Istituto Nazionale di Fisica Nucleare
Sezione di Ferrara

中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

OPERATION AND READOUT OF THE CGEM INNER TRACKER

ILARIA BALOSSINO
on behalf of the working group

The 16th Vienna Conference
on Instrumentation

BESIIICGEM FEST
RISE
HORIZON 2020

FOLLOW ME

INTO THE PROJECT

Where

What

Why

Who

How

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FOLLOW ME

INTO THE PROJECT

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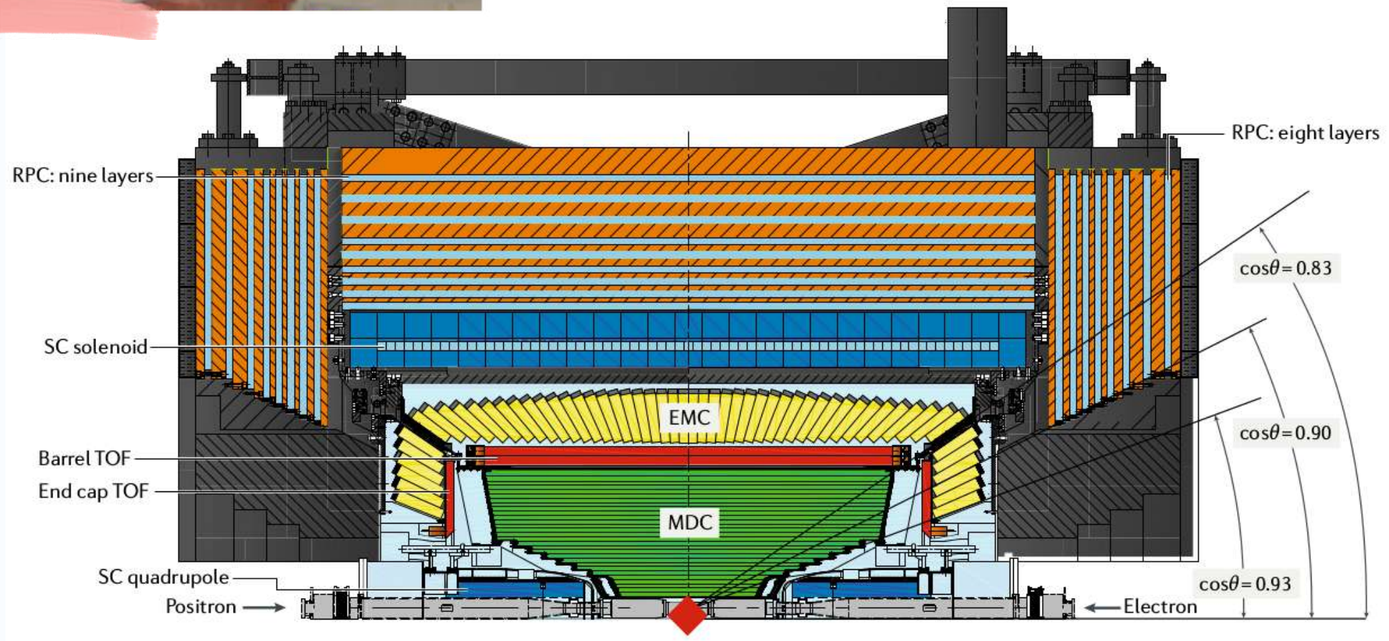
Where the experiment is

What

Why

Who

How

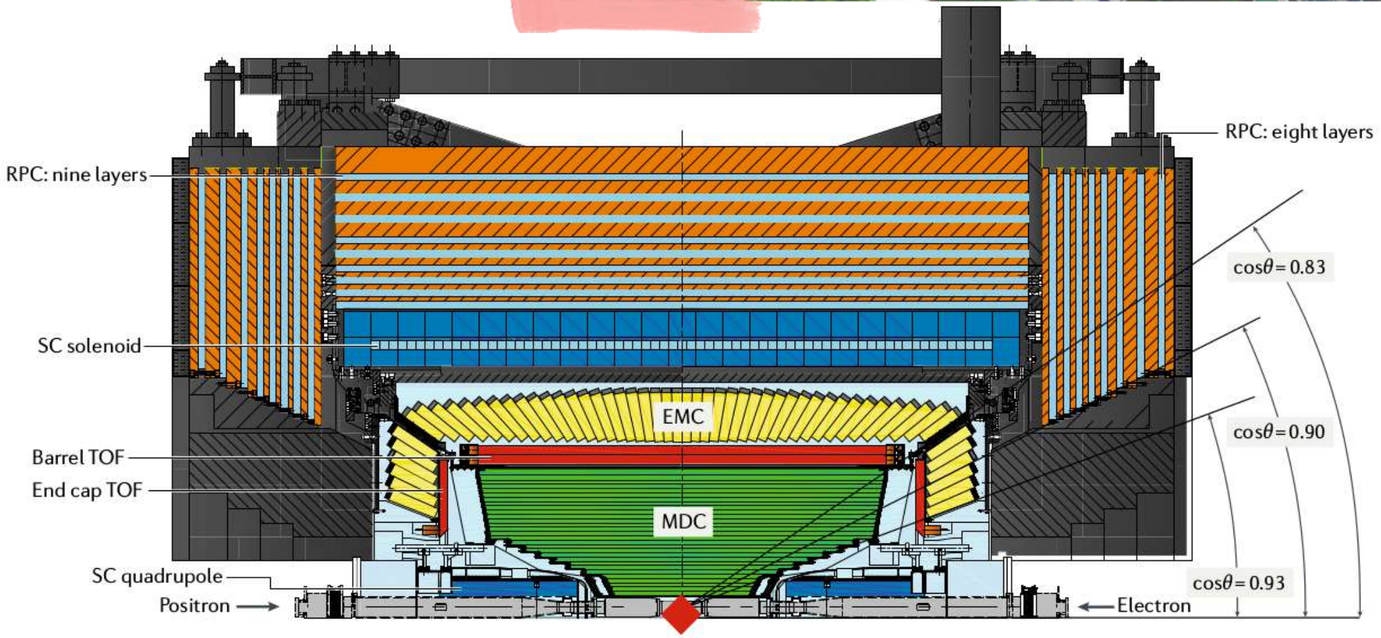


WHERE

Institute of High Energy Physics
BEIJING, PRC

It is a Chinese Academy of Sciences research institute; it is China's biggest laboratory for the study of particle physics.

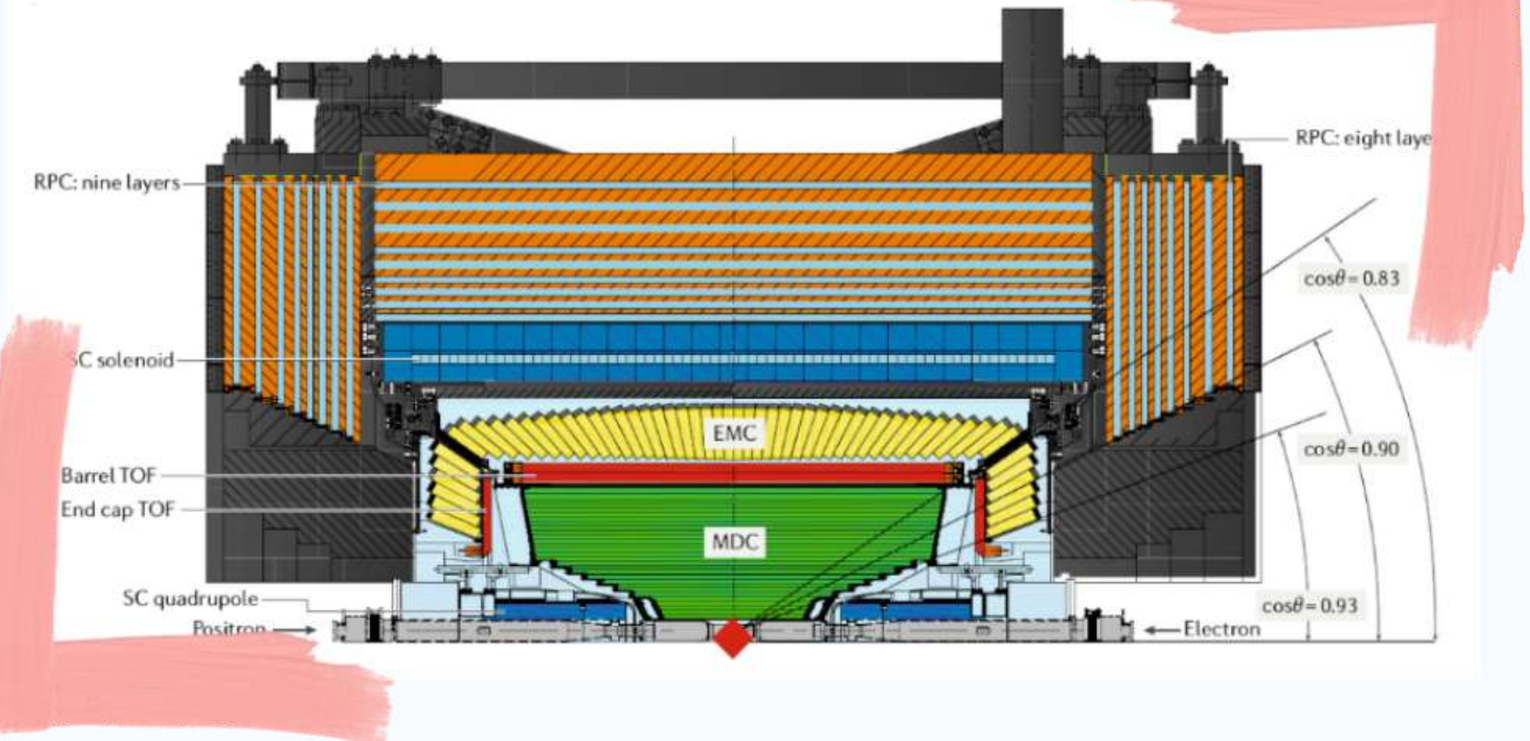
http://english.ihep.cas.cn/doc/1745.html



WHERE

Beijing **E**lectron **P**ositron **C**ollider **II** generation

- Electron-Positron Collider
- Running since 2009
- Double rings with tiny crossing angle
- E_{cm}: 2 - 4.95 GeV
- L_{peak} : 1.0 10^{33} /cm^2 s

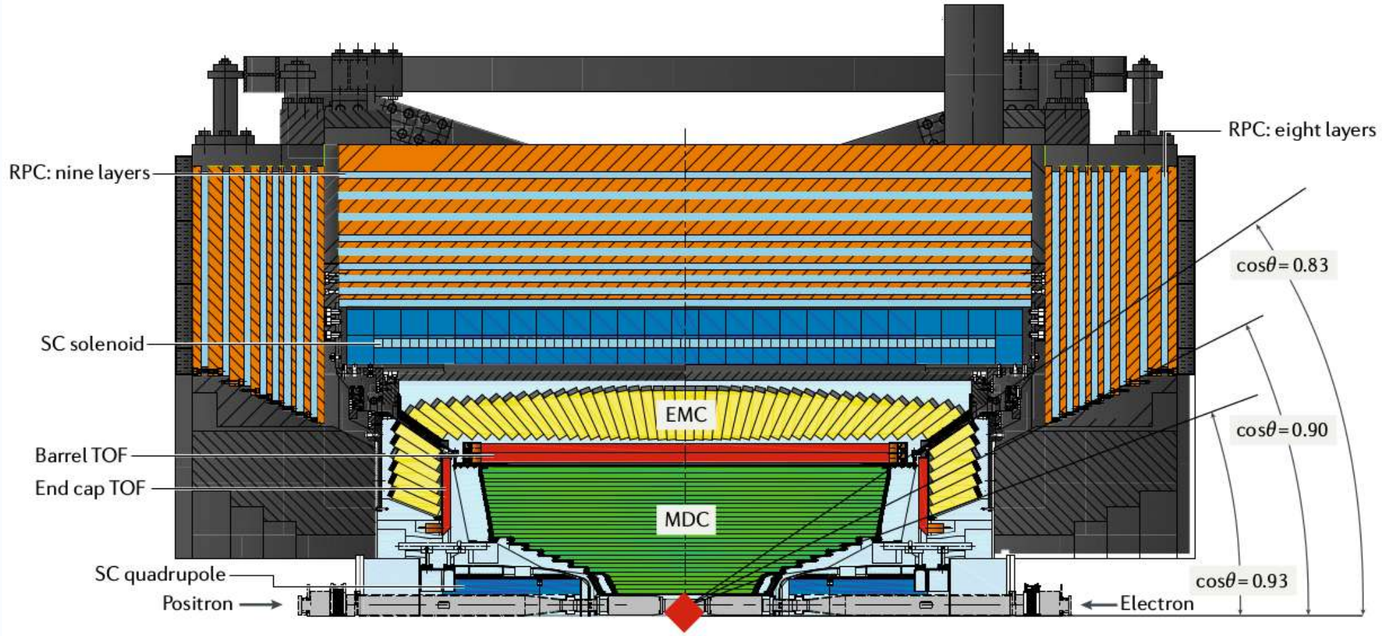


WHERE

BEijing **S**pectrometer **III** generation

- Multilayer Drift Chamber
- Time Of Flight
- ElectroMagnetic Calorimeter
- Magnetic Field 1T
- Muon Chamber

Design and Construction of the BESIII Detector.
https://doi.org/10.1016/j.nima.2009.12.050



WHERE

IHEP BEIJING, PRC

BEPCII

BESIII

- Hadronic physics with meson and baryon spectroscopy
- Charmonium and XYZ states
- Charm physics, CPV, D mixing, charmed baryon decays

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WHAT

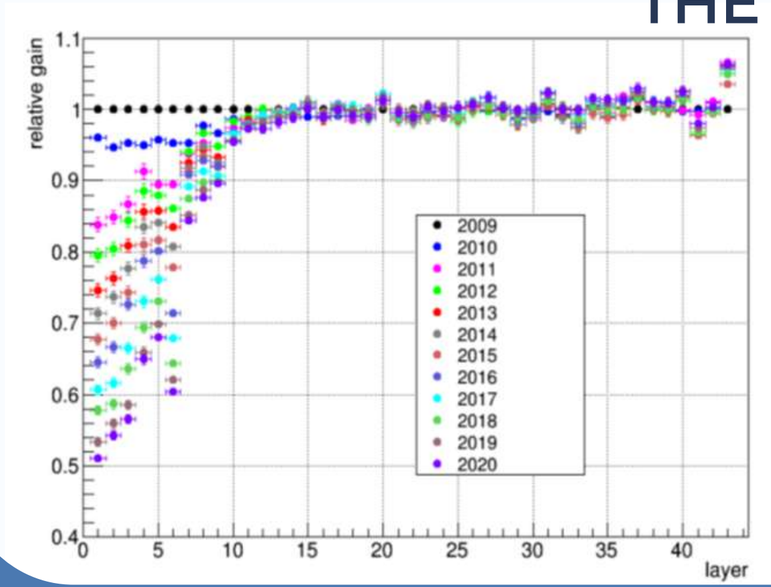
INNER TRACKER UPGRADE

With the extension of data taking to 2030 (at least) a new inner tracker would help to improve position resolution and secondary vertex reconstruction

White paper on future physics program
Chinese Physics C, vol. 44, no. 4, 2020

THE PRESENT INNER TRACKER

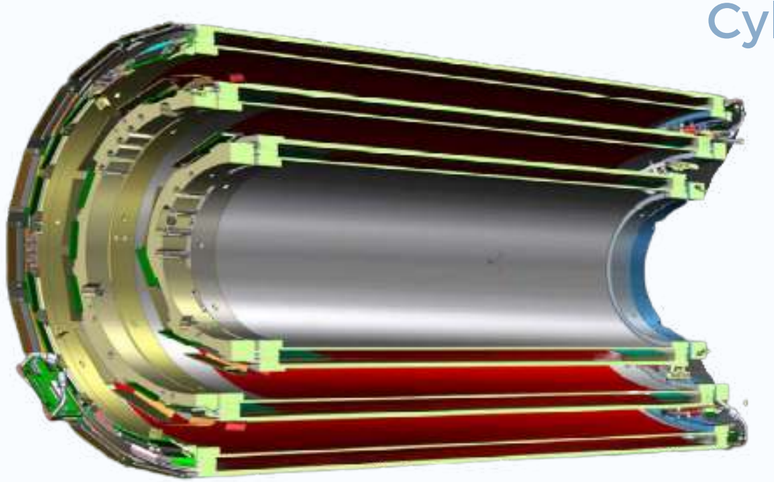
Multi layer drift chamber



The inner layers suffer from ageing: ~4% gain loss/year

THE PROPOSED INNER TRACKER

Cylindrical Gas Electron Multiplier



Three independent Triple-GEM detectors

Inspired by the KLOEII Inner tracker

The cylindrical GEM detector of the KLOE-2 experiment http://doi.org/10.1088/1748-0221/12/07/c07016

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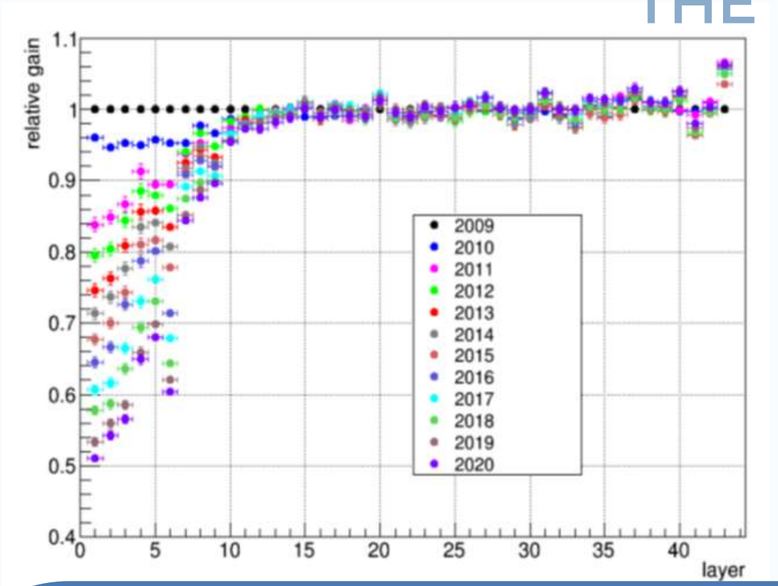

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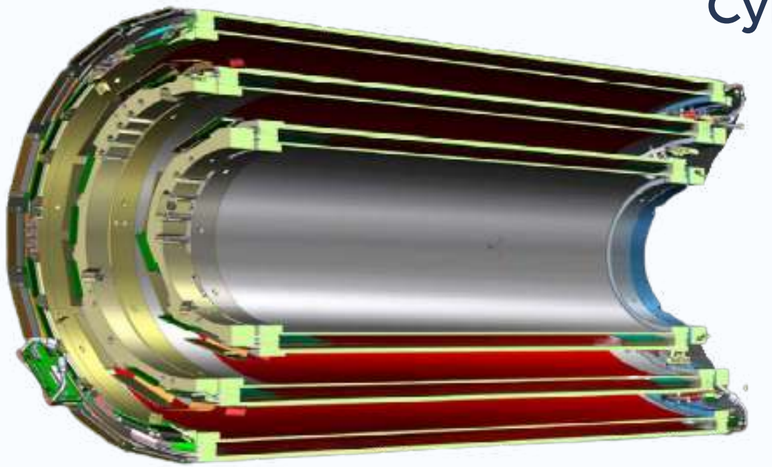

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WHY | GEM DETECTOR

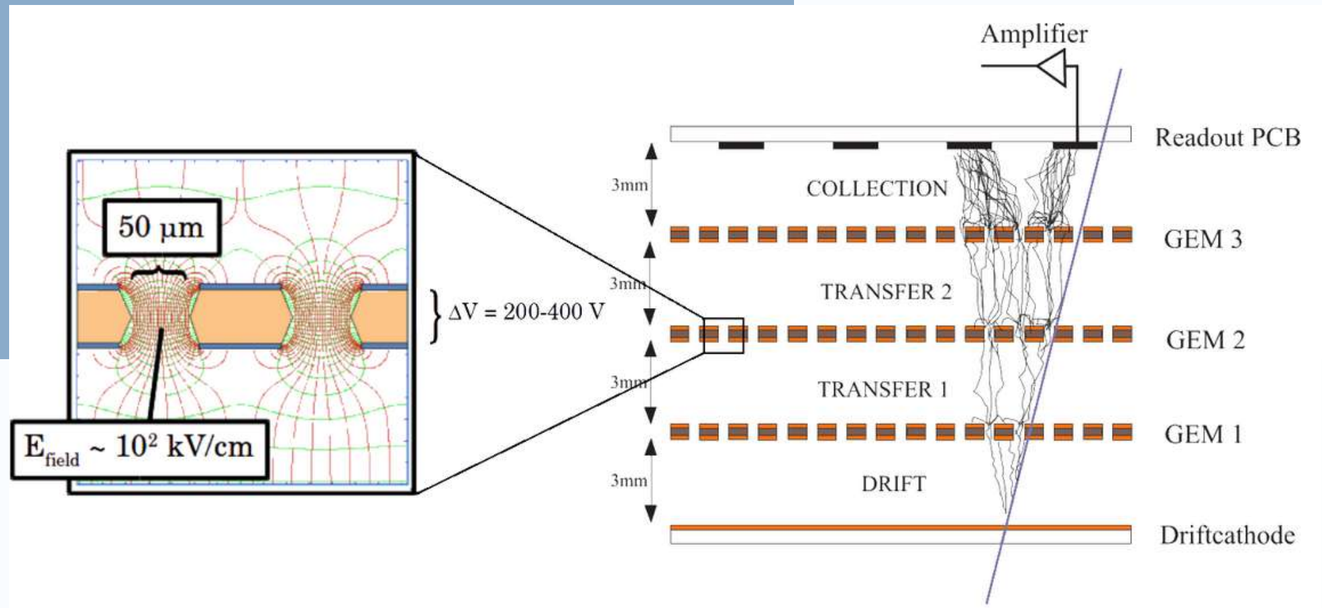
GEM technology was invented in 1997

GEM: A new concept for electron amplification in gas detectors.
https://doi.org/10.1016/S0168-9002(96)01172-2

F. SAULI

Kapton foils 50μm thick cladded on both faces in copper 5μm thick and pierced with high density of holes

GEM FOIL



OPERATION

The electrons created by primary ionization are driven in the GEM holes where an electron avalanche is created. Three amplification stages grant the possibility to reach gains up to 10^4

CHARACTERISTICS

- **High Rate Capability**
- **High Radiation Hardness**
- **Scalable and flexible geometry**

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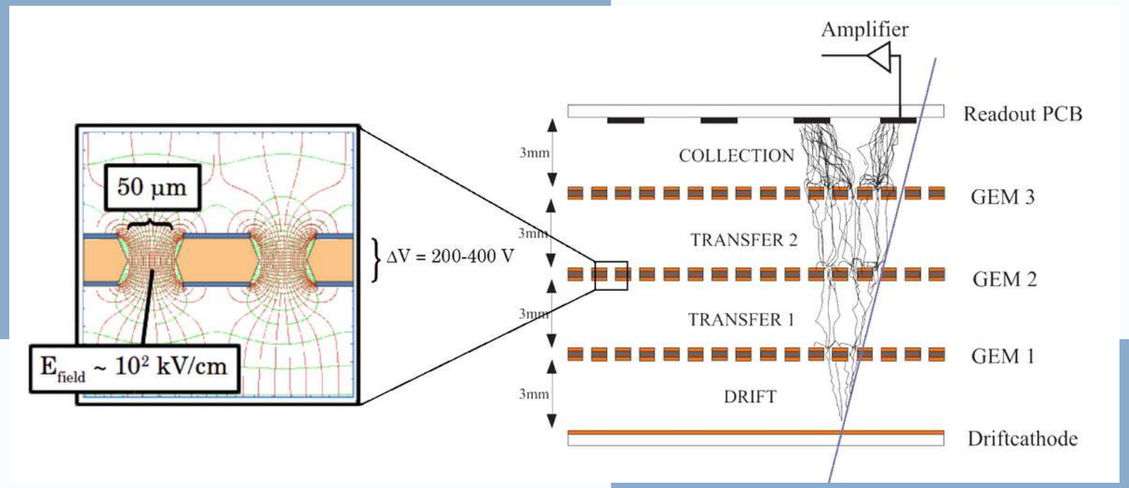

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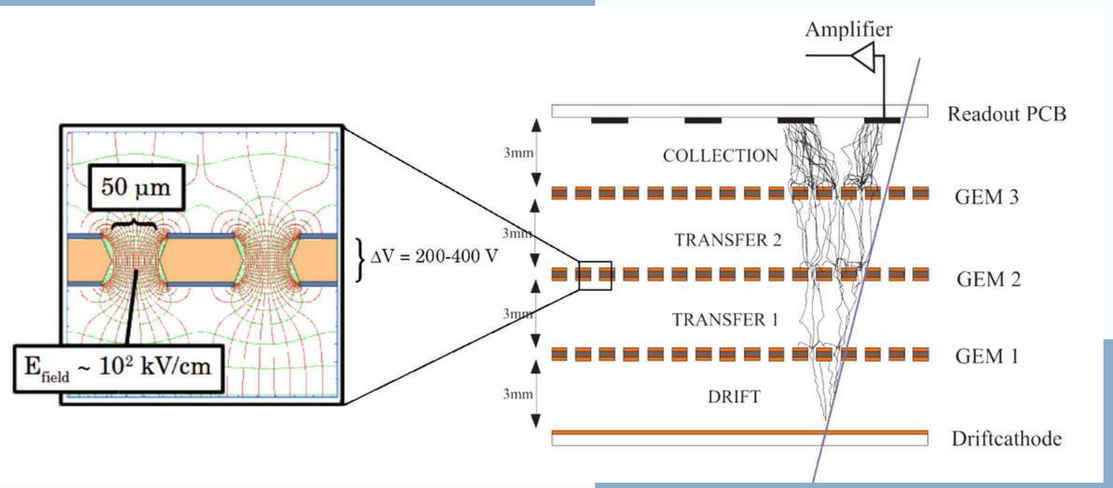

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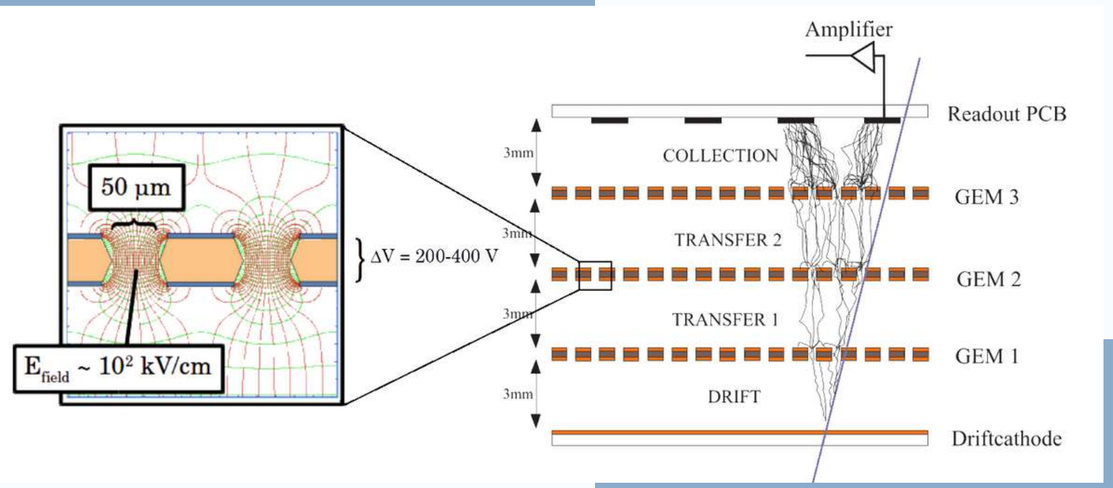

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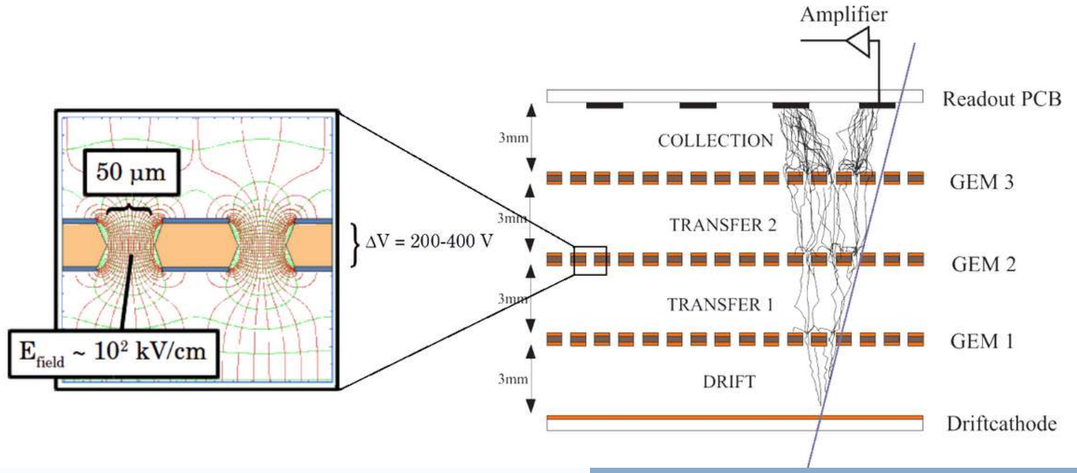

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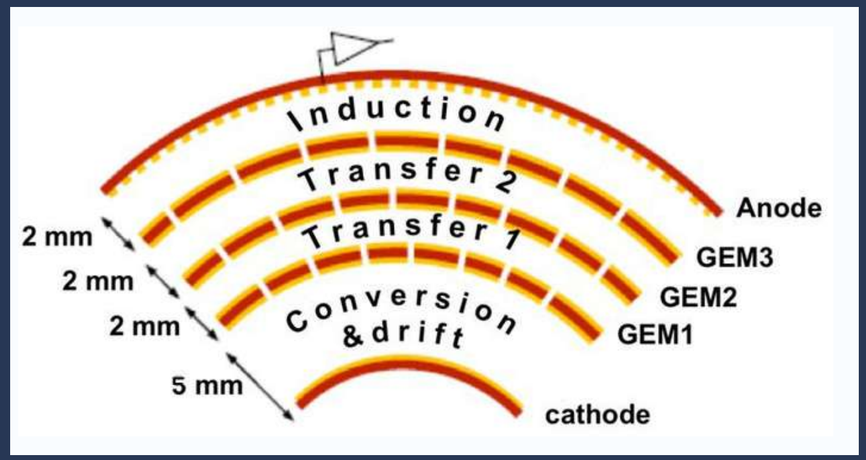
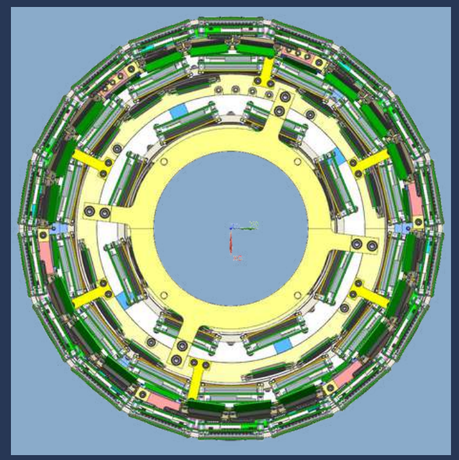
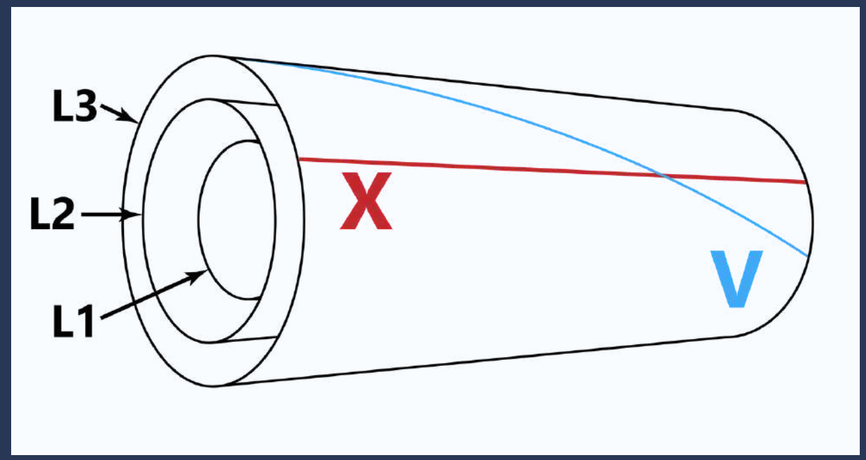
THE CGEM-IT

WHO

Three layers of cylindrical triple-GEM
Two views on the readout plane of each layer allow reconstructing the 3D particle position







- σ_{xy} ~ 130 μm
- σ_{z} ~ 350 μm
- $\sigma p_t / p_t$ ~ 0.5% @ 1 GeV/c

- Material budget ≤ 1.5% X_0
- High rate capability: 10^4 Hz/cm^2
- Operation in 1T magnetic field

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How the development is going

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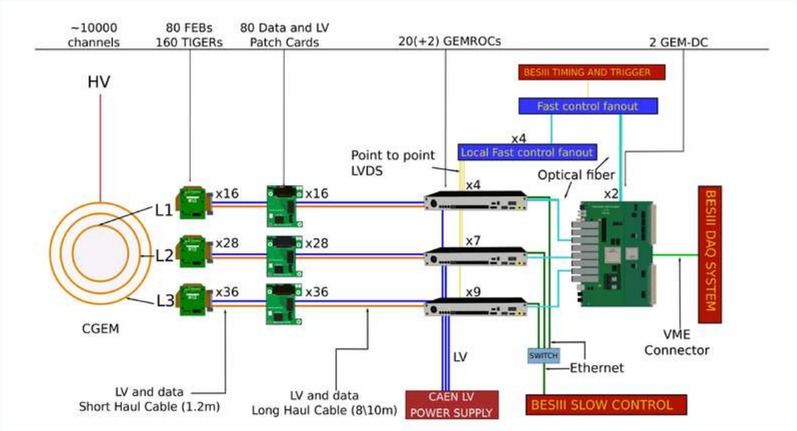
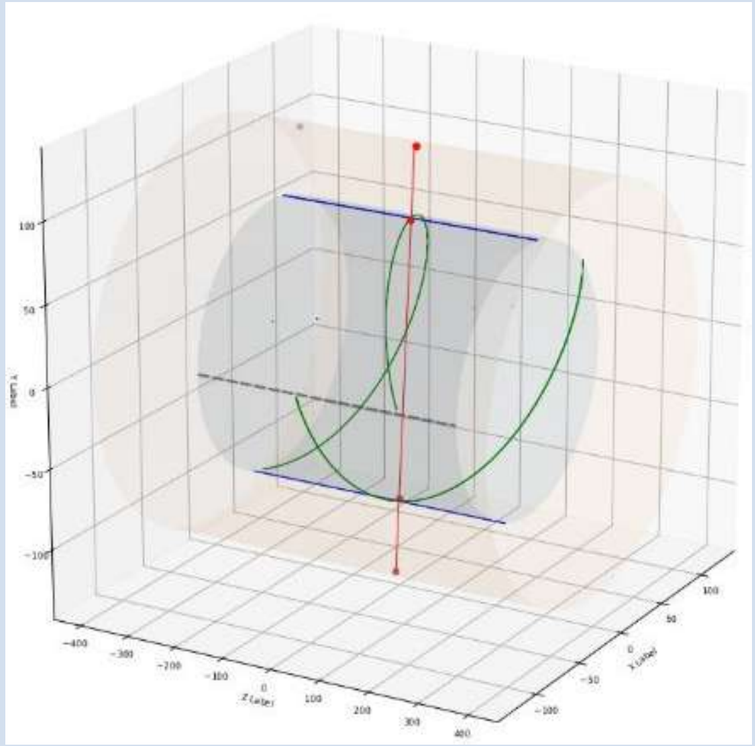
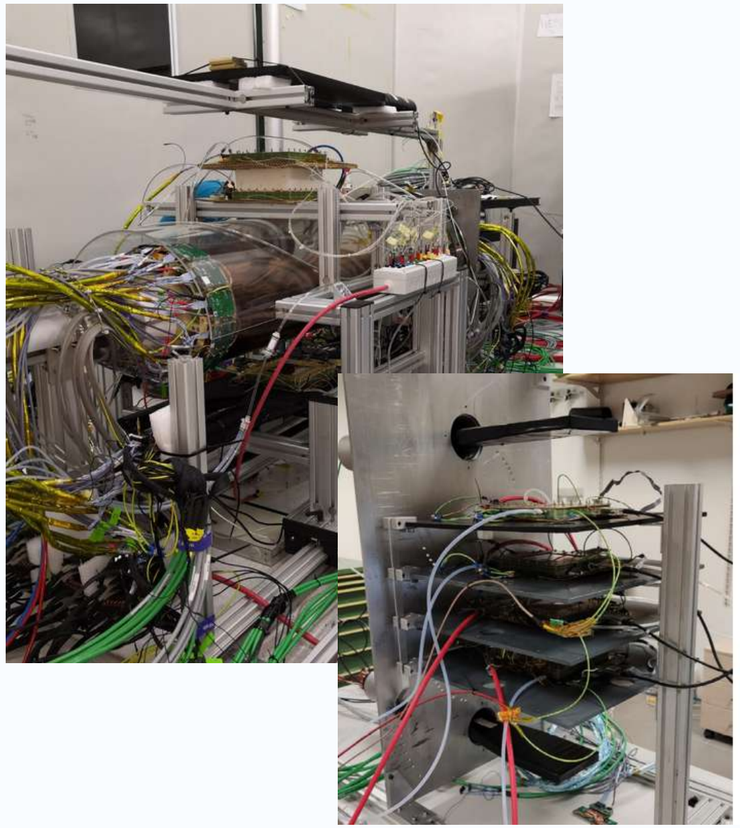
HOW



READOUT CHAIN



SOFTWARE



DATA TAKING

HOW READOUT CHAIN

TIGER

- 64-channels ASIC
- Charge and Time readout
- Sample&Hold
- Time Over Threshold

GEMROC

- Power the FEBs
- Monitor chips voltages and temperature
- Configure the chips
- Receive timing signals
- Control data acquisition via optical links/Ethernet

TIMING

- Fast Control System Fanout
- Fast Control System Local Fanout

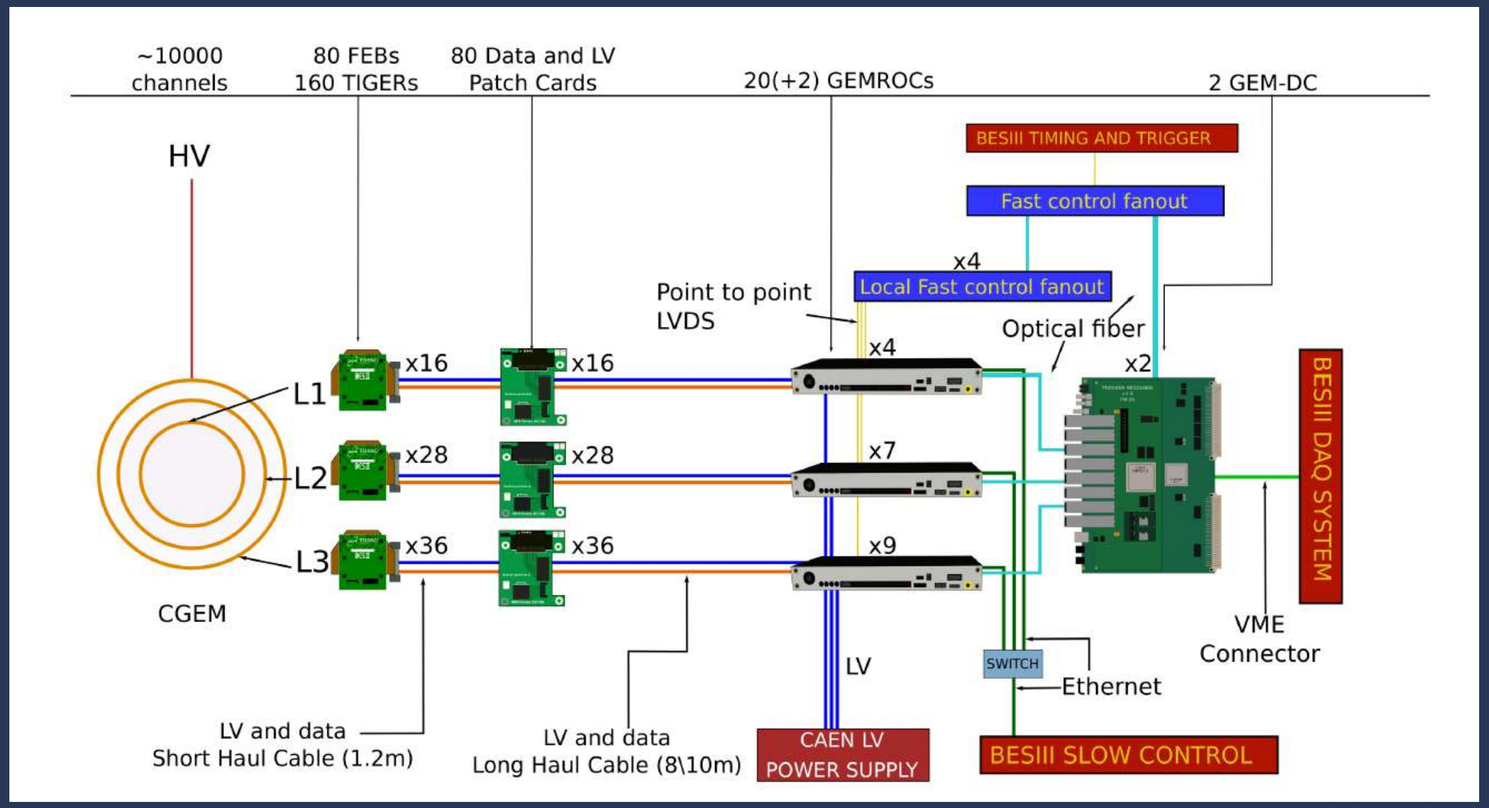
to receive and distribute BESIII clock and trigger to each GEMROC

GUFI

- Graphical User Frontend Interface
- Python based software
- Test, characterize and debug the system

Torino Integrated GEM Electronics Readout
ASIC FEATURES:

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



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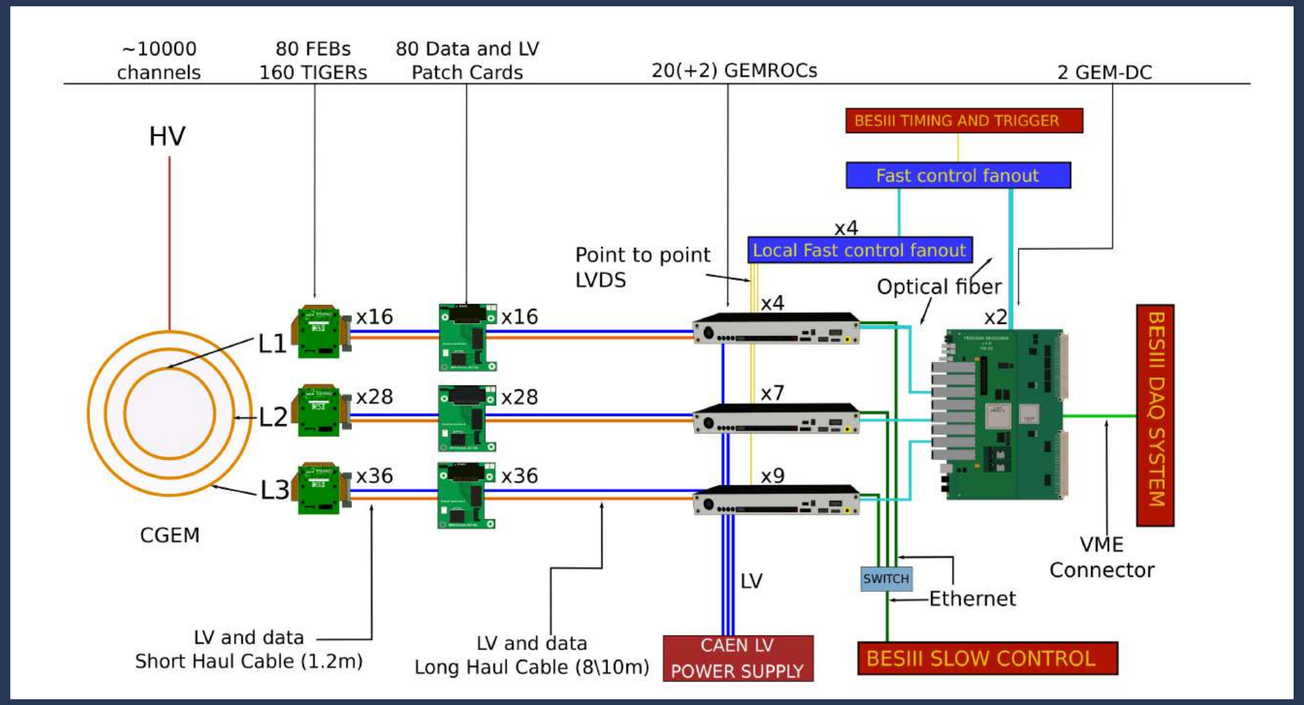

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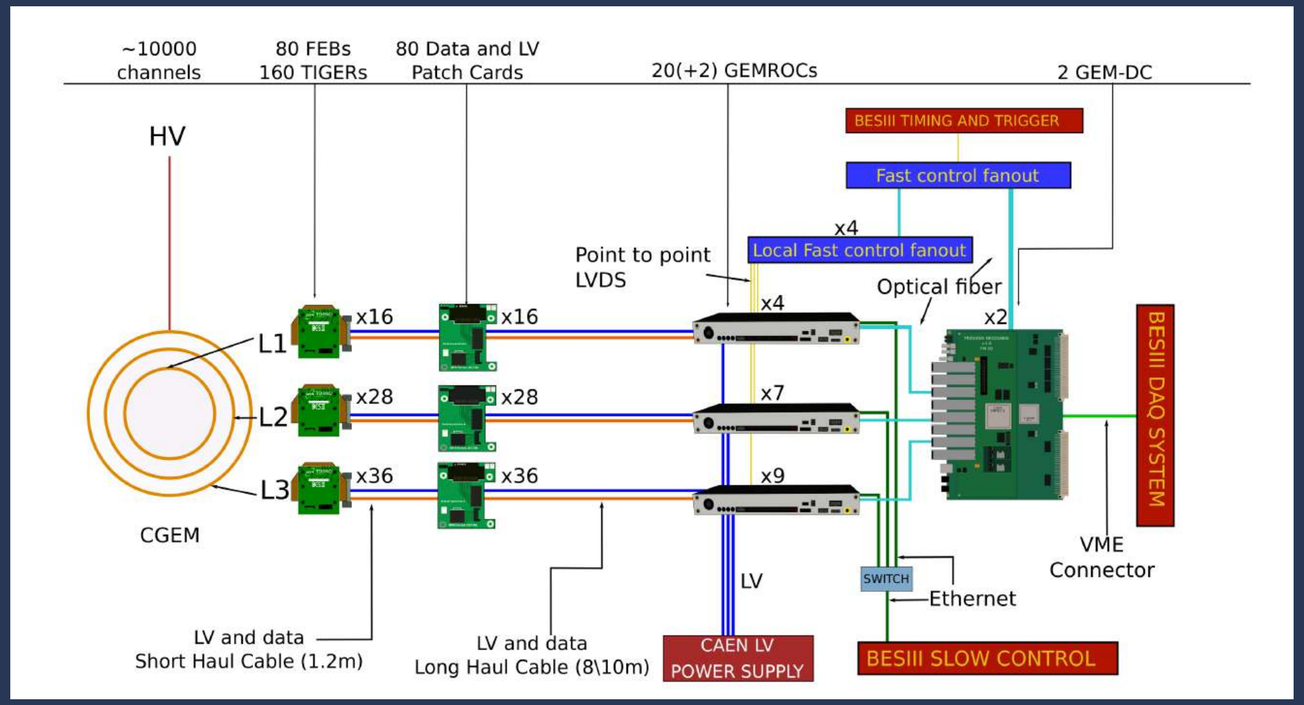

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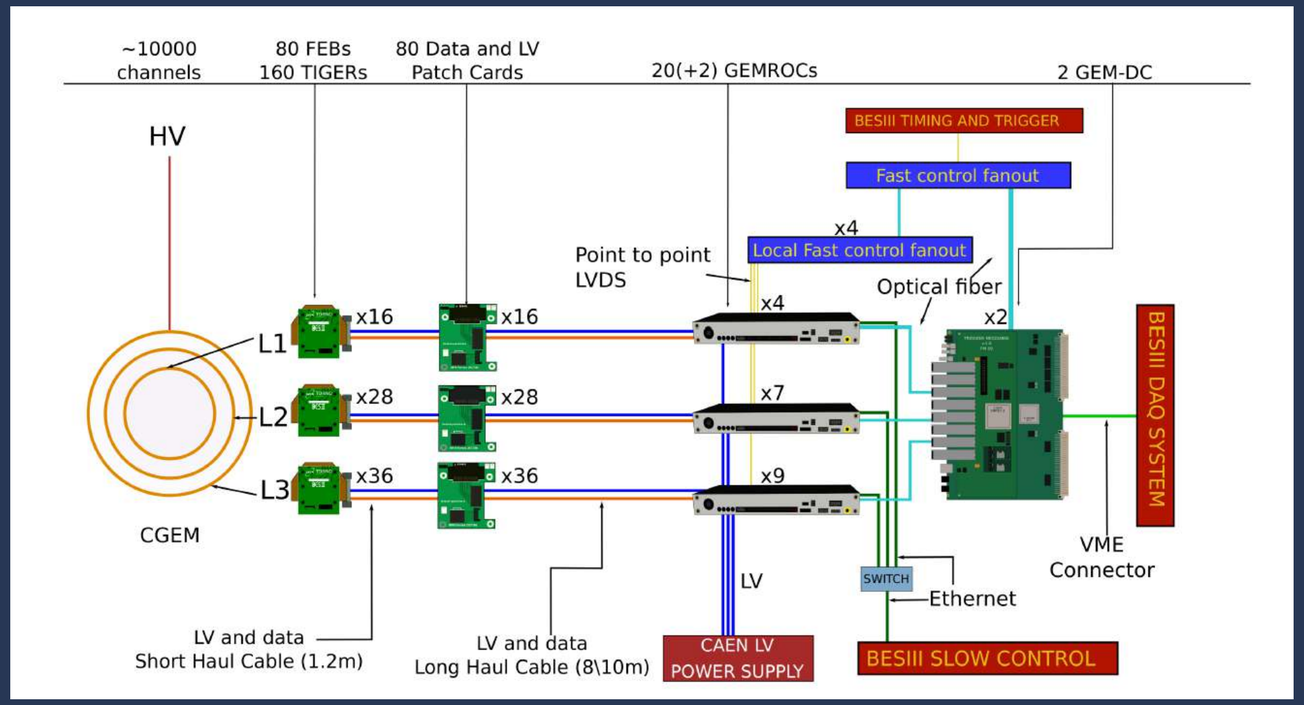

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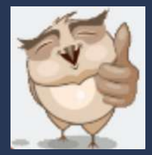

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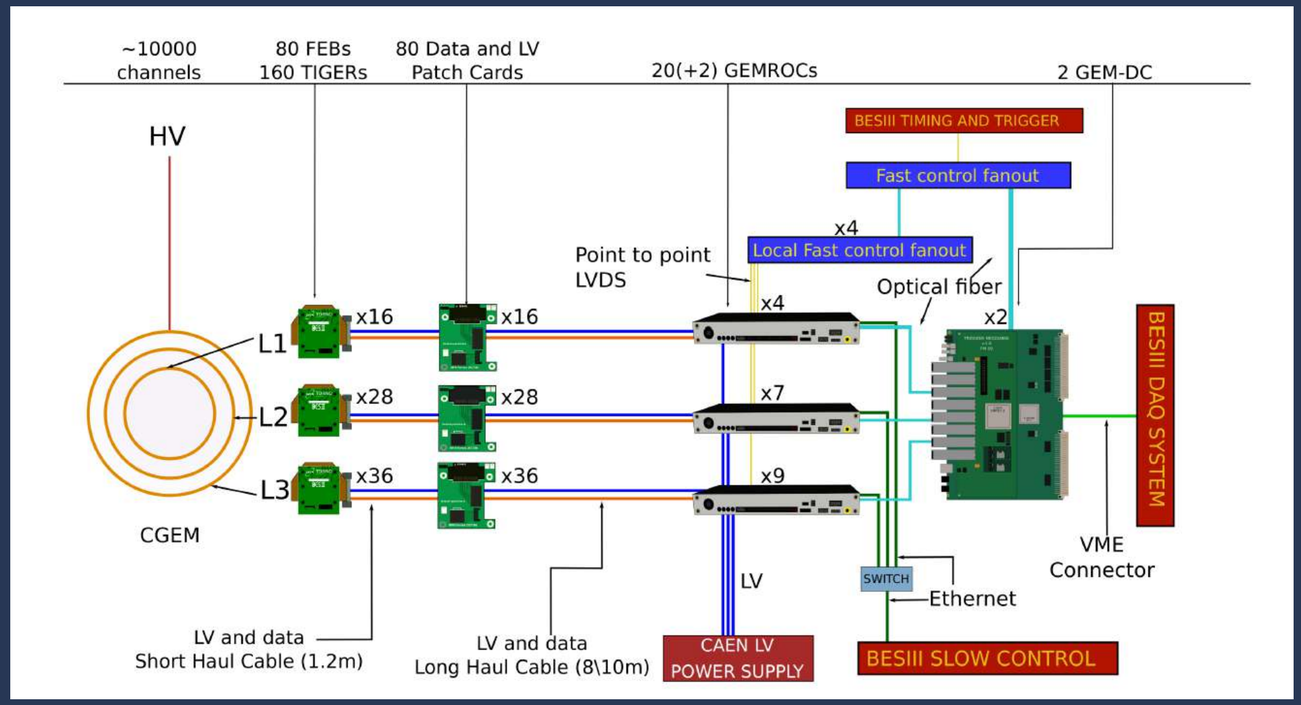

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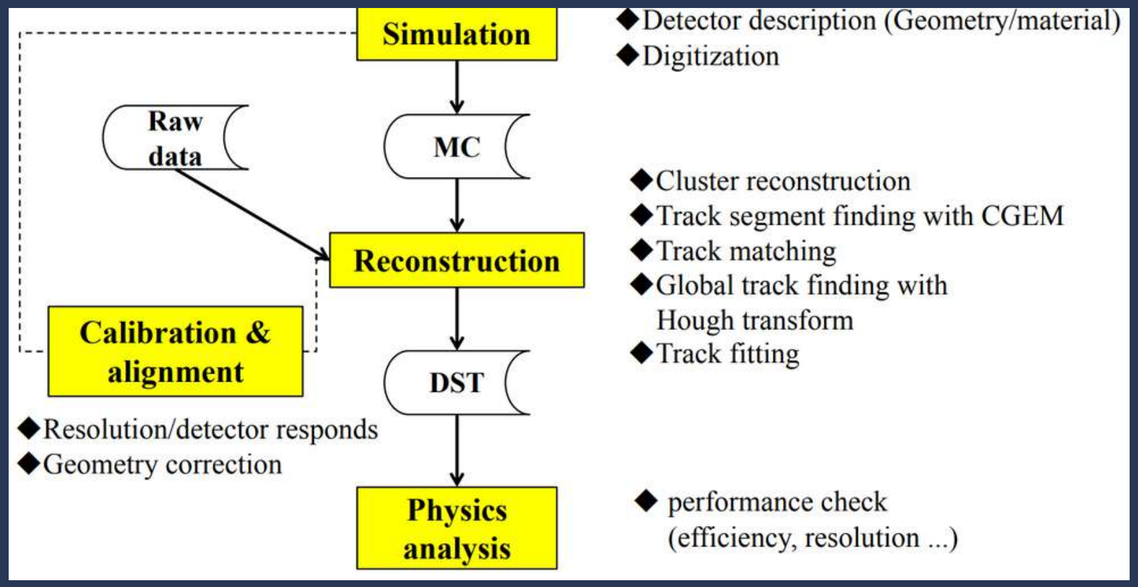
HOW SOFTWARE DEVELOPMENT

CGEMBOSS

- BESIII Offline Software System
- Data reconstruction
- Simulation
- Physics Analysis

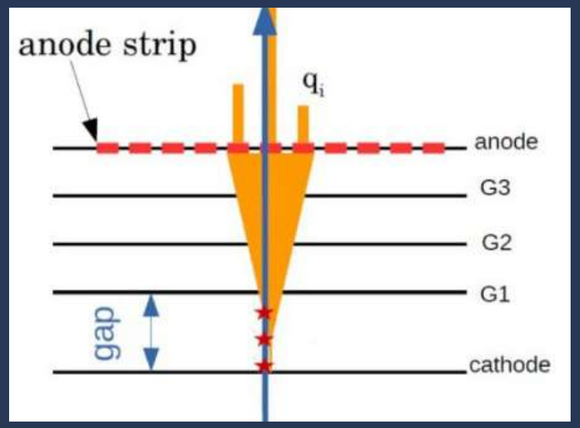


POSITION RECONSTRUCTION

- Contiguous strips fired on the anode form a cluster
- A merge of two algorithm is used
- To optimize the recontruction at different angle in 1T magnetic field

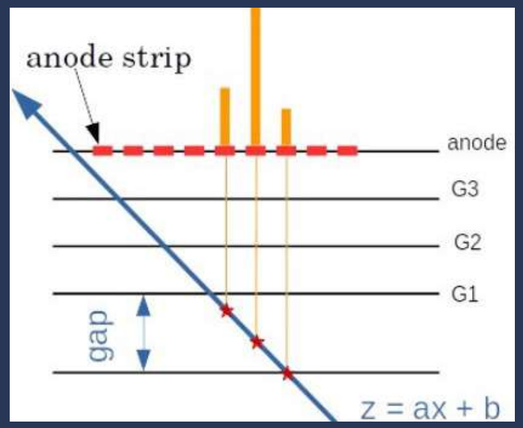
CHARGE CENTROID

$$x_{\mathrm{CC}} = \frac{\sum_i^{N_{\mathrm{hit}}} Q_{\mathrm{hit},i}\, x_{\mathrm{hit},i}}{\sum_i^{N_{\mathrm{hit}}} Q_{\mathrm{hit},i}}$$



microTPC

$$x_{\mu\mathrm{TPC}} = \frac{gap/2 - b}{a}$$



https://inspirehep.net/literature/1750024

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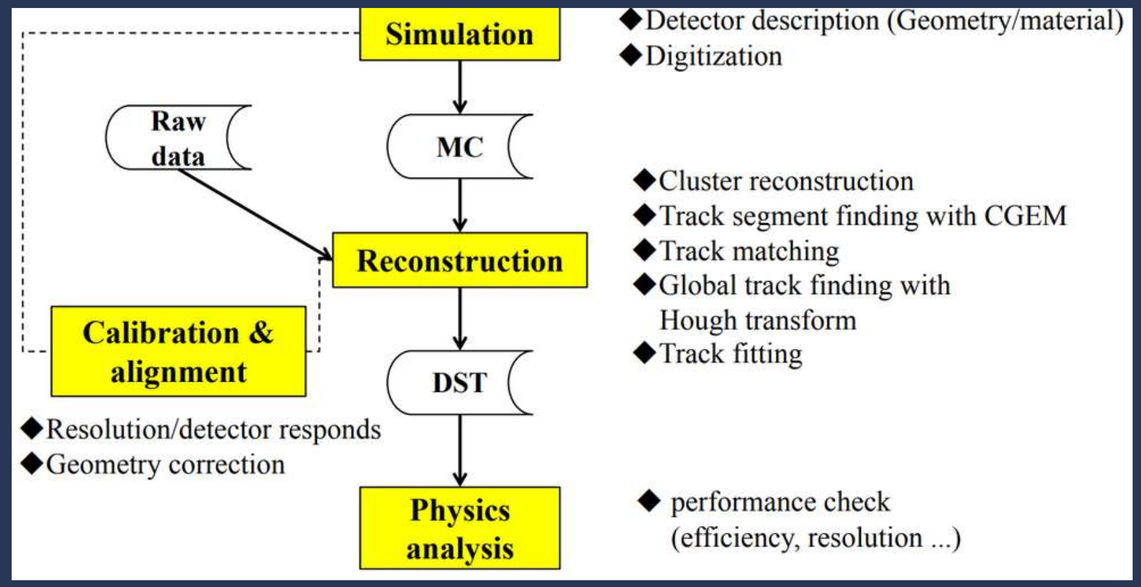

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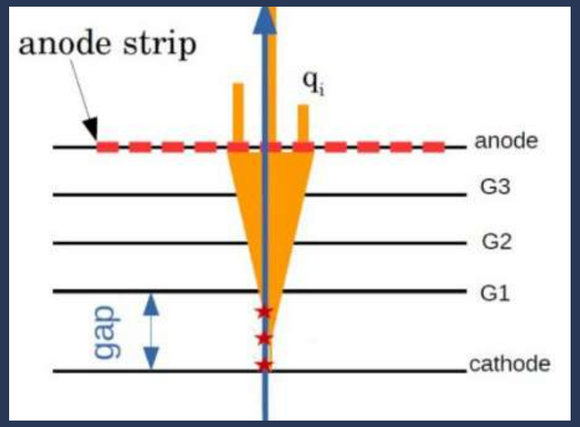

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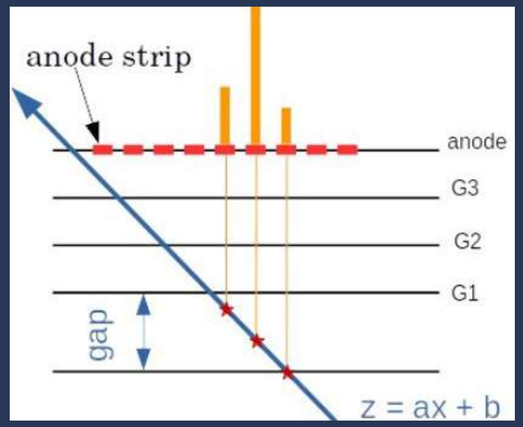

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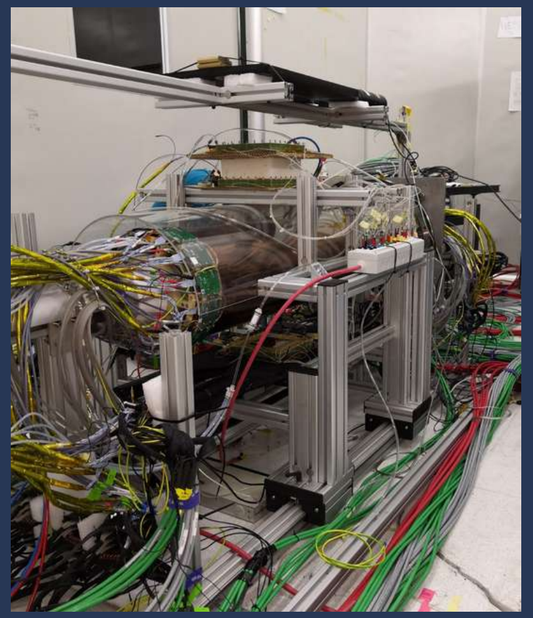
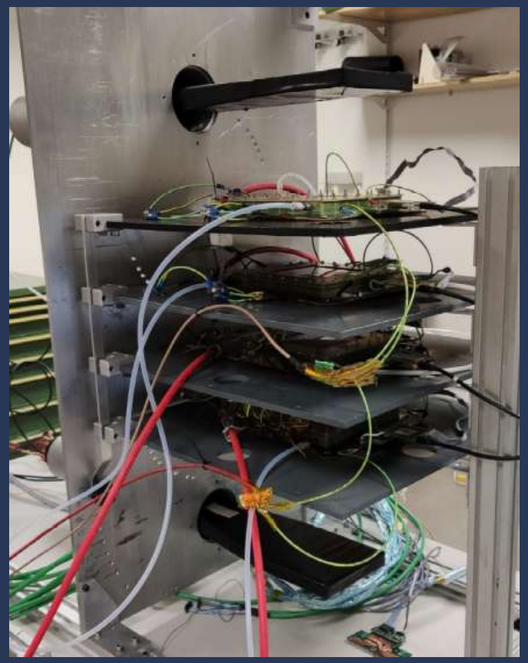
HOW DATA TAKING

WITH FINAL DETECTORS

- In Beijing
- Cosmic stand instrumented on top of the assembly machine
- Two (out of three) CGEM layers
- ~5.6k channels connected
- Final LV and HV systems
- Remote control and on-site maintenance

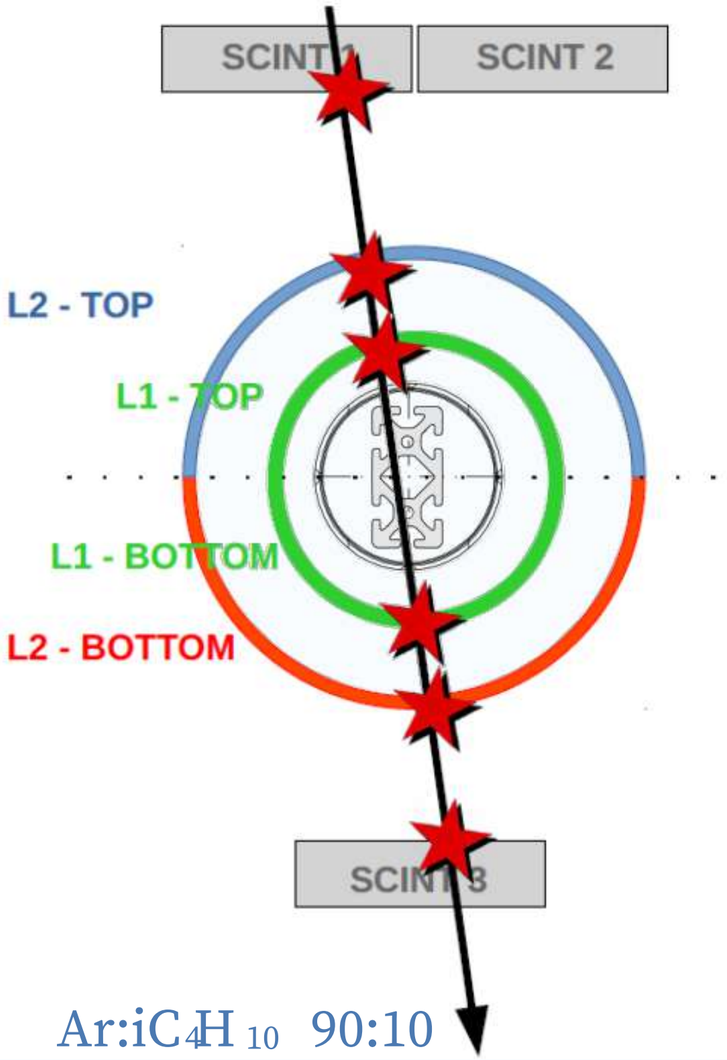




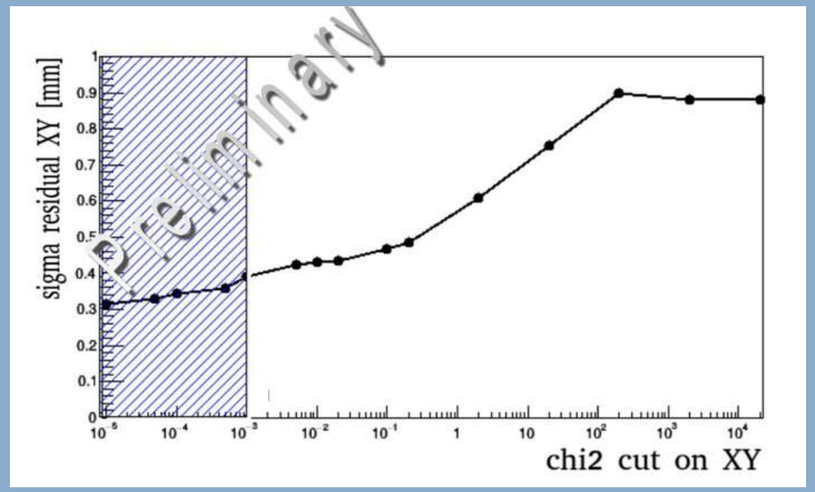
WITH PLANAR PROTOTYPES

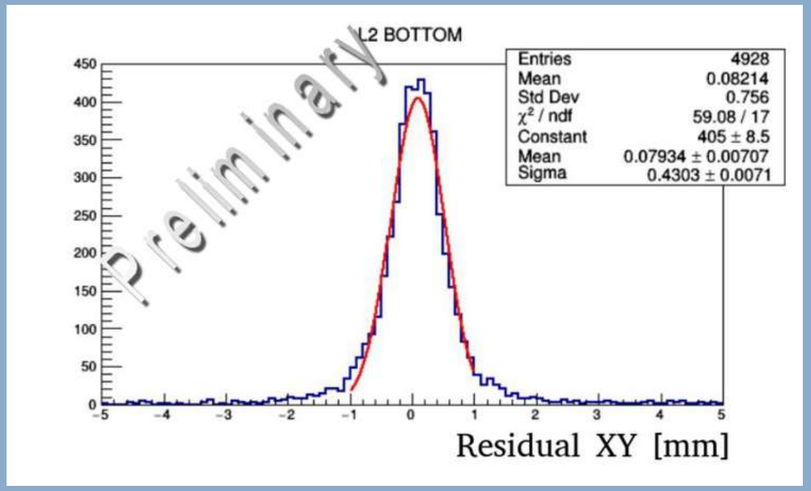
- Telescope for cosmic in Ferrara
- Telescope for test beam in H4 line at CERN
- Four planar triple-GEMs
- Simpler HV system
- Benchmark with APV/SRS electronics
- Tests with TIGER/GEMROC on-going
- Fanout modules
- Online and offline analysis

The cosmic ray is reconstructed with three point tracks. The fourth point characterize the detector.

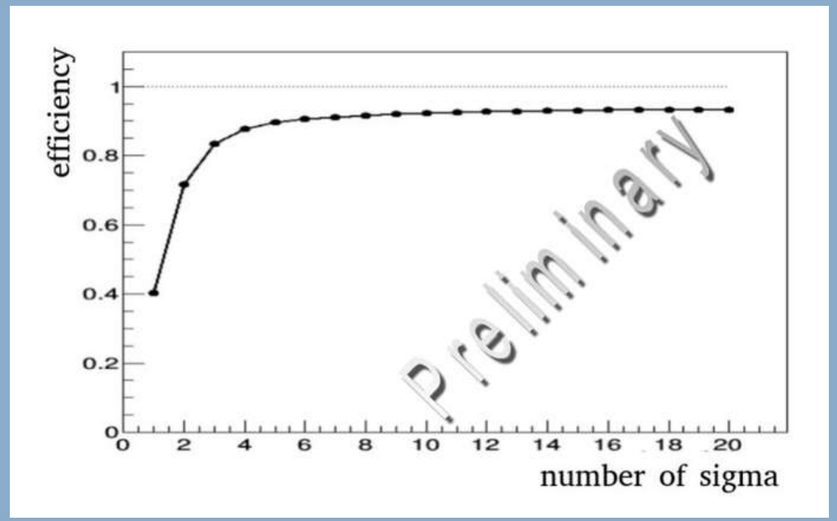


$Ar:iC_4H_{10}$ 90:10



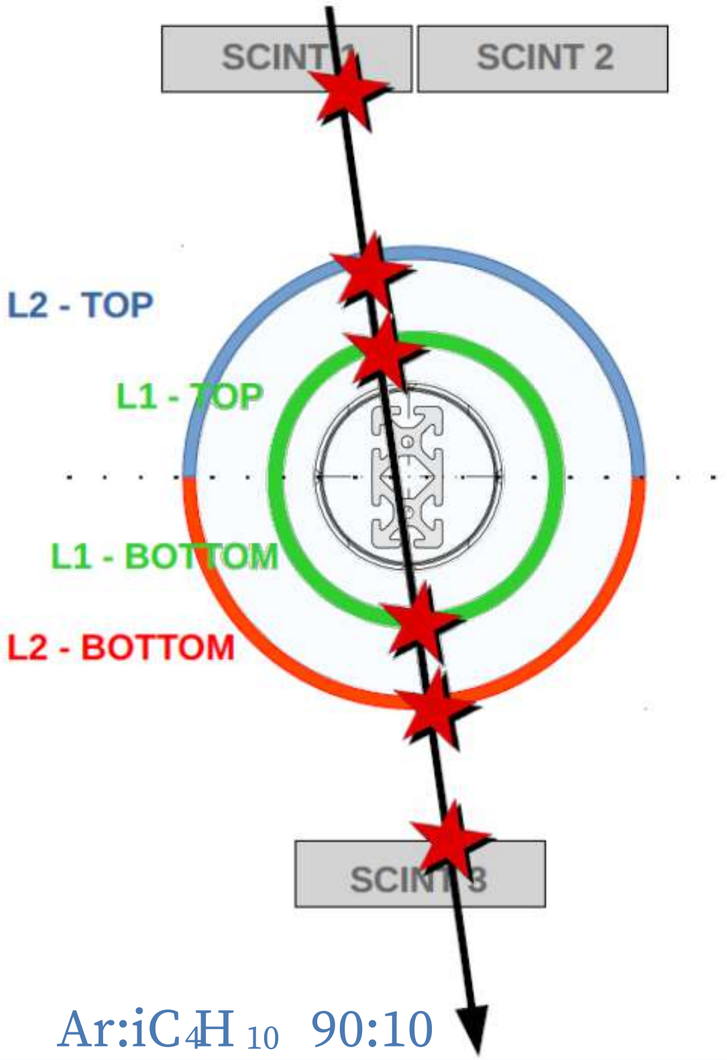


The good tracks are selected with a χ^2 cut. The sigma of the residual distribution is then extracted for the plane under test.

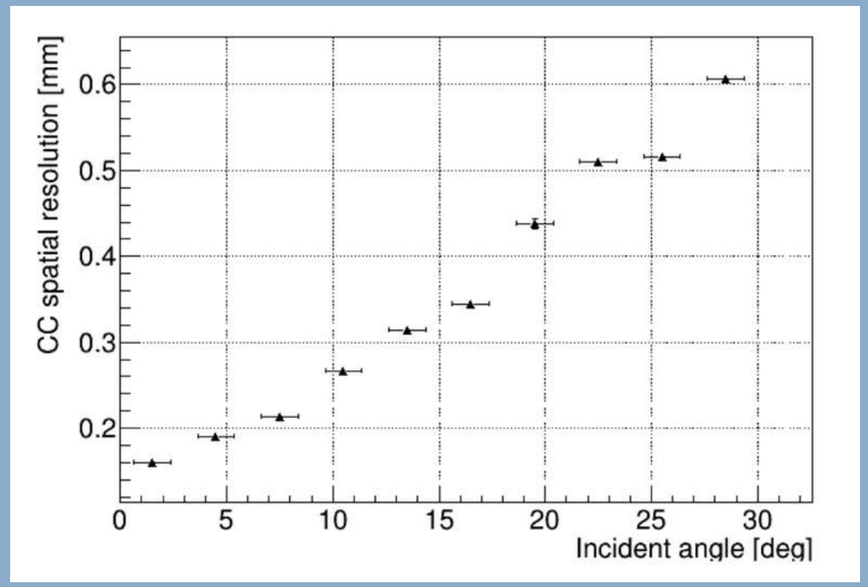


A preliminary measurement shows a 90% of efficiency.

The cosmic ray is reconstructed with three point tracks. The fourth point characterize the detector.

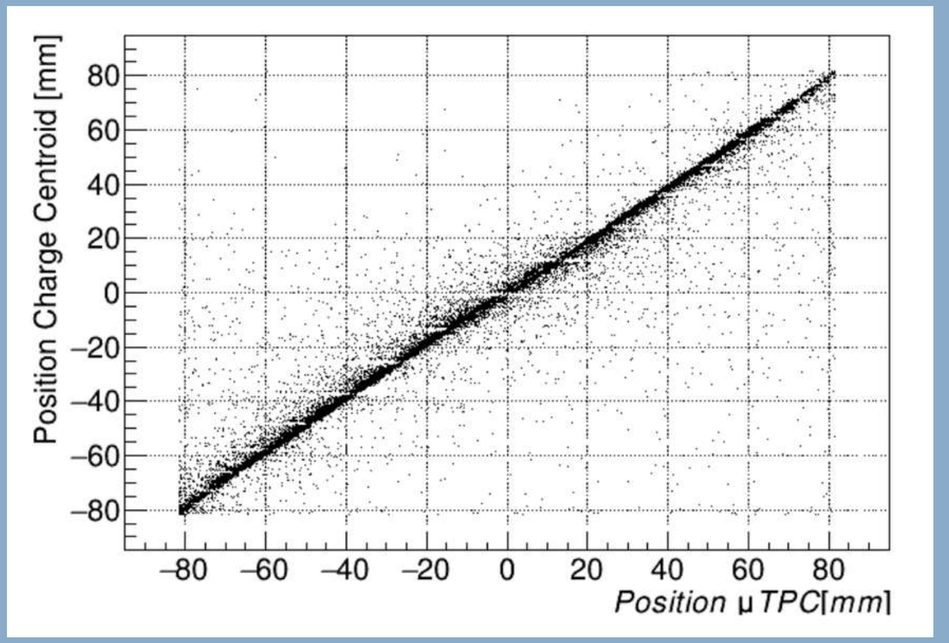


$Ar:iC_4H_{10}$ 90:10



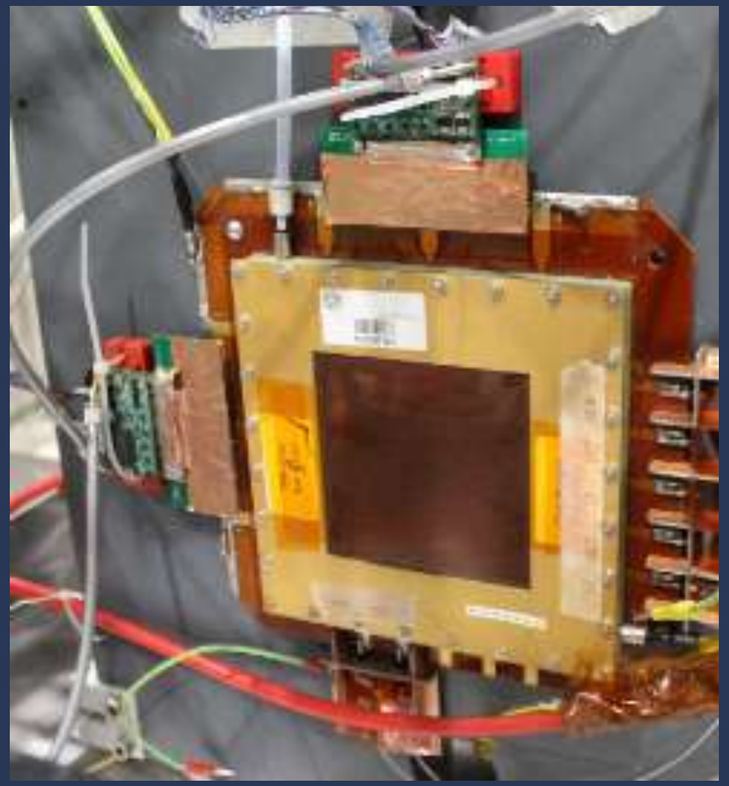
While the incident angle between the cosmic ray and CGEM surface increases, the charge distribution collected at the anode is not Gaussian anymore and the charge centroid degrades.

A first implementation of the μTPC method has been included in CGEMBOSS and the preliminary result shows a good correlation with the charge centroid.



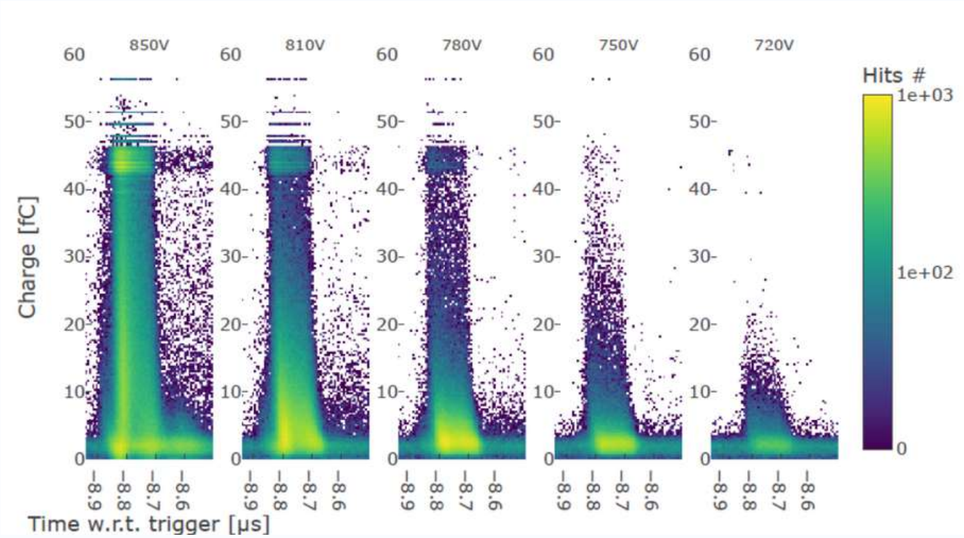
APV/SRS & TIGER/GEMROC

Ar:iC_4H_{10} 90:10

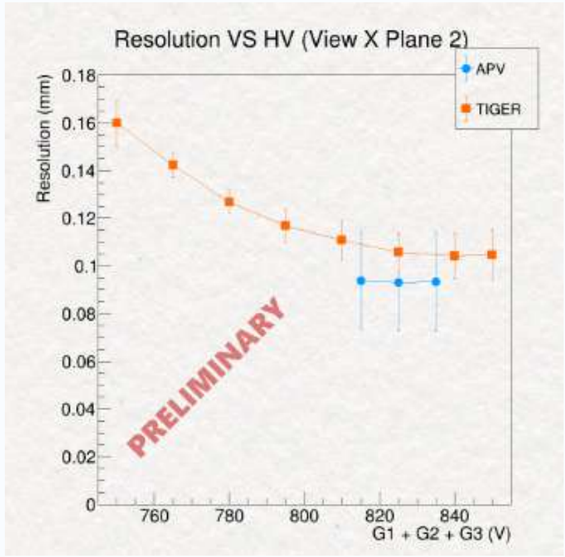


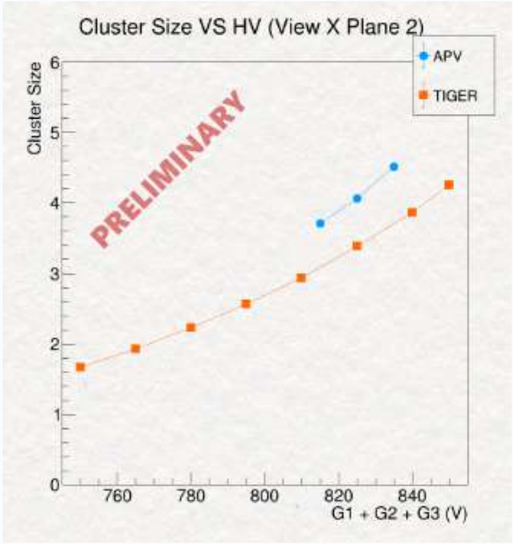
- HV scan (gain scan)
- Angle scan
- Drift field scan
- Threshold scan
- Integration time

Charge versus time plots at different gains (increasing from right to left)



A preliminary comparison between the performance of APV-SRS and TIGER-GEMROC readout chains was performed through the analysis of similar datasets.





The preliminary results obtained for APV-SRS and TIGER-GEMROC are compatible within the errors.

FOLLOW ME

INTO THE PROJECT

Where the experiment is

What stimulated this project

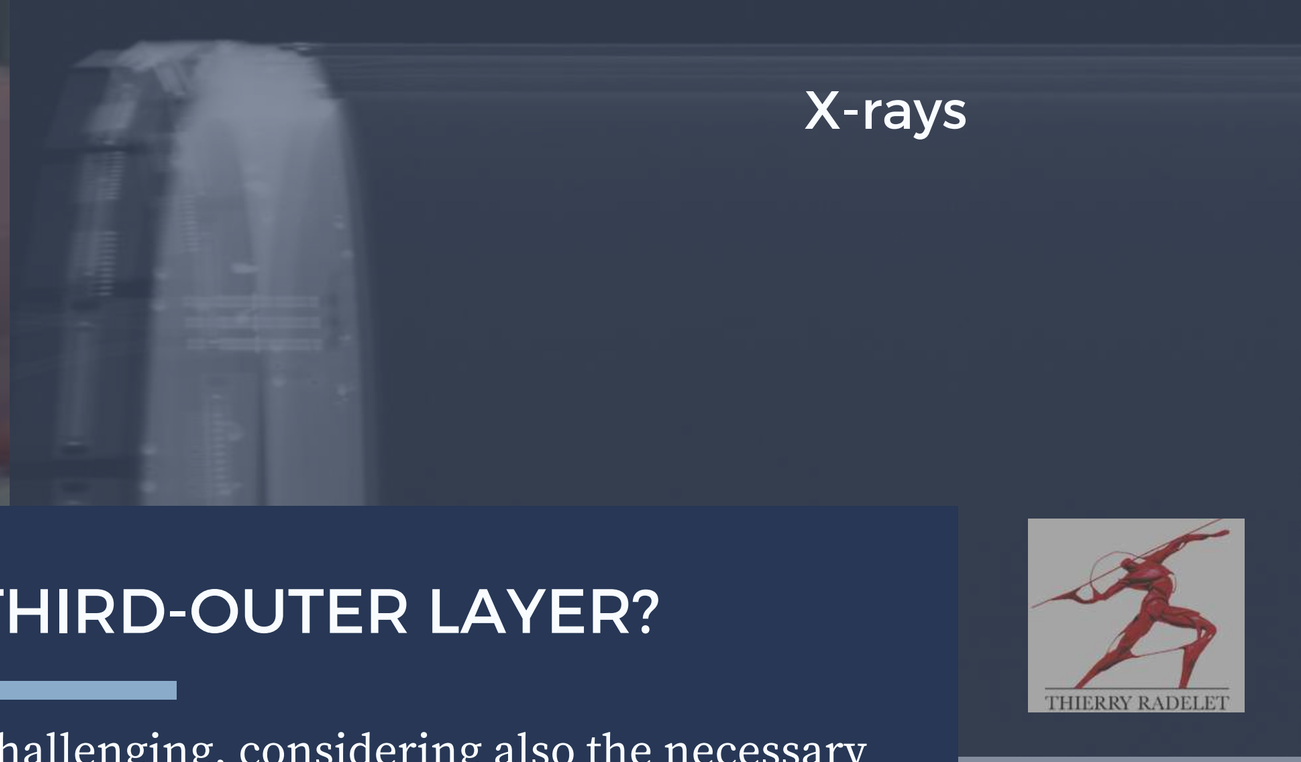
Why it was chosen

Who is the protagonist

How the development is going*

ILARIA BALOSSINO

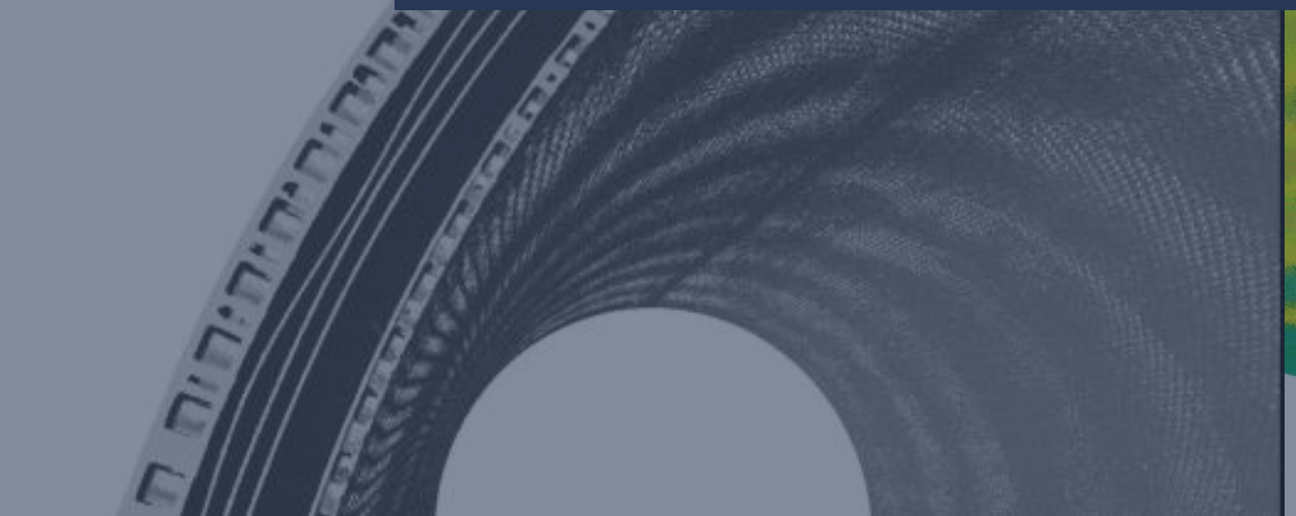
Detector after construction

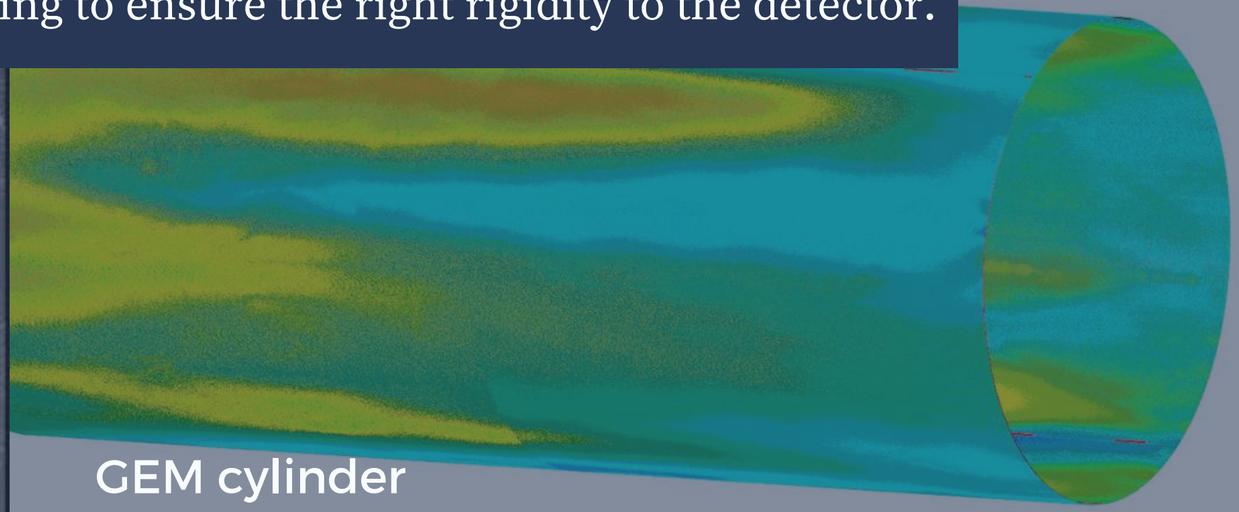


X-rays

WHAT ABOUT THE THIRD-OUTER LAYER?

The construction of the third layer is challenging, considering also the necessary handling and movement needed before the final installation.
Thorough investigation and test are on-going to ensure the right rigidity to the detector.





GEM cylinder buckling analysis

THIS JOURNEY IS OVER

...OURS IS NOT

We were able to continue the characterization in China with remote shifts and on-site maintenance.

In the same period in Italy we worked with planar GEM detector to continue the electronics/detector integration.

The setup in Beijing shows a good stability in time.

The performance of the final detectors is good.

Lot of work is still on-going and needs to be done once we can start travel again.

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thanks

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