GEM applications – updates for Digital Hadron Calorimetry and Rare Kaon Decay Experiment

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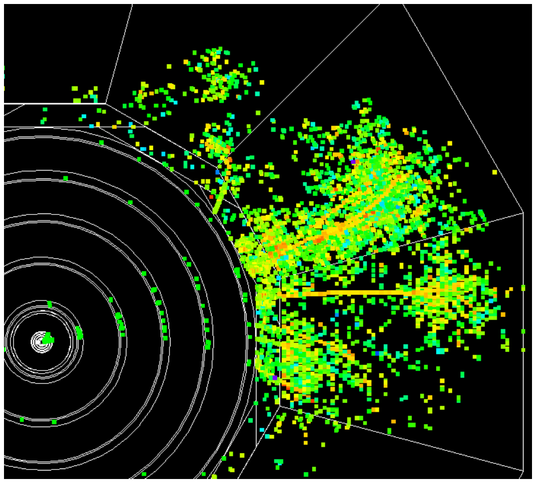
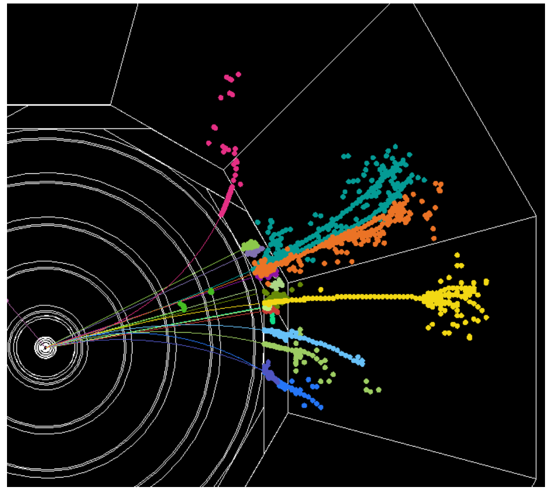
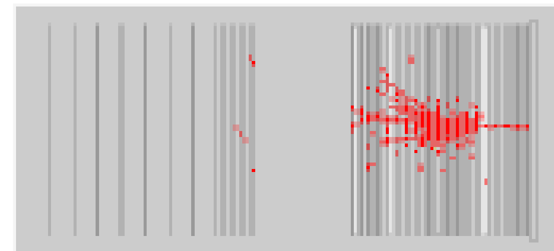
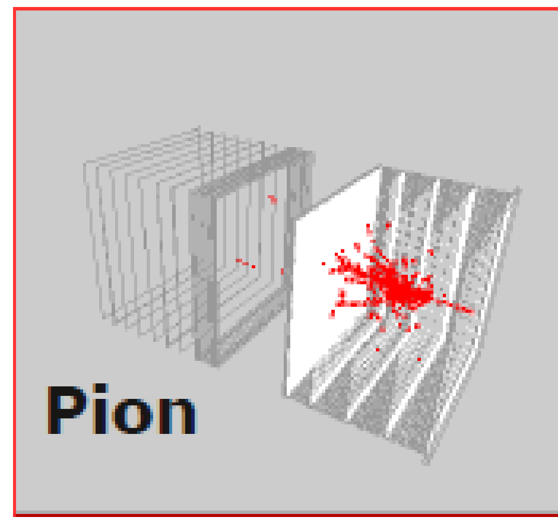
RD51 Collaboration Meeting – CERN, January 2013

Motivation (1)
Particle Flow Calorimetry – technology choice





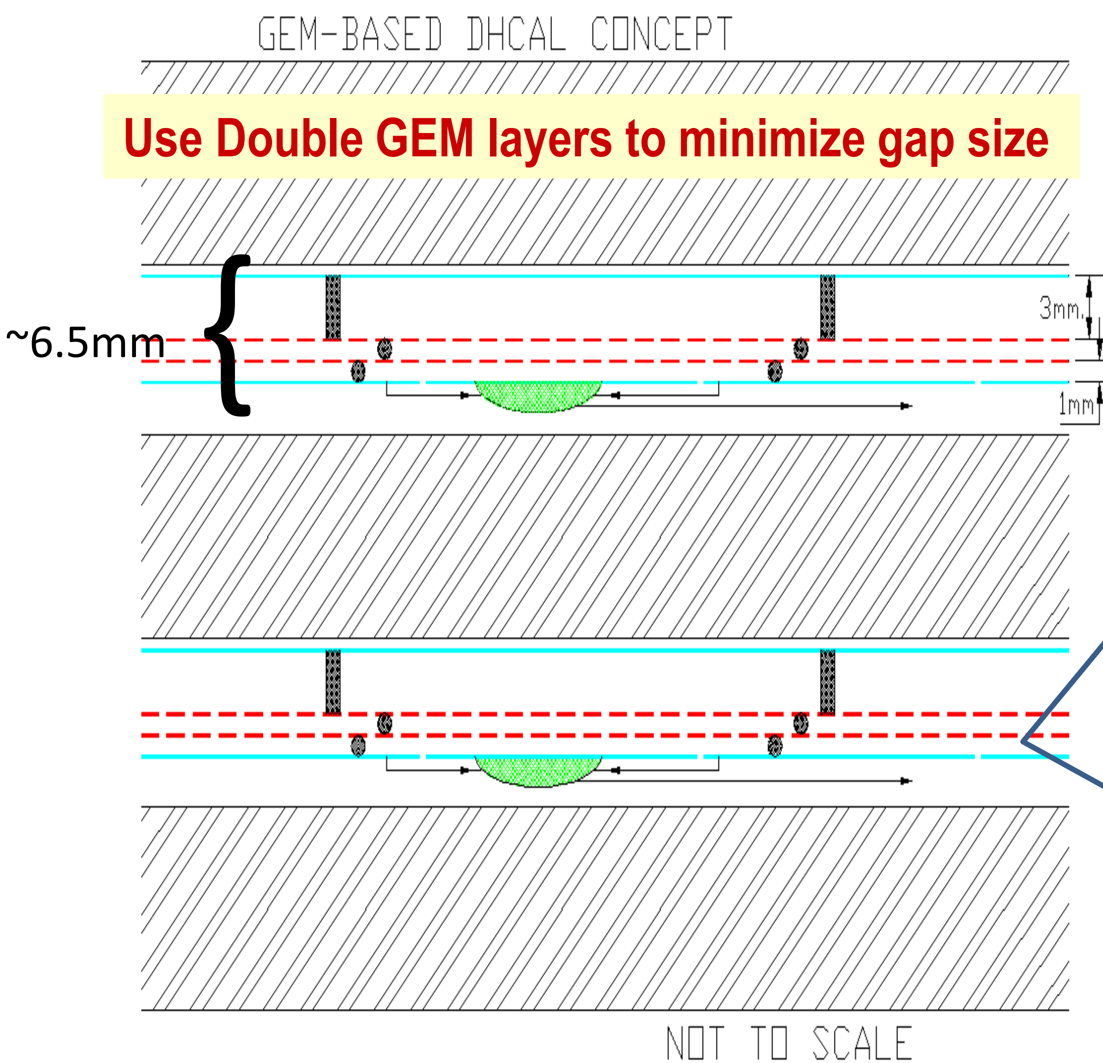


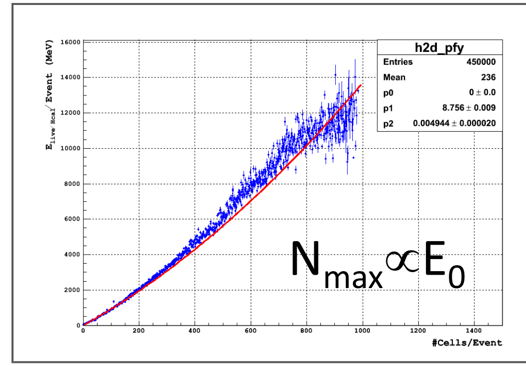


Results from RPC stack

GEM-based Digital Calorimeter Concept

Use Double GEM layers to minimize gap size





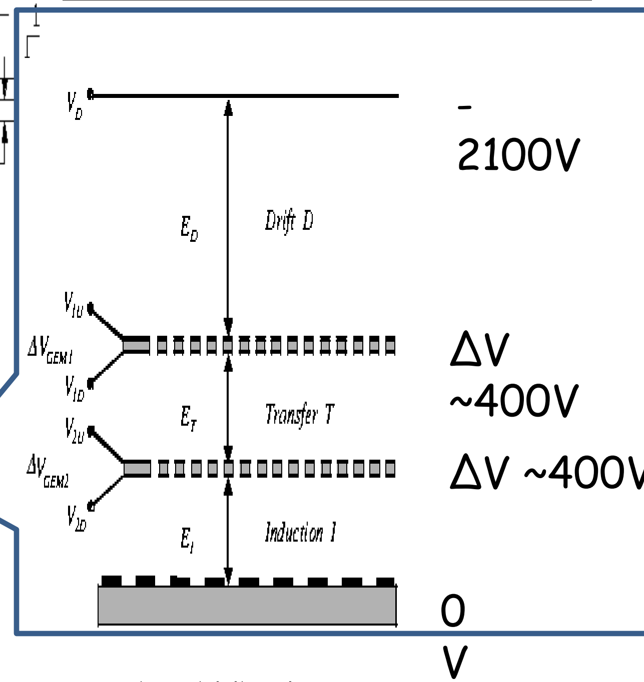
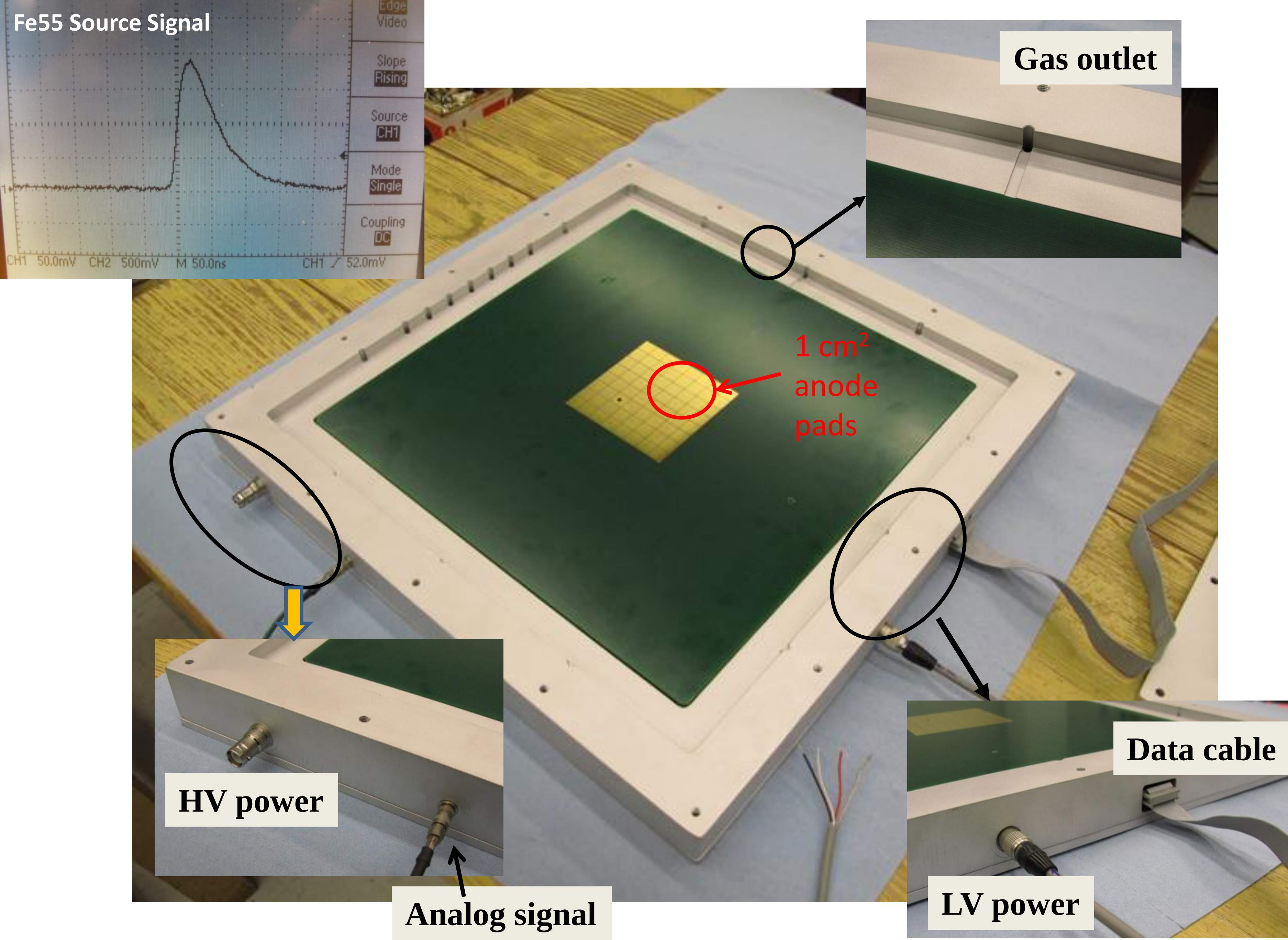


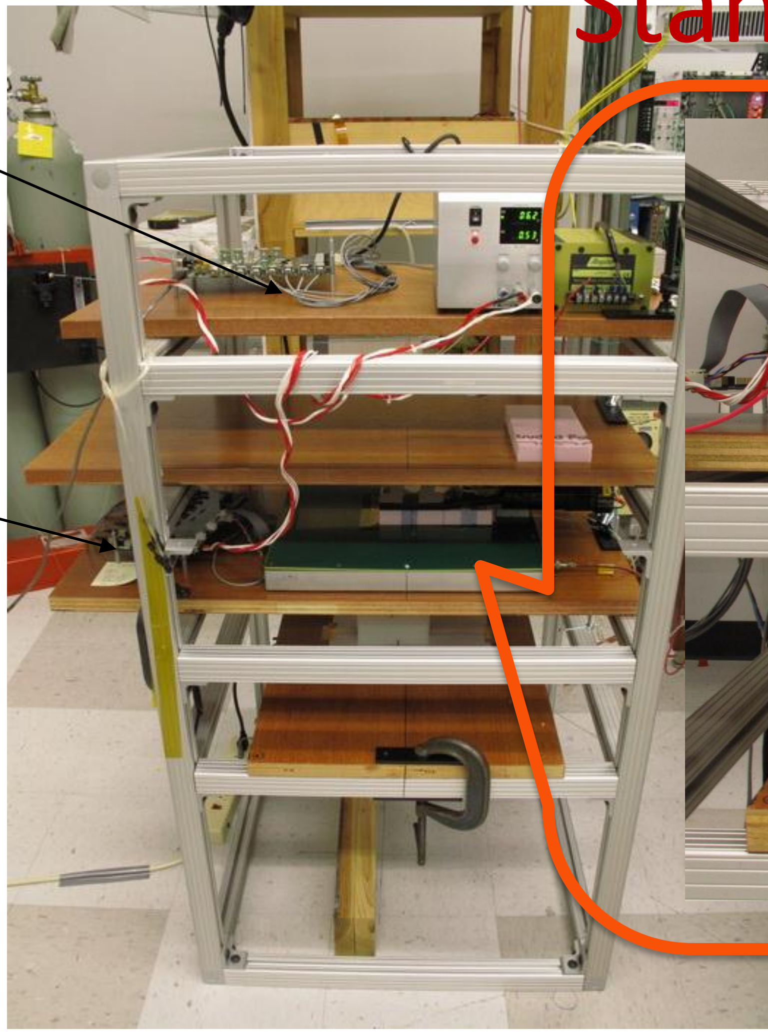
Fig. 1: Schematics of a double-GEM detector.

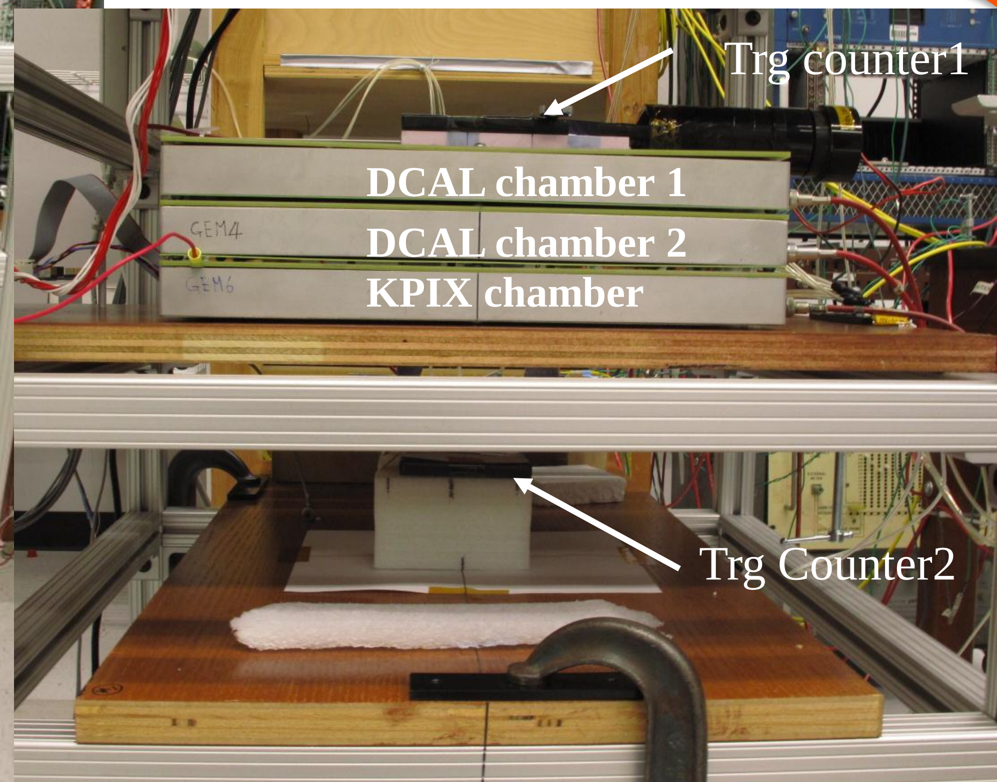

Fe55 Source Signal
Edge
Video
Slope
Rising
Source
CH1
Mode
Single
Coupling
DC
CH1 50.0mV CH2 500mV M 50.0ns CH1 ∕ 52.0mV
Gas outlet
1 cm²
anode
pads
HV power
Analog signal
Data cable
LV power

UTA GEM-DHCAL Cosmic Test Stand

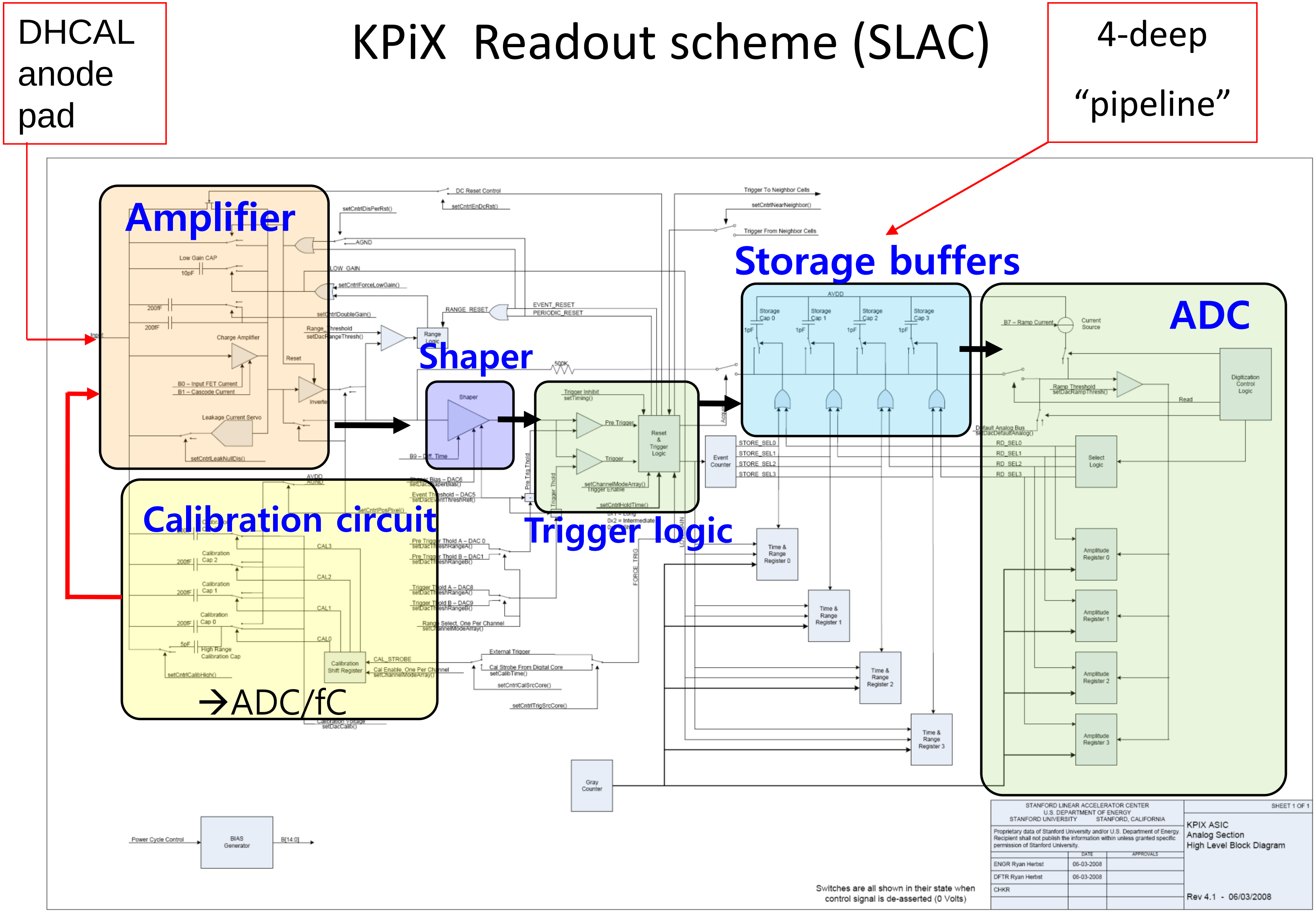
KPiX FPGA board

KPiX Interface board





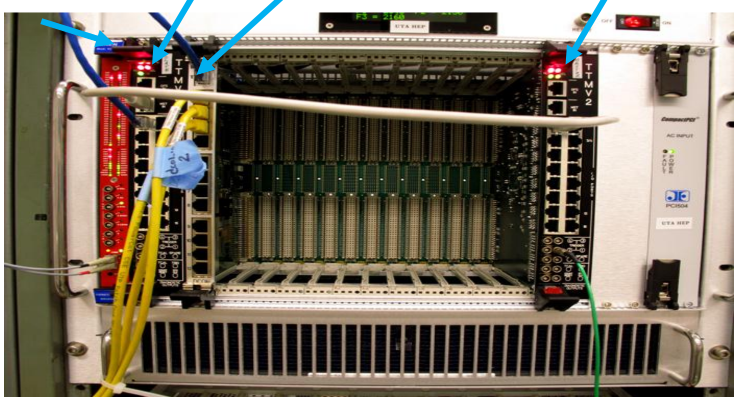
KPiX Readout scheme (SLAC)

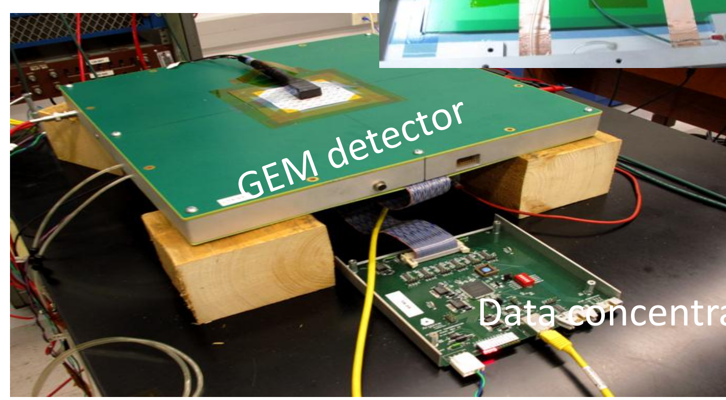


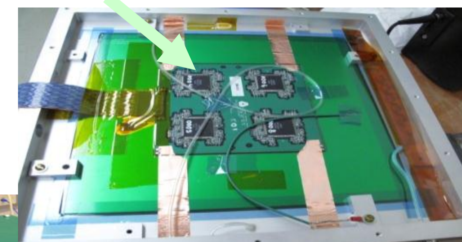
GEM Integration with DCAL Chip

Goal: Enable readout of GEM/DHCAL planes via DCAL as the ultimate readout electronics of a $1m^3$ stack ➔ Chip has been well tested with RPC DHCAL stack (ANL)

- 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.

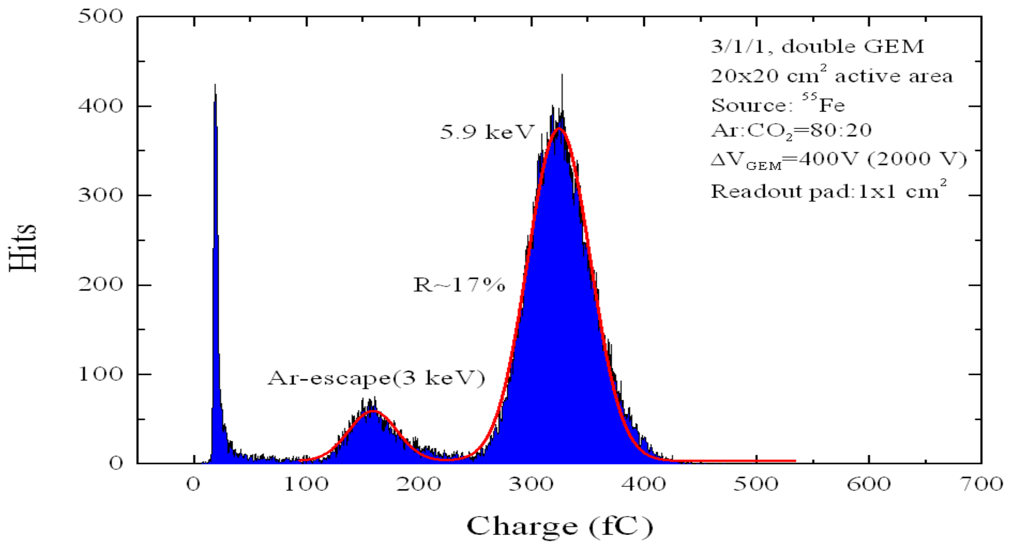


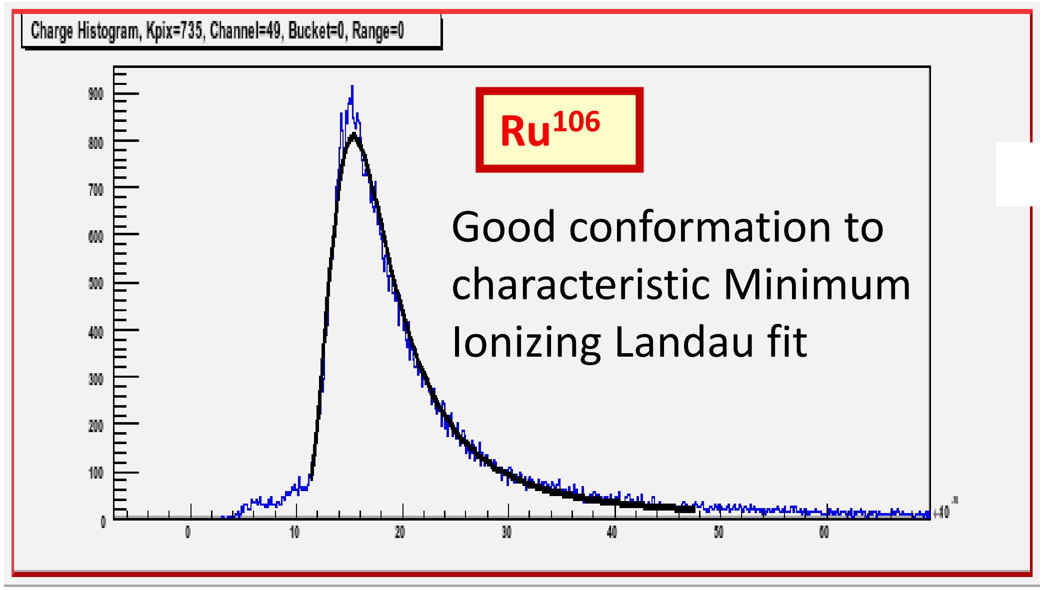




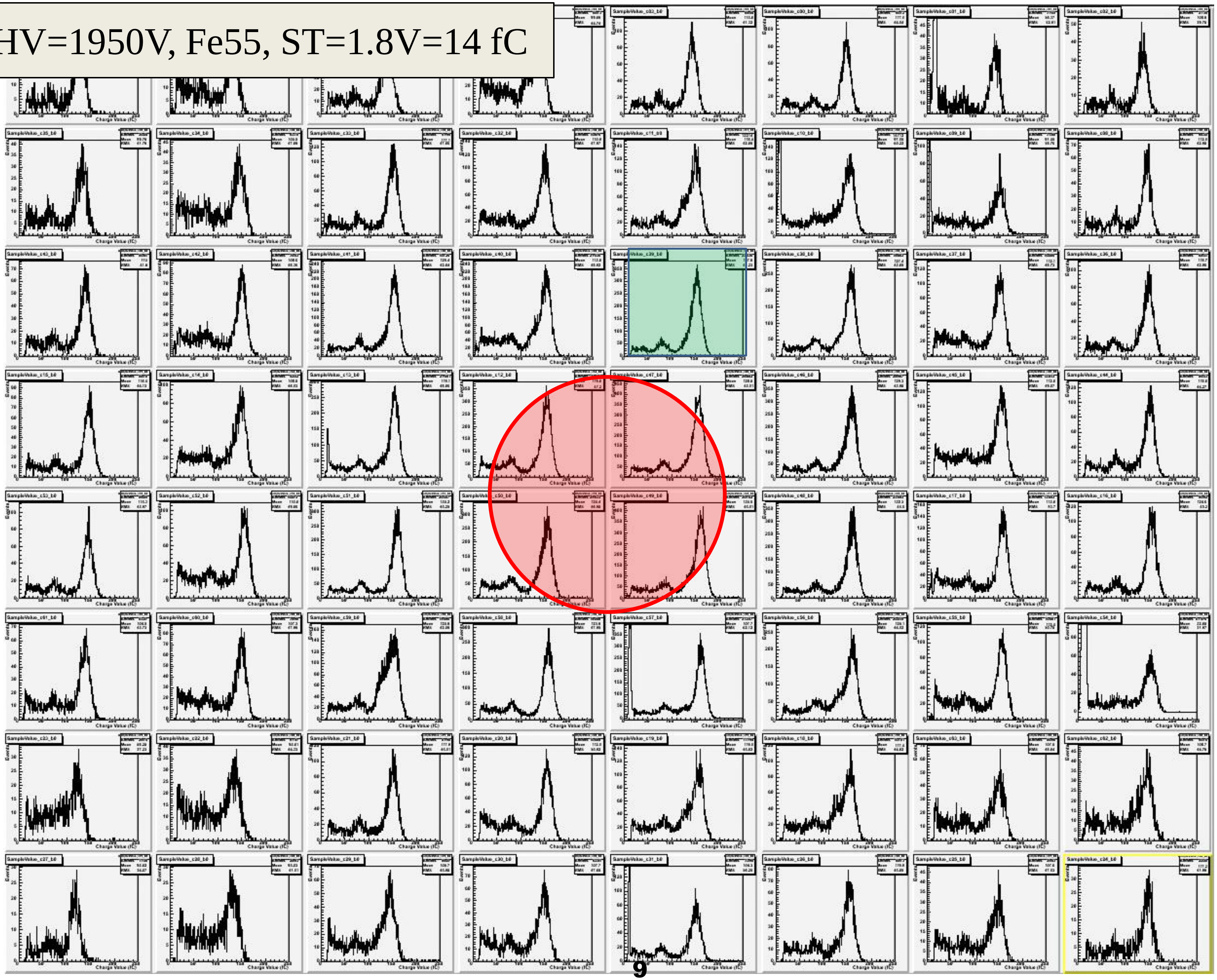
*Many thanks to ANL colleagues! J. Repond, L. Xia, G. Drake, J. Schleroth, J. Smith (UTA student at ANL) and H. Weerts.

GEM+KPiX7 Fe^{55} and Ru^{106} Spectra





HV=1950V, Fe55, ST=1.8V=14 fC



KPiX Long-term stability

- Determine the degree of MPV variation over extended period

- Monitor atmospheric pressure for corrections

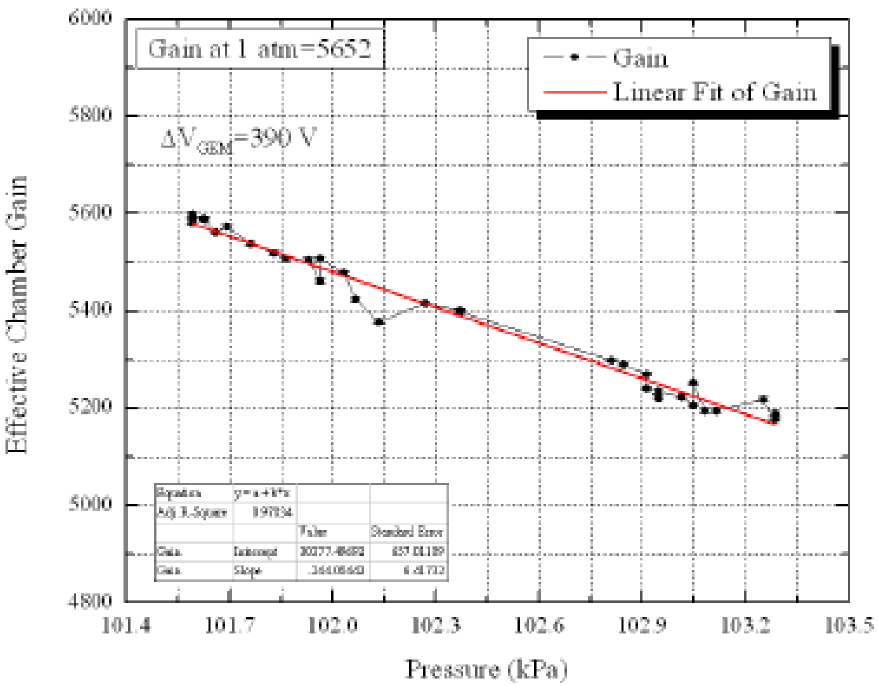
- Data taken on continuous basis by UTA students

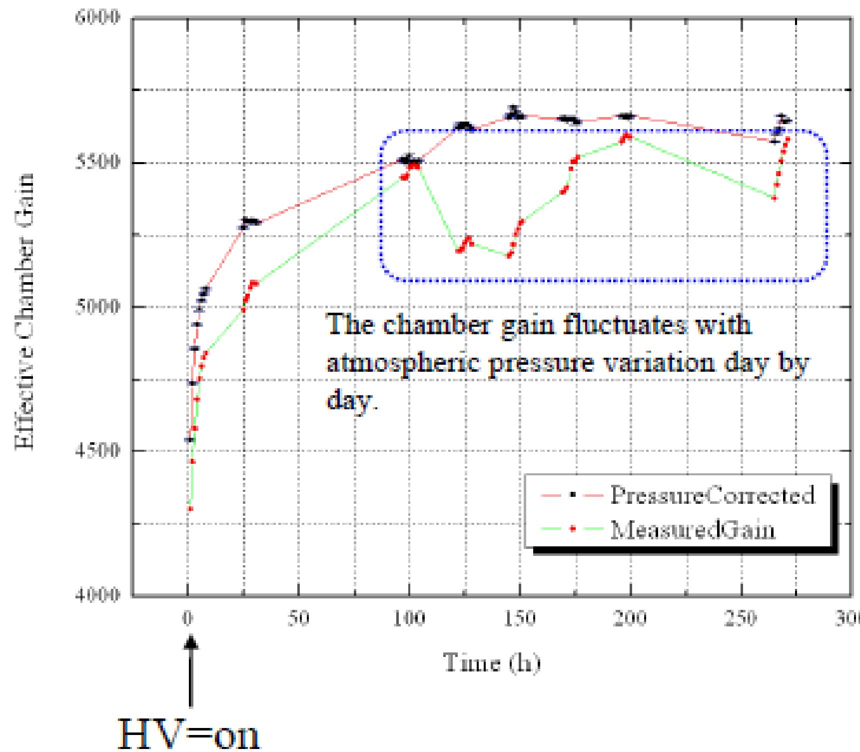
- Determine stability vs. probable threshold(s) for digital hadron calorimeter operation.

- Assess whether HV operating region is sufficiently above threshold *and* away from any discharge region.

Pressure Dependence of Gain

HV =1950V (ΔV_{GEM}=390 V)





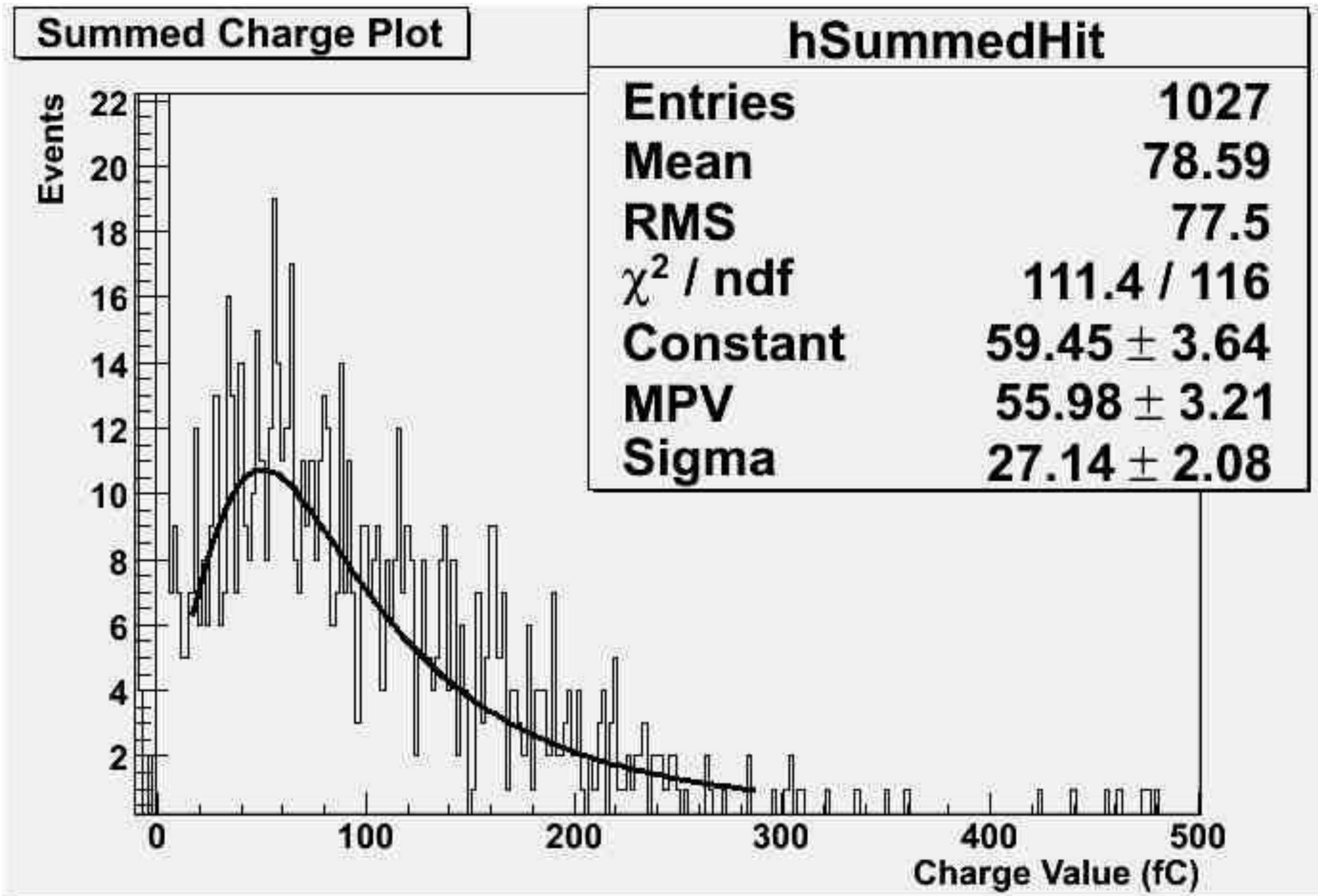
We use an open gas system (gas flows at atmospheric pressure).

Thus, pressure inside chamber is affected by the atmospheric pressure directly.

This pressure change affects the chamber gain.

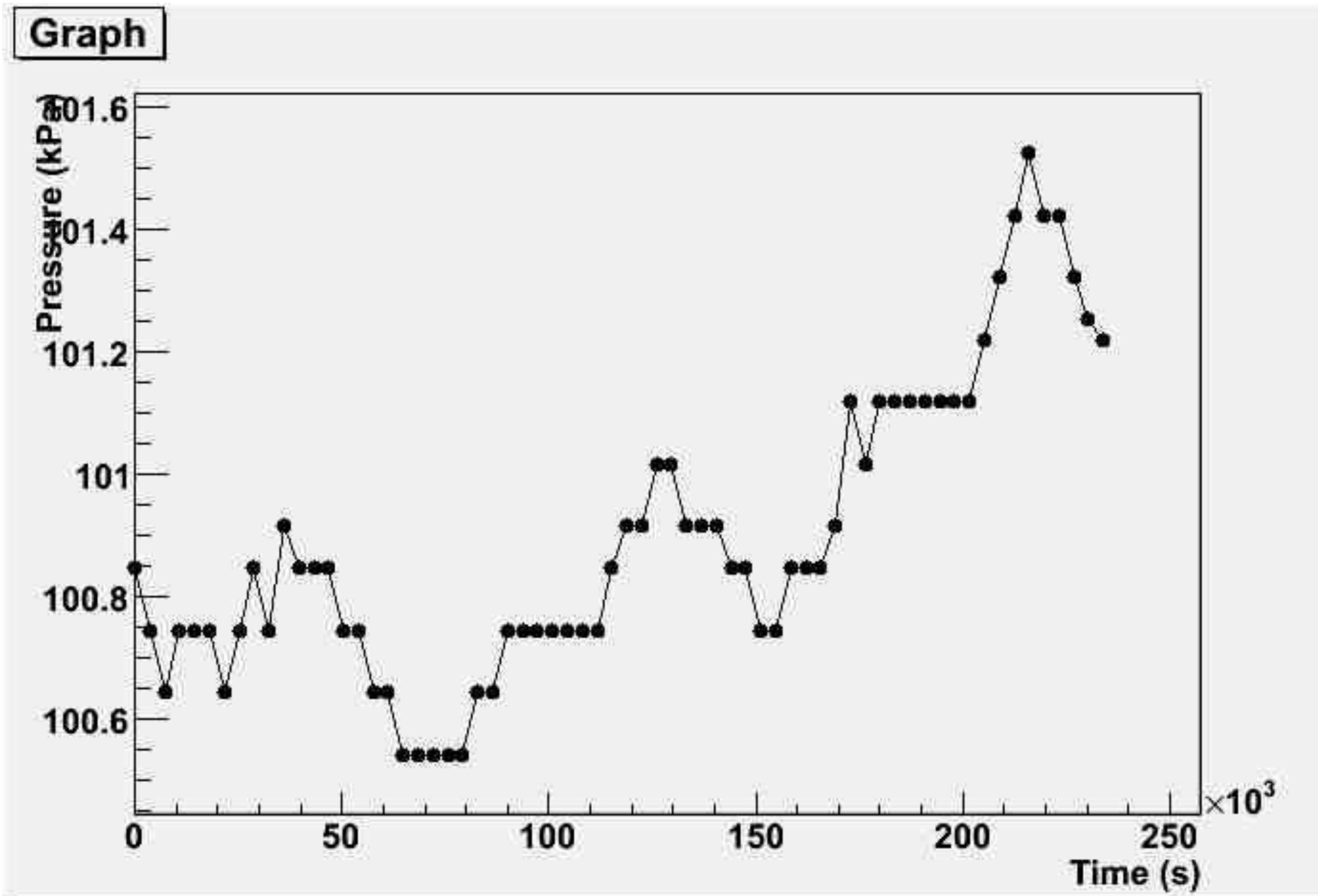
The chamber gains were recalculated to the values at 1 atm.

4-29

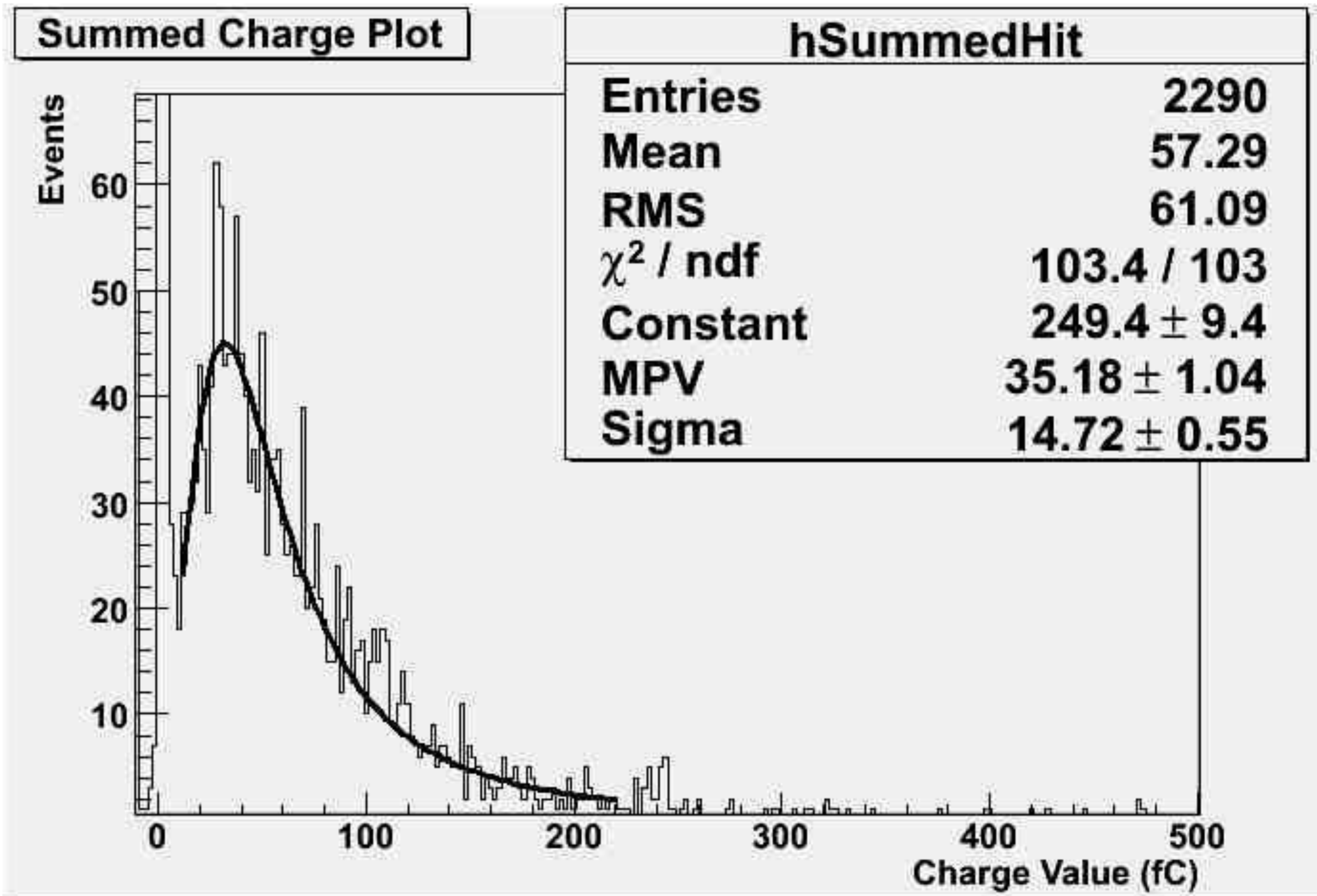


Summed Charge Plot
hSummedHit
Entries 1027
Mean 78.59
RMS 77.5
χ² / ndf 111.4 / 116
Constant 59.45 ± 3.64
MPV 55.98 ± 3.21
Sigma 27.14 ± 2.08
Events
22
20
18
16
14
12
10
8
6
4
2
0
100
200
300
400
500
Charge Value (fC)

Pressure variation 4-29

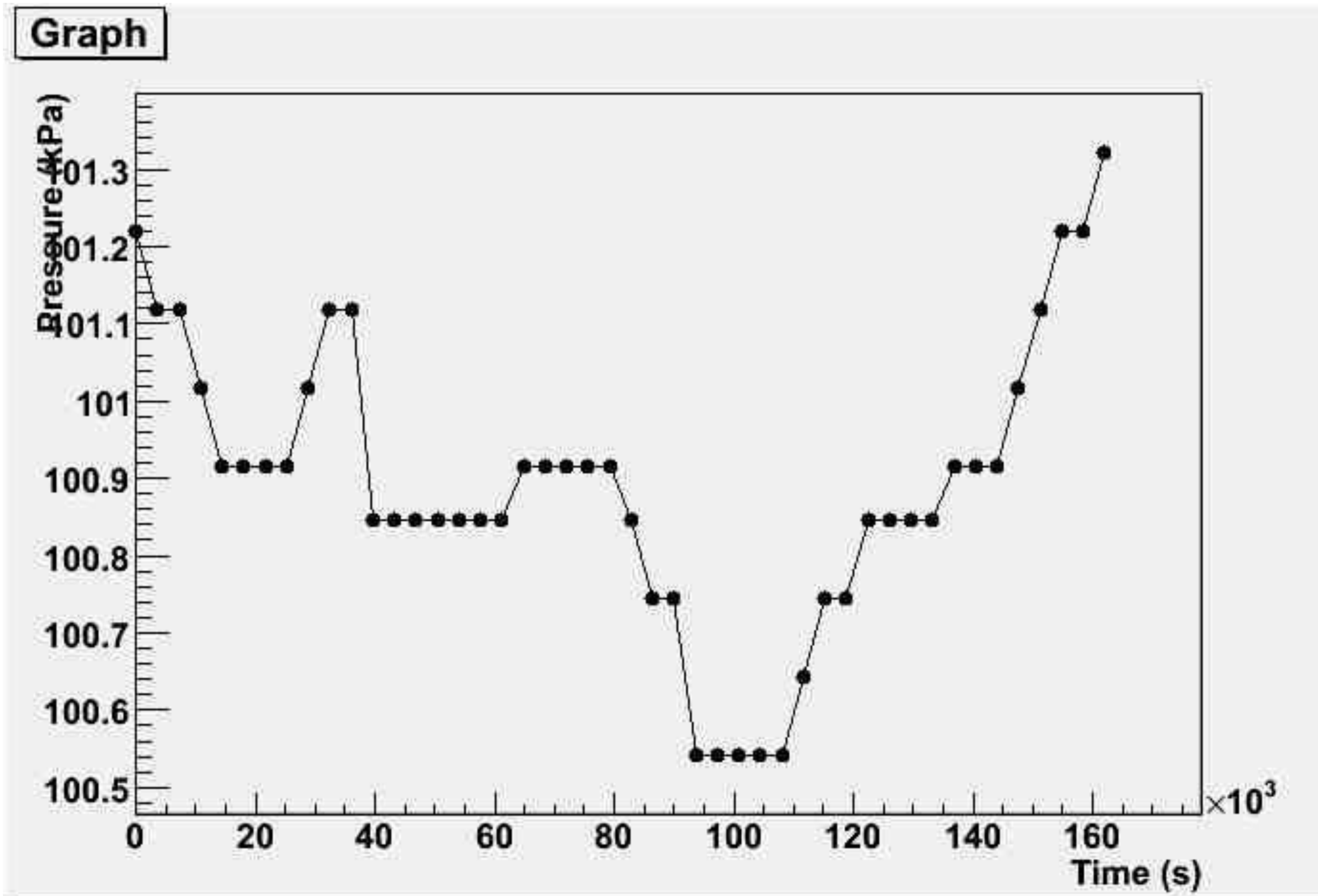


8-29

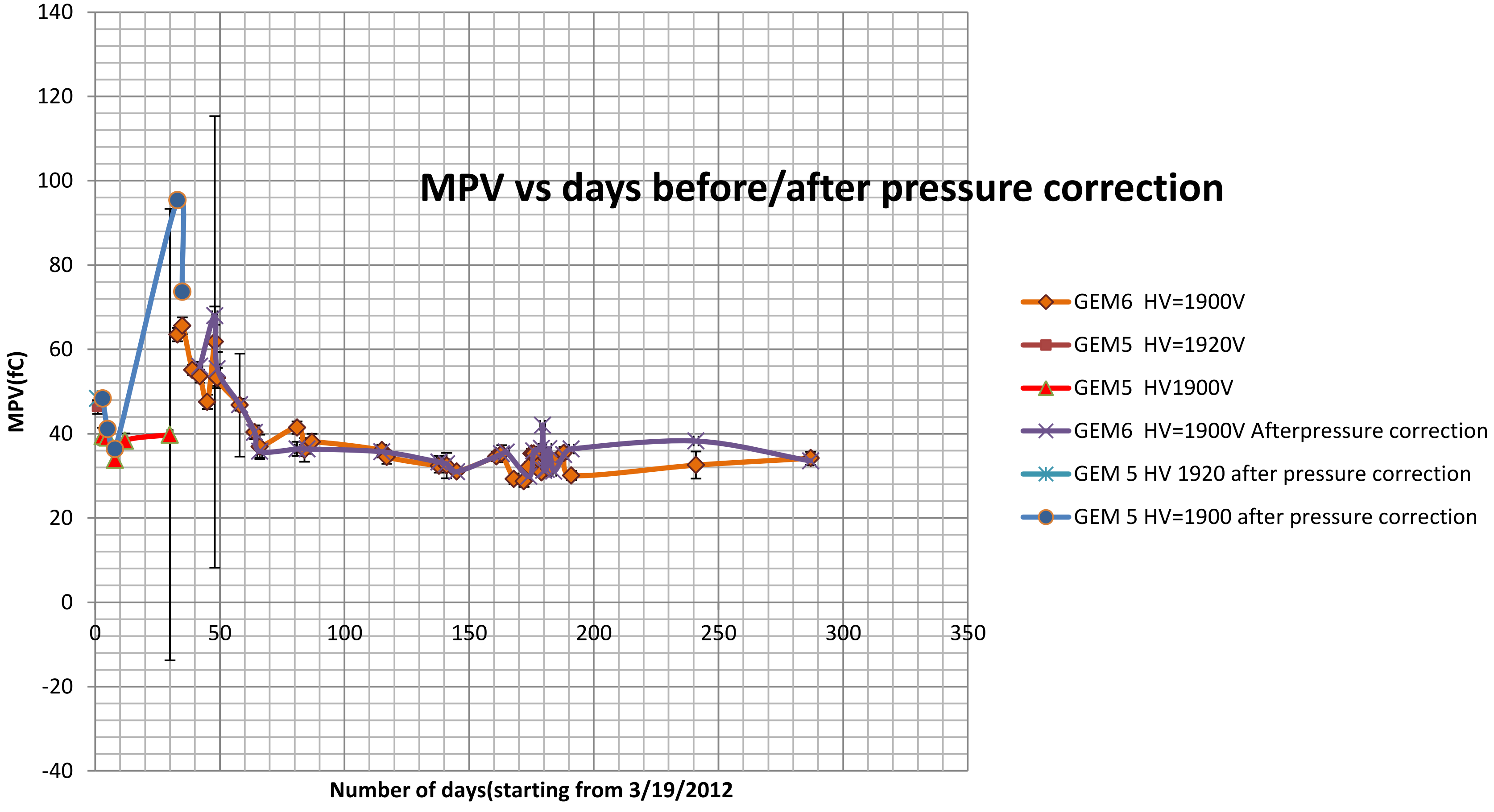


Summed Charge Plot
hSummedHit
Entries 2290
Mean 57.29
RMS 61.09
χ² / ndf 103.4 / 103
Constant 249.4 ± 9.4
MPV 35.18 ± 1.04
Sigma 14.72 ± 0.55
Events
60
50
40
30
20
10
0
100
200
300
400
500
Charge Value (fC)

Pressure variation 8-29



KPiX Long-term stability

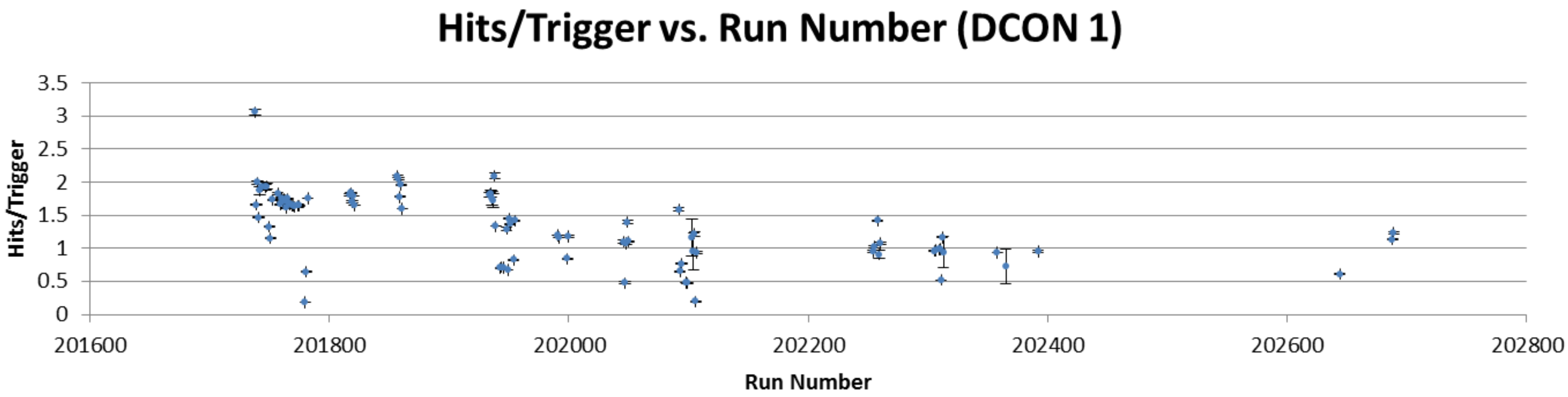


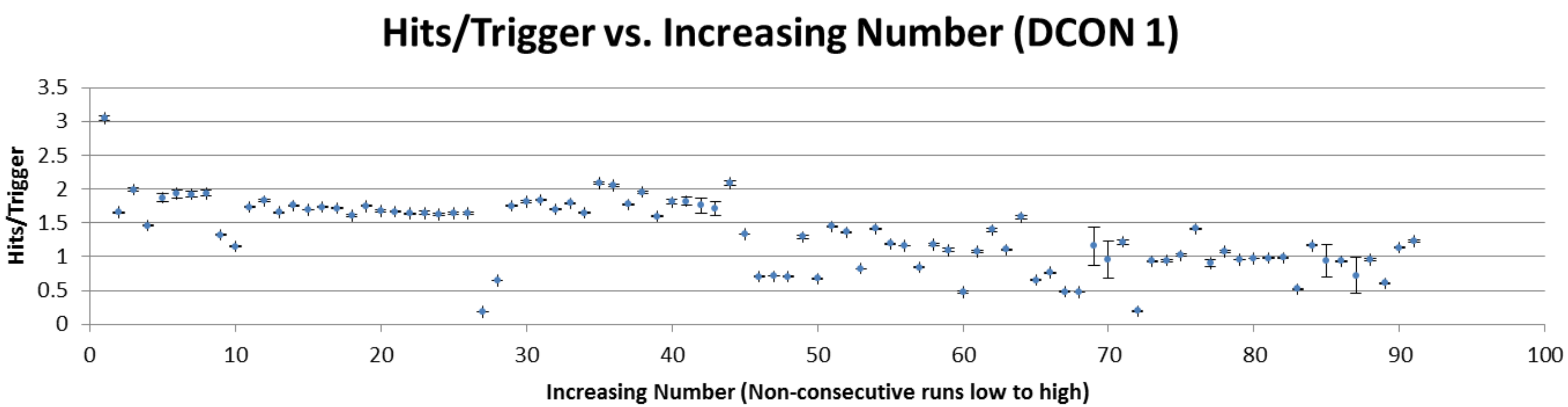
Stability study for DCAL chamber

Plots for DCON 1 (GEM 5)

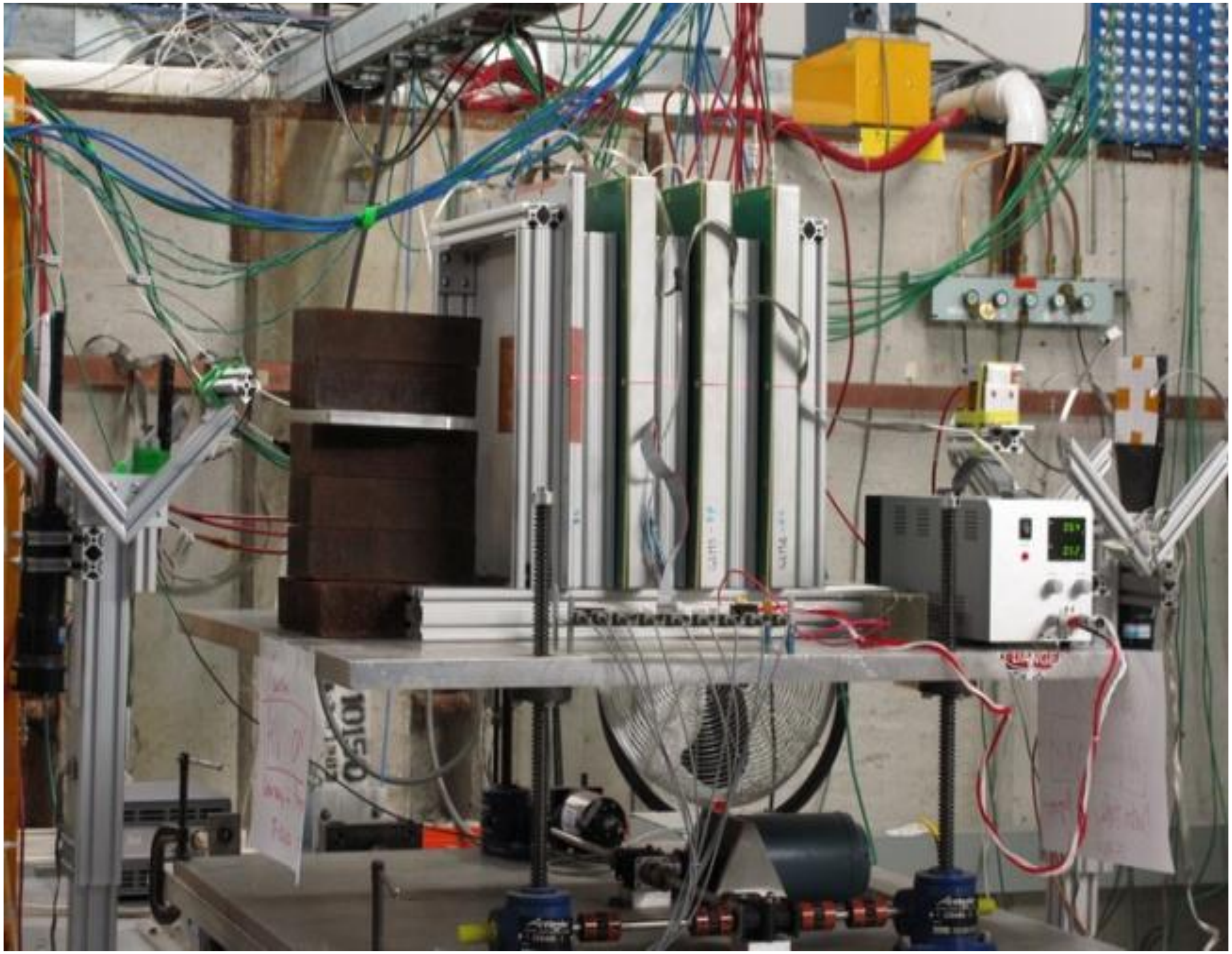
Avg. hit/trigger: 1.334

Avg. uncertainty: 0.028

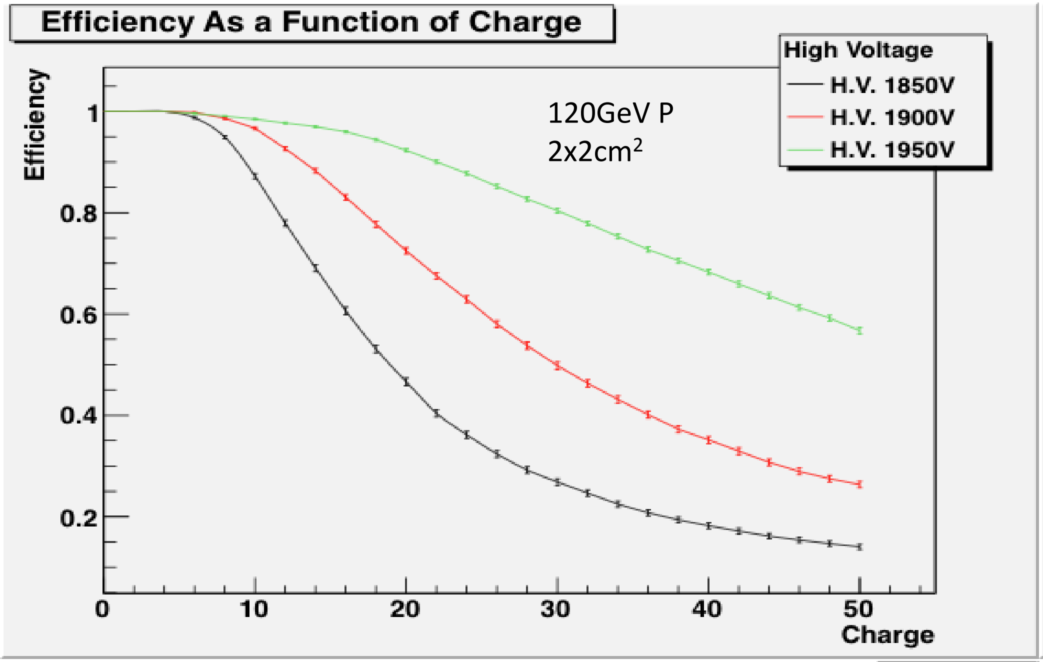


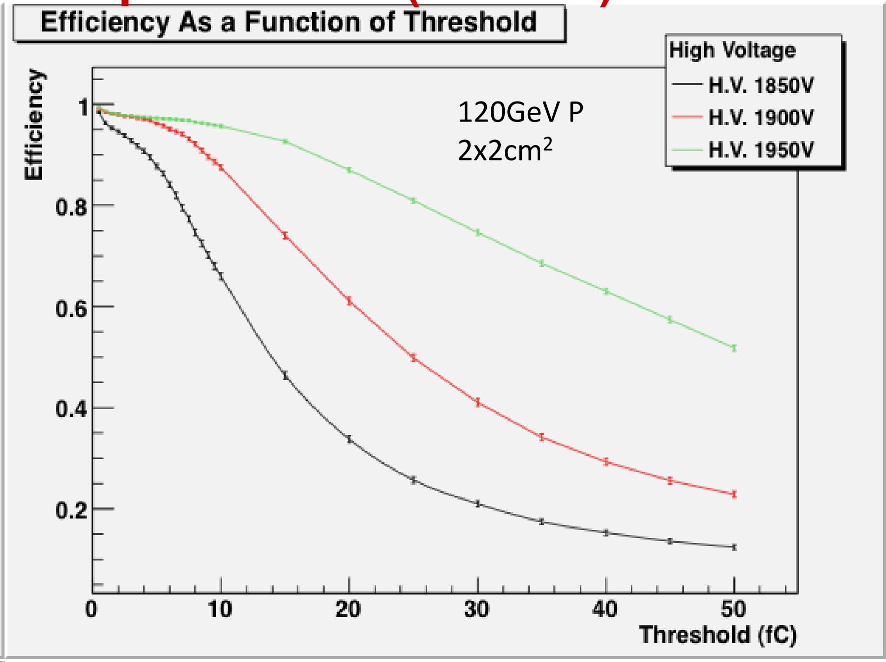


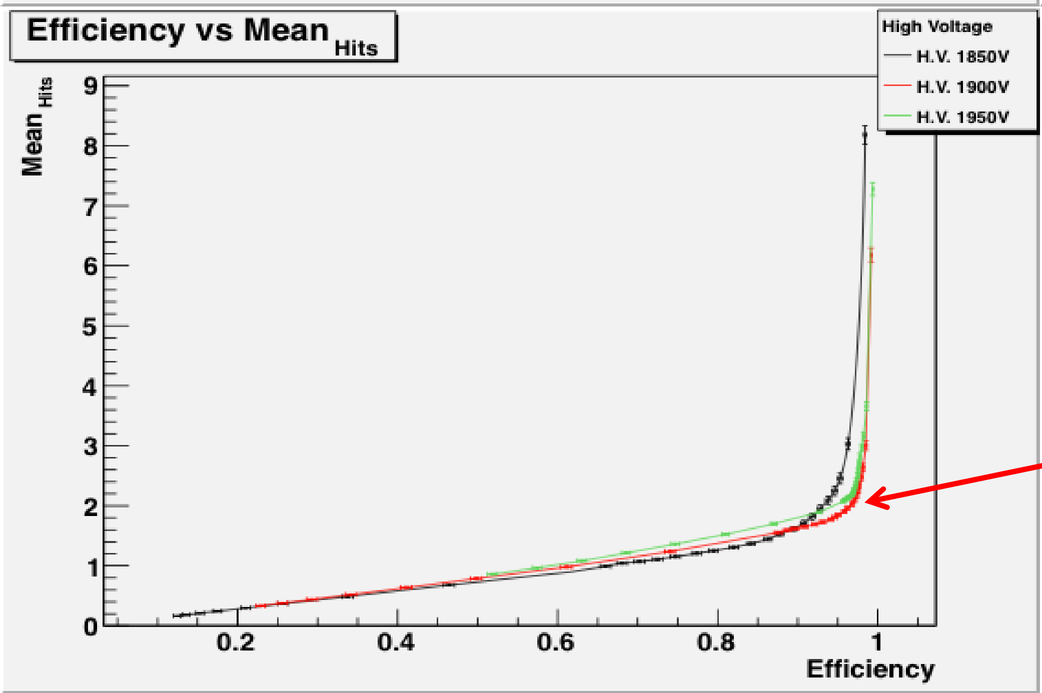
T-1010 Experiment Setup



Efficiencies and Hit multiplicities (KPiX)



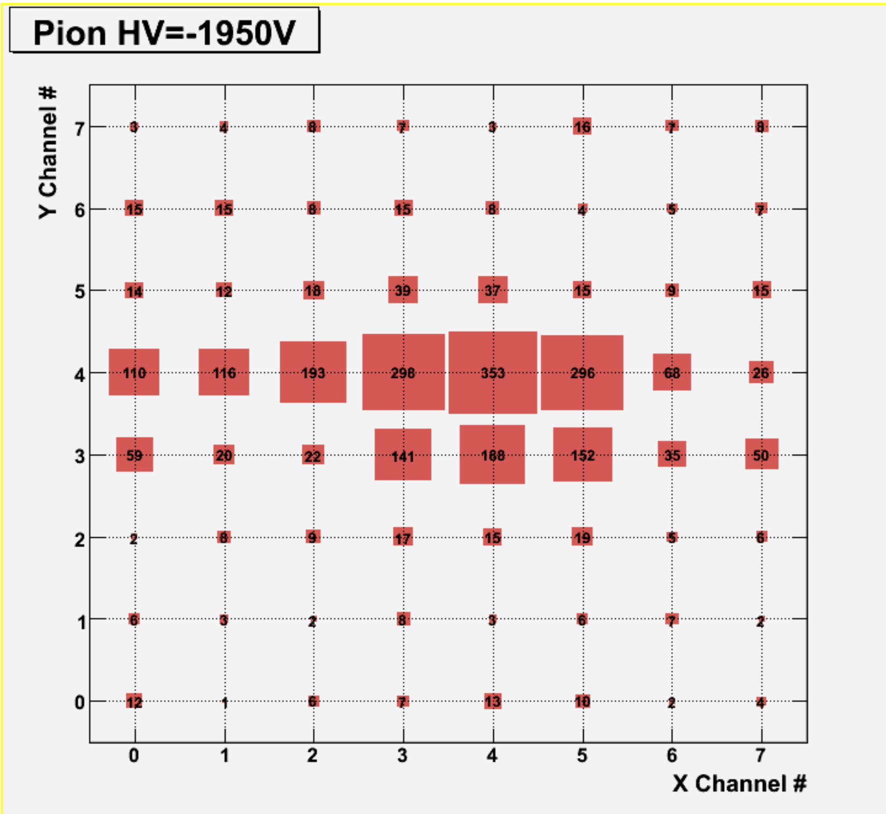


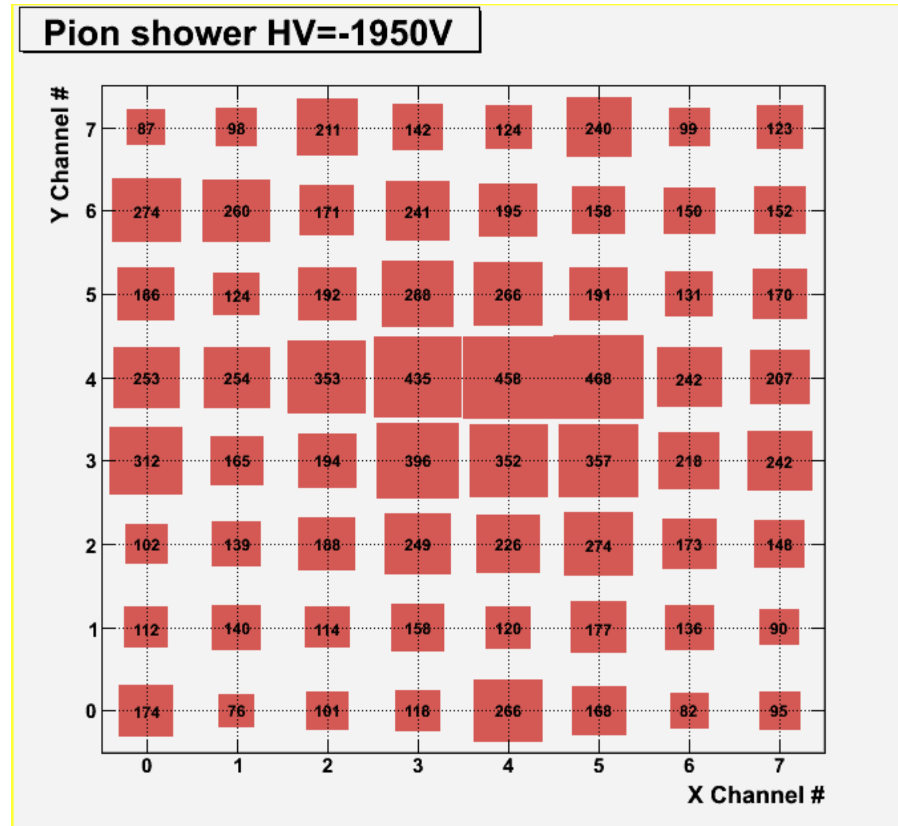


Preliminary results, pressure corrected

Potential operating region:
- High efficiency
- Low multiplicity

Hit Map for Pions vs Pion Showers (KPiX)





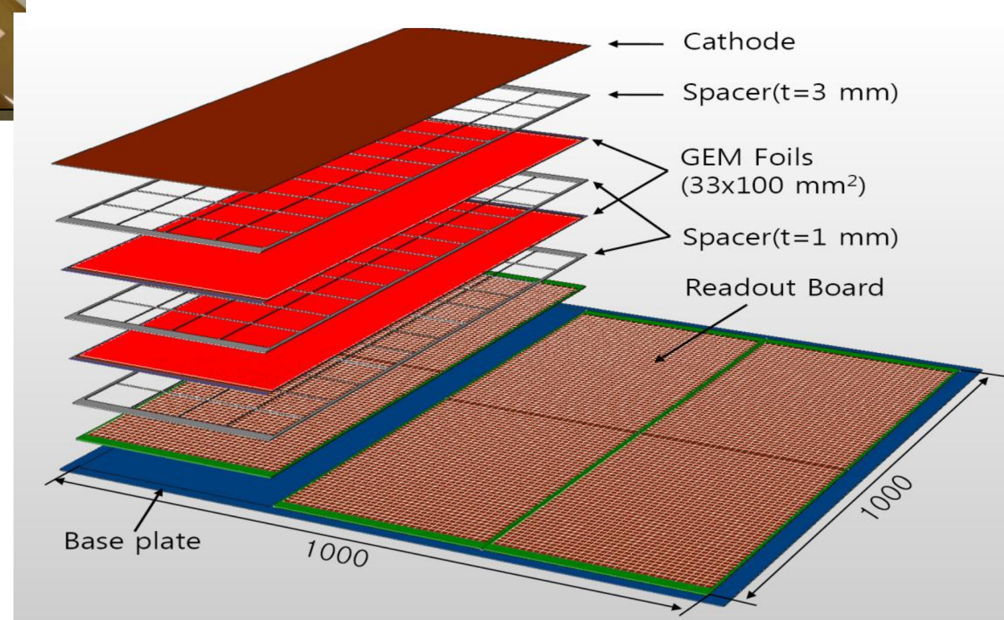
Hits above 5fC were counted and normalized to 1000

Demonstrates the KPIX capability to take many hits simultaneously

Toward 100cmx100cm GEM Planes

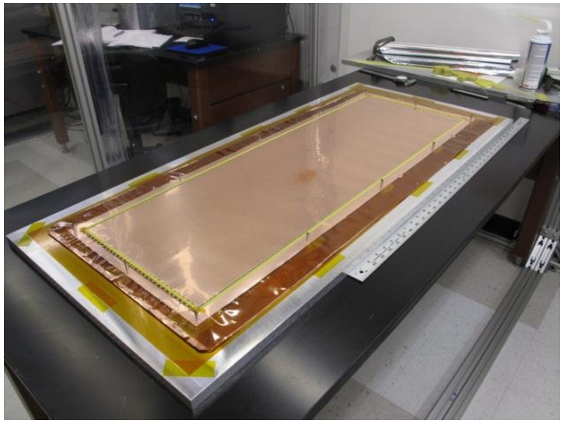
CERN GDD Workshop delivered the first 5 of 33cmx100cm GEM foils in 2010 ➔ Qualification completed!!

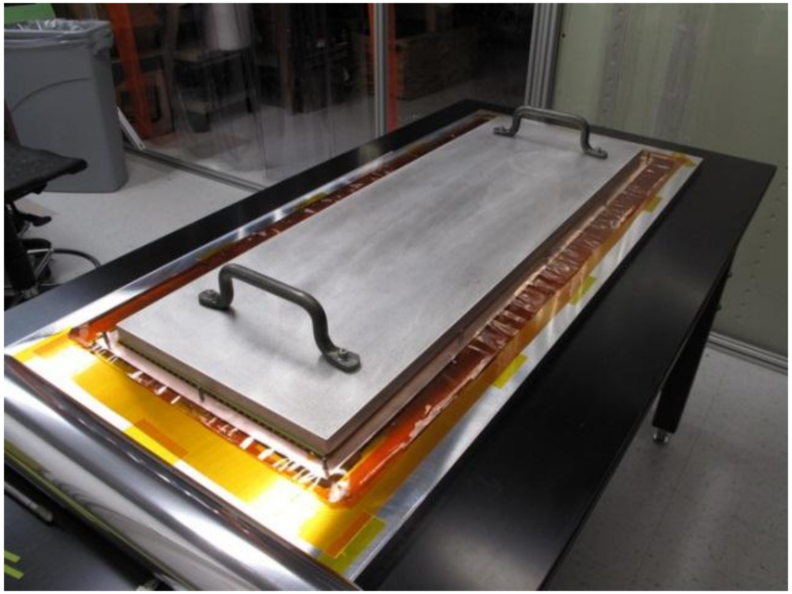
Foil Name	$N_{strip-pass}$	$<t_{saturation}>$	N_{strip}>2000s	Qualification	Note
LGEM 1	31	1725 s	4	Pass-med	Strips 1, 2, 10 & 23 >2000s
LGEM 2	30	1692 s	3	Pass-med	Strip 22 failed Strips 4, 5 & 29>2000s
LGEM 3	31	1484 s	0	Pass-high	
LGEM 4	31	1491 s	1	Pass-high	Strip 20 >2000 s
LGEM 5	Untested				Free-Delivered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

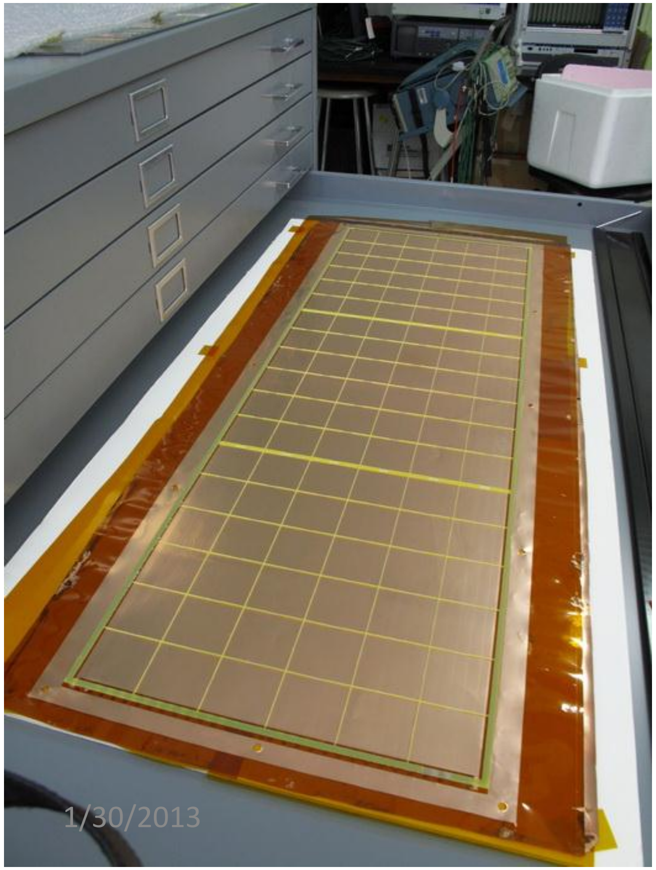


Each of the GEM 100cmx100cm planes will consist of three 33cmx100cm unit chambers

Preparation for LGEM Assembly







Status:

- Working with SLAC to design/produce anode boards

- On hold due to difficulties with detector R&D funding

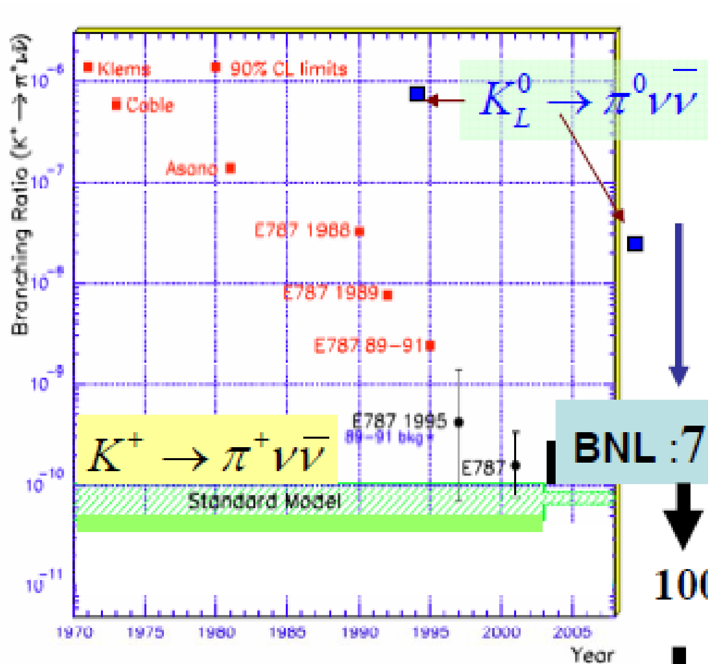
- Now have secured FY13 support – complete/test one large chamber

Motivation (2)
Range Stack for Rare Kaon Decay Experiment

Precise Measurement of $K^+ \to \pi^+ \nu \bar{\nu}$

$B_{SM}(K^+ \to \pi^+ \nu \bar{\nu}) = (7.8 \pm 0.8) \text{ x } 10^{-11}$

$B_{SM}(K_L^0 \to \pi^0 \nu \bar{\nu}) = (2.8 \pm 0.4) \text{ x } 10^{-11}$

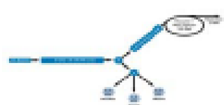


JPARC KOTO (Phase 1, $K_L^0 \to \pi^0 \nu \bar{\nu}$ to SM observation level)

BNL :7 events $K^+ \to \pi^+ \nu \bar{\nu}$

100 ***CERN NA62***

Project X

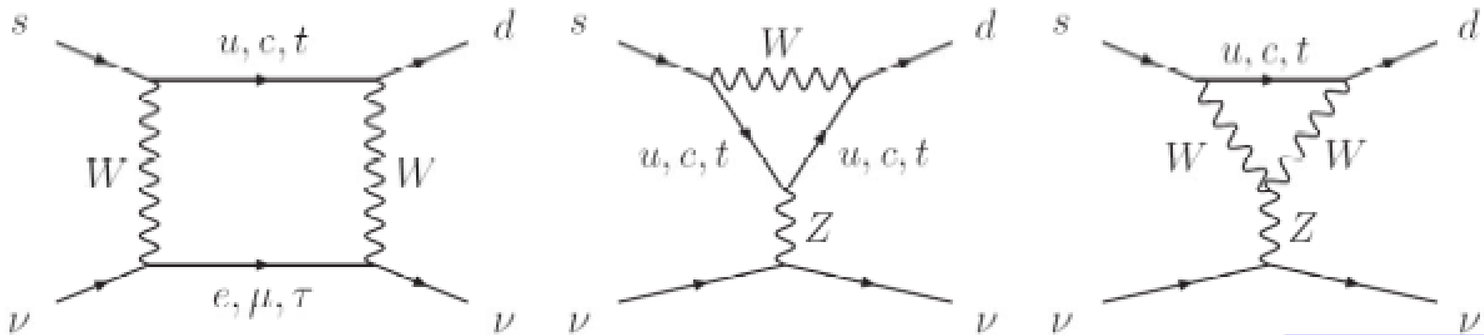


*** ORKA***

$K_L^0 \to \pi^0 \nu \bar{\nu}$ **1000** $K^+ \to \pi^+ \nu \bar{\nu}$

$K^+ \to \pi^+ \nu\bar{\nu}$ in the Standard Model

One of the few precisely precicted FCNC decays with quarks.



$$B_{SM}(K^+ \to \pi^+ \nu\bar{\nu}) = (7.8 \pm 0.8) \text{ x } 10^{-11}$$

ORKA aims for 1000 event sensitivity: 30% deviation from the SM would be a 5σ signal of NP

Range Stack in ORKA detector

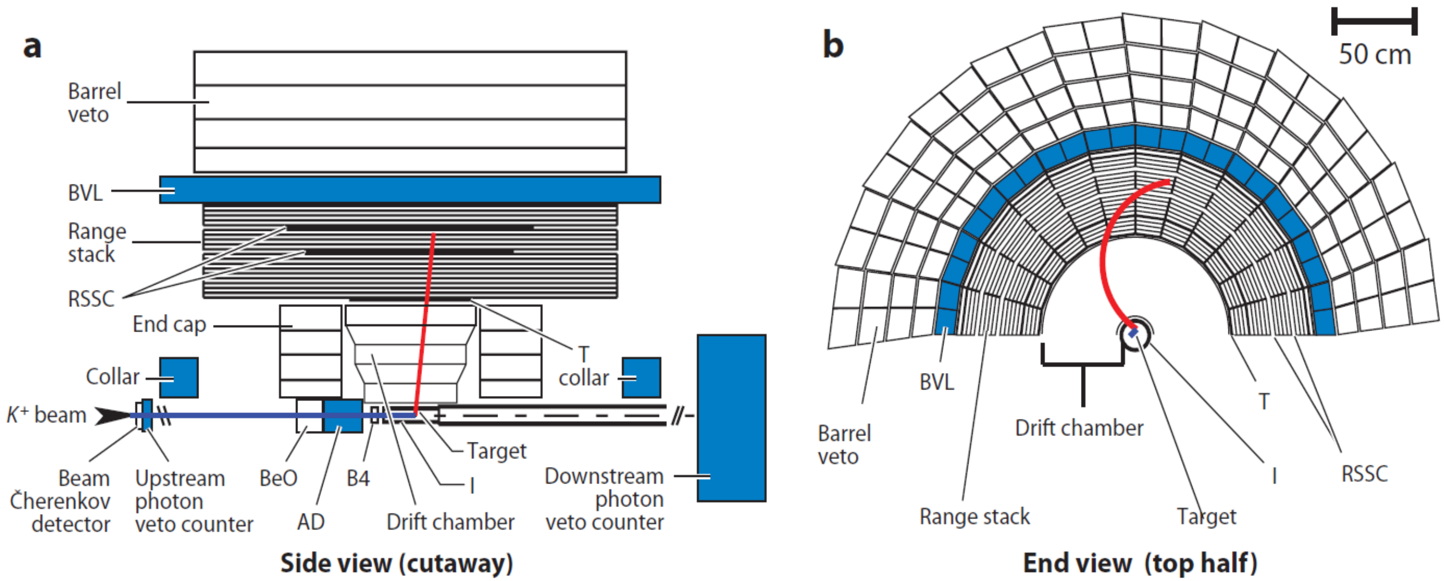
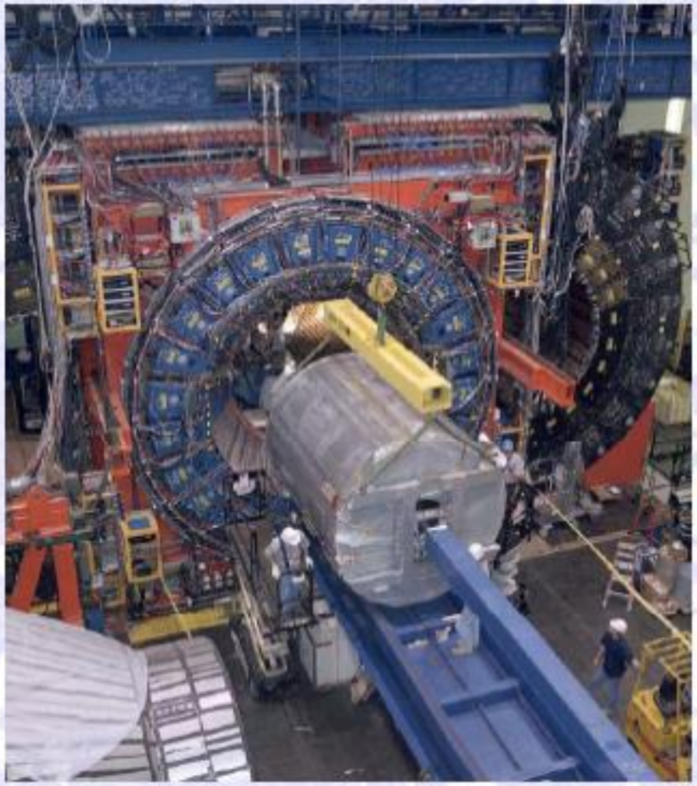


Figure 1

Elevation side view and end view schematic of the BNL E787 and E949 technique. (*a*) The 700-MeV/*c* K^+ beam enters from the left. (*b*) The stopped K^+ decays in the stopping target, and the subsequent decay π^+ track is momentum-analyzed by the tracker. The decay π^+ then stops in the range stack, where its range and energy are measured. The range stack STRAW chamber (RSSC) measures the position of the putative charged pion with the range stack. The barrel veto liner (BVL) is an upgrade of photon veto performance in E949 and E787. Abbreviations: AD, active degrader; DPV, UPV.

RS: Measure the energy, range and decay sequence of charged particles with good resolution



The ORKA new detector payload replaces the CDF tracker volume-ε.

Steve Kettell with the BNL-E949 Central tracker (similar diameter to ORKA)

GEM in Range Stack

- Need highly efficient identification of the decay sequence

$$\pi \rightarrow \mu \rightarrow e$$

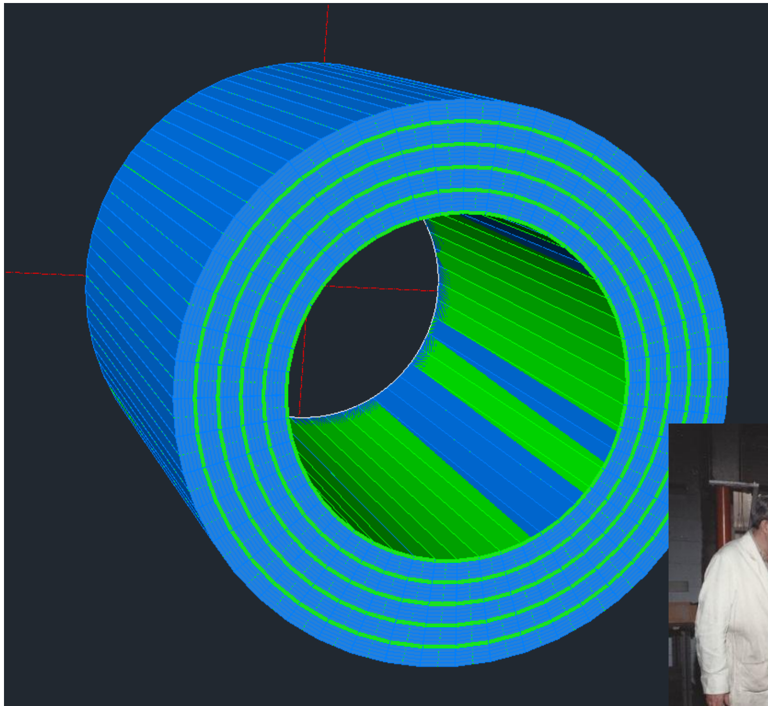
from pions ranging out in the stack.

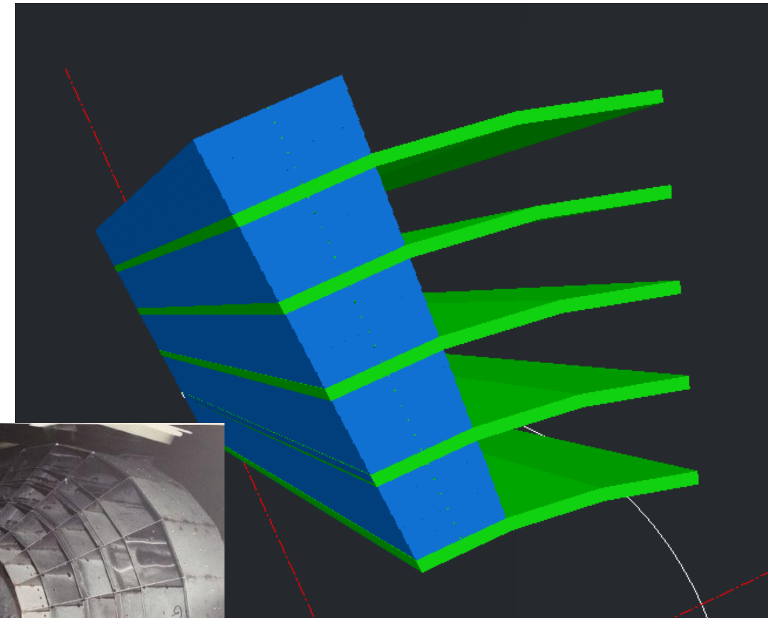
- The chambers must be low mass (in a previous experiment, straw tubes were used).

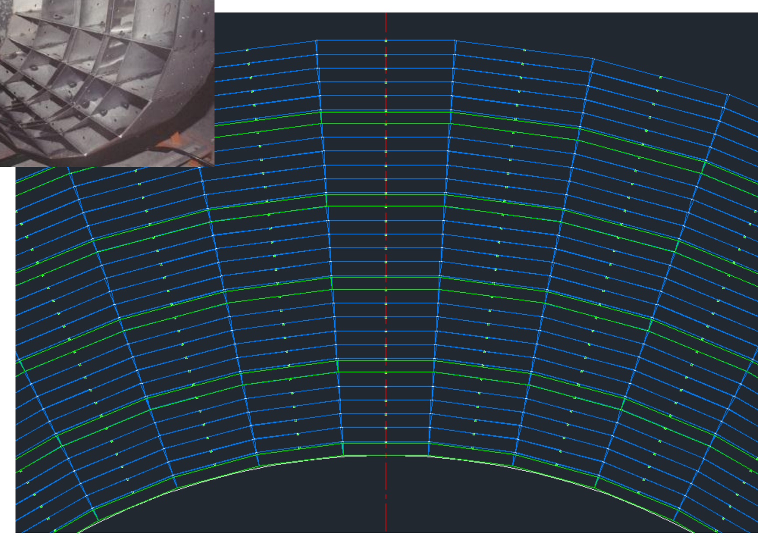
- High rate experiment :

Range stack total rate 3700 MHz
Range stack per channel 1300 KHz

GEM in Range Stack



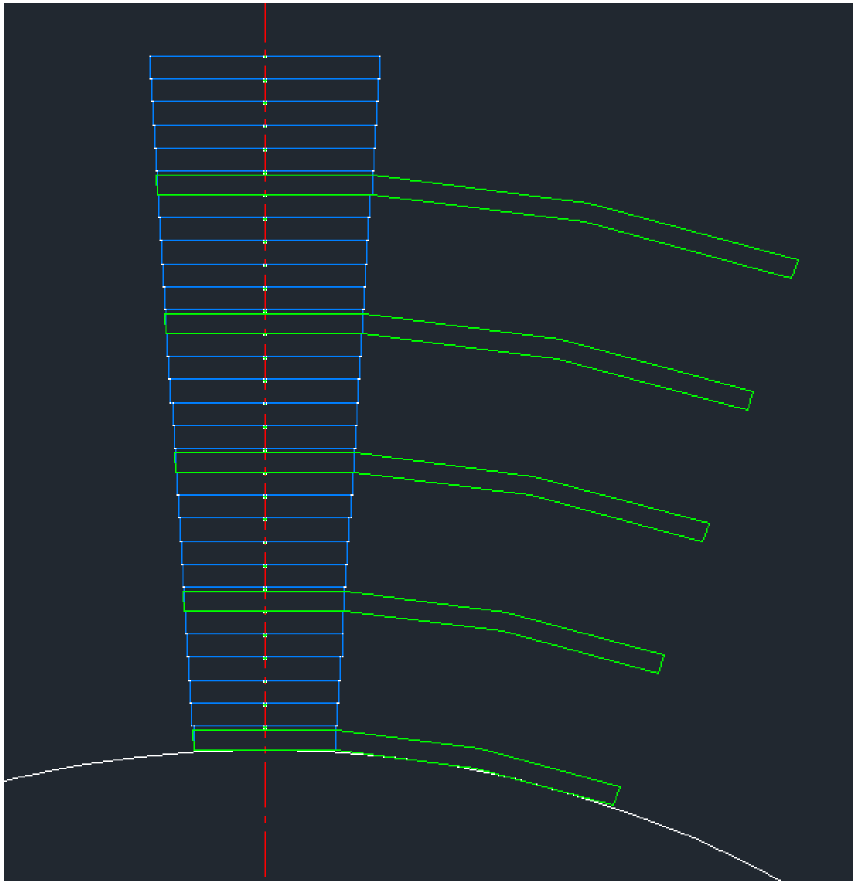


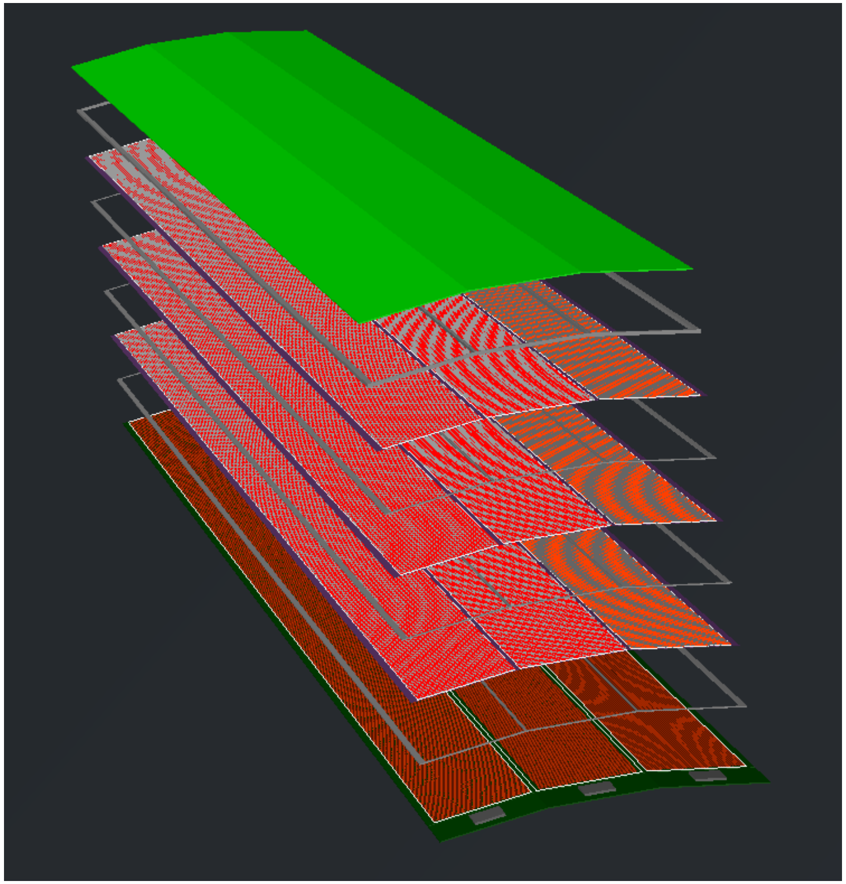


- Total 30 layers
- 48 scintillation sectors in 25 layers
- 16 sectors in 5 GEM layers(Green)
- Both ends are supported by spider-web like frame

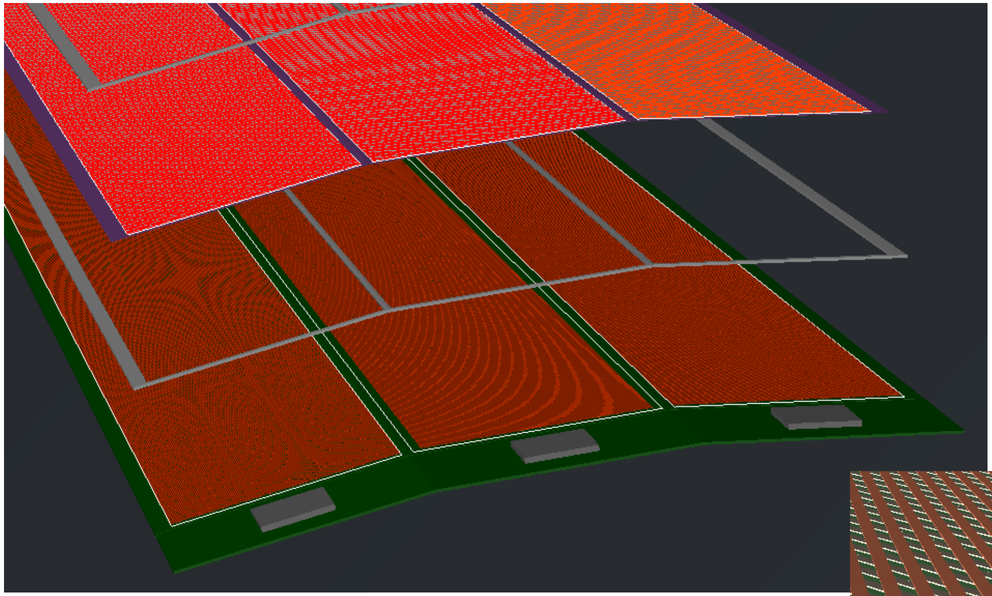
GEM design with angled shape

Triple GEMs with crossed strip readout structure

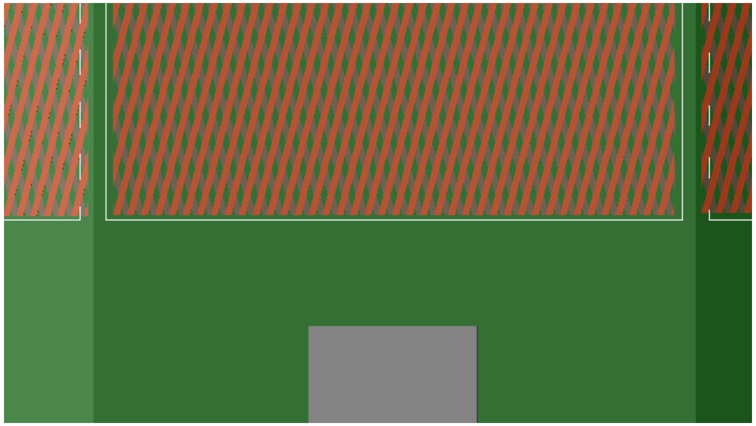


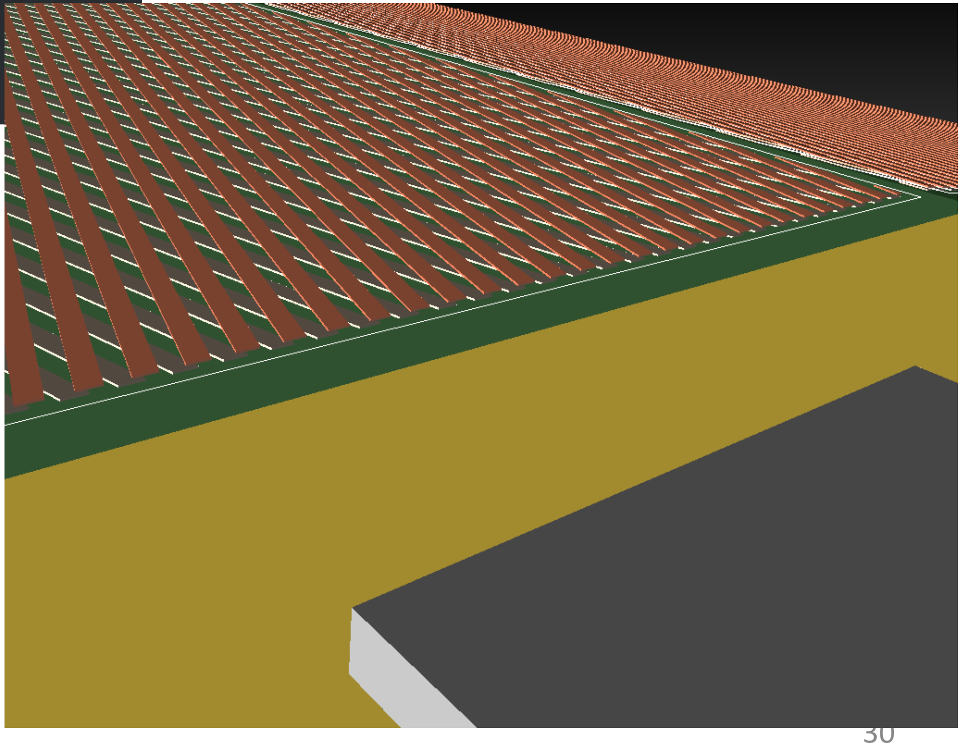


Crossed strip readout structure



5mm and 2mm spacer frame thickness





GEM in Range Stack

- Study hit precision requirements/anode patterns

- Need low mass chambers:
  Tensioning GEM foils – without thick walls/supports?

-? Build low mass ~1.9m x (5-10)cm chambers on a strongback…transfer to external tensioner – no “endcaps”?

- STATUS: Developing solution concepts…the simulation to test design and identify issues…