Beam Profile Monitor Instrumentation in the Fermilab M-Test Beam

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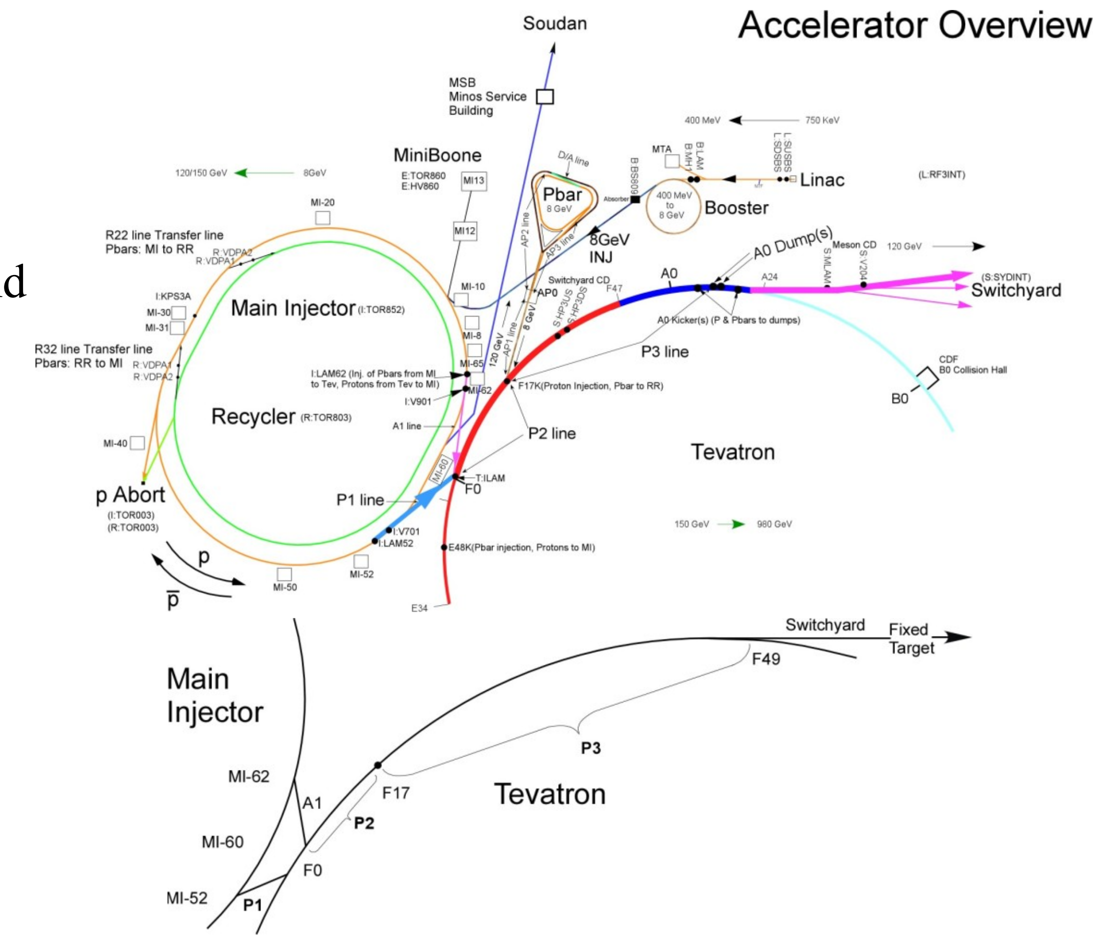
The Site

Beam to M-Test

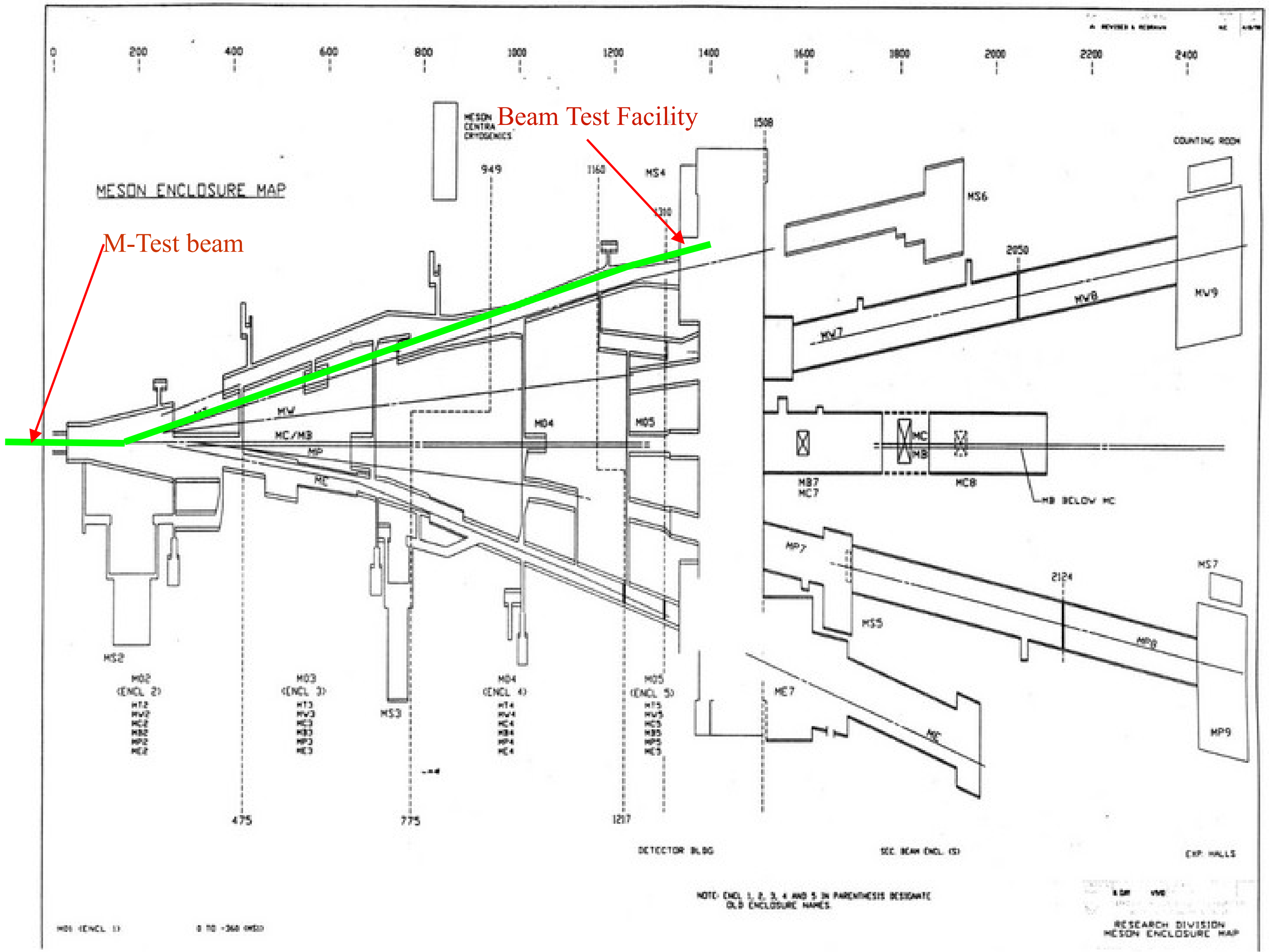
- Beam destined for M-Test via Switchyard is accelerated to 120 GeV in the Main Injector. It can be extracted in two ways: slow spill and single-turn extraction. Slow spill, currently the most common operational method, uses the QXR quadrupole circuit to resonantly extract beam over 1 second (TEV event 20) or 4 seconds (TEV event 21). In single-turn extraction, beam is extracted with the MI-52 kicker/Lambertson combination.
- Switchyard begins in the Transfer Hall at F49, where the P3 line ends and the beamline branches away from the Tevatron to continue onwards through the Transfer Hall and eventually to M-Test



Mode of Operation:

- Proton mode 120 GeV protons reach MT6 experiment
- Pion mode 8 to 66 GeV pion.
- Low energy pion mode where pion fluxes down to 1 GeV can be selected.

M-Test Beam Layout



M-Test Profile Monitors

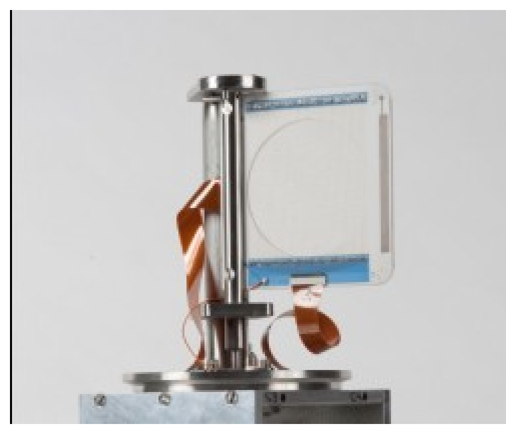
- The energy range - 120 GeV down to 1 Gev at the experiment
- The beam intensity – from about $4x10^{11}$ ppp to a few thousand particles at the experiment
- All of the devices described below are interceptive and therefore cause beam losses.
- Multiwire/SEMs - Based on secondary emission phenomenon
  - Used in medium and high intensity beamlines
- SWICs - Segmented Wire Ion Chamber – Based on ionization
  - Middle and low intensity range
- PWCs - Proportional Wire Chamber - Ionization
  - low and very low intensity range
- SFPMs - Scintillation Fiber Profile Monitor
  - Very low intensity range

Electronics

- FNAL uses the same electronics for all beamline profile monitors – designed by Al Franck
- Scanner has 48 integrating inputs in both X,Y planes
- Integration time is programmable from 5 μsec - 6.5 sec
- Trigger timing can use Tevatron clock events or a remote trigger
- The A/D for each plane processes +/- 10 volt signals. The amplifier is programmable for 1, 10 or 100 gain settings placed between the integrator outputs and the A/D inputs
- Noise ≅ 0.2% of full scale
- A calibration option is included to check for proper operation of all channels
- A network of scanners can be realized by connecting the scanners via Arcnet to a frontend which interfaces to the control systems
- Dynamic range – Scanner can display a minimum of around 5 pCoul. Depending on mode of operation, M-Test secondary beamline could have very low intensity. - a few 1000's particles which translates to a few pCoul
- Typical minimum beam intensities:
  - SEMs ≅ 10^{10} particles
  - SWICs ≅ 10^{4} particles
  - PWCs ≅ 10^{3} particles
  - Fibers – first prototype a few thousand

SEMs - 1

- Medium to high beam intensity
- Located in the P1, P2 and P3 beamlines.
- These detectors have been made by first winding a 75 µm diameter AuW wire at 80 g of tension on a transfer frame, then, transferring the wind over the bare board, then soldering the wires on the pads on G-10 strips. Each paddle contains both a horizontal and a vertical set of 50 wires.
- No clearing field
- HV plane: 25 µm dia. AuW wire
- Limitations
  - Poor mechanical stability
  - Loss of wire tension
  - Poor vacuum due to G-10



SEMs - 2

New SEMs

- Ceramic substrate
- “Flash test” option
- Kapton tape
- Bake assembly to over 100 C
- Vacuum to 10^9 Torr

Types:

- Cut-out to avoid insertion losses
- Figure 8 for lower residual losses
- Ti substrate made by UTA with 5μm Ti strips

Signal strength: Q = εNe where

- ε secondary emission efficiency – around 3%
- N is th number of particles through a wire
- e is the electron charge 1.602×10^{19} Coul

Programs that estimate the of the charge on a wire by knowing ε, the beam FWHM, and the wire diameters:

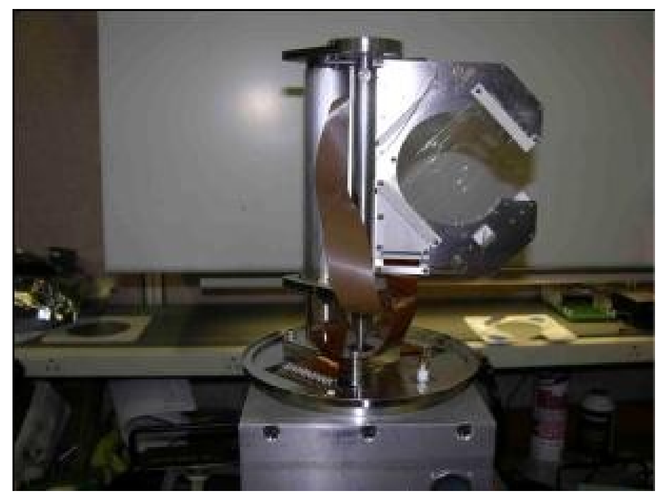
10^{12} ppp, FWHM=2 mm, 75 μm wire Q= 170 pF

10^{12} ppp, FWHM=6 mm, 50 μm wire Q= 37 pF

or about 10 times above background

Figure 8

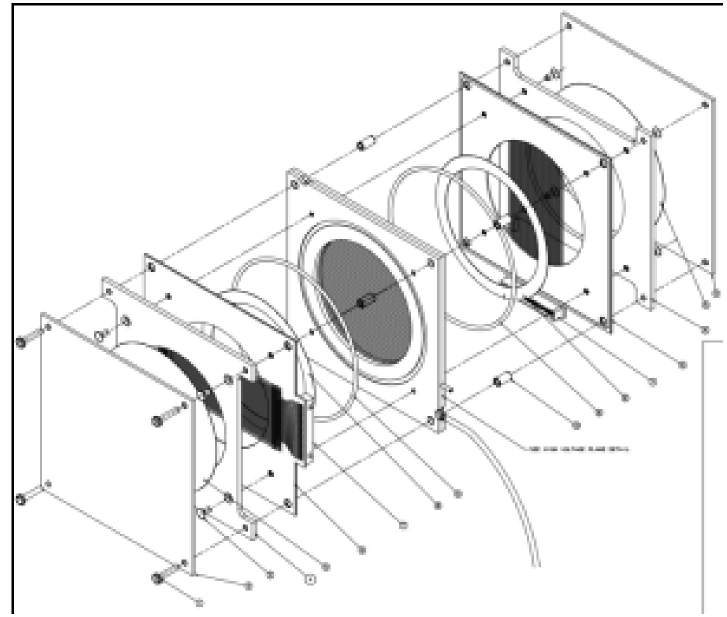
Cut out



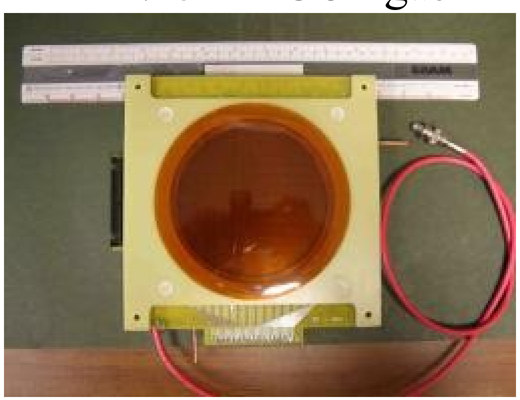
Ti substrate

SWICs

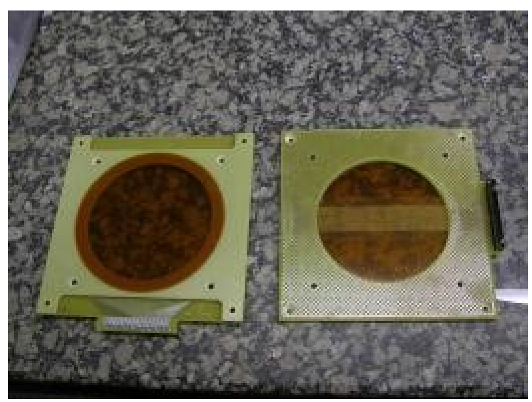
- Segmented Wire Ion Chamber
- Medium intensity beamlines, to 10^{12} ppp
- Chamber has a HV plane sandwitched between a X, Y plane
- Signal planes: wound 75 μm AuW wire at 80 g tension. Pitch 0.5 to 3 mm
- HV plane: 25 μm AuW wire wound at 20 g tension. Pitch 2 mm
- Gas: ArCO2 80/20 %
- Gas gain 10^5 at +2400 Volts
- Material in the beam:
  - (2) 3 mil Ti windows
  - (2) 3 mil Kapton windows
  - 1.25" ArCO2 gas



Chamber design



Complete Chamber

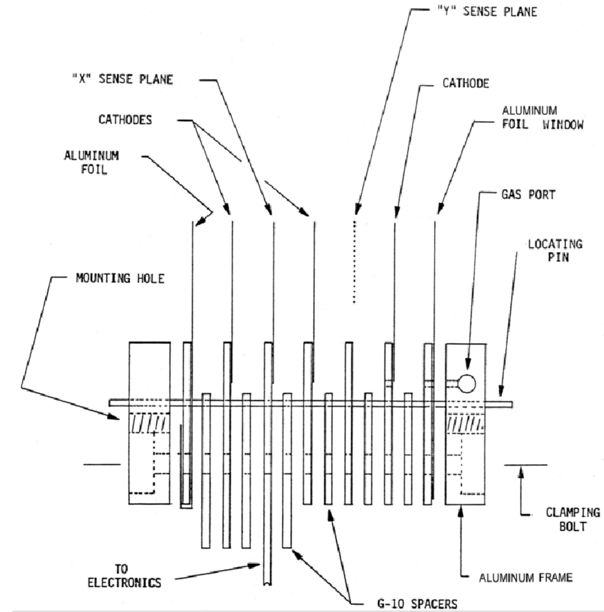


Signal Planes

Installed Assembly

PWCs

- Proportional Wire Chamber. It enables us to display beam profiles down to a few thousand particles per pulse with background subtraction.
- **Chamber Specifications**
- Require vacuum break, typically 2
  75 µm Ti windows
- Modular
- X,Y sense plane between HV foils
- Signal wires 12.5 µm AuW. These wires are fragile and an arc can break them. That's why these chambers are modular
- Material: 60 µm Al foils, 12.5 µm diameter W, 2 cm gas
- Gas: Ar/Co_2 at 80/20 % ratio

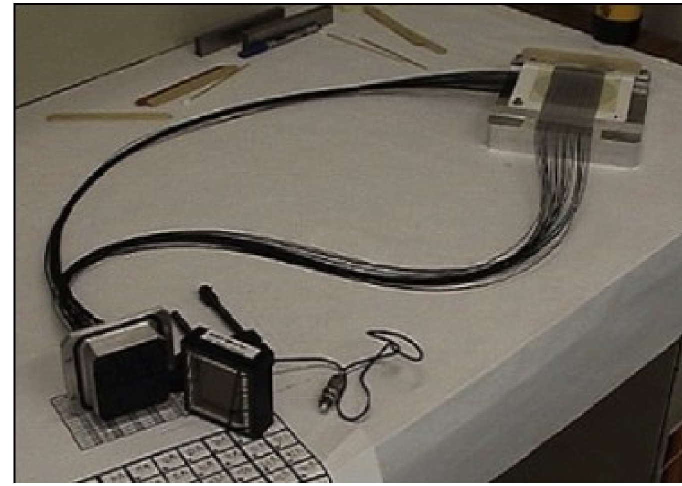


Chamber Layout

Completed chamber

SFPMs -1

- Reduce beam losses of SWICs and PWCs
- M-Test beam energy range – 1-120 GeV
- Low beam intensity - down to a few ppp
- **Detector Specifications:**
- Fiber type – St. Gobain BCF-12MC
- Fibers are mated to 64 channel microchannel plate PMT for electron multiplication:
- Burle Planacom #85011-501
- HV = -2300 (Gain = 800,000)
- Light output – 5 photo-electrons/MIP/fiber/
- **Detector Assembly:**
- Set of 32 fibers/plane having Diameter 0.75 mm are epoxied to both sides of a ceramic board at a pitch of 2 mm.
- Fibers are bundled and epoxied into a vacuum feed-through called "cookie" that match the optical inputs of the Planacon PMT.
- Vacuum to 10^{-7} Torr – limited by the epoxy
- Tests showed noise overcame signal around 2000 particles with background subtraction.

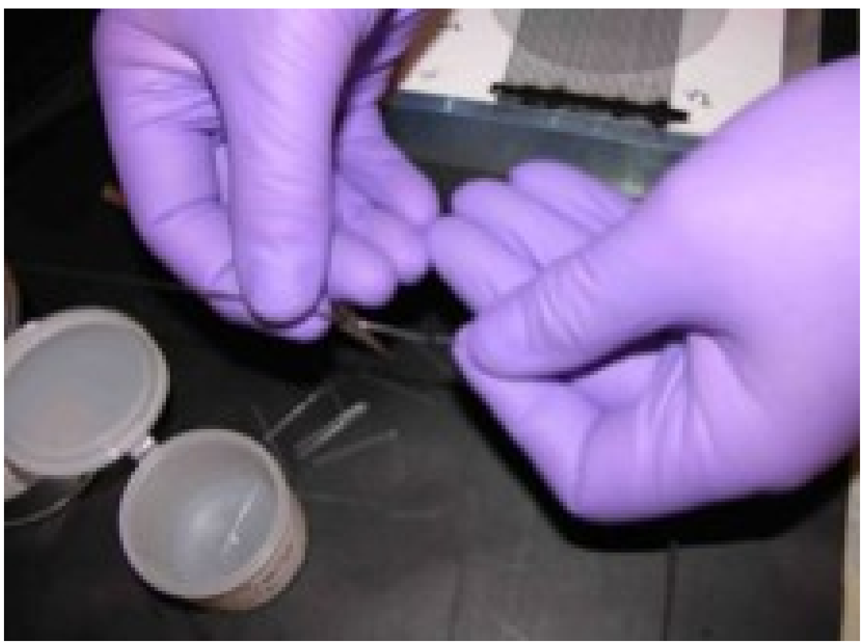


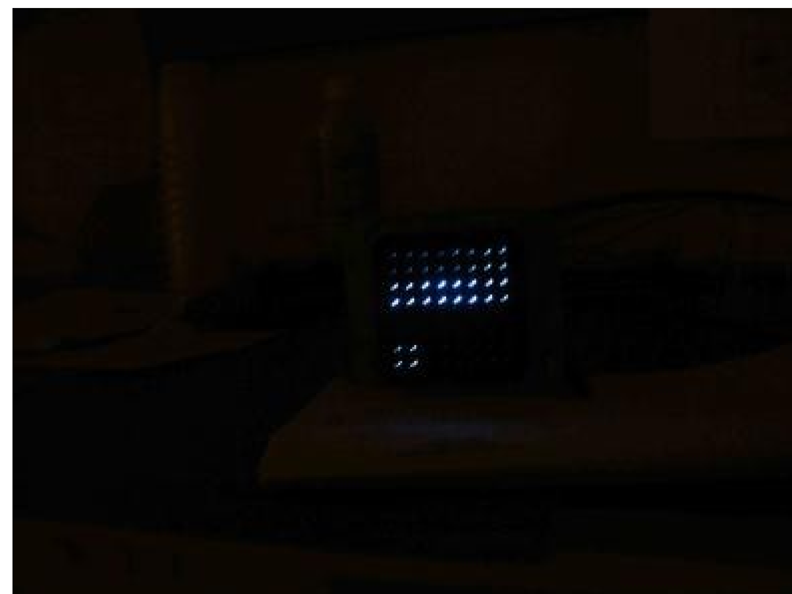
SFPM assembly

SFPM in vacuum can

SFPMs -2

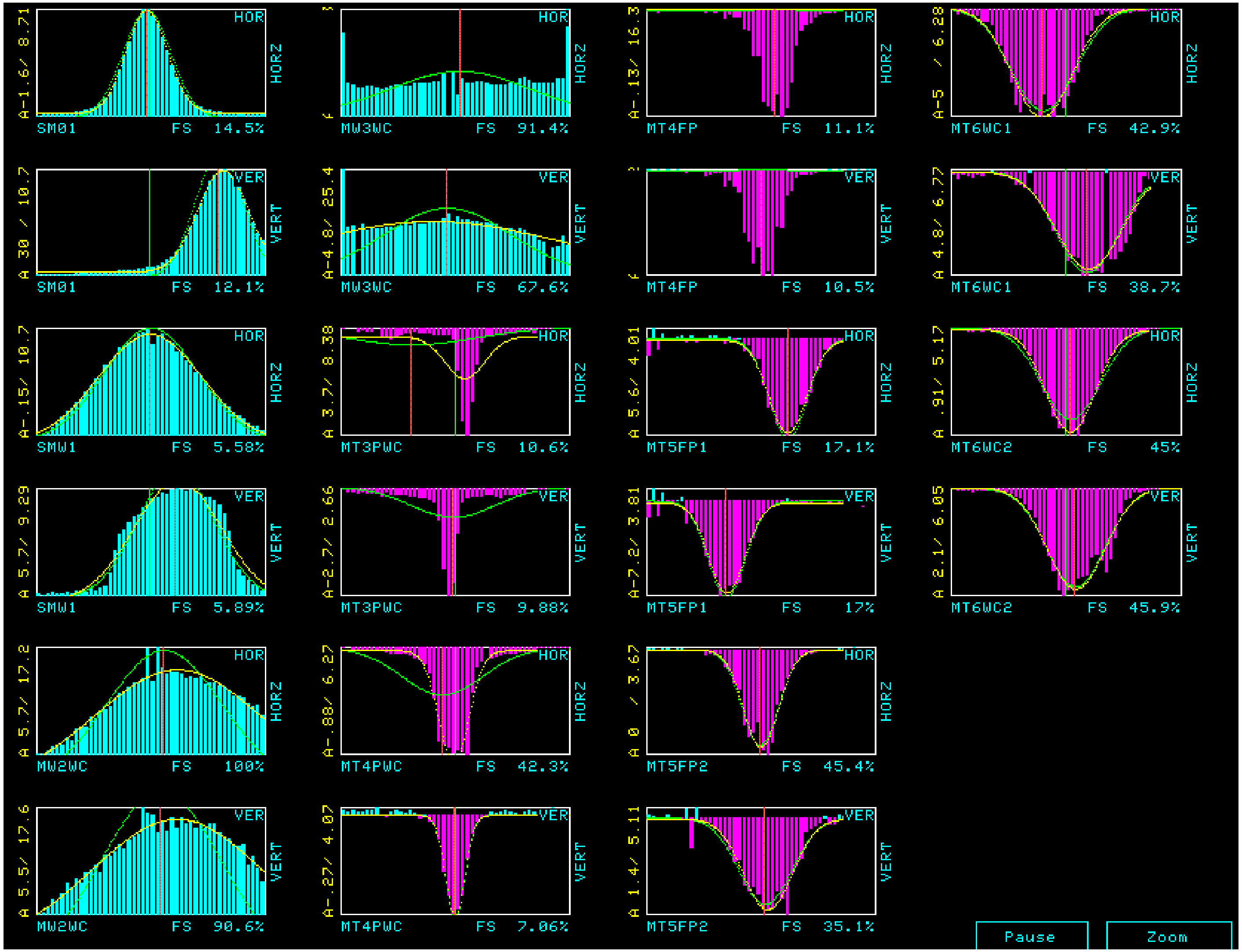
- **New Design:**
- Reduced length of scintillation fibers to beam active area
- Picture to the right shows assembly of fibers on ceramic substrate to cookie
- Picture below shows how the scintillation fibers are spliced to clear fibers using Bicron BC-600 optical grade epoxy
- Image below-right show light check raster scan of fibers with a light source





SWIC/PWC/Fiber signal

- Display of SWIC starting in Switchyard, PWCs and Fibers downstream of target
- Beam on target E = 120 Gev, 2E11ppp - Secondary beam 32 GeV, 200,000 ppp



Beam Losses

- Rick Coleman studied the transmission of the secondary beam and found that it gets degraded by the profile monitors and the air gaps
- The scintillation fibers of a SFPM intercept only 10 – 20 % , depending on spot size, of that of a scintillator paddle listed in the table
- By replacing all or even some of the SWICs and PWCs with SFPMs the quality of the beam would improve

Type of Material	Radiation Length (X_0)	Interaction Lengths (λ)
Air	0.055	0.022
17 Windows	0.049	0.007
Scintillator paddle	0.038	0.020
PWCs	0.036	0.008
Total	0.18	0.057

Conclusion

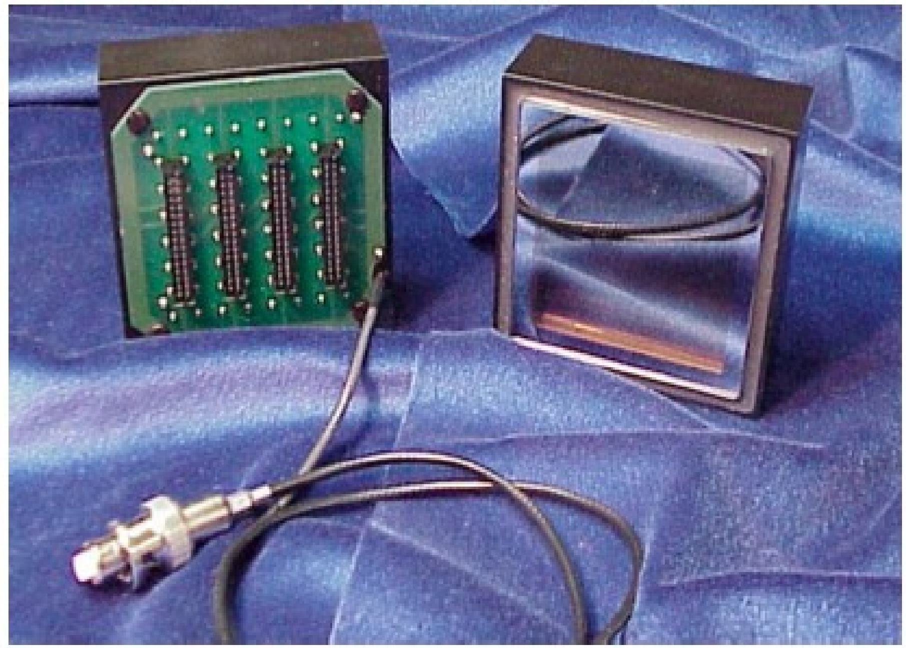
- Efforts continue to seek to improve the beam quality of the M-Test beamline by improving the detectors design to display low intensity beams while minimizing beam losses
- We are in the process of assembling an improved Scintillation Fiber Profile Detector that will enable us to display lower beam intensities
- Finally, for more information about the Beam Facility please click on:

  http://www-ppd.fnal.gov/FTBF/

MCT-PMT

TUBE ASSEMBLY
85011-501

July 2005



The 85011 assembly is based on a new photomultiplier tube that uses microchannel plates (MCP) for electron multiplication, the PLANACON™. This 51 mm square head-on MCP-PMT has a very low profile, less than one inch thick including the voltage divider network. The sixty-four anodes provide 6 mm position resolution when used as a discrete pixel device. Improved resolution can be obtained using a charge-sharing technique. The dual MCP multiplier provides excellent time response, good gain, and extremely high pulse linearity. Response uniformity over the full active area is exceptional, typically 1:1.5. The assembly comes with ribbon cable connectors and an SHV cable for ease of use. Applications include specialized medical imaging, ring