Prototyping Studies
for
a Scintillator (semi)Digital HCal
and
a Tail-Catcher/Muon Tracker

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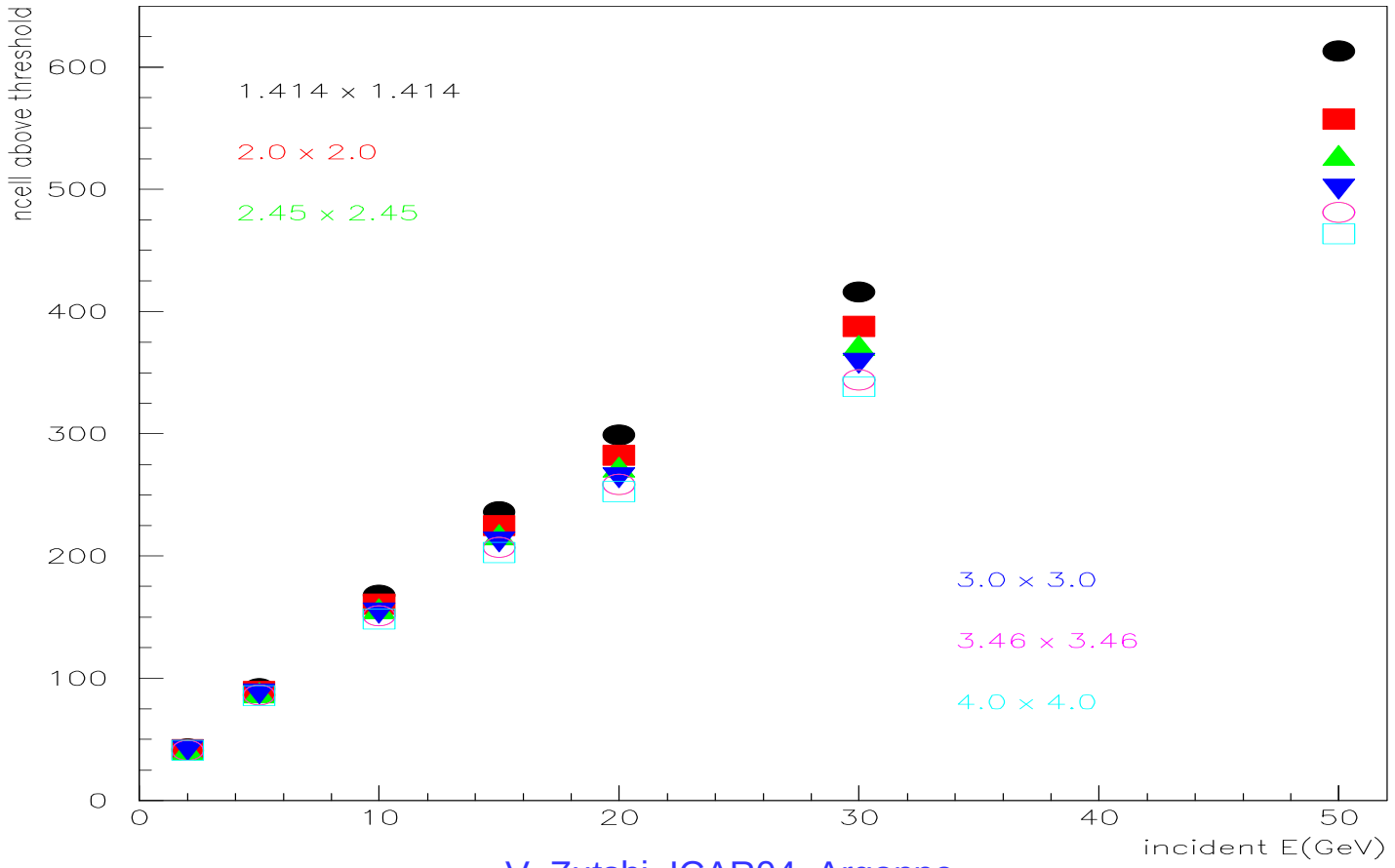
for
NIU/NICADD

Outline

- A scintillator-based 2-bit hadron calorimeter
  - MC studies
  - Hardware Prototyping
  - Plans
- Tail-catcher/Muon tracker
  - MC studies
  - Hardware Prototyping
  - Plans

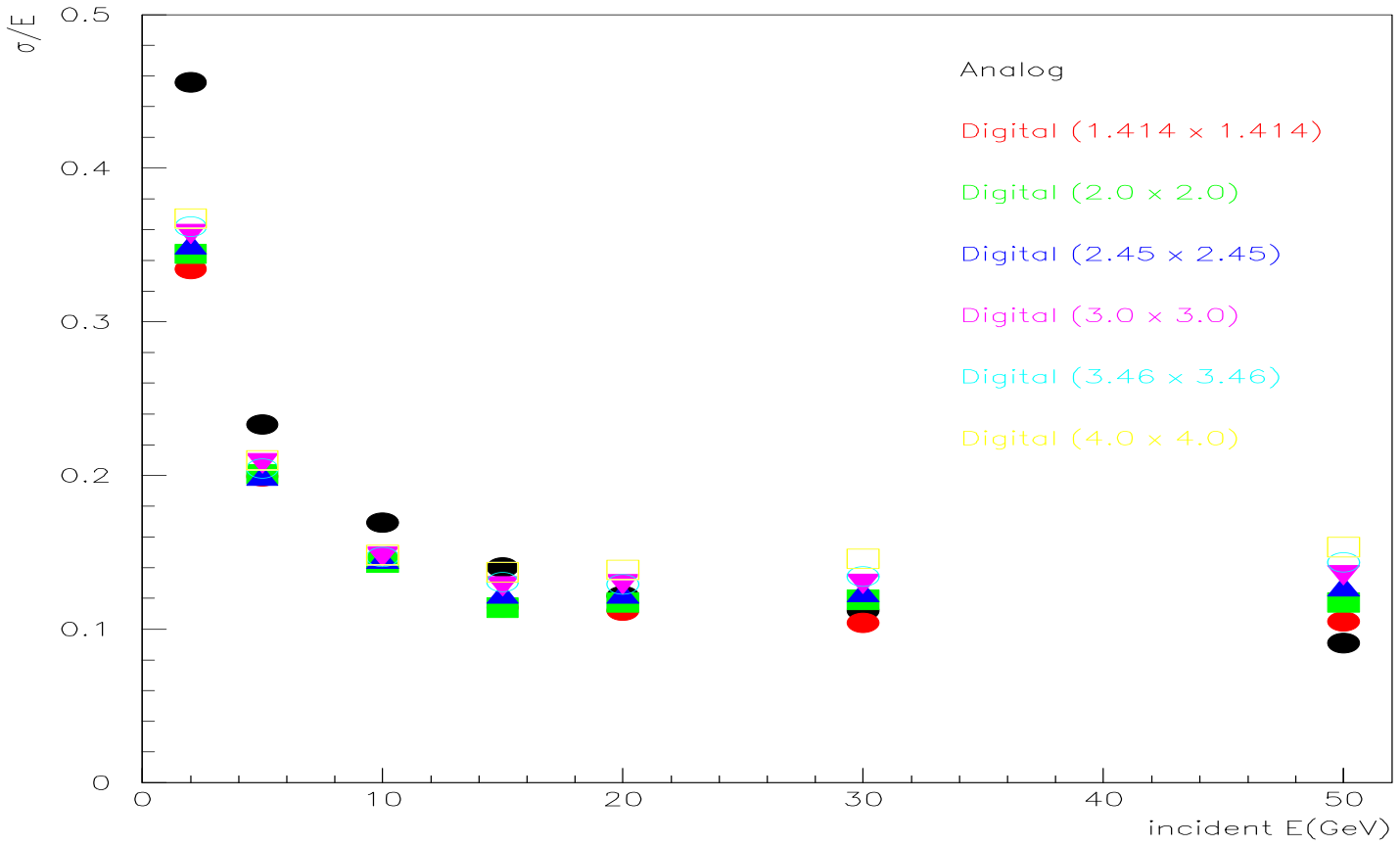
N vs. E (single hadrons)



0.25mip threshold

Simple counting of cells above threshold

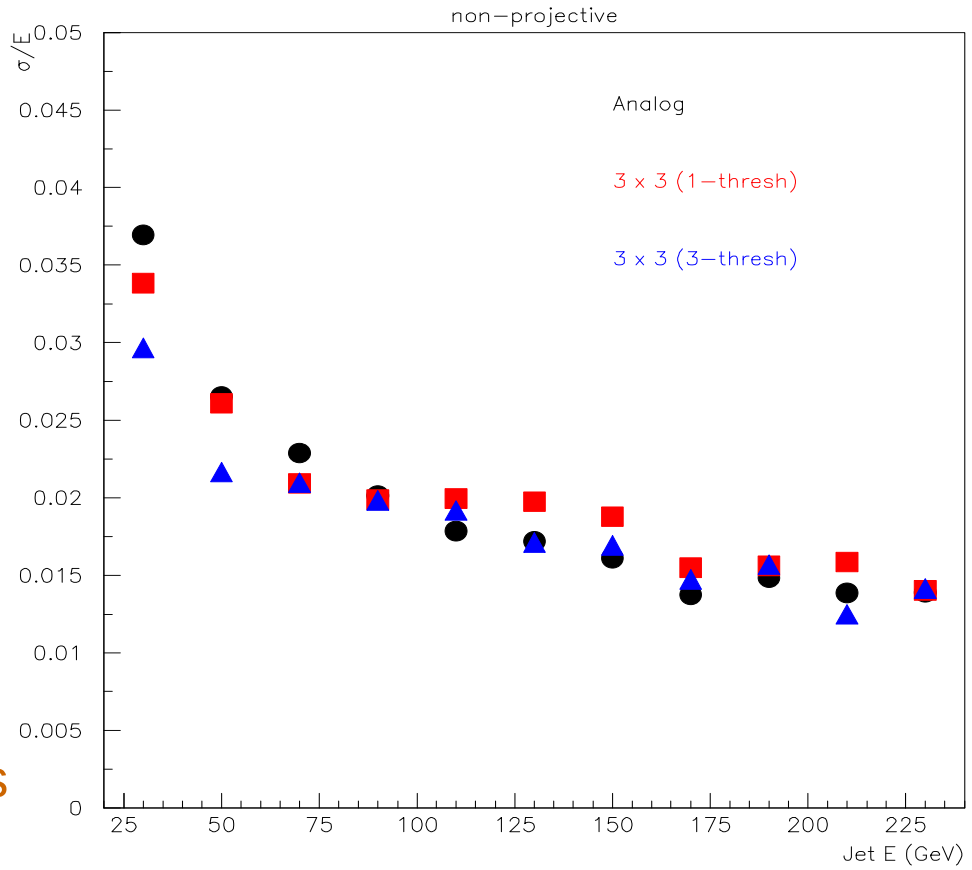
Single Particle E Resolution



Non-projective geometry

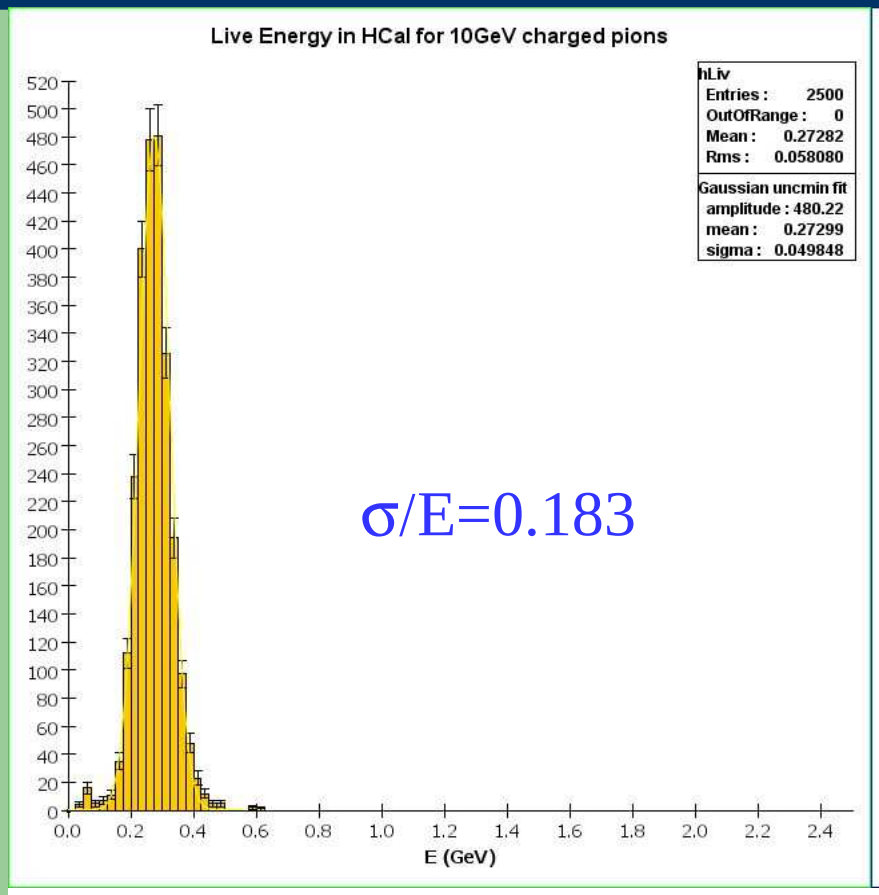
Parameterized Jet E Resolution

- Energy Smearing
  - Fit σ as a function of incident E (slide4) and smear neutral hadrons accordingly
  - γ ~ 17%/sqrt(E), generated E for charged hadrons
- Jet Reconstruction
  - pT order stable MC particles (ignoring neutrinos)
  - start with highest pT particle and cluster in 0.7 cone
  - repeat for remaining particles

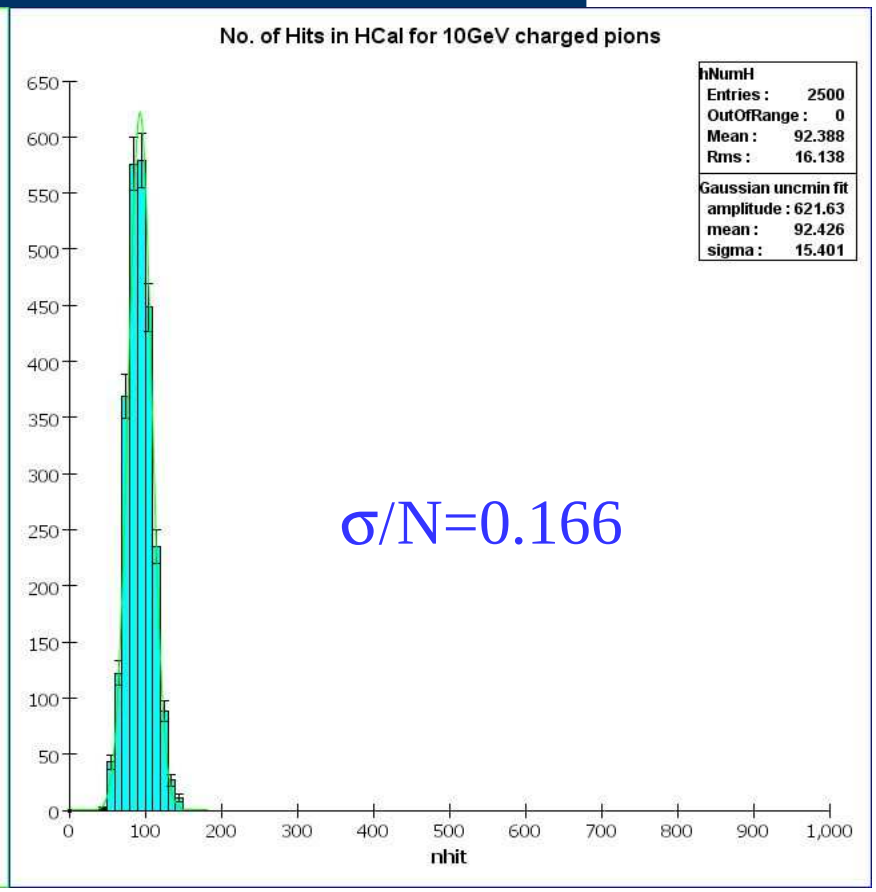


9cm^2 cells

Single Particle Resolution (10GeV)



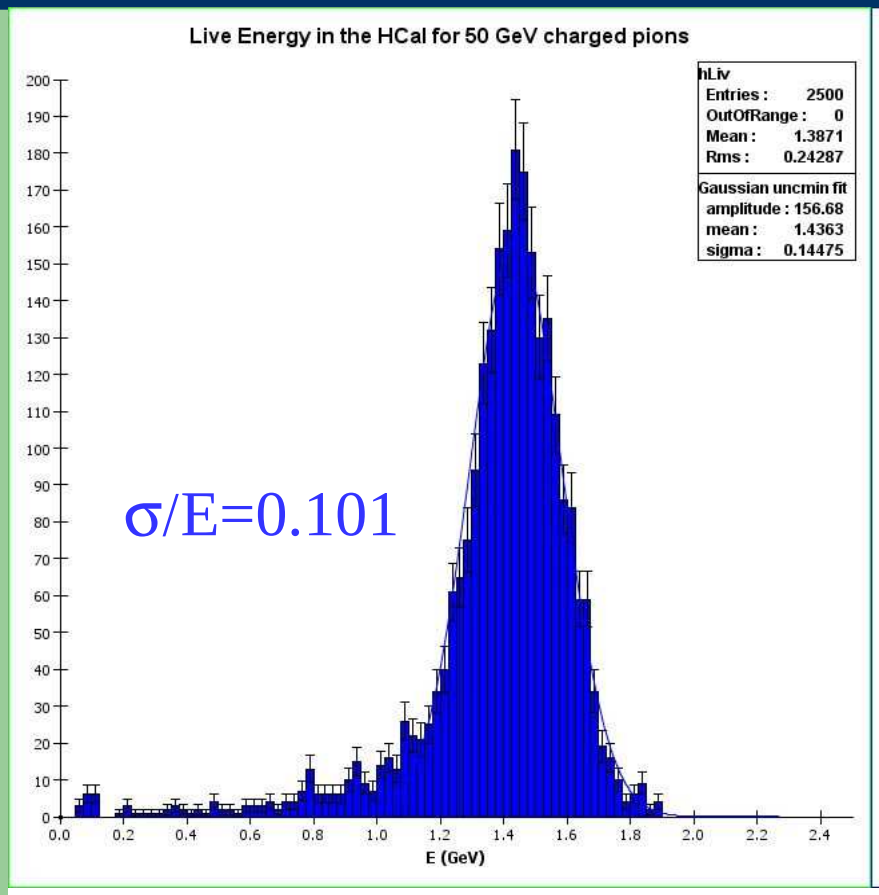
$\sigma/E=0.183$



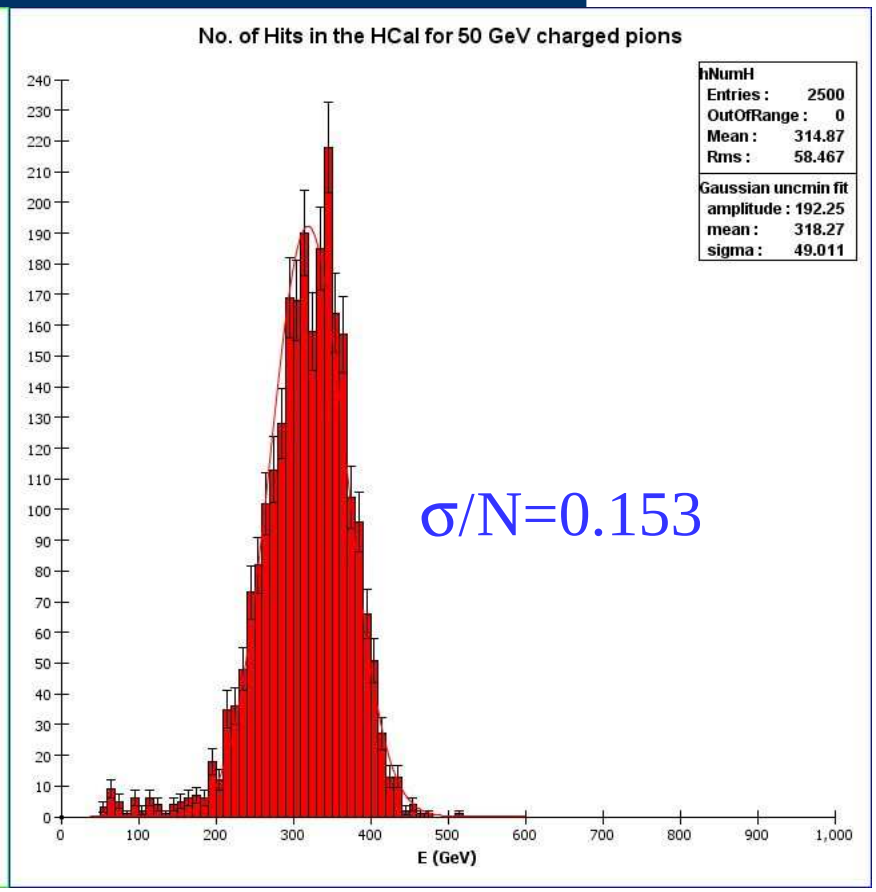
$\sigma/N=0.166$

9cm^2 cells

Single Particle Resolution (50GeV)



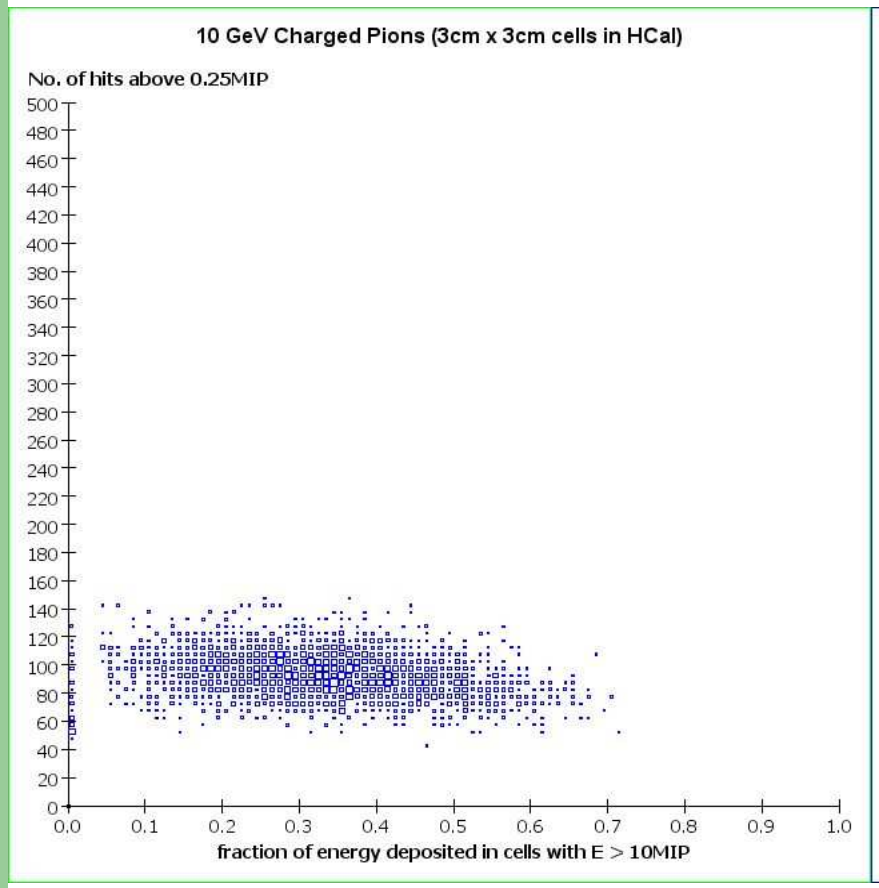
$\sigma/E=0.101$

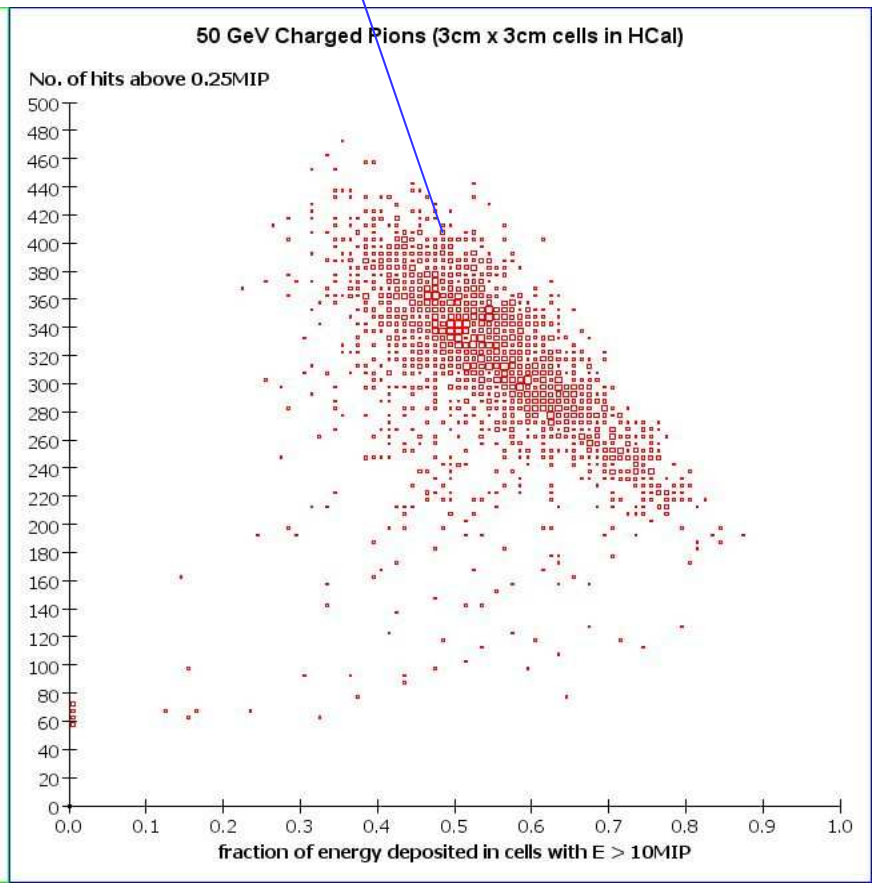


$\sigma/N=0.153$

Can be flattened with multiple thresholds

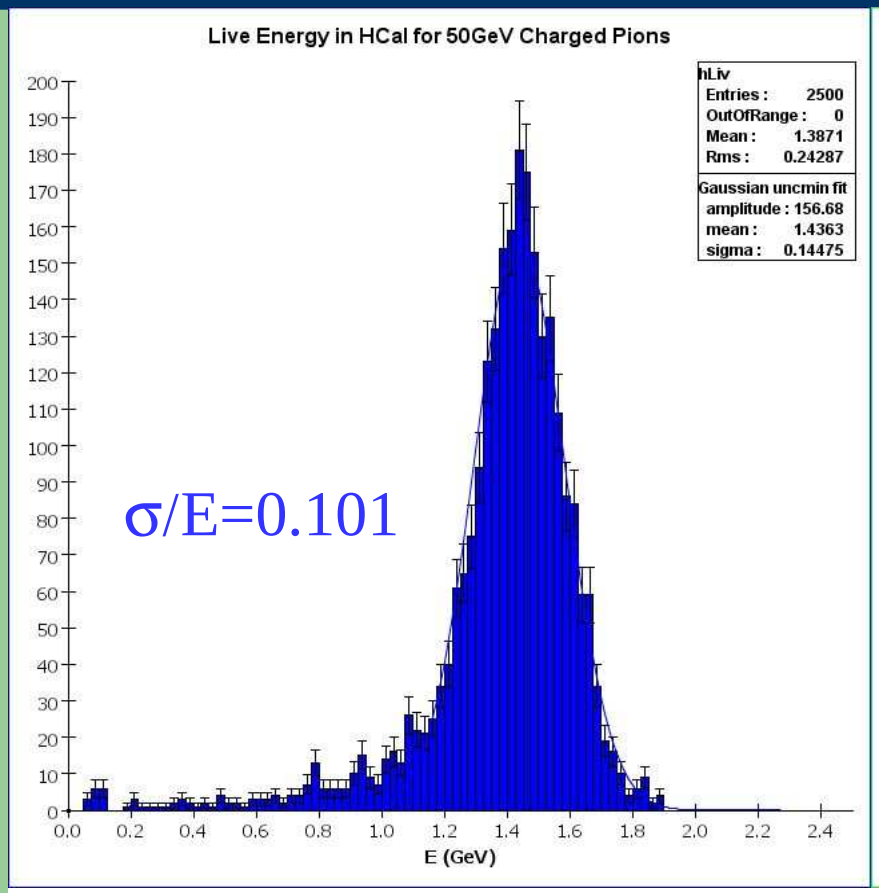
The Culprit

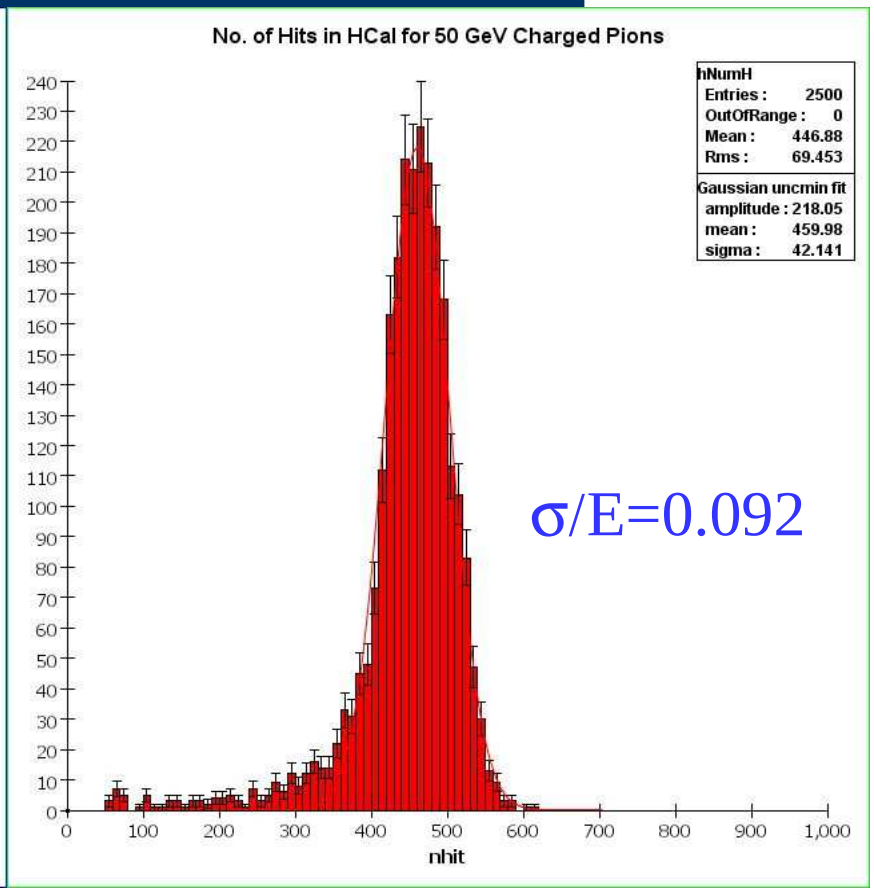




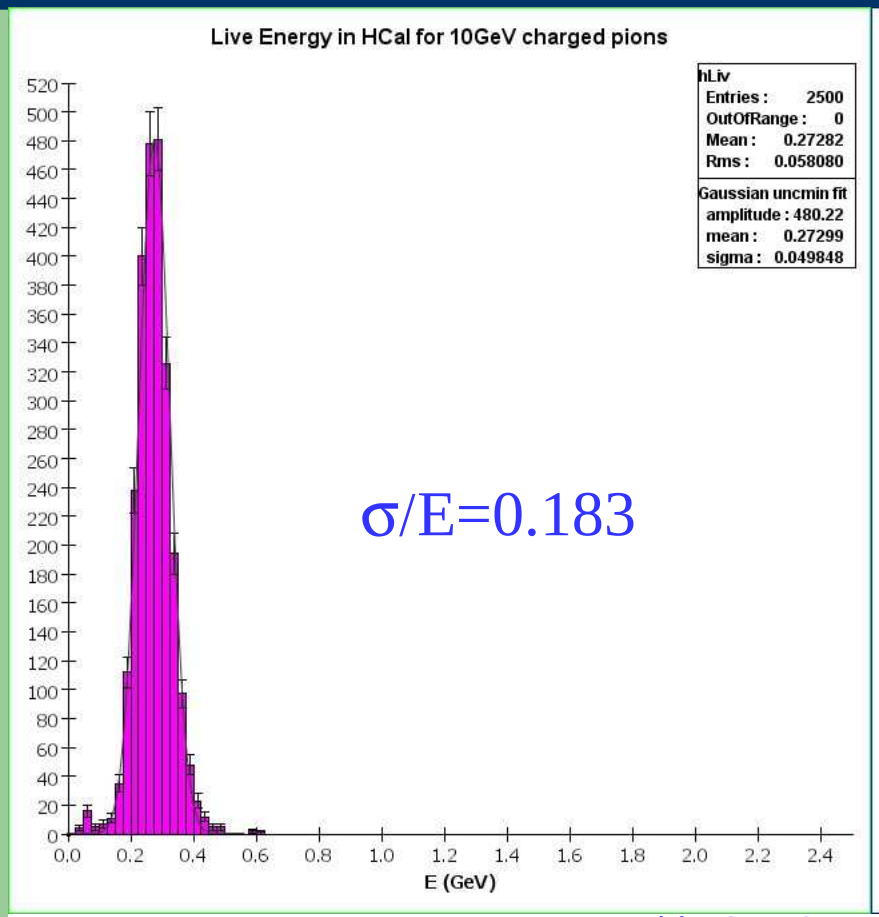
After threshold-based weighting of cells

Single Particle Resolution (50 GeV)

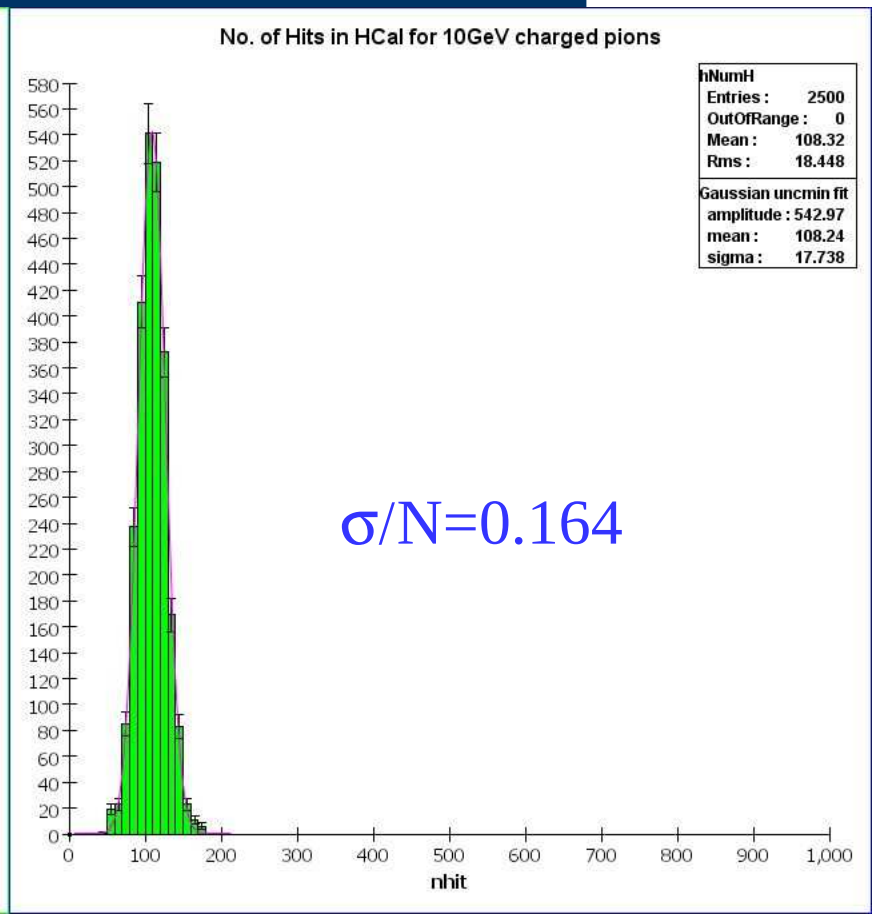




Similar treatment to 10 GeV….

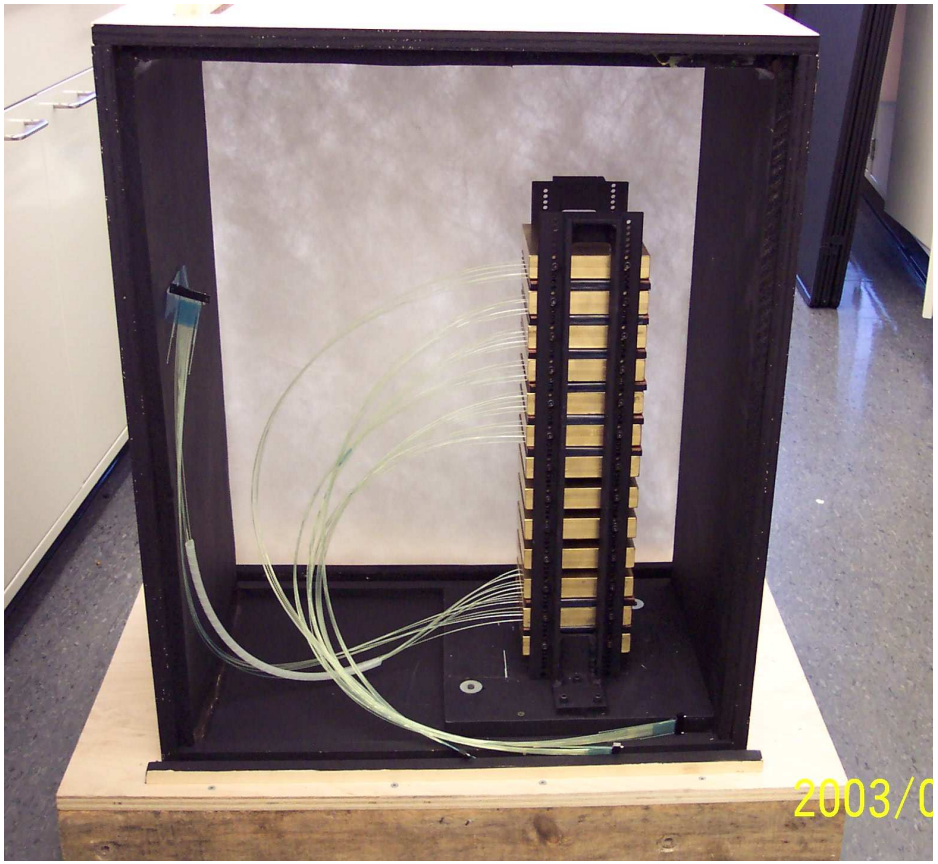


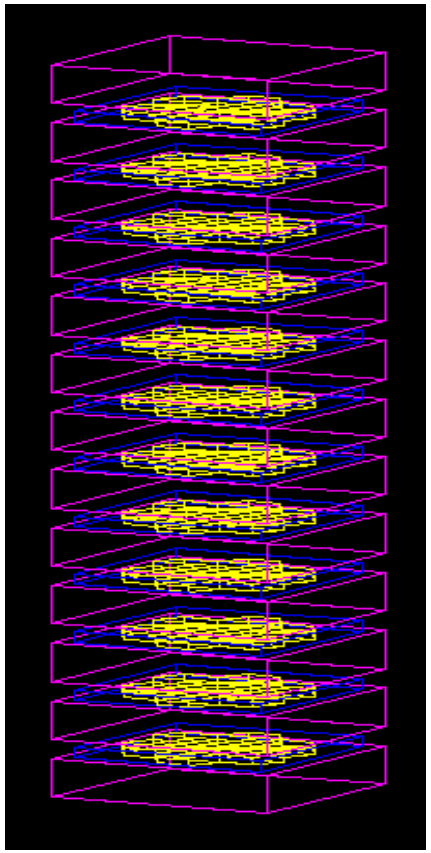
$\sigma/E=0.183$



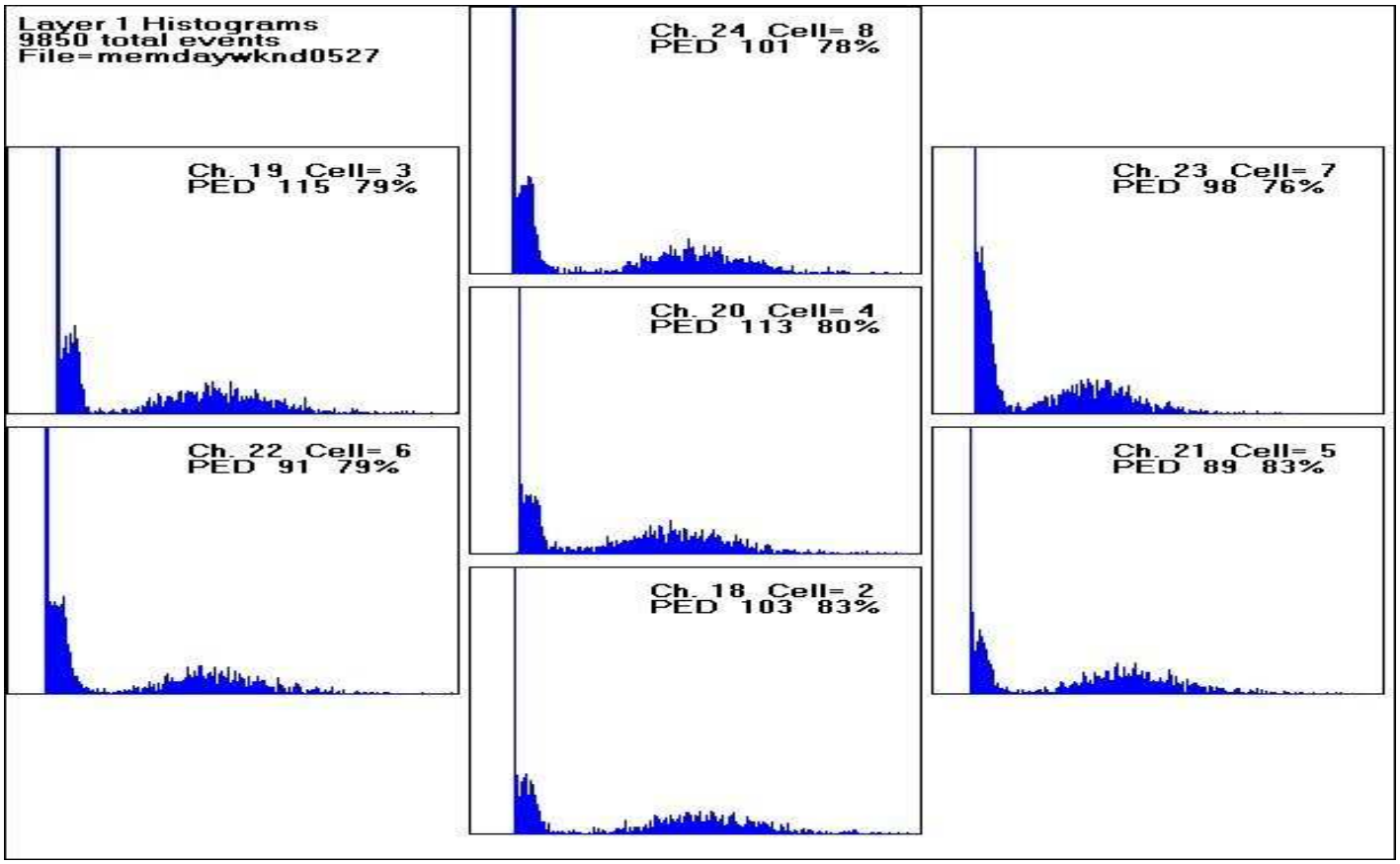
$\sigma/N=0.164$

Layer Stack



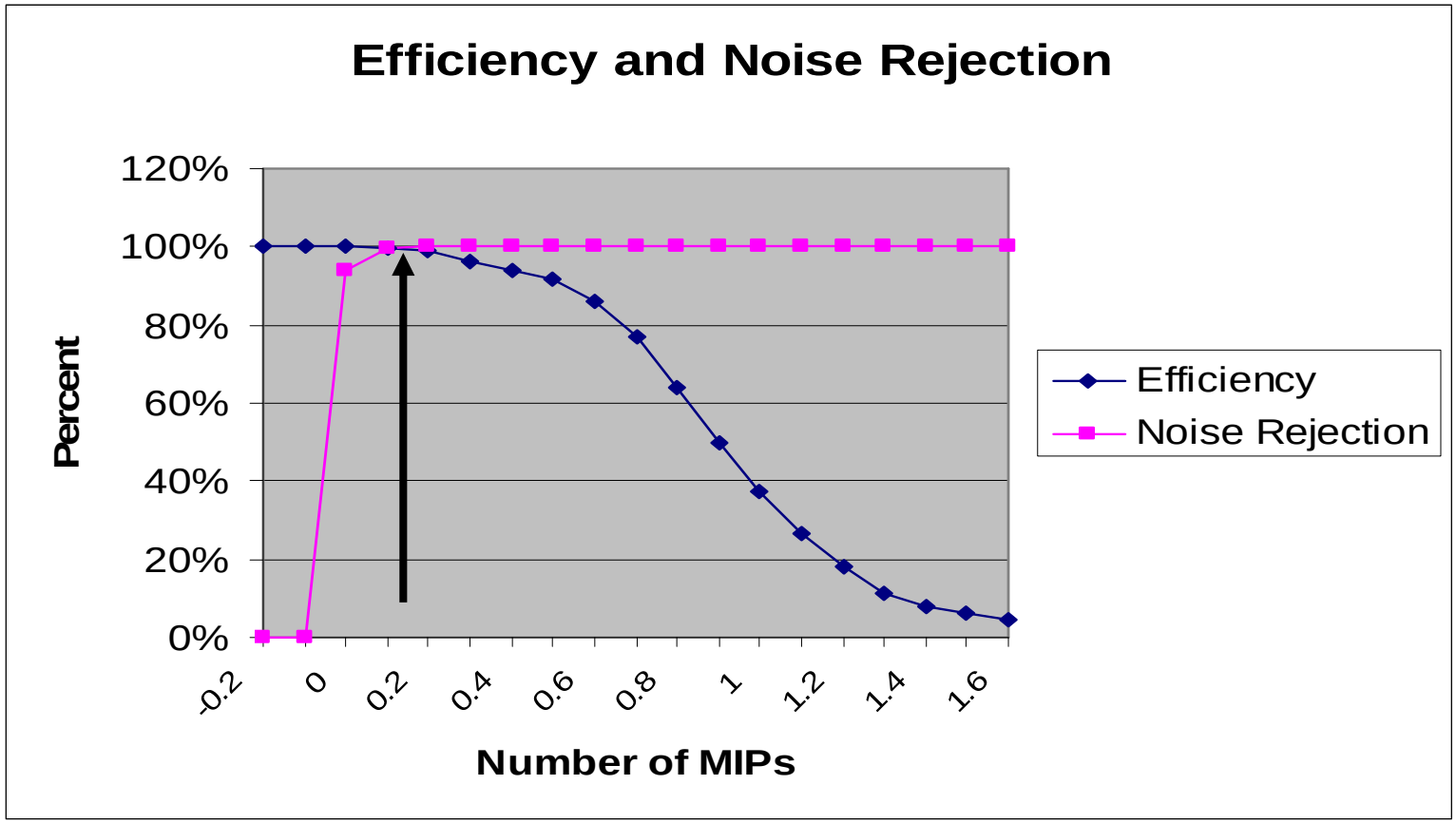


Cosmic Data with PMT



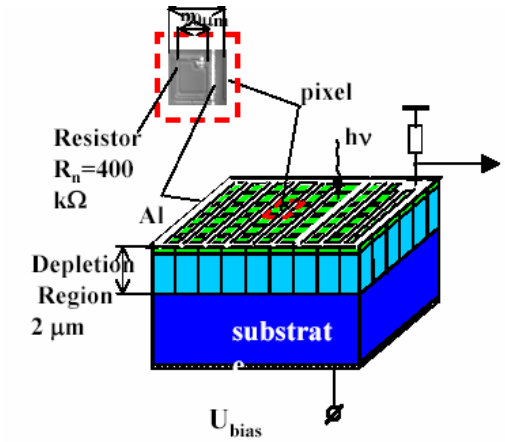
Started with 11pe now ~14 p.e being regularly achieved

Efficiency vs. Noise Rejection



Si-PM and MRS

Pixilated (500 to 1000 on ~1mm^2) Geiger mode sensor with high gain and modest Quantum*geom. efficiency



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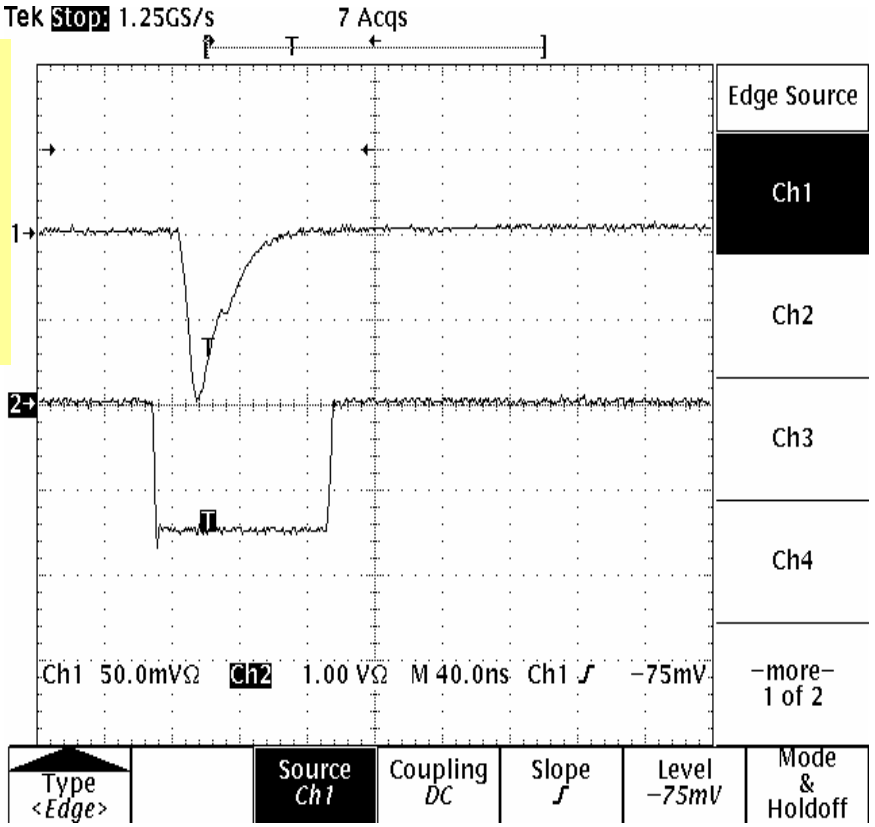
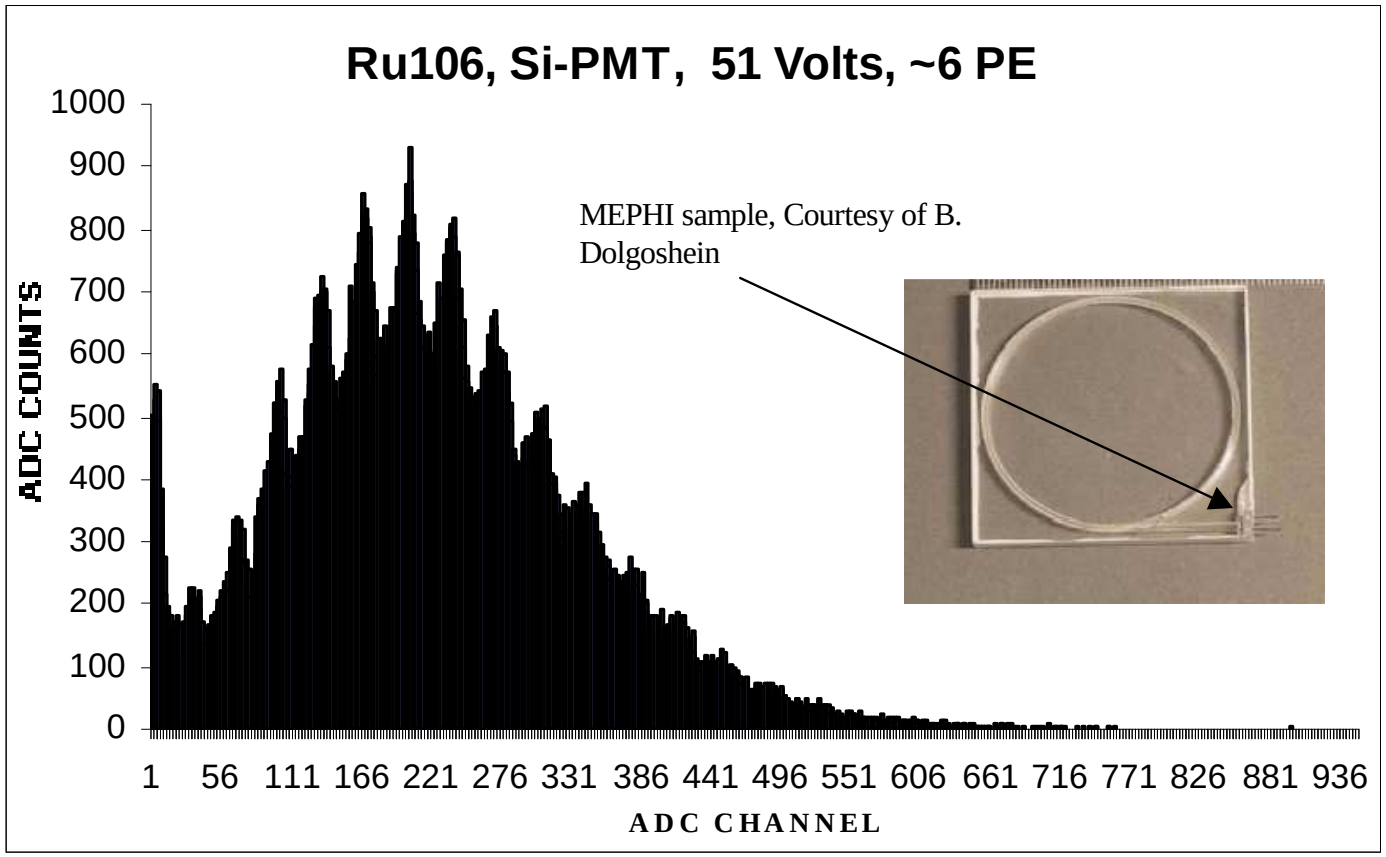
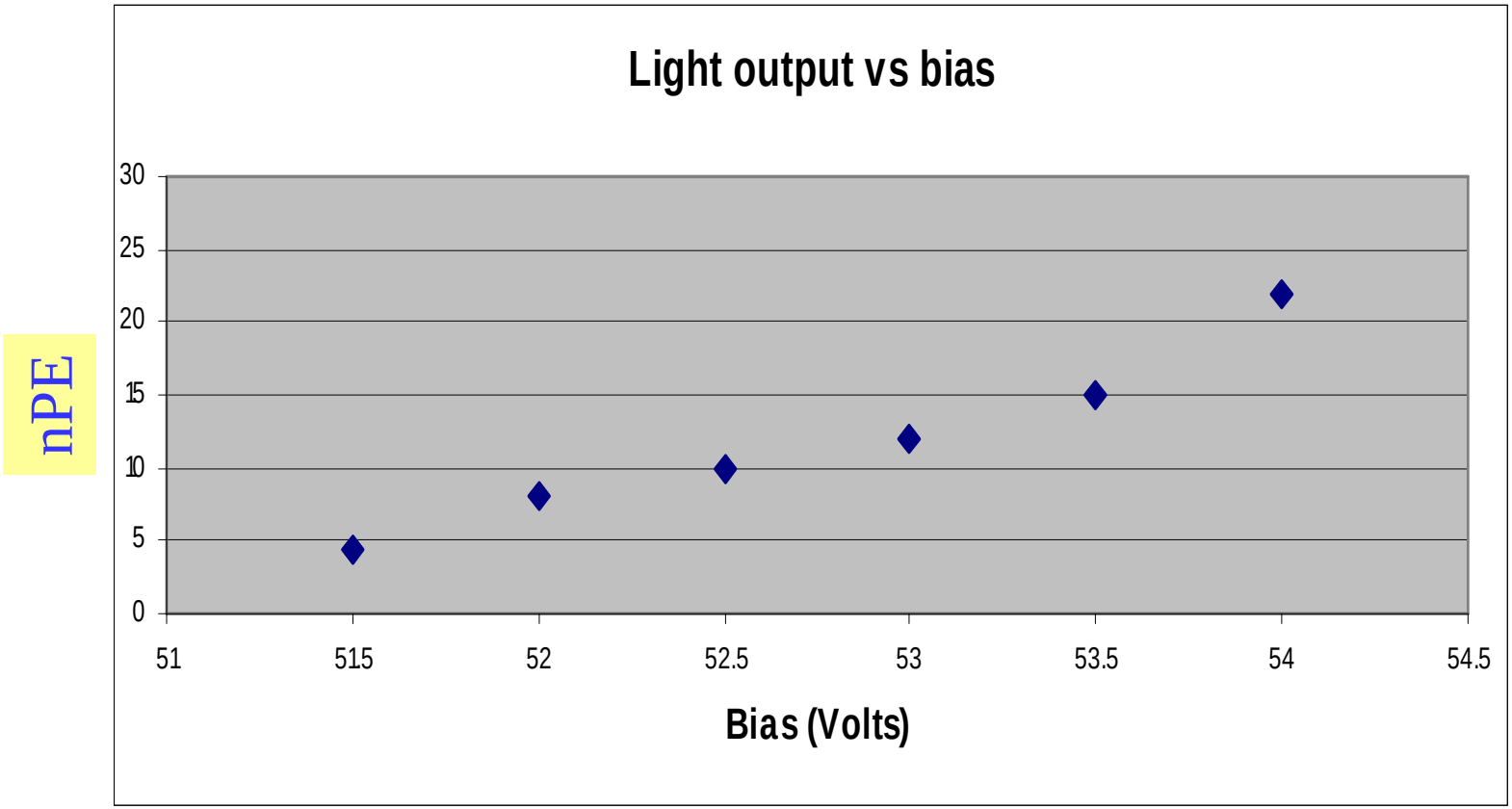


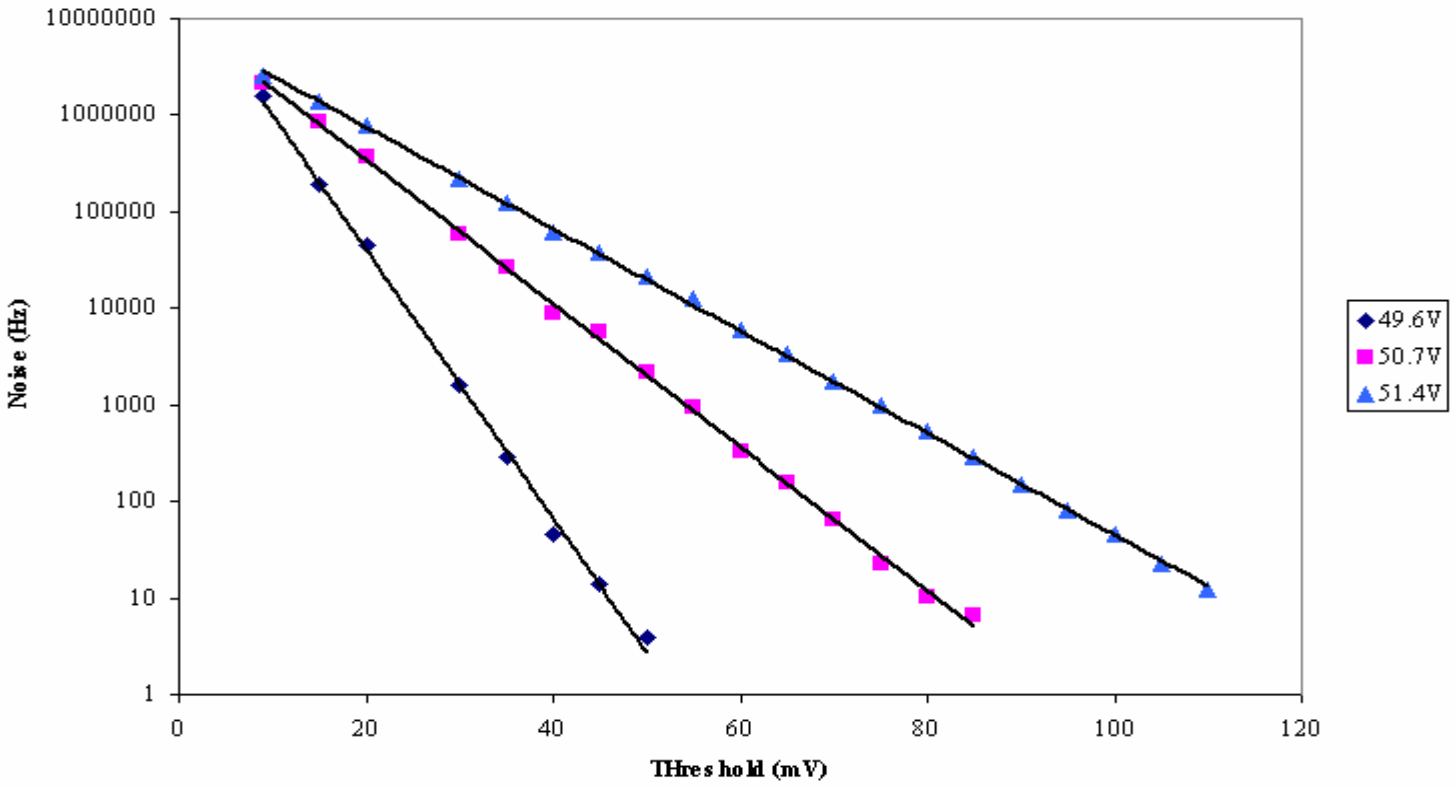
Si-PM's


Ru106, Si-PMT, 51 Volts, ~6 PE
ADC COUNTS
1000
900
800
700
600
500
400
300
200
100
0
1 56 111 166 221 276 331 386 441 496 551 606 661 716 771 826 881 936
ADC CHANNEL
MEPHI sample, Courtesy of B. Dolgoshein

Cosmic Data with Si-PM



MRS Dark Noise Rate



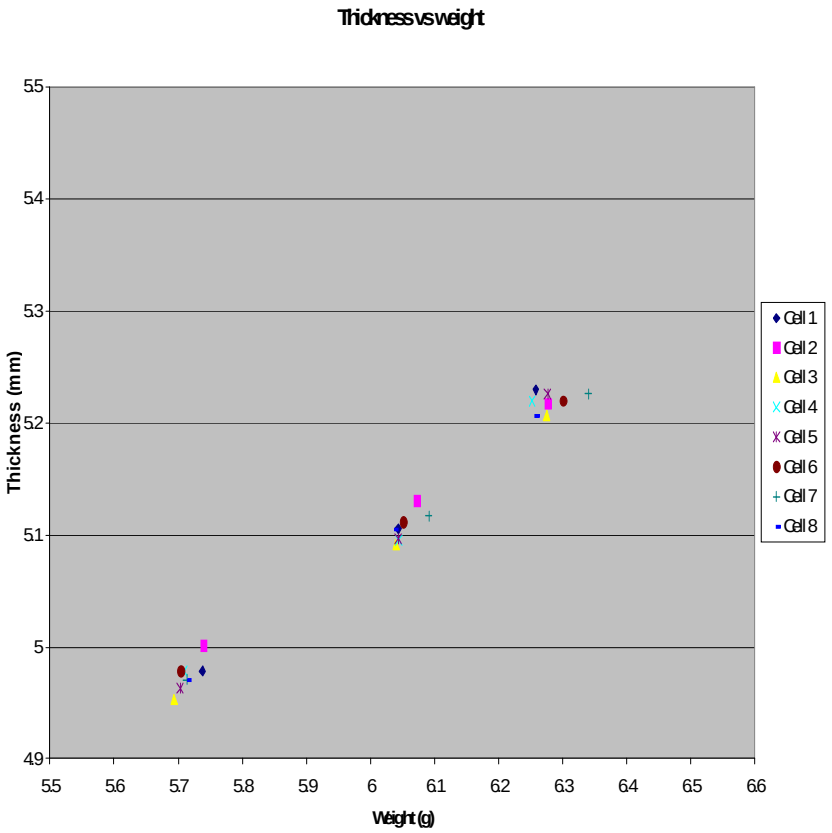
Surface Treatment/Wrapping

UNPOLISHED TOP AND POLISHED BOTTOM	POLISHED TOP AND POLISHED BOTTOM	UNPOLISHED TOP AND UNPOLISHED BOTTOM
0.98	1.00	1.02

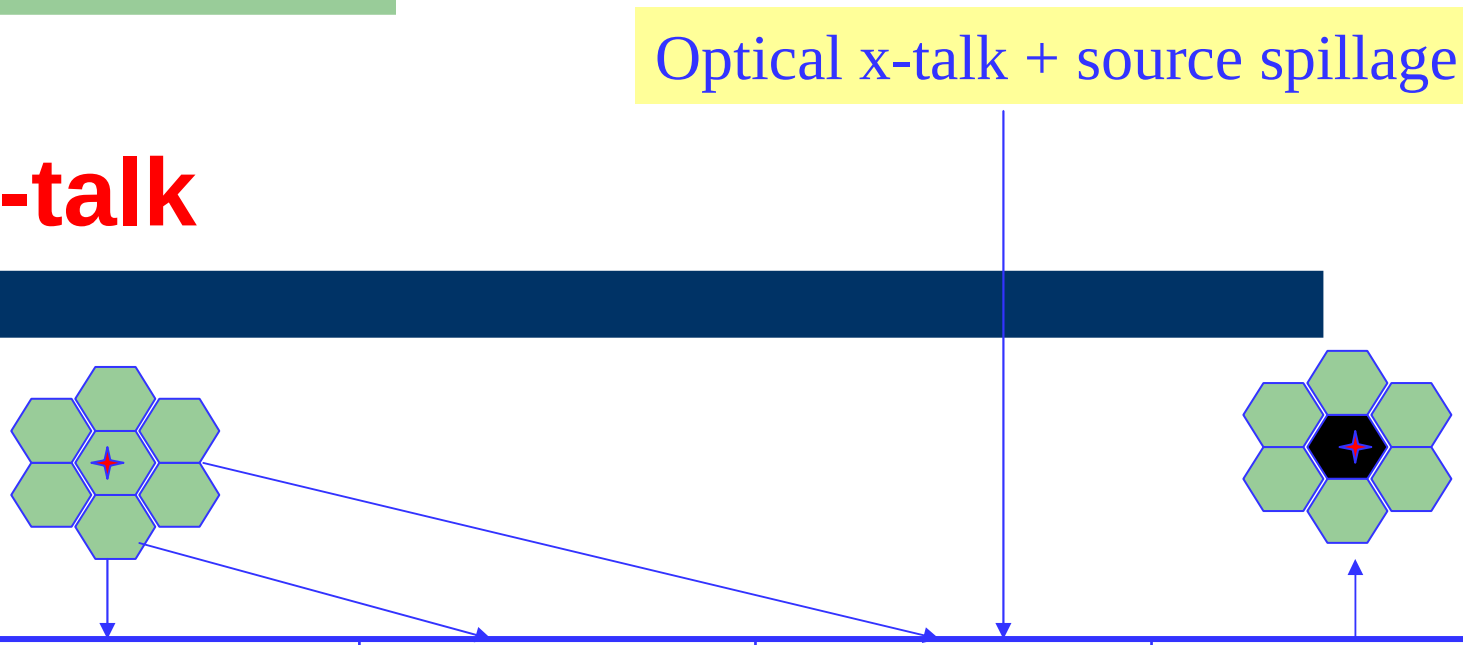
Tyvek	Paint	VM 2002	Mylar	CM590	CM500	Alum Foil
1.00	0.89	1.08	0.83	0.28	0.44	0.63

Thickness vs. weight

- If weight and thickness track each other, then it may be possible to monitor paint application via weight only
- Check to see if thickness and weight track each other by plotting thickness vs. weight:

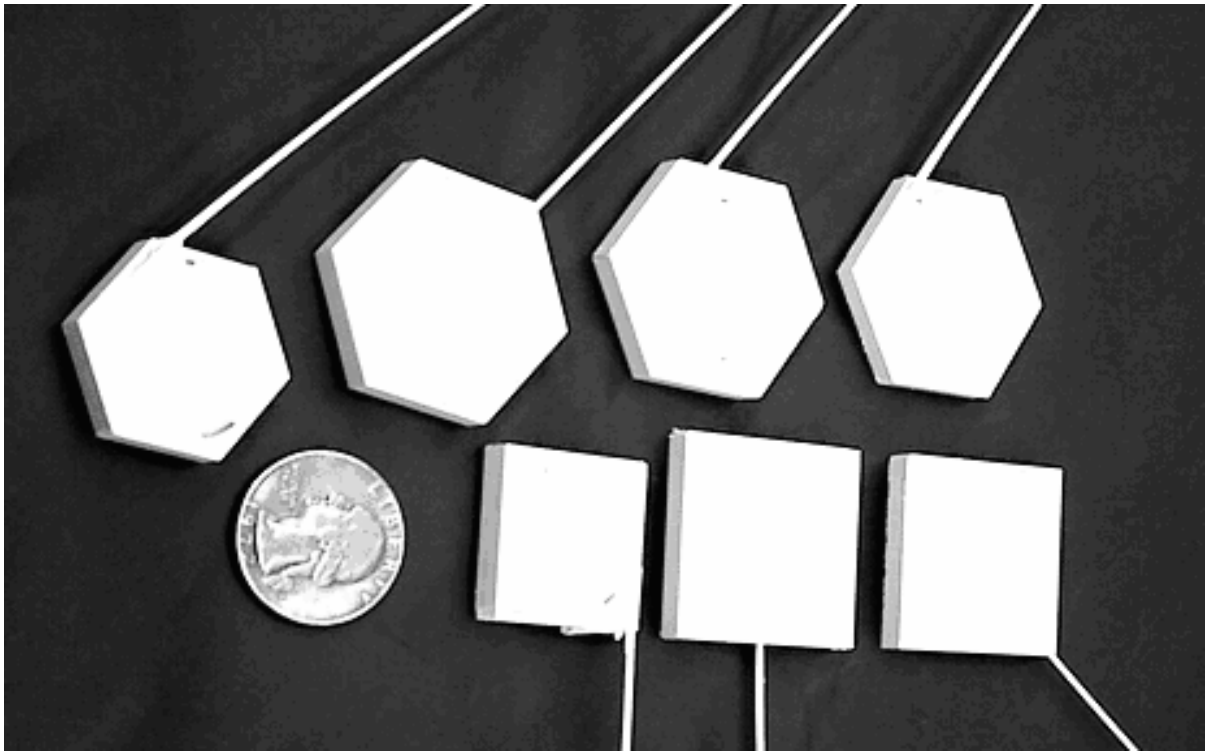


X-talk

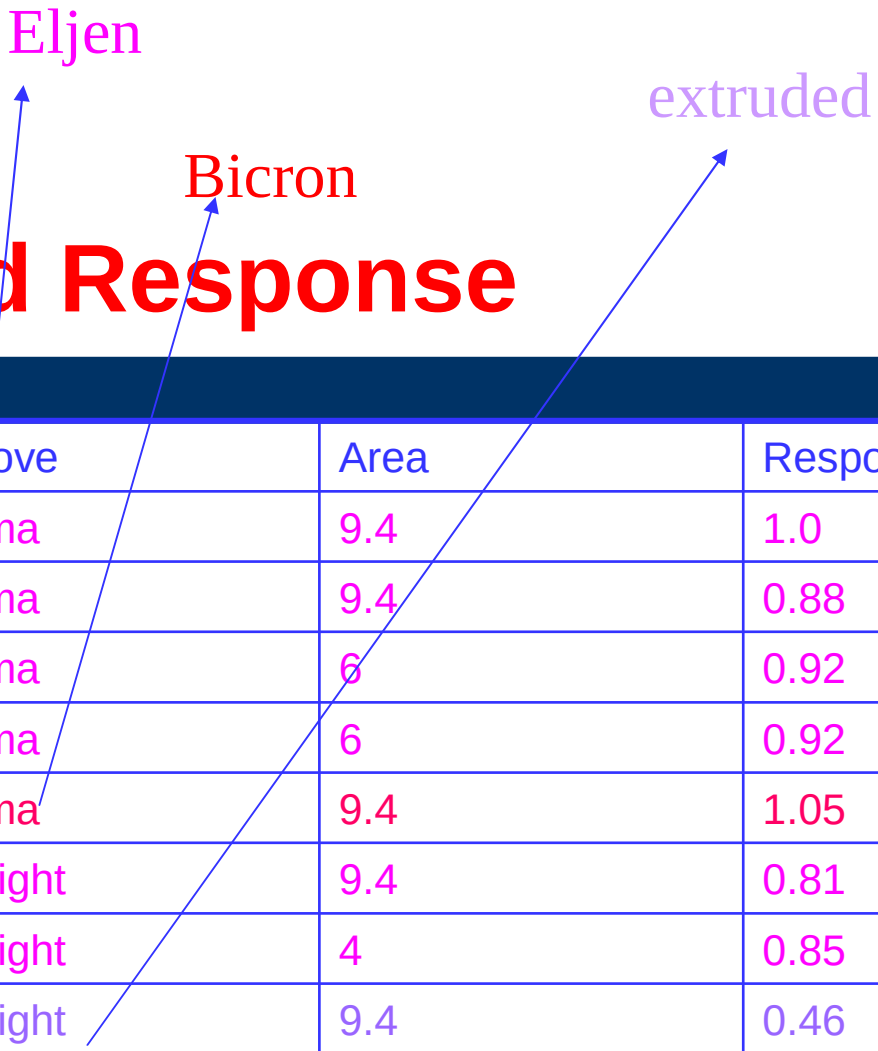


All cells connected to pmt	Only central cell connected	Only neighbors connected	Only neighbors connected
1.000	0.985	0.008	0.006

Cells Fabricated



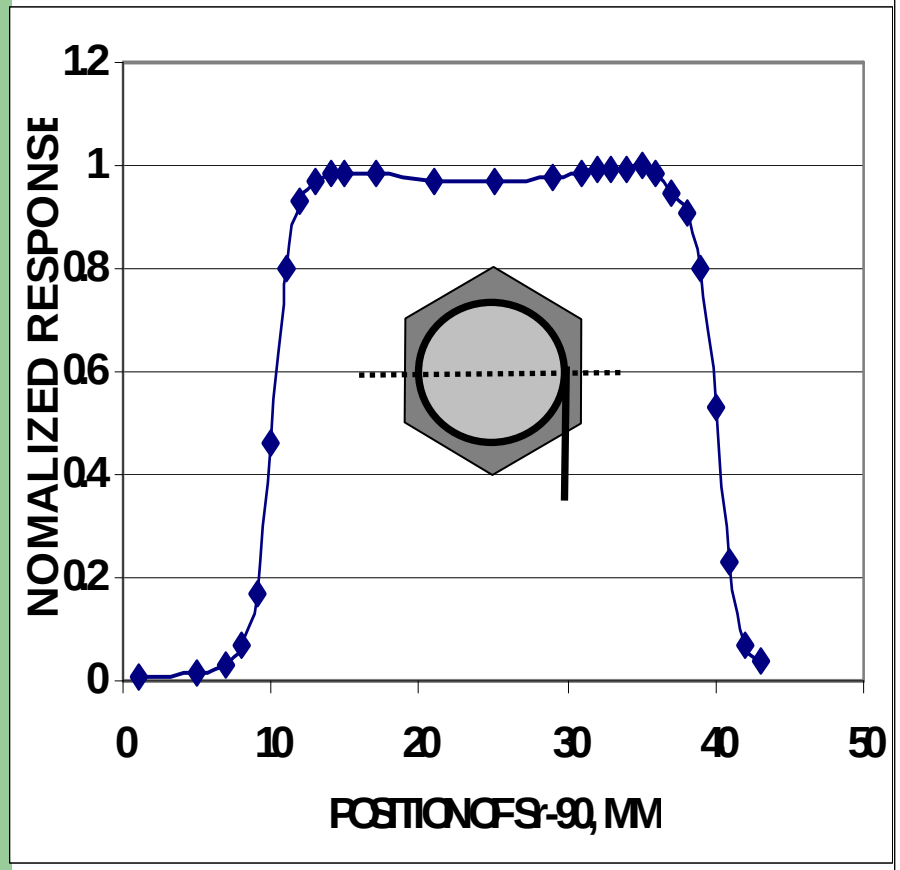
Normalized Response

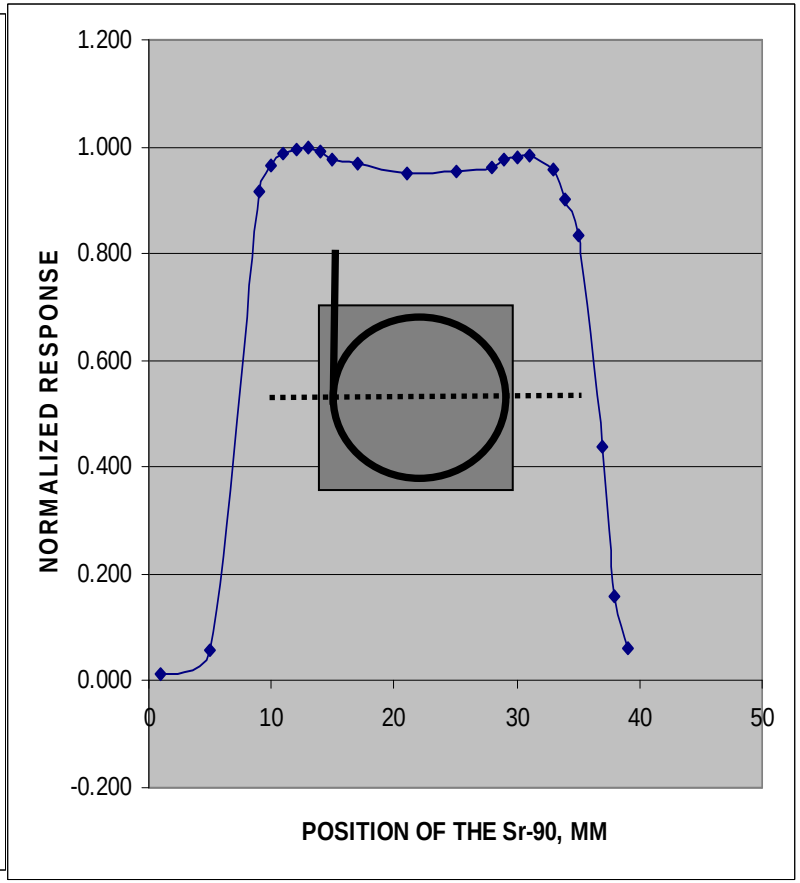


Cell	Groove	Area	Response
Hexagon	Sigma	9.4	1.0
Square	Sigma	9.4	0.88
Square	Sigma	6	0.92
Hexagon	Sigma	6	0.92
Hexagon	Sigma	9.4	1.05
Square	Straight	9.4	0.81
Square	Straight	4	0.85
Square	Straight	9.4	0.46
Hexagon	Straight	9.4	0.48
Hexagon	Sigma	9.4	0.58

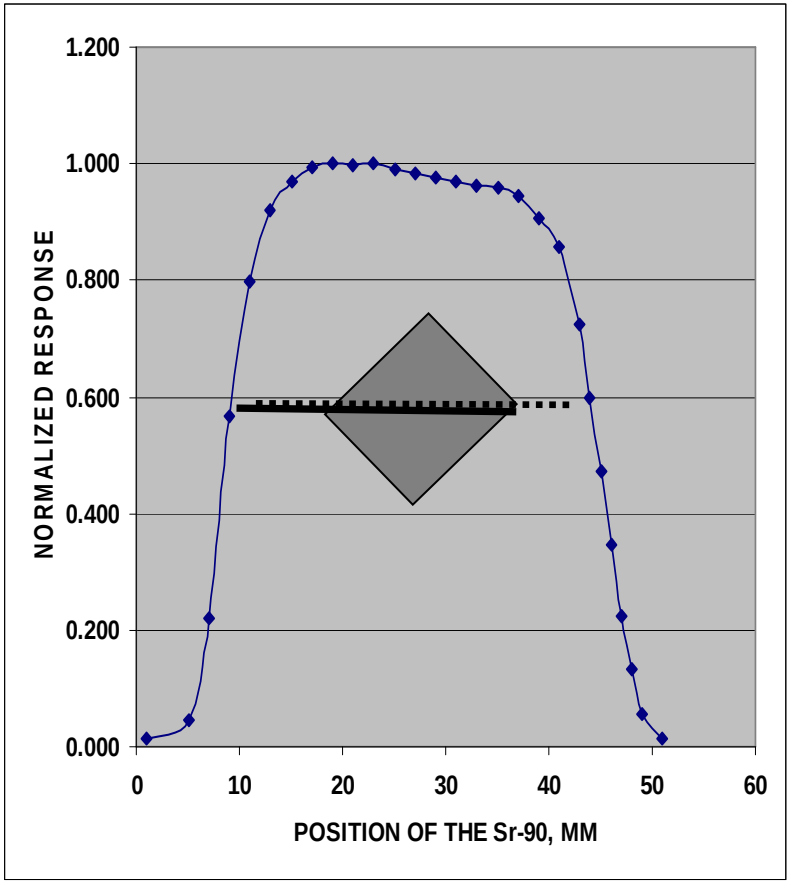
Since light ample, can optimize for ease of construction

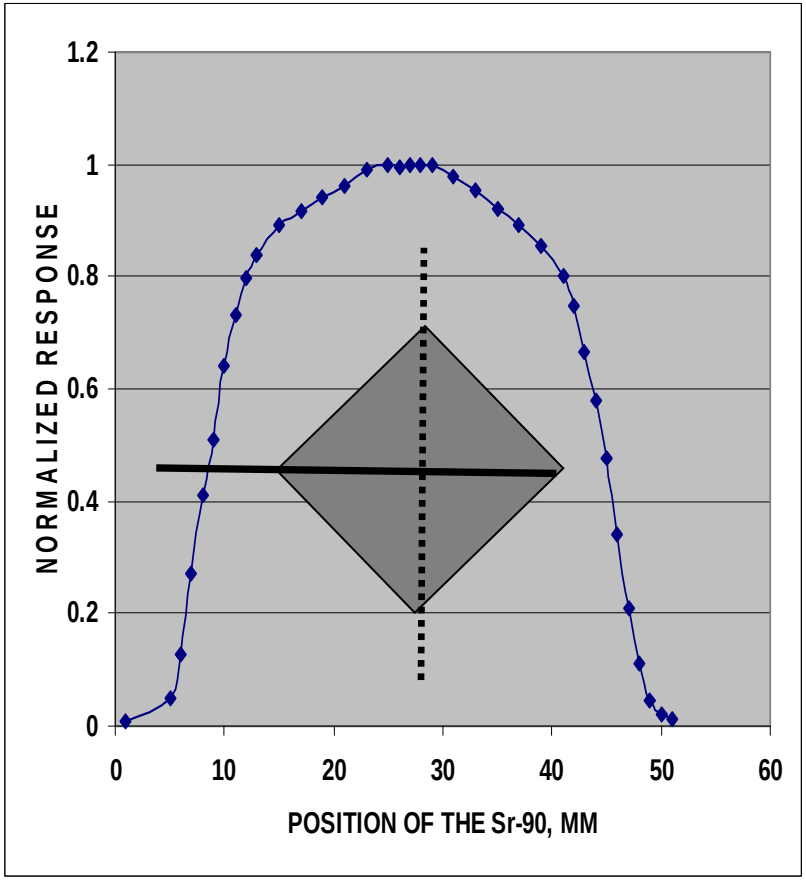
Sigma Groove Uniformity



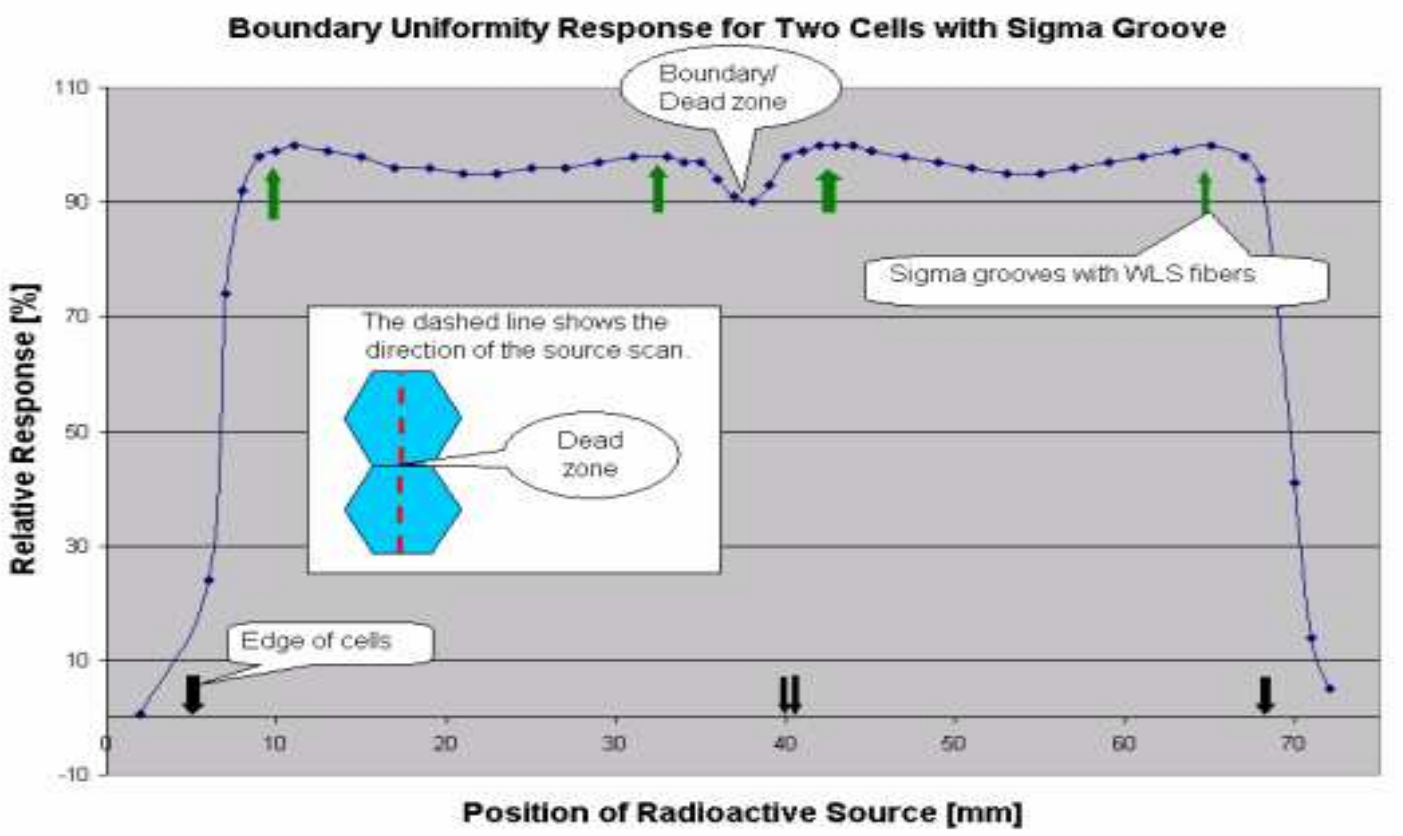


Straight Groove Uniformity



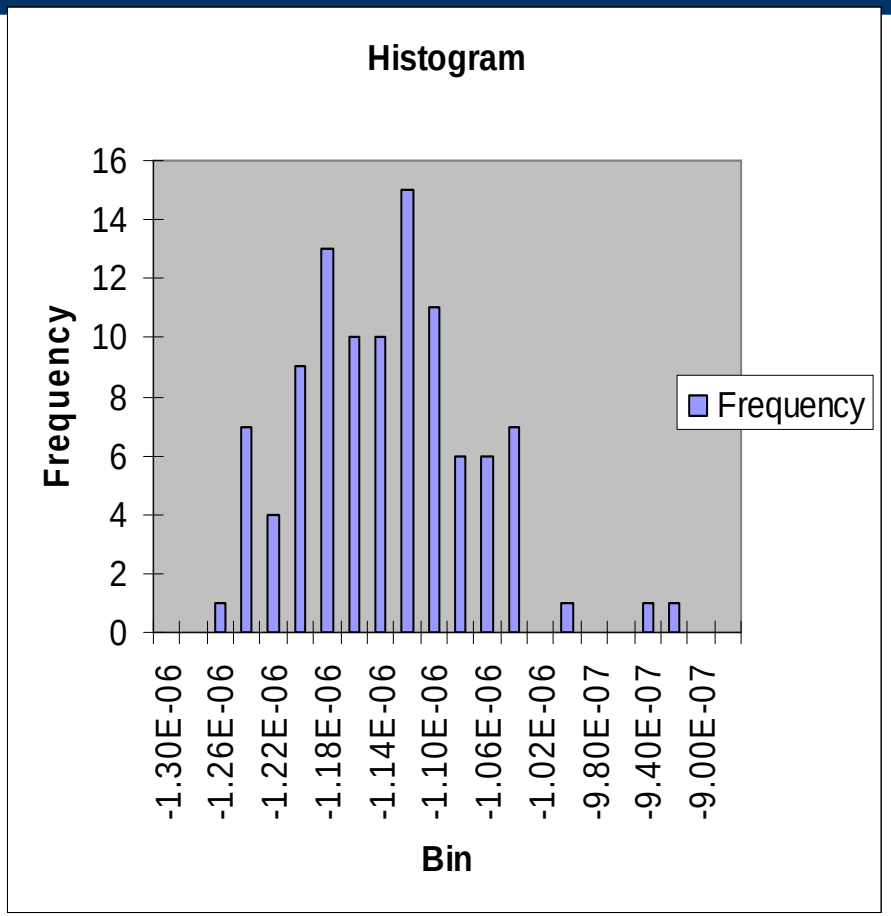


Scanning over the neighbors



Overall dispersion<10%

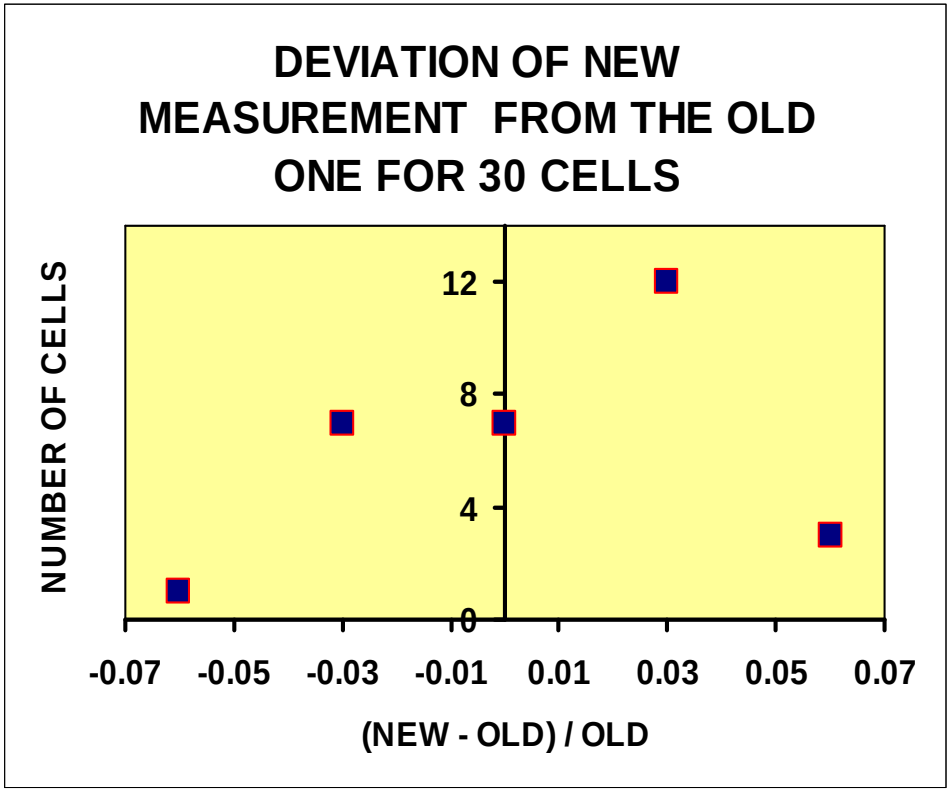
Response Dispersion



Column1	
Mean	**-1.14599E-06**
Standard Error	6.53057E-09
Median	-1.1464E-06
Mode	-1.10134E-06
Standard Deviation	**6.59555E-08**
Sample Variance	4.35012E-15
Kurtosis	0.427712361
Skewness	0.44298345
Range	3.4981E-07
Minimum	**-1.27961E-06**
Maximum	**-9.298E-07**
Sum	-0.000116891
Count	**102**
Largest(1)	-9.298E-07
Smallest(1)	-1.27961E-06
Confidence Level(95.	1.29549E-08

0.993 ± 0.006

RESPONSE LONG AFTER PRODUCTION

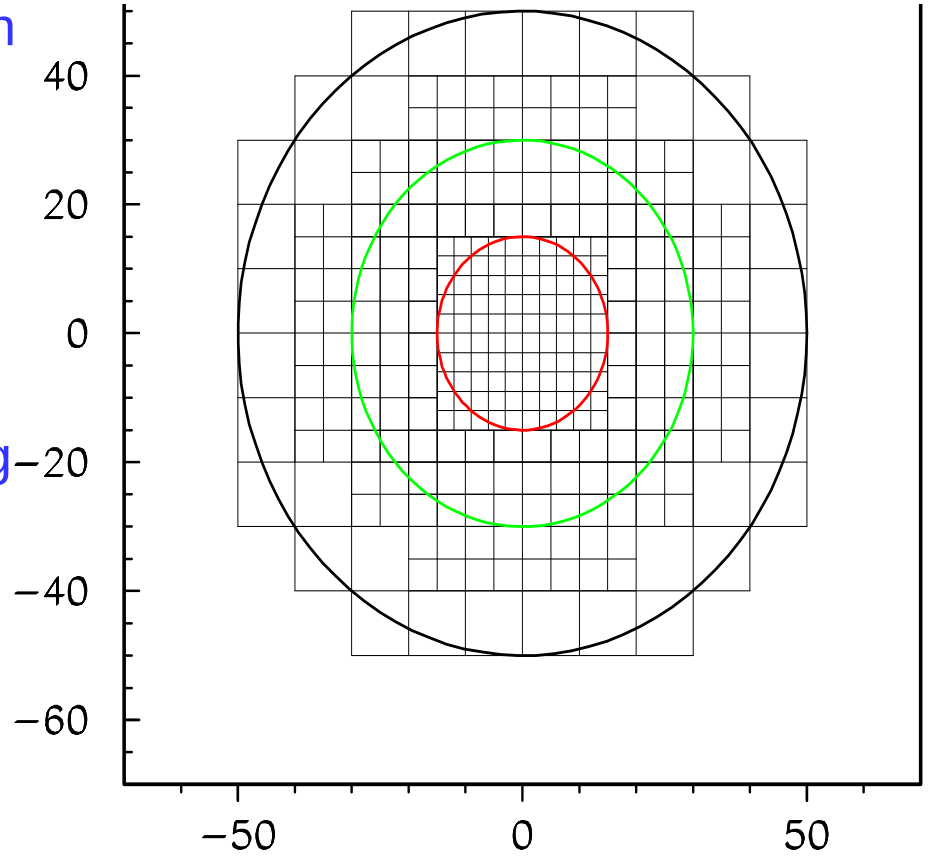


Column1	
Mean	0.992641
Standard Error	0.005622
Median	0.994932
Mode	#N/A
Standard Deviation	0.030794
Sample Variance	0.000948
Kurtosis	-0.64168
Skewness	0.171597
Range	0.117636
Minimum	0.935048
Maximum	1.052684
Sum	29.77922
Count	30

Scint. (s)DHCAL looks like a very competitive option….

Summary/Plans

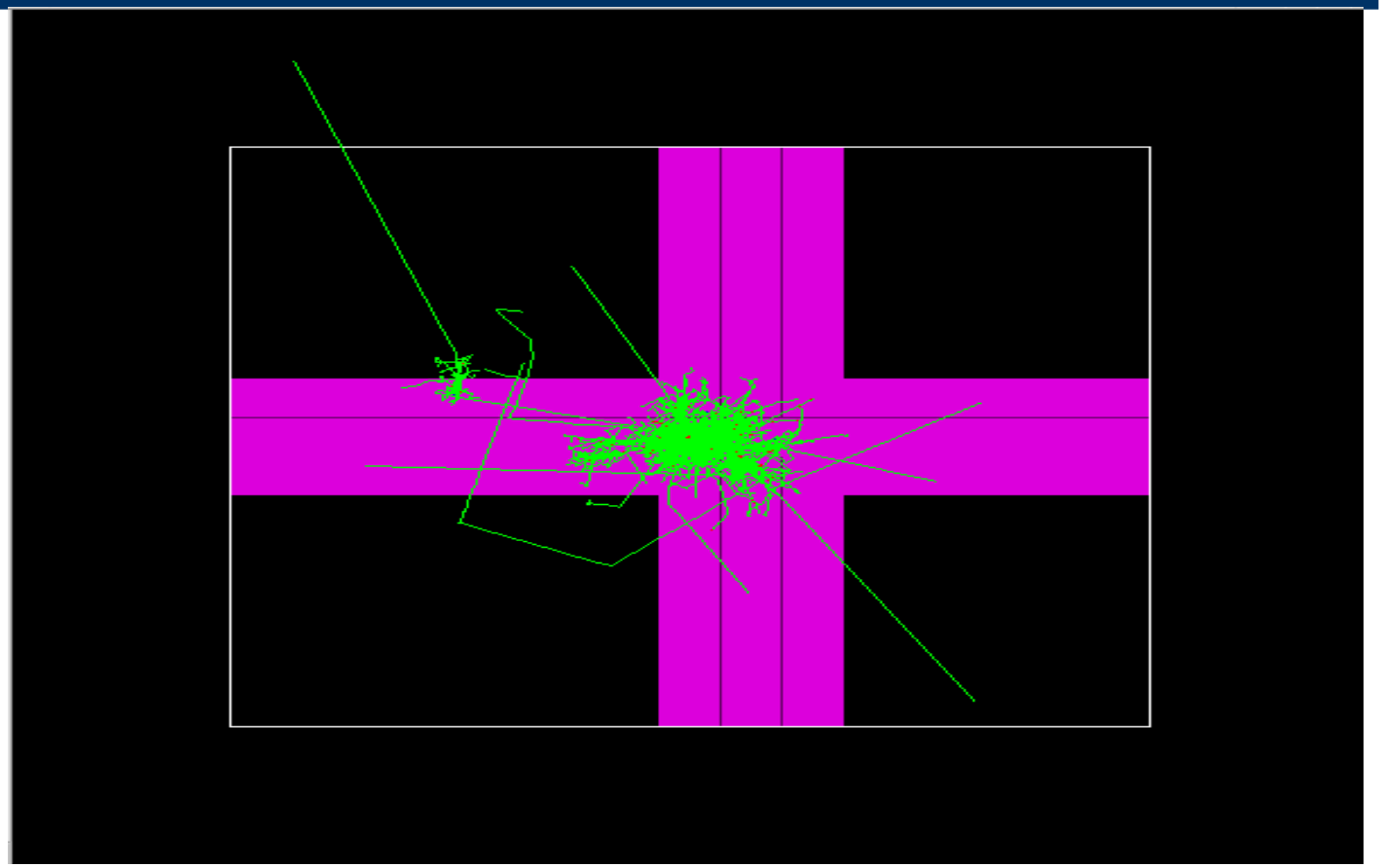
- Simulations indicate approach competitive with analog
- Prototypes indicate there is sufficient sensitivity (light x efficiency) & uniformity.
- Outlook for optimizing materials & construction to minimize cost looks promising
- Intend to take part in the CALICE test beam in collaboration with the Tile-Cal group in 2005



Publications

- "Towards a Scintillator Based Digital Hadron Calorimeter for the Linear Collider Detector" accepted for publication in IEEE, Transactions on Nuclear Science.
- "Small Scintillating Cells as the Active Elements in a Digital Hadron Calorimeter for the e^+e^- Linear Collider Detector" accepted for publication in Journal of Physics G.

Tail-catcher/Muon System

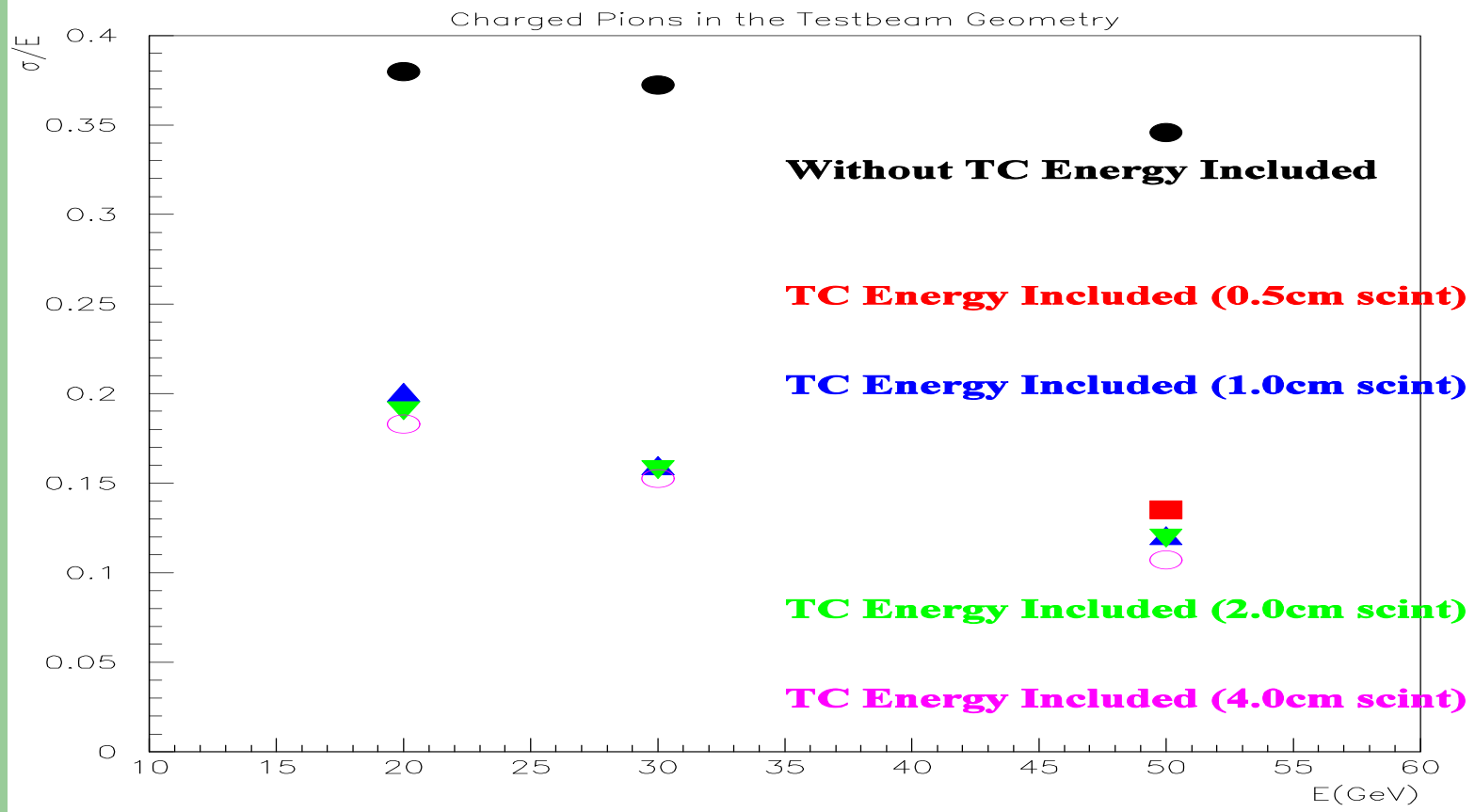


Goals for the TC/Muon System

- Provide a reasonable snapshot of the tail-end of the shower for simulation validation
- Prototype detector with high-fidelity to what is imagined for a generic LCD
  - correcting for leakage
  - understanding the impact of coil
  - muon reconstruction + eflow
  - fake rate

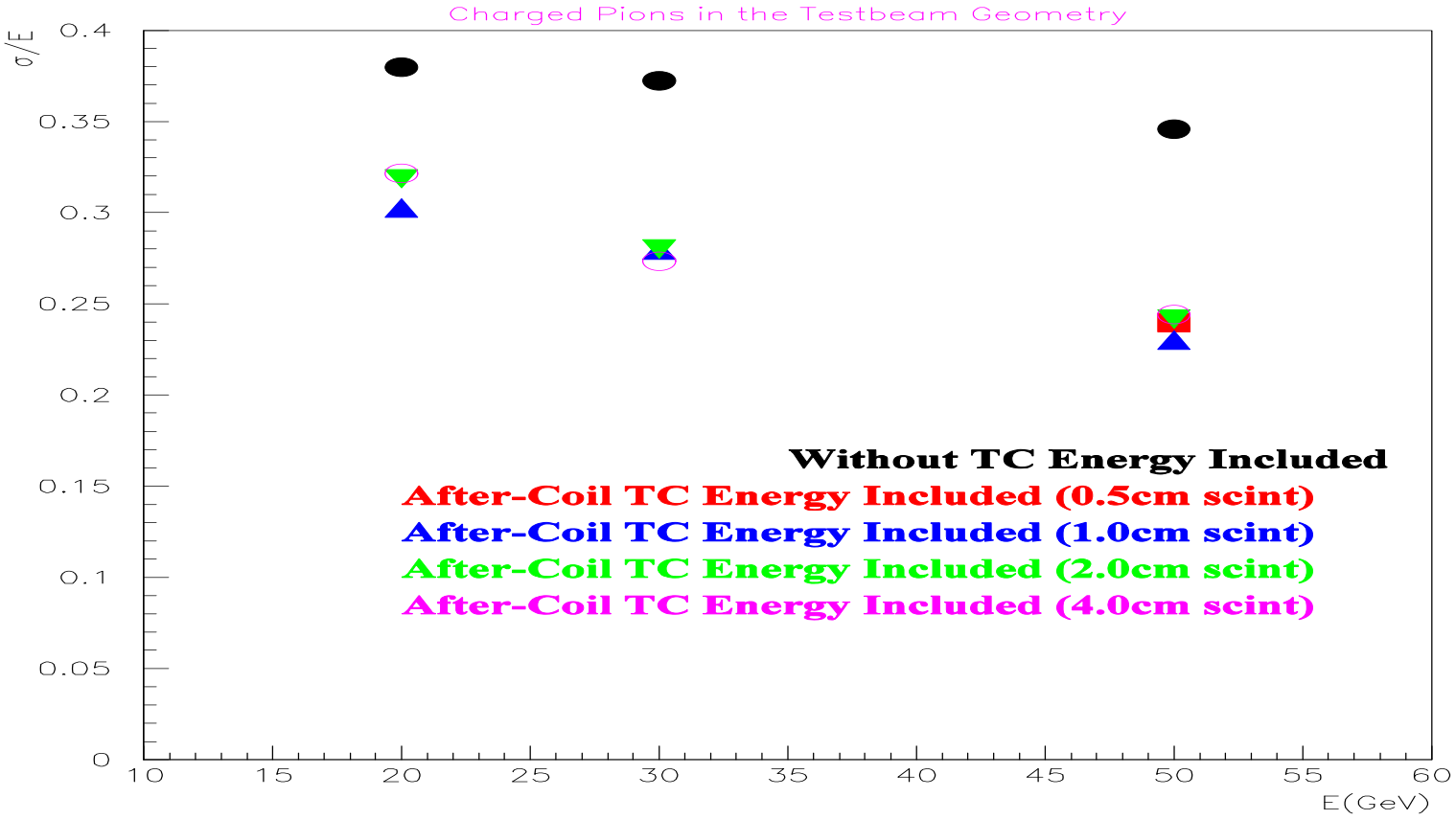
For charged pions with >5% of E inside TC

On tail-catching



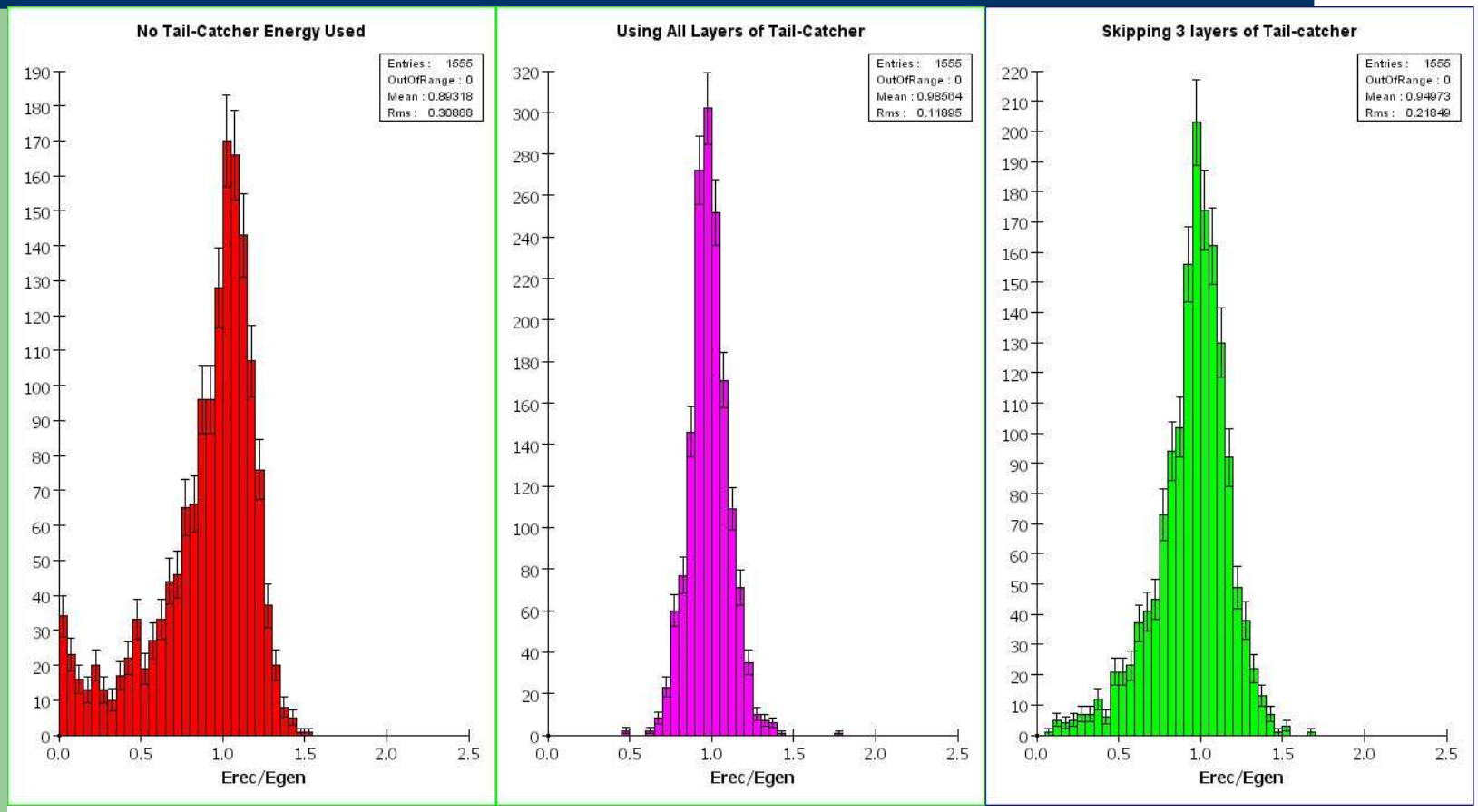
10cm absorber plates

Accounting for material in the coil...

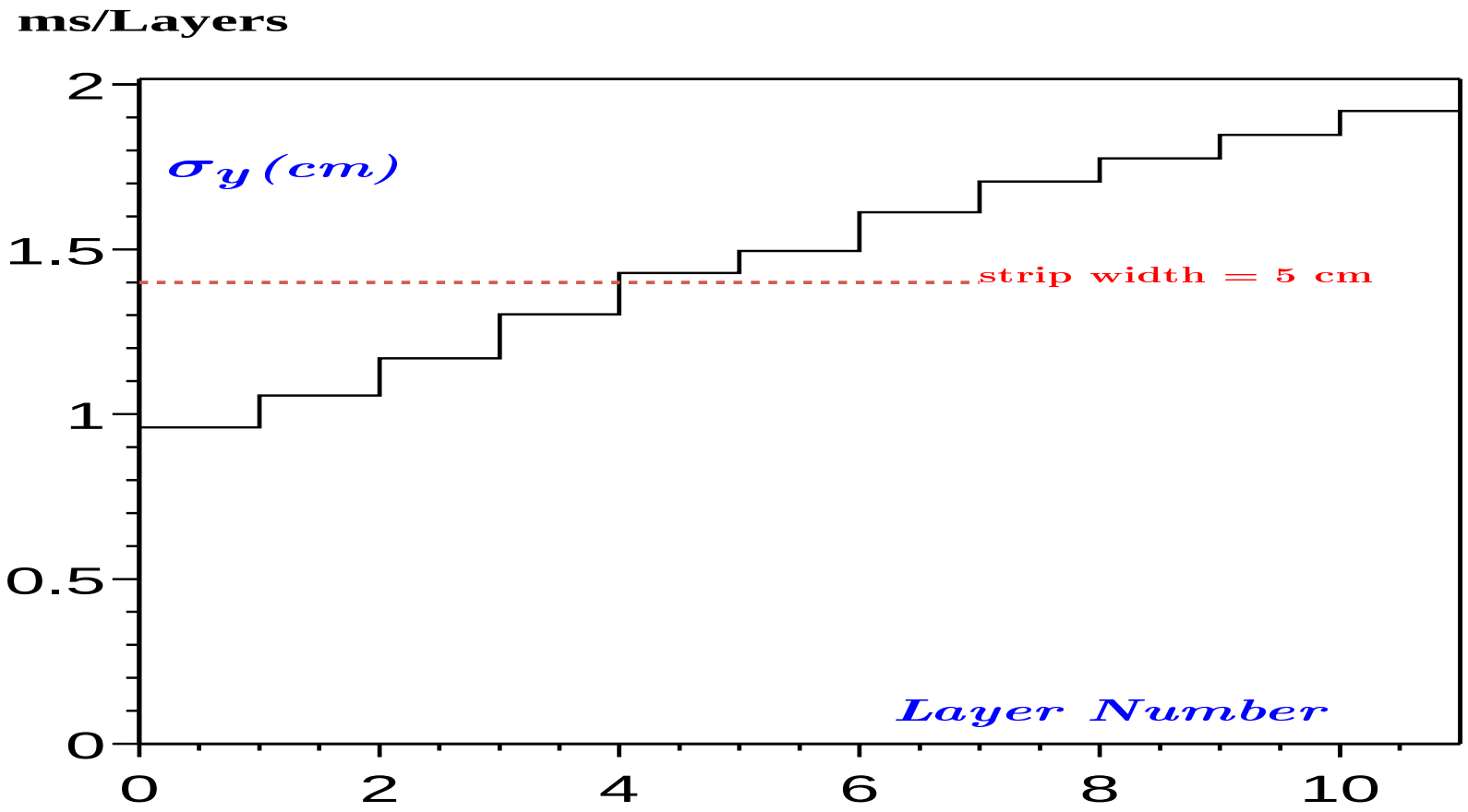


135%/sqrt(E)

E_{rec}/E_{gen} 50 GeV $\pi^{\pm}$



Strip Width

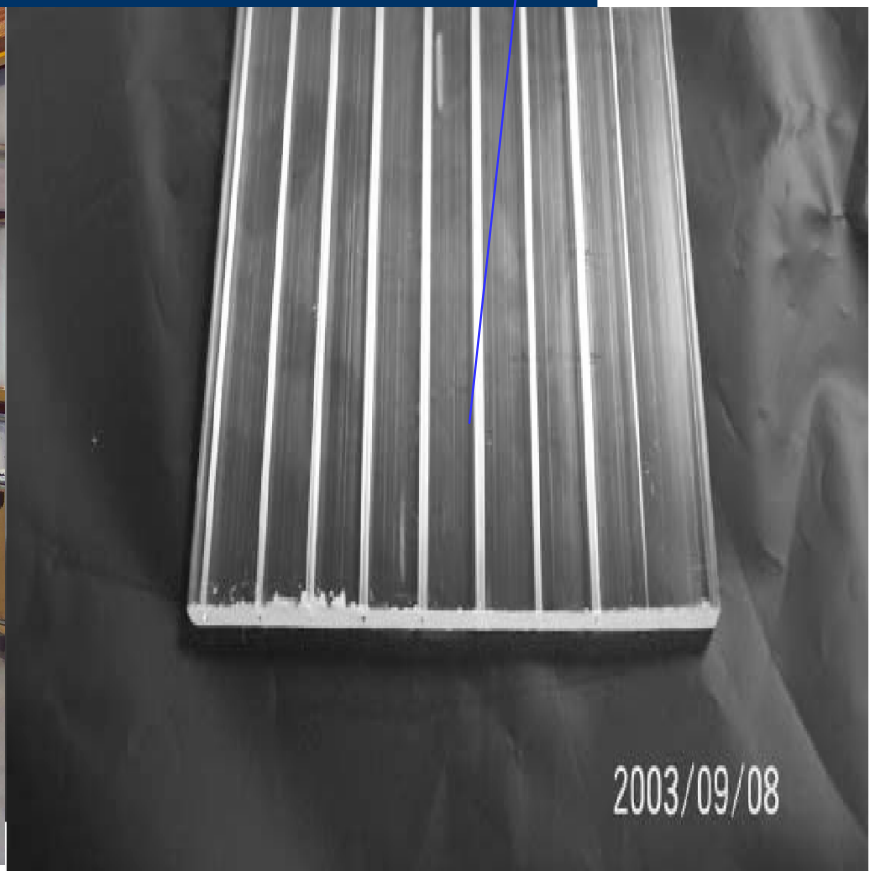

ms/Layers
2
1.5
1
0.5
0
σ_y (cm)
strip width = 5 cm
Layer Number
0
2
4
6
8
10

Current Design

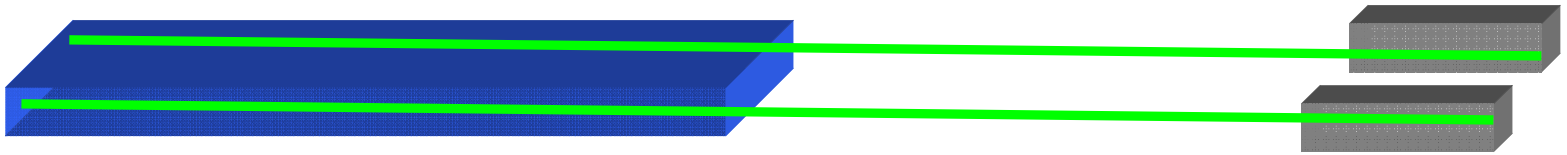
- "Fine" section (8 layers)
  - 2cm Steel, 0.5 cm thick scintillator
- Following "coarse" section (8 layers)
  - 10cm Steel, 0.5 cm scintillator
- 5cm wide strips, 1m long
- Tyvek wrapping
- Alternating x-y orientation
- Si-PM photo-detection

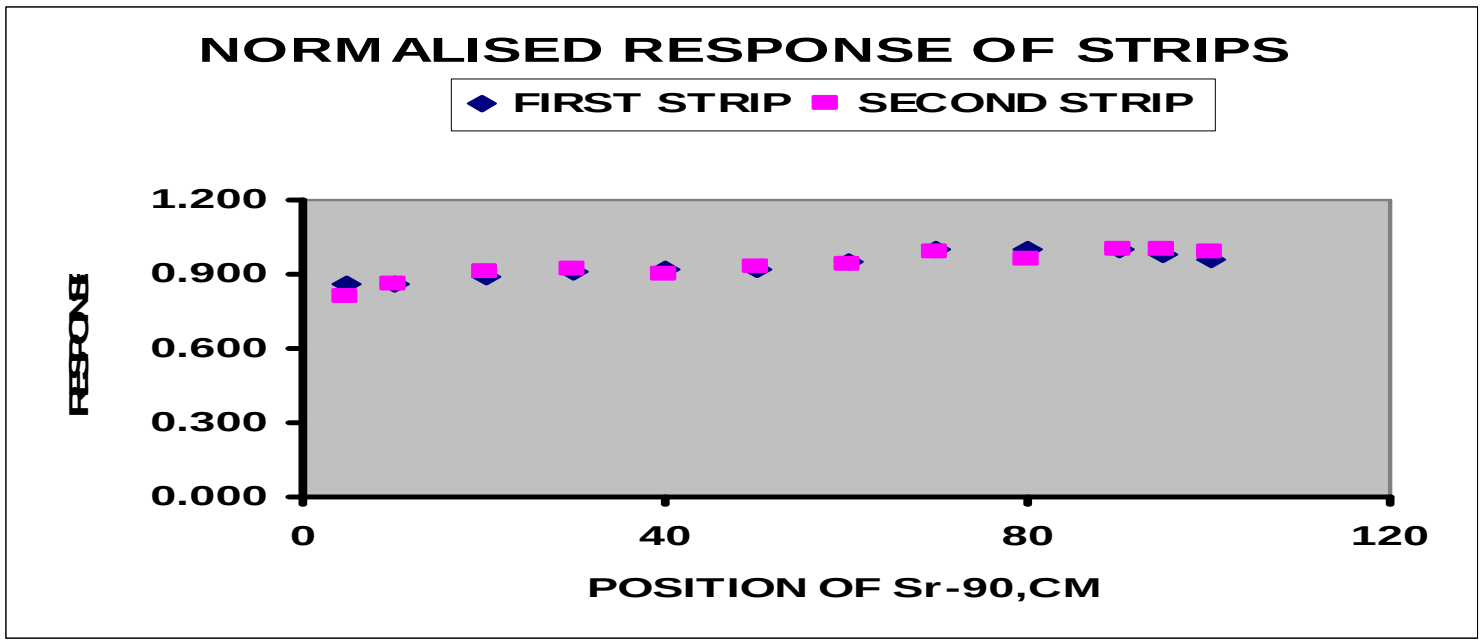
10cm wide, 5mm thick

Fermi-NICADD Extruder Line

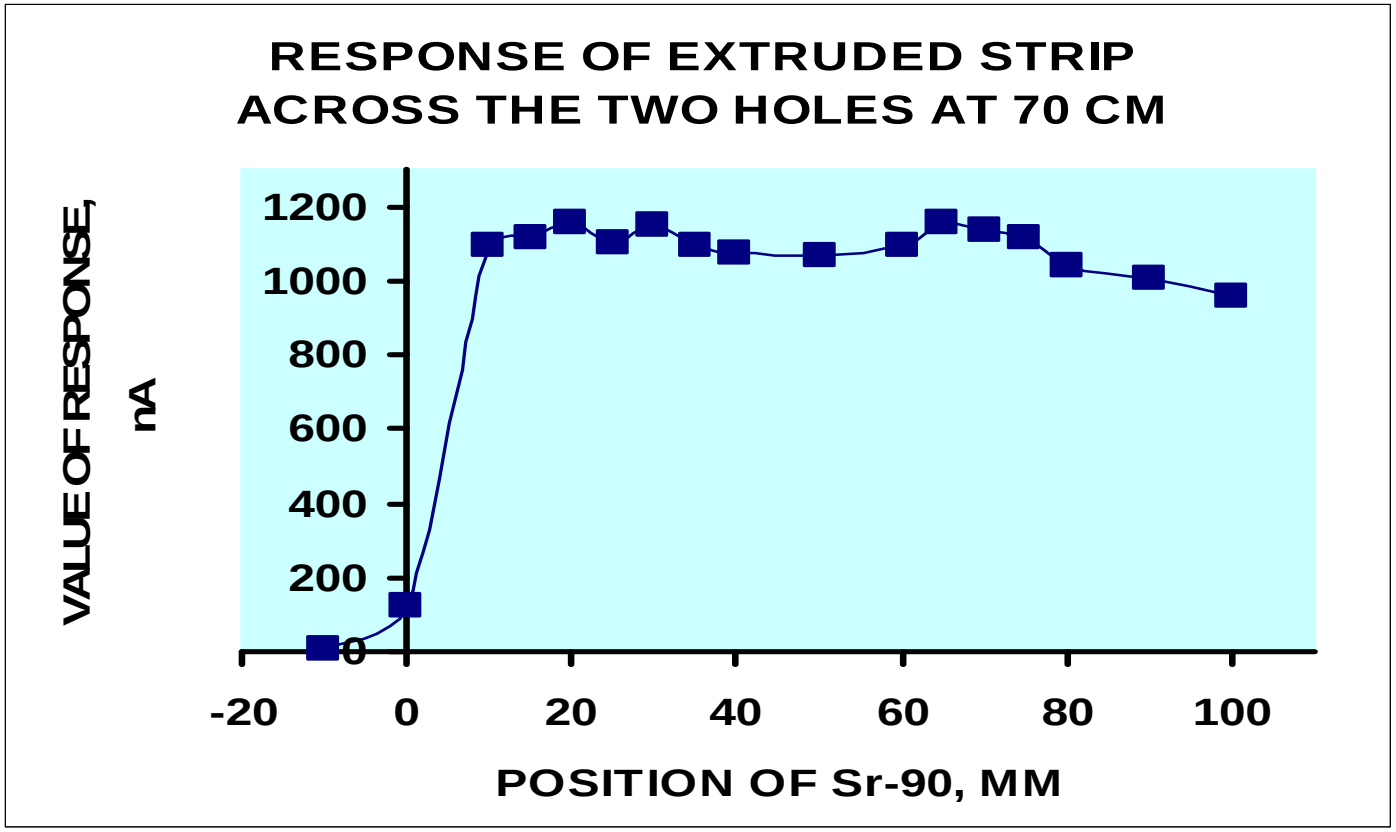


First Measurements



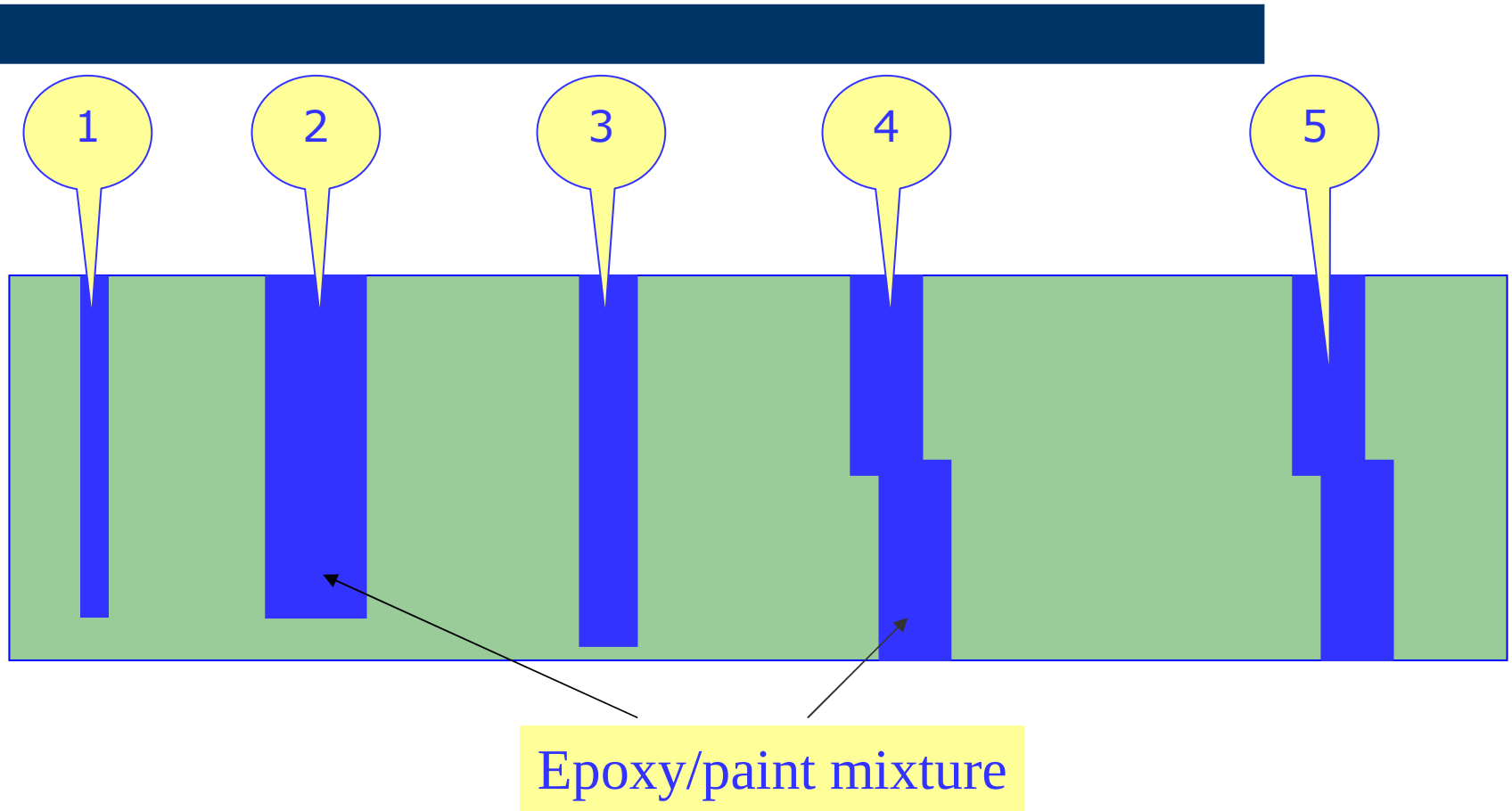


Uniformity

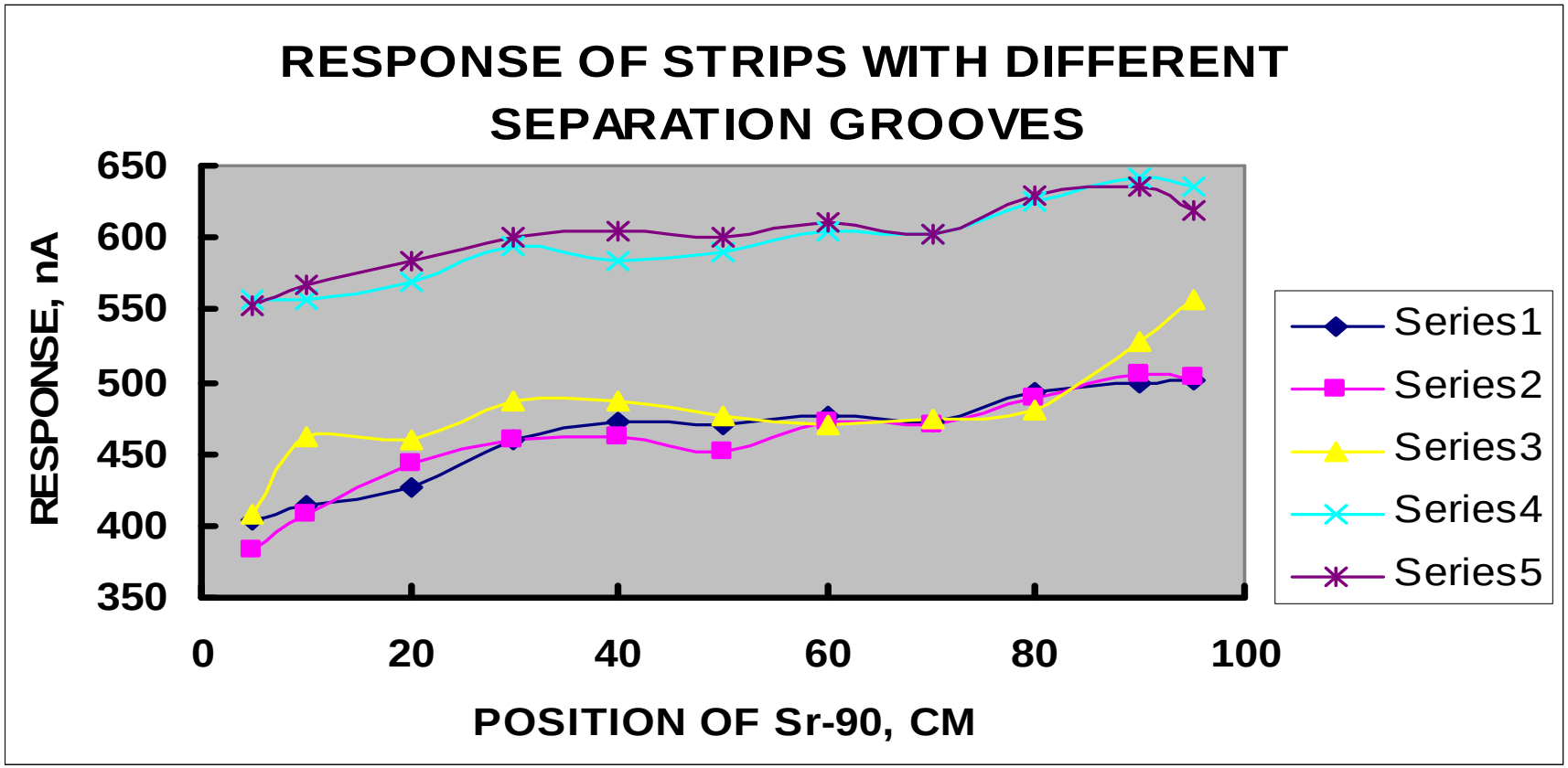

RESPONSE OF EXTRUDED STRIP
ACROSS THE TWO HOLES AT 70 CM
VALUE OF RESPONSE, nA
1200
1000
800
600
400
200
0
-20
0
20
40
60
80
100
POSITION OF Sr-90, MM

Provides better rigidity

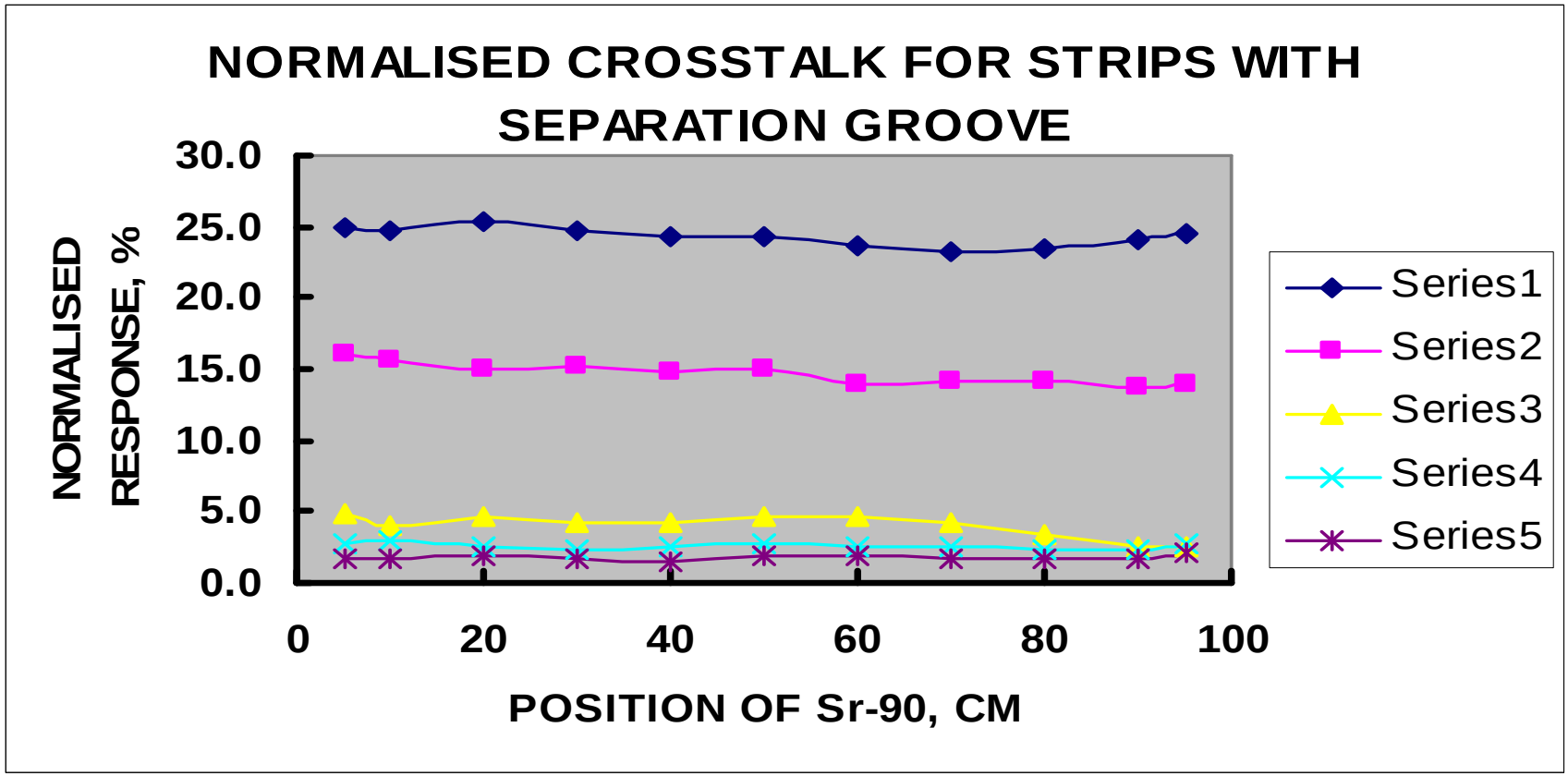
Separation Grooves



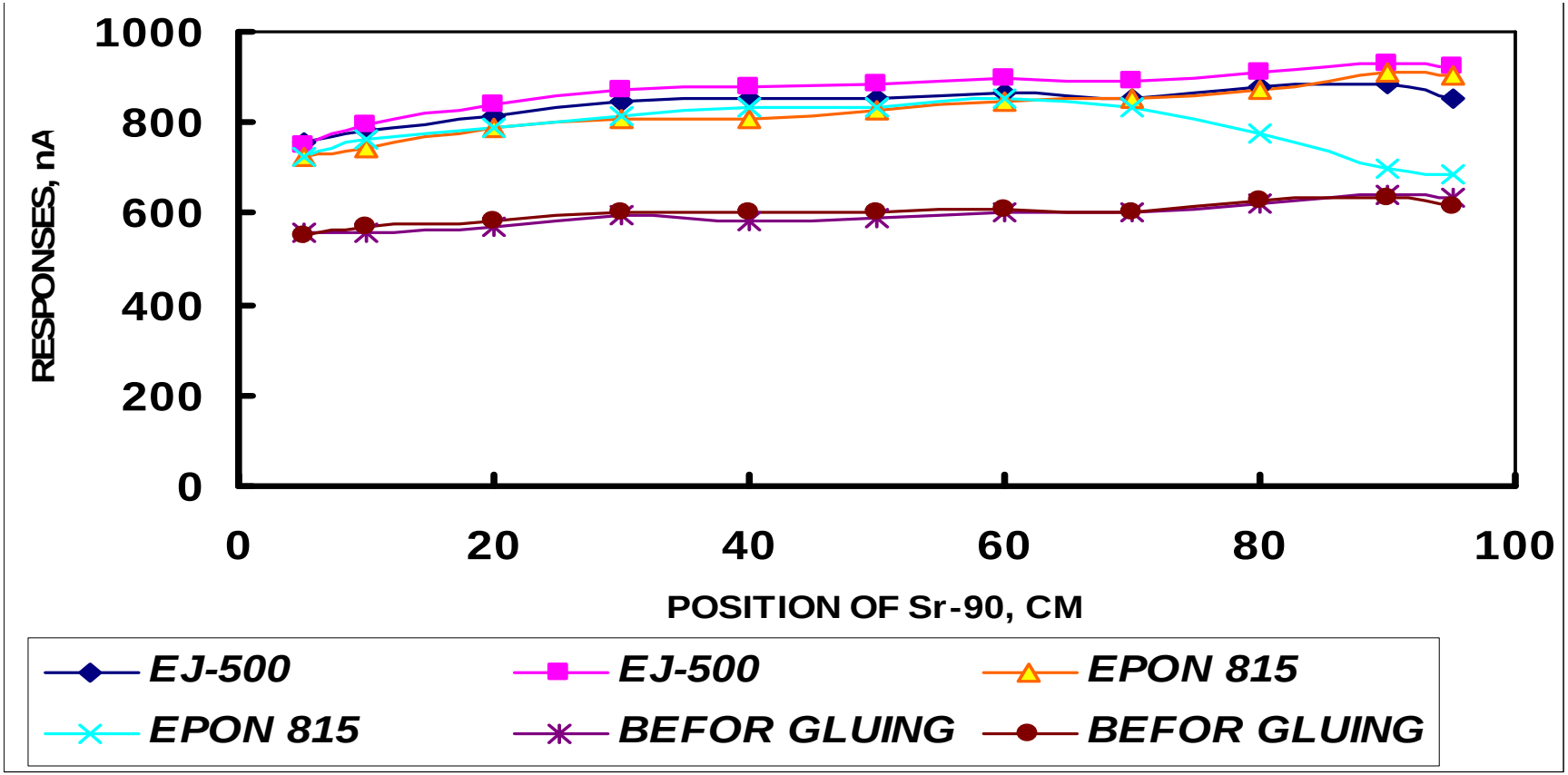
Response


RESPONSE OF STRIPS WITH DIFFERENT SEPARATION GROOVES
RESPONSE, nA
650
600
550
500
450
400
350
0
20
40
60
80
100
POSITION OF Sr-90, CM
Series1
Series2
Series3
Series4
Series5

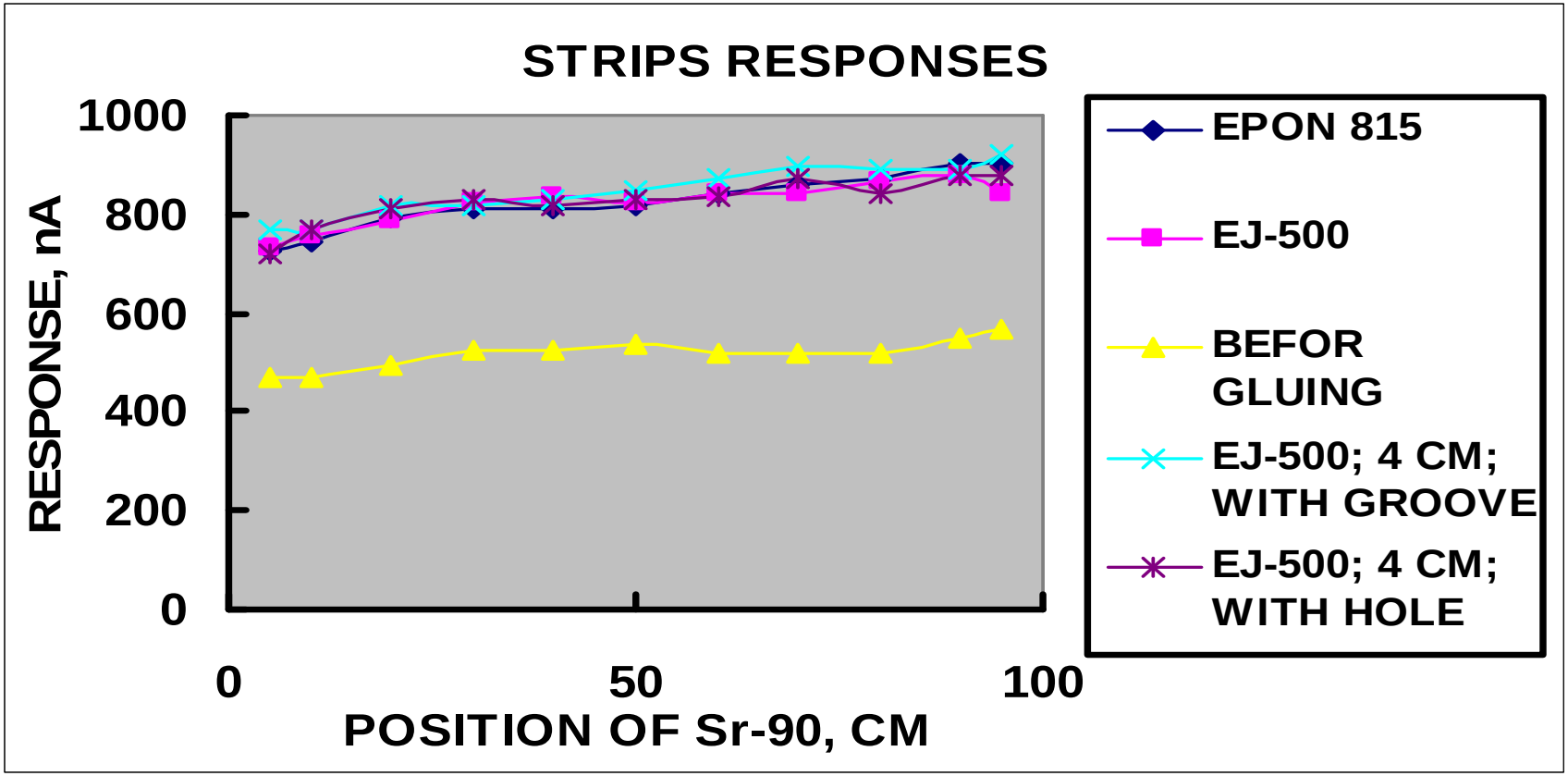
X-talk


NORMALISED CROSSTALK FOR STRIPS WITH SEPARATION GROOVE
NORMALISED RESPONSE, %
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
20
40
60
80
100
POSITION OF Sr-90, CM
Series1
Series2
Series3
Series4
Series5

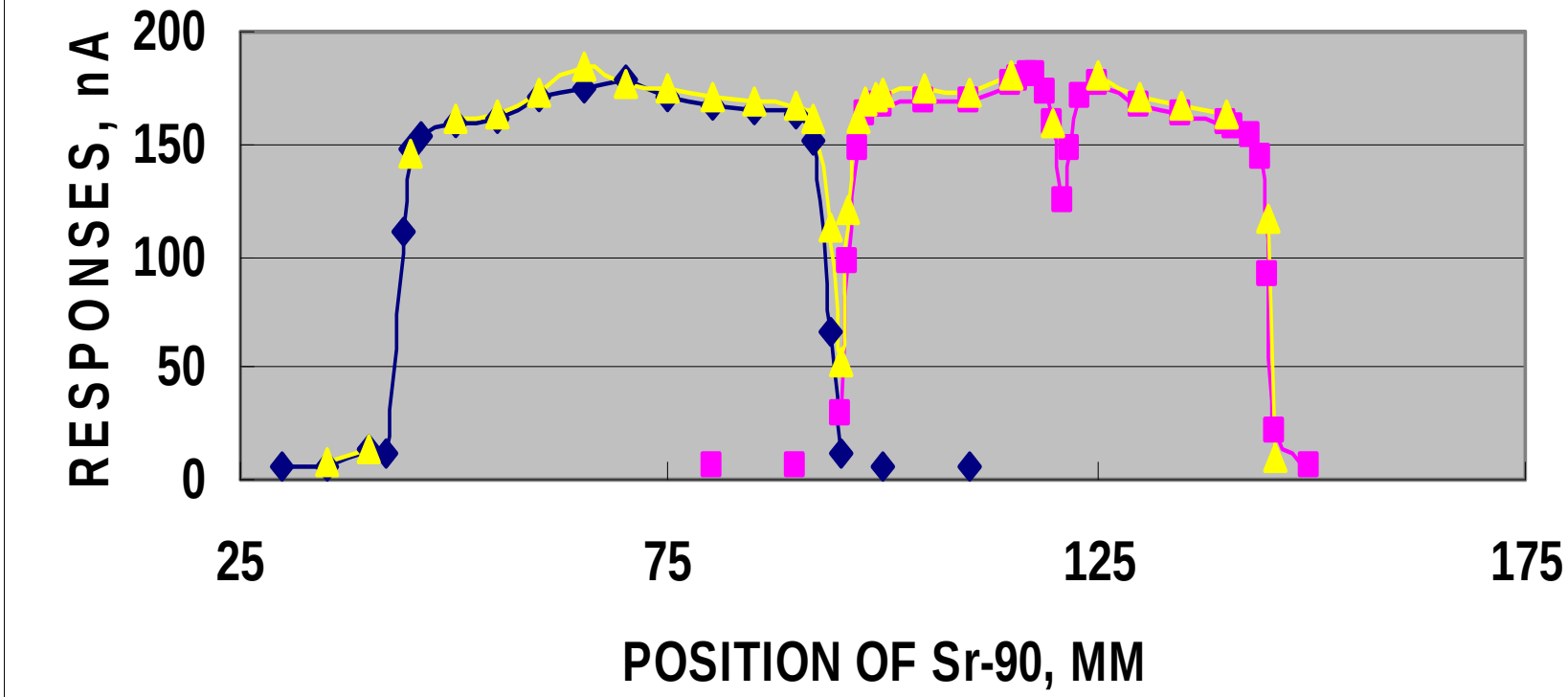
The Power of Glue



Response and Strip Fabrication

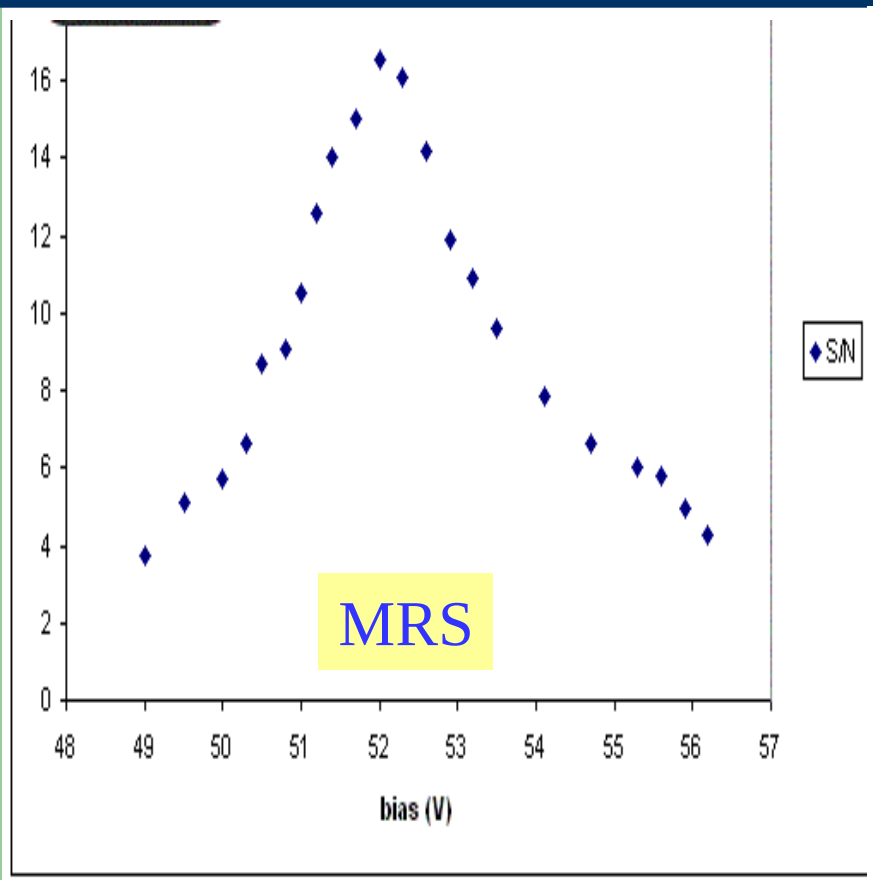


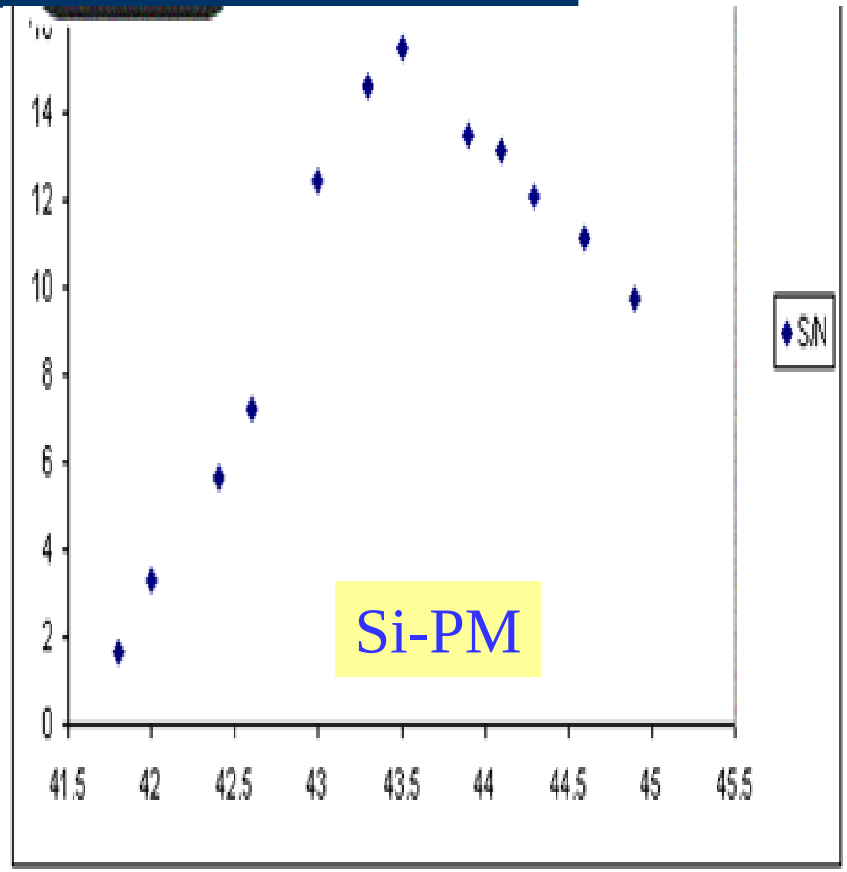
Uniformity Scan



S/N

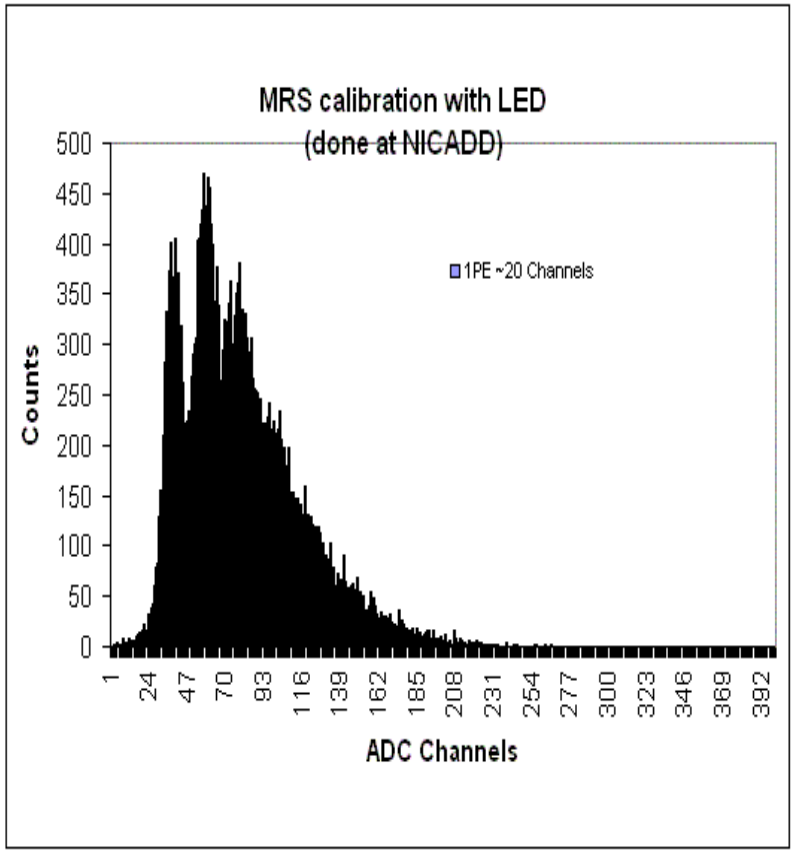
$$\frac{\text{Signal amplitude}}{\text{Noise amplitude}}$$

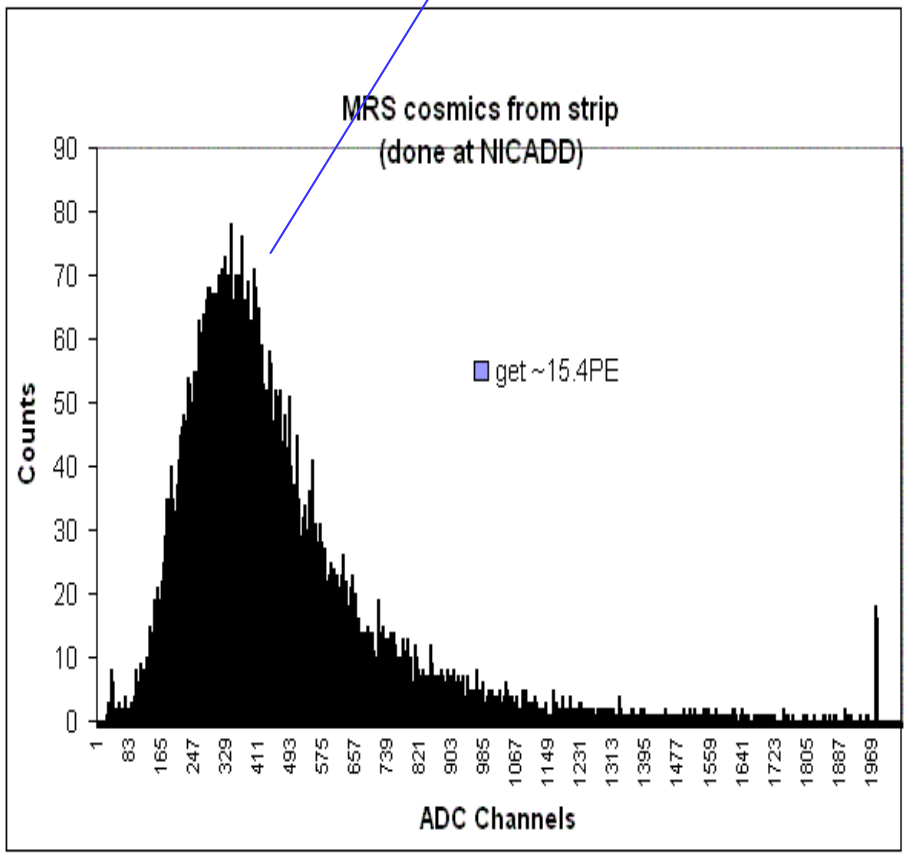




Strip Light Yield

15 p.e.





Summary/Plans

- 5mm thick Fermi-NICADD produced extruded strips used in combination with Si-PM/MRS planned for use in tail-catcher/muon tracker.
- Strip-fiber configuration being finalized.
- Putting together mechanical module to understand and resolve assembly issues.
- Working with Fermi for cart design and construction.

A vigorous program of

LC Detector R&D Underway