The MiniBooNE Air Wire Chamber

NBI2003

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BARTOSZEK ENGINEERING

People involved in the air multiwire project:

- Larry Bartoszek, ME, Bartoszek Engineering
- Al Dyer, EE, FNAL
- Rick Ford, physicist, FNAL
- Jim Lackey, physicist, FNAL
- Eric Prebys, physicist, FNAL
- Dan Schoo, EE, FNAL
- Dan Snee, Fabrication specialist, FNAL
- Salman Tariq, ME, FNAL
- Gianni Tassatto, Engineering physics, FNAL
- Wanda Newby, technician, FNAL

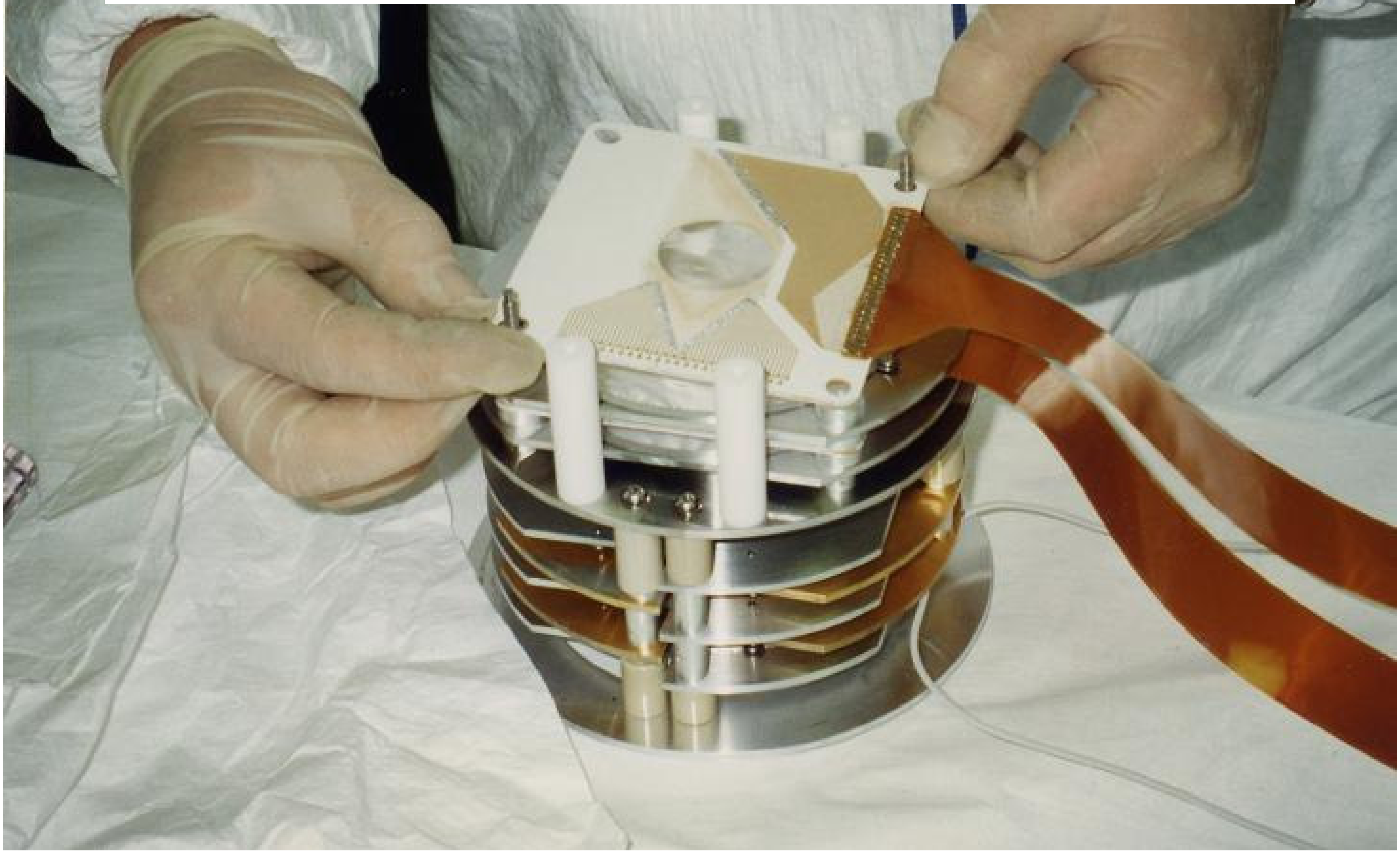
History of the wire chamber

- The Beam Position Monitor Module was calibrated in beam before the horn was finished
- The calibration was done with a standard multiwire downstream of the BPMs
- There was no room for a standard multiwire inside the horn box to maintain the calibration
- Without a multiwire, we couldn't be sure the BPMs meant the same thing after horn installation

BPM module temporarily mounted in MiniBooNE beam line for calibration

It was decided with ~1 month to go to build a brand new air wire chamber out of rejected ceramic boards available at FNAL

What the ceramic boards looked like prior to cutting (picture shows their original application)



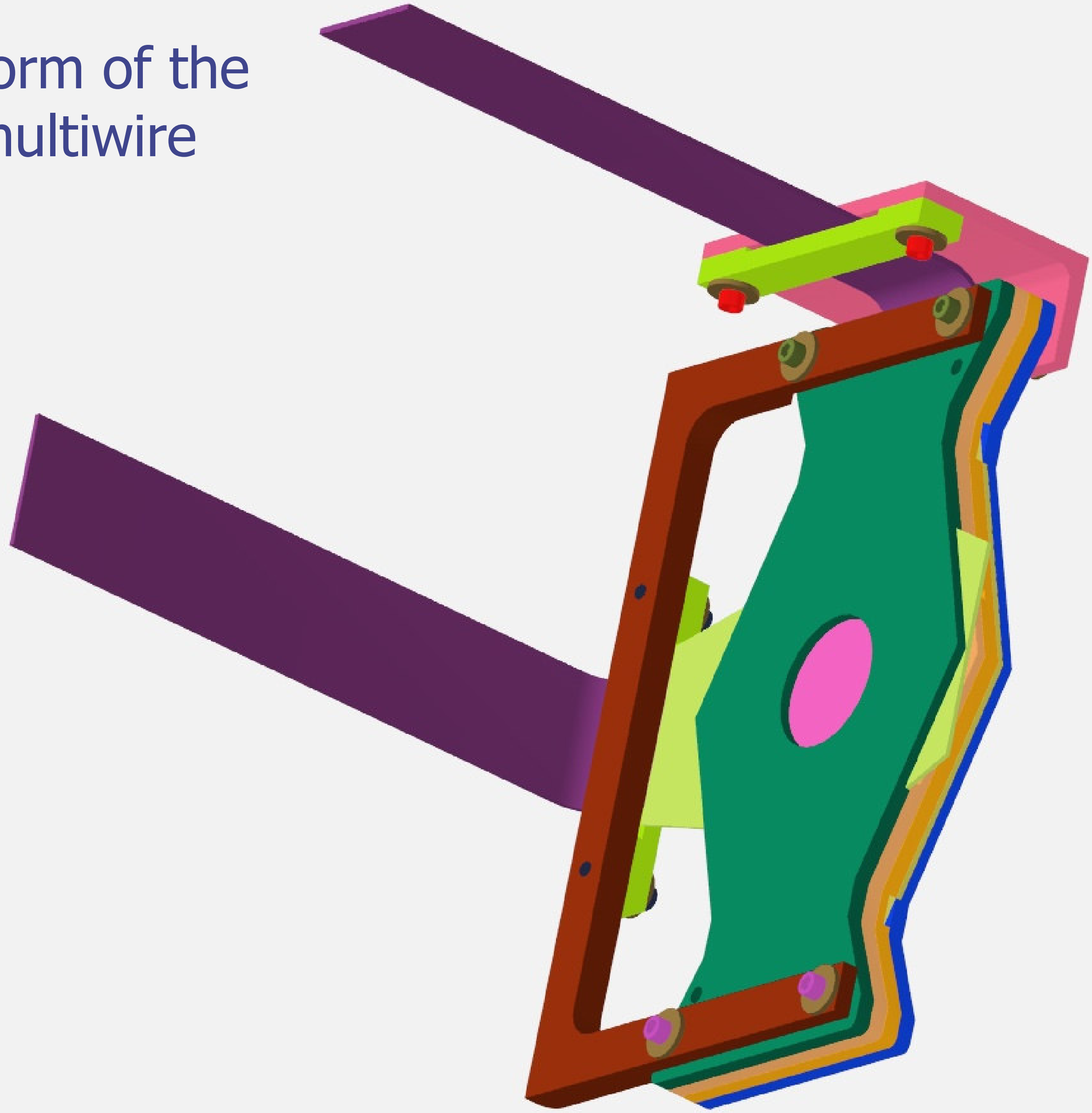
A bumpy beginning

- The boards were rejected because the traces did not reliably stick to the ceramic
- Soldering the wires to the traces caused them to lift off the board
- FNAL had a new style of board that had overcome this problem, but there were none of these available

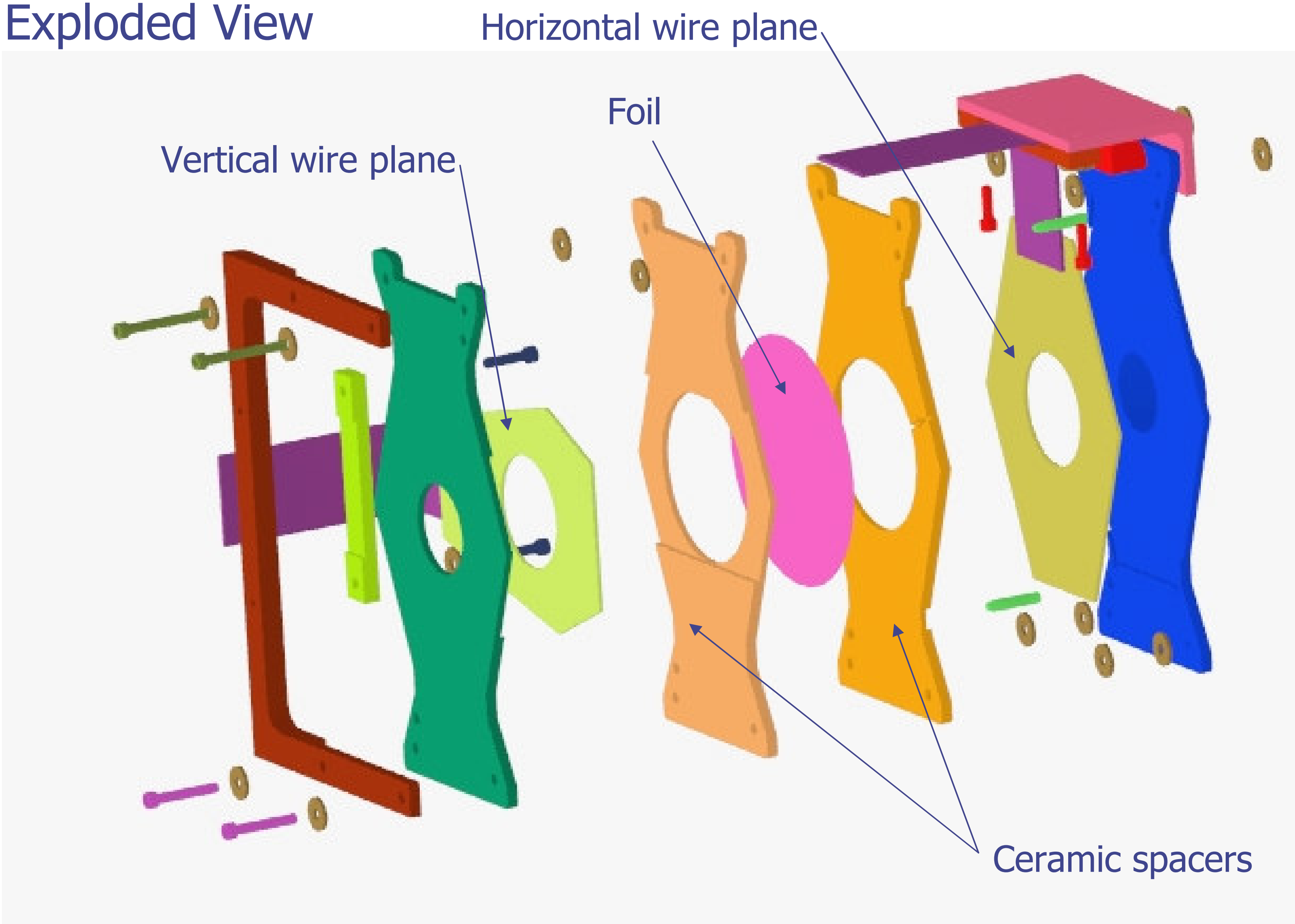
Board Characteristics

- .5 mm pitch between wires
- Gold plated tungsten wires, .003 inches diameter

Final form of the air multiwire



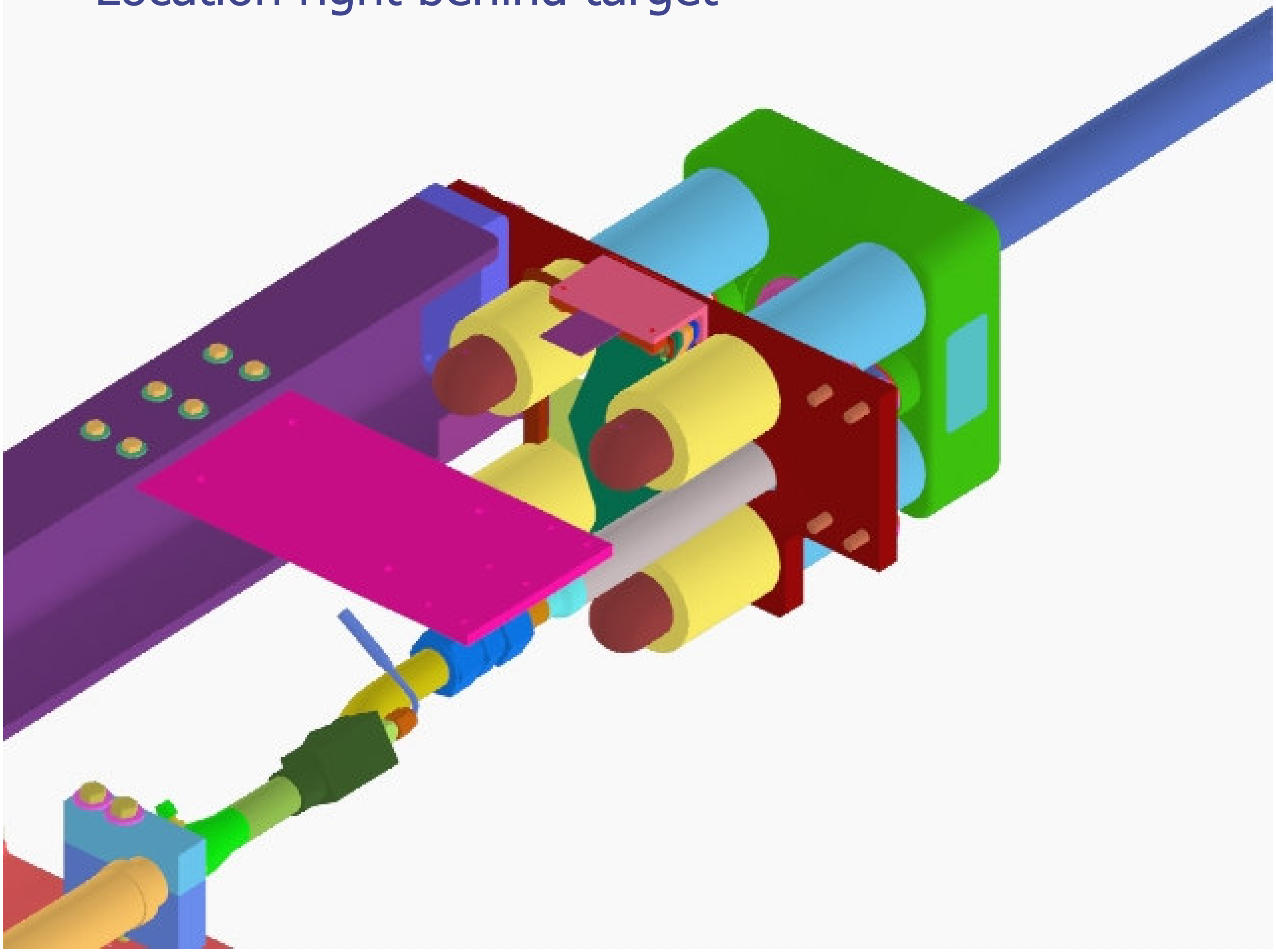
Exploded View



Design choices

- We originally thought that we would mount the wire chamber right behind the target
  - This is the decision that caused us to cut the ceramic boards to shape
  - We did not know at this time what voltage would be needed on the foil to get a clear signal out
  - Cutting the boards turned out to be a mistake

Multiwire designed into original
Location right behind target



Problems encountered

- Machining the ceramic boards to shape smeared metal from the traces along the edge of the board, shorting between traces
- The boards had to be chemically and mechanically etched to eliminate the shorts—took days

More problems

- Since soldering caused traces to lift, each wire had to be individually strain relieved with epoxy after soldering
- This process made the soldering take many days longer than expected and was excruciating for Al Dyer, a man used to painstaking work
- The boards were not uniform in thickness after all the epoxy

Position in the module changes

- Since we didn’t know what voltage we would have to operate the foil at, we became worried that putting the multiwire too close to the target would prevent us from operating it at any reasonable voltage because of the air ionization from the target
- We moved it about 10 inches upstream (eliminating the need to cut the boards, but it was too late—they were cut.)

Yet more problems

- The mechanical design switched hands between the fabrication of the multiwire and the integration into the target module
- I discovered rather late that strain reliefs needed to be designed for the wires to hold them after the boards were assembled together
  - The horizontal plane wires had to make a sharp 90 degree bend to exit the target module
  - The soldered on wires could not be allowed to pull on the traces at all during wire bending
  - Final assembly took at least 5 years off my life!

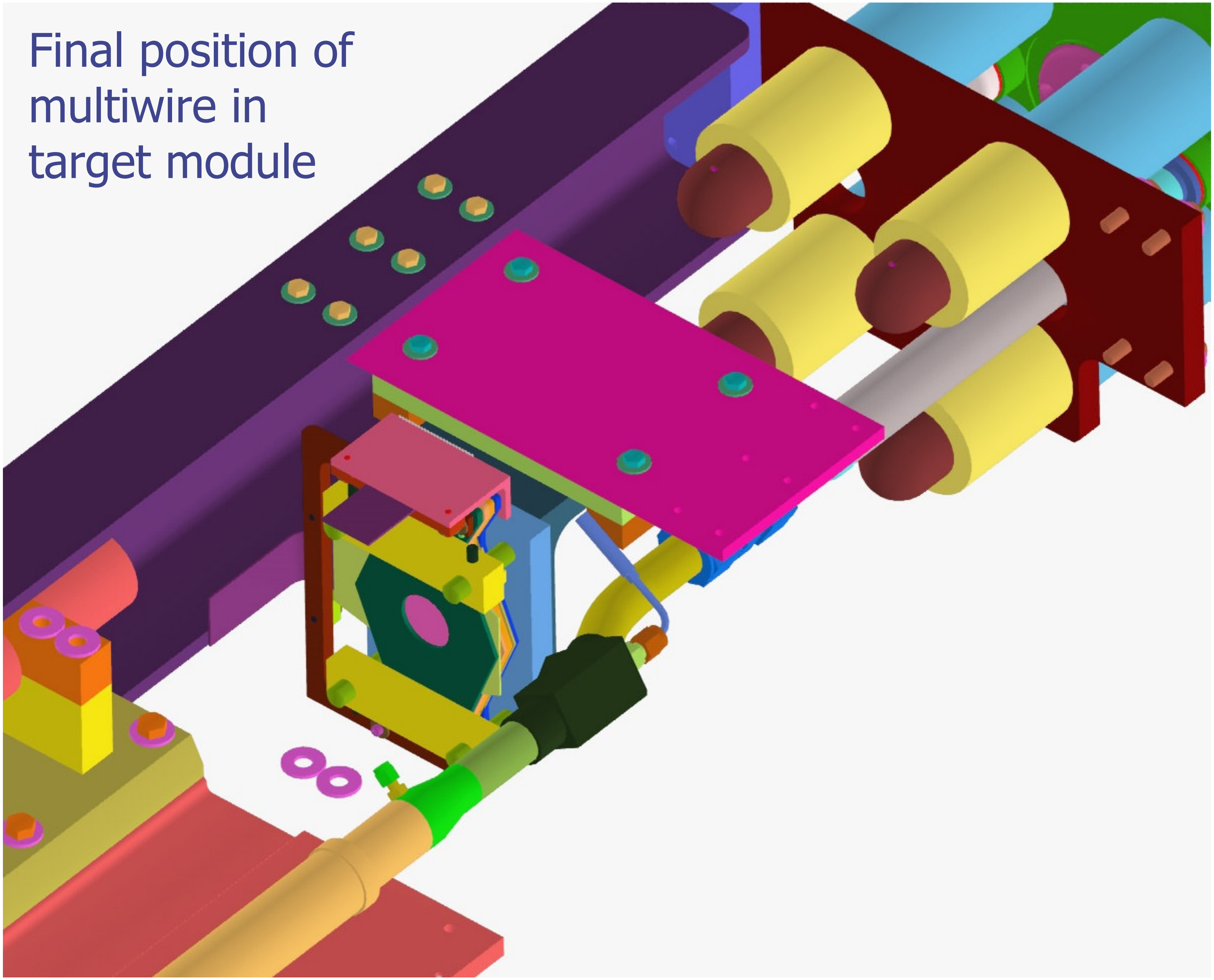
Another design decision

- My philosophy in the design of the target and BPM modules was to build in the locational accuracy with machined and/or shimmed features, not with adjustable mechanisms
  - I was very concerned about vibration loosening fasteners and changing the relative positions of things
- The multiwire is the only adjustable device on these modules

Reason for decision

- I knew from bench survey of the multiwire that it had no good features to locate from
- I doubted our ability to place it correctly with respect to the target without being able to change its position easily
- I incorporated a custom X-Y adjustable mounting fixture

Final position of multiwire in target module



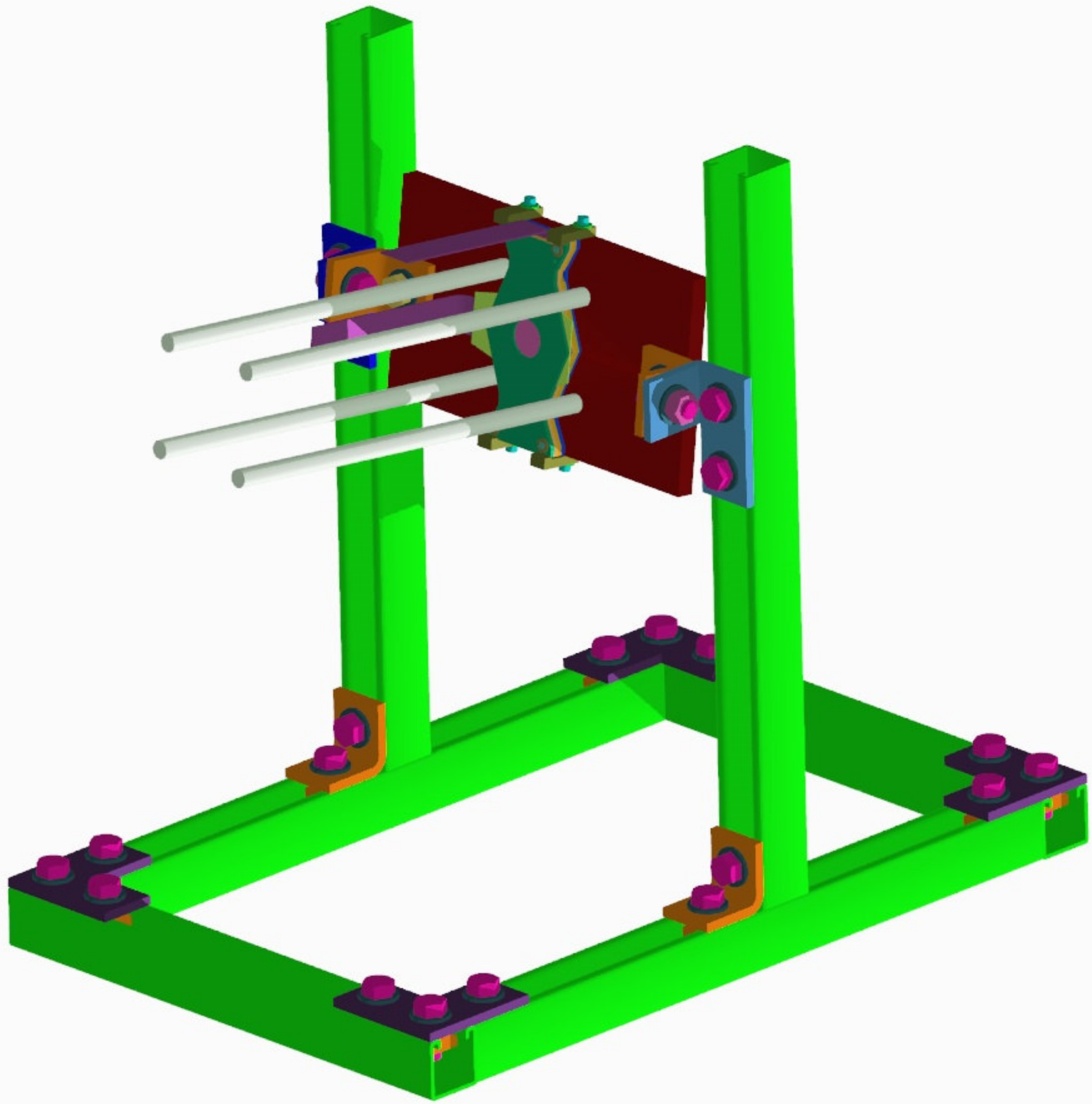
Testing the multiwire

- It was decided that we would not install the new multiwire until it had been tested in beam to see if it did anything
- The Booster dump line was the only place available

The Booster dump line goes down into a trough in the floor

At the end of this trough is a standard multiwire and a space to mount the new air multiwire

Test fixture to mount the wire chamber in the dump line

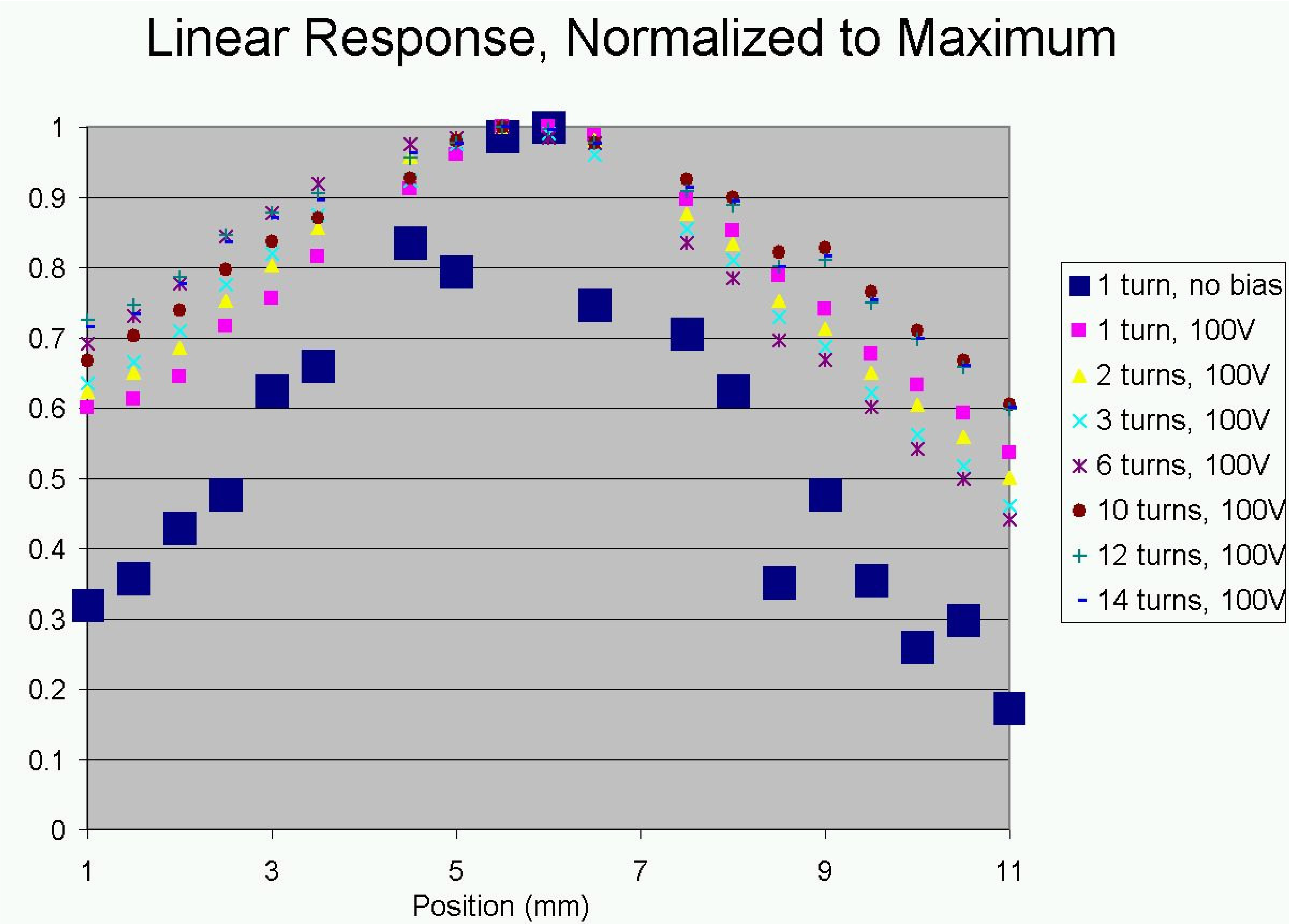


Results of the Booster Test:

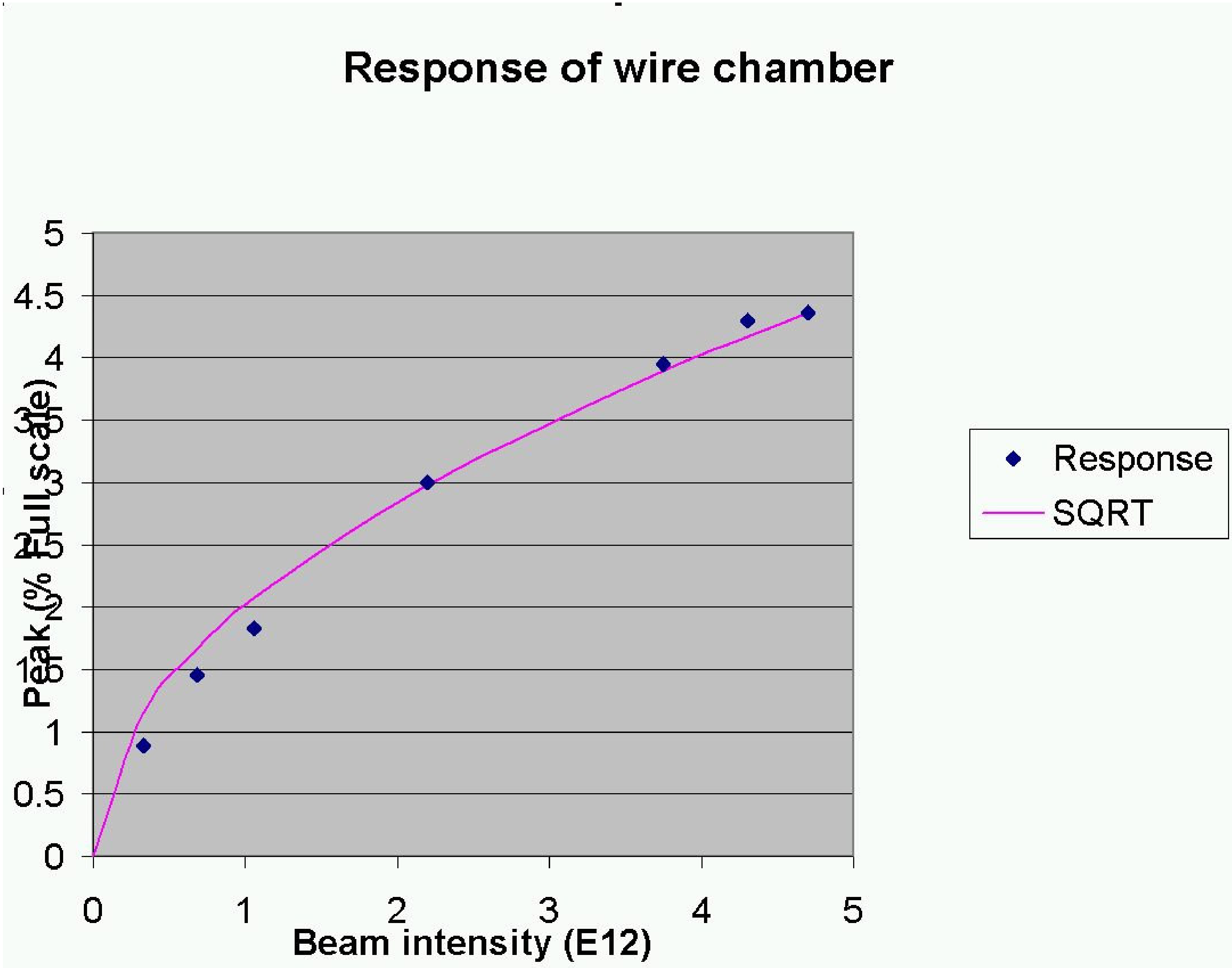
- Eric Prebys of FNAL analyzed this first test data
- With no bias voltage and 1-2 turns (~5E11 protons/turn) of Booster beam there was a "ratty but believable" profile
- With any more beam, the chamber signal became unusable
- With 100V of bias, there was a much smoother but broader profile all the way up to 14 turns
- Profile continued to broaden with intensity

More results from test

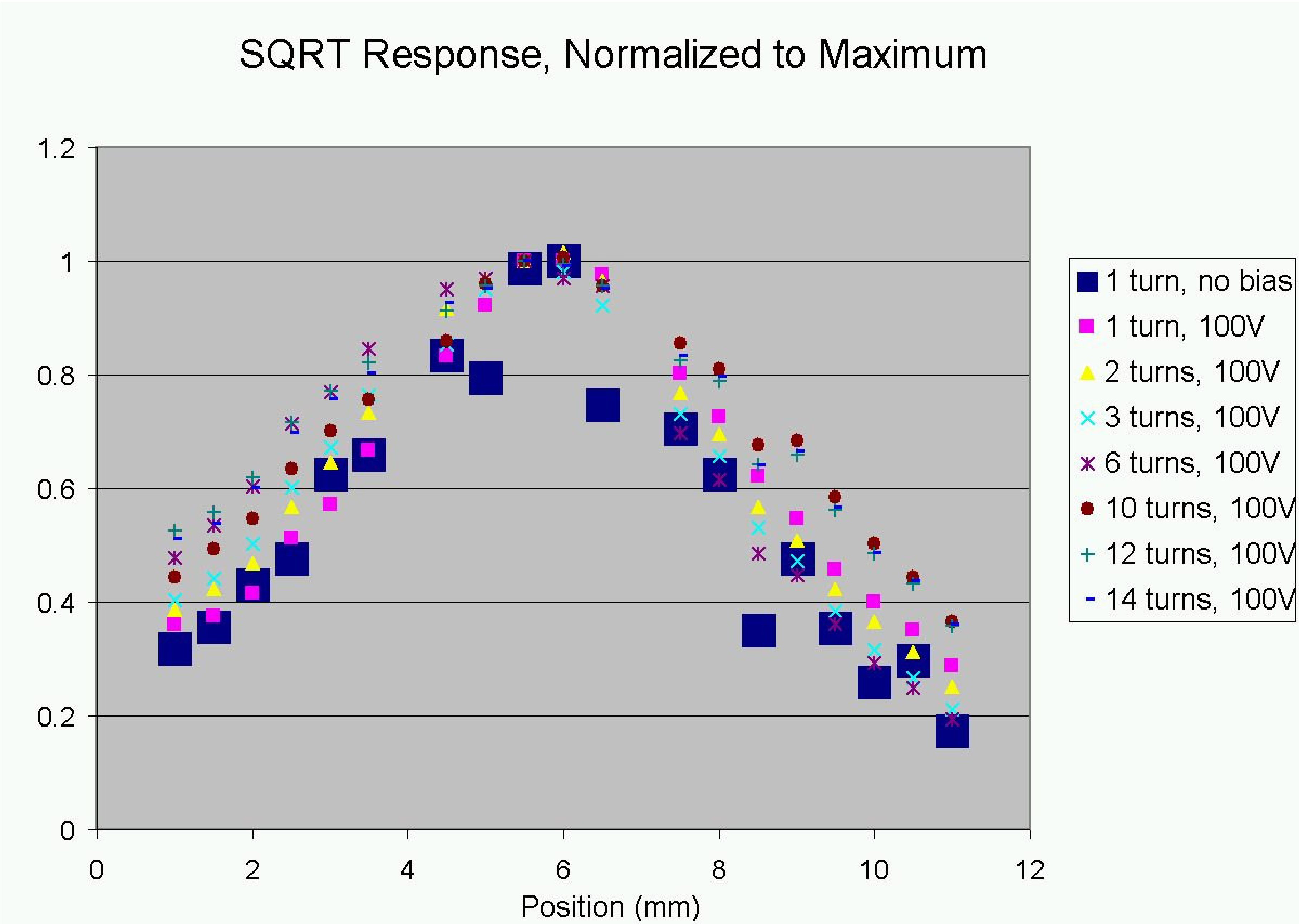
- Multiwire has nonlinear response as a function of Booster intensity
- Eric noticed it looked like a square root function
- Because of this resemblance, he found a better fit to the data using the square of the chamber signal



Linear Response, Normalized to Maximum
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
3
5
7
9
11
Position (mm)
1 turn, no bias
1 turn, 100V
2 turns, 100V
3 turns, 100V
6 turns, 100V
10 turns, 100V
12 turns, 100V
14 turns, 100V



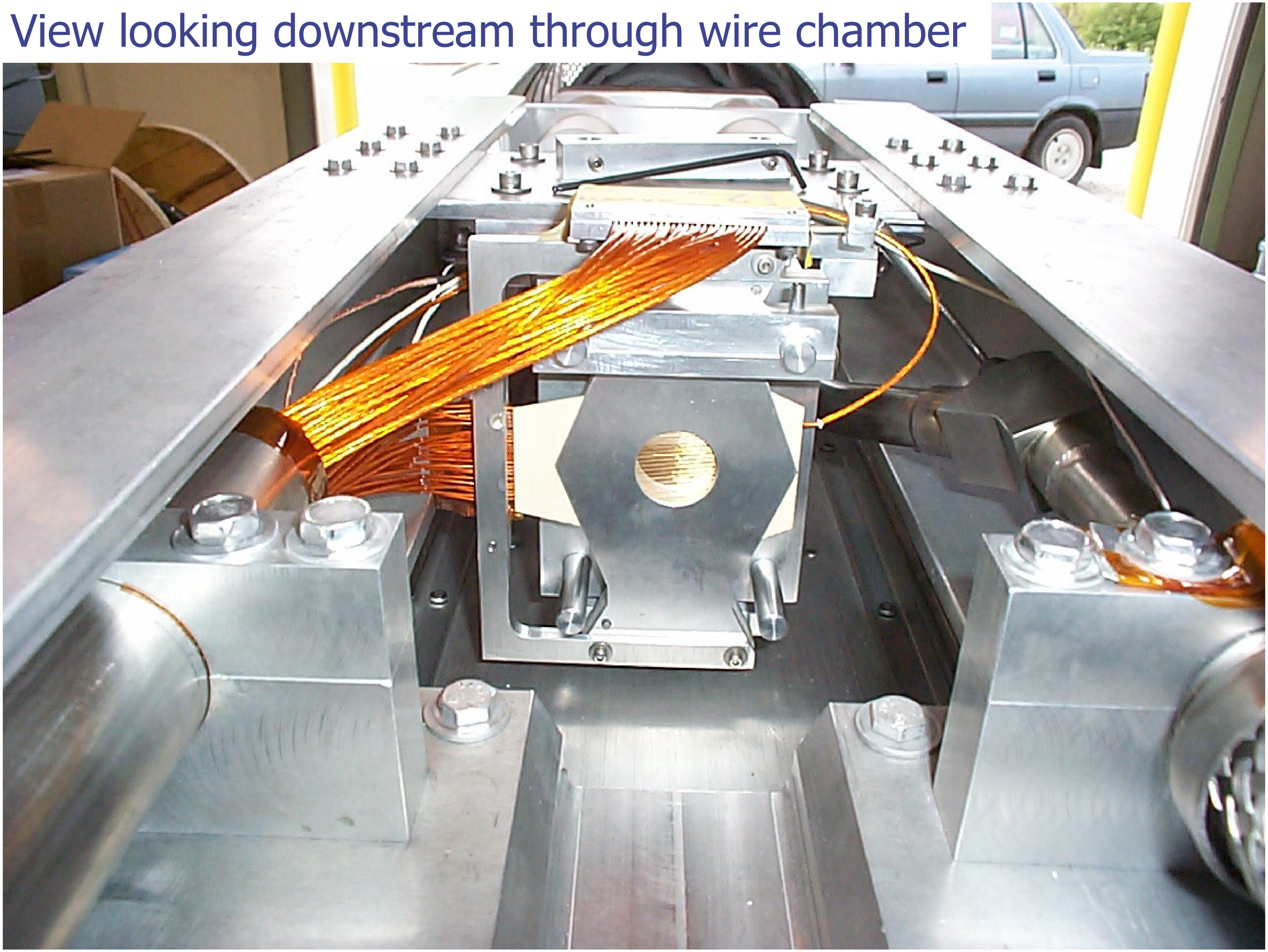
Response of wire chamber
Peak (% Full scale)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
Beam intensity (E12)
Response
SQRT



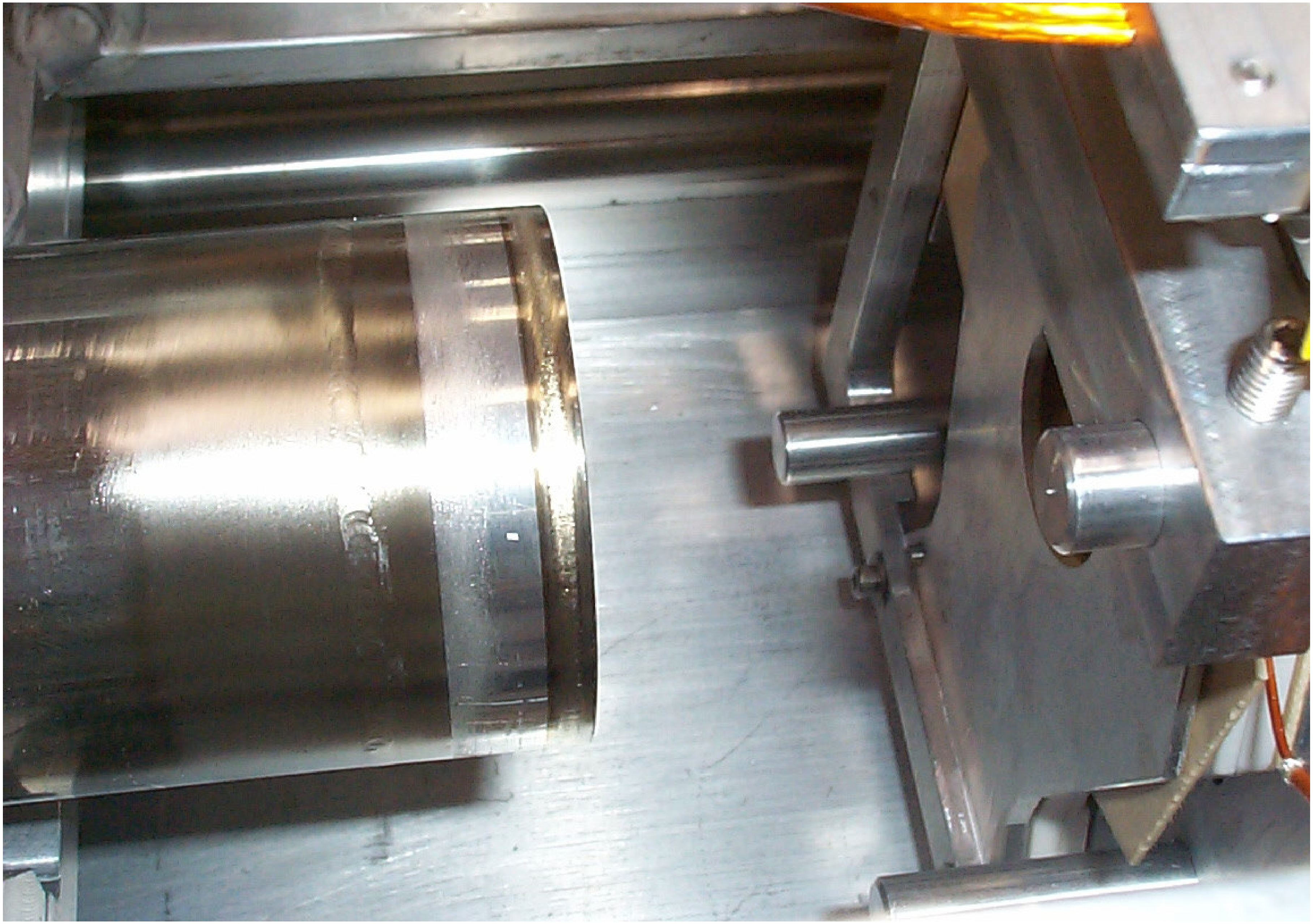
SQRT Response, Normalized to Maximum
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Position (mm)
1 turn, no bias
1 turn, 100V
2 turns, 100V
3 turns, 100V
6 turns, 100V
10 turns, 100V
12 turns, 100V
14 turns, 100V

In August of 2002 the Multiwire was integrated into the target module and assembled into horn

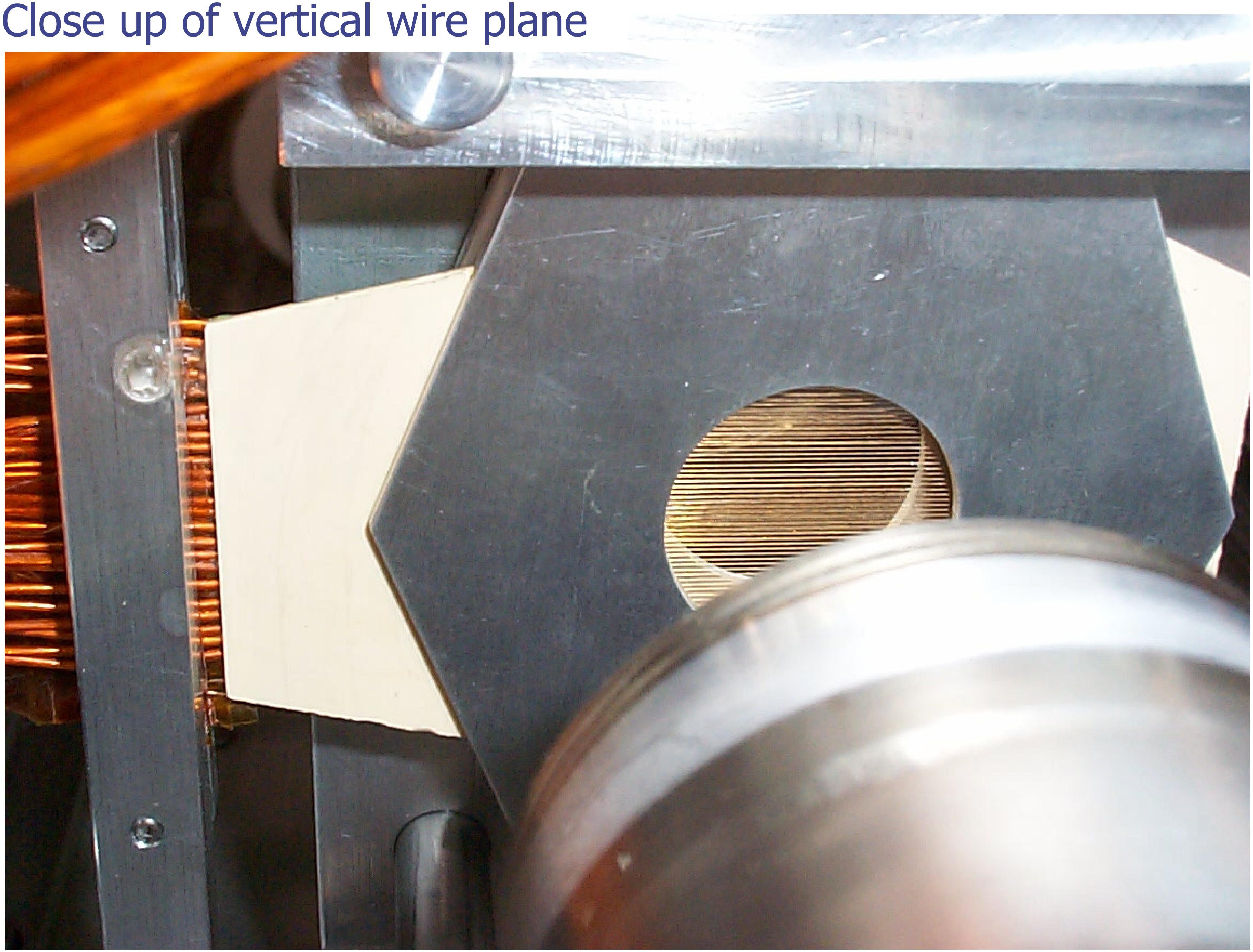
View looking downstream through wire chamber

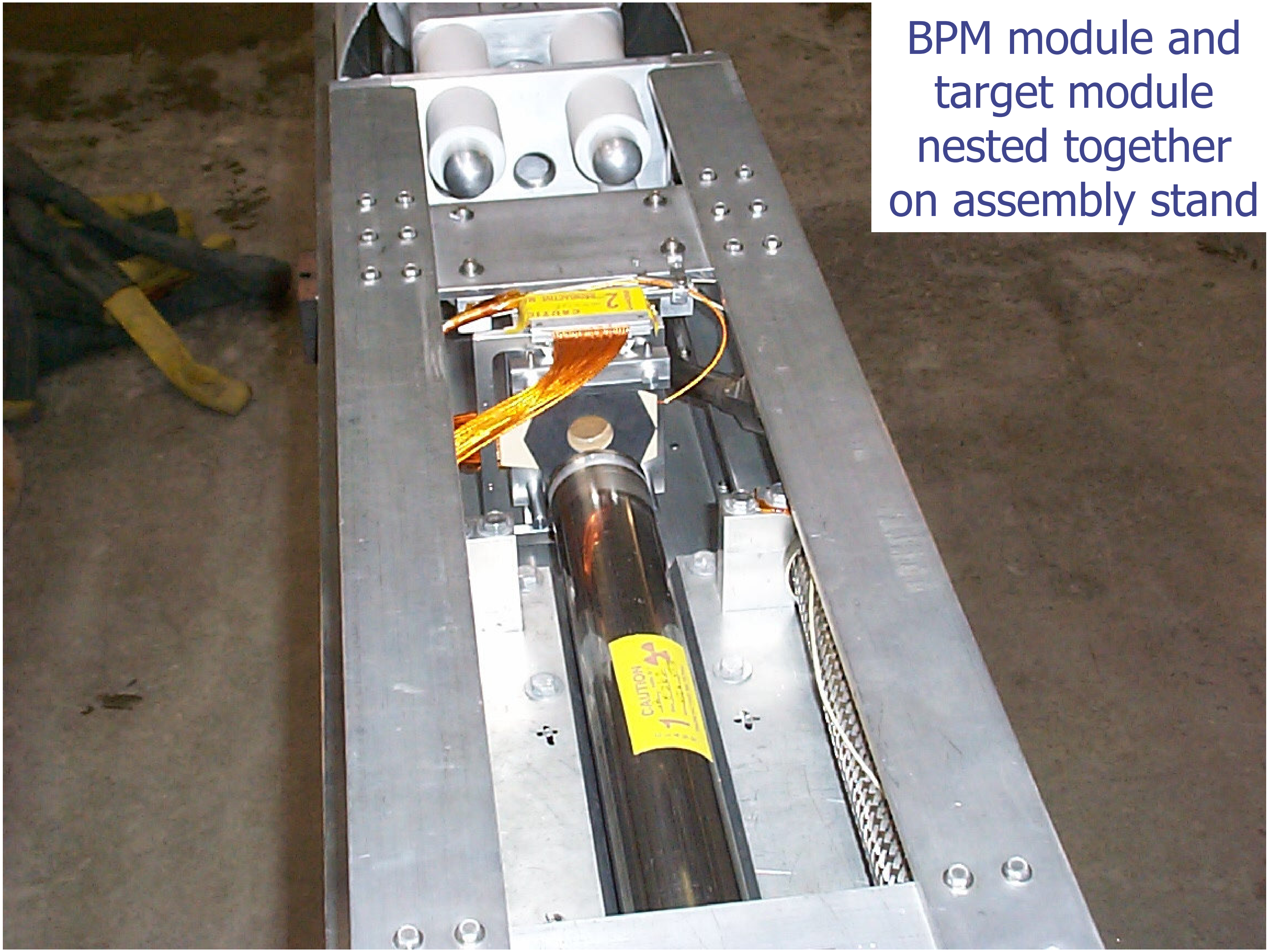


Ti window on end of beam pipe just upstream of wire chamber



Close up of vertical wire plane





BPM module and target module nested together on assembly stand

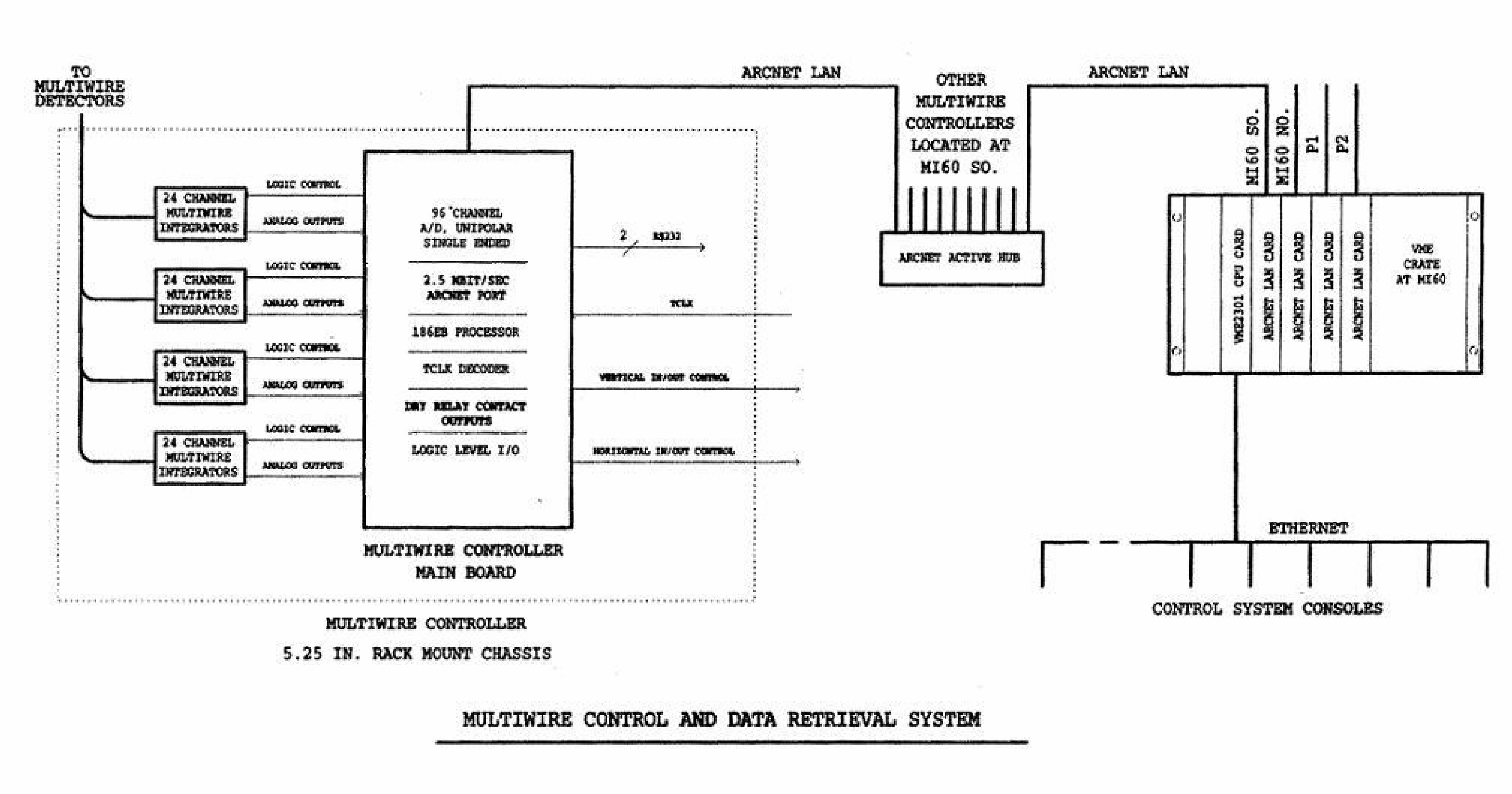
View looking upstream

Target and BPM modules being readied for insertion into horn box

Read-out of the multiwire

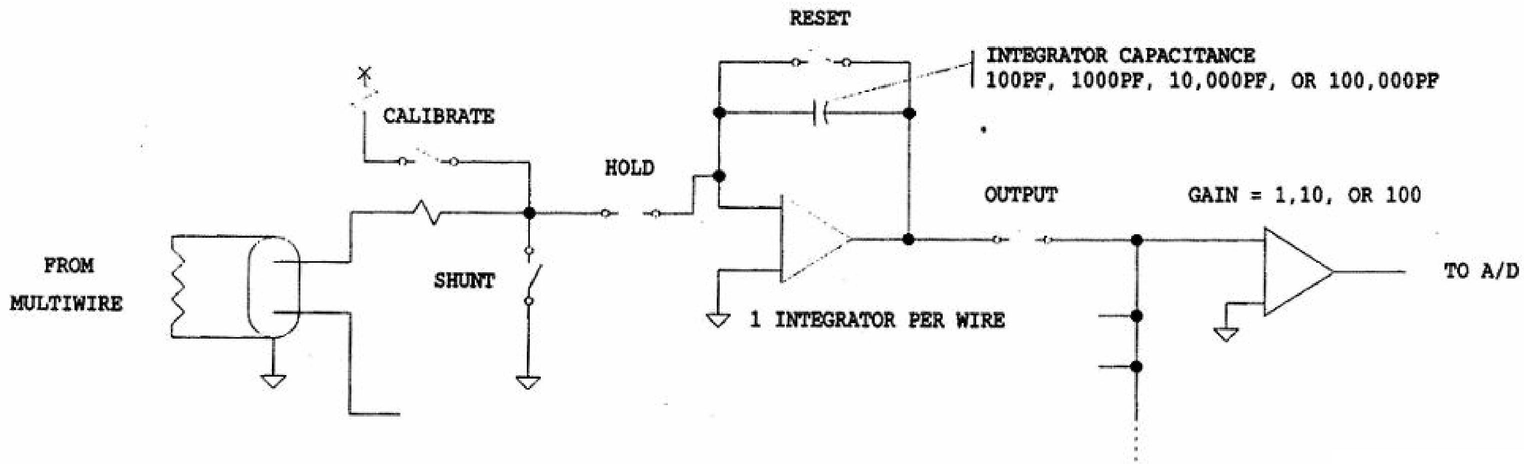
- The same electronics is used to read out the air multiwire as all the other multiwires in the beam line
- Capacitor values in the integrators can be changed to adjust to different beam intensities

Block diagram of multiwire read-back system

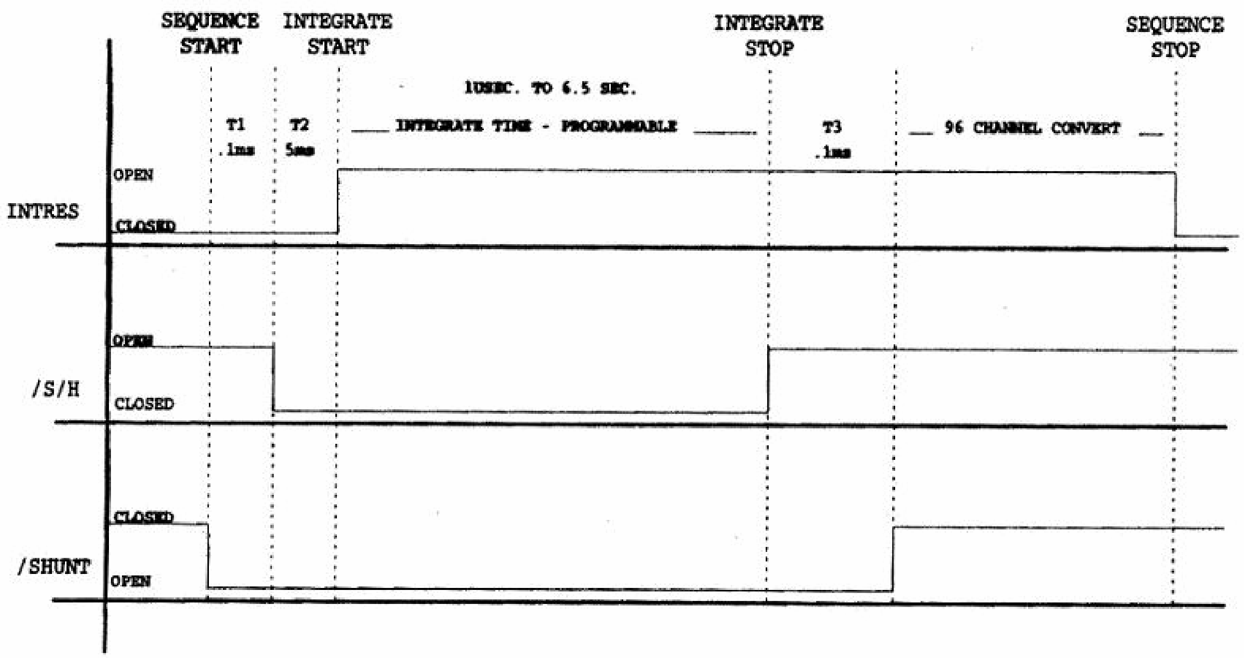


Picture courtesy of Gianni Tassotto

Integrator circuit diagram and cycle timing diagram

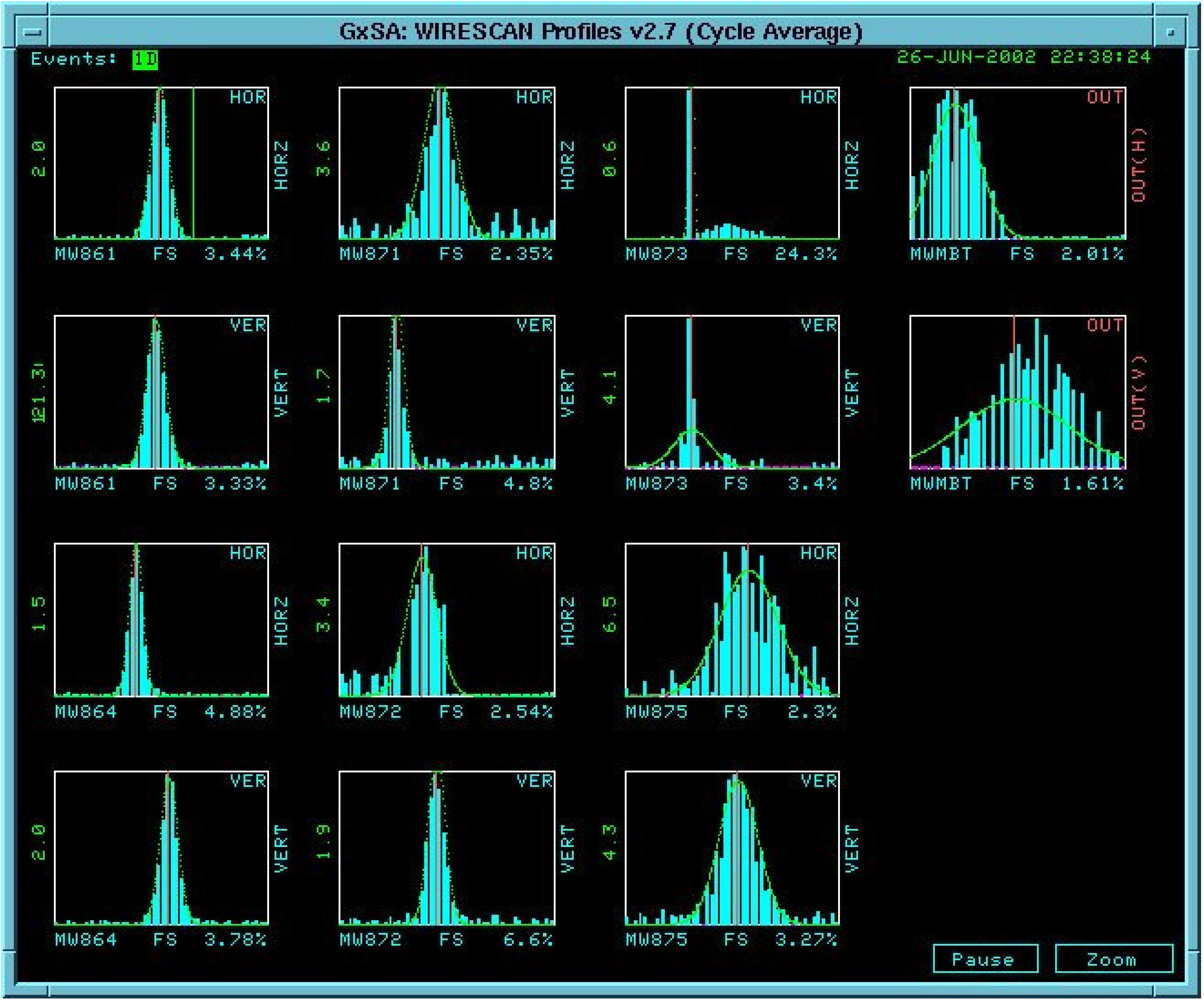


REPEAT CIRCUIT 96 TIMES

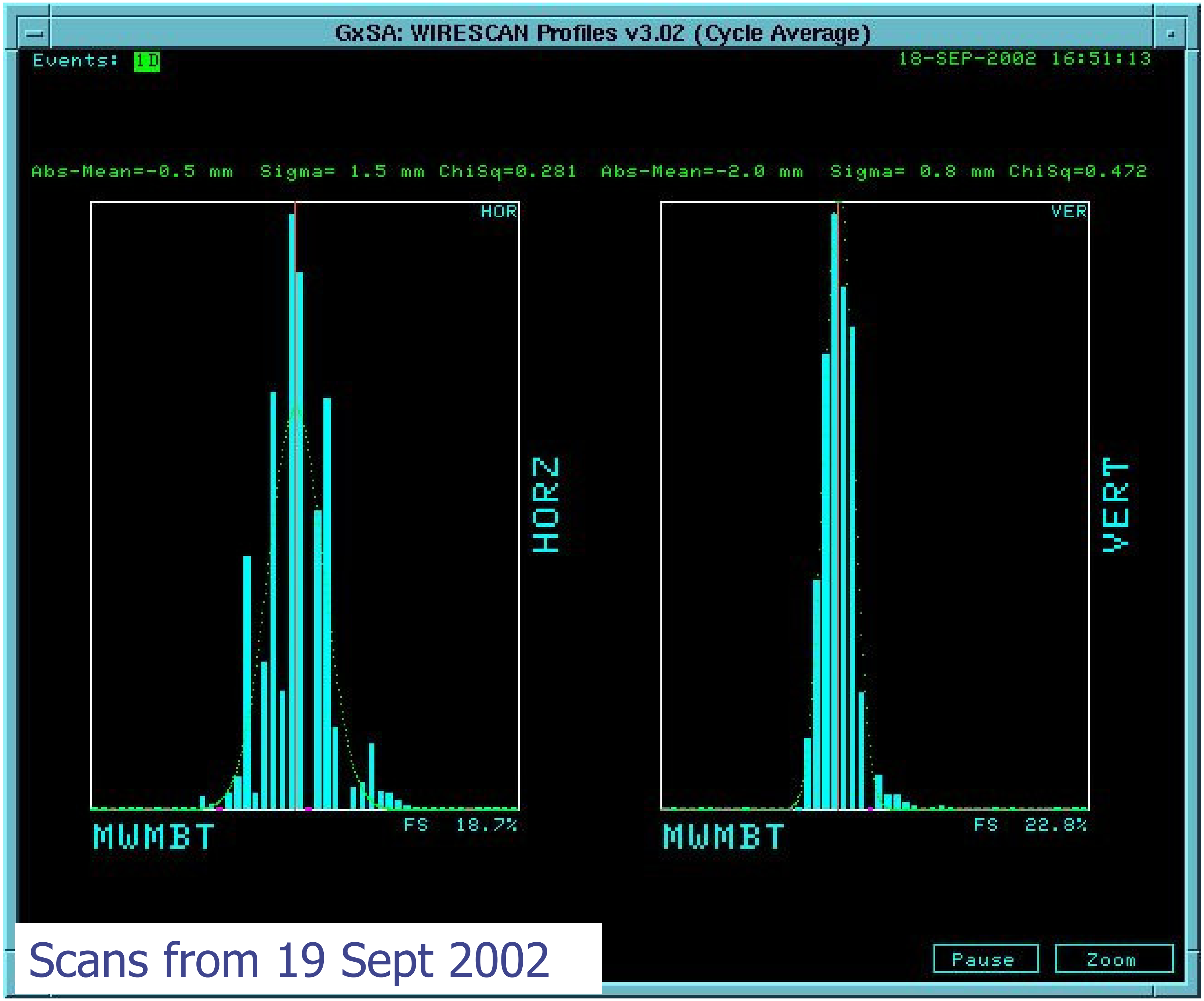


INTEGRATE CYCLE TIMING DIAGRAM

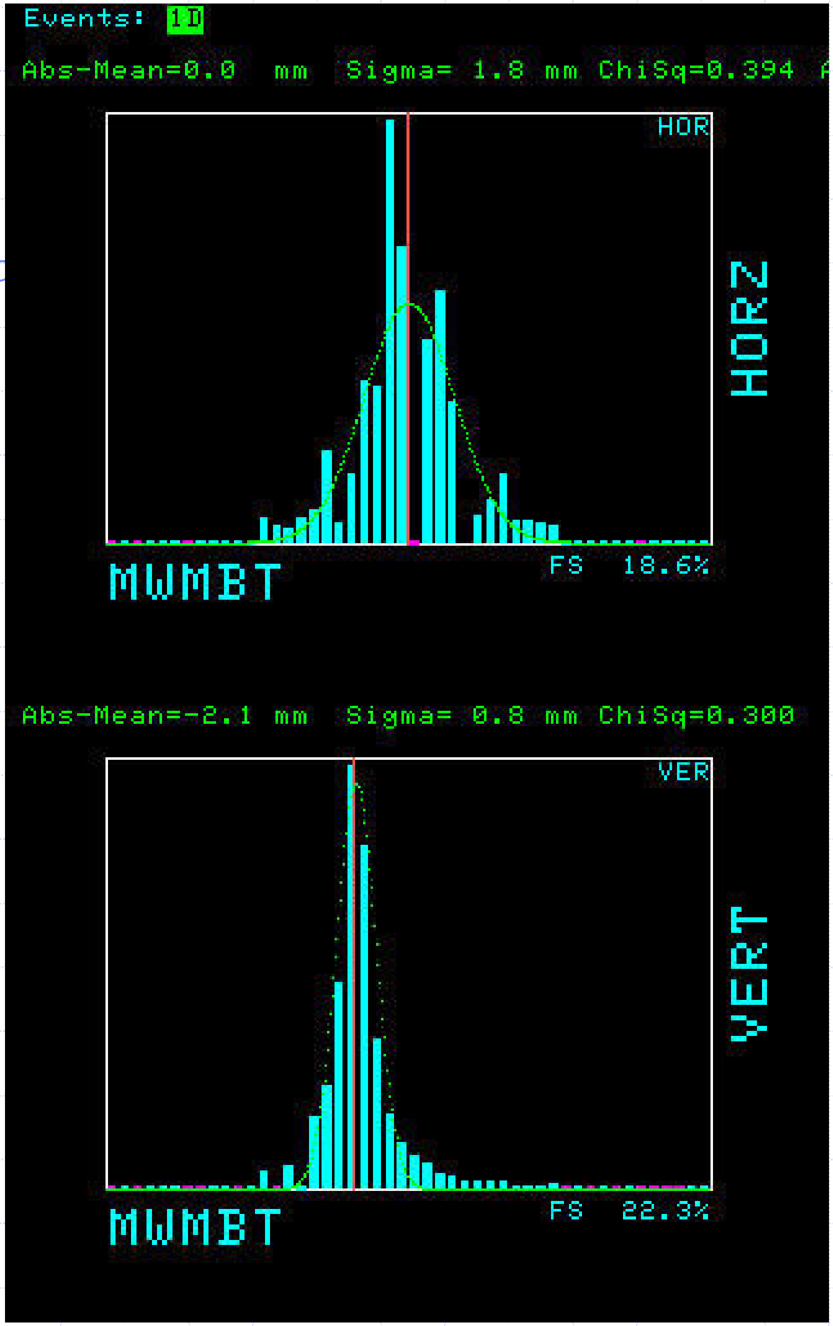
Beam profiles from all the multiwires in the MiniBooNE beam line, shortly after installation in August, 2002



GxSA: WIRESCAN Profiles v2.7 (Cycle Average)
Events: 10
26-JUN-2002 22:38:24
HOR
HORZ
2.0
MW861 FS 3.44%
HOR
HORZ
3.6
MW871 FS 2.35%
HOR
HORZ
0.6
MW873 FS 24.3%
OUT
OUT(H)
MWMBT FS 2.01%
VER
VERT
121.3
MW861 FS 3.33%
VER
VERT
1.7
MW871 FS 4.8%
VER
VERT
4.1
MW873 FS 3.4%
OUT
OUT(V)
MWMBT FS 1.61%
HOR
HORZ
1.5
MW864 FS 4.88%
HOR
HORZ
3.4
MW872 FS 2.54%
HOR
HORZ
6.5
MW875 FS 2.3%
VER
VERT
2.0
MW864 FS 3.78%
VER
VERT
1.9
MW872 FS 6.6%
VER
VERT
4.3
MW875 FS 3.27%
Pause
Zoom



Scans from 19 Sept 2002



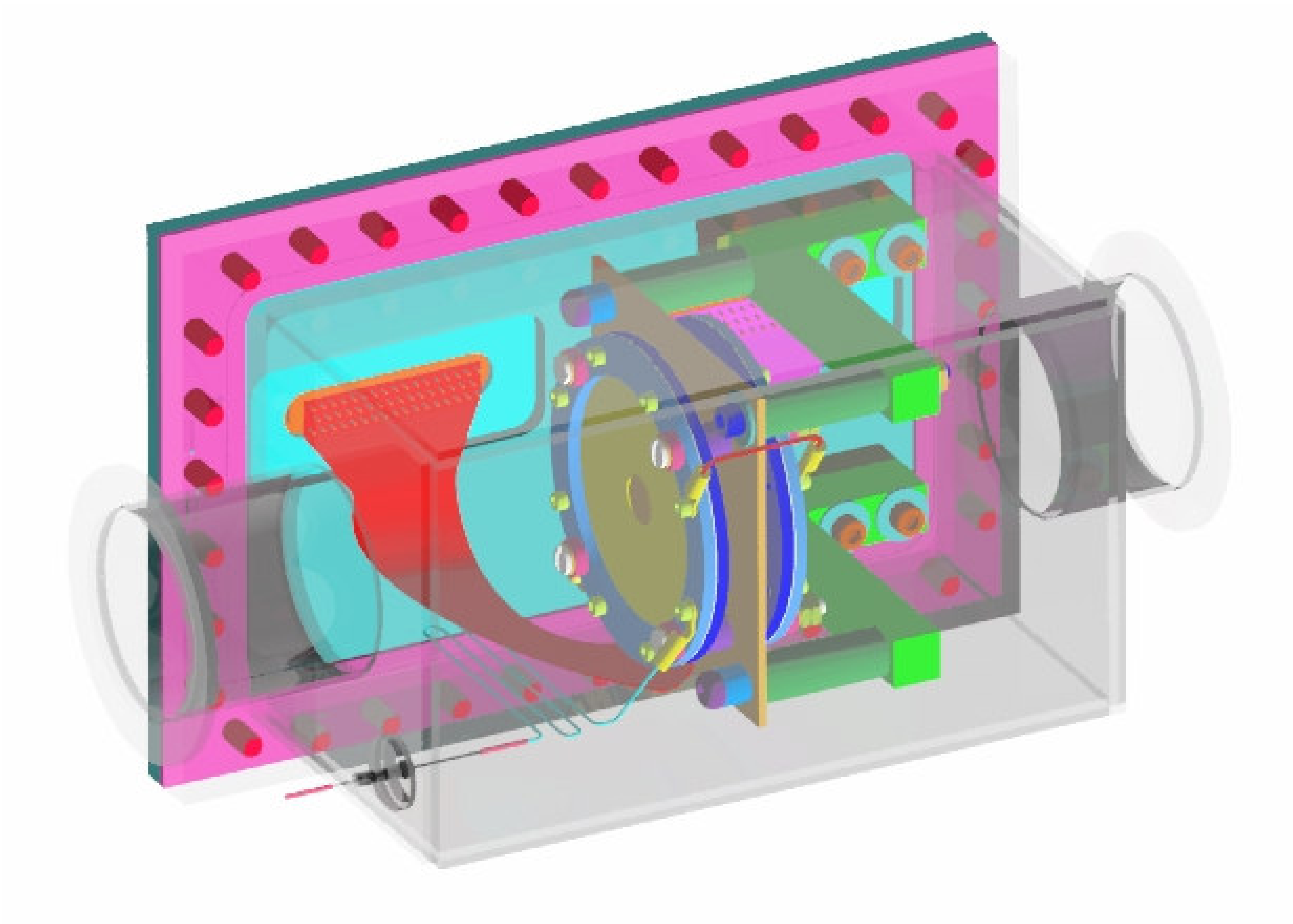
Profiles from 30 April 2003

Horizontal has always looked worse than vertical because more wires were damaged in board cutting

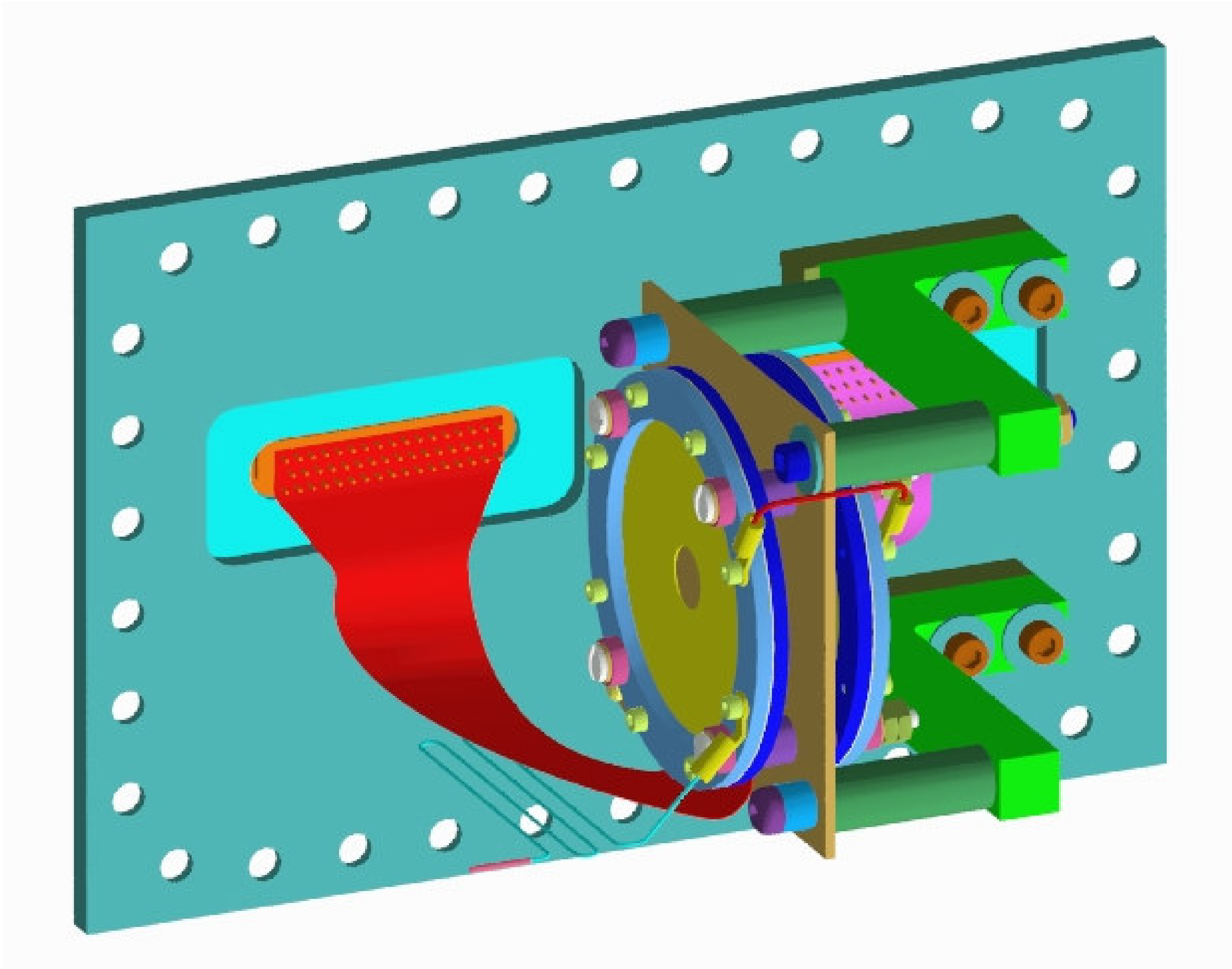
The multiwire lives on!

- It has been a year of operation and the multiwire still produces a usable signal
  - Some think the signal has degraded but there have been no studies of this
- We have designed a new vacuum multiwire for the spare target and BPM
  - New vacuum multiwire will be permanently connected to the BPM module, not the target module

New vacuum multiwire for the spare BPM module



Close-up of how everything attaches to the top flange



Parts on the bench waiting for assembly

Check in with us in a few months to see how well the new multiwire works!