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
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: $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

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

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The upgrade of the inner MDC: CGEM-IT

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

Requirements:

- $\sigma_{xy} \sim 130 \, \mu m$
- $\sigma_z < 1 \, mm$
- $\sigma_{pt}/p_t \sim 0.5\% @ 1 \, GeV/c$
- Operation in 1T magnetic field
- Material budget < 1.5 $X_0$ for all layers
- Maximum rate: $10^4 \, Hz/cm^2$
- 93% of $4\pi$ angular coverage
- Efficiency $\sim 98\%$
**GEM detectors**

GEMs (Gaseous Electron Multipliers) 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
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.

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

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
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

Developed together with Chinese and American colleagues
Contiguous fired strips on the anode form a **cluster**

Cluster reconstruction

\[ x_{CC} = \frac{\sum_{i} Q_{hit,i} x_{hit,i}}{\sum_{i} Q_{hit,i}} \]

\[ x_{\muTPC} = \frac{gap/2 - b}{a} \]

M. Alexeev et al 2019 JINST 14 P08018
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

https://grafana.com/
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 $\sim 1 \text{ fC}$

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

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

Plateau of efficiency $\sim 90\%$ 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.
From residual distribution, it is possible to extract the expected spatial resolution – effect of the tracking extracted from toyMC
Comparison with previous R&D

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!

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