CPAD Instrumentation Frontier Workshop 2021

Virtual Event @ Stony Brook University, March 18-22, 2021

The CGEM-IT of the BESIII experiment:

preliminary results of the cosmic data taking

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On behalf of the CGEM-IT collaboration

INFN
Istituto Nazionale di Fisica Nucleare

FE
BESIII

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Outline

- BESIII @ IHEP
- CGEM-IT project
- CGEM-IT @ IHEP

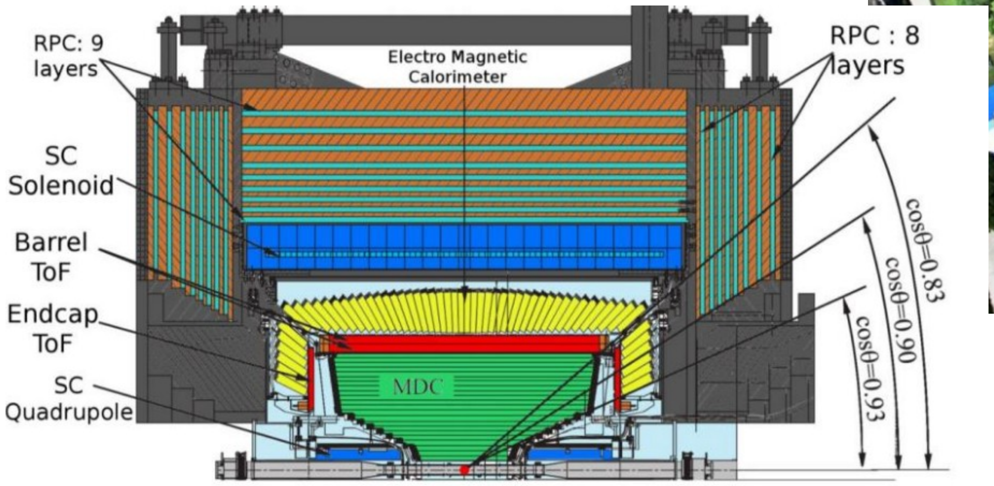
IHEP particle café

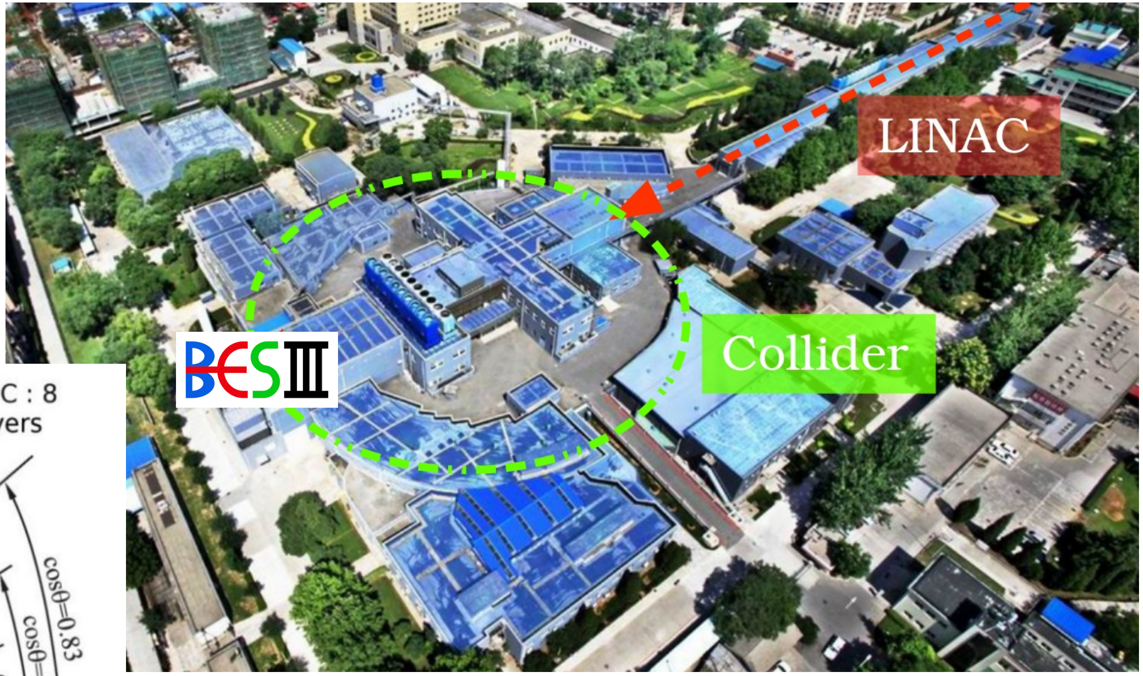
BESIII @ IHEP

BESIII is a central detector hosted at the leptonic collider BEPCII

The center of mass can span the 2-4.946 GeV energy range

Peak luminosity: 10^{33} cm^{-2} s^{-1}





BESIII has collected the J/psi world largest data sample (10B)

It has been approved an extension of the data taking for 10 years – presented white paper

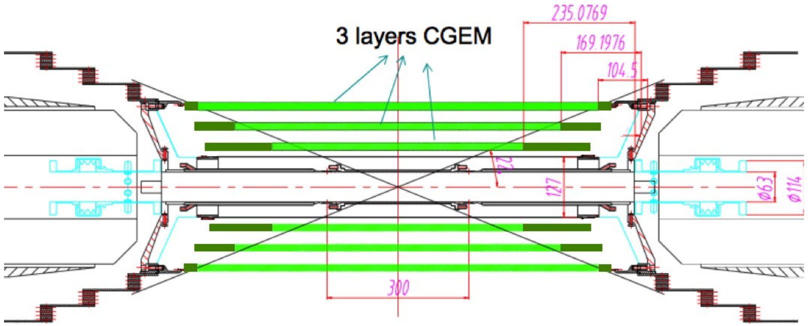
Chinese Physics C, vol. 44, no. 4, 2020

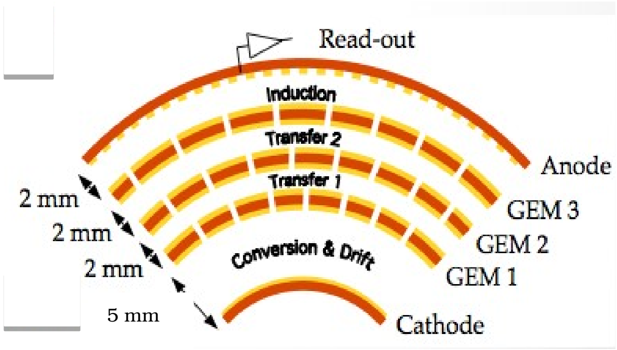
The upgrade of the inner MDC: CGEM-IT

Collaboration: INFN (IT) – Mainz (D) – Uppsala (SW) – Indiana (US) – IHEP (PRC)

Requirements:

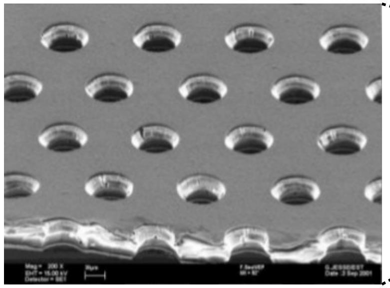
- **σ_{xy} ~ 130 μm**
- σ_z < 1 mm
- σ_{pt}/p_t ~ 0.5% @ 1 GeV/c
- **Operation in 1T magnetic field**
- Material budget < 1.5 X_0 for all layers
- Maximum rate: 10^4 Hz/cm^2
- 93% of 4π angular coverage
- Efficiency ~ 98%

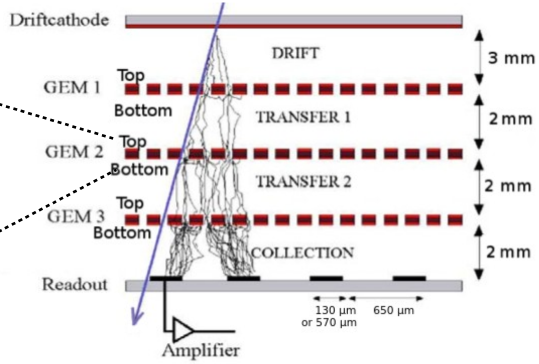




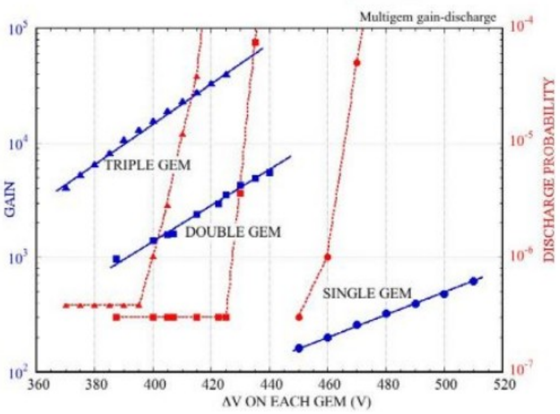
GEM detectors

GEMs (**G**aseous **E**lectron **M**ultipliers) are a well established Micro Pattern Gas Detector, firstly invented by Sauli in 1997



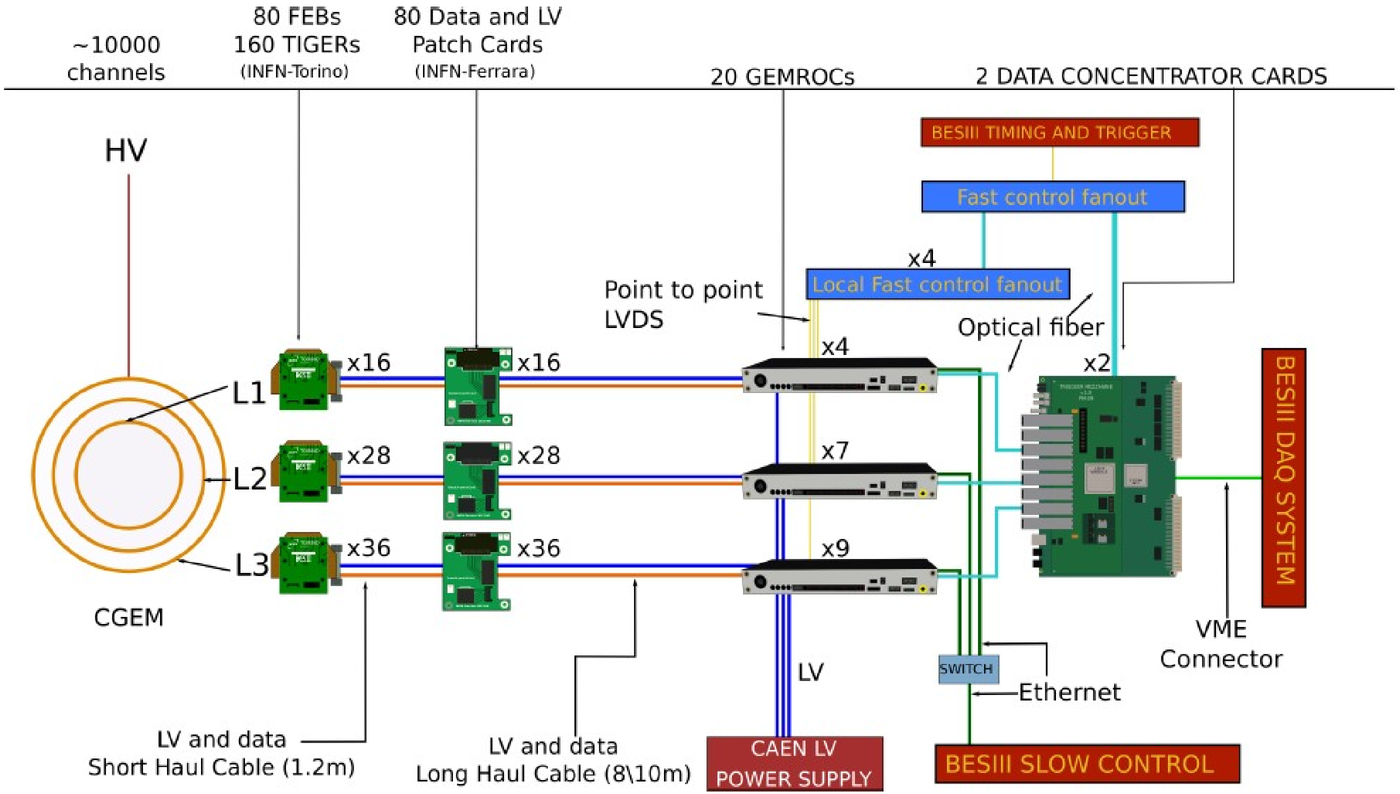


- High rate capability
- High radiation hardness
- Scalable and flexible geometry



Mature technology with very different fields of application

Readout chain



Composed by:

- On detector:
  - Front-End Boards
- Off detector:
  - Data-LV patch cards
  - GEMROC
  - Data concentrator
- Ancillary modules

Article in preparation

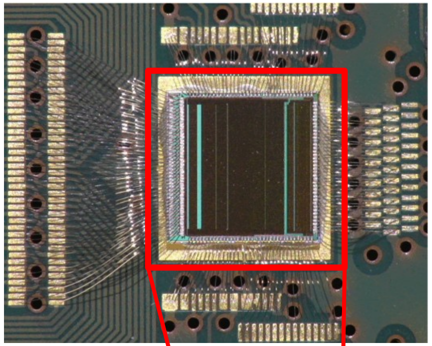
A dedicated ASIC: TIGER

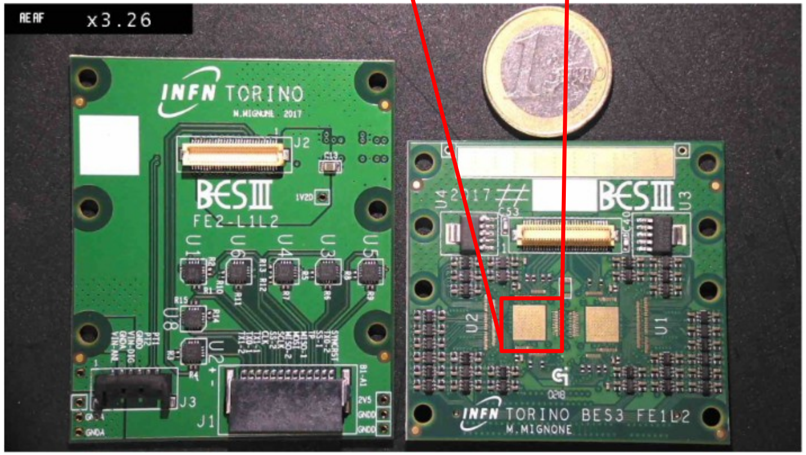
TIGER (Torino Integrated Gem Electronics Readout) is a 64-channels ASIC with simultaneous **charge** and **time** readout developed by INFN-Torino

It can operate in ToT and S&H readout mode

JINST 12 C07017

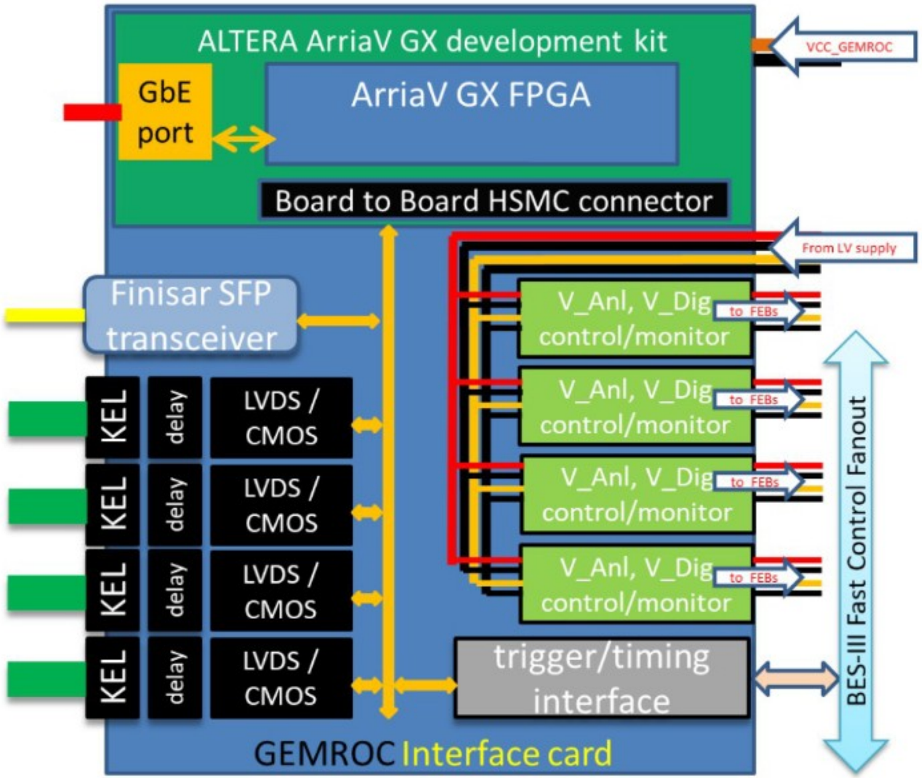
Parameters	Value
Input Charge	2-50 fC
Input Capacitance	Up to 100 pF
Data Rate	60 kHz/ch
Readout Mode	Trigger-less
Non-linearity	<1%
Charge Collection Time	60 ns
Time resolution	<5 ns
Power Consumption	<12 mW/ch
Technology	110 nm process





By M. Mignone (INFN-TO)

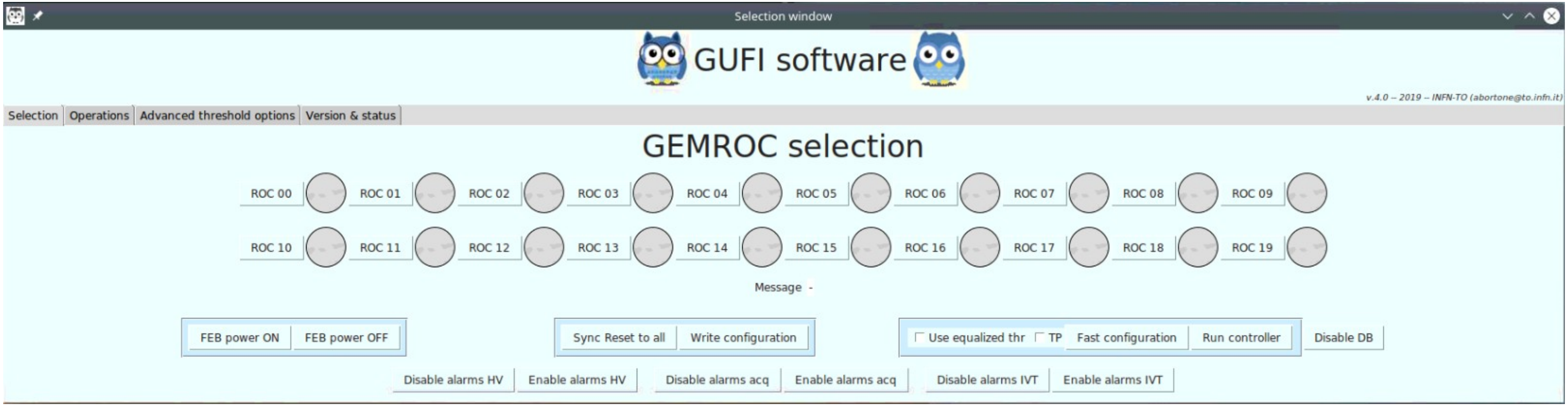
GEM Read Out Cards (GEMROCs)



Readout cards based on ArriaV GX FPGA developed by INFN-FE:

- **Power** the FEBs
- **Configure** the chips
- **Distribute** clock to the chips
- **Monitor** FEB currents and temperature
- **Organize** data to be sent to the DAQ computers via optical links/UDP

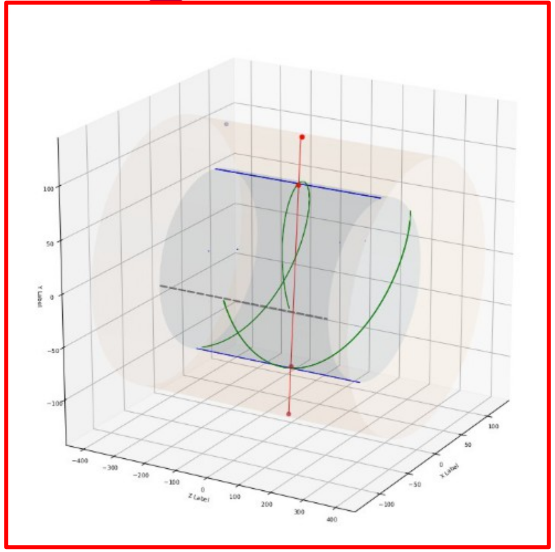
Graphical User Interface: GUFI

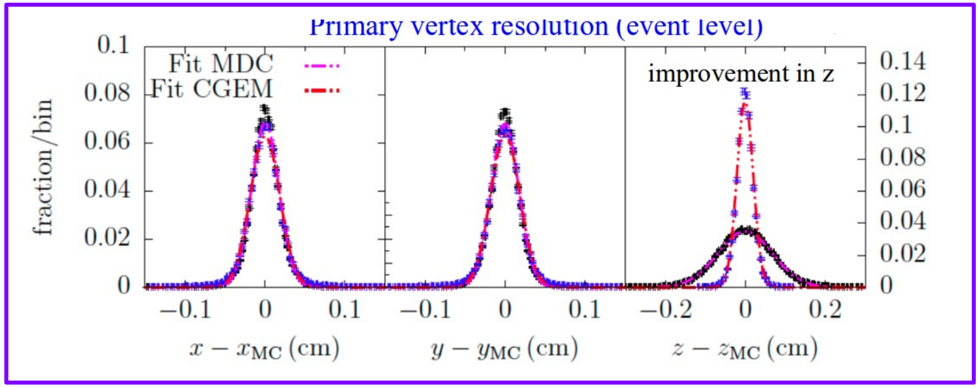


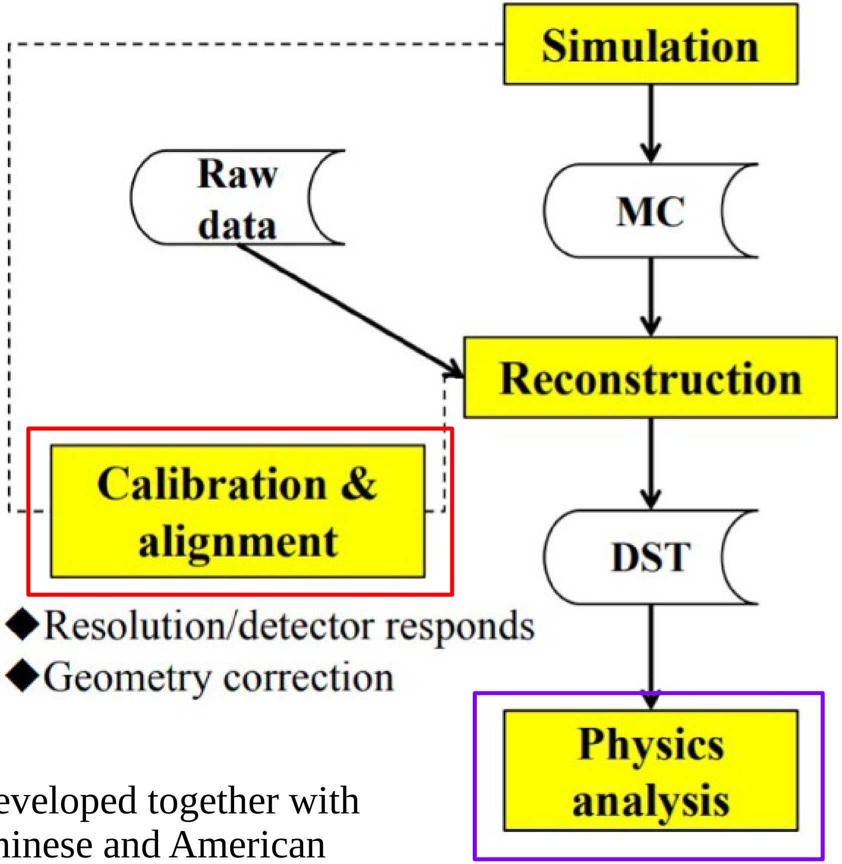
Python-based graphical user interface (developed by INFN-TO) to operate the GEMROCs, run the acquisition, and monitor the status of the FEBs.

It has different routines to evaluate the noise level and set the threshold of the channels

Integration with BESIII Offline Software





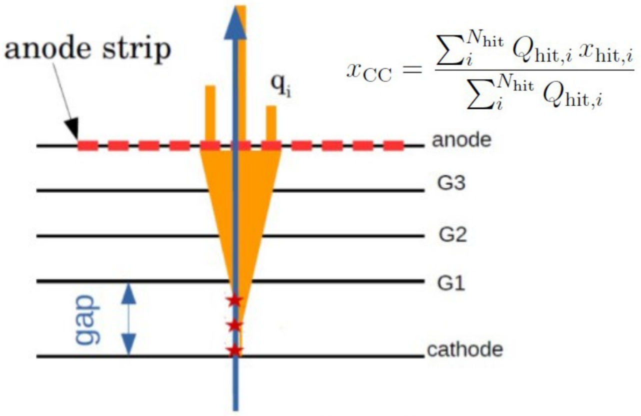


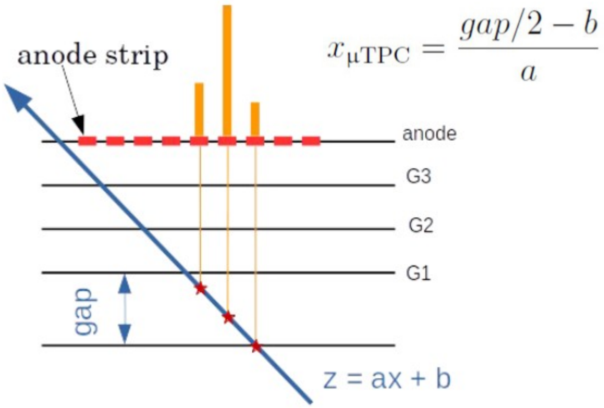
- Resolution/detector responds
- Geometry correction

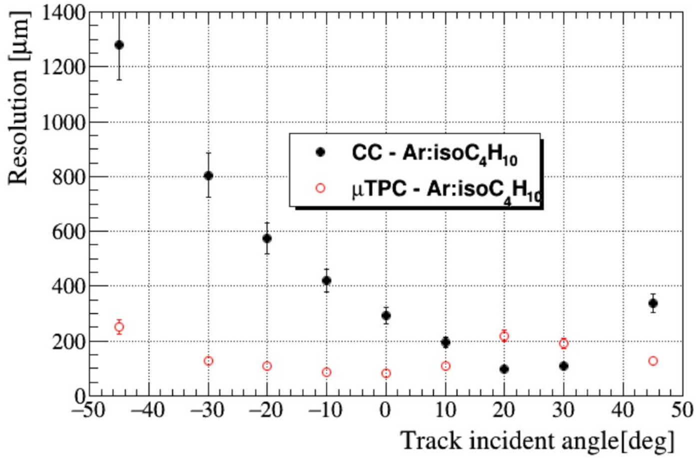
Developed together with Chinese and American colleagues

Cluster reconstruction

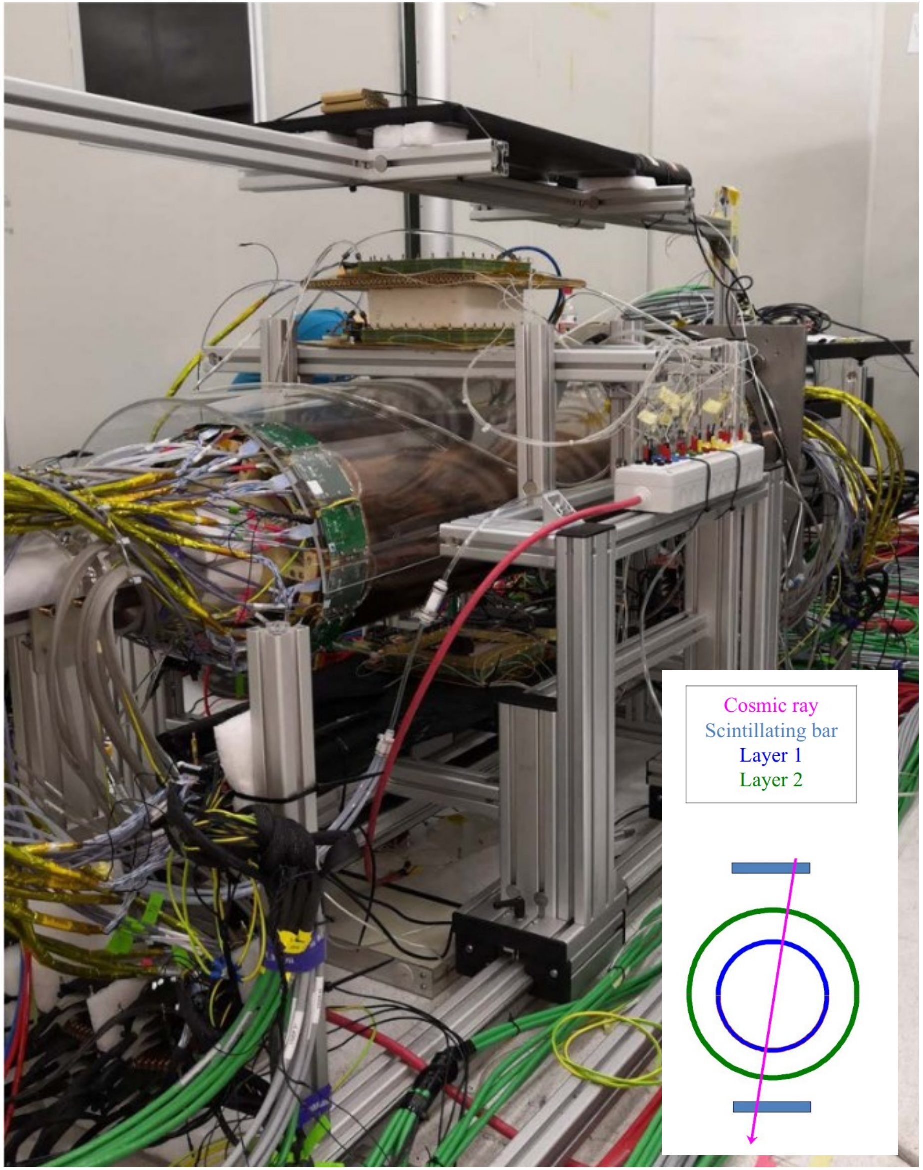
Contiguous fired strips on the anode form a **cluster**







M. Alexeev et al 2019 JINST 14 P08018
R. Farinelli PhD Thesis, arXiv: 1904.06548



CGEM-IT @ IHEP

Two final layers are taking data at IHEP since Nov 2019

Stable operation!

Instrumented a cosmic stand to validate and test the layers, the full readout chain, and assess the performance

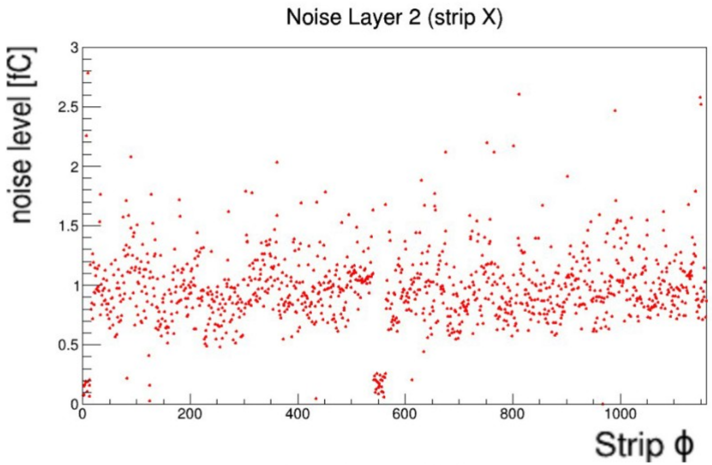
~5.6k channels connected

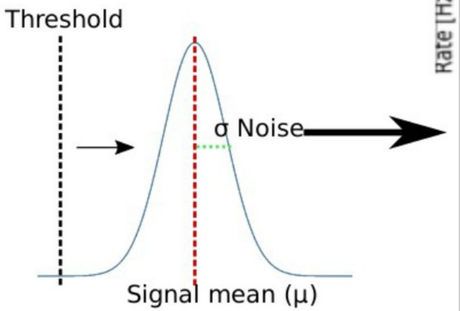
Remote monitoring

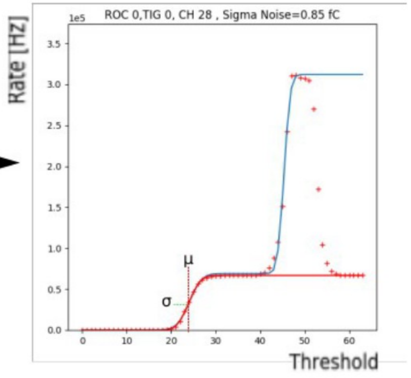
Setting up the measurements: threshold

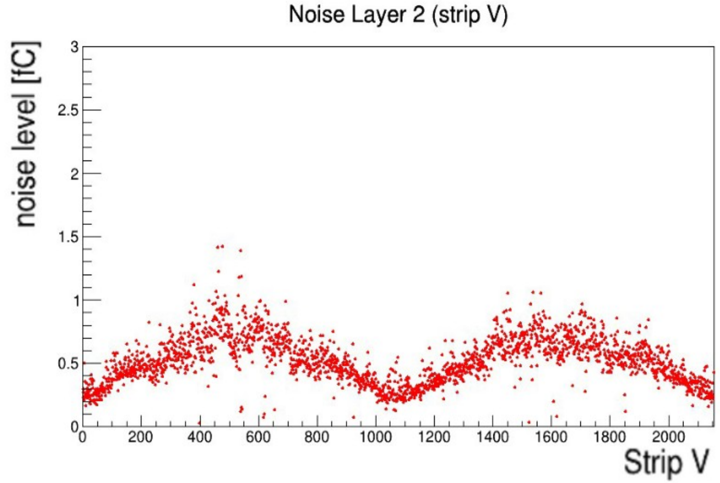
GUFI allows to perform automatic threshold scans to evaluate the noise level and set the proper threshold on each channel
General noise level ~ 1 fC

Two different operative threshold can be set:
- number of noise sigma
- noise rate of each channel







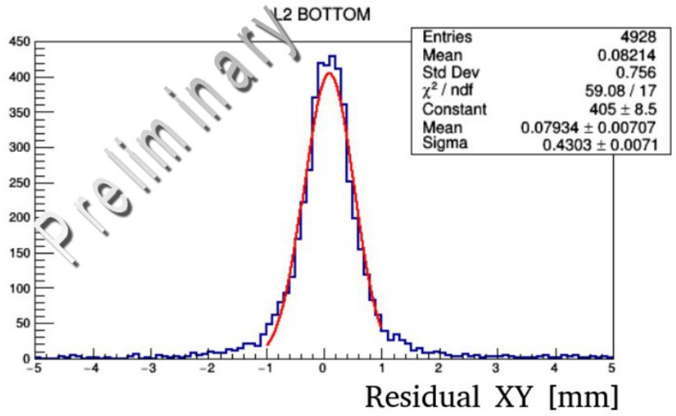


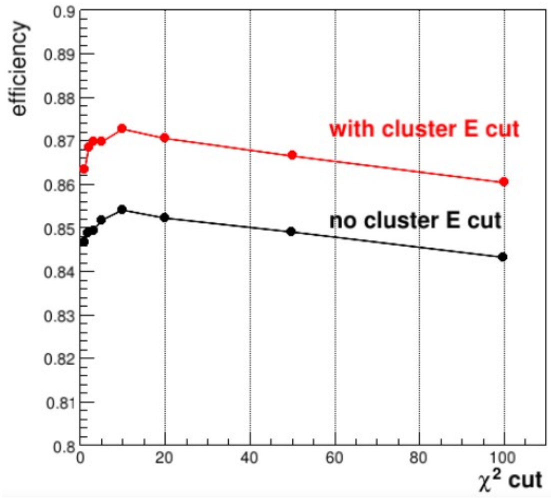
Setting up the measurements: tracking

To extract the performance we perform a **3D tracking** with 4 planes: L2 and L1 are divided in two halves

To select the **good tracks** we look at the **chisquare** on both projection (XY and RZ) with different selections on clusters

The reconstructed position is compared to the expected point to extract the residual distribution



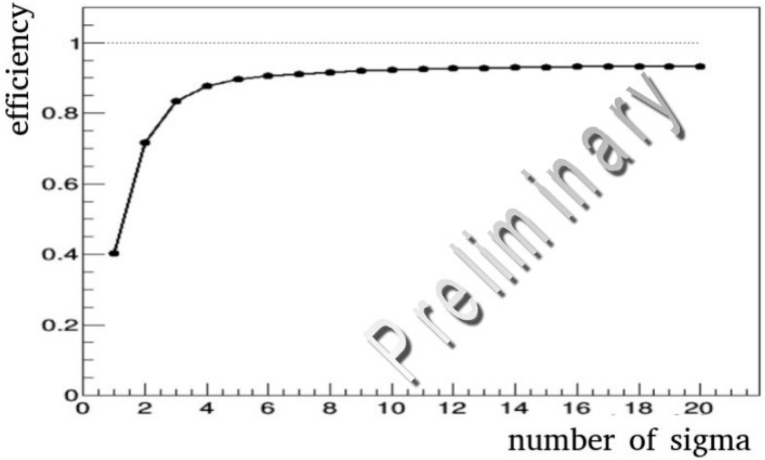


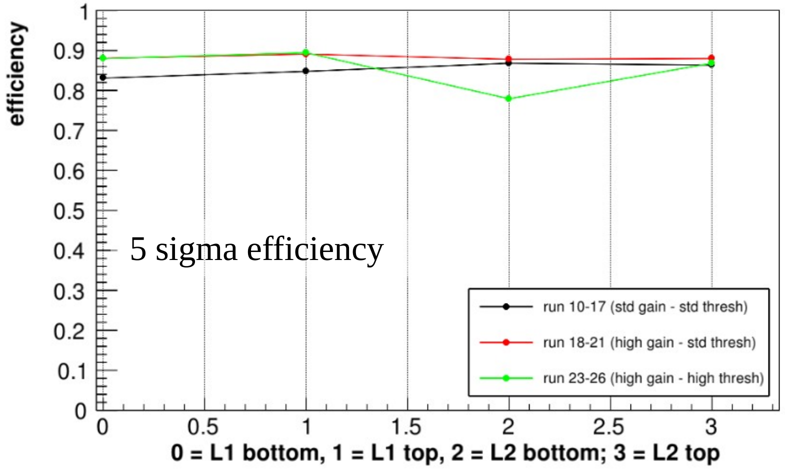
Efficiency vs tracking

$$\varepsilon = \frac{\text{number events with both residuals in N sigma}}{\text{number good tracks}}$$

Plateau of **efficiency ~ 90%** after 4 sigma

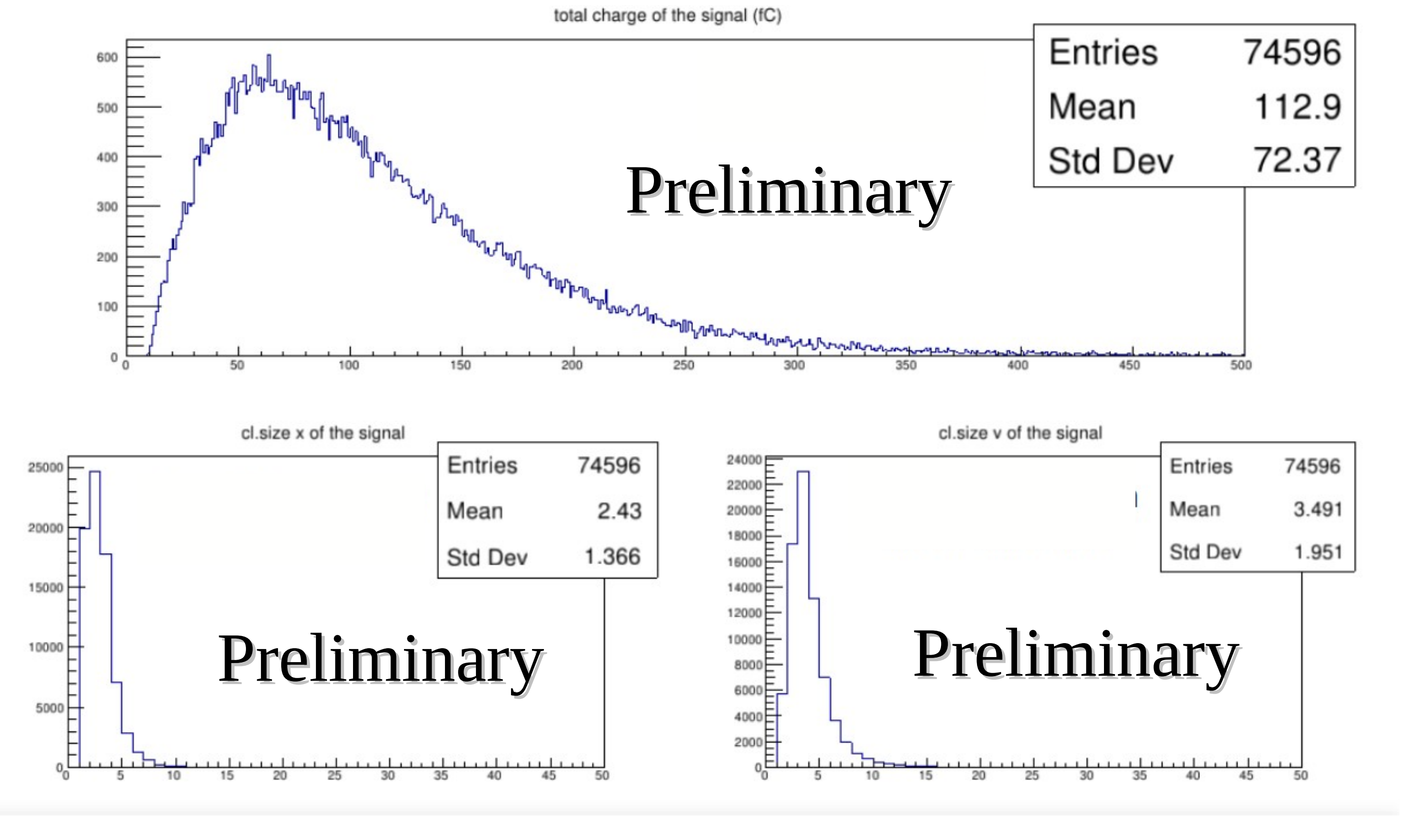
More studies on understanding the effects of features of CGEM-IT are on-going, but good uniformity in different running conditions





Studying the signals

We studied the signal cluster information: **2D charge** and **cluster size** compatible with expectation based on previous planar test beam studies

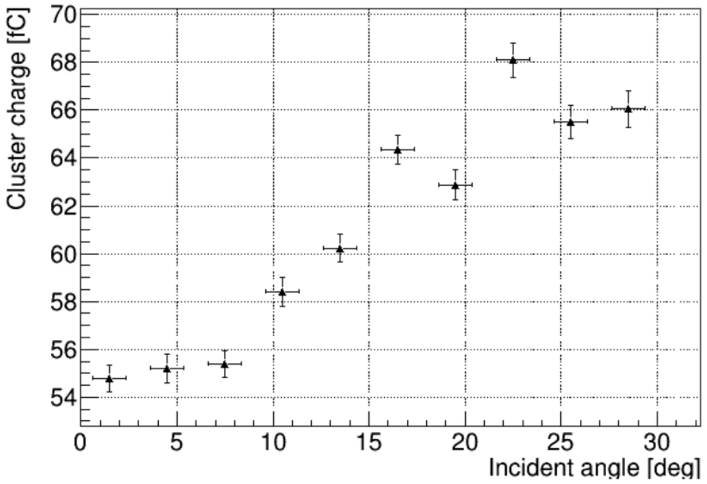


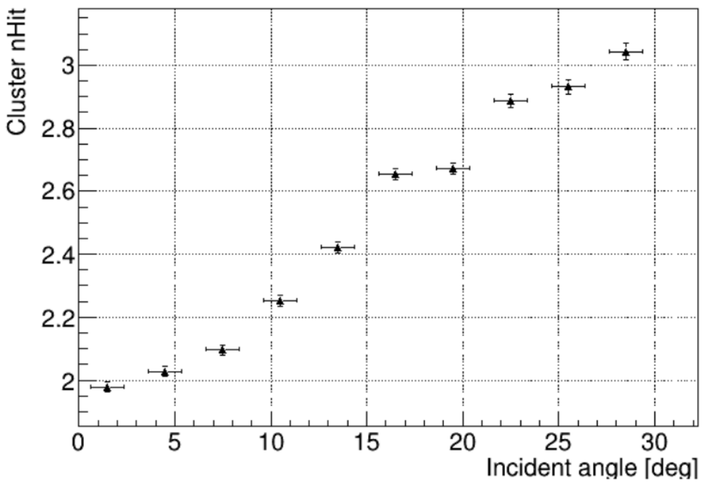
Preliminary results with Charge centroid

Cosmic rays angular distribution and cylindrical geometry allows to study performance at different incident angles.

First values are extracted with charge centroid – more straightforward operation

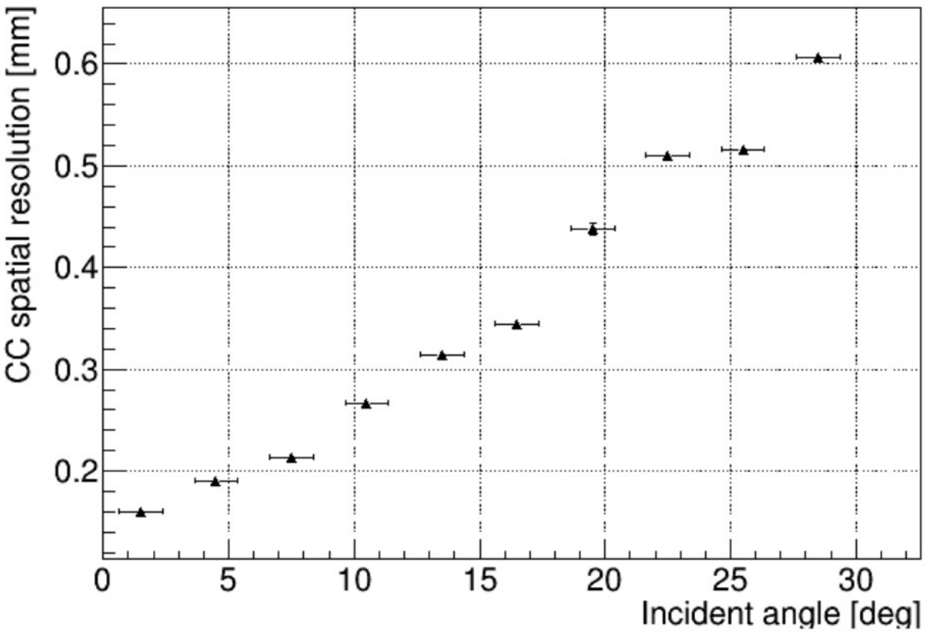
Charge and cluster size increase with increasing incident angles





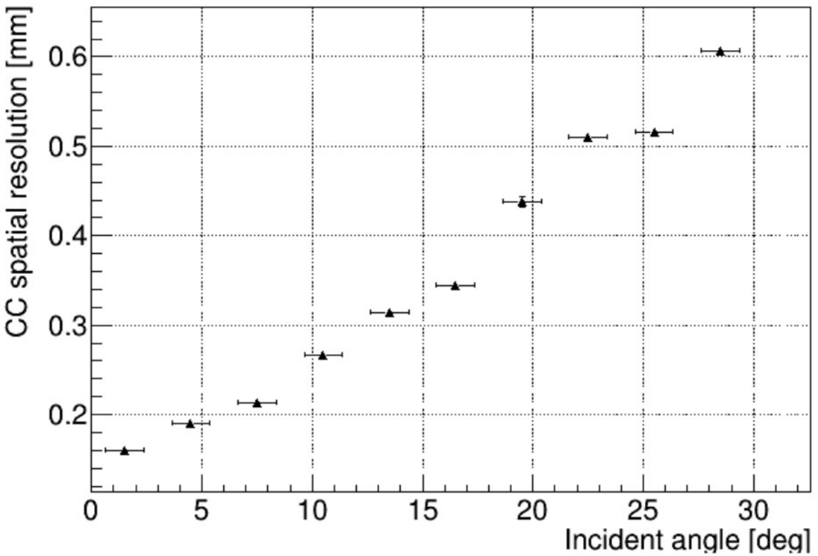
Preliminary results with Charge centroid - 2

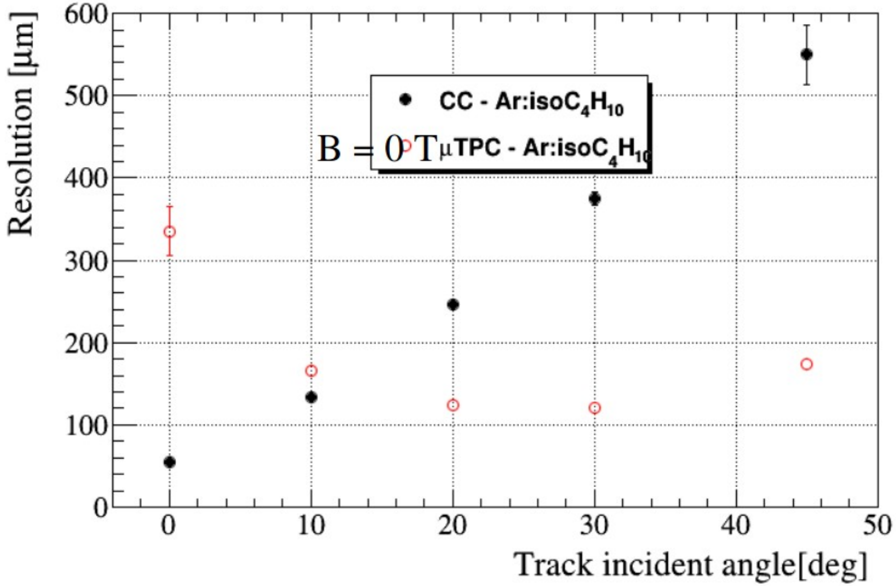
From residual distribution, it is possible to extract the expected spatial resolution – effect of the tracking extracted from toyMC



Comparison with previous R&D

JINST 14 (2019) 08, P08018

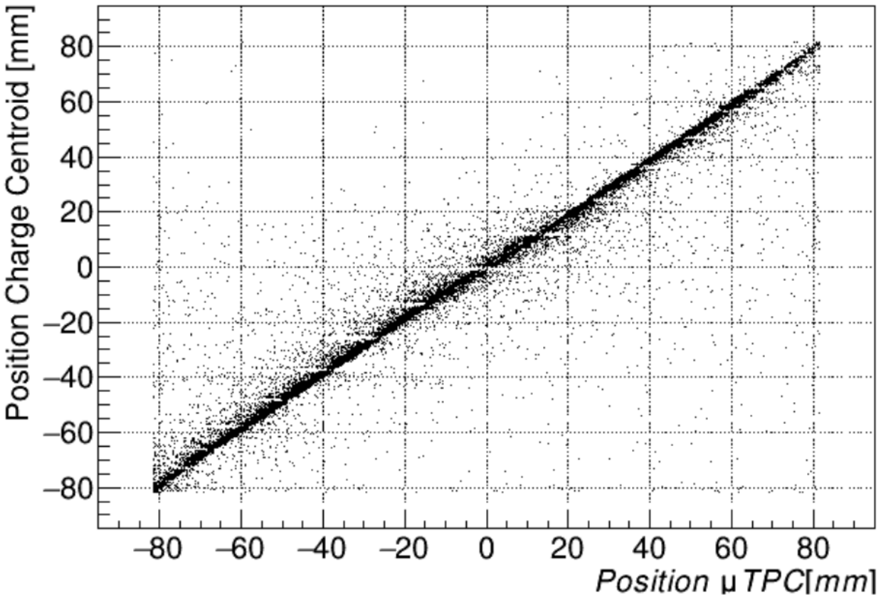




By comparing the results with TB data, we observe similar behaviour.

The steepness of the curve is similar

First μTPC outputs



μTPC readout is extremely crucial to obtain the required performance with different incident angles in magnetic field

First implementation in cylindrical geometry shows good agreement with respect to the position extracted with CC

Further studies are on-going to apply time walk and time reference correction to exploit fully the TIGER capabilities

Summary and outlook

- The CGEM-IT continues its studies to deploy the new inner tracker for the BESIII experiment

- Preliminary results with cosmic rays show good performance

- Despite the pandemic, data taking never stopped, so we are able to continue the detector characterization and development

- Other activities are on-going in Italy to be ready when we will be able to travel back to China

THANKS!

The CGEM-IT project is funded by the EU commission by the RISE-MSCA-H2020-2019 program within the FEST consortium