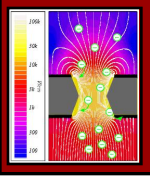


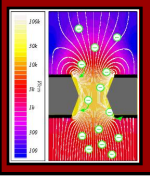
Gas Electron Multiplier (GEM)

Status of the GEM/DHCAL project

Seongtae Park

University of Texas at Arlington, USA

LCWS12
University of Texas at Arlington, USA
22~26 October 2012

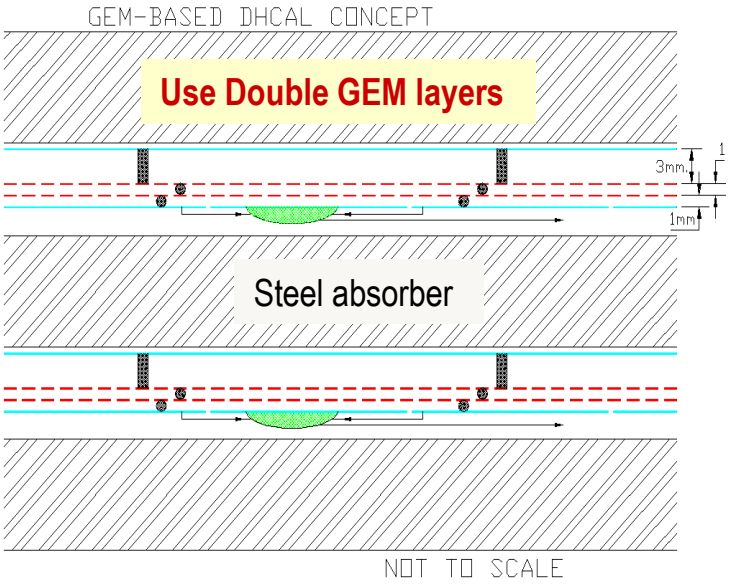


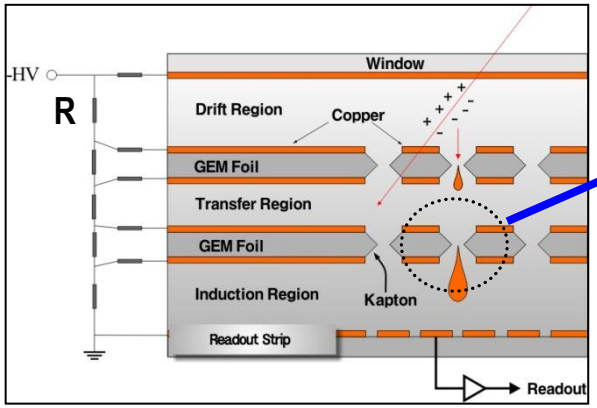
Outline

1. Introduction to GEM based DHCAL
2. Prototype GEM detectors
   - ✓ DAQ: KPIX, DCAL
3. Test results: Radiation source, Cosmic rays
4. Test results: FNAL beam test
5. Progress on LGEM construction
   - ✓ Structure & assembly
   - ✓ LGEM qualification
6. Summary

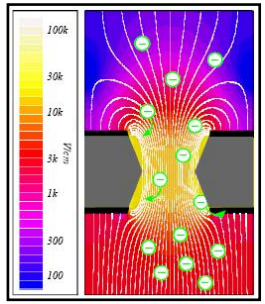
DHCAL concept and GEM Detector

- GEM detector is composed of a chamber, HV supplier, anode board, readout electronics, and DAQ program



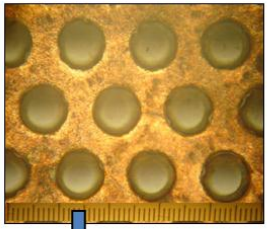


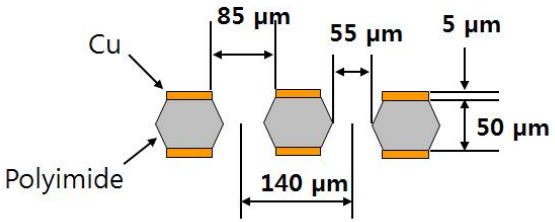
Electron Avalanche
→ Amplification



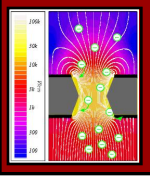
Chamber filled with gas

$$Ar : CO_2 = 80 : 20$$





- Passive (material) and Active (GEM) layers
- Increase spatial resolution (1 x 1 cm² readout pads)



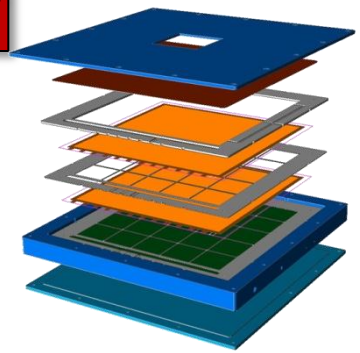
Why GEM's for DHCAL?

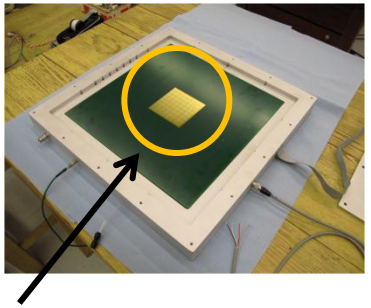
- Flexible configurations: allows small anode pads for high granularity
- Robust: survives ~10^{12} particles/mm^2 with no performance degradations
- Fast: based on electron collection, ~few ns rise time
- Short recovery time → can handle high rates
- Uses simple gas (Ar/CO_2) – no long-term issues
- Runs at relatively low HV (~400V across a foil)
- Stable and robust operations

30x30 prototype GEM chamber and Readout Electronics

Chamber

- GEM Foils(CERN)
  - 310x310 mm^2
  - Active area : 280x280 mm^2
- Active gas room
  - 350x350x6 mm^3 → For 3/1/1 gaps
- KPIX:64, DCAL:256 readout channels



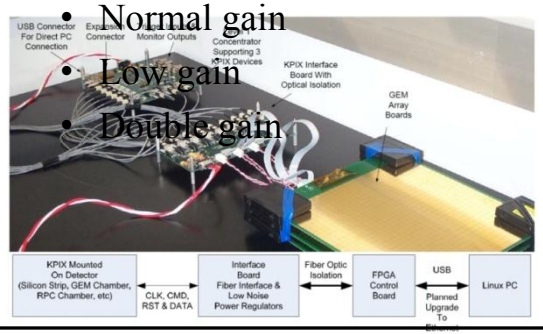


64-readout pads

Readout system

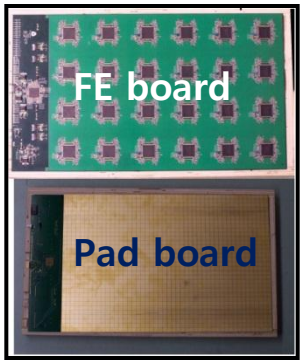
❖KPiX readout system/SLAC

- ✓ 13 bit resolution(ADC)
- ✓ Designed to handle 1024 channels/chip, currently 64/chip (ver.7)
- ✓ 3 gain ranges
  - Normal gain
  - Low gain
  - Double gain



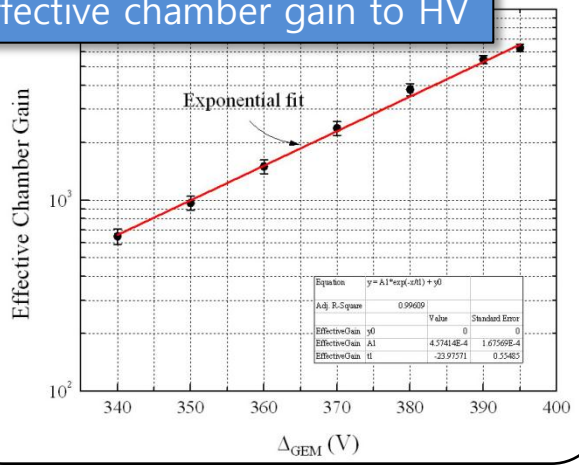
❖DCAL readout system/ANL

- ✓ 1 bit resolution(ADC)
- ✓ 64 channels/chip
- ✓ 2 gain ranges
  - High gain for GEMs (10 fC~200 fC signals)
  - Low gain for RPCs (100 fC~10 pC signals)

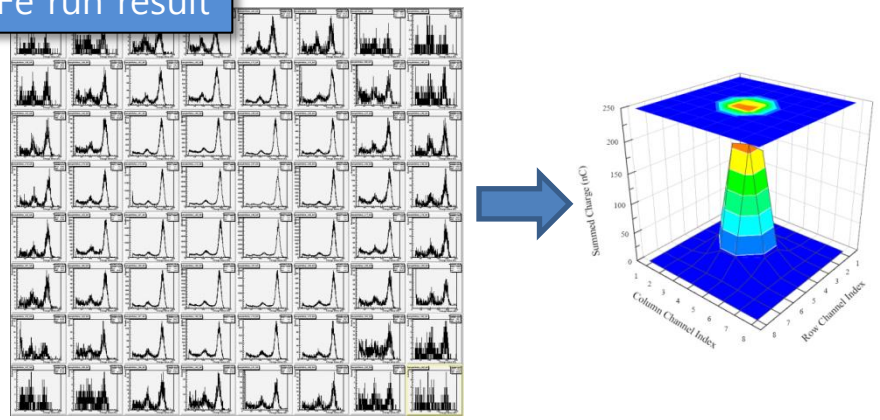


Some test results with 30x30 cm^2 chamber/KPiX

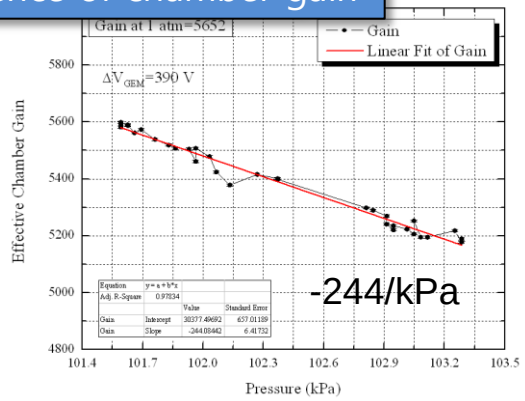
Effective chamber gain to HV



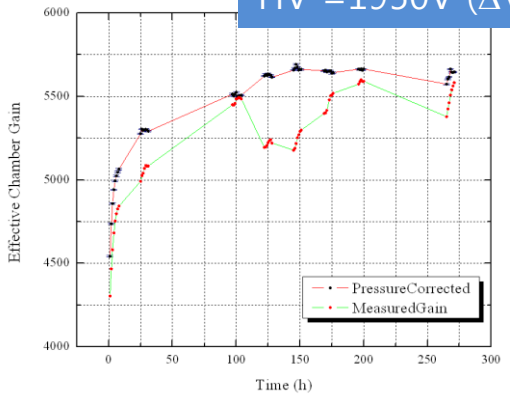
^{55}Fe run result



Pressure dependence of chamber gain

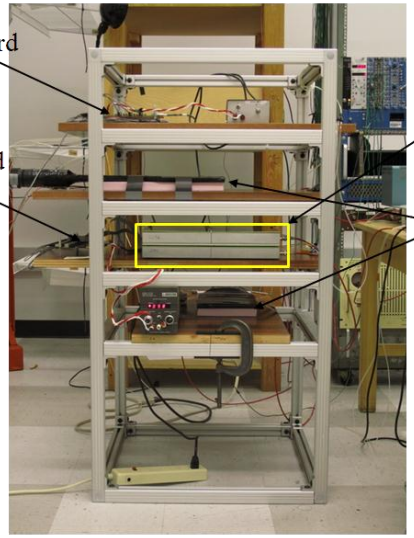


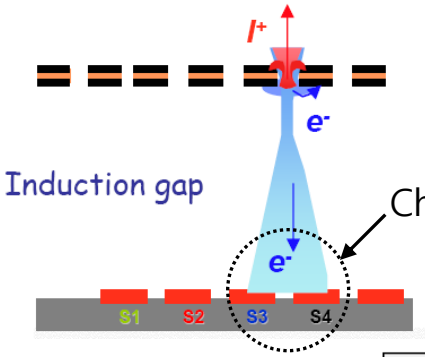
HV =1950V (ΔV_{GEM}=390 V)

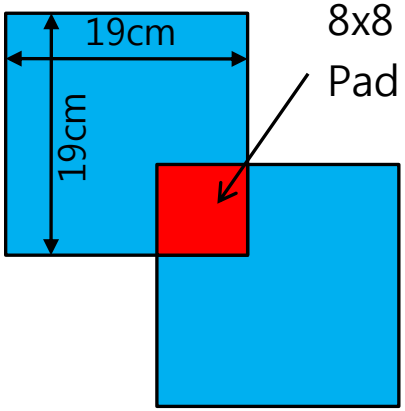


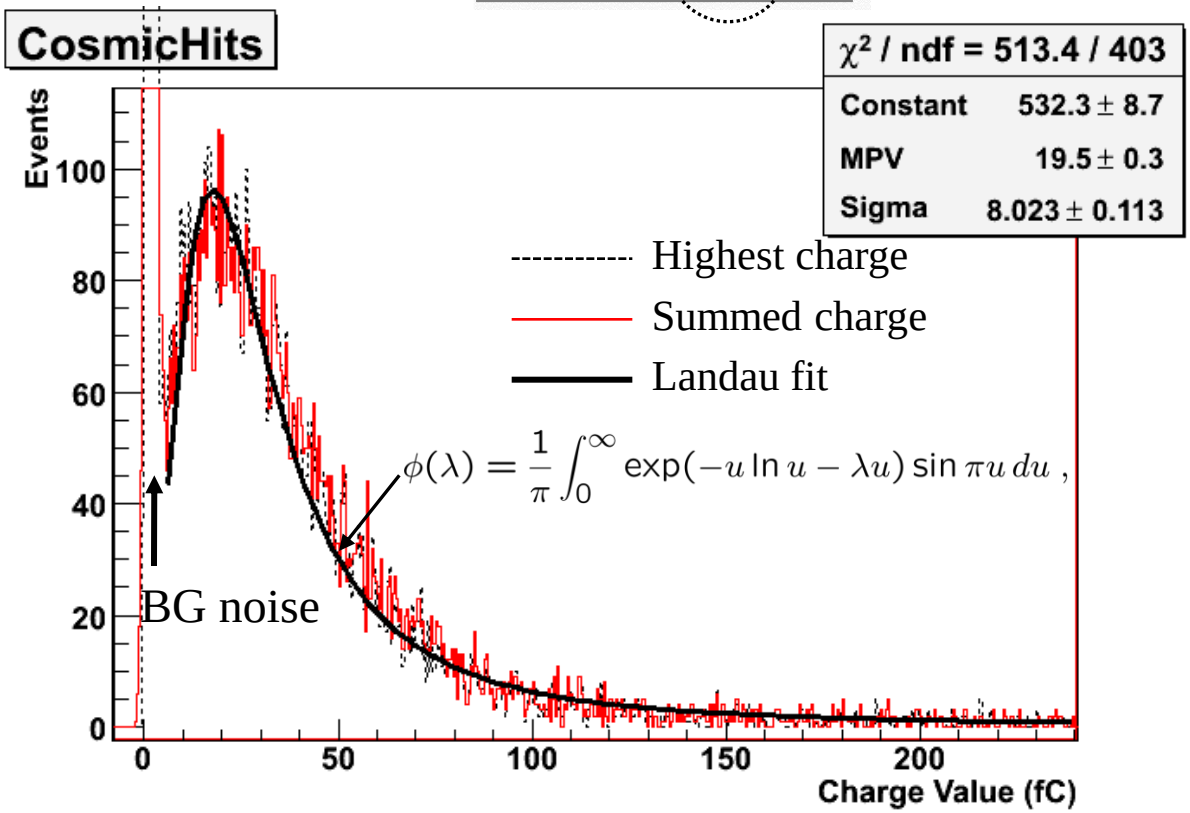
We use an open gas system (gas flows at atmospheric pressure).
Thus, pressure inside chamber is affected by the atmospheric pressure directly.
This pressure change affects the chamber gain.
The chamber gains were recalculated to the values at 1 atm.

Cosmic run/KPiX

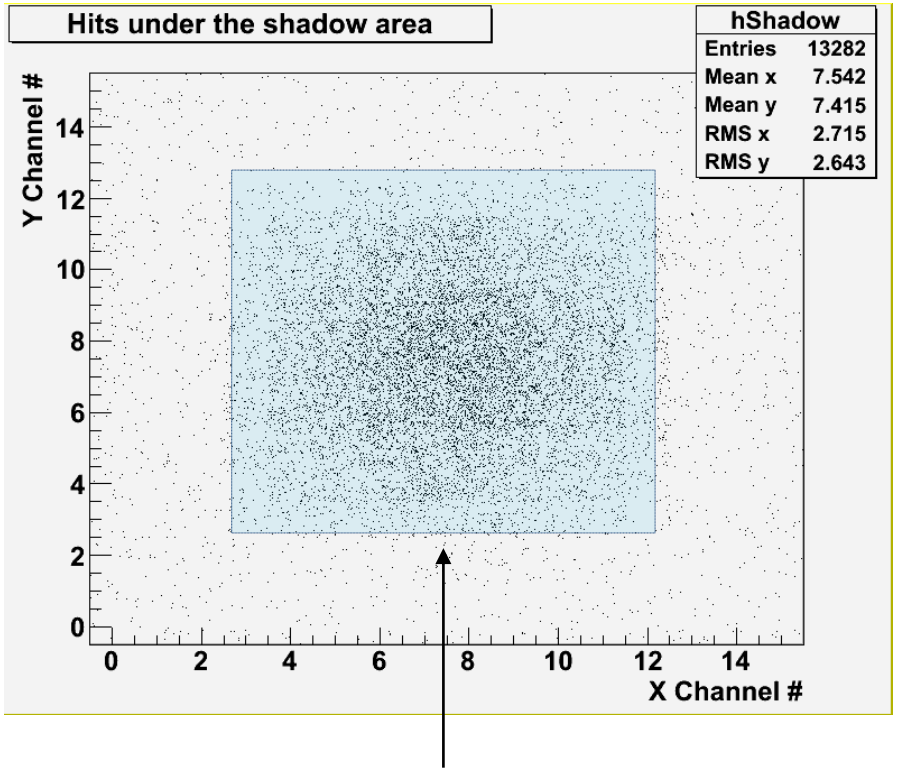




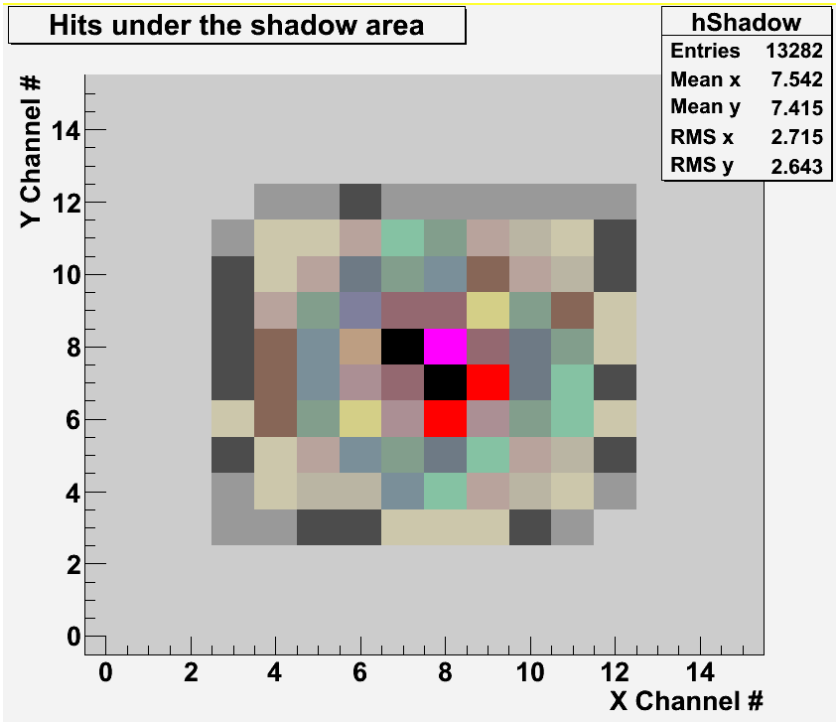




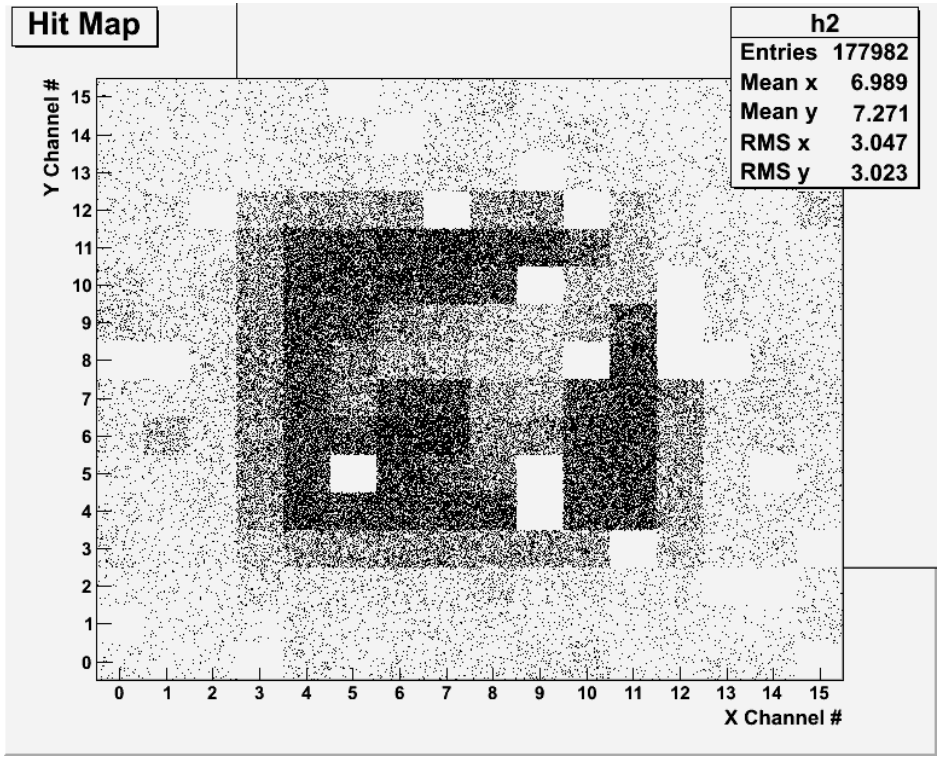
Cosmic Run/DCAL

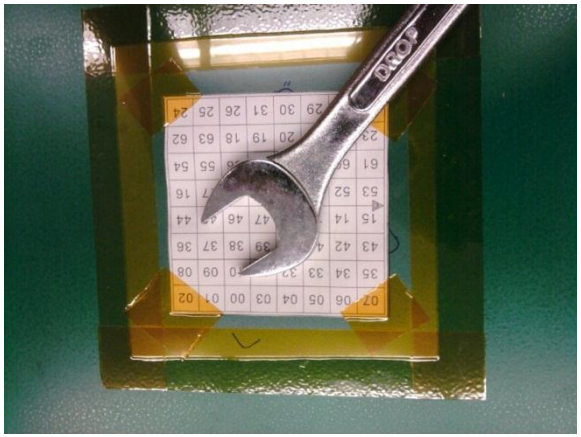


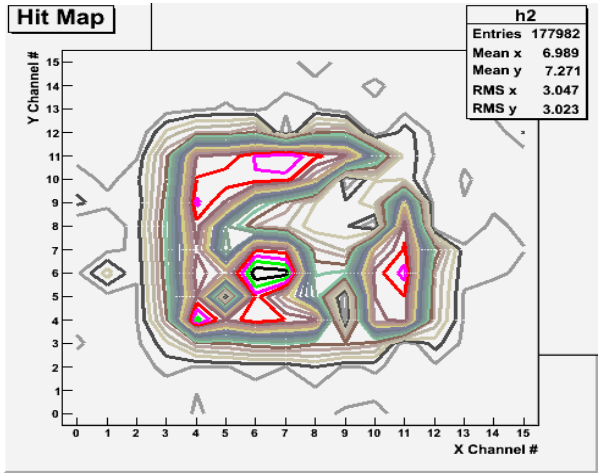
10cmx10cm Cosmic Trigger area



Radioactive Source Run/DCAL



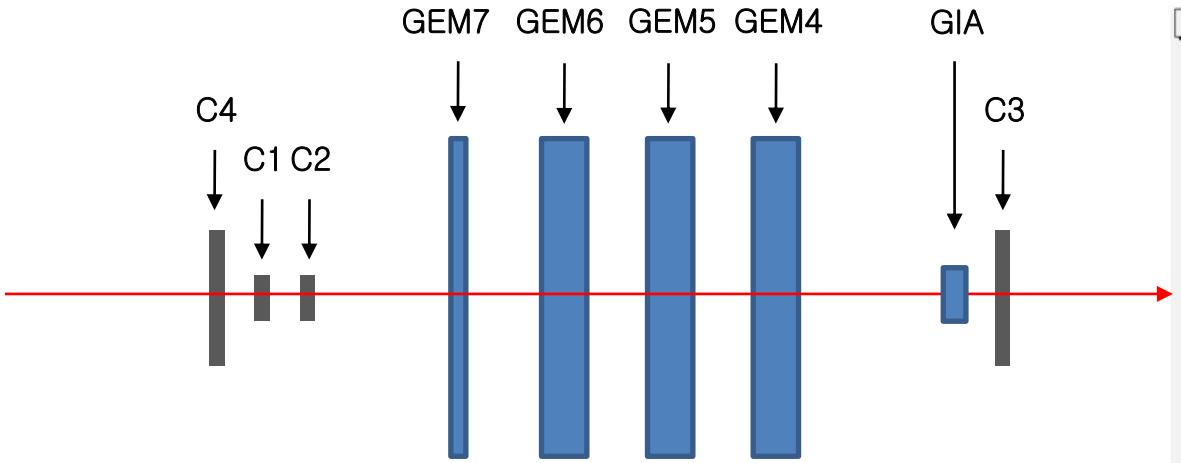


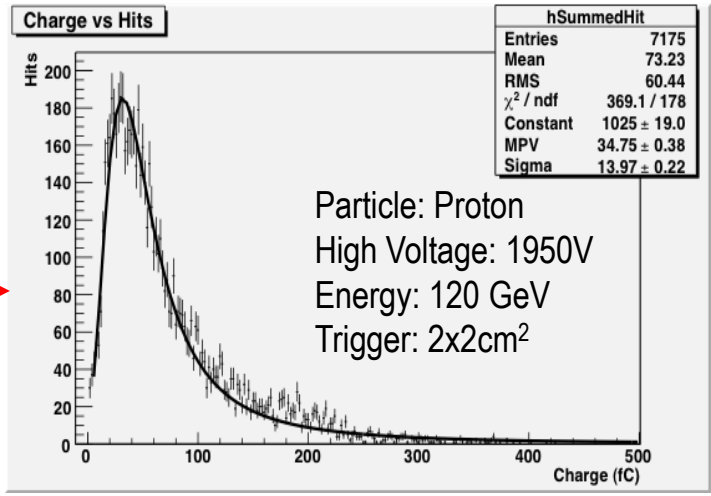


Source: Ru-106(β−ray), 20cm elevation from the chamber window
HV=-1950V(ΔV_{GEM}=390V)

FNAL beam test/Setup

GEM6: KPIX
GEM7, GEM5, GEM4: DCAL
C1,C2: 2x3 cm^2 → 2x2 cm^2 overlap
C3,C4:10x10 cm^2
Beams: 32GeV Muon, Pion, 120GeV Proton

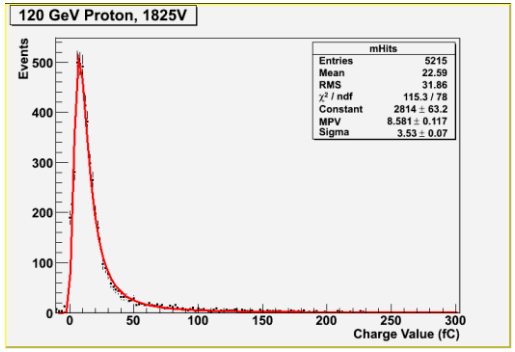


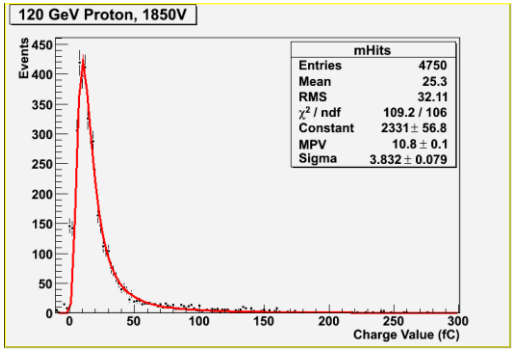


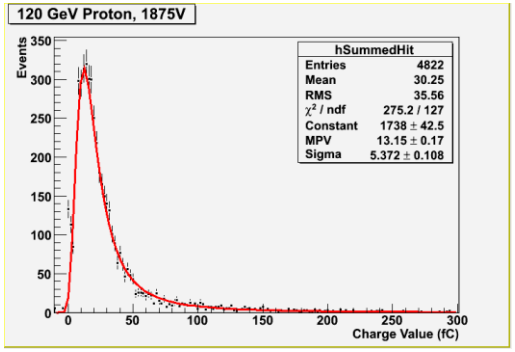
GEM6: Read out by 13bit KPiX designed for the ILC time line
GEM7, GEM5, GEM4: Read out by 1bit DCAL chip by ANL and FNAL
GIA: Medical image intensifier prototype with 12 bit ADC in-house readout
Triggers formed off the motion table:

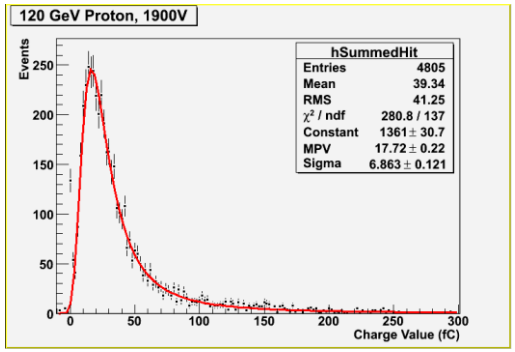
1. 10x10 coincidences for guaranteed beam penetration through the detector array
2. 2x3 coincidences arranged perpendicular to each other for 2x2 coverage in the center of the detector array
3. Coincidence of 1*2: Guaranteed beam penetration with center 2x2 coverage (efficiency ~95%)

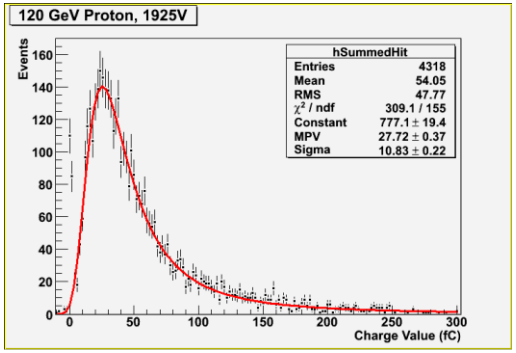
HV scan with 120 GeV Proton beam

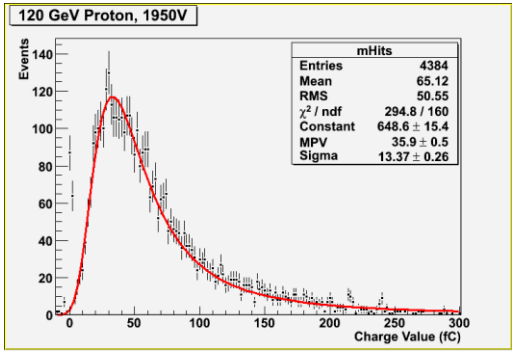


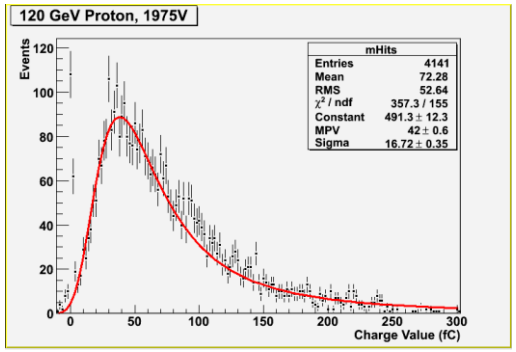


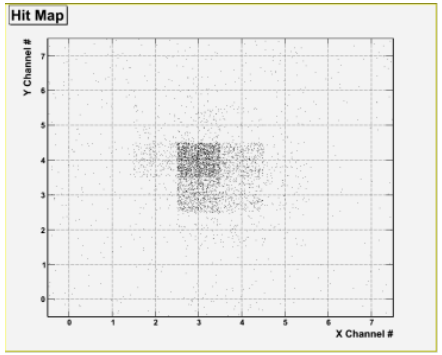


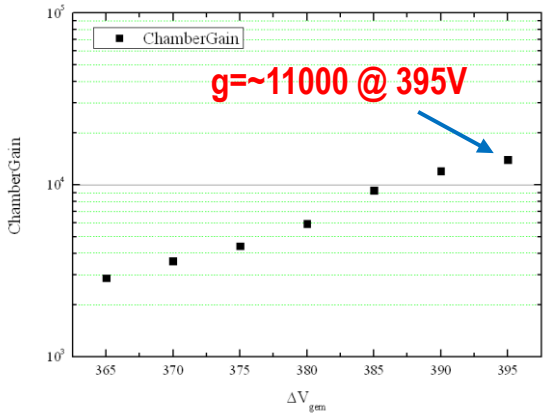






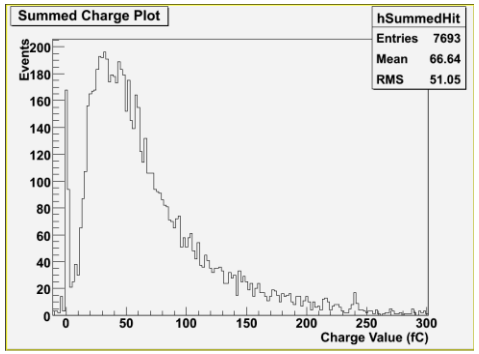




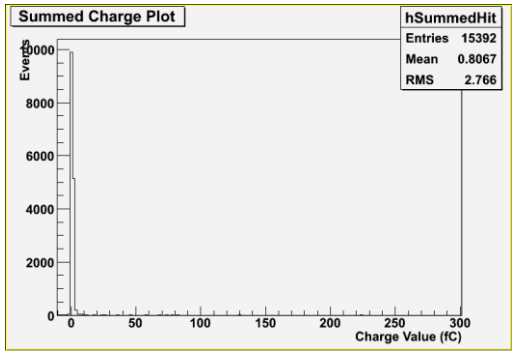


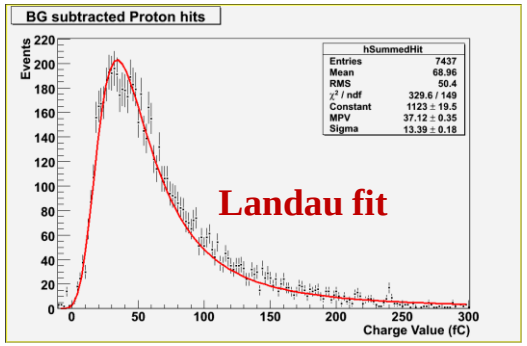
Noise subtraction and efficiency curves

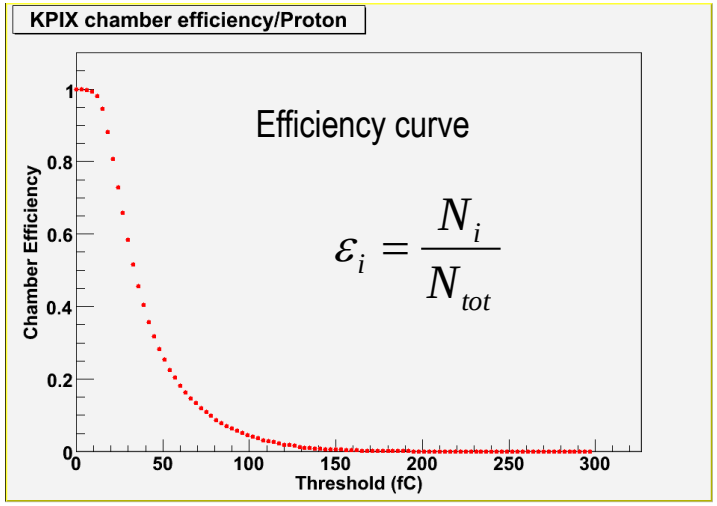
Proton(120 GeV) signal



BG noise

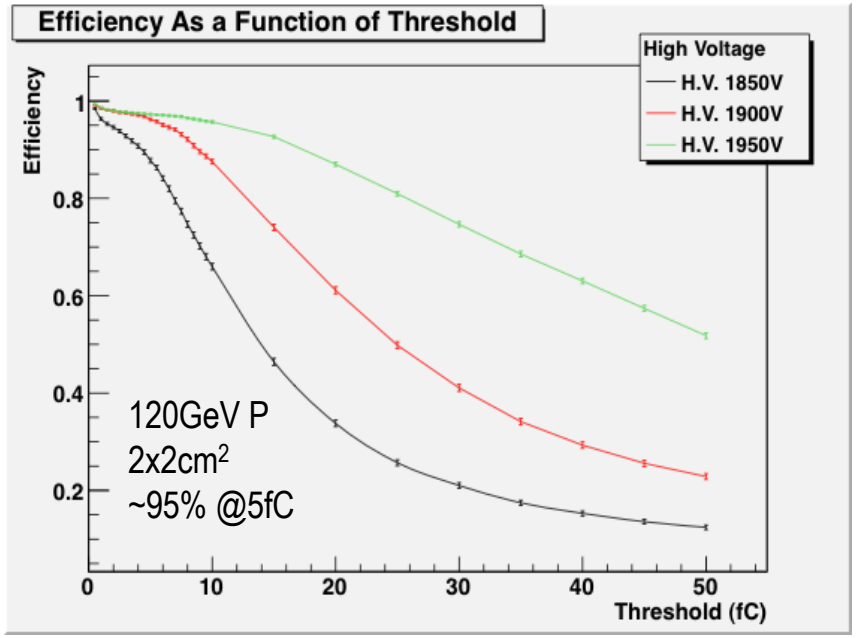




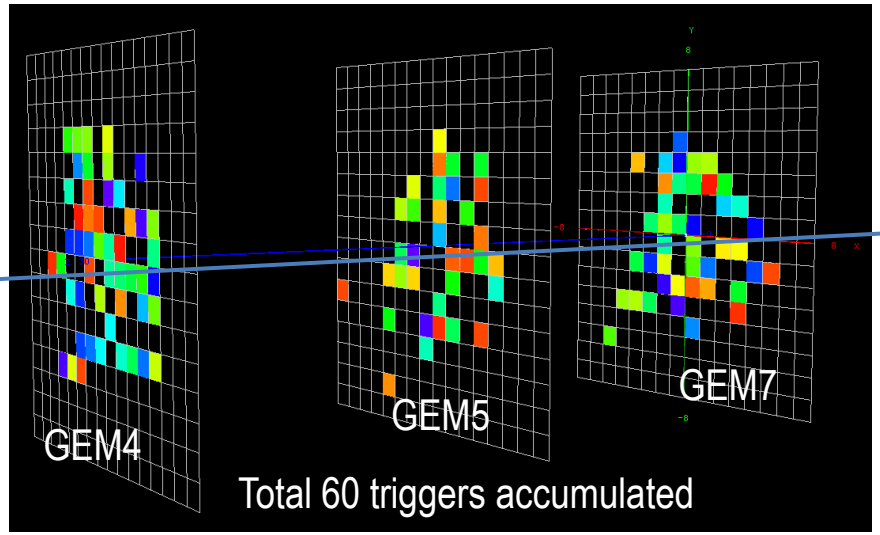


N_i=number of hits above threshold

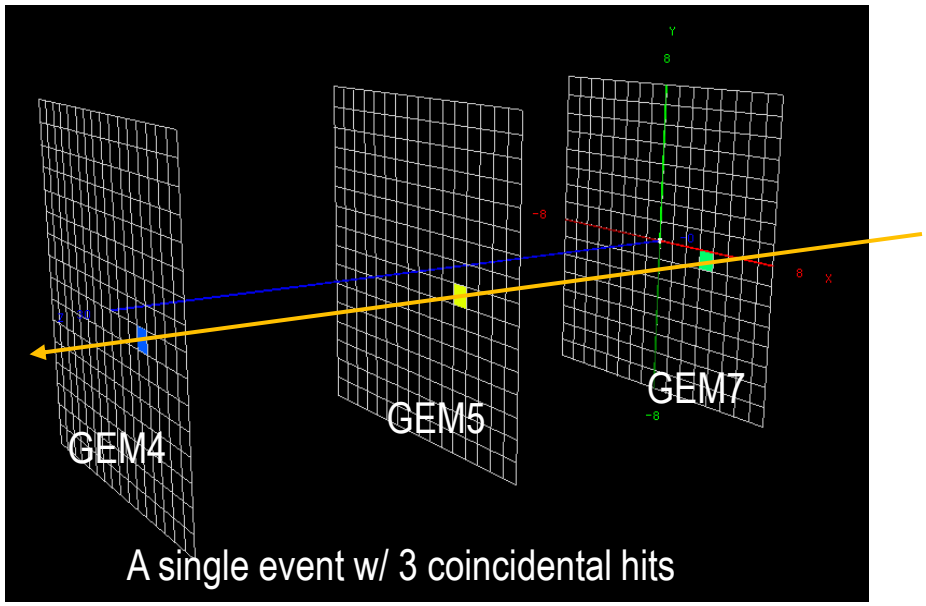
N_{tot}=total number of hits

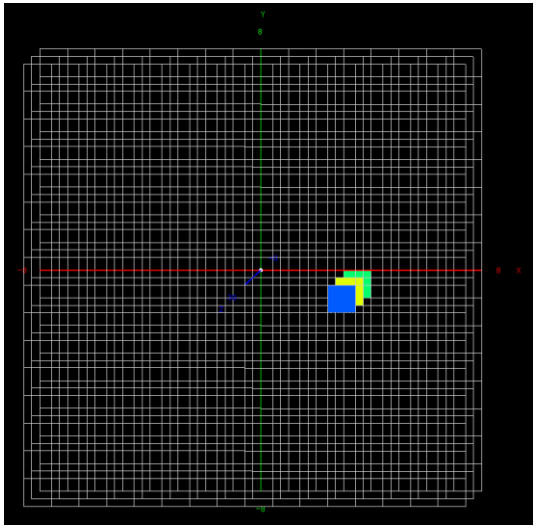


3 DCAL GEM Chamber Event Display



Beam direction
(120 GeV Protons)



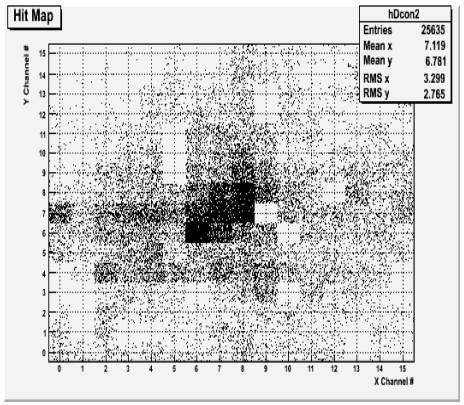


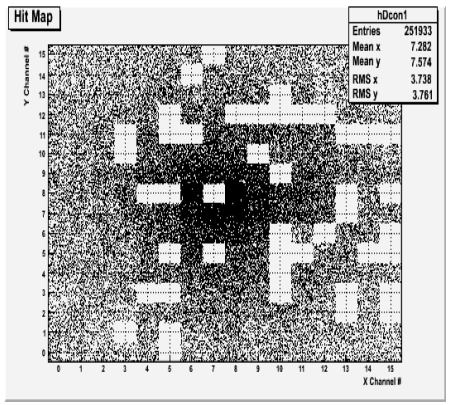
Hits from Pion Showers

GEM 7- Upstream

GEM4- Downstream

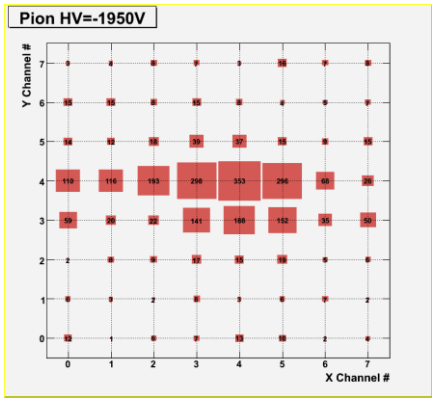
DCAL

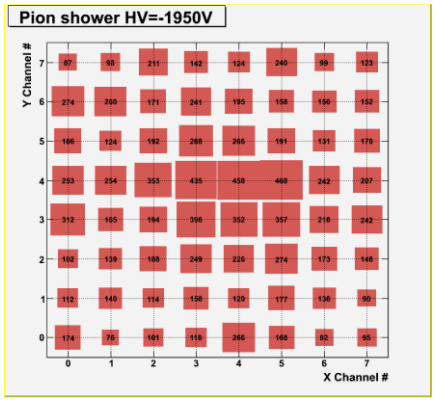


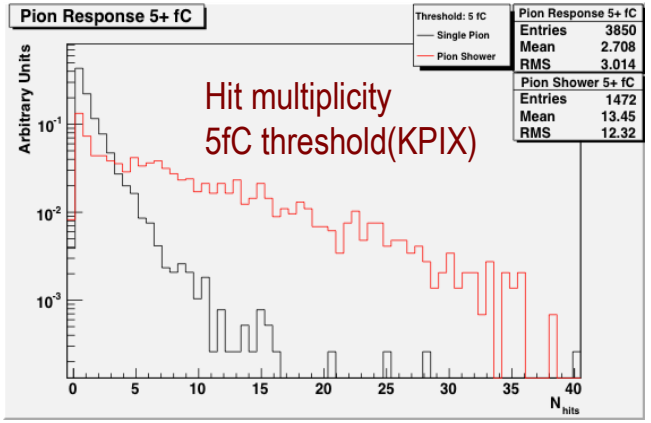


- Holes are dead channels or suppressed noisy channels
- 2 chamber and 3 chamber coincidence hits show minimal fraction of events with multiple particle hits per trigger

KPIX



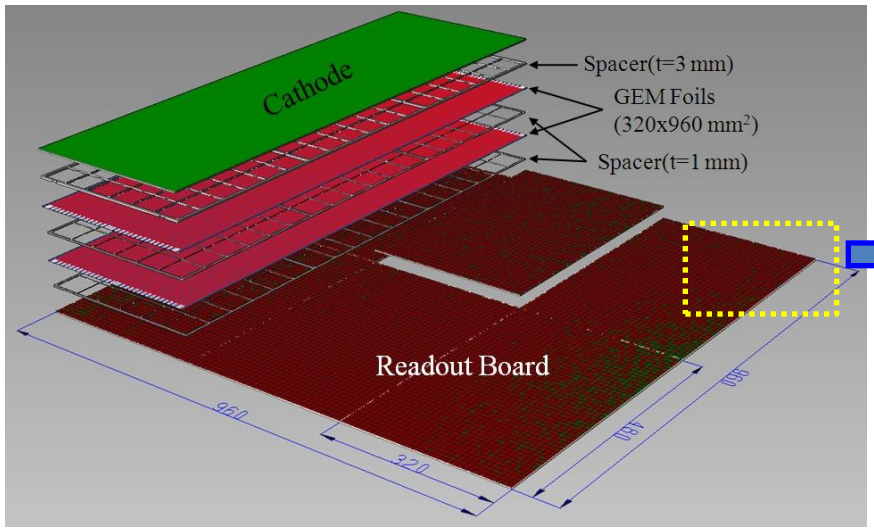




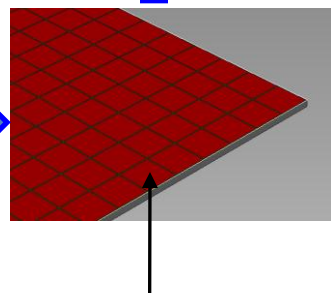
Hits above 5fC were counted and normalized to 1000

Demonstrates the KPIX capability to take many hits simultaneously

96x96 cm^2 large GEM chamber

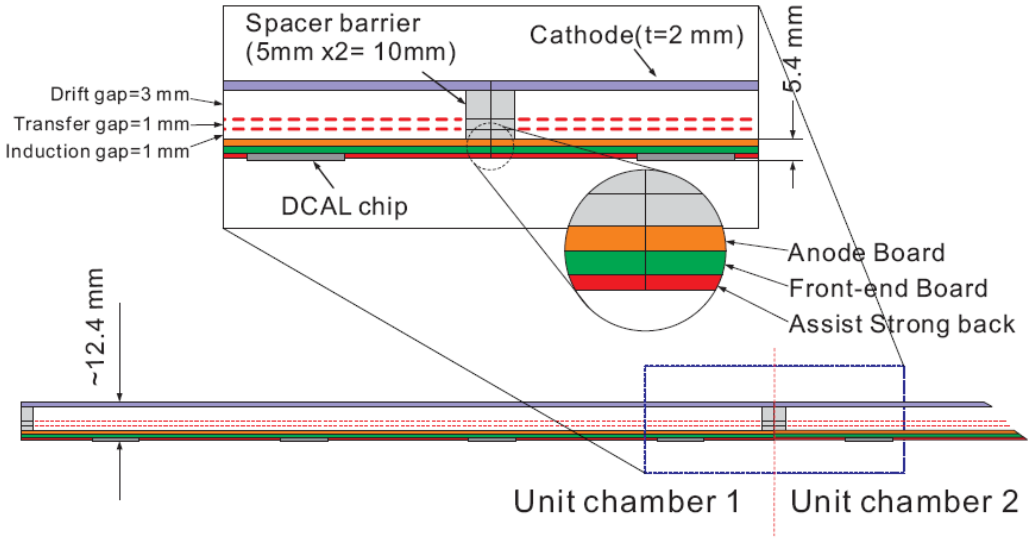


❖ 32x96x3=9,216 readout channels/chamber



Anode pad:1x1 cm^2

✓ CERN-UTA joint developed 32cmx96cm GEM foil
✓ Single-side etching technique

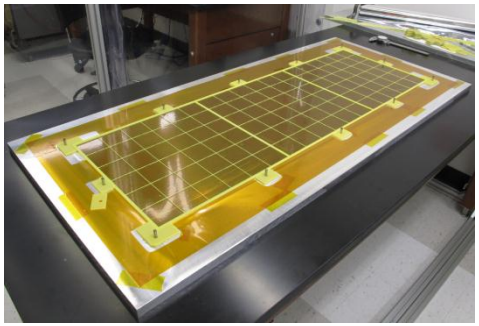


Steel, t=18 mm
Gap=13 mm
1x1 m^2 area

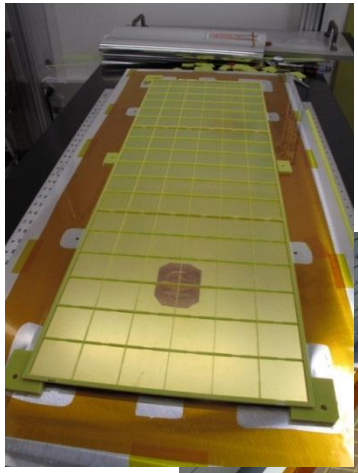
Assembling LGEM+spacer

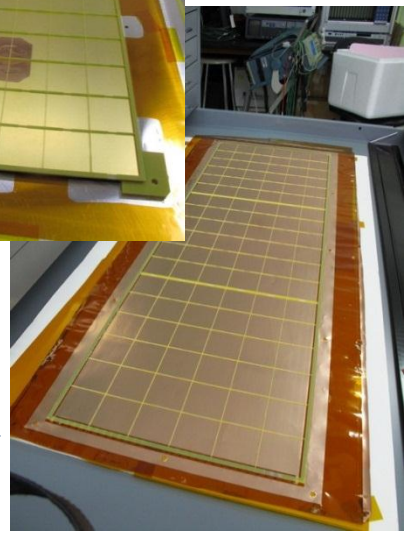
Class 10,000 clean room (12'x8')

Locate spacer on the jig plate

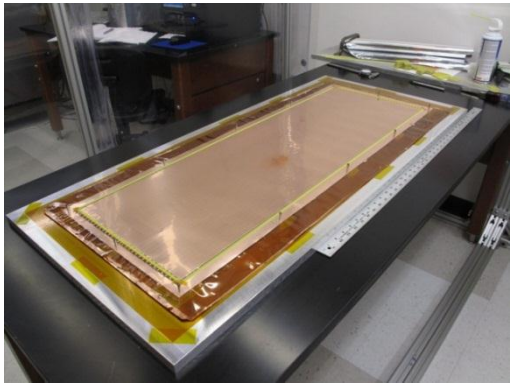


Cathode with spacer



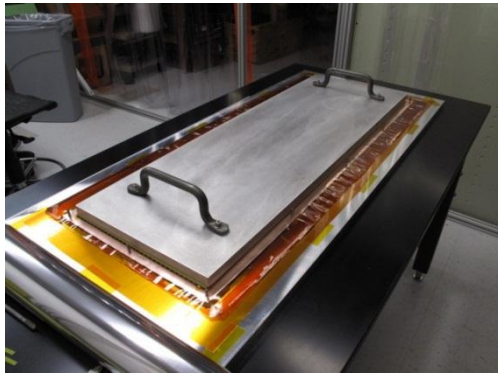


LGEM with spacer



Gluing(Epoxy glue)

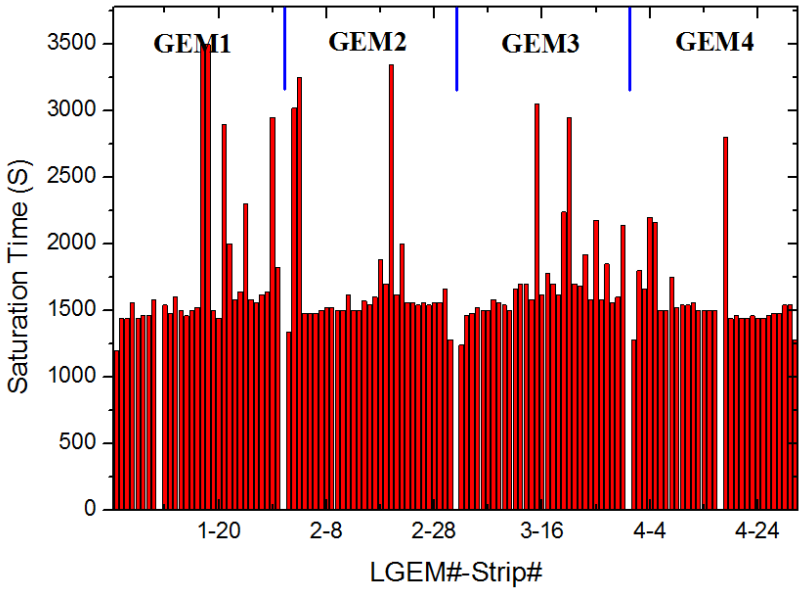
Curing

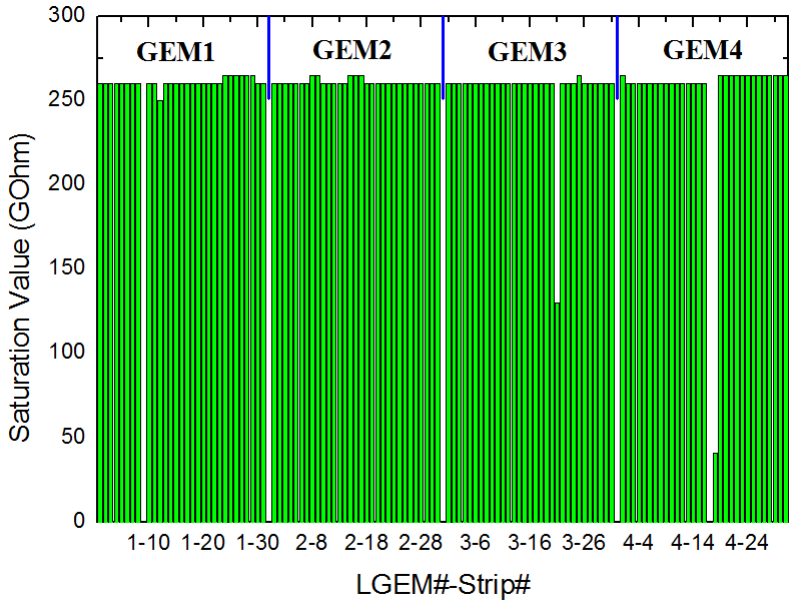


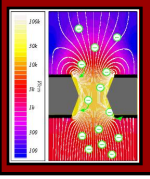
*Spacer wall thickness=0.5mm

LGEM qualification(resistance measurement)

FOIL NAME	$N_{strip\text{-}pass}$	$<t_{saturation}>$	N_{strip} >2000s	Notes
LGEM1(I)	30	1790	5	Strip 9 failed Strips 17, 18, 21, 23 & 30 >2000s
LGEM2(T)	31	1720	3	Strips 2, 3 & 20 > 2000s
LGEM3(I)	31	1711	4	Strip 21 R_{sat} @ 130GOhms Strips 15, 20, 26 & 31 > 2000s
LGEM4(T)	29	1549	2	Strip 17, 18 failed Strips 4 & 5 > 2000s





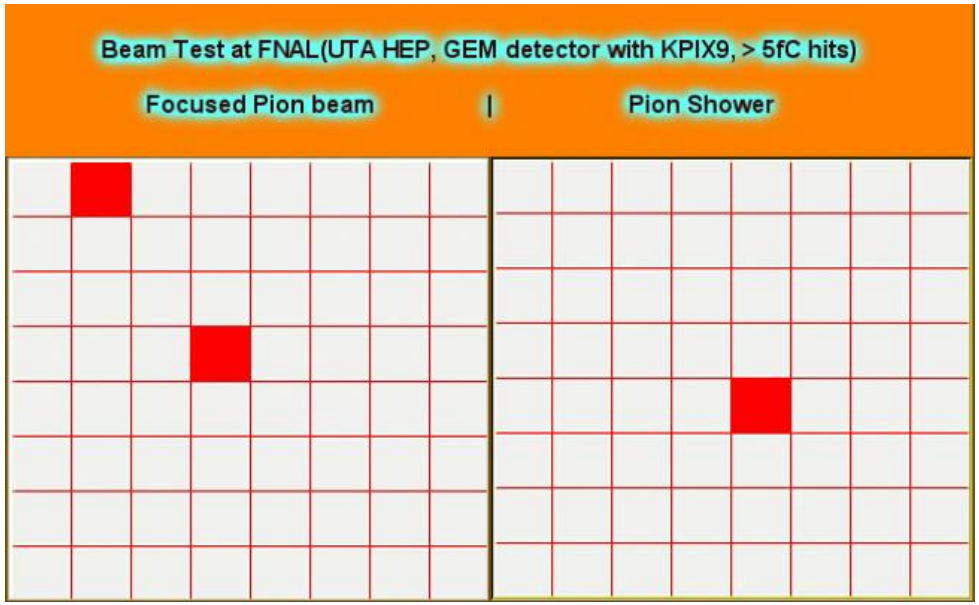


Summary

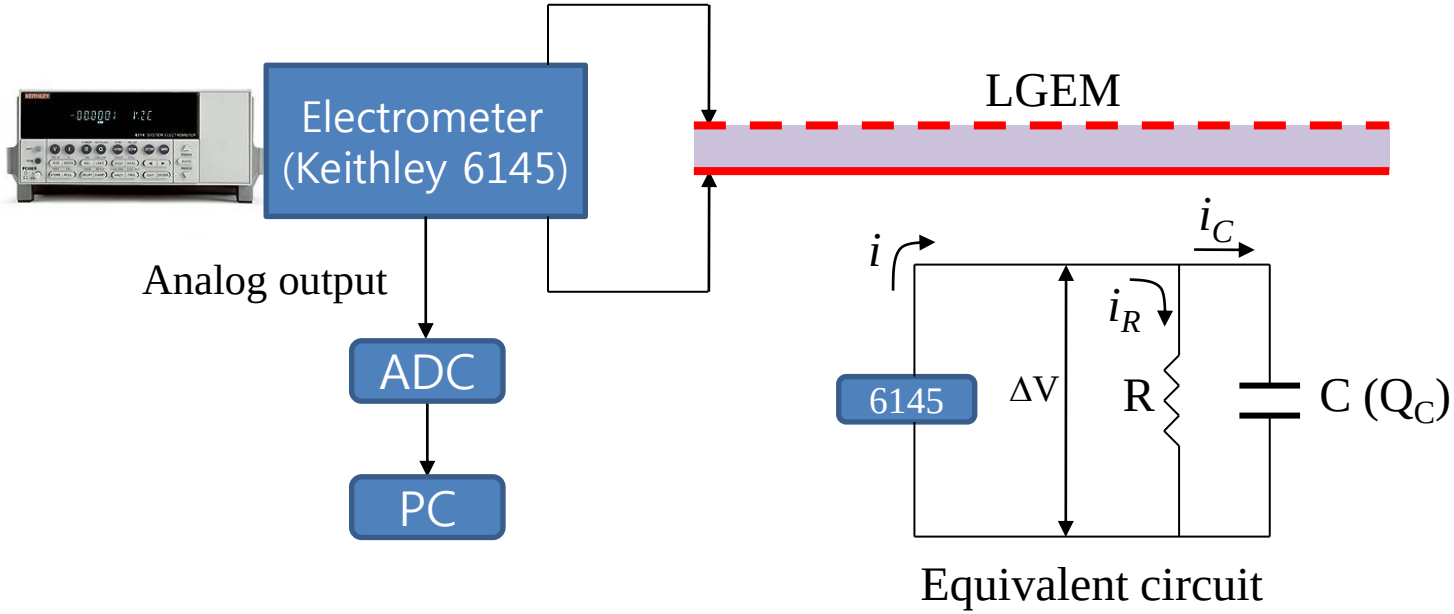
- 30cmx30cm GEM prototype chambers and test runs
  - ✓ Construction of 4 prototype GEM chambers using 30x30cm^2 GEMs
  - ✓ Equipped with KPIX(64ch) and DCAL(256ch) DAQ system
  - ✓ Test with radiation sources(Fe-55, RU-106, Cs-137 etc.), cosmic rays
  - ✓ FNAL beam test
  - ✓ Analyses of over 7M beam test events from Aug. 2011 run in progress
  - ✓ Continue taking cosmic ray data with these four chambers
- 32cmx96cm unit chamber construction proceeding
  - ✓ Built mobile clean room for foil certification and chamber construction
  - ✓ First 5 foils of 32cmx96cm delivered and qualification completed
  - ✓ G10 spacers delivered and assembling of spacers and LGEMs completed
- Mechanical design of anode boards for 32cmx 96cm unit chambers being working on with SLAC(KPIX) and ANL(DCAL)

Backup

Reconstructed event animation



Setup for LGEM resistance measurement



During the R measurement, 6514 is sourcing a known constant current *i* (1 nA).
Thus, R=V (Gohm) for the Ohmic material.