GEM Digital Hadron Calorimetry

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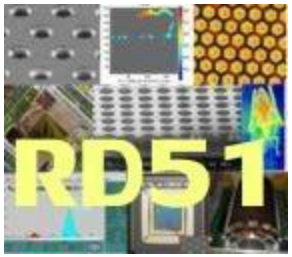
- Introduction
- What has been done?
- 2D readout with KPiX chip
- TGEM Beam Test at CERN
- Large GEM Foil Certification
- Large Chamber Mechanics Design
- Summary



• From talk given by J. Yu at CALICE Meeting – September 2010 and talk by A. Breskin at RD51 meeting in Bari – October 2010

Acknowledgments

- GEM foil based detectors designed and constructed by Dr. Seongtae Park, UTA with help of UTA students.

- GEM foils from 3M, and (more recently) from CERN – much assistance from R. D'Olveira and RD51 colleagues.

-THGEM based detectors designed and constructed by Amos Breskin and colleagues from Weizmann Institute, and Joao Veloso and colleagues from U. Aveiro and U. Coimbra.

- Facilities and help of RD51 MPGD Collaboration for CERN Test Beam.

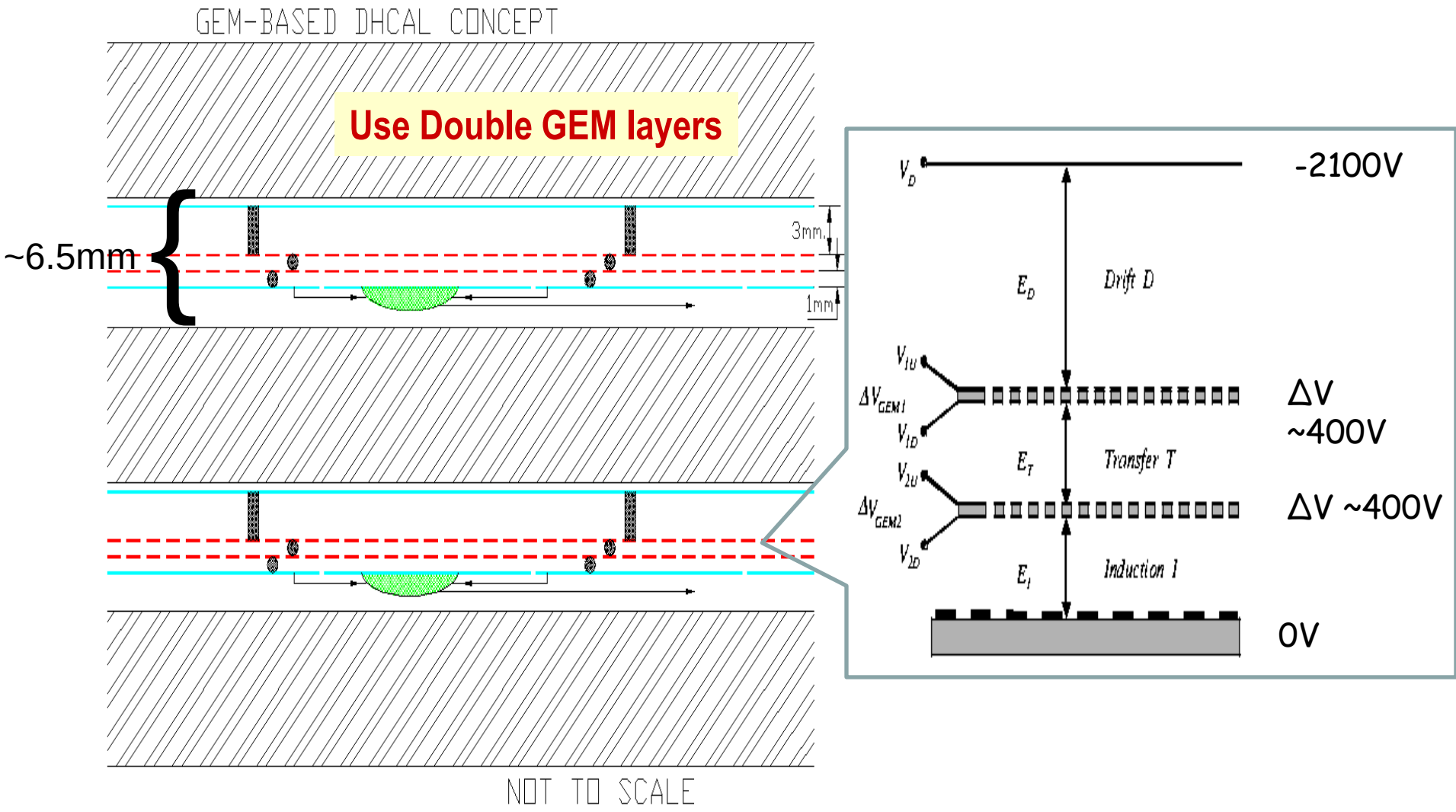
- KPiX electronics and anode pad boards supplied by SLAC group of M. Breidenbach, G.Haller, D.Freytag and R. Herbst

- DCAL electronics for large area GEM's – G.Drake and colleagues, ANL.

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
- …and thick-GEM – all the above and easier mechanics/handling, greater stability?

GEM-based Digital Calorimeter Concept

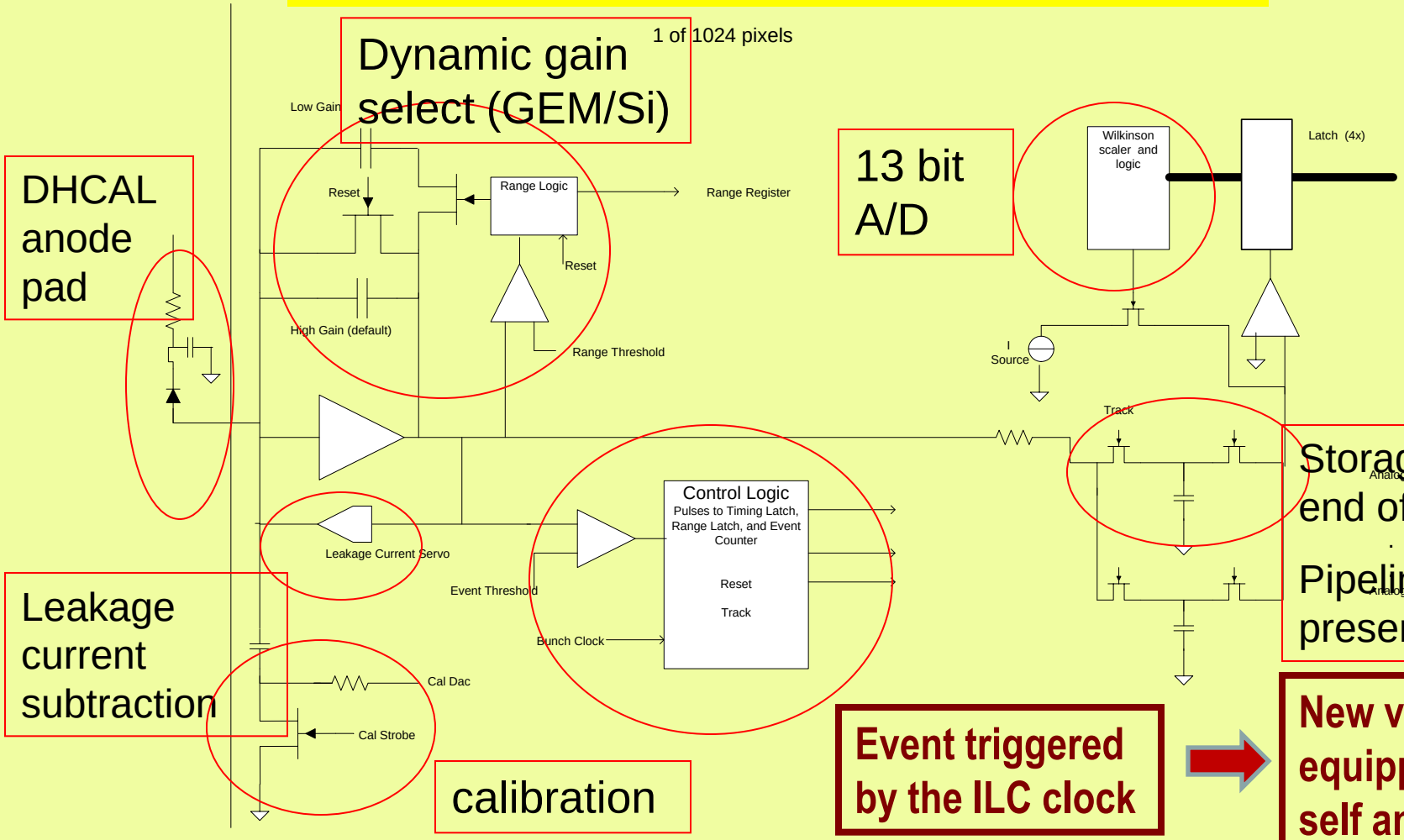


What has been done so far?

- 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

…Initial thick-GEM tests at CERN

KPiX Analog Readout for GEM DHCAL



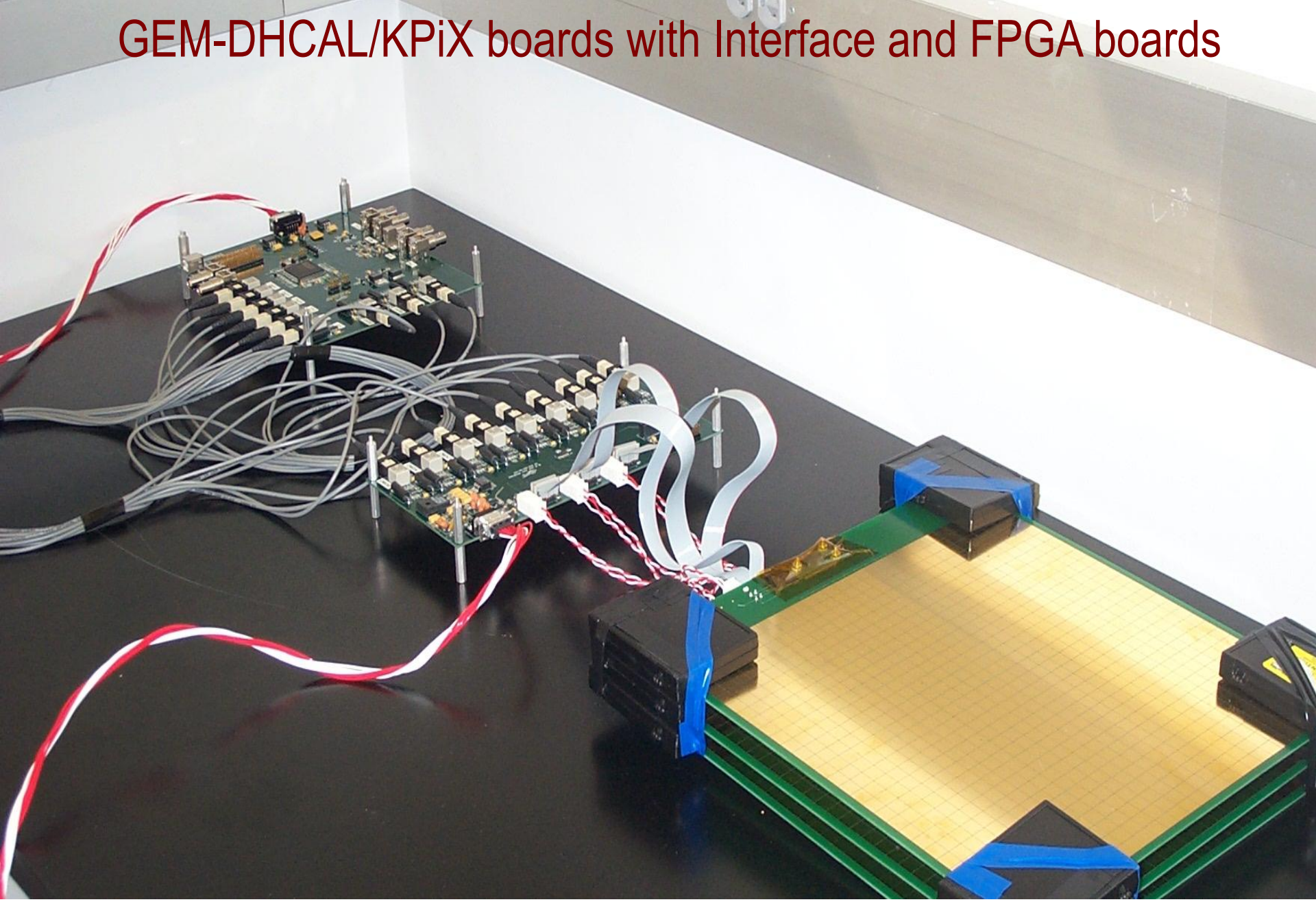
Simplified Timing:

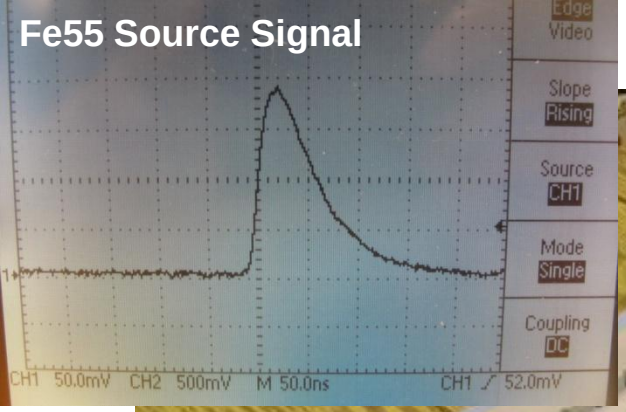
There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

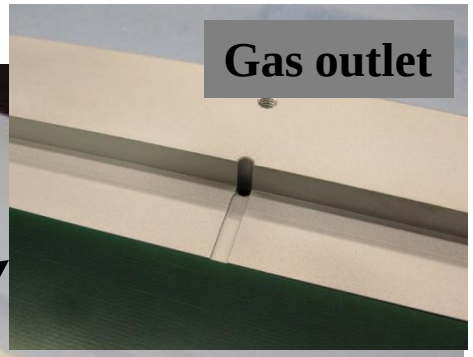
Say a signal above event threshold happens at bunch n and time T0.
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range 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

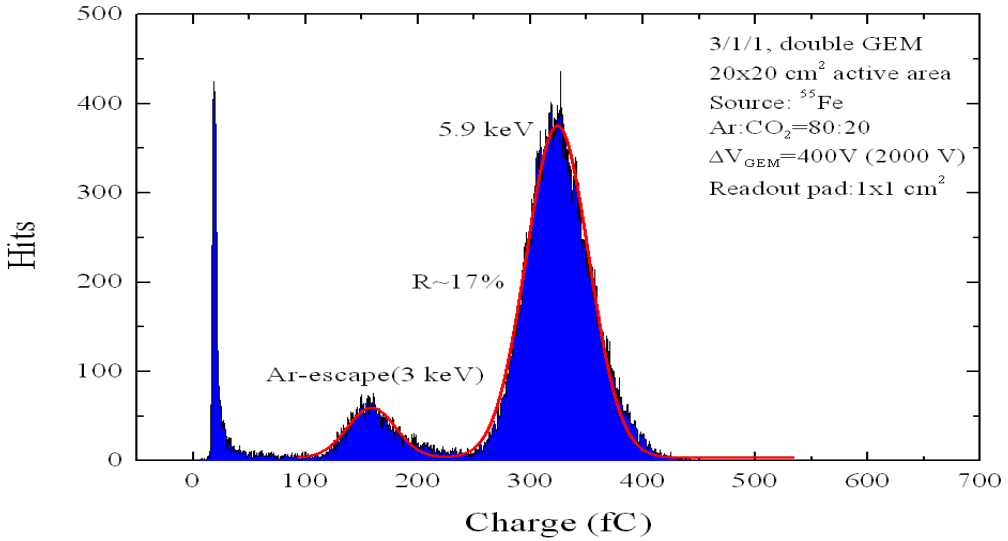


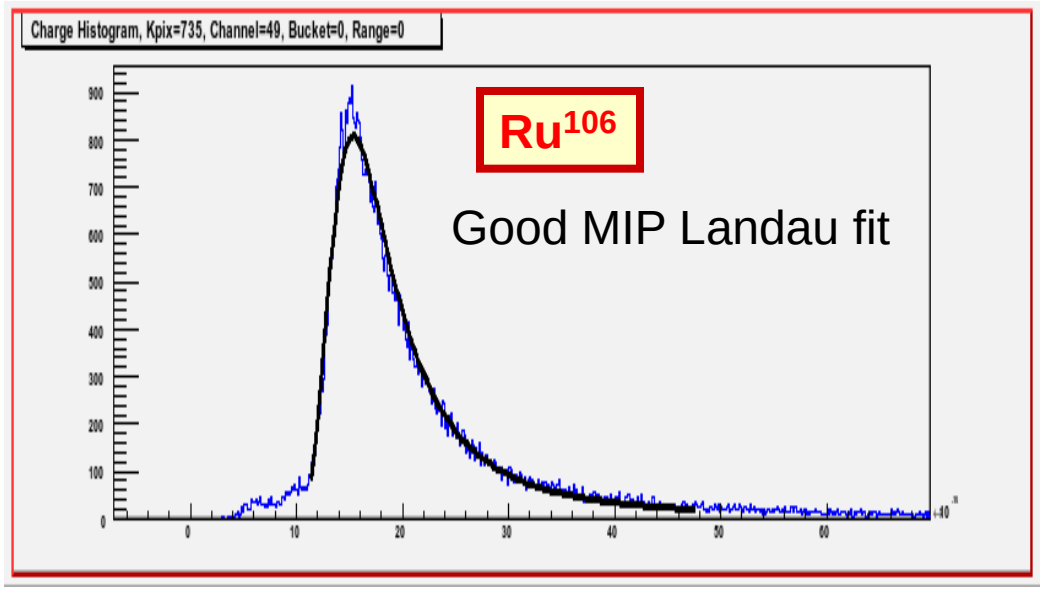

Fe55 Source Signal
Edge
Video
Slope
Rising
Source
CH1
Mode
Single
Coupling
DC
CH1 50.0mV CH2 500mV M 50.0ns CH1 52.0mV

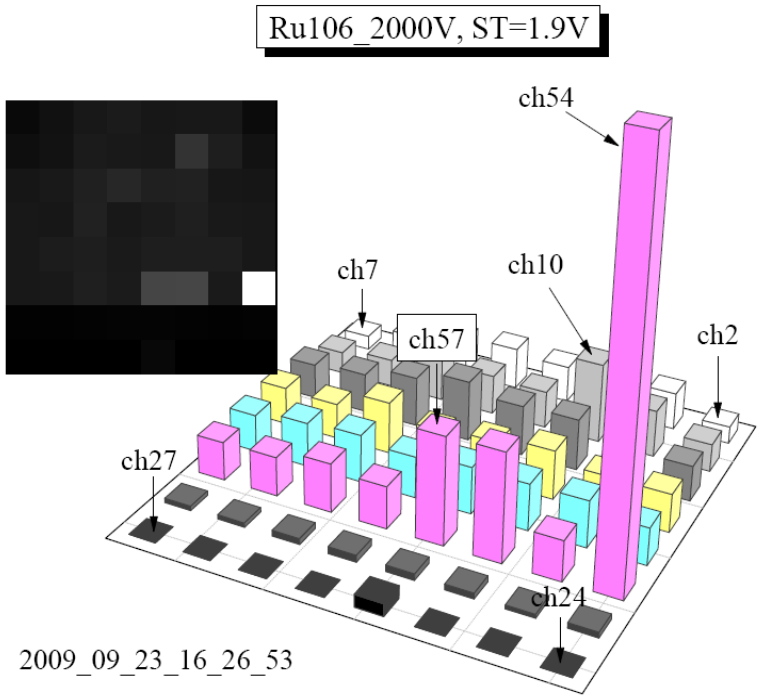

Gas outlet

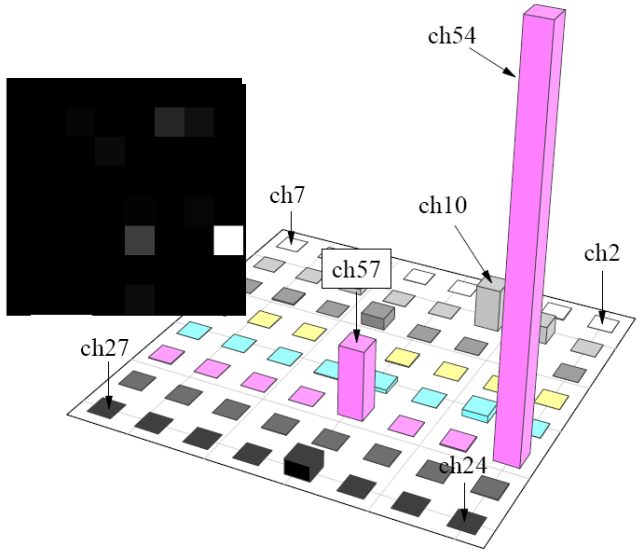
HV power
Analog signal
Data cable
LV power

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

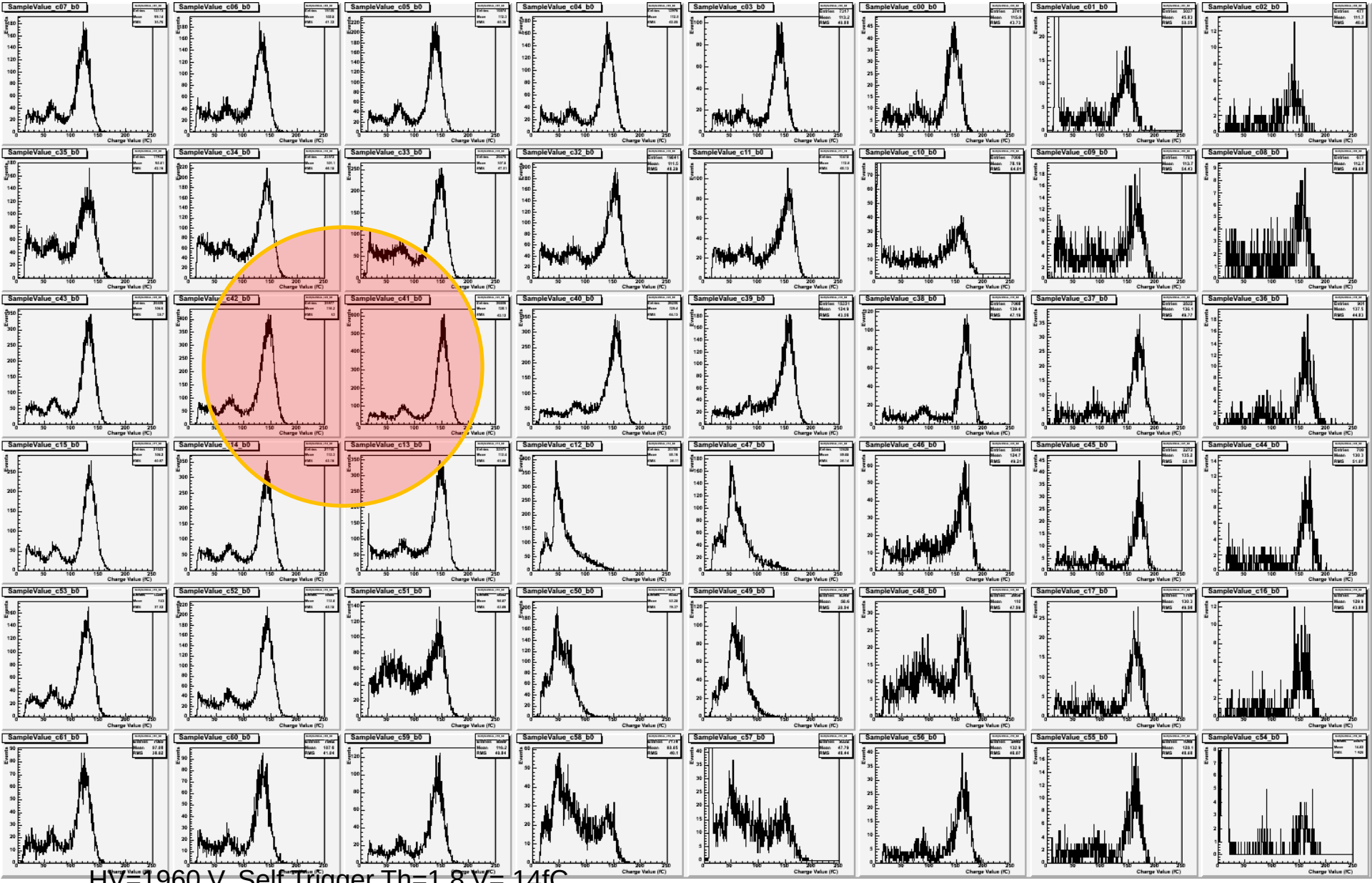






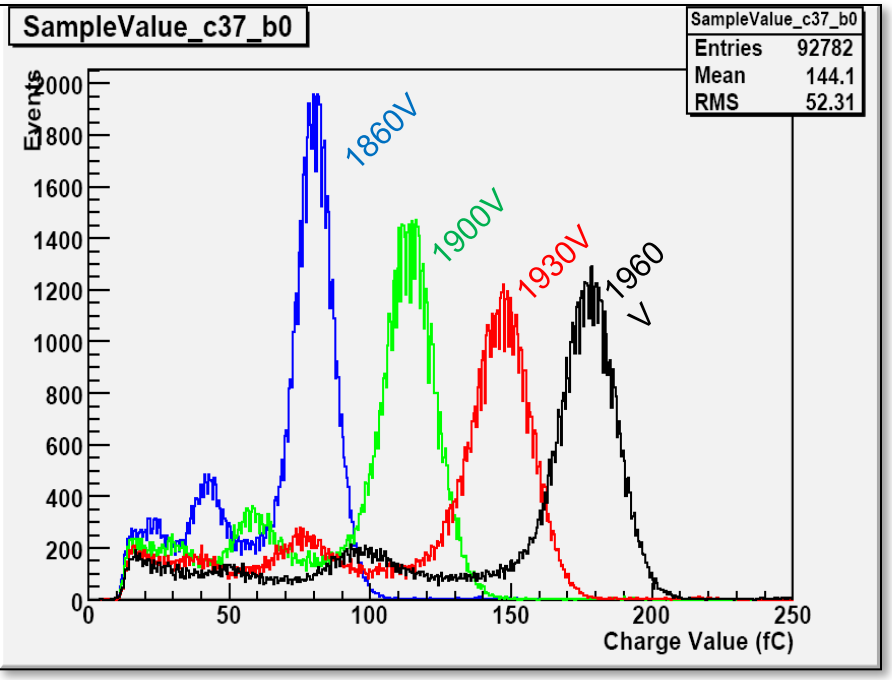


Histogram Map for Fe55

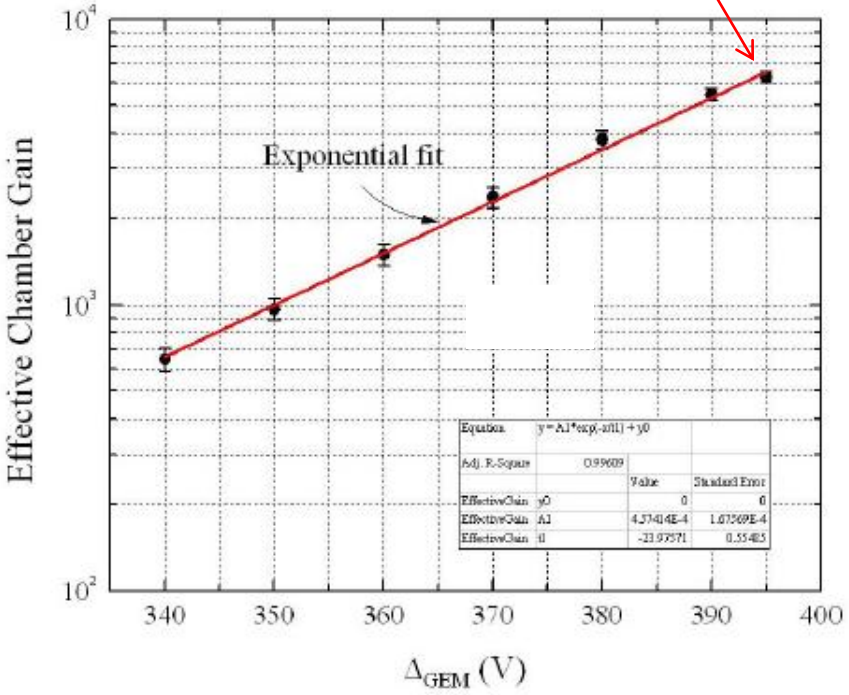


HV=1960 V, Self Trigger Th=1.8 V= 14fC

Gain vs HV

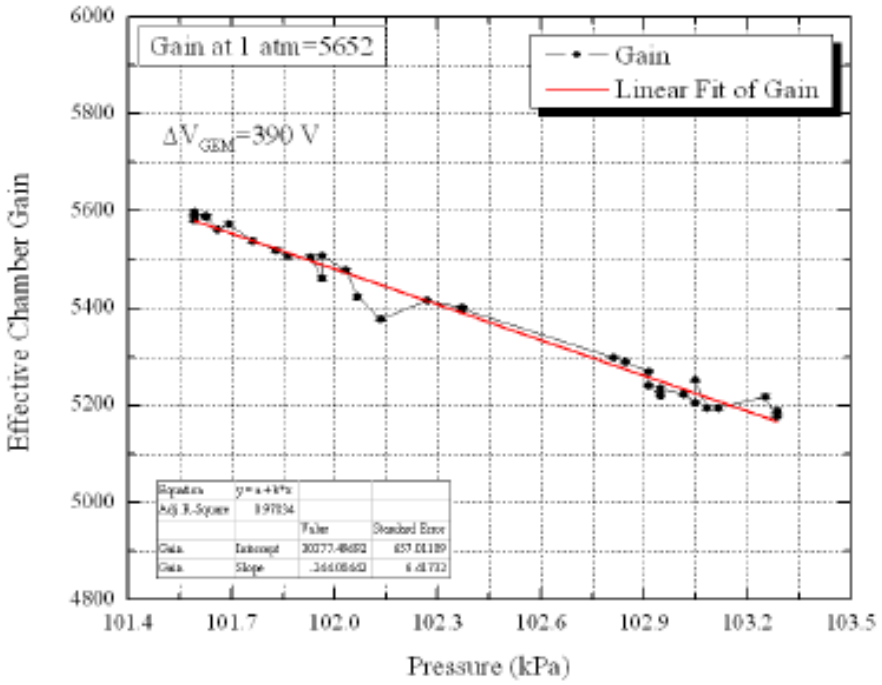


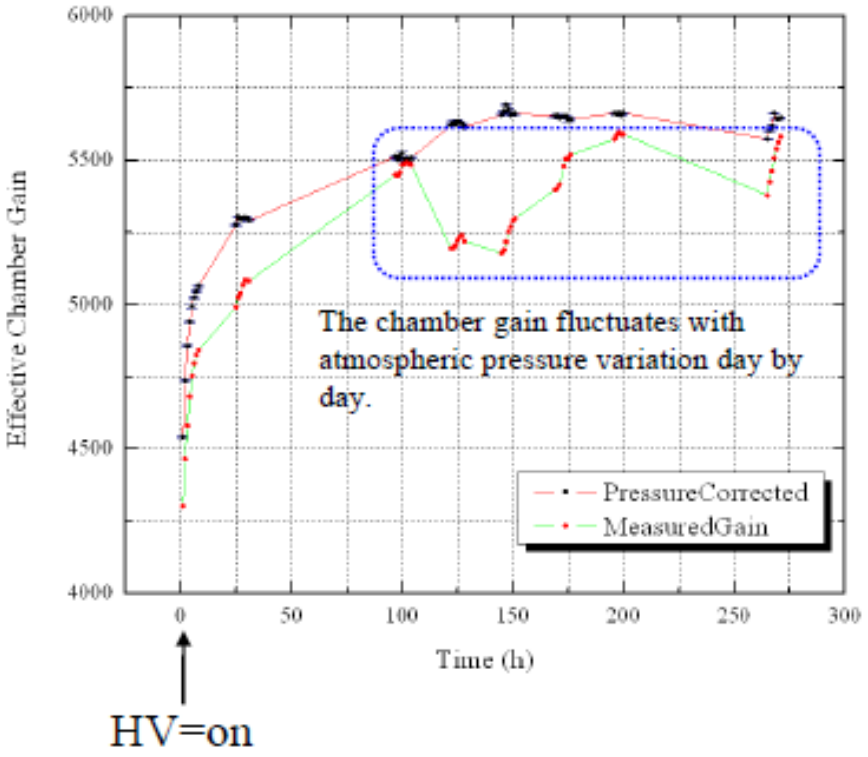
Typical operating point:
Gain ~6000



Pressure Dependence of Gain

HV =1950V (ΔV_{GEM}=390 V)





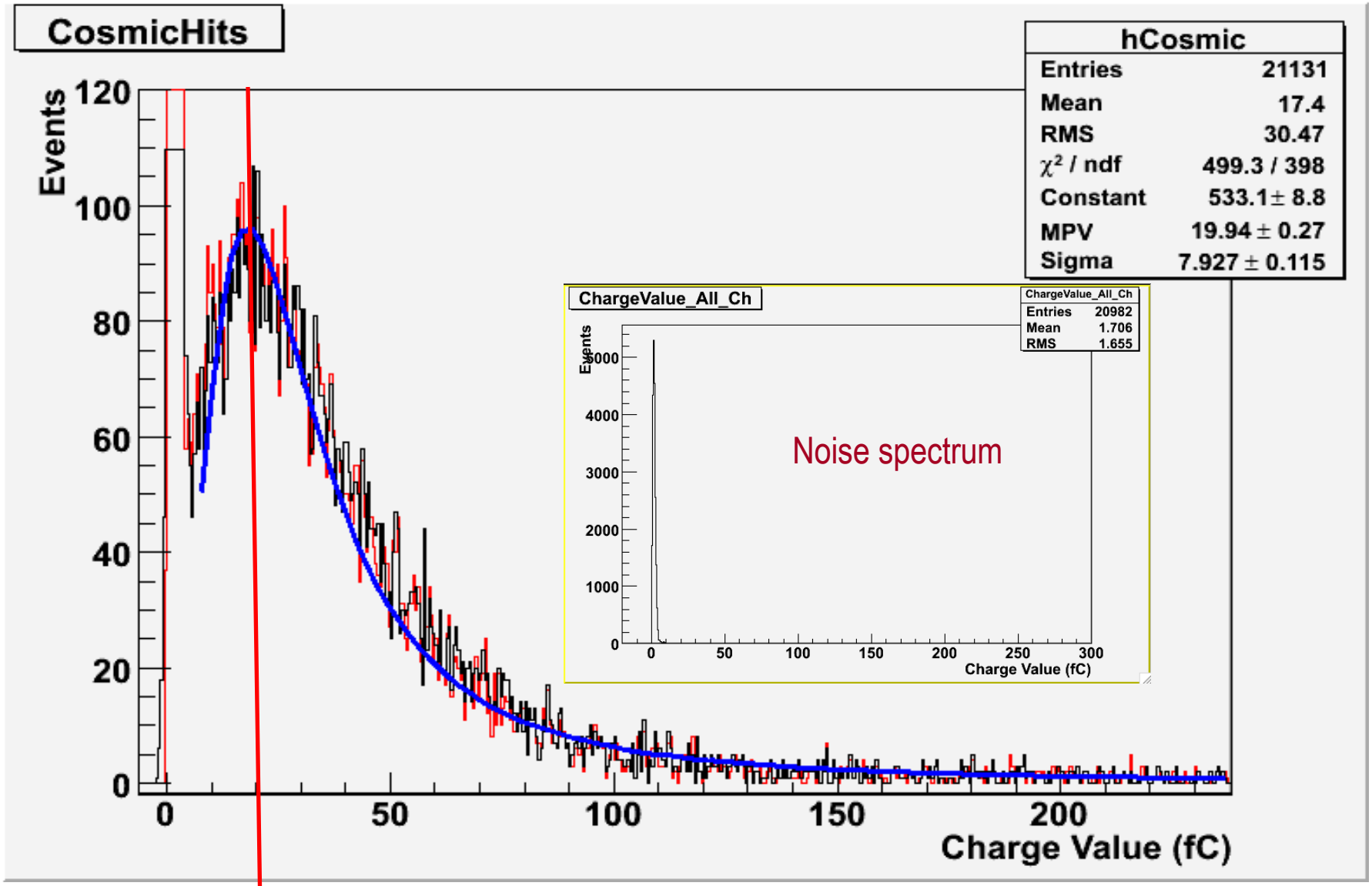
We use an open gas system (gas flows at atmospheric pressure).

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

This pressure change affects the chamber gain.

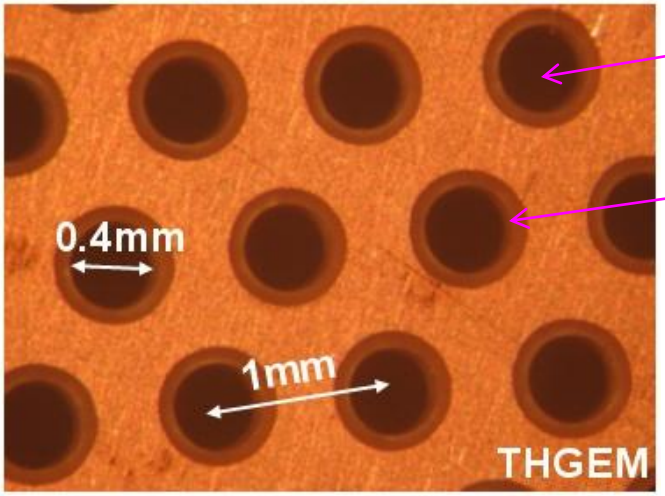
The chamber gains were recalculated to the values at 1 atm.

Cosmic Ray Data with External Trigger – kPiX

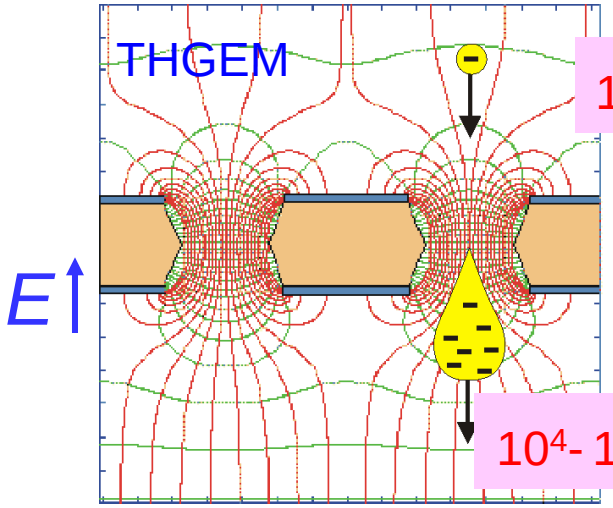


Thick Gas Electron Multiplier (THGEM)

~ 10-fold expanded GEM



Thickness 0.5-1mm



Double-THGEM: 10-100 higher gains

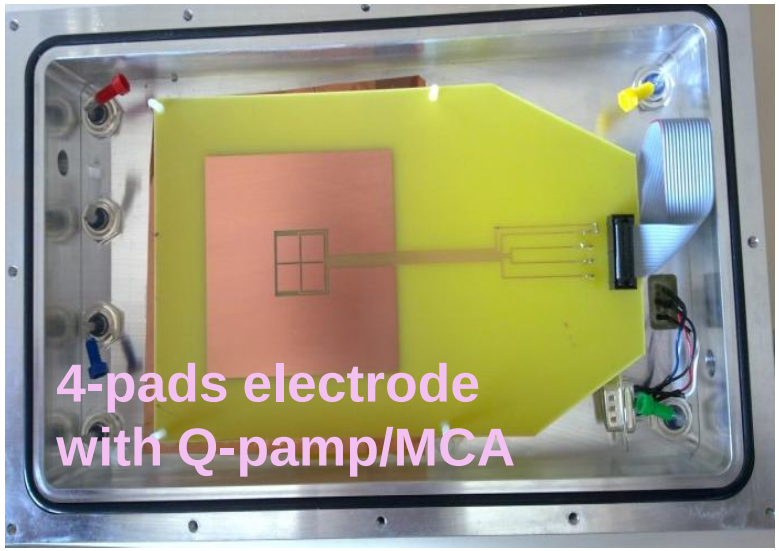
SIMPLE, ROBUST, LARGE-AREA

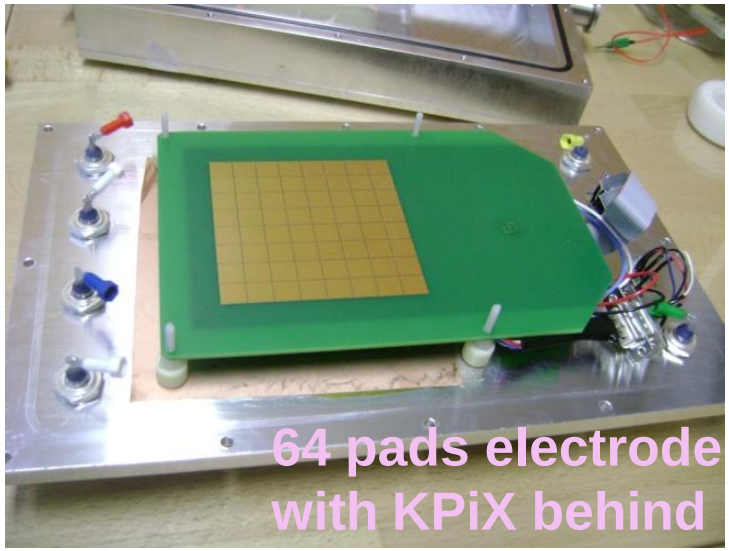
➔Intensive R&D
➔Many applications

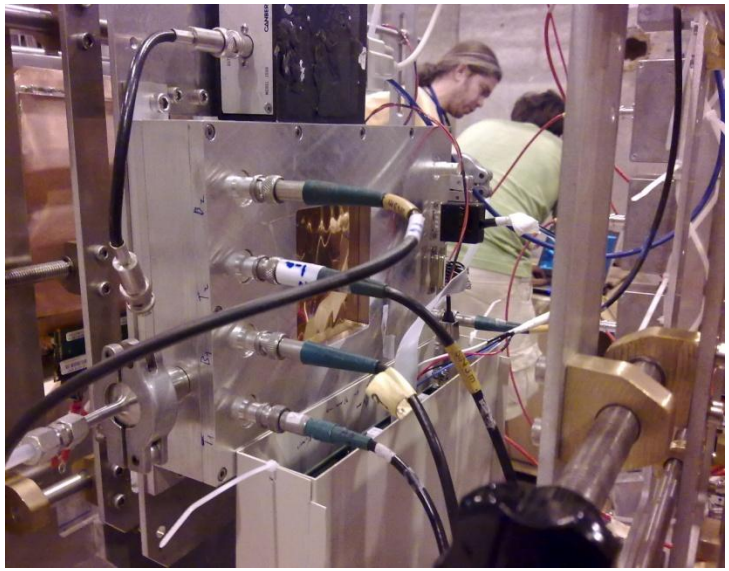
- PCB Based GEM ➔ Cost effective
- 0.5 – 1mm thick PCBs
- Drilled 0.4mm holes with 1mm pitch
- Expected to have higher gain per GEM
- 10cmx10cm tested, up to 30cmx30cm produced

THGEM Recent review
NIM A **598** (2009) 107

CERN test-beam detector





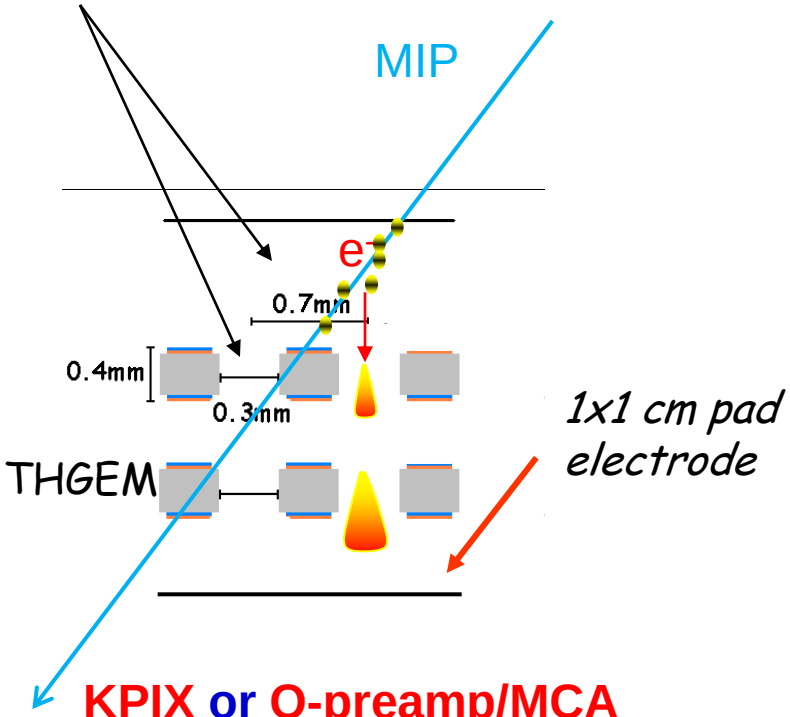


August 2010, and now back at CERN test beam…

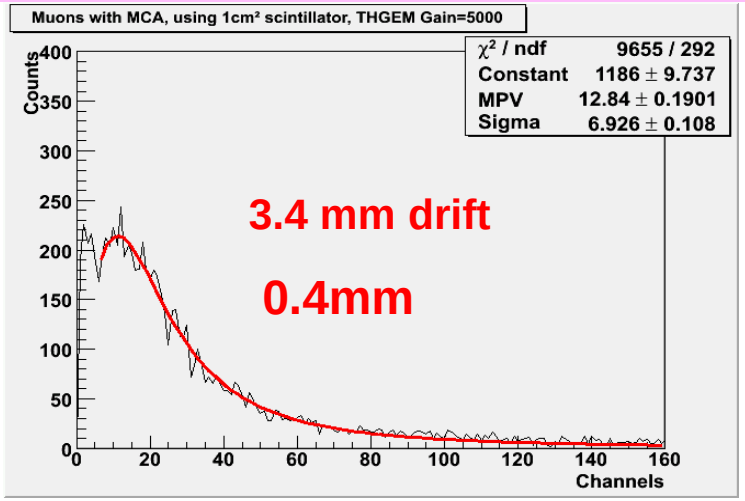
Muons w Double-THGEM KPIX or Q-preamp/MCA

Here we had:

0.5mm holes / 1mm space

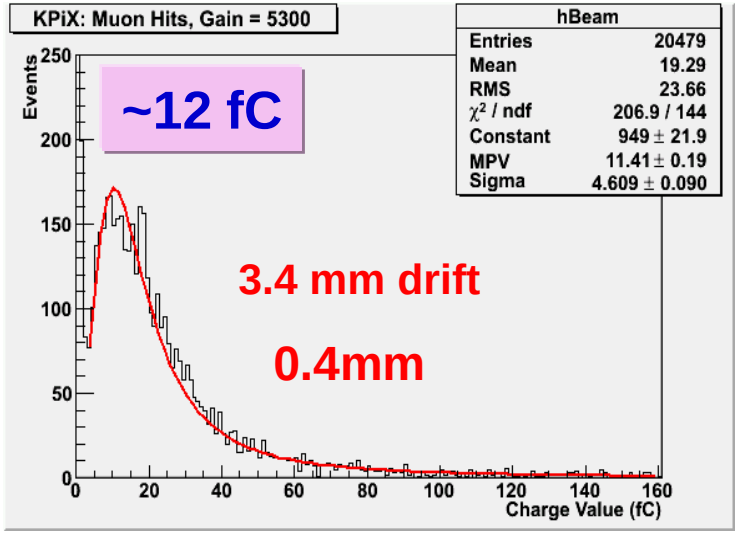


2-THGEM BEAM TESTS with Q-preamp/MCA



Double-THGEM, Ne/5%CH4; Average gain ~5000

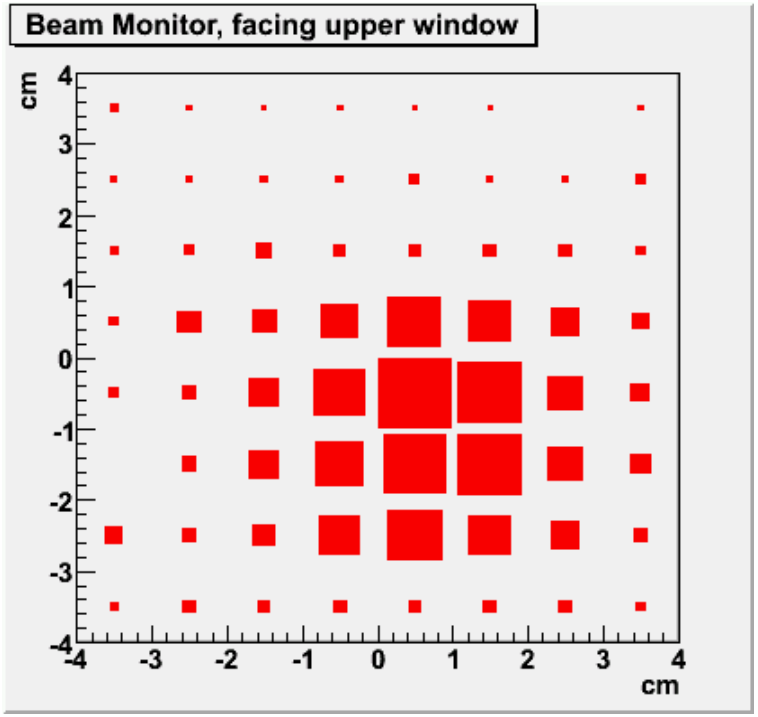
2-THGEM BEAM TESTS with KPIX



Double-THGEM, Ne/5%CH4; Average gain ~5300

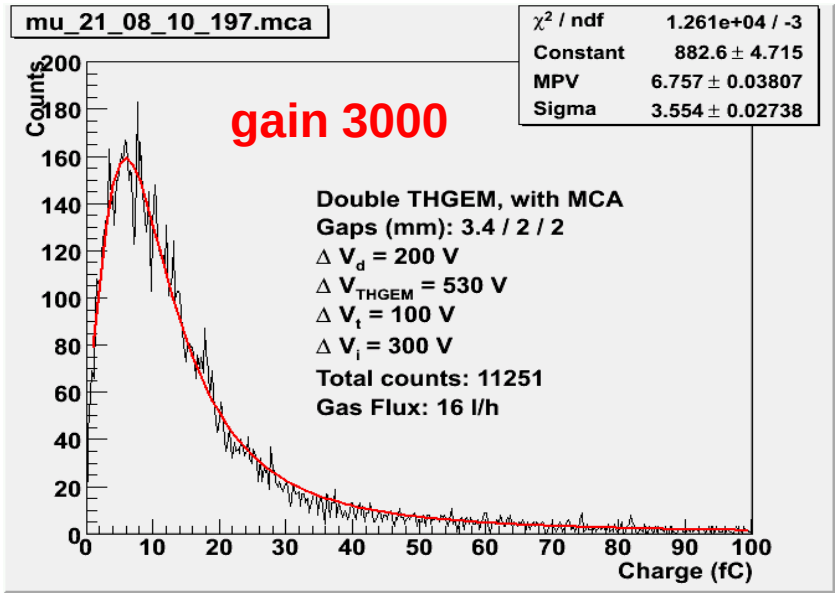
August 2010

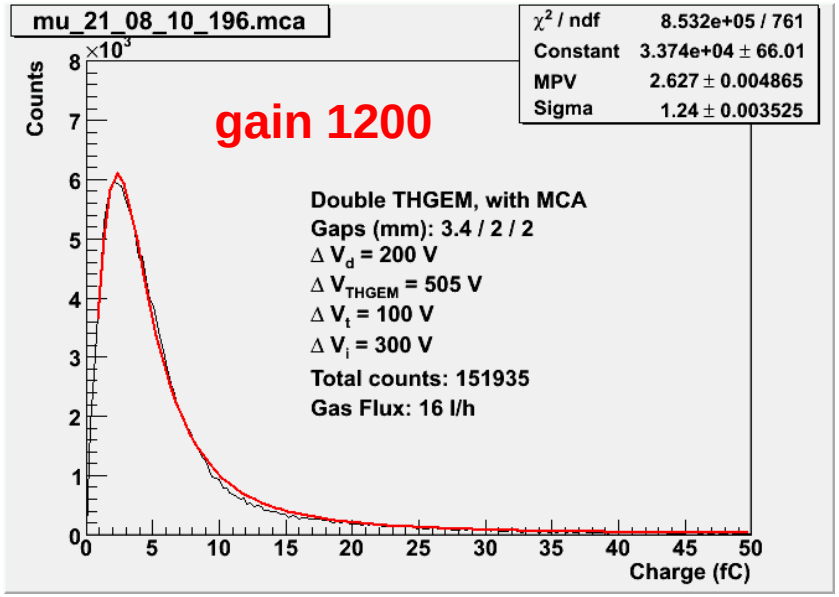
Double-THGEM & KPiX



Muon beam profile

Muons with double-THGEM



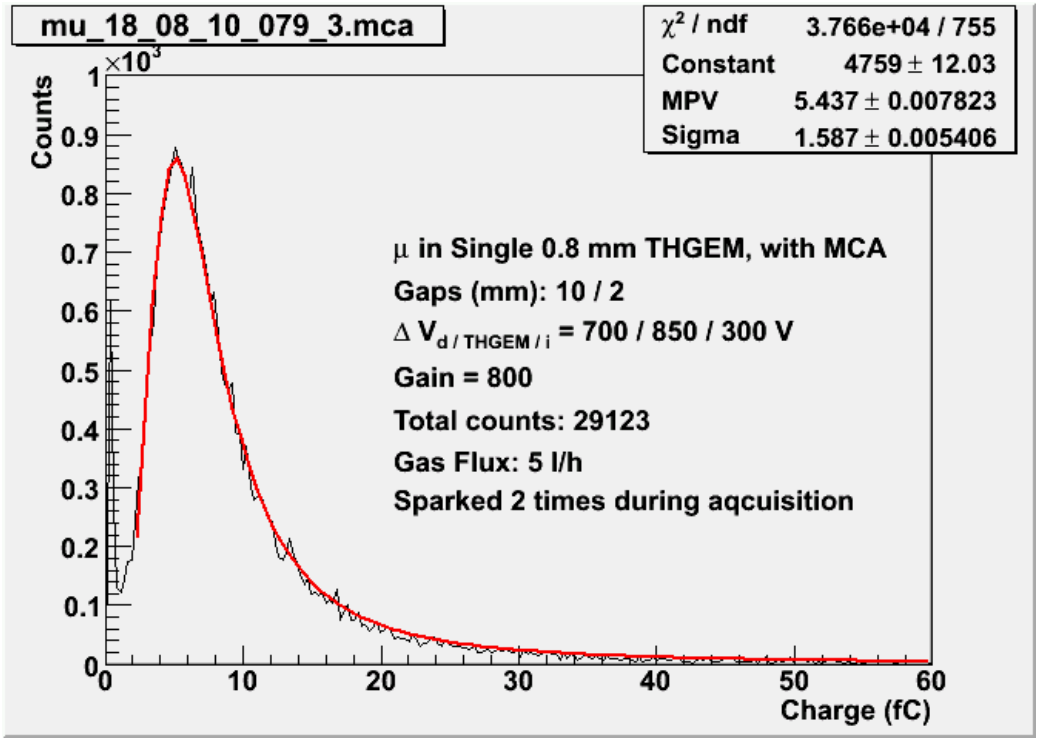


Double-THGEMs in Ne/5%CH_4. Landau distributions recorded with an MCA.

Thickness: 0.4mm

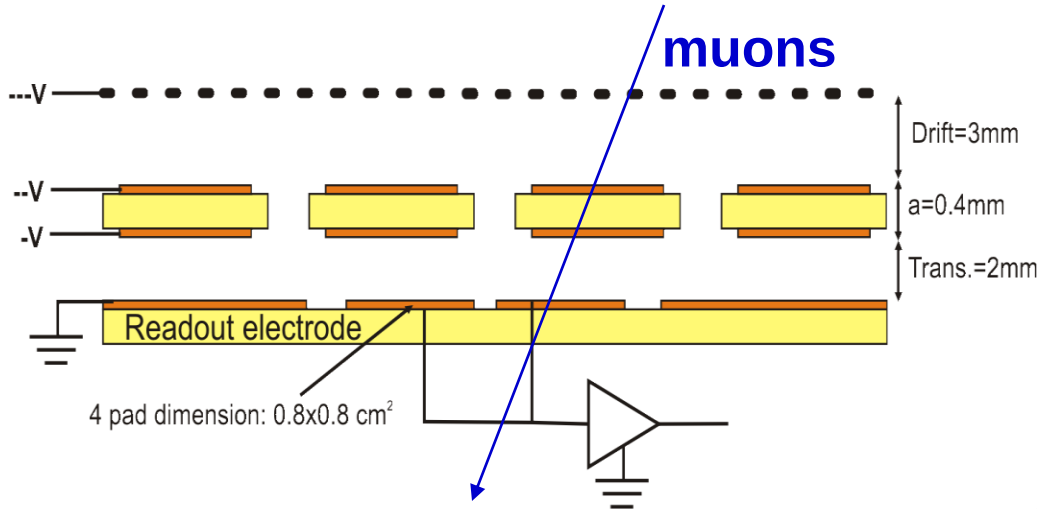
Drift gap: 3.4mm

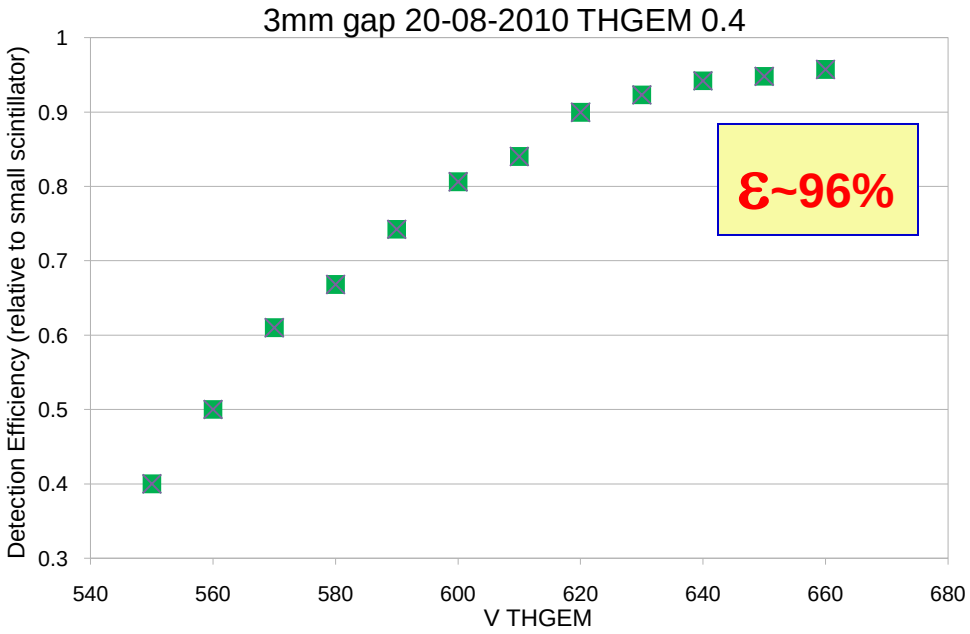
Single-THGEM, 10mm drift gap, muons



Single-THGEM with muons
Landau distribution at a gain of 800.
Thickness: 0.8mm
Drift-gap: 10mm

Single-THGEM with muons: efficiency

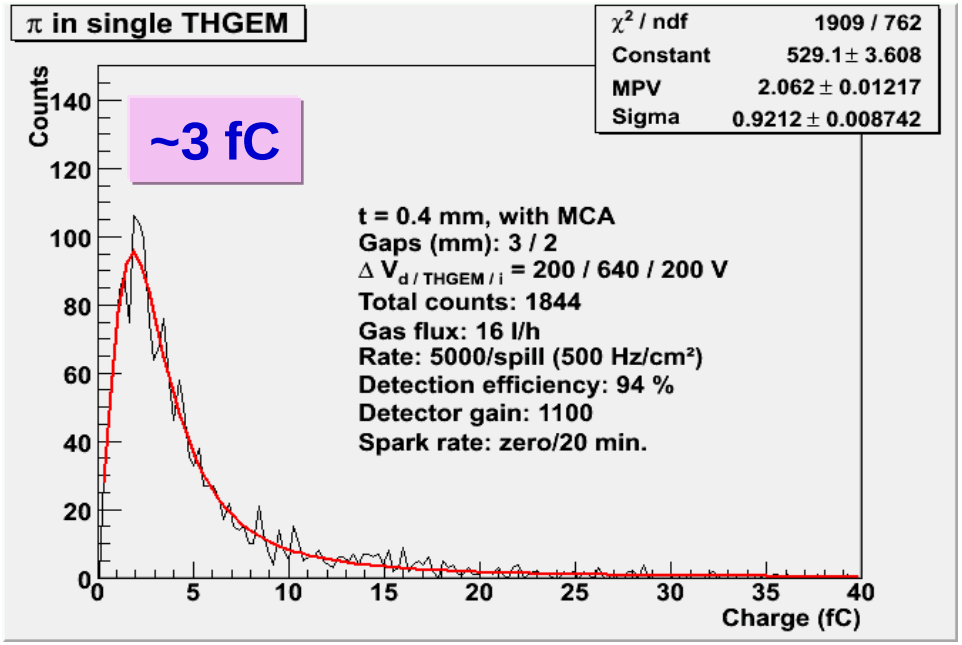




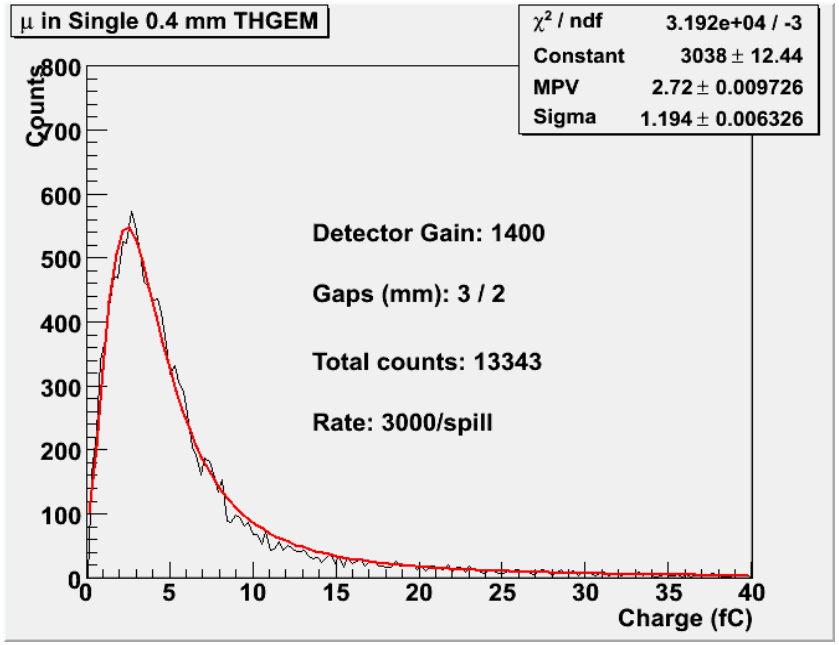
Single THGEM
10x10 cm
Thicknes: **0.4 mm**
Particles: muons
Gas: Ne/5%CH_4
Drift gap: **3 mm**
Charge preamp/MCA
0.5 cm^2 trigger

Single-THGEM/3mm drift

PIONS



MUONS



Measured very low discharge rates even with pions @ rates >>ILC

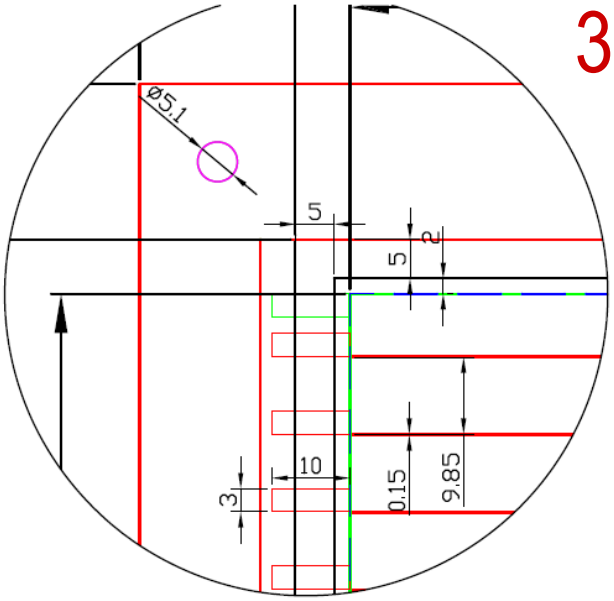
THGEM: 0.4mm

Gain: 1200-1400

THGEM for DHCAL: next…

- October 2010: run at CERN with muons/pions – NOW…but no beam until Friday 1600 !!
- Investigations with **1-THGEM & 2-THGEM with KPIX**
- Gain & Efficiency
- Crosstalk between pads
- Discharge rates with μ/π (continuation study)
- With SLAC: improving KPIX protection
- 30x30 cm THGEMs
- Other gases (Ne/CF4?)

33cmx100cm GEM Foil Design



Designed to work with DCAL boards

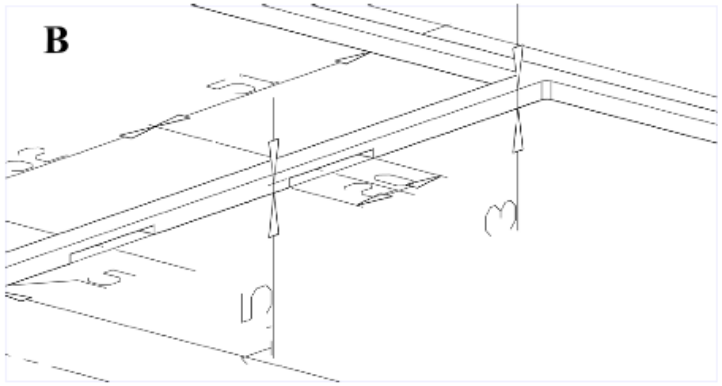
Active area 468x306 mm^2

Number of HV sectors = 32x2=64

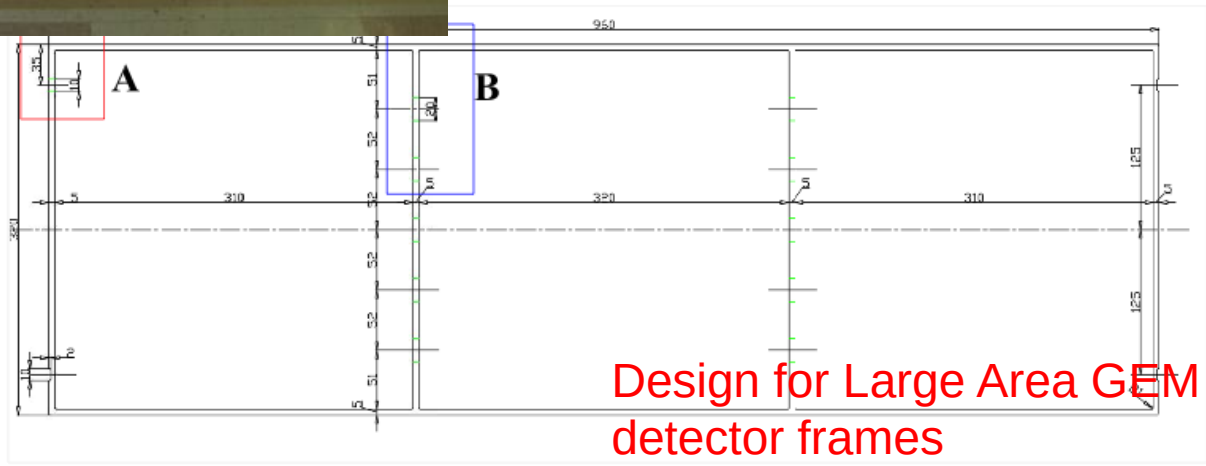
HV sector dimension= 9.9x479.95 mm^2

33cmx100cm Large Area GEM

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

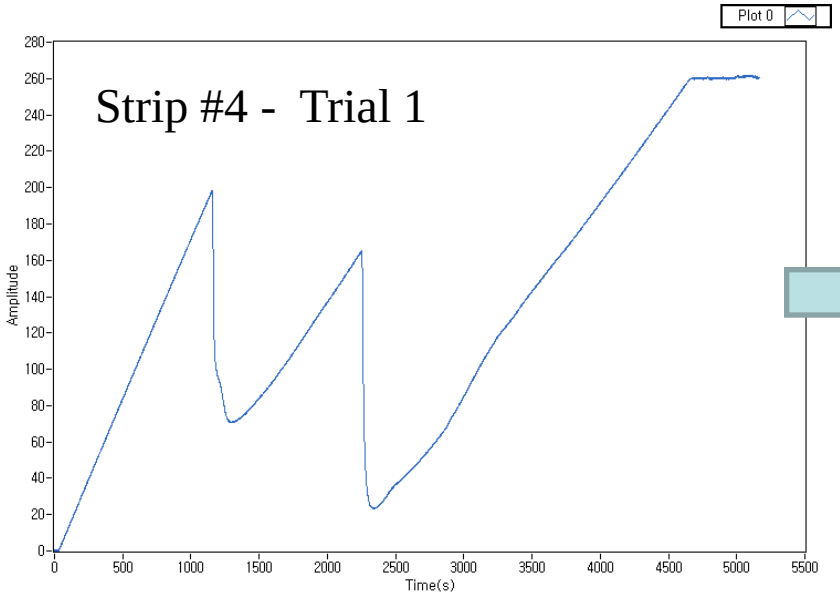


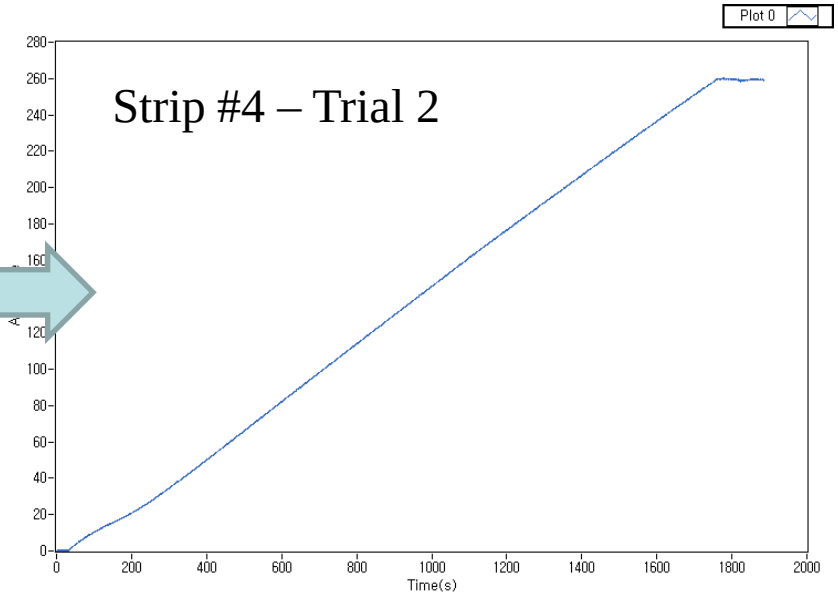
Spacer for drift gap

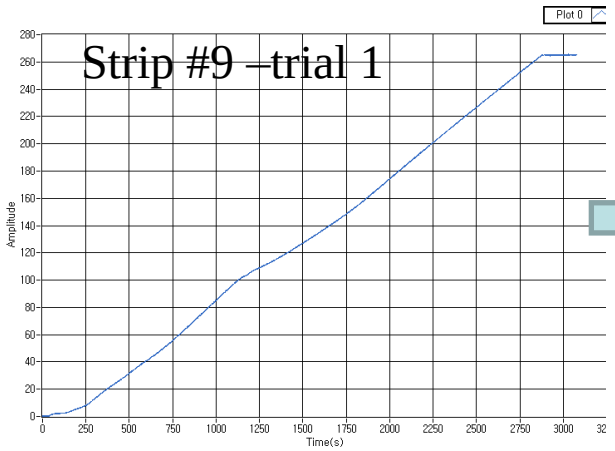


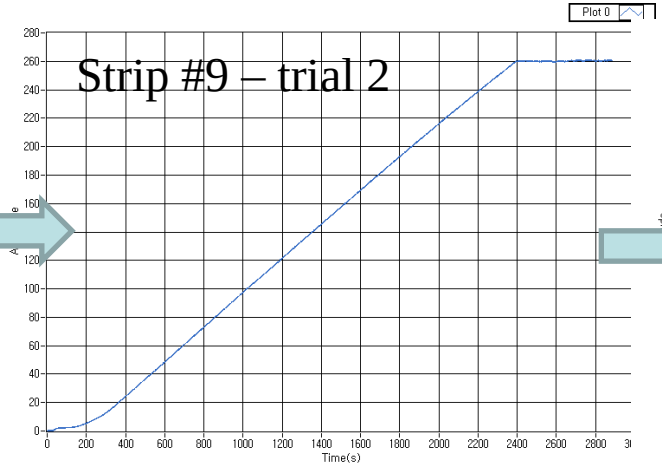
Design for Large Area GEM detector frames

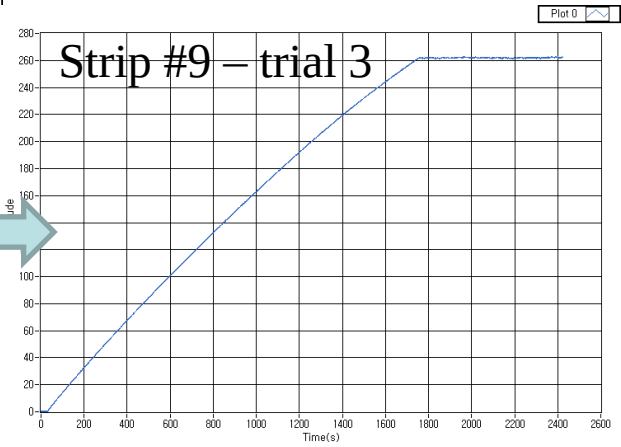
Temporal Behavior of Strips



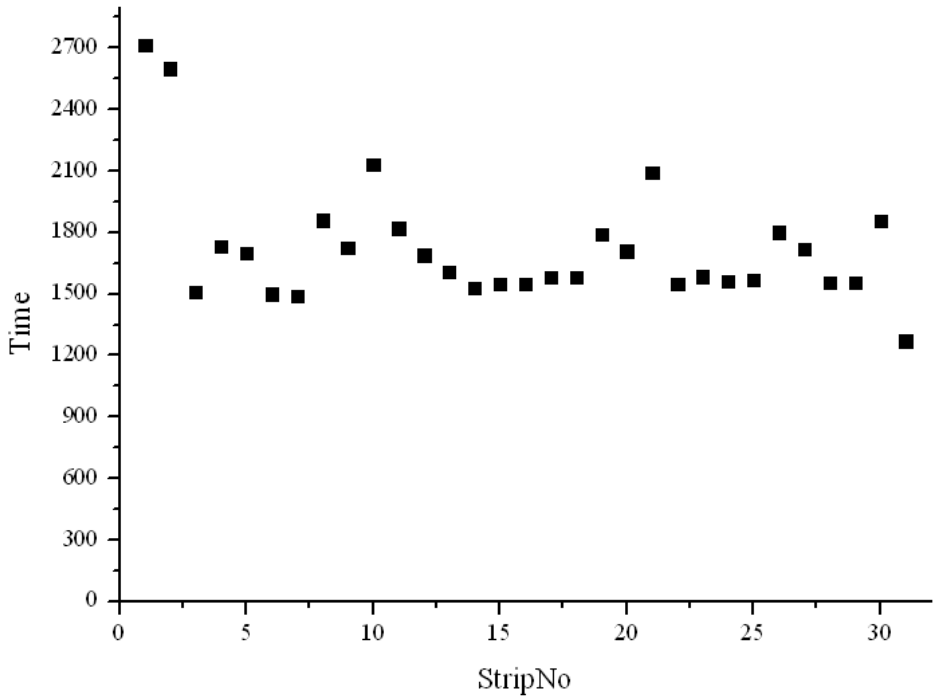






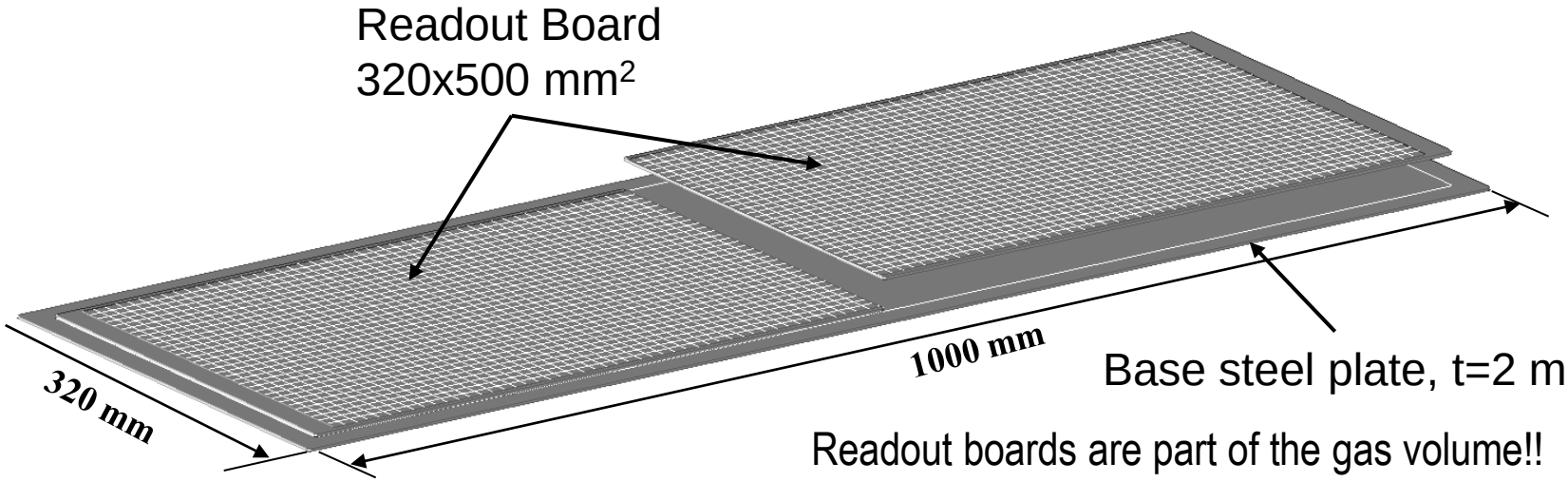


Times to reach full charge saturation



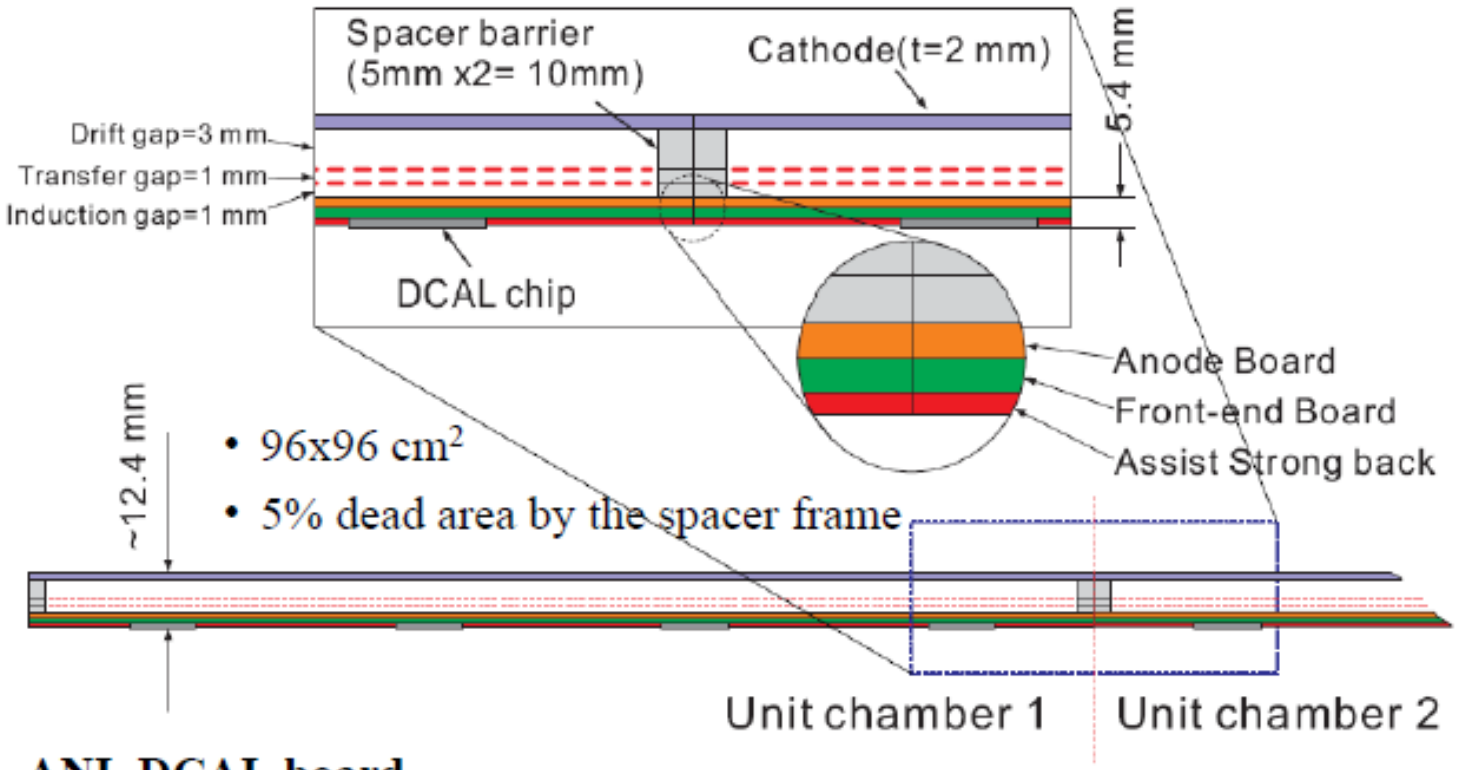
- Indication of general health of each strip
- Most of them reach full charge up in 30min
- Two strips took 15min longer
- Resistance of each strip is over 260GOhms!!

33cmx100cm DHCAL Unit Chamber Construction

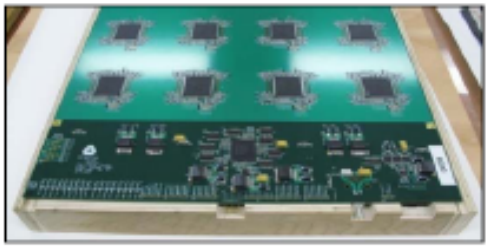


Readout boards are part of the gas volume!!
How do we mate these together with minimal dead area?

UTA's 33cm x 100cm DHCAL Unit Chamber



➢ **ANL DCAL board**

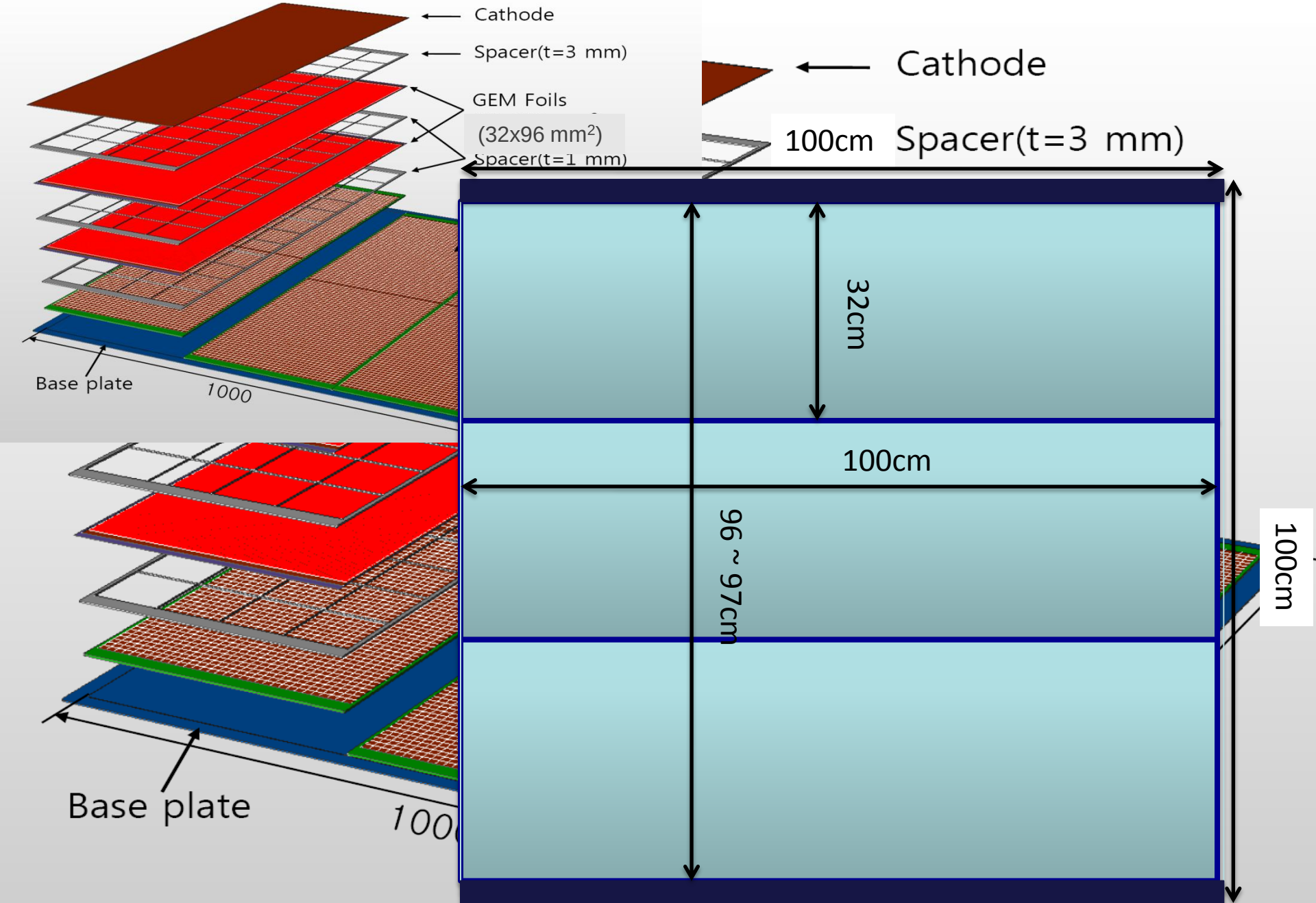


Pad board: 320x480x1.5 mm³

Front-end board: 320x555x1.5 mm³

Glue the boards directly on their edges??

UTA's 100cmx100cm Digital Hadron Calorimeter Plane



GEM DHCAL Plans

- Phase I ➔ Completion of 30cm x 30cm characterization
  - Mid 2010 – Early 2011: using one to three planes of 30cm x 30cm double GEM chamber with 64 channel KPiX7 and DCAL chips
  - Oct. 2010: Joint Test with THGEM/KPiX at CERN (Using RD51 setup)
- Phase II ➔ 33cm x 100cm unit chamber construction and characterization
  - Early 2011 – late 2011 at FTBF: Using available KPiX chips (V9?) and DCAL chips
- Phase III ➔ 100cm x 100cm plane GEM DHCAL performances in the CALICE stack
  - Late 2011 – Late 2012 at Fermilab's FTBF *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

Summary

- Steady 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
  - Getting ready to beam test these chambers
  - Higher channel count (512 channel) KPiX V9 chips available
  - Pressure dependence measured and data corrected
- TGEM made a quantum jump and had a beam test at CERN
  - Will are having another one in Prevesin NOW! ➔ RD51 setup
- 33cmx100cm unit chamber construction proceeding
  - First 5 foils of 33cmx100cm delivered and one HV tested
- Mechanical design being worked out for constructing 33cmx100cm unit chambers and 1mx1m planes for DHCAL testing