מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

The 7th International Conference on
Micro Pattern Gaseous Detectors 2022
Weizmann Institute of Science, Rehovot, Israel

December 11-16, 2022

Operation and readout of the CGEM Inner Tracker

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on behalf of
BESIII CGEM-IT working group
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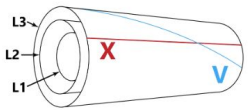
INFN
Istituto Nazionale di Fisica Nucleare

BESIIICGEM FEST RISE
HORIZON 2020

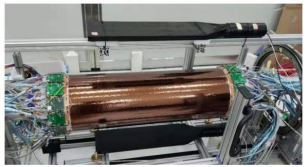
BESIII

OUTLINE



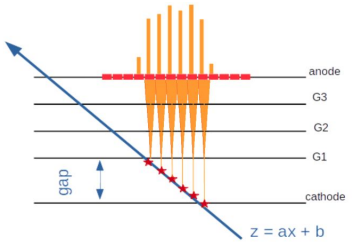
1: THE CGEM-IT DETECTOR

2: FULL DETECTOR COMMISSIONING



3: SETUPS UNDER TEST

4: PERFORMANCE



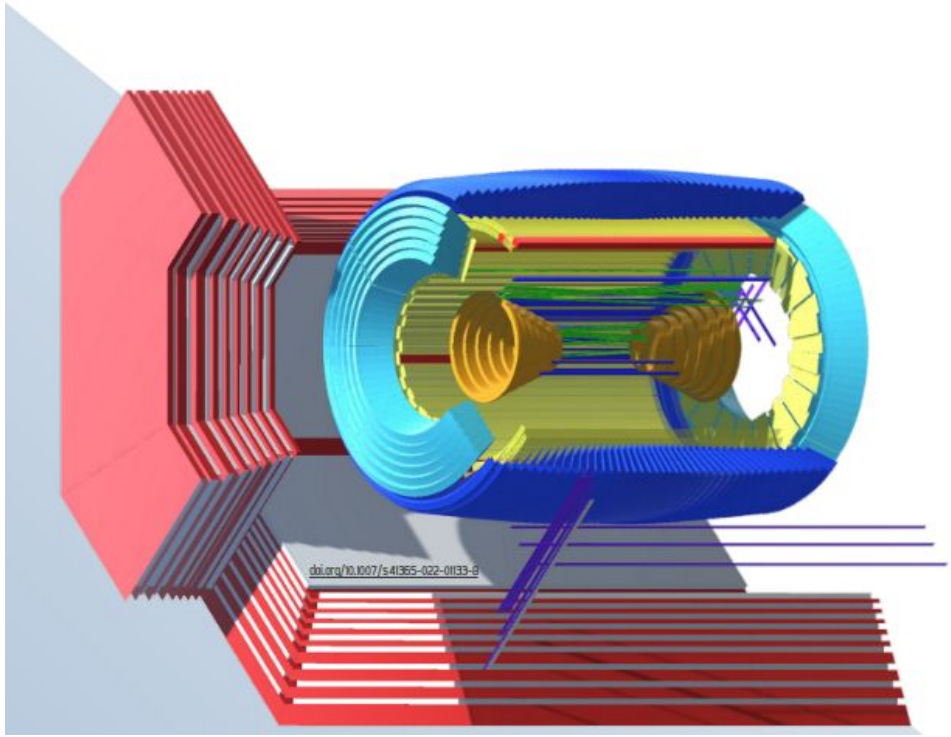
BESIII experiment

e^+e^- collider @ BEPC II

E_{cm} = 2 – 4.95 GeV

L = 10^{33} $cm^{-2}s^{-1}$

Collected 10^9 J/Ψ



Nucl. Instrum. Methods Phys. Res. Sect. A 2010, 614, 345

MDC aging

inner MDC layer

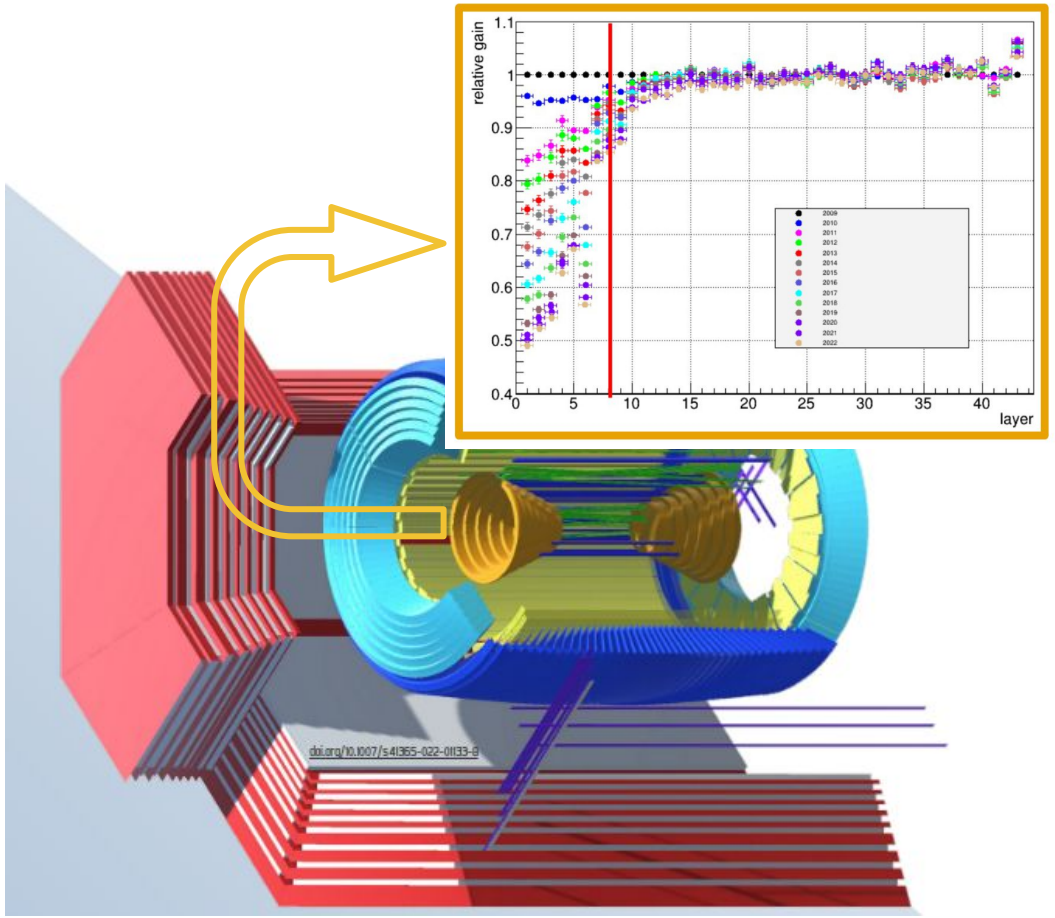
gain loss ~ 4%/year

↓

new inner tracker

to be installed

in 2024



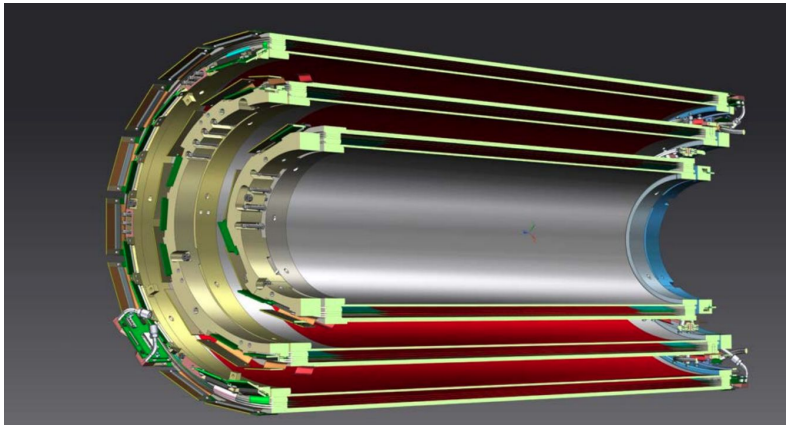
Chin. Phys. C 2016, 40, 016001

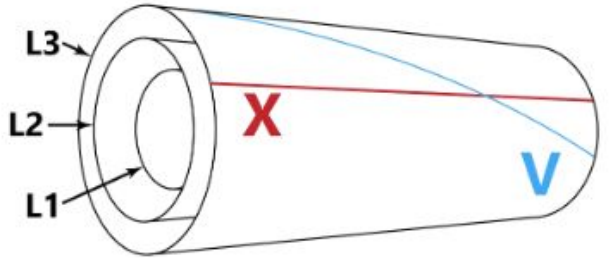
CGEM-IT Requirements

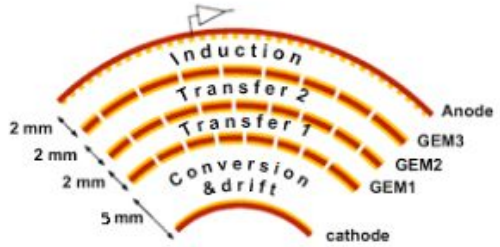
Time and Charge
analogue readout

Improved spatial resolution
@ B = 1 T

σ_z ~ 350 μm
σ_{xy} ~ 130 μm
σ_{pt} ~0.5% @ 1 GeV/c







Symmetry 2022, 14, 905

CGEM-IT Design

Triple-GEM technology

3 Layers (L1,L2,L3)

93% Solid Angle Coverage

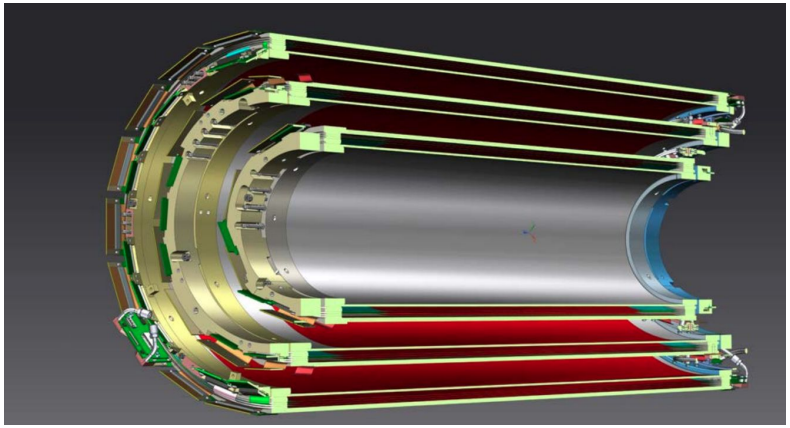
Low Material Budget <1.5% X_0

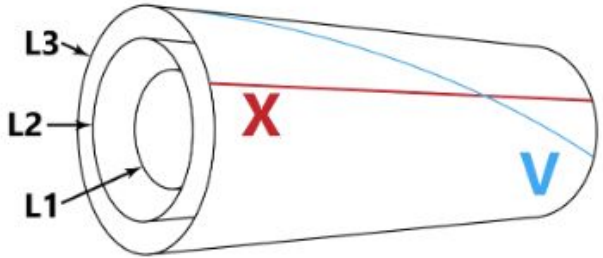
High Gain

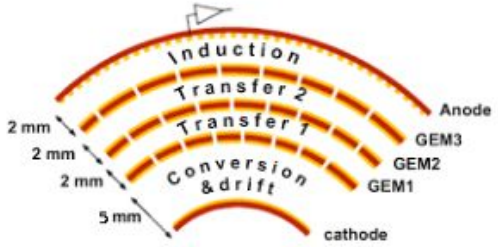
Low discharge Probability

High Rate

High Radiation Hardness







CGEM-IT electronics

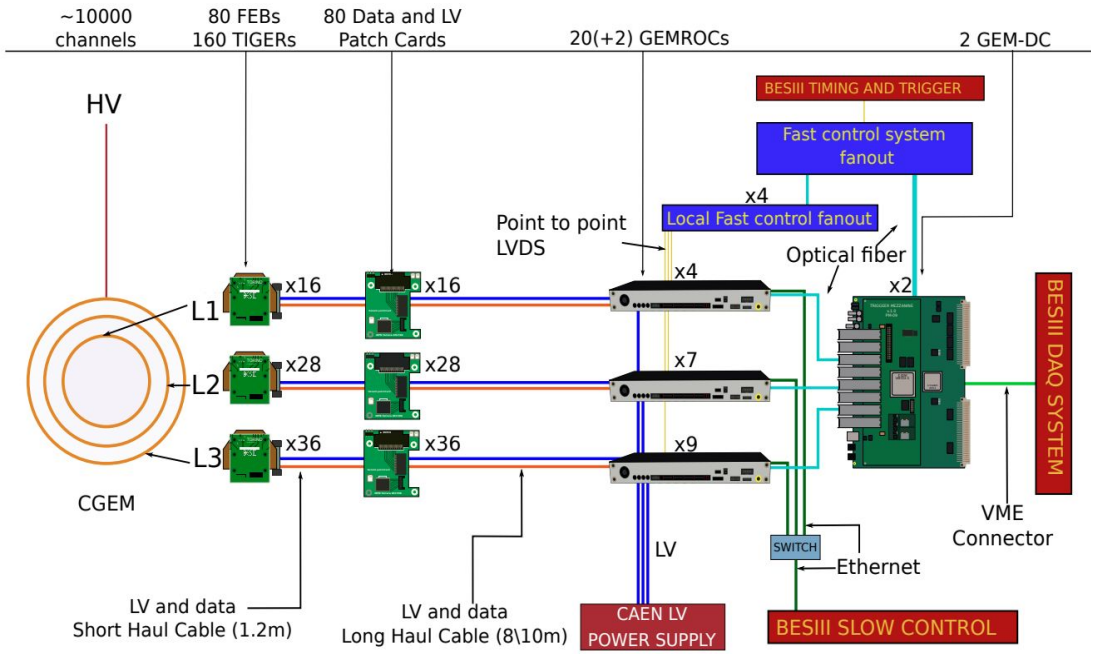
Torino **I**ntegrated **G**EM **E**lectronics for **R**eadout + **GEM** **R**ead**O**ut **C**ard are a versatile and modular readout system for MPGD

64 channel/TIGER
8 TIGER/GEMROC

TIGER: 110 nm CMOS fabrication technology
Analog input - digital output
S/H or **ToT** for energy measurement
Simultaneous time and charge measurement
Triggerless operation capability
Suitable for capacitances up to 100 pF and charges up to 50 fC

GEMROC : Distribute digital and analog voltage levels
Configure the TIGERs
Monitor currents and temperatures during operation
Collect and organize output data from the TIGERs
Receive trigger signal for **trigger-matched** operation

GUFI: Python-based interface for configure, threshold, acquisition and online monitor

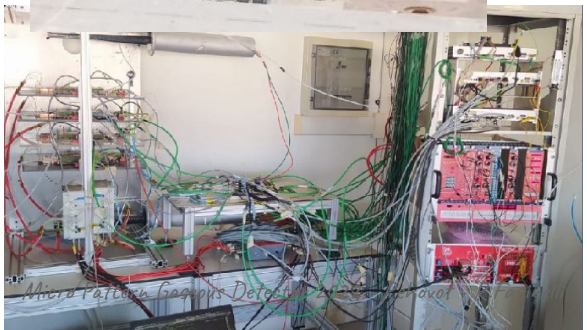


Setup under test

L1+L2 cosmic-ray data-taking @ Beijing

Planar triple-GEM testbeam @ H4-SPS

Local setup for debug @ Ferrara



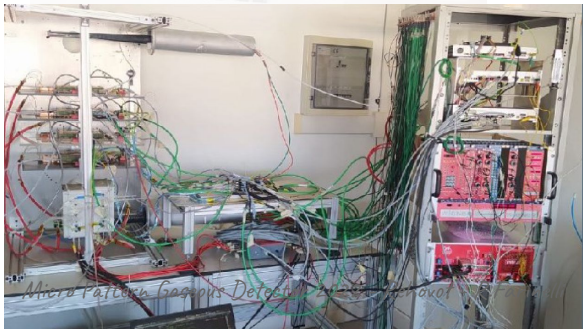
Setup under test

L1+L2 cosmic-ray data-taking @ Beijing

Planar triple-GEM testbeam @ H4-SPS

Local setup for debug @ Ferrara

mostly for firmware upgrade
and interlock development



Setup under test

L1+L2 cosmic-ray data-taking @ Beijing

Planar triple-GEM testbeam @ H4-SPS

High rate
Golden performance
Large range of configuration tested
Benchmark with APV/SRS electronics

Local setup for debug @ Ferrara

Setup under test

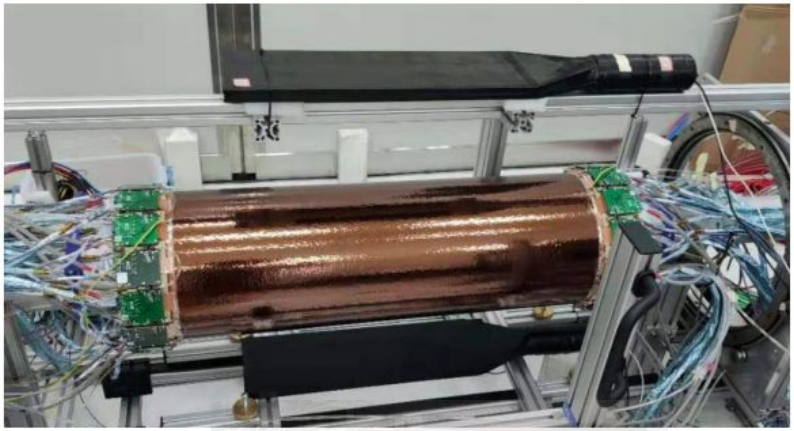
L1+L2 cosmic-ray data-taking @ Beijing

Calibration, Software-development,
Performance, Long-term test
in the final environment

L1+L2 are taking data
remotely since 2020

The pandemic slowed
down the operation

After almost 3 years **we are back!**



Planar triple-GEM testbeam @ H4-SPS

Local setup for debug @ Ferrara

monitoring

HV and current **monitor**

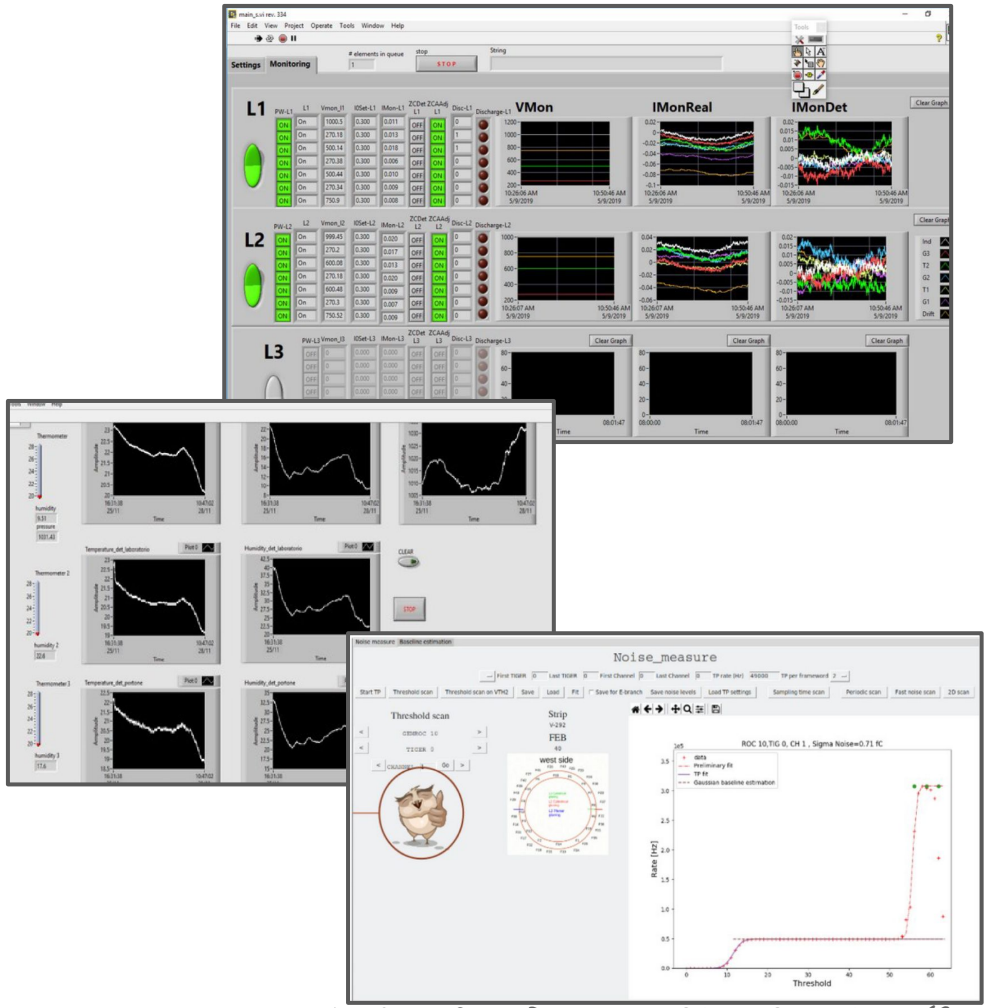
Temperature, Pressure and Humidity

Channel **noise** scan

Cosmic data-taking
with shifter supervision

Online and offline analysis

Interlock safety mechanics

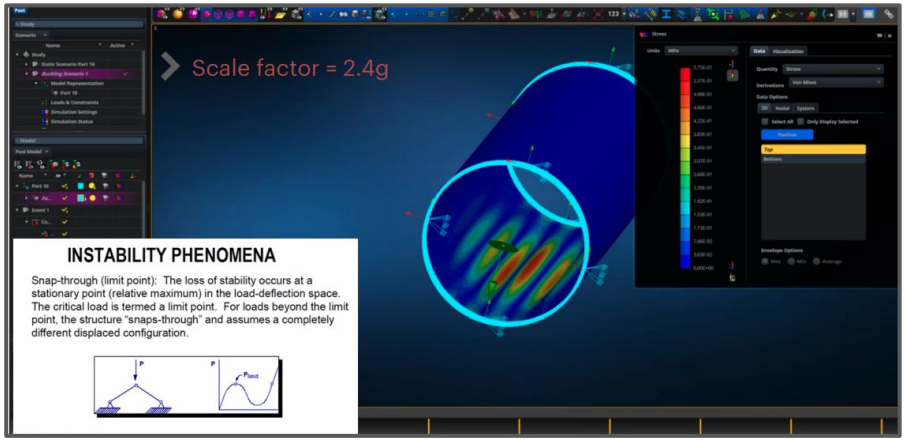


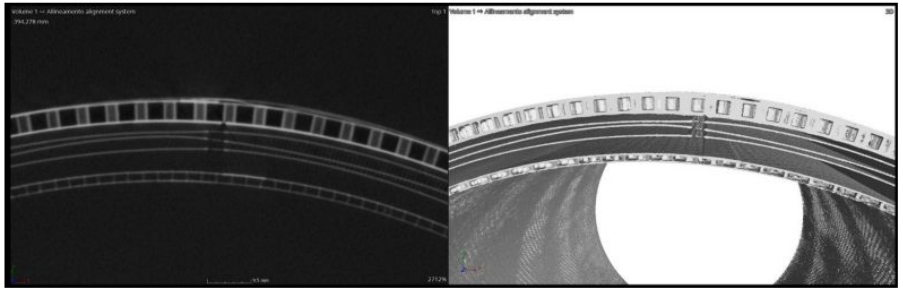
ABOUT Layer 3

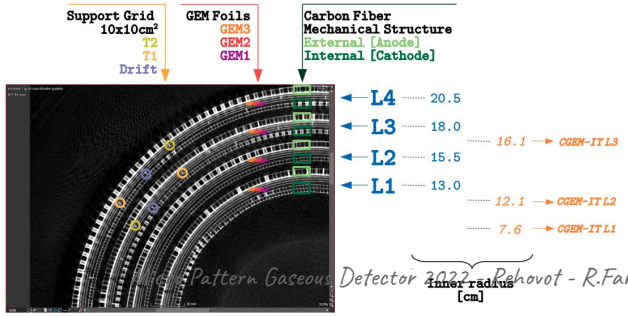
Mechanical analysis shows **buckling effects** on large radius and length of the CGEM

CT scan on the first L3
shows a not homogeneous behavior
in the gap between electrodes

While no buckling is present
in KLOE-2 CGEM-IT thanks to
a shorter length of the detector
and **spacing grids**





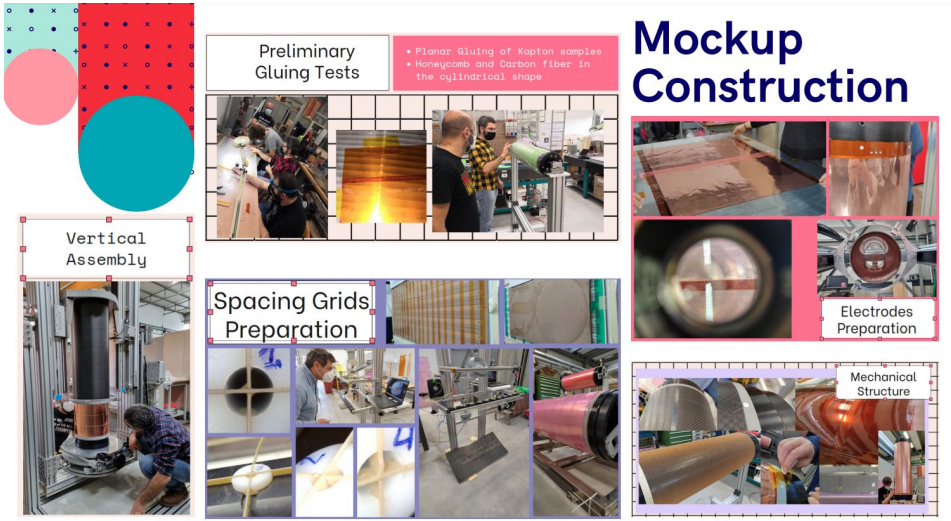


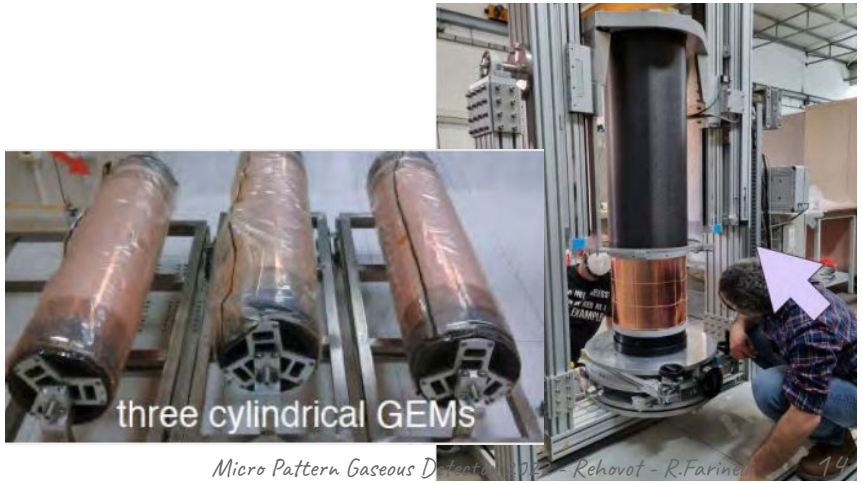
ABOUT Layer 3

A **mock-up** with spacing grid manufactured in 2022 and tested with acceleration up to **7.5g**

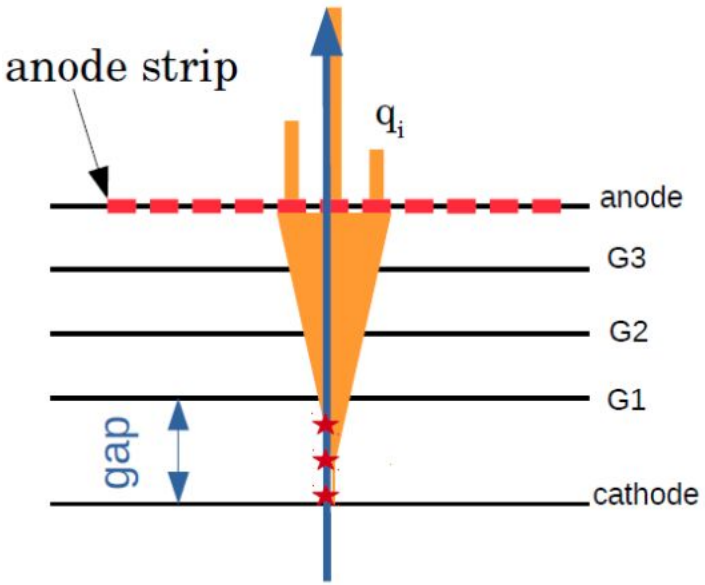
In 2023 an **hybrid construction** will follow between Italy and China

Electrodes shaped in Ferrara
L3 final assembly in Beijing

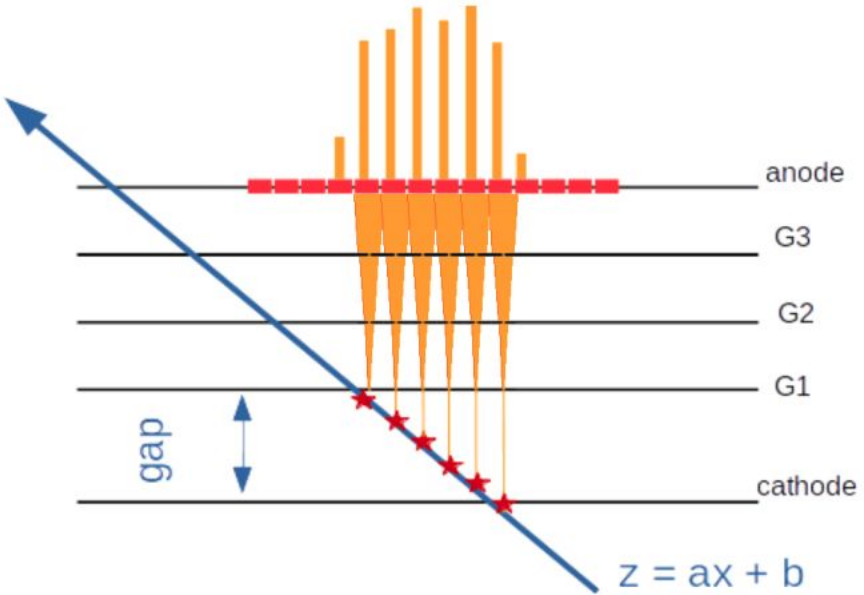




Tracking Performance

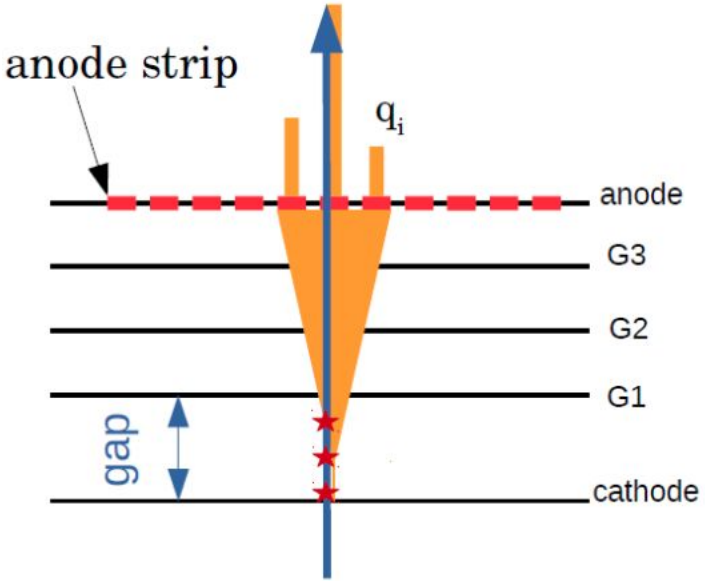


Charge Centroid

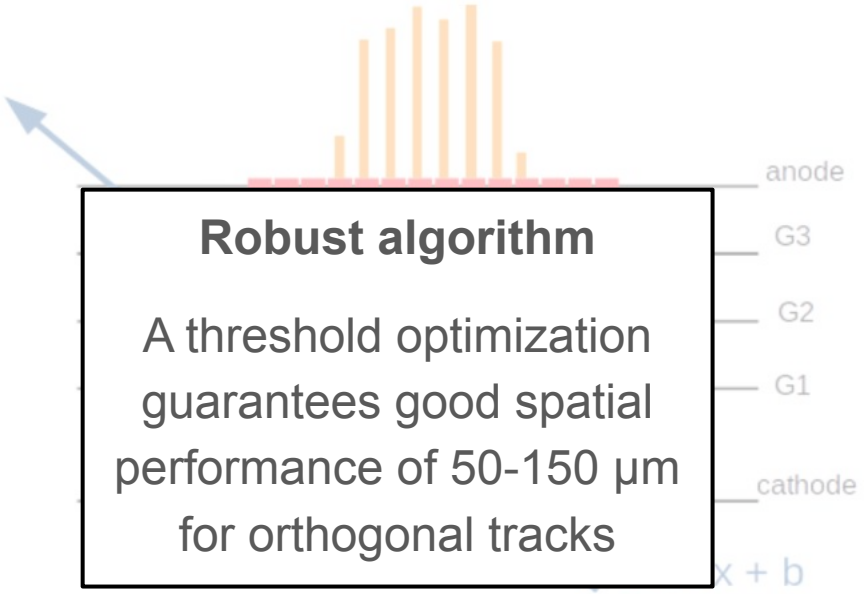


μ-TPC

Tracking Performance



Charge Centroid



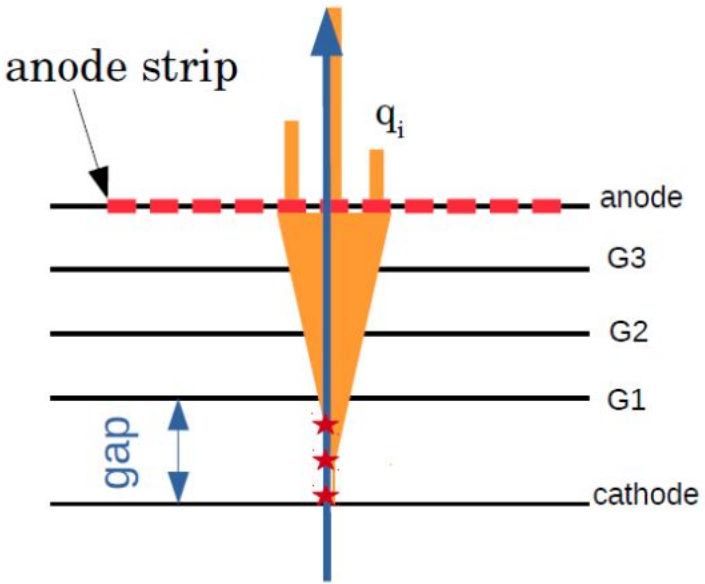
Robust algorithm

A threshold optimization guarantees good spatial performance of 50-150 μm for orthogonal tracks

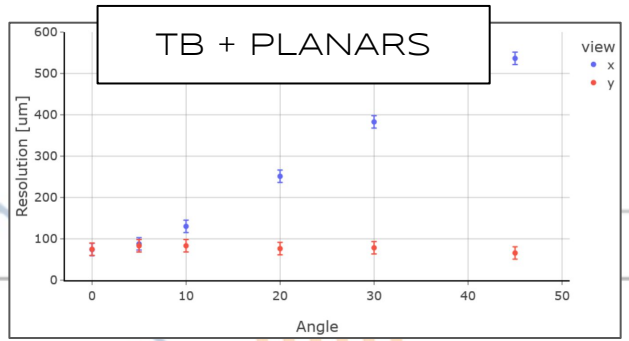
μ-TPC

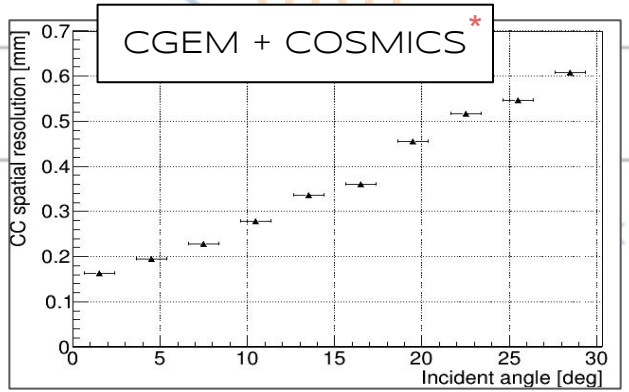
* tracking contribution to be removed

CC performance



Charge Centroid



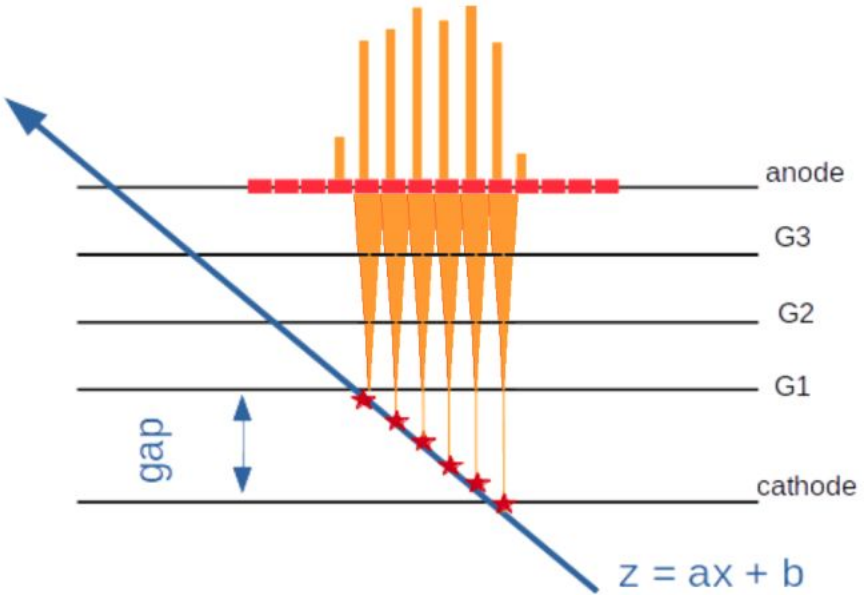


Tracking Performance

Challenging algorithm

Good performance
of 150-300 μm
are reached after
proper calibrations

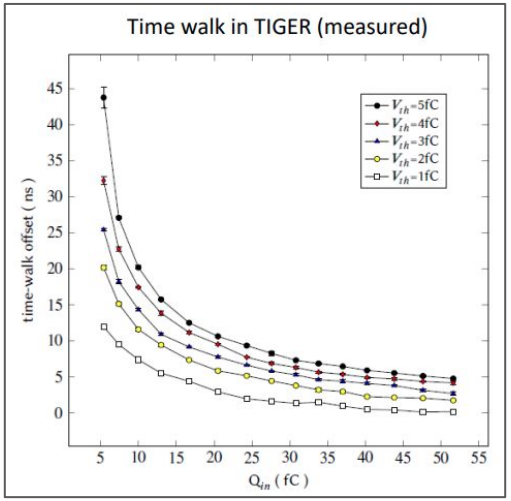
Charge Centroid



μ-TPC

μTPC calibrations…

Time-walk impacts from 5 to 40 ns on the time measurement.
μTPC **errors** based on **$1/q_{hit}$** reduce their contribution

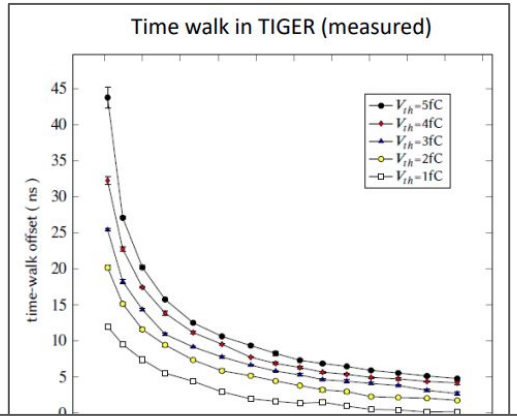


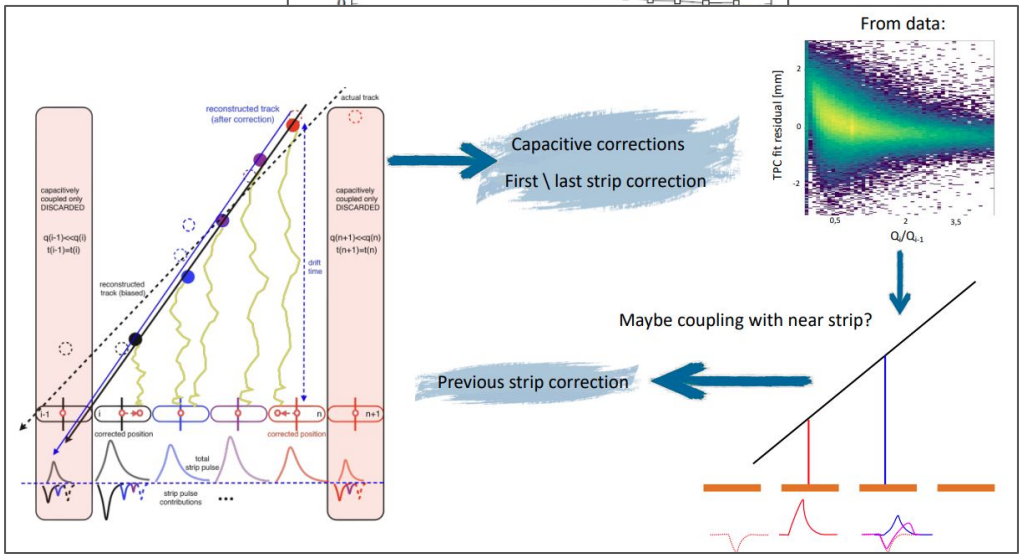
Capacitive effects contribution is reduced with **MicroMegas** corrections based on neighbor **charge ratio** and **ghost hits** removal

μTPC calibrations…

Time-walk impacts from 5 to 40 ns on the time measurement. Calibration and errors based on $1/q_{hit}$ reduce their contribution

Capacitive effects contribution is reduced with **MicroMegas** corrections based on neighbor **charge ratio** and **ghost hits** removal

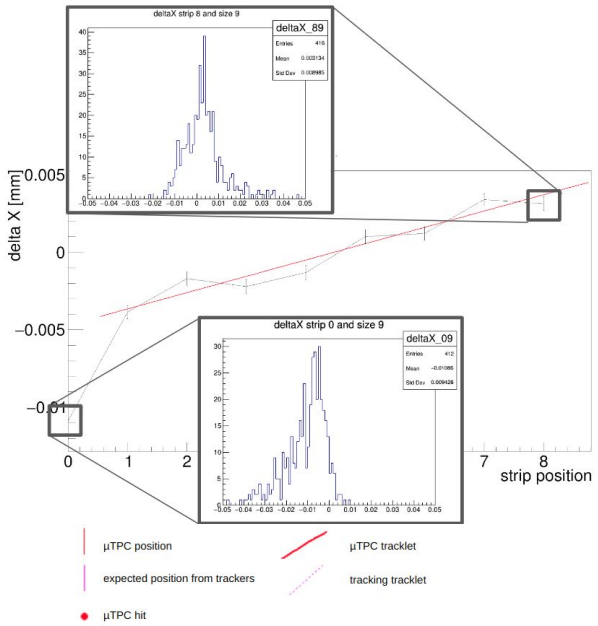


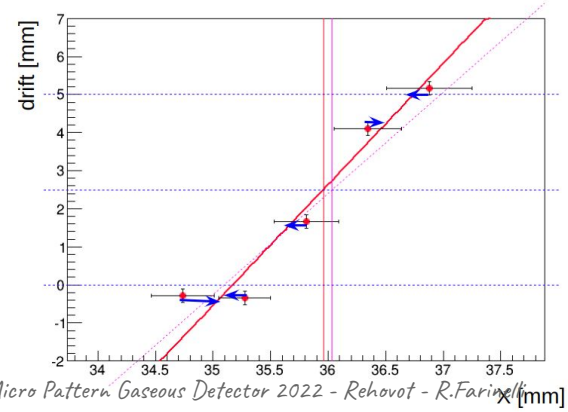


...μTPC calibrations

Alignment of the μTPC **hits** based on cluster size and the hits residual

Rotation of the hits based on the cluster size to match the tracking angle





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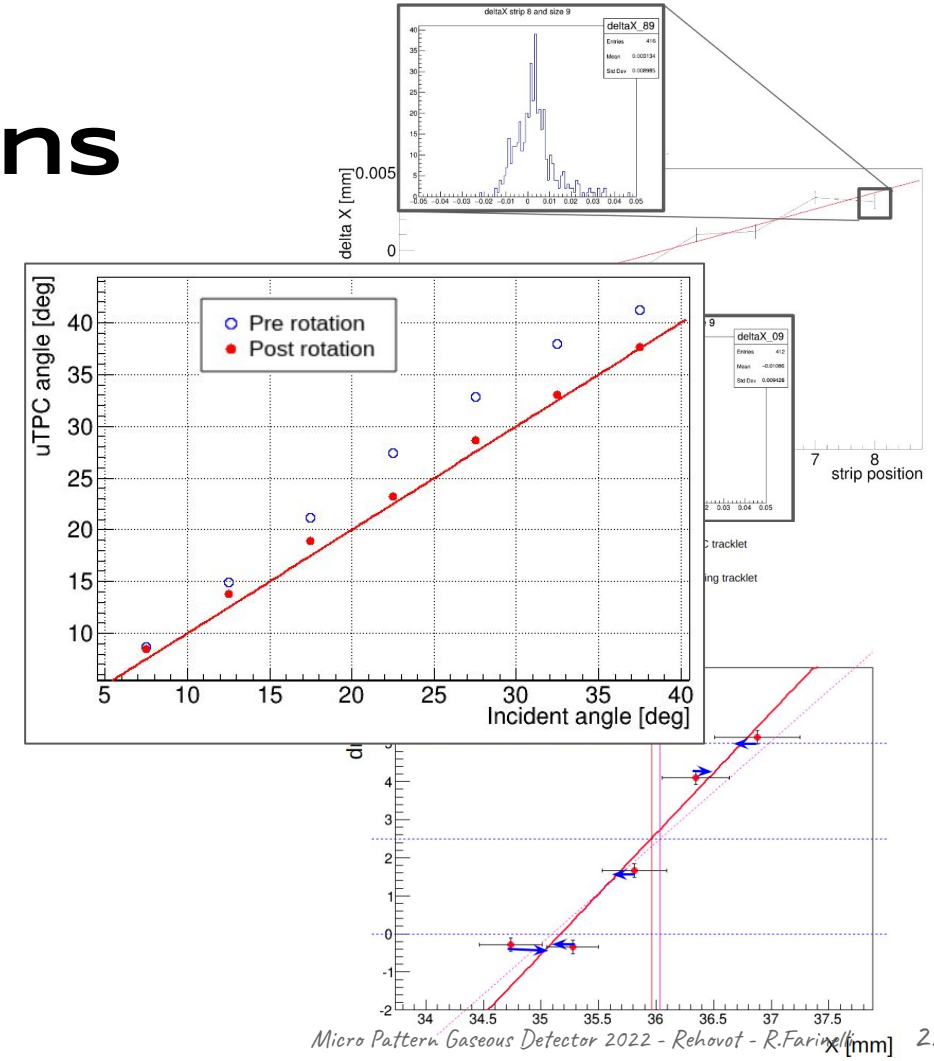


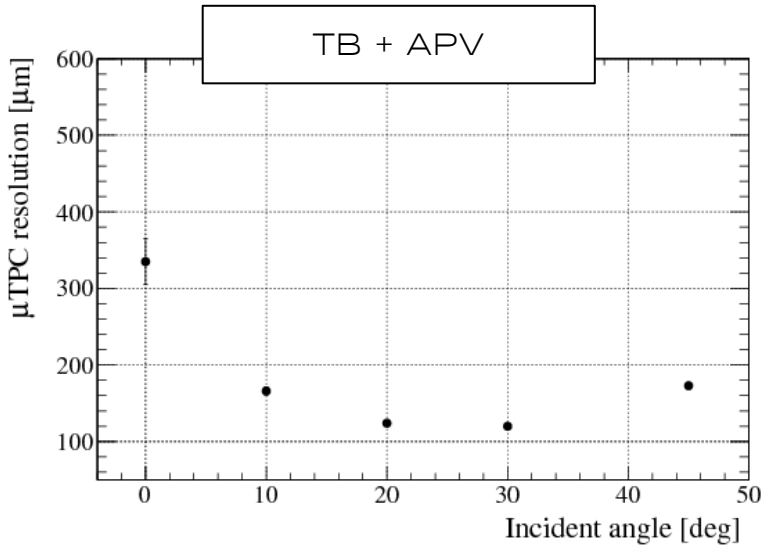
* tracking contribution to be removed

μTPC FIRST IMPLEMENTATION

The corrections have been tested on a TB with planar GEM and APV

The development and the implementation of those calibration is under study on with the **TIGER** electronics

Very preliminary results shown large improvements in the μTPC resolution both on **TB + planar GEM** ~250 μm and **cosmics + CGEM** ~350 μm *
A lot of work is still needed !



JINST 2019, 14, P08018

conclusion

The CGEM-IT **commissioning** has started

the pandemic slowed down the operation

L1+L2 have been **taking data since 2020** and

integration, calibration and optimization activities

are on the right path

An hybrid construction of the L3 is on going

with a schedule focused to

the CGEM-IT **installation in mid 2024**

A **readout system** with analogue readout

is fully deployed from the hardware to the software

Resolution and efficiency **performance**

of the technology are measured and

they match the BESIII requirements

Thank You