GEM Simulation & Test

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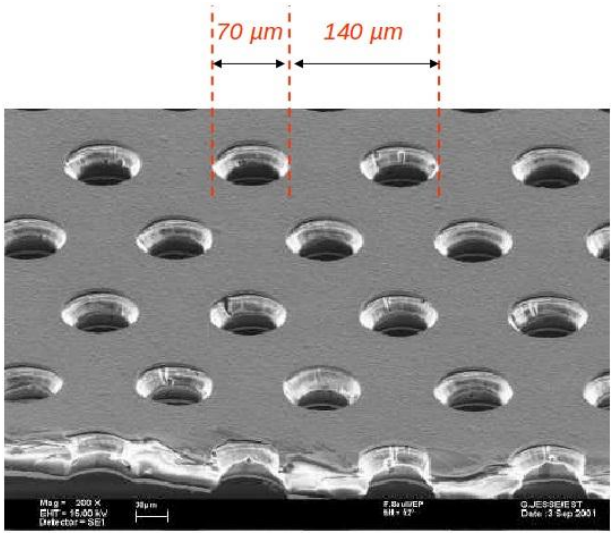
Outline

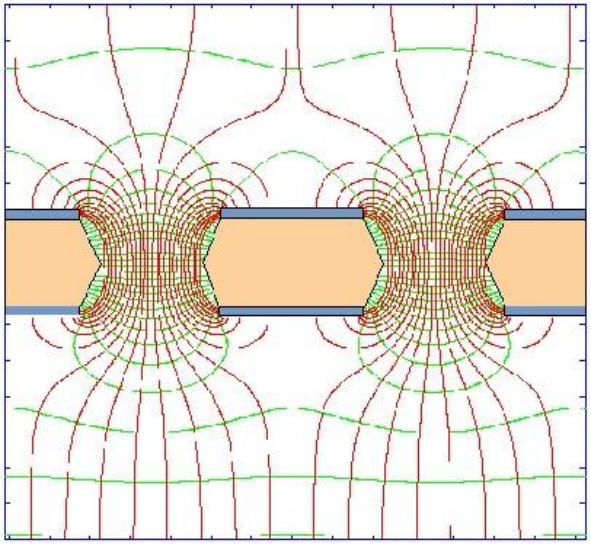
1. Introduction
2. GEM Simulation
3. GEM foil
4. JLab GEM Test
5. Summary

Introduction

1. Core Part: GEM Foil.
2. Typical GEM Foil has 3 layers, two 5-micron thick copper foils and one 50-micron thick kapton foil in the middle.
3. The foil is patterned with an array of holes.
4. Diameter of the hole is 70 microns, and the distance between them is 140 microns.
5. Apply electric voltages on the two copper layers.
6. Electric Field is very strong in the hole area, and weak outside the hole area.



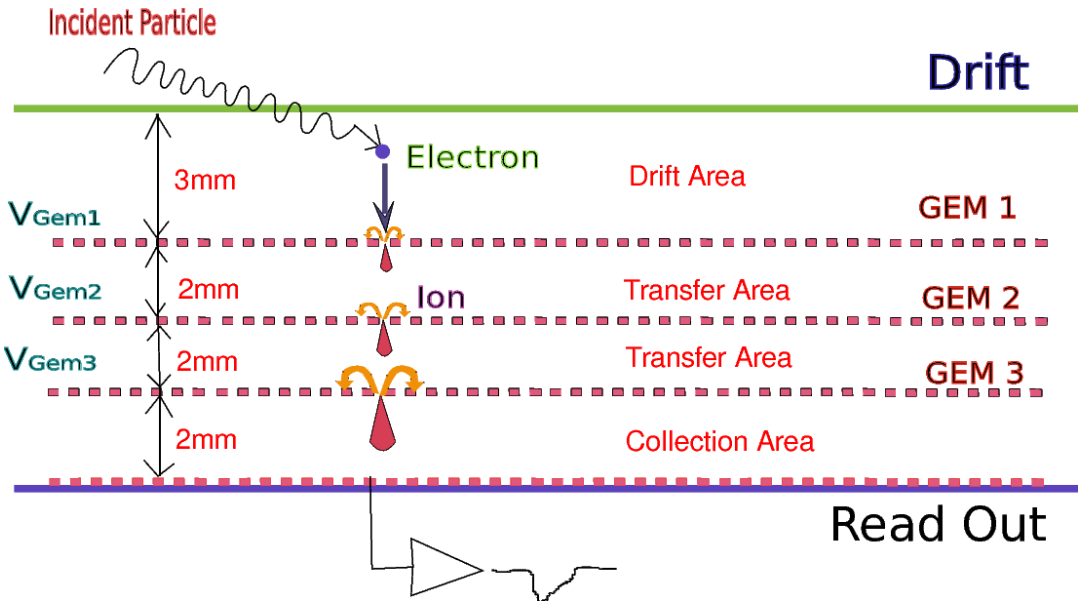
GEM Foil



GEM Field

Introduction

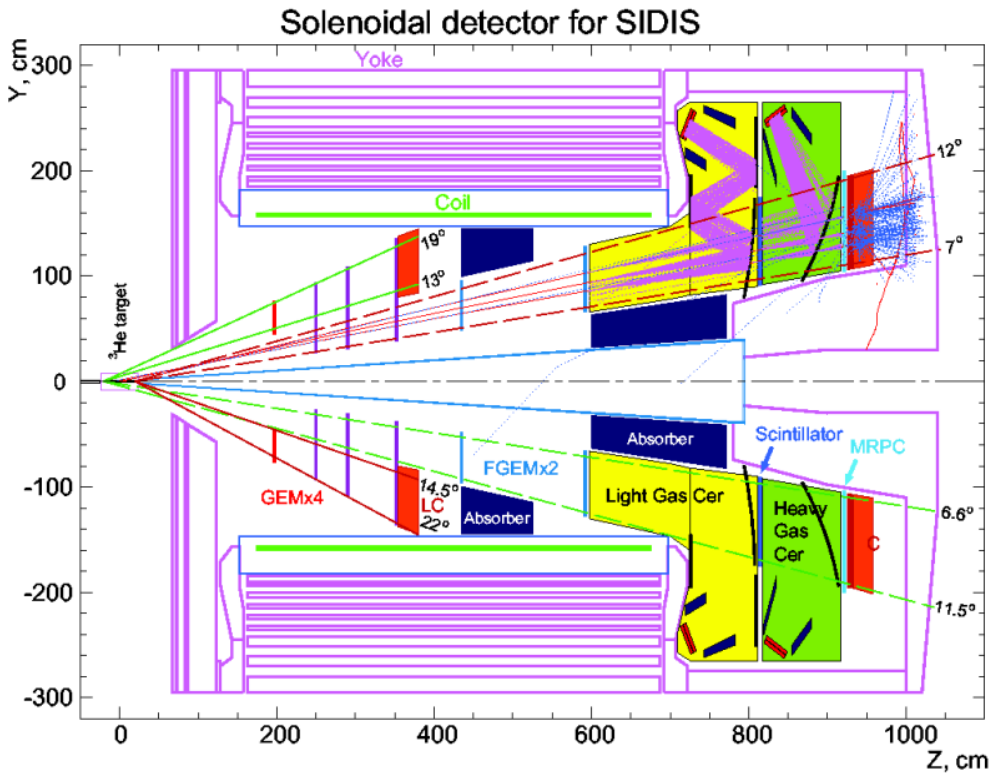
1. Avalanche happens in the hole area only. This improves the spatial resolution in a large extent.
2. For the triple-foil GEM detector, the total gain is the multiply of the gain of each gem foil.



Triple-Foil GEM Detector

Introduction

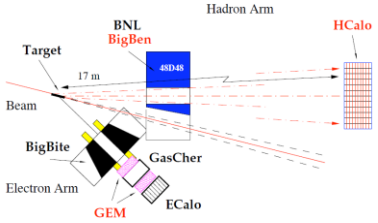
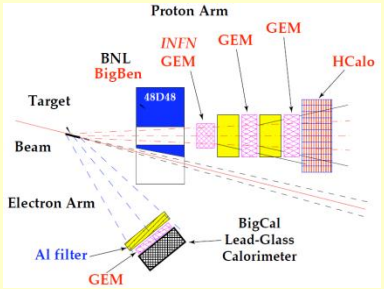
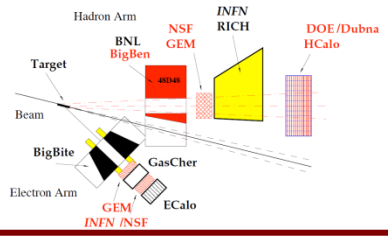
1. Six layers of GEM detectors in all.
2. SIDIS (Semi-Inclusive Deep Inelastic Scattering) experiment is one kind of the experiments that will be conducted on this spectrometer.



SoLID Spectrometer

Refer to GEM status by Evaristo

Different (e,e'h) experimental configurations

Experiments	Luminosity $(s \cdot cm^2)^{-1}$	Tracking Area (cm^2)	Resolution		
			Angular (mrad)	Vertex (mm)	Momentum (%)
GMn - GEn 	up to $7 \cdot 10^{37}$	40x150 and 50x200	< 1	<2	0.5%
GEp(5) 	up to $8 \cdot 10^{38}$	40x120, 50x200 and 80x300	<0.7 ~1.5	~ 1	0.5%
SIDIS 	up to $2 \cdot 10^{37}$	40x120, 40x150 and 50x200	~ 0.5	~1	<1%

High Rates ***Large Area*** ***Down to ~ 70 µm spatial resolution***

Maximum reusability: same trackers in different setups

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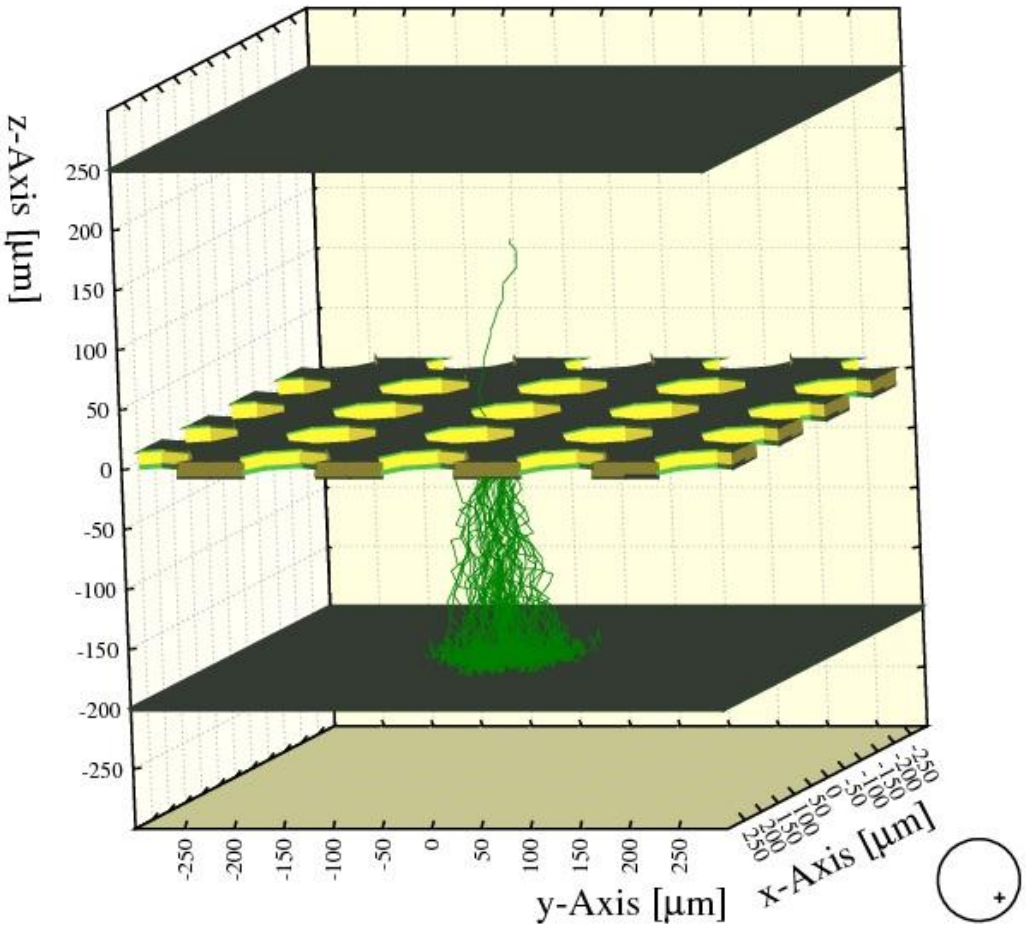
GEM Simulation

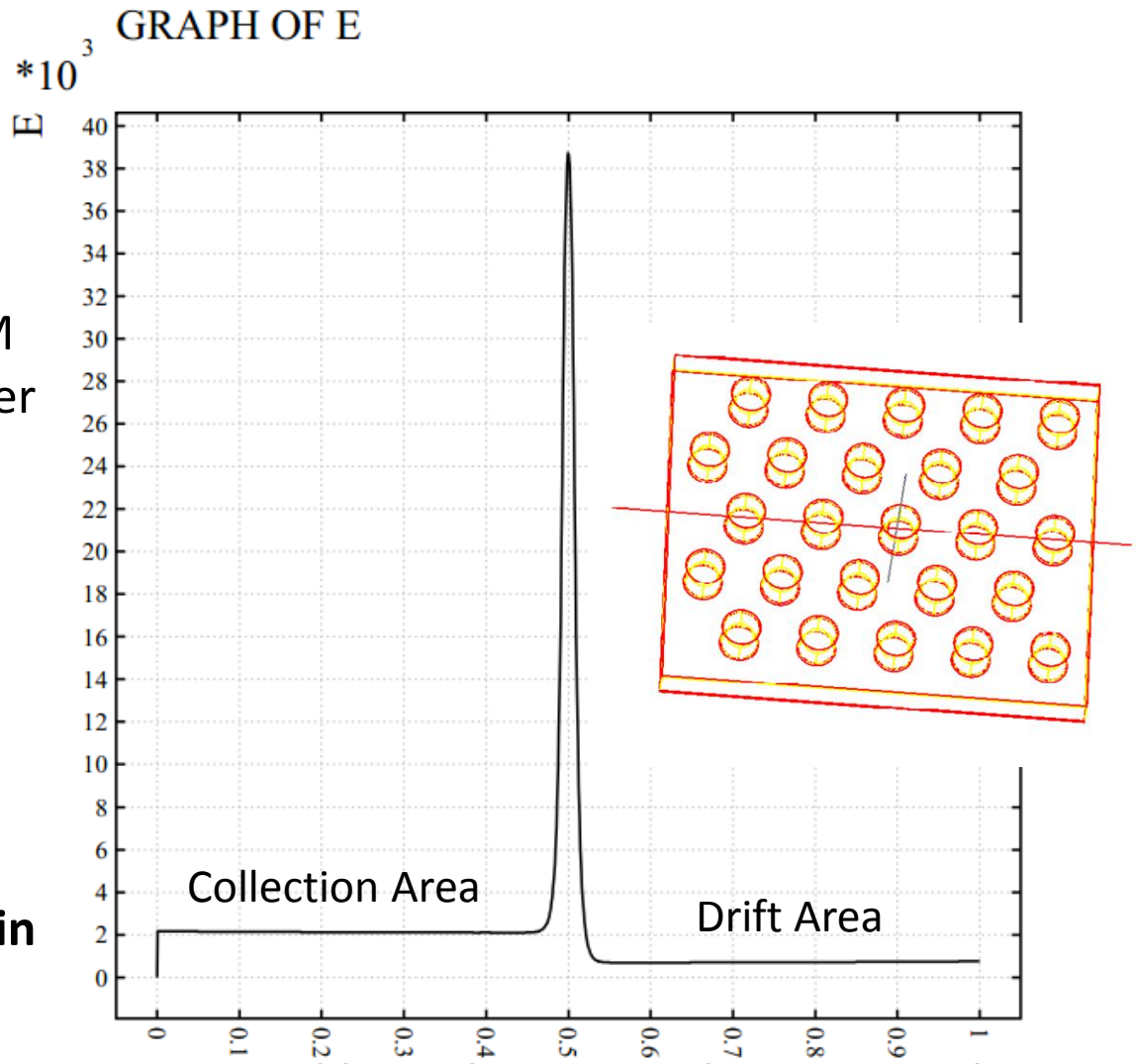
1. Maxwell + neBEM for the electric field calculation.
2. Garfield + Magboltz + Heed for the Calculation of electron transportation in Gas.
3. We simulated the **Spatial Resolution**, **Gain**, **Electron Transparency** of gem foils, and the **Counting Rate**.



Avalanche in a Single-Foil GEM Detector

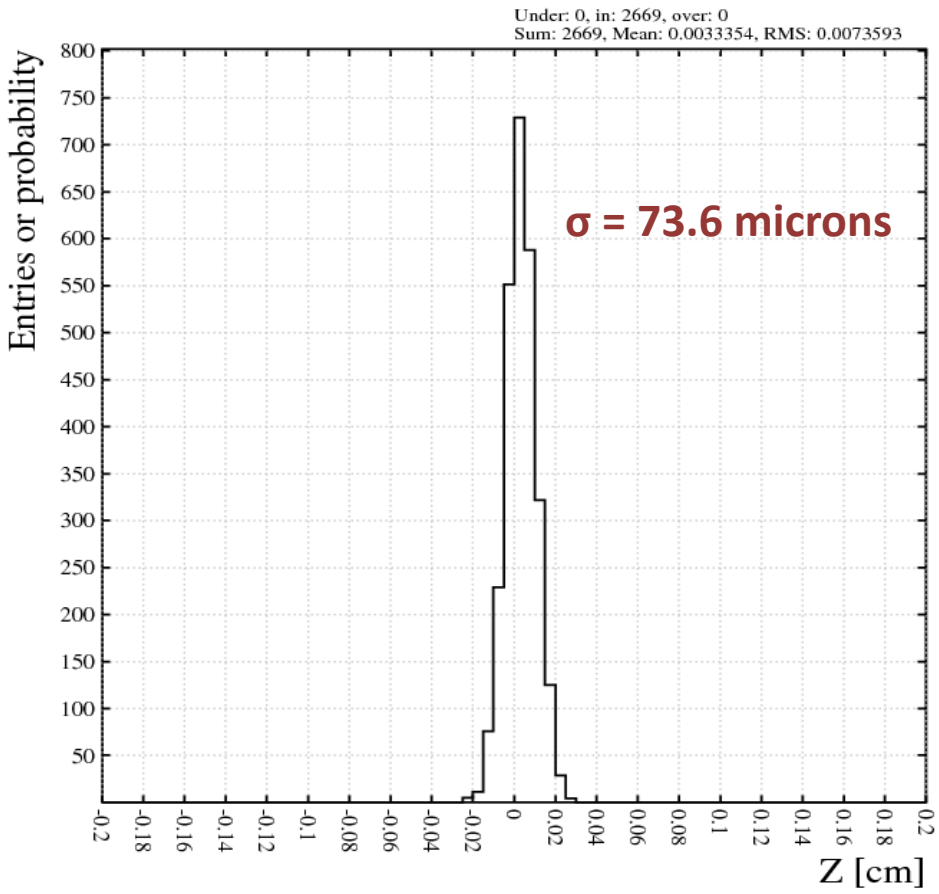
Electric Field Distribution

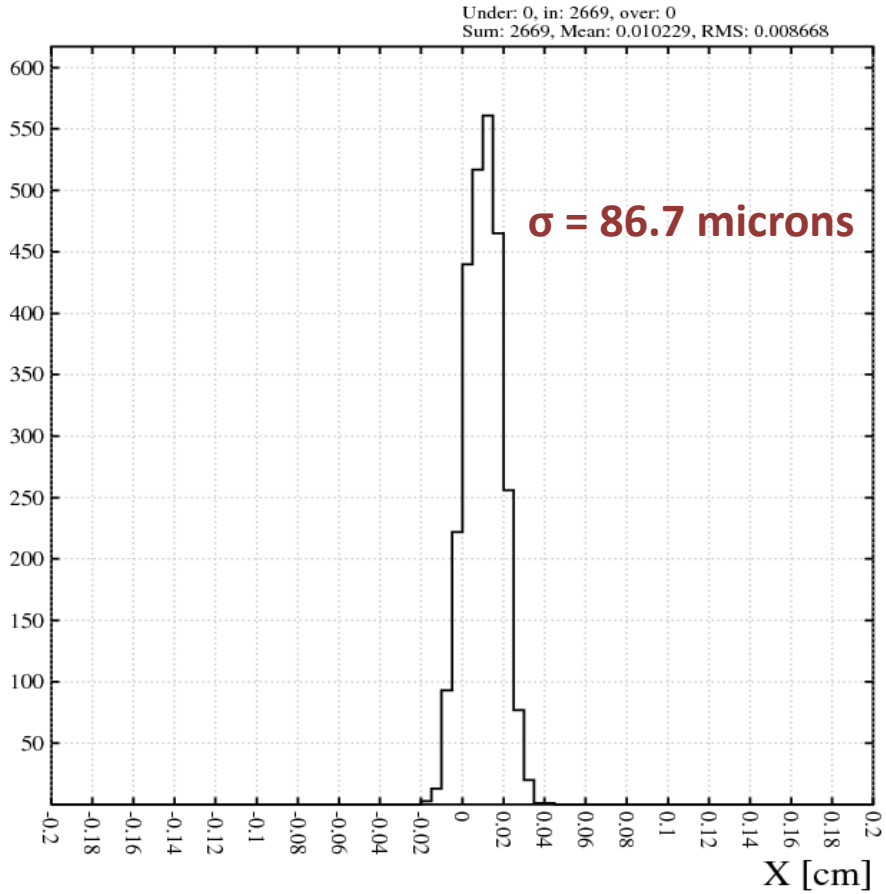
1. Electric Field Distribution along the line which is perpendicular to the GEM foil and crossing the center of a hole.
2. Electric field reaches its maximum value at the center of the hole.
3. During our simulation, avalanche won't happen when E < 5 kV/cm, thus **avalanche only happens in the hole area**.



Field Distribution on a line crossing the centre of a hole

Spatial Resolution



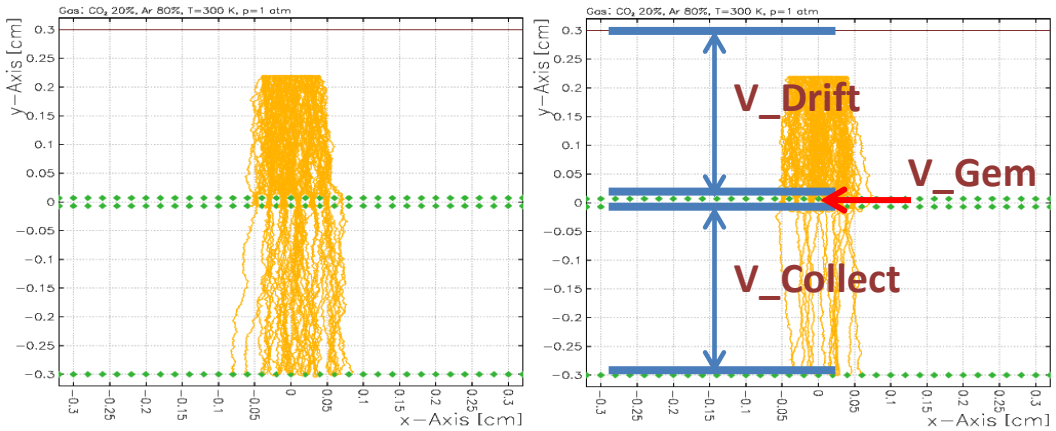


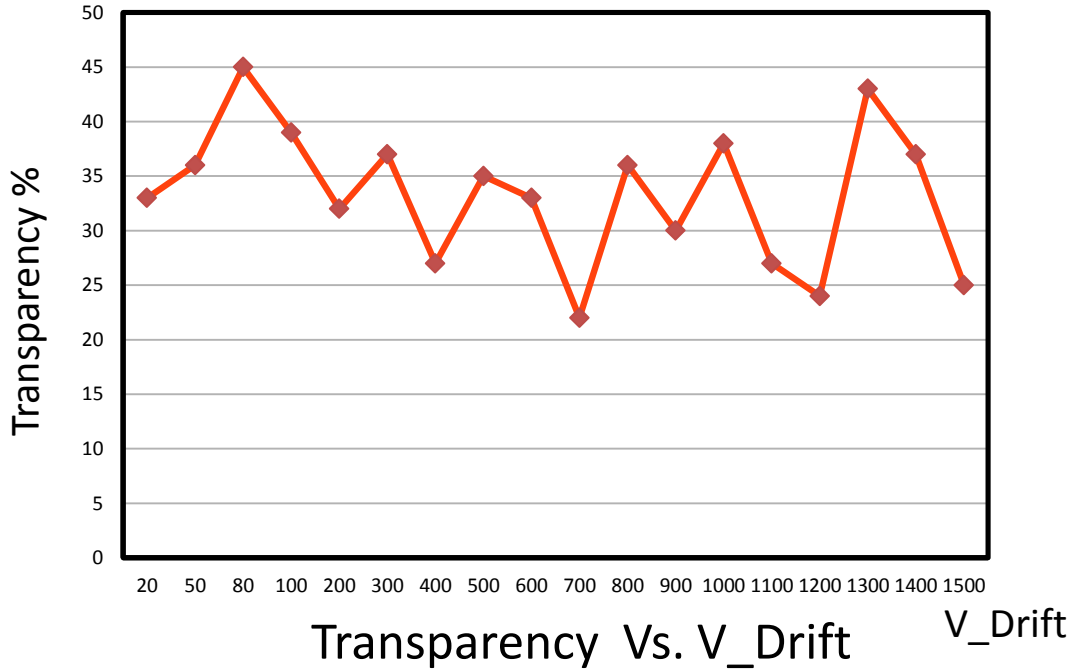
Avalanche Cluster Distribution on the Readout Plane

Electron Transparency

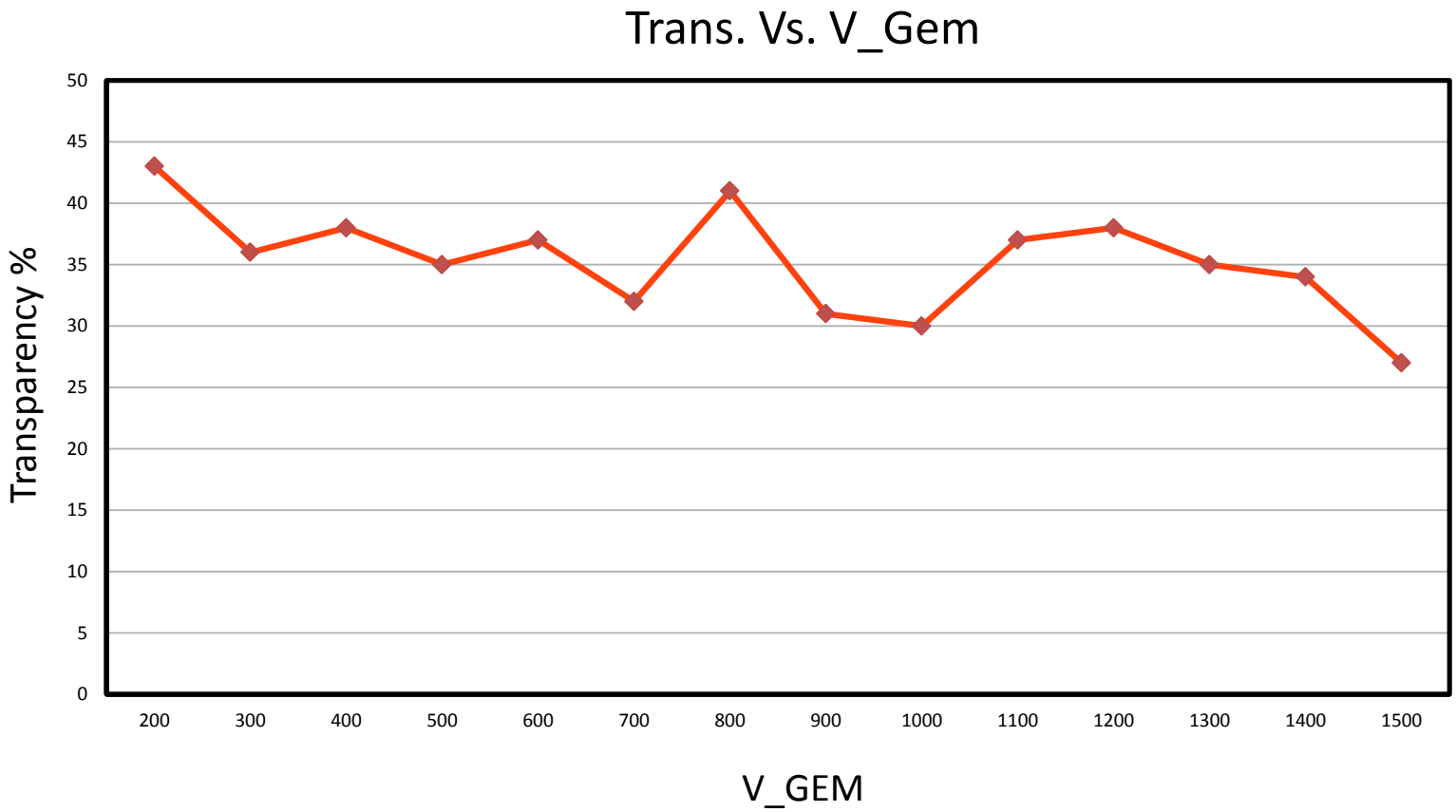
Transparency is dependent to the voltages applied on the drift area, collection area and gem foil.

When two of them are fixed, how the transparency varies with the third one?

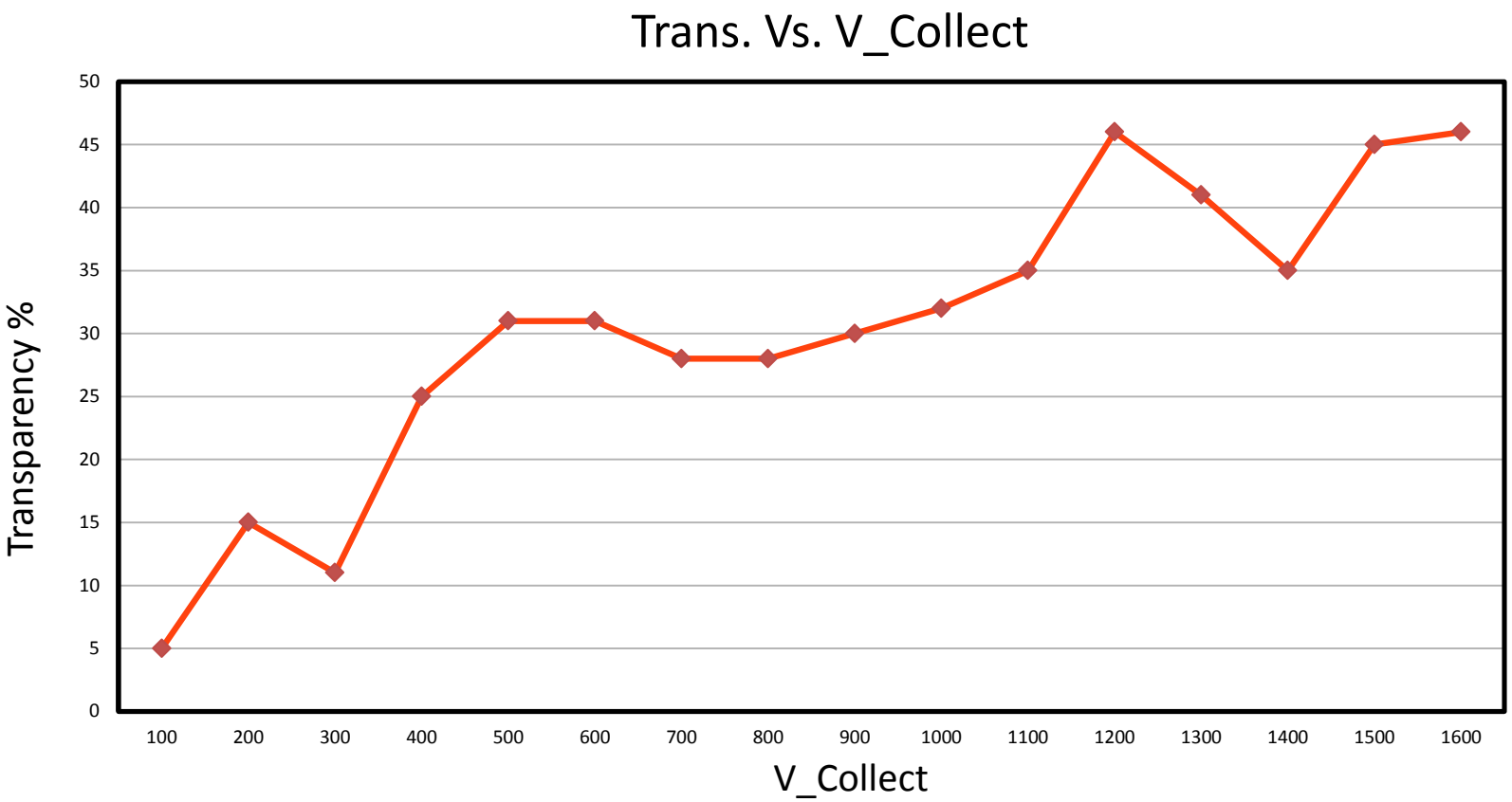




Electron Transparency



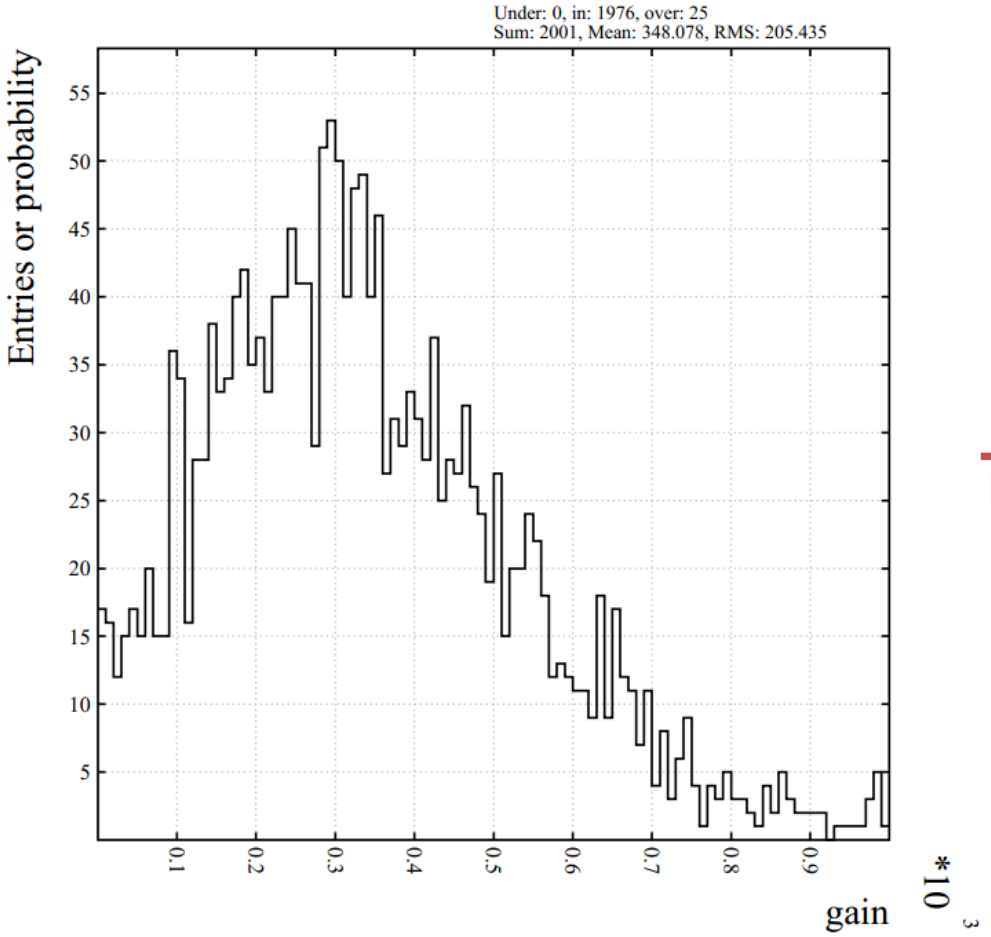
Electron Transparency



Gain

Energy Resolution of GEM detectors is dependent to its gain performance.

Gain is not stable both from the experiment and from the simulation.



Distribution of Gain of Single-Layer GEM Detector

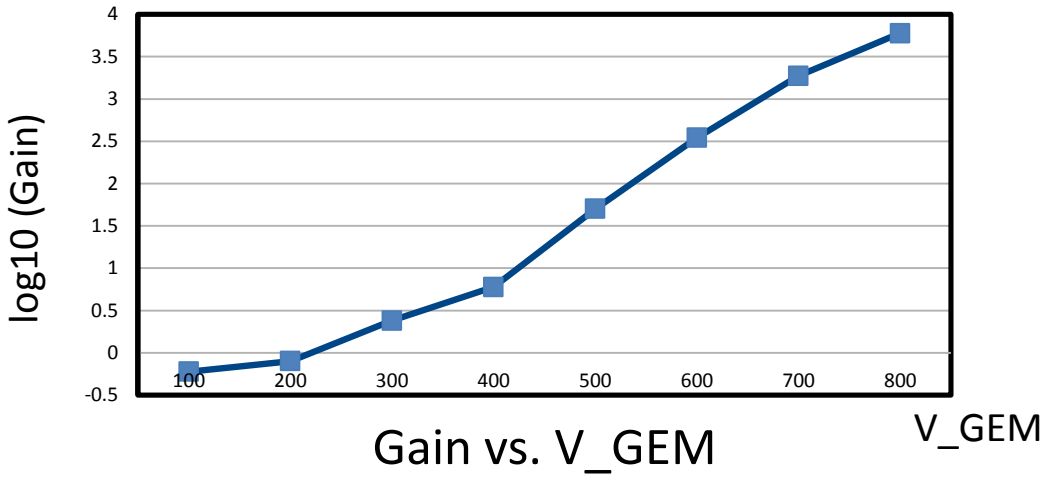
$$\frac{\text{RMS}}{\text{Mean}} = 0.6$$

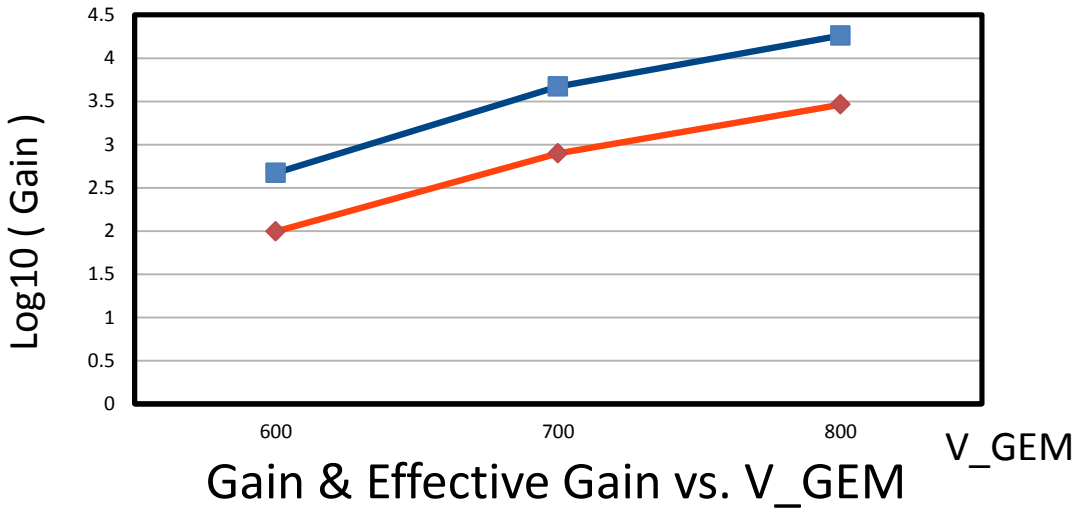
Gain

How gain varies with the voltage applied on the GEM foil.

Gain:
Number of electrons from all of the avalanches.

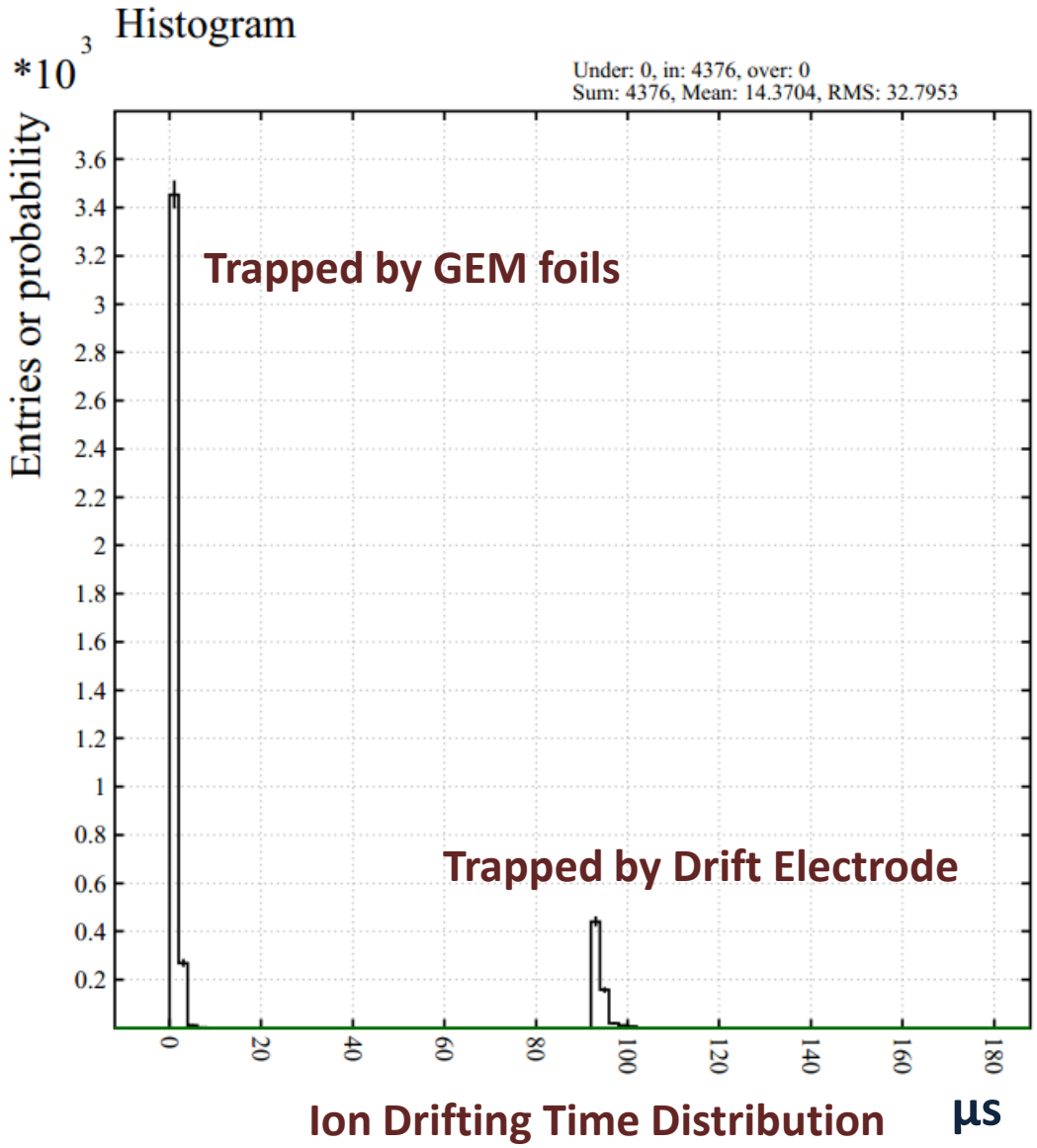
Effective Gain:
Number of electrons that reach the readout board.





Counting Rate

1. Shut down the attachment process, there will be two ends for ions.
2. Trapped by GEM foils and Trapped by the Drift Electrode.
3. Most of the ions will be trapped by gem foils, where they are produced, which leads to a very short drifting time for ions.



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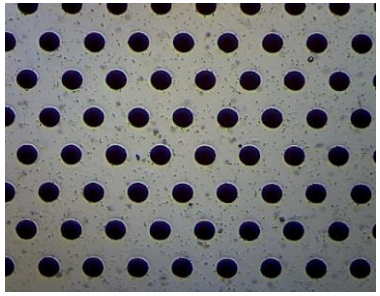
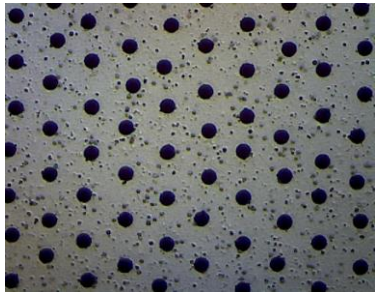
The Construction of Clean Room at CIAE for GEM Foil R&D



Mask plate from CERN
60um diameter

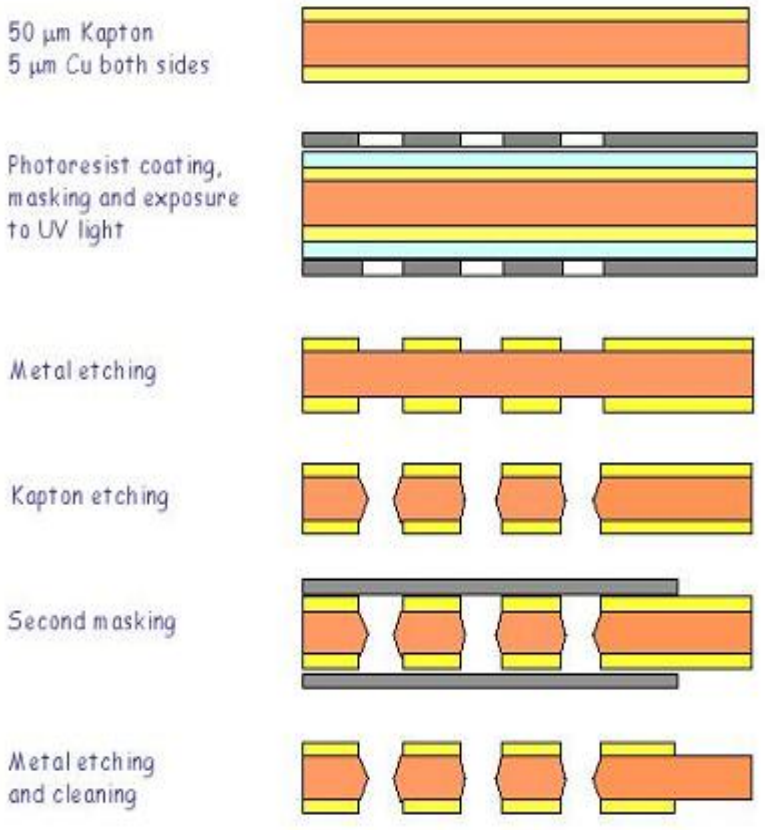


Mask plate from CIAE
50um diameter

After half year negotiation, CIAE has signed officially the **LICENSE AGREEMENT FOR MANUFACTURING AND COMMERCIALISATION OF GEM FOILS AND GEM-BASED PRODUCTS** with CERN, and will get full technology support from CERN.

The Study of GEM foil at CIAE

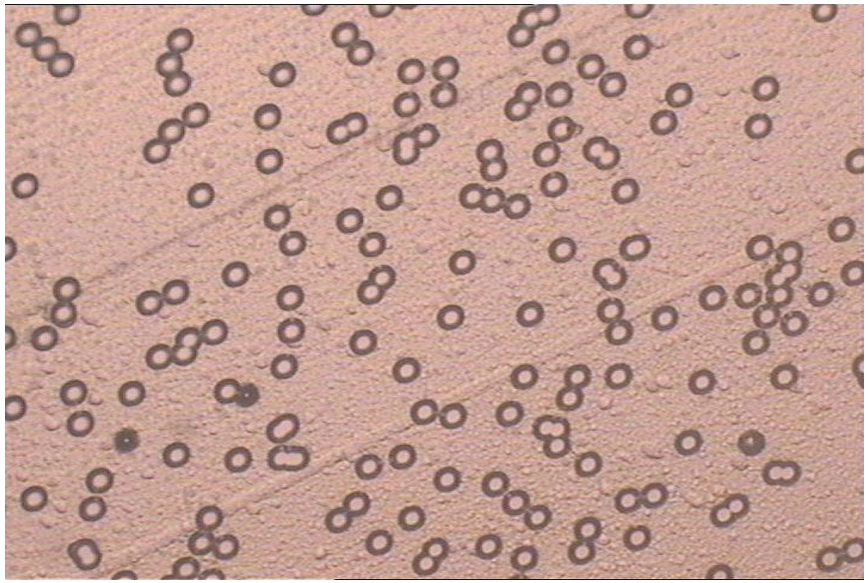
1. We can reach a minimum thickness of 12 microns of the copper foil coated on the Kapton layer.
2. Exposure and developer have some problems. We will try the recipe of the etchant provided by CERN.
3. Copper etching. Etching success rate < 70% with the hole diameter of 70 microns.
4. Kapton etching. CIAE has over 20 years nuclear pore foil production and kapton etching experience.
5. Clean room and GEM test lab is ready at CIAE.



Process flow diagram of GEM foil

CIAE Nuclear Pore Foil

HI-13 tandem accelerator



1. Particles which are accelerated by HI-13 pass through the kapton foil.
2. kapton etching， 20um.
3. control the hole size by etching time .

Building Collaboration with a PCB Factory

Laminator

Photoetching machine

Etching machine

The PCB factory is located in the south of Beijing. They would like to make the GEM foils for us if we provide the technology support.

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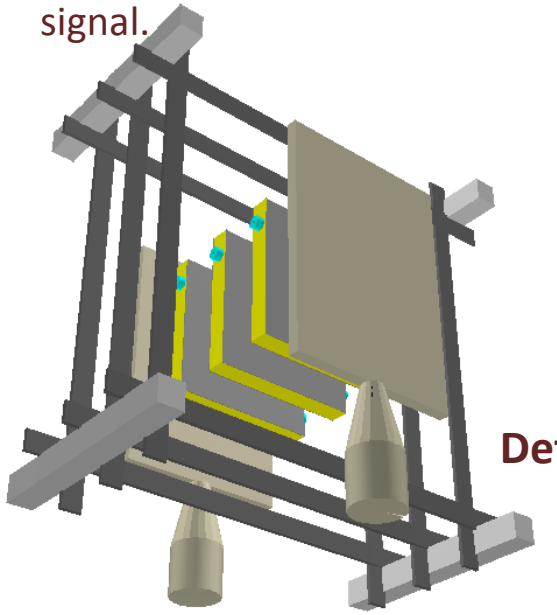
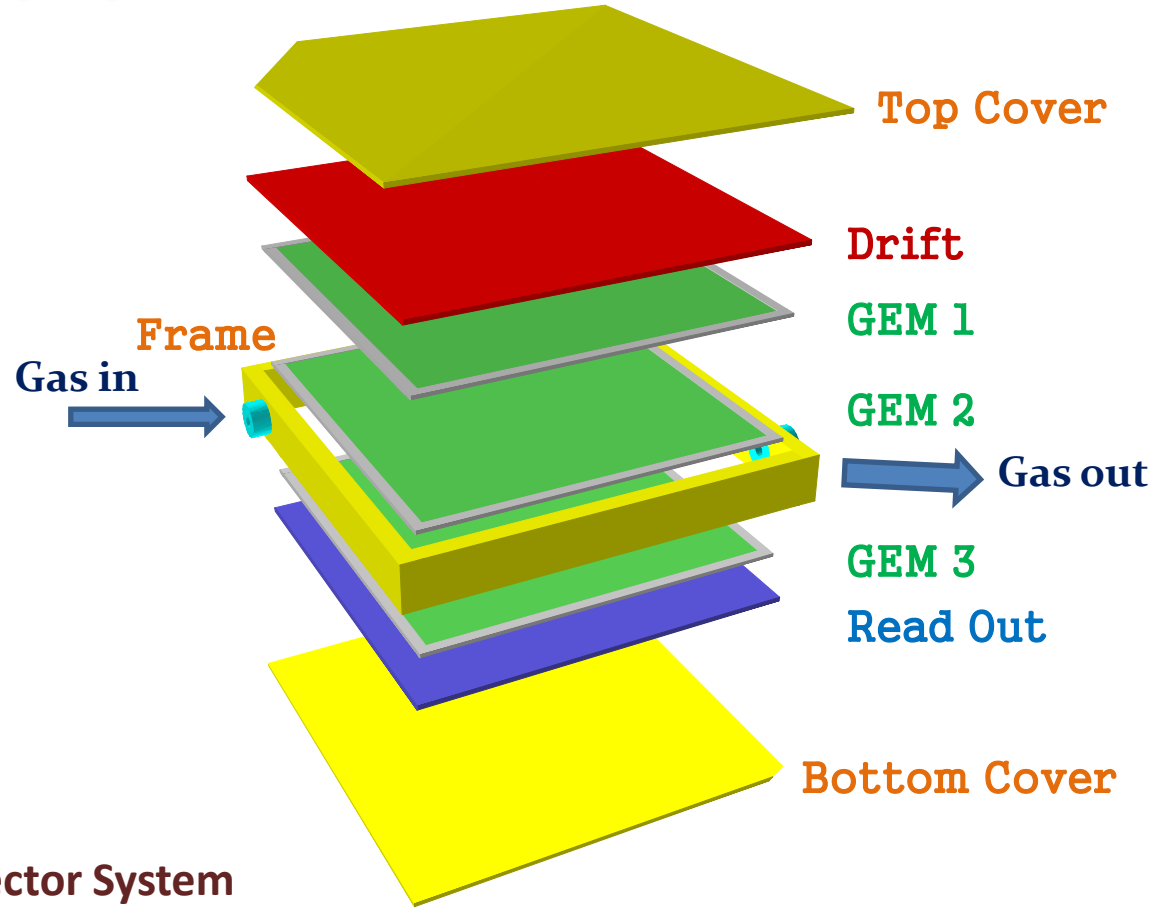
Chamber Structure

1. Three-Foil GEM Detector.
2. Work Gas Argon/CO2 = 70%/30%.
3. The whole Detector Setup consists of three chambers.
4. We used two scintilators to construct the coincidence signal.



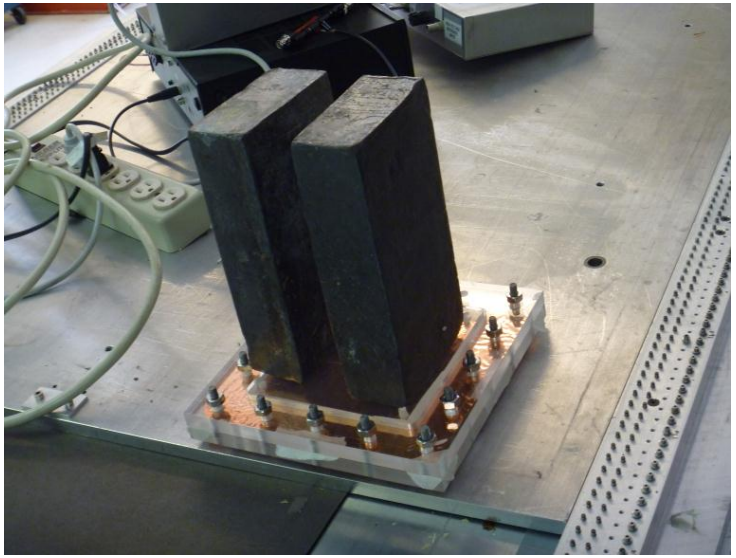
Detector System



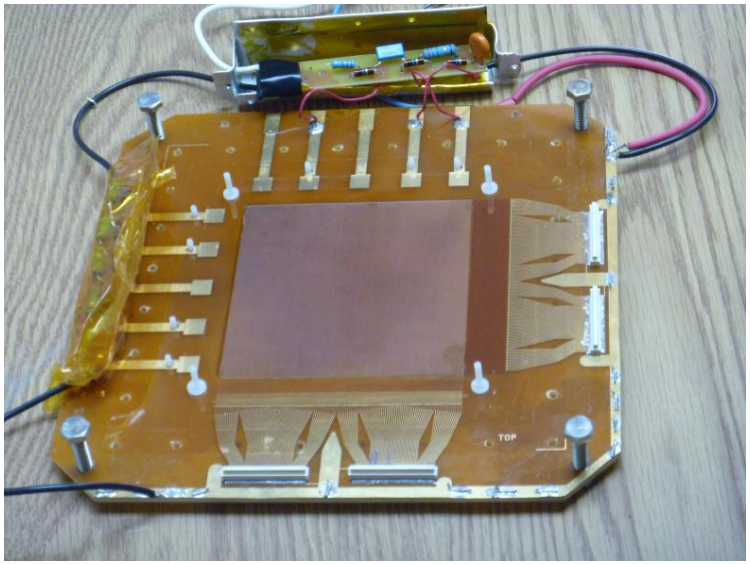
Composition of a chamber

Chamber Construction

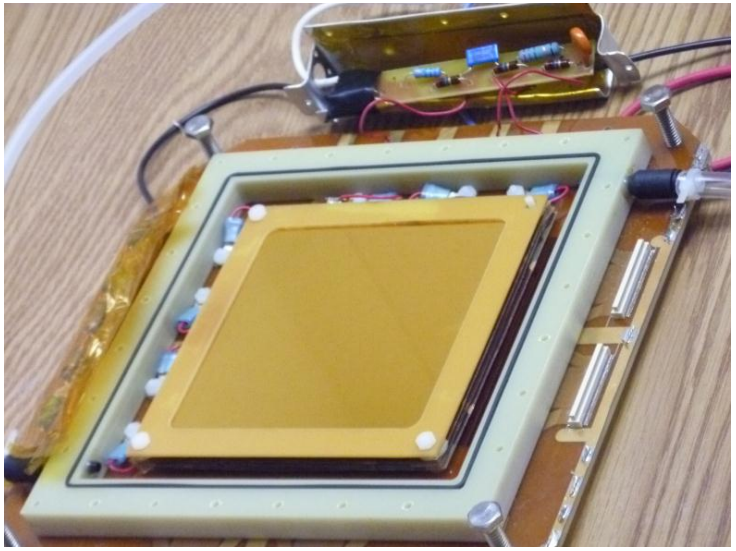
Stretch System



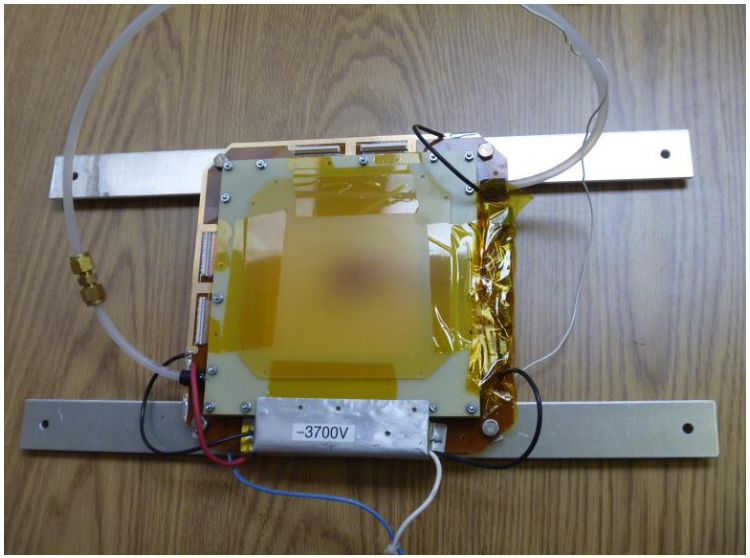
Readout Board



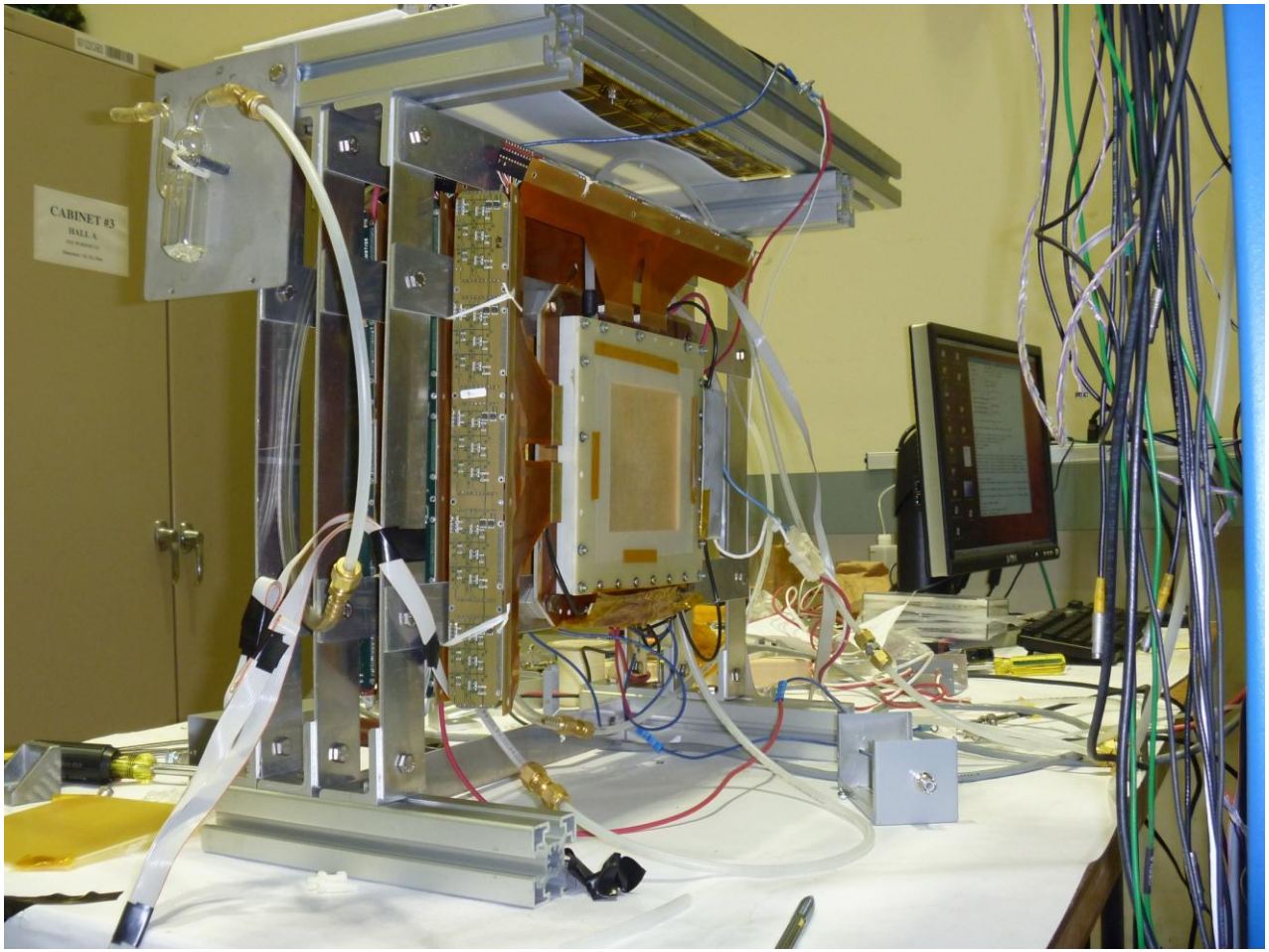
Chamber in building



Chamber built

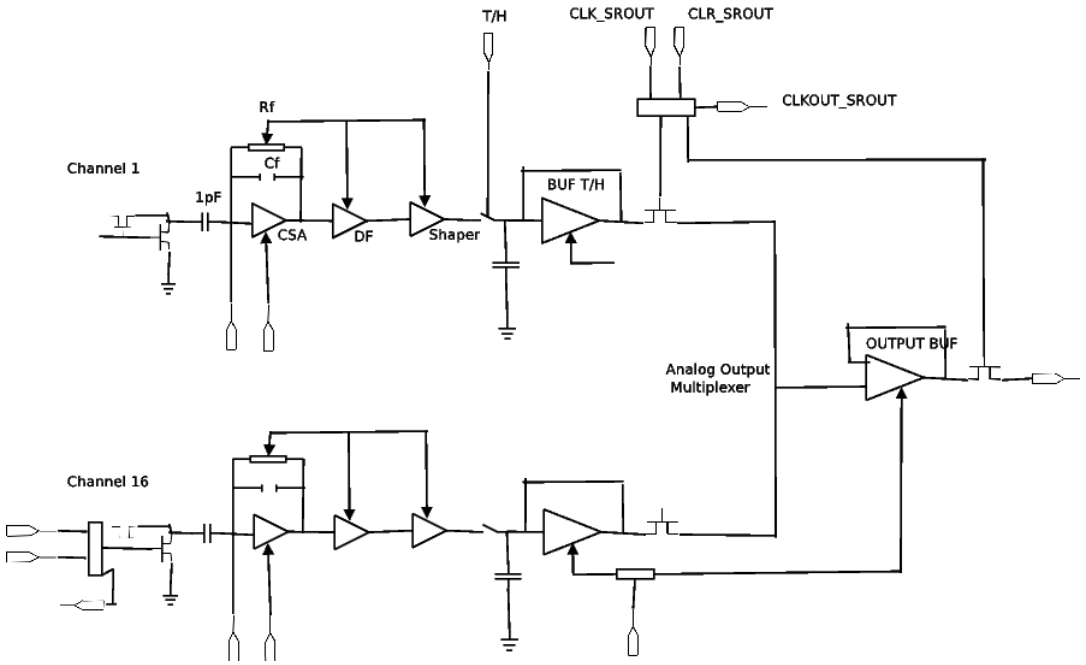


Detector Prototype



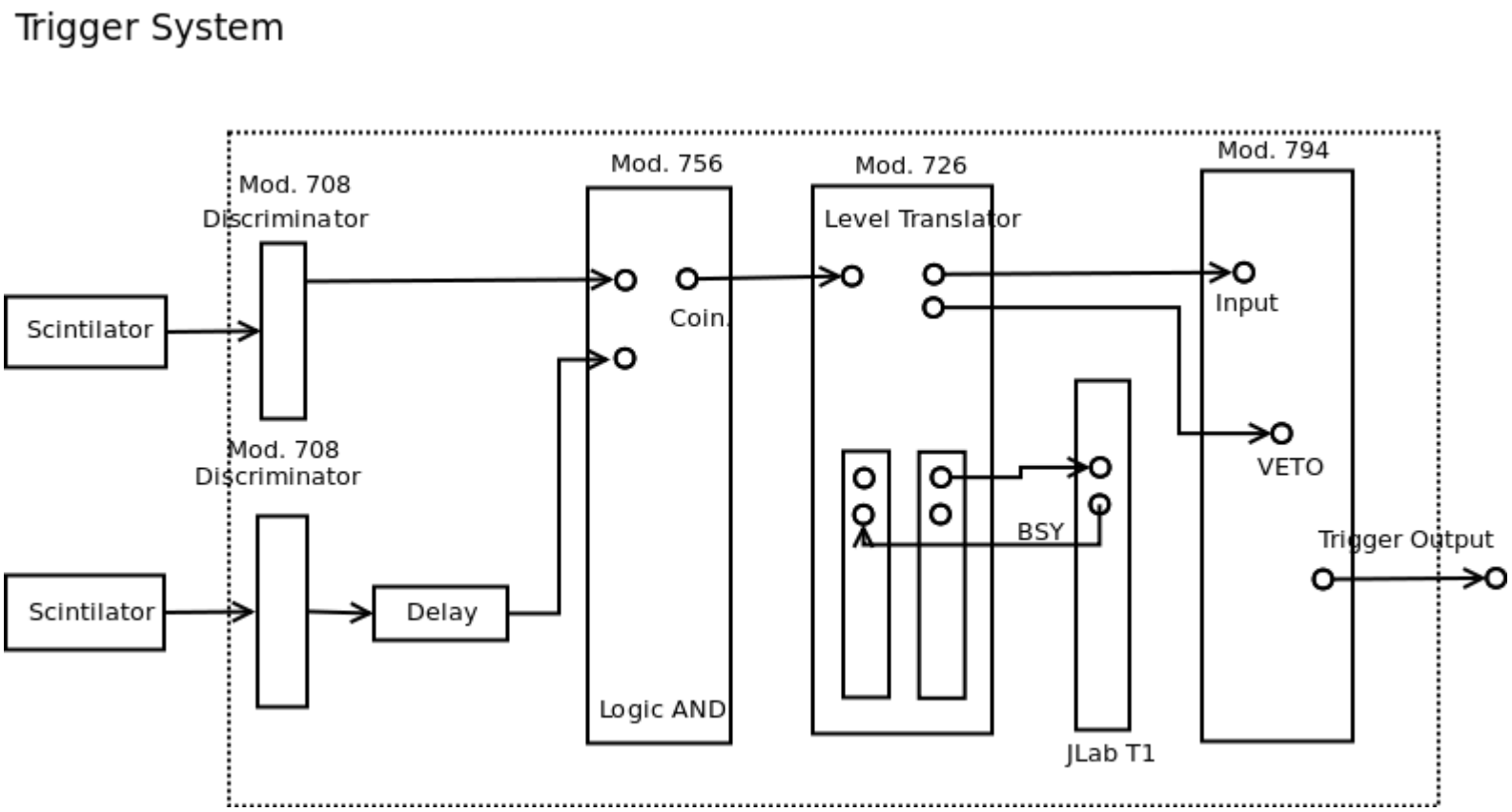
Readout Chip

Gassiplex Readout (not optimized for negative charge), 700 ns shaping time.



Gassiplex Functional Module

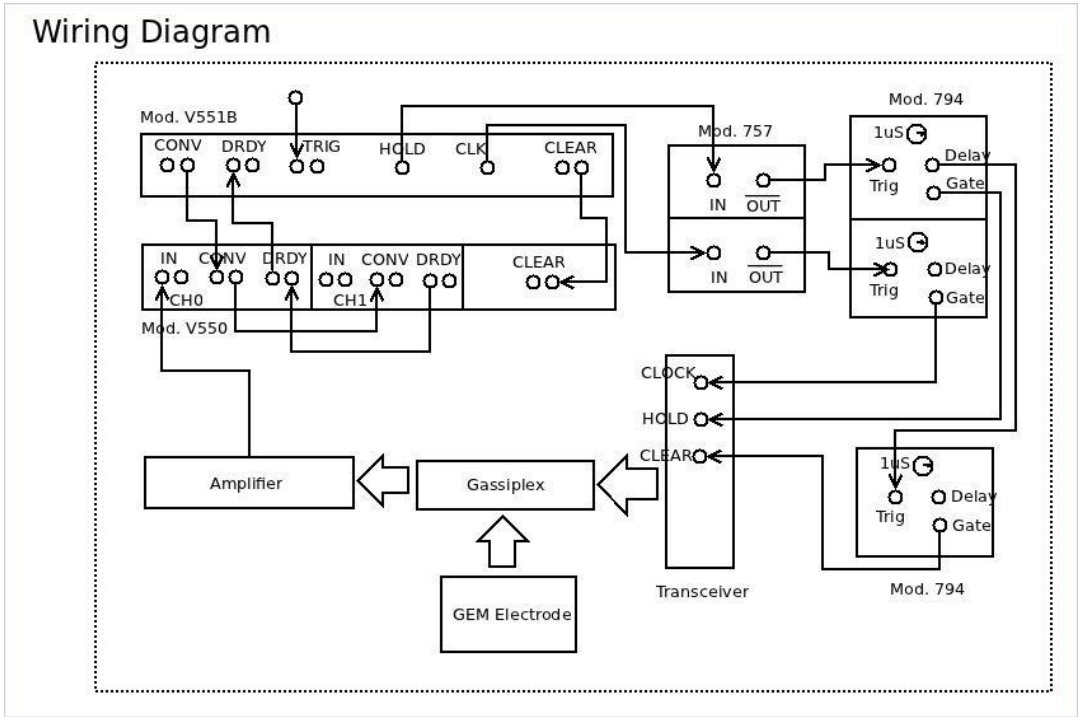
Trigger System



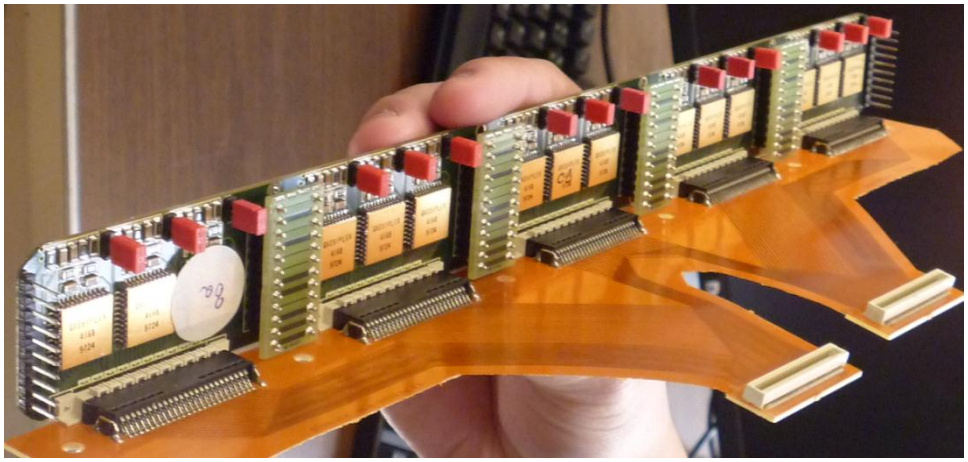
Electronic System

1. Mod V551b controls the time sequence.

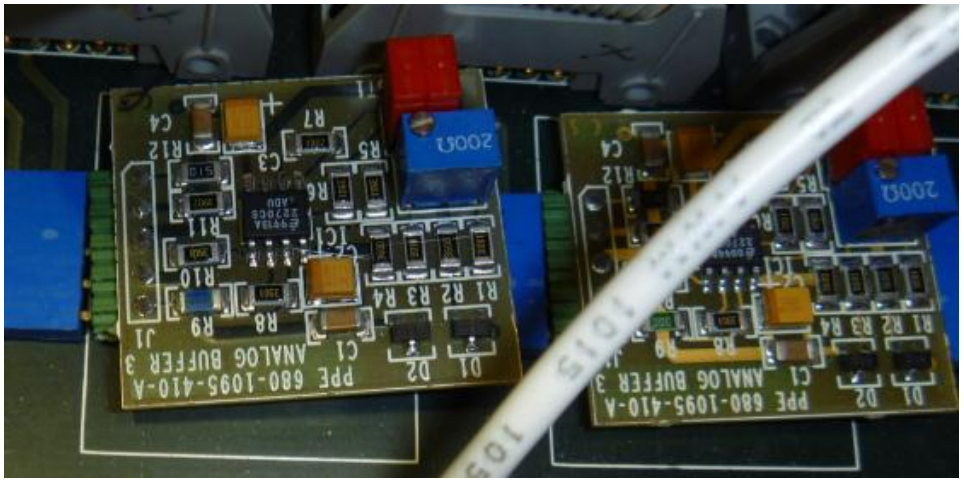
2. Mod V550 as the ADC Module.



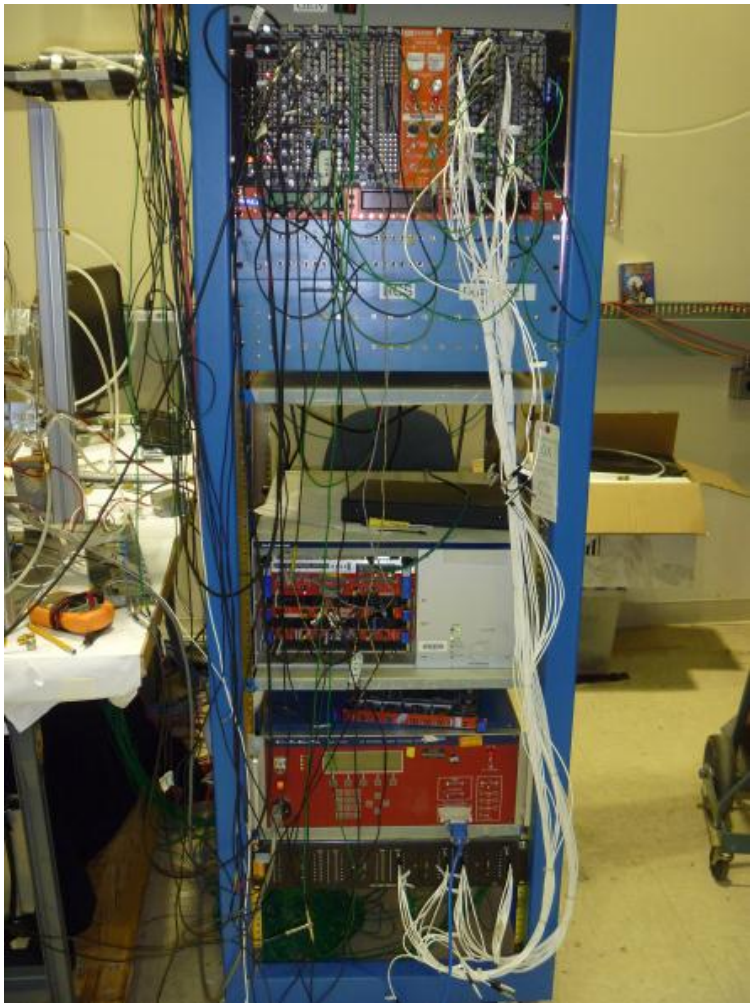
Electronic System



Gassiplex Board

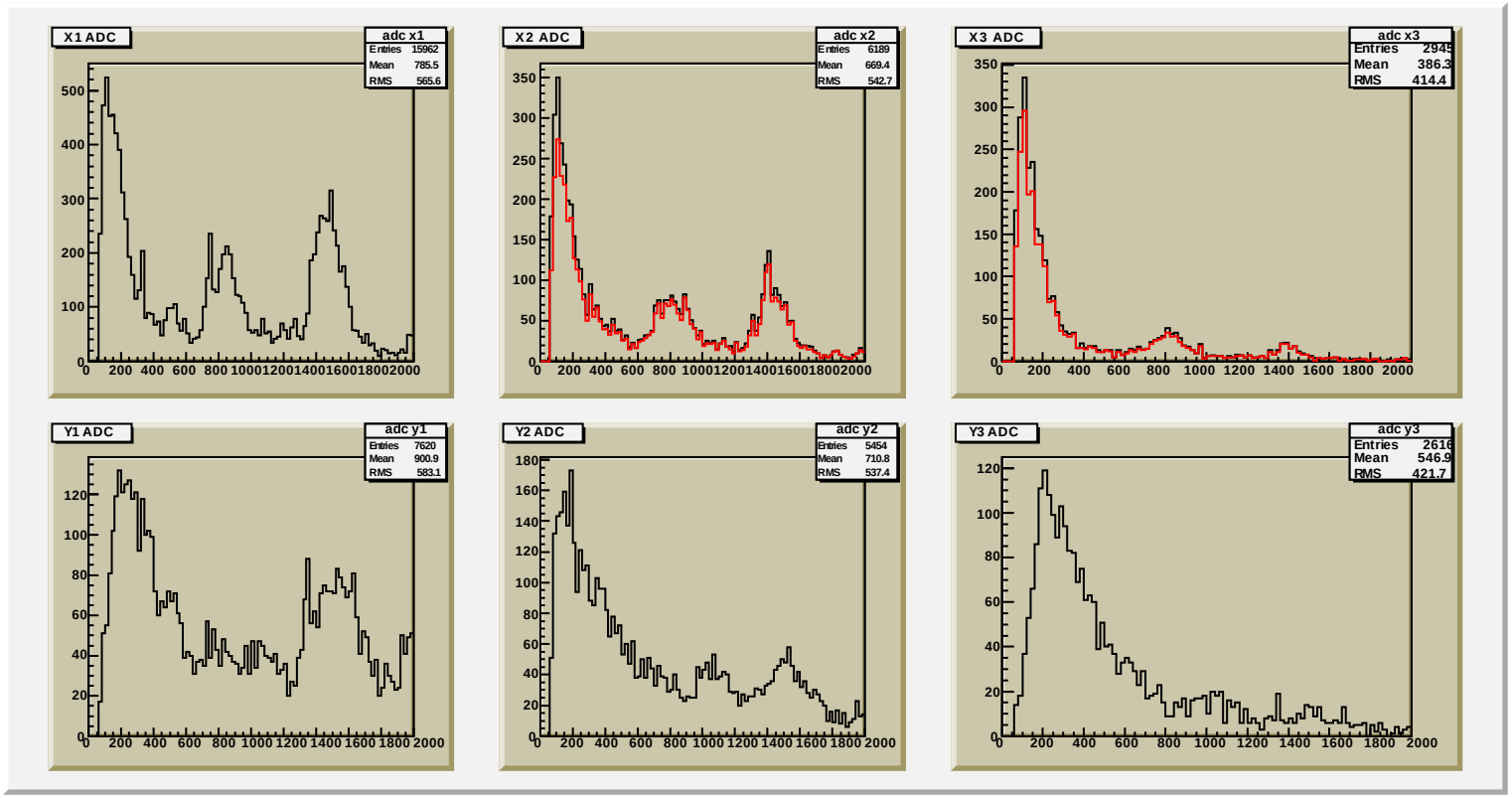


Pre-Amplifier



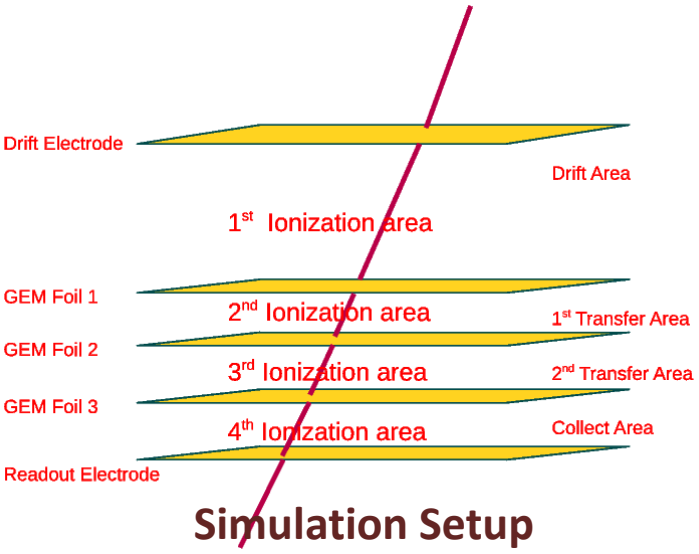
Electronics System

ADC Distribution

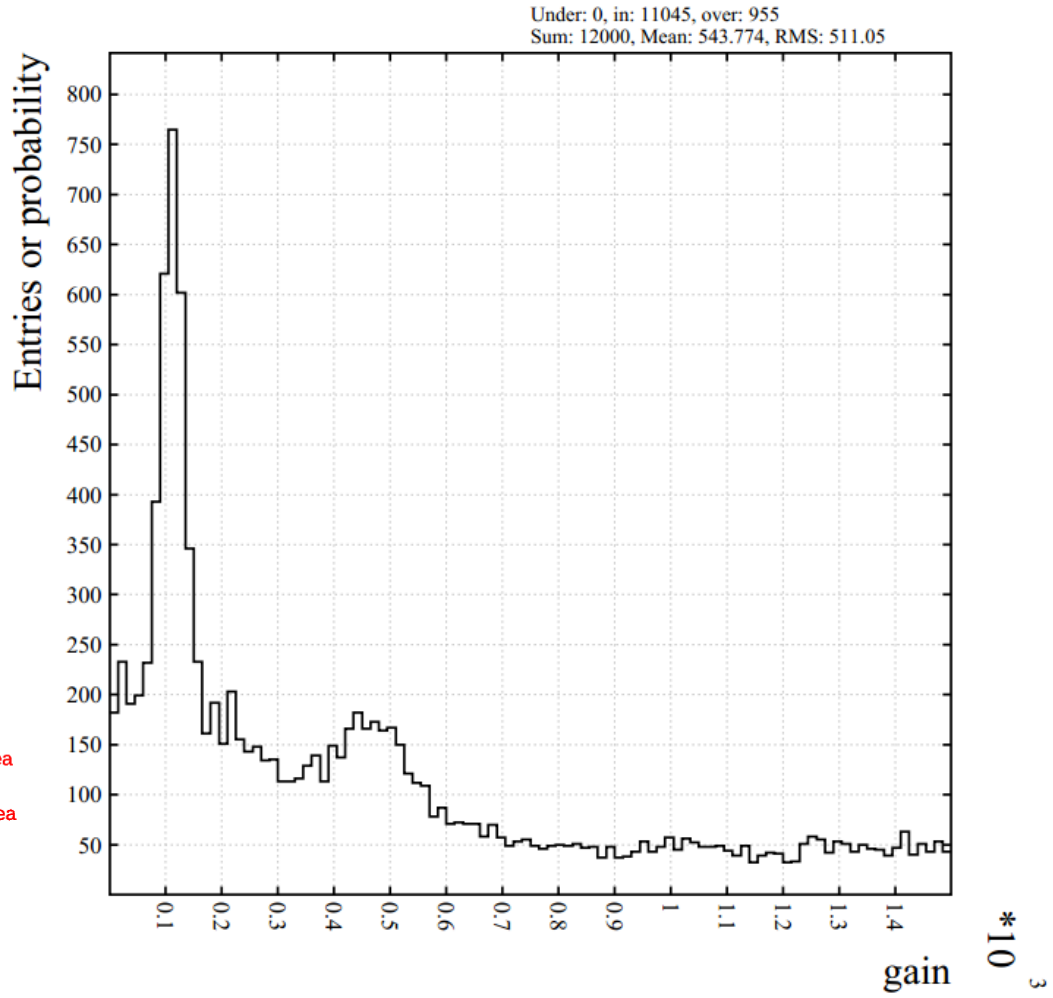


ADC Distribution from Simulation

1. We can produce two peaks of the three.
2. The third peak is difficult to get due to the unstable gain.

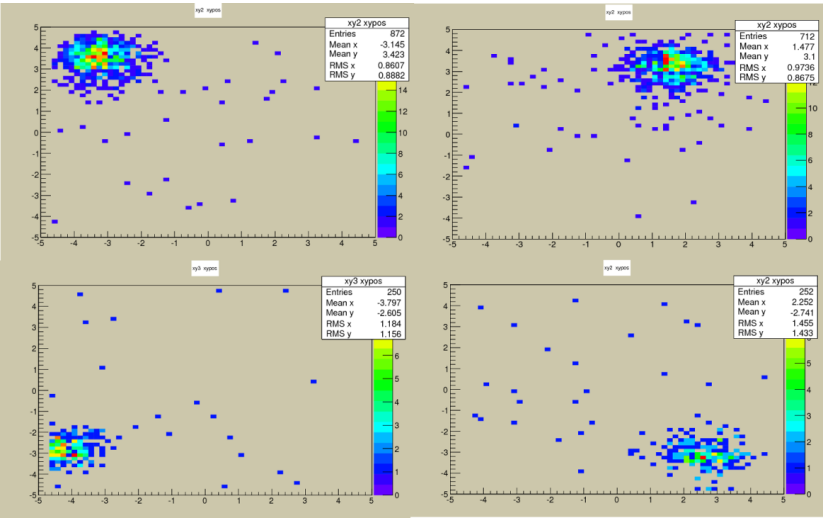


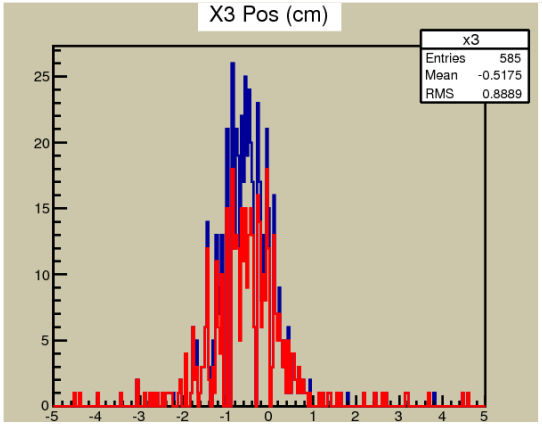
Simulation Setup

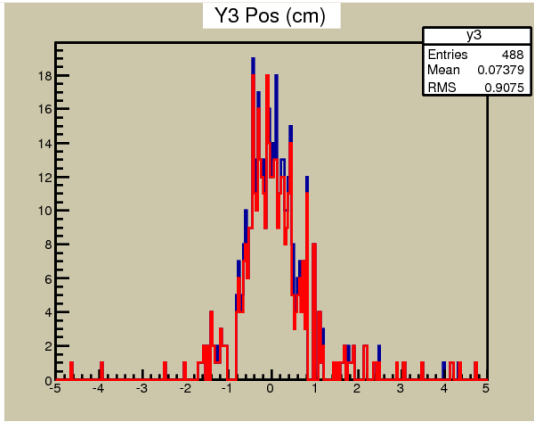


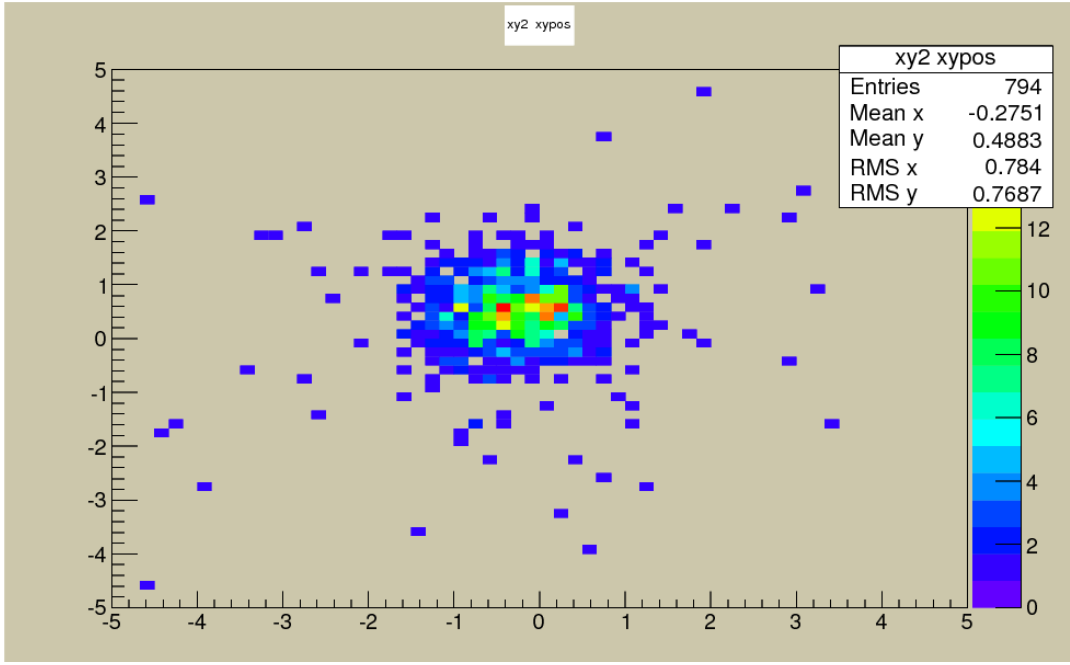
Simulation Results

Radiation source results









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Summary

1. We got some preliminary simulation results.
    - Gain
    - Spatial Resolution
    - Counting Rate
    - Transparency
2. Further study of GEM foil
3. We will compare results from simulation and experiments in details.

Thank you!