Hadron Calorimeter with GEMs

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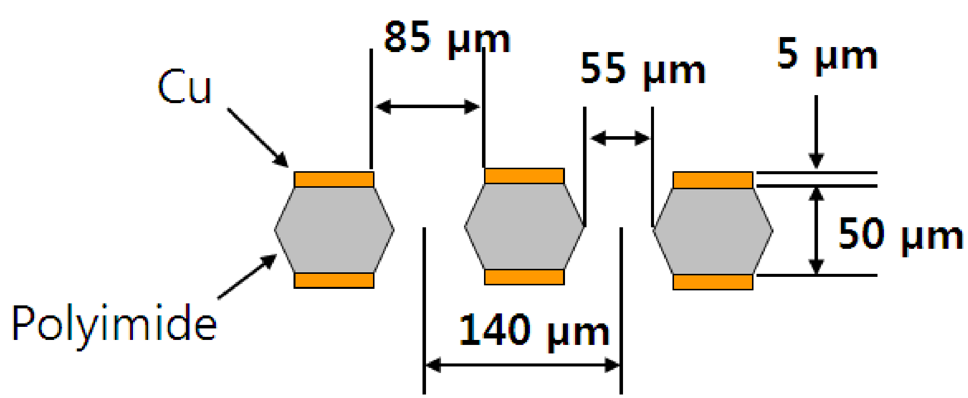
CALICE Workshop, UTA
(Mar. 10~12, 2010)

GEM DHCAL Accomplishments

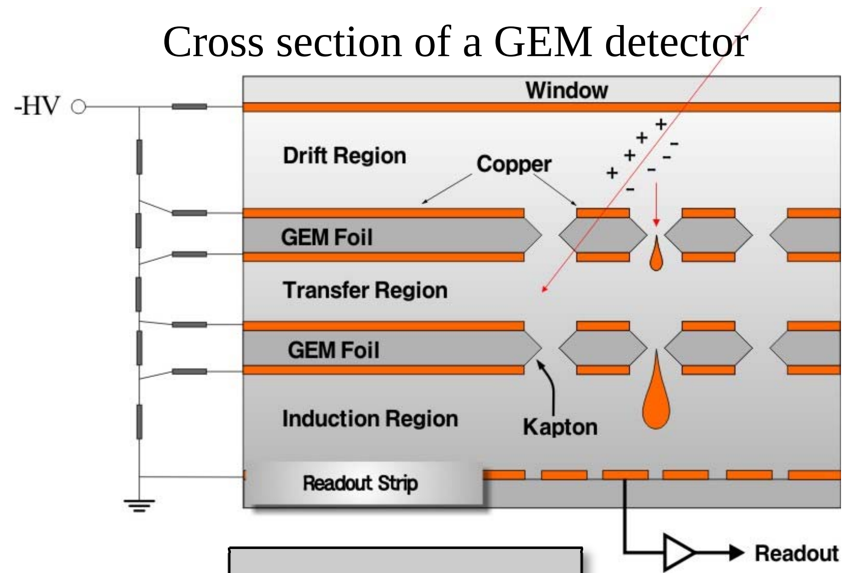
- GEM detector with an optimal gas flow spacer design constructed and integrated with SLAC KPiX V7 readout
- Two dimensional readout of 30cmx30cm chamber using KPiX successful
  - ✓ Benchmark Fe^{55} from single channel analog electronics
- Two additional 30cmx30cm chambers constructed
  - ✓ One at ANL for DCAL chip readout testing
  - ✓ Two at UTA for continued chamber characterization
- Completed the design of 32cmx96cm GEM foil
  - ✓ Construction of first five 32cmx96cm foils has begun at CERN GDD workshop Feb. 2010
- Mechanical consideration for large chamber construction in progress

What's GEM?

- **GEM foils** F. Sauli & R. D. Oliveira, CERN(NIM A386, 531, 1997)



Cross section of a GEM detector



$Ar:CO_2=80:20$

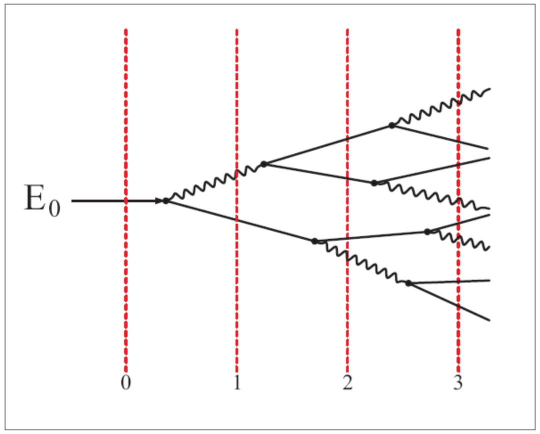
Applications

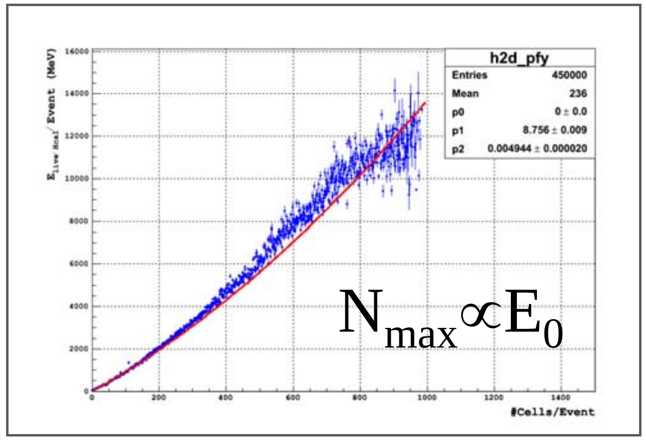
- ✓ X-ray radiography (*A. Bressan et al, Nucl. Instr. and Meth. A 425(1999)254)*
- ✓ X-ray polarimeter(*E. Costa et al, Nature 411(2001)662)*
- ✓ GEM photomultiplier (*A. Breskin et al, Nucl. Instr. and Meth. A 478(2002)225)*
- ✓ As an intensifier for CCD camera
- ✓ Muon tomography(radio active material detection, *Florida Institute of Technology*)
- ✓ Photo converter with CsI coating coating(*Weizmann institute of science*)
- ✓ Amplifiers in MSGC or Micromegas
- ✓ etc…

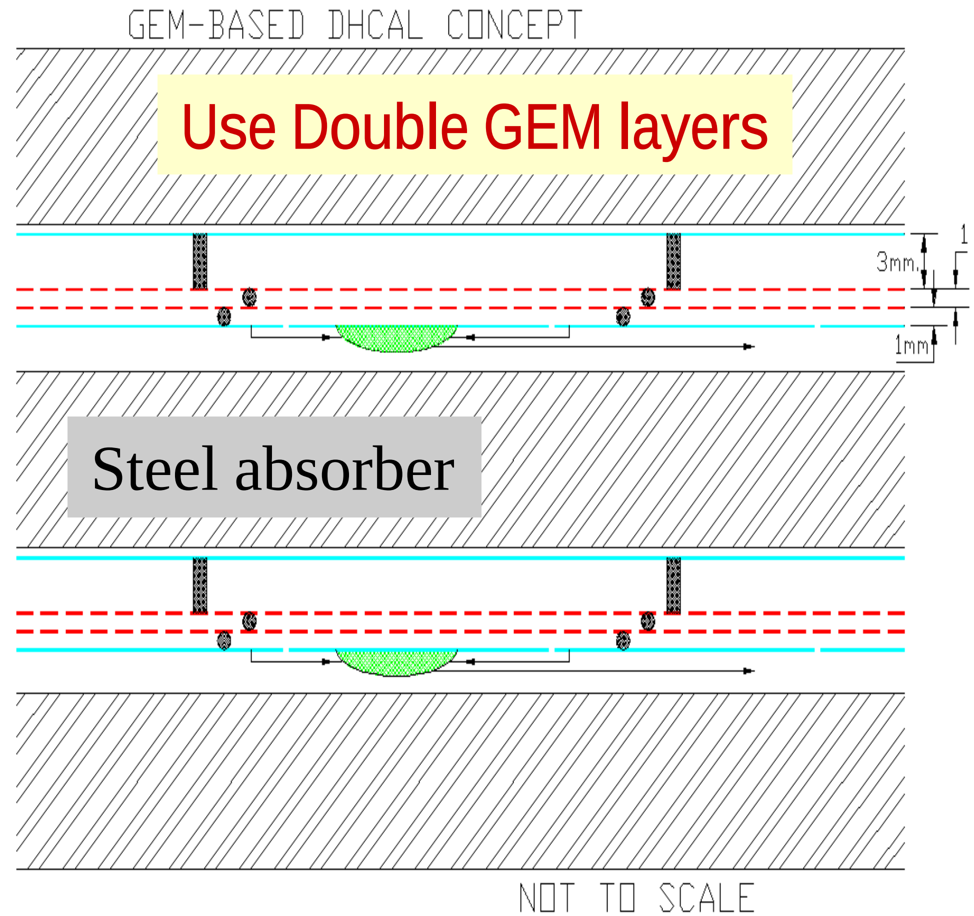
Why GEM's for DHCAL?

- 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

GEM-based Digital Hadron Calorimeter Concept



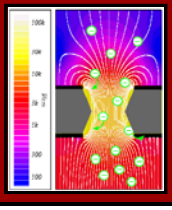




- The energy of the incident particle is directly proportional to the maximum number of particles in the shower.
- Thus, it is important to **count** total number of particles in the shower.
- **"Count"→ digital method** in the data acquisition.

→ **Digital Hadron CALorimeter (DHCAL)**

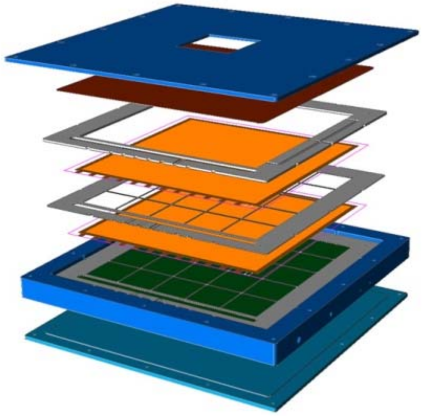
- Passive (material) and Active (GEM) layers
- Increase spatial resolution (1 x 1 cm² readout pads)

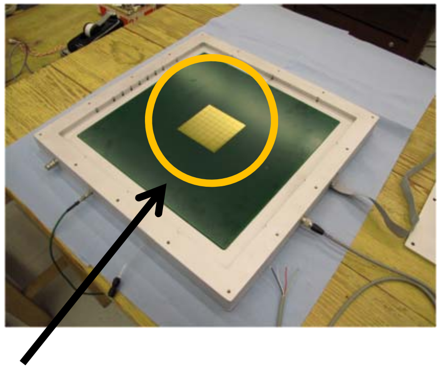


GEM chamber and KPiX

Chamber

- GEM Foils(3M)
  - 310x310 mm^2
  - Active area : 280x280 mm^2
- Active gas room
  - 350x350x6 mm^3 → For 3/1/1 gaps(d/t/i)
- 64 readout channels(1x1 cm^2)





64-readout pads

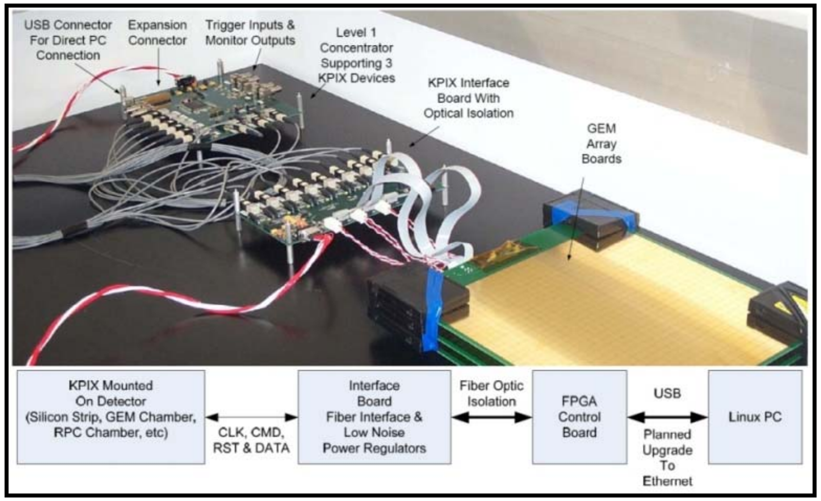
Readout system

- Eventually 1024 pixels → Thus working name KPiX
- Developed at **Stanford Linear Accelerator Center(SLAC)**

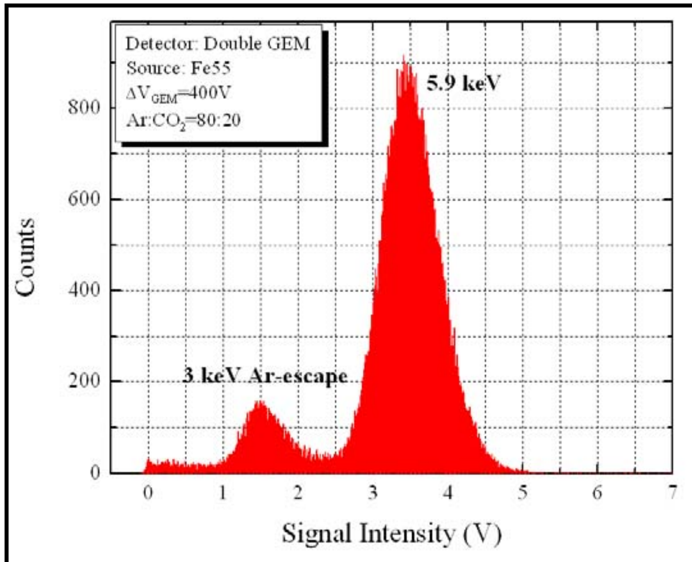
❖ **FPGA Control Board**
- USB Interface to PC
- Interface To External Logic
  - Beam Line Triggers
  - Scintillators
  - Laser Triggers

❖ Optically Isolated To **KPIX Interface Board**

❖ C++ API Under Linux

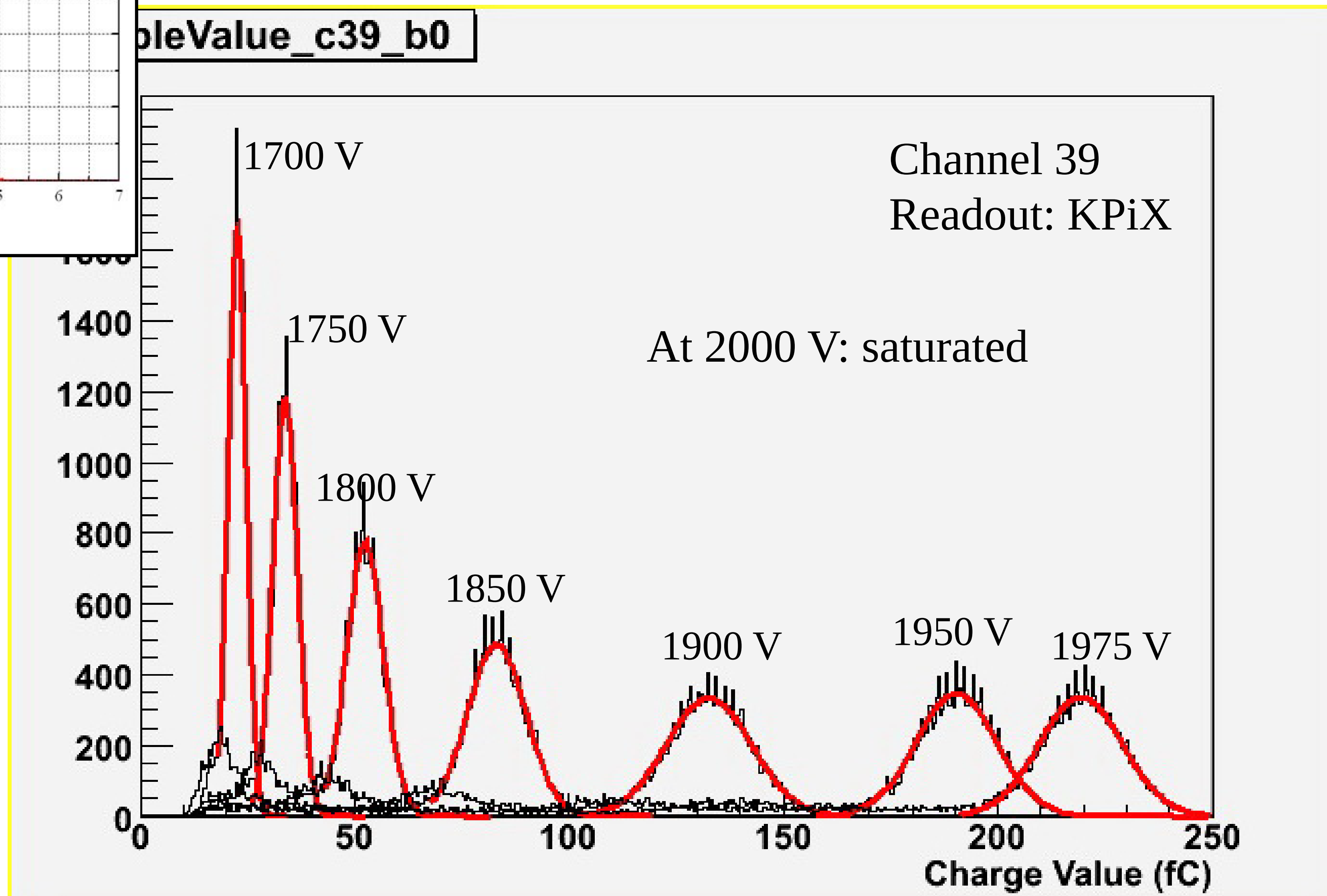


HV dependence of Fe55 spectrum



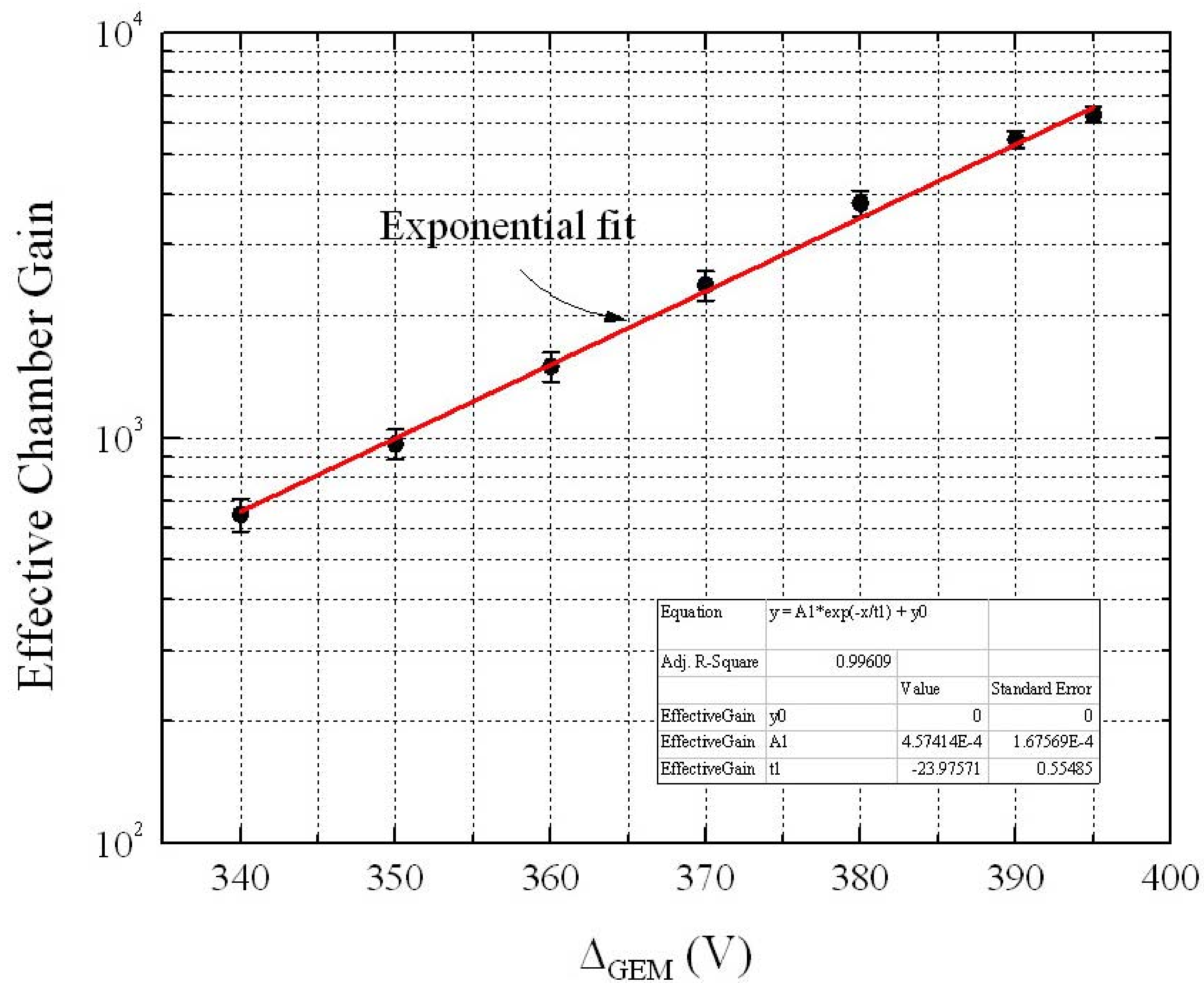
Typical Fe55 spectrum from an Ar-based gas detector

Readout:
A225+A206(AmpTek)



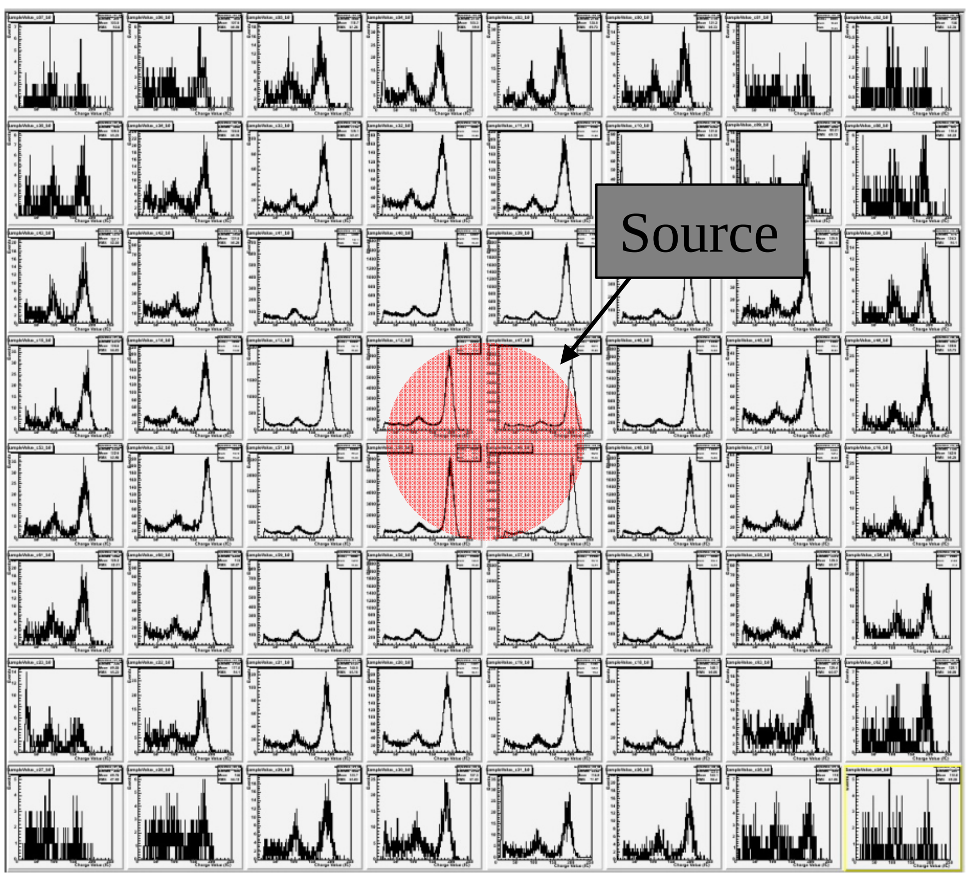
Effective Chamber Gain

Chamber gain increases nonlinearly with high voltage

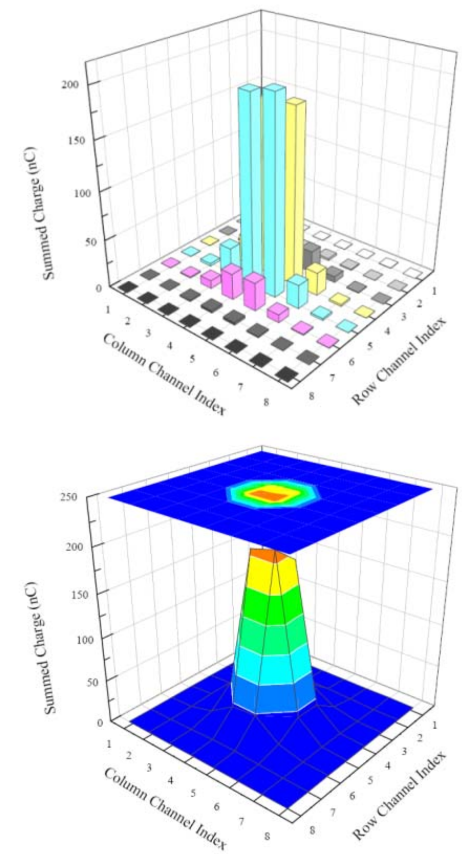


Signal distribution over the entire channels

Source (Fe55) was put on the detector window.
Each histogram corresponds to each anode pad on the readout board.

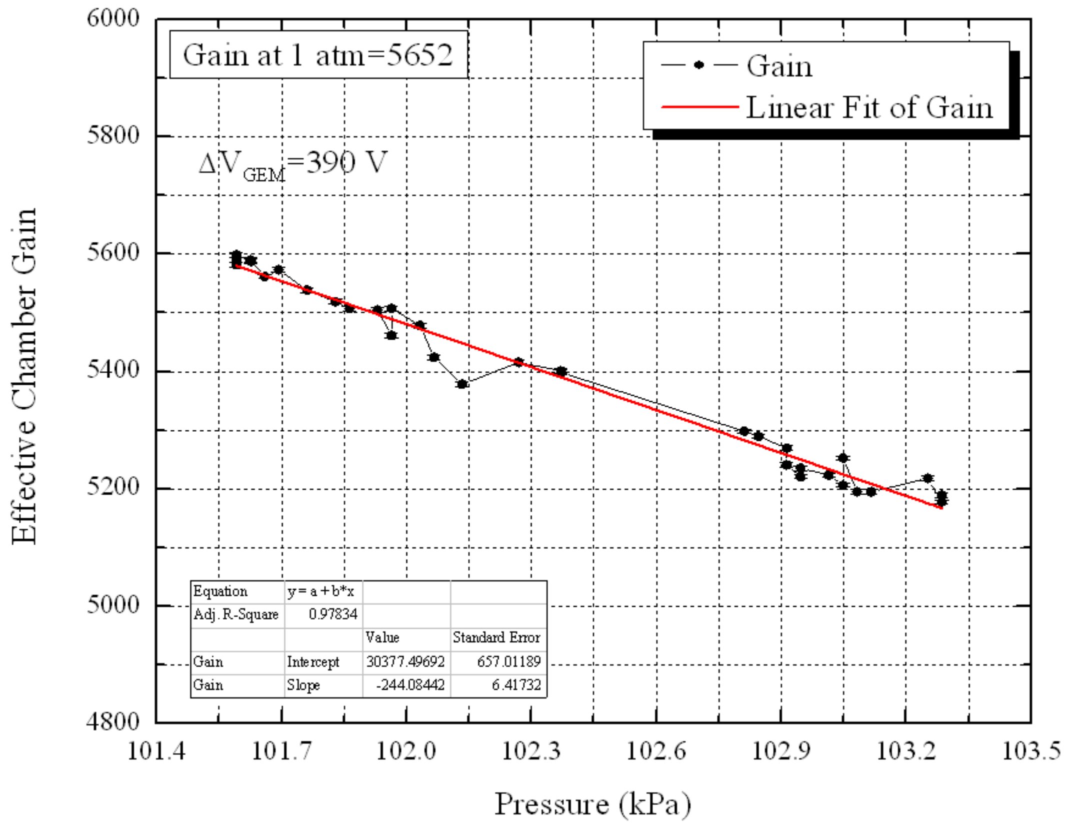


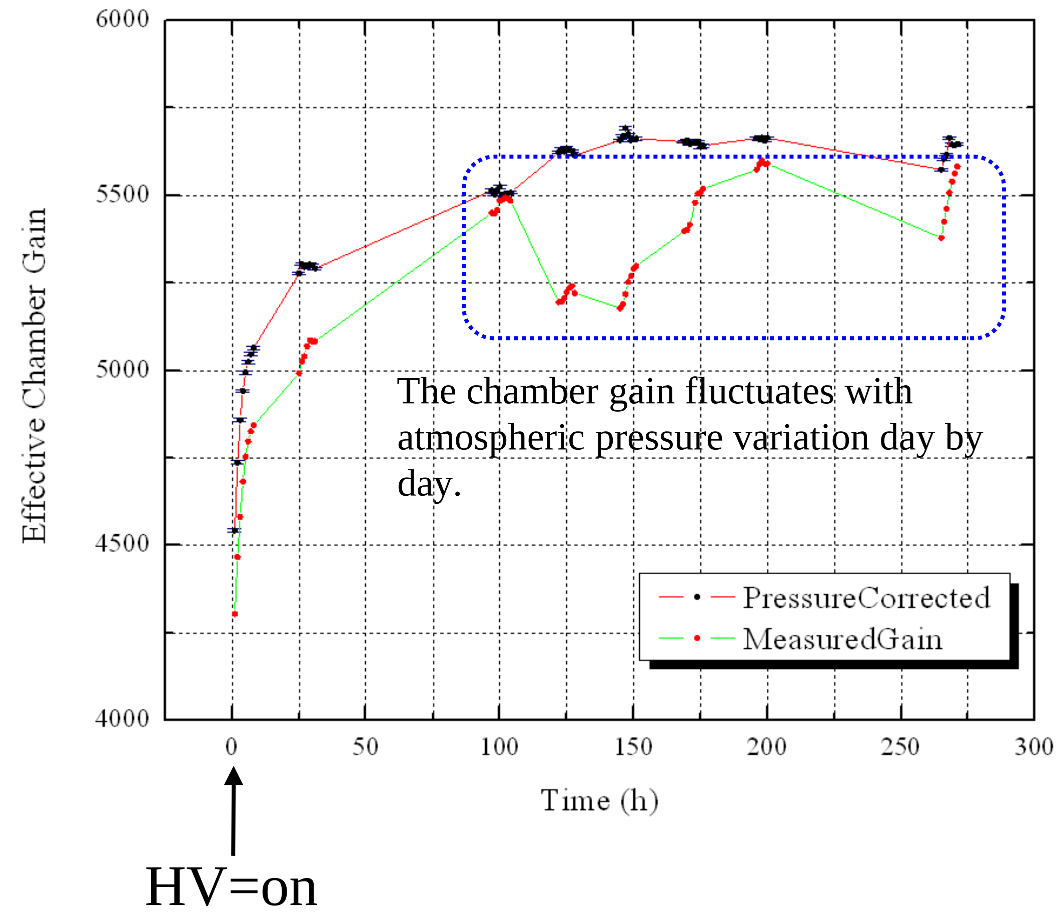
3-dimentional view of the source intensity distribution



Pressure dependence of chamber gain

HV =1950V (ΔV_{GEM}=390 V)





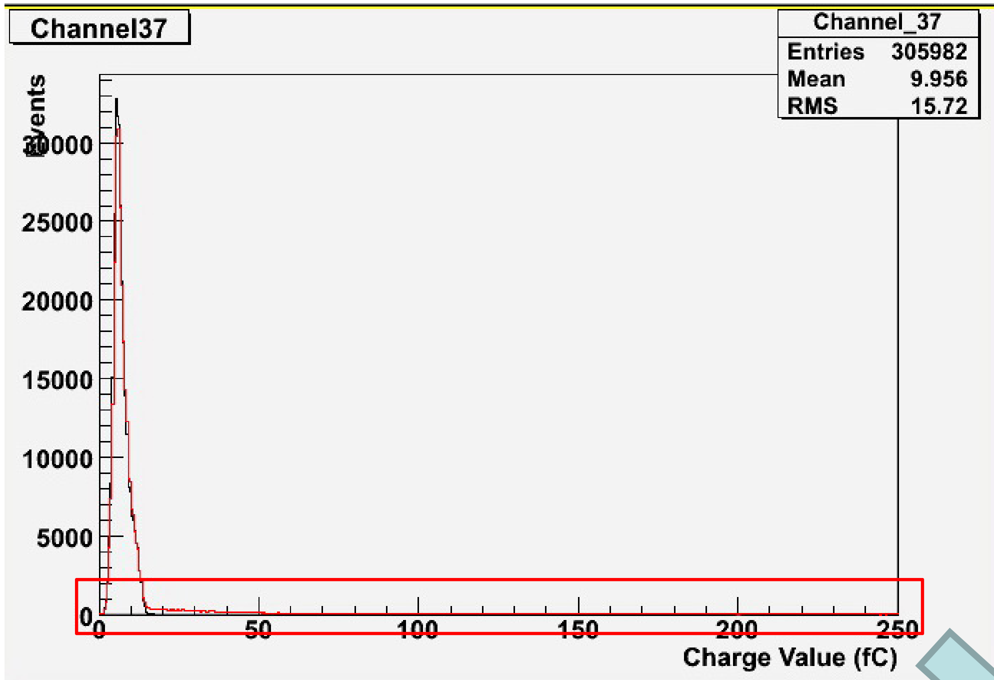
We use an open gas system (gas flows at atmospheric pressure).

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

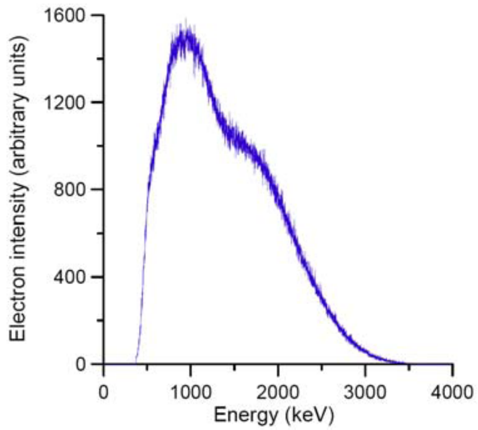
This pressure change affects the chamber gain.

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

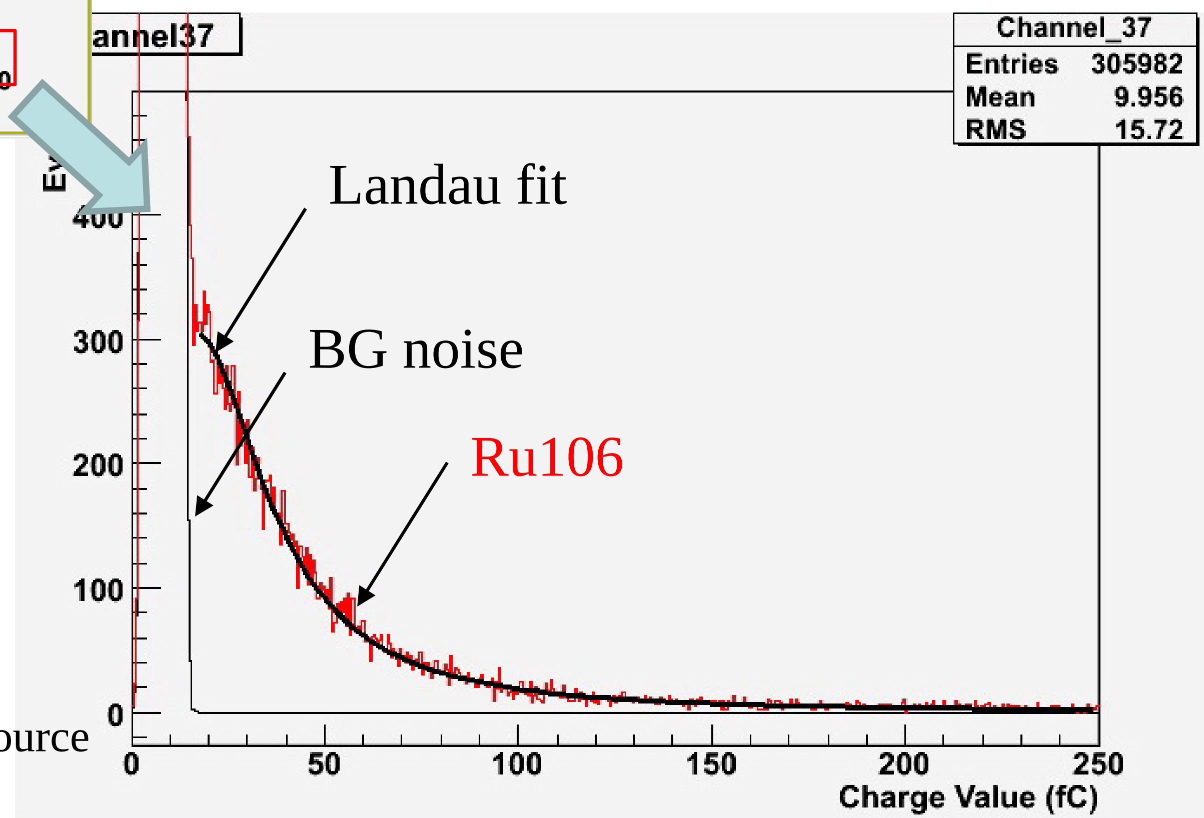
^{106}Ru spectrum



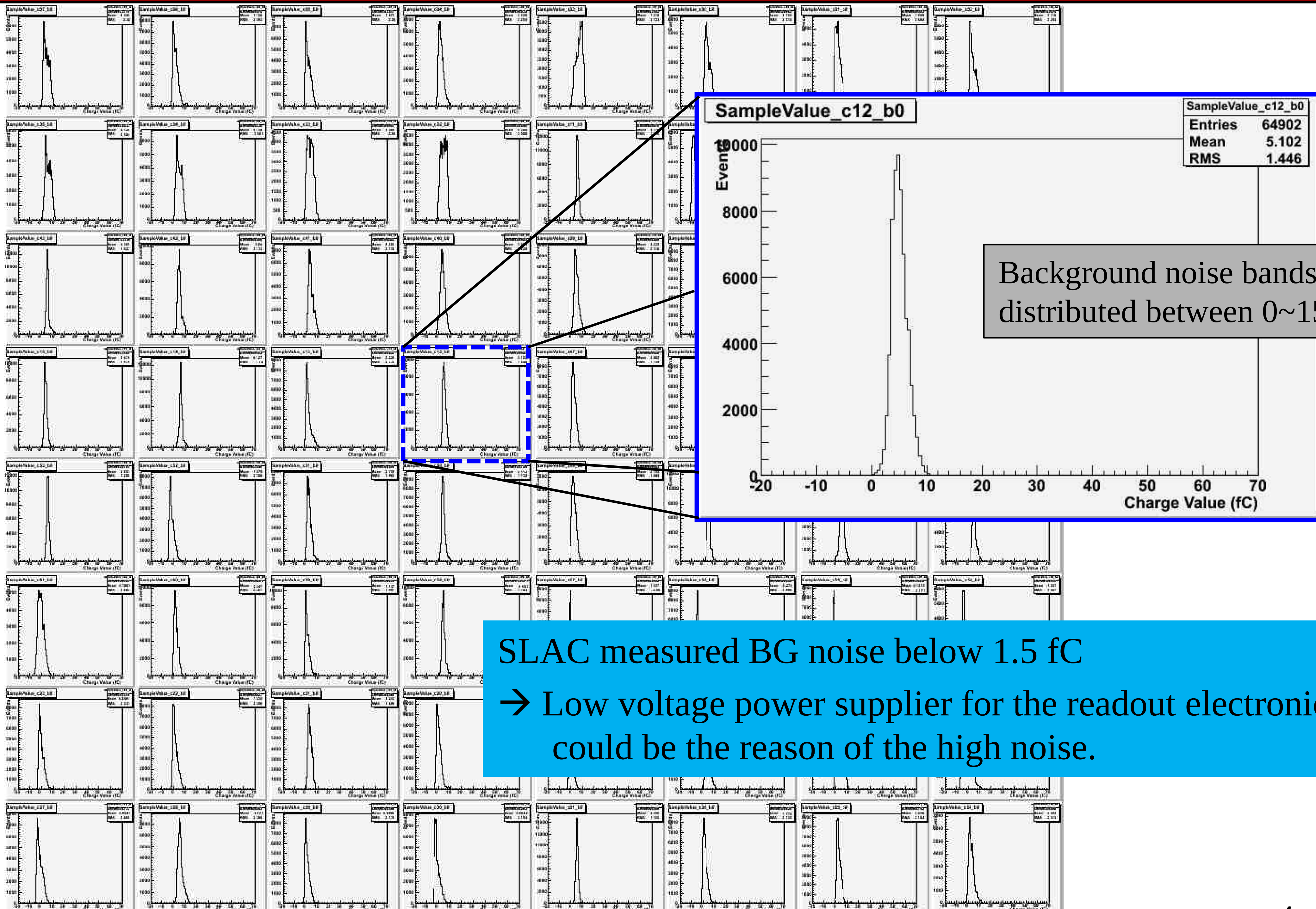
Ru106, 1960V, ST=2.4V=2 fC
Background, 1960V, ST=2.4V=2 fC



Energy spectrum of Beta emission from a Ru106 source



Background Noise

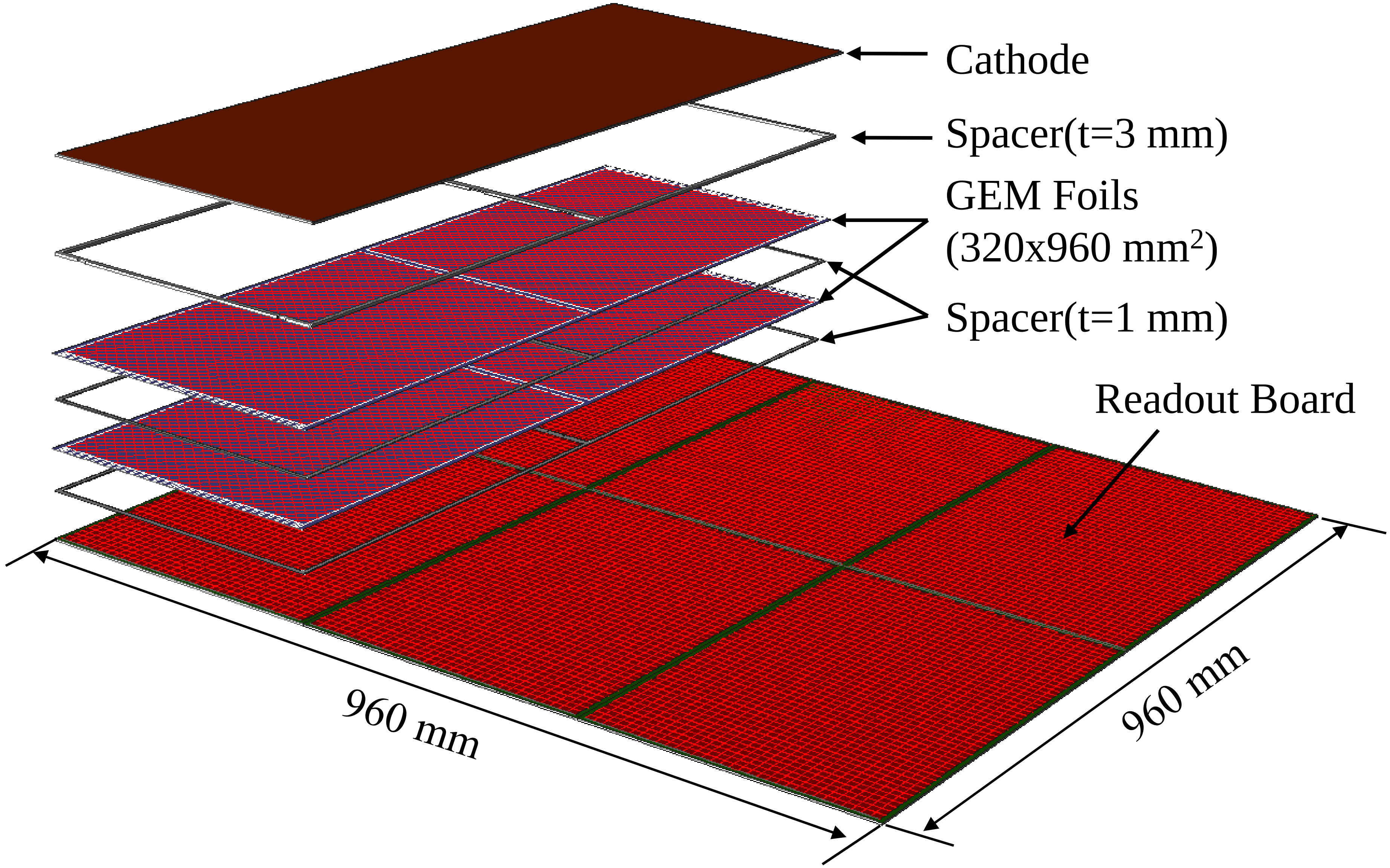


Background noise bands are distributed between 0~15 fC.

SLAC measured BG noise below 1.5 fC

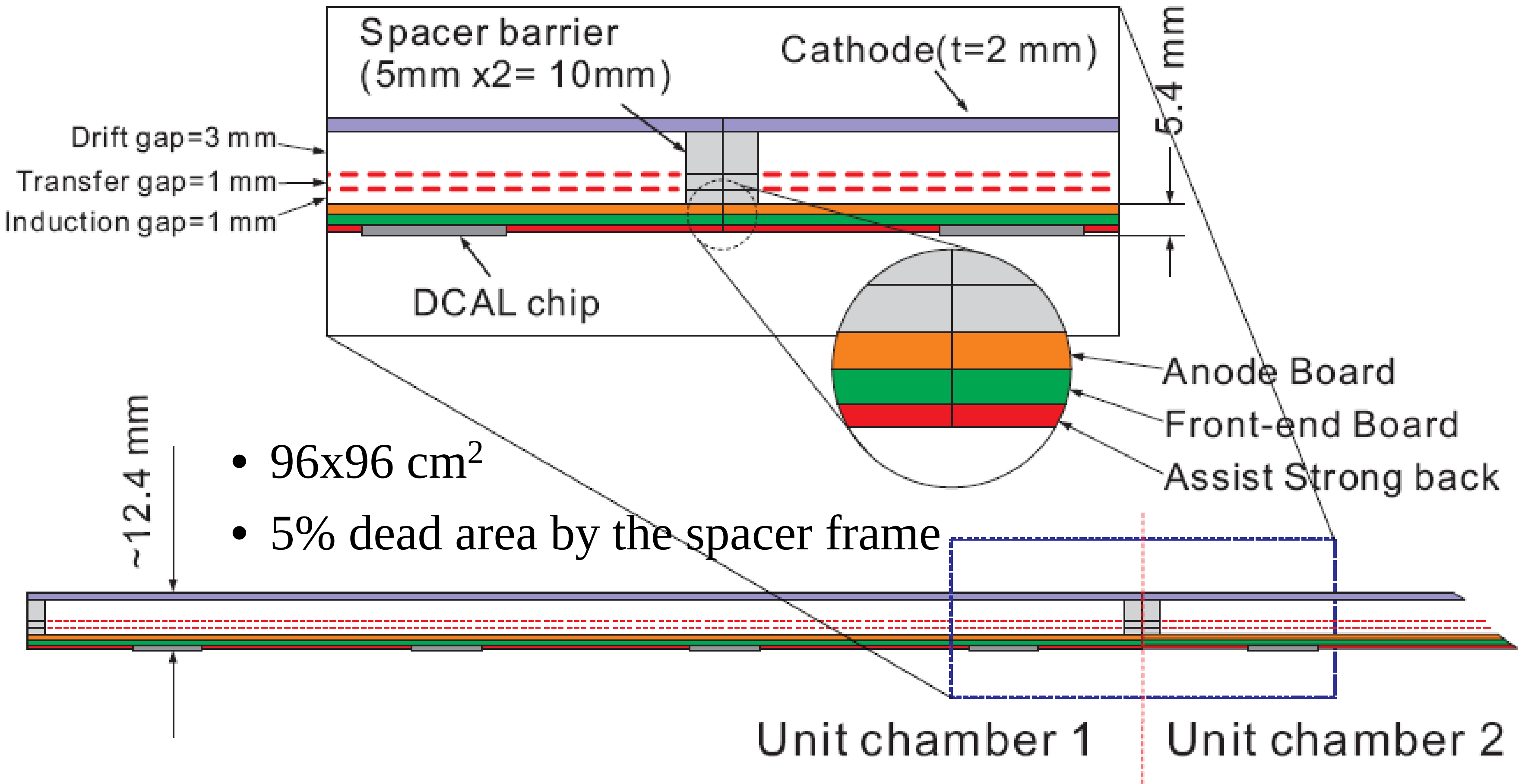
→ Low voltage power supplier for the readout electronics could be the reason of the high noise.

Future work / 1x1 m^2 large chamber (square meter GEM, SMGEM)



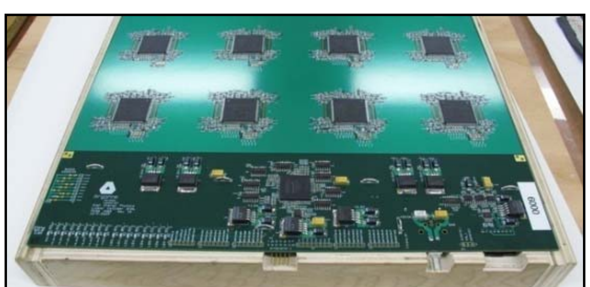
☞ We are developing 32x96 cm^2 GEMs with **CERN's printed circuit workshop.**

Cross section of 1x1 m^2 GEM chamber



- 96x96 cm^2
- 5% dead area by the spacer frame

➢ **ANL DCAL board**



Pad board: 320x480x1.5 mm^3

Front-end board: 320x555x1.5 mm^3

GEM DHCAL Plans

- Through mid 2010
  - Complete 30cmx30cm chamber characterization using radioactive source, cosmic ray and particle beams
    - ✓ Need to understand electronic noise affecting MIP
  - Start producing 32cmx96cm GEM foils
  - Begin construction of 32cmx96cm GEM unit chambers and characterize them using source, cosmic ray and particle beams
- Mid 2010 ~ Late 2011
  - Complete construction of fifteen 32cmx96cm chambers and construct five 96cmx96cm GEM (SMGEM) DHCAL planes
  - Beam test GEM DHCAL planes in the CALICE beam test stack together with RPC
  - If available construct TGEM and RETGEM chambers

GEM DHCAL Beam Test Plans

- Phase I ➔ Completion of 30cmx30cm characterization
  - Mid 2010: using one to two planes of 30cmx30cm double GEM chamber with 64 channel KPiX7
- Phase II ➔ 32cmx96cm unit chamber characterization
  - Mid 2010 – mid 2011 at MTBF: Using available KPiX chips and DCAL chips
- Phase III ➔ 96cmx96cm plane GEM DHCAL performances in the CALICE stack
  - Early 2011 – Late 2011 at Fermilab's MTBF or CERN
  - Five 100cmx100cm planes inserted into existing CALICE calorimeter stack and run with either Si/W or Sci/W ECALs and RPC planes in the remaining HCAL

Summary

- Construction of 30x30 cm^2 prototype GEM detector for basic study of the DHCAL development.
- The detectors have been characterized with various radiation sources and cosmic ray.
- The high voltage dependence of the effective chamber gain was measured.
- Pressure dependence of the chamber gain was surveyed.
- For the construction of 96x96 cm^2 large GEM detectors, we are working on 32x96 cm^2 large GEM production.

Thank you!