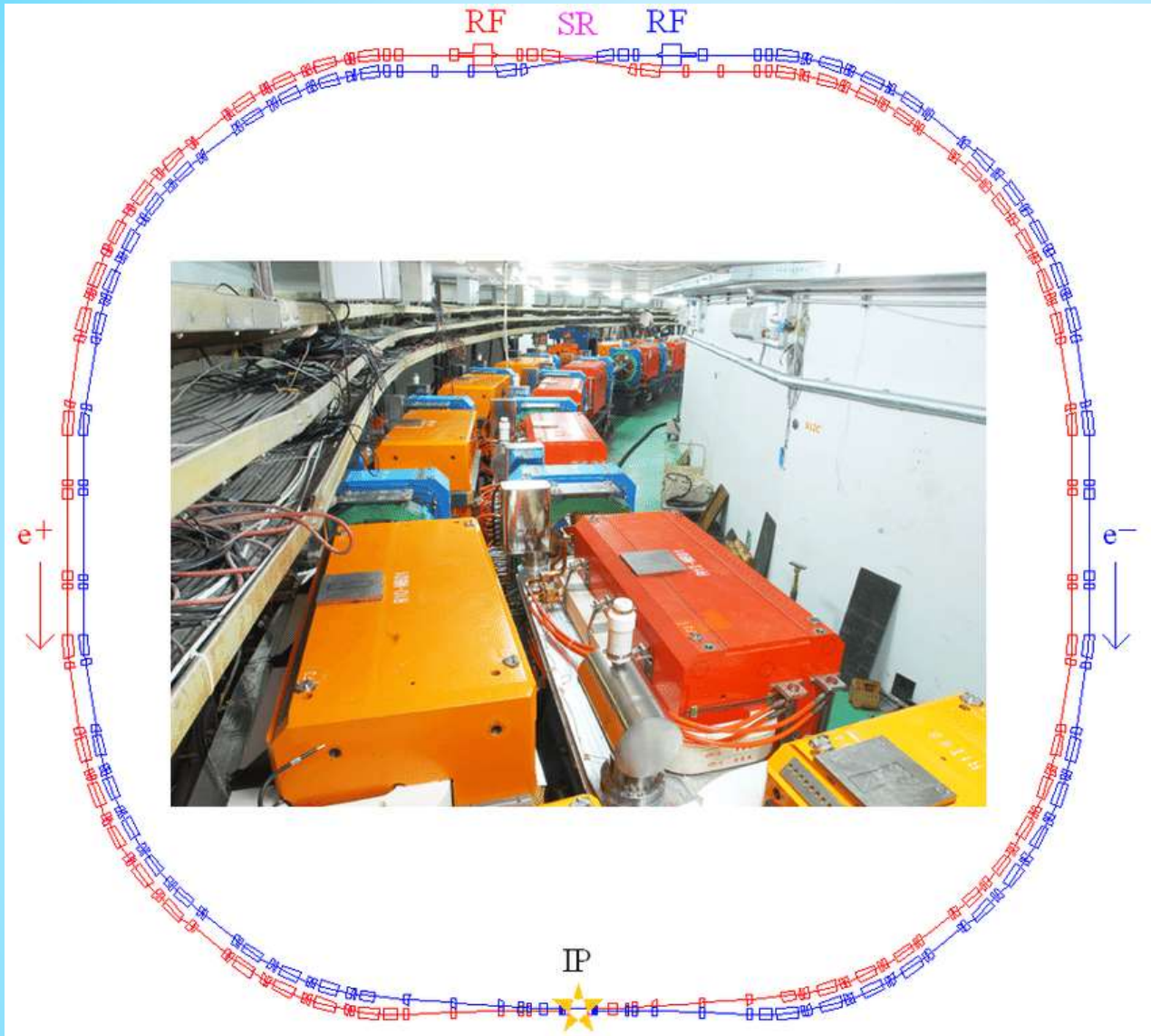
CONSTRUCTION, COMMISSIONING, AND INSTALLATION OF THE **CYLINDRICAL GEM** INNER TRACKER OF THE **BESIII** EXPERIMENT

Based on:

1. CGEM-IT Rewiew (https://doi.org/10.3390/sym14050905)
2. The dissertation Stefano Gramigna (https://arxiv.org/abs/2505.20952v1)

Speaker – Andrey Sokolov

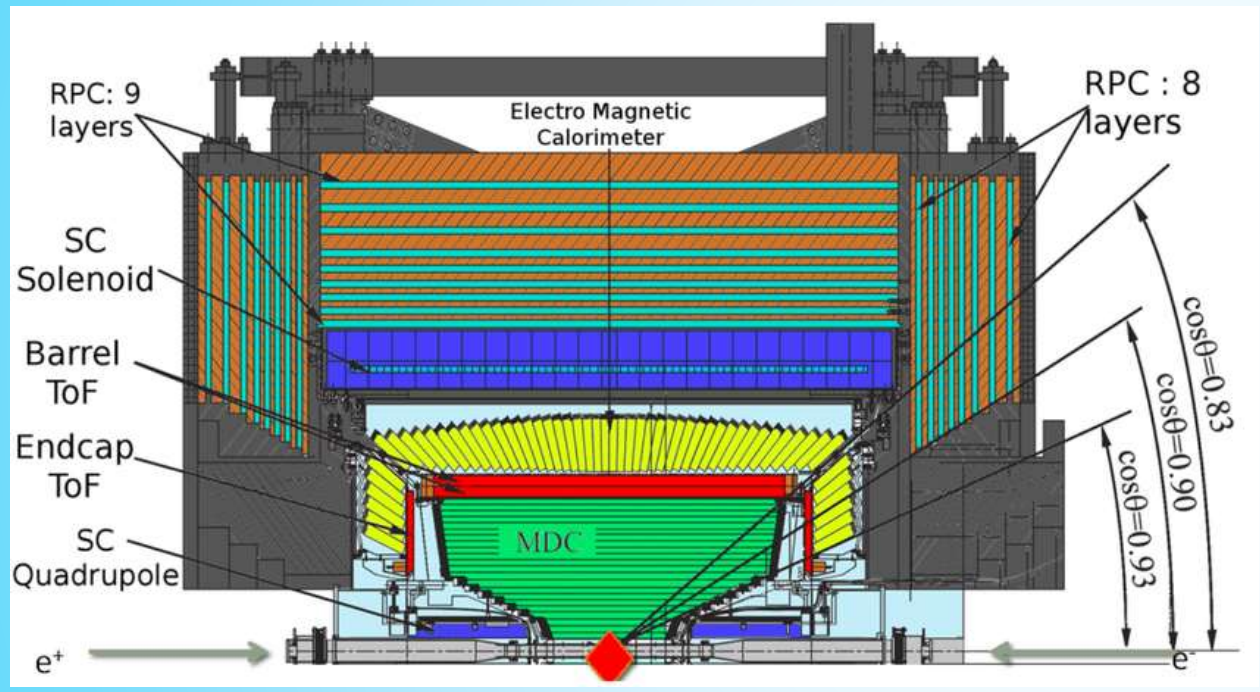


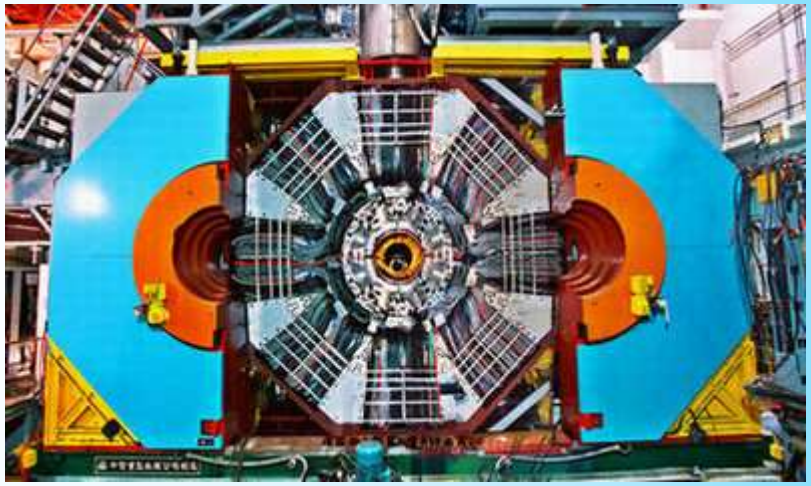
BEPCII Design Parameters

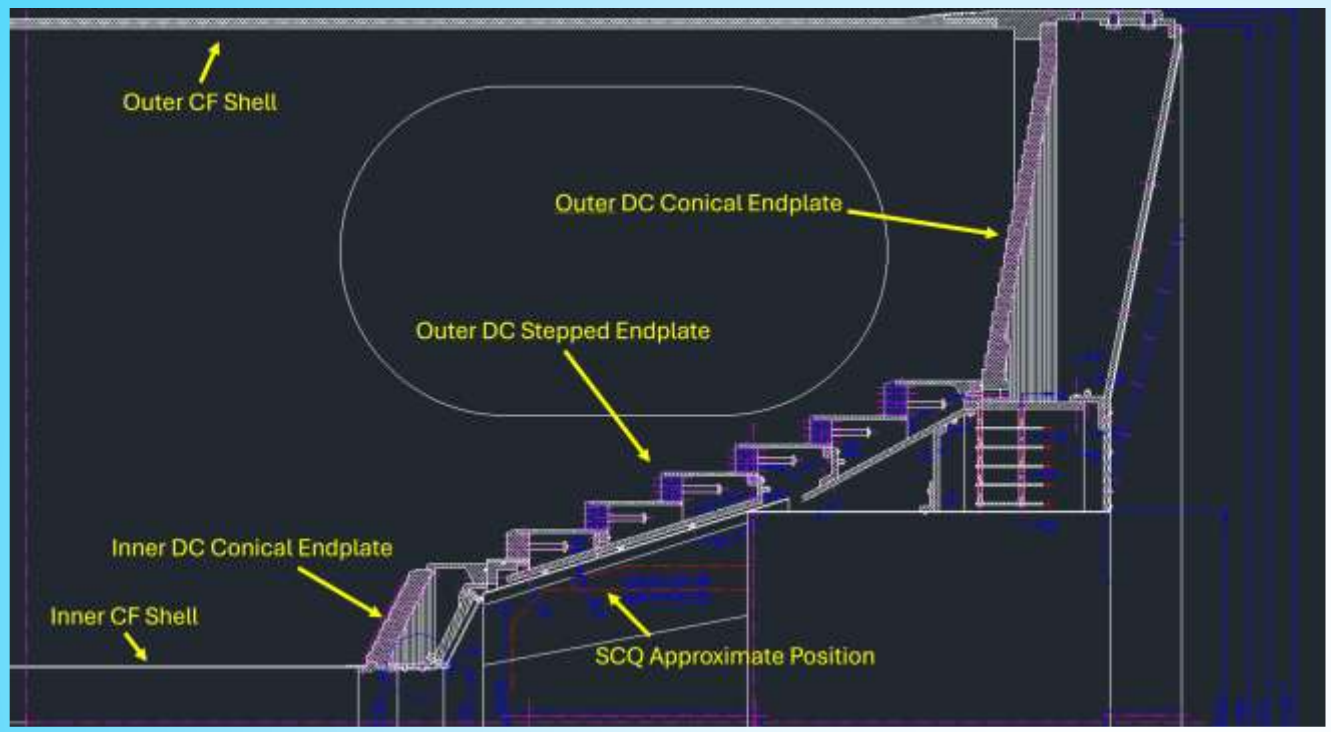
Beam energy	1 - 2.3 G
Optimum energy	1.89 G
Luminosity	10^{33} cm^{-2}s^{-1} @ 1.89 G
SR current	250mA @ 2.5 G

BEPC II @ IHEP

BES III DETECTOR

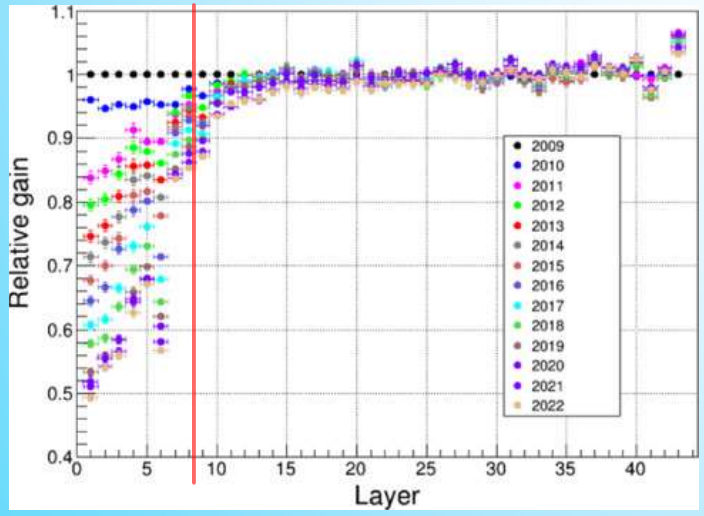






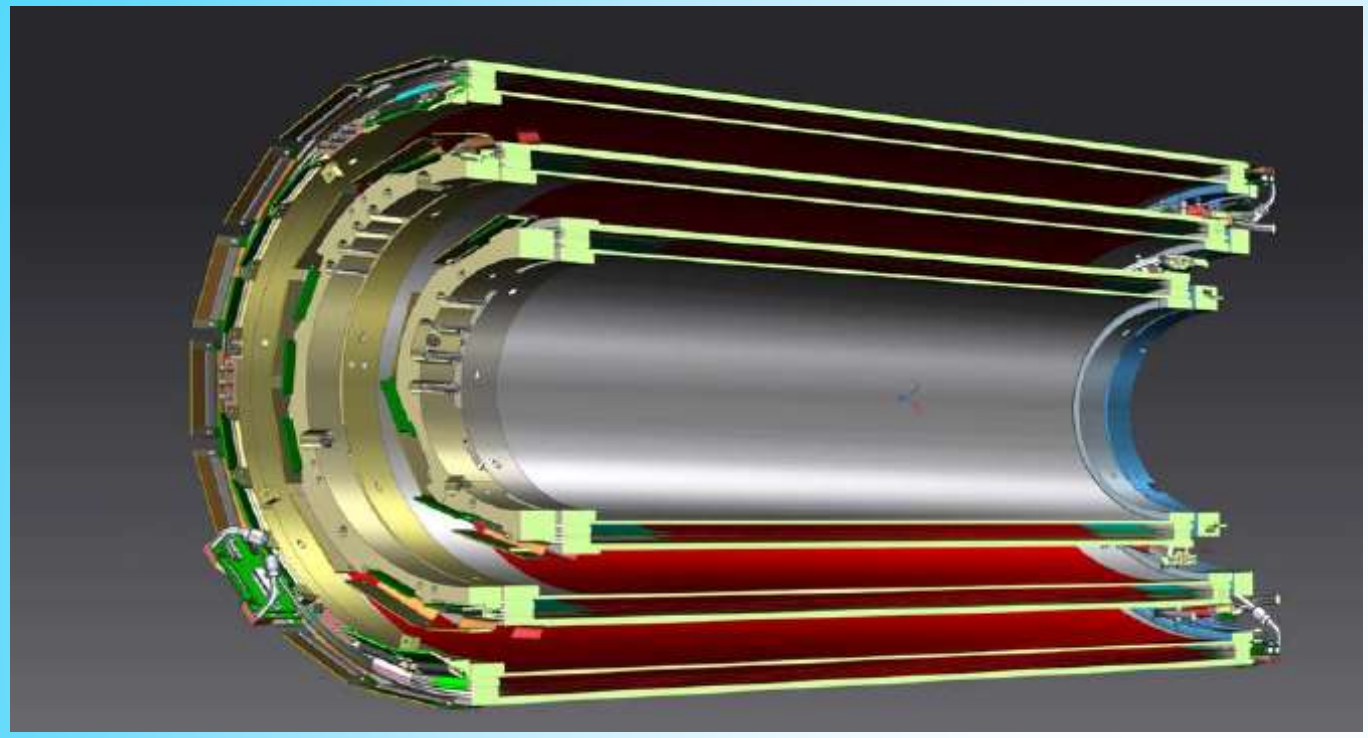
BES III MDC

Outer radius	810 mm
Inner radius	59.2 mm
Number of layers	42 (24 stereo)
Anode wire	25μm (W/Re)
Gas mixture	He:C_3H_8 (60:40)
Gas gain	30000



Two solutions:

1. New IDC with shorter inner layers
2. CGEM-IT

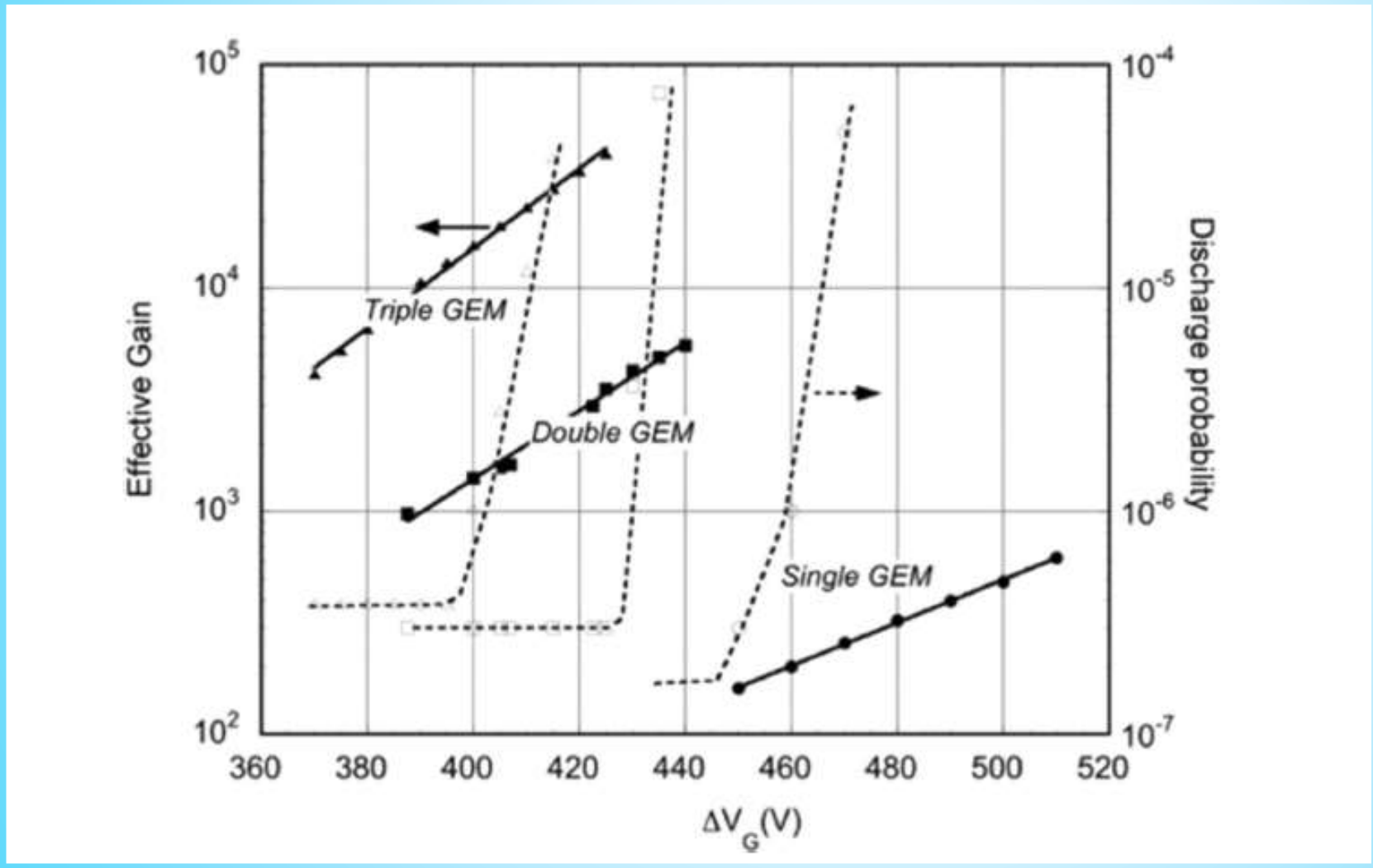


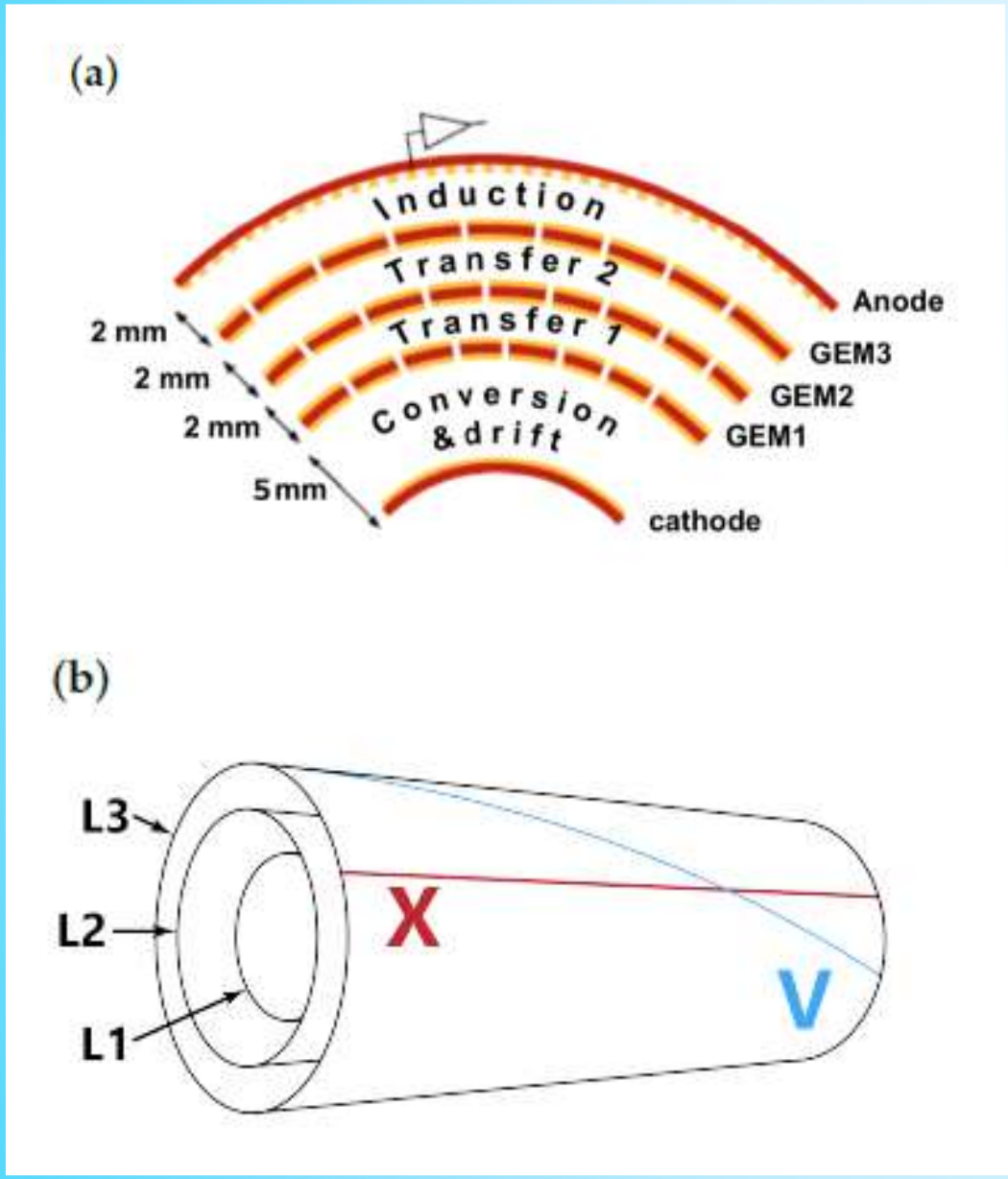
CGEM-IT

Charachteristic	Goal
Angular Coverage	93% @4π
Material Budget	≤1.5% X_0
Rate Capability	10^4 Hz/cm2
$\sigma_{r\varphi}$	≤130μm
σ_z	≤1 mm
dp/p @ 1 GeV/c	0.5%

Layer	Inner Diameter	Active Area Length	Strips Stereo Angle
Inner	153.8mm	532mm	46.7°
Middle	242.8mm	690mm	−31.0°
Outer	323.8mm	847mm	32.9°

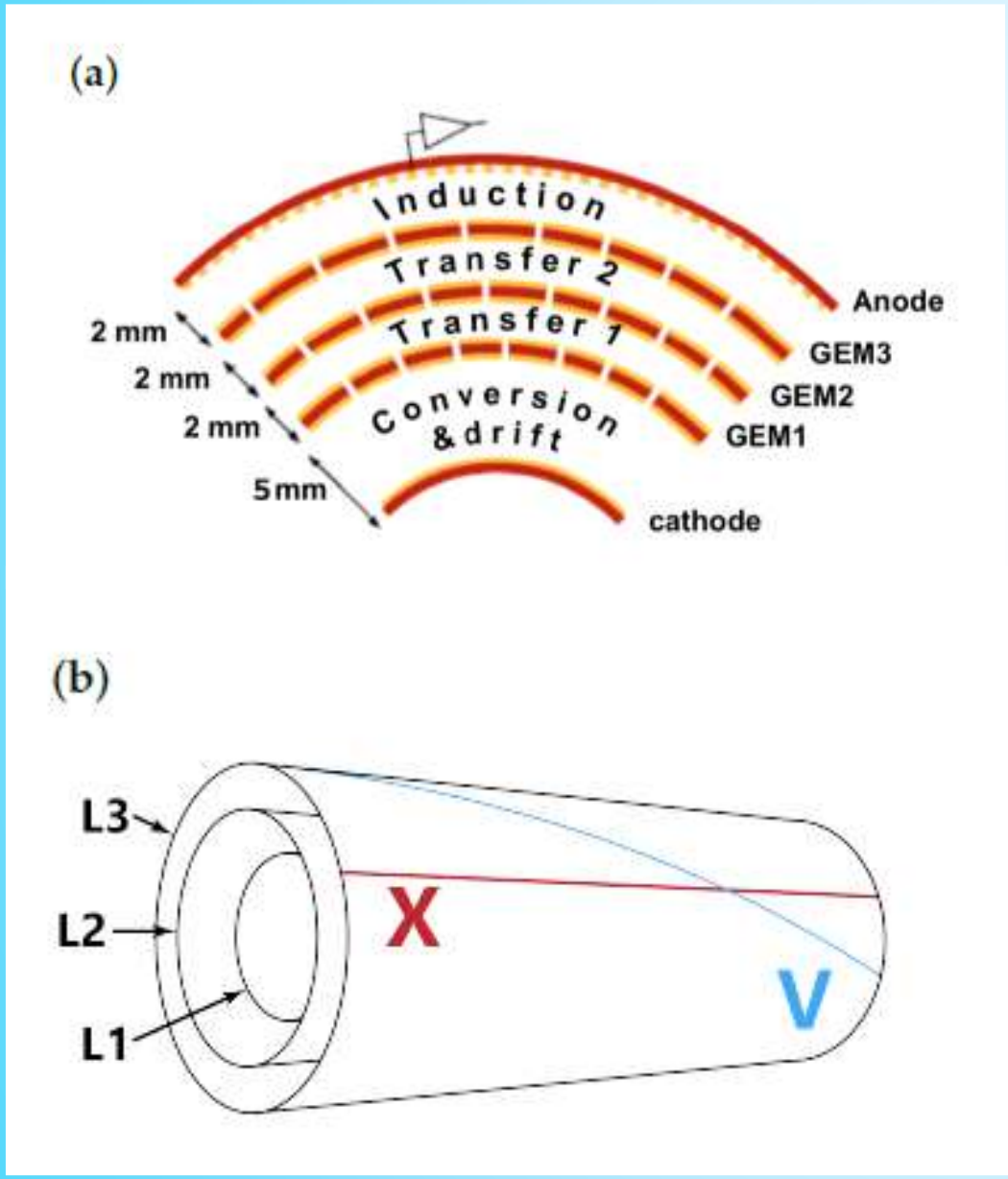
GAIN OF GEM'S STACK





SINGLE LAYER LAYOUT

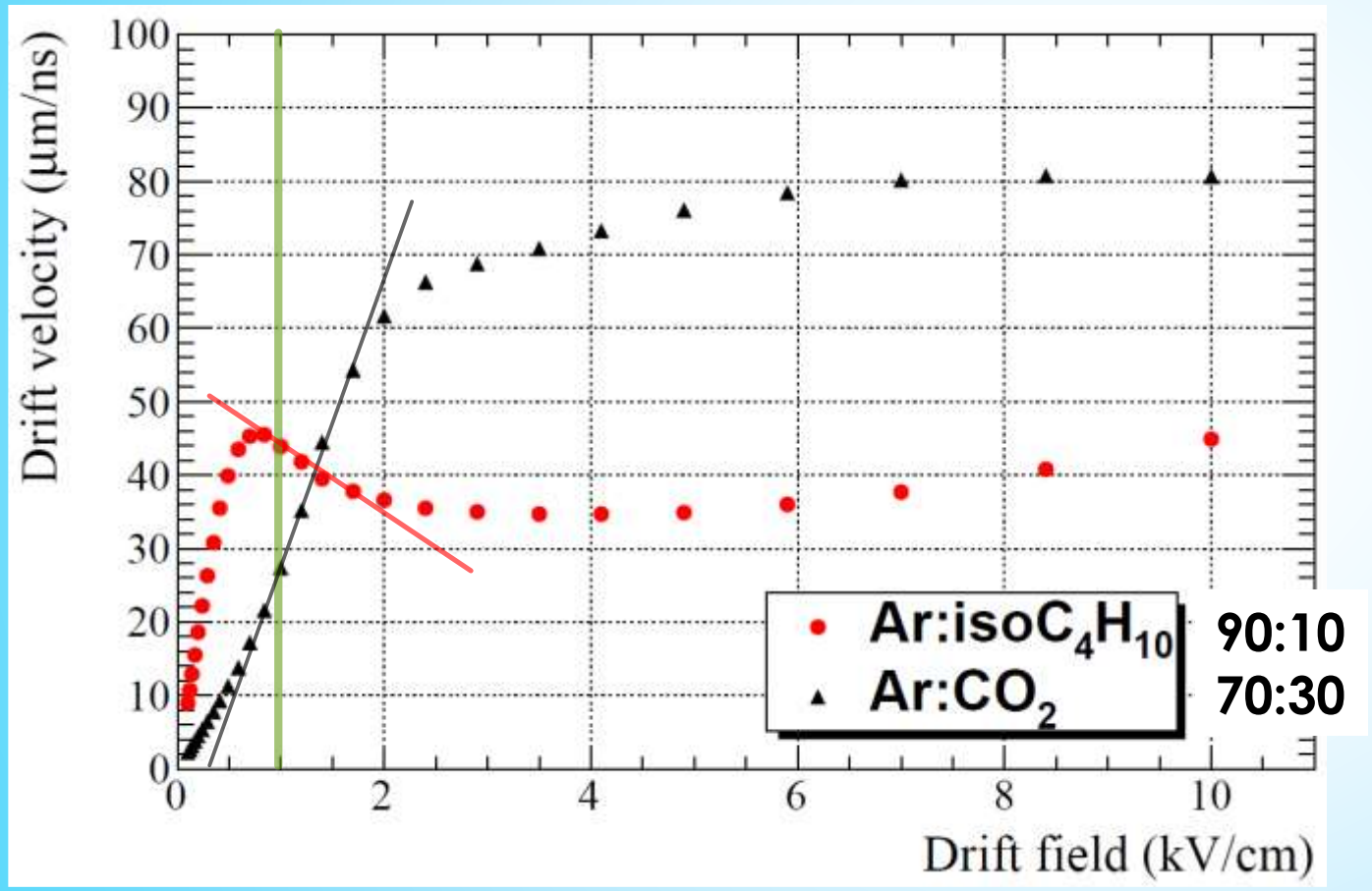
- The GEM foils have 5 μm copper on both sides and a specific segmentation for the two faces.
- Readout plane is segmented in 5 μm thick strips etched on both the copper sides on the Kapton foil and sealed with an additional foil of 25 μm Kapton glued on them.
- The strips on the two sides are oriented with different angles. X strips, parallel to the beam axis, provide the azimuthal coordinate and are 570 μm wide; V strips, 130 μm wide, are oriented in each layer with different stereo angle.
- The pitch for all the strips is 650 μm.

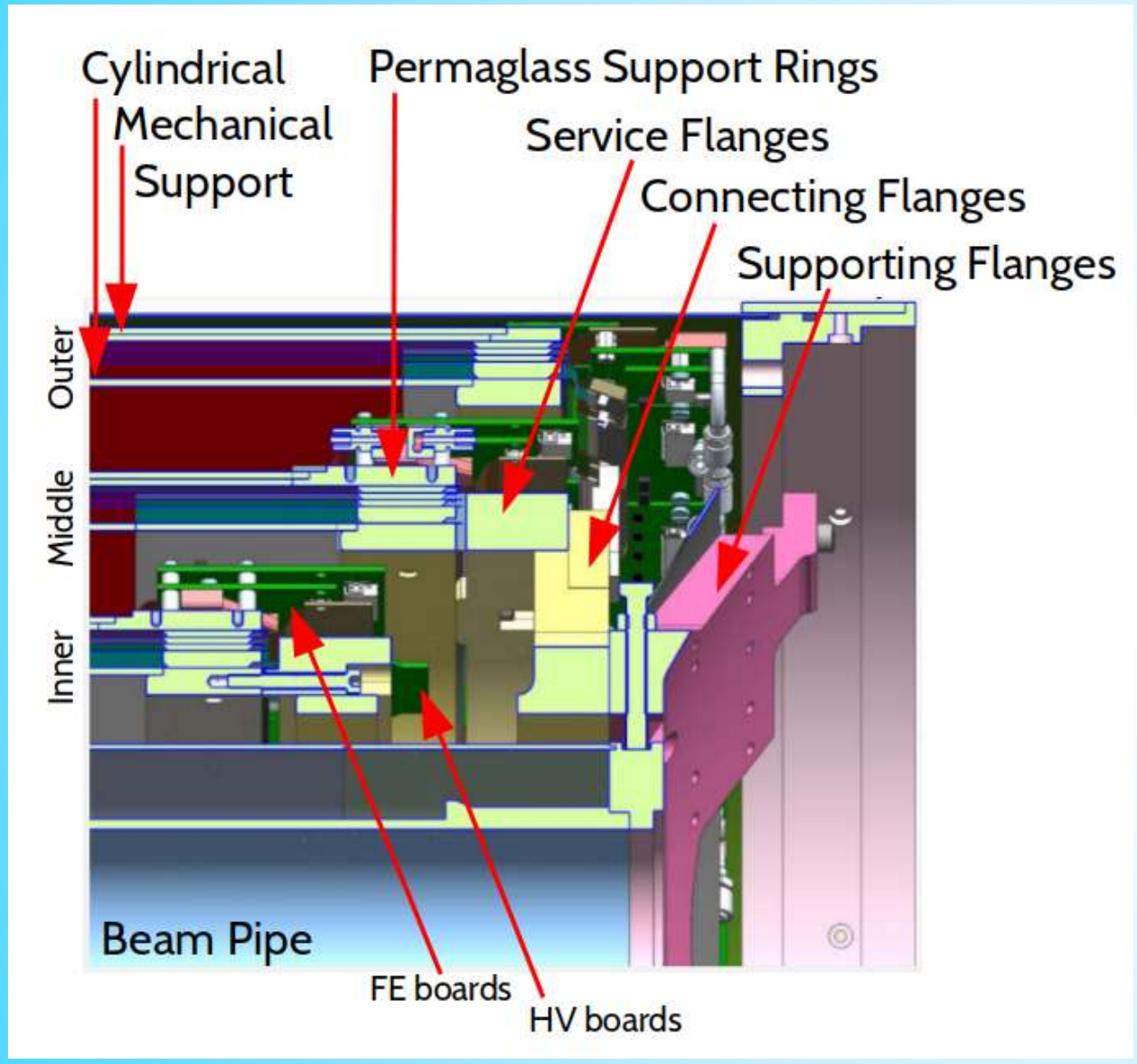


SINGLE LAYER LAYOUT

- Each GEM copper plane facing the anode is divided in the so-called **macrosectors**. The other copper part is segmented into 10 **microsectors** for each macrosector.
- The gas mixture chosen is Ar:iC_4H_{10} with (90:10) proportions.
- The electric fields intensities equal to (1.5/3/3/5) kV/cm; the GEM voltage difference are (280/280/275)V, from GEM1 to GEM3, corresponding to a gain of the order of 10^4 with a discharge probability below 10^{-6}.

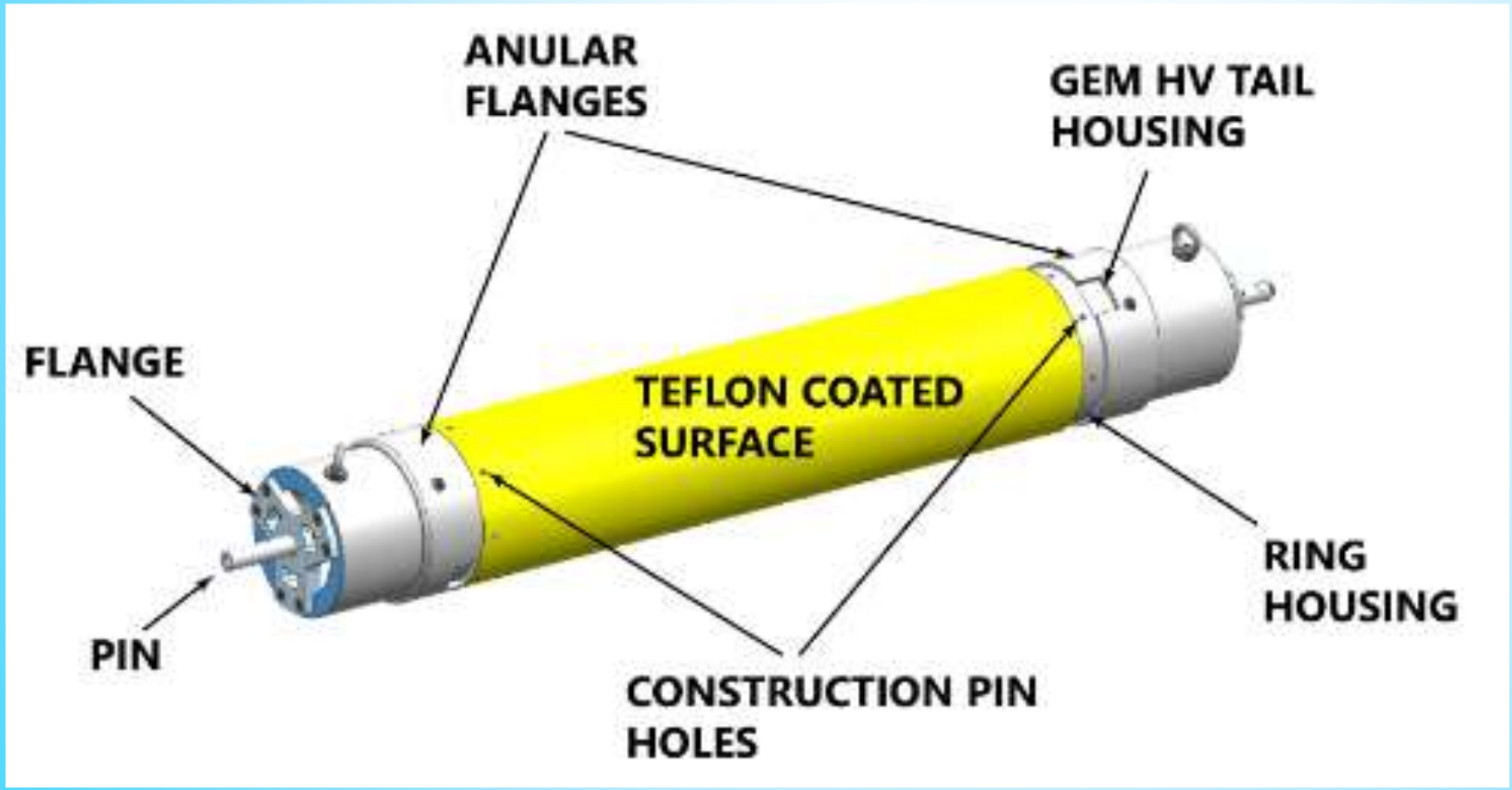
GAS MIXTURE CHOICE



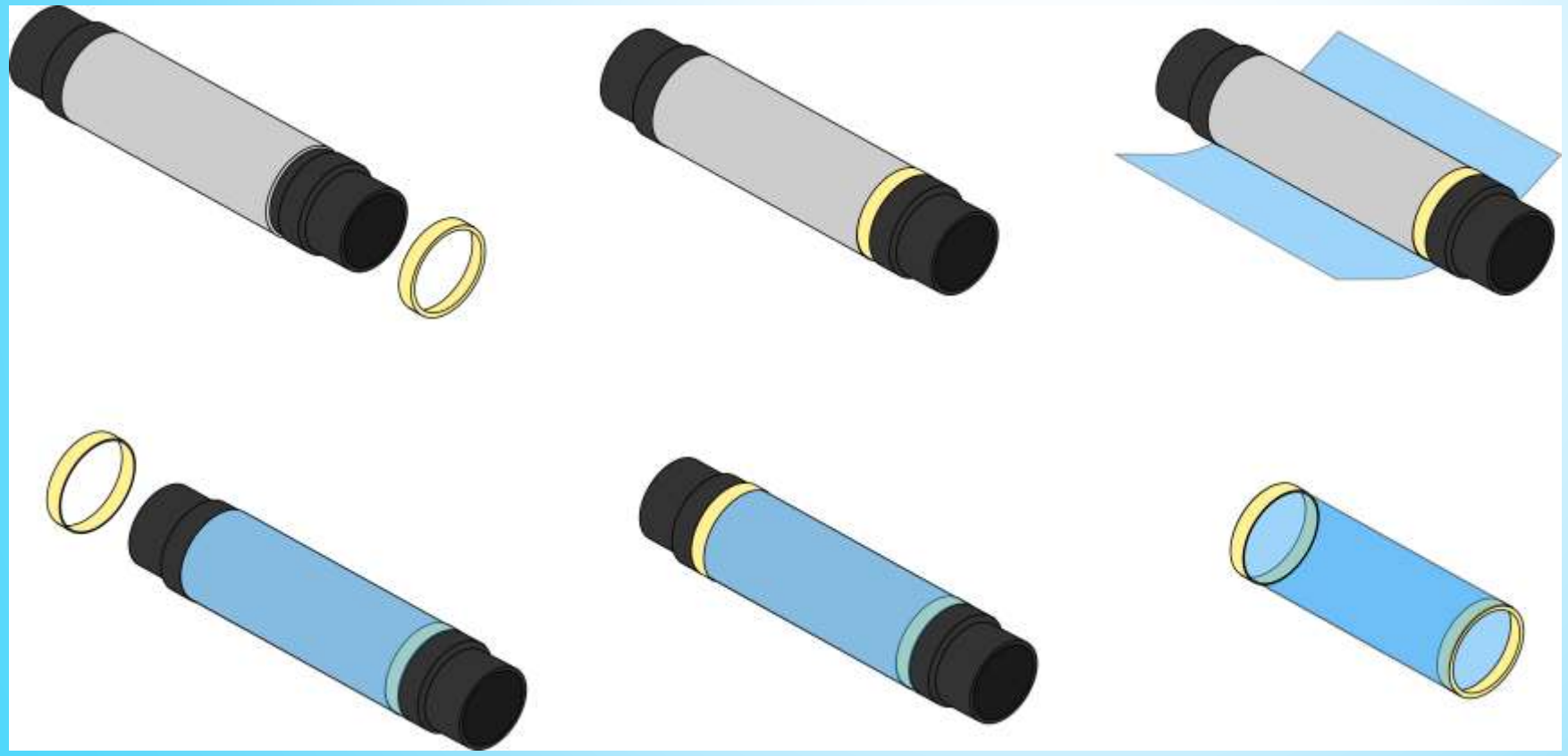


CGEM-IT MECHANICS

- The support rings are in Permaglass, a fiber-glass reinforced epoxy resin, which guarantees the necessary robustness and the gas sealing.
- The mechanical structure is laminated carbon fiber foils on an Honeycomb structure.

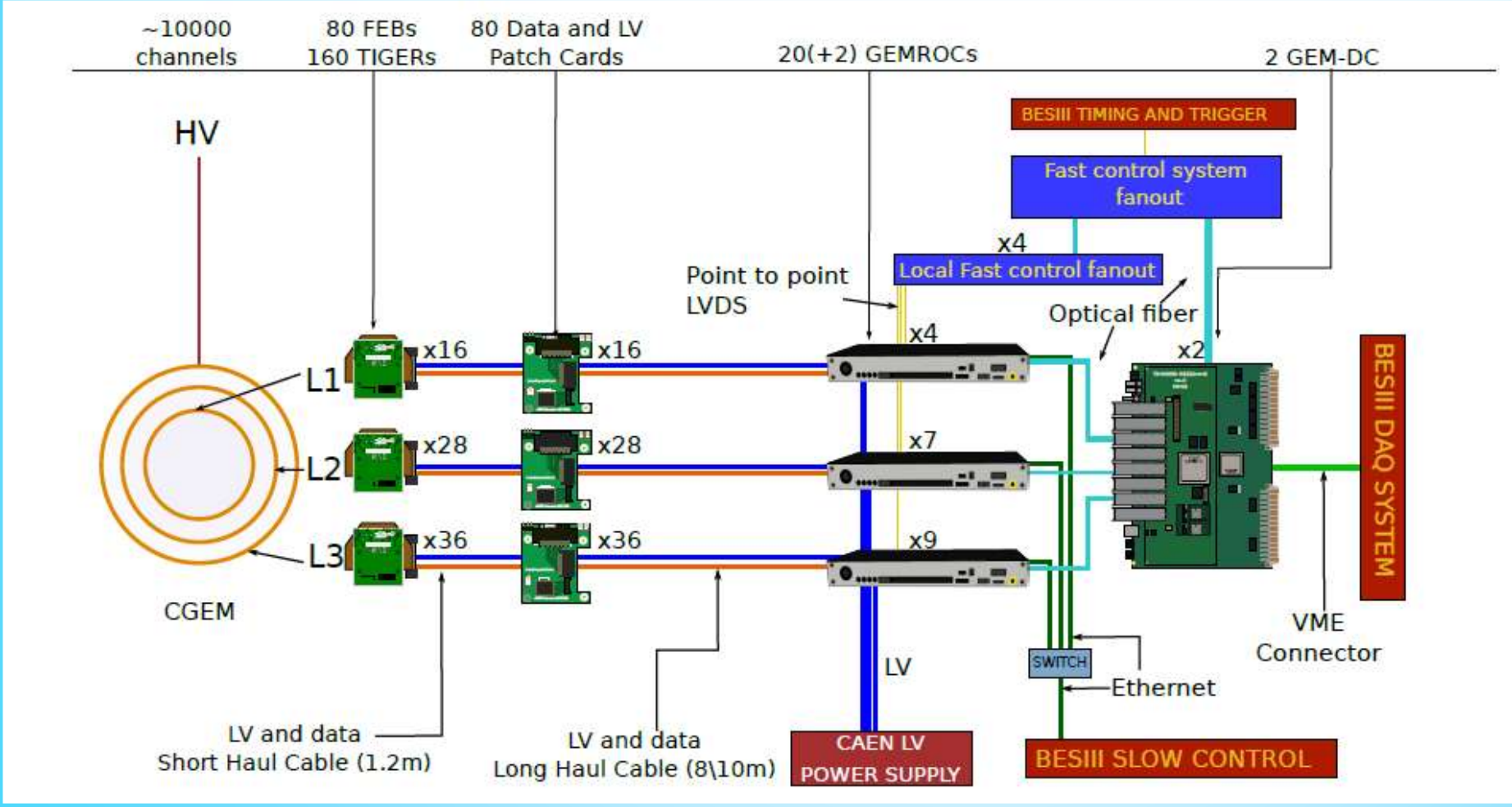

ANULAR
FLANGES
GEM HV TAIL
HOUSING
FLANGE
TEFLON COATED
SURFACE
RING
HOUSING
PIN
CONSTRUCTION PIN
HOLES

SUB-LAYER PREPARATION

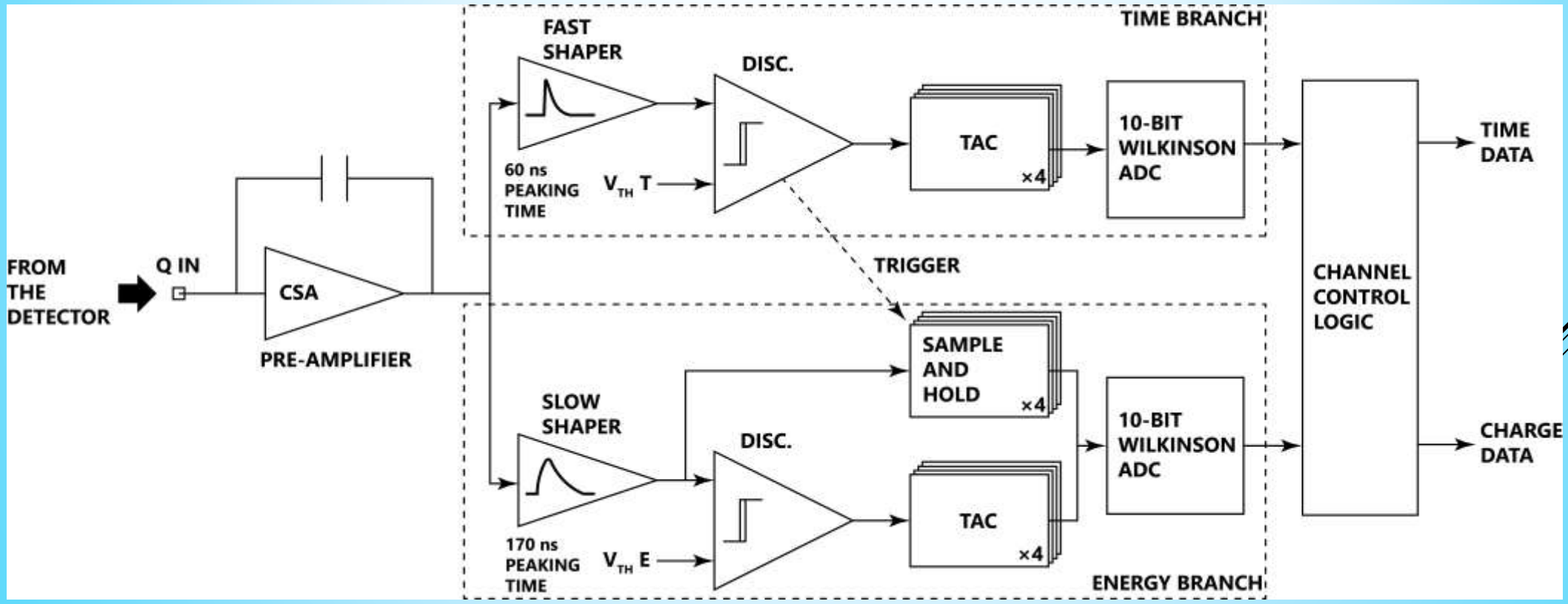


VERTICAL INSERTION MACHINE - **VIM**

CGEM-IT READOT CHAIN



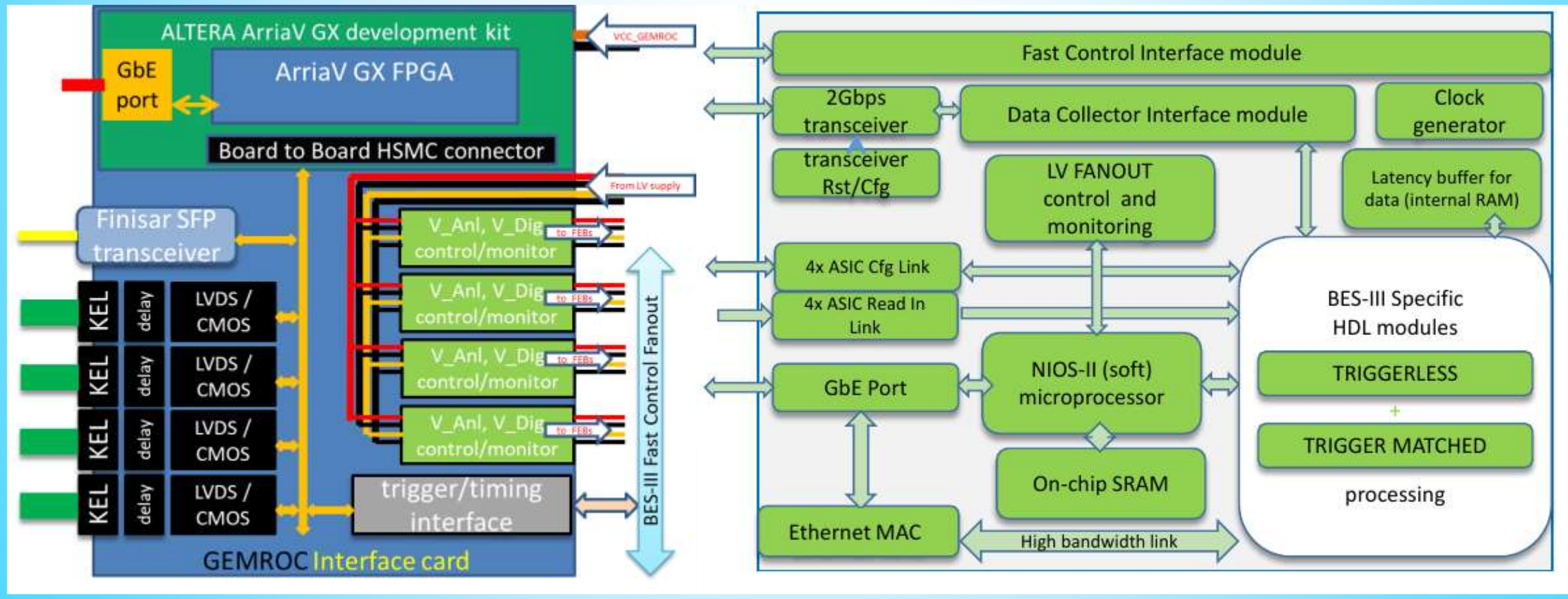
Torino Integrated Gem Electronics for Readout (TIGER)

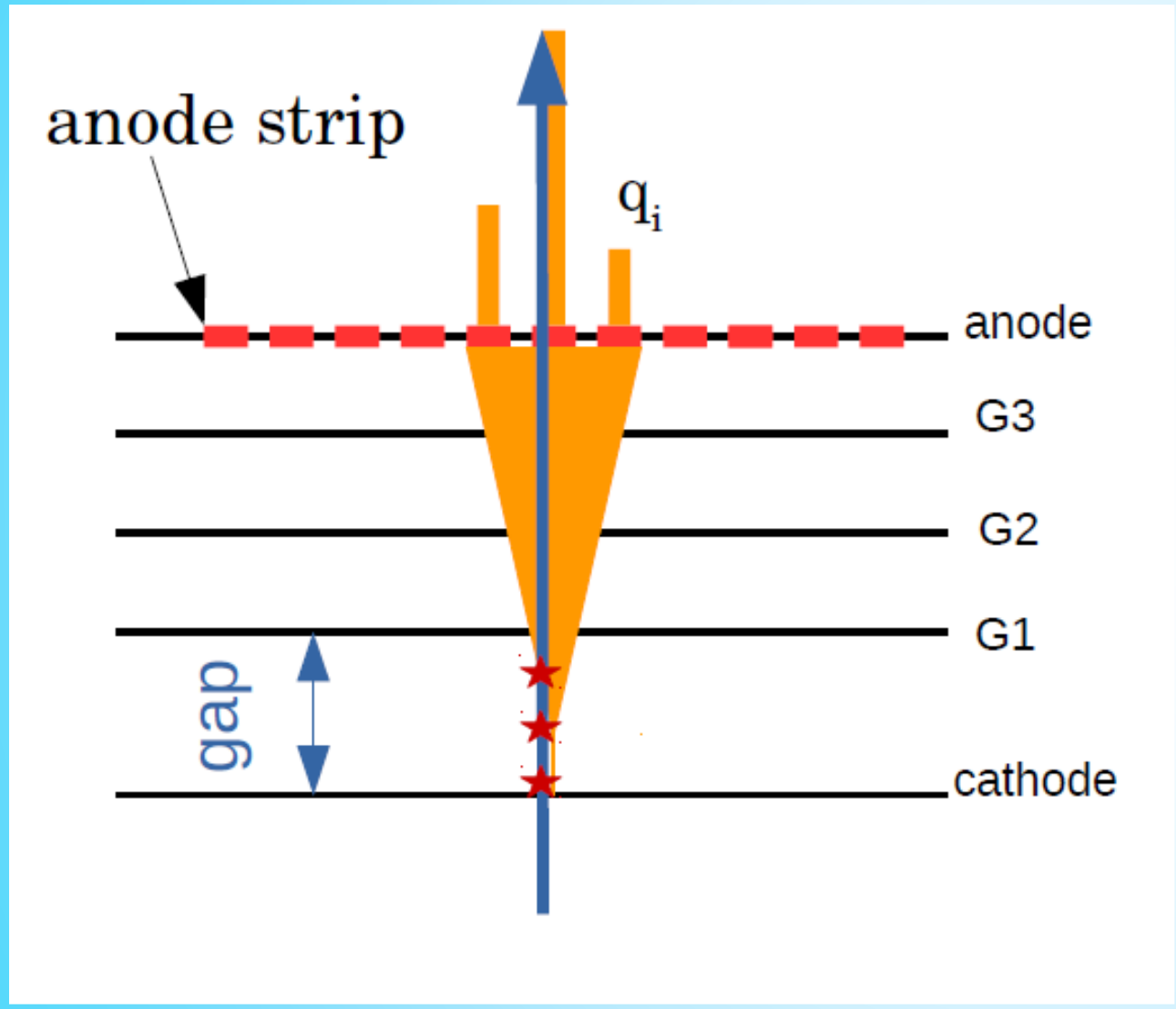


TIGER PARAMETERS

Parameters	Value
Number of channels	64
Clock frequency	160–200 MHz
Input capacitance	Up to 100 pF
Input dynamic range	2–50 fC
Front-end gain	12 mV/fC
Non-linearity	<2%
ENC	<2000 e^-
TDC time binning	50 ps
Maximum event rate	60 kHz/ch
Readout mode	Trigger-less
Charge collectiontTime	60 ns
Time resolution	<5 ns
Power consumption	<12 mW/ch
Technology	CMOS 110 nm

GEMROC INTERFACE CARD



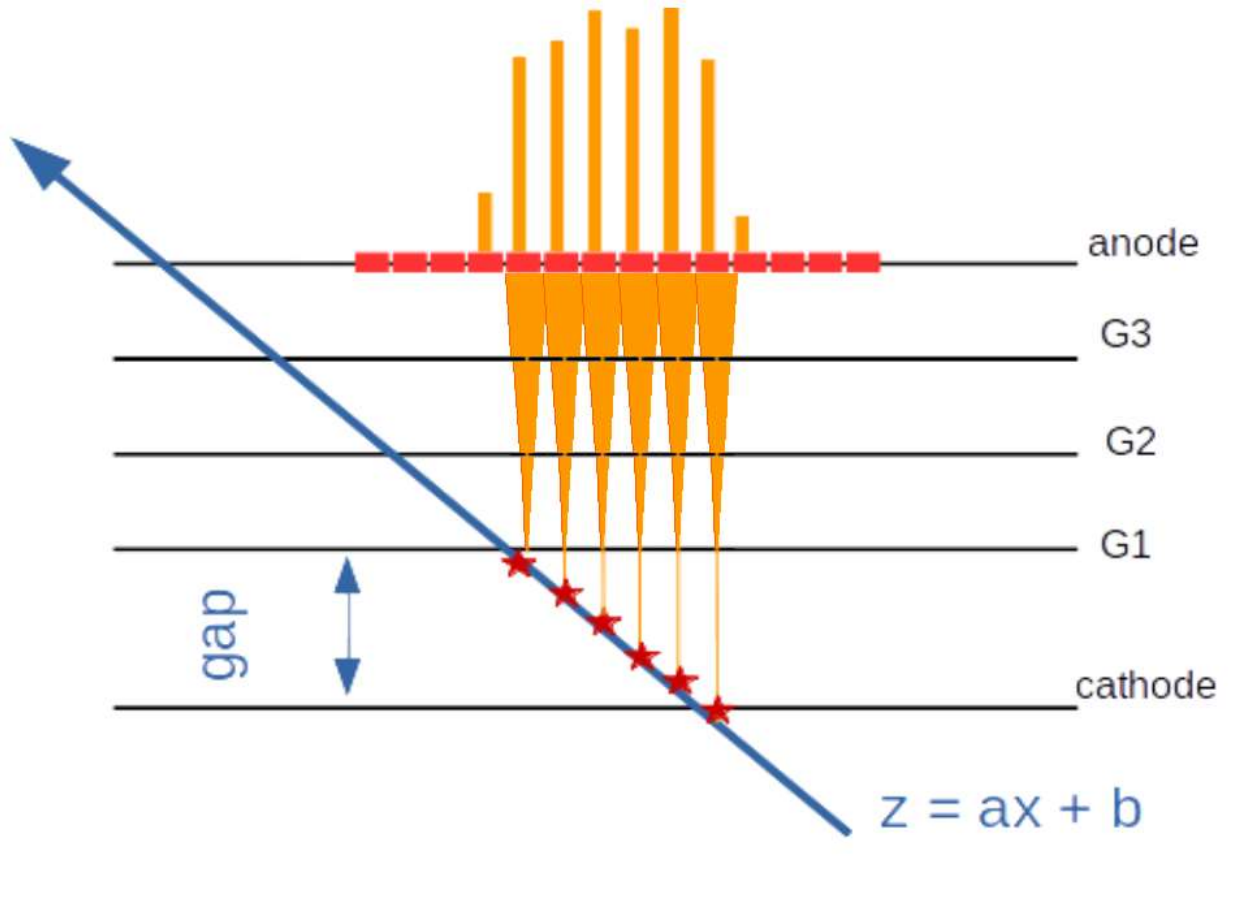


CHARGE CENTROID METHOD

$$x_{CC} = \frac{\sum_{i=0}^{n_x} x_i q_i}{\sum_{i=0}^{n_x} q_i},$$

$$v_{CC} = \frac{\sum_{i=0}^{n_v} v_i q_i}{\sum_{i=0}^{n_v} q_i},$$

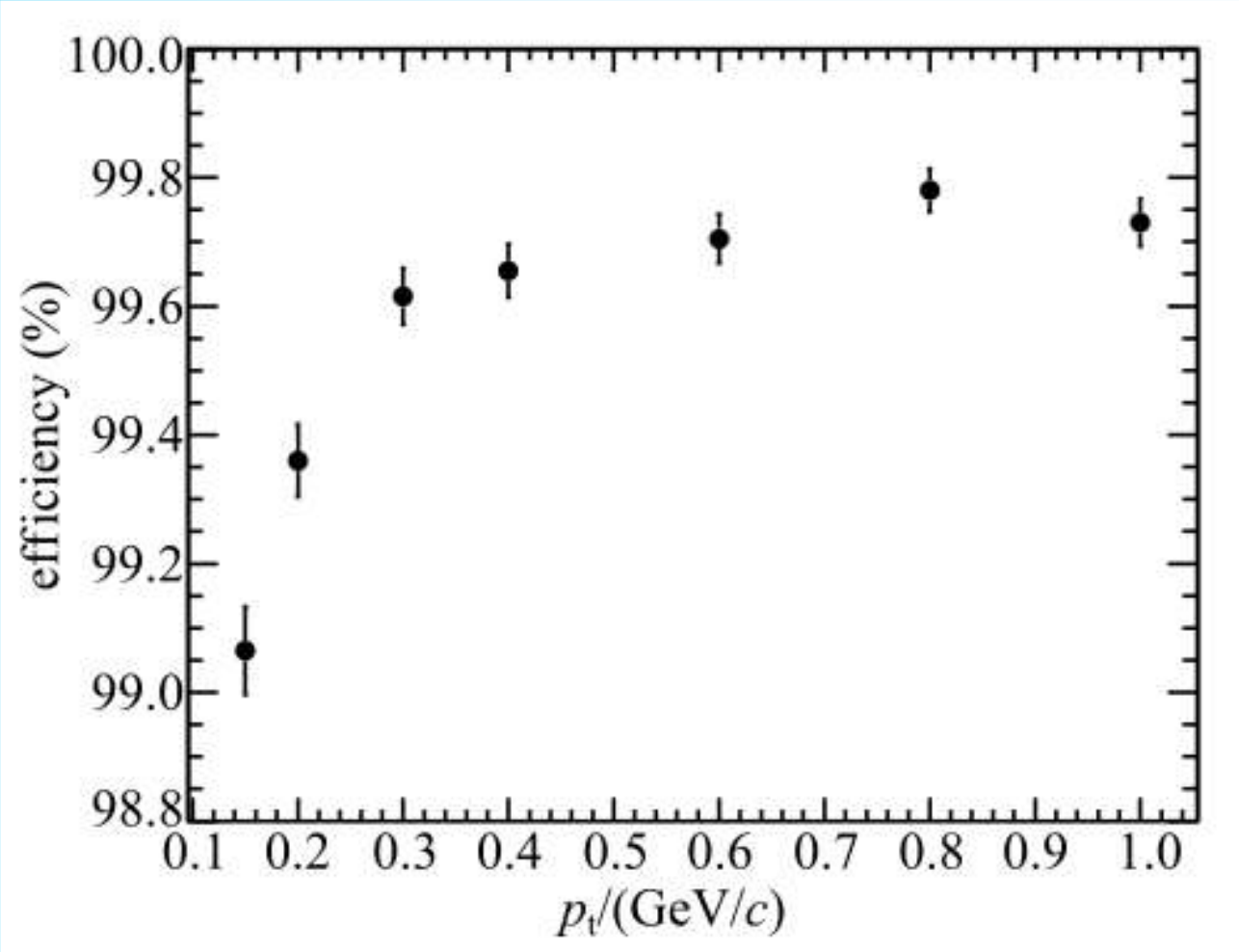
MICRO-TPC METHOD



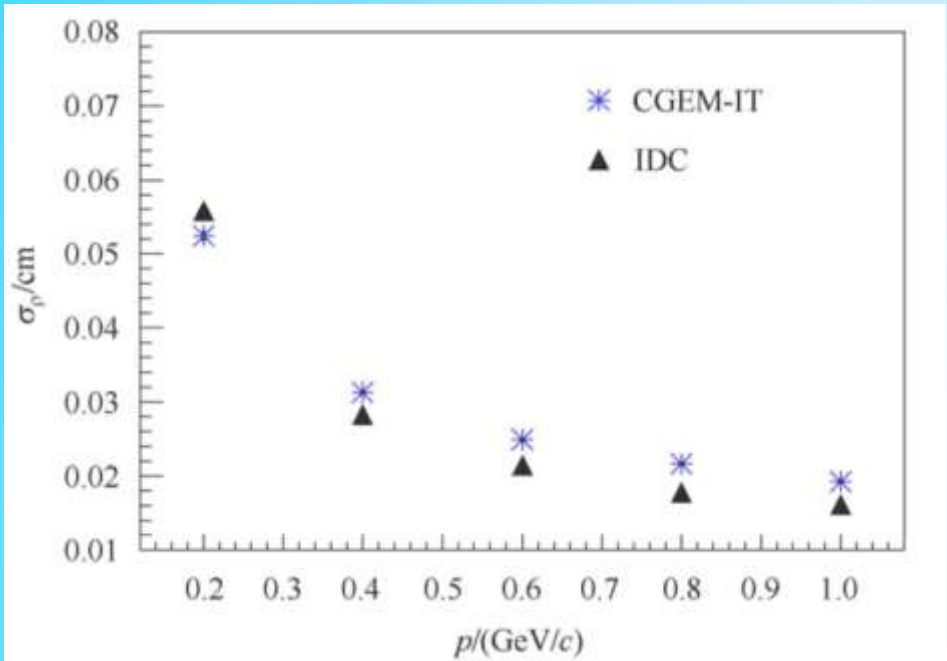
$$x_{\mu TPC} = \frac{gap/2 - b}{a}$$

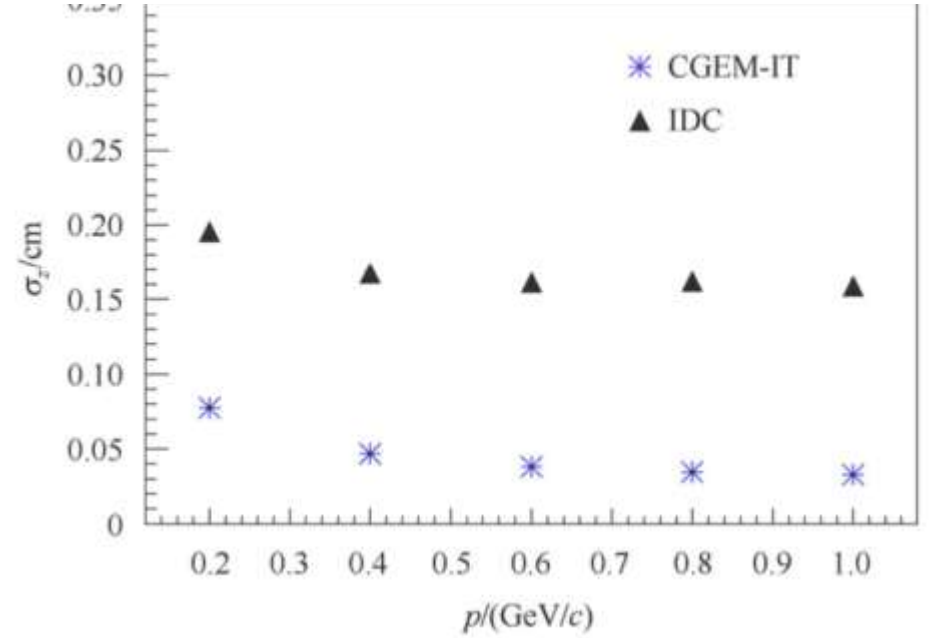
$$x_{merge} = w_{CC}\, x_{CC} + (1 - w_{CC})\, x_{\mu TPC}$$

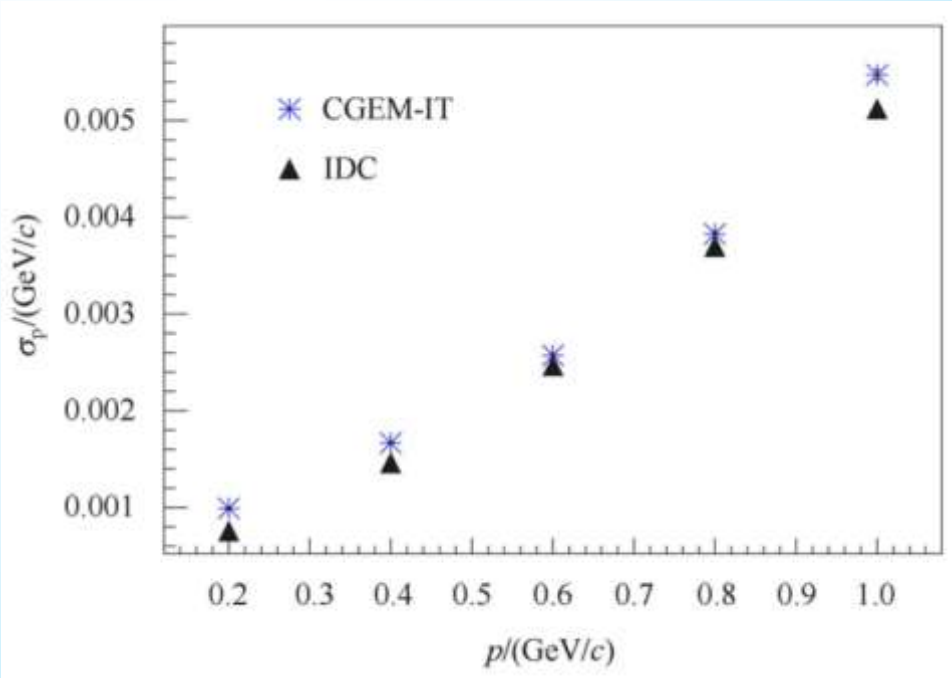
TRACK SEGMENT FINDER EFFICIENCY



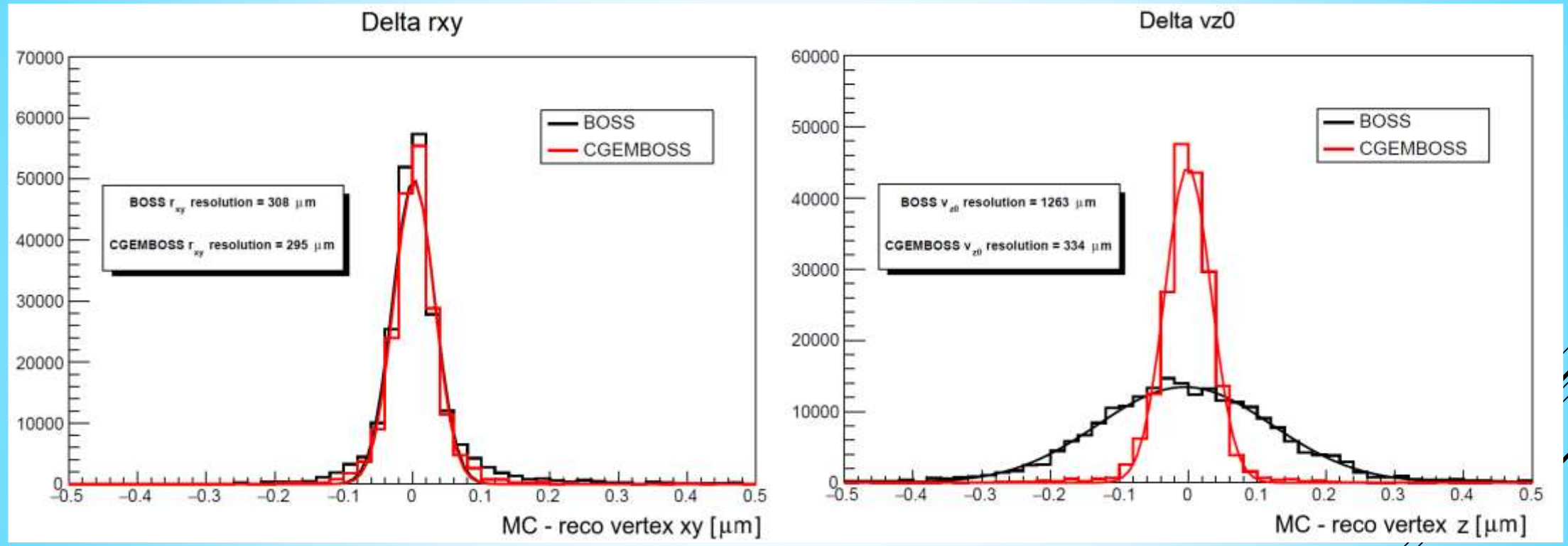
TRACK RECONSTRUCTION RESOLUTION



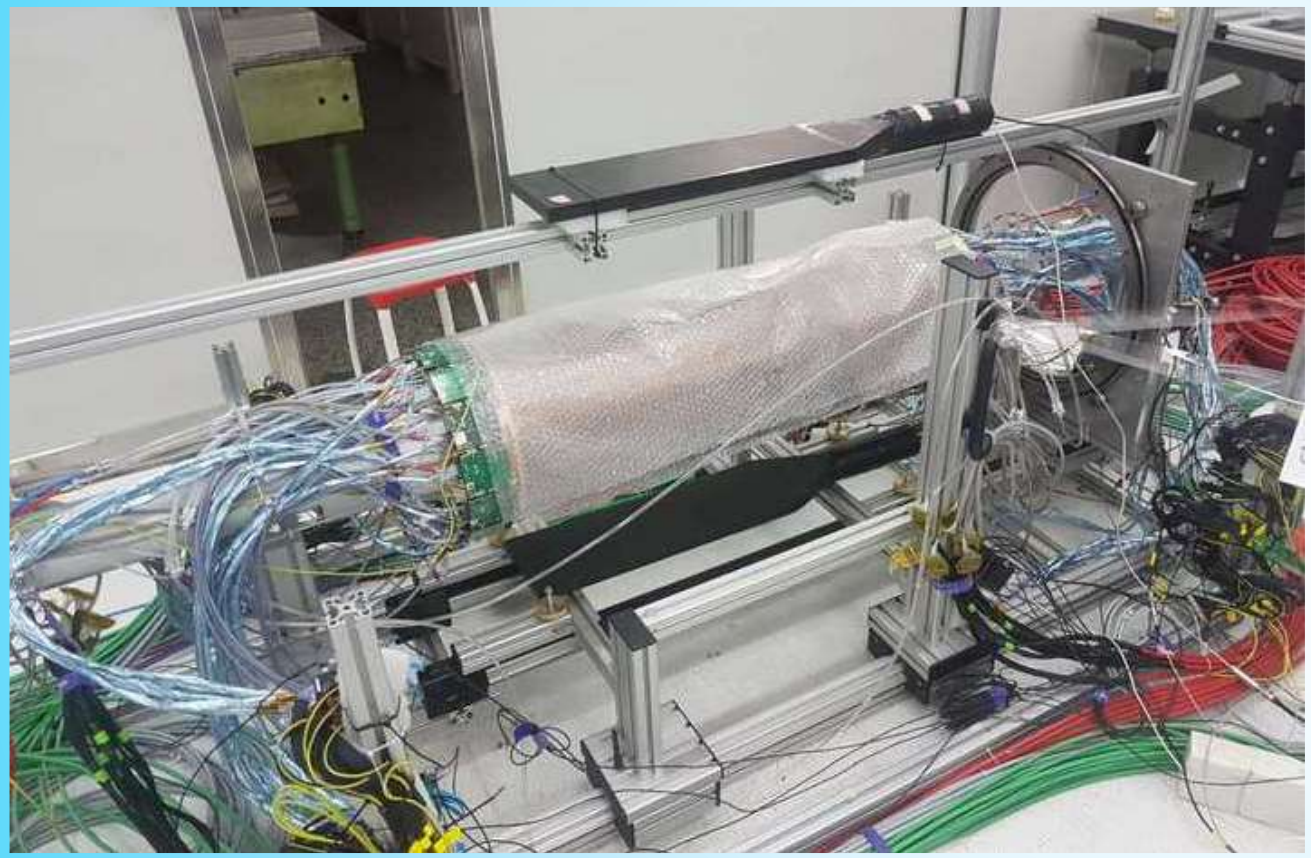




J/PSI VERTEX POSITION



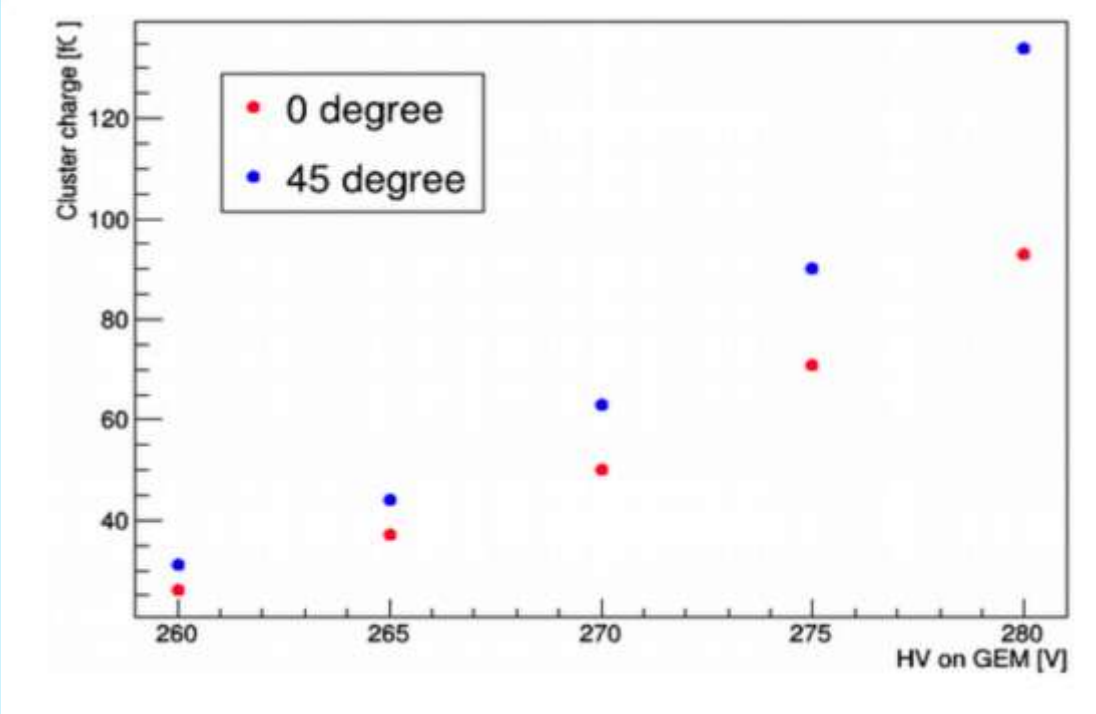
BESIII Offline Software System (BOSS)

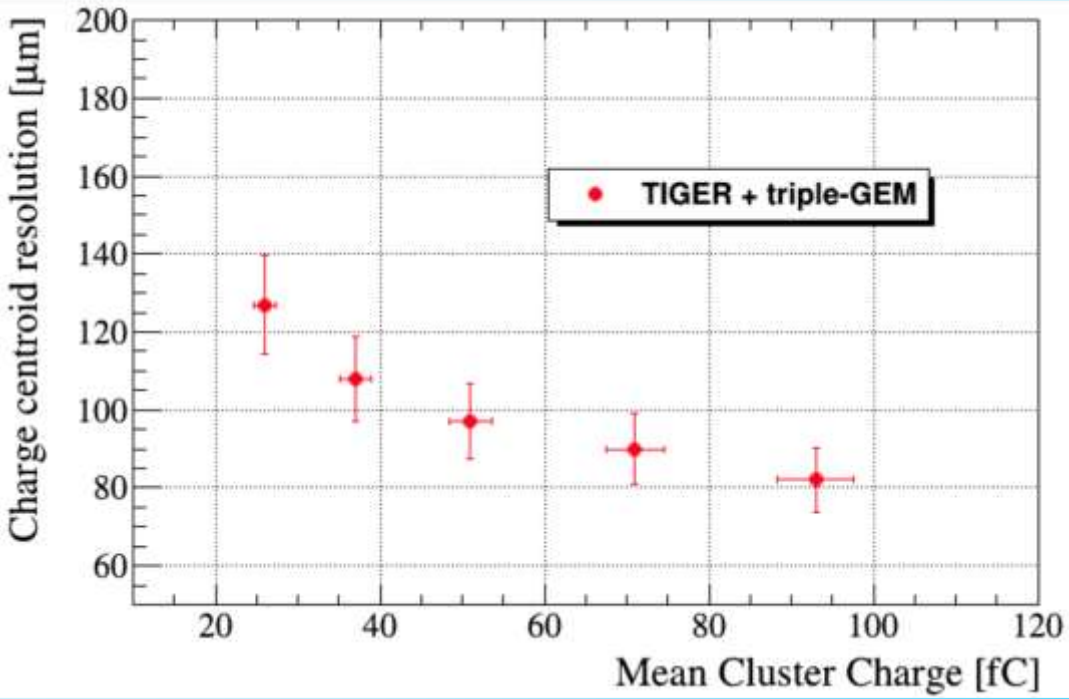


COSMIC RAY TEST

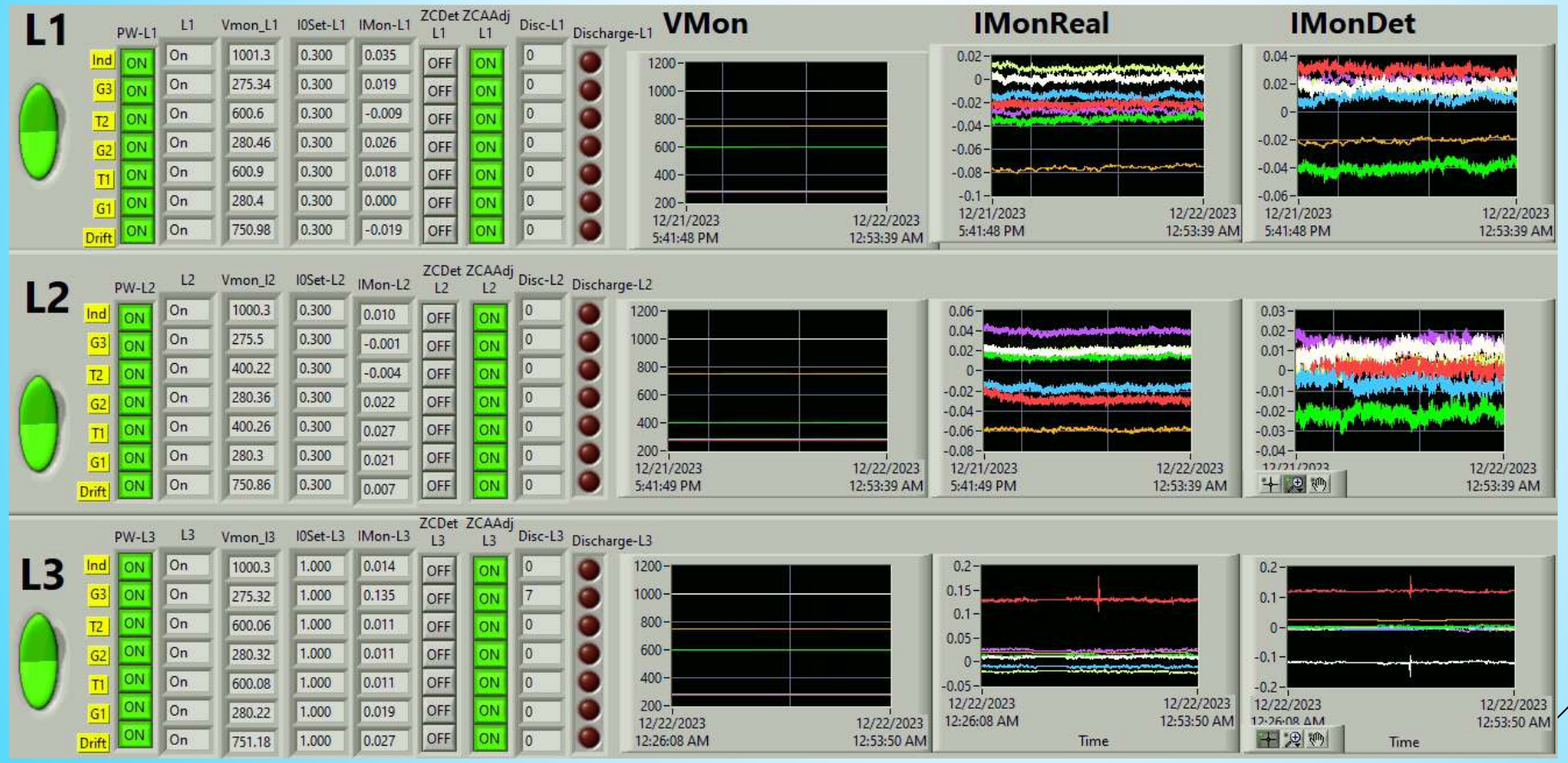
The inner and middle layers are assembled, one inside the other, as in the final BESIII experiment. The detectors are flushed with an Ar:iC_4H_{10} (90:10) gas mixture and operated at a gain of 10,000–12,000, with the electric fields between the electrodes set to 1.5/3/3/5 kV/cm (from cathode to anode).

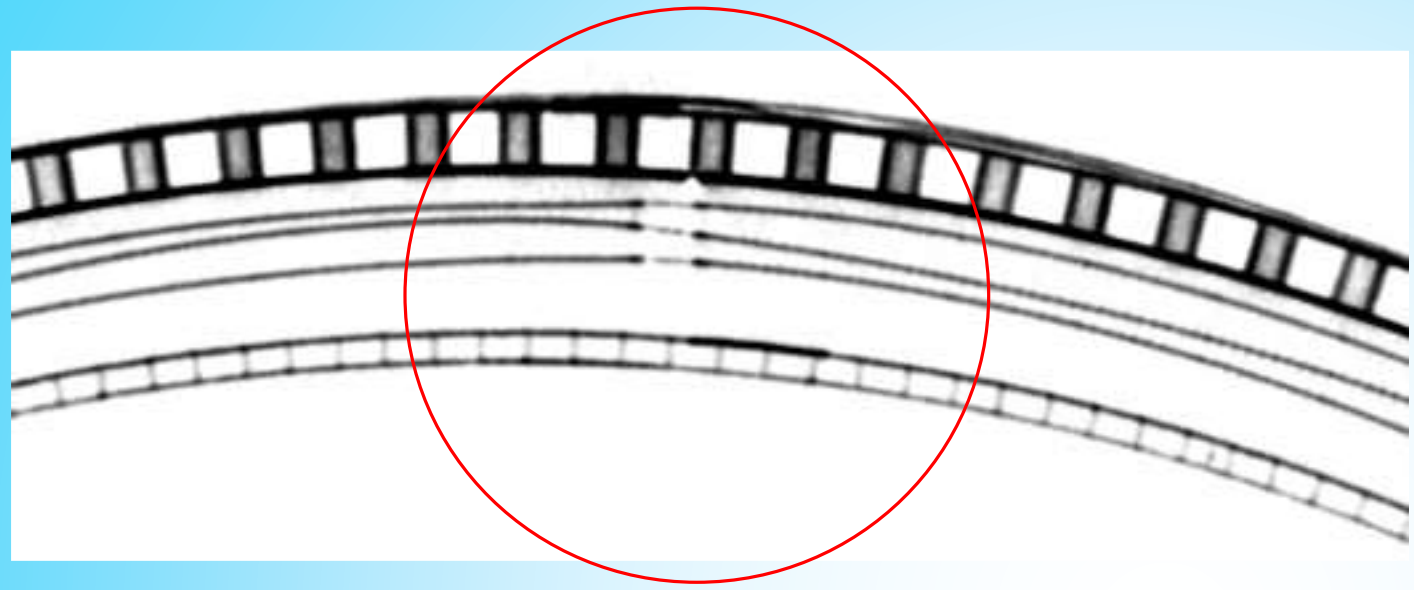
TESTBEAM RESULTS FROM A TRIPLE-GEM SETUP AND TIGER ELECTRONICS



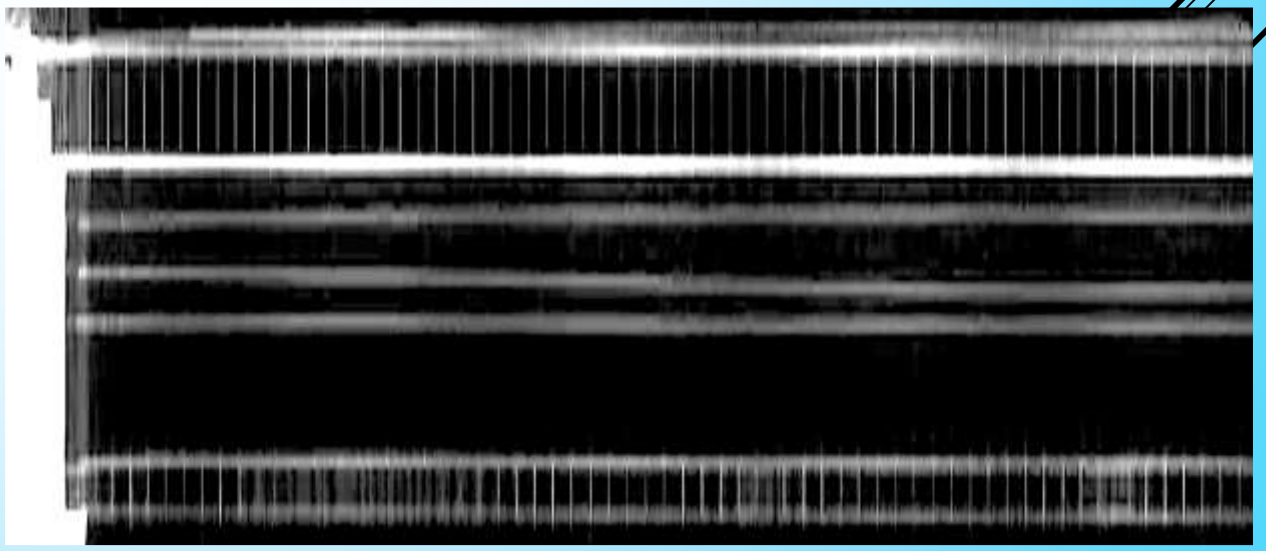


CONTROL AND MONITORING INTERFACE OF THE HV POWER SUPPLY

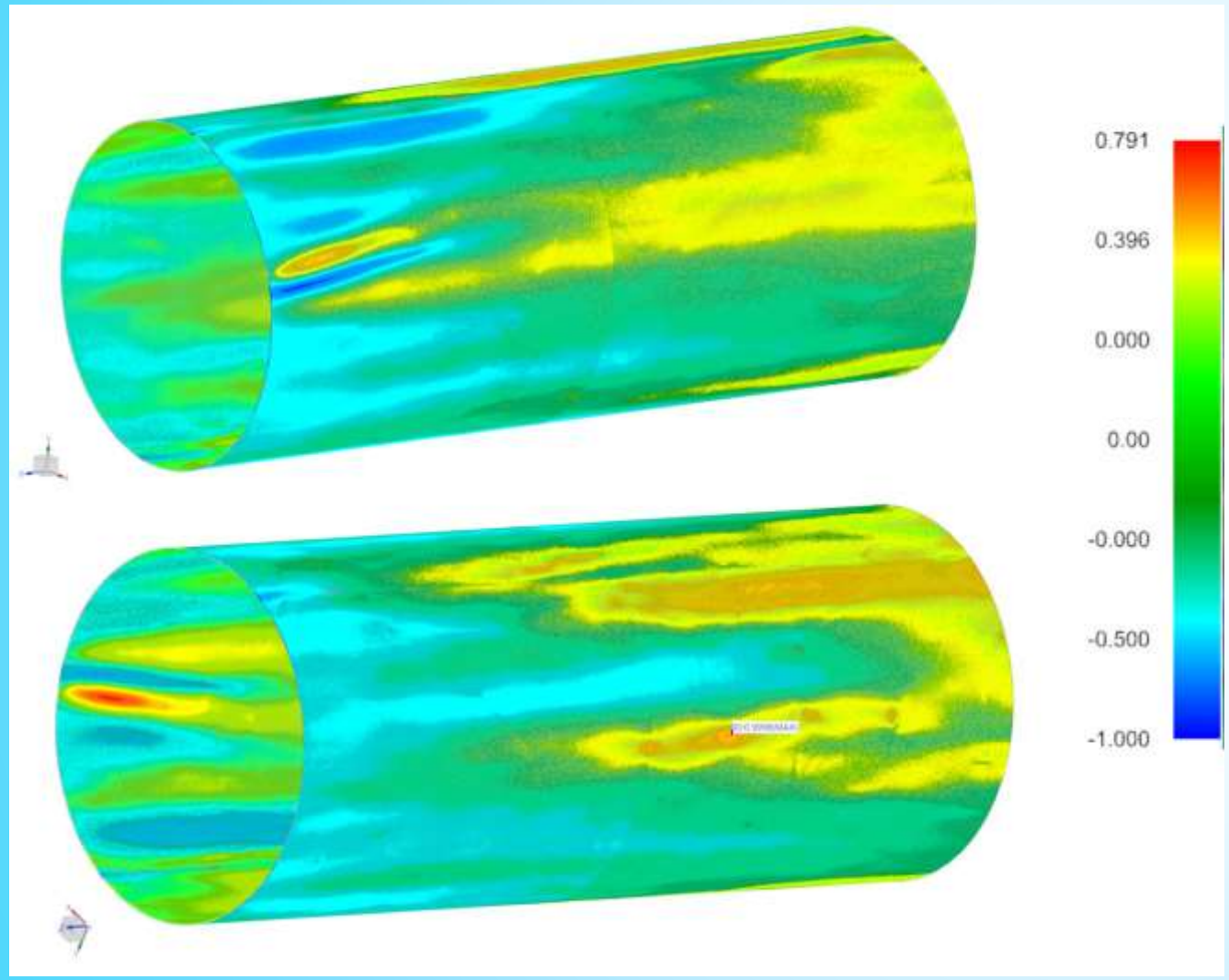




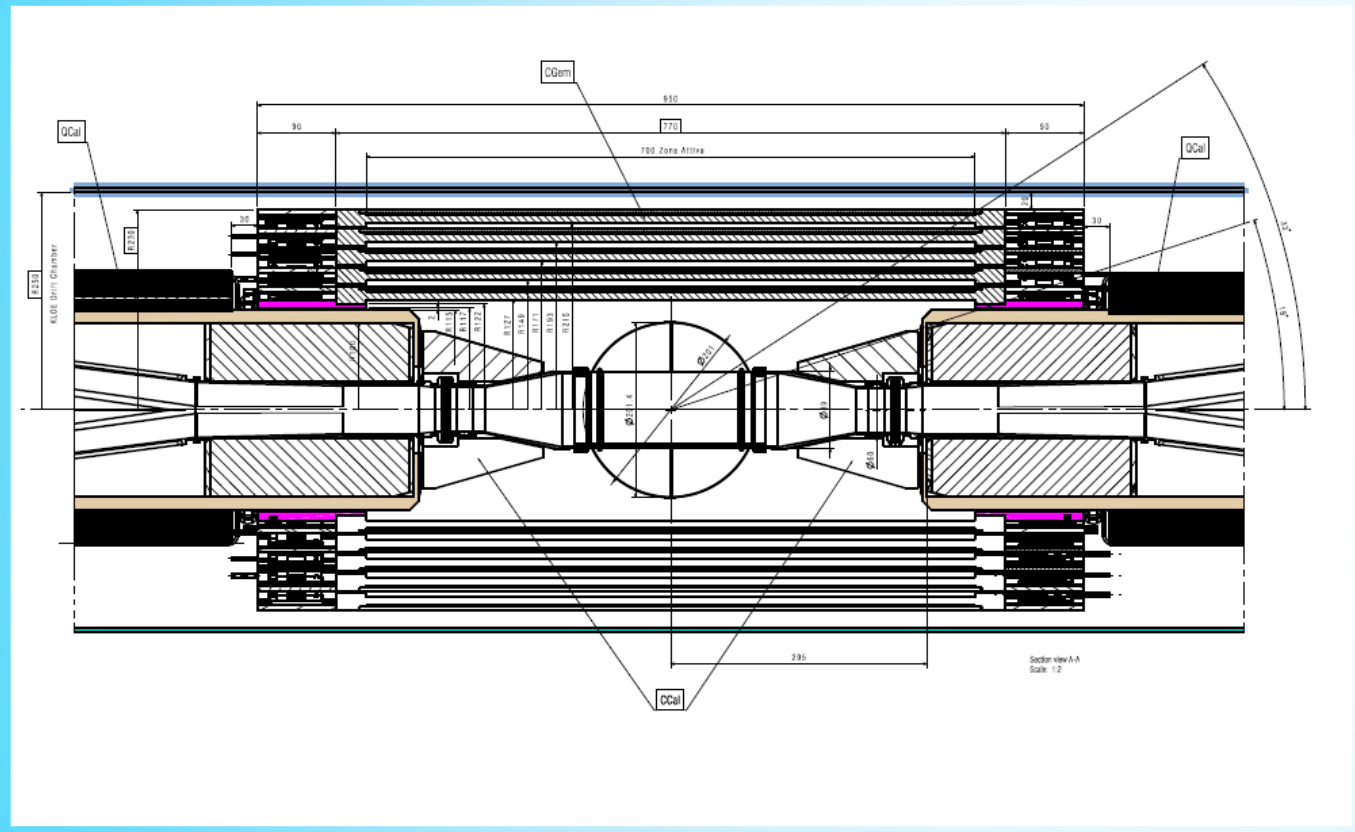
CT SNAPHOT

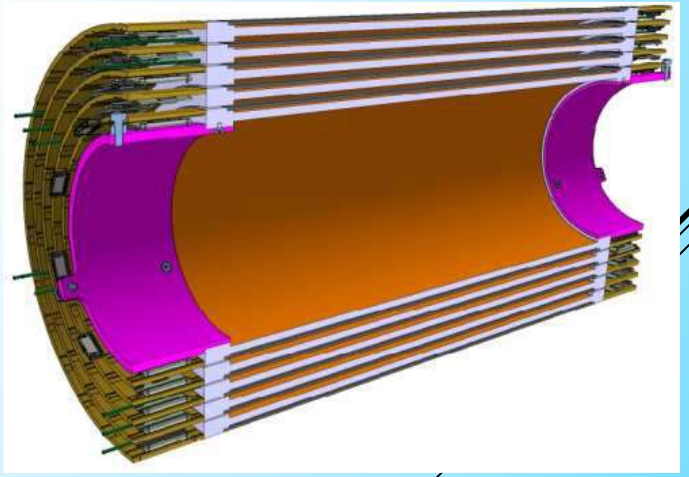


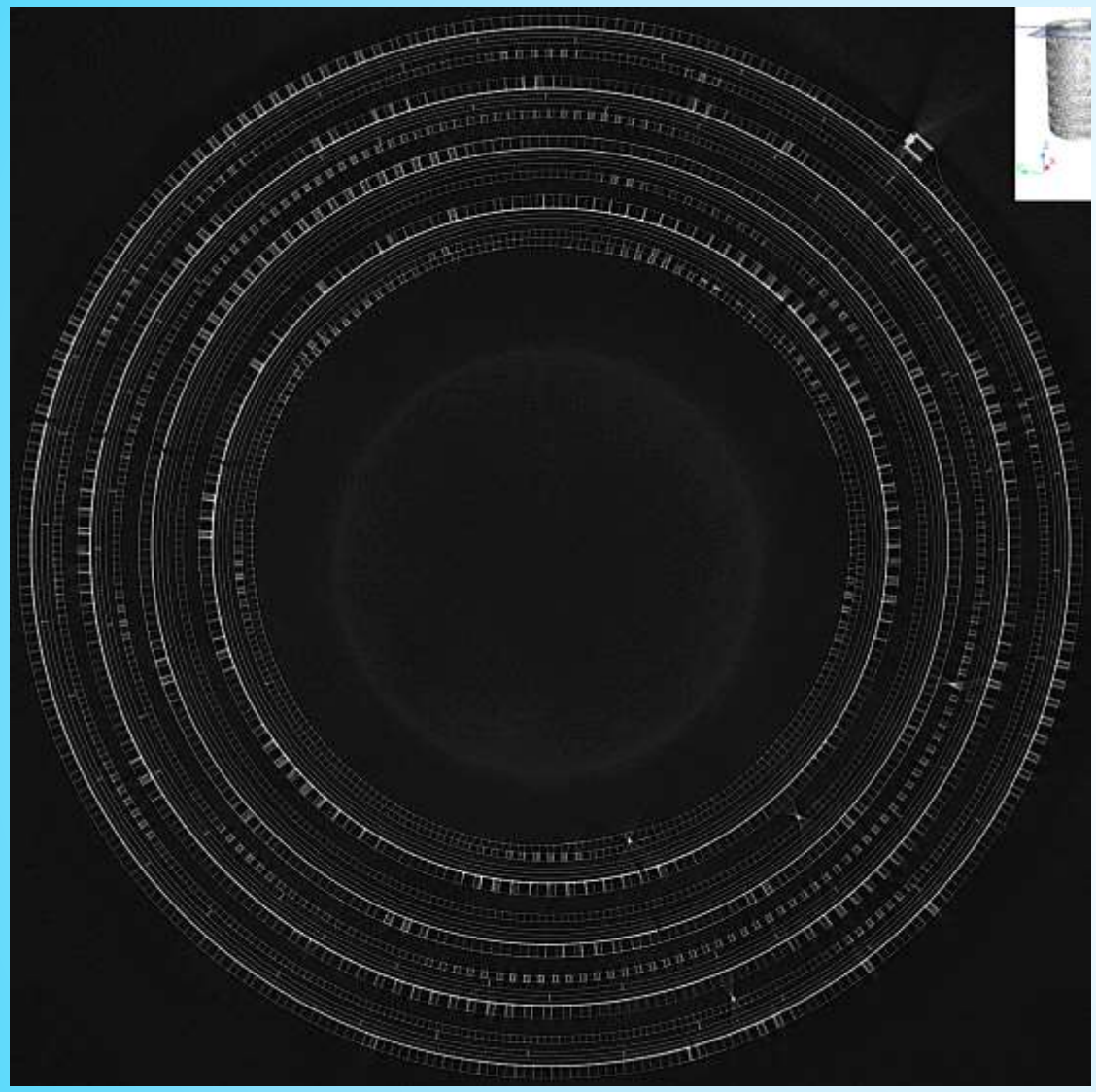
CT SCAN RECONSTRUCTION OF GEM 3 LAYER



KLOE 2 CGEM-IT





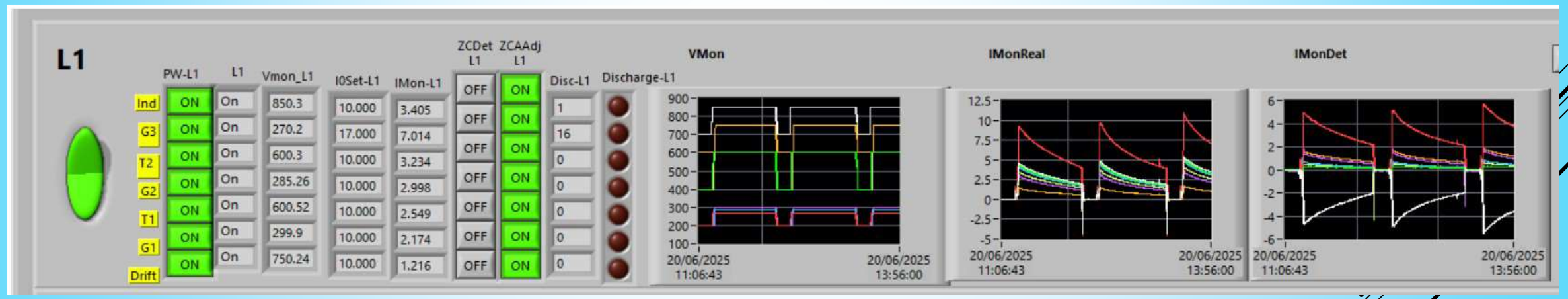


CT OF KLOE2 CGEM-IT TRACKER

NEW 3 LAYER ASSEMBLY

October 2024

HV MONITOR DURING CGEM-IT COMISSIONING



HAPPY END !