Operation and readout of CGEM Inner Tracker

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Università degli Studi di Ferrara

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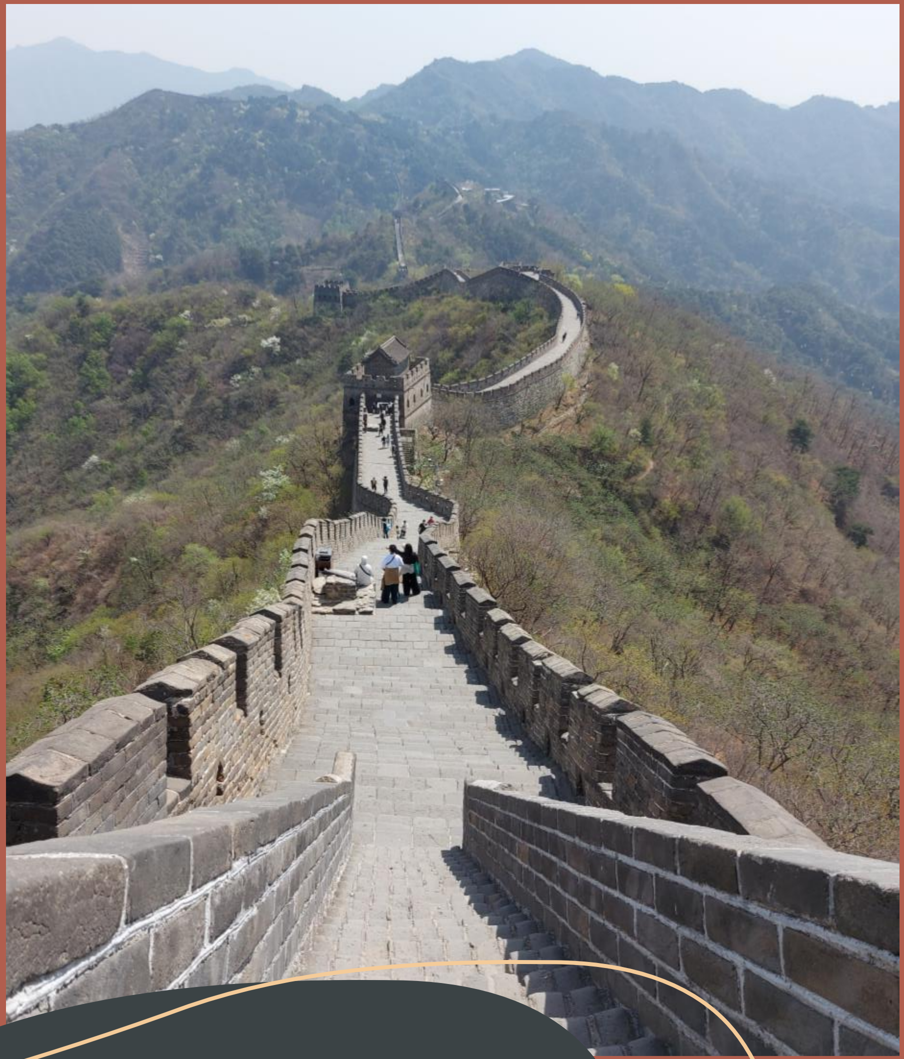


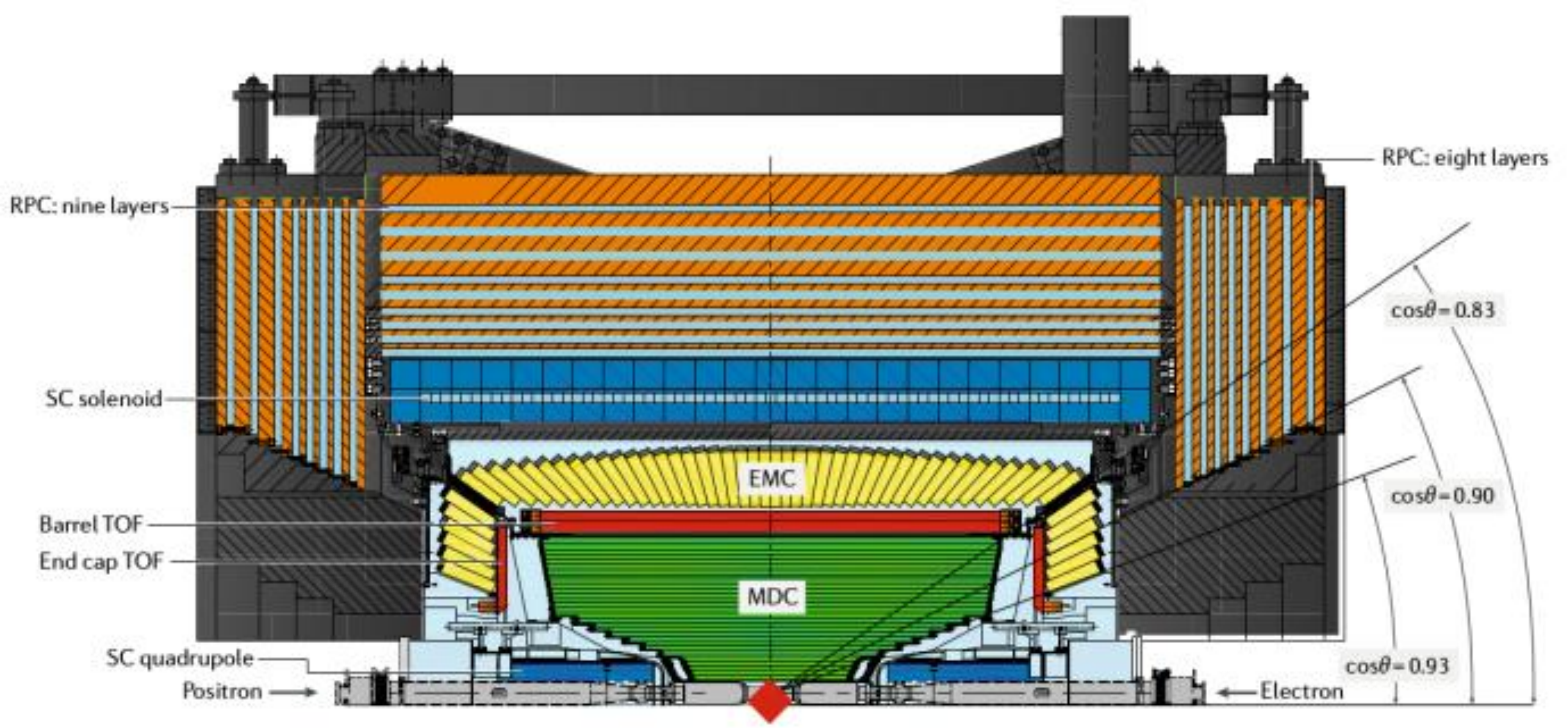
OUTLINE

1. BEPCII & BESIII
2. DRIFT CHAMBER & NEW CGEM-IT
3. CGEM-IT COMMISIONING
4. PERFORMANCE & STABILITY STUDIES
5. FUTURE PLANS

BEPCII & BESIII

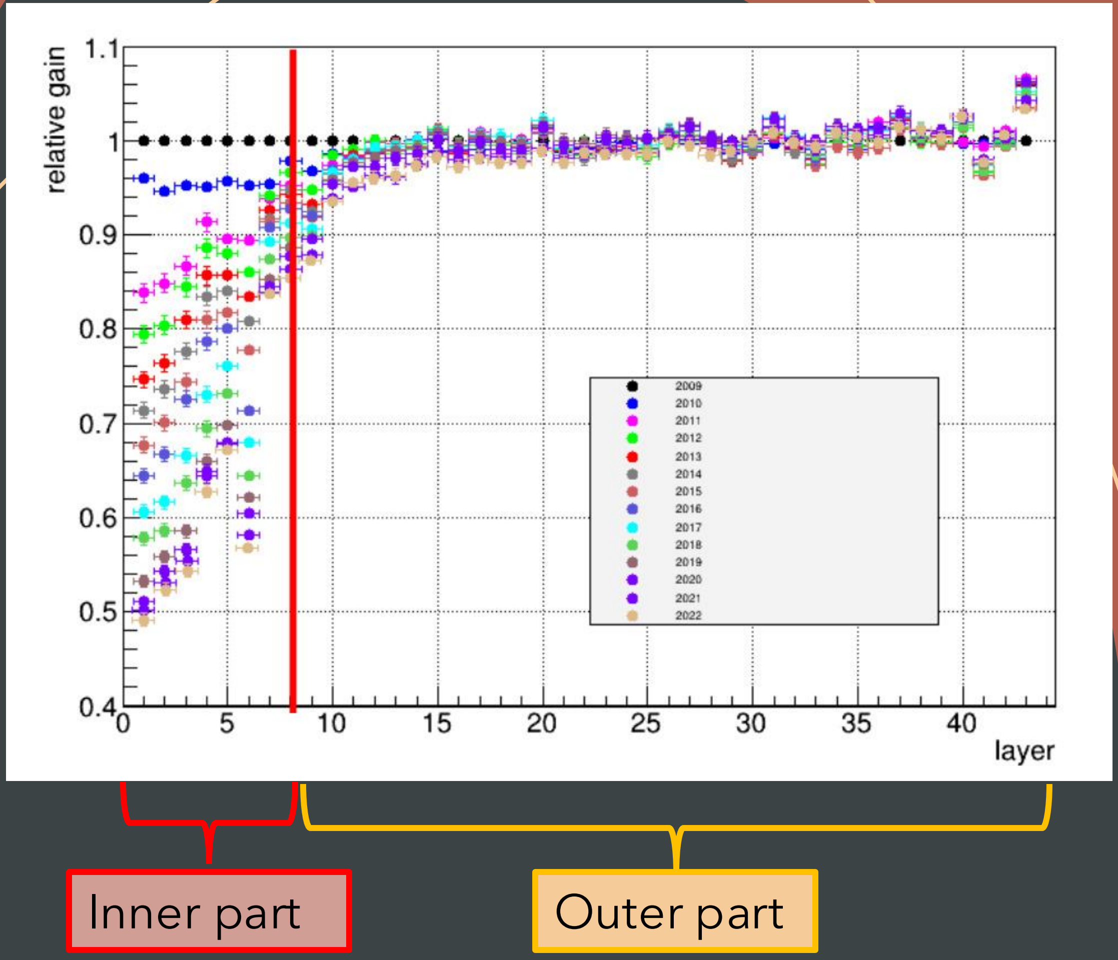
- The BEijing Spectrometer III (BESIII) is optimized for the studies of hadron physics and tau-charm physics
- BESIII is placed at the interaction point of the Beijing e^-e^+ collider II (BEPCII) at the **Institute of High Energy Physics** (IHEP)
- BEPCII C.M. energy range [2.00,4.95] GeV
- BEPCII peak luminosity: 1.05 x 10^33 cm-2s-1 @ psi(3770) achieved in January 7th, 2023

The BEijing Spectrometer III (BESIII)



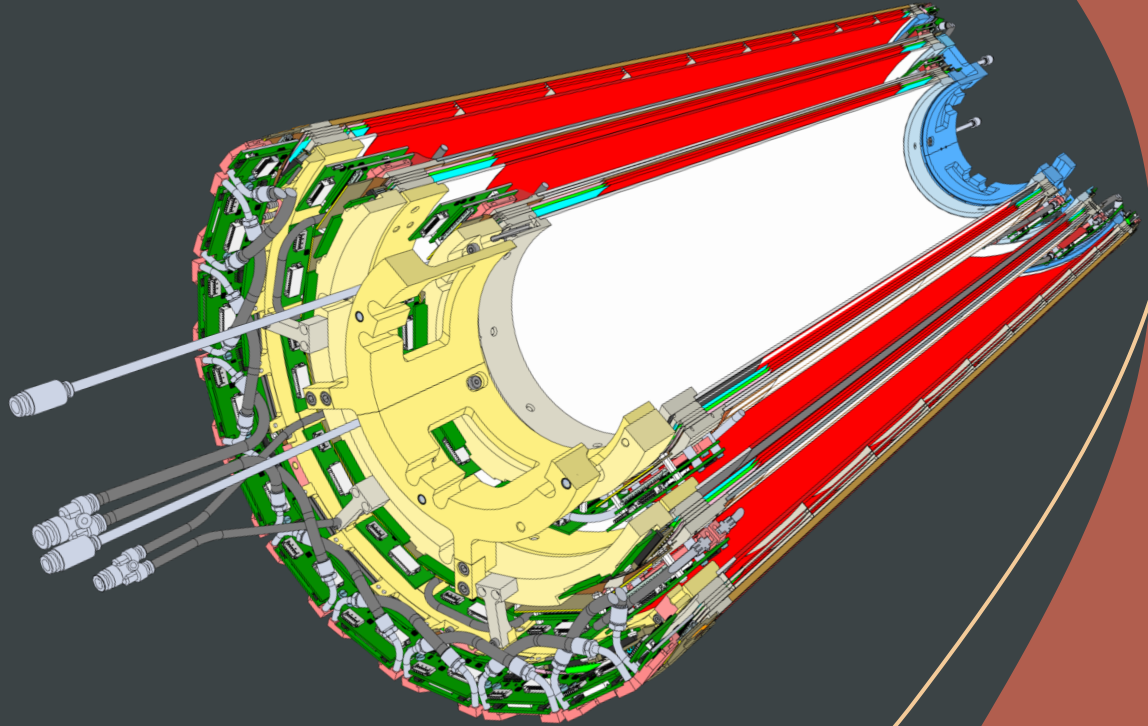
- The BESIII physics program includes studies of hadron spectroscopy and exotic states
- It is composed of: a MUon Counter (MUC), an Electro-Magnetic Calorimeter (EMC), a Time Of Flight system (TOF), and a Main Drift Chamber (MDC)

The MDC ageing



- The MDC is divided into an Inner and Outer parts, which share the same gas volume
- The inner part is suffering from ageing due to beam induced background, with a gain drop of about the 51% for the first layer in 2022
- This gain loss led to the decision to replace the inner part

For more details:
[Dong M. Y. et al. "Aging effect in the BESIII drift chamber", Chinese Physics C, vol.40, no. 1, 201]



The CGEM-IT project

- A system based on Cylindrical Gas Electron Multiplier (CGEM) has been proposed by a group of institutes led by the Italian members of BESIII
- The CGEM-IT consists of 3 independent cylindrical **triple GEM** layers, called Layer 1 (L1), Layer 2 (L2) and Layer 3 (L3)
- The CGEM-IT allows an improvement of the radiation hardness, rate capability, and spatial resolution along the beam axis, while keeping the same momentum resolution

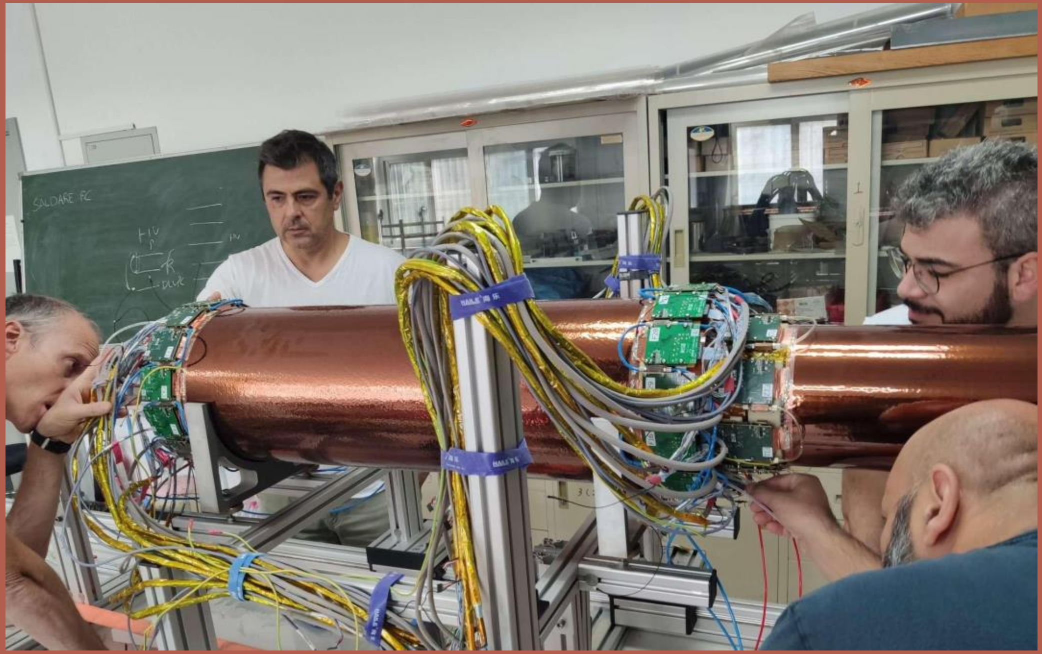
CGEM-IT COMMISSIONING

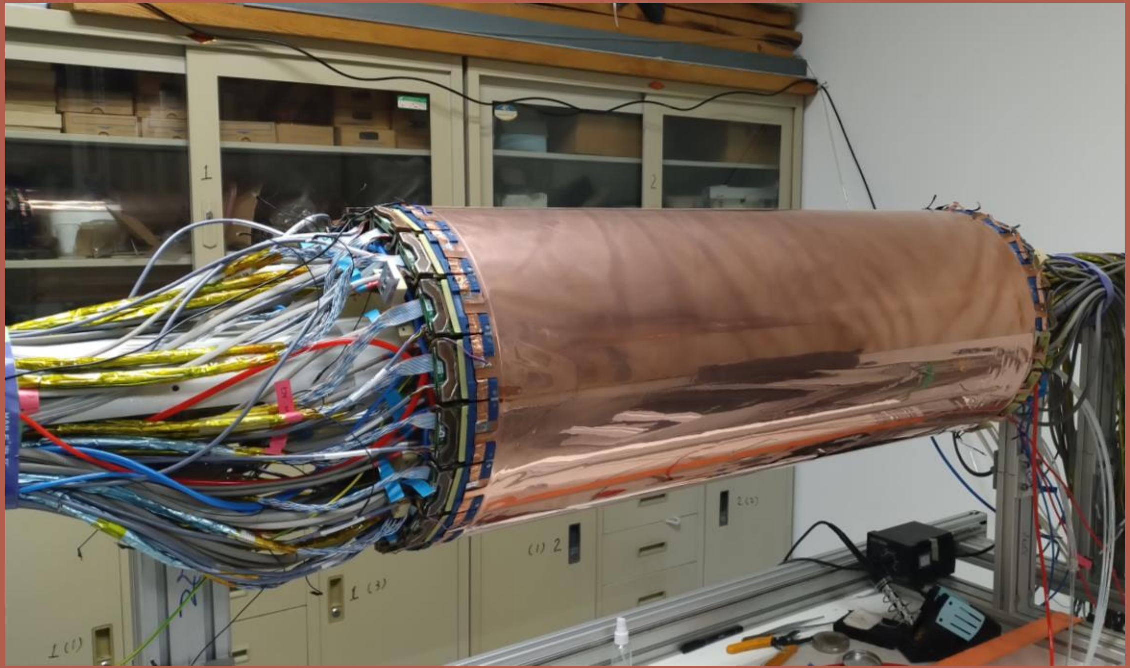
LAYER 3 CONSTRUCTION & INSERCTION

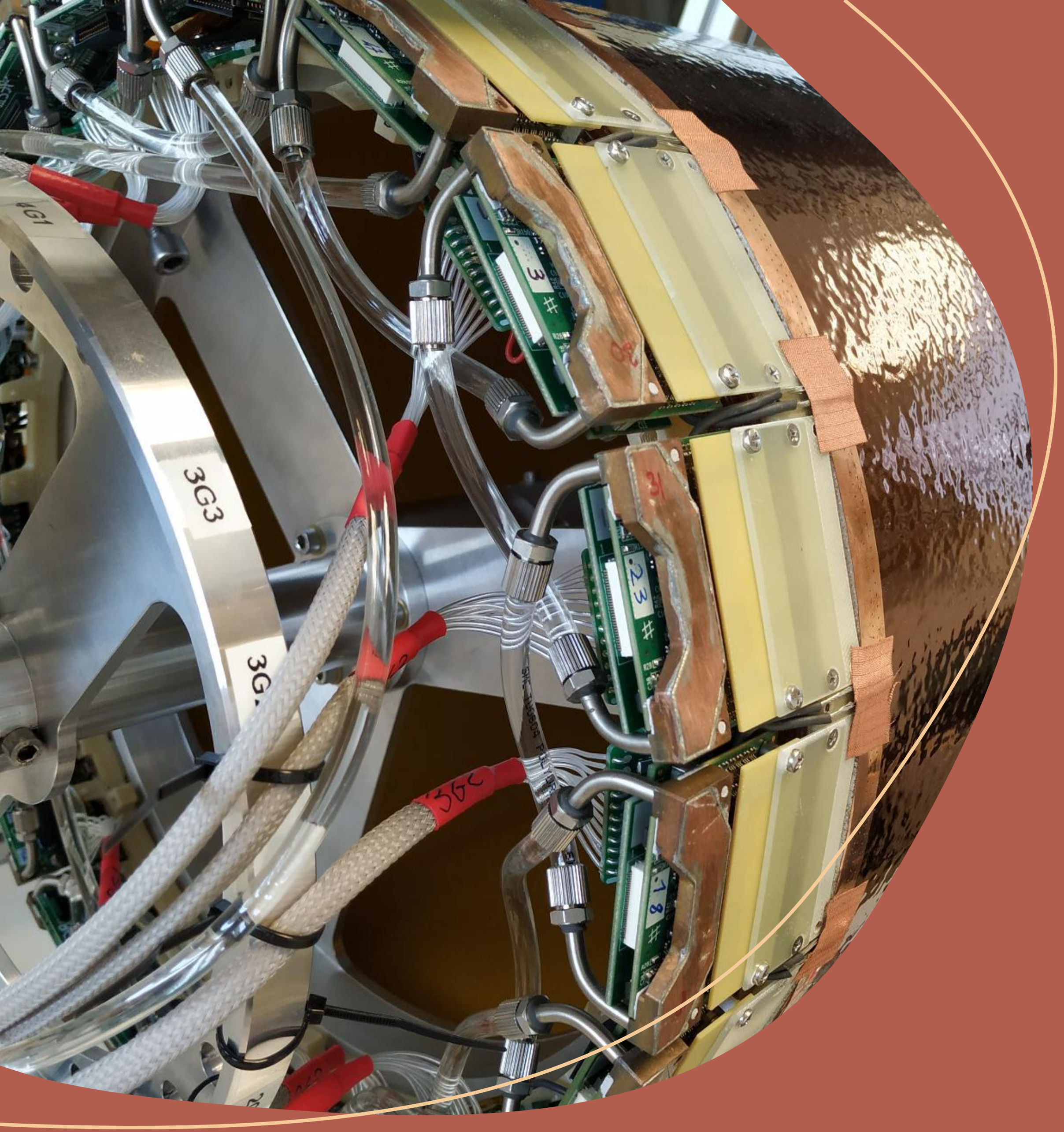
- The construction of the last layer took place in a clean room dedicated to Beijing, in summer 2023
- In August 2023, L3 was moved from the clean room to the laboratory having **validated** the **HV system** and the **Gas system**
- In September 2023, the very first cosmic ray data taking on L3!

CGEM-IT COMMISSIONING

After all the tests on the dectors, in **October 2023**, the 3 layers were finally **assembled**!



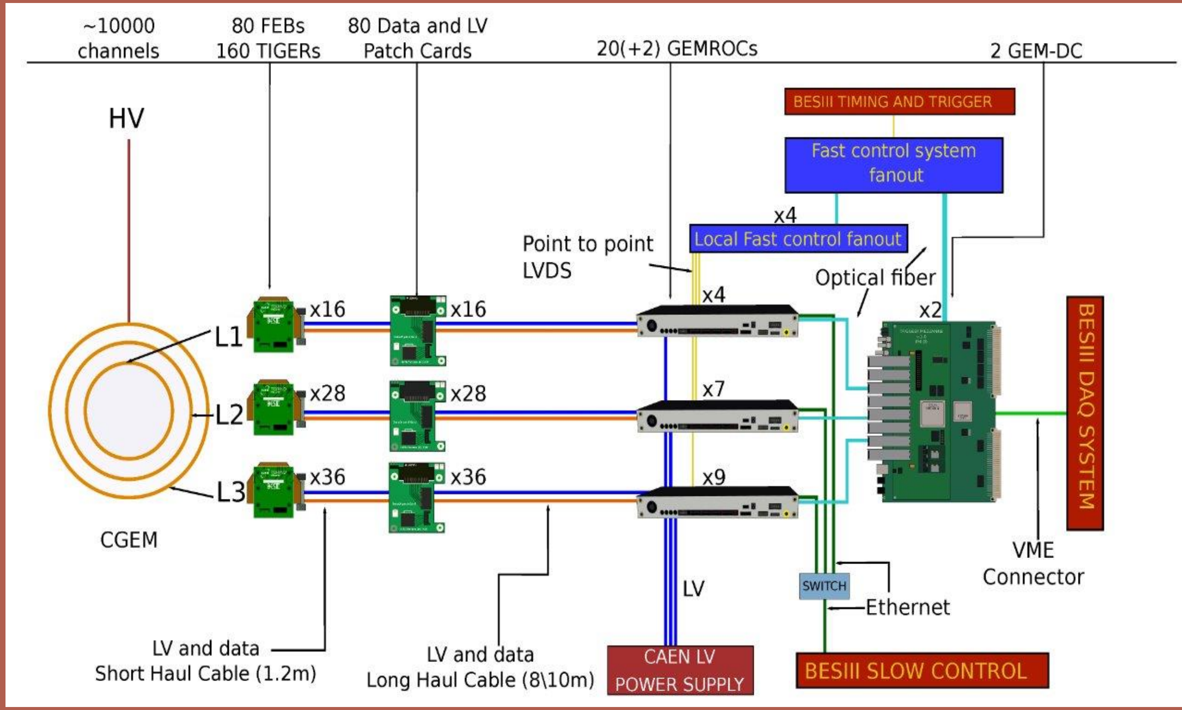




CGEM-IT READOUT CHAIN

CGEM-IT READOUT CHAIN

- The about 10^4 strips of the CGEM-IT are read by a dedicated readout chain
- The readout chain consists of **ON-detector** and **OFF-Detector** elctronics
- The OFF-detector electronics is based on GEM Read-Out Cards (GEMROC) and Data Low Voltage Patch Cards (DLVPC)
- GEMROC is an FPGA based backend module for configuring the ON-detector electronics, powering it, and managing data flow during acquisition



ON detector

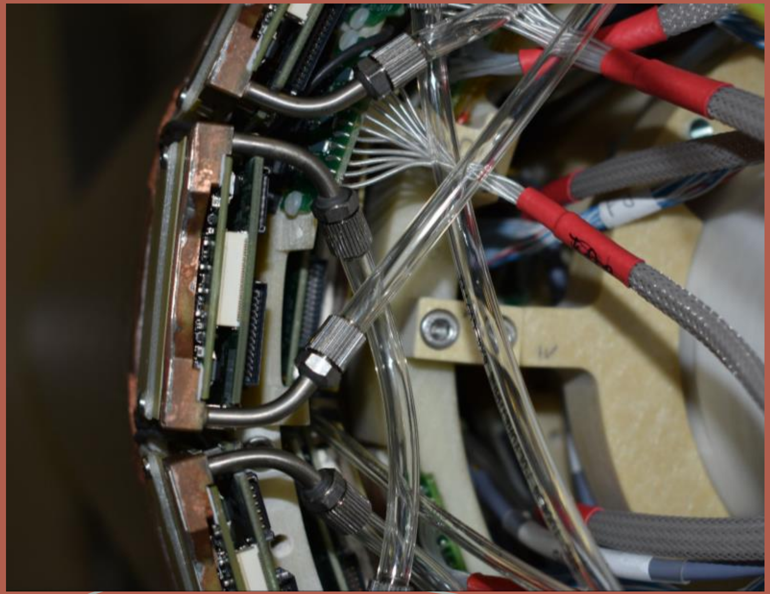
OFF detector

For more details: The CGEM-IT readout chain - A. Amoroso et al 2021 JINST 16 P08065

CGEM-IT READOUT CHAIN

- The **ON-Detector electronics** is composed by Front-End-Boards (FEBs). Each FEB host two **TIGER** ASIC chip
- TIGER (Torino Integrated GEM Electronics for Readout) is a 64-channel mixed signal ASIC capable of performing simultaneous charge and time measurements
- Each FEB was calibrated and tested by **INFN Turin** before being installed
- A cooling system ensures a constant operating temperature

Photo by M.Mignone



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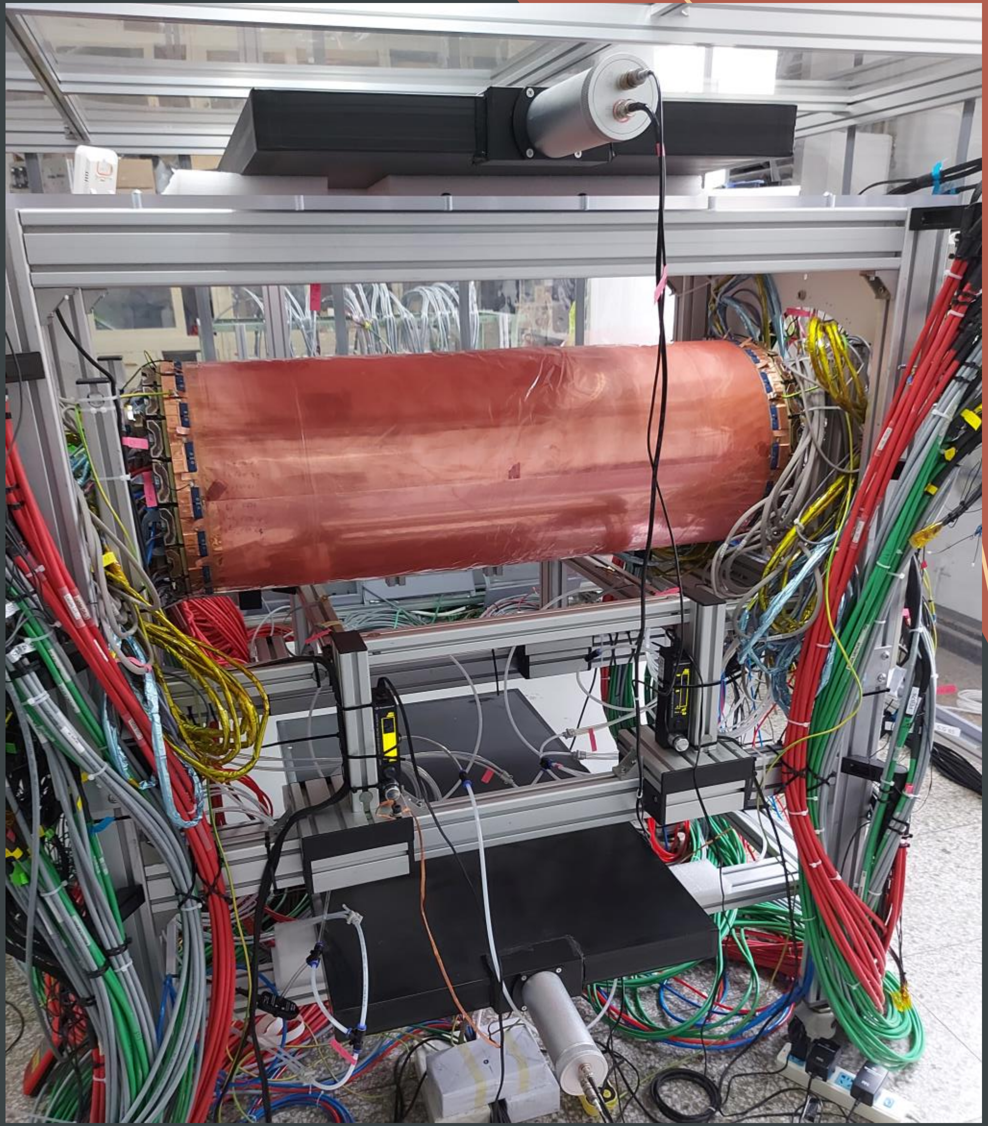
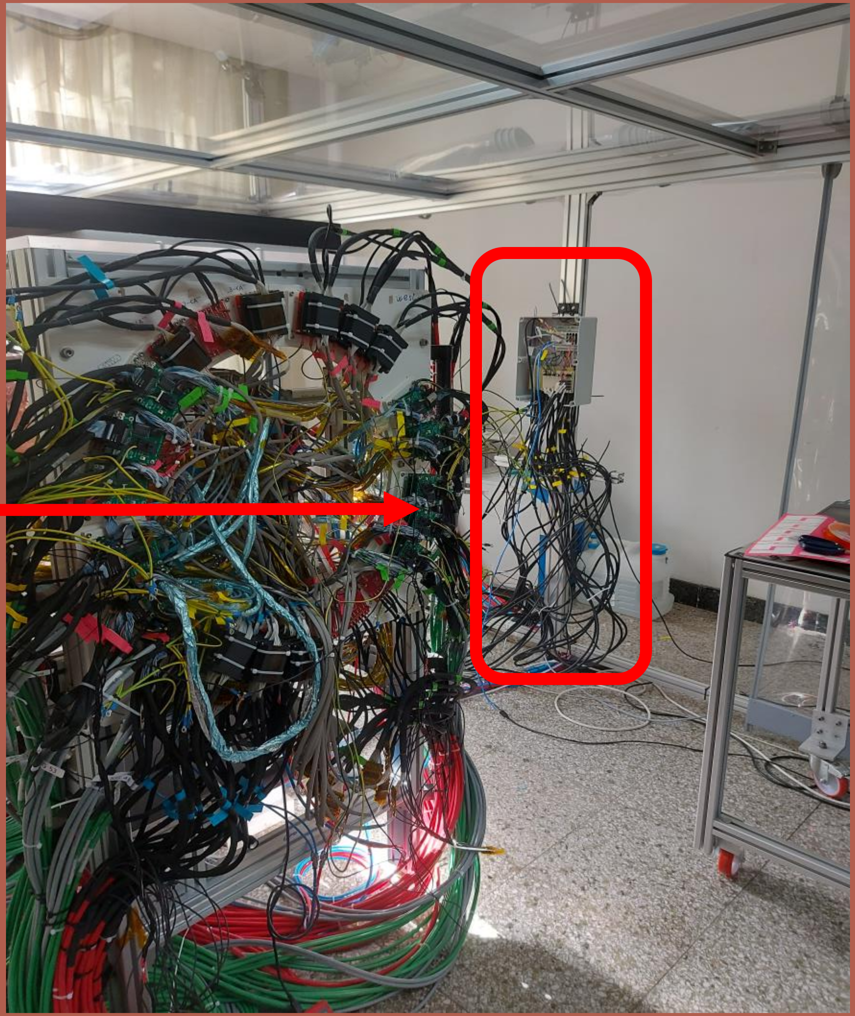


COSMIC RAY DATA TAKING

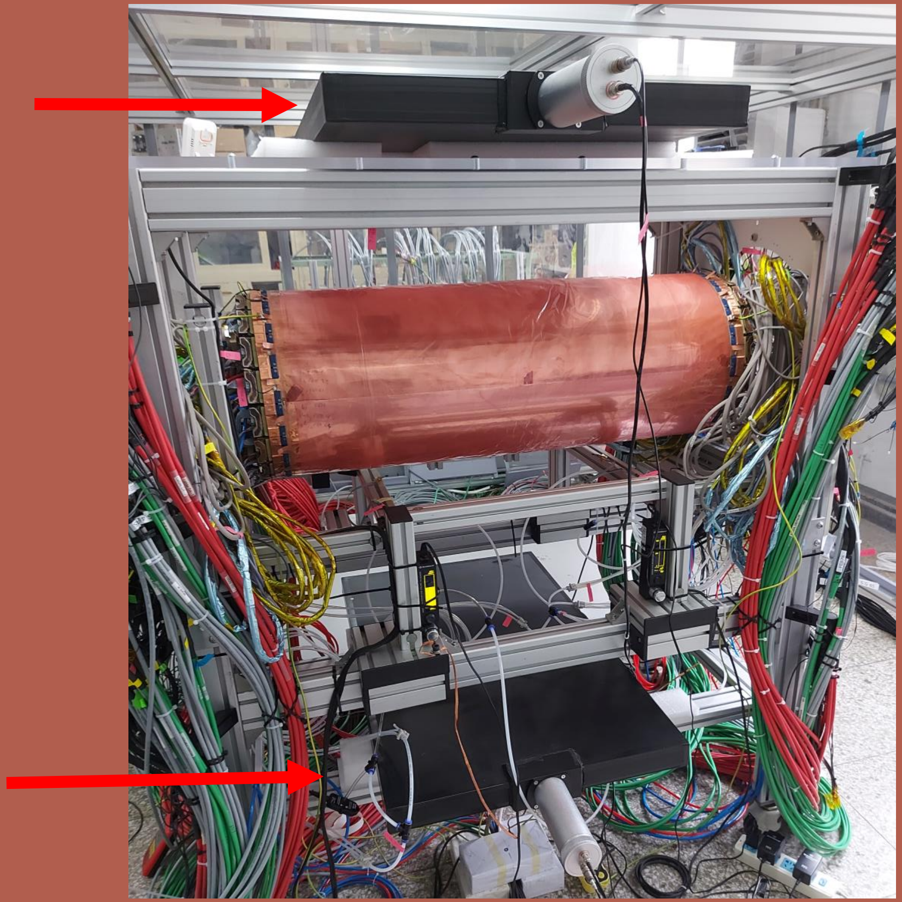
Cosmic Ray data taking

- The detector was equipped with a dedicated **Interlock System (IS),** to allow long periods and remotely controlled safe operation
- The IS continuously measures the main detector parameters, such as gas flow, cooling flow, temperature & humidity
- Based on the measurements made, the IS is able to classify the system configuration, and if it is found to be dangerous it **automatically** returns the detector to a safe condition and notifies the experts



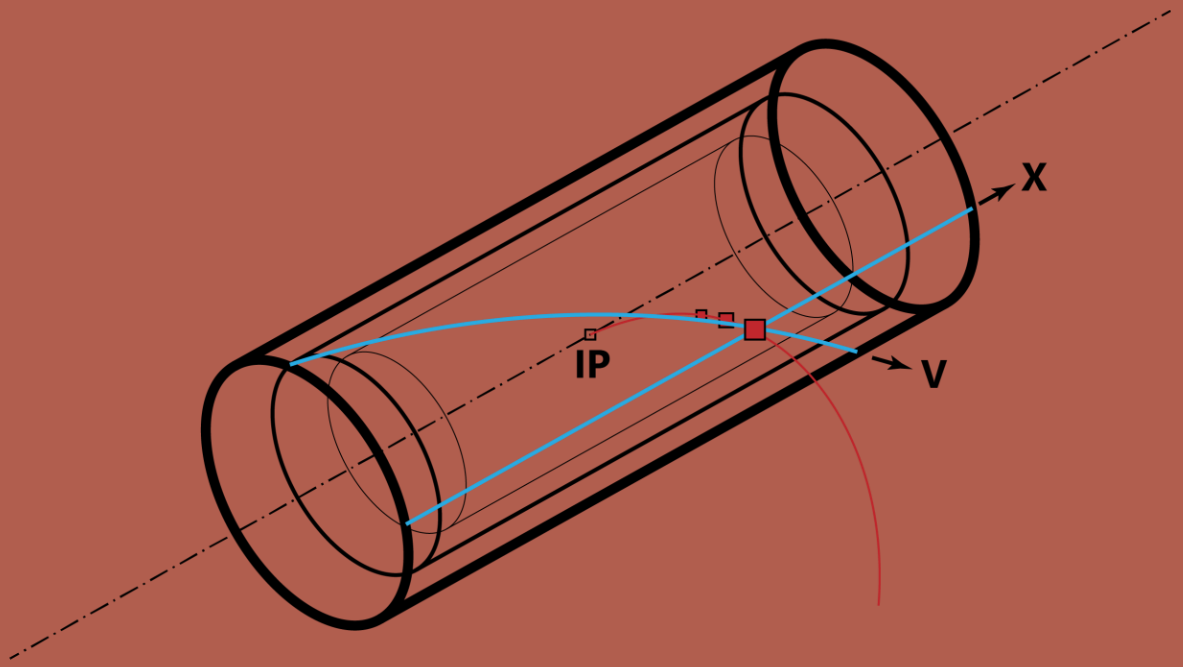
Cosmic Ray data taking

- The scintillators are placed above and below the detector, and have been moved to test **different areas of the detector**
- Data taking began in December 2023 and ran until May 2024



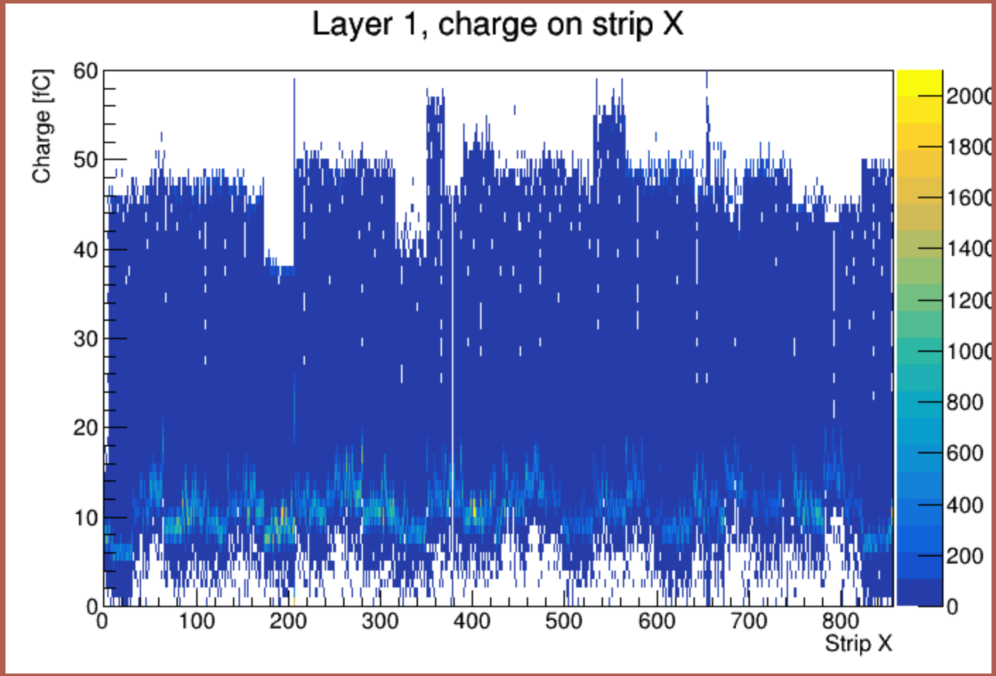
DATA

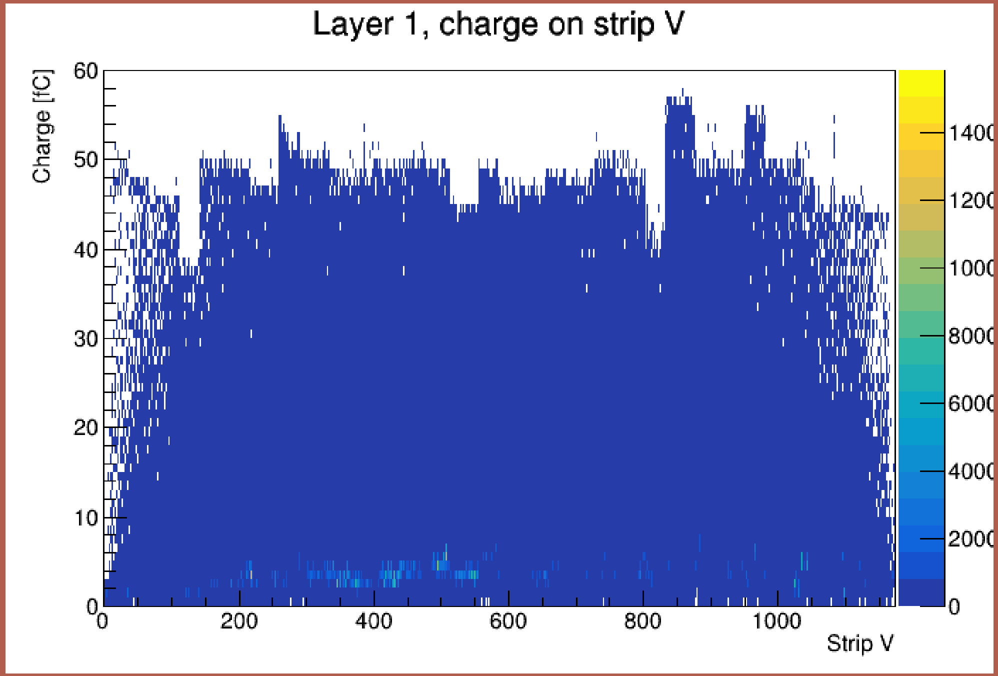
- The detector detector reconstructs tracks thanks to about 10^4 X & V strips
- X strips parallel to the beam axis,
- V strips provide the azimuthal coordinate and for each layer are oriented with a different stereo angle



DATA

All the detector strips **collect charge** and are **read correctly by the electronics**

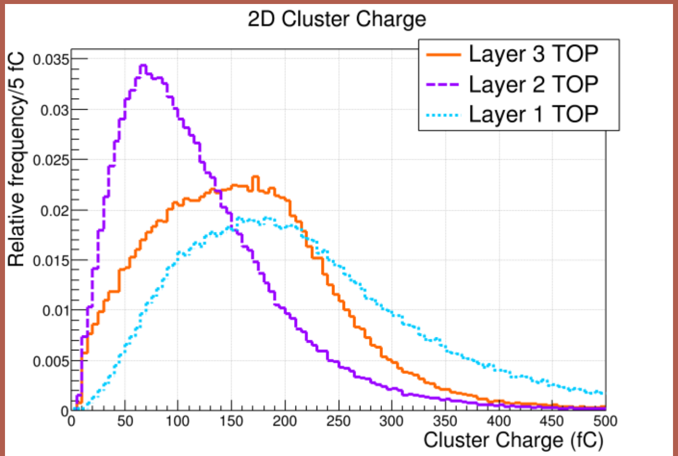


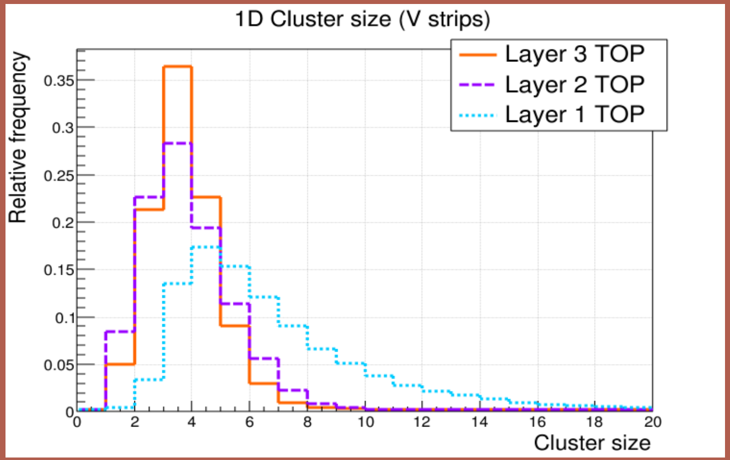


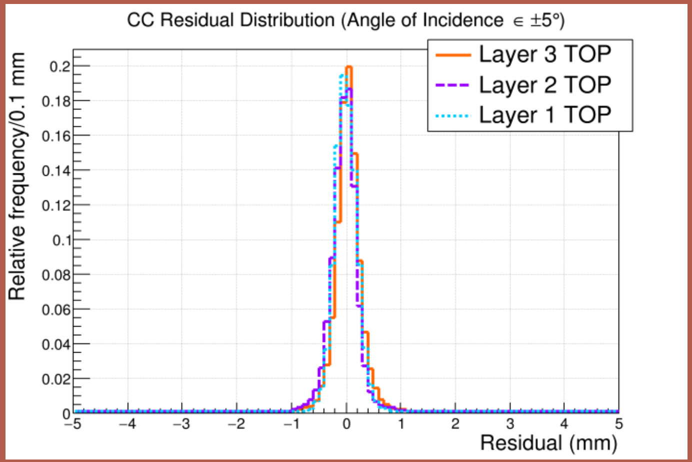
[the X and V strips of the innermost layer]

DATA

The data collected are very useful for **characterizing** the detector and testing the **reconstruction** software







FUTURE

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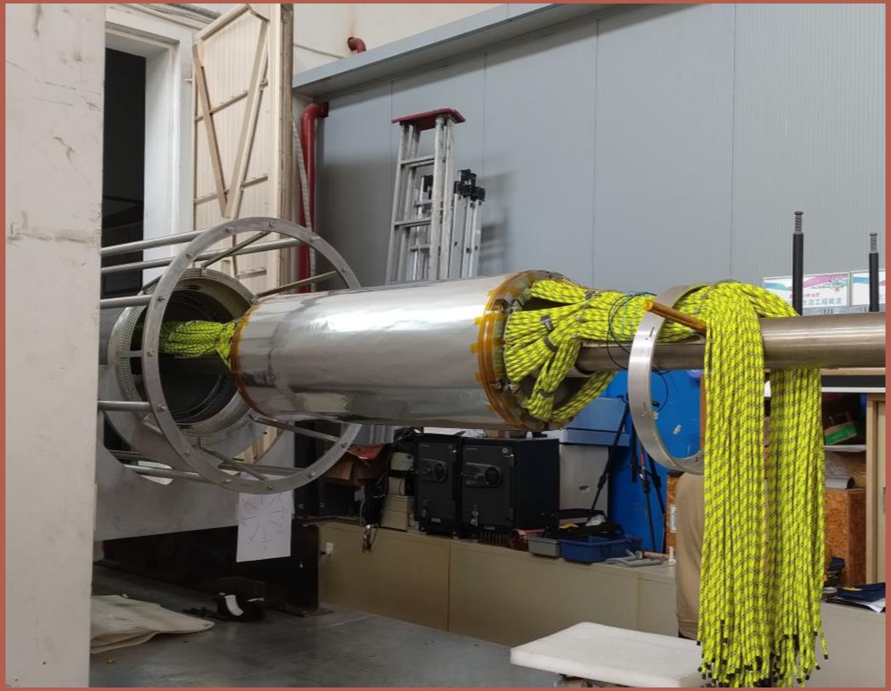
- Several activities are on-going to guarantee a smooth installation and commissioning next year



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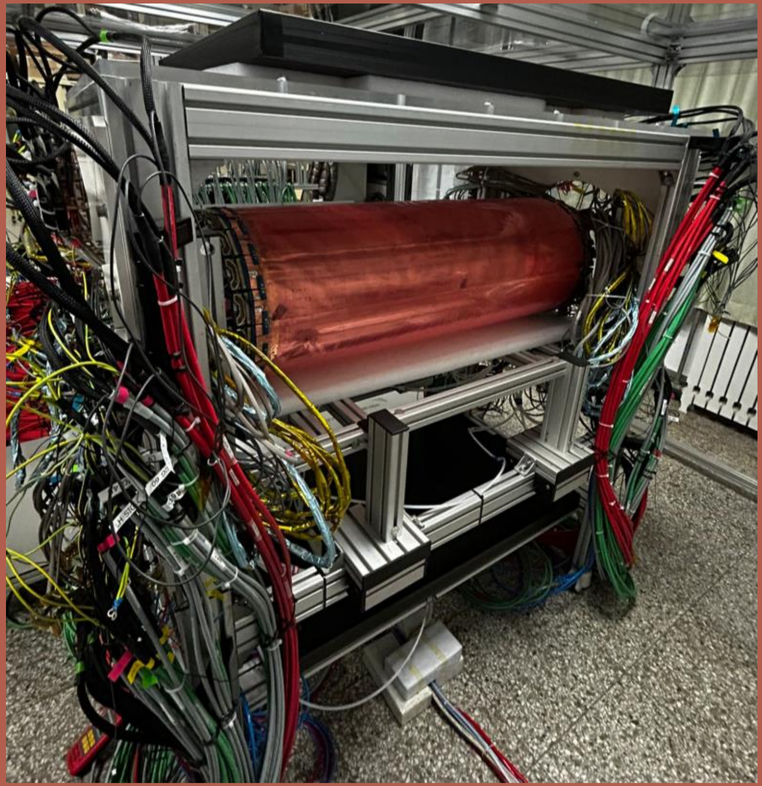
- The cosmic ray data taking and the data analysis continues in parallel with other activities



FUTURE

- Several activities are on-going to guarantee a smooth installation and commissioning next year
- The cosmic ray data taking and the data analysis continues in parallel with other activities
- The data acquired were submitted to an internal review committee, which **recommended the installation of CGEM-IT in BESIII**

THANK YOU FOR THE ATTENTION!

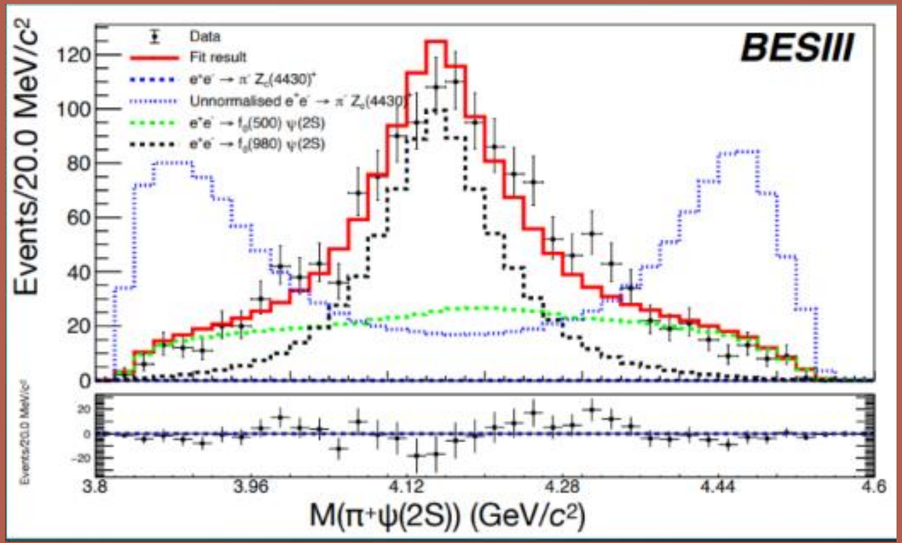
BACKUP SLIDES

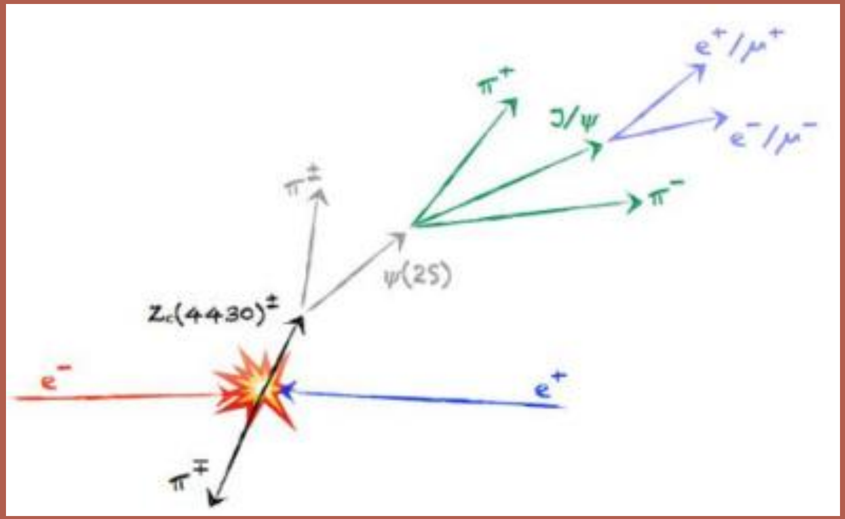
BESIII PHYSICS PROGRAM

- τ − QCD: R-value, $R = \sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$
- 2. LIGHT HADRON SPECTROSCOPY (10 billions of J/ψ, HYBRIDS AND GLUEBALLS)
- 3. CHARMONIUM: SPECTROSCOPY + EXOTIC STATES
- 4. CHARM: INPUT FOR CKM PARAMETERS CALCULATIONS, LEPTON FLAVOR VIOLATION
- 5. NEW PHYSICS....

CHARMONIUM-LIKE XYZ STATES

- spectrum features supernumerary states
- Exotic states don’t fit potential model predictions
- e+e− → π+π−ψ(2S) offers the possibility to probe the XYZ secotor
- e+e− → Y(4660) → π±Zc(4430) → π+π−ψ(2S) → π+π+π−π−J/ψ → π+π+π−π−l+l−
- Zc(4430) was observed and studied in the B-decays in the πψ(2S) invariant mass by BELLE and LHCb

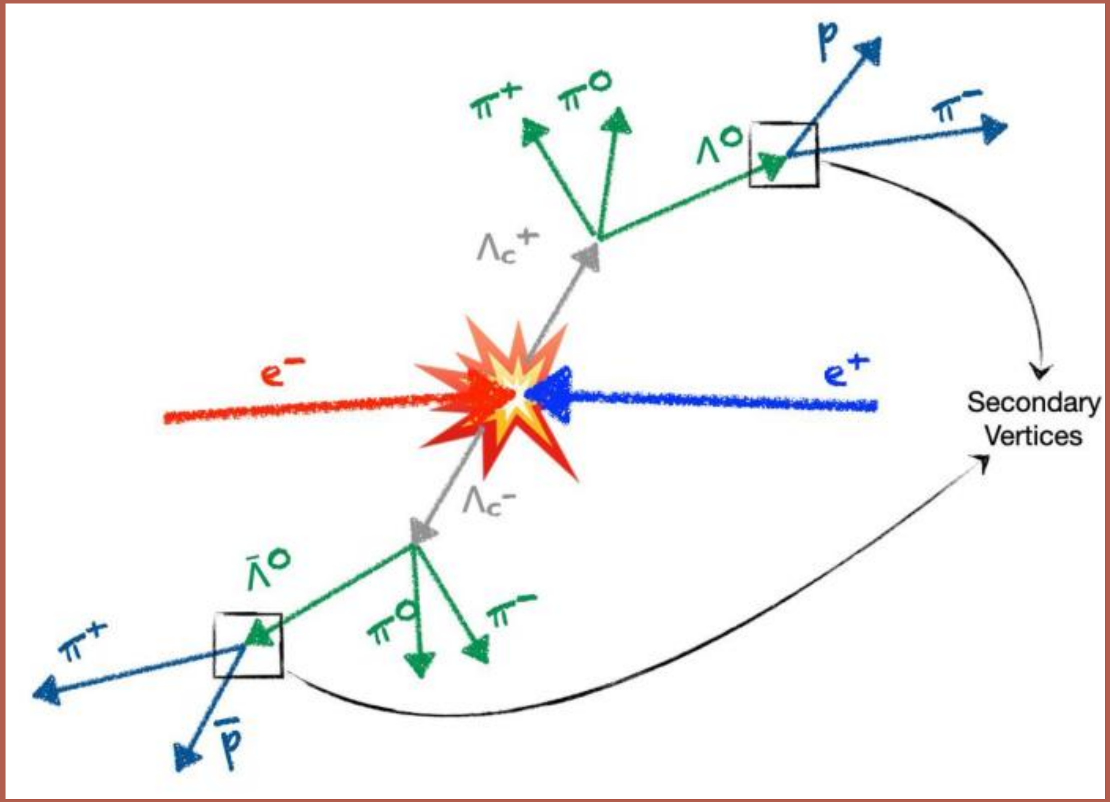




SECONDARY VERTEX

Λ^+_C is the lighest charmed baryon:
- Mass: 2286.46 ± 0.14 MeV
- Mean Life: (200 ± 6) 10^{-15} s

The knowledge of its properties is important to study other charmed baryons
Λ_0 is a strange baryon
- Mass: 1115.683 ± 0.006 MeV
- Mean Life: (2.632 ± 0.020) 10^{-10} s



SECONDARY VERTEX RECONSTRUCTION

$\Lambda \rightarrow p\pi$
$Ks^0 \rightarrow \pi^+\pi^-$

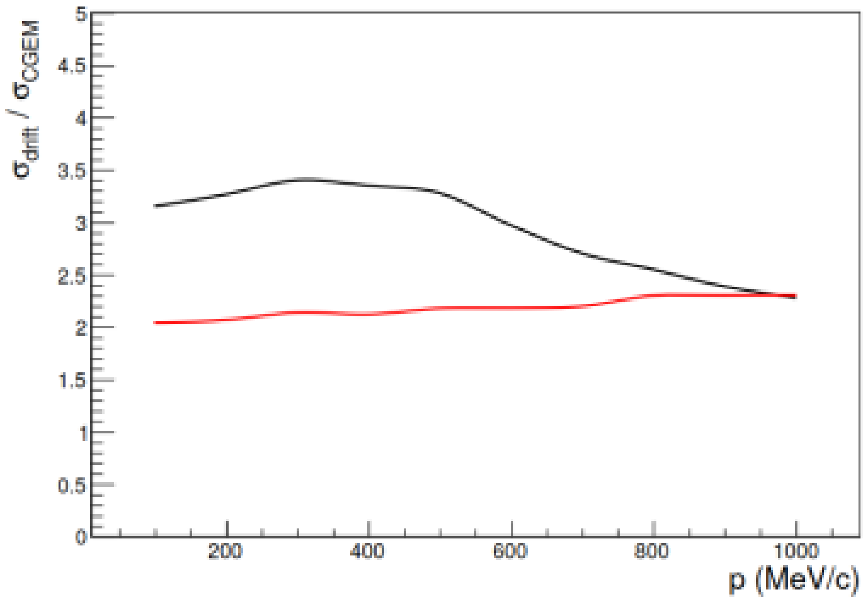
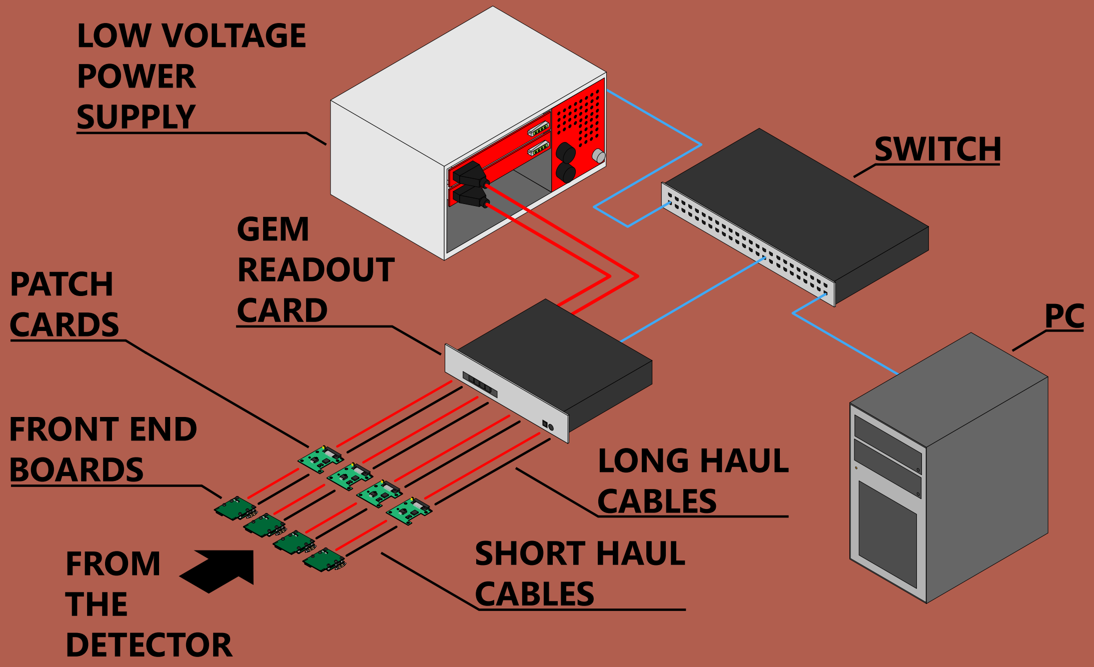


Figure 7.10: Ratio of the resolutions with which the secondary vertices corresponding to Λ (red line) and K_S^0 (black line) charge mode decays are reconstructed by the DC-IT and the CGEM-IT.

TIGERs PARAMETERS

TIGER Parameters

- Input capacitance up to 100 pF
- Input dynamic range from 2 to 50 fC
- Noise on the Energy branch < 1800 e- ENC (0.29 fC)
- Jitter on the Time branch < 4 ns
- Thermal load 12.5 mW per channel
- Rate capability 60 kHz per channel



LAYER-3 CONSTRUCTION

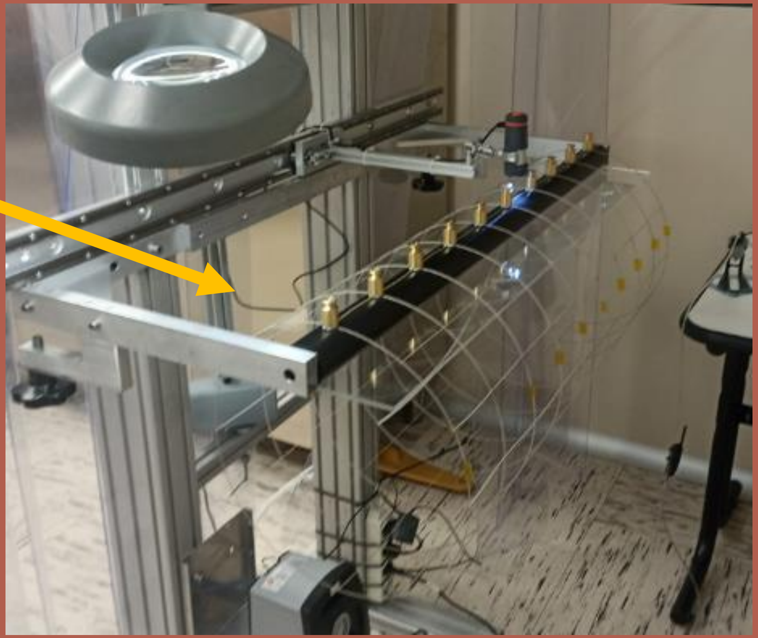
- In 2023 the construction of the last layer (L3) was completed
- Each GEM foil has been carefully tested electrically
- Each electrode was glued into its final cylindrical shape in Ferrara, then shipped to Beijing

LAYER-3 CONSTRUCTION

- **PEEK spacer grids** were inserted between the GEM sheets to ensure the mechanical stability of the detector

- Once in Beijing, the L3 electrodes were assembled into their final configuration, thanks the"Vertical Insertion Machine" (VIM)

- All testing, glueing, and assembly operations were carried out in a **clean room** through careful procedures to avoid external contamination

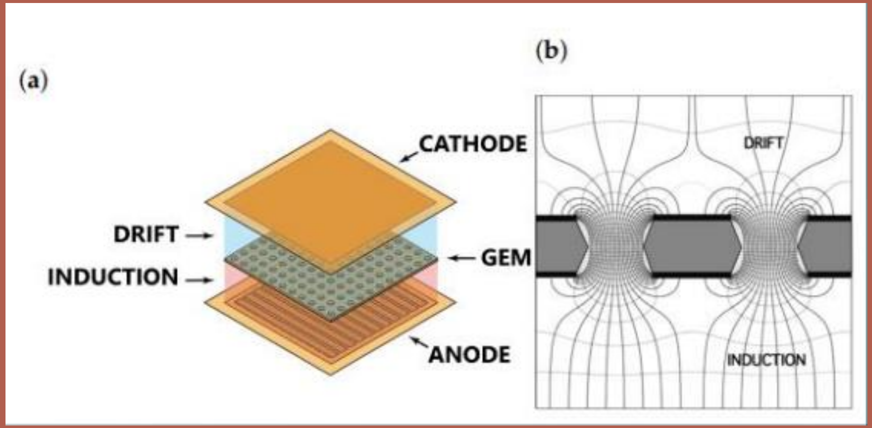


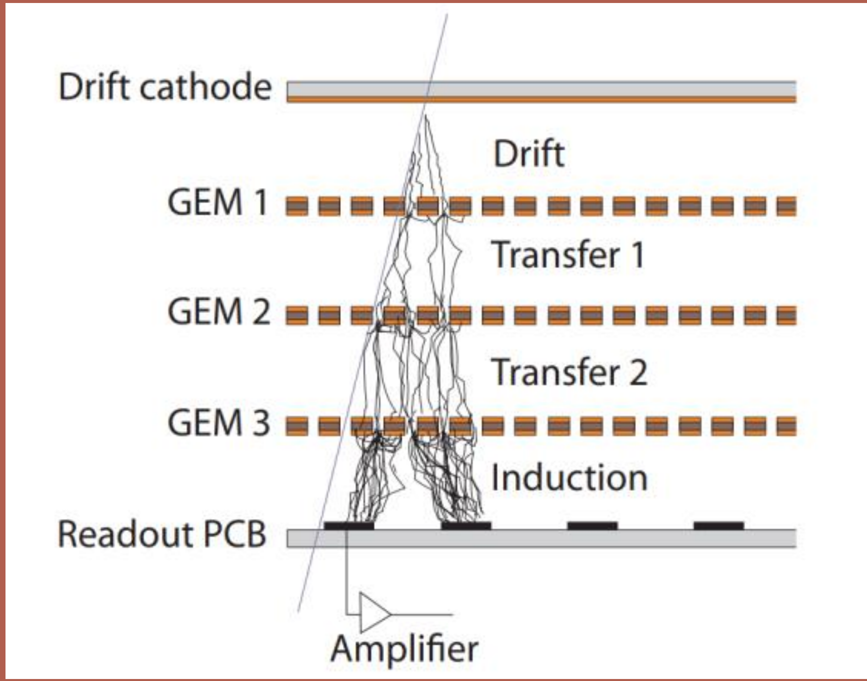
LAYER-3 CONSTRUCTION

- **PEEK spacer grids** were inserted between the GEM sheets to ensure the mechanical solidity of the detector
- Once in Beijing, the L3 electrodes were assembled into their final configuration, thanks to a dedicated machine called "CLESSIDRA"
- All testing, bonding, and assembly operations were carried out in a **clean room** through careful procedures to avoid external contamination

GEM detector

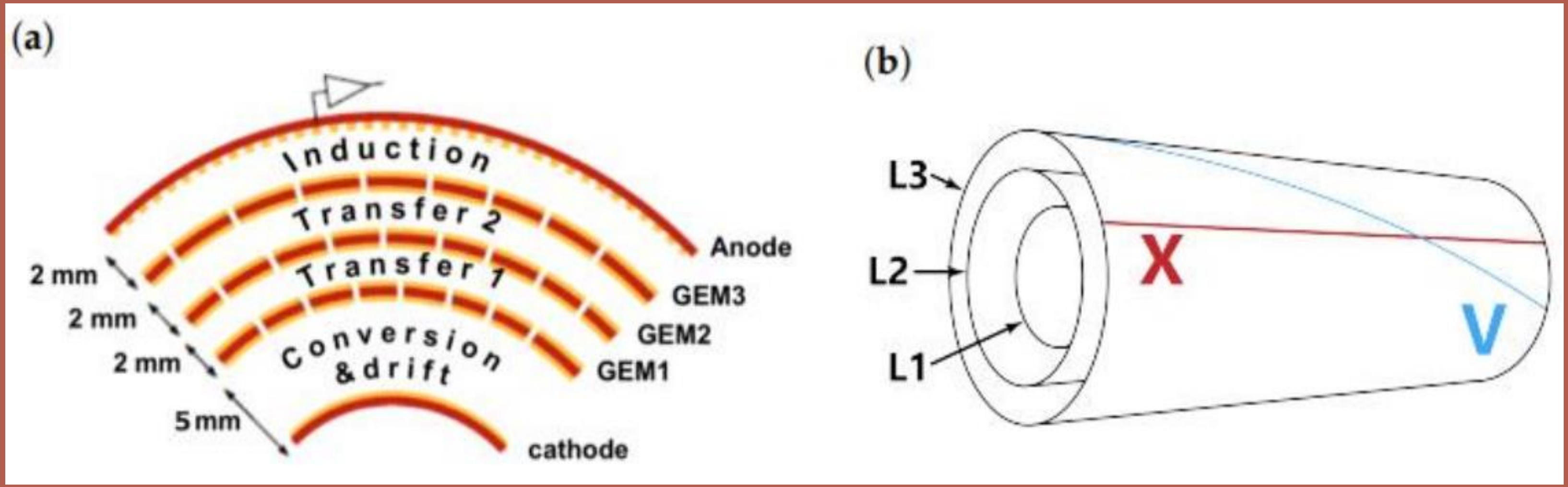
- The volume of this detector can be divided into three main regions: the drift gap, the multiplication region, and the induction gap
- Single GEM gain of the order of 10^2–10^3
- The triple-GEM structure gain is ~ 10^4
- Time resolution is ~ 10 ns,
- The spatial resolution ~ 50μm (depends on the strip pitch, limited by the Delta electrons)
- Drift velocity ~ 4 cm/μs





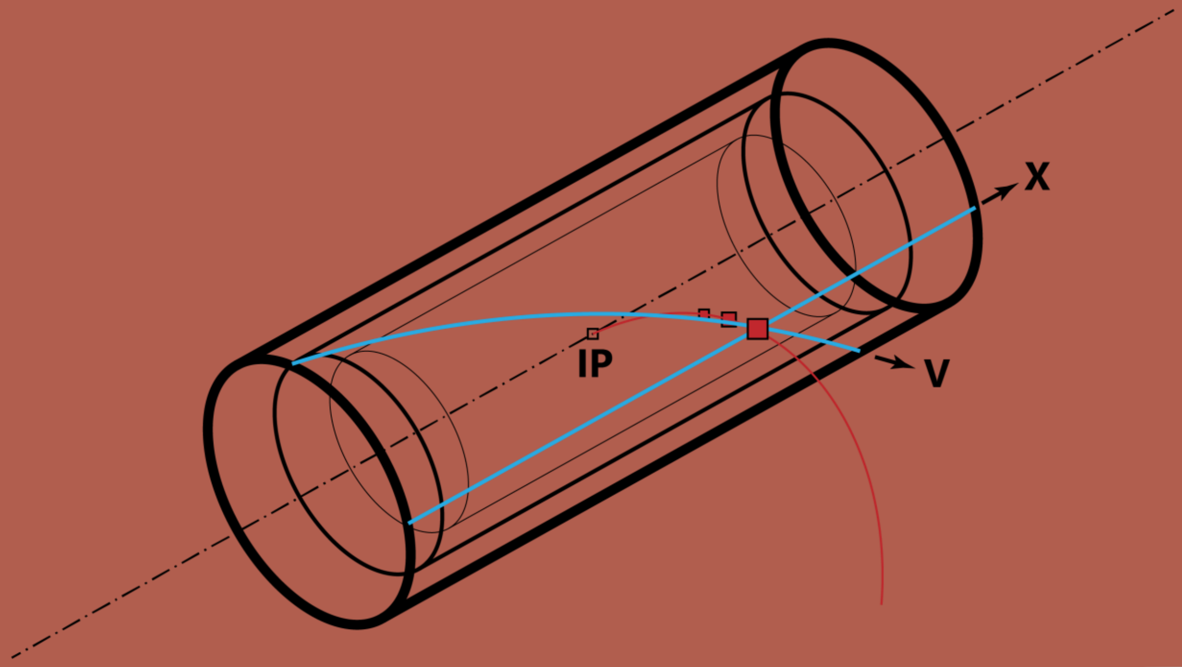
CGEM-IT

- The operating values of the fields are: 1.5 kV/cm for the drift, 3kV/cm for T1 and T2, and 5 kV/cm for the induction
- The GEM voltage difference 280 V, 280 V, and 275 V
- This structure has a gain ~ 10^4 (discharge probability below ~ 10^6)



CGEM-IT

- The readout anode circuit, hosts the readout plane which is segmented in **5 μm thick strips**. The **strip pitch is 650 μm**, with a **570 μm wide X-strips** parallel to the CGEM axis providing the coordinates in a plane perpendicular to the beam pipe (the coordinates XY). **V-strips are 130 μm** wide and are oriented in each layer with a different stereo angle
- The V-strips present a stereo angle with respect to the X-strips. They give, together with the information on the X, the measure of the **z-coordinate** (the coordinate parallel to the beam direction).

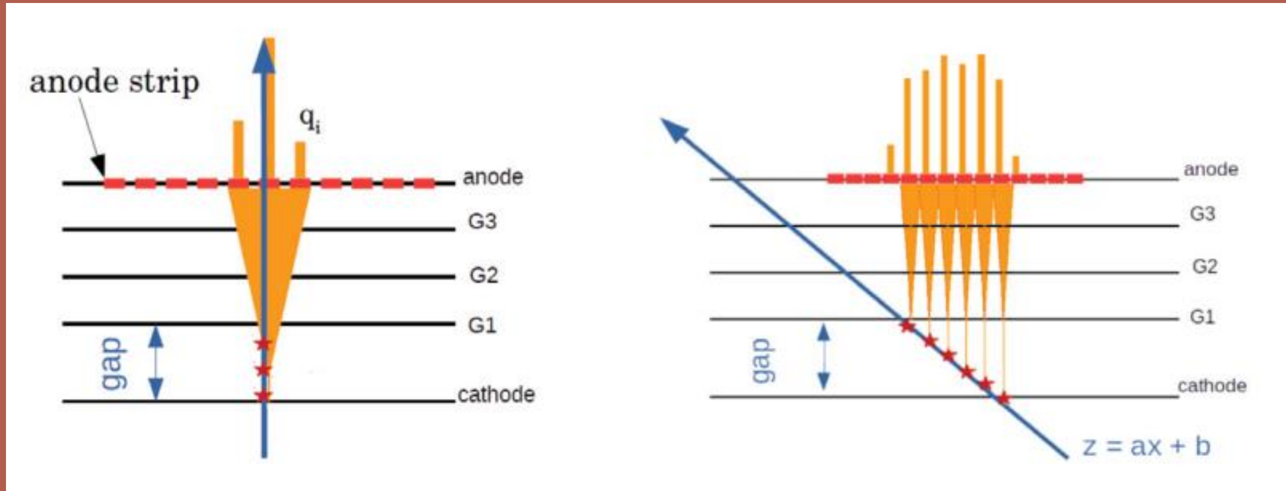


CGEM-IT & MDC FEATURES

- Value Requirements
  - $\sigma_{xy} < 130\ \mu m$
  - $\sigma_z < 1$ mm
  - dp/p for 1GeV/c 0.5 %
  - Material budget ≤ 1.5 %X0
  - Angular Coverage 93 % × 4π
  - Hit Rate 10^4 Hz/cm^2
  - Minimum Radius 65.5 mm
  - Maximum Radius 180.7 mm

- MDC
  - σ_{xy} (at 1 GeV, singel wire) ~130 μm
  - σ_z (at 1 Gev) ~ 2 mm
  - σ_p/p (at 1 GeV) 0.5 %
  - $\sigma_{dE/dx}$ (at 1 GeV) 6 %

Charge centroid & µTPC concepts



(a) Charge centroid method (b) μ TPC method

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

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

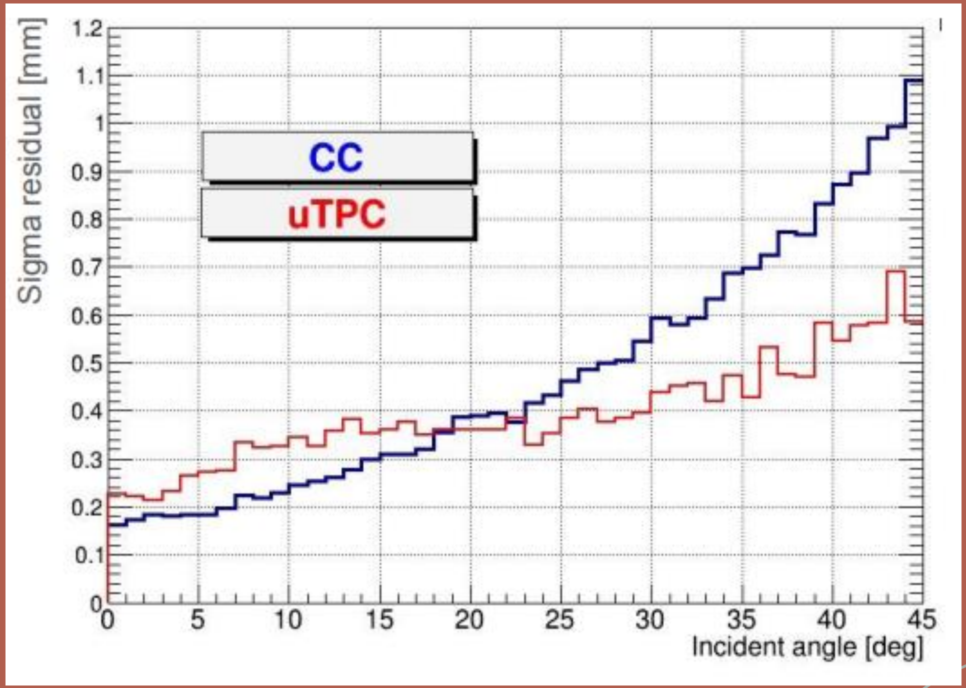
- The CC averages the charge of all the strips of the cluster by weighting it by its charge
- The μTPC instead considers the drift gap as a tiny TPC and with position and time information, it associates each strip with a bi-dimensional point and uses a linear fit to extrapolate the particle position

Charge centroid & µTPC CGEM-IT state

Preliminary result, also need to take into account:

- time calibrations to be optimized (contribution of 200-250µm)
- the contribution of tracking must be subtracted (contribution of 100-200 µm)

PRELIMINARY PLOT



EFFICINCY L1 BOTTOM - 1D EFFICIENCY