Status of GEM DHCAL

Jae Yu

For GEM DHCAL Group

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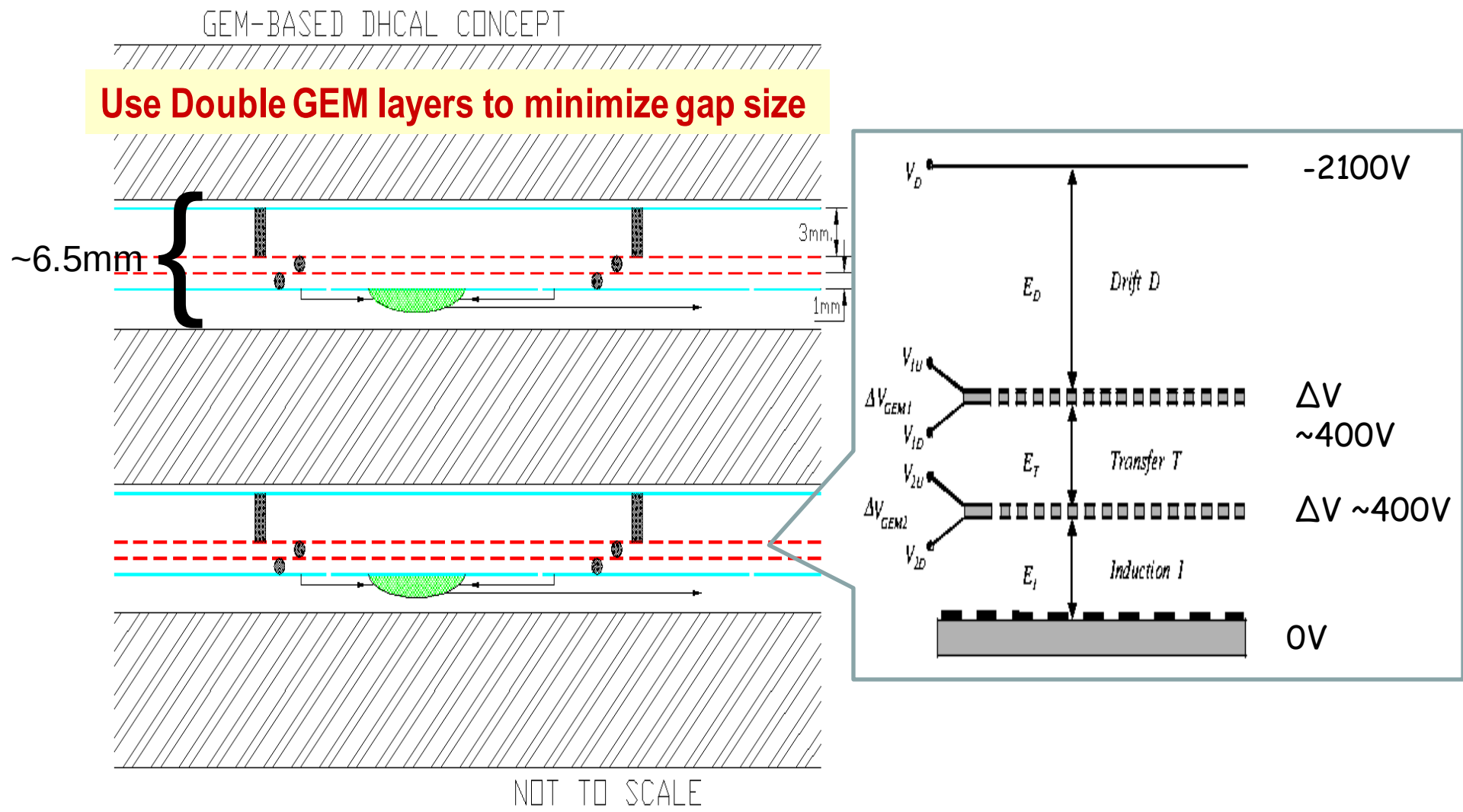
KILC Workshop, KNU

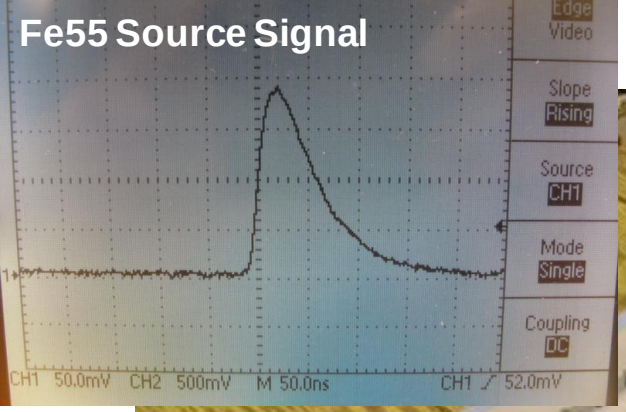
- Introduction
- KPiX V9 and DCAL Integration
- FTBF Beam Test Setup
- Beam Test Analysis Results
- Large Chamber Development
- GEM DHCAL Plans
- Summary

The Goals?

- Develop and construct precision calorimeter for future accelerators
- Demonstrate suitability of DGEM layer as active element of DHCAL
- Construction/testing of DGEM chamber/layers of various sizes – to $1m^2$.
- Study of the response of double-GEM chambers to charged particles
- Use of analog (kPiX) and digital (DCAL) readouts with GEM.
- Debugging series of kPiX chips with SLAC.
- Measurement of DGEM chamber/layer characteristics
- Understanding of issues with chambers/layers (sparks, cross-talk,…)
- Develop large GEM foils with CERN MPGD Workshop.
- Develop design (frame/spacers/gas/HV…) for large chambers (~1m x 33cm).
- Establish operating conditions for large GEM/DHCAL chambers

GEM-based Digital Calorimeter Concept





Gas outlet

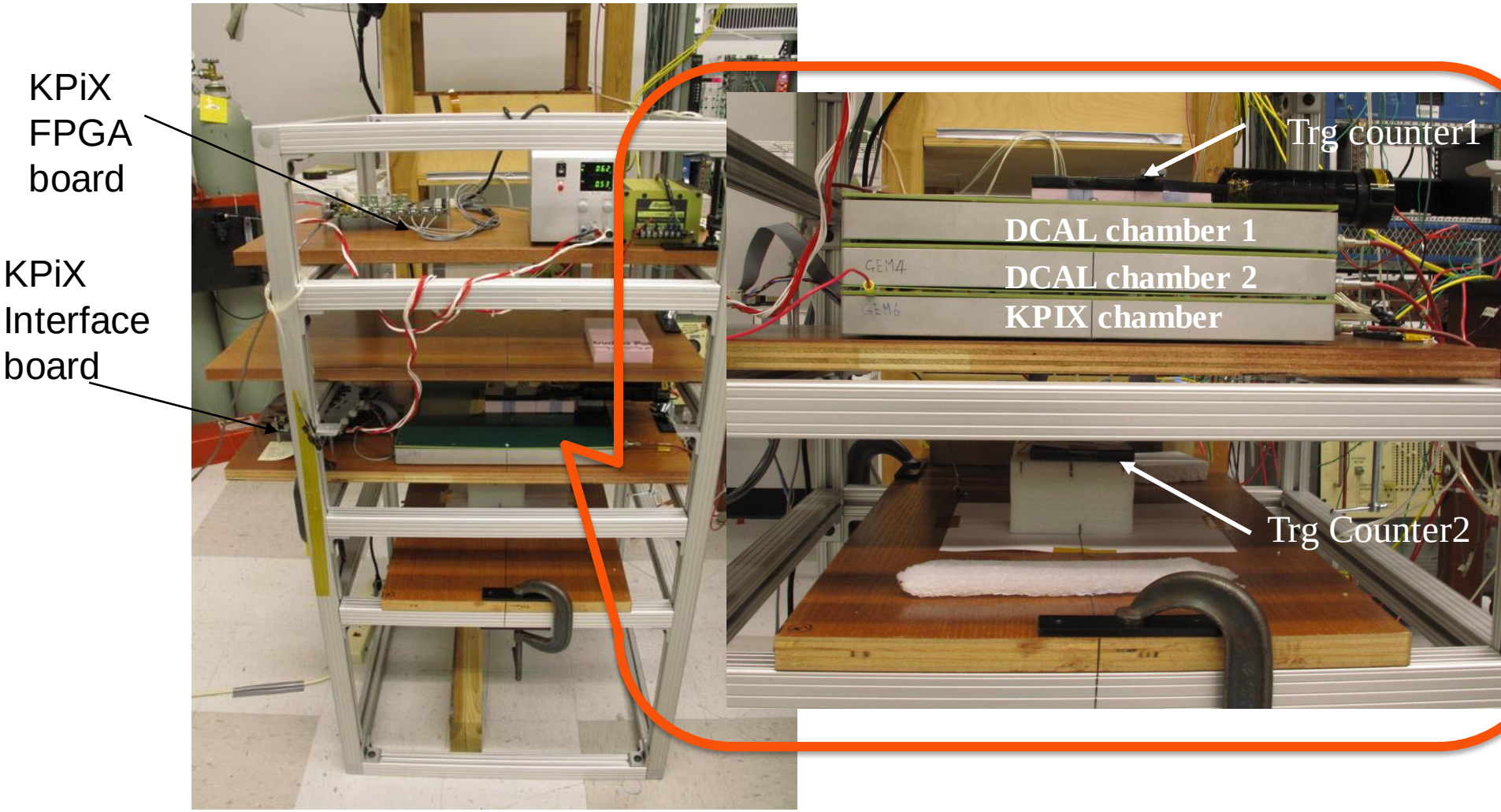
HV power

Analog signal

Data cable

LV power

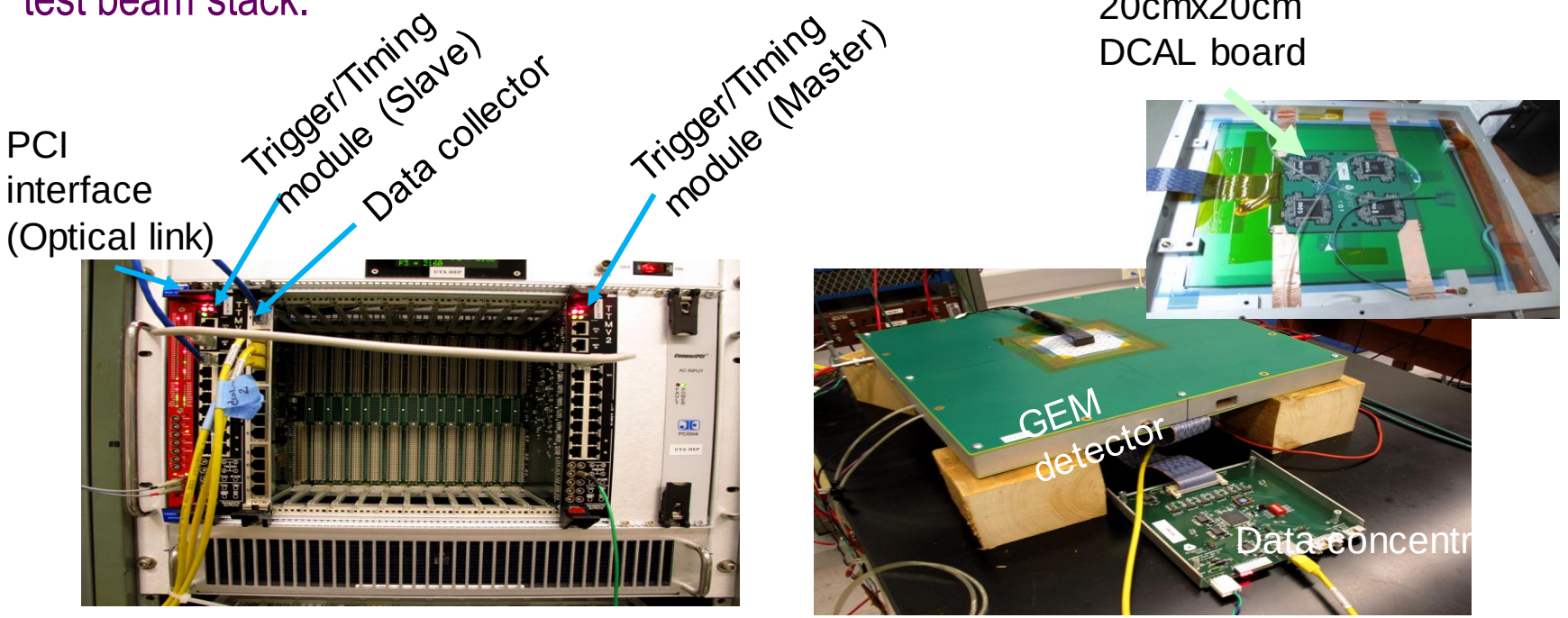
UTA GEM-DHCAL Cosmic Test Stand



GEM Integration with DCAL Chip

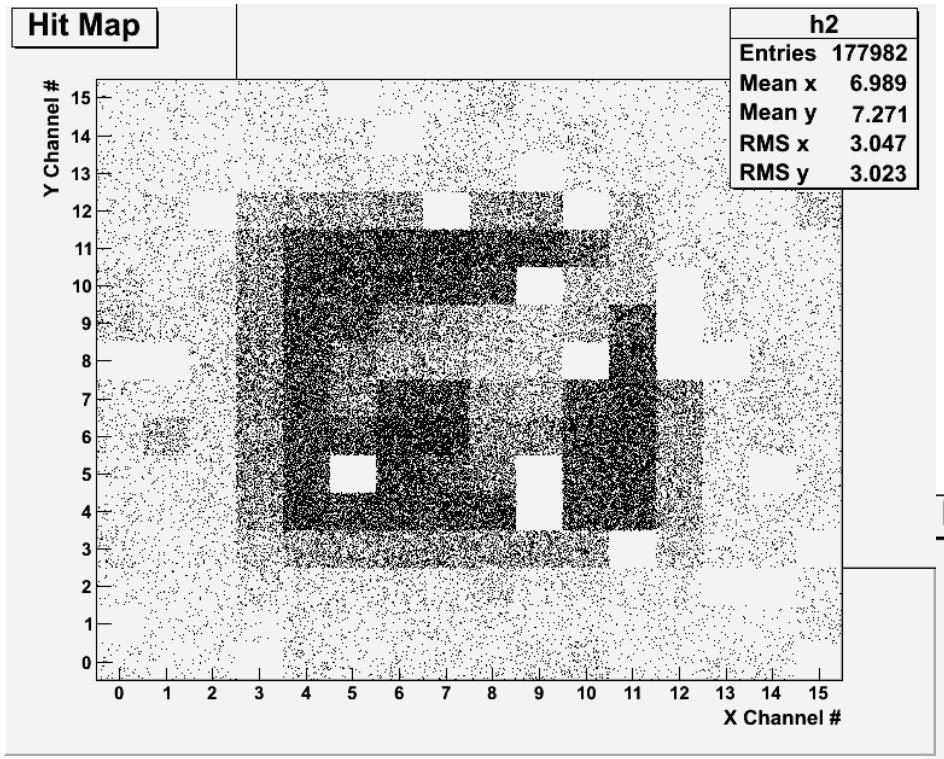
Goal: Enable readout of GEM/DHCAL planes via DCAL as the ultimate readout electronics of a $1m^3$ stack ➔ Chip has been battle tested!!

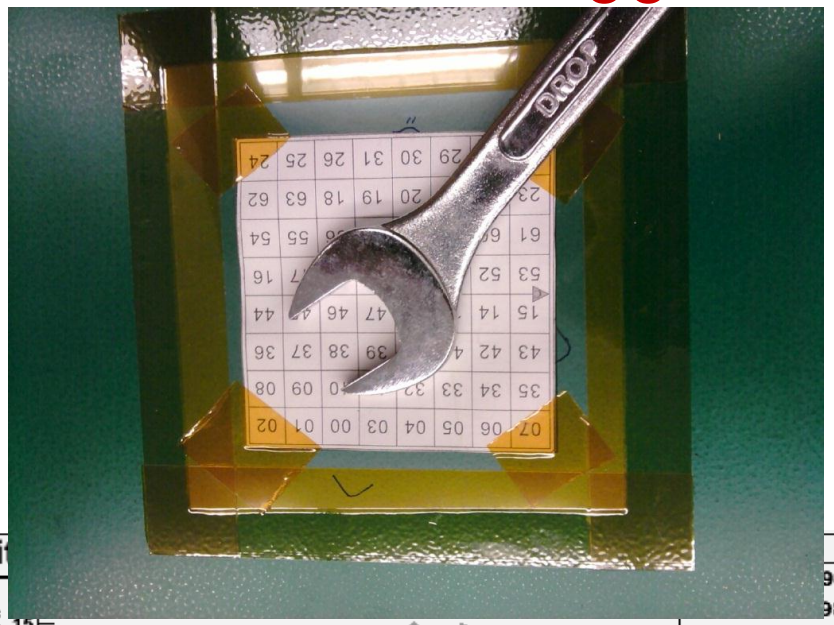
- Use DCAL in high-gain mode to establish MIP signals.
- Determined noise level for DCAL/GEM combination
- Determined operating threshold(s) for DCAL
- Determine efficiency/uniformity/multiplicity for GEM/DCAL
- Understand issues of using DCAL readout system with $1m^2$ GEM/DHCAL planes in a test beam stack.

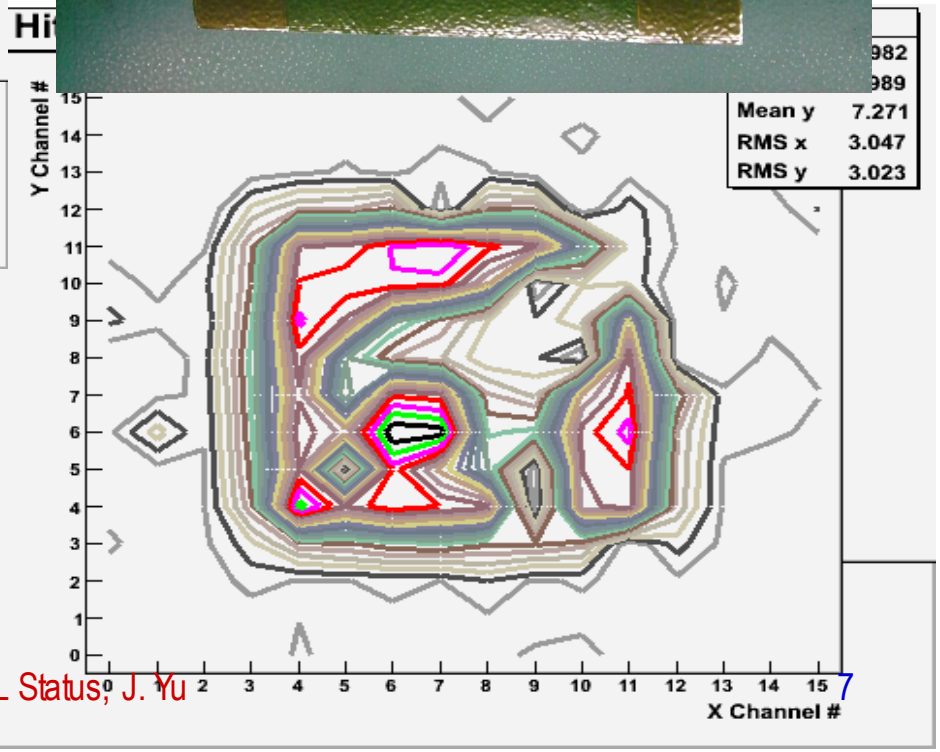


*Many thanks to ANL colleagues! J. Repond, L. Xia, G. Drake, J. Schlereth, J. Smith (UTA student at ANL) and H. Weerts.

Radioactive Source Run with Internal Trigger



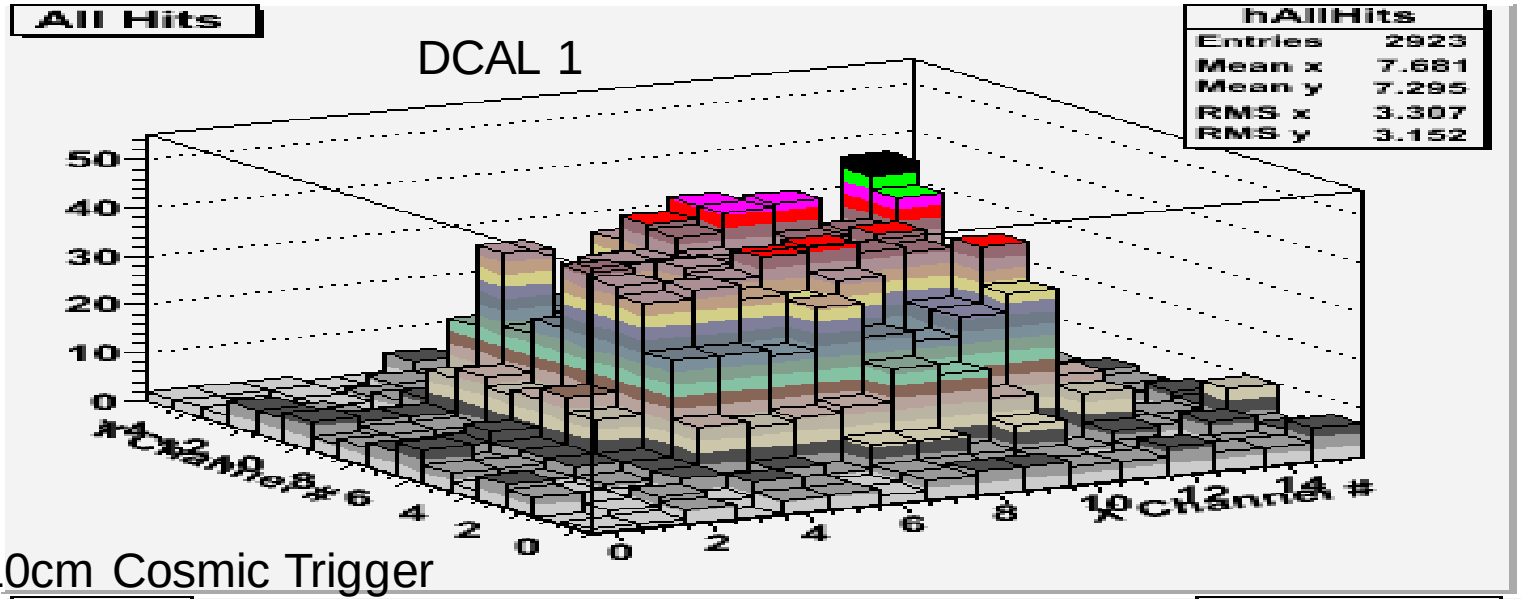




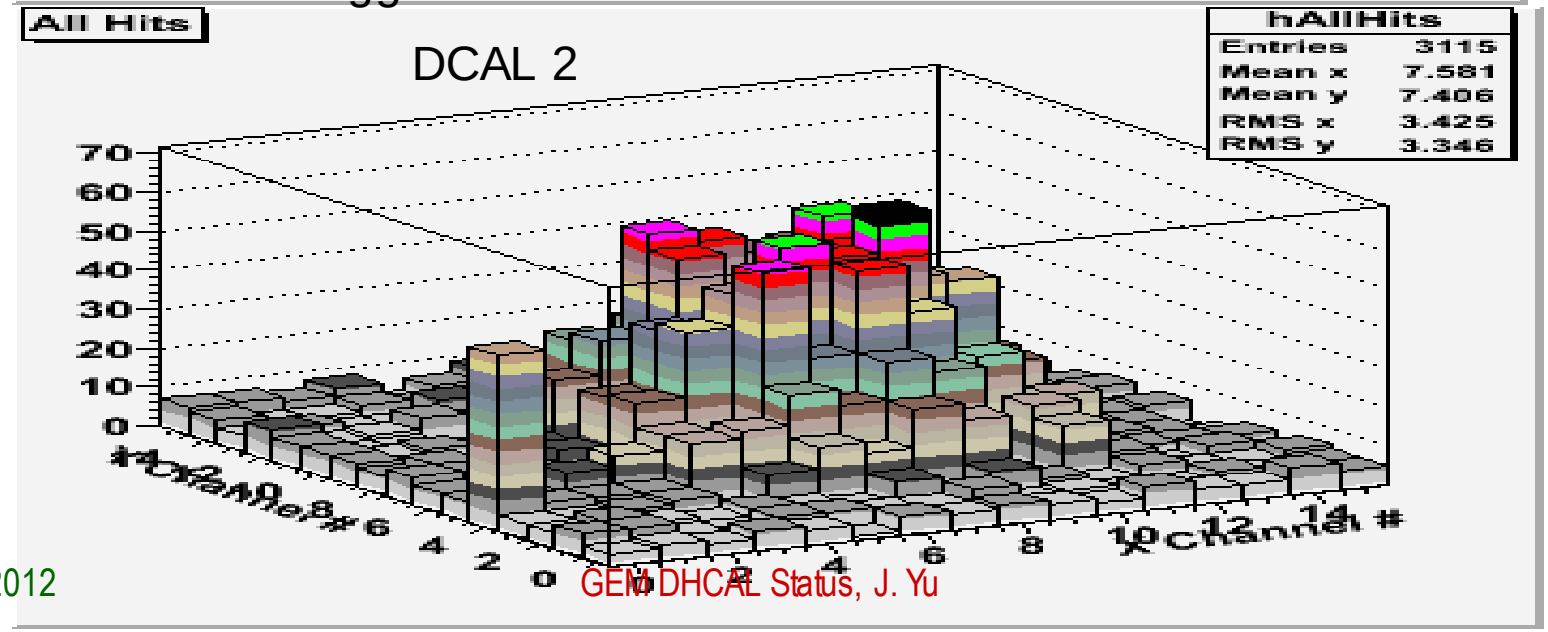
Noisy channels masked out!

Can you see what the object is?

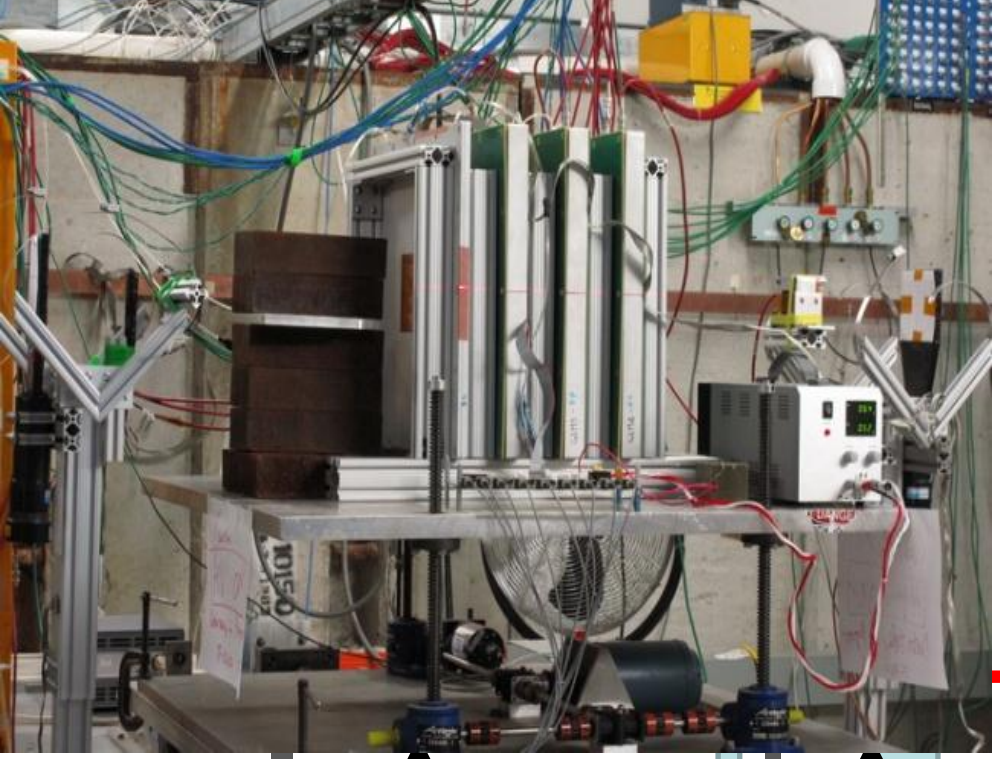
Cosmic Rays with DCAL and Ext. Trg

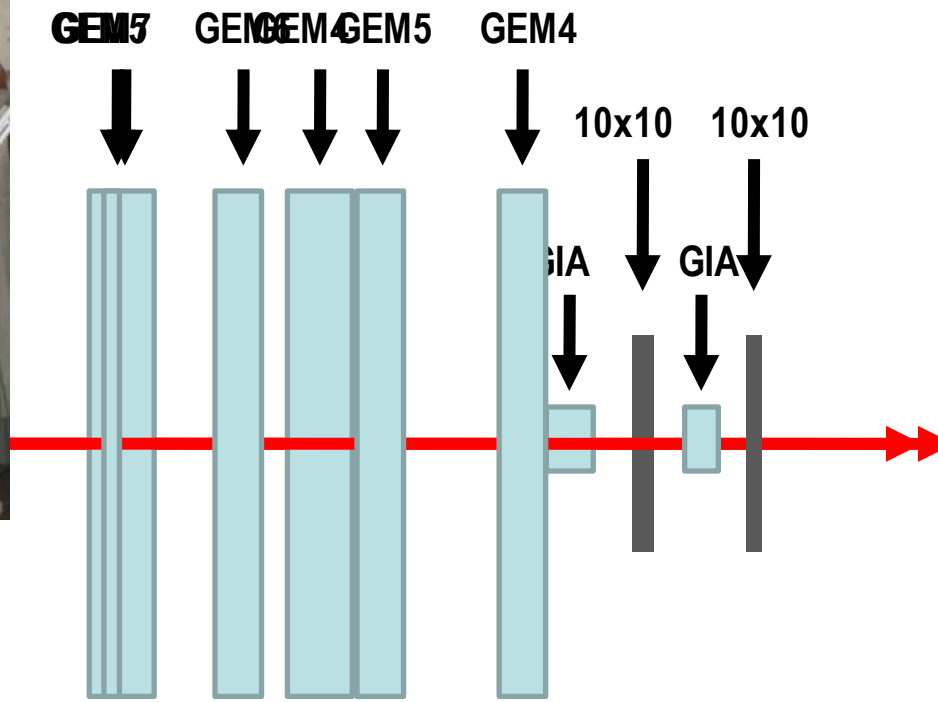


10cmx10cm Cosmic Trigger



riment Setup





GEM6: Read out by 13bit KPiX designed for the ILC time line
GEM7, GEM5, GEM4: Read out by 1bit DCAL chip by ANL and FNAL
GIA: Medical image intensifier prototype with 12 bit ADC in-house readout
Triggers formed off the motion table:

1. 10x10 coincidences for guaranteed beam penetration through the detector array
2. 2x3 coincidences arranged perpendicular to each other for 2x2 coverage in the center of the detector array
3. Coincidence of 1*2: Guaranteed beam penetration with center 2x2 coverage (efficiency ~95%)

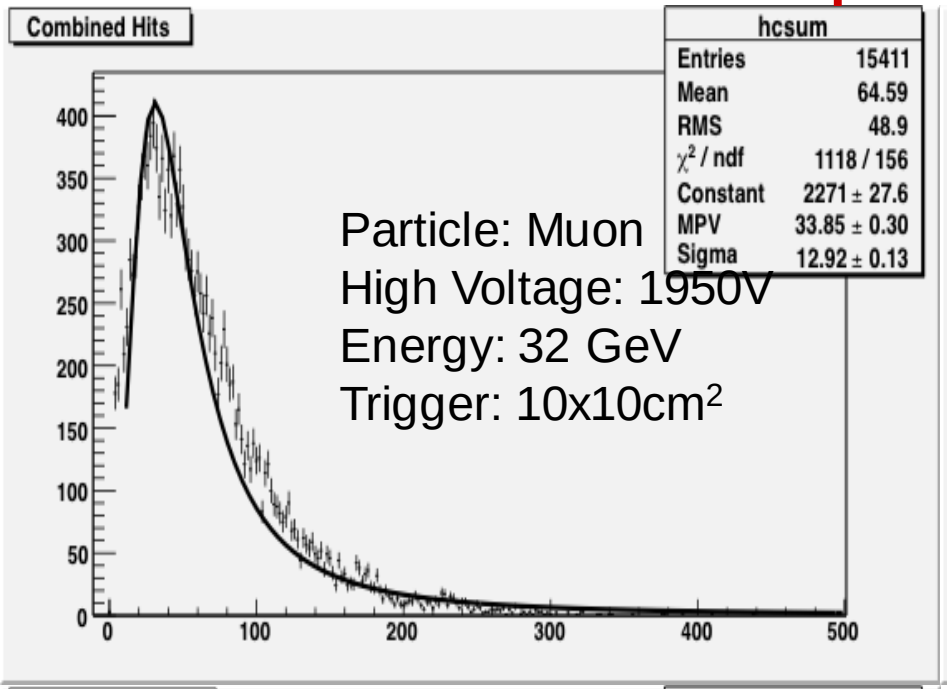
GEM(T-1010) Test Beam Run Plans

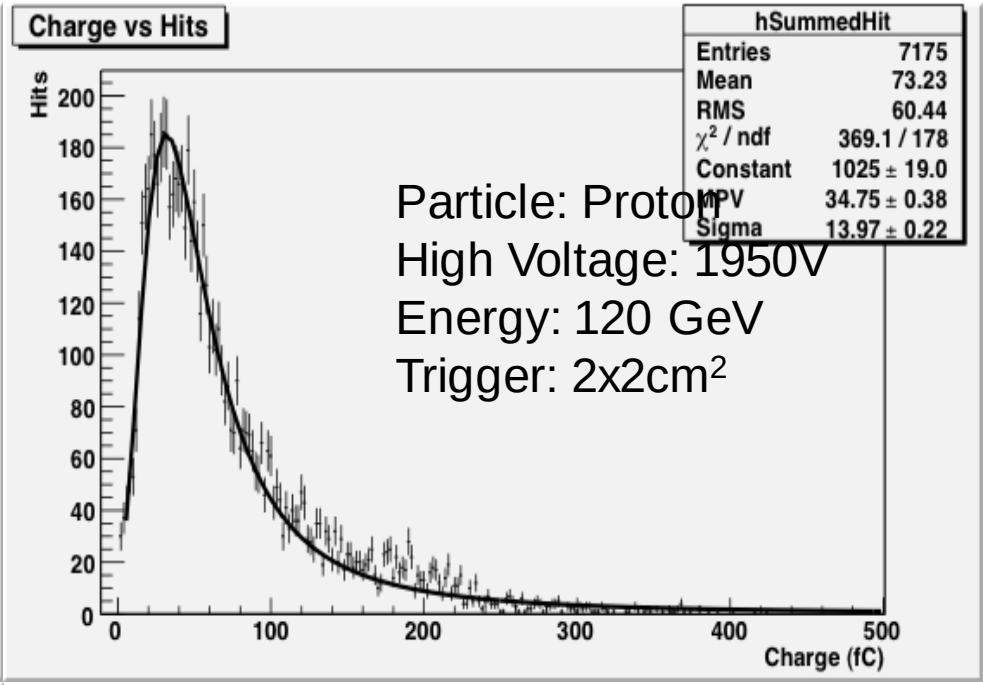
- Response run
  - Measure chamber responses
- DCAL THRESHOLD SCAN
  - Measure efficiency vs threshold
  - Determine the optimal threshold for the three chambers
- HV SCAN
  - Measure response, gain and efficiency vs HV
- POSITION SCAN
  - Measure response, efficiency vs position and determine the uniformity of the chamber efficiencies
- PION RESPONSE & PION SHOWER
  - Measure particle dependence of the chamber responses & test operation under multiple hit environment
- NOISE: Run overnight everyday with random noise trigger ➔ measure noise rate per trigger per pad to 1% precision

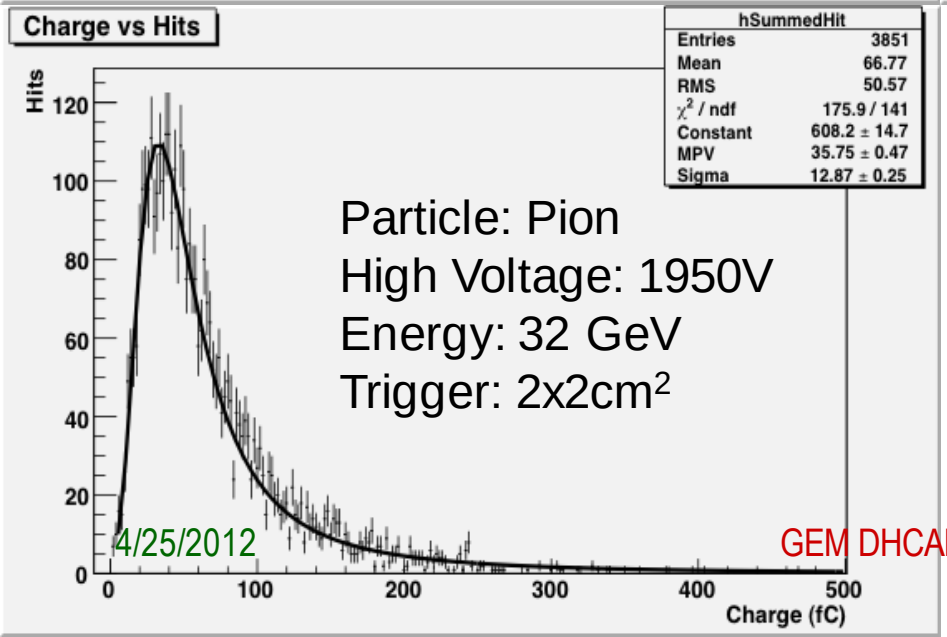
GEM TB Run Schedule

- 32 GeV Muons: first 3 days (8/3 – 8/5)
  - KPiX Resposne
  - DCAL Threshold scan
- 120GeV Protons: 10 days (8/6 – 8/15)
  - KPiX and DCAL HV Scan
  - KPiX and DCAL Position Scan
  - KPiX Response and efficiency
  - DCAL Threshold vs efficiency
  - GIA Response and HV Scan
- 32GeV Pions: 1 day (8/16)
  - KPiX, DCAL and GIA Response
  - GIA HV Scan
  - Pion shower caused by 8in steel bricks in front of the chamber array
- Took over 7M beam events in total of 12.5 days out of 14 days

GEM Response with KPiX

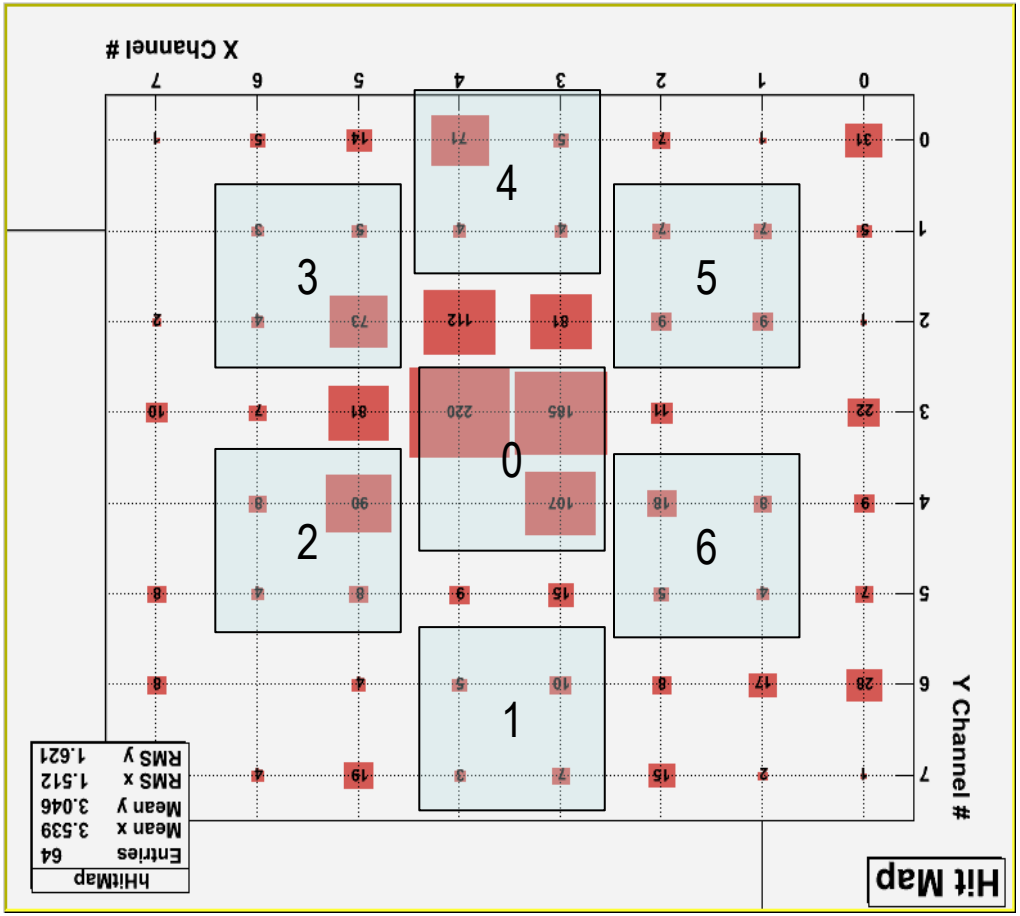






Preliminary results
Pressure corrected

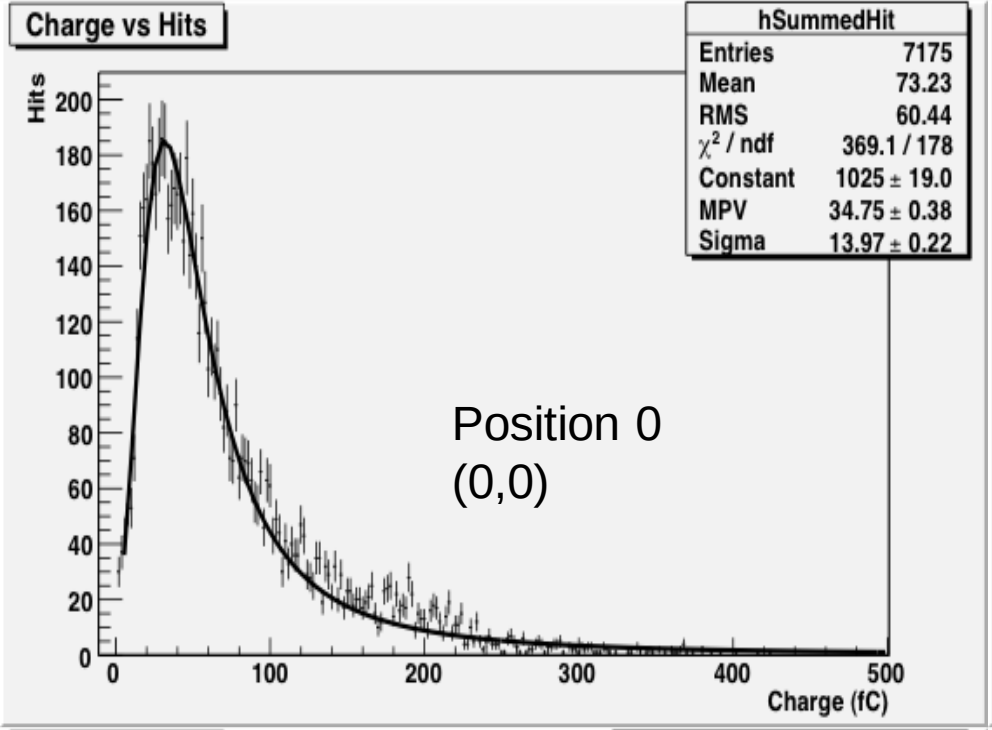
Position scan/hit map

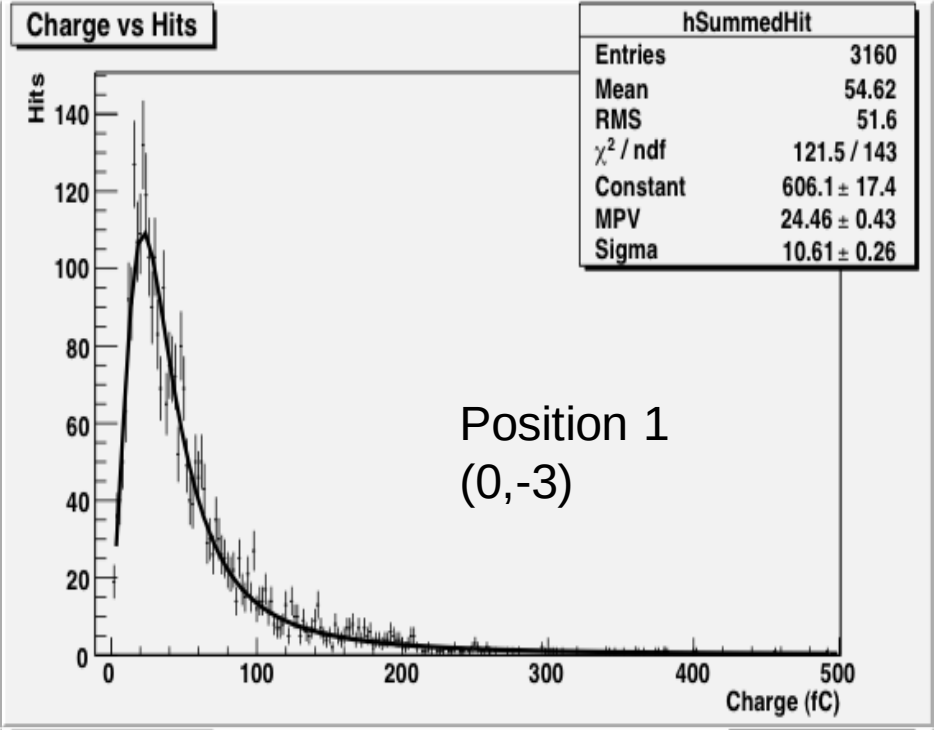


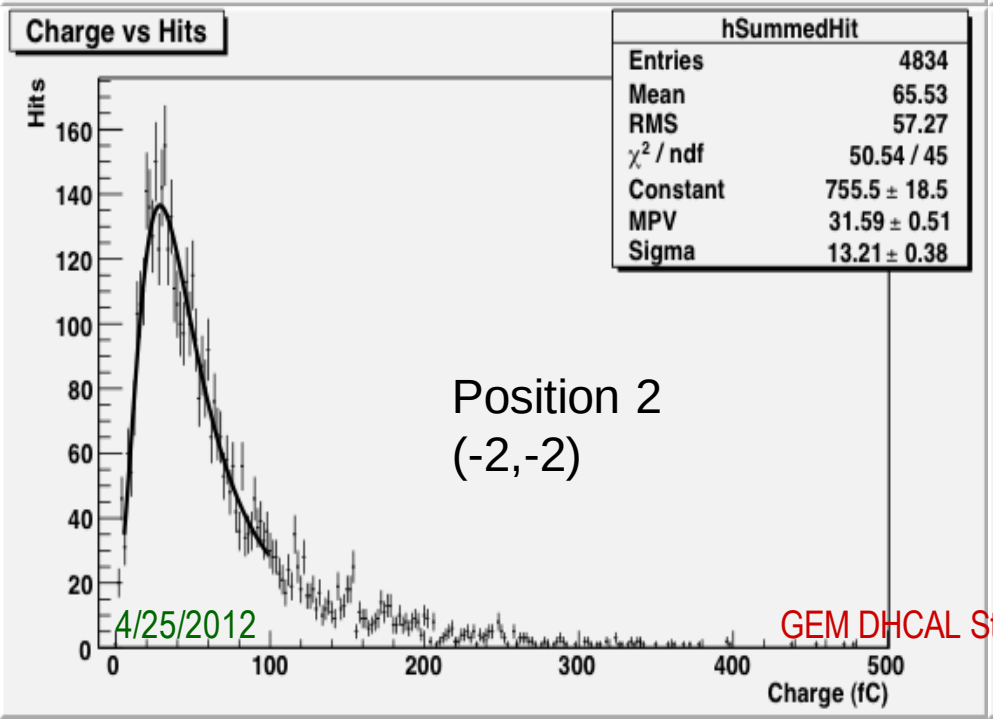
127	126	95	94	63	62	31	30
255	254	223	222	191	190	159	158
383	382	351	350	319	318	287	286
511	510	479	478	447	446	415	414
385	384	417	416	449	448	481	480
257	256	289	288	321	320	353	352
129	128	161	160	193	192	225	224
1	0	33	32	65	64	97	96

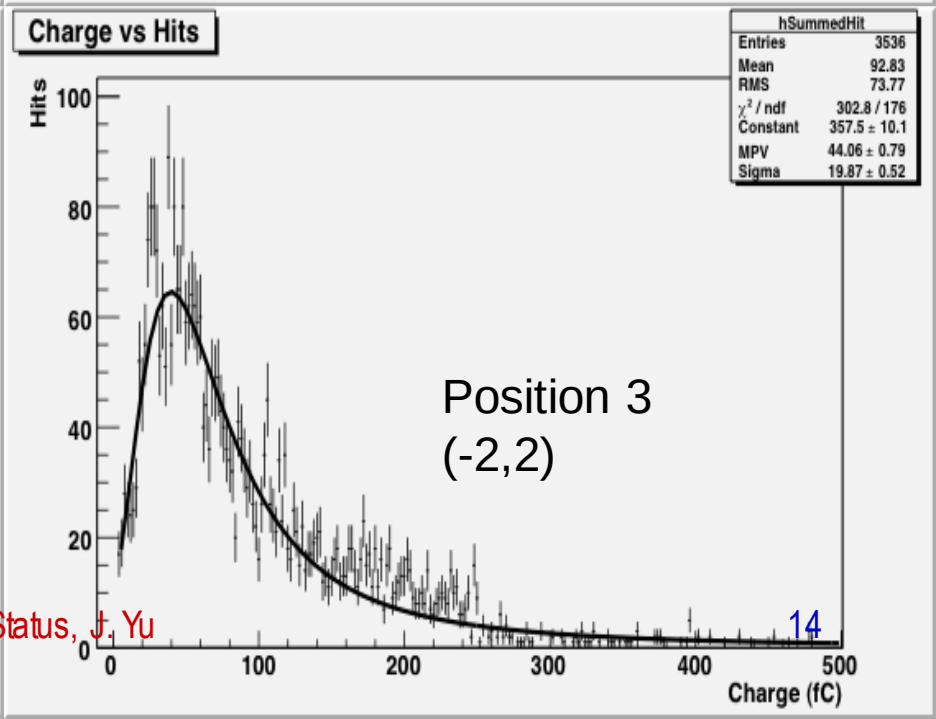
All data pressure corrected

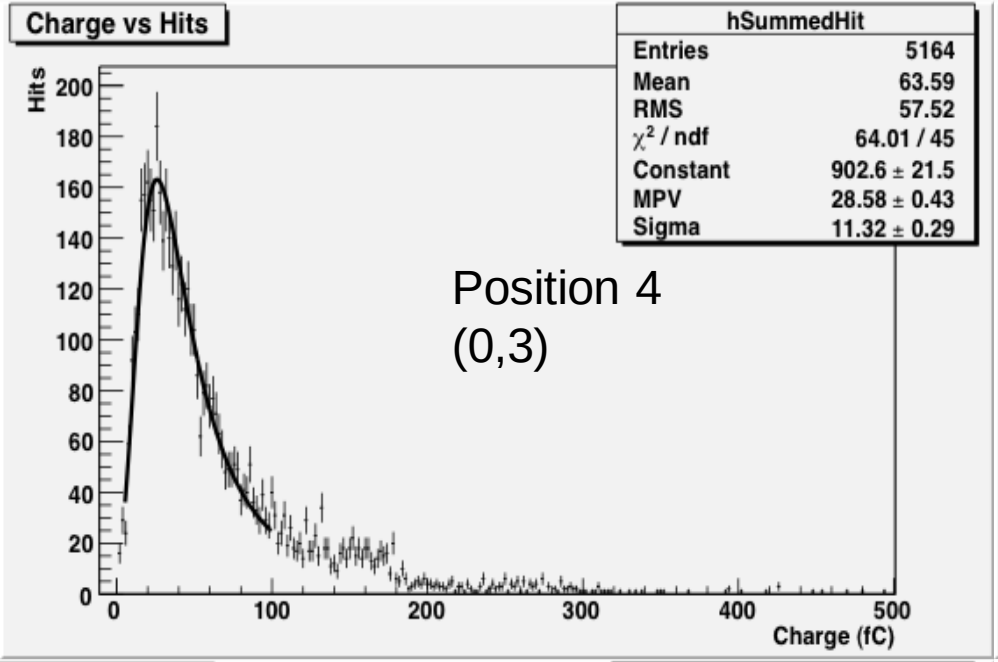
Some data points need to be refit

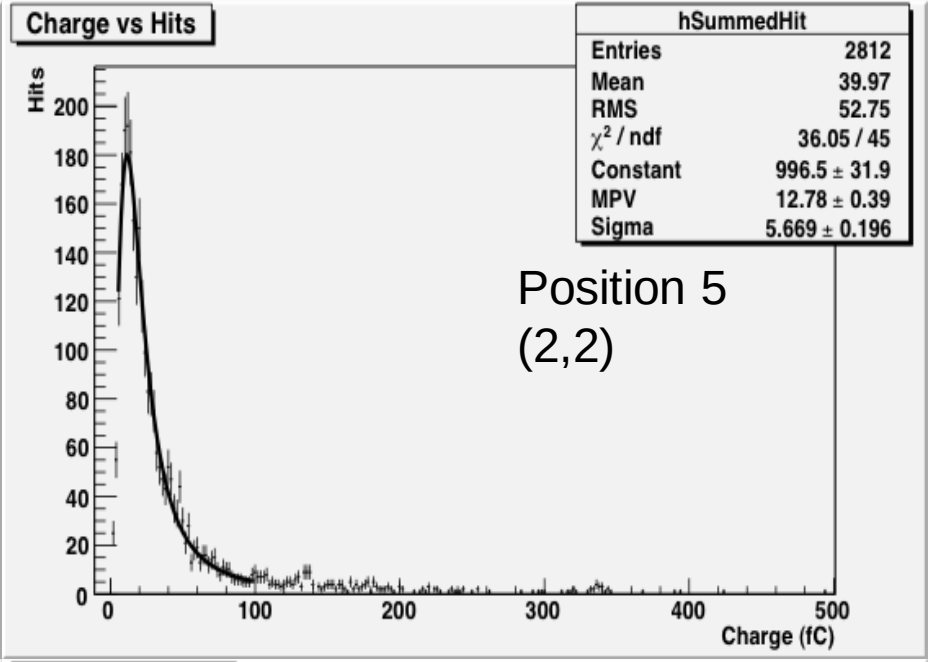

Charge vs Hits
hSummedHit
Entries 7175
Mean 73.23
RMS 60.44
χ² / ndf 369.1 / 178
Constant 1025 ± 19.0
MPV 34.75 ± 0.38
Sigma 13.97 ± 0.22
Hits
Charge (fC)
Position 0
(0,0)

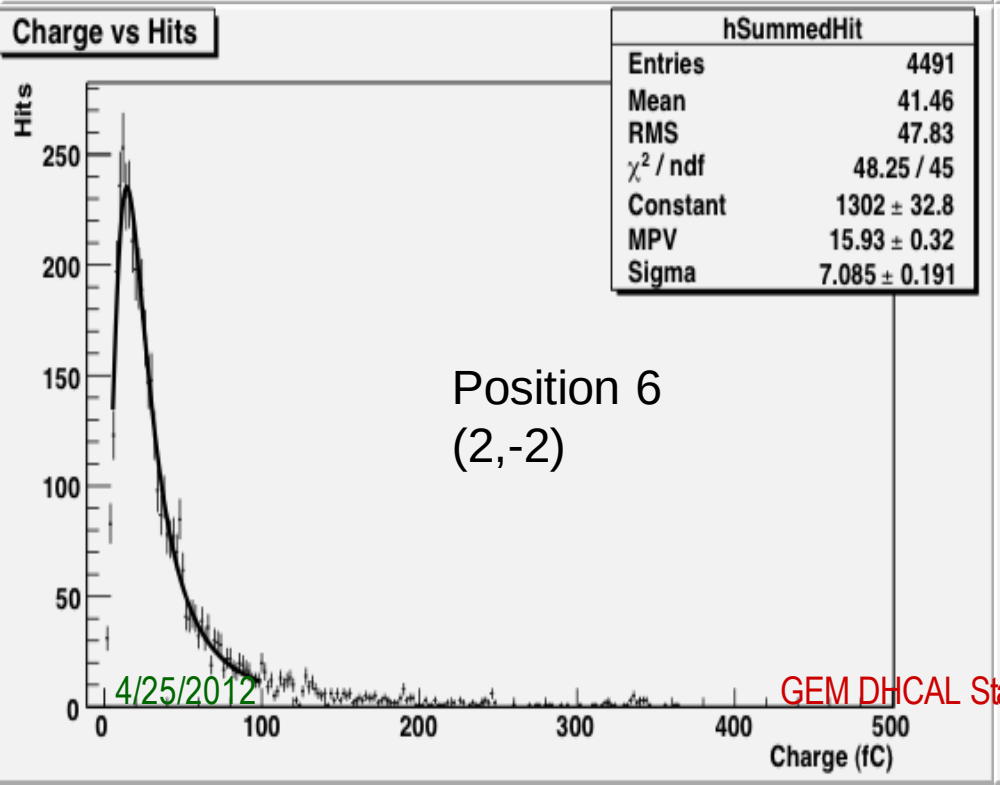

Charge vs Hits
hSummedHit
Entries 3160
Mean 54.62
RMS 51.6
χ² / ndf 121.5 / 143
Constant 606.1 ± 17.4
MPV 24.46 ± 0.43
Sigma 10.61 ± 0.26
Hits
Charge (fC)
Position 1
(0,-3)

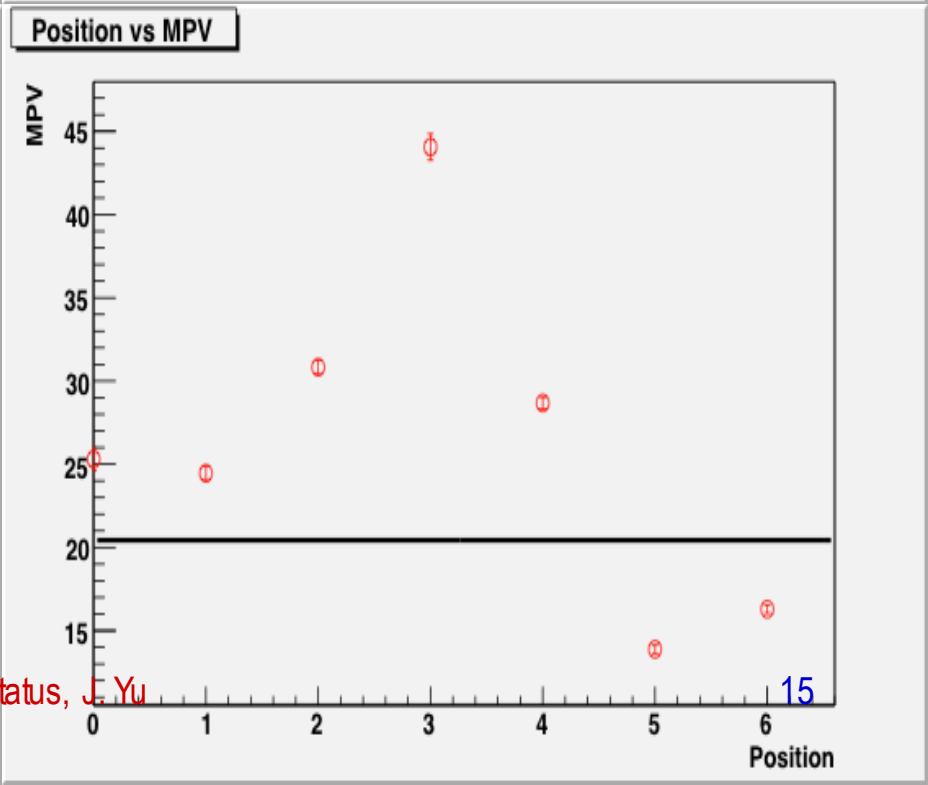

Charge vs Hits
hSummedHit
Entries 4834
Mean 65.53
RMS 57.27
χ² / ndf 50.54 / 45
Constant 755.5 ± 18.5
MPV 31.59 ± 0.51
Sigma 13.21 ± 0.38
Hits
Charge (fC)
Position 2
(-2,-2)


Charge vs Hits
hSummedHit
Entries 3536
Mean 92.83
RMS 73.77
χ² / ndf 302.8 / 176
Constant 357.5 ± 10.1
MPV 44.06 ± 0.79
Sigma 19.87 ± 0.52
Hits
Charge (fC)
Position 3
(-2,2)

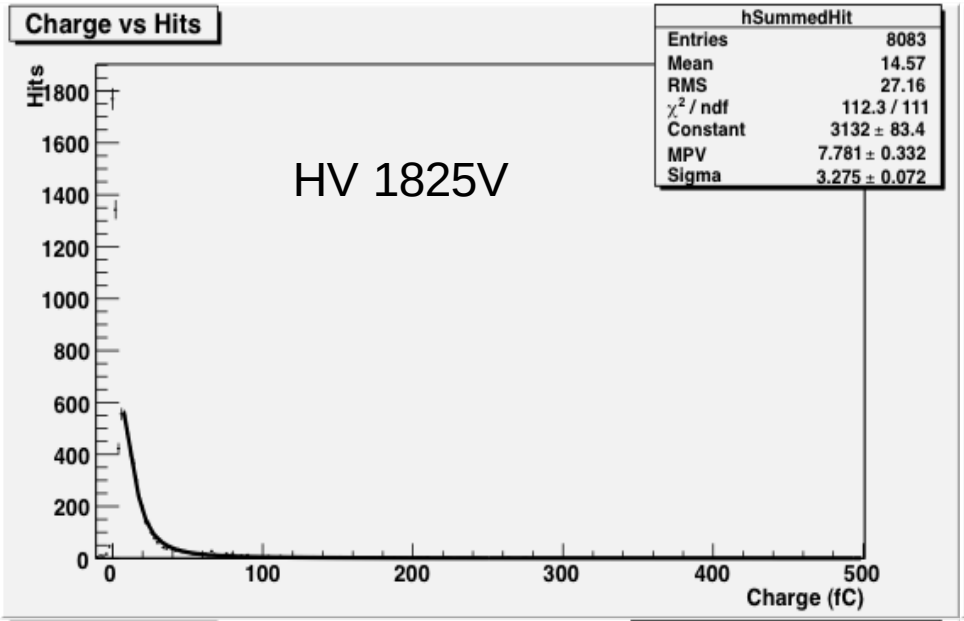

Charge vs Hits
hSummedHit
Entries 5164
Mean 63.59
RMS 57.52
χ² / ndf 64.01 / 45
Constant 902.6 ± 21.5
MPV 28.58 ± 0.43
Sigma 11.32 ± 0.29
Hits
Charge (fC)
Position 4
(0,3)

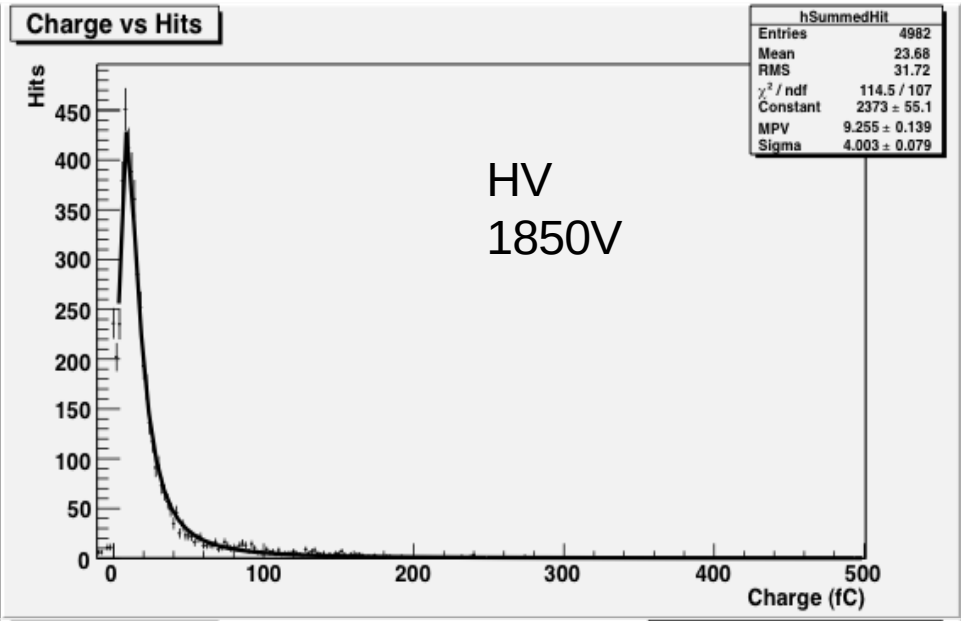

Charge vs Hits
hSummedHit
Entries 2812
Mean 39.97
RMS 52.75
χ² / ndf 36.05 / 45
Constant 996.5 ± 31.9
MPV 12.78 ± 0.39
Sigma 5.669 ± 0.196
Hits
Charge (fC)
Position 5
(2,2)

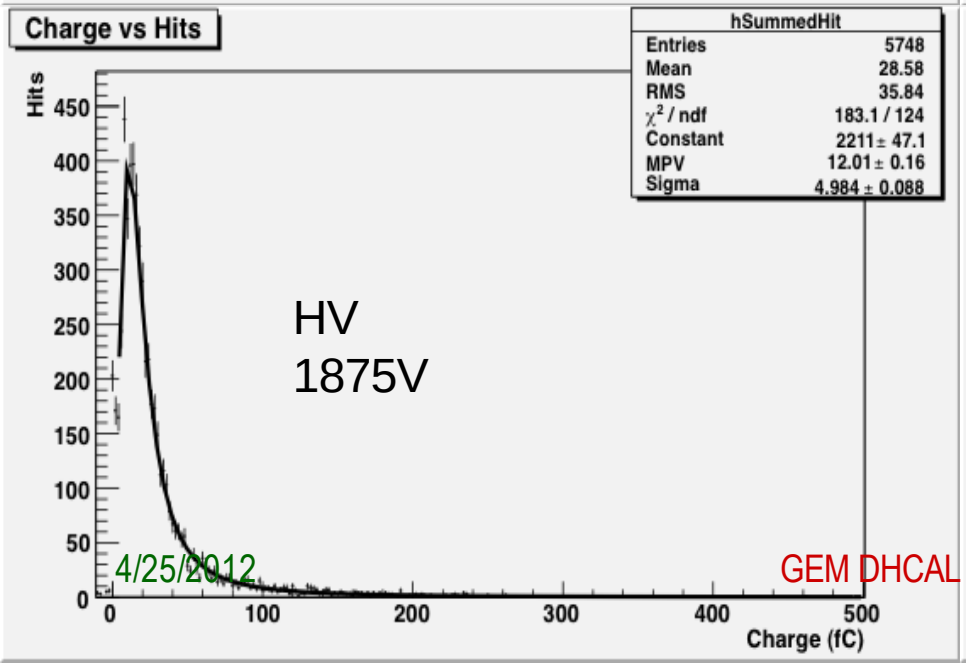

Charge vs Hits
hSummedHit
Entries 4491
Mean 41.46
RMS 47.83
χ² / ndf 48.25 / 45
Constant 1302 ± 32.8
MPV 15.93 ± 0.32
Sigma 7.085 ± 0.191
Hits
Charge (fC)
Position 6
(2,-2)

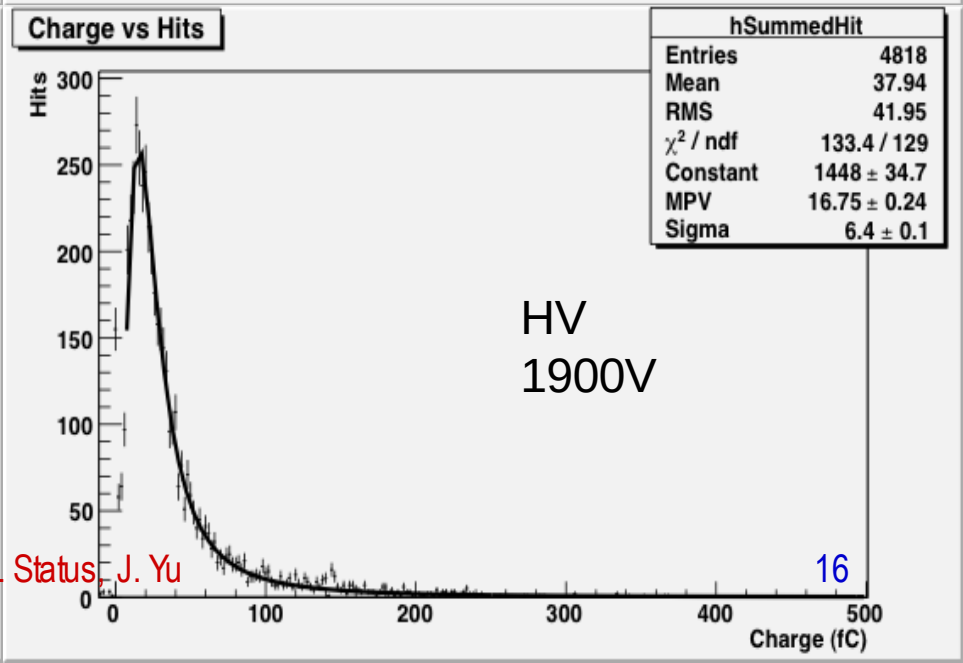

Position vs MPV
MPV
Position

HV Dependence and Gains (KPiX)

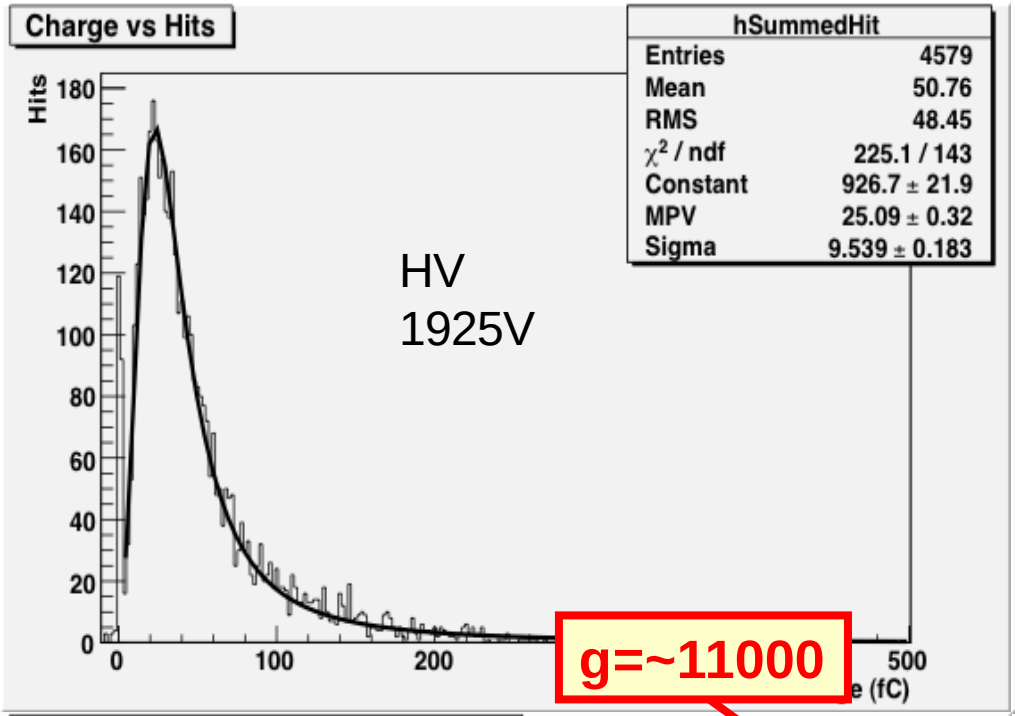


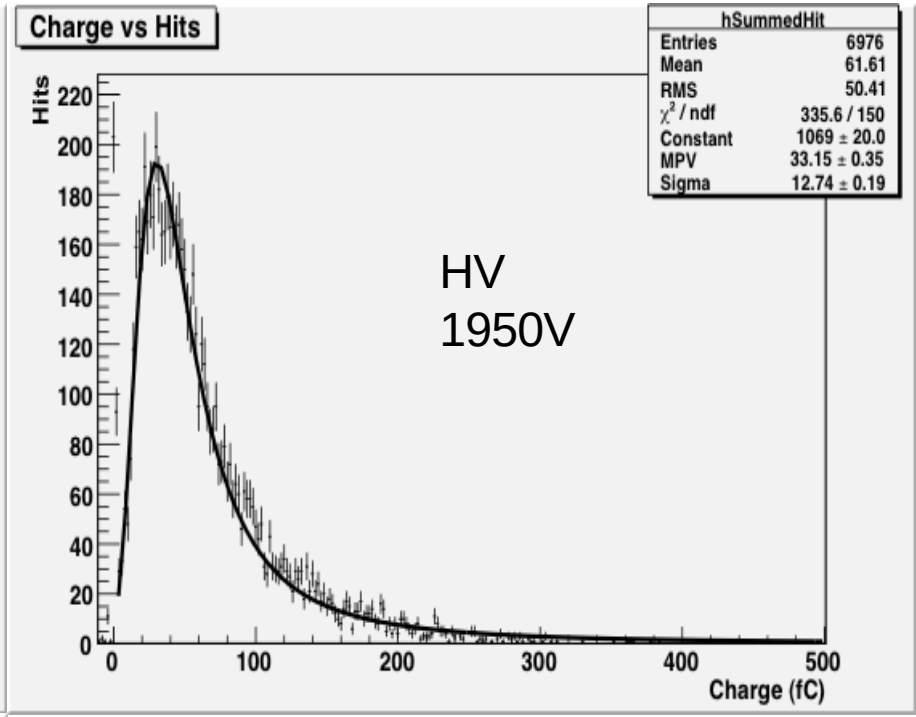


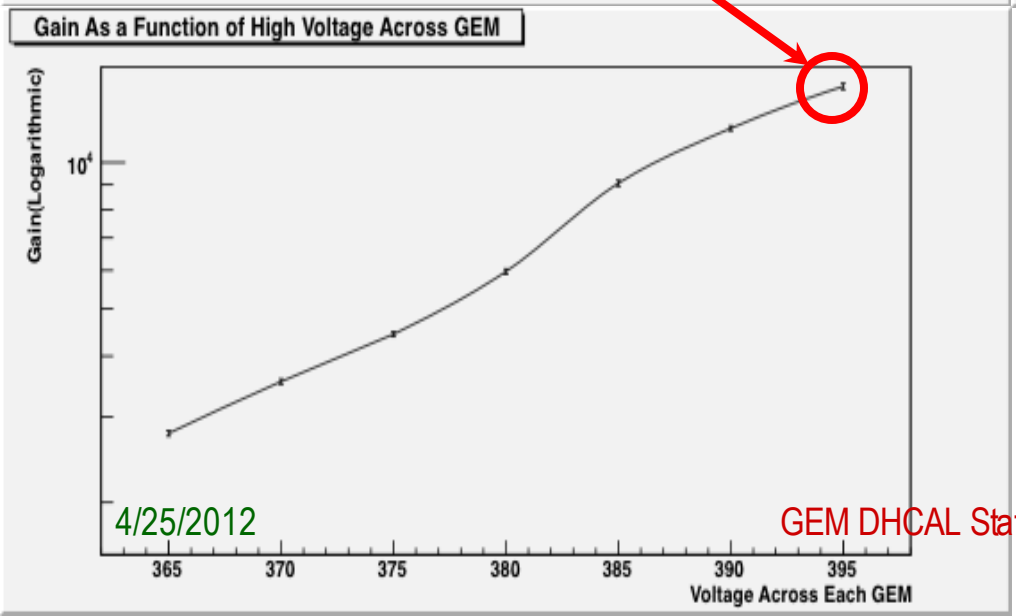




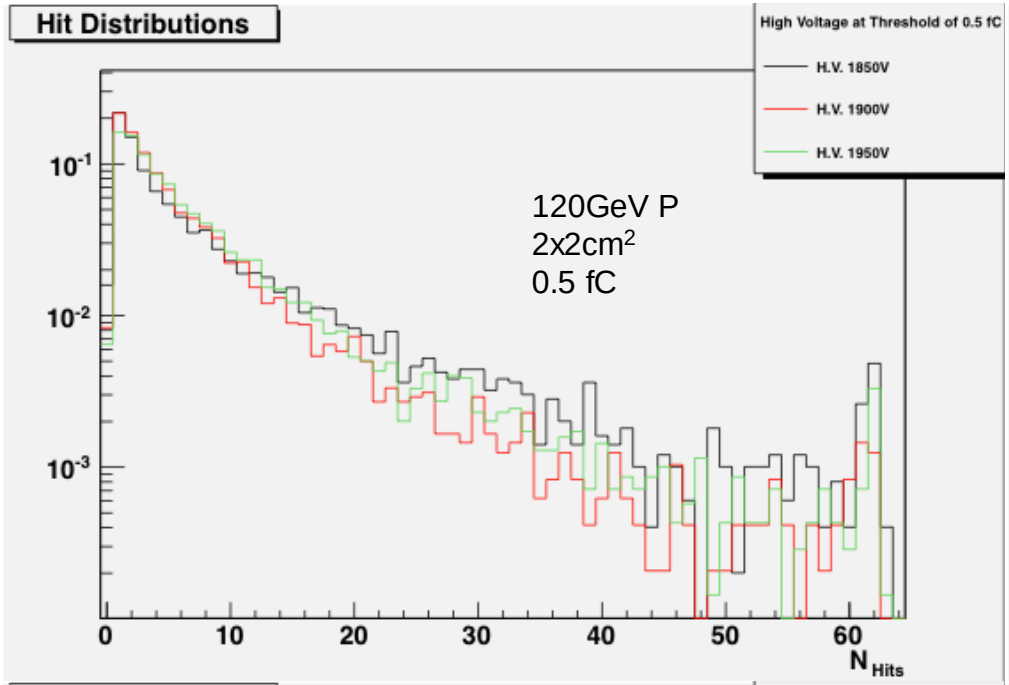
HV Dependence and Gain (KPiX)

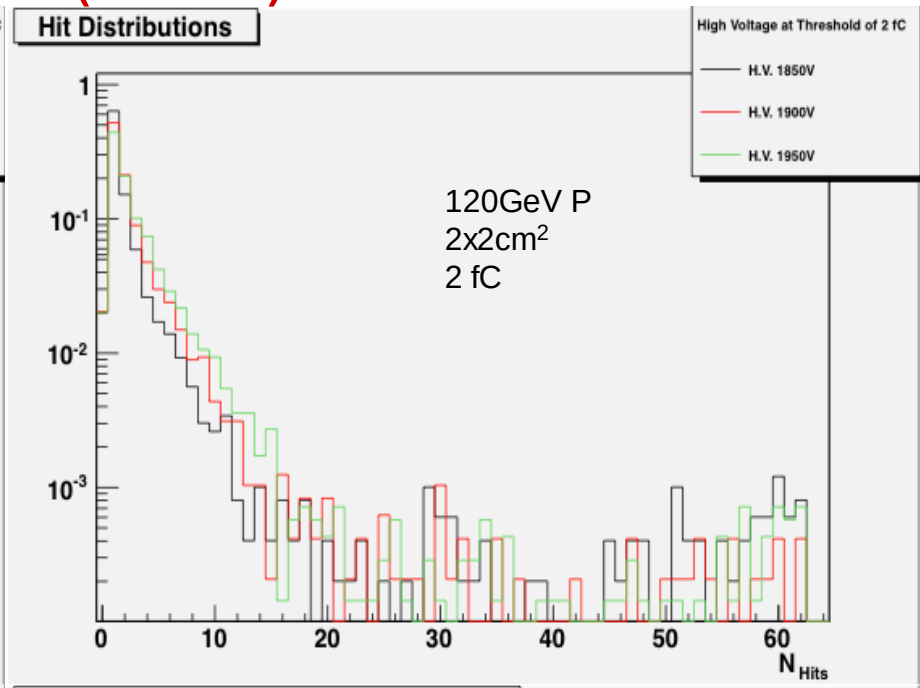


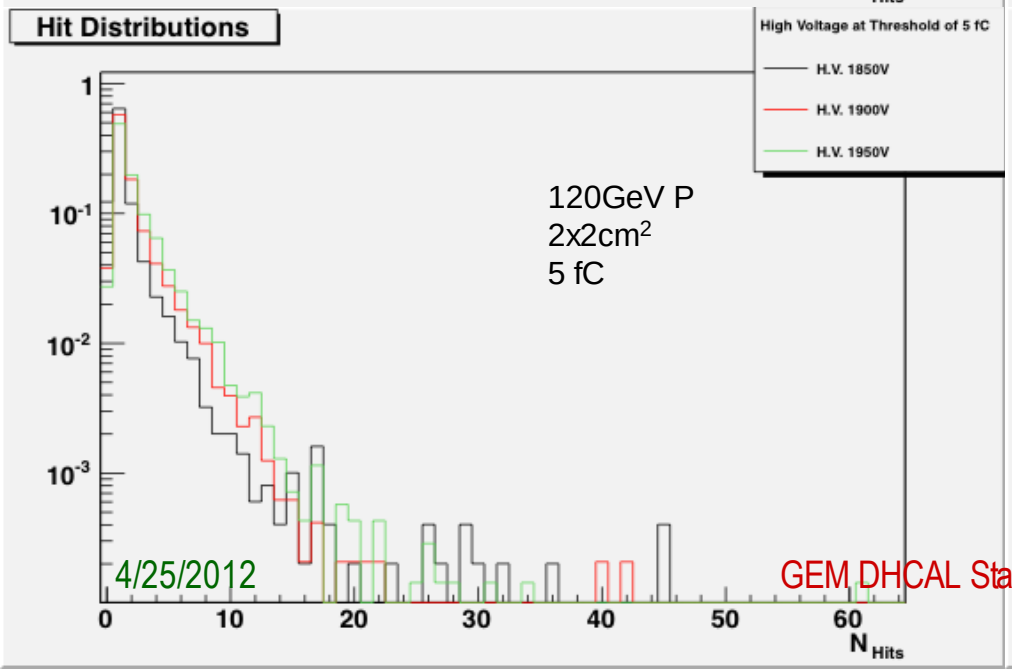


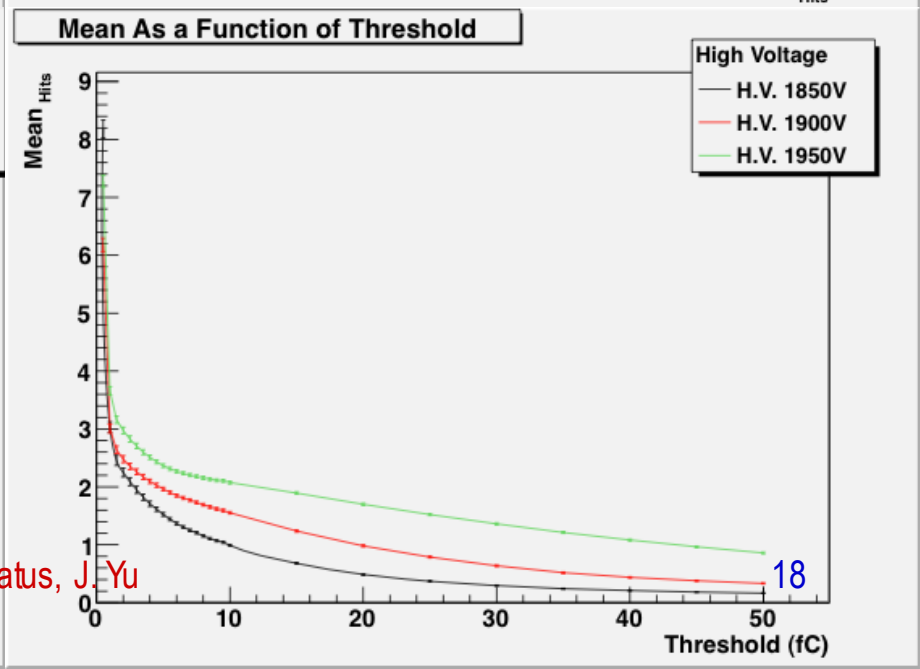


Nhits vs HV (KPiX)

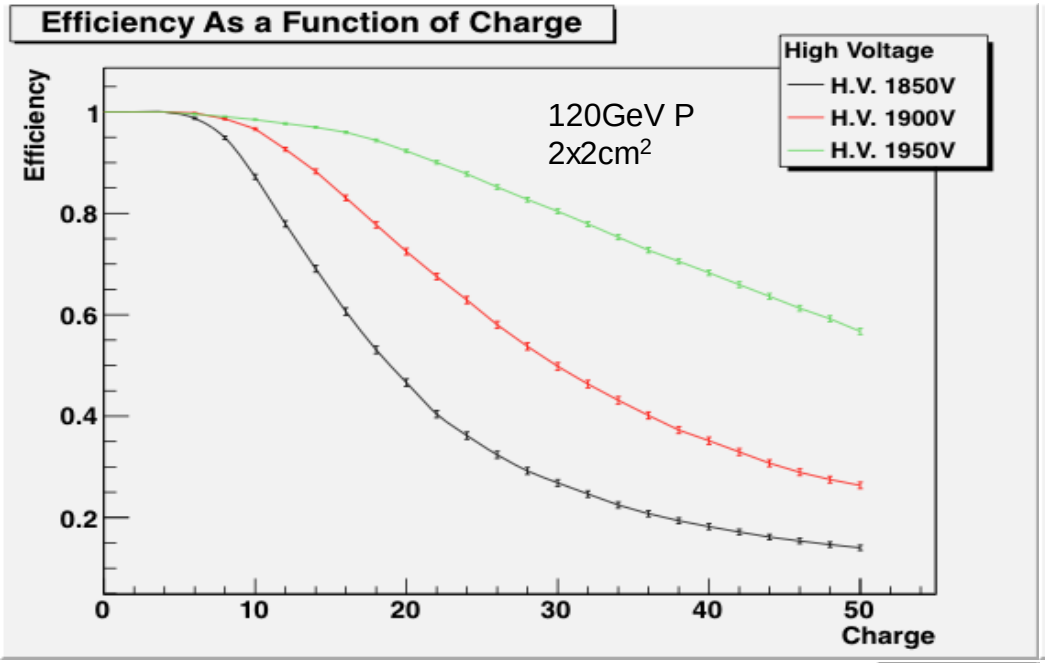


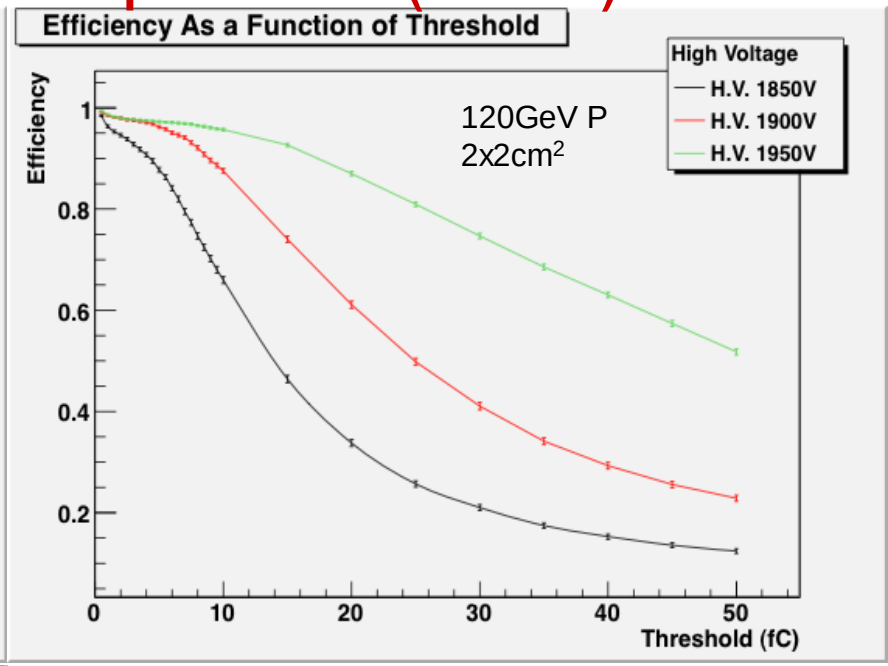


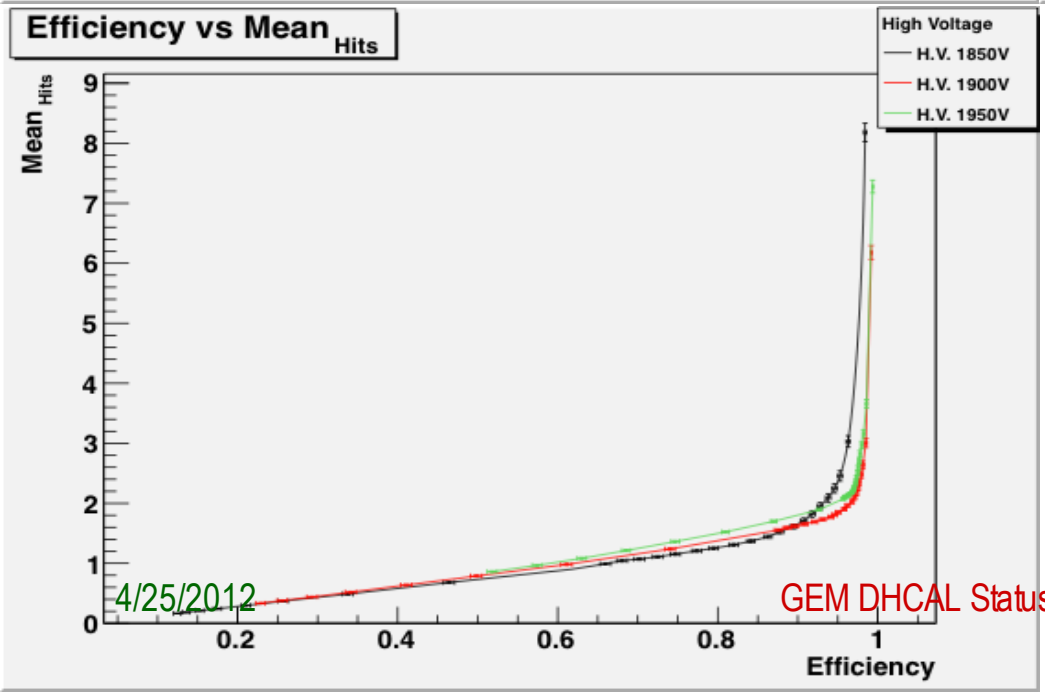




Efficiencies and Hit multiplicities (KPiX)

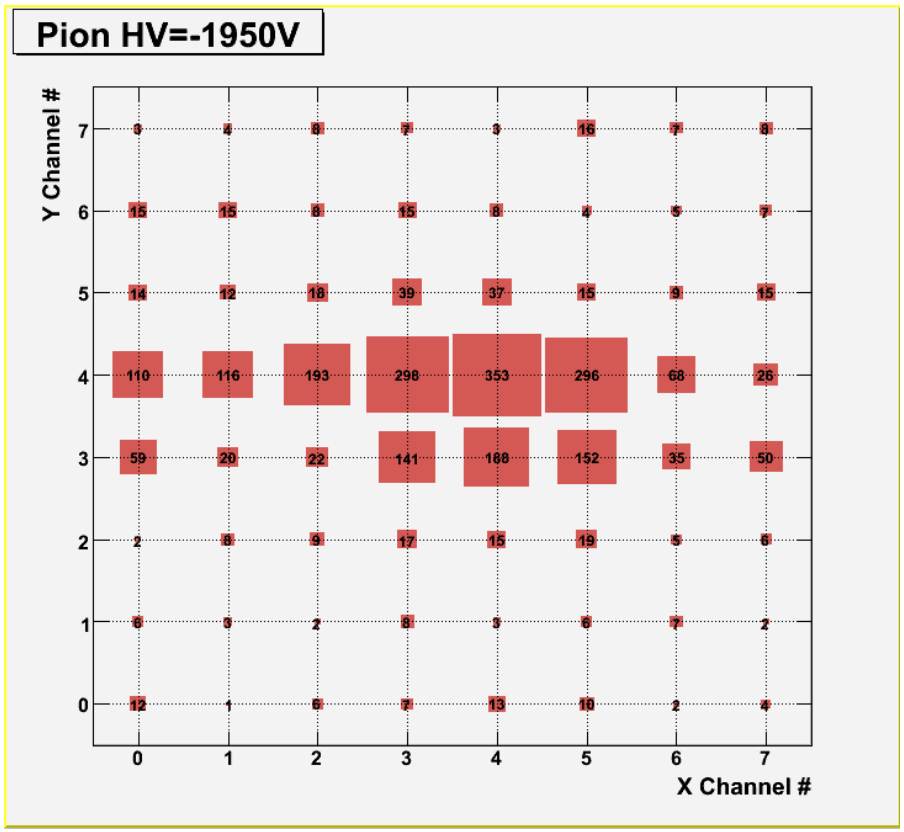


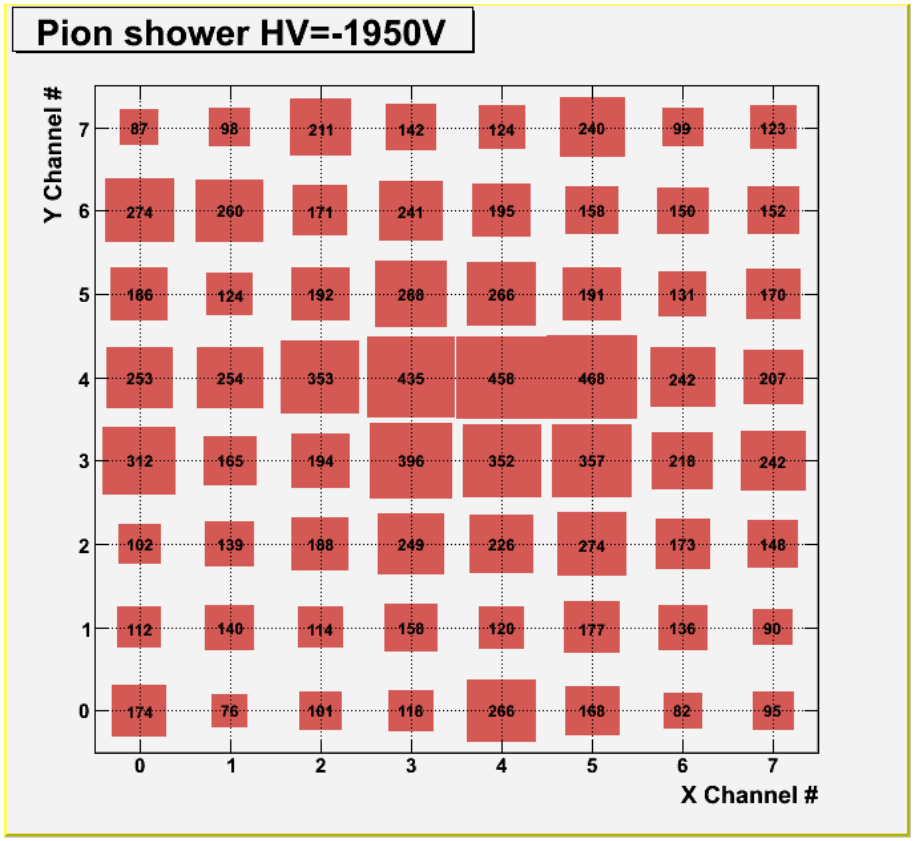




Preliminary results, pressure corrected

Hit Map for Pions vs Pion Showers (KPiX)

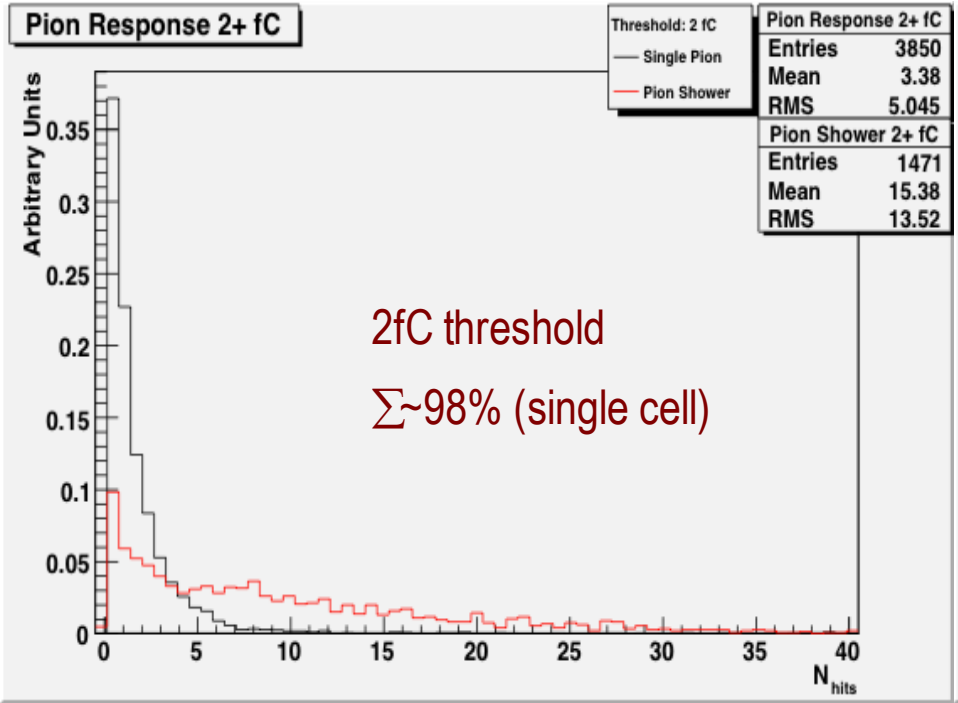


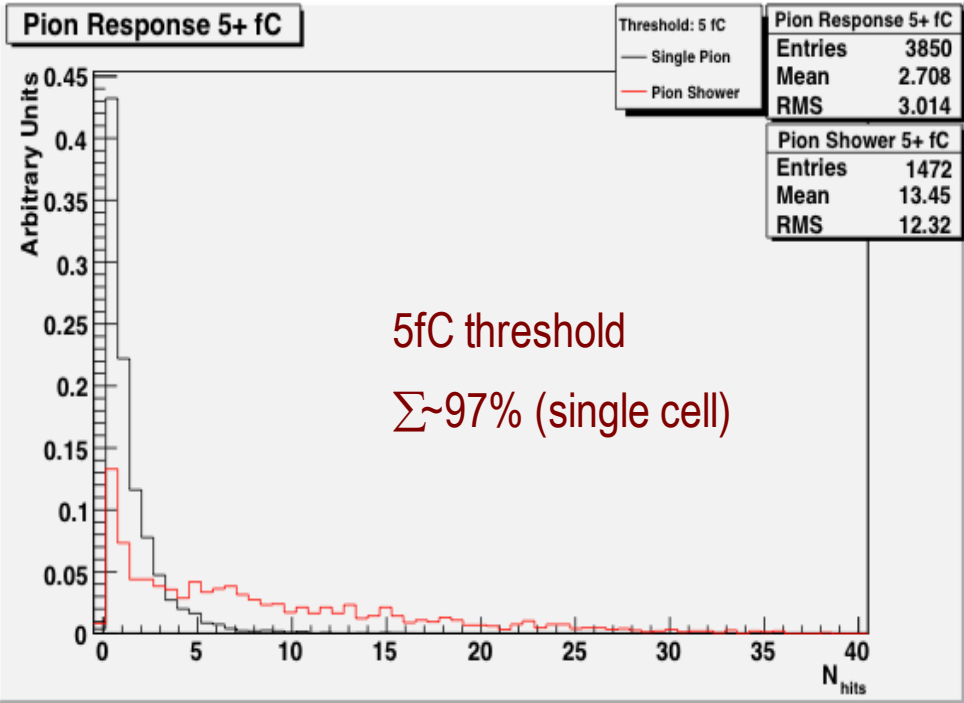


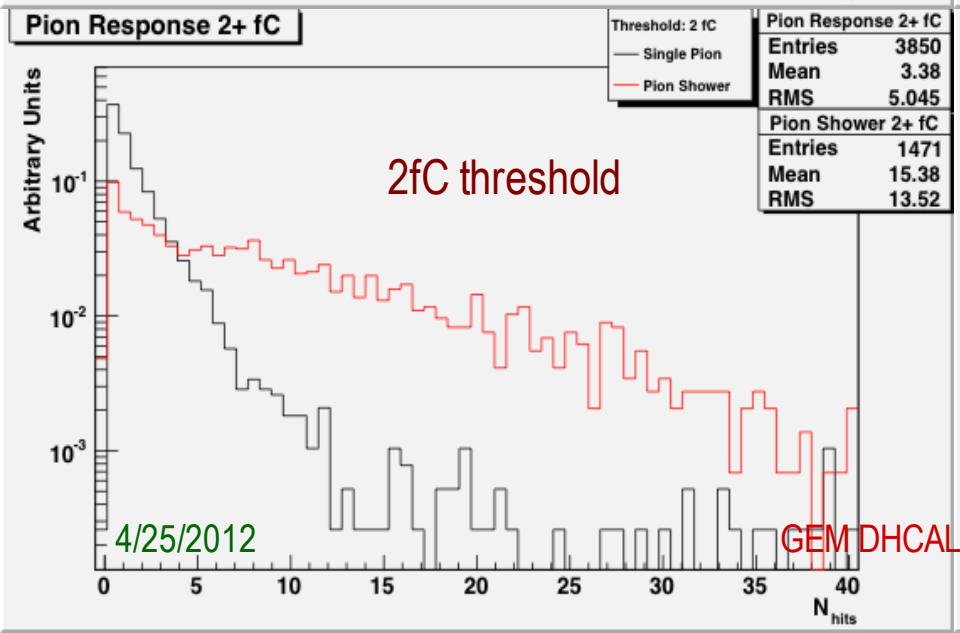
Hits above 5fC were counted and normalized to 1000

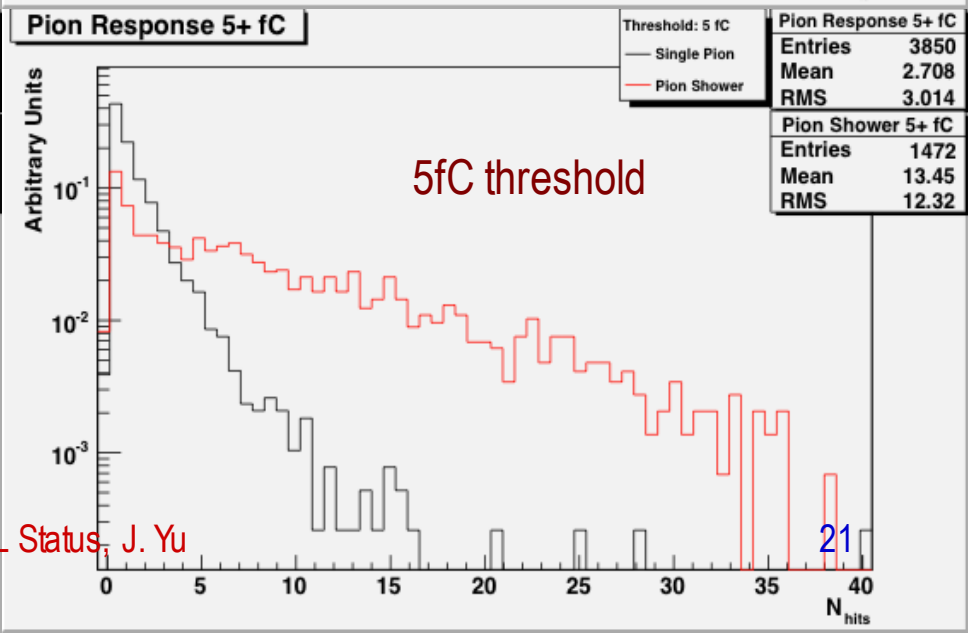
Demonstrates the KPIX capability to take many hits simultaneously

Hit Count Distributions for Pions vs Pion Showers (KPiX)

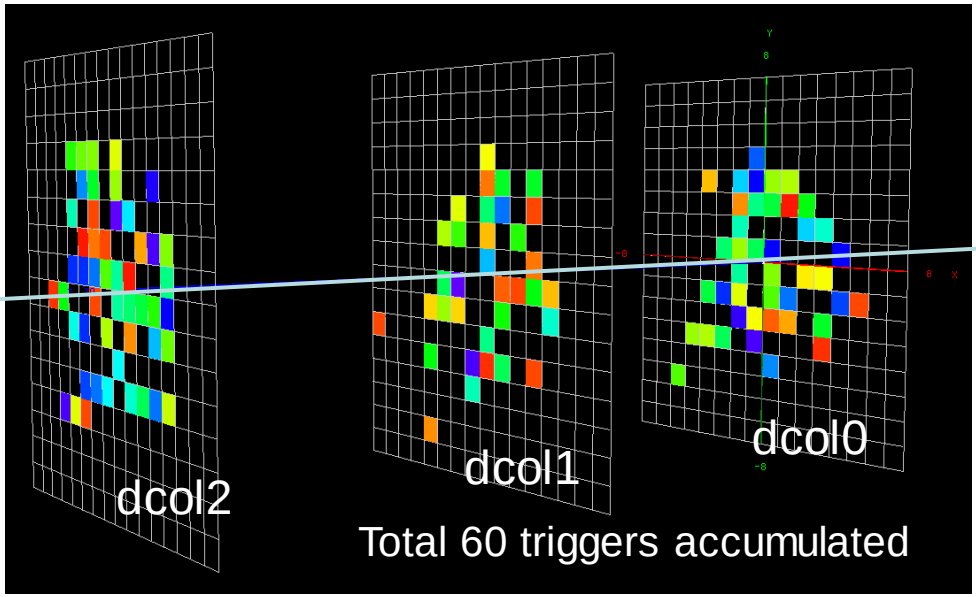




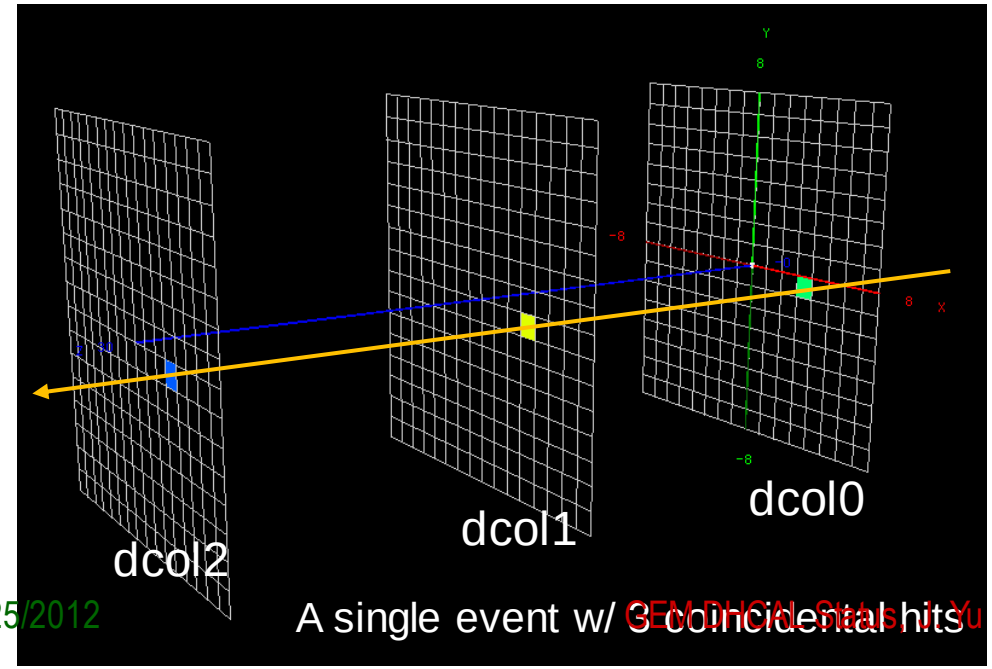


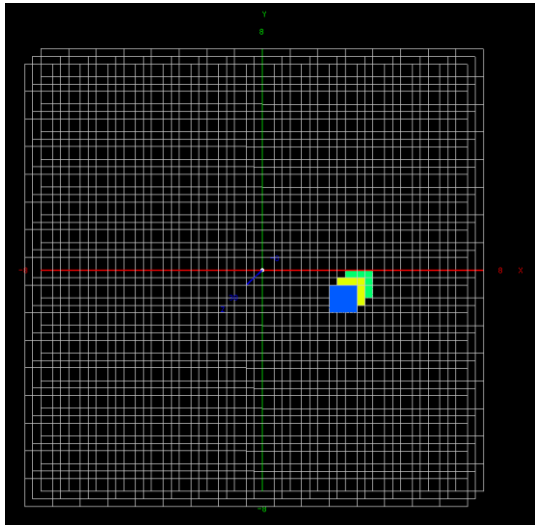


3 DCAL GEM Chamber Event Display

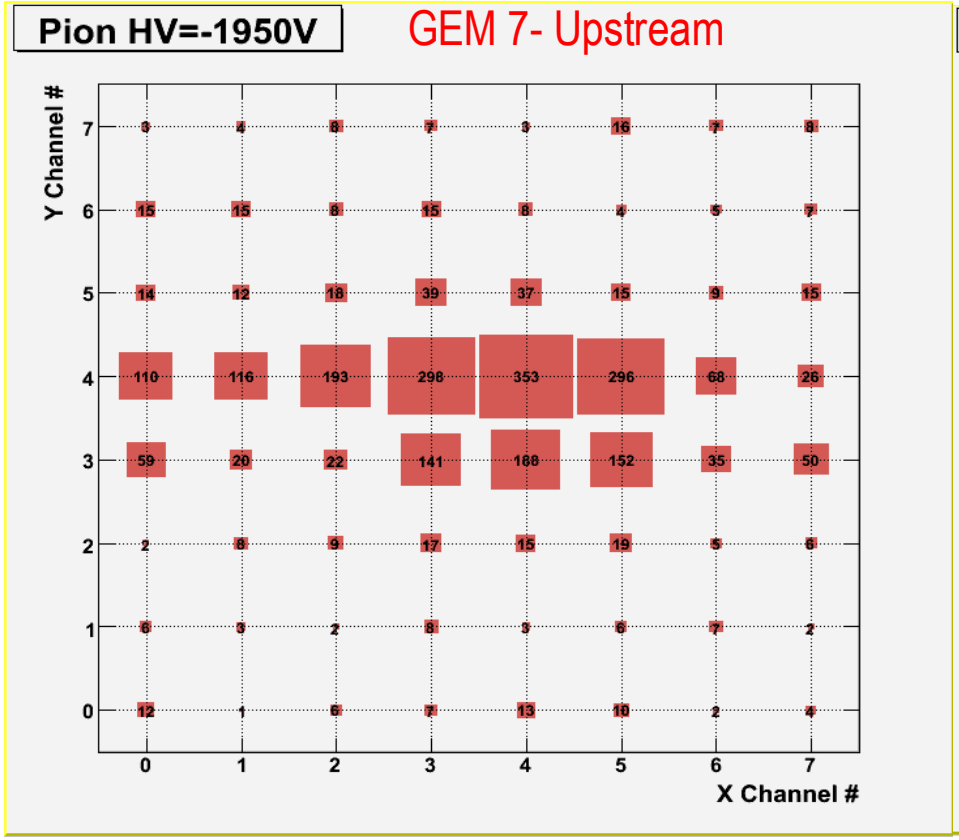


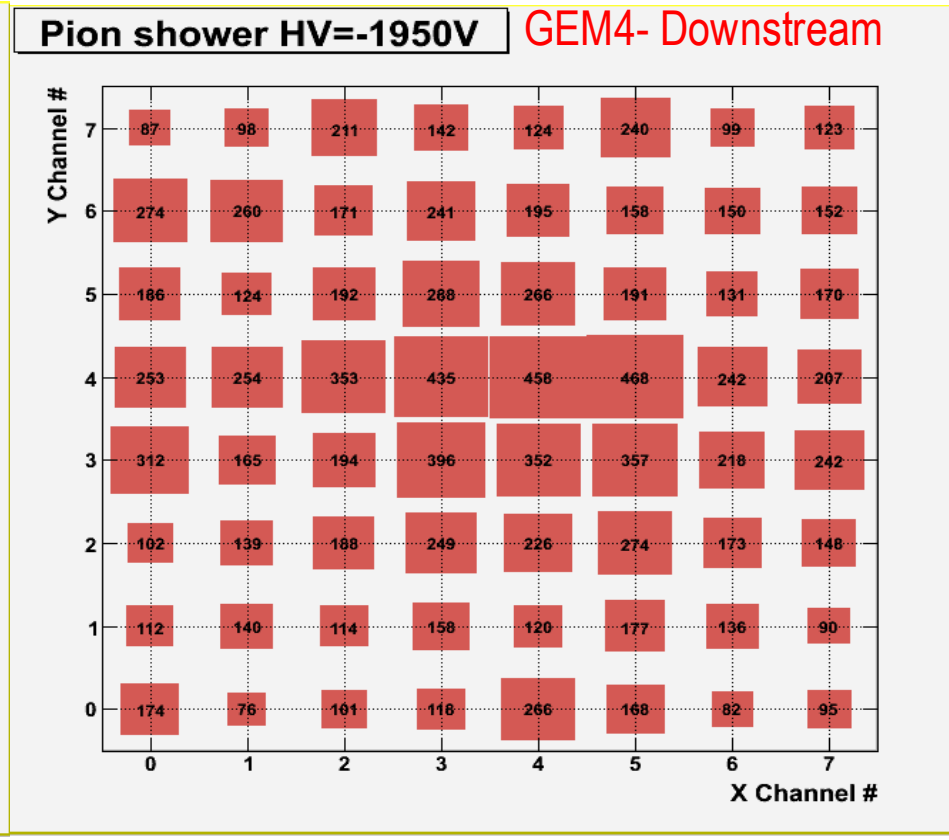
Beam direction





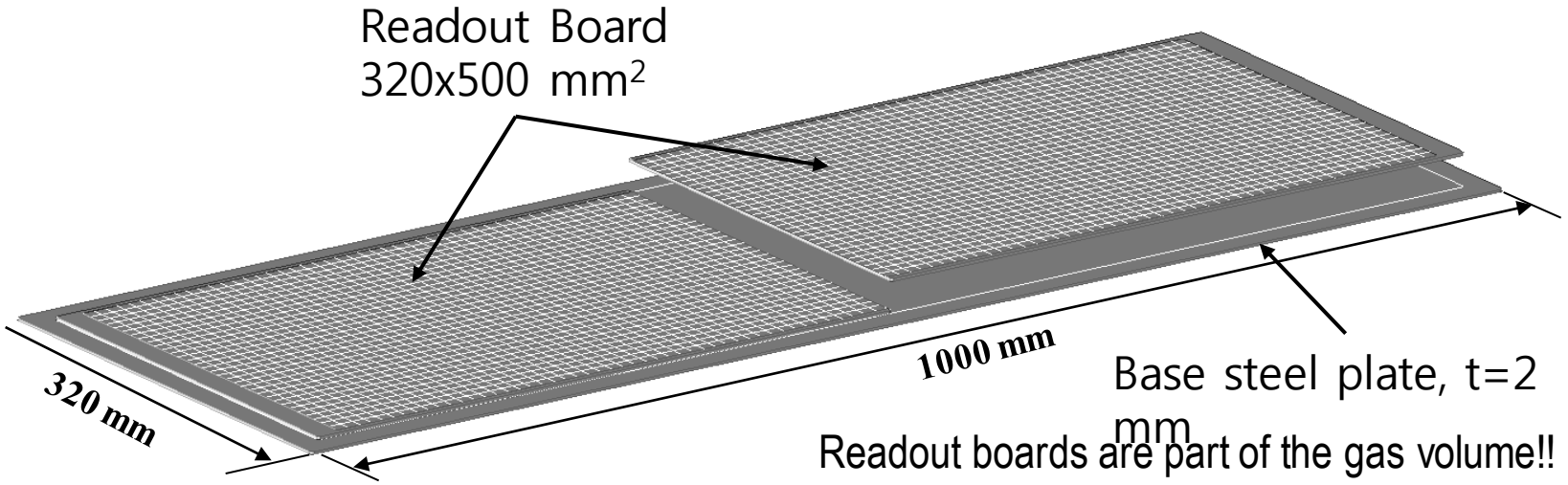
Hits from Pion Showers (DCAL)



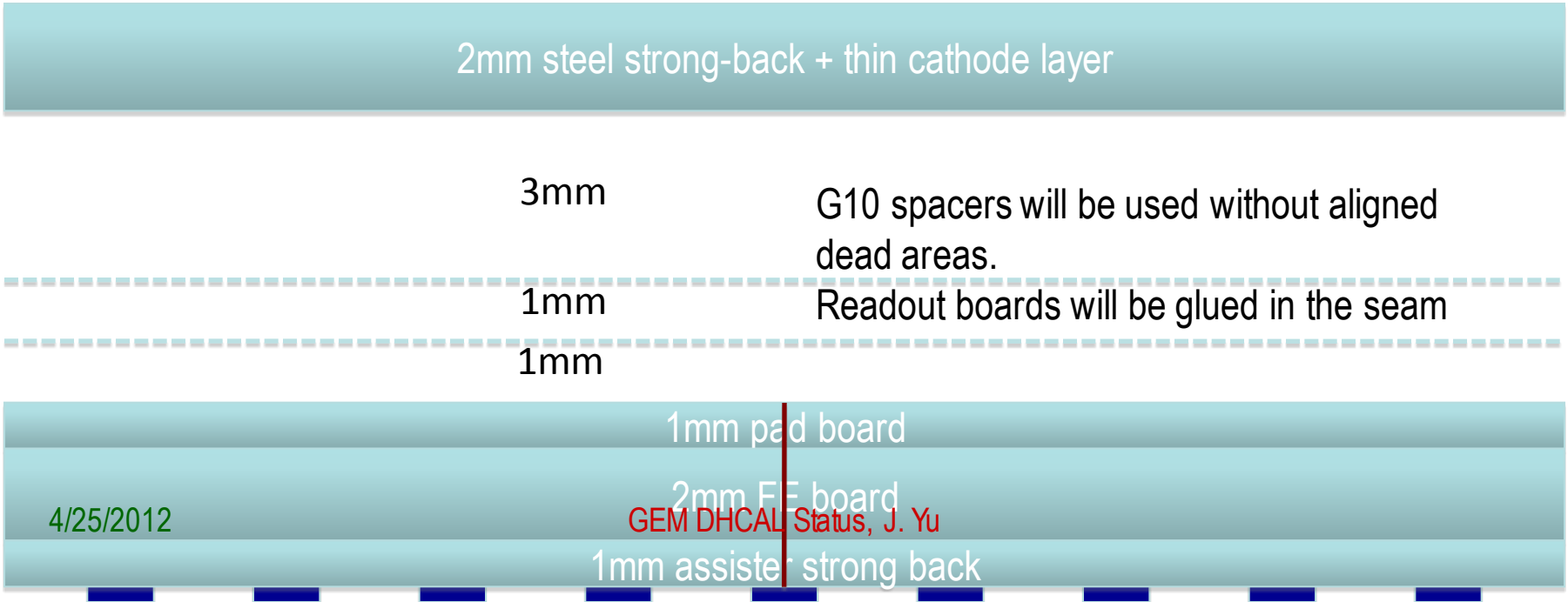


- 2 chamber and 3 chamber coincidence hits show minimal fraction of events with multiple particle hits per trigger
- The efficiency obtained using chamber hit coincidences are not consi stent with what we observe from charge distributions!

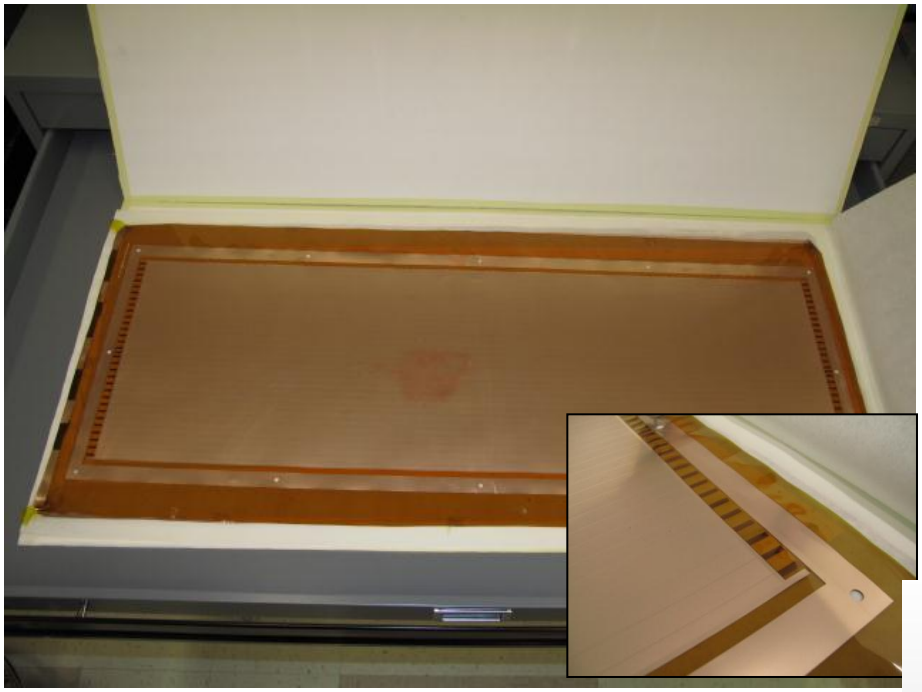
33cmx100cm DHCAL Unit Chamber Construction



Readout boards are part of the gas volume!!
GEM foils with 31 HV strips delivered



Toward 100cmx100cm GEM Planes!!



CERN GDD Workshop delivered the first 5 of 33cmx100cm GEM foils in 2010 ➔ Qualification completed!!

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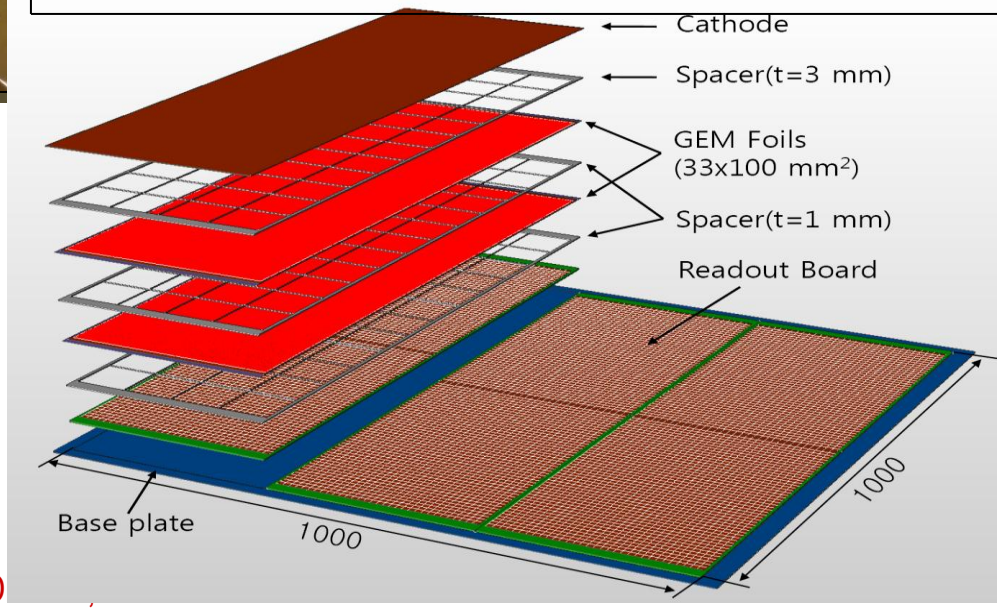


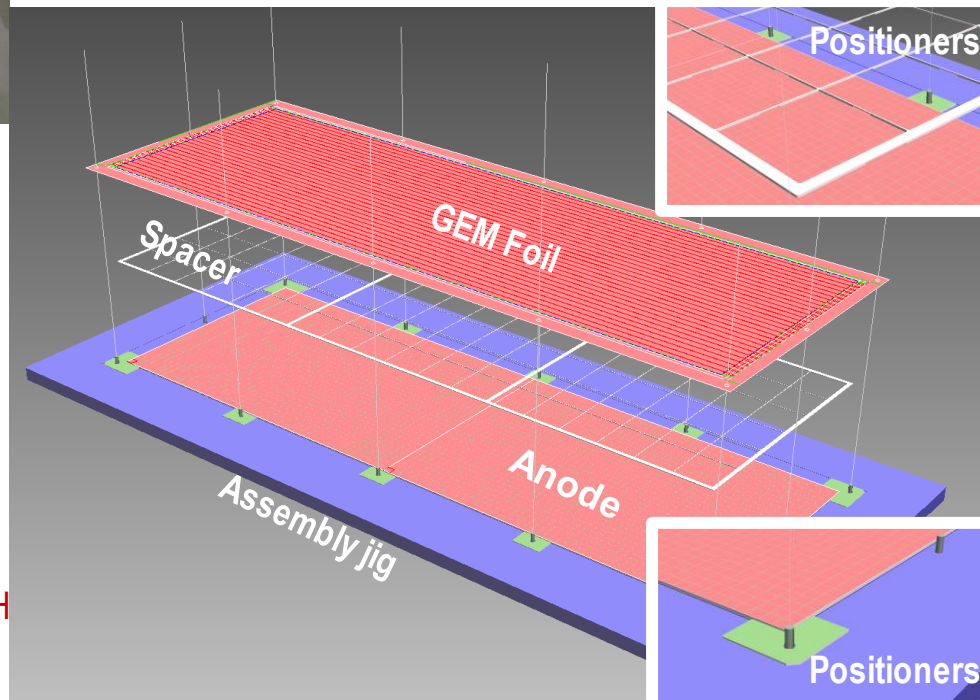
Each of the GEM 100cmx100cm planes will consist of three 33cmx100cm unit chambers

Toward 100cmx100cm GEM Planes!!

Class 10,000 clean room (12'x8') construction completed

Two 33cmx100cm chamber parts delivered

Jig for 33cmx100cm chamber being procured



GEM DHCAL Plans

- ✓ Phase I (Through late 2011) ➔ Completion of 30cm x 30cm characterization with KPiX and DCAL chip integration
  - Performed beam tests @ FTBF with 30cm x 30cm double GEM chambers, one with KPiX9 and 3 with DCAL
  - Completion of 33cmx100cm large foil evaluation
- Phase II (late 2011 – early 2013): 33cm x 100cm unit chamber development and characterization
  - Begin construction of 2 unit 100cmx33cm chambers, one with kPiX and one with DCAL
  - Bench test with sources and cosmic rays and beam tests
  - Construction of 100cmx100cm plane
- Phase III (Early 2013 – mid 2014): 100cmx100cm plane construction
  - Construct 6 unit chambers with DCAL for two 100cmx100cm planes
  - Characterize 100cmx100cm planes with cosmic rays and beams
- Phase IV (Mid 2014 – late 2015): 100cm x 100cm plane GEM DHCAL performances in the CALICE stack
  - Complete construction of five 100cm x 100cm planes inserted into existing CALICE calorimeter stack and run with either Si/W or Sci/W ECALs, and RPC or other technology planes in the remaining HCAL

Summary

- 30cmx30cm GEM prototype chambers and beam test run
  - kPiX readout: Established good 2D working condition with v9 (512 channel) and took a successful beam test data
  - DCAL integration very successful, took beam test data with three chambers ➔ Trying to understand the beam test data
  - Analyses of over 7M beam test events from Aug. 2011 run in progress
  - Continue taking cosmic ray data with these four chambers
  - Responses seem to be consistent between various runs
    - Finalization of the response to particle dependence – proton, pion and muon
    - Multiplicity vs threshold show reasonable behavior (~1.8 at 98% efficiency)
    - Efficiency at around 98% at 5fC
  - Gains at around 11,000 with 1950V operation HV
    - Need to finalize with refined fits
  - Preliminary results show the response to be uniform within the uncertainty
- THGEM making good progress, readout with KPiX V9
  - Completed a beam test and analysis in progress

Summary, cntd

- 33cmx100cm unit chamber construction proceeding
  - First 5 foils of 33cmx100cm delivered and qualification completed
  - G10 spacers for the large chamber and the construction parts delivered
  - A mobile clean room for foil certification and chamber construction ready to be built
- Commercial production of GEM foils successful
  - Prototype (8cmx8cm) tested at CERN successfully
  - Larger (10cmx10cm) foil samples produced and sent to CERN for testing
- Mechanical design being worked out for constructing 33cmx 100cm unit chambers and 1mx1m planes for DHCAL testing
  - Class 10,000 clean room of size 12'x8' completed
  - Construction jig being procured