage cathodes made with 12.5 μm Al foils. A set of 12 μm Al foils complete the assembly. Ar/CO2 at a mix ratio of 80/20% is used as the ionizing gas. Figure 2 shows a PWC layout details.

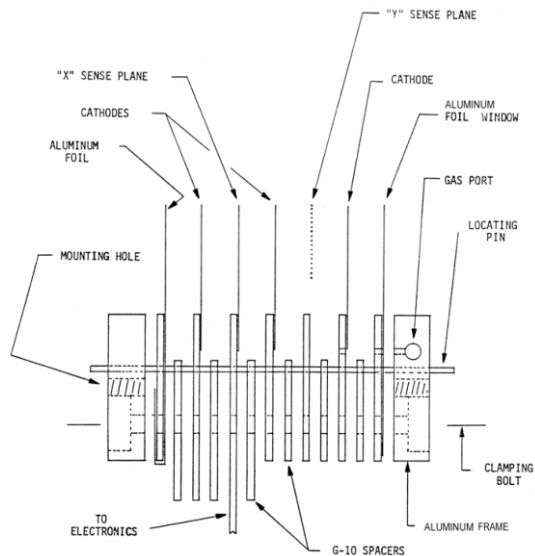


Figure 2. PWC layout

The beamline installation of a PWC requires a vacuum

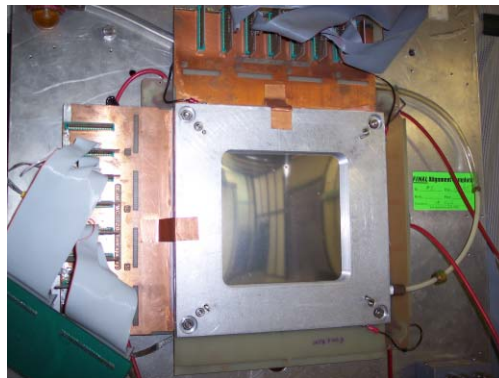


Figure 3. PWC detector

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break and therefore about 150 μm of Ti per beamline window,. A typical PWC has 60 μm of Al, 2 cm of ArCO_2 and 0.05 μm of tungsten corresponding to 0.007 radiation Lengths. This amount of material degrades the beam quality. Figure 3 shows a complete PWC detector.

FIBER PROFILE MONITOR

The Fiber Profile Monitor (FPM) is designed to sample the beam via scintillating fibers in vacuum, thereby minimizing the material seen by the beam. The fibers are mated to a 64 channel multianode microchannel plate PMT (MA-MCP-PMT) via a vacuum “fiber cookie” feed through. This allows all electronics to remain outside the vacuum. The MA-MCP-PMT model is the Burle Planacon # 85011-501 (Planacon PMT).

Two detectors (“MT6WC3” and “MT5FP2”) have been built, installed, and tested so far. The MT6WC3 operates in air, while MT5FP2 operates in vacuum.

Fiber Plane Assembly

A set of 32 scintillating fibers having a diameter of 0.75 mm and 2 mm pitch were epoxied on both sides of a ceramic board in an X and Y configuration. Figure 4 shows both fiber planes as they are epoxied on a ceramic board.

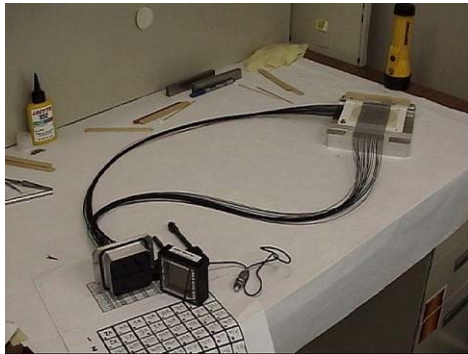


Figure 4. Fiber Plane Assembly

The two sets of fibers were then bundled together, with a heat-sealable Tedlar, to protect the fibers’ coating from rubbing against the inside of the vacuum can. The fibers were then bundled and epoxied into a vacuum feed-through “cookie” which has the function to space the fibers evenly over the surface of the epoxy, to match the inputs of the Planacon PMT, and to maintain a vacuum of 10-7 Torr. Figure 5 shows the finishing detail of a cookie

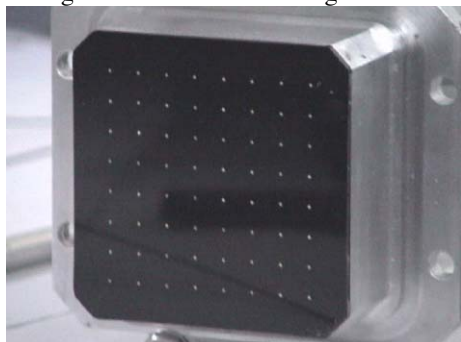


Figure 5. Details of a “Cookie”

Beamline Installation

The fiber plane assembly is then installed in a vacuum can. Figure 6 shows detector MT6WC3 during installation.

A set of flat-to-round cables take the individual signals from the Planacon PMT from the tunnel to the electronics located about 100 m away in a service building.



Figure 6. FPM installation

Electronics

Both PWC and FPM use the same readout electronics designed at Fermilab [2]. The readout electronics has a total of 96 integrator channels divided into 48 for horizontal and 48 for vertical. The integration time is programmable from 1 μsec to 6.5 sec. with a dynamic range of 16 bits. The sensitivity is 0.312 mV/ADC count, and the noise is about 0.2% of full scale.

INITIAL RESULTS

We have profiled secondary beams of various energy and intensity and compared them with typical PWC profiles. Figure 7 shows the profile of the first vacuum fiber monitor MT5FP2 (left) as compared with a PWC (right) located about 40.5 m downstream. The secondary beam intensity was about 100,000 particles as displayed by a scintillating counter. The wire spacing of the PWC is 1 mm and that of the FPM is 2 mm. The bias voltages were set to -1800 Volts for the FPM and -2000 for the PWC.

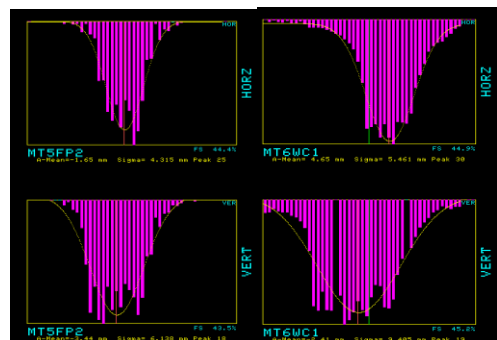


Figure 7. FPM vs. PWC profile

Figure 8 shows the profile of a secondary beam whose intensity was 30,000 particles. The bias voltages were set to -2000 Volts for the FPM and -2200 Volts for the PWC.

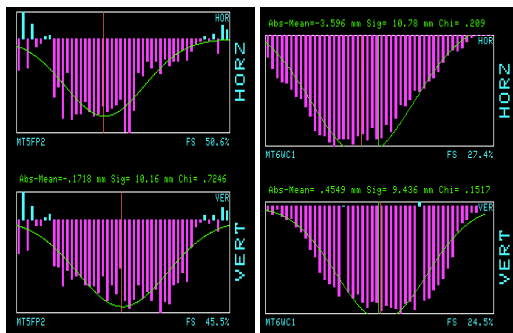


Figure 8. FPM vs. PWC profile

As the beam energy is decrease the profile becomes broader and the noise increases to the point that it did require a background subtraction after the beamline is tuned and the PMT HV was optimized. Figure 9 shows the profiles of about 2000 particles at an energy of 4 GeV. At this level the PWC shows only noise. The bias voltages were set to -2400 Volts for the FPM and -2400 Volts for the PWC.

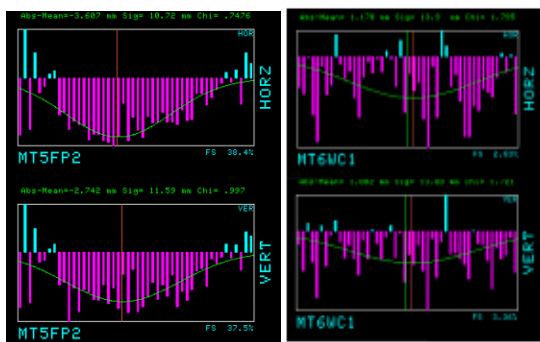


Figure 9. Beam Profiles of 2000 particles

NOISE CONSIDERATIONS

As beam intensity decreased the signal to noise ratio became worse. The PWCs were limited to a maximum of -2500 Volts and did not display any profile at intensities less than about 10,000 particles. We were able to display a profile using the vacuum FPM down to about 2000 particle at a MCP voltage of 2400 Volts and after subtracting the background. The noise was much worse in the case of the FPM in air. For the vacuum FPM, the pedestal background current is approximately 10% of the ADC dynamic range. The source of this is currently unknown and cannot be accounted for by the Planacon PMT dark current. The pedestal time variation is also larger than expected. We also noticed that there was a large amount of unevenness of signal strength due to channel-to-channel gain variation in the Planacon PMT for about the same beam intensity per channel.

CONCLUSION

We have built and tested 2 FPMs and compared their profiles to PWCs. We have also been able to profile beams down to 2000 particles per spill at an energy of 4 GeV. Next we plan to tune the beam down to 1 GeV and make some profile measurements. Before the next FPM installation the plan is to map every MCP channel using a collimated Sr⁹⁰ source. We also are looking at improving the shielding around the detector connectors to minimize sources of electronic noise.

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- [2] W. Kissel, B. Luublynsky, A. Franck, "New SWIC Scanner/Control System", ICALEPCS '95, Chicago, IL, Oct. 1995