

DETECTOR AND ELECTRONICS INTEGRATION FOR THE CGEM INNER TRACKER

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On behalf of the CGEM-IT working group



Institute of High Energy Physics
Chinese Academy of Sciences



BESIII experiment

Design

Readout chain

CGEM-IT OVERVIEW

Data taking

Control & Monitor

Integration test

Results^{preliminary}

CGEM-IT ACTIVITIES

OUTLINE

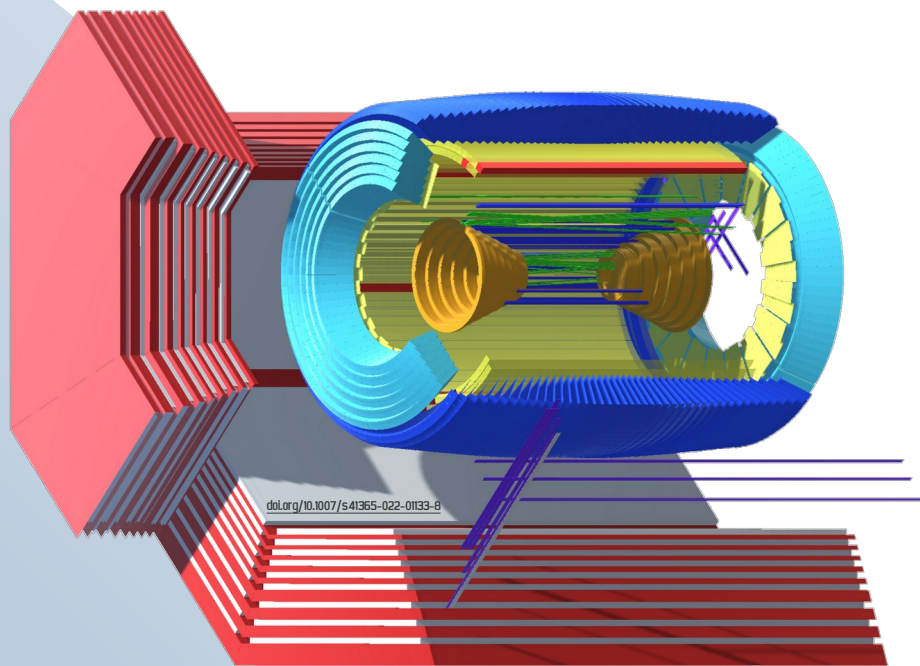
@BEPCII

e^+e^- collider

τ -charm factory

$E_{\text{cm}} = 2 - 4.95 \text{ GeV}$

$L = 10^{33} / \text{cm}^2\text{s}$



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3

MDC 0.5% at 1 GeV/c

CsI(Tl) calorimeter 2.5% @ 1 GeV

BTOF 70 ps

ETOF 60 ps

dE/dx 6% e⁻ from Bhabha scattering

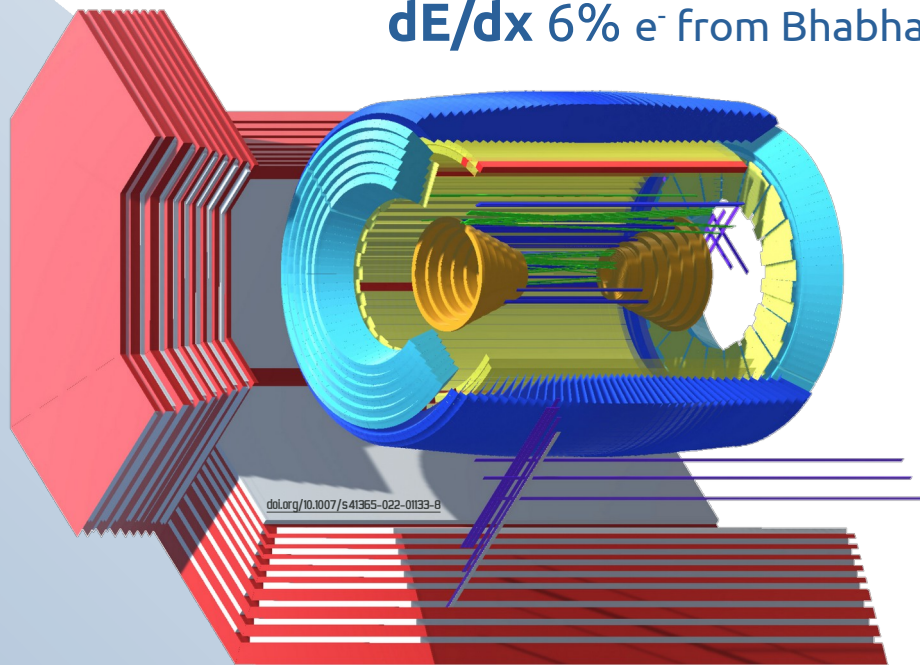
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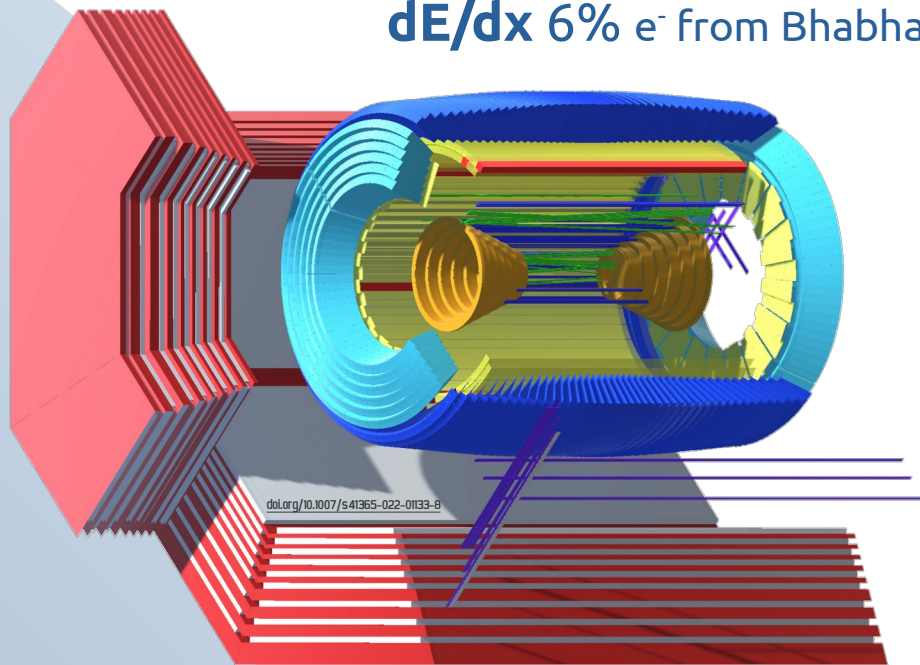
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We have
collected

10B of J/ψ !

*The world
largest
data sample*

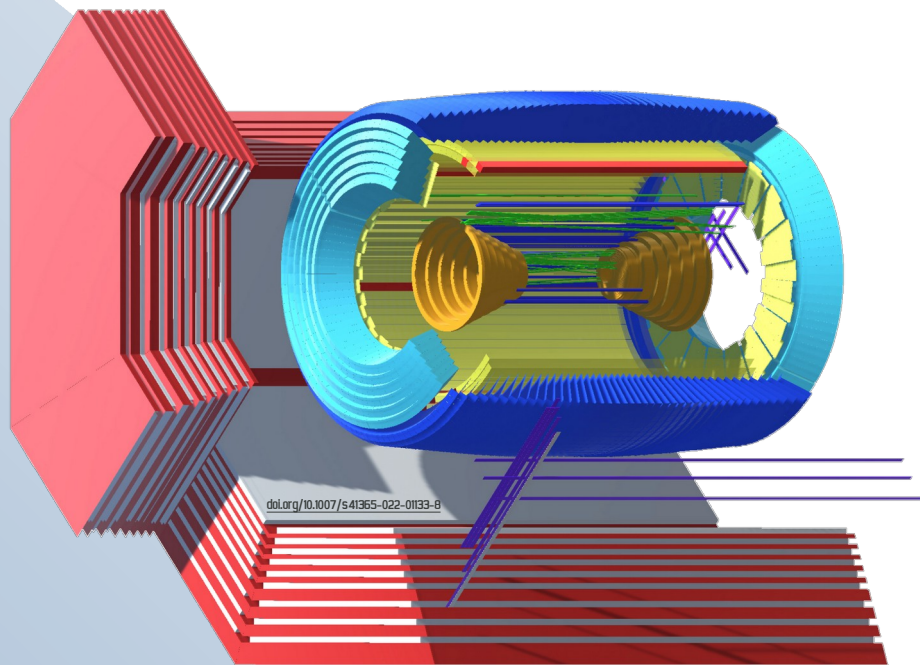
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Extension of
the data taking
for other

10 years!

iopscience.iop.org/article/10.1088/1674-1137/44/4/040001

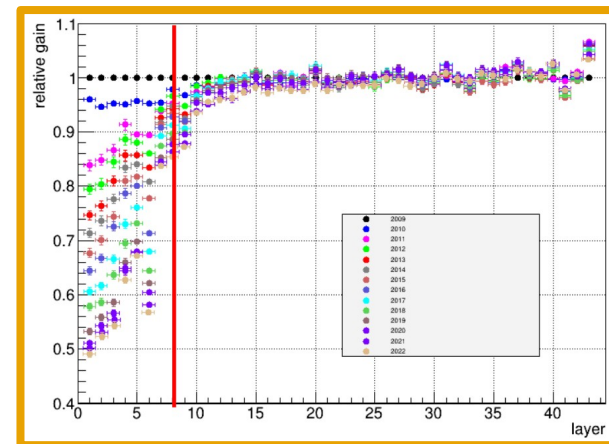


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MULTI LAYER DRIFT CHAMBER

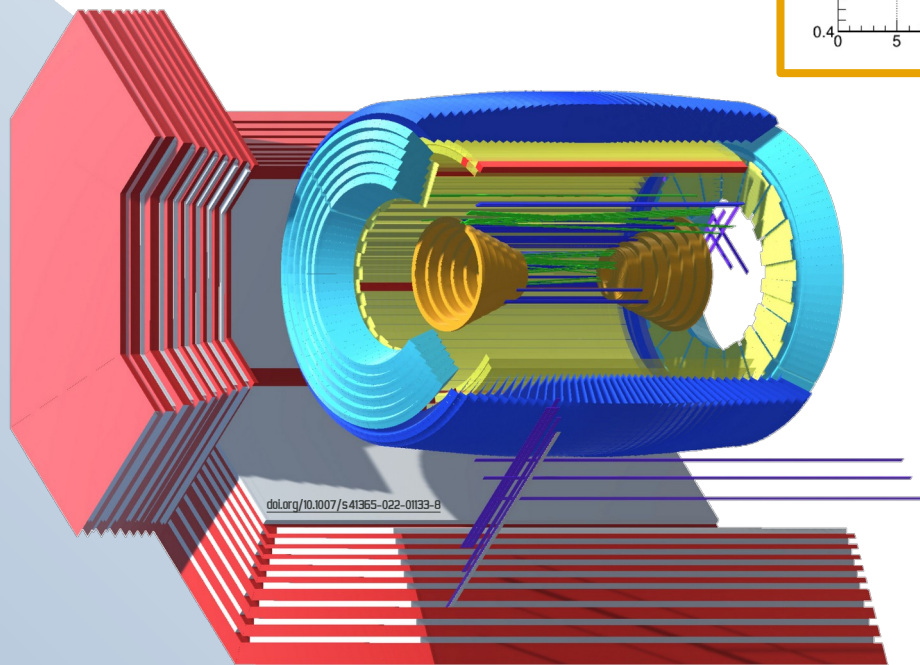
INNER LAYERS
Gain loss / year $\sim 4\%$



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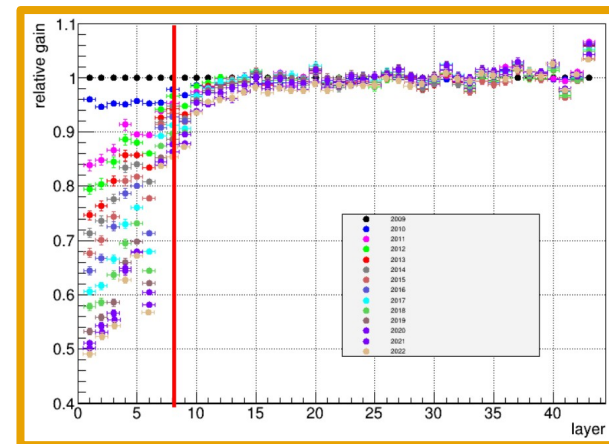
doi.org/10.1007/s41365-022-01133-8

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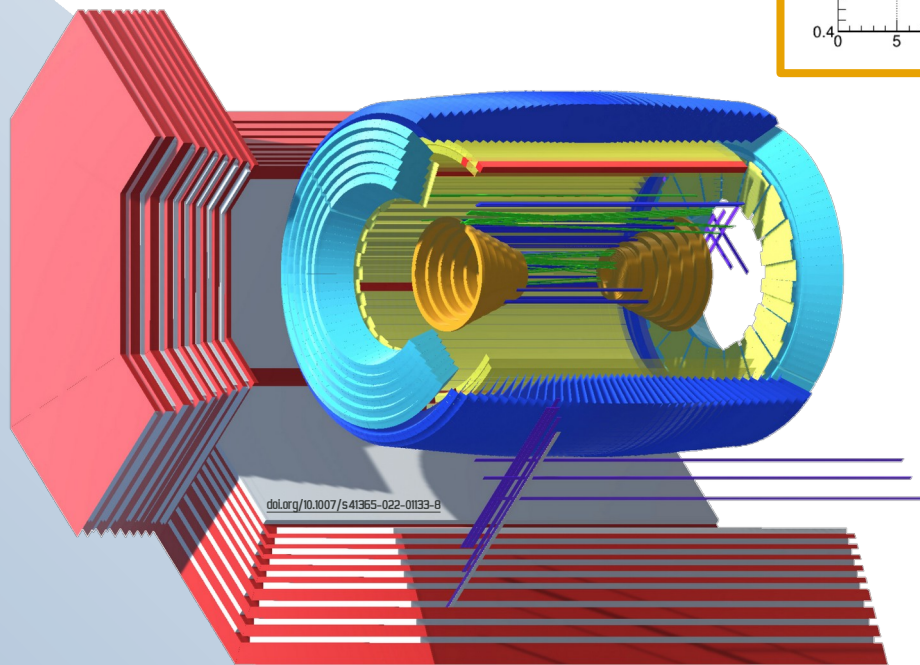
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NEW INNER TRACKER

to be installed
in 2024

BESIII

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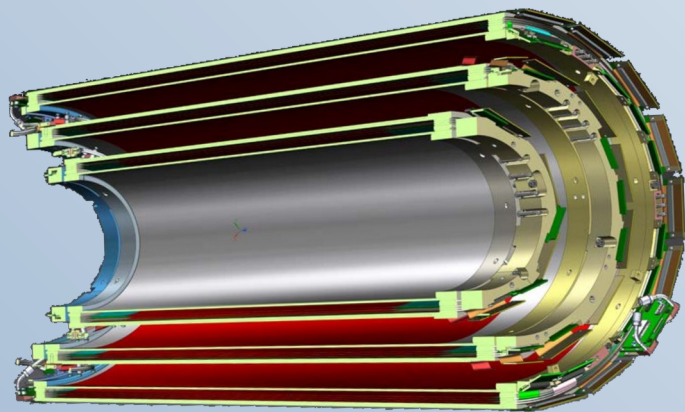
Cylindrical Triple GEM Inner Tracker

High Rate

High Radiation Hardness

93% Solid Angle Coverage

Low Material Budget $<1.5\% X_0$

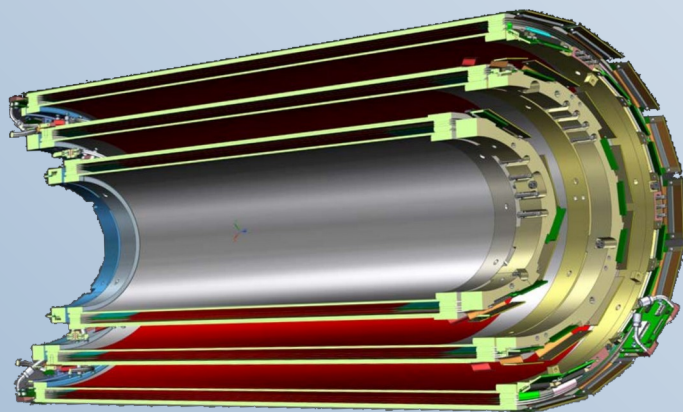
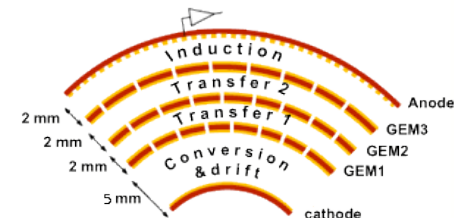
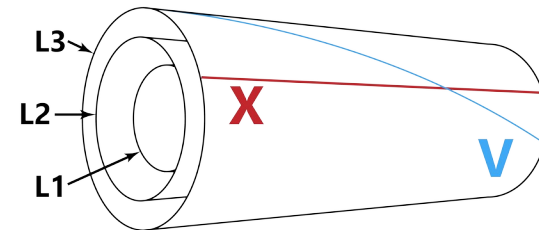


DESIGN

Cylindrical Triple GEM Inner Tracker

High Rate
High Radiation Hardness
93% Solid Angle Coverage
Low Material Budget $<1.5\% X_0$

Triple GEM
X-V Anode Segmentation
Time and Charge Analogue Readout

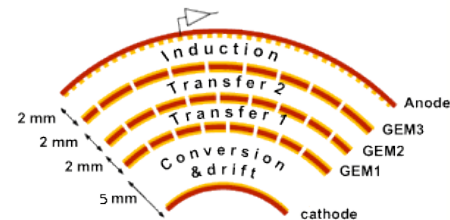
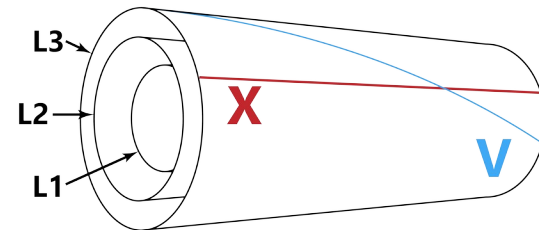
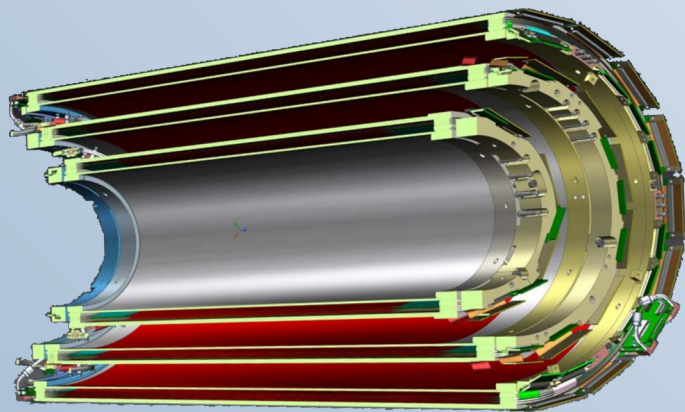


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High Gain
Low discharge Probability
Improved spatial resolution
 $\sigma_z \sim 350\mu\text{m}$
 $\sigma_{xy} \sim 130\mu\text{m}$
 $\sigma_{pt} \sim 0.5\% @1 \text{ GeV}/c$

DESIGN

6

Contiguous strips fired on the anode form a cluster

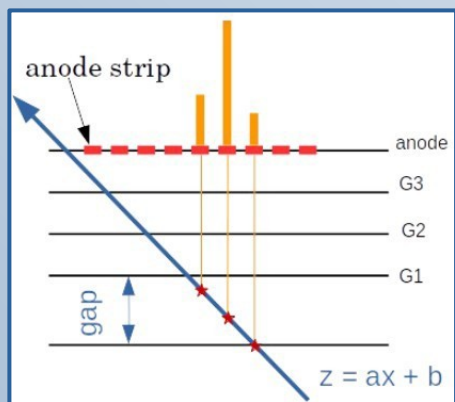
To optimize the reconstruction at different angles in 1T magnetic field,
a merge of two algorithm is used

SOFTWARE

6

Contiguous strips fired on the anode form a cluster

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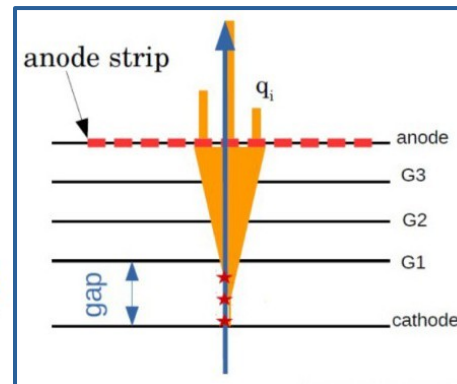


μ-TPC

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

**CHARGE
CENTROID**

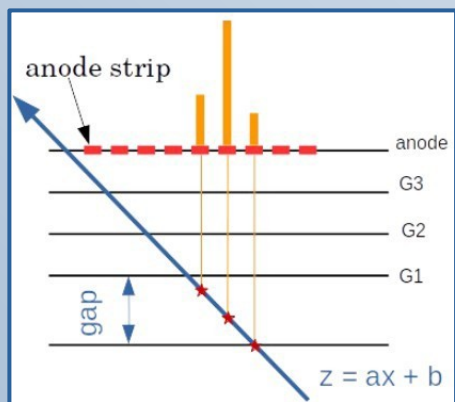
$$x_{CC} = \frac{\sum_i^{N_{\text{hit}}} Q_{\text{hit},i} x_{\text{hit},i}}{\sum_i^{N_{\text{hit}}} Q_{\text{hit},i}}$$



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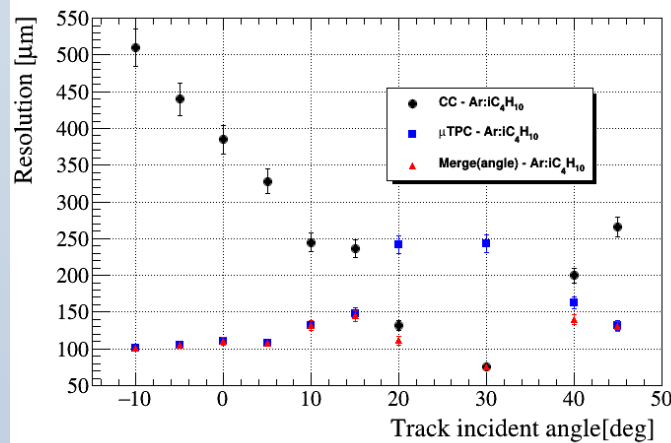
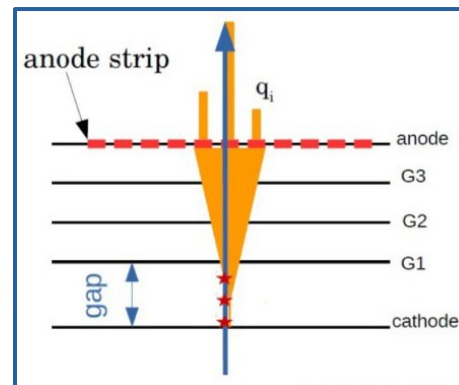


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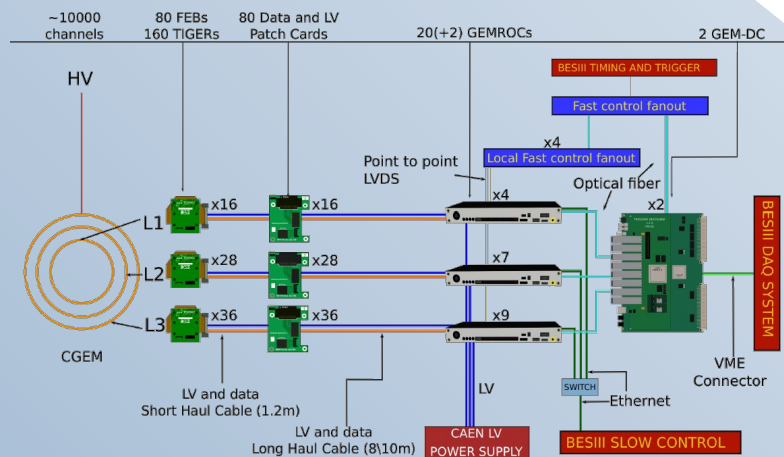
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SOFTWARE



READOUT

Torino
Integrated
GEM
Electronics for
Readout
TIGER + GEMROC

Read
Out
Card

64-channels ASIC

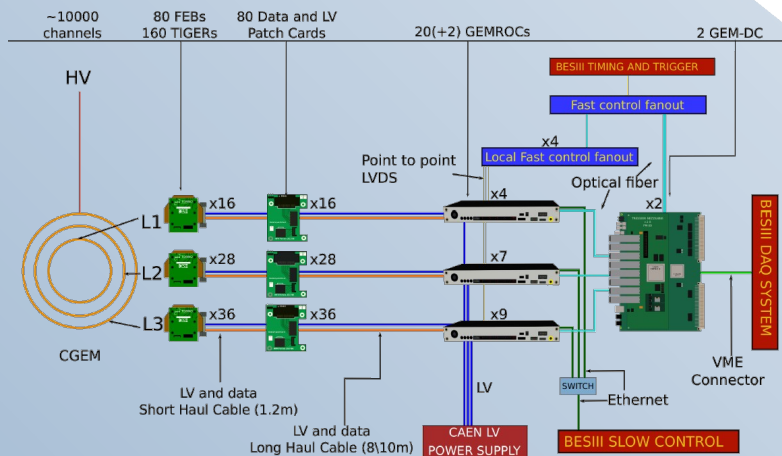
Charge & Time readout

Sample&Hold

Time Over Threshold

TIGER

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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TIGER**GEMROC**

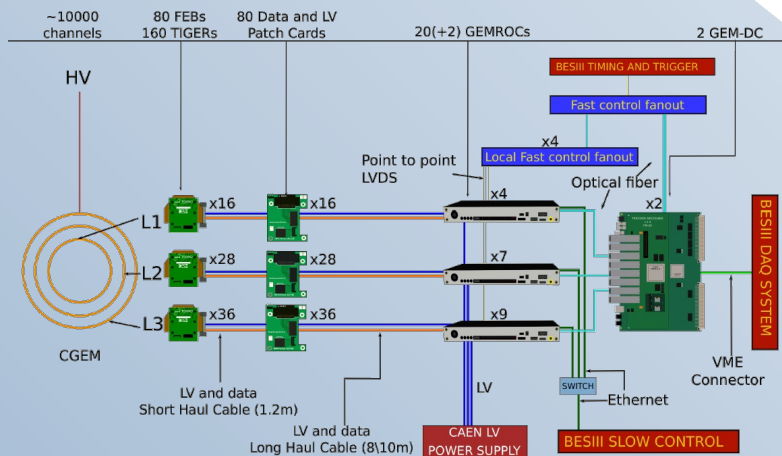
Power the FEB

Configure the chips

Receive timing signals

Monitor chips voltages and temperature

Control data acquisition via optical links/Ethernet



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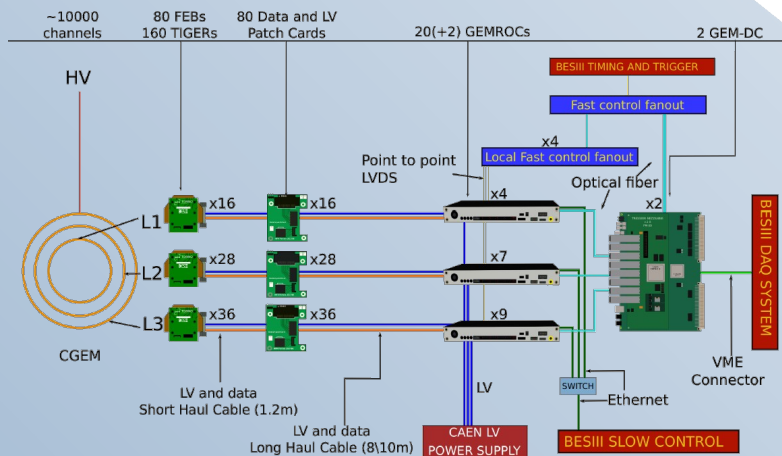
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TIMING SIGNALS

Fast Control System Fanout

Fast Control System Local Fanout to receive and distribute BESIII clock and trigger to each GEMROC

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TIGER + GEMROC
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64-channels ASIC

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TIGER

GEMROC

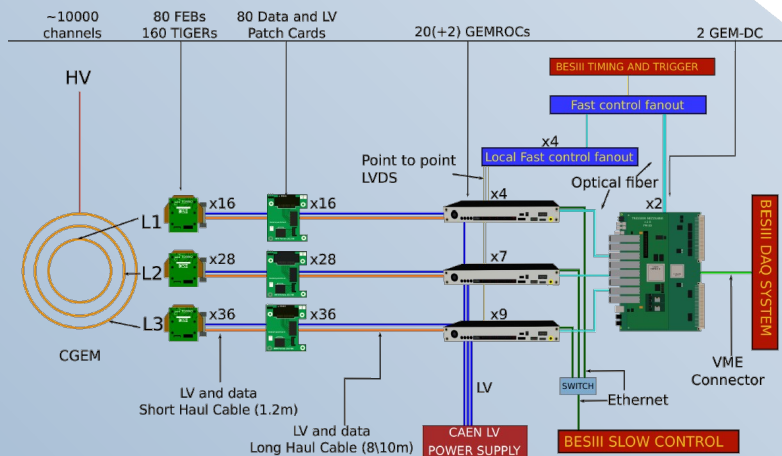
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USER INTERFACE

Graphical User Frontend Interface (GUFI)

Python based software

Test, characterize and debug the system

READOUT

Torino
Integrated
GEM
Electronics for
Readout

Read
Out
Card

TIGER + GEMROC

8

@Beijing

Temporary cosmic stand

Two (out of three) CGEM layers

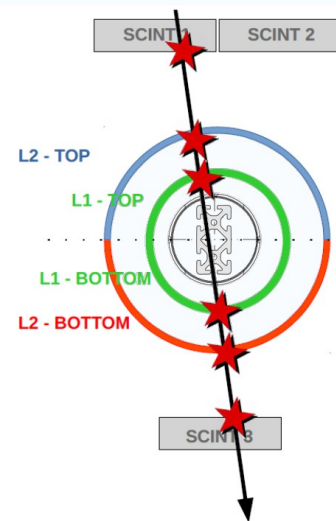
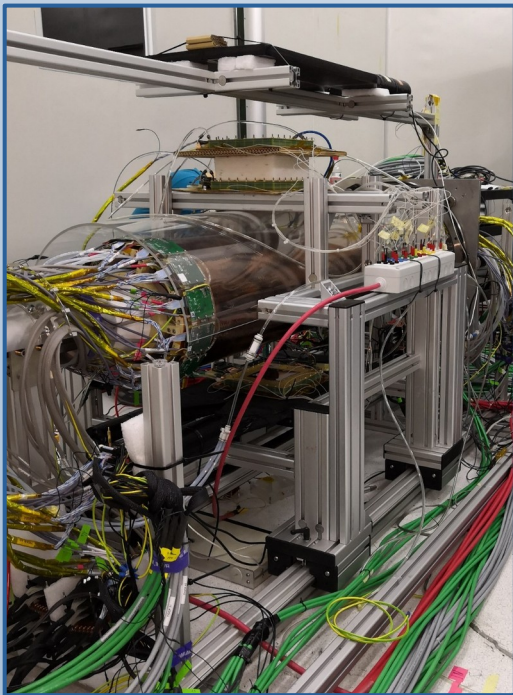
~5.6k channels connected

Final LV and HV systems

Remote control

On-site maintenance

Ar:iC₄H₁₀ 90:10



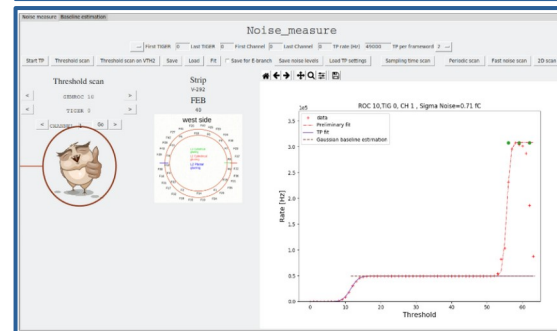
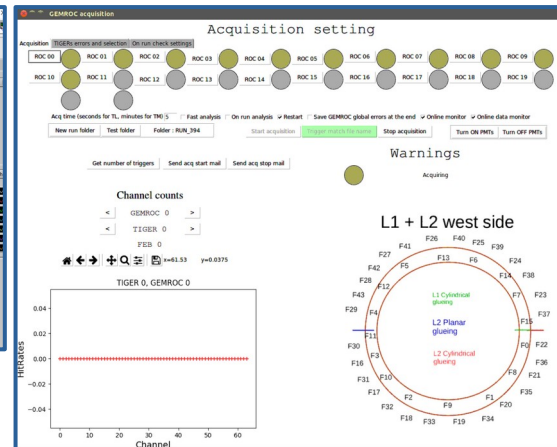
DATA TAKING

since 2019

HV & LV Custom Controls



Power on/off
Current absorption
DAQ operations
Noise tests

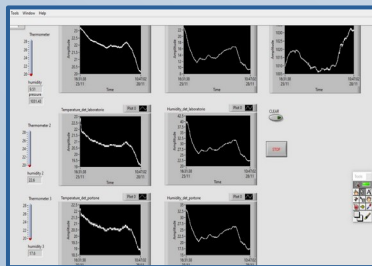


To test the system
for commissioning

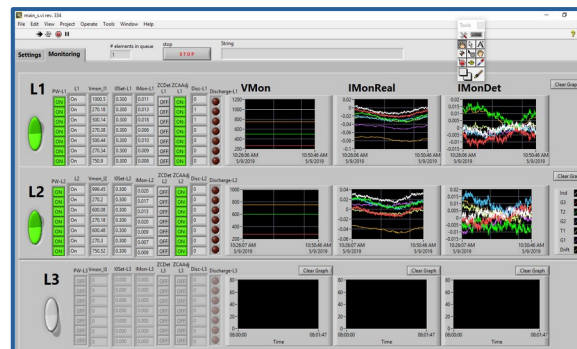
CONTROL & MONITOR

HV & LV Custom Controls

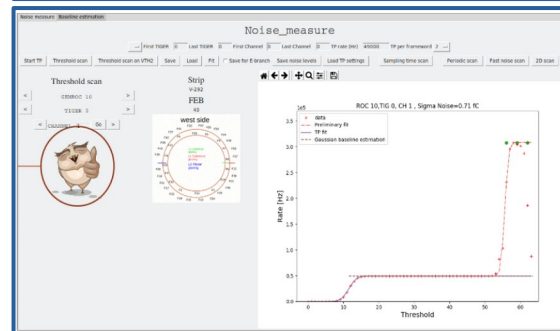
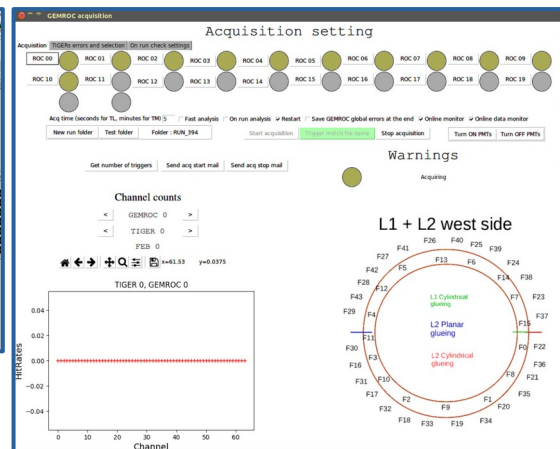
Environment Parameters



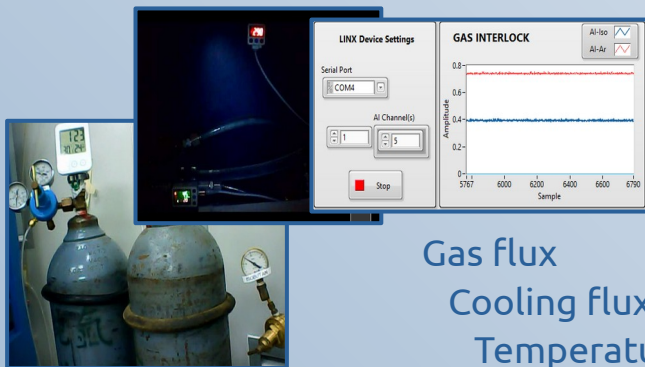
To guarantee the
detector safety



Power on/off
Current absorption
DAQ operations
Noise tests



To test the system
for commissioning



Gas flux
Cooling flux and pressure
Temperature, Humidity and Pressure

CONTROL & MONITOR

10

@Beijing

Temporary cosmic stand

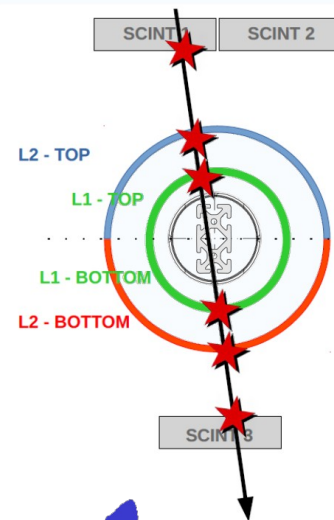
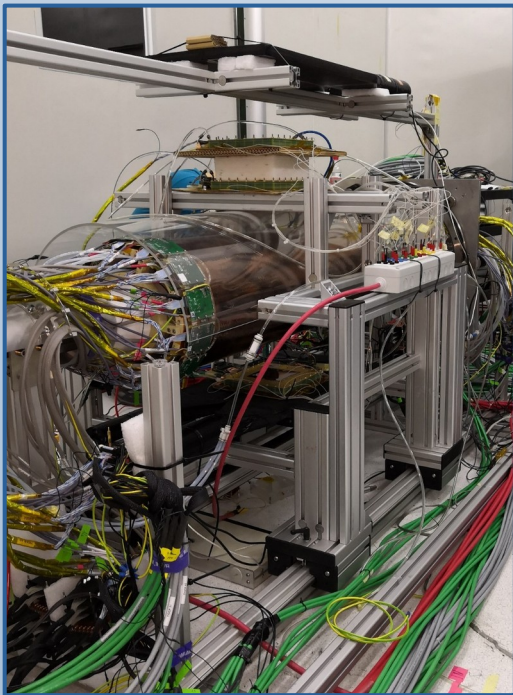
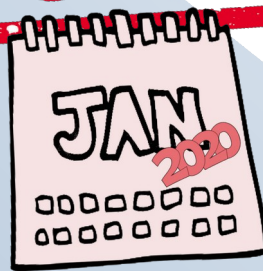
Two (out of three) CGEM layers

~5.6k channels connected

Final LV and HV systems

Remote control

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Ar:iC₄H₁₀ 90:10**REORGANIZE!****DATA TAKING** since 2019

10

@Beijing

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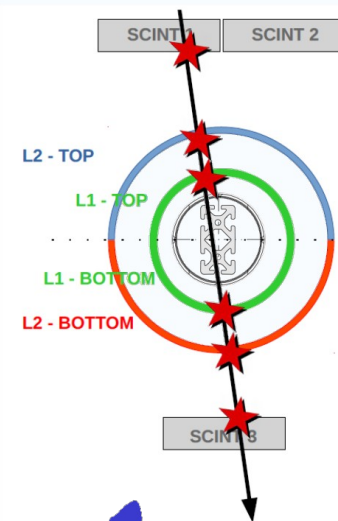
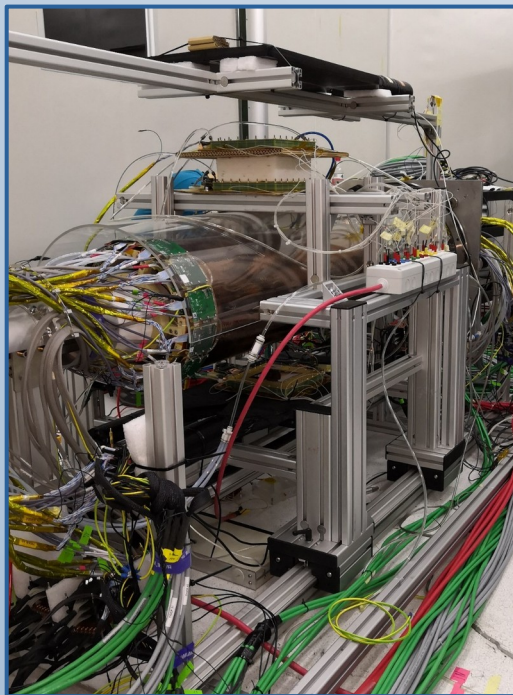
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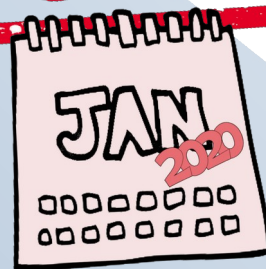
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Ar:iC₄H₁₀ 90:10

REORGANIZE!



Remote data collection from Italy

On-site help from BESIII colleagues

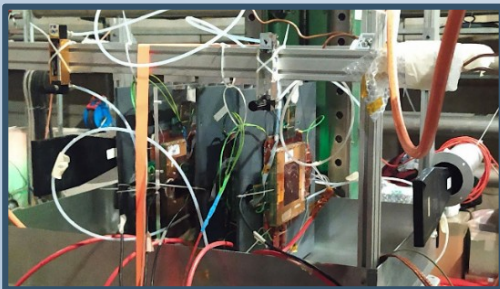
Thorough operations' monitoring

DATA TAKING

since 2019

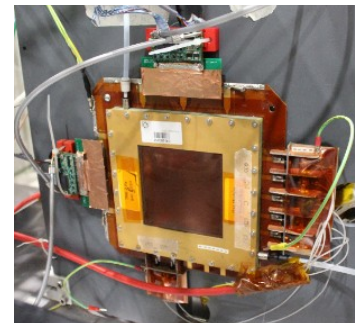
Local setup to overcome the impossibility to travel to China

@CERN SPS H4
80 GeV muon beam

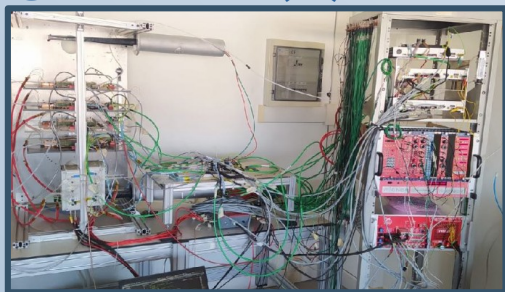


Telescope for cosmic in Ferrara

Telescope for test beam in H4 line at CERN



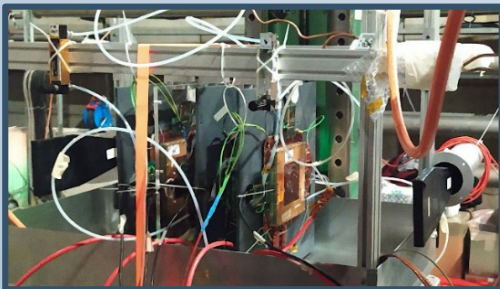
@FERRARA (IT)



INTEGRATION² Since 2020

Local setup to overcome the impossibility to travel to China

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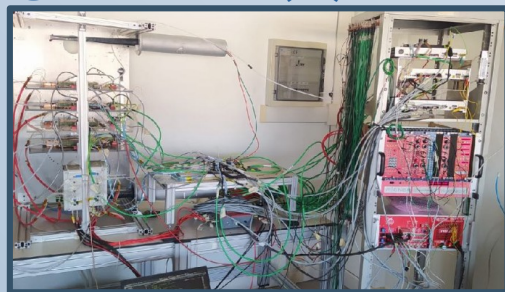
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Four planar triple-GEMs

Tilting mechanics (*x-view*)

Simpler HV system

@FERRARA (IT)

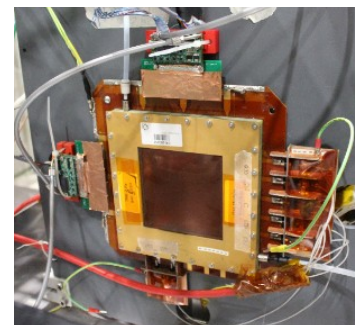


Benchmark with APV/SRS electronics

Tests with TIGER/GEMROC on-going

Fanout modules

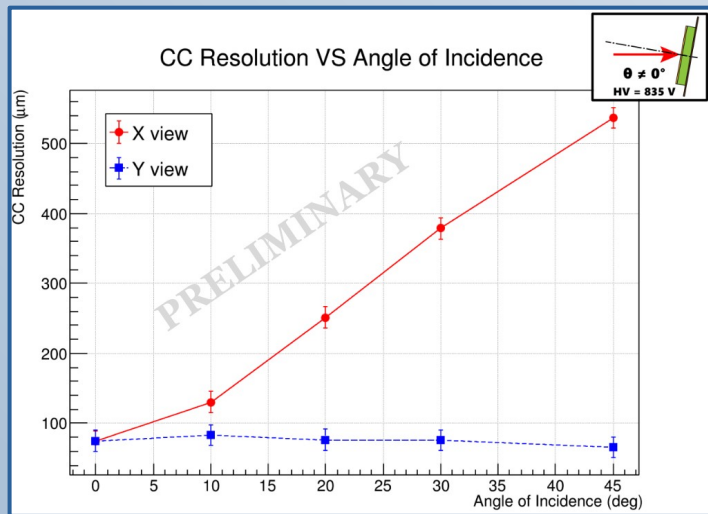
Online and offline analysis



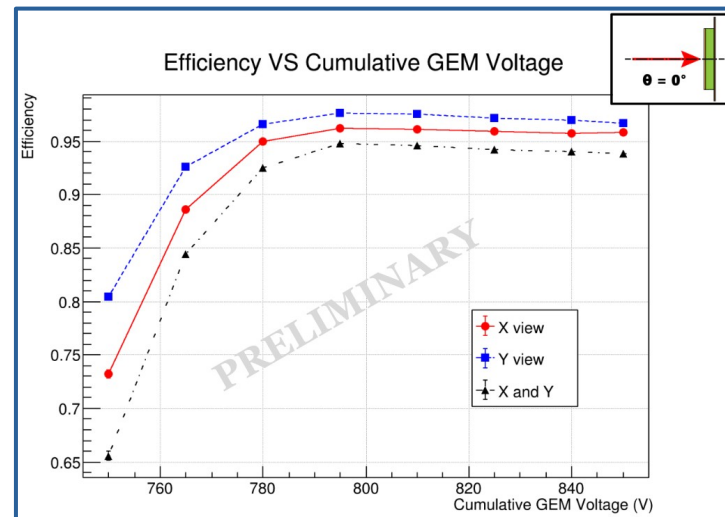
INTEGRATION² Since 2020

EFFICIENCY

At $\theta = 0^\circ$ about $60 \mu\text{m}$
 μ -TPC analysis in progress to
 improve resolution at large angles



CHARGE CENTROID



Grounding scheme and data buffering
 improvements are being upgraded to
 try to solve this efficiency losses

RESULTS

The commissioning of the CGEM-IT started...

The pandemic slowed down the operation

Two layers are taking data remotely since 2020

The detectors safety were guaranteed by a thorough monitoring

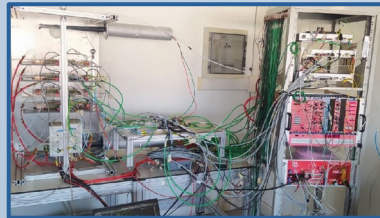
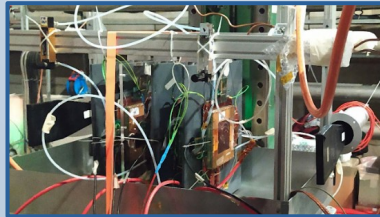
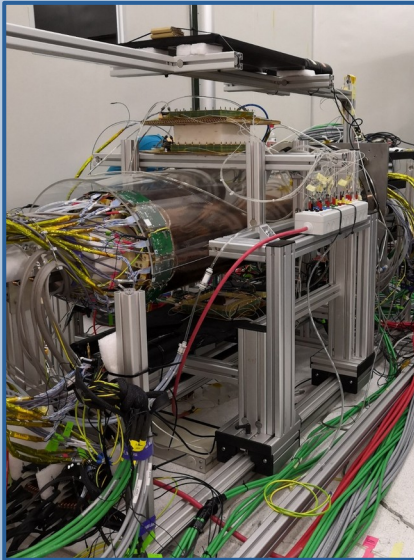
The third layer is under construction

A simpler/narrower setup have been implemented

The development of the integration is on-going

The preliminary results are promising

@Beijing
@Italy
@CERN



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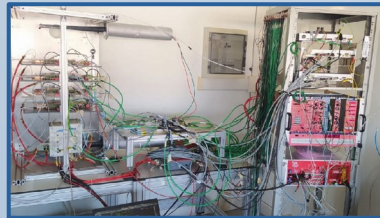
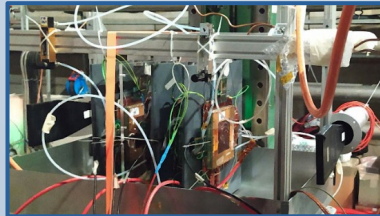
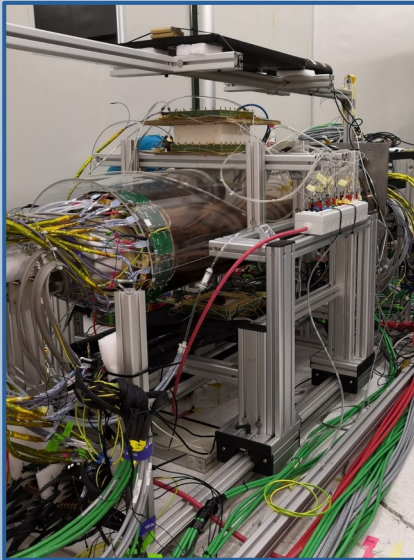
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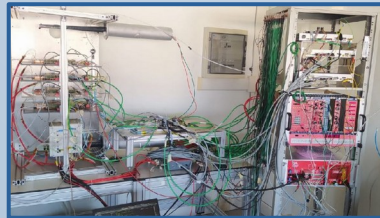
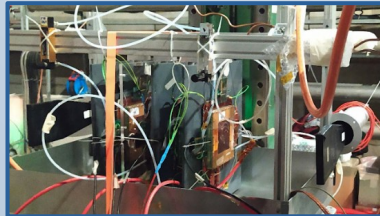
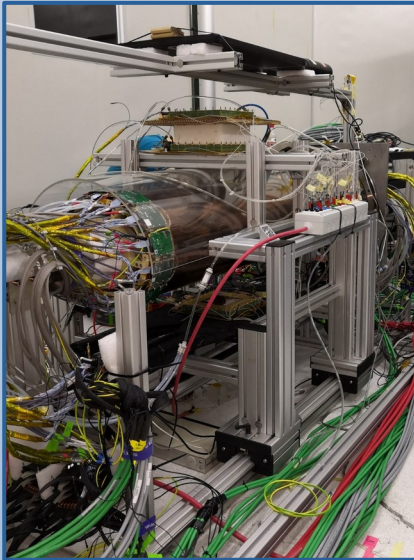
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