Fermilab

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M-4 Beamline Profile and Intensity Monitors

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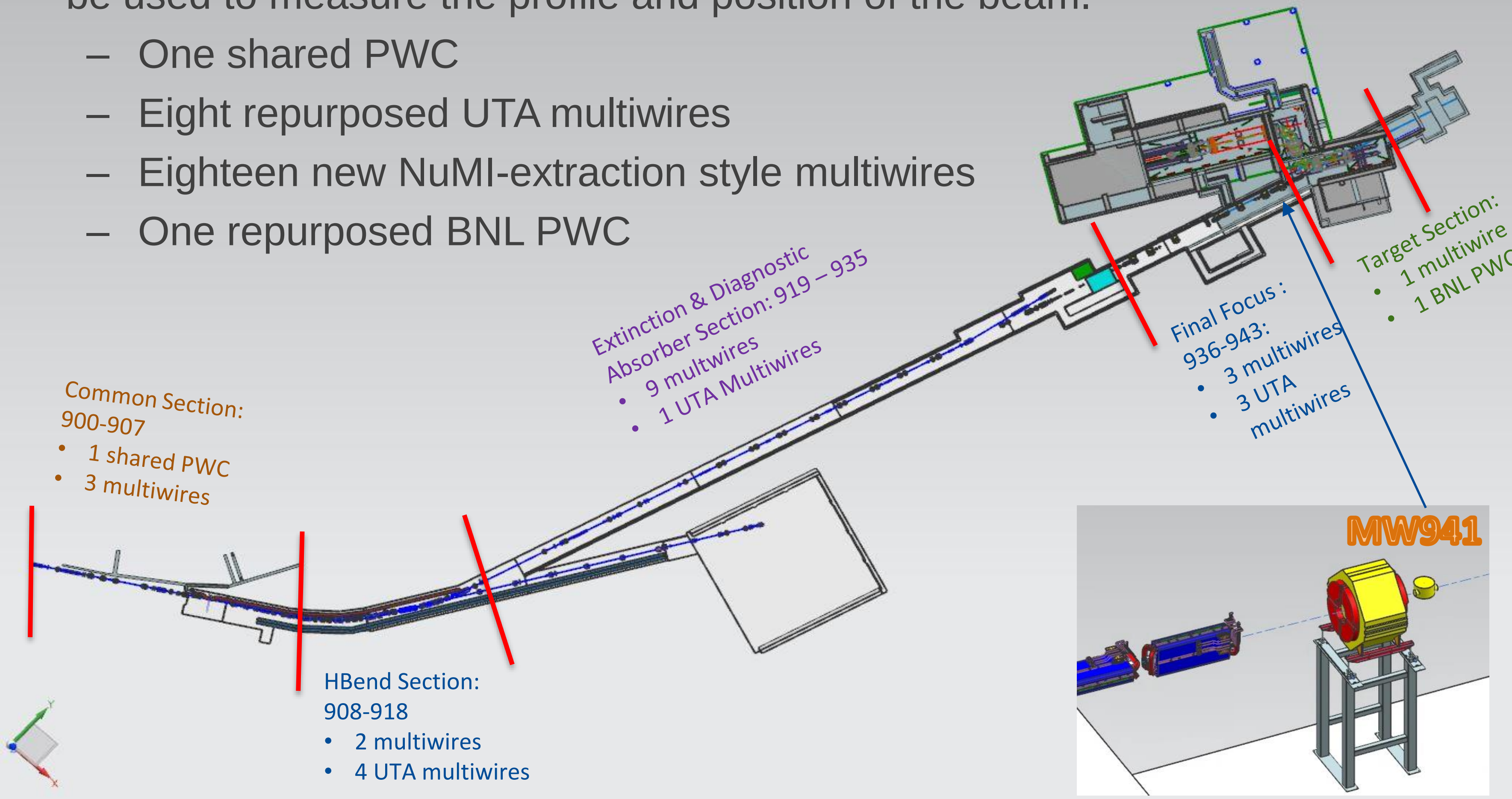
External Beamline & Instrumentation Independent Design Review
6 October 2015

Extraction Beamline Multiwires

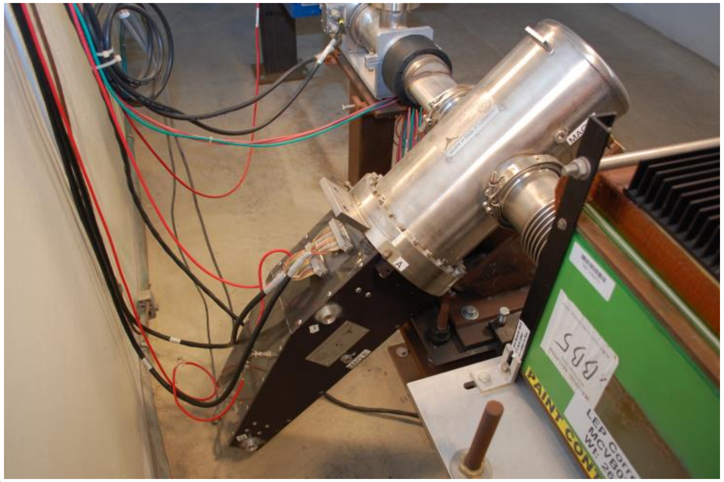
- Based on the lattice design, the M4 line will contain 28 profile monitors that will be used to measure the profile and position of the beam.
  - One shared PWC
  - Eight repurposed UTA multiwires
  - Eighteen new NuMI-extraction style multiwires
  - One repurposed BNL PWC



Vacuum Cans

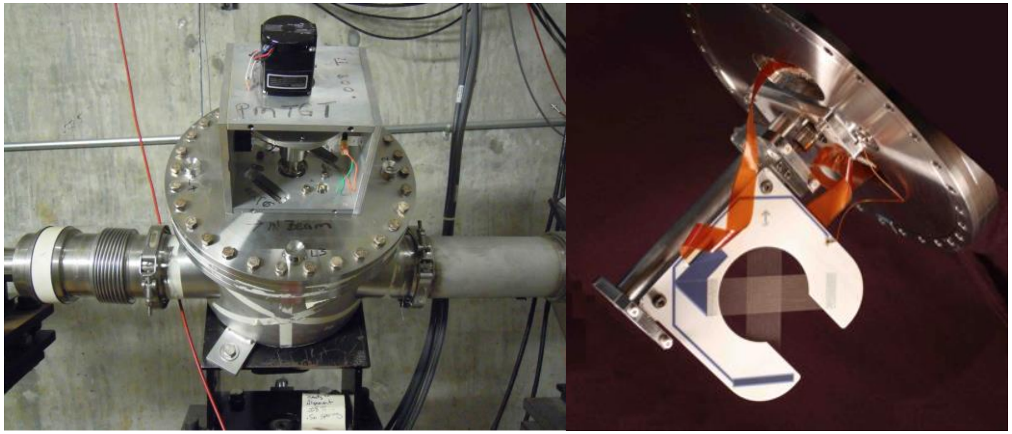
Two types of vacuum cans will be used.

- Fermilab design – rotary motion
- University of Texas design (UTA) – linear motion

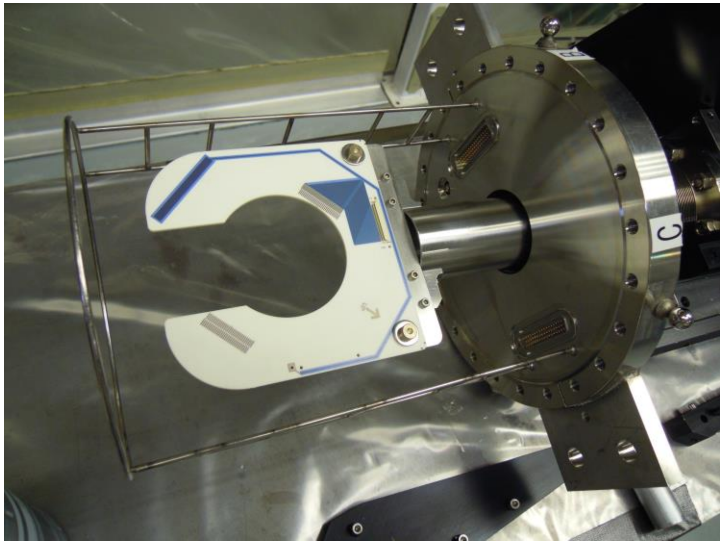


Mechanical reliability of rotary feedthrough

- Life tests conducted during the prototyping of the NuMI profile monitors.
- Cycled prototype 500,000 times. After the test inspected mechanical parts i.e., switches, rotary feed through etc. No functional damage was detected.



Fermilab Design (rotary motion)



UTA Design (linear)

Wire planes

Ceramic substrate

- Alumina 96 Ceramic
- Fired Ag-Pd metallization
- Surface mounted connectors

Wires

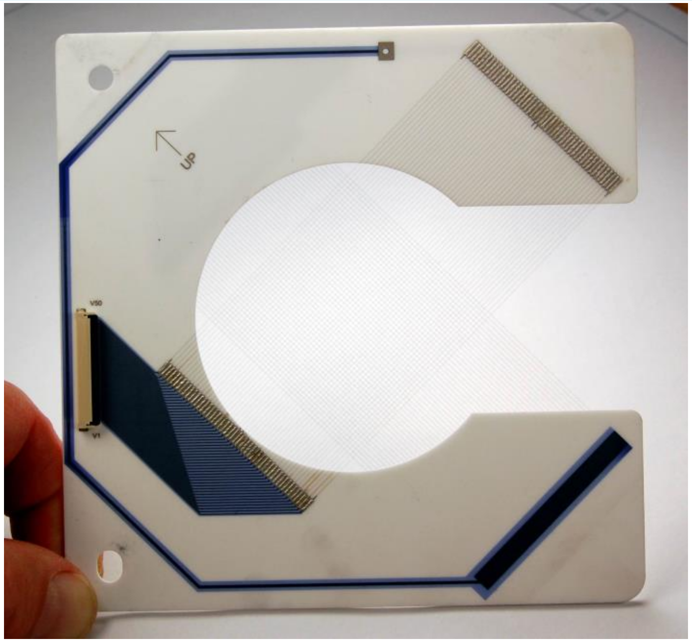
- Titanium wires or foils
- Wire pitch 0.5 and 1mm

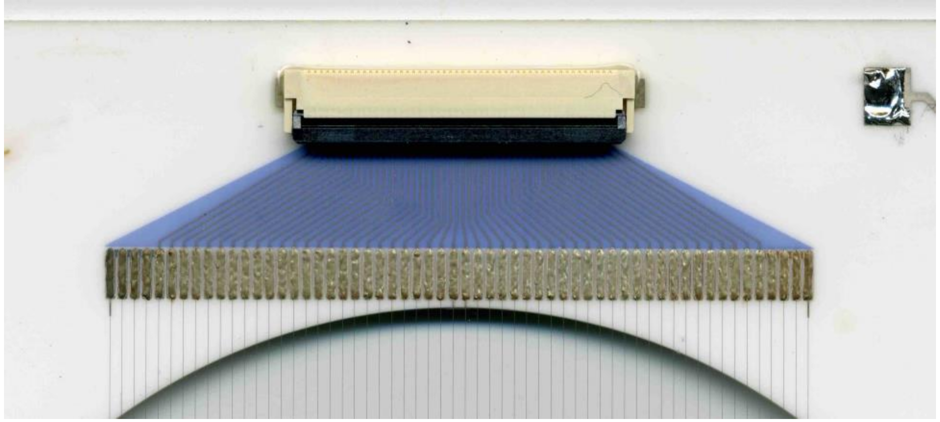
Electrical Tests

- Continuity
- Wire to wire leakage
- Flash test

Pitch Measurements

Made at SiDet using Avant 600 made by Optical Gaging Products. The uncertainty in position was +/- 10 µm.



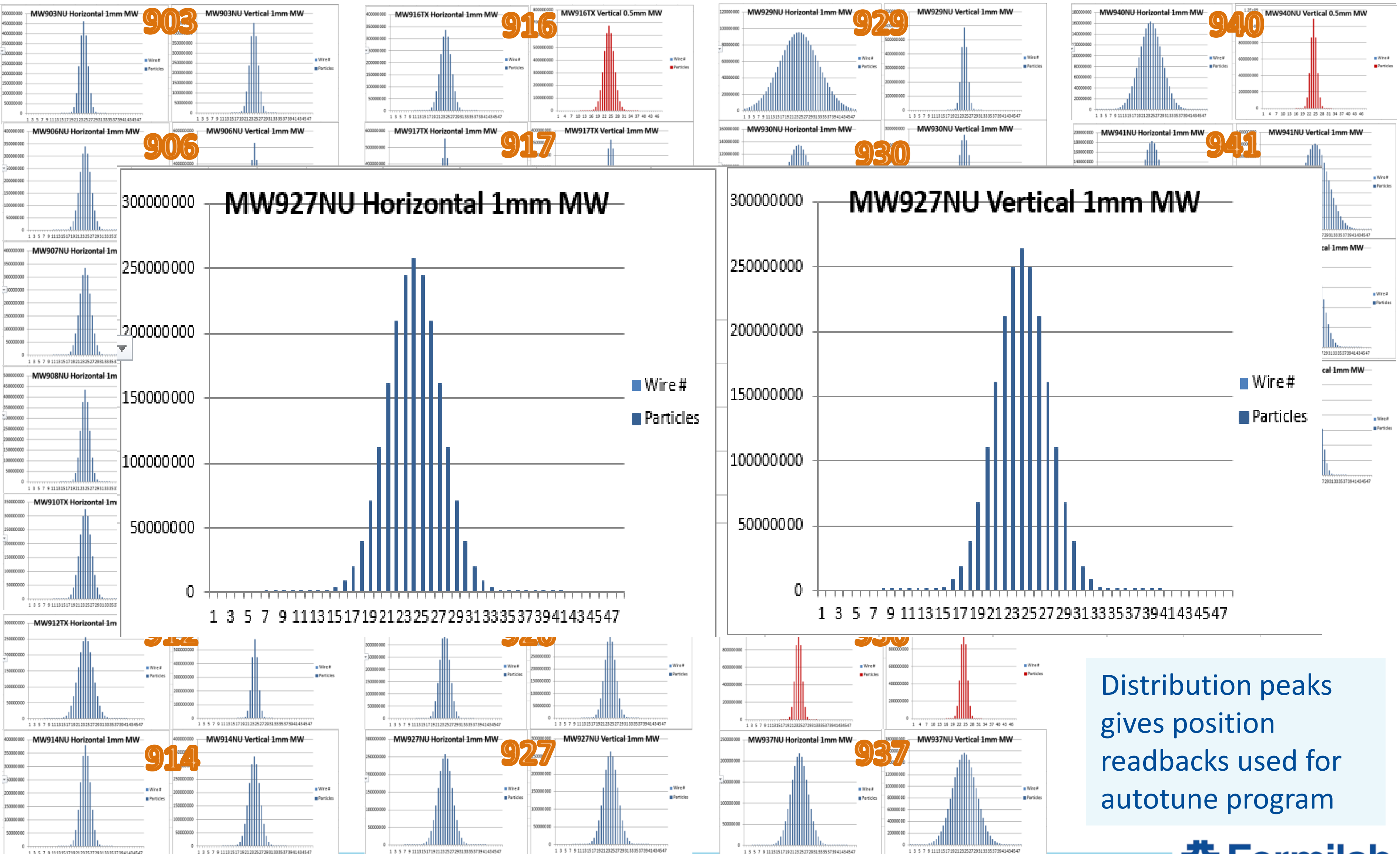


Charge Estimate

- The charge generated by the beam on a wire is a function of: 1. The beam intensity 2. The dimensions of the wire/foil 3. The Full Width Half Maximum beam size assuming a Gaussian distribution. The table below shows the estimated charge generated by a total integrated intensity of 1E12 for two multiwires each seeing a different FWHM. Both use a wire diameter of 75 µm and a assuming a 3% Secondary Emission Efficiency.
- MW929 - FWHM = 28.8 mm
- MW936 - FWHM = 5.4 mm
- Tests show that a simulated charge of 10 pico coloumbs at beam center is sufficient for the scanner in order to produce a useable plot. 100 pC = full scale
- We should be able to display a few slices of the beam during spill.

Name	Wire Diameter (µm)	FWHM (mm)	Spill Intensity	Charge/spill (pCoul)
MW923	75	28.8	1E12	11.7
MW936	75	5.4	1E12	62.6

Simulated Profile Sizes for 0.5mm and 1.0mm wire spacing

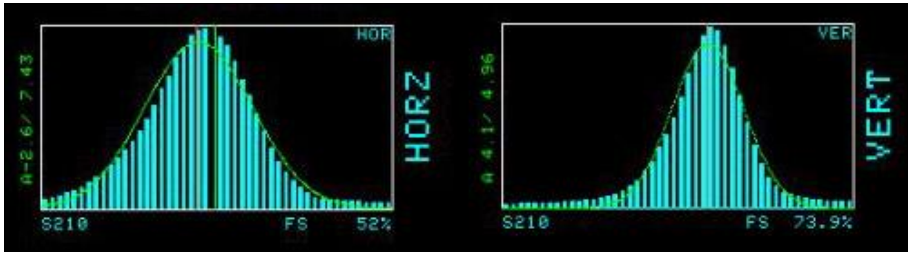


Distribution peaks gives position readbacks used for autotune program

SWIC Scanners Overview

- SWIC Scanners capture signals from all types of wireplane profile detectors and provide a plot of the beam profile.
  - P-Bar foil SEM Profile Monitor
  - Proportional Wire Chamber (PWC)
  - Texas Multiwire
  - Reilly Stacked Plane Multiwire (NuMI type)
  - Segmented Wire Ion Chamber (SWIC)

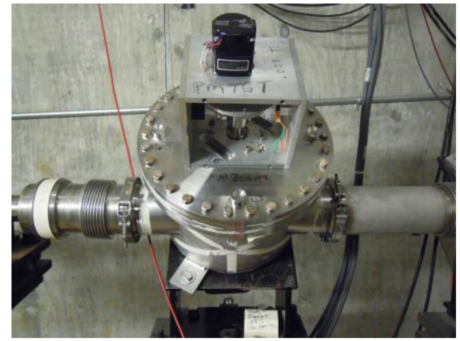
SWIC Scanner

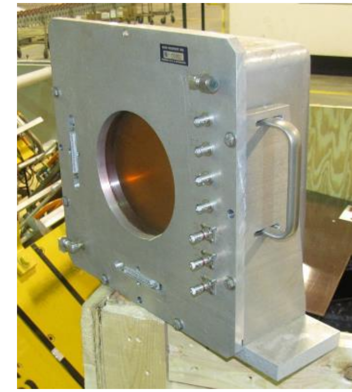


Typical Plot

PreTarget and PostTarget Multiwire

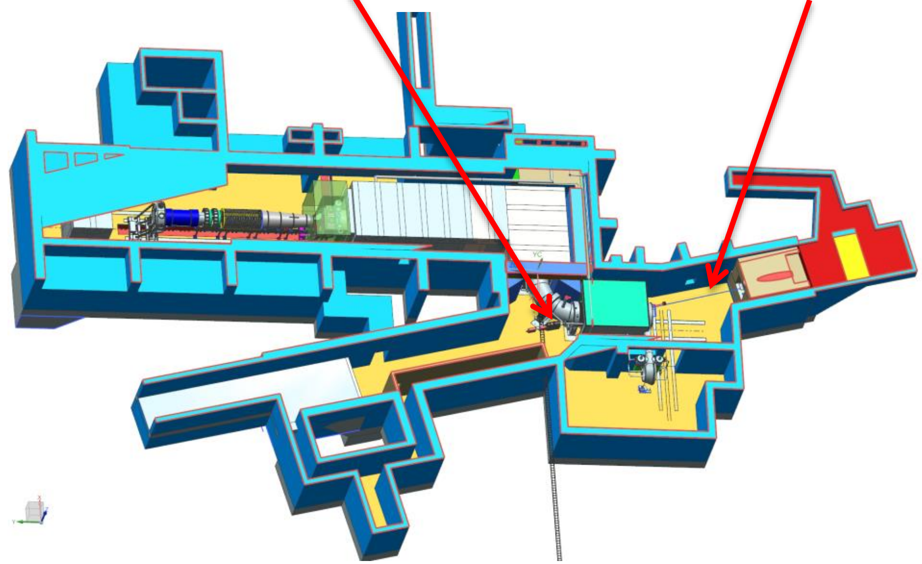
- Two profile monitors were added to the scope of this WBS.
  - Upstream of production solenoid will be a standard Multiwire
  - Downstream of the production solenoid will be a BNL air SWIC.





Pre-target vacuum MW

Post-target air BNL SWIC

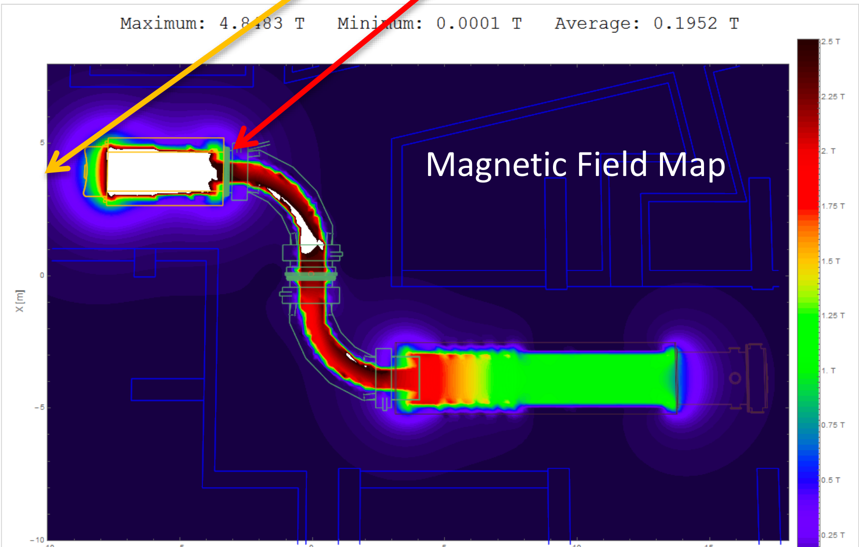


Design considerations: MW's in magnetic field

- Need to examine the effects of magnetic field on the multiwire just upstream of the target solenoid.
  - Does the magnetic field impact the motion control (PreTarget MW only)?
  - Does the magnetic field impact the signal?

PostTarget MW: 0.2Kg magnetic field

PreTarget MW: 1.2Kg magnetic field



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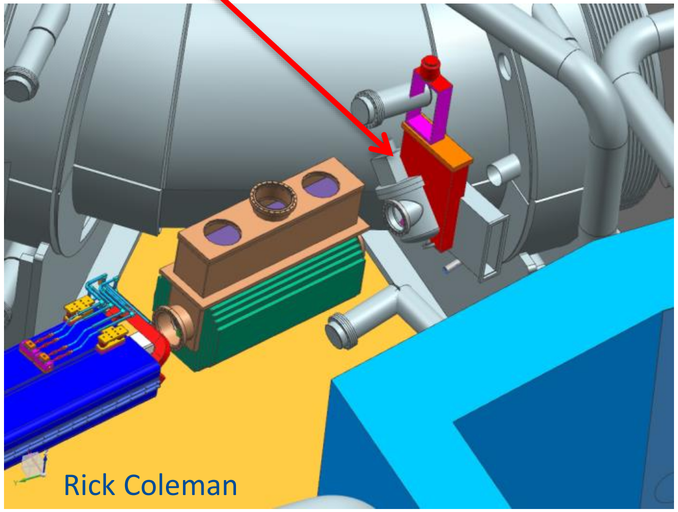

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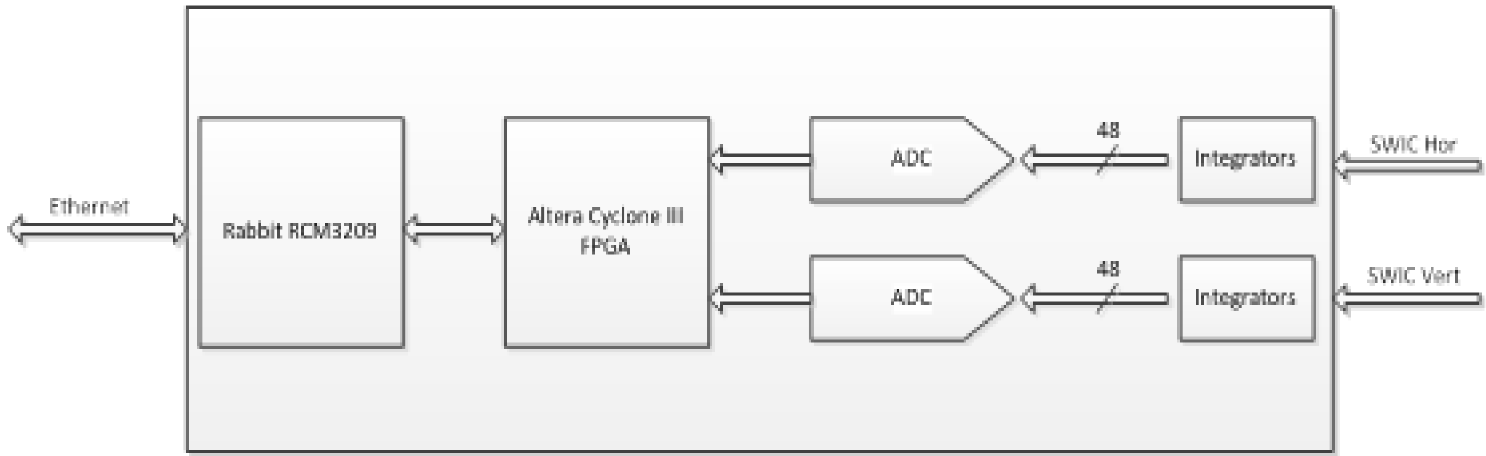
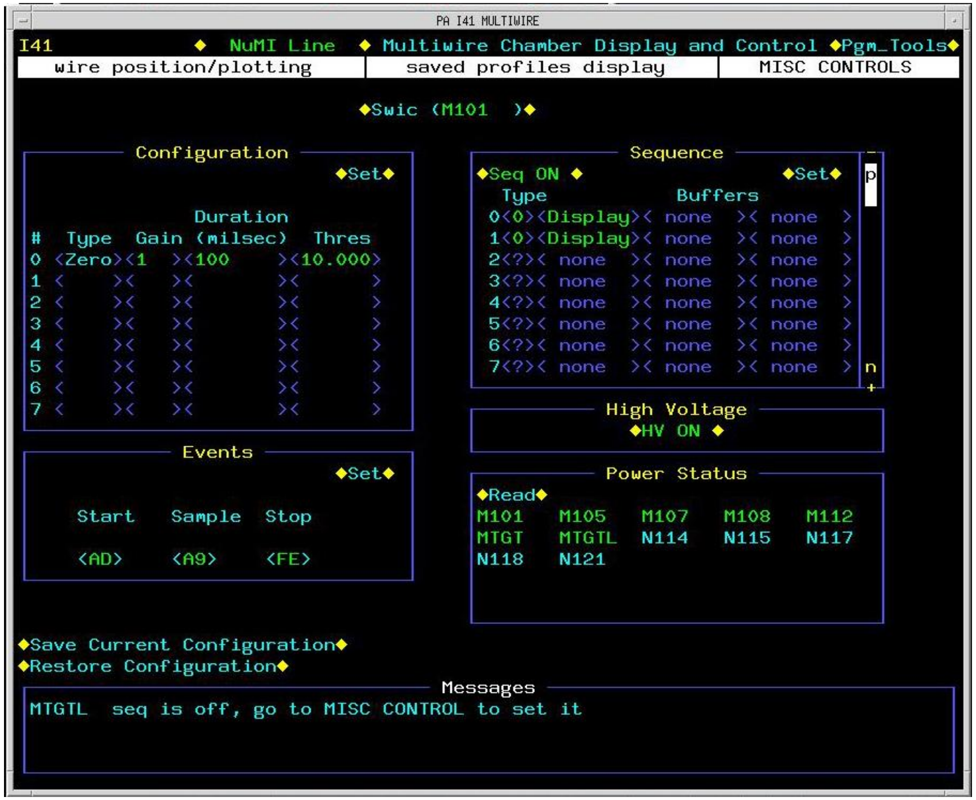
SWIC Scanner Internals

- Charge from particle beam is collected by a grid of detector wires (up to 48 each H and V) and integrated onto capacitors.
- Capacitor voltages converted by 16-bit ADCs
- Results sent to control system for plotting and other analysis



SWIC Scanner Configuration

- Integration is triggered by a TCLK Event or external pulse input
- Programmable delay between trigger and start of integration
- Programmable integration time
- Multiple integrations can be performed and stored in a programmable sequence

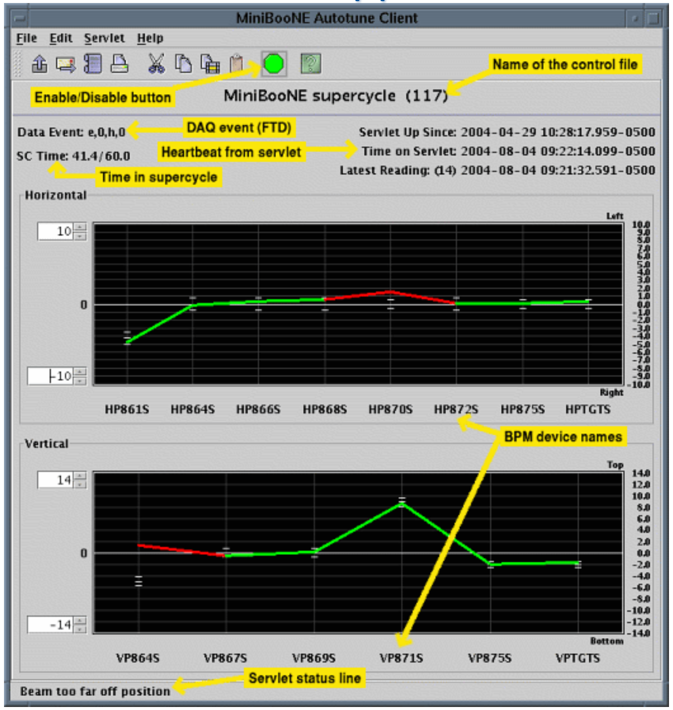


Plotting Application Page

Autotune

- We will develop a M4 beamline autotune based on the autotune system that is already used for the NuMI and MiniBooNE beamlines.
  - Reads beam positions
  - Changes trim settings to keep the beamline tuned up.

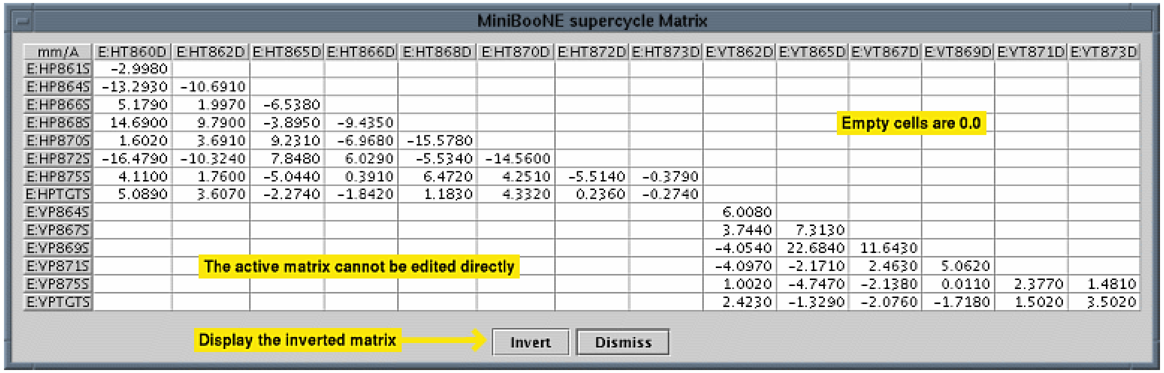
Autotune Application



Autotune Documentation:

http://www-bd.fnal.gov/controls/autotune/doc/#main

Autotune Correction Matrix



MiniBooNE supercycle Matrix

mm/A	E:HT860D	E:HT862D	E:HT865D	E:HT866D	E:HT868D	E:HT870D	E:HT872D	E:HT873D	E:VT862D	E:VT865D	E:VT867D	E:VT869D	E:VT871D	E:VT873D
E:HP861S	-2.9980													
E:HP864S	-13.2930	-10.6910												
E:HP866S	5.1790	1.9970	-6.5380											
E:HP868S	14.6900	9.7900	-3.8950	-9.4350										
E:HP870S	1.6020	3.6910	9.2310	-6.9680	-15.5780									
E:HP872S	-16.4790	-10.3240	7.8480	6.0290	-5.5340	-14.5600								
E:HP875S	4.1100	1.7600	-5.0440	0.3910	6.4720	4.2510	-5.5140	-0.3790						
E:HPTGTS	5.0890	3.6070	-2.2740	-1.8420	1.1830	4.3320	0.2360	-0.2740						
E:VP864S									6.0080					
E:VP867S									3.7440	7.3130				
E:VP869S									-4.0540	22.6840	11.6430			
E:VP871S									-4.0970	-2.1710	2.4630	5.0620		
E:VP875S									1.0020	-4.7470	-2.1380	0.0110	2.3770	1.4810
E:VPTGTS									2.4230	-1.3290	-2.0760	-1.7180	1.5020	3.5020

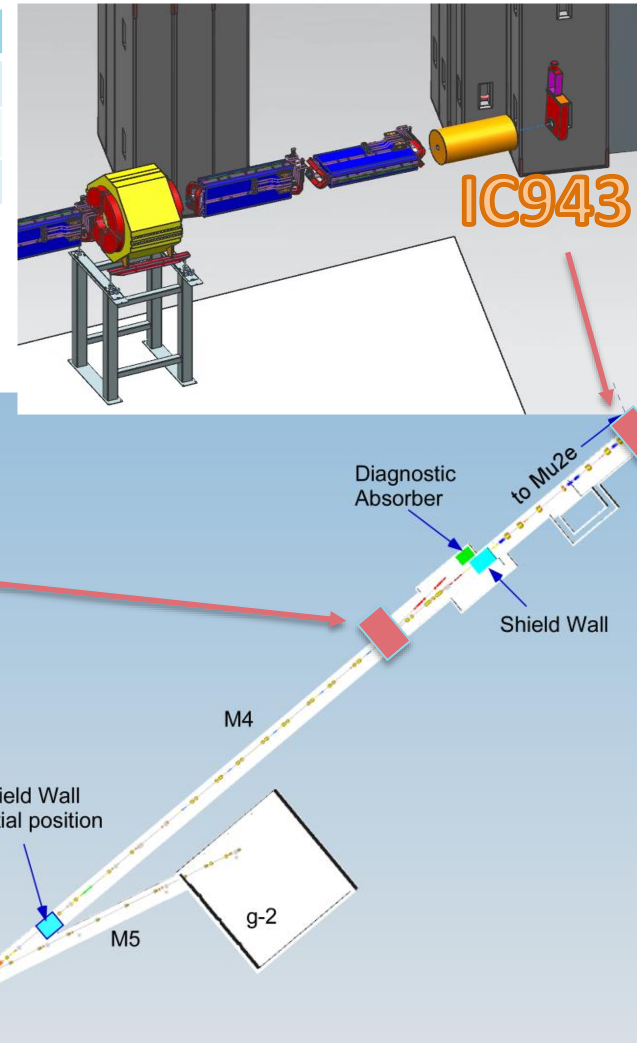
Empty cells are 0.0
The active matrix cannot be edited directly
Display the inverted matrix
Invert
Dismiss

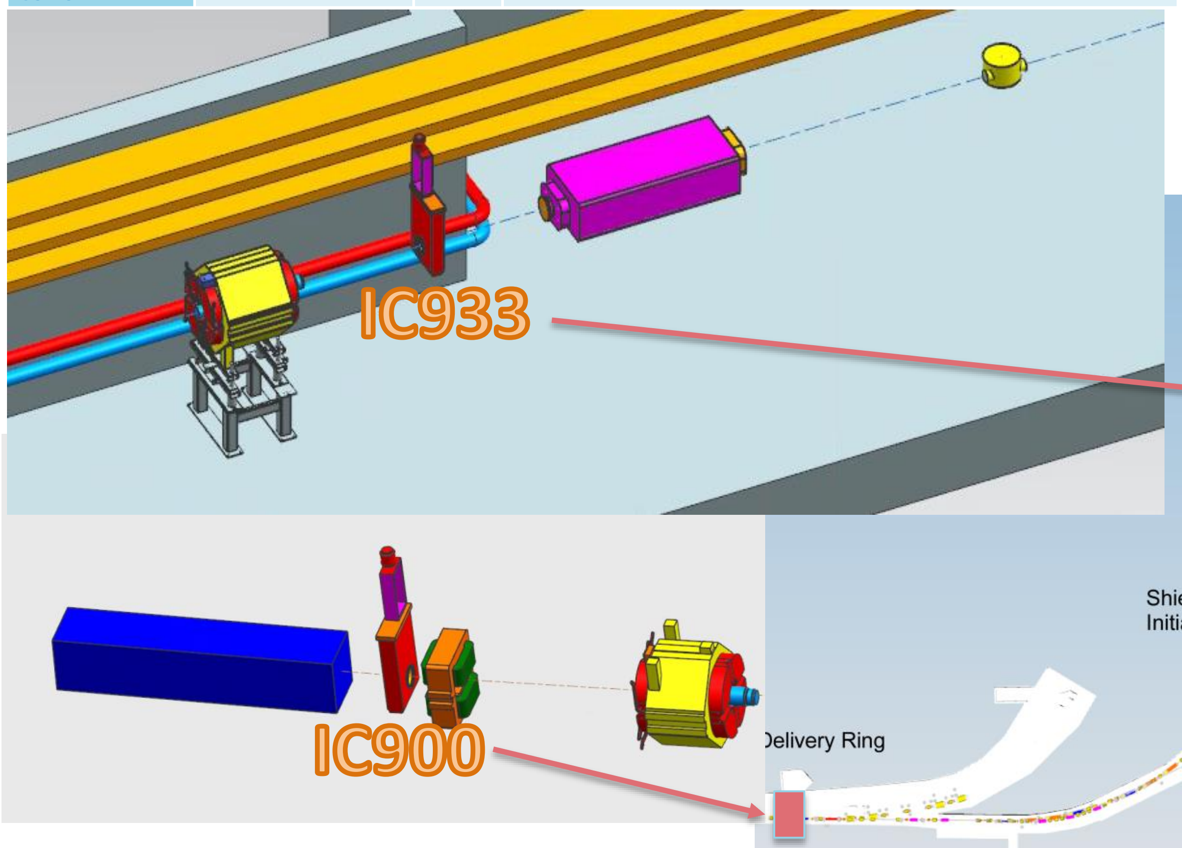
The Mu2e Autotune System

- The Mu2e autotune system will be used primarily to keep the beam position tuned on target.
  - Multiwires will be moved into the beam as needed.
  - Horizontal and vertical profiles will be collected from each Multiwire.
  - Checks will be made on the distribution to verify that we have a valid profile.
  - Horizontal and vertical positions are collected if the profiles are valid.
  - A square matrix of trims and multiwires will be used to determine what correction element trim corrections are needed to steer the beam back to the desired orbit.
  - A fraction of the desired correction is sent.
  - Repeat as necessary.
  - Multiwires are pulled out of the beam when not in use.

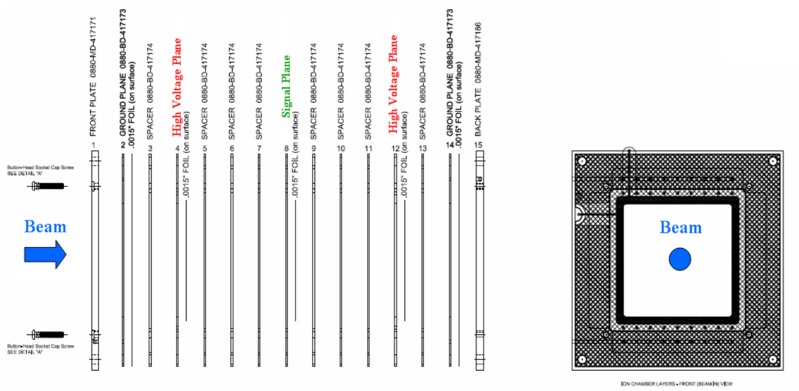
Extraction Beamline Ion Chamber Locations

Name	Device	BL	Specific Location
IC900	Ion Chamber	M4	Immediately downstream of the c-magnet
IC933	Ion Chamber	M4	Immediately downstream of VT933
IC943	Ion Chamber	M4	Last element in the M4 beam line

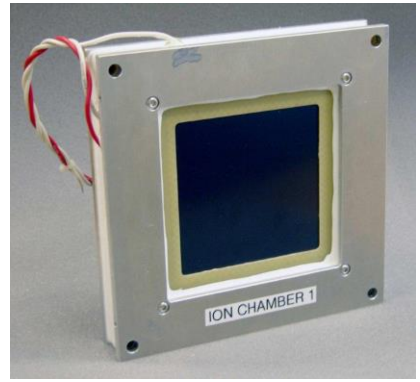




Ion Chambers

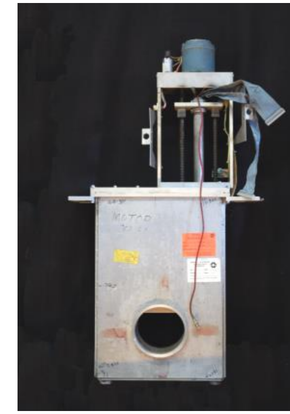


Internal Construction



Ion Chamber

Anti-Vacuum Box



Bayonet Drive

- Ion chamber uses tested FNAL design.
- The ion chamber fits in existing anti-vacuum box.
- The anti-vacuum boxes will be installed inside of bayonet vacuum vessels that are being repurposed from Switchyard
- The bayonet type drive slides the ion chamber linearly into and out of the beam with a screw drive system.
- The detector linear drive shaft is housed in a collapsible bellows that seals it from atmosphere.

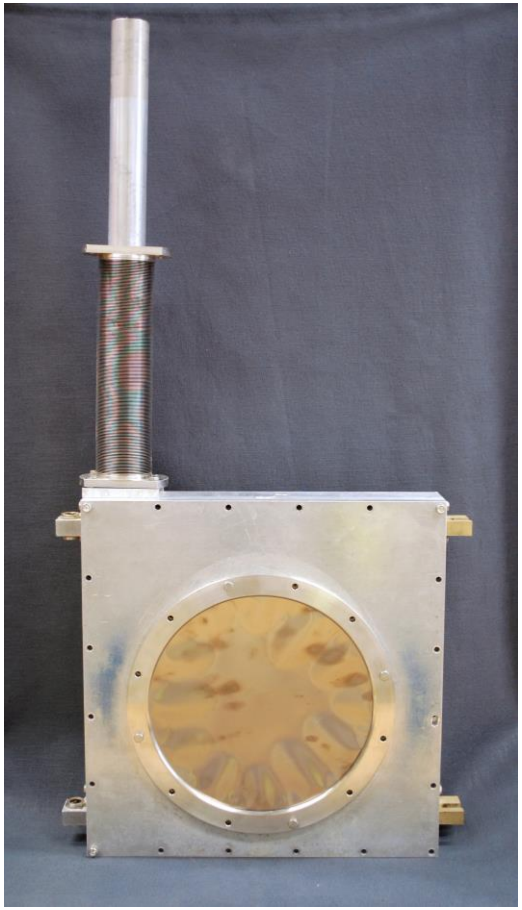
Bayonet Vacuum Can Modifications

Issues:

- The new ion chamber requires a deeper anti-vacuum can.
- Vacuum window leak problems.

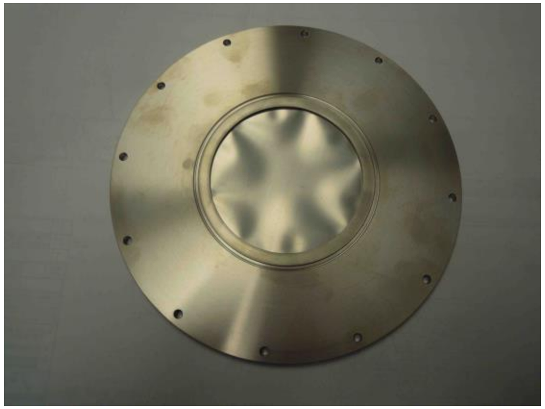
Modifications:

- Increase the depth by 0.4” to accommodate the ion chamber.
- Replace O-Ring sealed windows on anti-vacuum can with smaller e-beam welded windows.



Bayonet drive anti-vacuum box
With 9 inch O-ring sealed window

Extension Spacer Installed

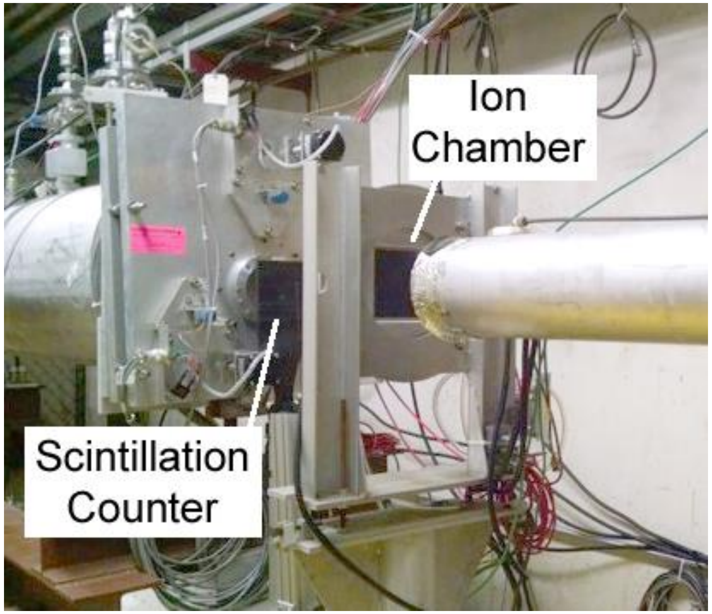


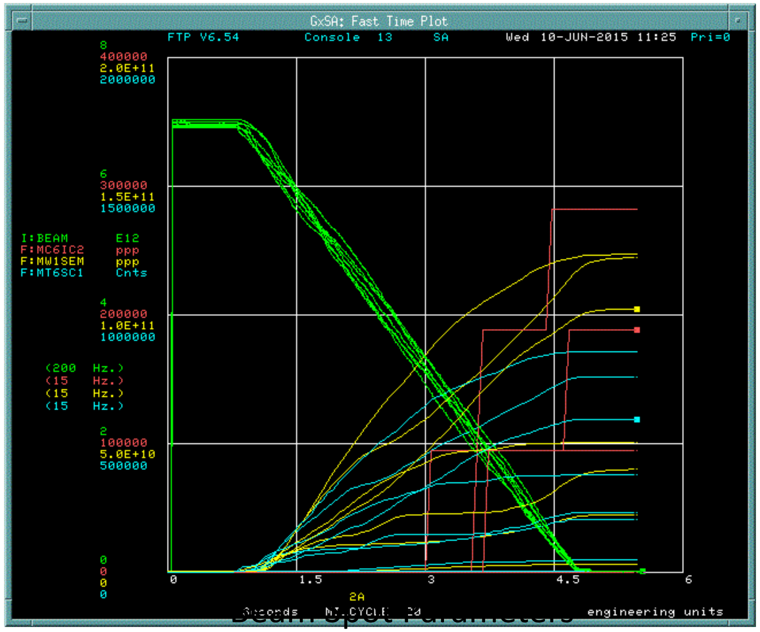
Replacement 4 inch E-Beam
Welded Window

Ion Chamber Beam Test

- Performed comparison beam tests between an Ion chamber and a scintillation counter to determine the lower Ion chamber reading limit.
- AD Instrumentation Current Digitizer Module Readout
- M-Test beam parameters
  - E = 120 GeV
  - Spill Length = 4 sec
  - Cycle = 60 sec

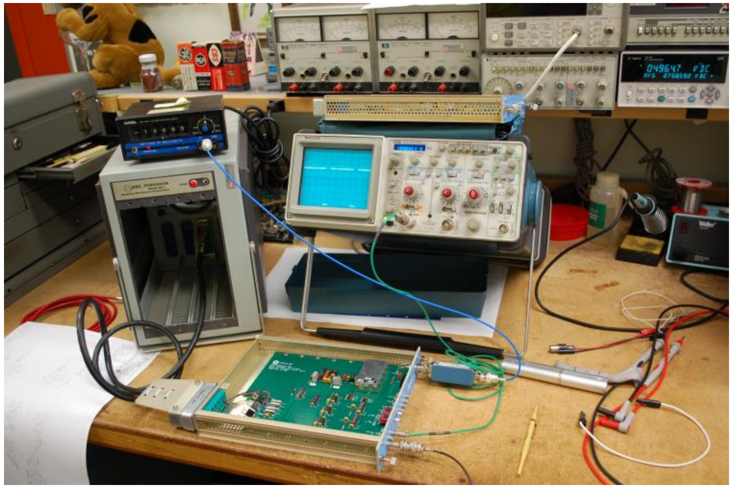
It was found that the ion chamber starts integrating around 1e5 counts.



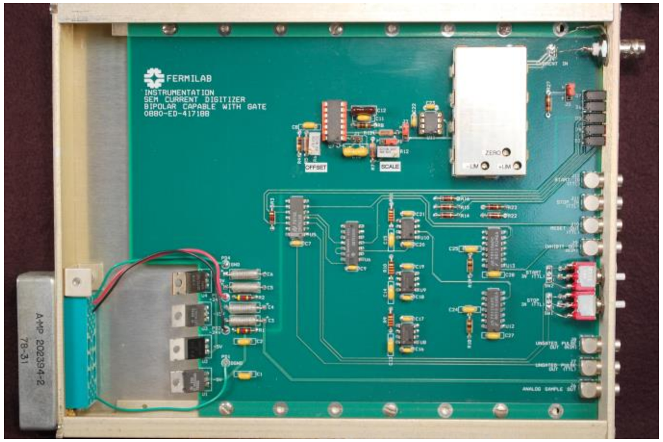


AD Instrumentation - Current Digitizer Module

- NIM Module based.
- Improved version of existing time-tested design.
- Charge to pulse train converter.
- 0 to 100KHz for 0 to 200 nanoampere dynamic range.
- 2% accuracy from 2 to 2000 nanocoulombs.
- 2 second time constant.
- Built in gate generator for CAMAC scaler module.
- Status display on the front panel.



Calibration Test Setup



Conclusion

- Final design for both Multiwire and Ion Chamber systems are nearing completion and we will be ready to begin implementation by the start of the CY ‘16 CD3 review.
- A lot of work has already been done to prove that the beam profiles and intensities are displayed accurately for the M4 beamline. This includes:
  - ***Modifications of the bayonet anti-vacuum cans to accommodate ion   chambers which include e-beam welding the new windows, add the new extension ring and then perform a vacuum leak check.***
  - ***Complete the modifications of the UTA vacuum cans to accept the new wire planes.***
- Design work that needs to be completed before the CD3 review include:
  - ***Finish assembly and vacuum testing of new Bayonet Can/Antivacuum Box design.***
  - ***Finish any design modifications required to make the PreTarget and Post Target MW’s work in the magnetic field of the production solenoid.***