UTA GEM Prototype Chamber Characterization using Cs^{137}

Snowmass 2005, Aug. 15 – 27, 2005

Jae Yu and ChangHee Hahn
University of Texas at Arlington
Chang Won National University, Korea

- Introduction
- UTA GEM Prototype Chamber
- The Problem
- The solution
- Results
- Conclusions and plans

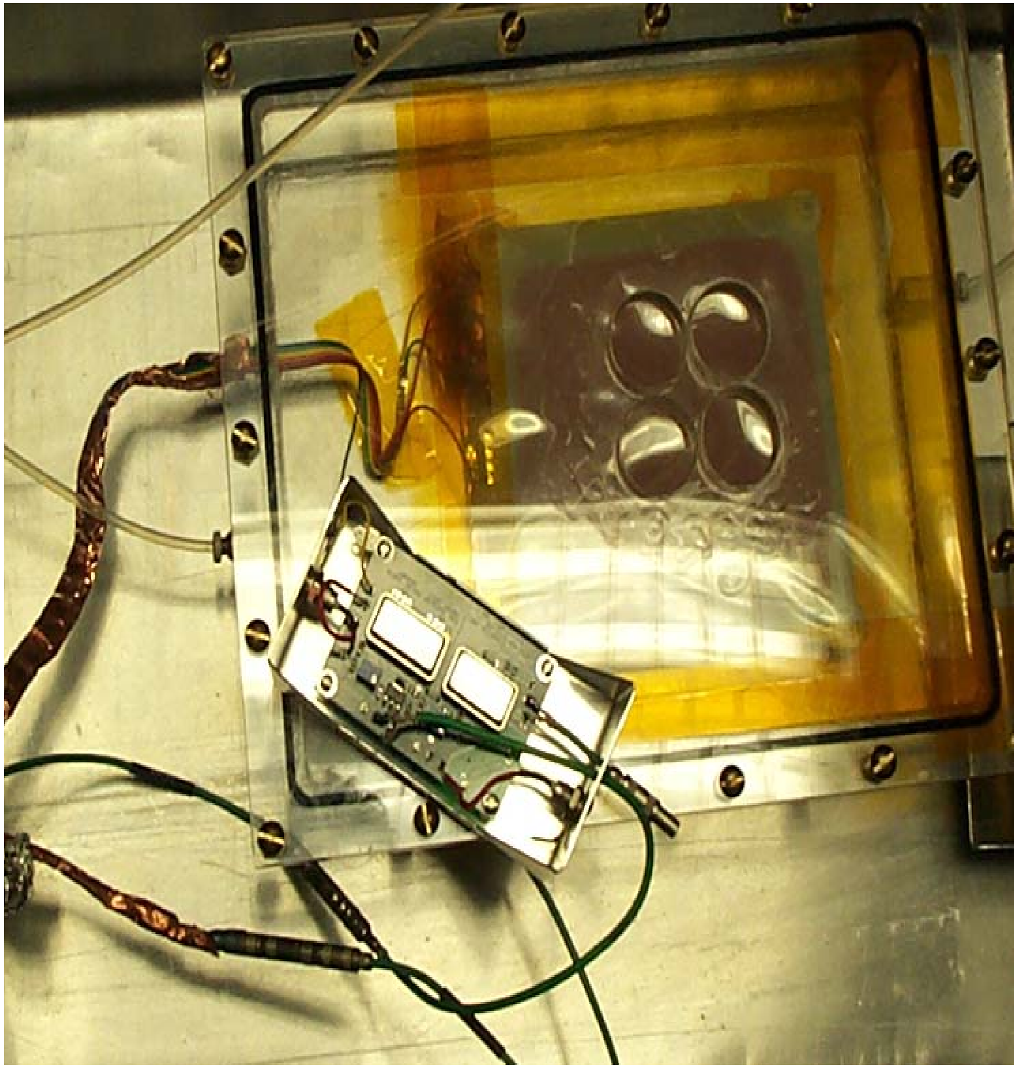
*On behalf of the HEP group at UTA.

Introduction

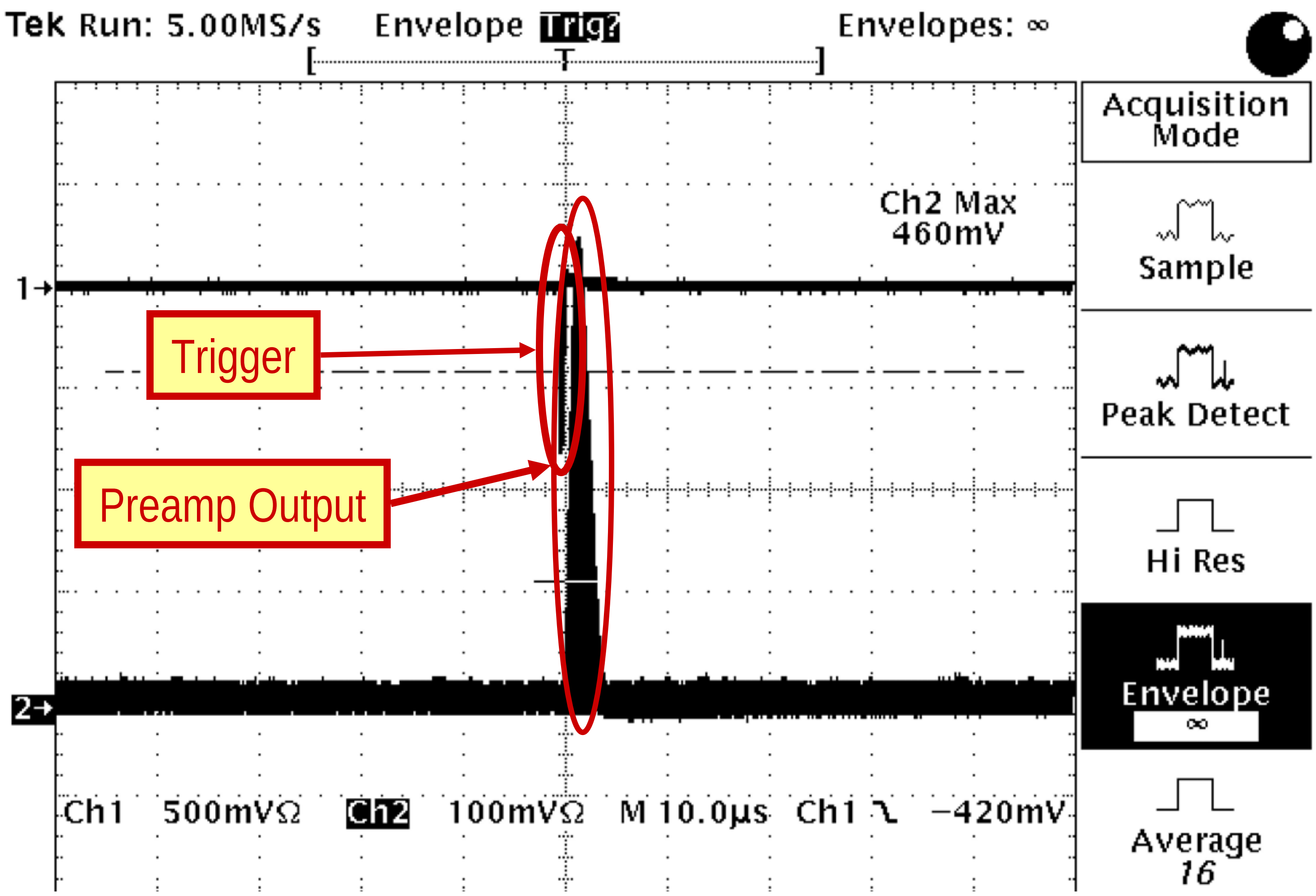
- Fine cell sizes needed for calorimeter cluster identifications and associations w/ tracks to minimize confusion in jet energy
- DHCAL: a solution for keeping the cost manageable for PFA
- GEM chamber characteristics good for a DHCAL for PFA
- A prototype chamber built w/ 10x10cm^2 CERN foils
  - Cs^{137} and Sr^{90} sources used for characteristics, along with cosmic ray

UTA GEM Prototype Chamber

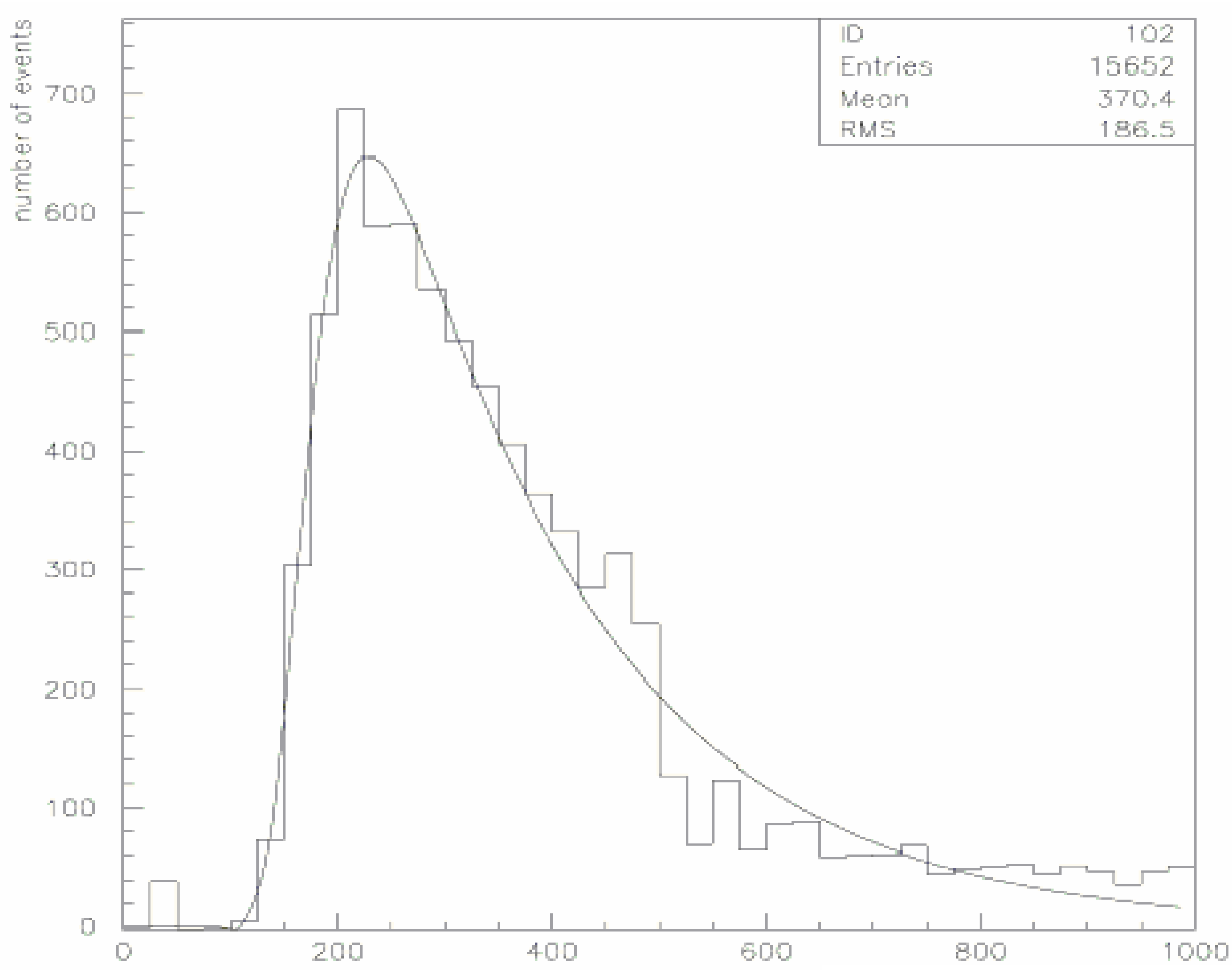
- Thinner plexiglass window for easier source penetration
- Single cell (1cmx1cm pad) readout
- Saw signal from cosmic-ray
- Measured Landau distribution using Cs137 source
- Measured double GEM intrinsic gain



UTA GEM Calorimeter Prototype Cosmic Event



Landau Distribution from Cs^{137} Source

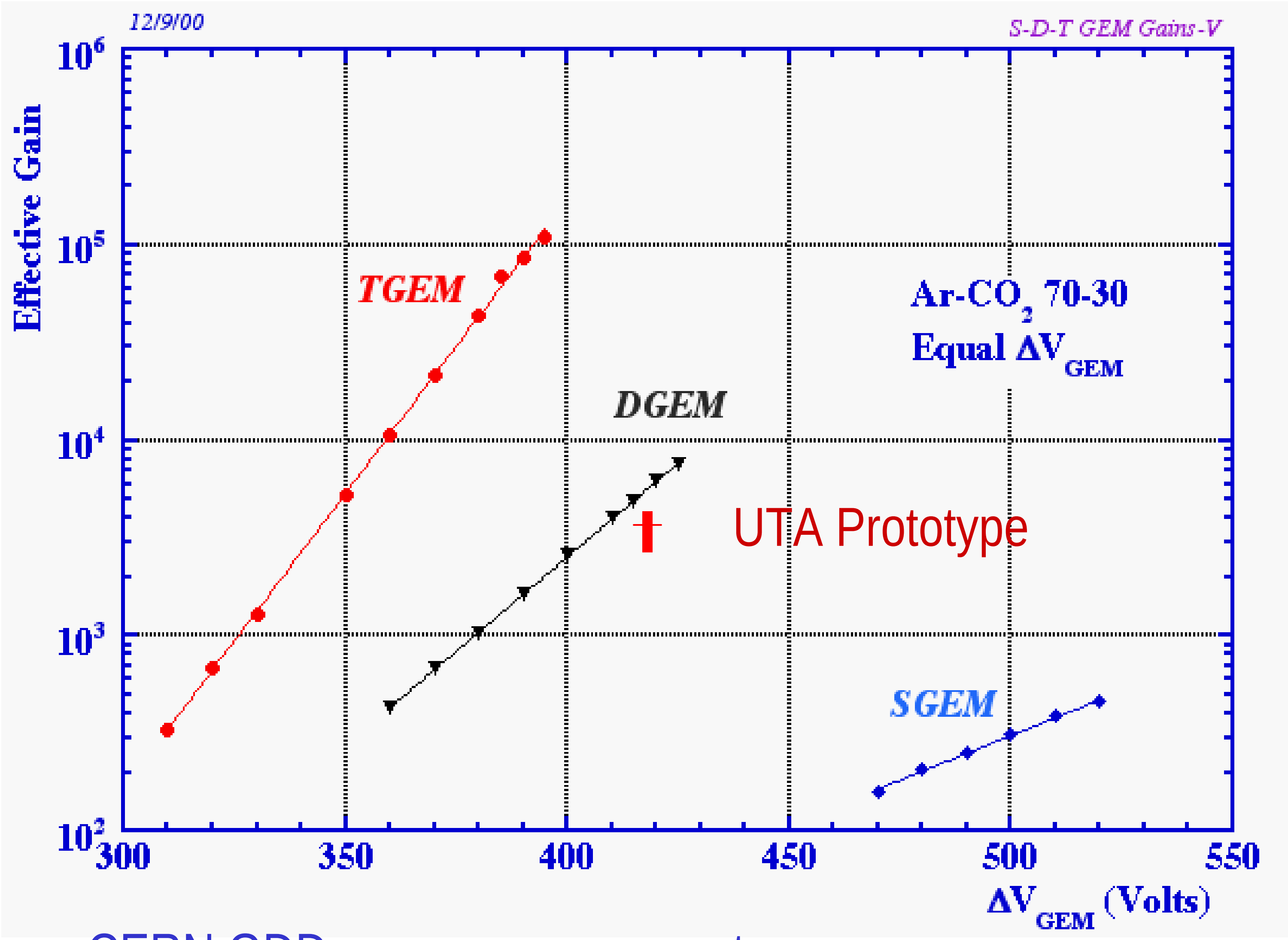


Signal Amplitude (mV)

GEM/MIP Signal Size Computation

- Double GEM – applied 419V/foil
- Total Ionization (C): ~93 i.p./cm
    - ➔ 48 e^- / MIP (5mm gap)
- Double GEM Intrinsic Gain: G
- Charge preamp sensitivity (GC) : 0.25 $\mu V/e^-$
- Voltage amp. gain 10 (G_V)
- Output signal = $C \times G \times G_C \times G_V$
- Observed ~370mV signal (mean of Landau)
    - ➔ **G = 3100 ± 20%**

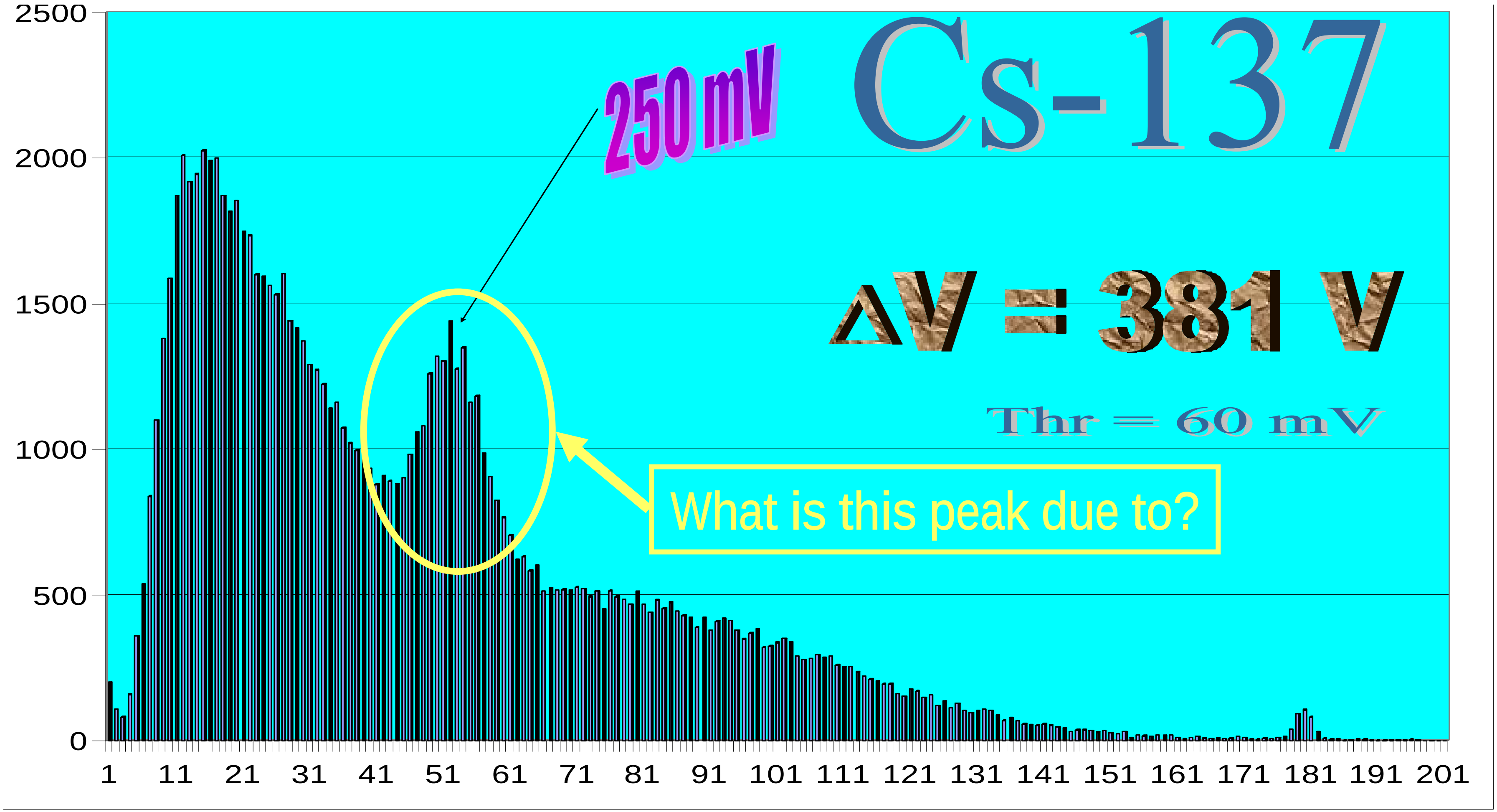
Measured UTA GEM Gains



CERN GDD group measurements

The problem

- When the chamber self-trigger was used, we saw



The decay characteristics of Cs^{137}

Decay modes of Cs^{137}_{55}

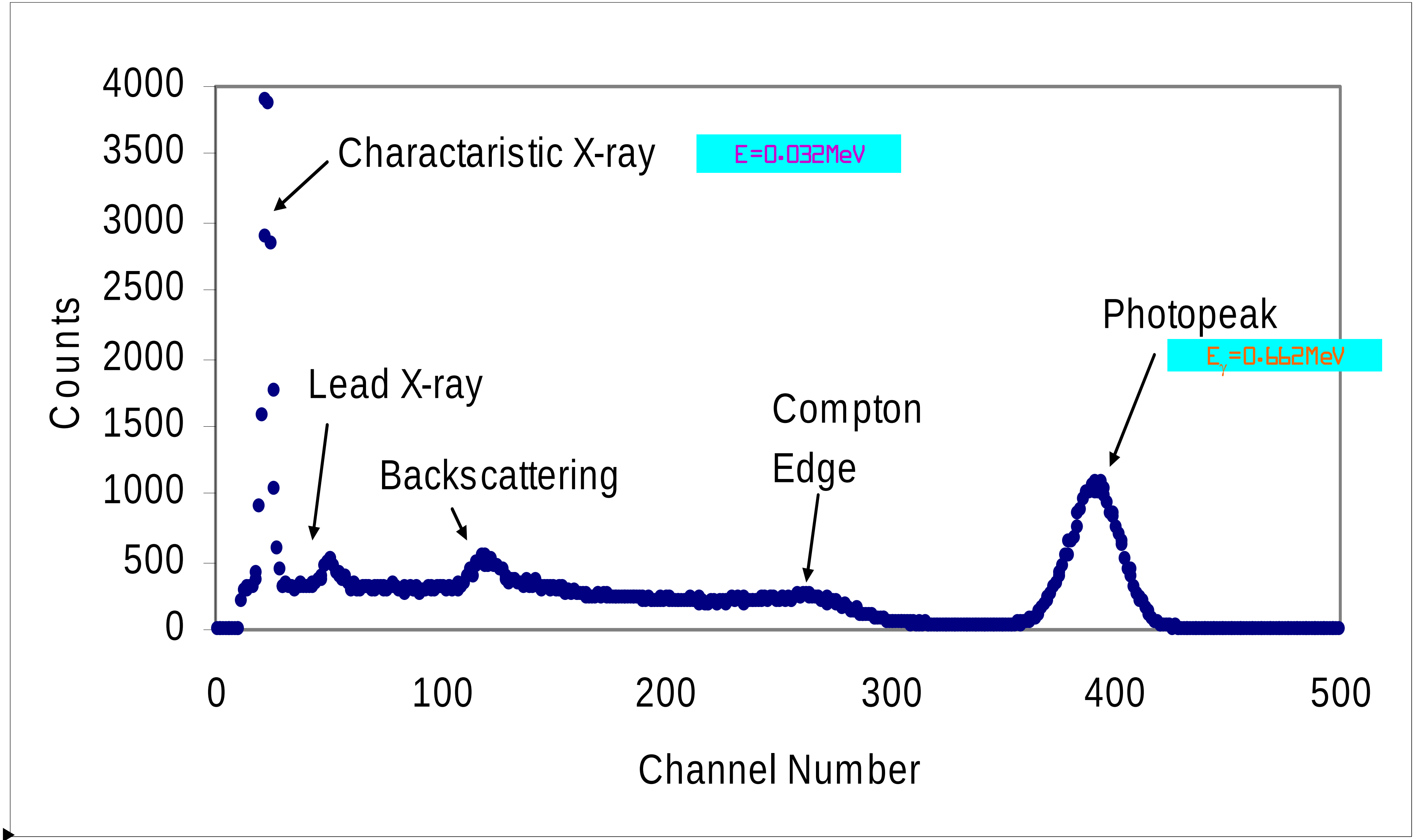
1. β-decays to excited Ba^{137}_{56}
   - End point energy 0.512 MeV
2. γ emission of Ba decays to Ba ground state: Monochromatic γ w/ E=0.662MeV.
3. Direct β-decay to Ba ground state
   - End point energy: 1.174MeV
4. Monochromatic e from internal conversion electrons (624, 656 and 660keV)
5. Monochromatic 32 keV X-ray through Coulomb interactions

Decay modes of Cs^{137}_{55}

	keV	Error (keV)	%
Gamma	661.645	0.004	85.0
	monochromatic energy		
X-ray	32.19(Ba-Kα1)	0.012	3.90
	31.82(Ba-Kα2)	0.007	2.11
	36.4(Ba-Kβ)	0.005	1.42
	Characteristic X-ray-(monochromatic energy)		
	Emax		
Beta	512		94.6
	1174		5.4
	Continuous energy spectrum		
Electron	624		8
	656		1
	660		0.6

Internal conversion electron or Auger electron (monochromatic energy)

Cs^{137} Decay Spectrum



Sr^{90} Results

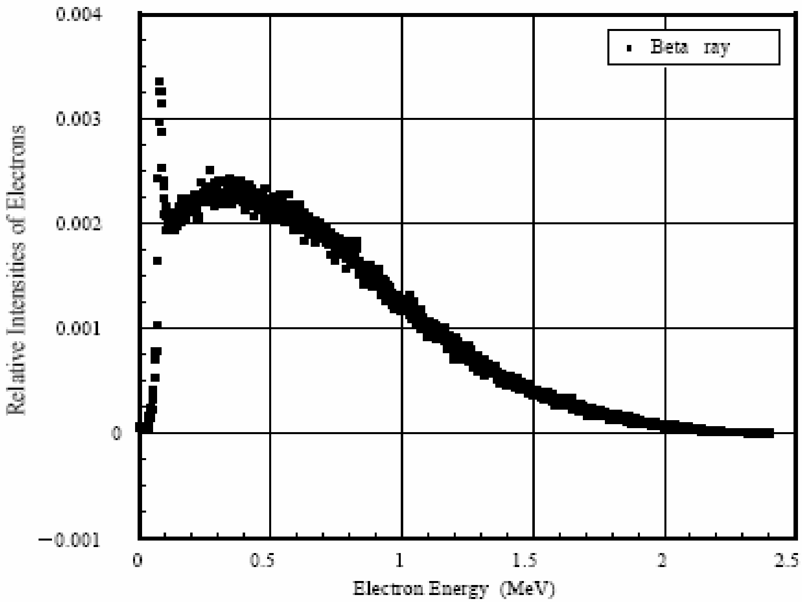
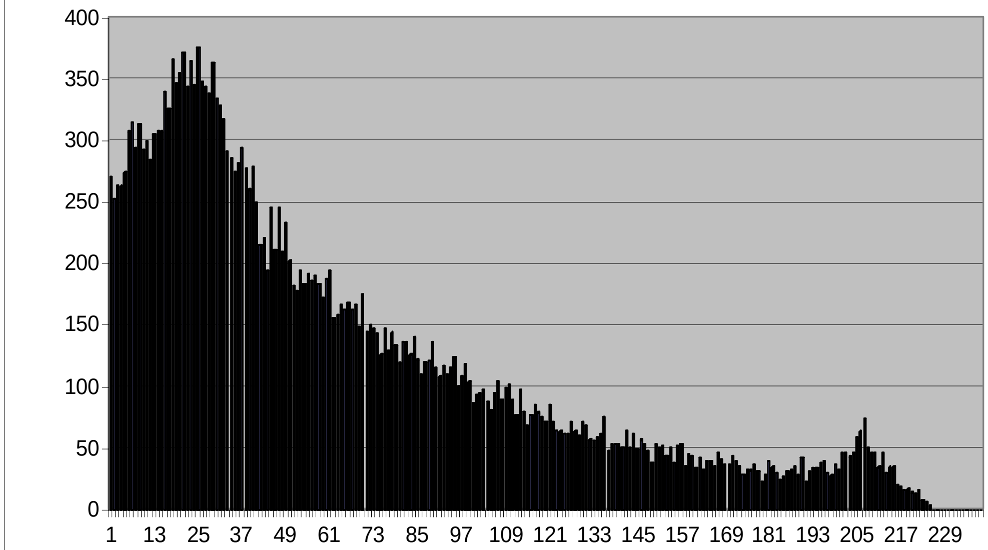
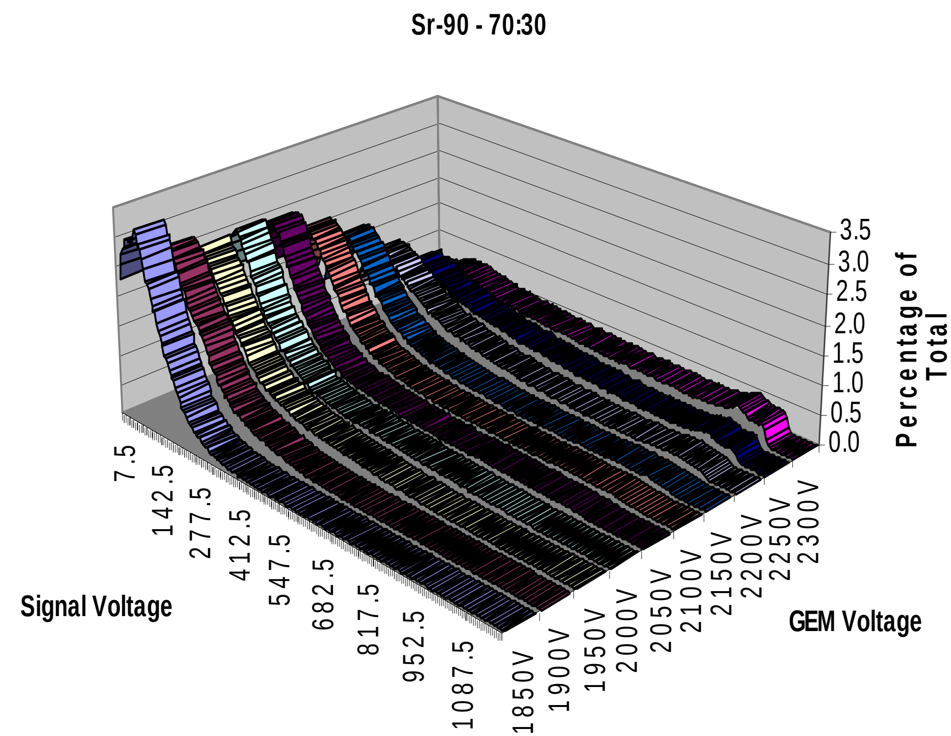


Fig. 3 Energy spectrum of ^{90}Sr–^{90}Y beta-ray source (measured)





The small peak in Cs^{137} does not appear in Sr^{90} beta source!

Decay Mode of Sr^{90}	E_{max} (keV)	%
E1	523	
E2	546	1
E3	2284	1

How do we separate Cs^{137} signals?

1. Use Sr^{90} source and 1.65mm Cu plate
   - Confirmed that all electrons from Sr^{90} are blocked by 1.65mm Cu and verified the stopping range expectation
2. Separate noise and cosmic ray, by removing the source
3. Separate pulse heights from all electrons and X-ray, using 1mm Cu plate
   - Provide pulse height distributions of 660keV γ-ray
   - These deposit energy through photoelectric and Compton effects
4. Use Cu of 0.65 mm to remove all betas but leave 660keV γ and X-rays
5. Use Cu of 0.1mm, 0.15mm and 0.2mm to determine whether the peak is due to internal conversion electrons or 32keV X-ray

Electron Stopping Range (EST)

In Copper : ρ= 8.960 [g/cm³]

r=R/ρ

0.512	MeV	0.1883	mm
0.624	MeV	0.2473	mm
1.0	MeV	0.4598	mm
1.1	MeV	0.5185	mm
1.174	MeV	0.56234	mm
1.2	MeV	0.5778	mm
2.284	MeV	1.2299	mm

EST for Kinetic Energy of Internal Conversion Electron

EST for End Point Energy of Cs-137 Beta

EST for End Point Energy of Sr-90 Beta

Therefore,
The 1.05mm copper plate can block all betas and IC electrons from Cs-137,
Because Q-values of betas of Cs-137 are 0.512, 1.174 MeV,
the kinetic energies of internal conversion electrons are 0.624, 0.656, 0.660 MeV.
and the signals of 32 and 36 keV X-ray can be removed in the data.
So, we can see only the signals of 662 keV gammas.

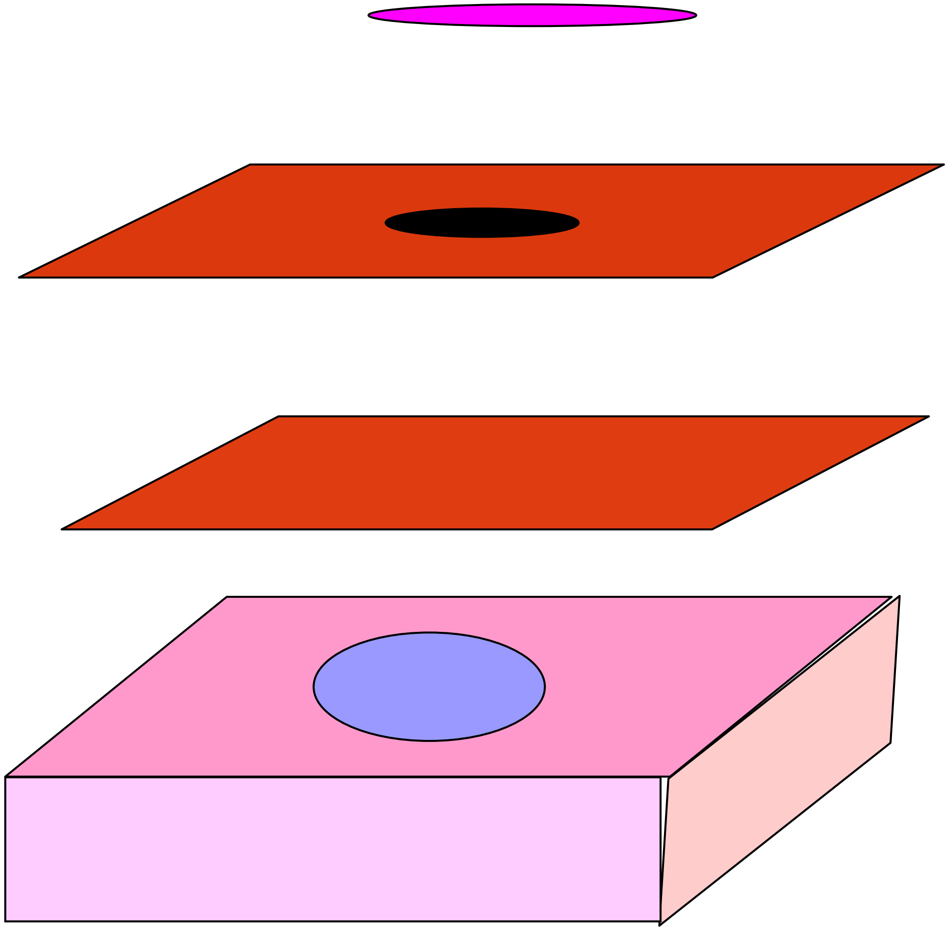
The 1.65mm Intercepting copper plate can intercept all betas of Sr-90.

If we use 0.65mm intercepting Cu plate, we can see noise, gamma 663 keV and X-ray 32, 36 keV because most of betas and internal conversions are intercepted.

Mean Energy Loss of Electrons and Mean Ion Pairs Produced by Various Electrons in $ArCO_2$(85:15)

Photoelectron by X-ray		
32keV	**1.226keV/mm**	**44.e /mm**
Photoelectron 662keV Gamma		
662keV	**0.261keV/mm**	**9.5e/mm**
End point energy of Beta-1		
512keV	**0.271keV/mm**	**9.9e/mm**
End point energy of Beta-2		
1174keV	**0.253keV/mm**	**9.2e/mm**

The Setup



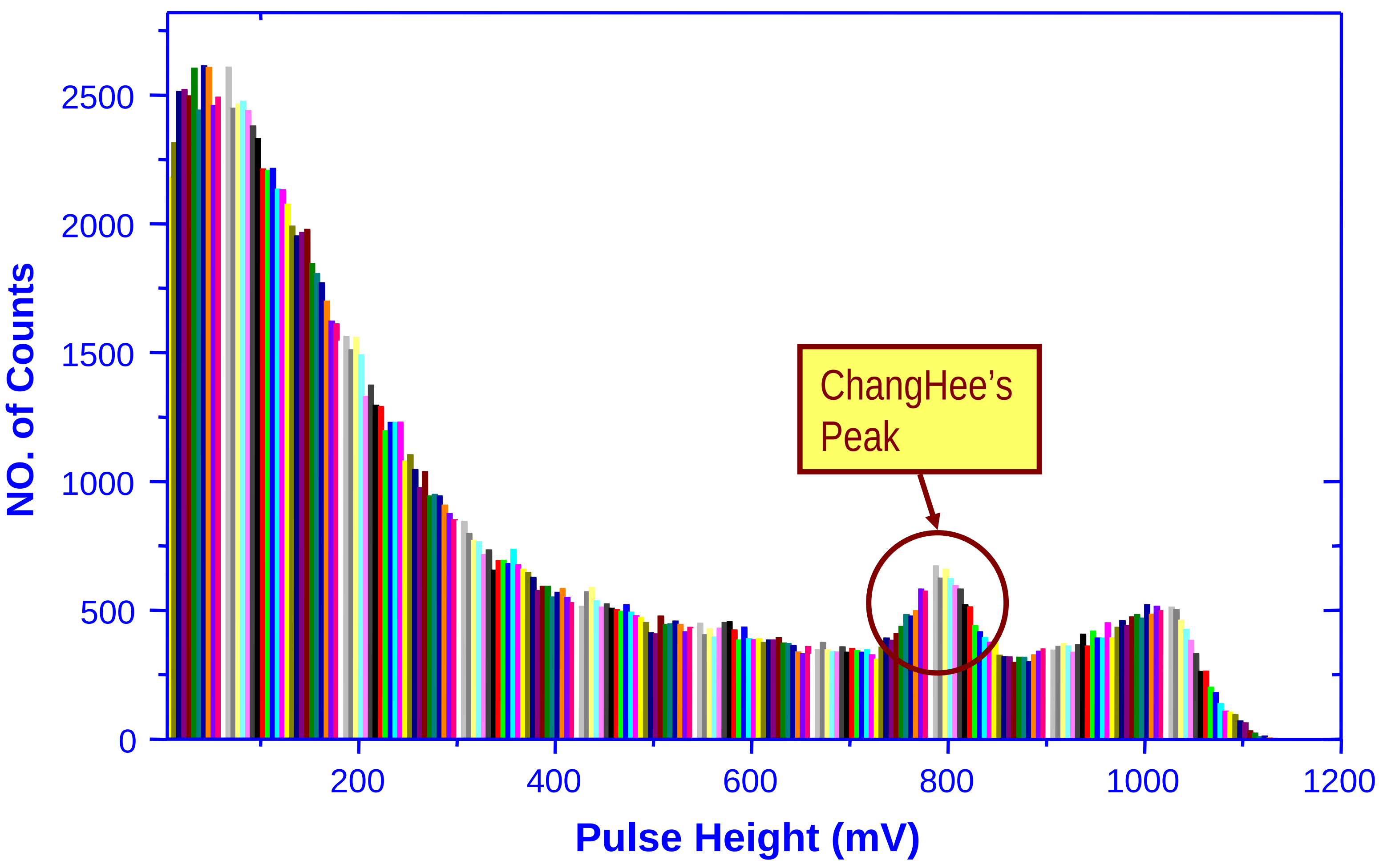
Radioactive source: Cs^{137}/Sr^{90}

2.1mm Cu collimator w/ a 5mm hole

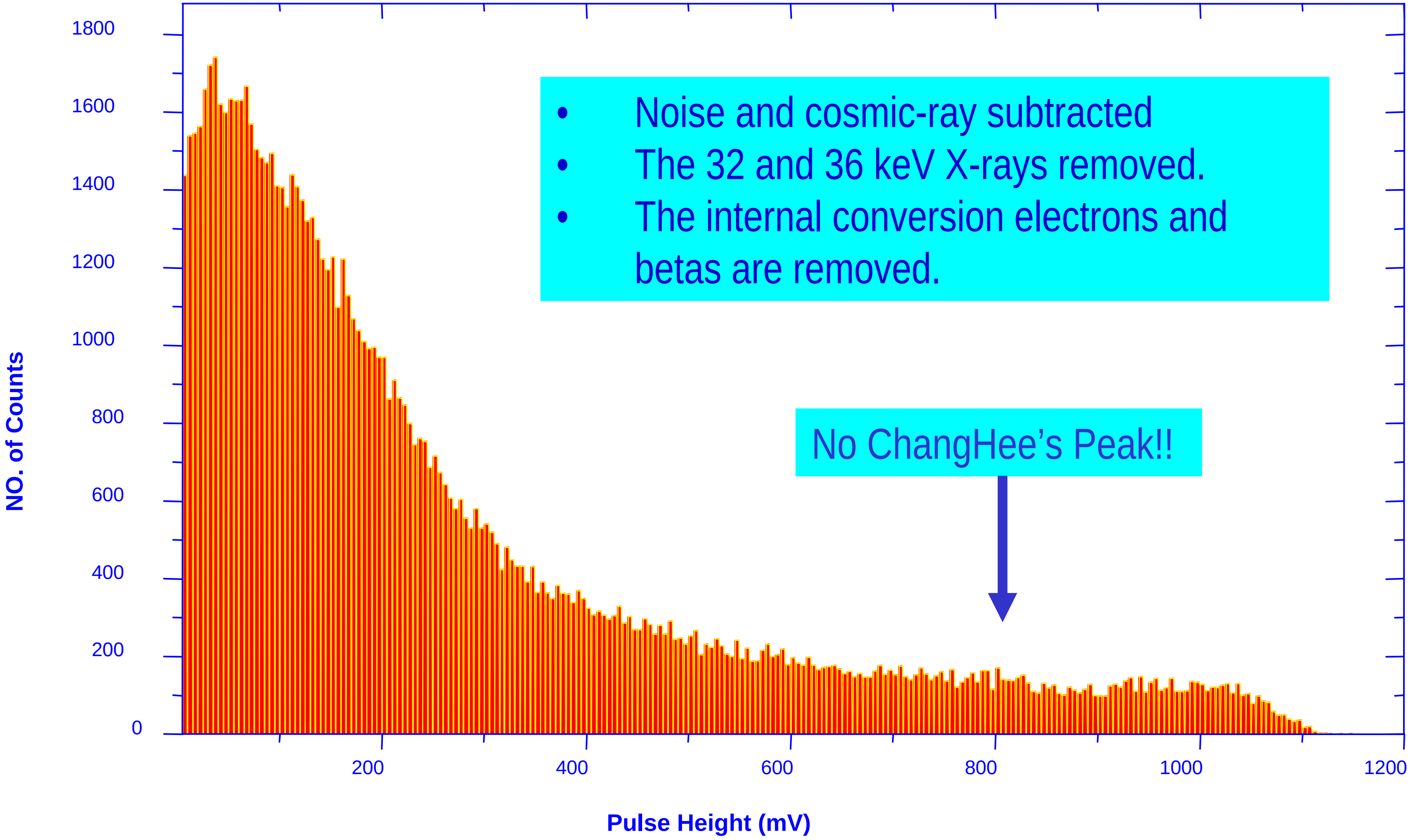
Interceptor copper plate w/ 0, 0.1, 0.15, 0.2, 0.3, 0.6, 1.05, 1.65 and 2.0 mm

GEM Chamber

Reproduction of Cs^{137} Result

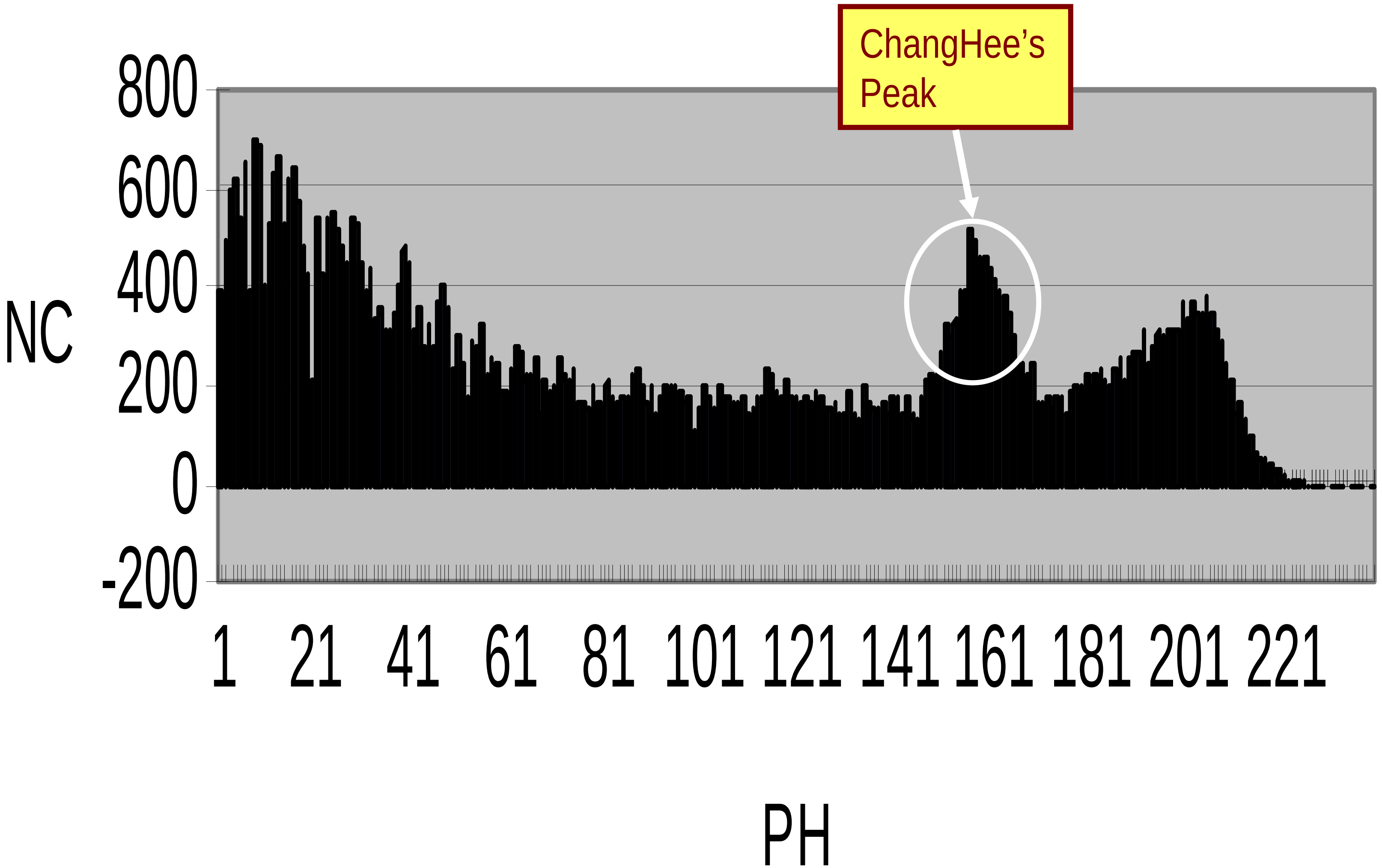


660keV γ Spectrum
(Corrected data w/ 1mm Cu plate)

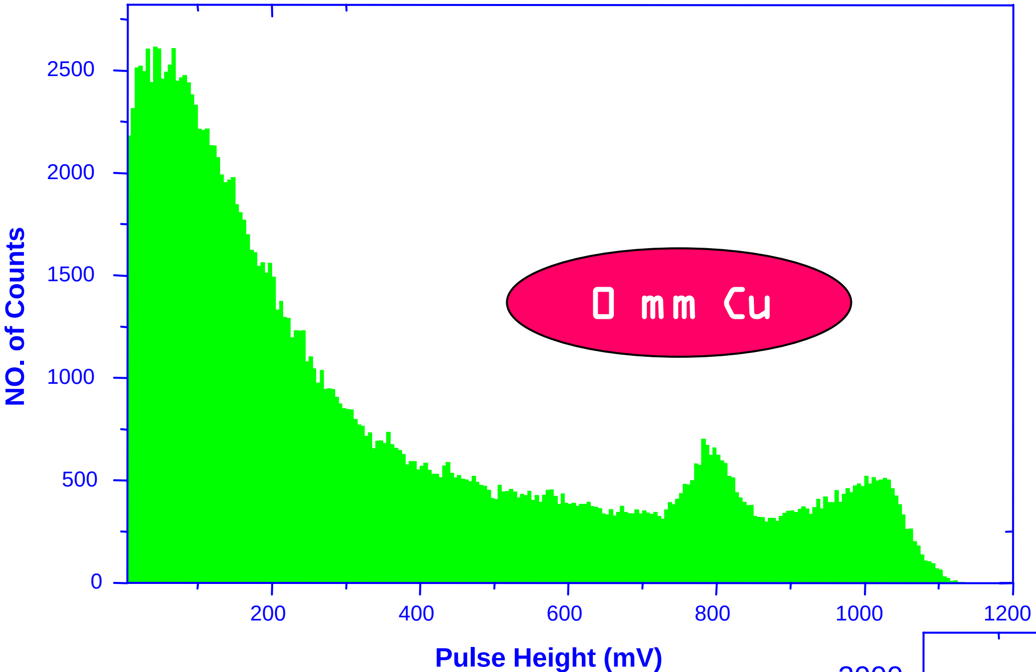


32keV X-ray Spectrum

(All – 660keV γ – all betas - noise)

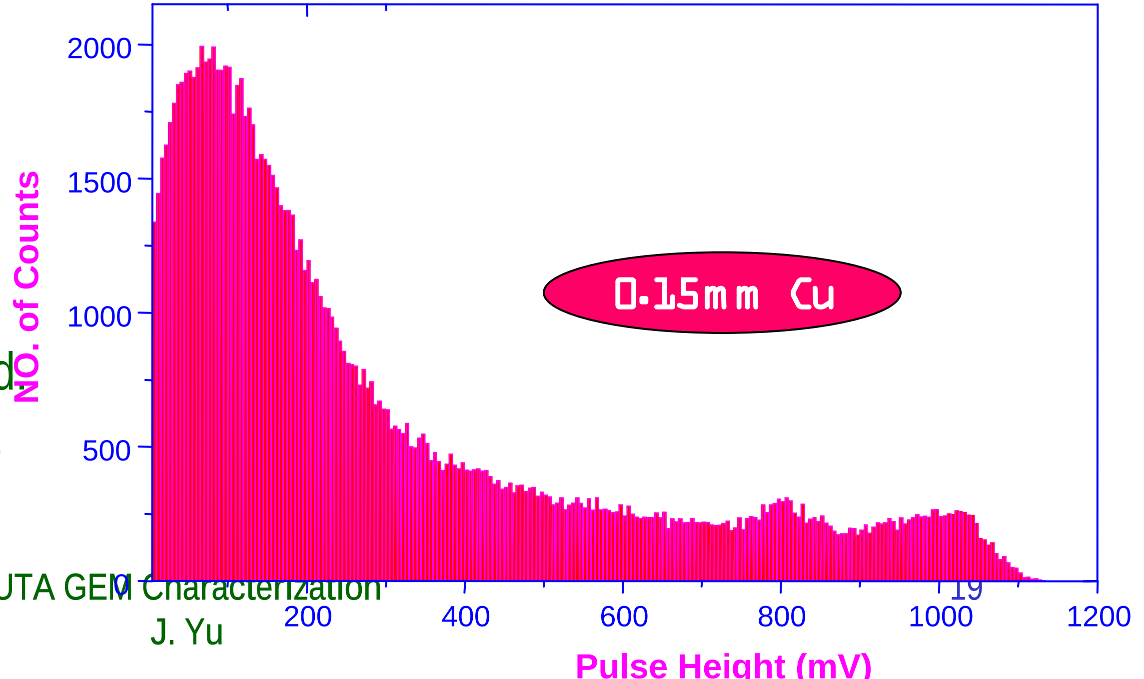


Separation of 32keV X-ray and Internal Conversion Electrons



- If ChangHee's Peak were caused by internal electrons its position will shift to right as Cu plate thickness increases since the electron energy reduces.
- If it's X-ray, its amplitude will reduce.

Studies with various thicknesses of Cu plates show that the peak stays at the same location but its amplitude reduced
➔ The peak is due to 32keV X-ray not due to conversion electrons



Conclusions

- UTA GEM Chamber characteristic study using CERN foils made good progress
  - Thanks for the help of our visiting professor from Korea
- Chamber gains consistent w/ other measurements within the uncertainties
- Electrons MiP signals observed from Sr^{90} and verified
- The origin of ChangHee's peak in Cs^{137} source measurement has been understood to be caused by photoelectrons from 32keV X-ray
- Electron MiP signals from Cs^{137} and 660keV γ isolated
- This study will be written up for NIM
- Will expand the study with 30x30cm^2 3M foils