Development of GEM DHCAL

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For GEM/DHCAL Group
July 20, 2010
RD51 Mini Week, CERN

- Introduction
- What has been done?
- 2D readout with KPiX chip
- Future Plans
- Summary

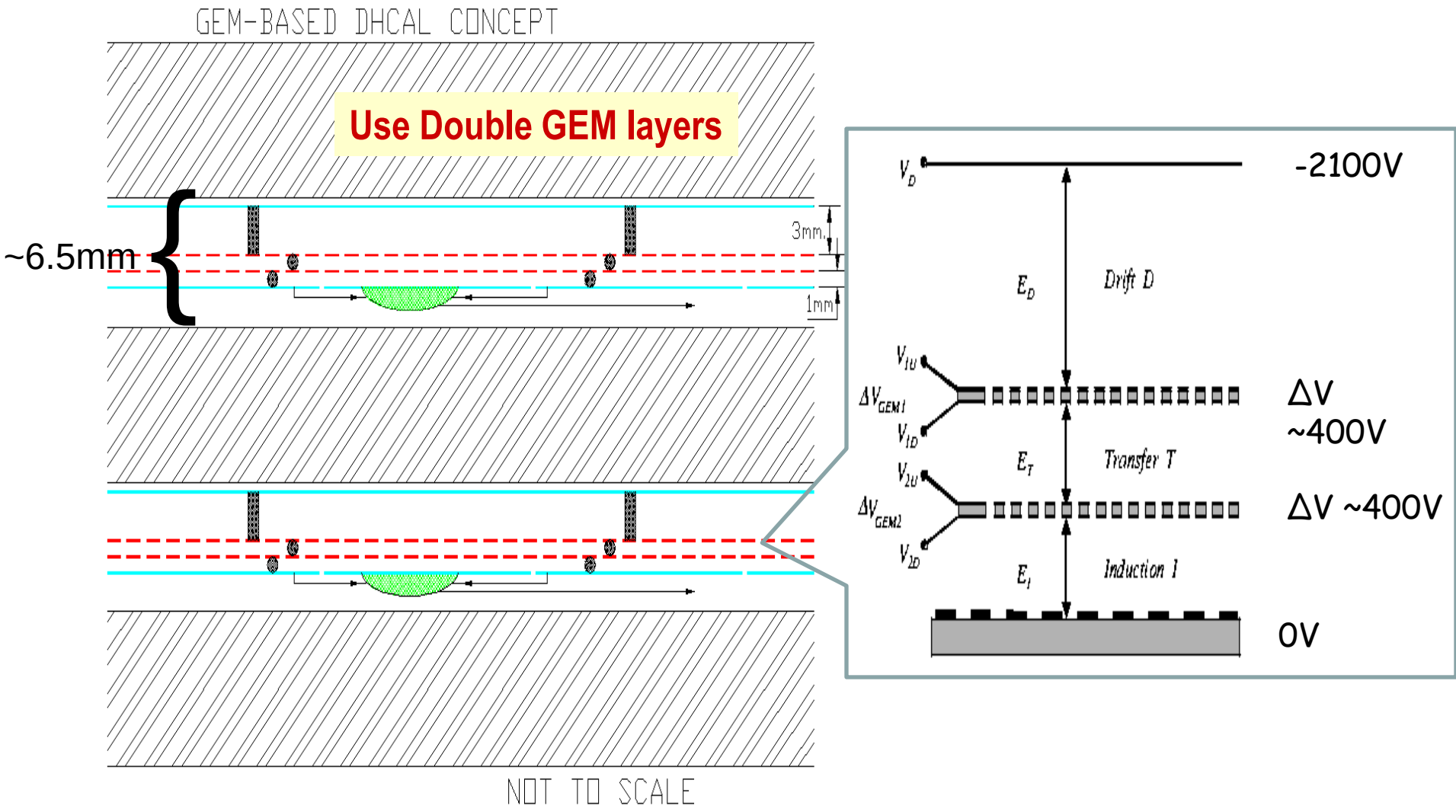
Introduction

- Precise jet quantity measurements required for physics at future experiments
  - Efficient jet separation and reconstruction
  - Excellent jet energy resolution
  - Excellent jet-jet mass resolution
- Particle Flow Algorithm is a solution to this
  - Use momenta measured in trackers for charged particles
  - Measure EM and neutral hadron energies using calorimeters
  - Require fine calorimeter granularity
  - Digital (one – two bit) readout a way to control costs

Why GEM?

- Flexible configurations: allows small anode pads for high granularity
- Robust: survives ~10^{12} particles/mm^2 with no performance degradations
- 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 operations

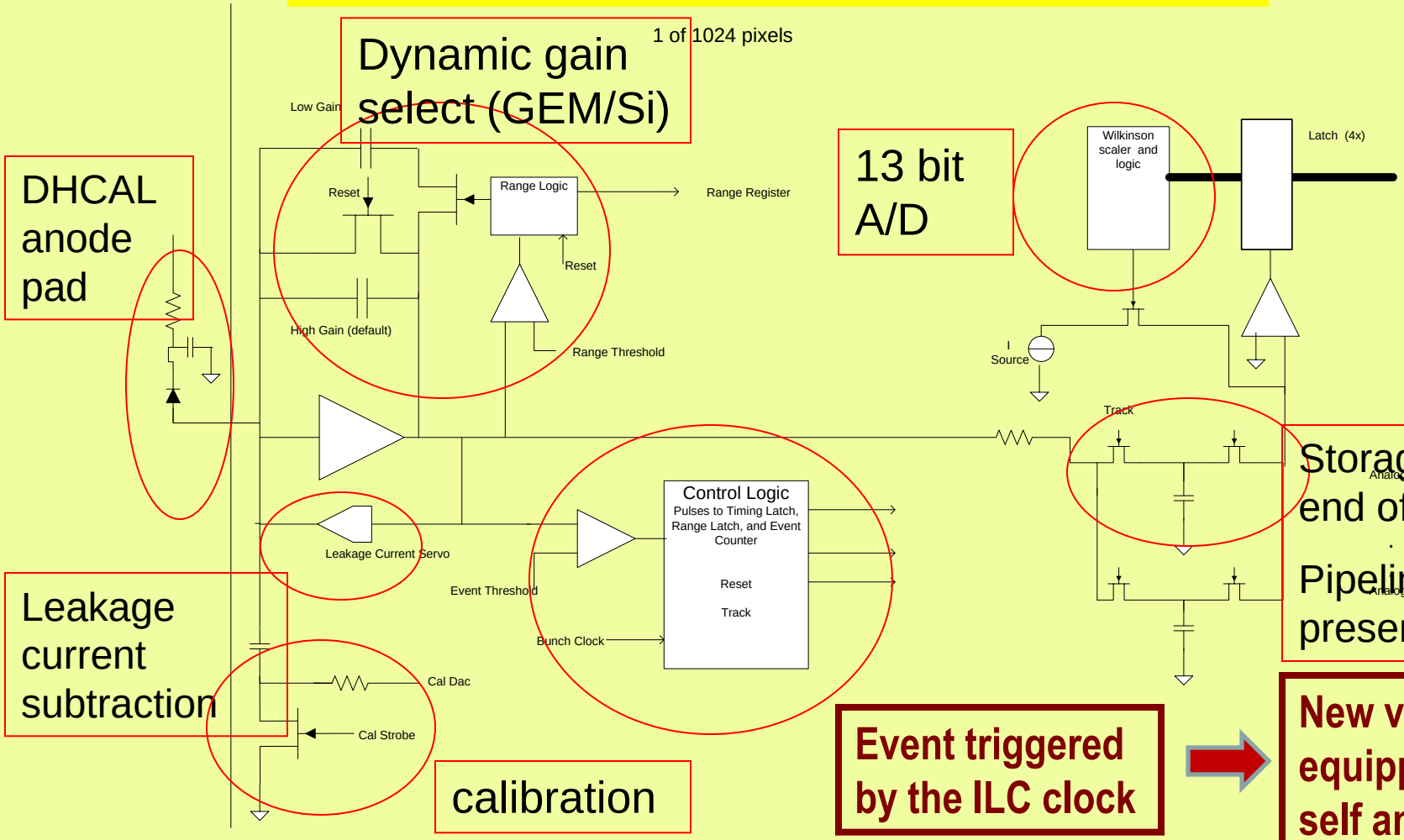
GEM-based Digital Calorimeter Concept



What have been done so far?

- Bench tested with various source and cosmic ray
  - Used QPA02 chip based preamp
  - Verified the signal shape, responses and gain
- Took a beam test at a high flux electron beam
  - Prototype chamber built with 3M's 30cmx30cm GEM
  - Used QPA02 chip based preamp
  - Verified that the chamber can survive
- Took two beam tests at FNAL's MTBF
  - Used QPA02 chip based preamp
  - 8 GeV pion beams and 120GeV proton beams
  - Measured chamber responses, efficiencies and gain

KPiX Analog Readout for GEM DHCAL



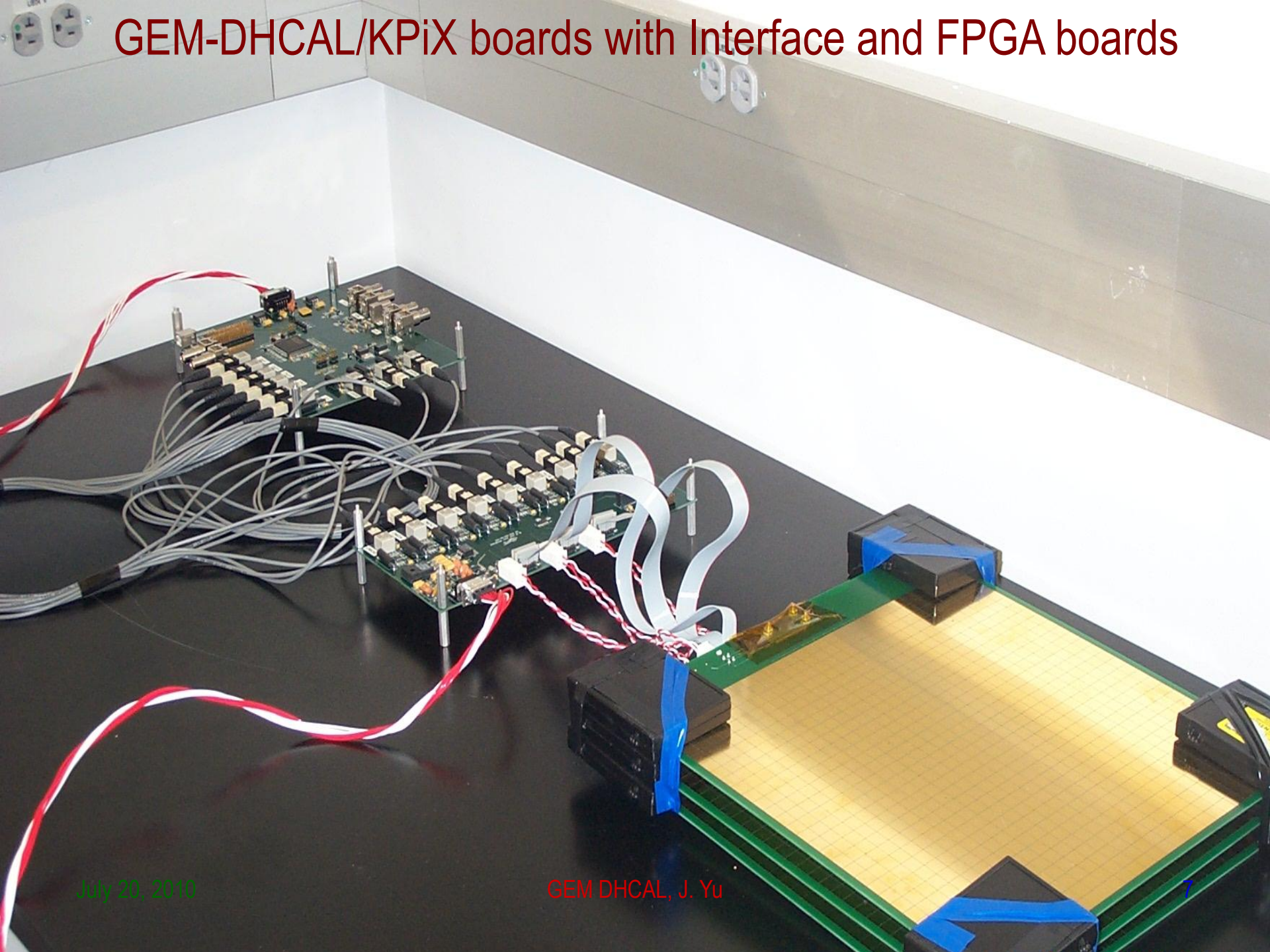
Simplified Timing:

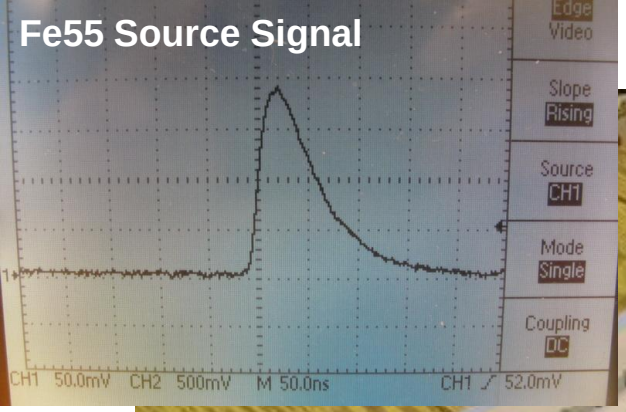
There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

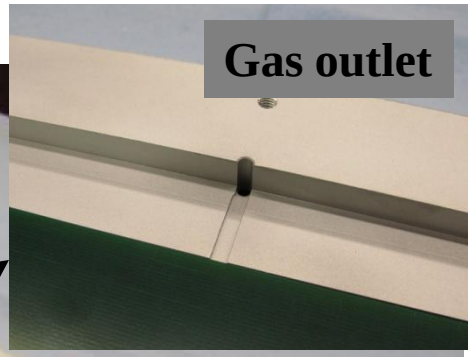
Say a signal above event threshold happens at bunch n and time T0.
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range switch has had time to settle, Track connects the sample capacitor to the amplifier outp
The Track signal opens the switch isolating the sample capacitor at T0 + 1 micro s. At this time, the amplitude of the sig
Reset is asserted (synched to the bunch clock) . Note that the second capacitor is reset at startup and following an even
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.

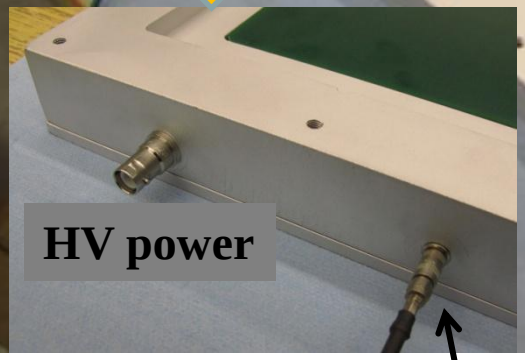
- 1024 channel 13 bit ADC chip
- Developed for Si/W ECAL@ SLAC

GEM-DHCAL/KPiX boards with Interface and FPGA boards

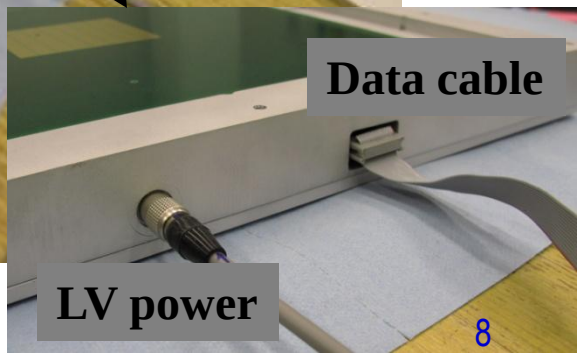




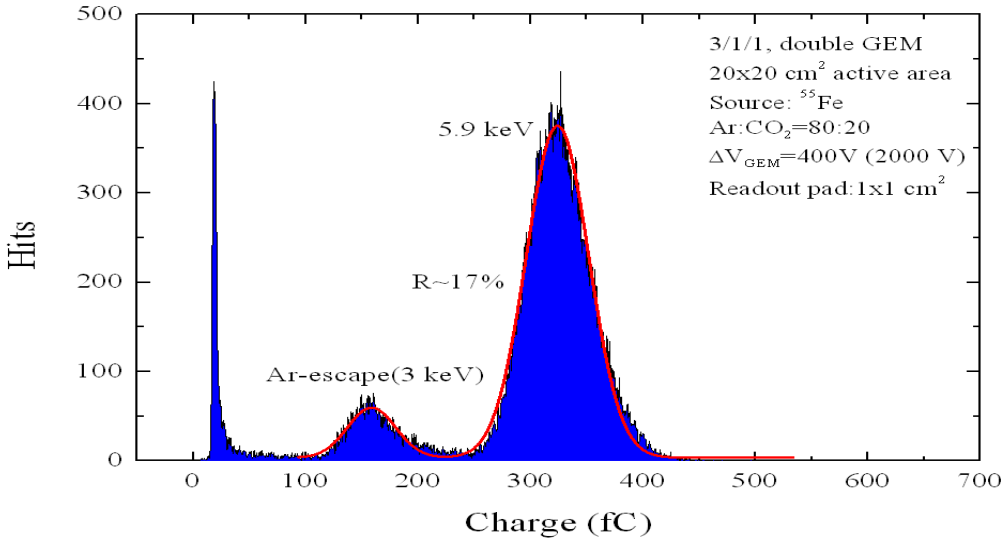


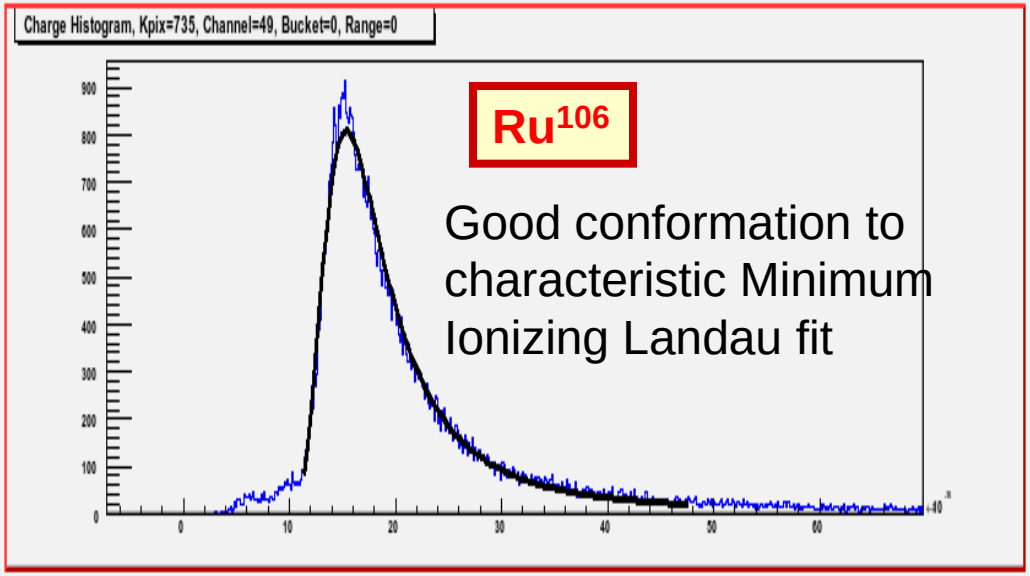


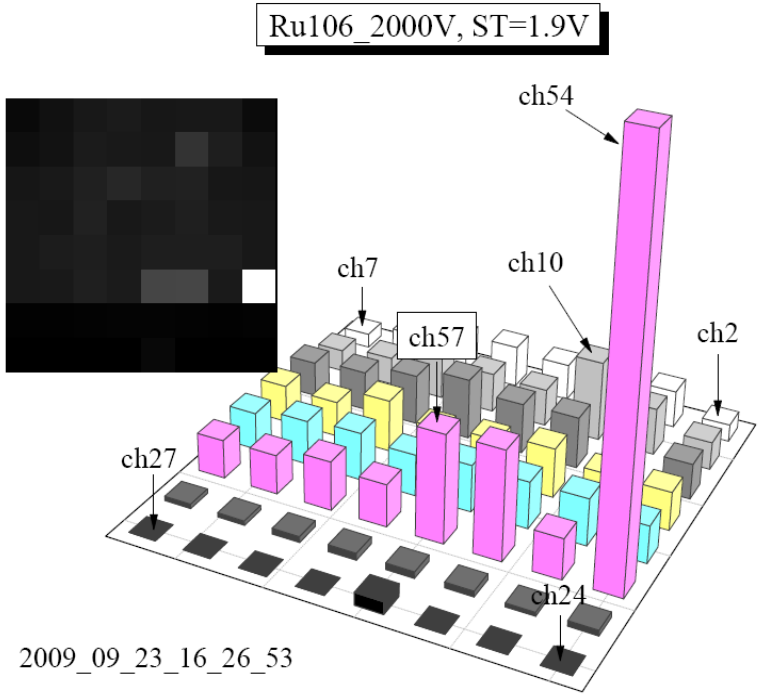
Analog signal

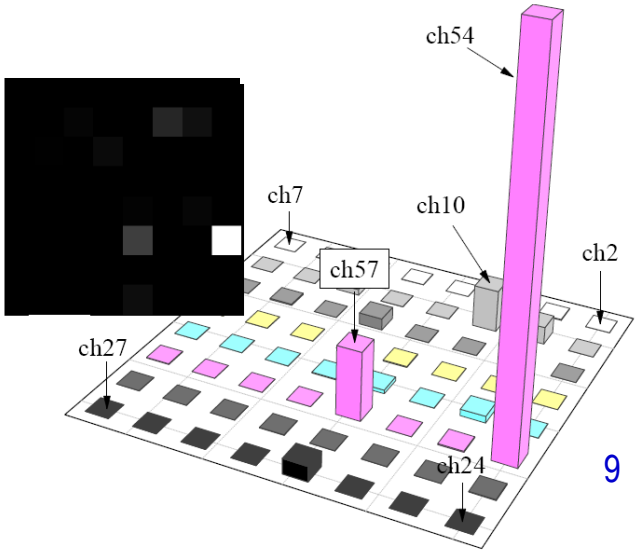


GEM+kPiX Fe^{55} and Ru^{106} Spectra

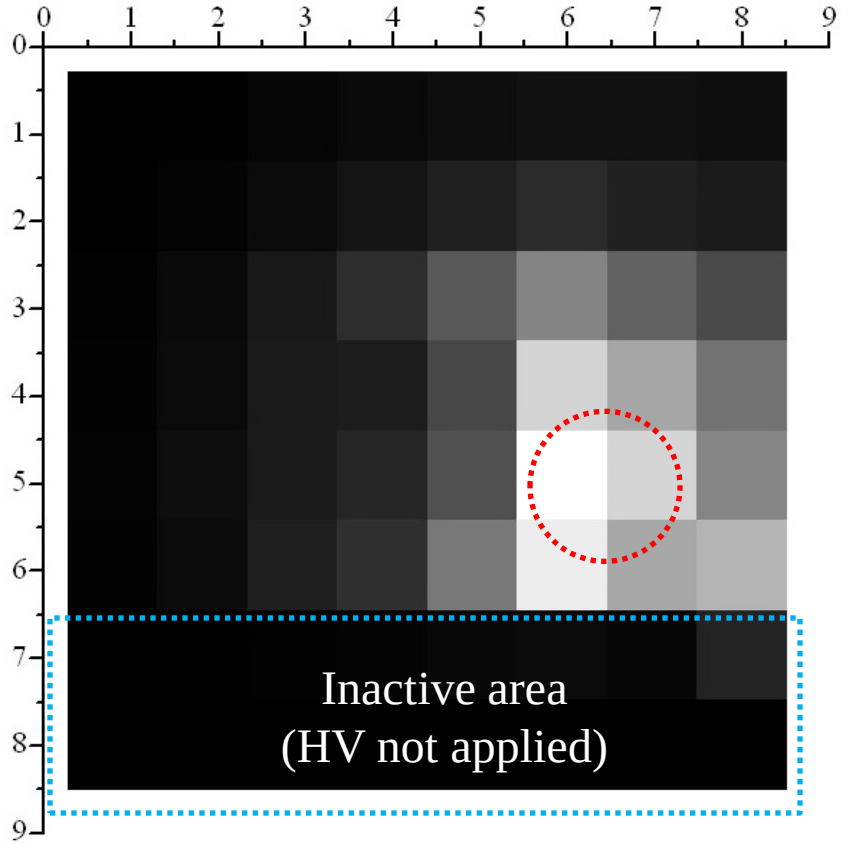


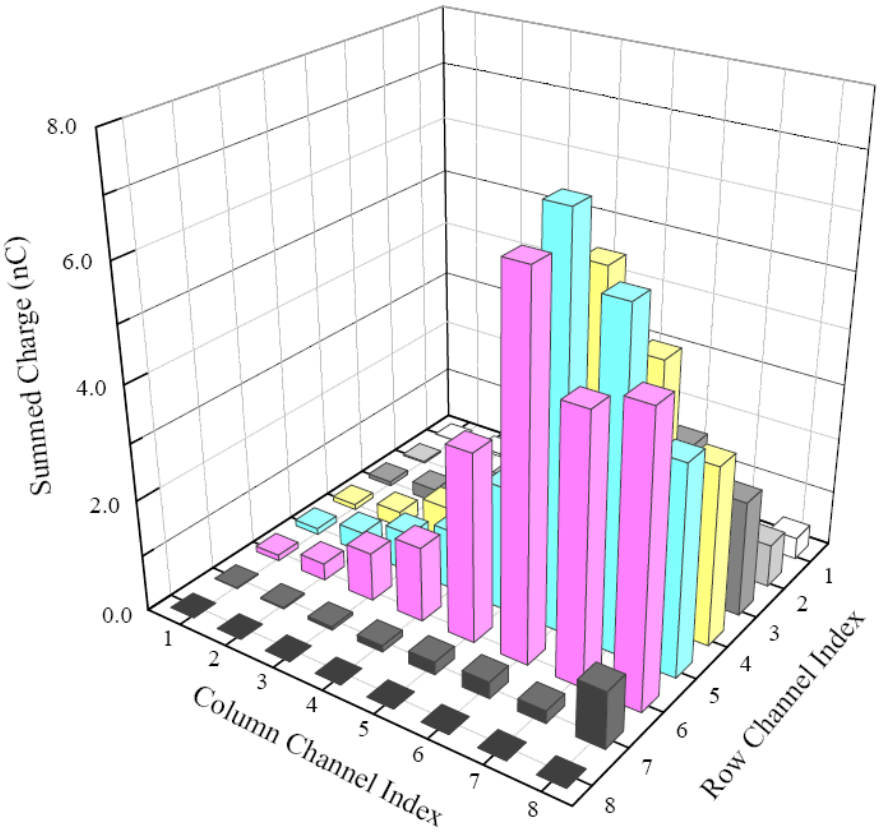






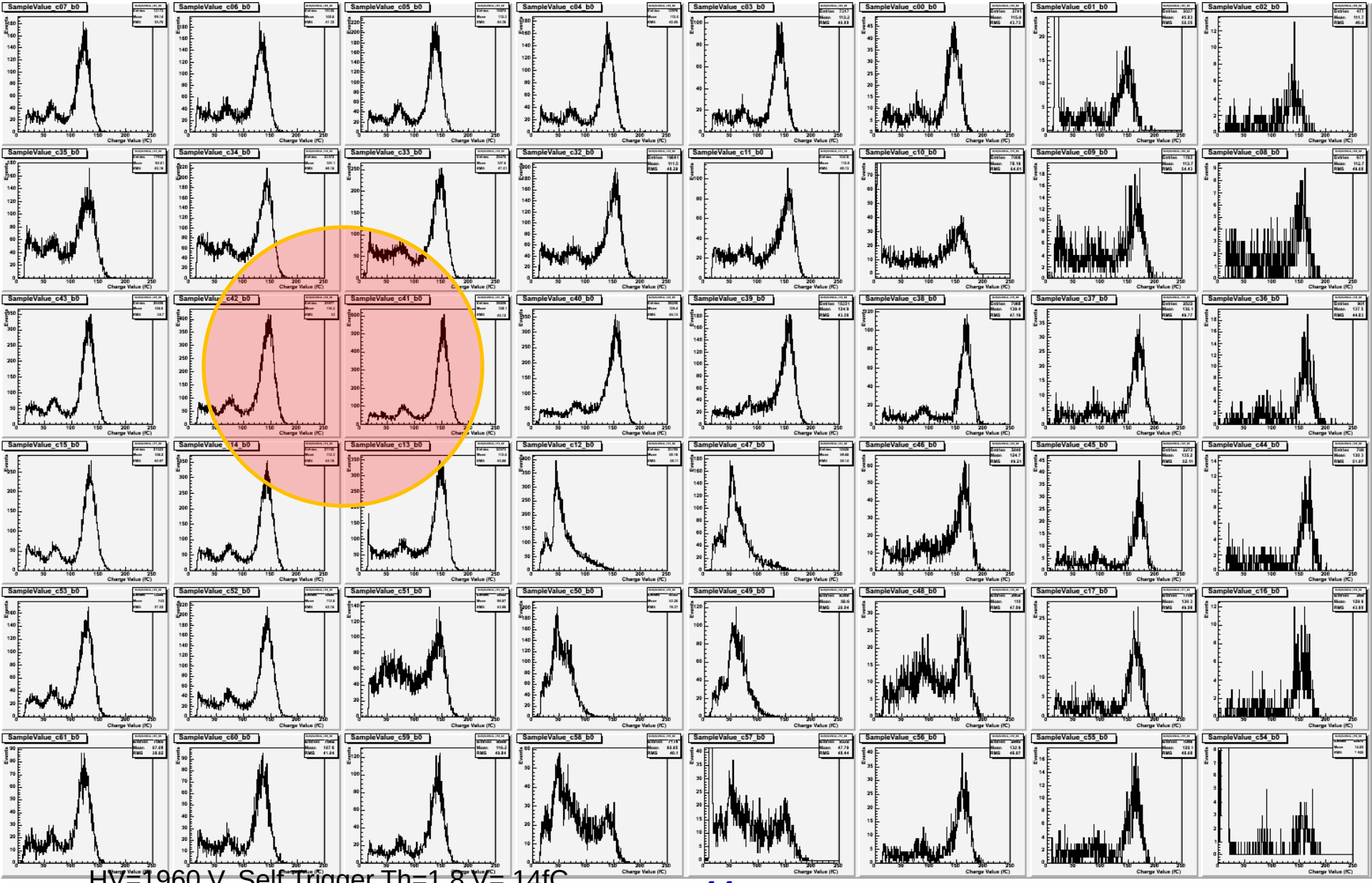
Charge Weighted Lego for Fe55





HV=1960 V, Self Trigger Th=1.8 V= 14fC

Histogram Map for Fe55



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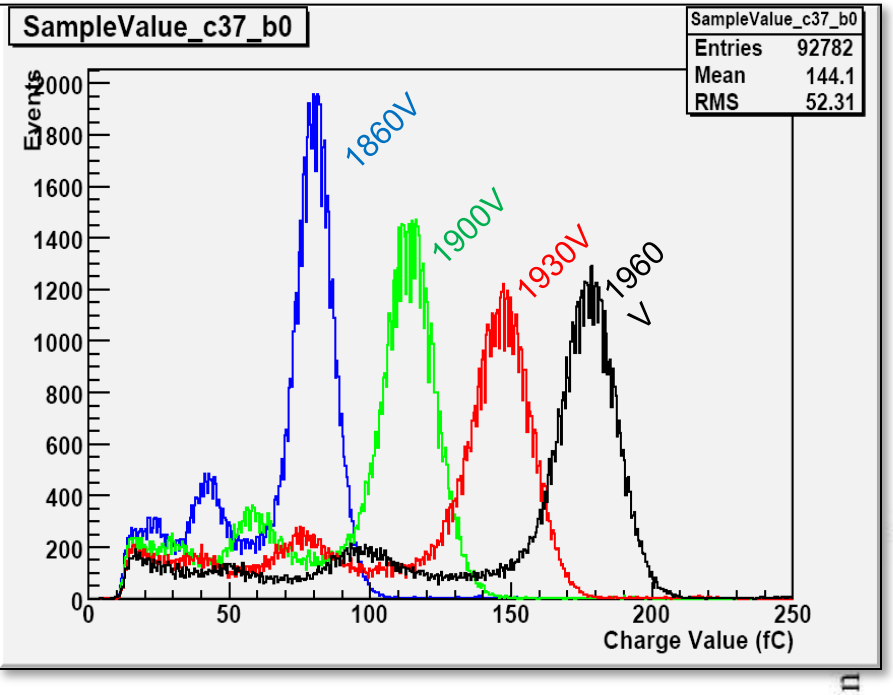
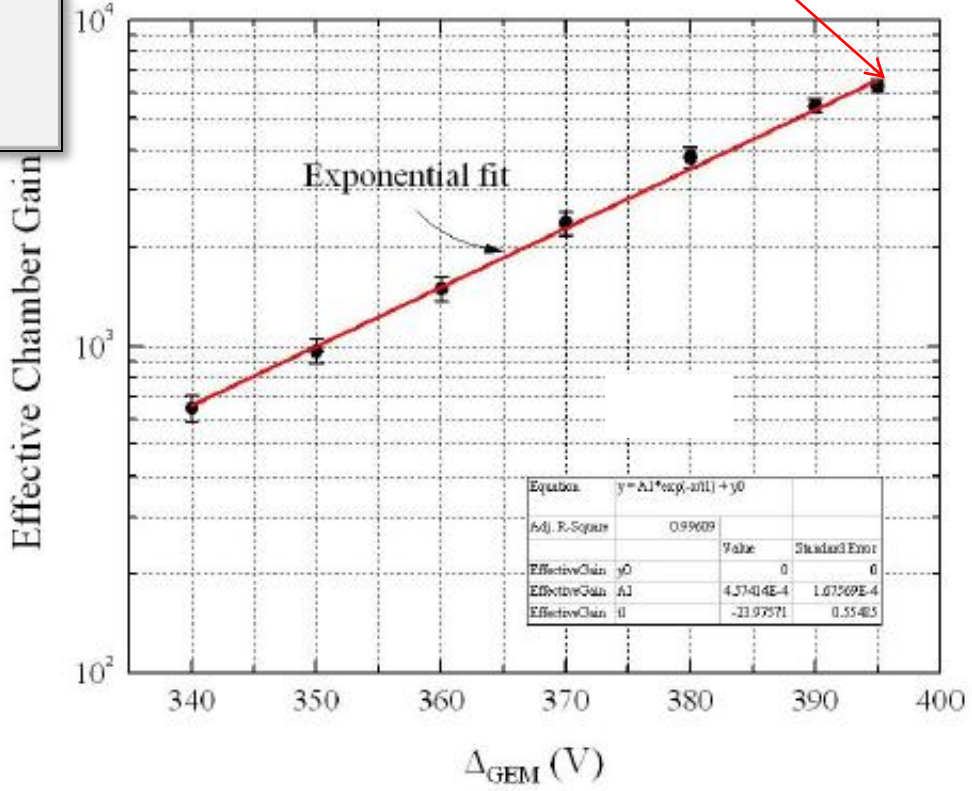
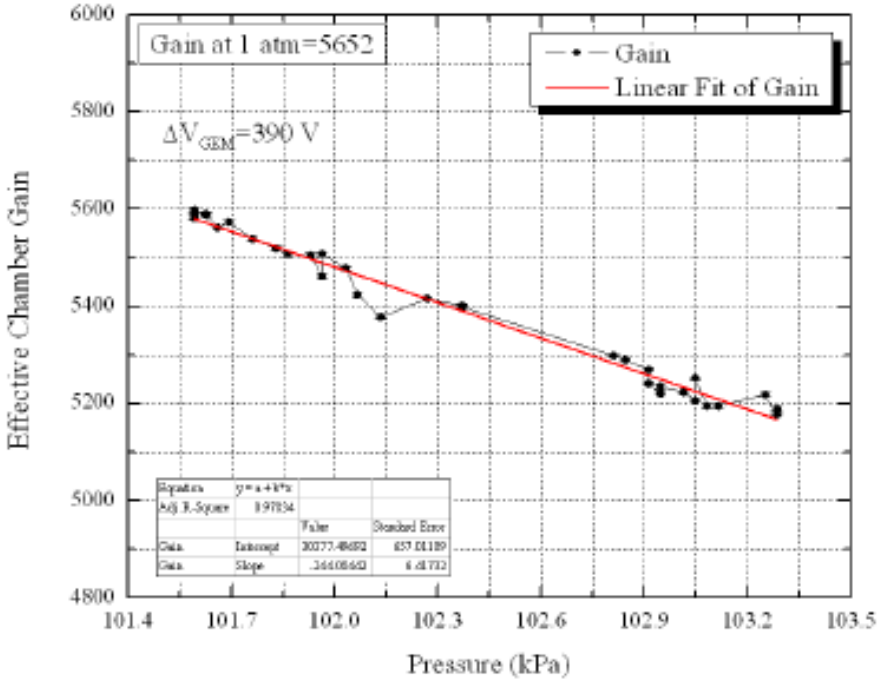


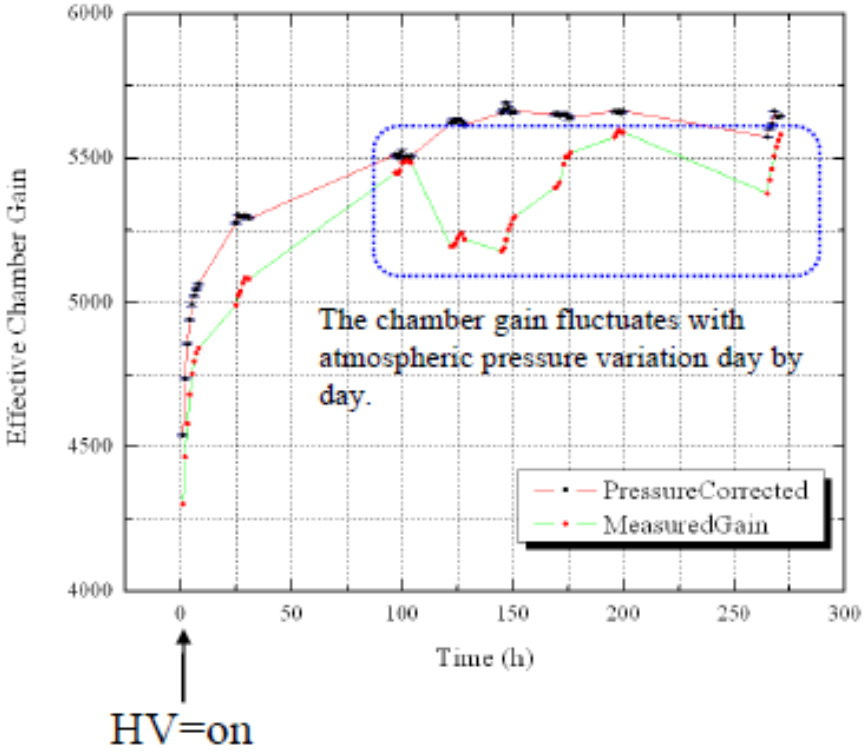
Typical operating point:
Gain ~6000



Pressure Dependence of Gain

HV =1950V (ΔV_{GEM}=390 V)





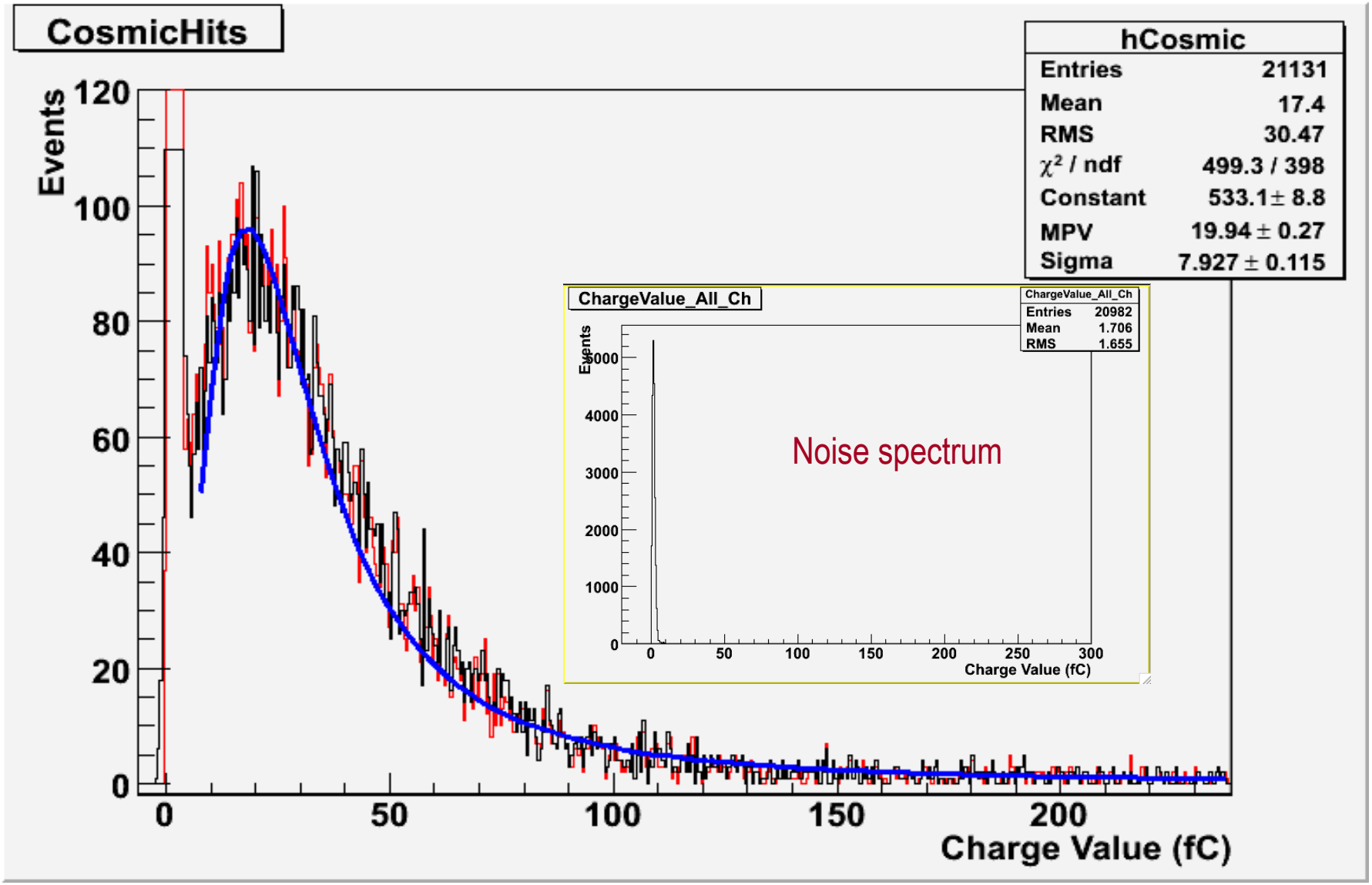
We use an open gas system (gas flows at atmospheric pressure).

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 equivalent 1 atm.

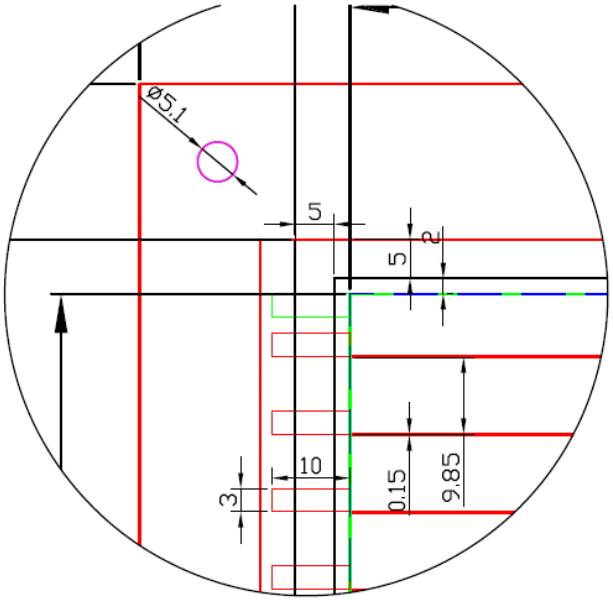
Cosmic Ray Data with External Trigger



GEM DHCAL Plans

- Phase I ➔ Completion of 30cm x 30cm characterization
  - Mid 2010: using one to two planes of 30cm x 30cm double GEM chamber with 64 channel KPiX7 and DCAL chips
  - Joint Test with THGEM/KPiX at CERN
- Phase II ➔ 33cm x 100cm unit chamber construction and characterization
  - Mid 2010 – late 2011 at MTBF: Using available KPiX chips and DCAL chips
- Phase III ➔ 100cm x 100cm plane GEM DHCAL performances in the CALICE stack
  - Mid 2011 – Early 2012 at Fermilab's MTBF *or CERN*
  - 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

33cmx100cm GEM Foils Design



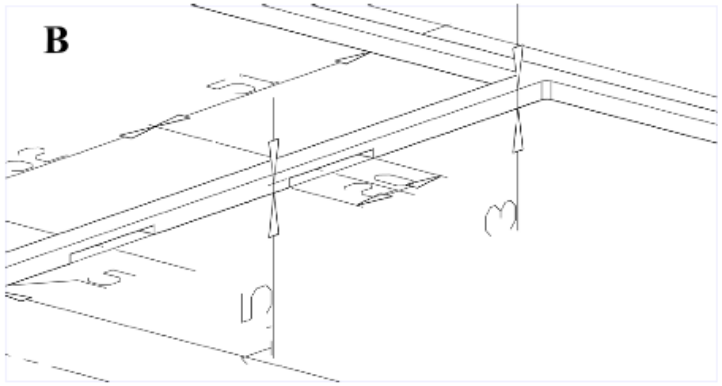
Active area 468x306x2 mm^2

Number of HV sectors = 32x2=64

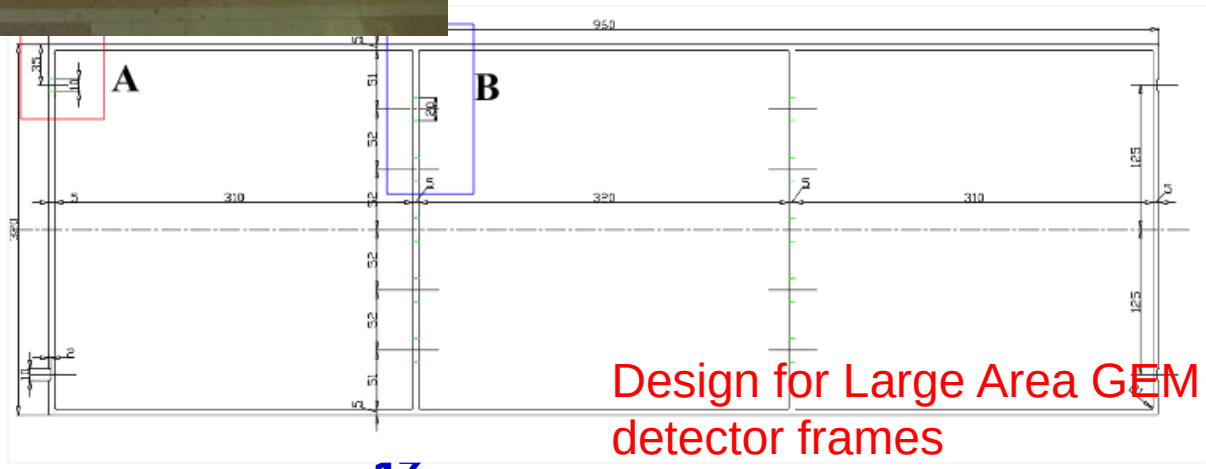
HV sector dimension= 9.9x479.95 mm^2

33cmx100cm Large Area GEM

First 5 of 33cmx100cm GEM foils delivered early July, 2010

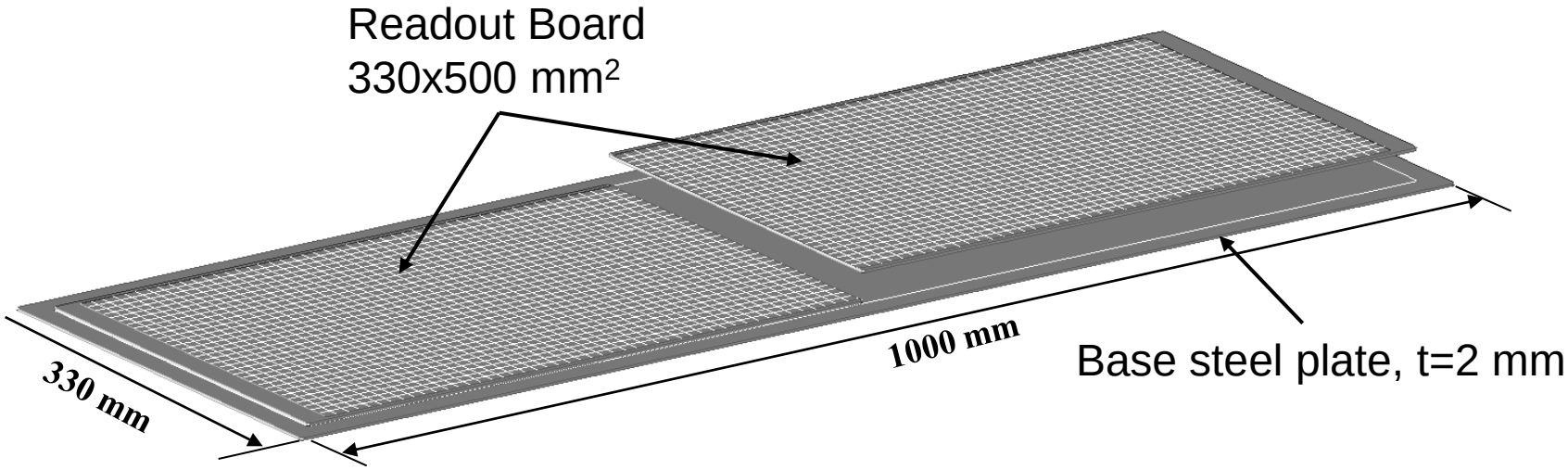


Spacer for drift gap

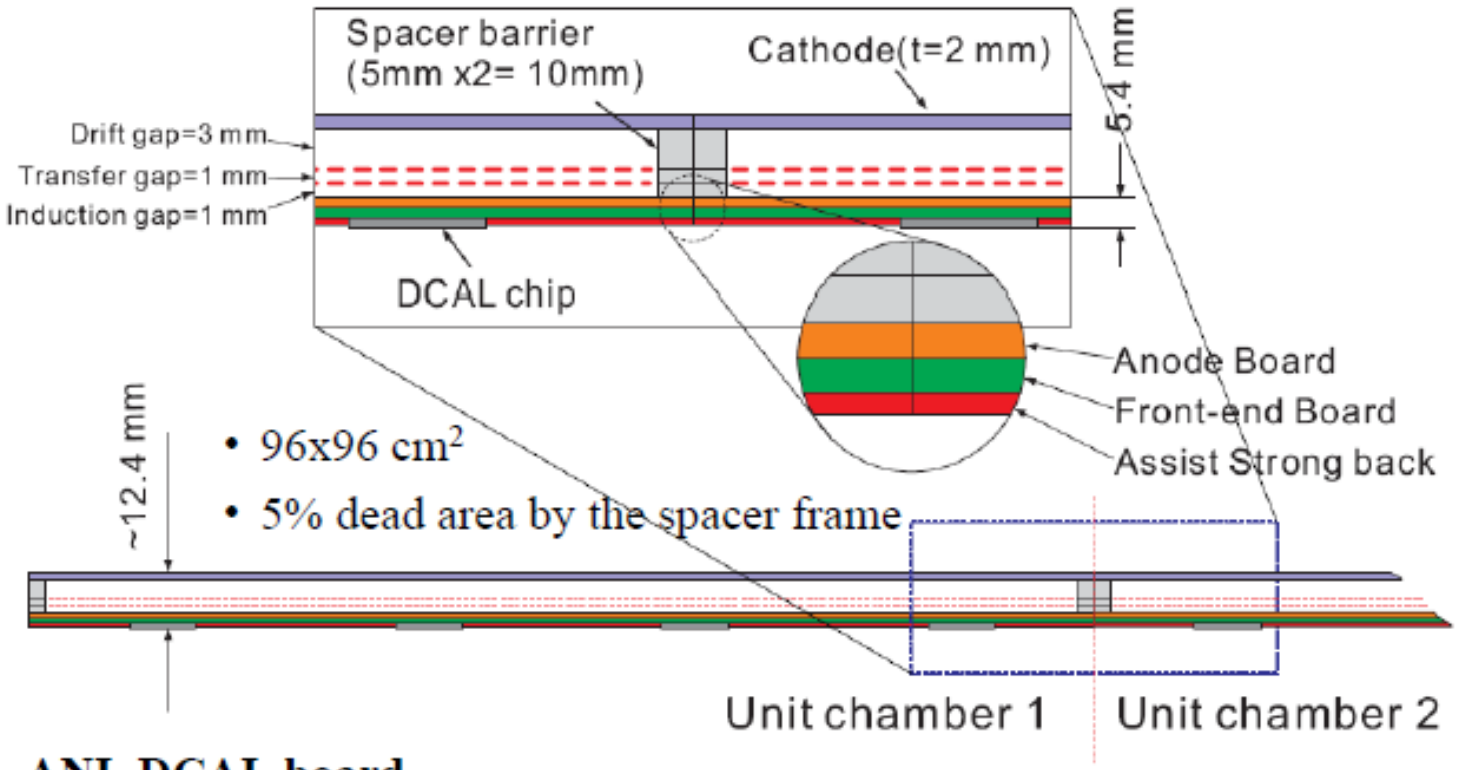


Design for Large Area GEM detector frames

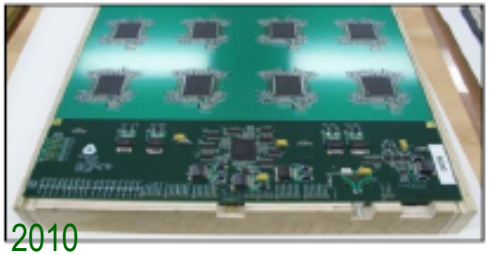
33cmx100cm DHCAL Unit Chamber Construction



UTA's 33cm x 100cm DHCAL Unit Chamber



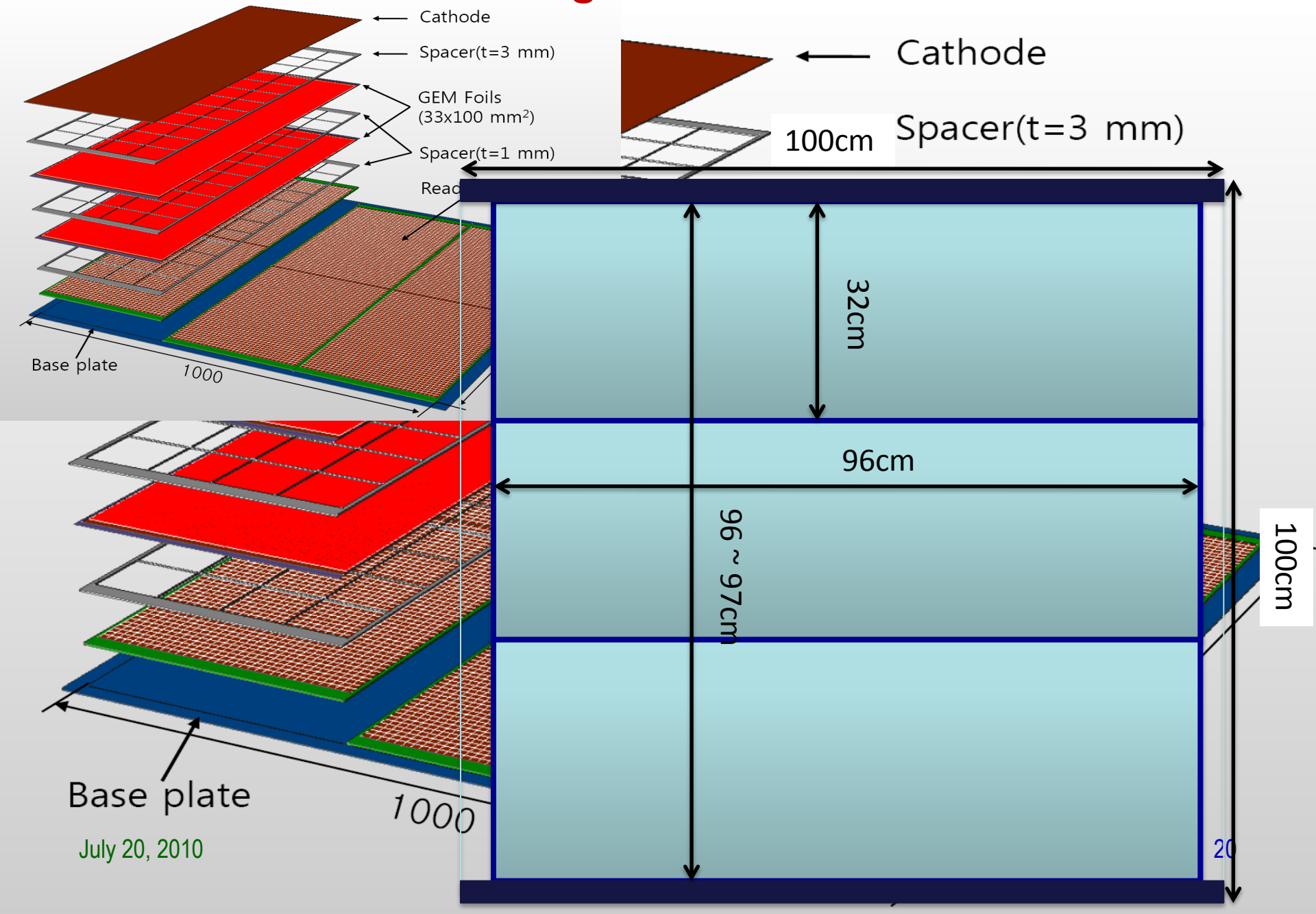
➢ **ANL DCAL board**



Pad board: 320x480x1.5 mm³

Front-end board: 320x555x1.5 mm³

UTA's 100cmx100cm Digital Hadron Calorimeter Plane



Summary

- Impressive progress has been made reading out 30cmx30cm GEM prototype chambers with 64 channel KPiX v7 chips
  - Observed clean characteristic peaks from Fe^{55} and Ru^{106} sources as well as cosmic ray muons
  - 2-D readout of the chamber routine now…
  - Higher channel count KPiX chips being developed
  - Pressure dependence measured and corrected
- Cosmic ray and source data taking and analysis in progress
- 33cmx100cm unit chamber construction proceeding
  - First 5 foils of 33cmx100cm delivered!!
- Mechanical design being worked out for constructing 1mx1m planes for DHCAL testing