SiD muon detector scintillator option: bits and pieces of interest from CMS, T2K and MINERvA

(mostly optical path, not so much about the readout)

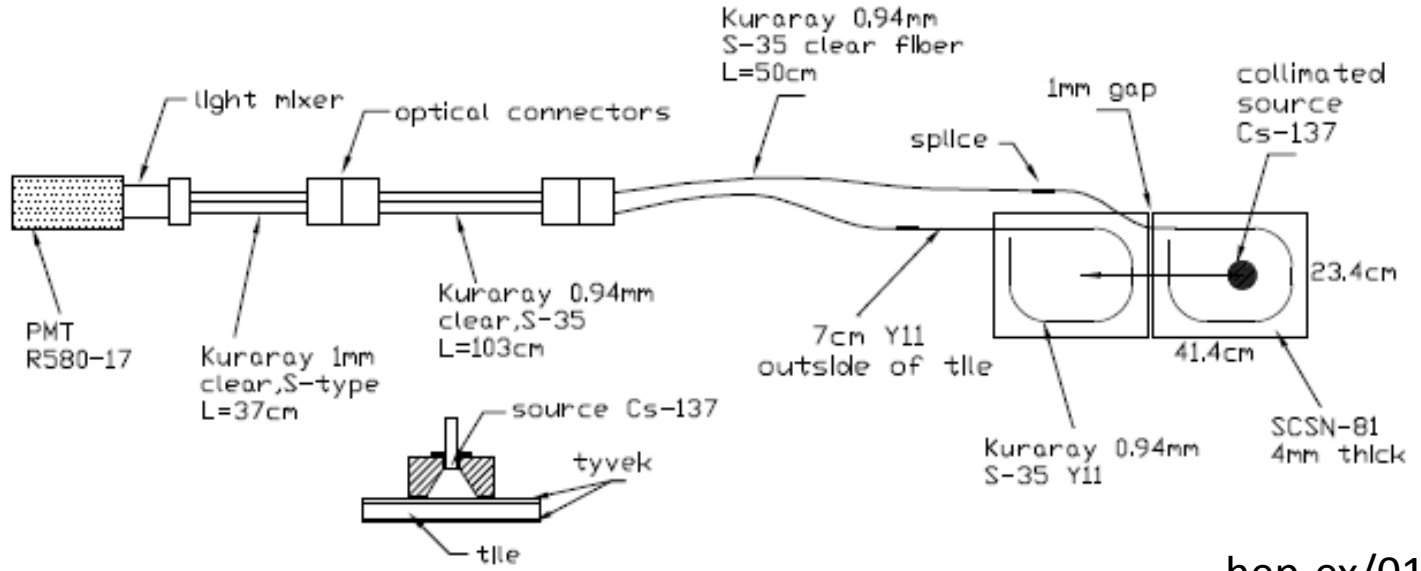
S. Manly (extensive use of information/slides from Howard Budd and other members of the Rochester group + T2K and MINERvA collaborators)

University of Rochester

SiD Meeting – SLAC – March 2-4, 2009

Fiber R and D for the CMS HCAL

H. S. Budd, A. Bodek, P. de Barbaro, D. Ruggiero, E. Skup



hep-ex/01020321

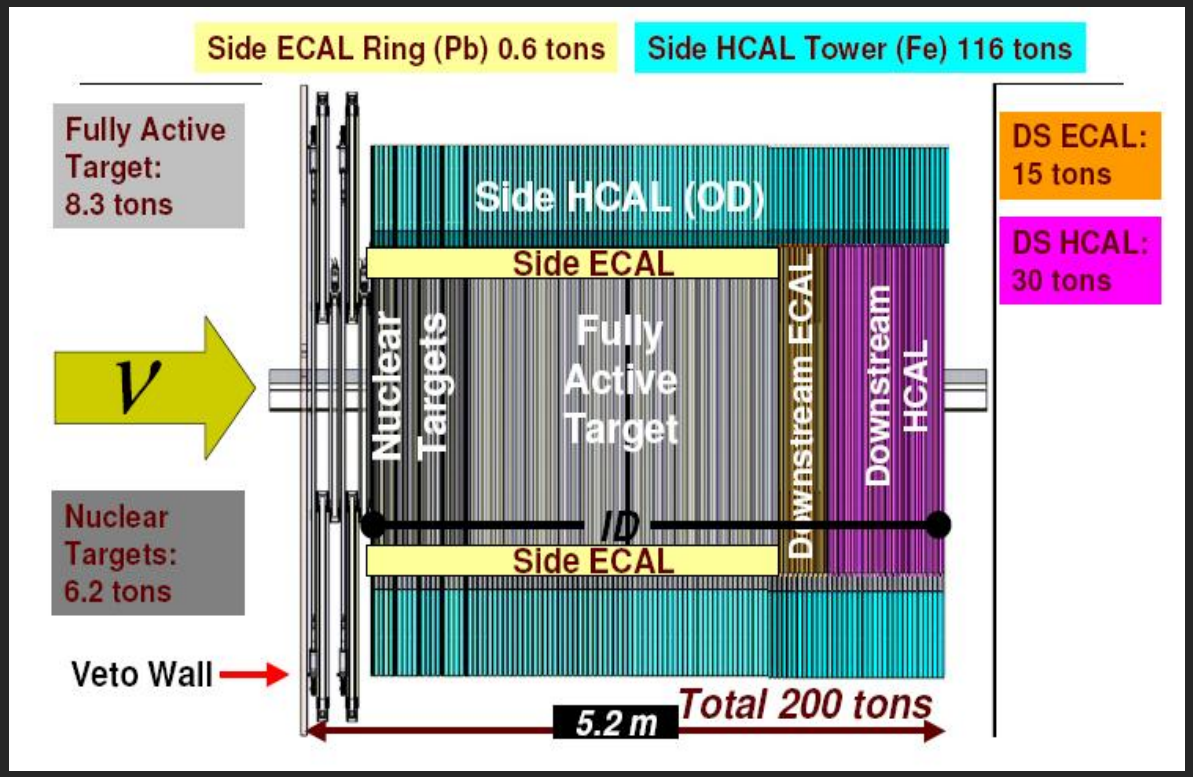
One setup for CMS HCAL R&D, just to give a flavor of components of light path

0.94 mm dia fiber Kuraray S-35 fiber (clear and Y-11 WLS fiber)

10-fiber cables/connectors

Connectors from Fujikura/DDK

MINERνA Detector

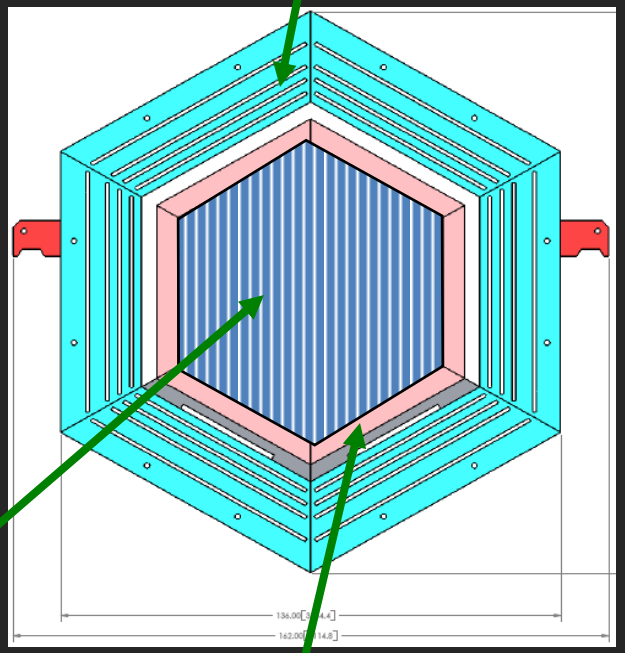


Side View

Front View

Outer Detector (OD) Layers of iron/scintillator for hadron calorimetry:

6 Towers



Inner Detector Hexagon – X, U, V planes for stereo view

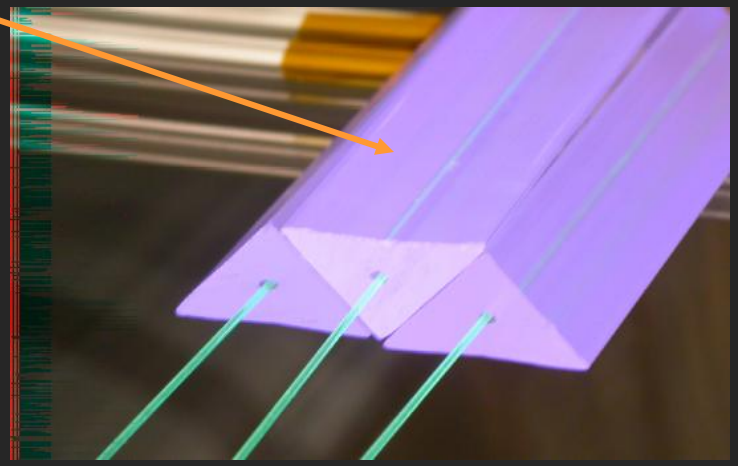
Lead sheets for EM calorimetry

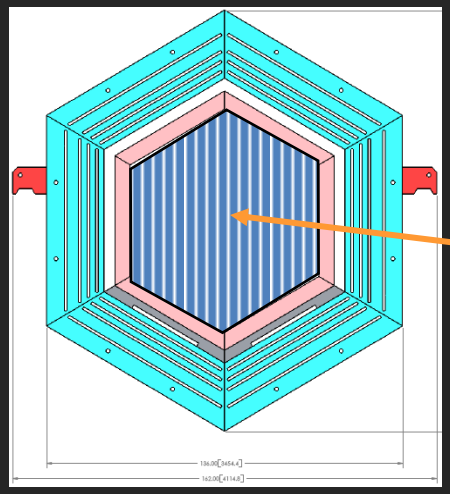
MINERνA Detector

Detector Channel Count:

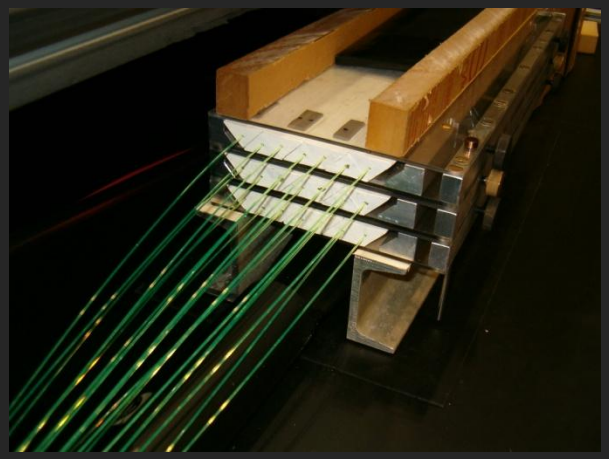
- **31,000 channels**
  - 80% in inner hexagon
  - 20% in Outer detector
- **503 M-64 PMTs** (64 channels)
- **128 pieces of scintillator per Inner Detector plane**

Active elements are 1.7x3.3 cm triangular bars of extruded scintillator with embedded 1.2 mm WLS fibers





Inner detector is totally active scintillator strip detector. Alternating planes rotated by 60 degrees to make 3 views (XUXV)



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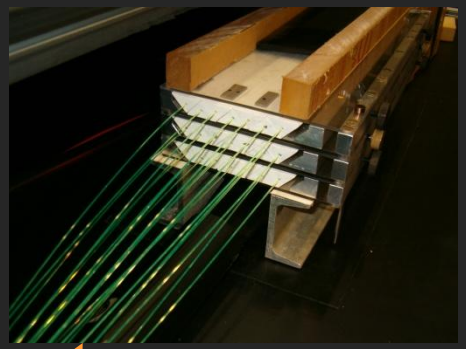
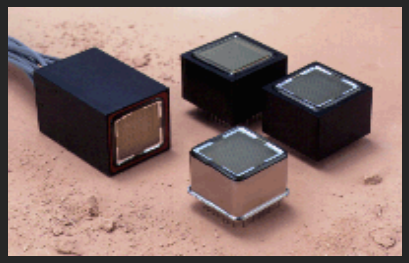
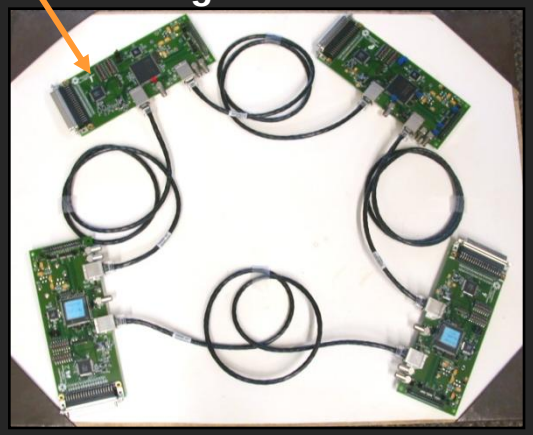


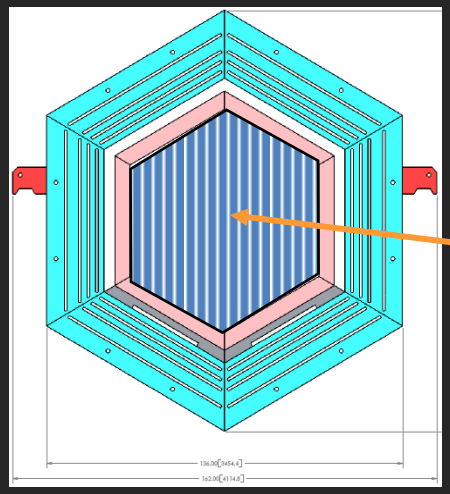


Readout by Hamamatsu M64 +

FE Readout Based on TriP-t ASIC and LVDS chain

ADC (triple range) plus few ns resolution timing





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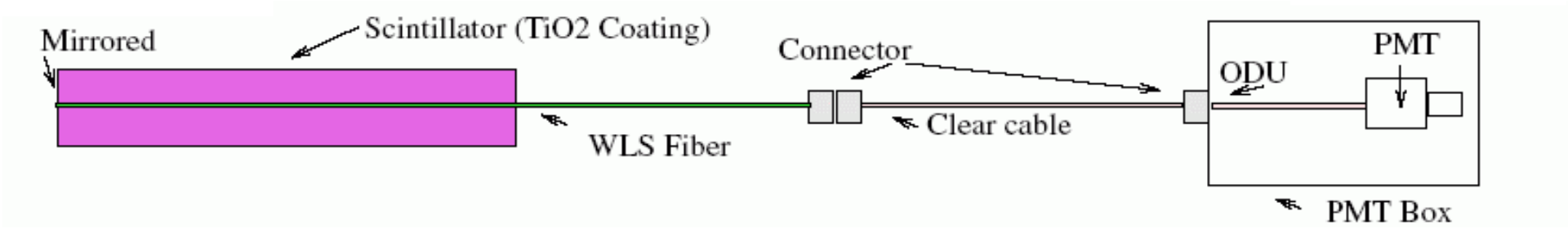
MINERνA: Optical system - overview

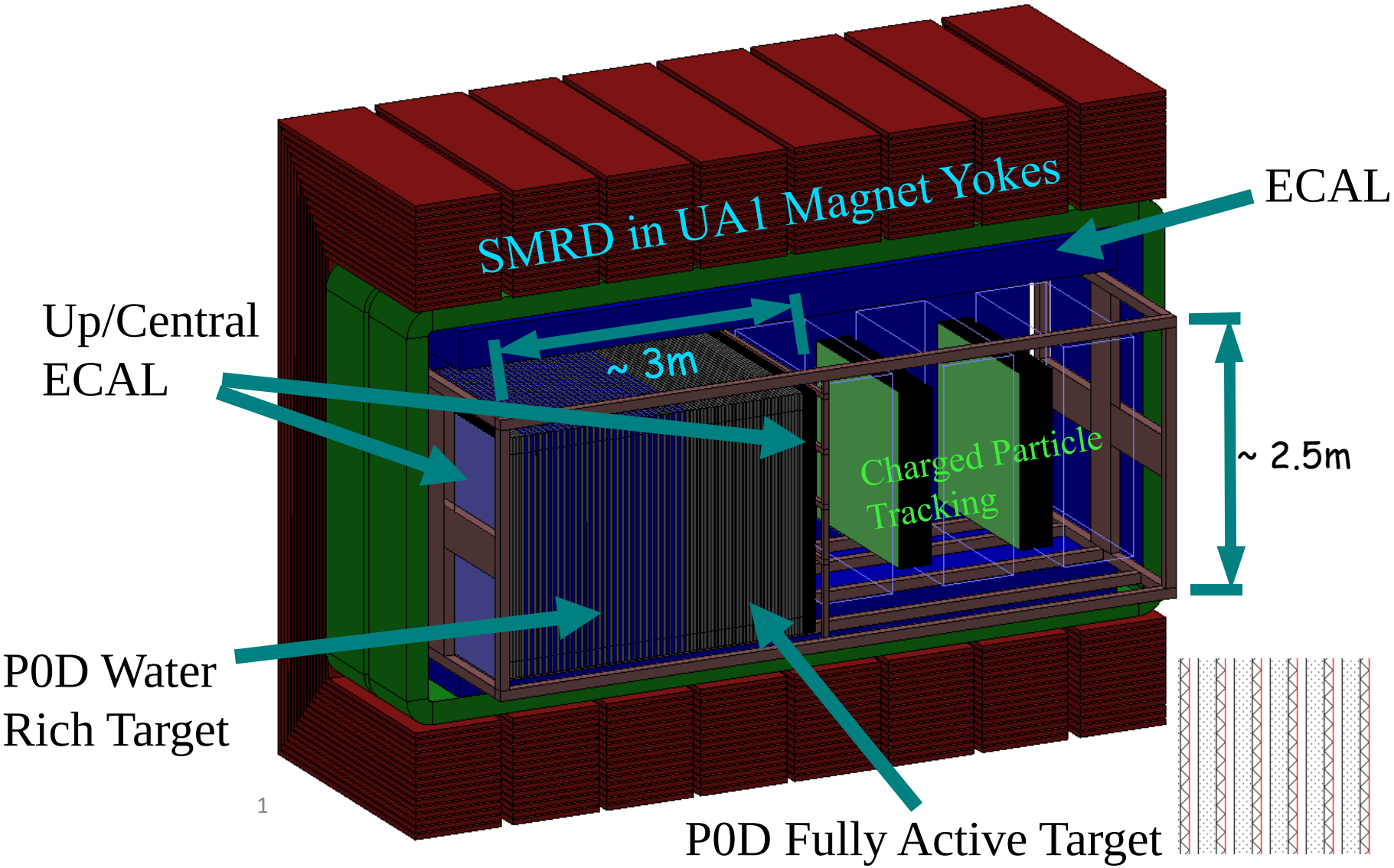


1.18 mm dia fiber Kuraray S-35 fiber (clear and Y-11 WLS fiber) glued in scintillator

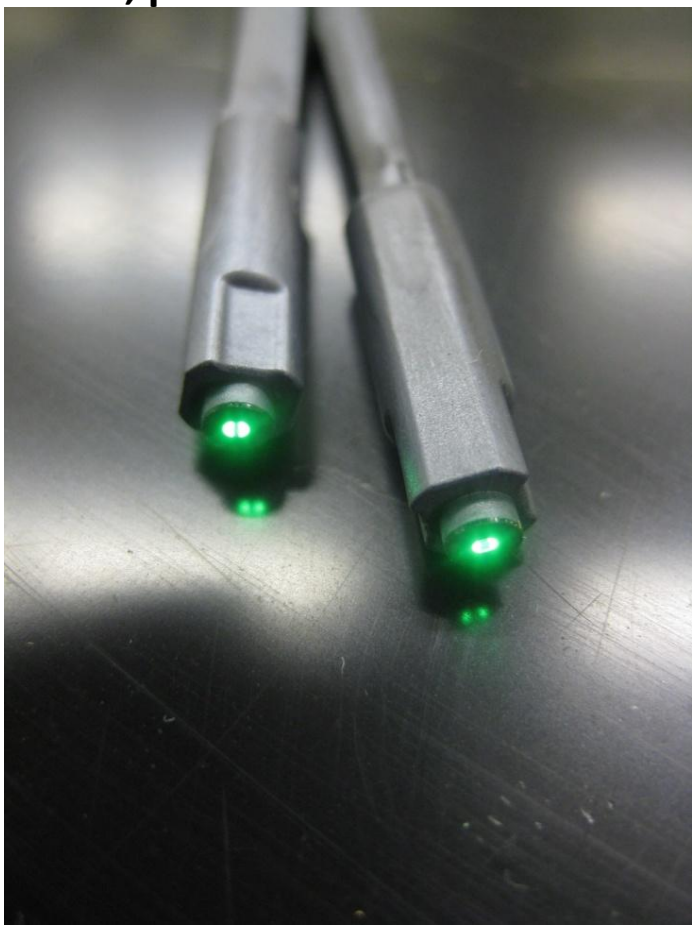
8-fiber cables/connectors

Connectors from Fujikura/DDK, Ferrules redone, the rest same as used for CMS

The T2K 280m Detector

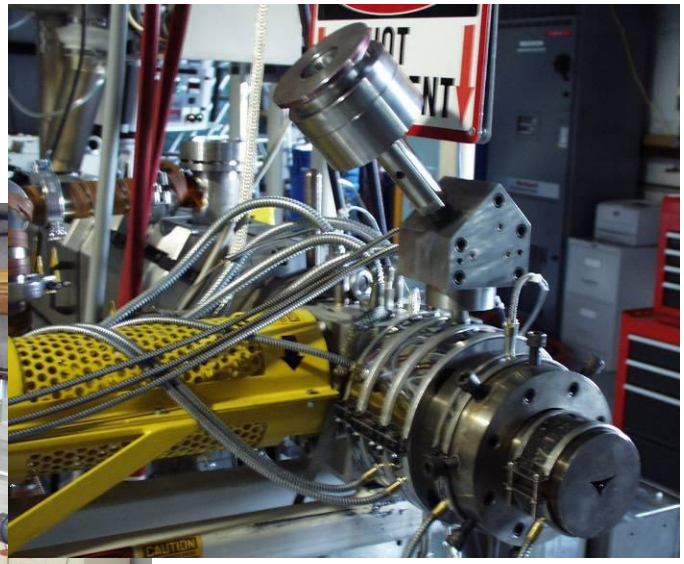


Fiber in ferrule, polished

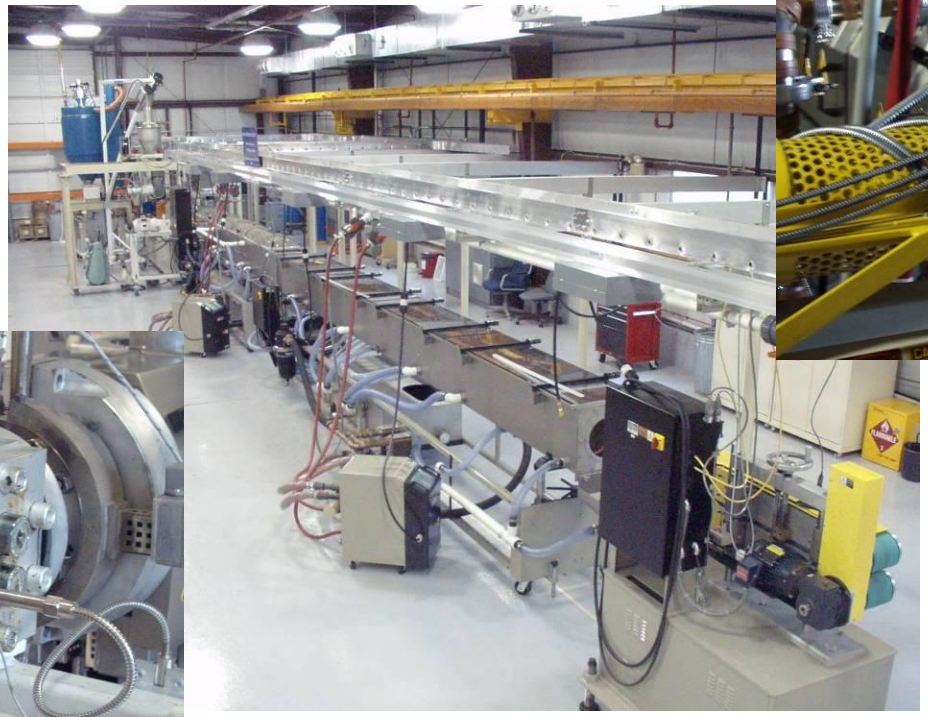


FNAL Extrusion Facility

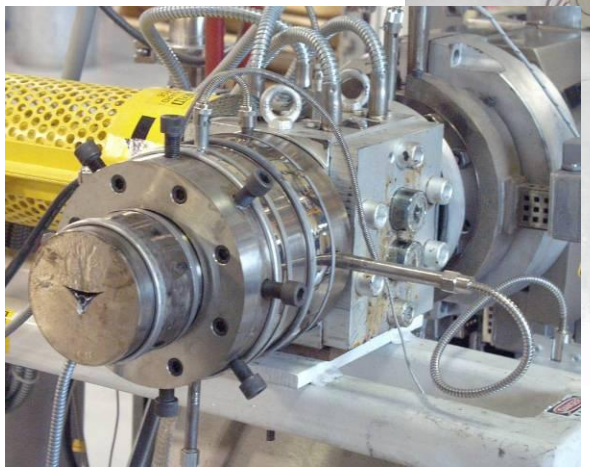
CO-EXTRUDER



PRODUCTION LINE



DIE



Chuck Serratella, Anna Pla and a big box of Polystyrene

Warm scintillator emerges from the die

For both T2K and MINERvA

Scintillator composition: polystyrene core (Dow Styron 663 W) doped with PPO (1% by weight) and POPOP (0.03% b weight.

Scintillator strips have a white, co-extruded, 0.25 mm thick TiO2 coating that is reflective and provides a good surface for gluing.

Cutting, Hole QA, Marking

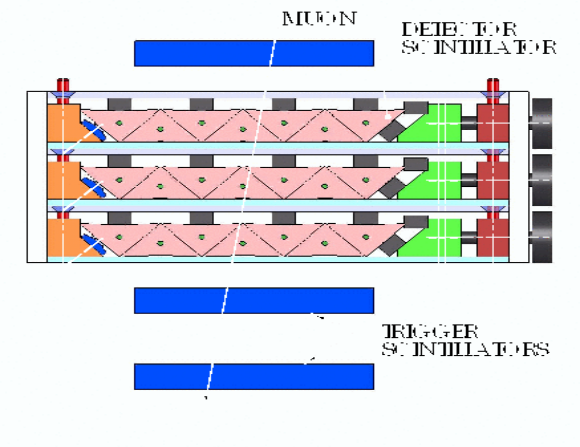
Completed Scintillator

T2K scintillator specifications

- Cross-sectional uniformity: 17.25mm height, 33.5mm base, +0-0.5mm tolerance (c.f., caliper meas. error ± 0.1mm)
  - spot checked with Go/No-Go gauge
- Length uniformity: min. lengths of 220 (5200 bars), 234cm (8000 bars)
- Minimum TiO_2 thickness: >0.13mm for efficient reflection
- Hole diameter at ends 2.4-2.8mm
- Light Output Uniformity: ±5%
  - σ_{meas}~1%, checked w/ fiber.
  - Short samples every ~100m
- Attenuation Length: >25cm w/o diffusively reflective coating

All dimensions are in mm.

MINERνA: Vertical Slice Test (VST)



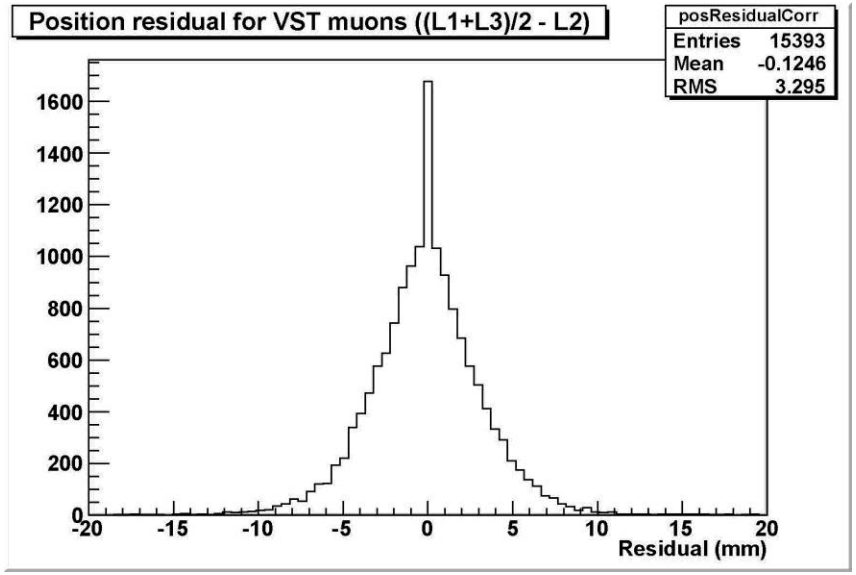
3-layer, 21 scintillator prototype

Mirrored WLS fiber glued into co-extruded scintillator bars and fed into prototype MINERνA electronics (no clear fibers or MINERνA connectors). Trigger scintillators above and below

Measured 21 pe/MIP for each layer

Led by Budd, analysis by Chvojka

Min-I track position resolution measured to be 3.4 mm



WLS fiber for both MINERvA and T2K P0D – Kuraray Y-11(175ppm), multi-clad, S-35, J-type optical fiber

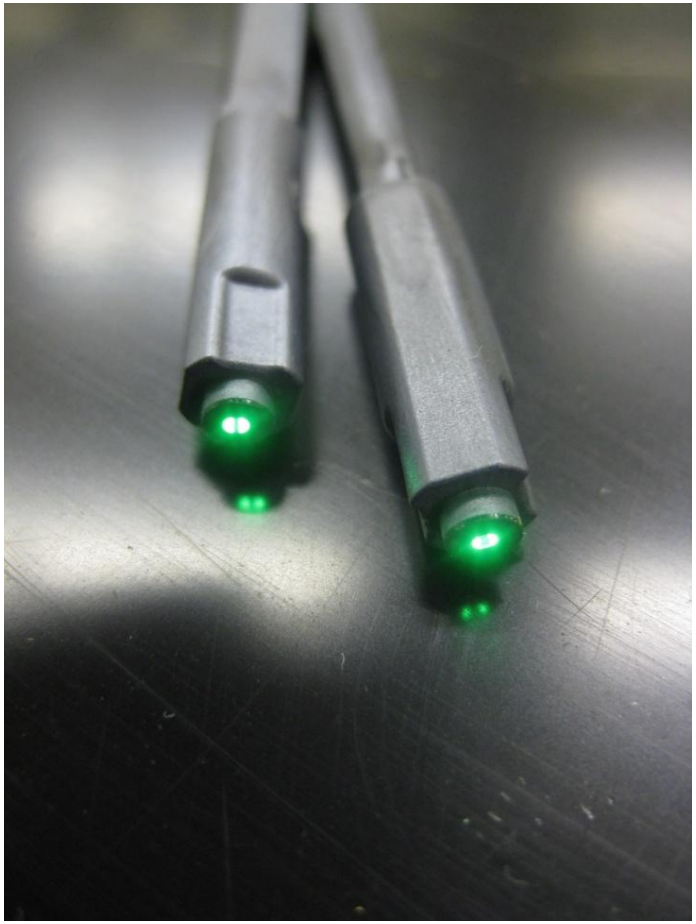
“S” fiber is more flexible than “non-S” fiber

MINERvA - diameter of 1.19+0.02-0.03 mm ($3.45/meter for large order in mid-2008)

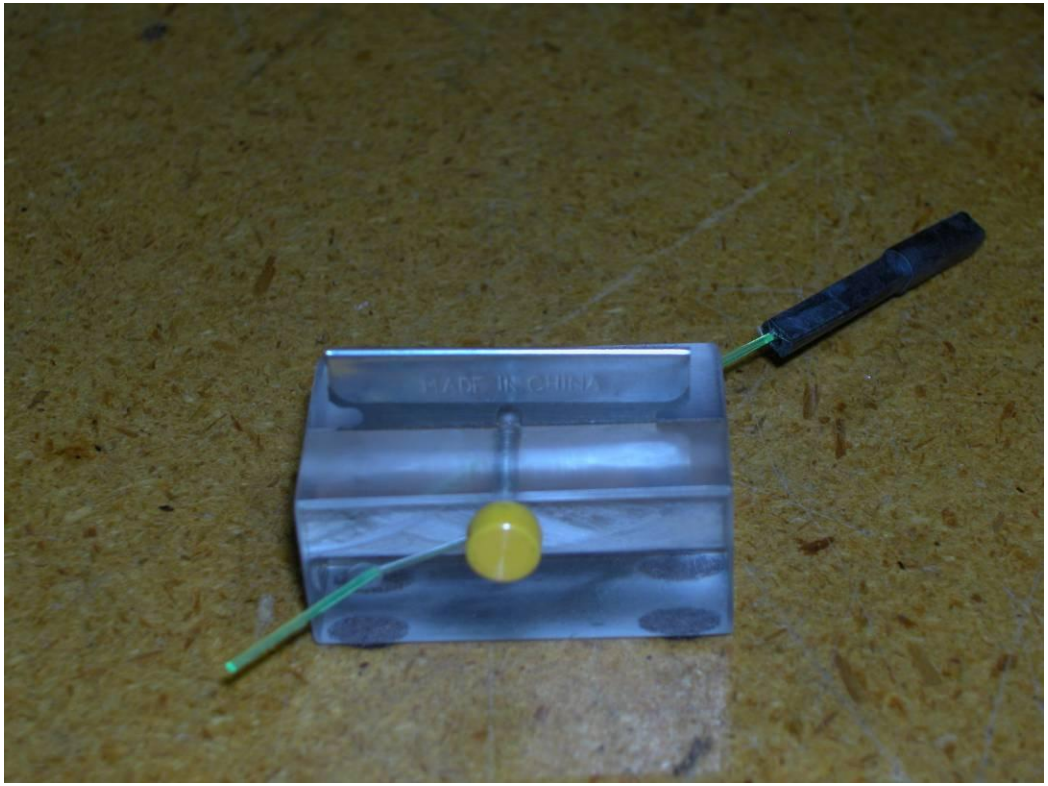
T2K – diameter of 1.00+0.02-0.03mm ($2.7/meter for large order at end of 2007)

Specified delivery in “canes” of particular lengths good to 1-2%

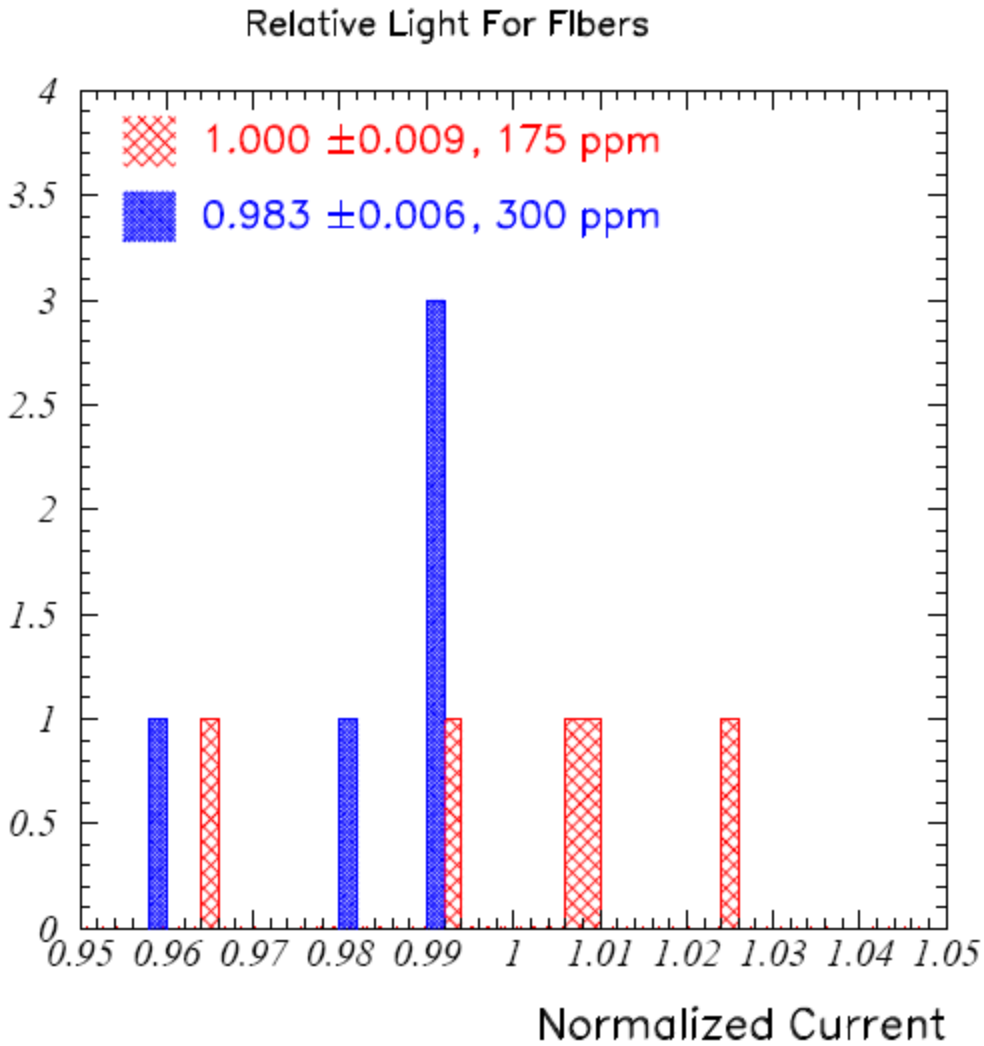
Delivery typically 6 weeks ARO



High tech fiber cutting tool … this or paper-cutter



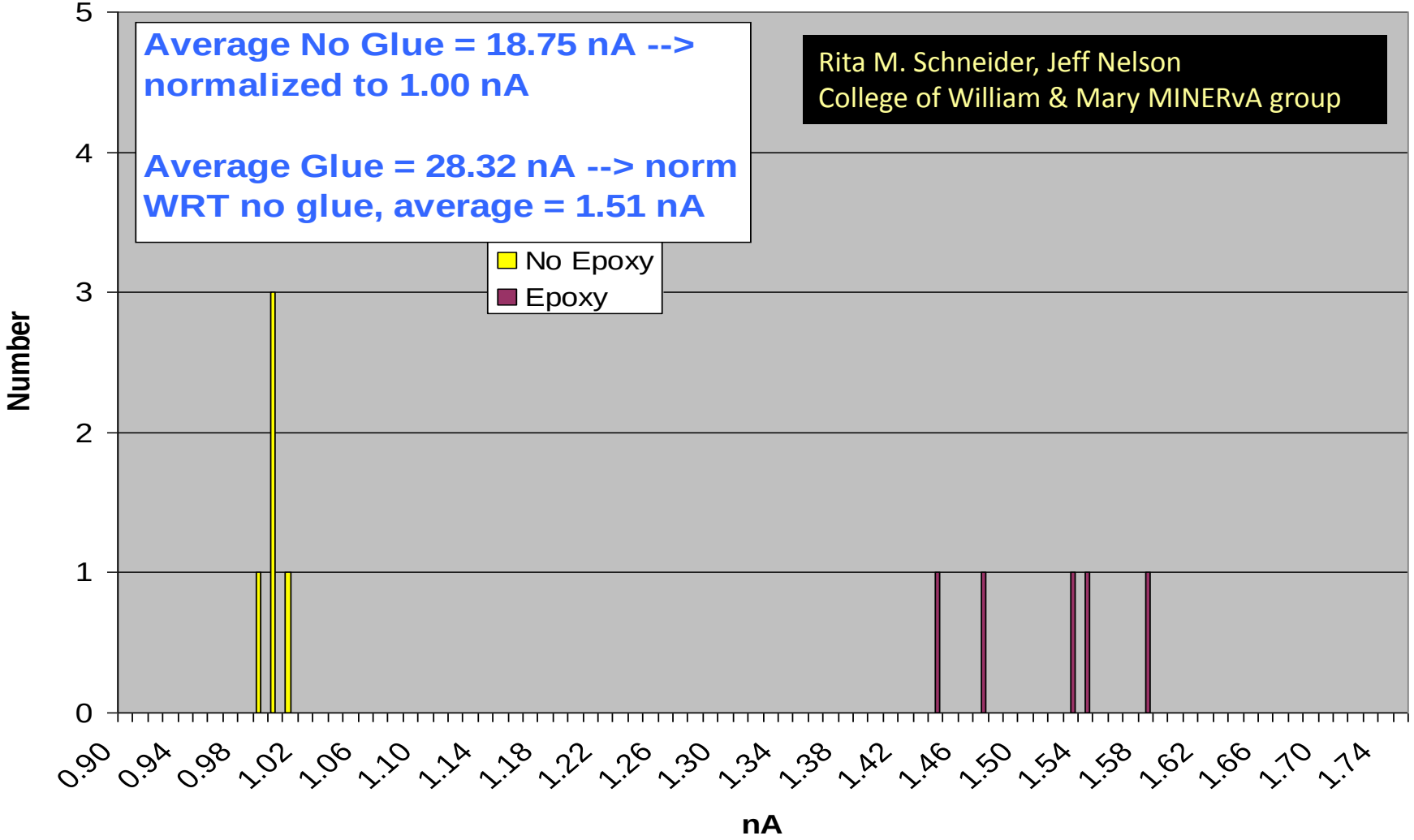
Found little difference in light production between 175 and 300 ppm 1.2 mm Y11 fiber in scintillator with a source



Attenuation length for the 175 ppm fiber is around ~340 cm

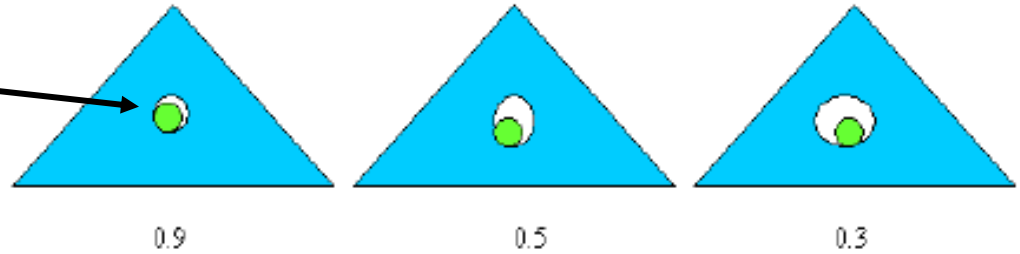
Comparing Glue VS No Glue

(Mirrored 1.2 mm Fiber, MINERvA scintillator with source)



Unglued Fibers and Light Collection

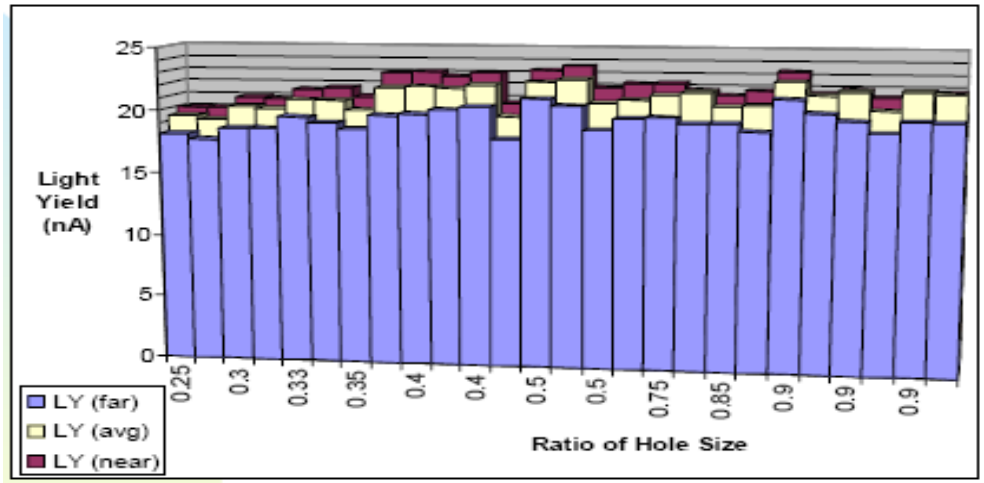
- Does light collection depend on hole size?
  - hole diameter varies. must be larger than fiber
  - probably not sustainable

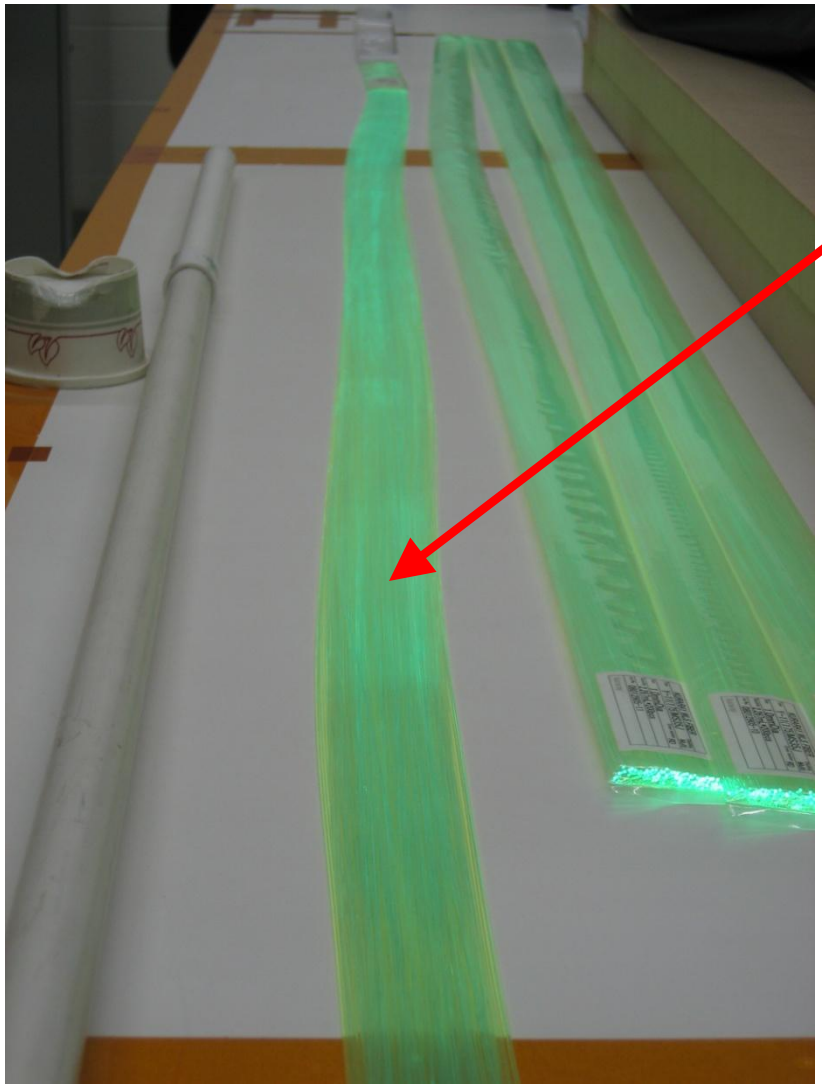


Ratio of surfaces = S_{fiber}/S_{hole}

- Answer: very little

- study by Victor Rykalin, Anna Pla for MINERvA ID triangles (same as T2K P0D)

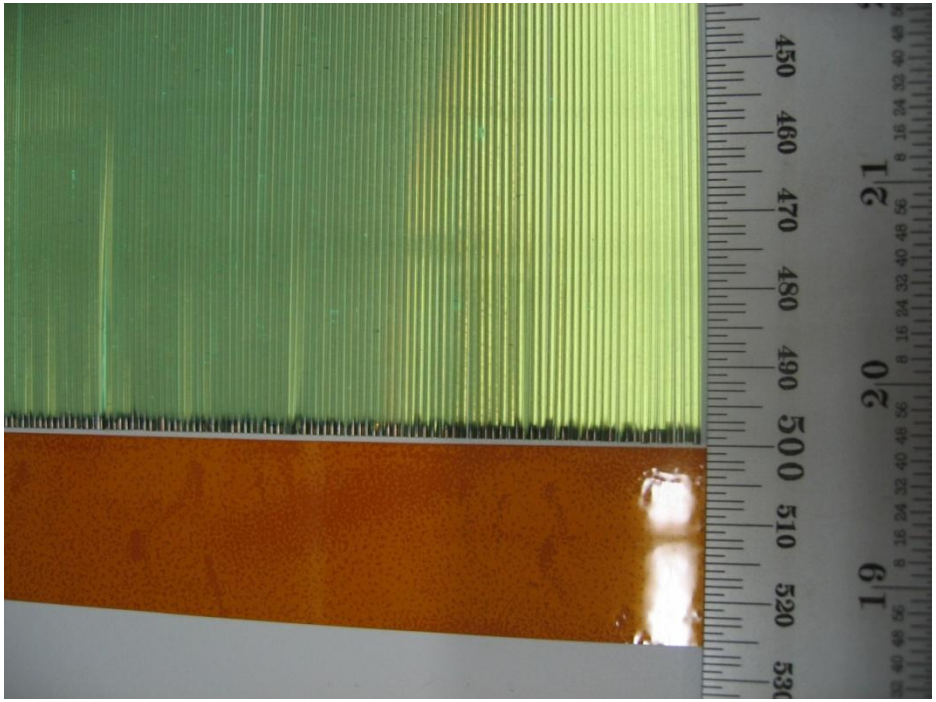




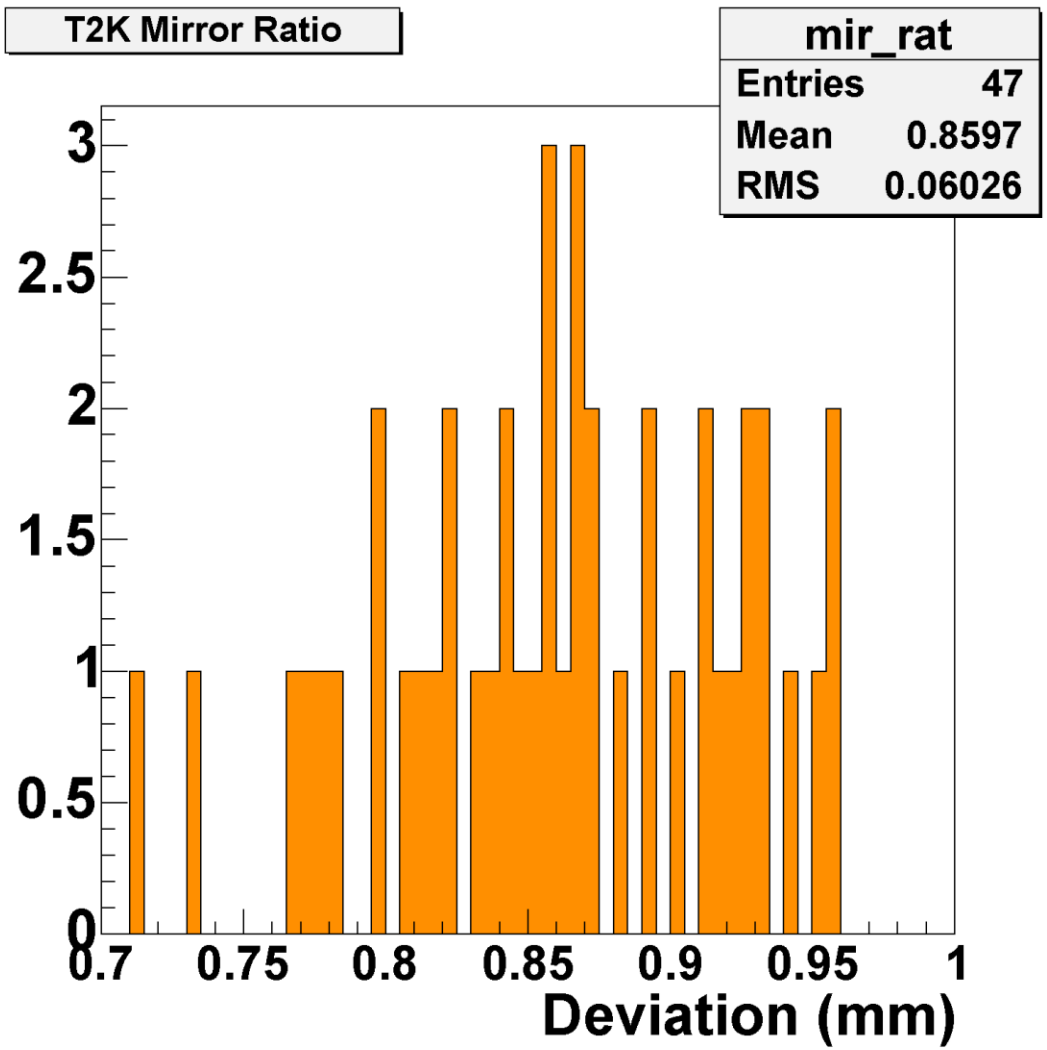
- While mirroring the fibers Eileen noticed bright streaks on most of the bags of fibers at certain specific points. In this case most of the fibers in the bag have a bright spot at the same point
- No evidence that this creates a problem for us

From MINERvA TDR: The reflective coating is applied in a vacuum system dedicated to optical fiber mirroring at Fermilab. The number of fibers that can be sputtered per load depends on the diameter, but typically 1000–2000 fibers per pumpdown per unit can be coated. A 99.999% chemically pure aluminum coating is a applied for good reflectivity. The coating is approximately 2500 Angstroms thick and is monitored using an oscillating quartz crystal sensor device. The aluminized ends are protected with a coat of epoxy. FNAL uses 'ice polishing' to prepare ends before reflective coating is added, see:

https://ed22lf.lnf.infn.it/alice/Module/Polishing/Documenti/fermilab-tm-2062.pdf



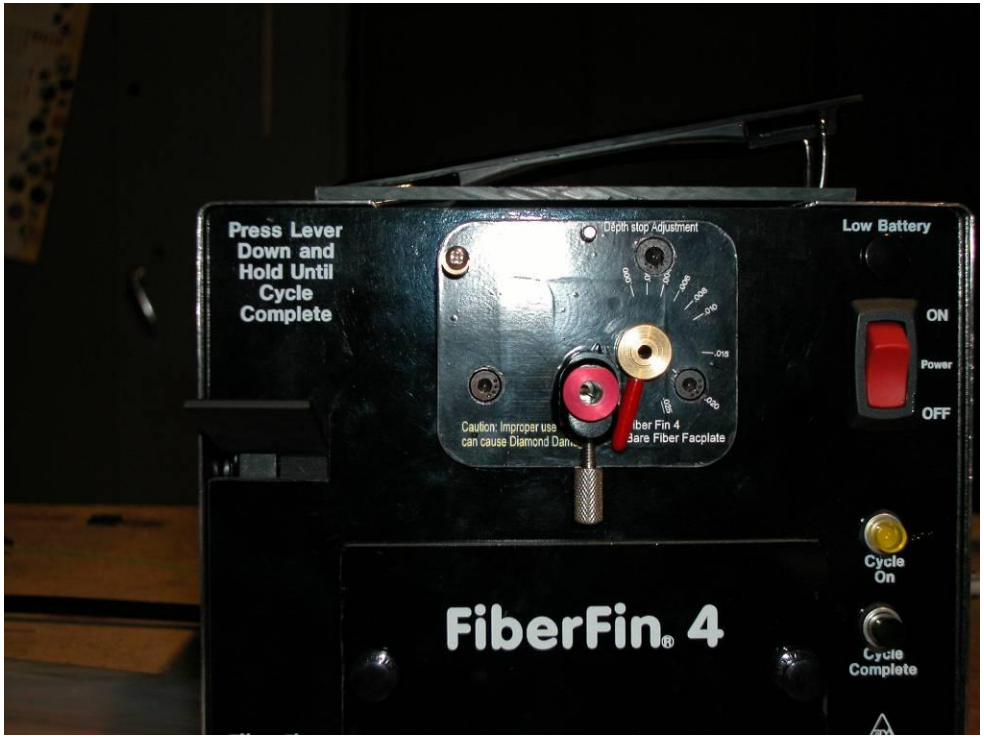
Reflectivity = mirror/black - 1



- Reflectivity of 86%
- For CMS the mirror reflectivity was 83% with an RMS of 6.5.
- The CMS reflectivity was measured in a different way, so it not clear that the 2 methods can be directly compared, but from the CMS result 86% with an RMS of 6.0 is reasonable

Polishing Ferrules/fiber end

Provides smooth surface to butt up against the photosensor. Reduces need to use optical grease (which we prefer to avoid if possible)

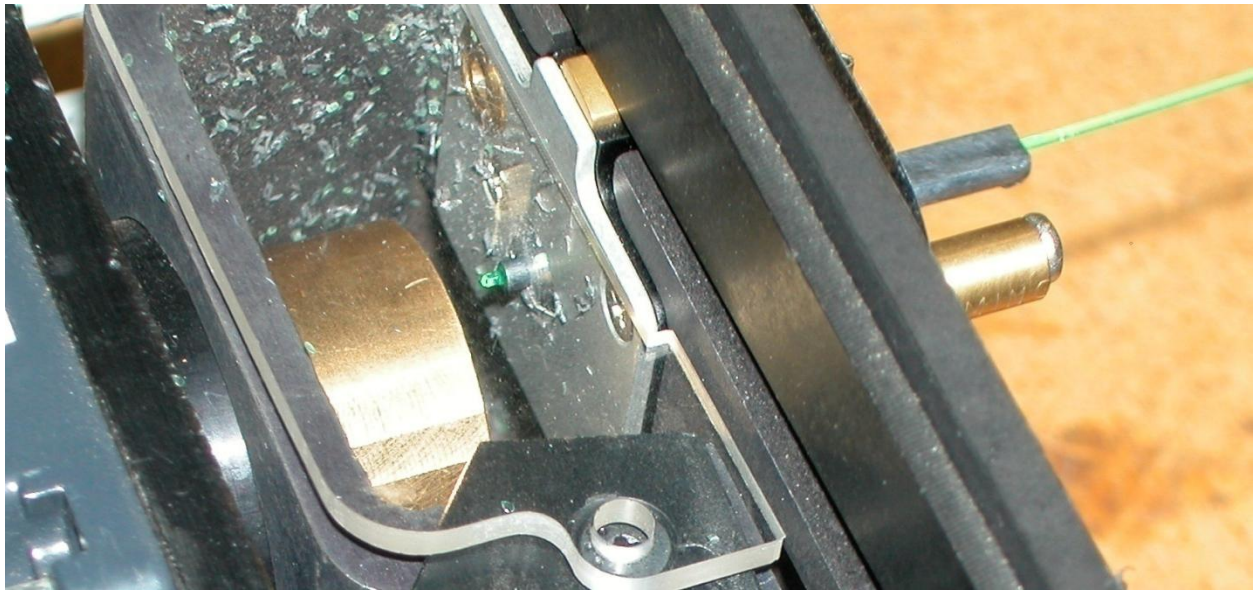


- For polishing ferrules we use a polishing machine sold by FiberFin in Morris Ill.
  - I think earlier variations or this variation was designed by Carl Lindenmeyer of FNAL
- The red circular donut is the collet
- The ferrule to be polished is inserted into the collet

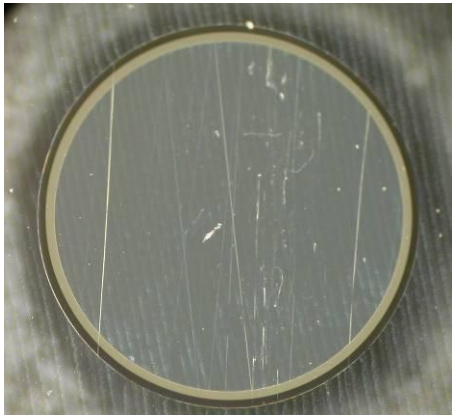
Collets for polishing

- To polish the ferrules the ferrule needs to held snuggly
- To do this Paul at FiberFin designed a set of collets
  - The collet grabs the nipple and holds it snuggly.
  - The polishing goes almost right up to the metal
- If the ferrule gets modified the collet will probably have to change, its about 1-2 mil fit
- In the last iteration we are using nylon collets, since if we accidental polish the collet its will give less damage to the diamond

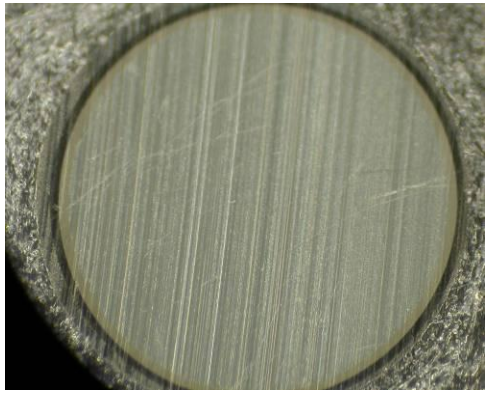
Polishing the ferrule



- The collet holds the fiber and is polished by the diamond on the rotating brass piece

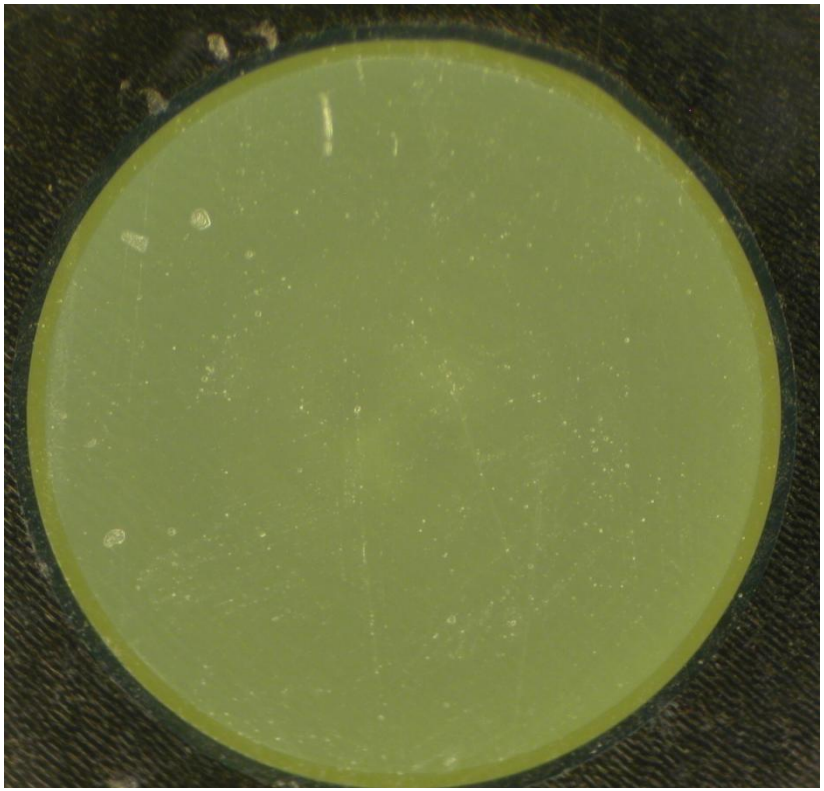


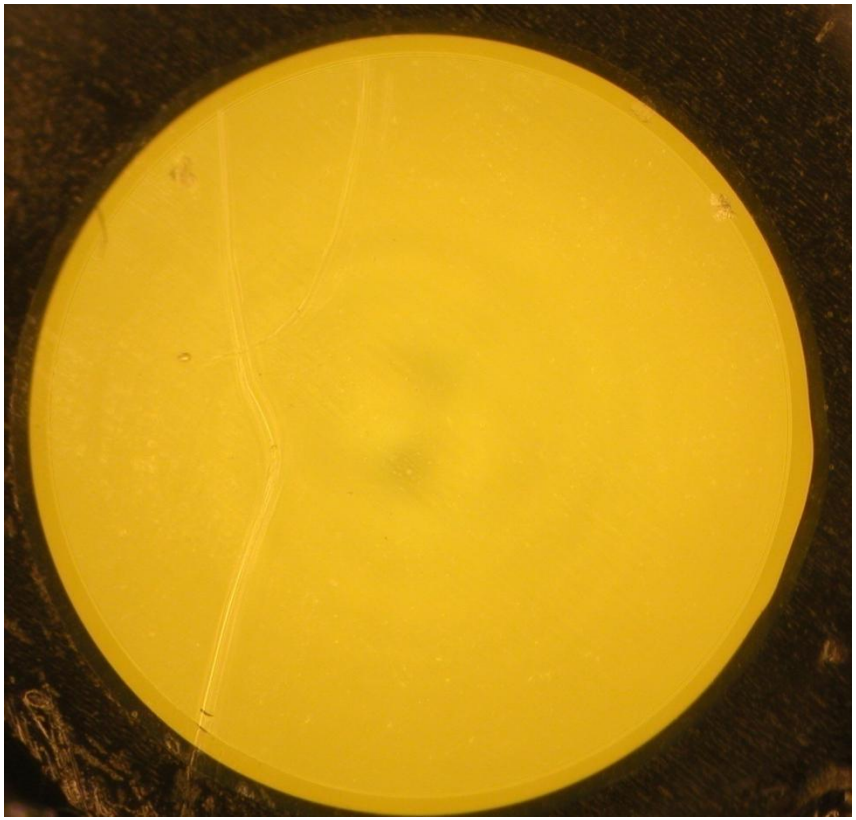
Production Polish



Fiber Glass Polish

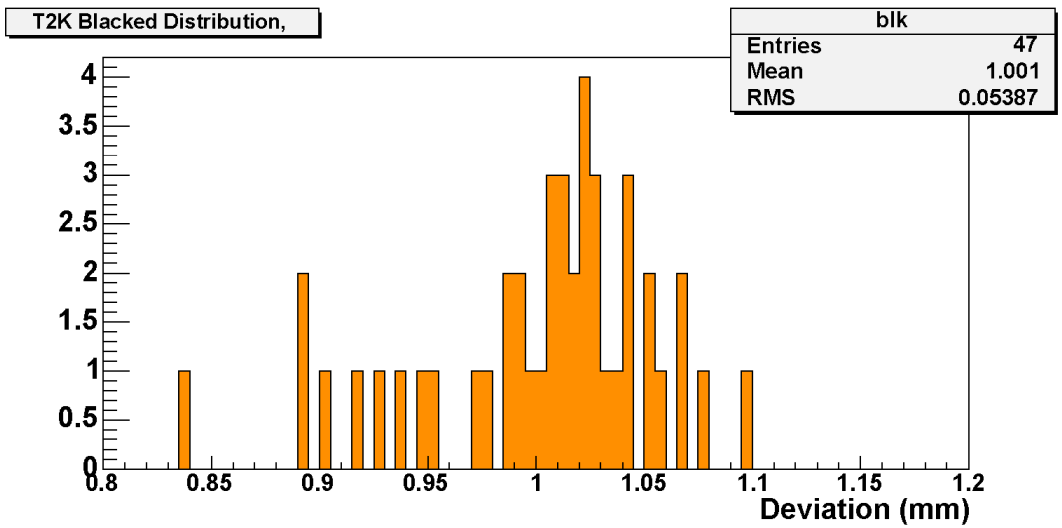
- DDK connectors have fiber glass
  - Fiber glass damages the polishing diamonds
  - After 50 polishes you can see significant differences in the polish visually by testing the polish on plexiglass pieces.
  - We stablished a polishing procedure in which we polish connectors without polishing fiber glass
  - 6% higher transmission without optical grease, but same transmission with optical grease
- MINERvA starts by shaving off the DDK connectors with a carbide bit
- Next, the fibers are put in and epoxy drips down and covers the connectors where the fibers are polished
- Then, the diamond polishes only the fibers and epoxy, not the ferrule (diamond does not touch the fiber glass)

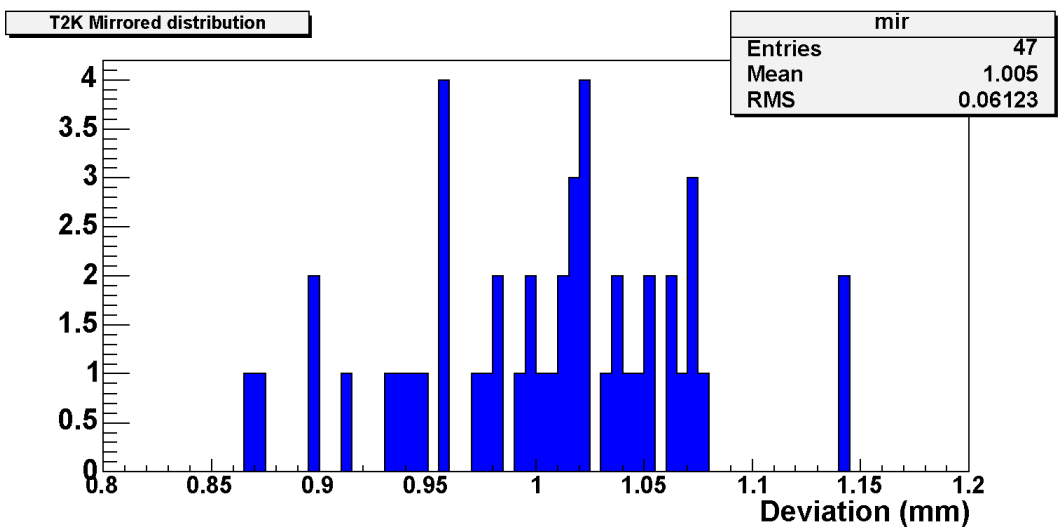




- Picture of 2 of the polishes of the fibers that were send to Stony Brook

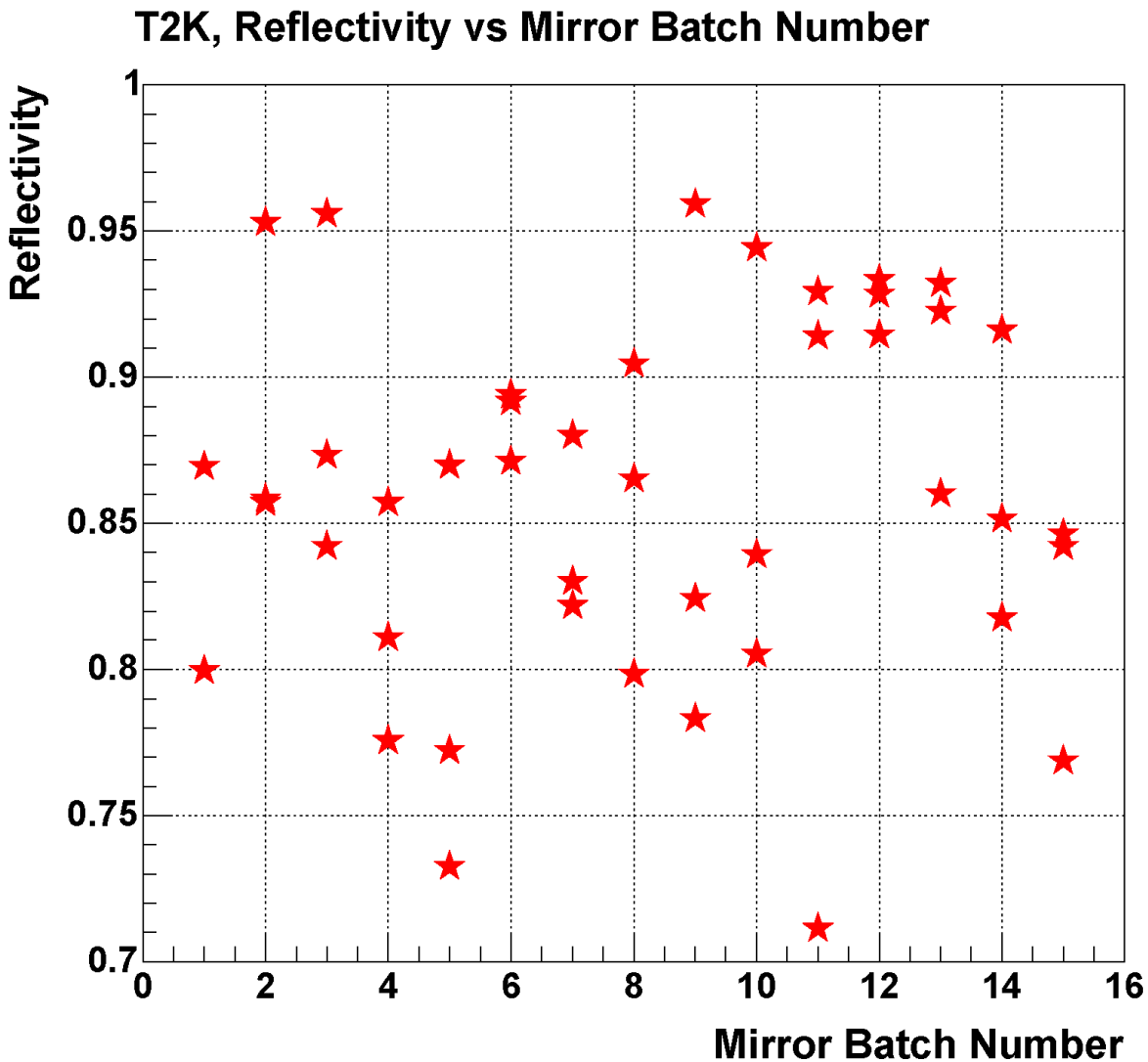
Distributions, Mirror & Blackened





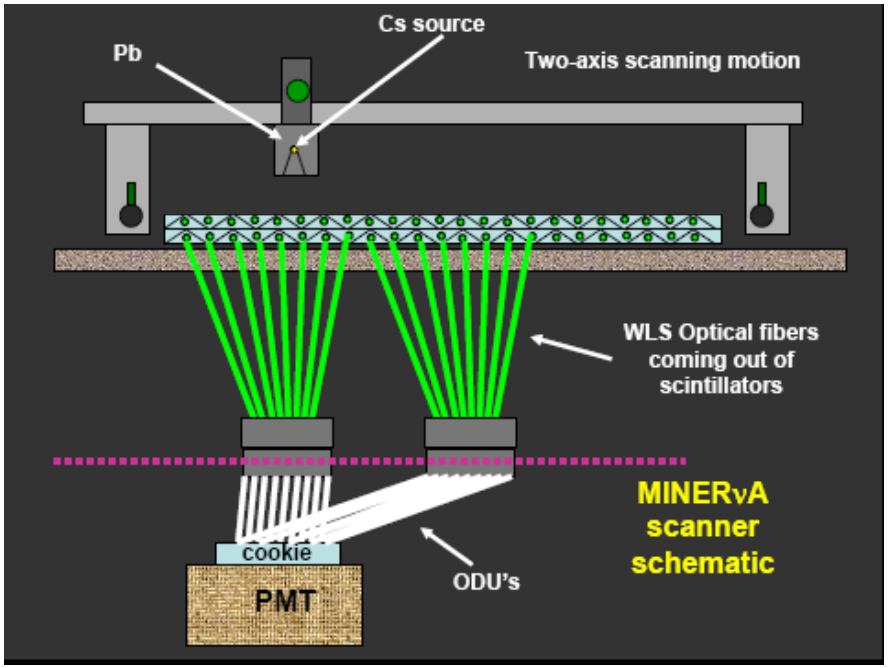
- Top plot is the blackend distribution and bottom plot is the mirrored end distribution. Plots are normalized so that the average is 1
- The RMS of the ratio is 3.5%
- The bottom RMS is consistent with the top plot and ratio RMS of 3.5%, i.e this 3.5% is from the mirroring.

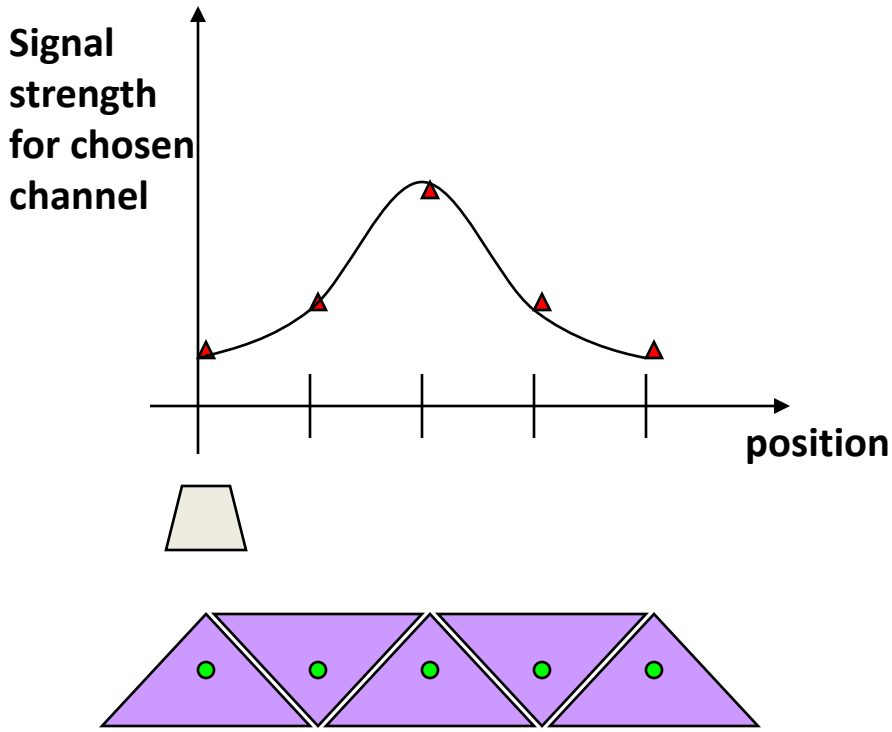
Reflectivity vs Mirror Batch



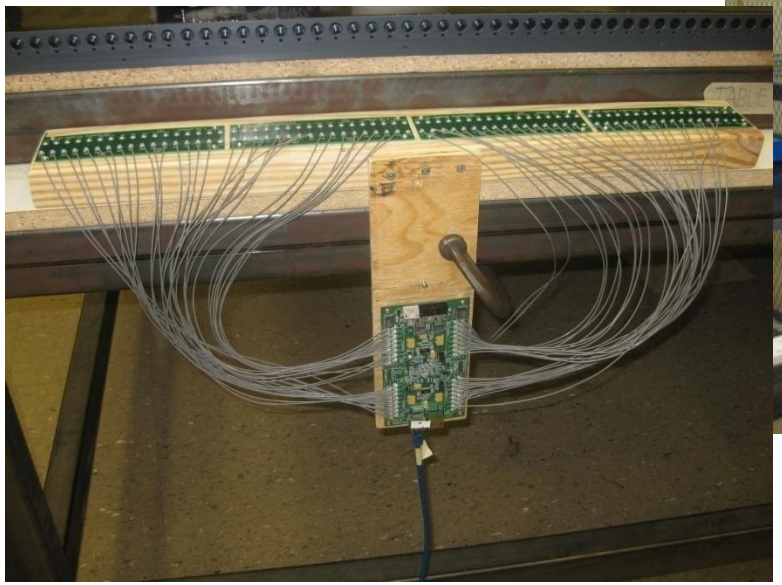
- We asked for 5 fibers/batch to do the mirror test
- We tested 3 fibers/batch and left 2 fibers/batch if there appeared to be a problem
- The reflectivity vs batch does not seem to show any problems
  - We will probably not test the other 2 fibers/batch
- It looks like the QC of the reflectivity makes sense

Scanning for QC and for initial alignment and response information

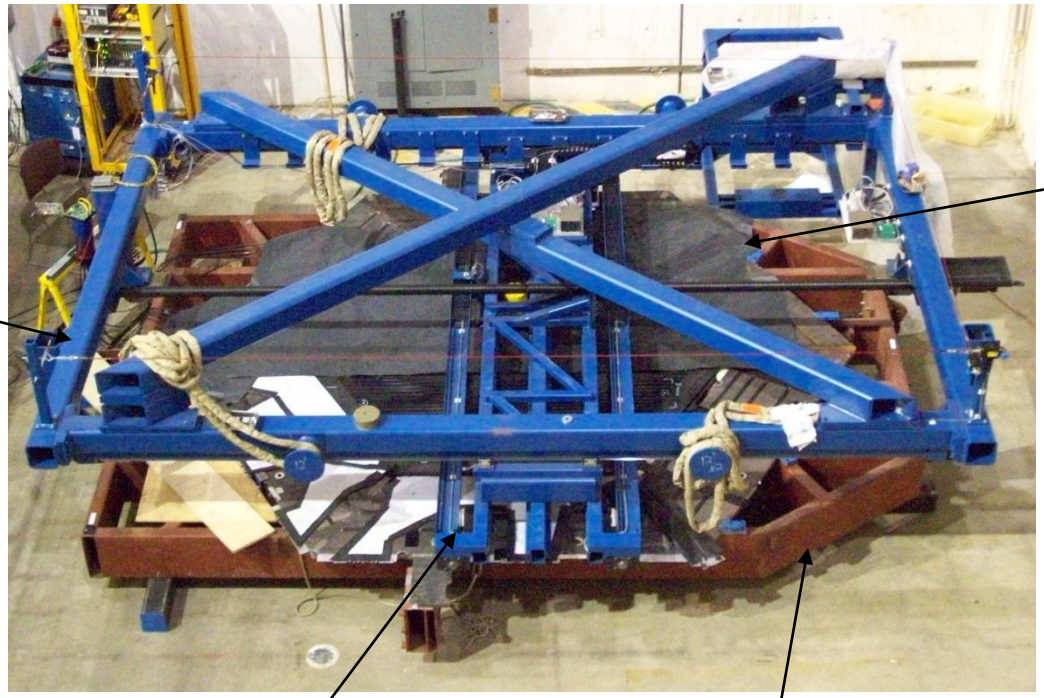




For T2K, we use a commercial routing table to control source position



For MINERvA, the planes are too large to make use of a commercial product as a scanner. Designed and built a custom device (Rochester).



Module

Structural steel – rigid enough to withstand lifting by crane.

Source carriage – Two 10 mCi Cs-137 sources.

Strongback

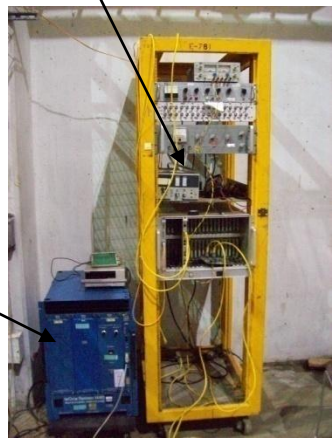
Hardware – DAQ and Motion Control

Control computer

- Code by Al Baumbaugh

DAQ

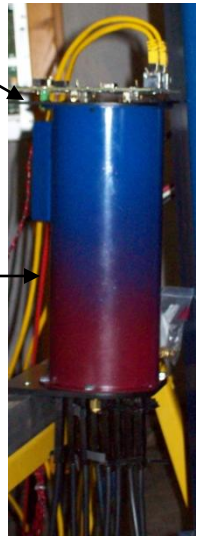
VME crate



HV supply

FEB

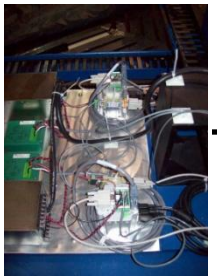
PMT



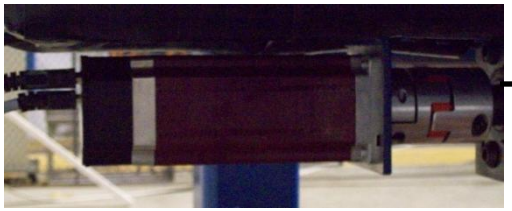
Motion Control

Junction Box

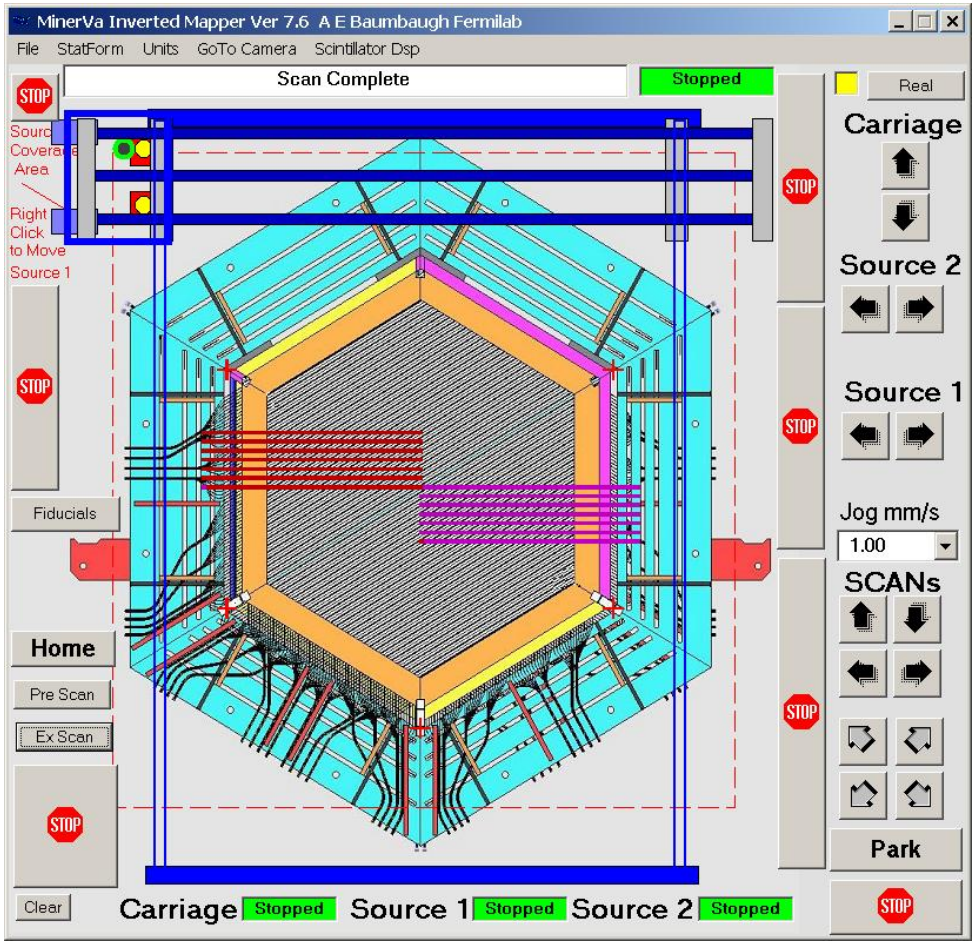
Controllers

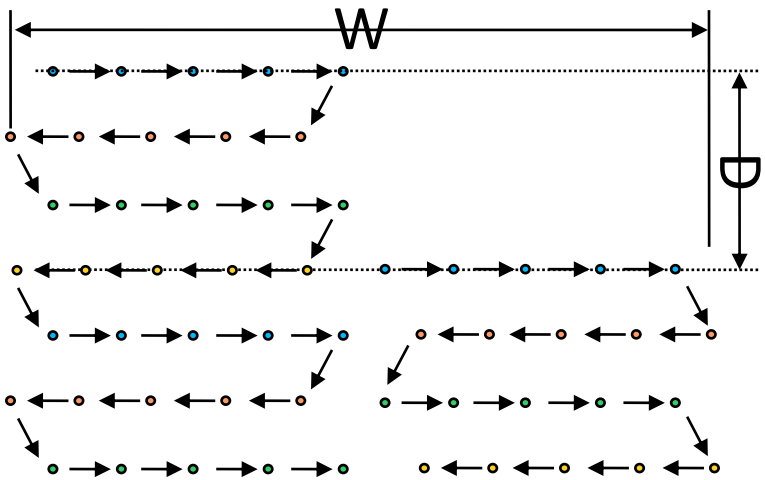


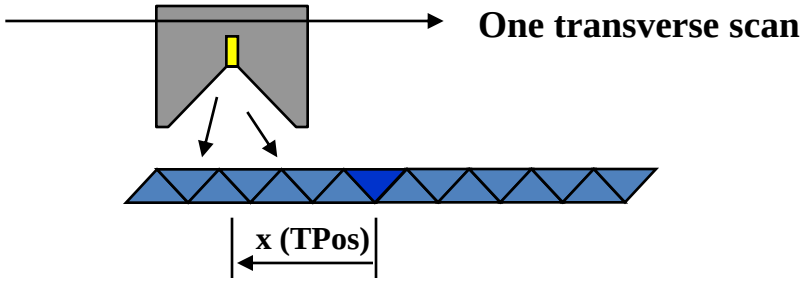
Motors

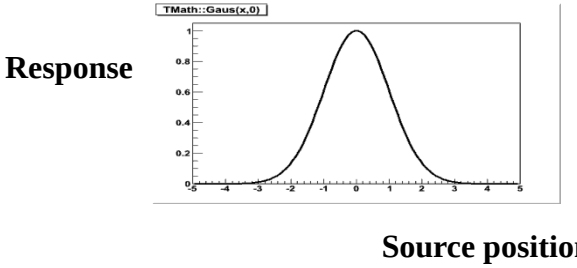


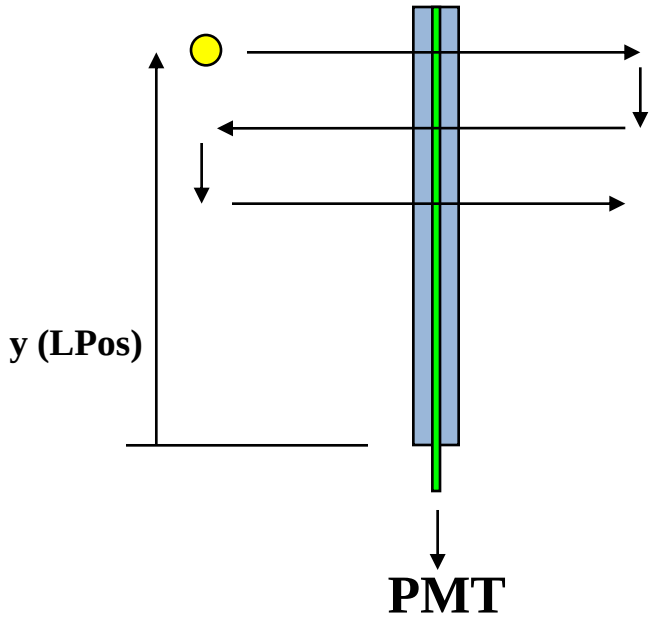
Source Carriage


MinerVa Inverted Mapper Ver 7.6 A E Baumbaugh Fermilab
File
StatForm
Units
GoTo Camera
Scintillator Dsp
Scan Complete
Stopped
Real
STOP
Source Coverage Area
Right Click to Move Source 1
Carriage
Source 2
Source 1
Fiducials
Jog mm/s
1.00
SCANs
Home
Pre Scan
Ex Scan
Park
Clear
Carriage Stopped
Source 1 Stopped
Source 2 Stopped

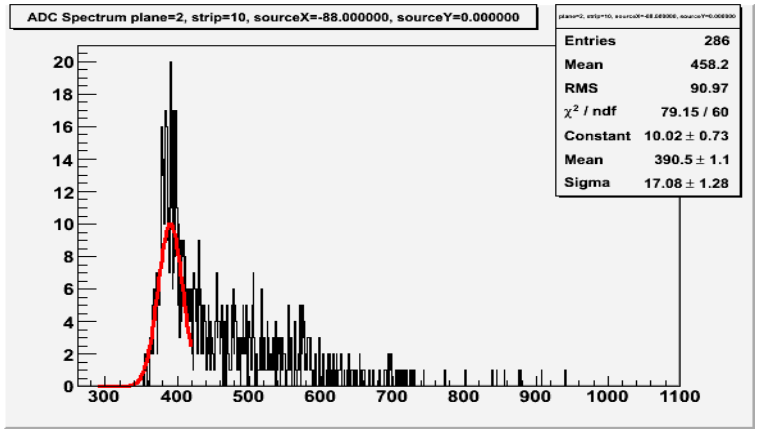

W
D







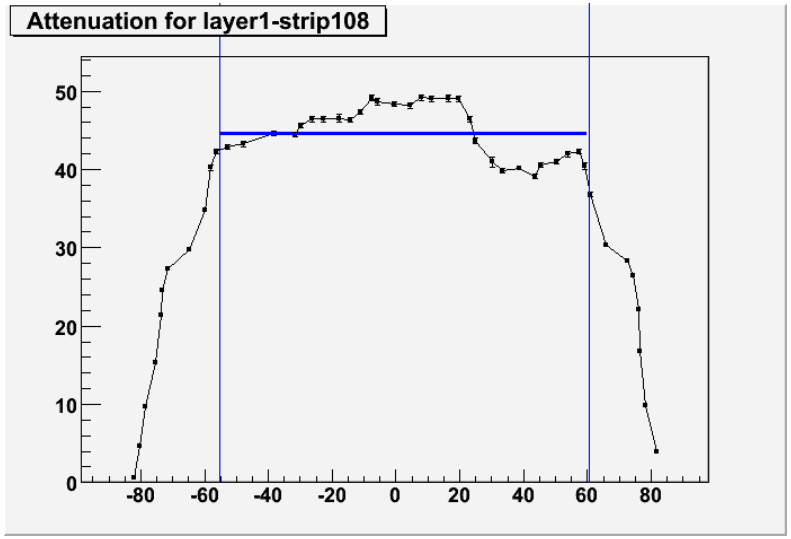
ADC histogram



- Response is amount of pedestal position shift
  - More strip gets radiation, more pedestal shift

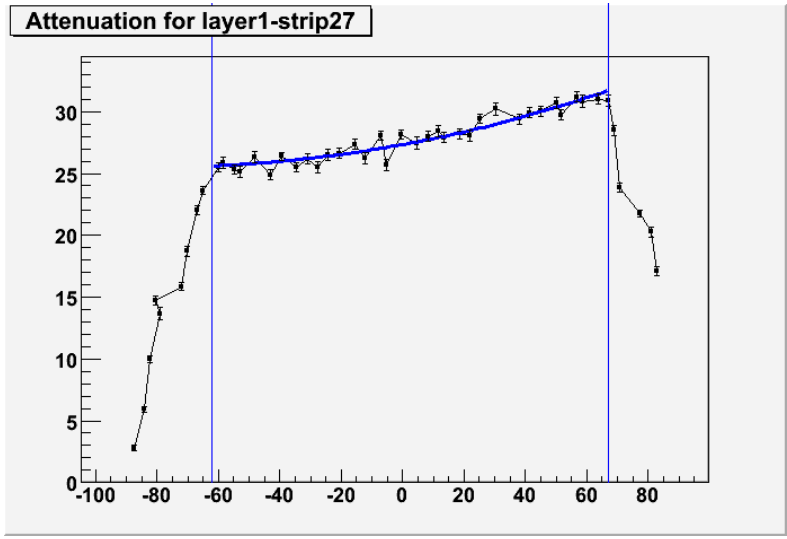
Real MINERvA scanner data for a few channels … work in progress

Ped Shift



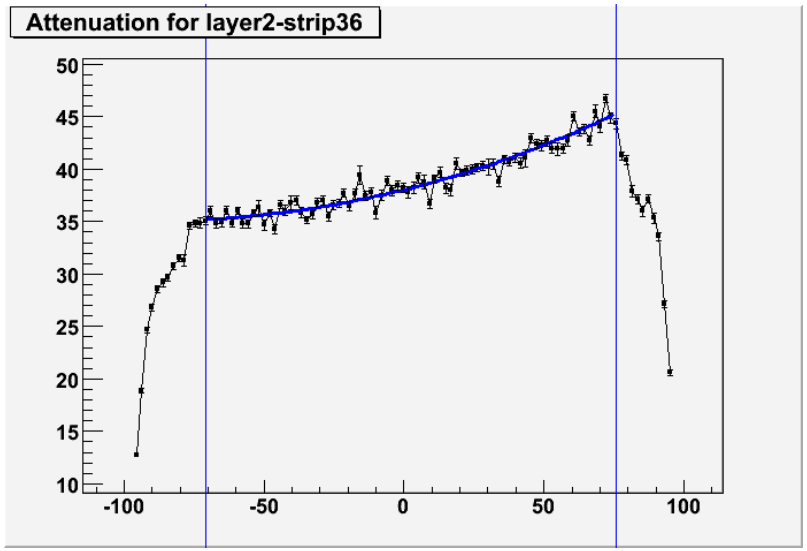
Y Position

Ped Shift



Y Position

Ped Shift



Y Position