14th Workshop on European Collaboration in Higher Education on Radiological and Nuclear Engineering and Radiation Protection

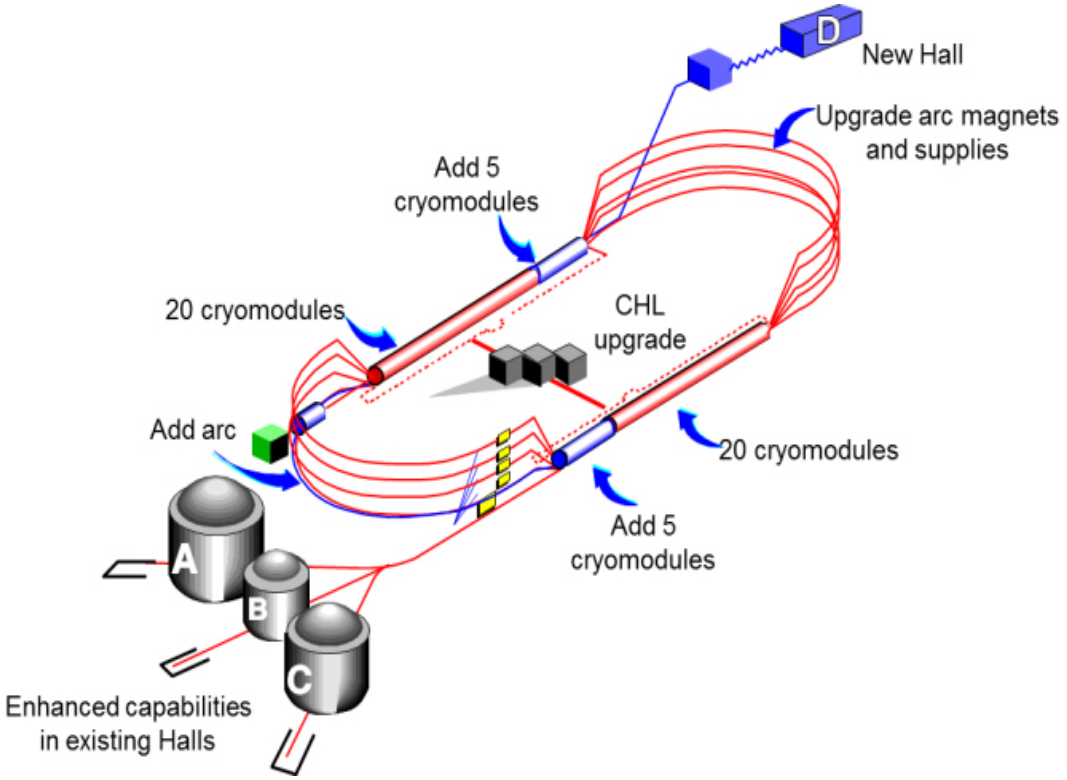
Tuesday 29 May 2018 - Friday 1 June 2018
Macugnaga (VB), Italy

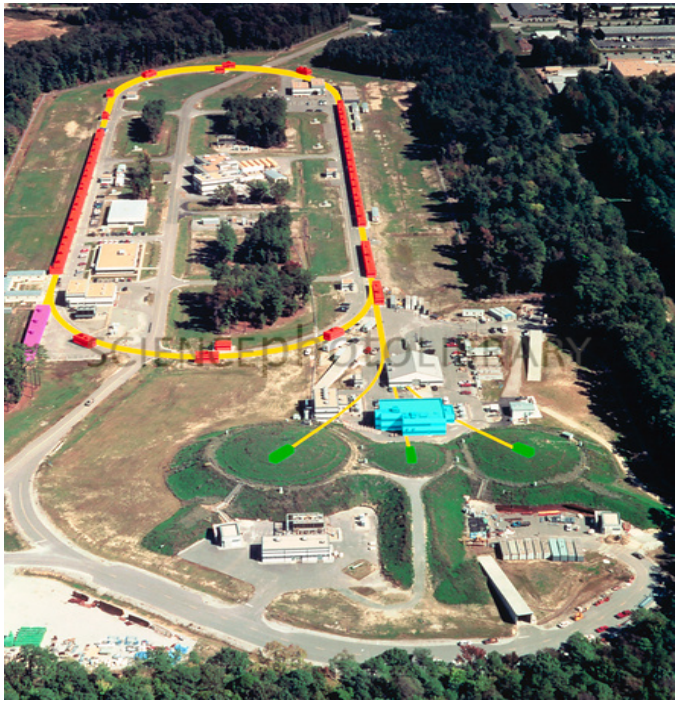
CHARACTERIZATION OF THREE GEM CHAMBERS FOR THE SBS FRONT TRACKER AT JLAB HALL A

Talk outline

The Continuous Electron Beam Accelerator Facility

Jlab Newport News (VA)





The high luminosity
(polarized) CEBAF electron beam:

- Current: up to 100 μA
- Energy: up to 12 GeV
- Longitudinal polarization: up to 85%
- 4 Experimental halls: A, B, C and D

Main Research fields

- Nucleon Form Factors
- Nucleon Structure
- Search for Exotic Mesons
- Nucleus Structure
- Parity violation

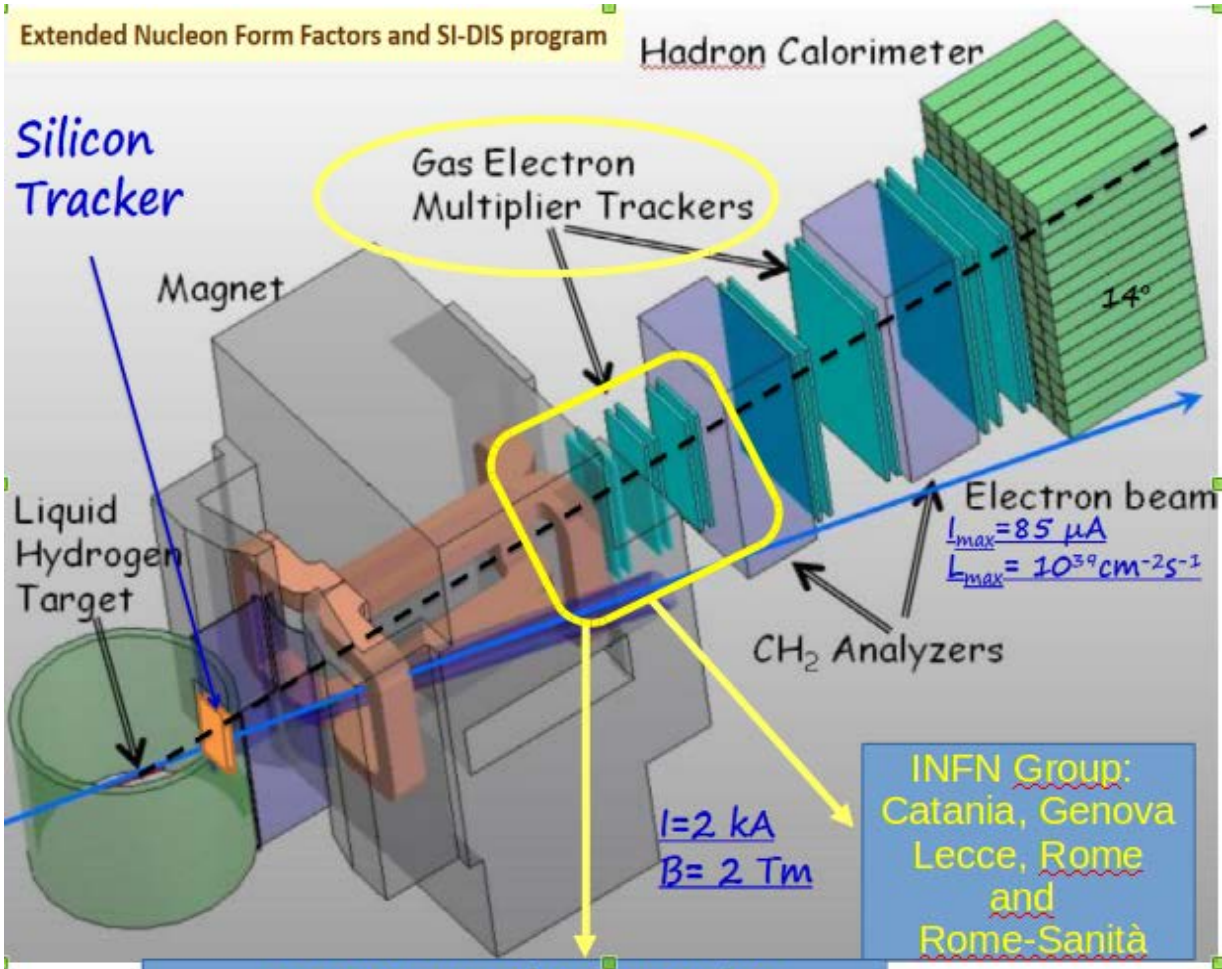
SuperBigbite Spectrometer (SBS) in Hall A

A Large-Acceptance forward angle Spectrometer is under commissioning at JLAB Hall A

- Large luminosity: 10^{38} $cm^{-2}s^{-1}$
- Moderate acceptance: 64 mrad
- Forward angles: down to 7 degrees
- Large momentum range: 2-10 GeV/c

Flexibility:
use the same detectors in different experimental setup

- SBS will consist, in its full configuration:
- Silicon tracker 10 x 20 cm^2
- Magnetic dipole
- 3 stations GEM planes (Front and Back)
- 2 CH_2 polarimeters
- Hadron Calorimeter (HCal-J)



Approved experiments for the CEBAF

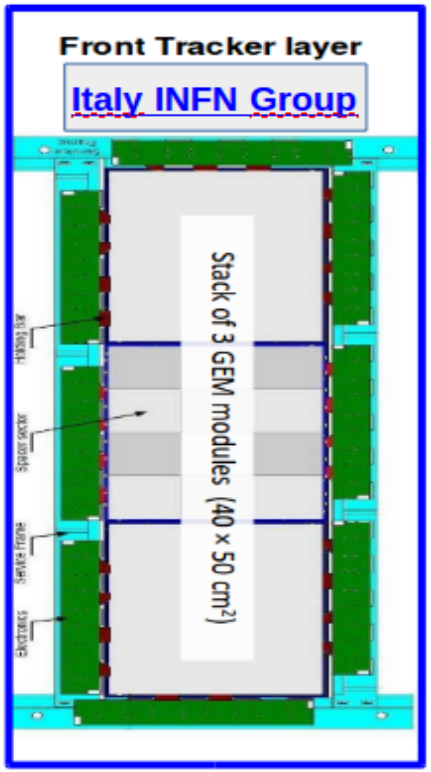
6 experiments that will use the Gas Electron Multiplier (GEM) Front Tracker

Reference	Label	Full Title	Apparatus
E12-17-004	GEn/GMn	Measurement of the Ratio $^2H(\vec{e}, e' \vec{n})p$ Reaction by the Double-polarized	BB(*) and NP
E12-09-016	GEn2	Measurement of the neutron electromagnetic form factor ratio at high Q^2	SBS and BB(*)
E12-09-019	GMN	Precision measurement of the neutron magnetic form factor up to Q^2=18.0 $(GeV/c)^2$ by the ratio method	SBS and BB(*)
E12-09-018	SIDIS	Measurement of the semi-inclusive pion and kaon electro-production in DIS regime from transversaly polarized ^3H target using the Super Bigbite and BigBite spectrometer in Hall A	SBS and BB(*)
E12-07-109	GEp5	Large acceptance proton form factor ratio measurements at 13 and 15 $(GeV/c)^2$ using recoil polarization method	SBS(*) and BB
E12-06-122	A1n	Measurement of neutron spin asymmetry in the valence quark region using 8.8 GeV and 6.6 GeV beam energies and Bigbite Spectrometer in Hall A	HRS and BB(*)

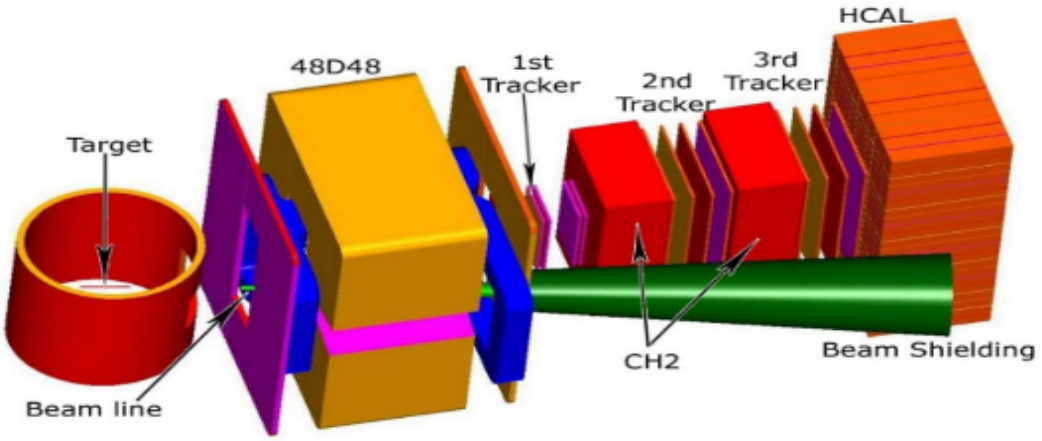
HRS: High Resolution Spectrometer
BB: BigBite spectrometer
NP: Neutron Polarimeter
(*) indicates in which spectrometer the INFN GEM Front Tracker will be included

FRONT TRACKER CHAMBERS

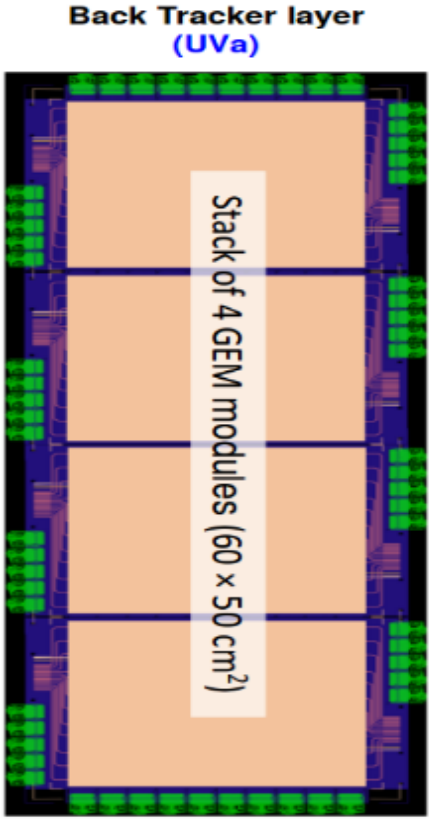
- Use of Gas Electron Multiplier (GEM) technology
- Modular design: one layer (chamber) consists of 3 independent GEM modules (40x50 cm^2) with small dead area
- Electronics around the module, direct connection; 90 degree bending between modules
- External support frame in carbon fiber (long bars) to minimize thermal deformation



- **Front Tracker (FT): Track of the recoil protons**
  - ⇨ **1st tracker:** 6 GEM layers, active area of 150 × 40 cm^2
  - ⇨ **Layer:** vertical stack of 3 GEM modules (50 × 40 cm^2)
  - ⇨ **Production:** 18 modules (+3 spares)
- **Back Trackers (BT): Polarimetry of the recoil protons**
  - ⇨ **2nd & 3rd Trackers:** 2 × 5 layers, active area of 200 × 60 cm^2
  - ⇨ **Layer**: vertical stack of 4 GEM modules (60 × 50 cm^2)
  - ⇨ **Production:** 40 modules (+ 8 spares)



Hadron arm in GEp(5)



Why GEM detector?

The SBS tracker system requires:
- High rate (~ MHz/cm^2)
- Good spatial resolution (< 100 μm) in trackers.

Gas Electron Multiplier detectors
provide a cost effective solution for high resolution tracking
under high rates over large areas

Comparison between different detectors

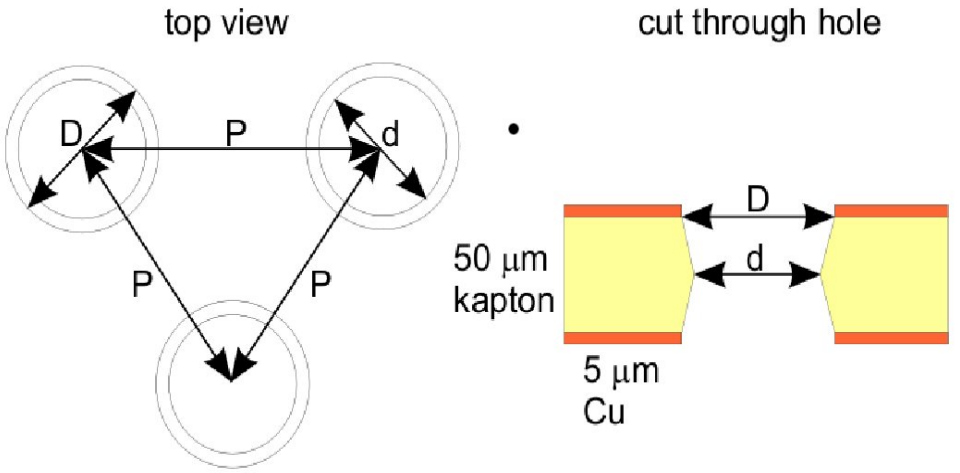
Detector	Maximum gain	Maximum hit rate [MHz/cm^2]	Spatial resolution [μm]
Silicon microstrip	/	Limited by electronics	~1-10
Triple GEM	~10^5	~100	~70-80
MSGC	~10^4	~10	~60
GEM	~10^3	~100	~70-80
Drift chamber	~10^3	~1	~50-150
MWPC	~10^3	~1	~200

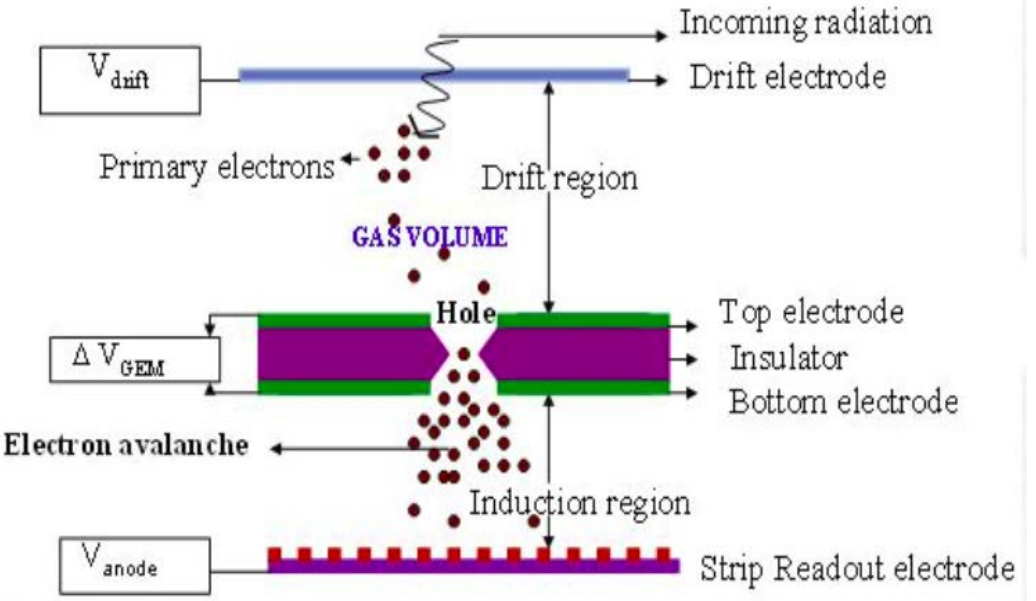
MSGC: MicroStrip Gas Chamber
MWPC: Multi Wire Proportional Chamber

GEM Technology 1/2

A Gas Electron Multiplier is a type of Gaseous Ionization Detector (GID)

- GID are able to collect the electrons released by ionizing radiation, guiding them to a region with a large electric field, and thereby initiating an electron avalanche up to create a charge large enough to be detected by electronics
- A GEM module consists of a detector with inside one or more GEM foils immerse in a gas mixture (tipically Ar/CO_2 70/30 or 75/25 %)

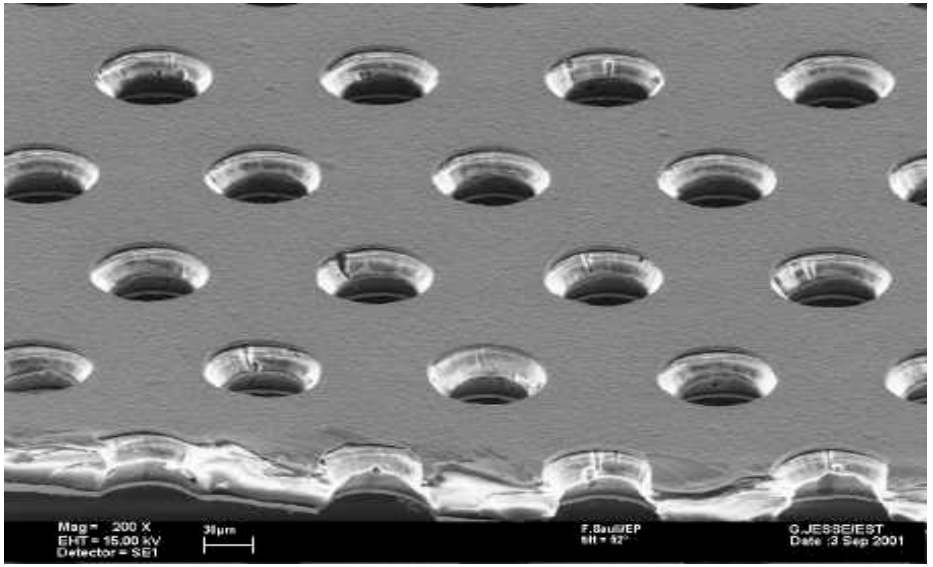


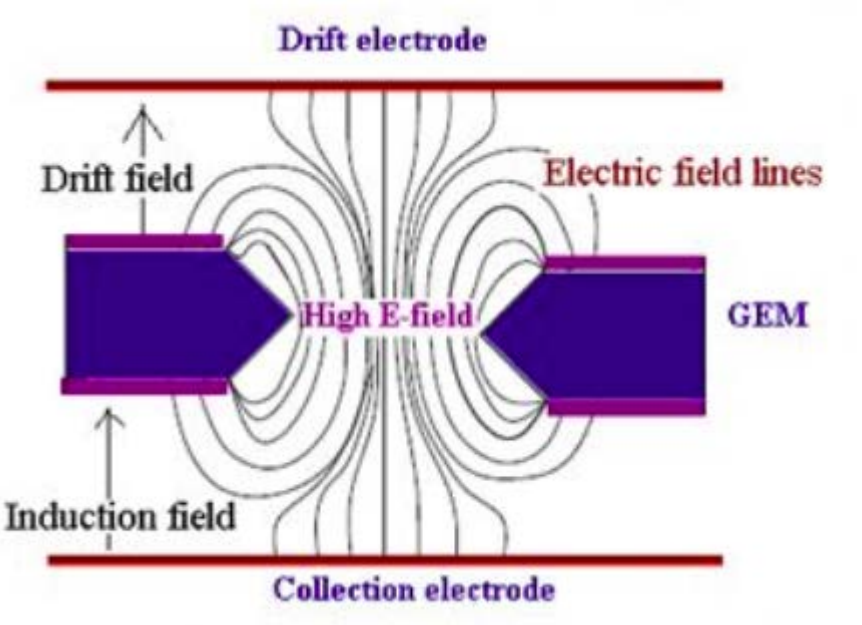


GEM foil:
50 µm thick Kapton + few µm copper on both sides
with holes: 70 µm major diameter (D),
50 µm minor diameter (d) , 140 µm pitch (P),

ΔV ~ 300-500 V

GEM Technology 2/2





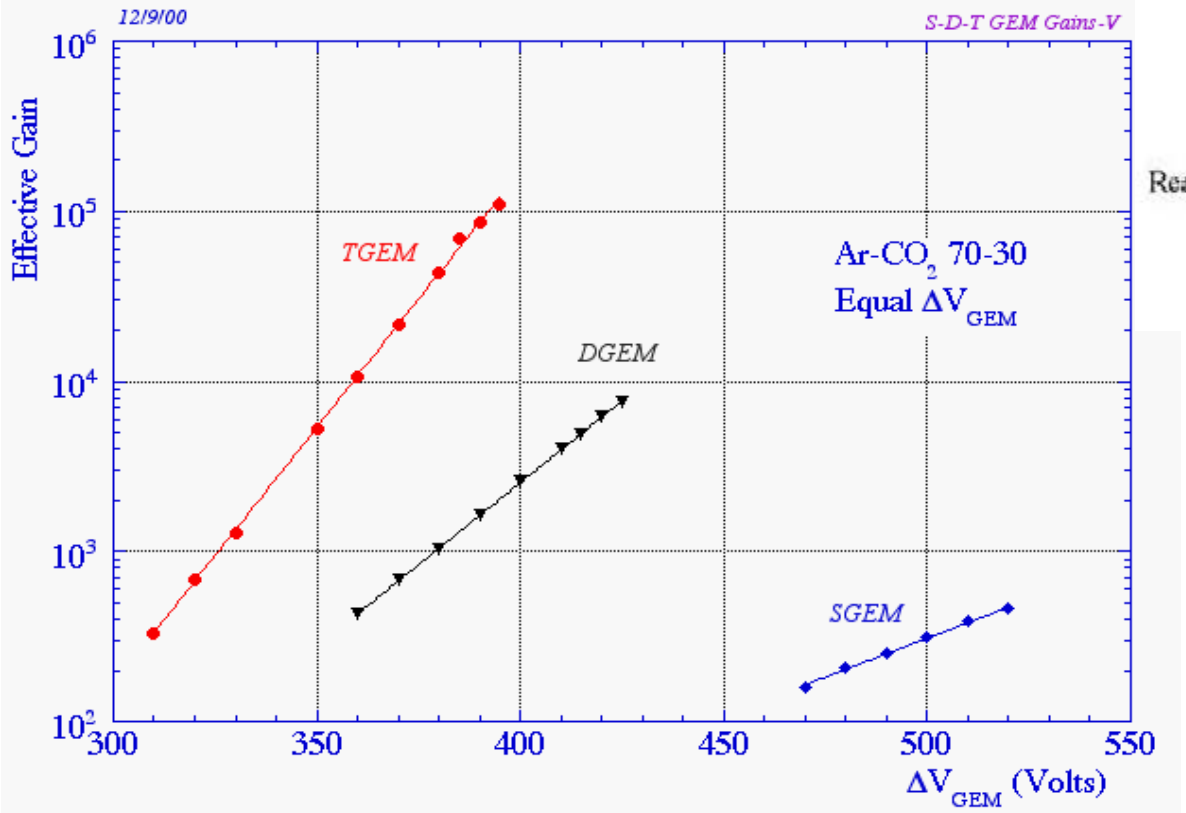
- Each foil is made by holes (biconical), arranged in a regular array
- Applying HV between the 2 copper sides creates a strong electric field in the small holes of a thin Kapton foil
- The avalanche occurs inside these holes
- WARNING: applying a too much high voltage (~ 500 V) might cause a breakdown between the foils

Triple-GEM detector

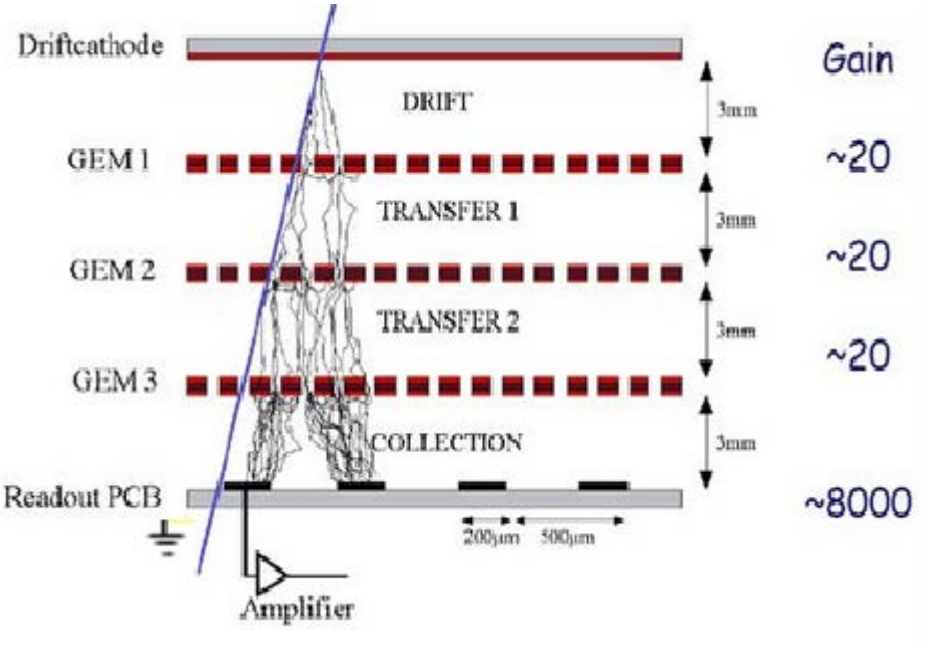
The best configuration for assembling several GEM modules is the **TRIPLE GEM** one

- **The triple-GEM is made of 3 GEM foils**
- **Composition:**

  cathode,
  drift region,
  3 GEM foil (with 2 transfer region),
  induction region (collection),
  anode (readout plane ground connected).



Triple-GEM detector scheme



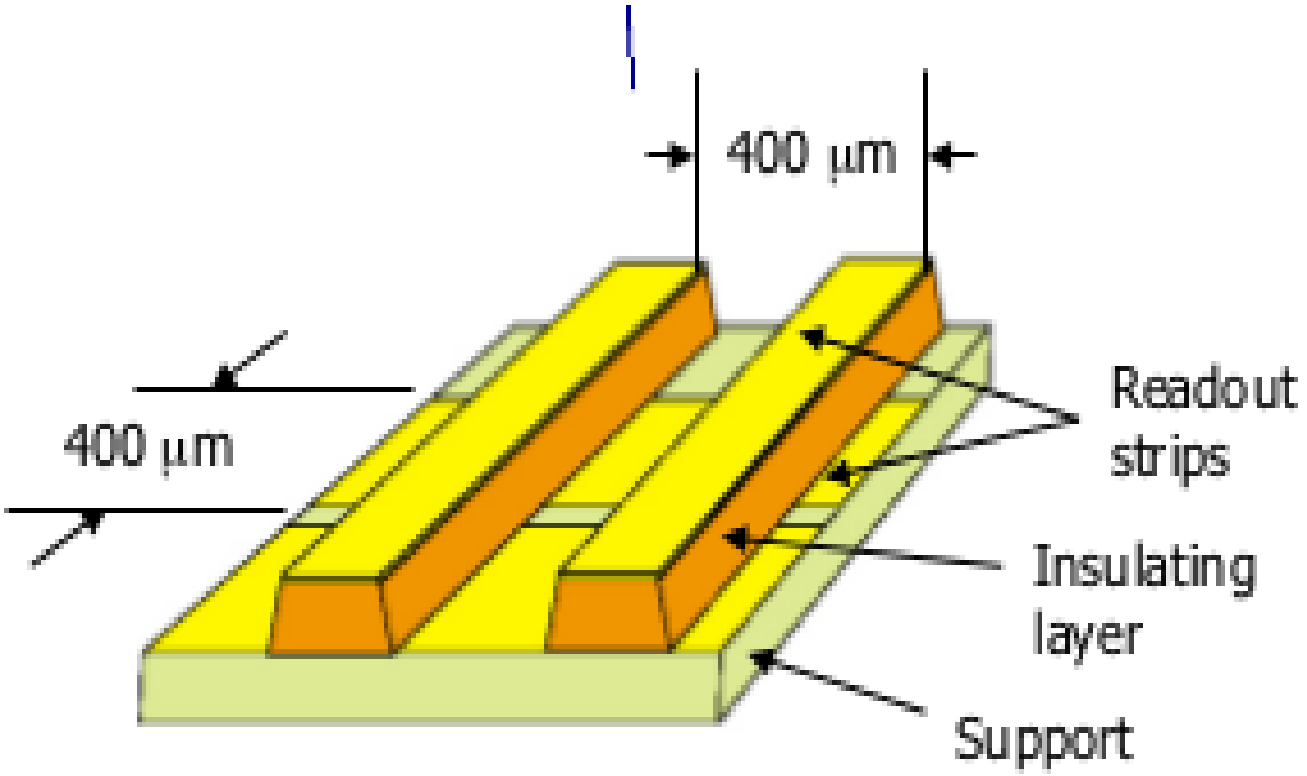
The use of a triple GEM allows to achieve a high gain without requiring too much high voltage applied to each foil

This configuration reduces the probability of discharge between the foils

Readout plane

- 0.5 μm thick copper strips, arranged in an array at 90° angle each other and made in such a way for the sake of collecting an equal charge distribution on the x and y coordinates

- In both layers, the strips have an extension (width + pitch) of 400 μm



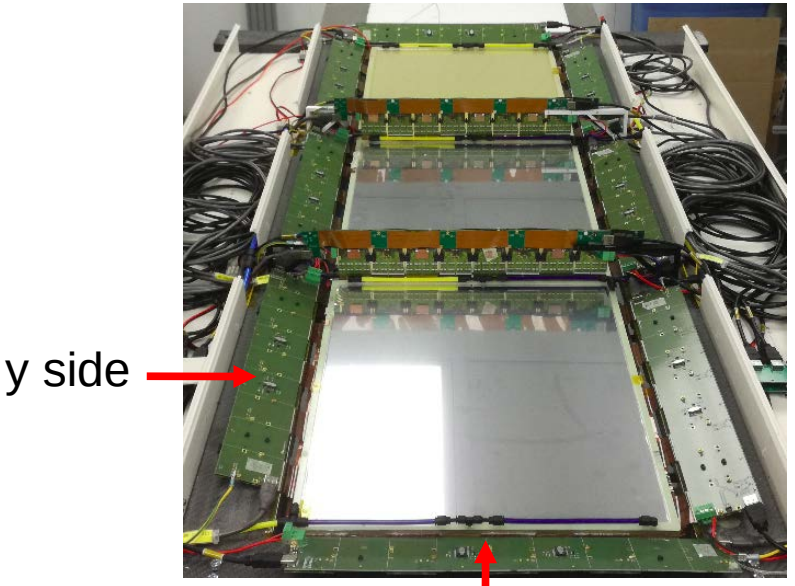
a typical readout plan is formed by a sheet of kapton copper on one side, with a strip pattern

Front-end electronic for SBS front tracker

- The electronic signals are acquired by one **Analogue Pipeline Voltage** (APV) **cards**
- Each card manage up to 128 channels
- 4 backplanes are assembled around each module in order to host the cards and provide the low voltage for the cards
- 18 APV cards are allocated on backplanes around each module:
  5 cards on y side (10 total cards on y)
  4 cards on x side (8 total cards on x)
- 2 **Multi-Purpose-Digitizer** (MPD) that collect the analog outputs of the cards
- Each MPD manage up to 16 APV cards

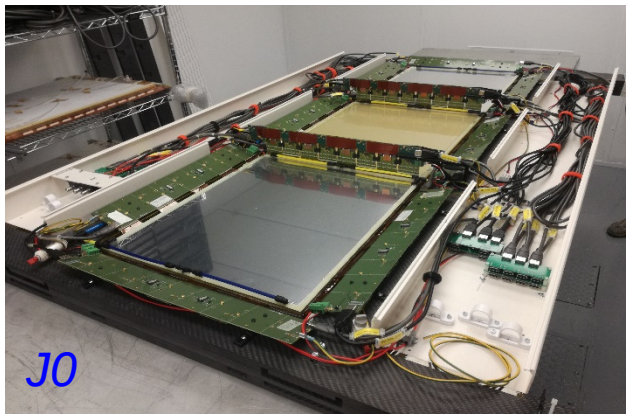
APV card

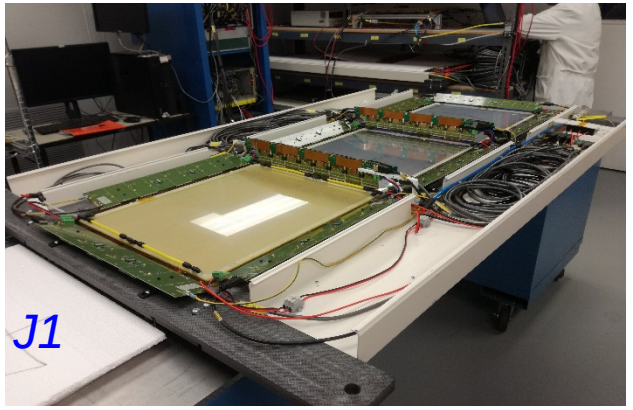
backplanes around the 3 modules

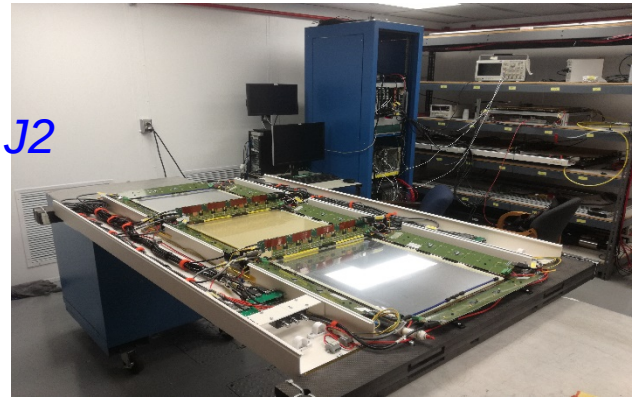


MPD

The first 3 GEM trackers at JLab







- The first tracker is called "*J0*" and its implementation was in July 2017
- J0 consists of:
  - module 15
  - module 9
  - module 12

15
9
12

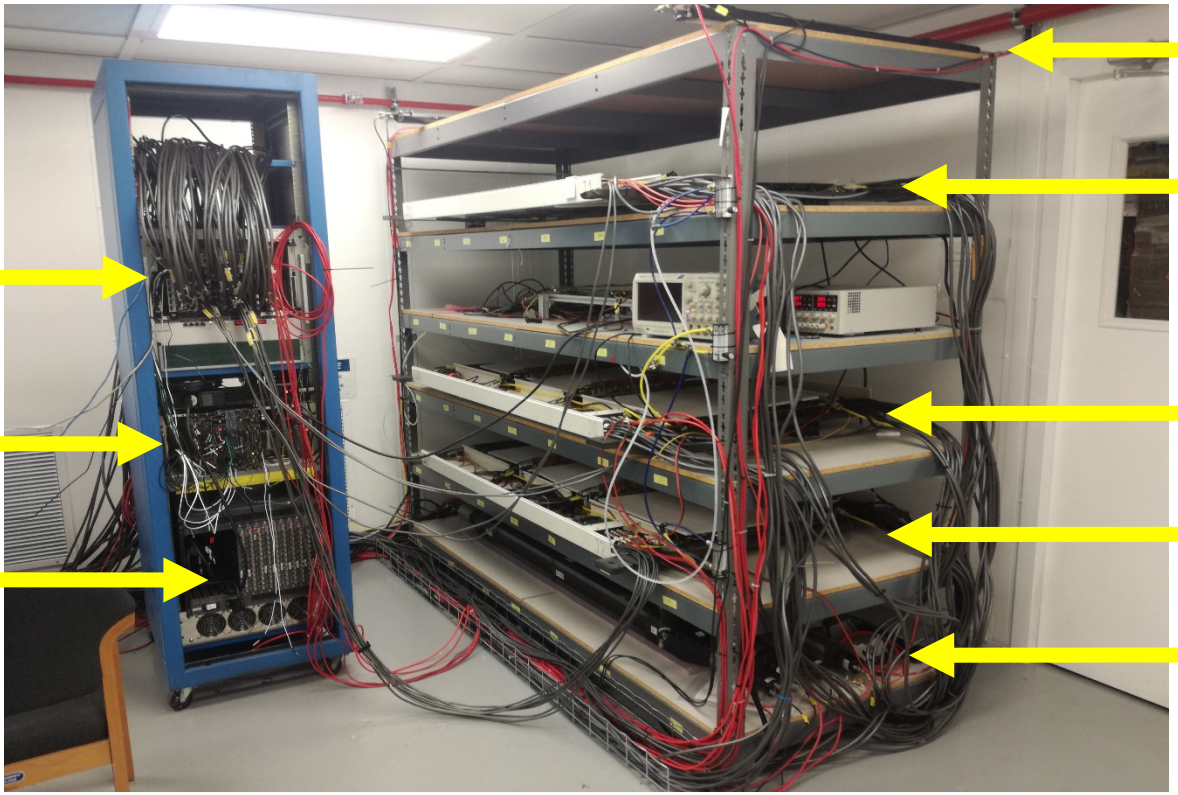
- The second tracker is called "*J1*" and its implementation was in November 2017
- J1 consists of:
  - module 11
  - module 14
  - module 13

11
14
13

- The third tracker is called "*J2*" and its implementation was in February 2018
- J2consists of:
  - module 4
  - module 0
  - module 1

4
0
1

Cosmic test stand at JLab



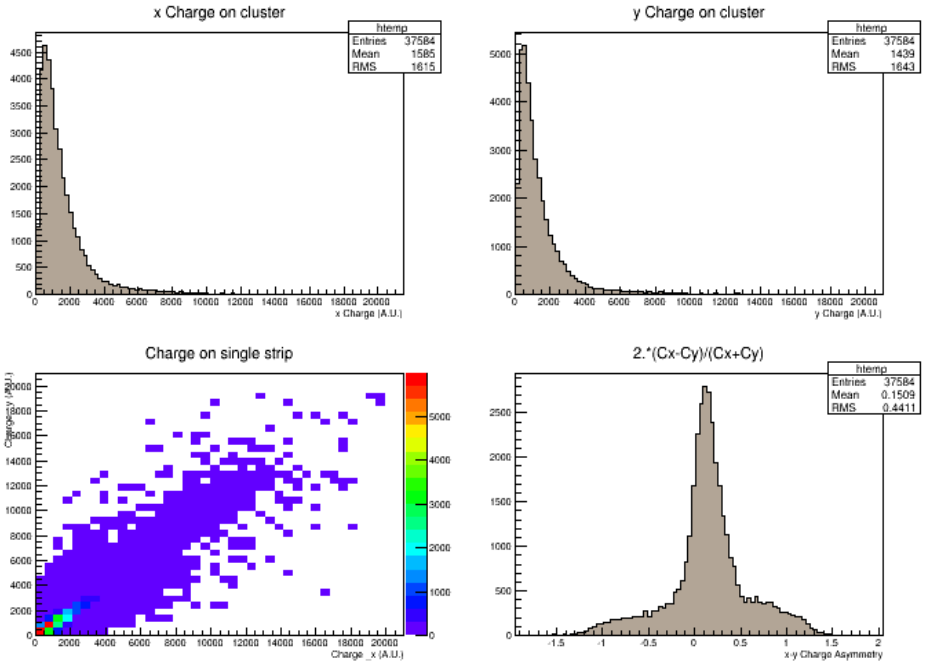
- 3 GEM chambers connected to 15 MPDs
- 162 APV cards connected
- 6 scintillator bars used as trigger (2 bars on the top and 4 smaller bars on the bottom; top and bottom cover same area)
- Gas mixture used at JLab: Ar/CO_2 (75/25 %)

TEST CURRENTLY IN PROGRESS

Cosmic test - J1- module 11
CLUSTER ANALYSIS 1/4

Different informations are gathered for each cosmic run, event by event:
- Charge collection
- Number of clusters (cluster = a group of adjacent strips.)
- (Cluster number)/event
- Cluster position

For example, we show only a few typical plots of one of GEM modules mounted on J1

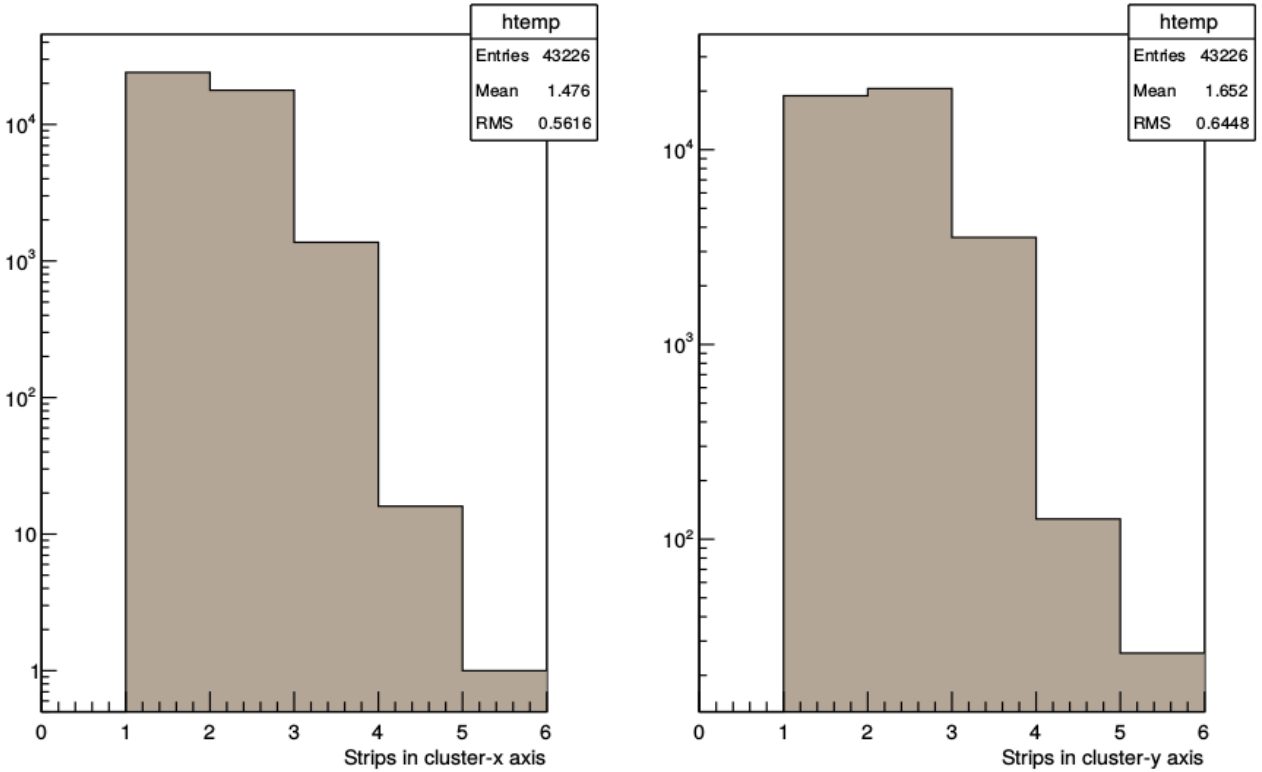


- Charge collection for each cluster, on x and y axis (top left and right respectively)

- Scatter plot and relative difference between the charge collected on x vs y axis (bottom left and right respectively)

The readout strips are made in such a way to collect an equal amount of charge in both coordinates; therefore the charge distribution on each axis is very similar to the other one; so the difference plot shows a peak centered around 0

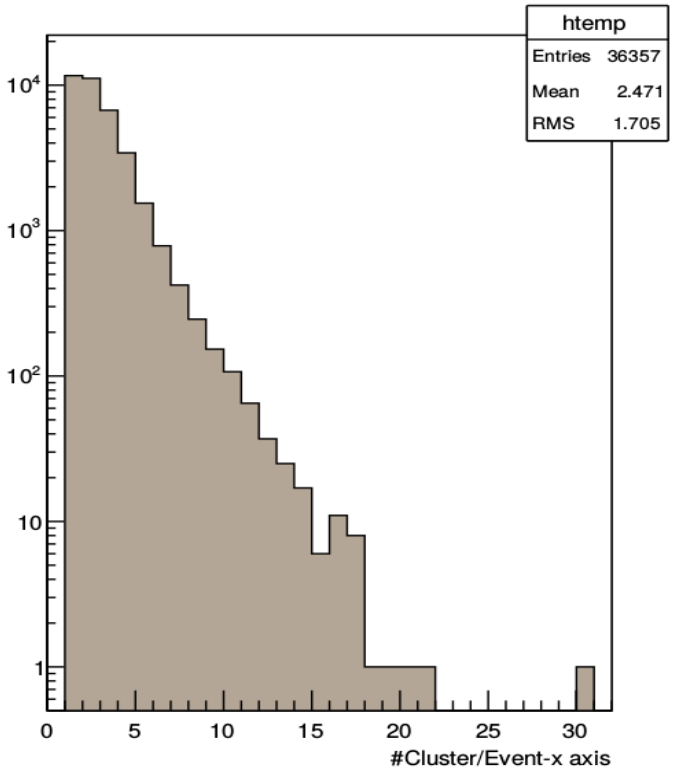
Cosmic test - J1- module 11
CLUSTER ANALYSIS 2/4

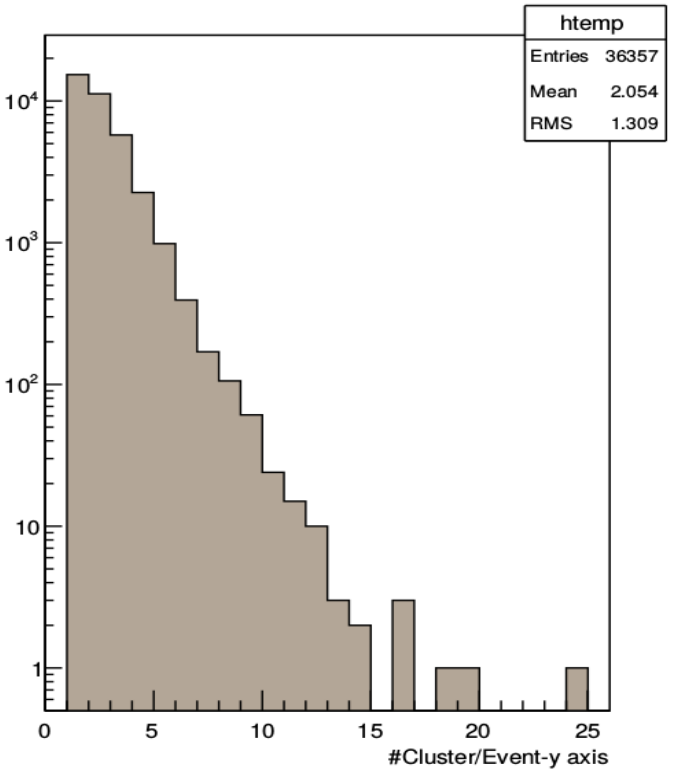


- Number of strips within a cluster (on x and y axis)

Considering that the electronic cloud collected from the strips is about 500 μm in size and the strips are 400 μm wide, therefore it is verified that a cluster consists of 1 or 2 strips, on average.

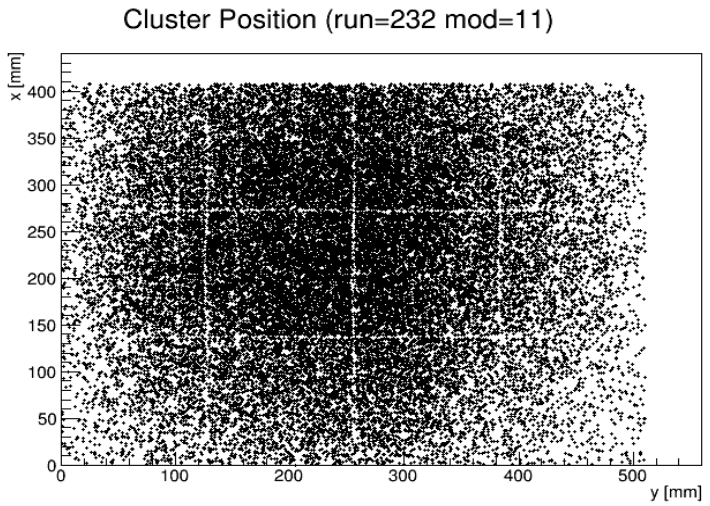
Cosmic test - J1- module 11
CLUSTER ANALYSIS 3/4





- Number of clusters formed for each event, on average 2 or 3 (on x and y axis)

Cosmic test - J1- module 11
CLUSTER ANALYSIS 4/4

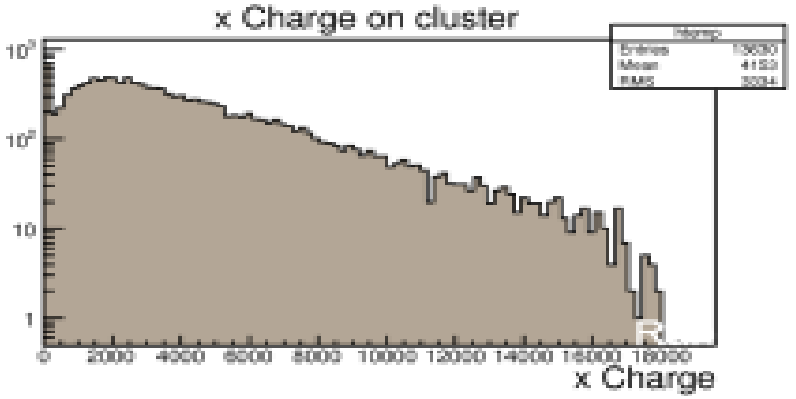


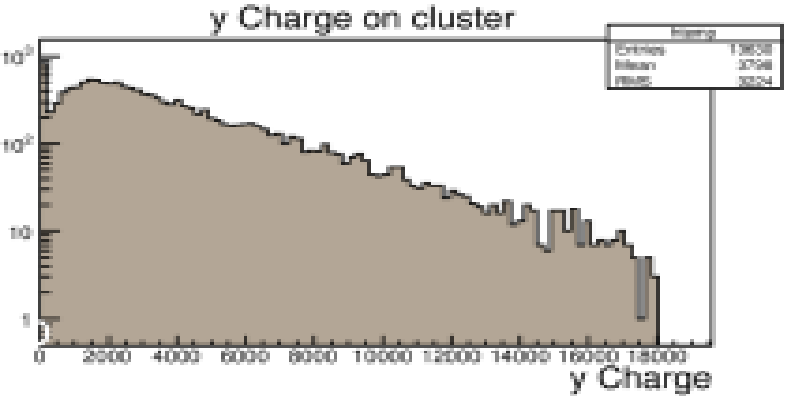
- The plot shows the mapping of the module 11 (cluster position)
- There is an almost complete coverage of the module and a good response in every sector of the module
- A slight inefficiency in the edges at the bottom, due to the not perfect alignment with the scintillators

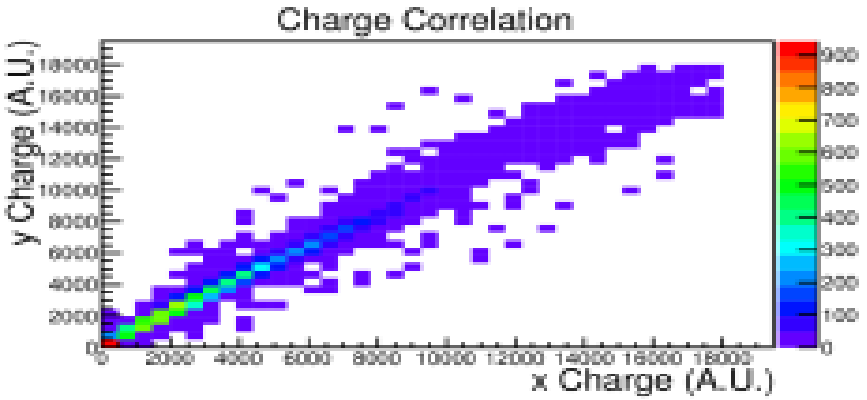
therefore the module 11 has been characterized in the correct way

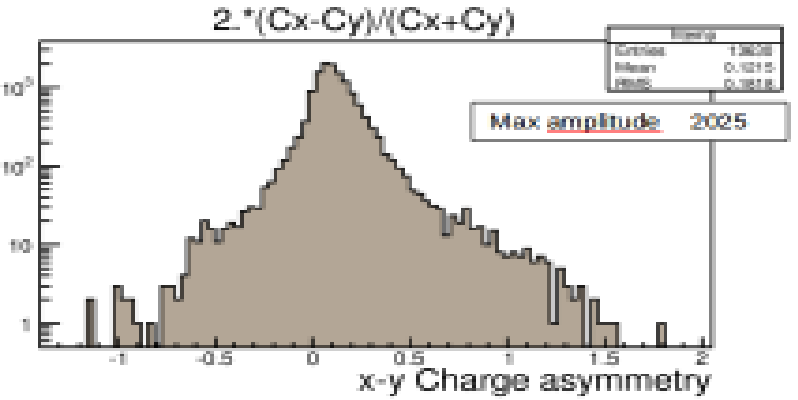
The same procedures are realized for all the other modules of trackers

Range 50-18000

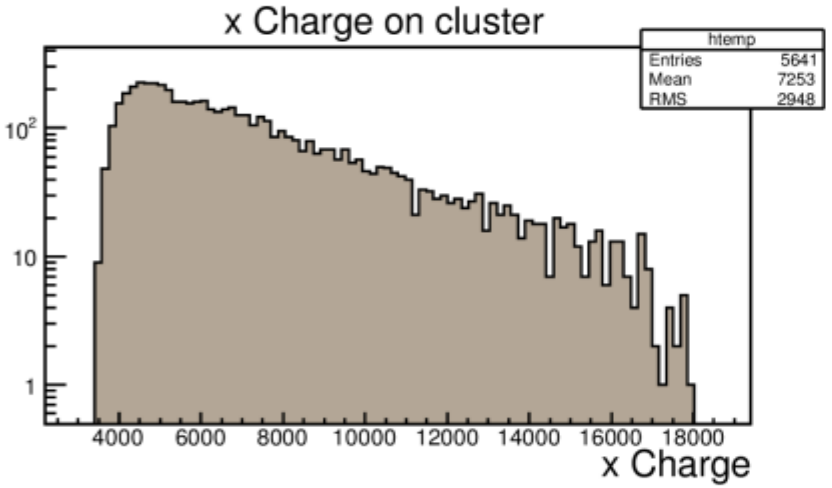


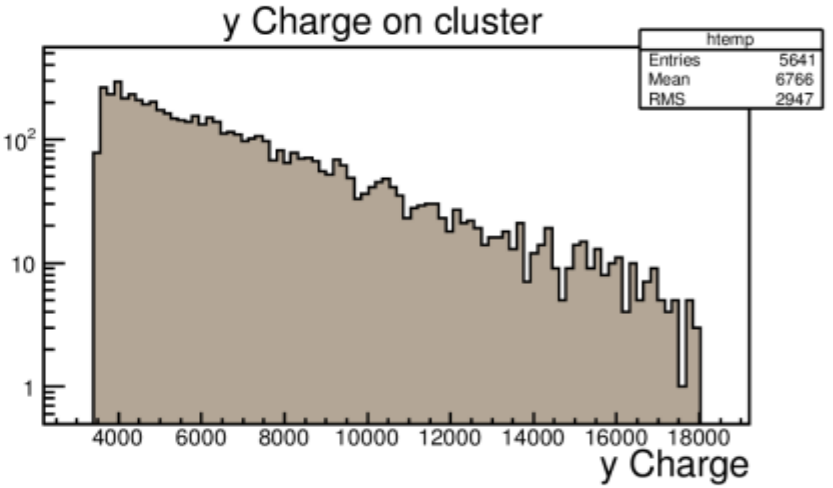


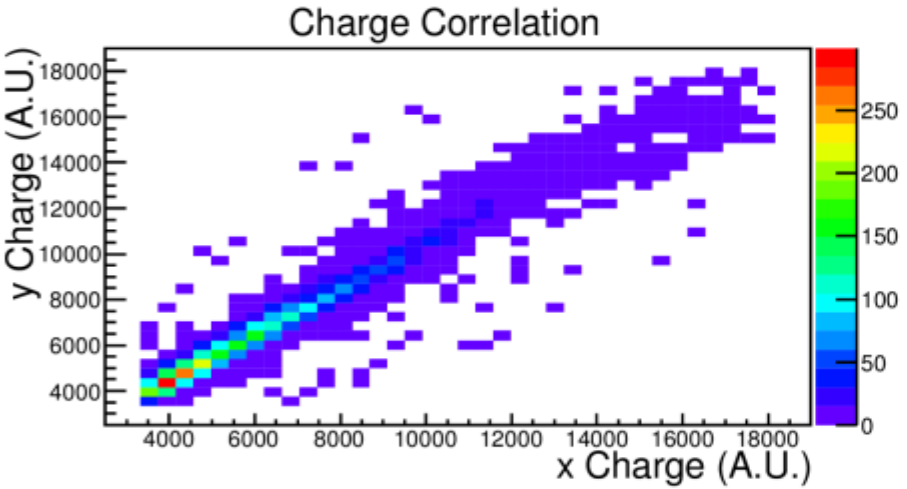


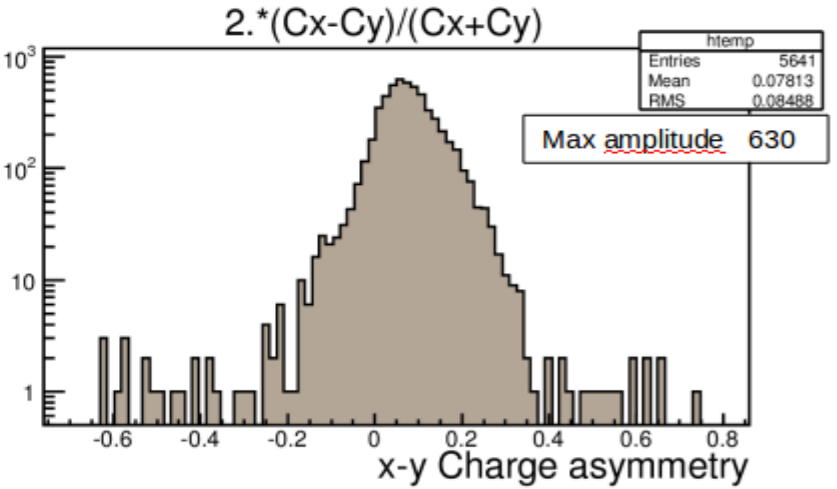


Range 3501-18000

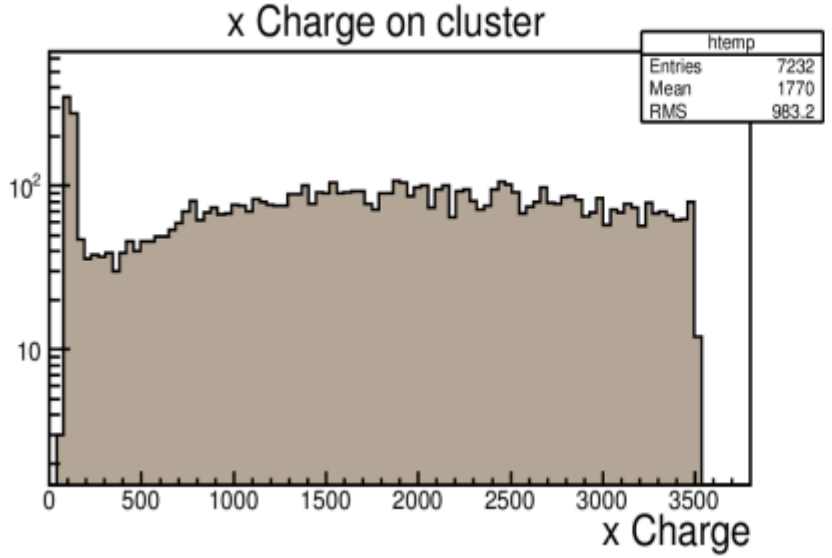


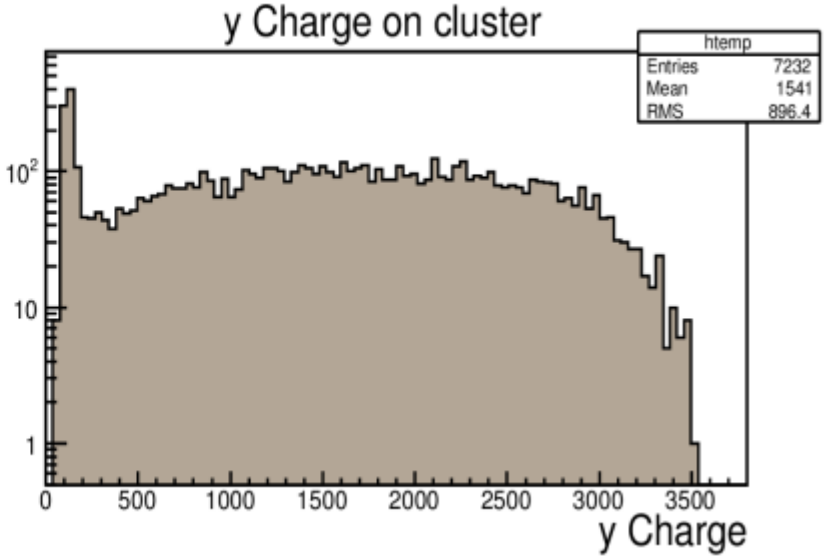


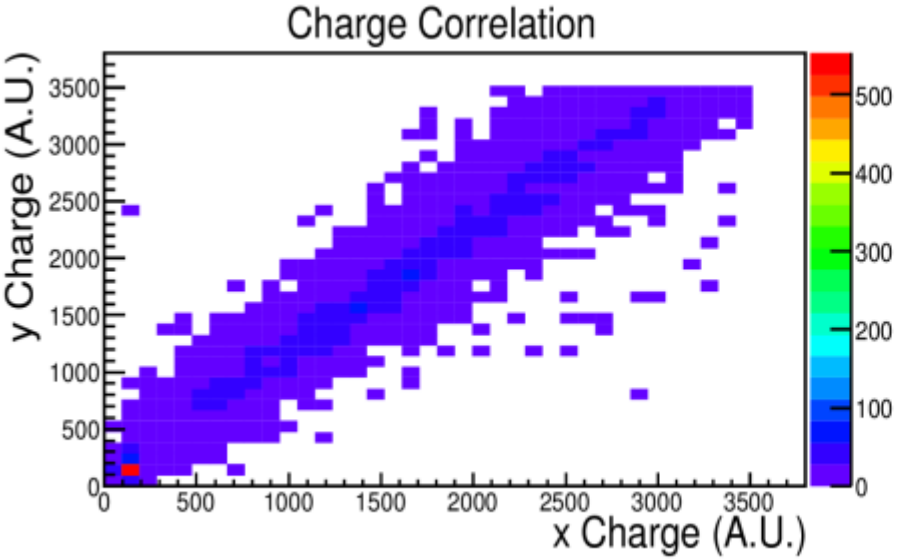


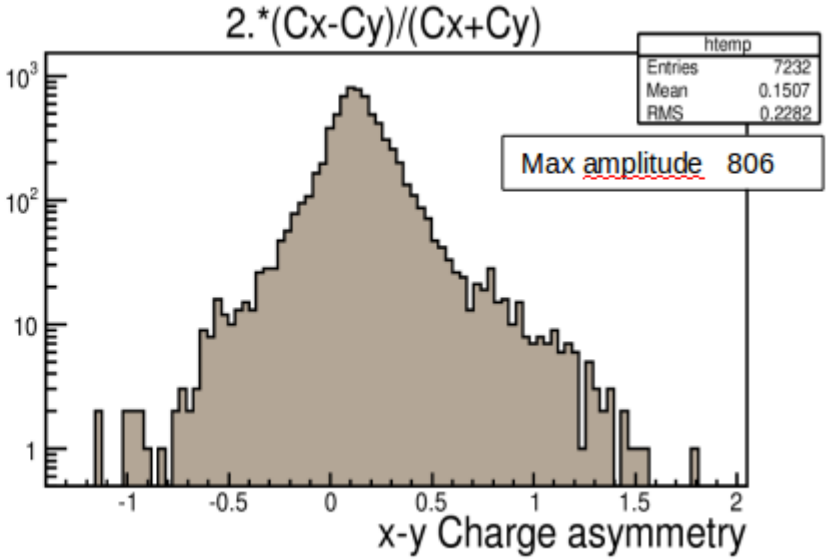


Range 50-3500









Perspective

1) The commissiong of the GEM Tracker will be achieved during the next year (2019)
2) The approved experiments using GEM tracker will be carried on during the next 3 years (2019-2021)
3) Hopefully our group will analyse and publish physical data starting from year 2020.