Application of Large Scale GEM for Digital Hadron Calorimetry

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For GEM DHCAL Group

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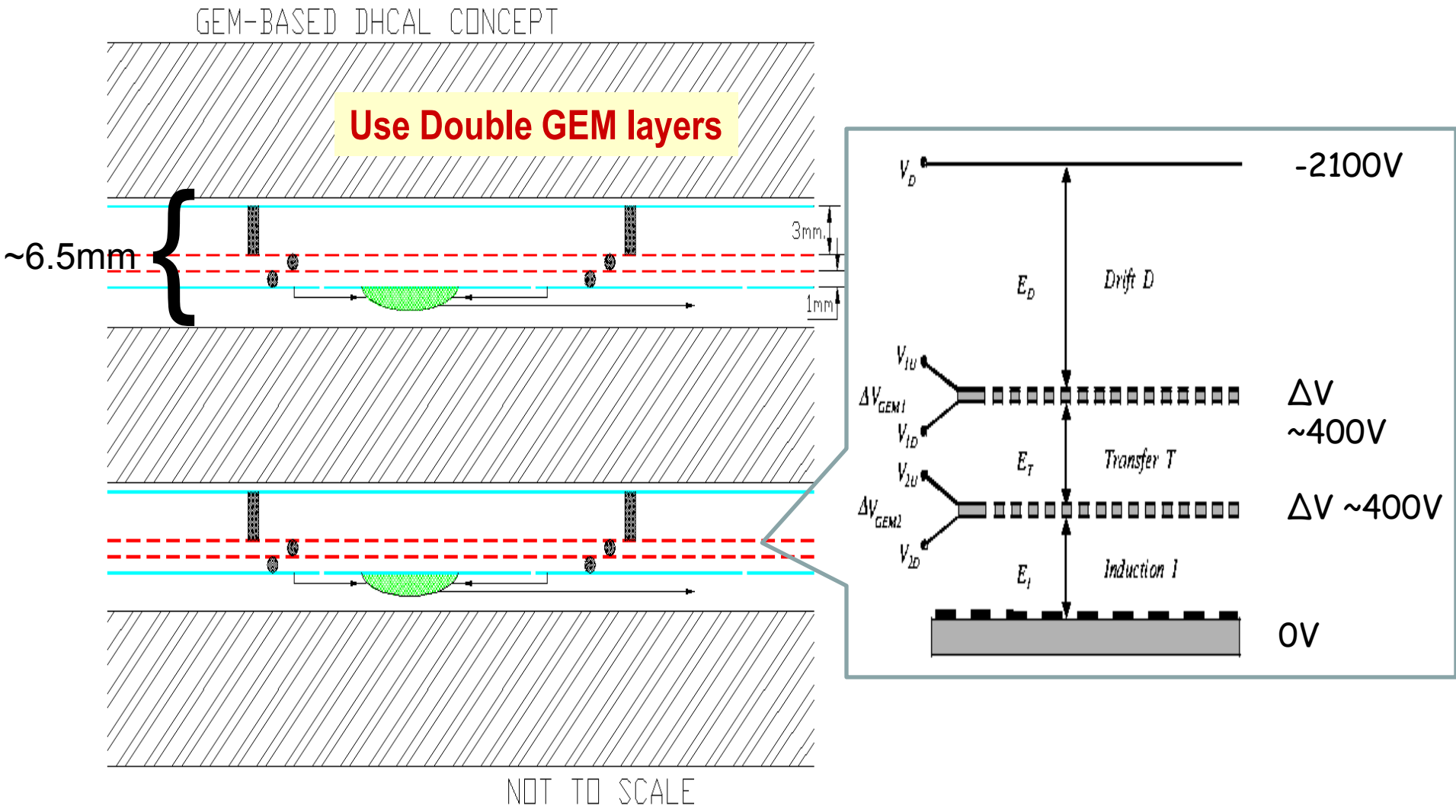
TIPP 2011

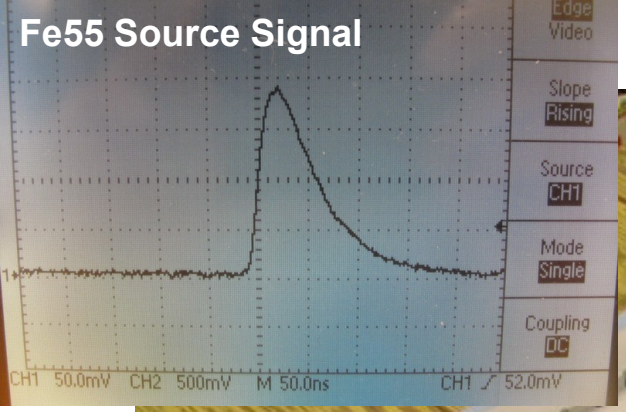
- The Goals
- 30cmx30cm 2D readout with KPiX chip
- GEM-DCAL Integration
- Large Chamber Development
- GEM DHCAL Plans
- Summary

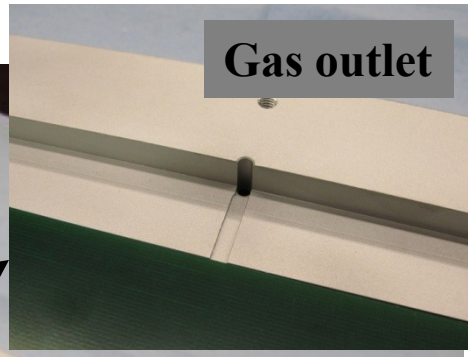
The Goals?

- 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

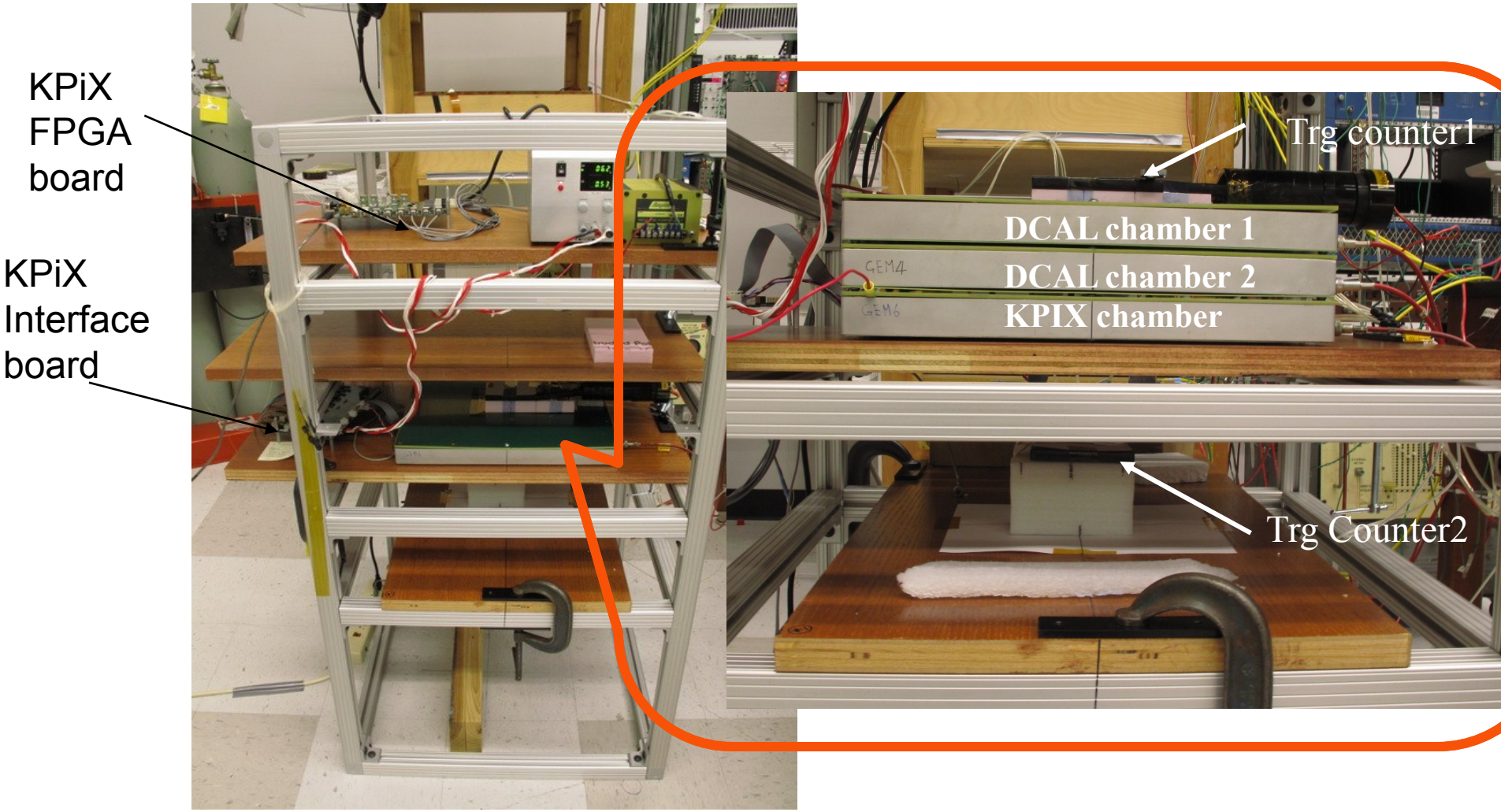






Analog signal

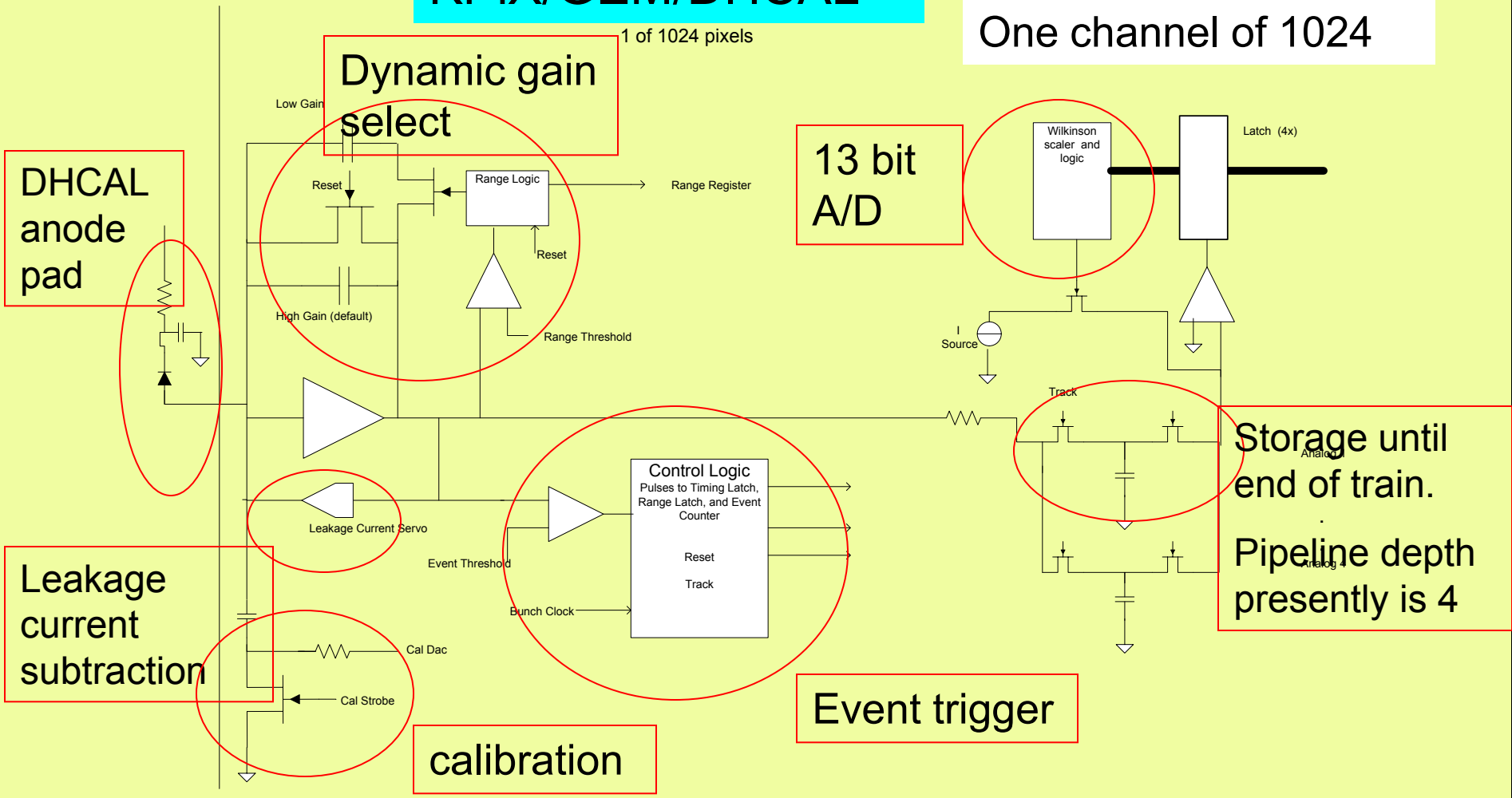
UTA GEM-DHCAL Test Stand



KPiX/GEM/DHCAL

KPiX chip

One channel of 1024



Simplified Timing:

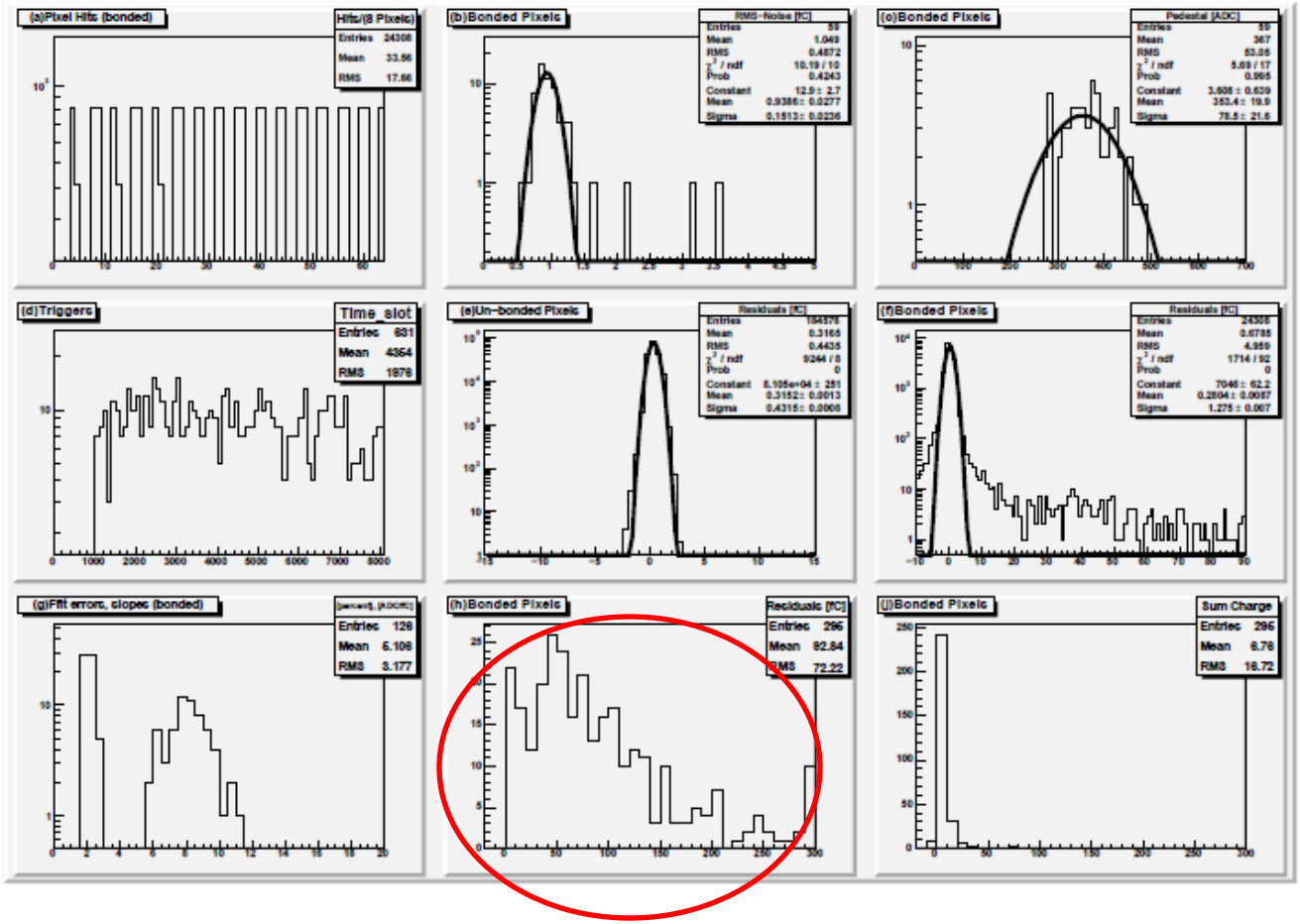
There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

Say a signal above event threshold happens at bunch n and time T0.
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit) and Event Counter (5 bits).
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range switch has had time to settle, Track connects the sample capacitor to the amplifier output. (~150 ns)
The Track signal opens the switch isolating the sample capacitor at T0 + 1 micro s. At this time, the amplitude of the signal at T0 is held on the Sample Capacitor .
Reset is asserted (synched to the bunch clock) . Note that the second capacitor is reset at startup and following an event, while the high gain (small) capacitor is reset each bunch crossing (except while processing an event)
The system is ready for another signal in ~1.2 microsec.
After the bunch train, the capacitor charge is measured by a Wilkinson converter.

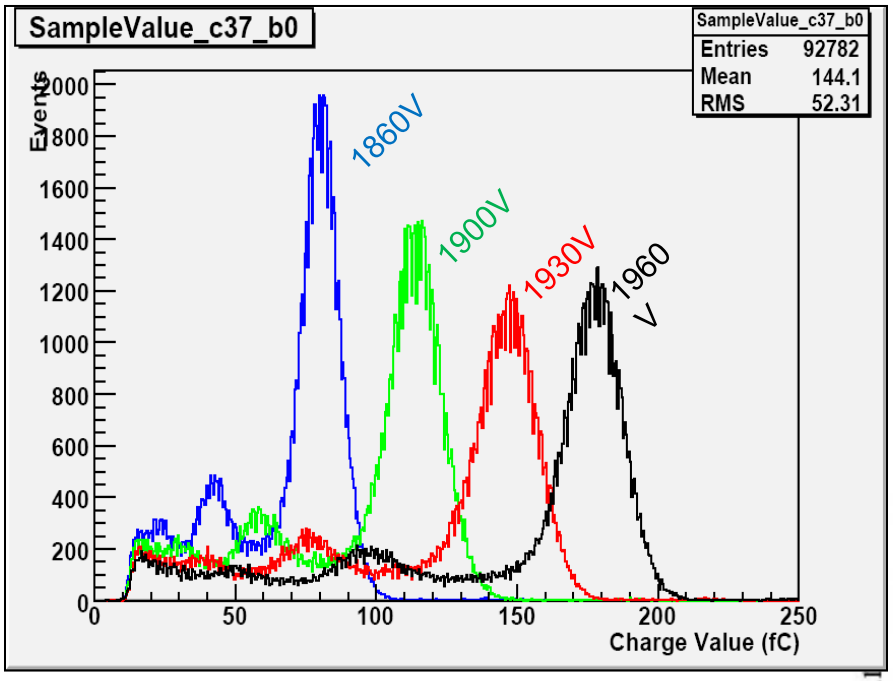
GEM DHCAL with KPiX

Work with SLAC colleagues on KPiX7,9 debugging/operation

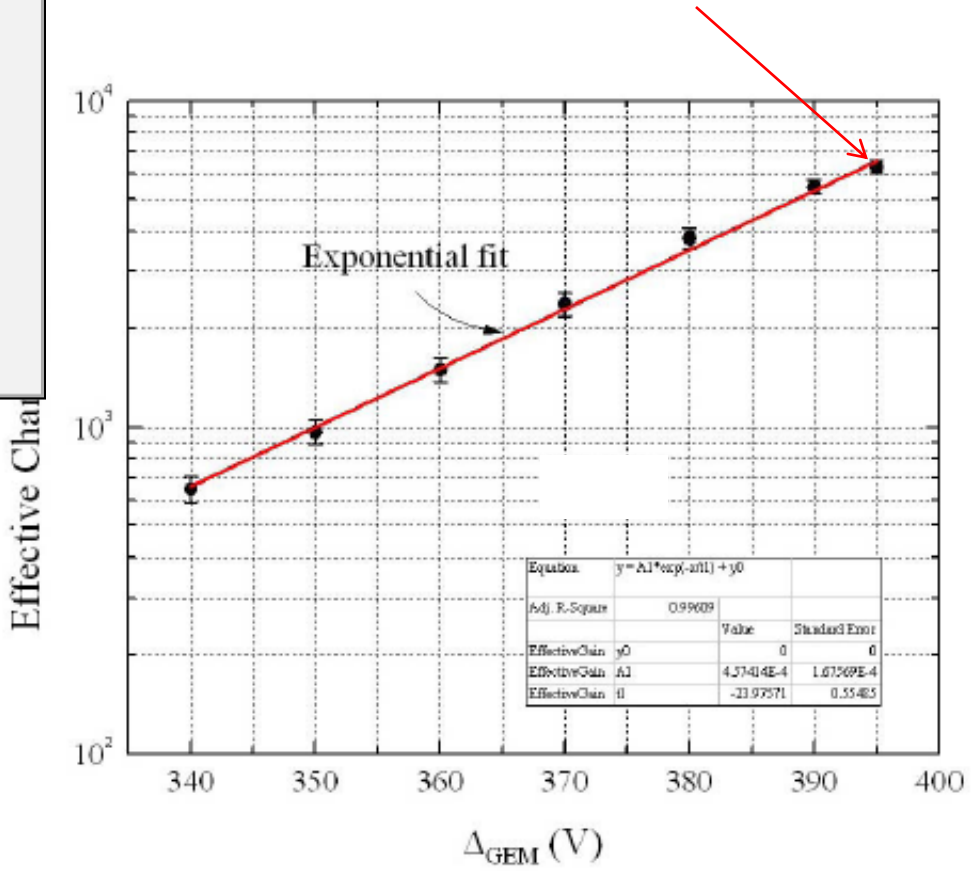
* Many thanks to M. Breidenbach, D. Freytag, R. Herbst



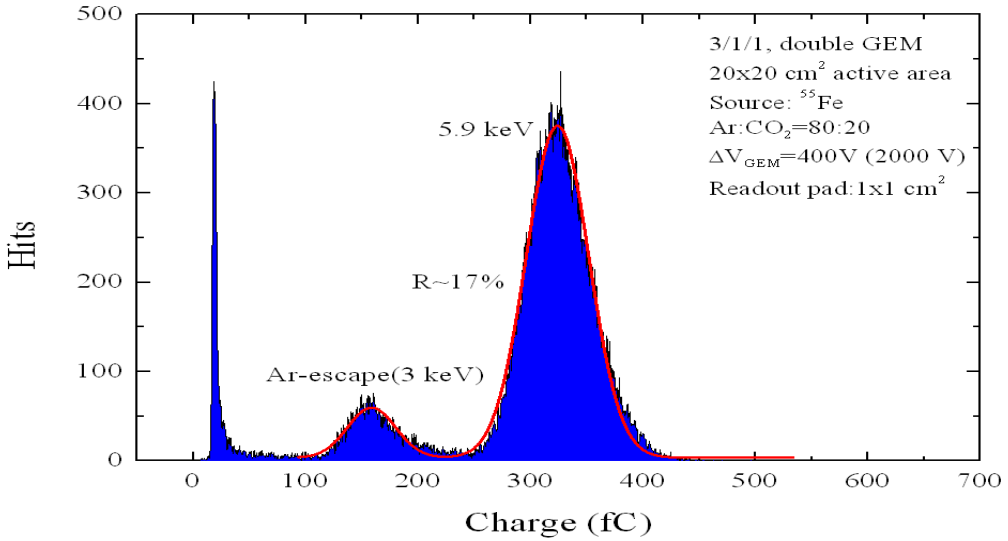
Gain vs HV

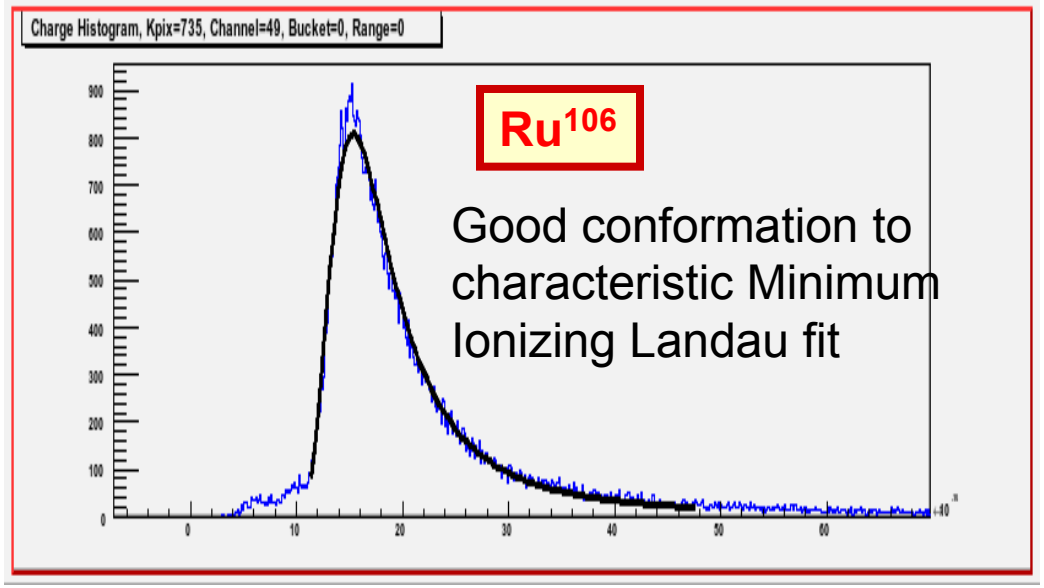


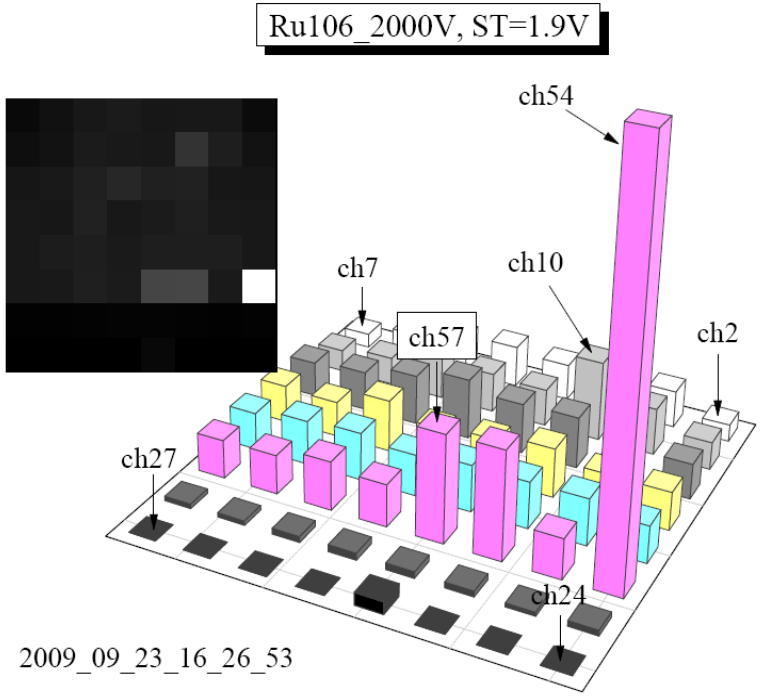
Typical operating point:
Gain ~6000

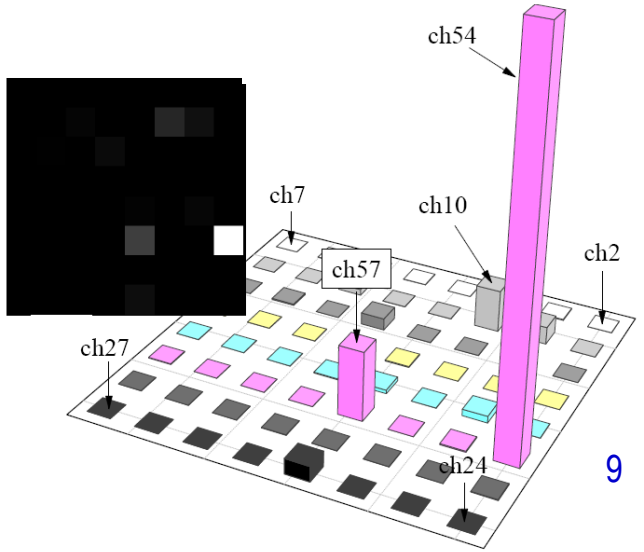


GEM+kPiX7 Fe^{55} and Ru^{106} Spectra

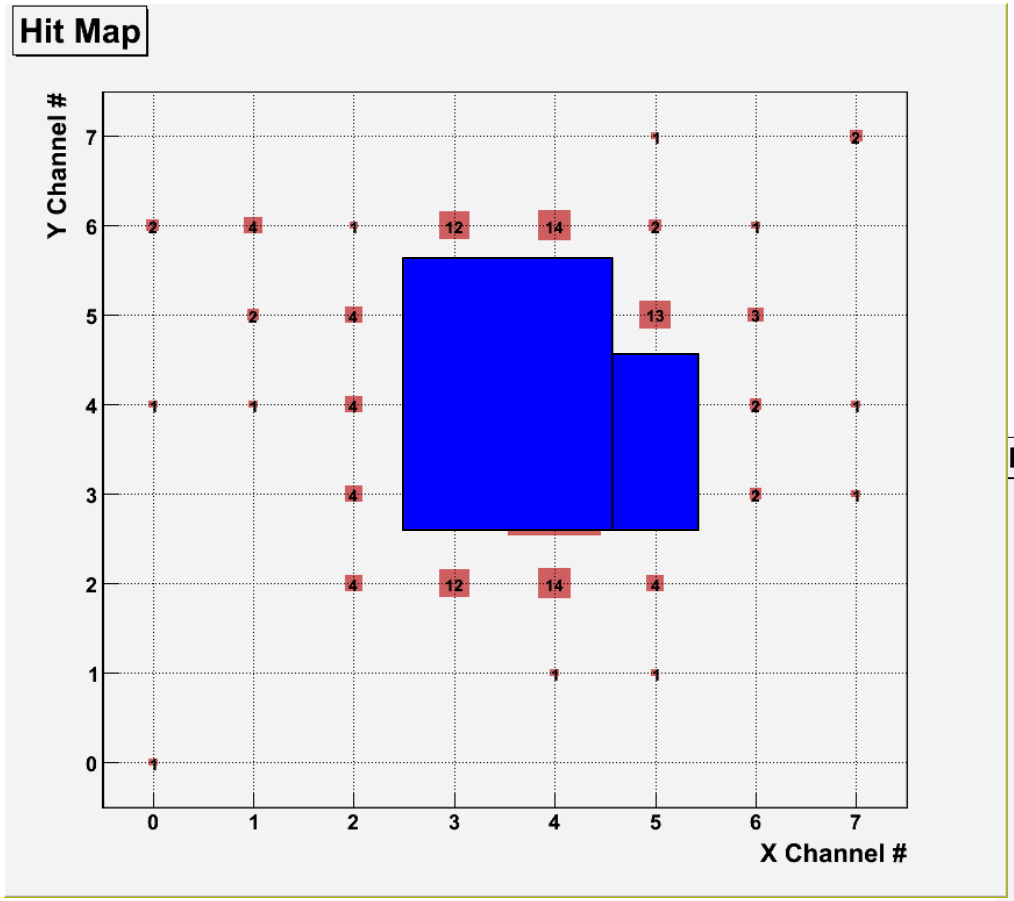




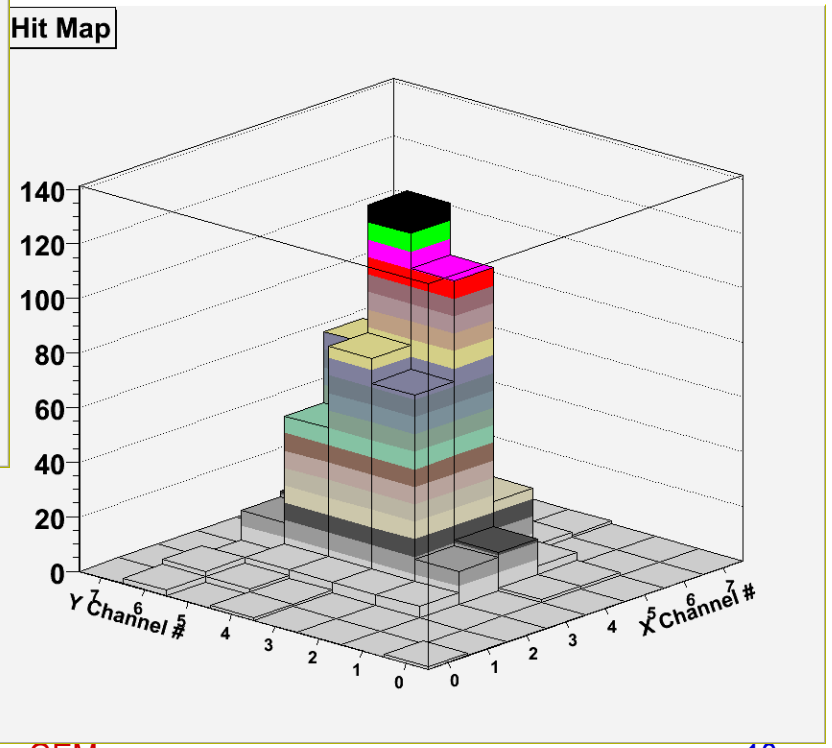




2D Cosmic Ray Hits – kPiX7



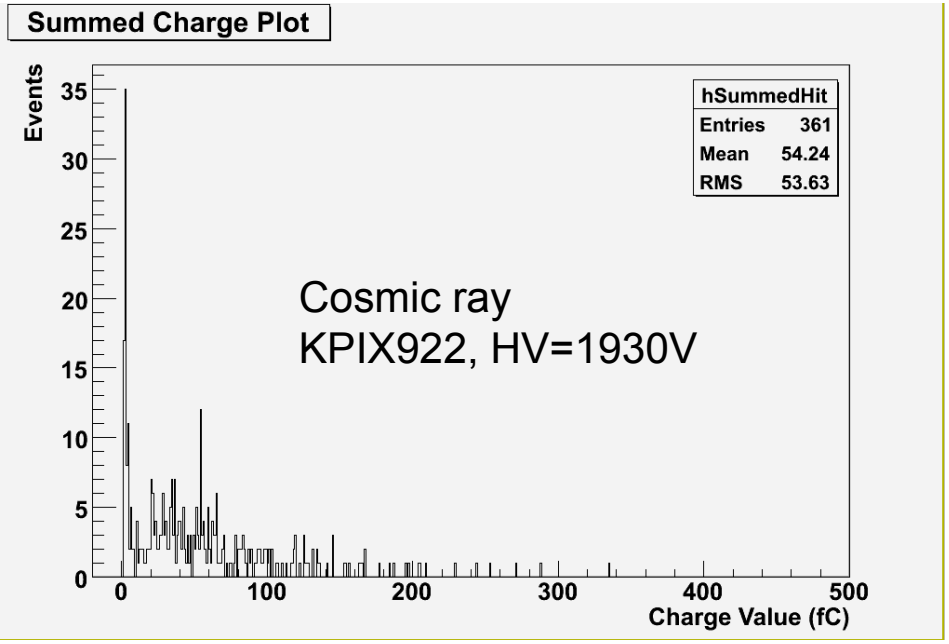
2 x 3 cm^2 trigger counter

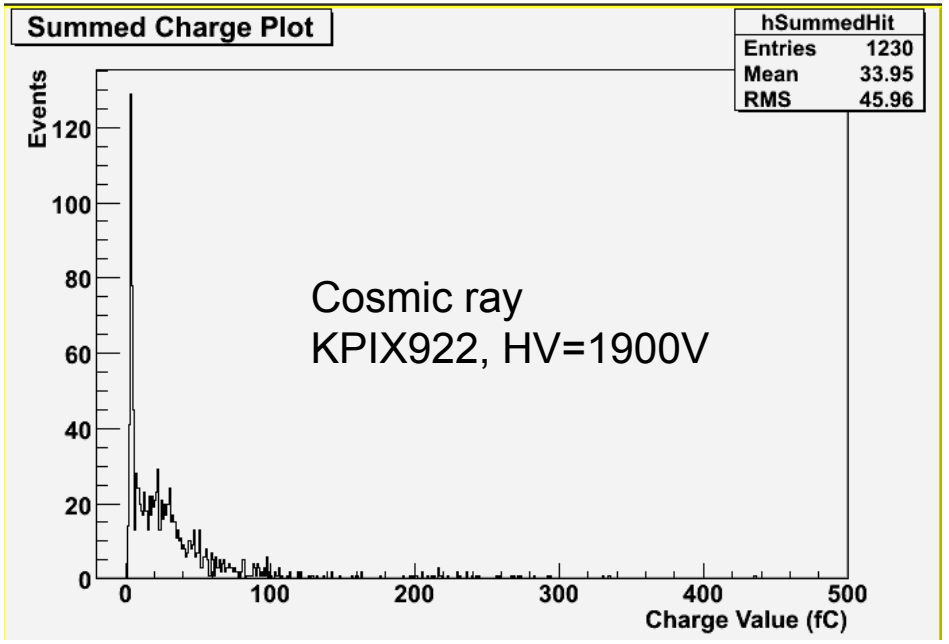


Three noisy channels removed
~4.5% kPiX duty factor

Testing/development with kPiX9

- kPiX9 – 512 channels – penultimate step to kPiXA (1024 ch.)
- 64 “bonded channels”
- Large effort between SLAC and UTA to:
    1) Use kPiX9 for GEM readout
    2) Understand KPiX9 characteristics
- GEM anode boards with kPiX9 loaded supplied by SLAC

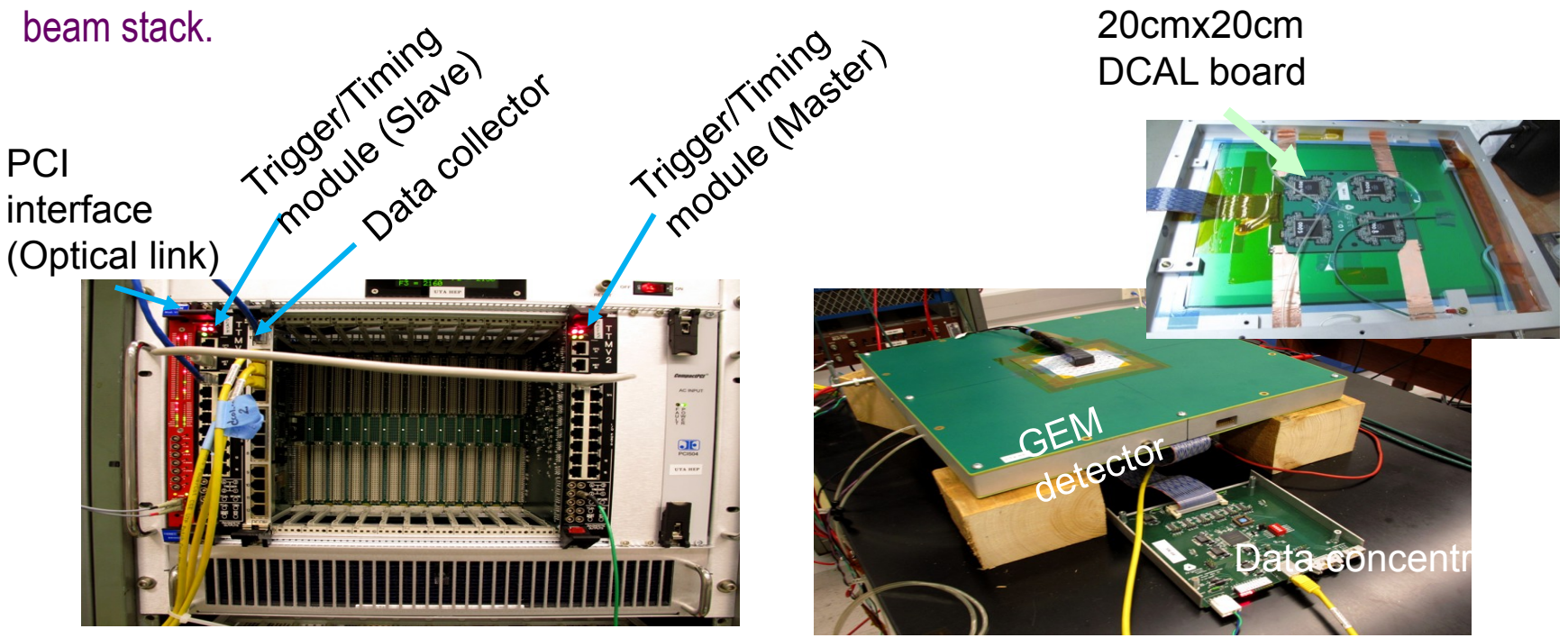




GEM Integration with DCAL Chip

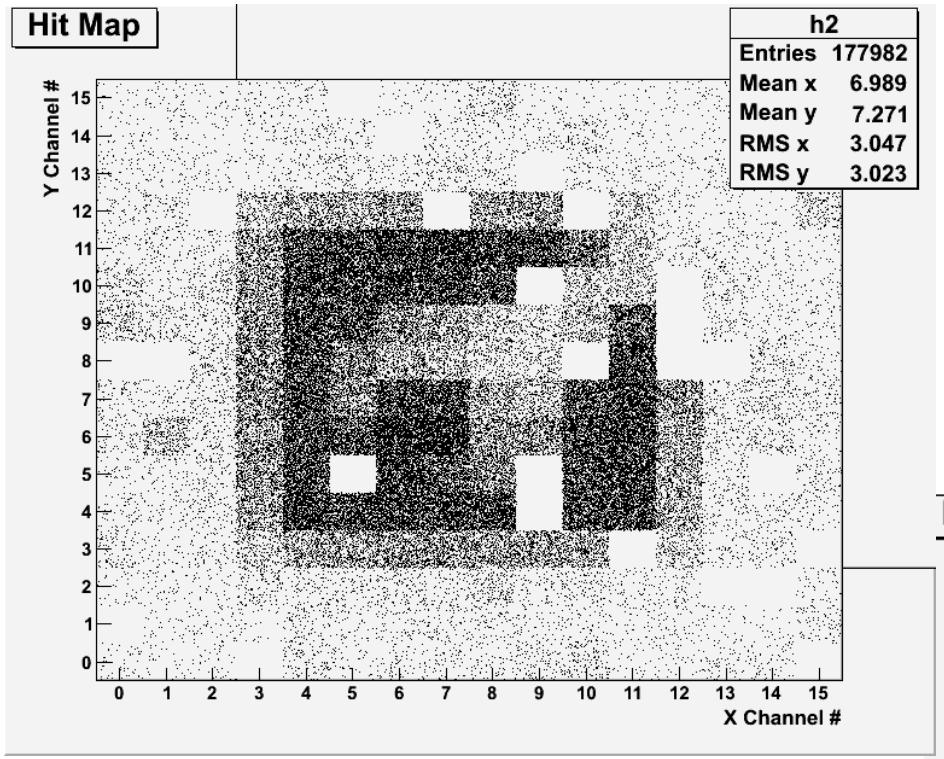
Goal: Enable readout of GEM/DHCAL planes via DCAL as the ultimate readout electronics of a $1m^3$ stack ➔ Chip has been battle tested!!

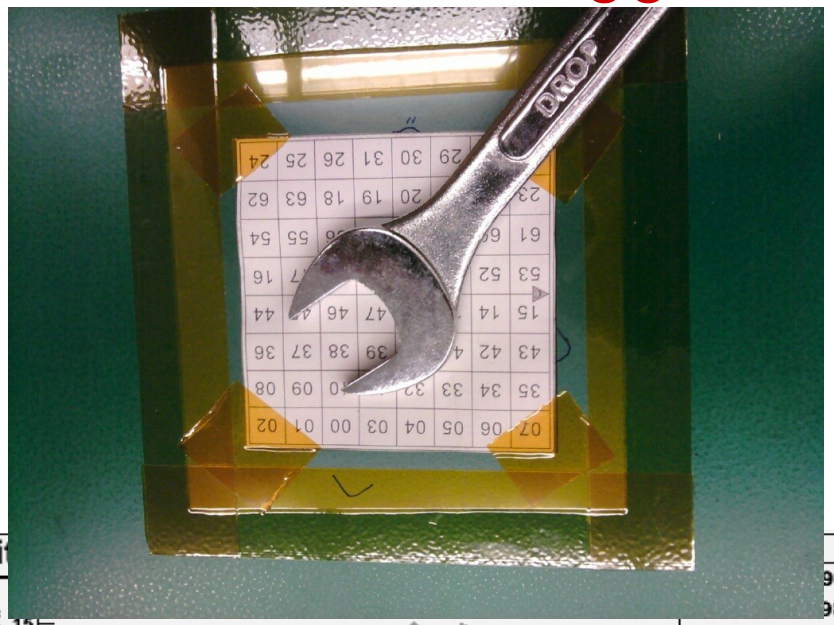
- Use DCAL in high-gain mode to establish MIP signals.
- Determine noise level for DCAL/GEM combination
- Determine operating threshold(s) for DCAL
- Investigate effects of sparks on DCAL chip.
- Determine efficiency/uniformity/multiplicity for GEM/DCAL
- Understand issues of using DCAL readout system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



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

Radioactive Source Run with Internal Trigger

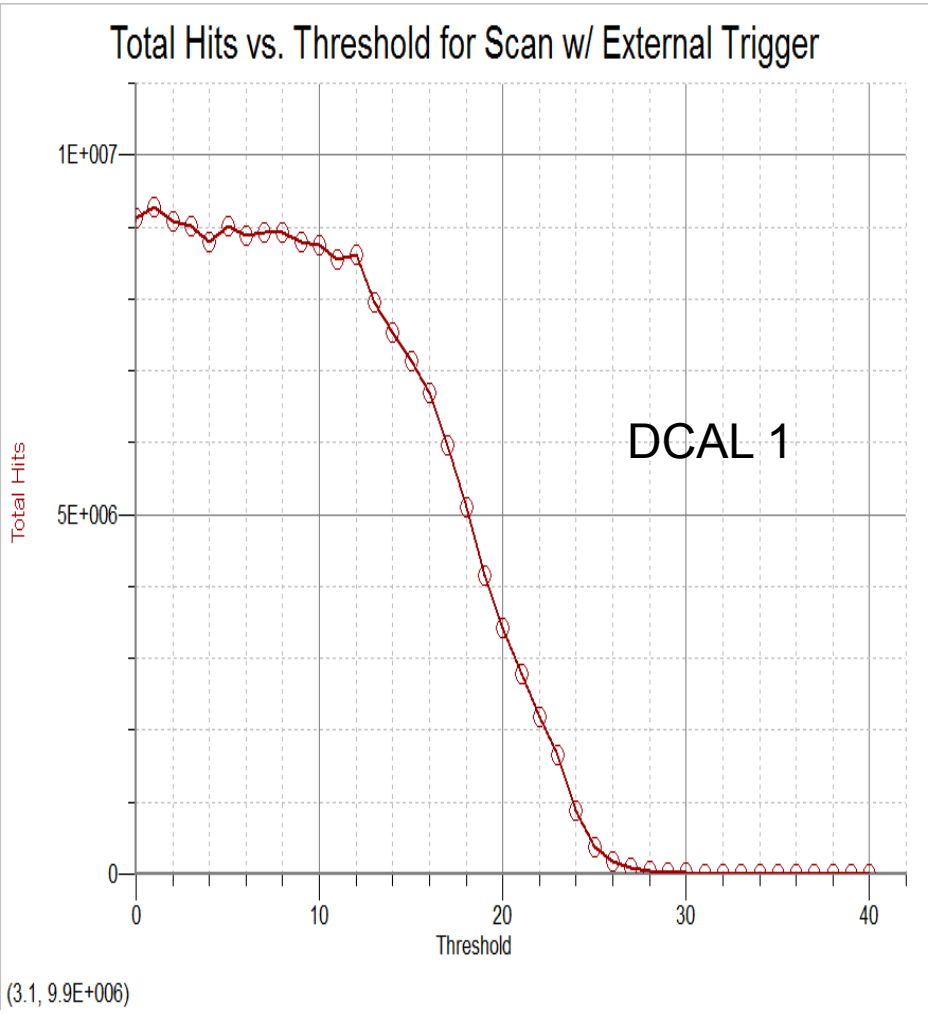


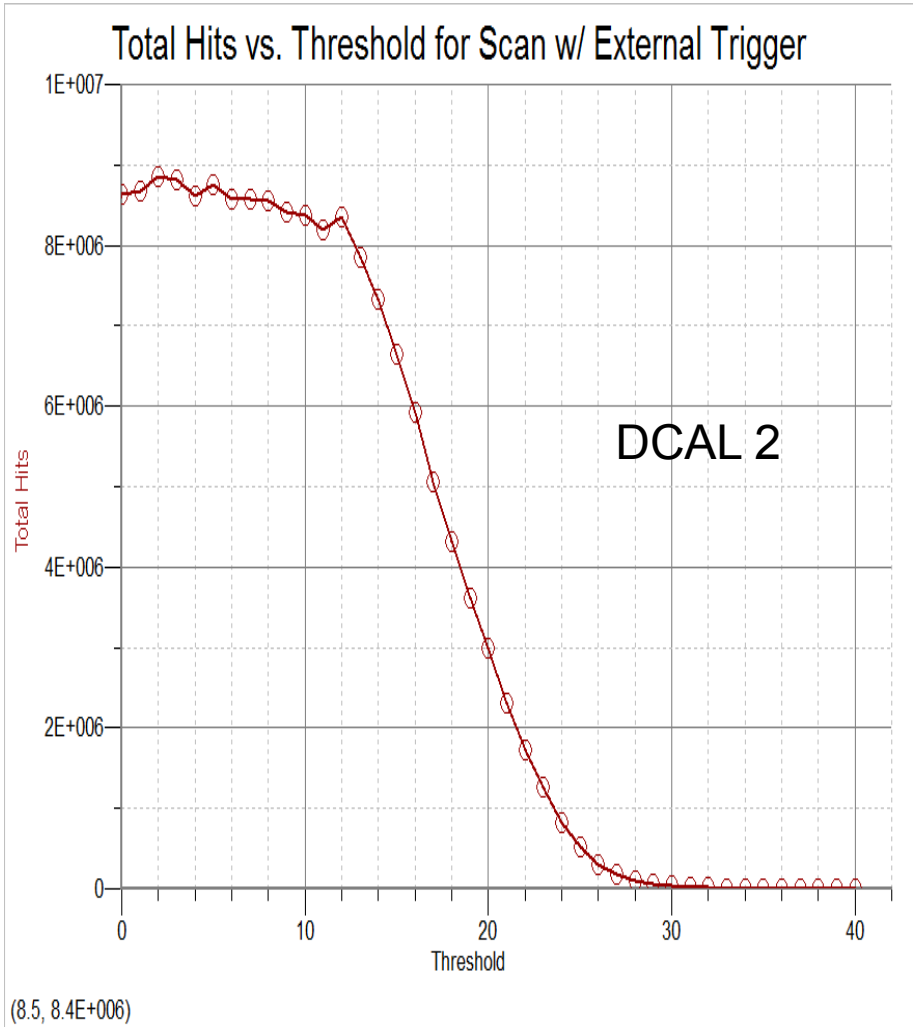


Noisy channels masked out!

Can you see what the object is?

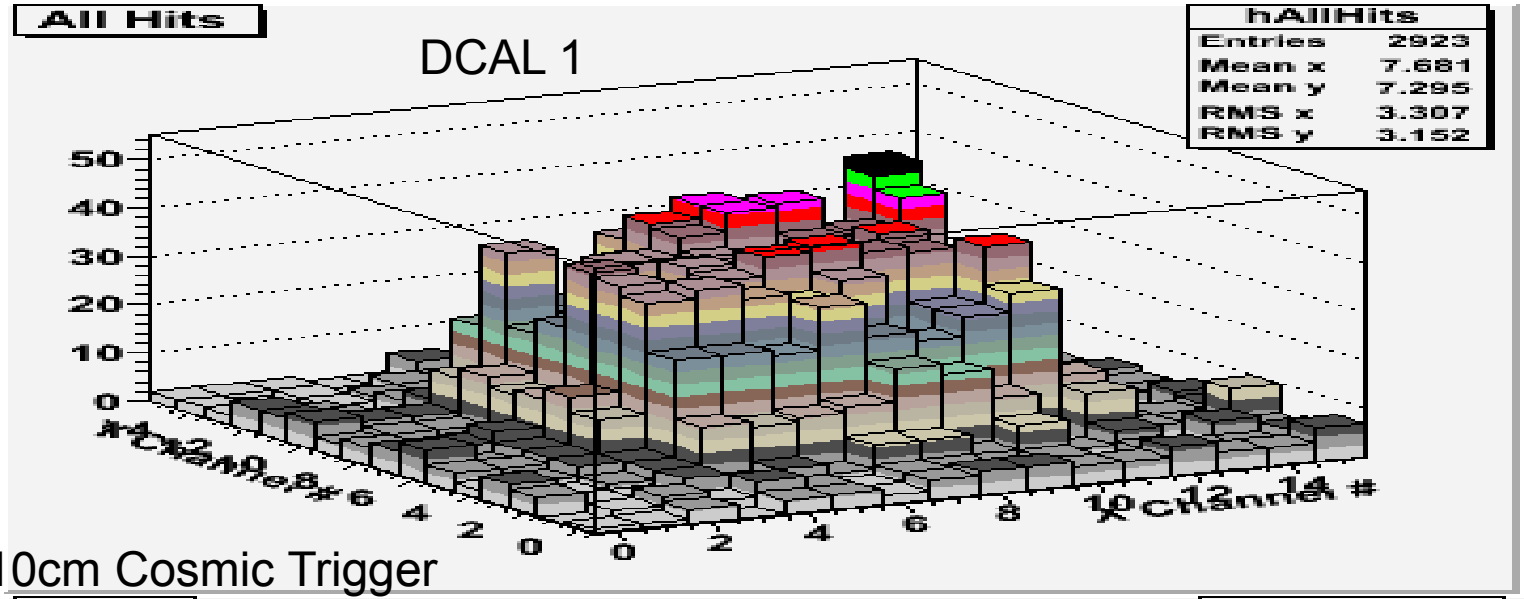
GEM+DCAL Threshold Scan w/ External Trigger



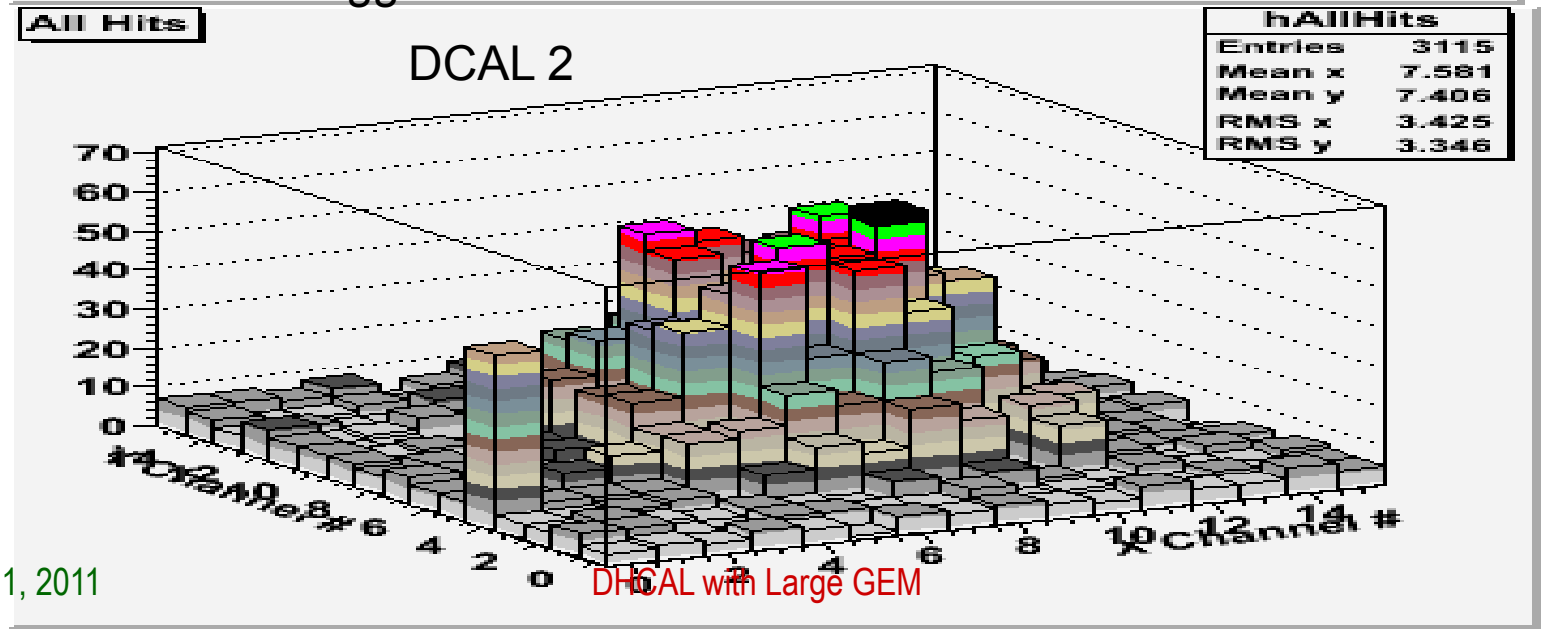


Two DCAL Chambers show consistent behaviors

Cosmic Rays with DCAL



10cmx10cm Cosmic Trigger

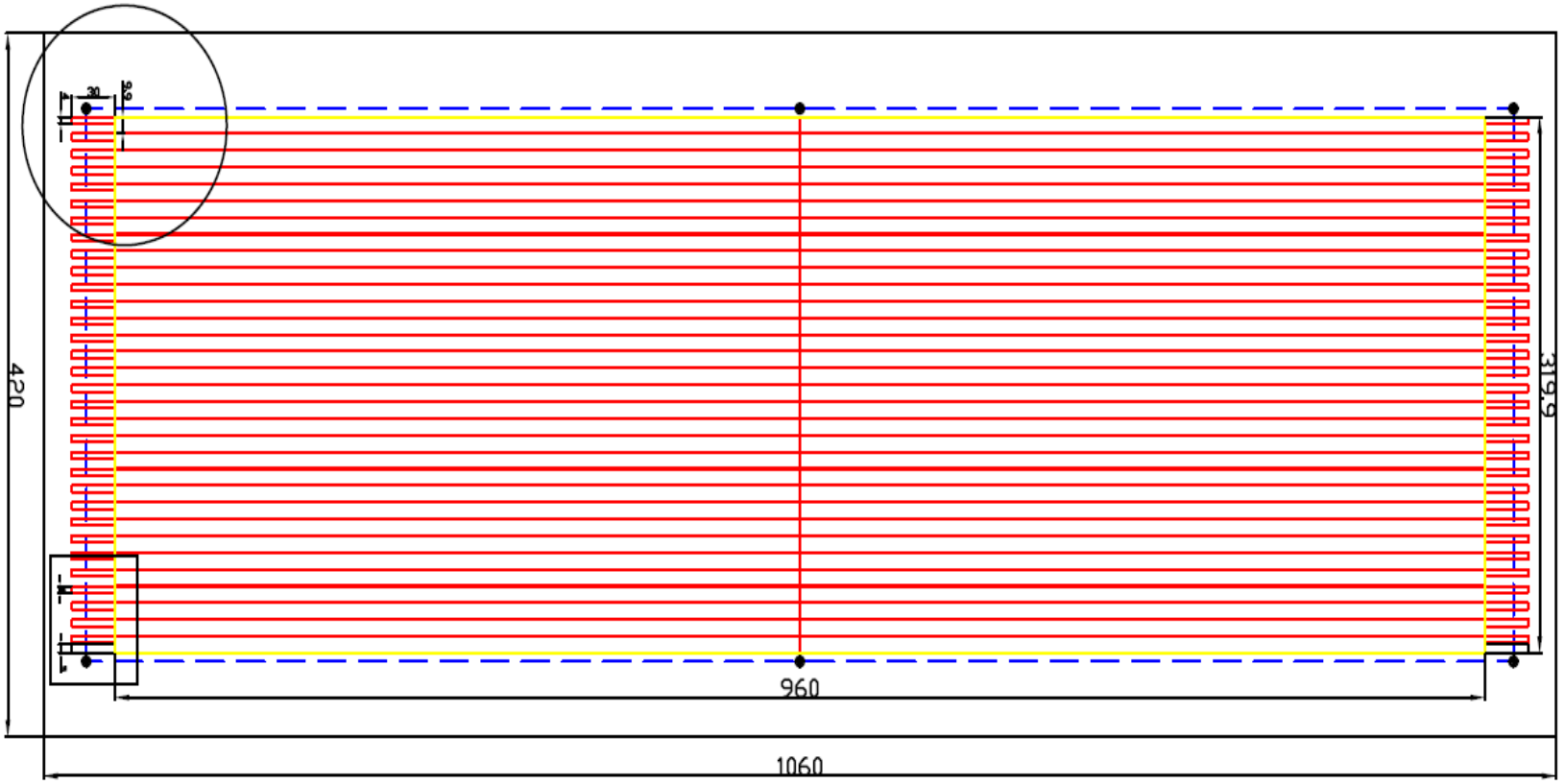


33cmx100cm GEM Foil Design

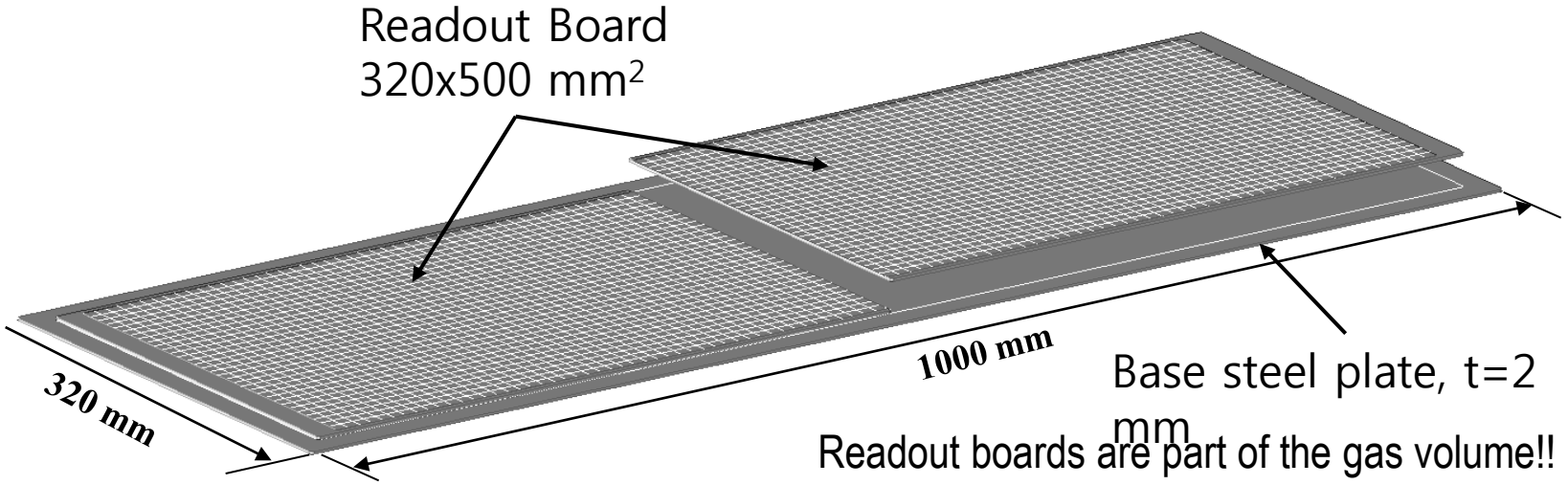
Designed to work with DCAL boards

Active area 940x306 mm^2

Divided into 31 independent 9.9x950mm^2 HV sectors

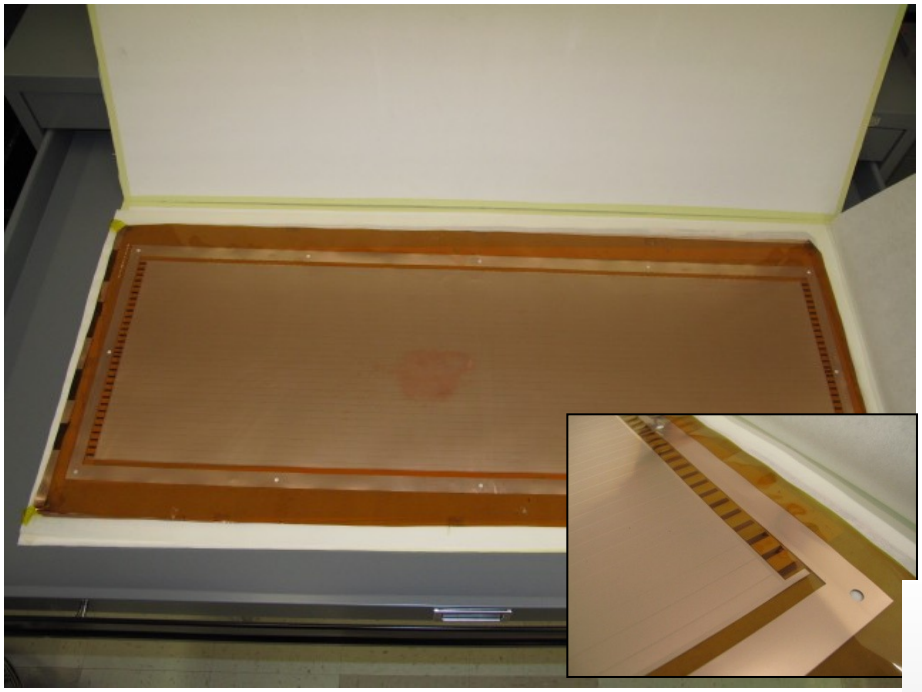


33cmx100cm DHCAL Unit Chamber Construction



Readout boards are part of the gas volume!!
How do we mate these together with minimal dead area?

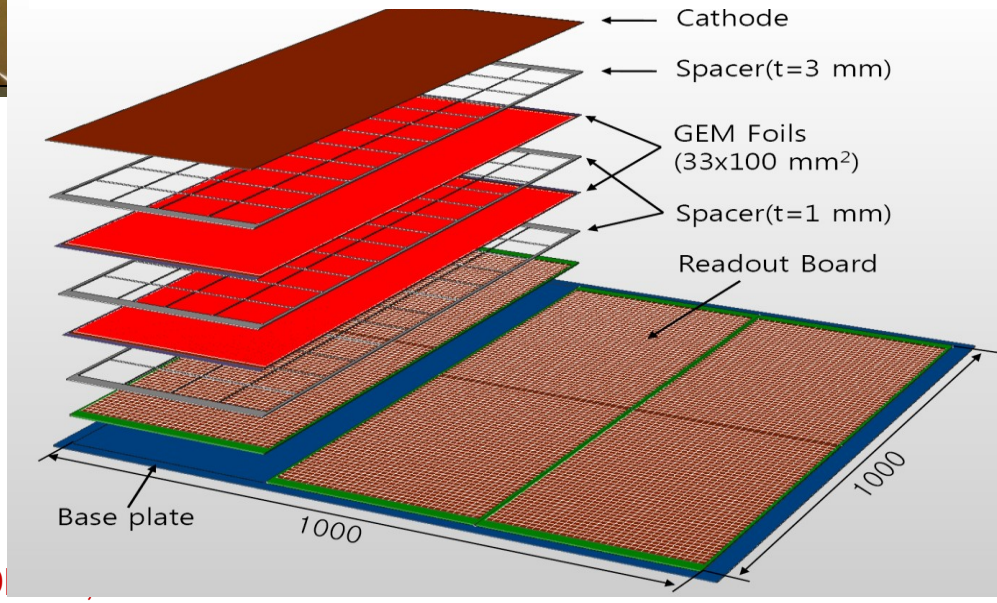
Toward 100cmx100cm GEM Planes!!



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

Foil Name	$N_{strip\text{-}pass}$	$<t_{saturation}>$	N_{strip}>2000s	Qualification	Note
LGEM 1	31	1725 s	4	Pass-med	Strips 1, 2, 10 & 23 >2000s
LGEM 2	30	1692 s	3	Pass-med	Strip 22 failed Strips 4, 5 & 29>2000s
LGEM 3	31	1484 s	0	Pass-high	
LGEM 4	31	1491 s	1	Pass-high	Strip 20 >2000 s
LGEM 5	Untested				Free-Delivered broken

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



GEM DHCAL Plans

- Phase I (Through late 2011) ➔ Completion of 30cm x 30cm characterization and DCAL chip integration
  - Perform beam tests @ FTBF with 30cm x 30cm double GEM chambers, one with KPiX9 and 2 – 3 with DCAL ➔ August 2011
  - 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
  - kPiX readout: Established good 2D working condition with v7 now working on v9 (512 channel) integration
  - DCAL integration very successful ➔ Fine tuning and multiple chamber cosmic ray testing in progress
  - Getting ready for beam test at FTBF in August 2011
- 33cmx100cm unit chamber construction proceeding
  - First 5 foils of 33cmx100cm delivered and qualification completed
  - Spacers to be ordered
  - Preparing a mobile clean room for foil certification and chamber construction
- Mechanical design being worked out for constructing 33cmx 100cm unit chambers and 1mx1m planes for DHCAL testing