TIGER-GEMROC

a versatile and modular readout system for micro-pattern gaseous detectors

By Stefano Gramigna on behalf of the CGEM-IT working group

Outline

A TIGER-GEMROC Readout Chain – Overview

- TIGER - On Detector Electronics
  - Channel Architecture
  - Charge Measurement
- GEMROC - Off Detector Electronics

Validation - Results from Test Beam @ H4 CERN NA

- Test Conditions
- Cluster Charge
- Cluster Size
- Charge Centroid Resolution
- Efficiency

A TIGER-GEMROC Readout Chain

System Overview

A (simple) TIGER-GEMROC Readout Chain

Torino **I**ntegrated **GE**M **E**lectronics for **R**eadout

GEM **R**ead**O**ut **C**ard

64 Channels each TIGER

2 TIGER ASICs each front-end board

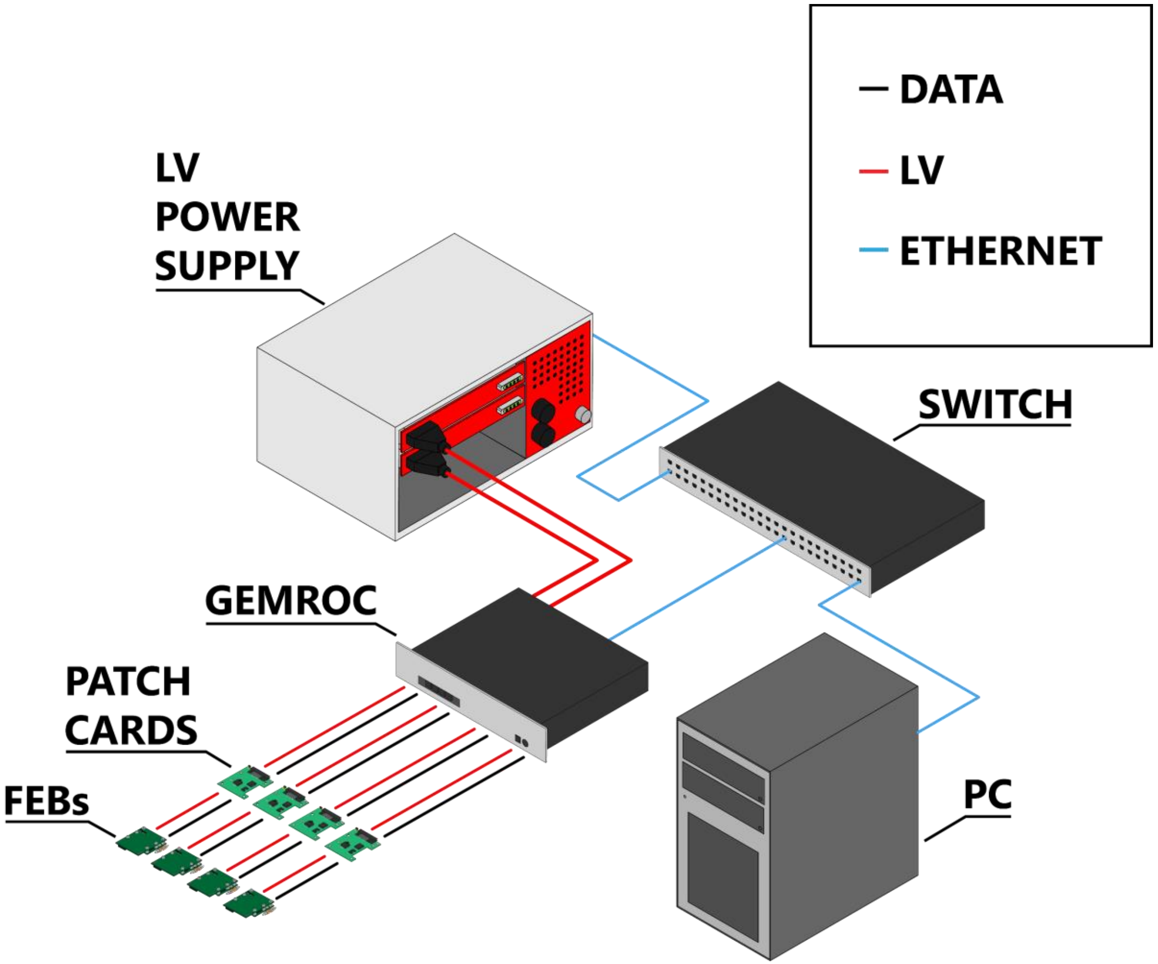
4 FEBs each GEMROC

Modular and **scalable** system

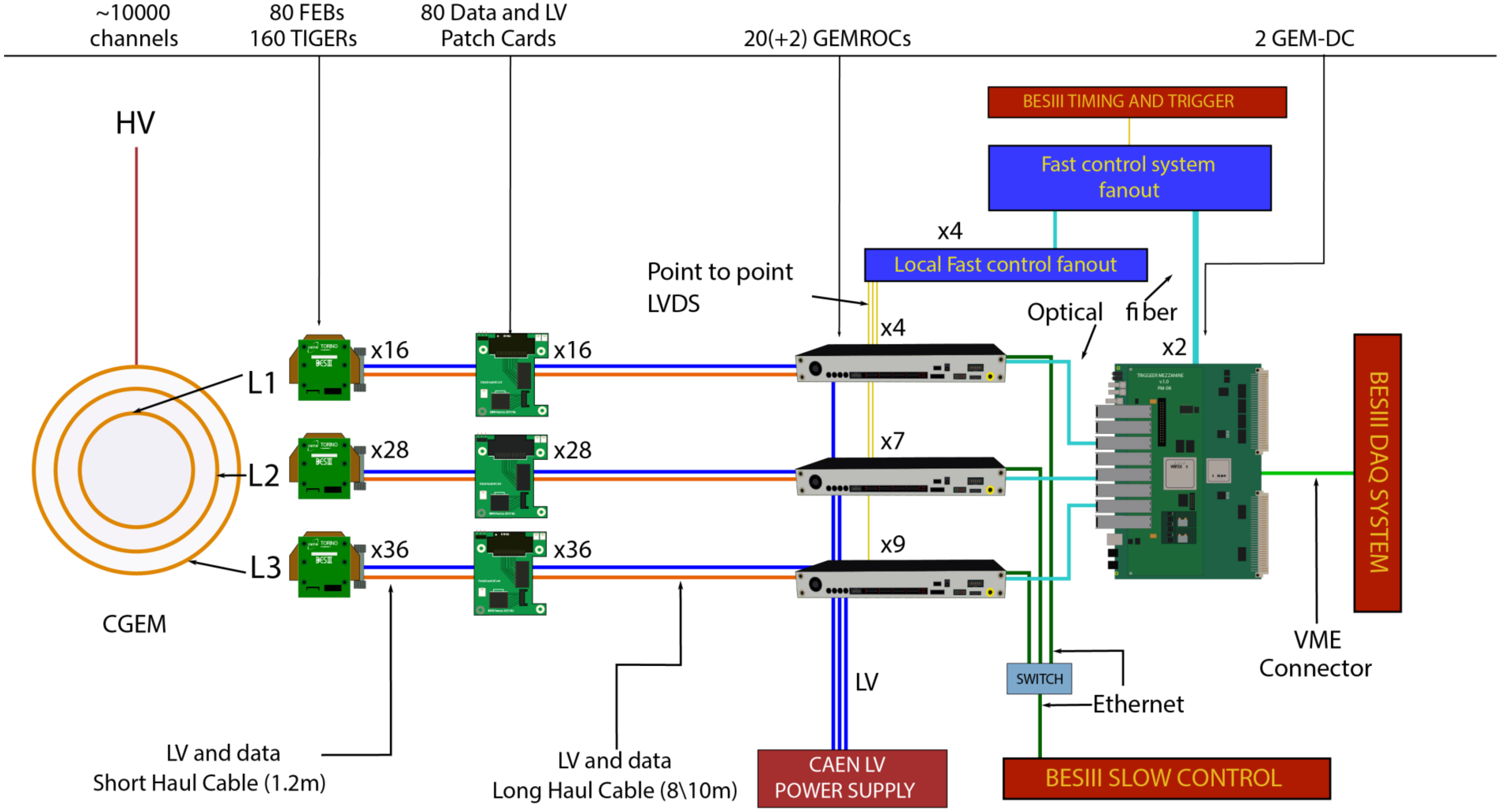
System rate capability > 60 kHz/channel

Designed for GEM detectors but suitable for similar MPGDs

Extensive suite of control and DAQ tools with a graphical user interface (GUFI)



A (complex) TIGER-GEMROC Readout Chain



A. Amoroso *et al.*, *The CGEM-IT readout chain*, JINST 16 (2021) 08, P08065

TIGER - On Detector Electronics

110 nm CMOS fabrication technology

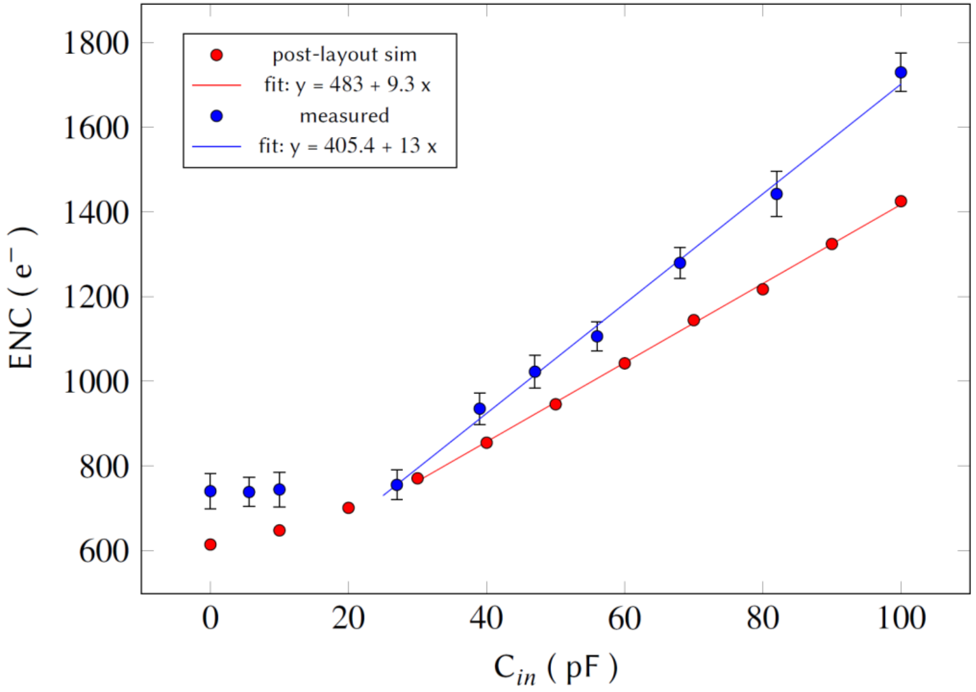
Analog input - digital output

Simultaneous **time and charge** measurement

Triggerless operation capability

Suitable for capacitances up to 100 pF and charges up to 50 fC

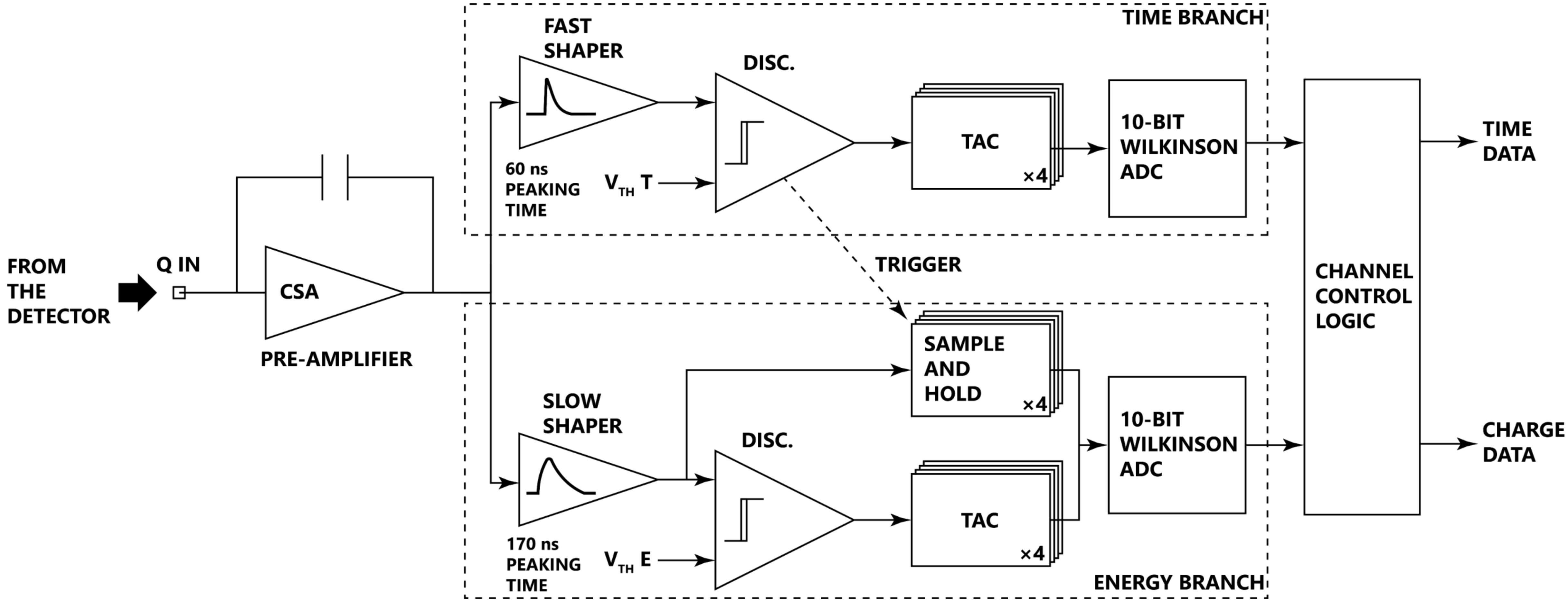
Energy Branch ENC VS Input Capacity



TIGER ASIC's Design Goals	
Input dynamic range	2-50 fC
Gain (E branch)	11.8 mV fC^{-1}
Noise (E branch)	< 1800 e^- ENC (0.29 fC)
Jitter (T Branch)	< 4 ns
Sample-and-Hold residual nonlinearity	< 1% in the whole dynamic range

F. Cossio, *A mixed-signal ASIC for time and Charge measurements with GEM detectors*, Ph.D. thesis, PoliTO, 2019

Channel Architecture



GEMROC – Off Detector Electronics

Intel/ALTERA ARRIA V GX family **FPGA** development kit

\+ custom interface card

The GEMROCs' job is to:

Distribute digital and analog **voltage levels**

Configure the TIGERs

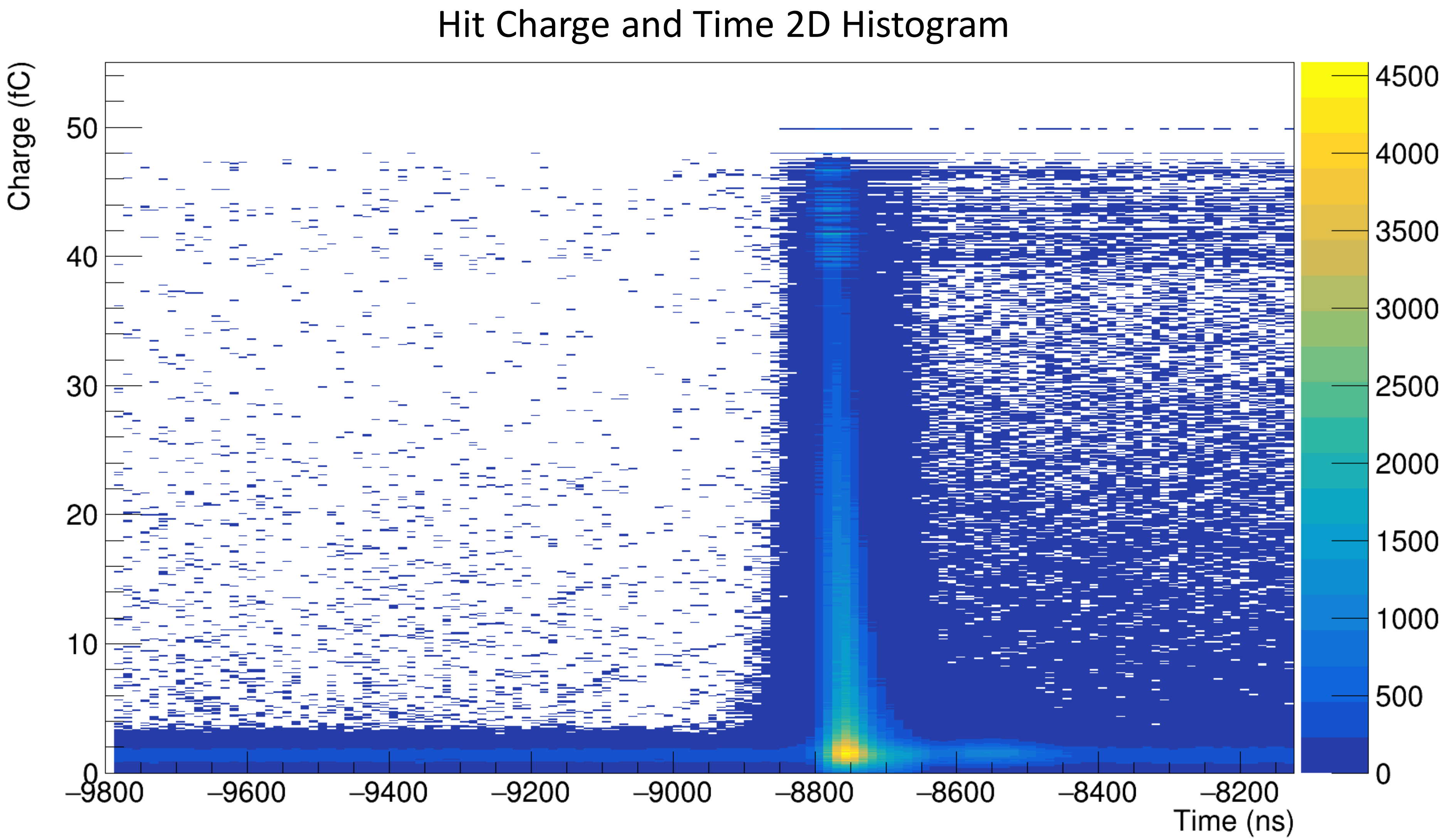
Monitor currents and temperatures during operation

Collect and **organize output data** from the TIGERs

Receive trigger signal for trigger-matched operation

The organized output data is finally transmitted via
Ethernet or **fiber optic links**

TIGER-GEMROC Raw Output



Validation

Results from Test Beam @ H4 CERN NA

Test conditions

80 GeV muon beam

Four triple GEM planar test chambers

- Active area ~ 8 x 8 cm^2
- Pitch 650 μm

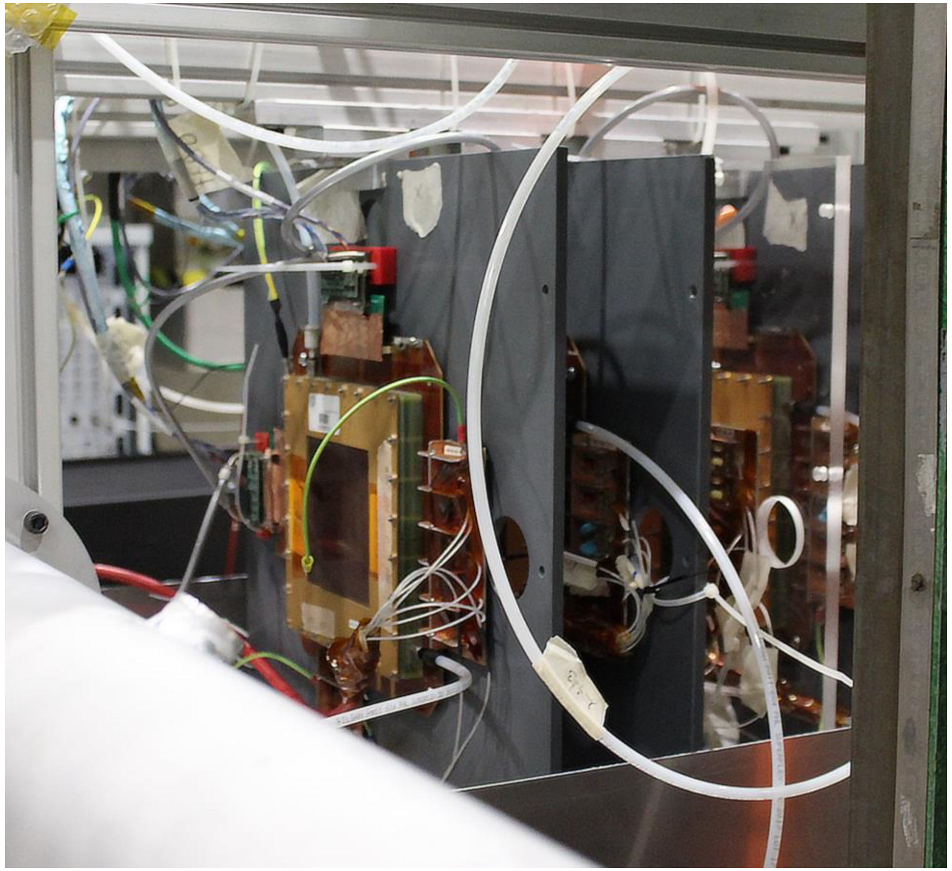
Scintillators + PMTs trigger system

Tilting mechanics for angle of incidence scans

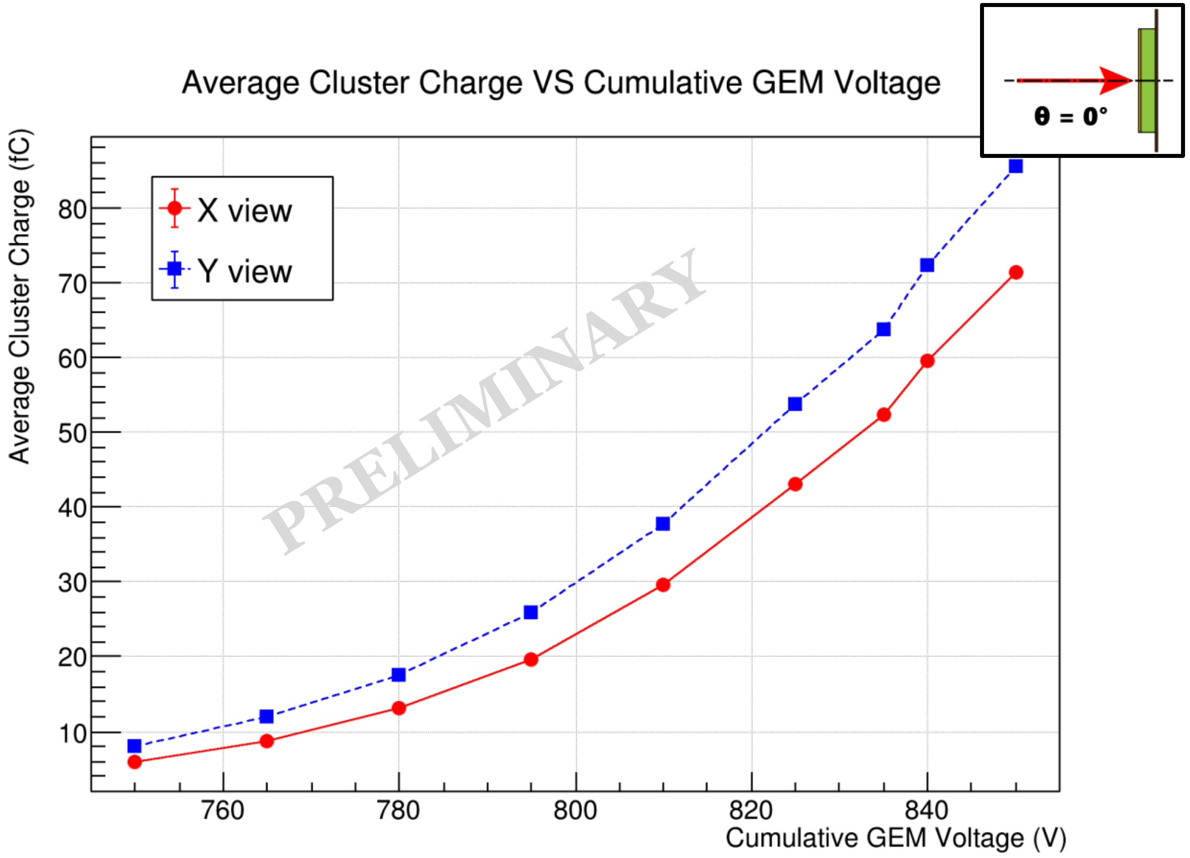
Ar-iC_4H_{10} (90:10) gas mixture

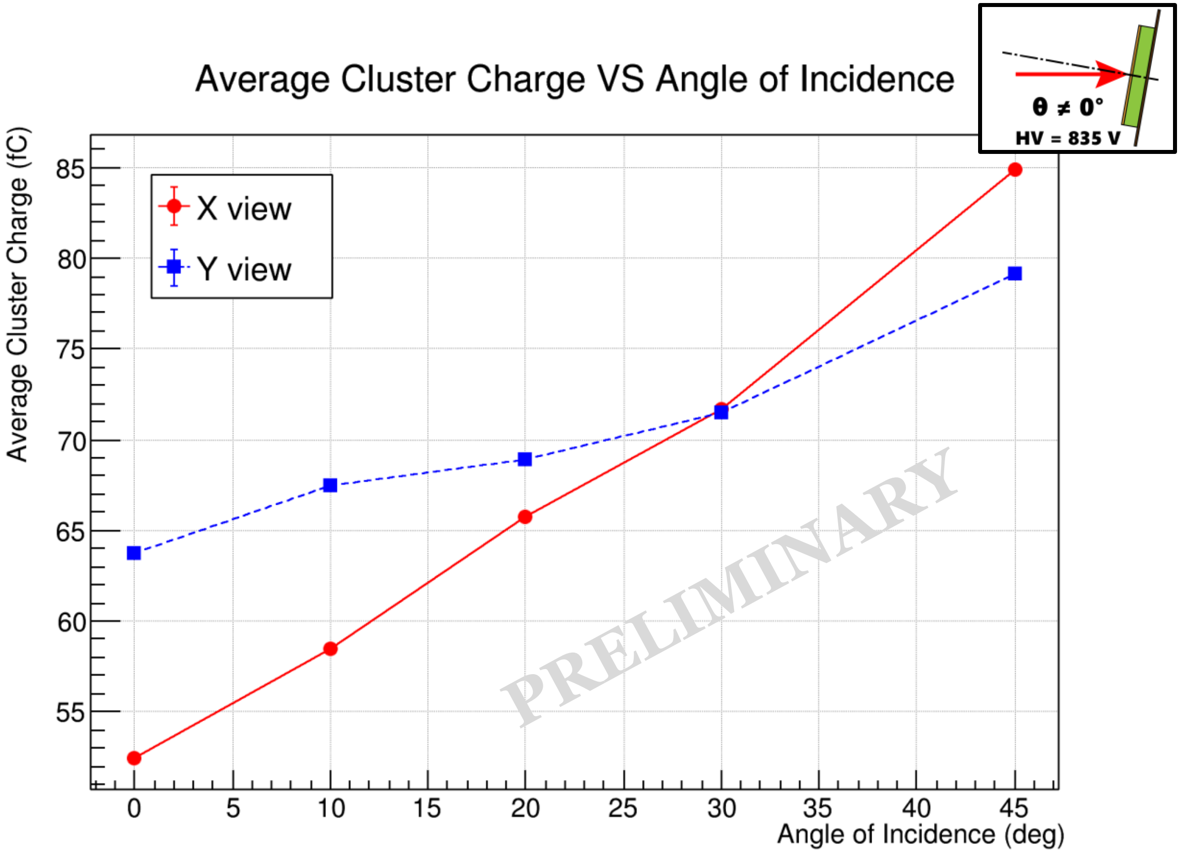
APV25-SRS used as benchmark

Fast analysis and online data validation thanks to the CIVETTA reconstruction and analysis software



Cluster Charge





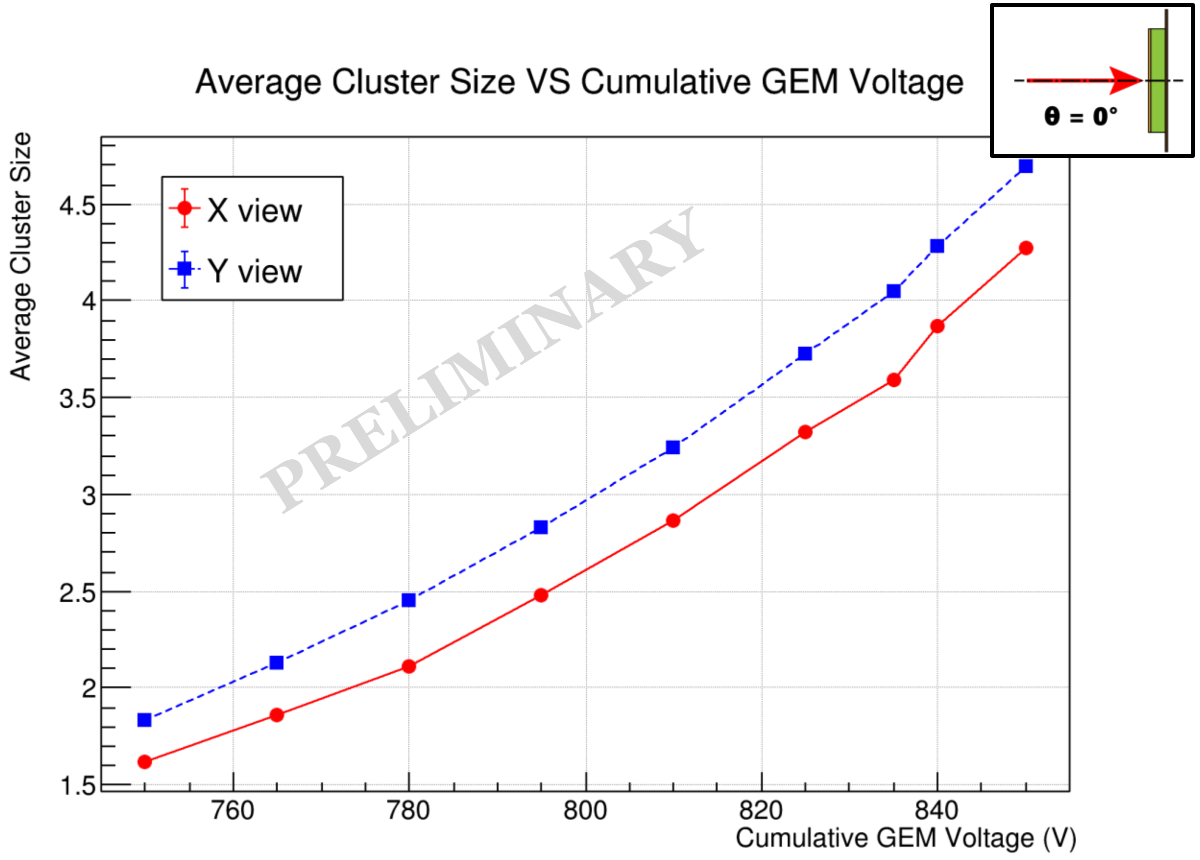
Higher voltages lead to an increase in cluster charge as expected

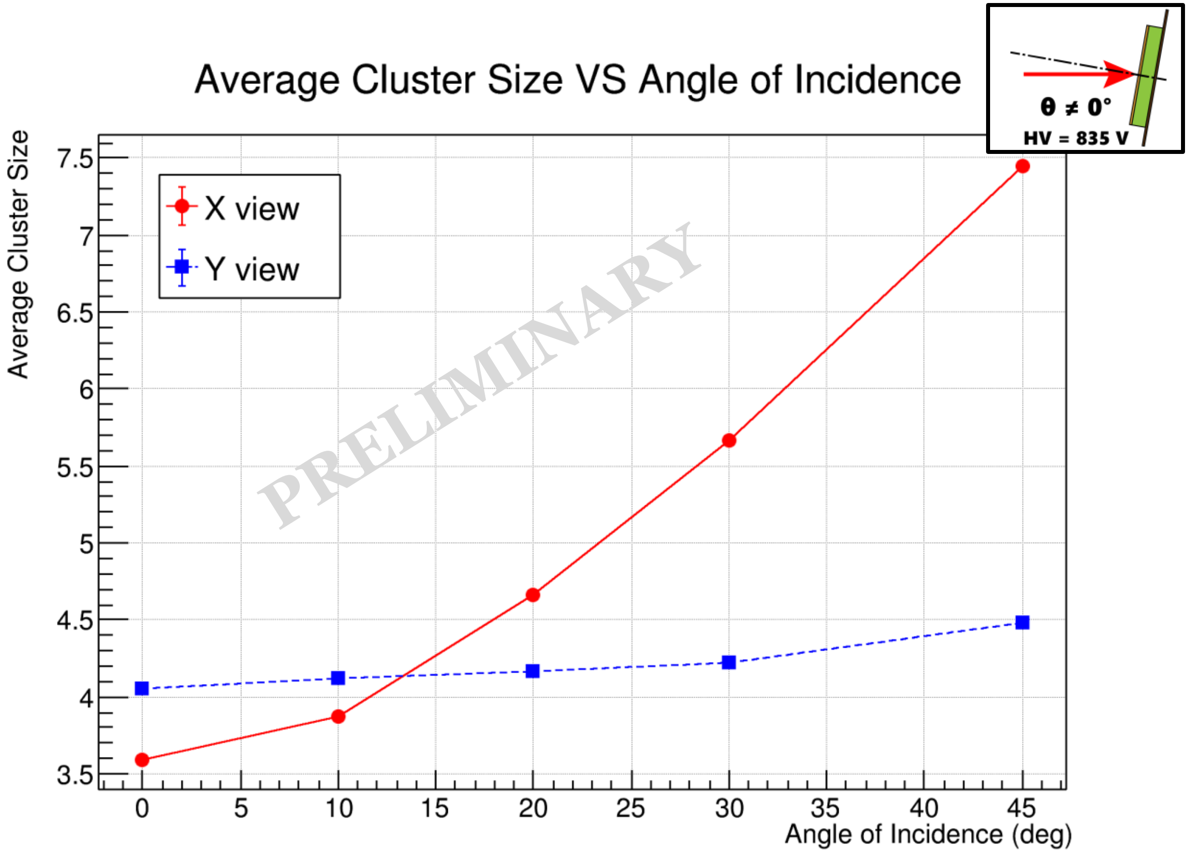
Longer path within the drift region -> more ionizations

The avalanche covers more strips -> less saturation

* The error bars are smaller than the markers displayed

Cluster Size





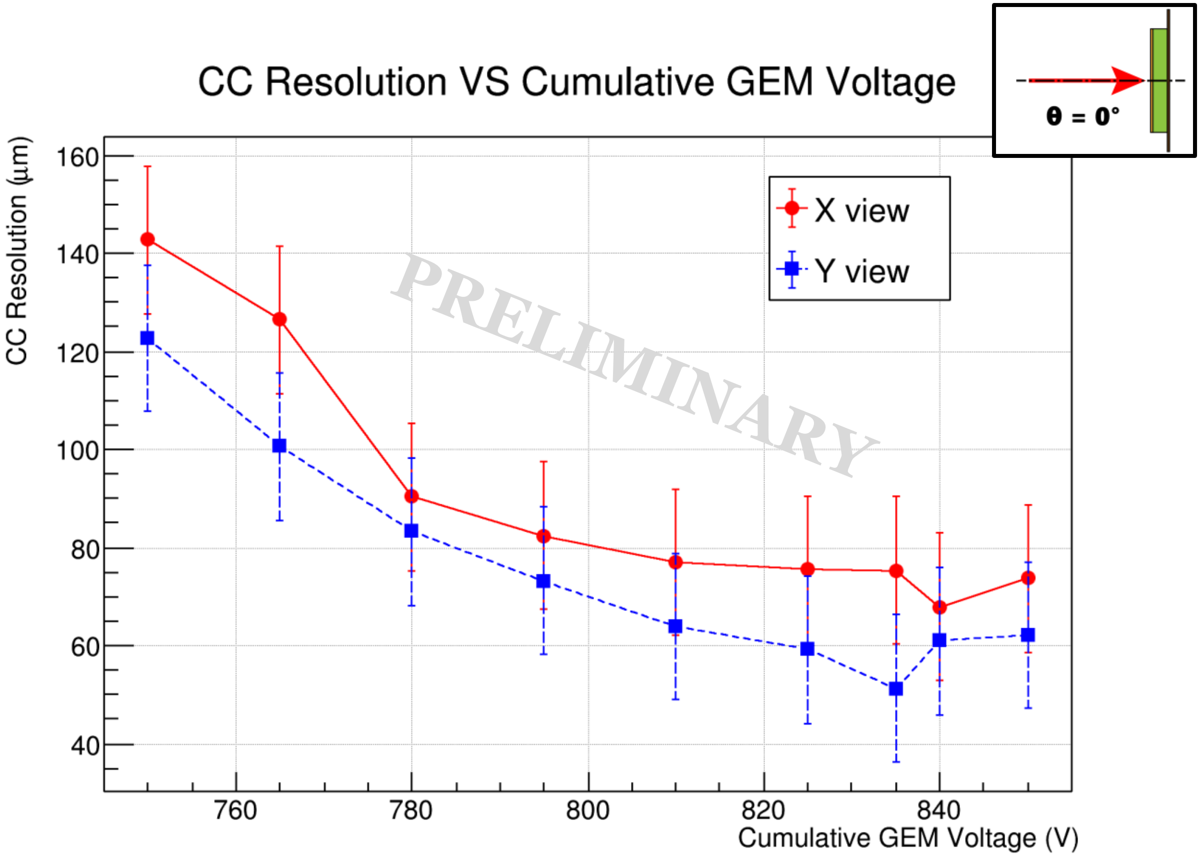
The cluster size increases with GEM voltages too

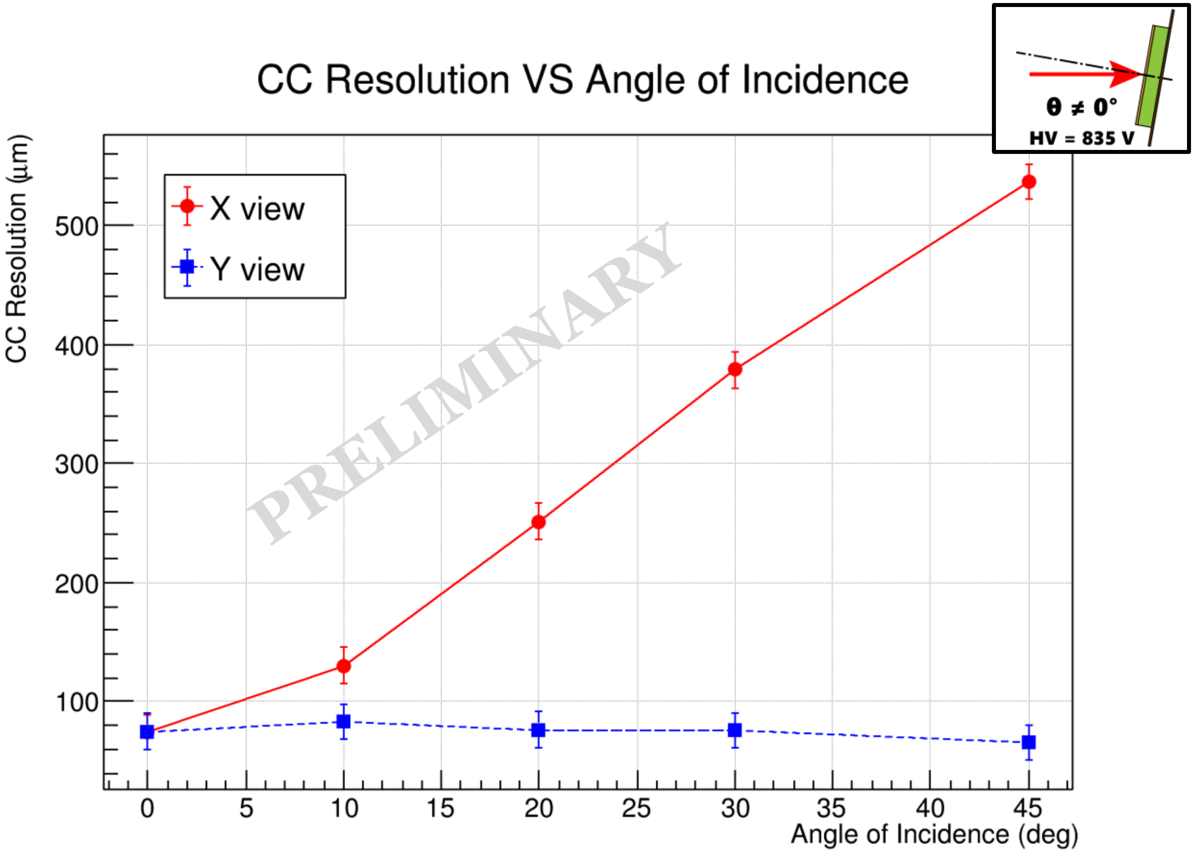
The cluster size increases for the tilted view, while it remains mostly unchanged for the other one

Both results match the expected behavior

* The error bars are smaller than the markers displayed

Charge Centroid Resolution





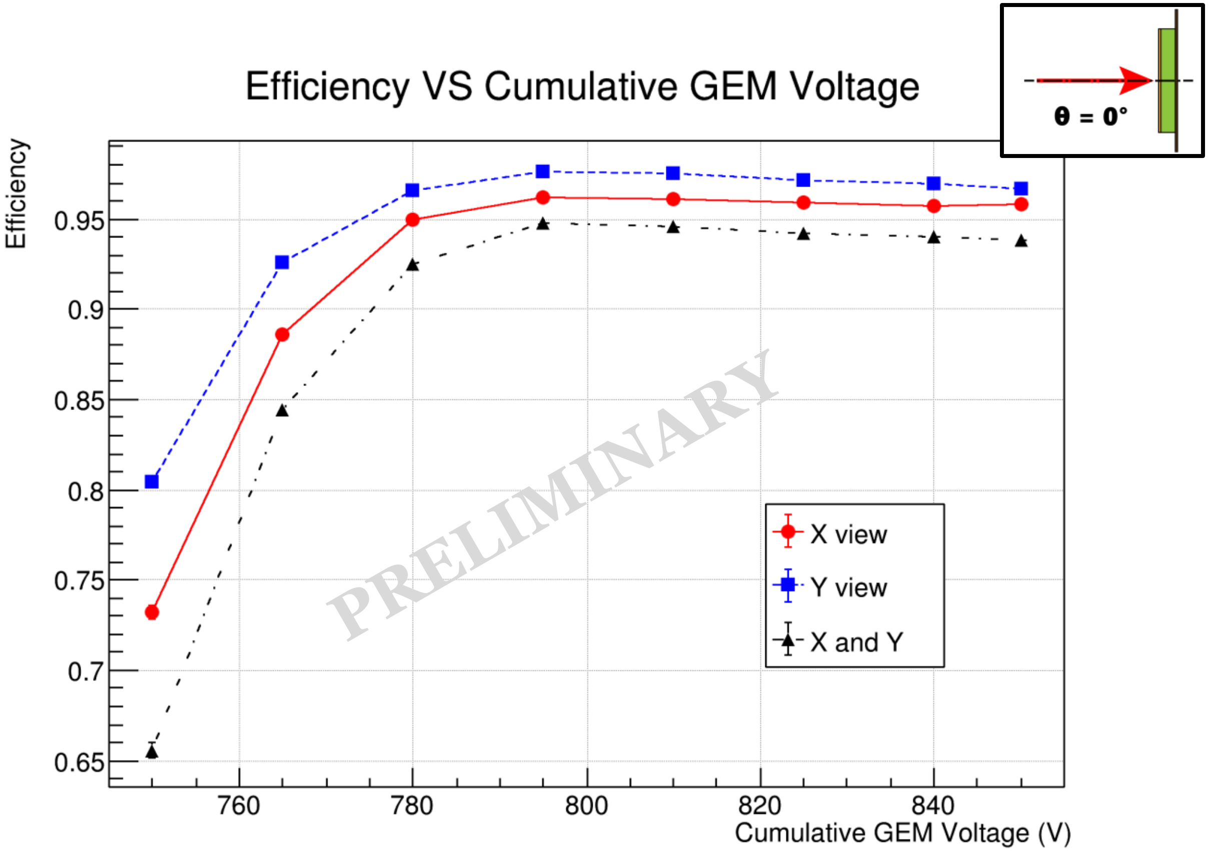
Spatial resolution improves at higher voltages

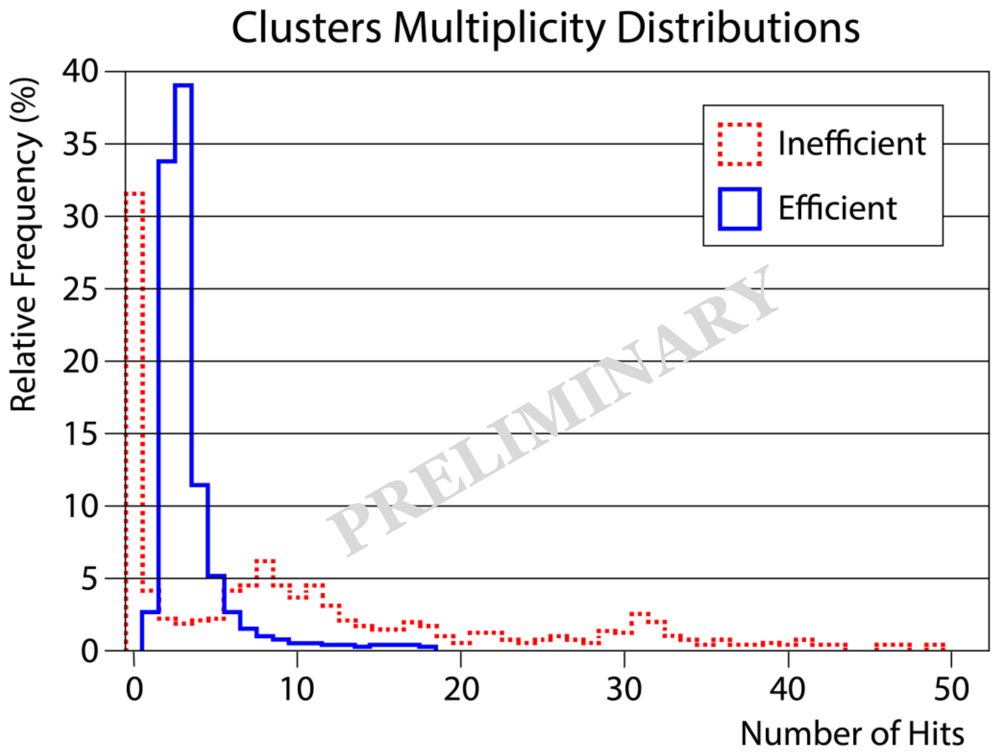
The error on the resolution is derived from the dispersion of the beam spread measurement

µTPC analysis in progress to improve resolution at larger angles

M. Alexeev *et al.*, Triple GEM performance in magnetic field, JINST 14 (2019) 08, P08018

Efficiency





Hits are considered efficient if within 5σ from the expected position

σ is the standard deviation of the exclusive residuals distribution

Efficiency losses mostly due to dead time noise spikes and high multiplicity delta rays event

Grounding scheme and GEMROC buffering are being optimized to address the issue

Conclusions

TIGER-GEMROC is a new, modular, and scalable system designed for the readout of MPGDs

Simultaneous charge and time measurements at rates up to 60 kHz/channel

The readout chain performance is being validated through data collected with an 80 GeV muon beam

Charge centroid resolution at $\theta = 0°$ about 60 μm

- μTPC analysis in progress, to improve resolution at large angles of incidence

5σ single view and 2D efficiency currently above 97% and ~ 95% respectively

- The efficiency losses observed are being addressed via grounding scheme and data buffering improvements

European Commission
Horizon 2020
European Union funding
for Research & Innovation

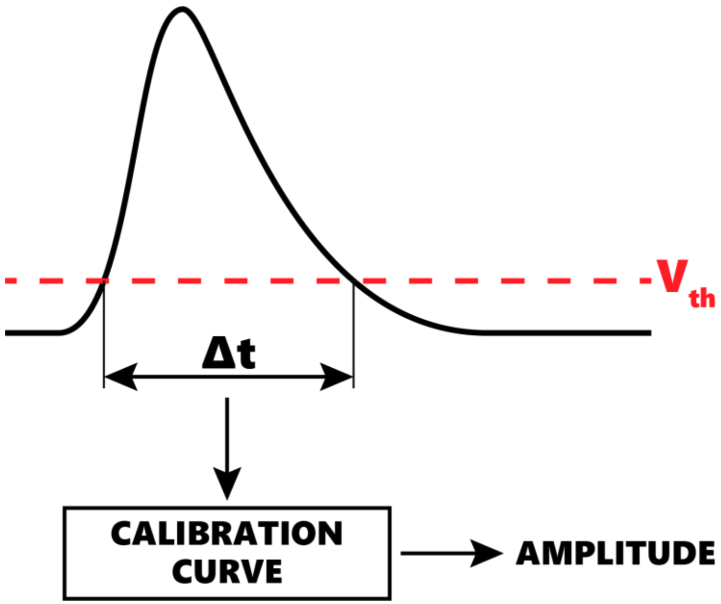
The research leading to these results has been performed within the BESIIICGEM Project (645664), funded by the European Commission within the call H2020-MSCA-RISE-2014, and within the FEST Project (872901), funded by the European Commission within the call H2020-MSCA-RISE-2019.

Thanks for your attention

Backup

Charge Measurement

Time-over-Threshold (ToT)



Can be performed on both the T and the E branch

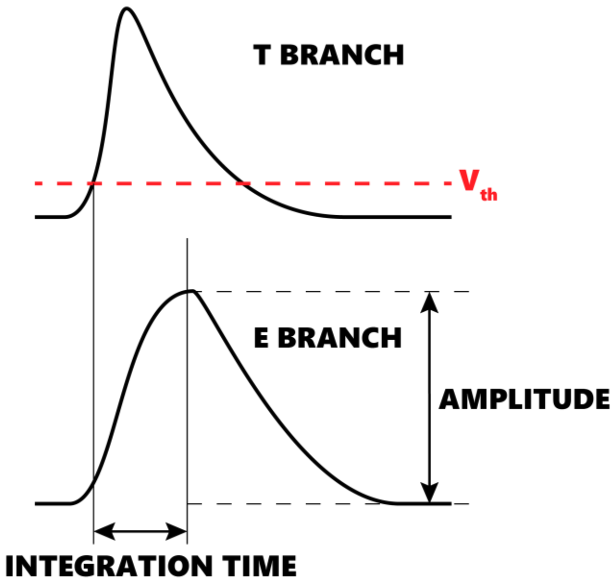
More affected by inhomogeneity in signals duration

More threshold dependent

Non-linear calibration curve

Allows to extend charge sensitivity above CSA saturation

Sample-and-Hold (S&H)



Measurement performed on the E branch signal

Less affected by inhomogeneity in signals duration

Less threshold dependent

Linear calibration curve

TIGER-GEMROC Control and Analysis Software

GUFI (Graphical User Front-end Interface)

- TIGER configuration
- TIGER-GEMROC communication diagnostics
- Data acquisition and run management
- Noise analysis and threshold optimization

CIVETTA (Complete Interactive VErsatile Test Tool Analysis)

- Data sampling
- Decode
- Calibration and mapping
- Clusterization
- Track reconstruction
- Cluster selection
- Software Alignment
- Sentinel Variables Analysis
- Extraction of figures of merit
- Event by event analysis

GEMROC Firmware

Triggerless Operation

Data from TIGER → GEMROC → Acquisition

GEMROC directly transmits all the unfiltered data

Mainly for debugging and calibration

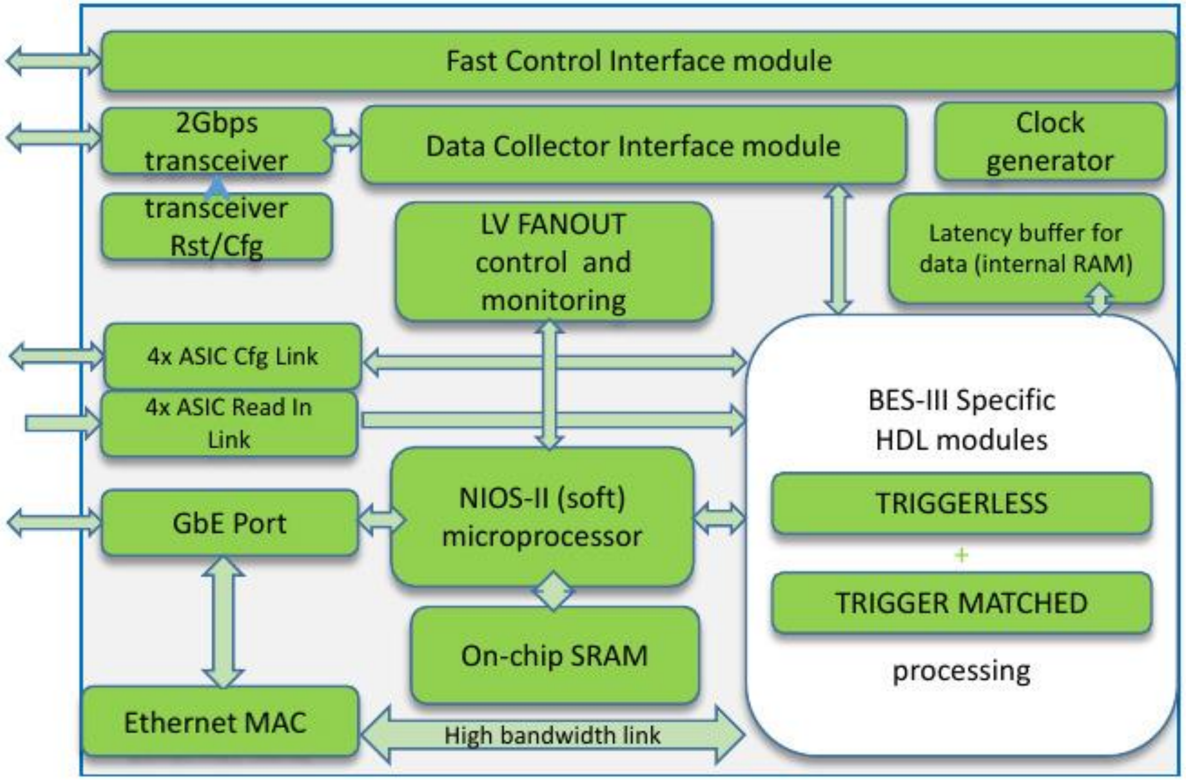
Trigger-Matched

External Trigger

Data from TIGER → GEMROC → Acquisition

Data is filtered by the GEMROC using the trigger

For physics run acquisition



Data Buffering

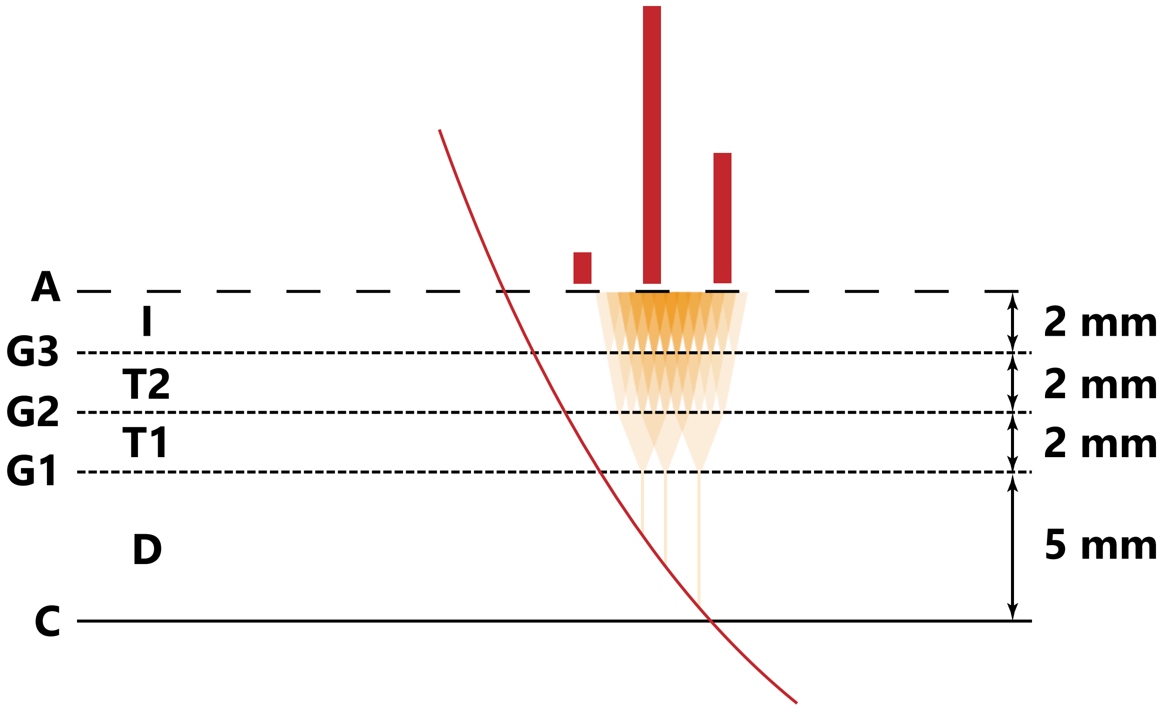
Clock generation and TIGER synchronization

TIGER Configuration

Voltage distribution and monitoring

Position Reconstruction Algorithms

Charge Centroid (CC)



Micro Time Projection Chamber (μTPC)