Test of two different readout electronics with triple-GEM detectors

Riccardo Farinelli
on behalf of
CGEM-IT group

image: Björn Kindler

RD51

BESIII

UNIVERSITÀ DEGLI STUDI DI FERRARA
EX LABORE FRUCTUS

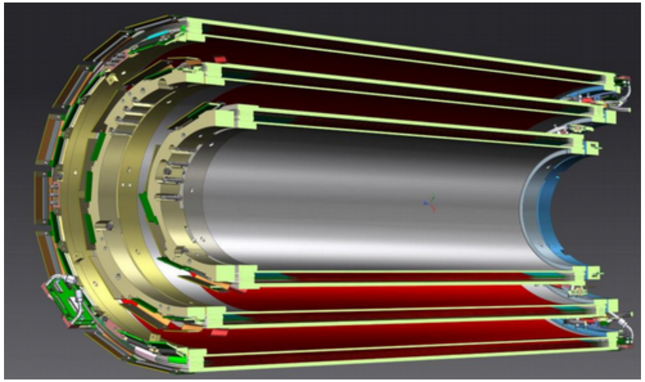
INFN
Istituto Nazionale di Fisica Nucleare

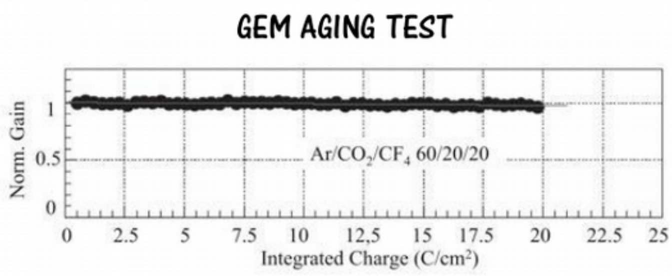
Outline

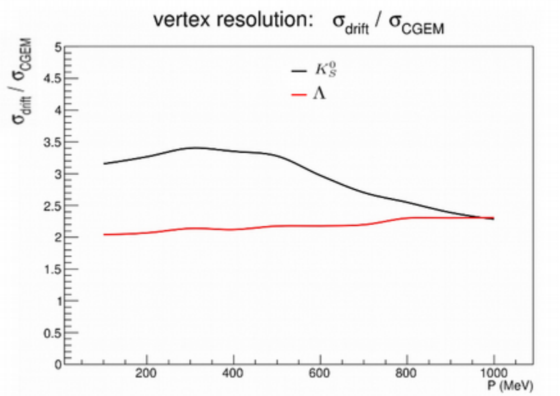
- Test beam setup(s)
- APV25 previous and future results
- TIGER chip and data taking

CGEM-IT

- The BESIII Inner Tracker (MDC) is aging and the Italian group proposed to replace the inner part of the DC with 3 independent layers of triple-GEM
- The new IT has to **match the MDC** tracking **performance** with 3 layers instead of 8:
  - ➢ It improves the radiation hardness
    - ➔ Aging test on this technology shows a **long-term stability**
  - ➢ **Improves the spatial resolution** in the beam direction
    - ➔ Benefit for decays with secondary vertex







Previous Test Beam

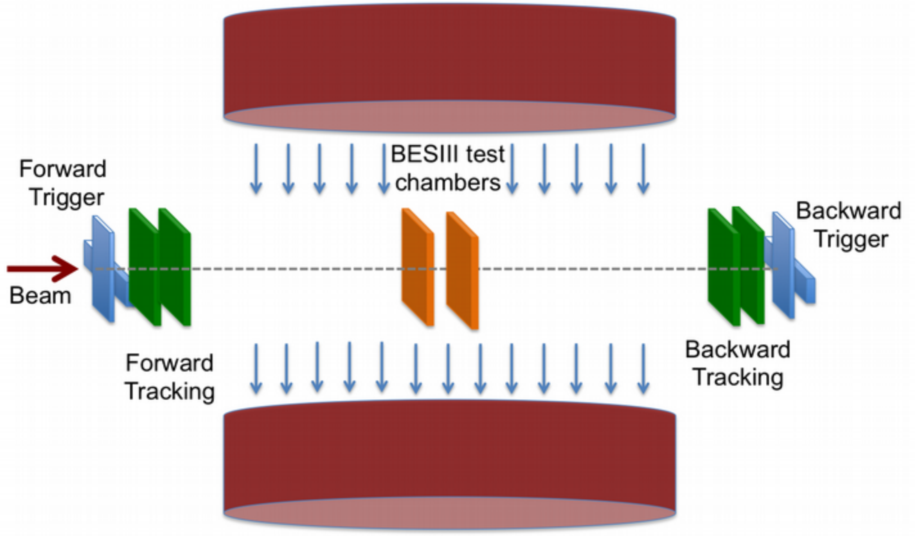
Detector:
- Planar triple GEM 10x10 cm^2 active area
- XY readout
- 650 μm pitch strip

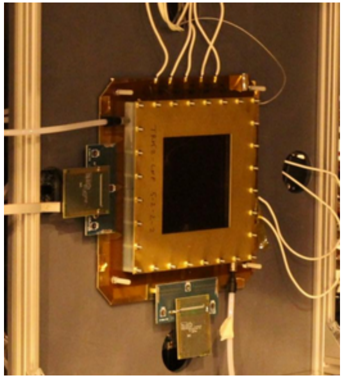
Geometries:
- 5 mm conversion gap
- 2 mm transfer gap
- 2 mm induction gap

Gas mixture:
- Argon:iC_4H_{10} (90:10)

Facility:
- CERN – H4
- Mainz Microtron

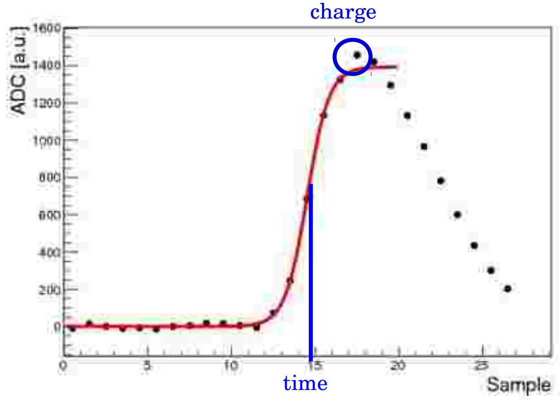
Electronics:
- APV25
- TIGER

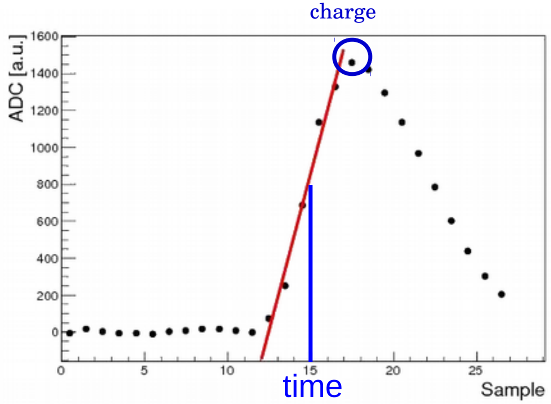




Previous Test Beam: APV time and charge

- Samples the integrated charge each 25 ns
- 27 sample each trigger
- The highest value is used as **charge** measurement of the strip
- A Fermi-Dirac function is used to fit the charge distribution as function of the samples to measure the **time** information
- If this algorithm fails then a linear fit is used

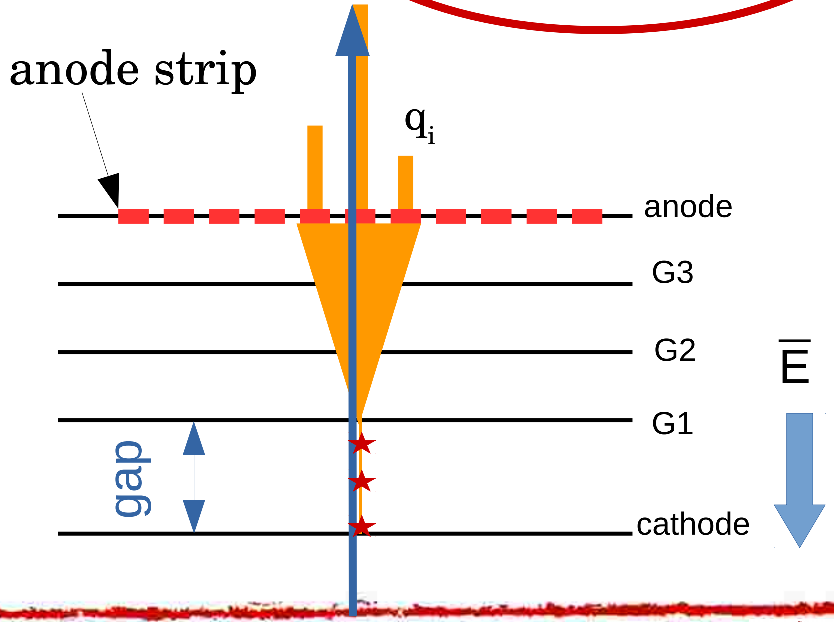




Previous Test Beam: Charge Centroid

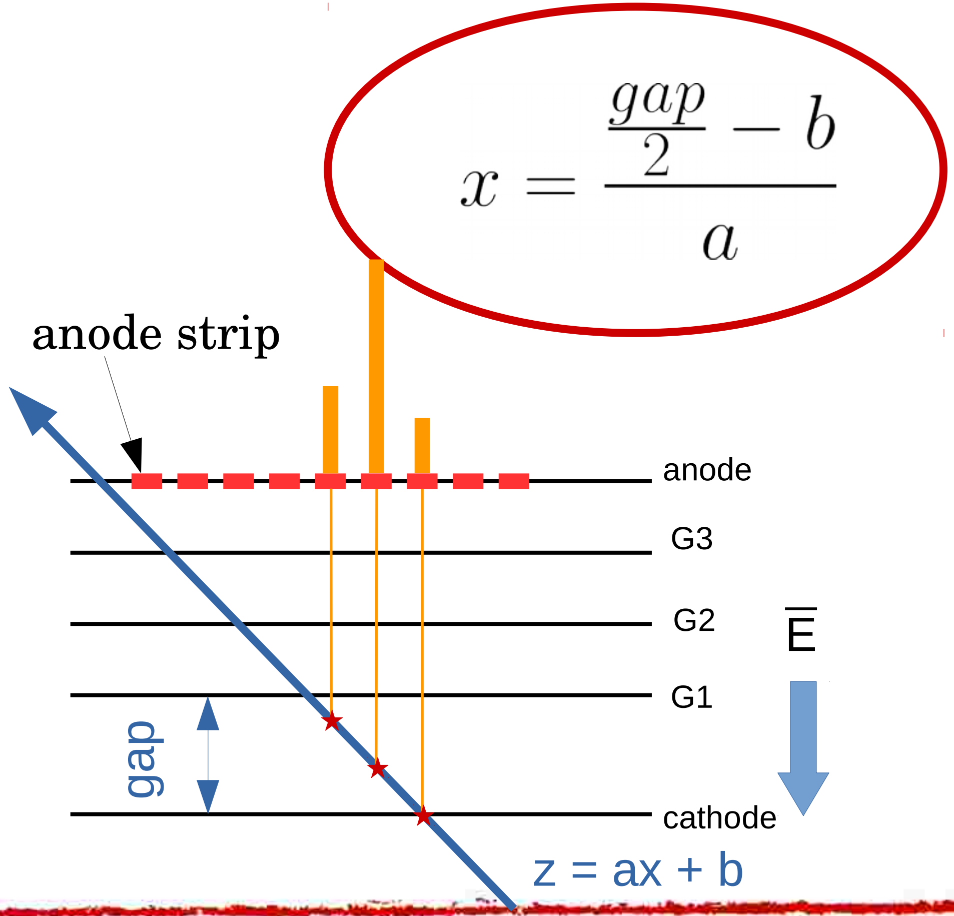
- Charge particles ionize the gas
- The primary electrons created in the drift region are amplified 3 times
- Diffusion effect takes place and **each electron generates a Gaussian charge distribution** at the anode
- Contiguous strips are considered to reconstruct the track position
- Each strip is read by an APV-25 channel
- CC uses the charge to average the position of the fired strips to measure the ionizing particle position

$$x = \frac{\sum x_i * q_i}{Q_{TOT}}$$



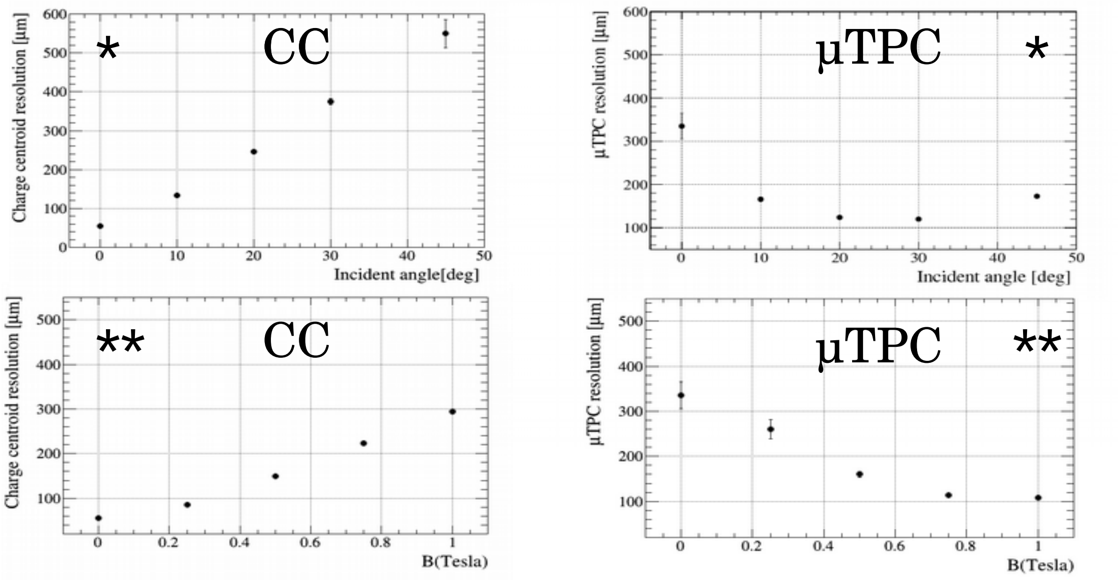
Previous Test Beam: µTPC mode

- The time information can be used to improve the spatial resolution in magnetic field and in case of non-perpendicular tracks.
- Use the drift velocity of the electron and the time measured by each fired strips
- **It assigns to the strips a bi-dimensional point** (x_strip, time * drift velocity).
- These points are used to reconstruct the track in the drift region
- **A linear fit reconstructs the path** and measures the particle position
- The initial development of this reconstruction technique has been performed by **Atlas** Collaboration with MicroMegas



Previous Test Beam: results

- Each primary electron that reaches the first GEM creates an avalanche with a Gaussian distribution on the anode
- If the track is not orthogonal then **the primaries reach the first GEM in different places**
- **More general**: if the track path is different from the electron drifting direction then each primary reaches the first GEM in a different place
- The charge distribution at the anode is no more Gaussian and the performances of the charge centroid degrade.
- As the cluster size increases the **µTPC reaches its best performance**



B = 0 T

B ≠ 0 T

Merging CC and μTPC

- The **mean cluster** size **has a minimum** in the focusing configuration and due to geometrical reasons **it increases** as the angle deviates from this configuration
- The idea is to assign **weights** to the CC and the μTPC and to **average** the two measurements

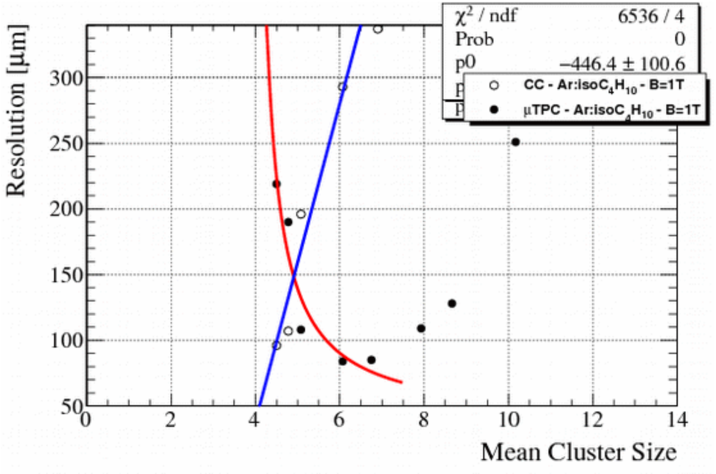
$$x_{merge} = \frac{x_{cc} \cdot w_{cc} + x_{tpc} \cdot w_{tpc}}{w_{cc} + w_{tpc}}$$

- As **Atlas** suggests, it is possible to use the cluster size to determine the weights of the merge:

  $w_{tpc} = (N_{hit}/N_{cut})^2$

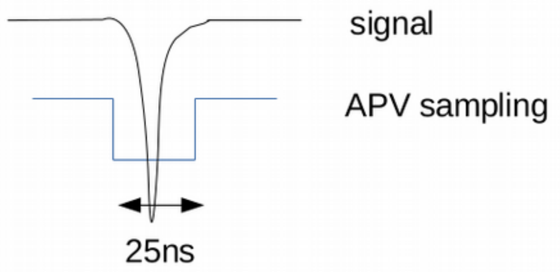
  $w_{cc} = (N_{cut}/N_{hit})^2$

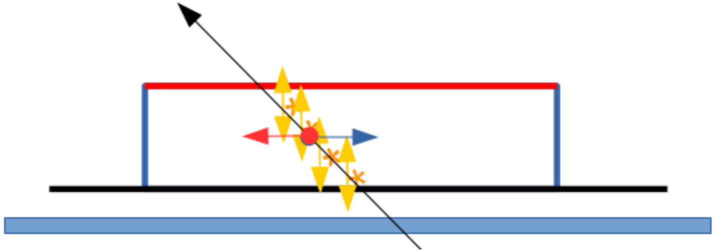
- Looking at the CC and μTPC resolution as a function of the cluster size it seems that $w_{cc} \sim N_{cut}$ and $w_{tpc} \sim (1/N_{cut})$



Merging CC and μTPC: the issue

- μTPC depends on the **time** measurement then on the trigger
- The **trigger** start has an **indetermination** of ~ 5 ns due to the 25ns time sampling of the APV
- CC does not depend on the time
- If you want to compare two measurements performed with the μTPC you can cancel this contribution but if you compare μTPC and CC you have to take it into account
- The idea is to **acquire the trigger** time and to remove the time indetermination in order to compare CC and μTPC



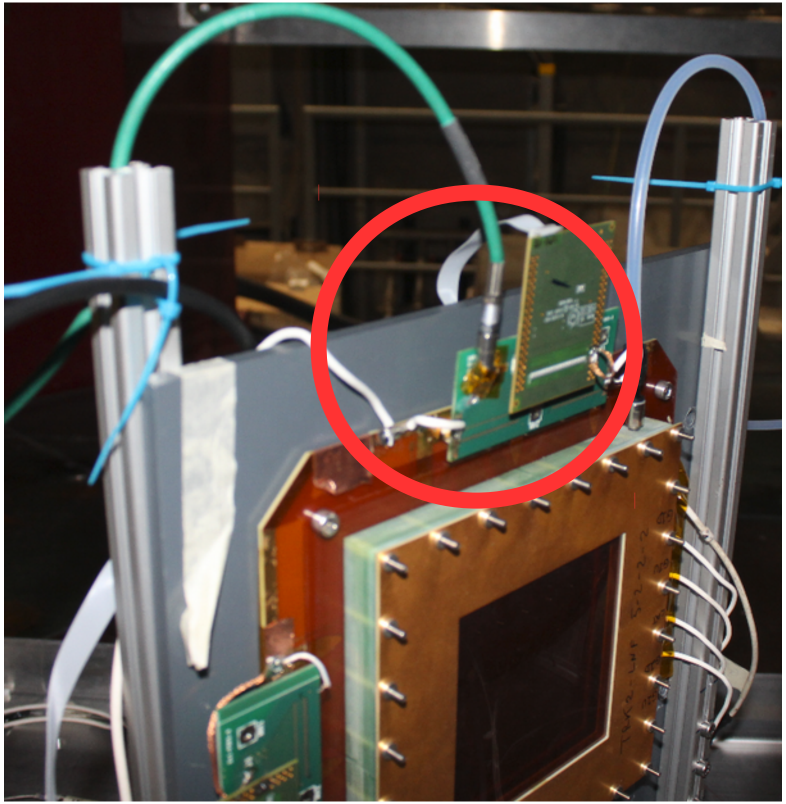


April Test Beam

The new setup APV25

- The new setup is almost similar to the previous one
- The trigger signal is injected in the transition board then to one of the APV25 channel
- The trigger signal is collected in 27 sample of 25 ns and its time is measured with the Fermi-Dirac
- Now the time of the strips is refereed to the trigger time

➔ Time resolution of the “detector + electronic” slightly improves



The new setup APV25: preliminary results

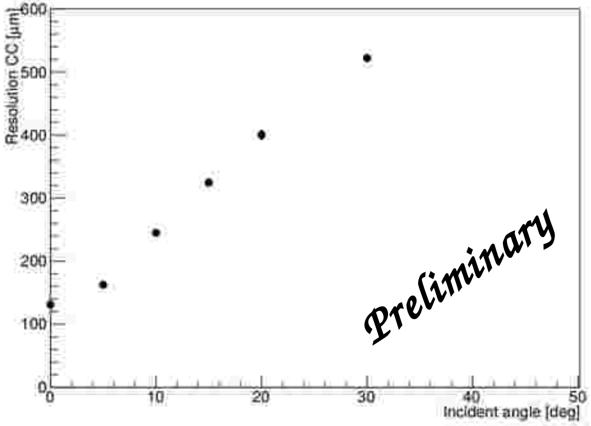
PRELIMINARY RESULTS:

- Results confirm the performance of CC and µTPC
- Merging the algorithms returns a spatial resolution between 100 and 200 µm

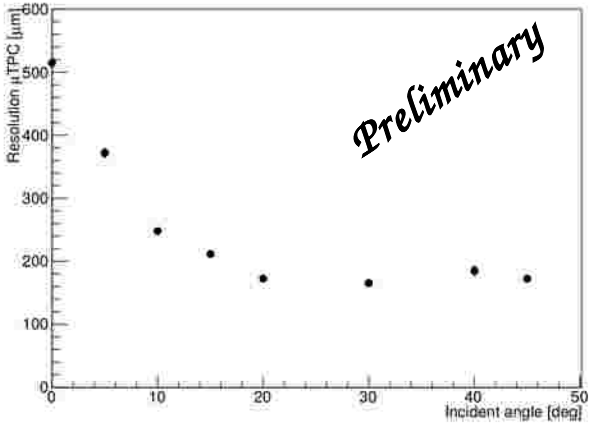
TO DO

- A different way to weight the two algorithm will use also the charge information

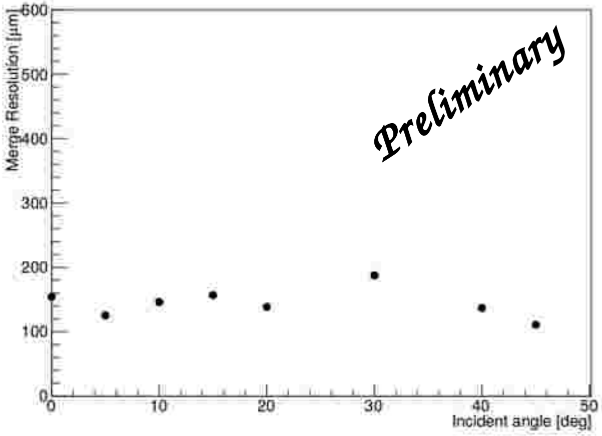
CC



µTPC



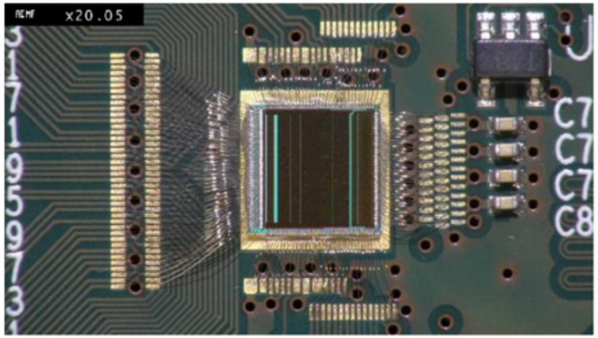
Merge

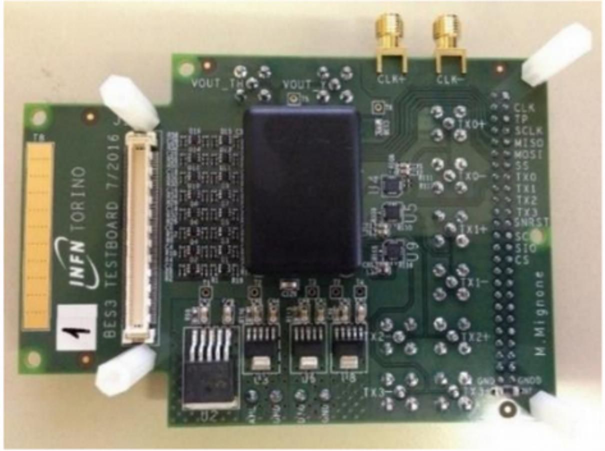


TIGER ASIC

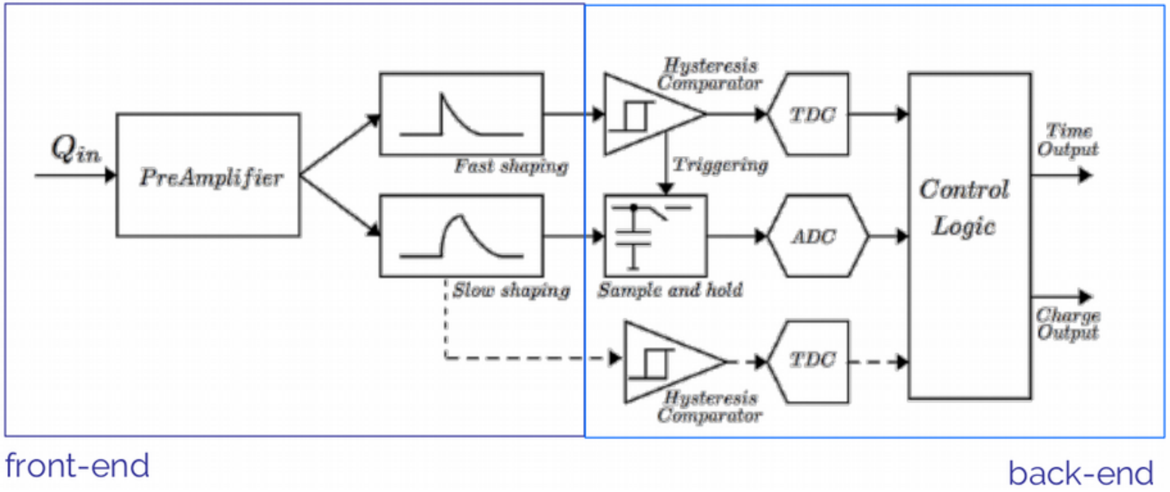
A new ASIC named TIGER

- TIGER: Torino Integrated Gem Electronics for Readout is a chip that provides **time** and **charge** measurement and features a fully-digital output
- Each chip has **64 channels**
- The expected signal from CGEM-IT:
  - Duration: 30-50 ns
  - Sensor capacitance: up to 100 pF
  - Time resolution: ~ 5ns
  - Rate per channel: 60 kHz
  - Power consumption: ~ 10 mW/channel





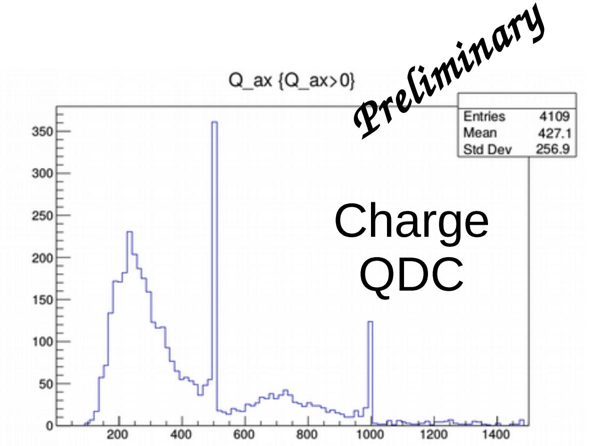
Channel circuit

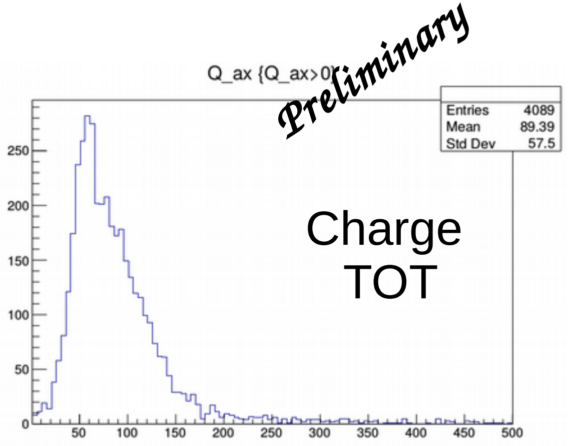


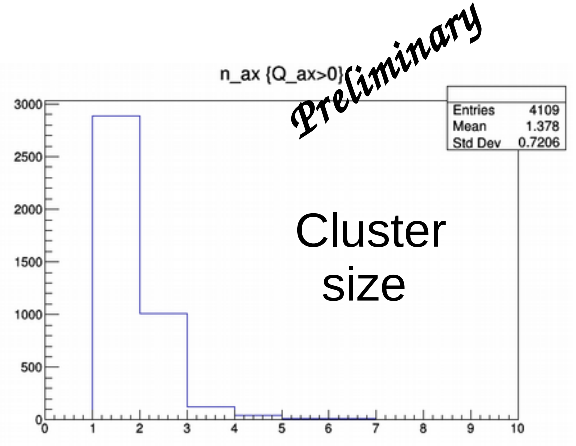
- The chip can work in two different modes: T-Branch and E-Branch
- T-Branch: timestamp on rising/falling edge (sub-50 ps binning quad-buffered TDC) charge measurement with **Time-over-Threshold**
- E-Branch: timestamp on rising edge (sub-50 ps binning quad-buffered TDC). **Sample-and-Hold** circuit for peak amplitude sampling. A slow shaper output voltage is sampled and digitized with a 10-bit Wilkinson ADC

TIGER @ Mainz: results

- The TIGER has two branches to measure the charge: QDC and TOT
  - QDC is more precise but it shows saturation effect
  - TOT does not suffer saturation but its values range is smaller
- Since those runs have been acquired with high threshold then the measurement of the cluster size is biased and it shows a distribution peaked in 1 (or 2 at higher gain)
- A charge centroid resolution of 300μm is far away from the literature results but it is a good starting point

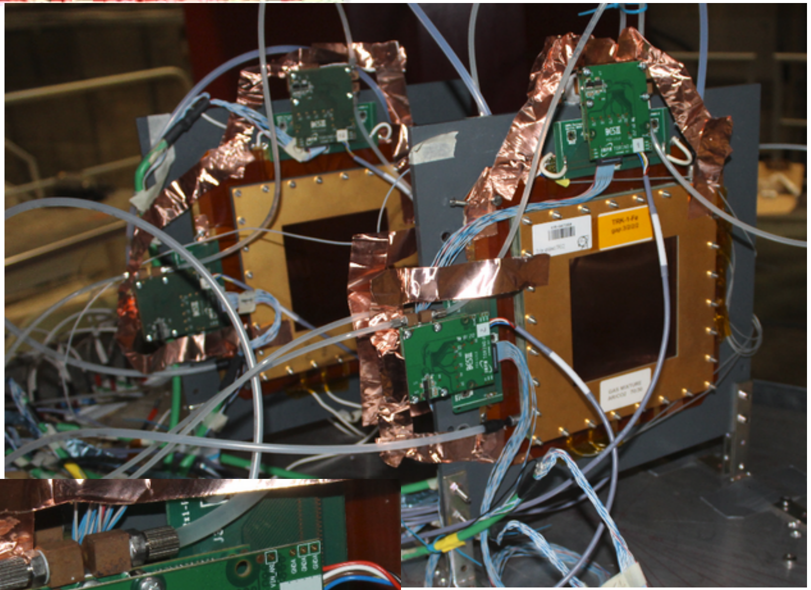


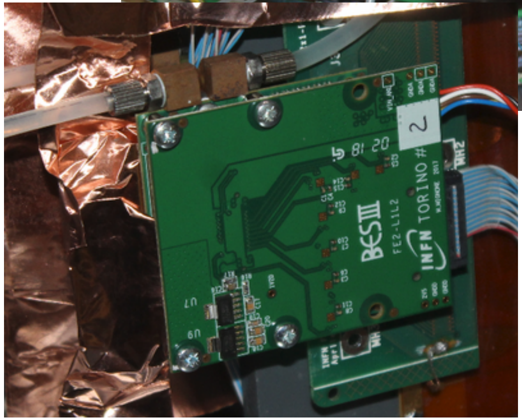




TIGER @ CERN: setup and aim

- Similar setup pf the APV25 …
  … but with more cables!
- The chip is refrigerated with a **chiller** in order to keep stable the temperature, then the threshold
- The final aim of this test beam is to validate the performance measured with the APV25 and obtain similar result





Conclusion

- R&D studies with APV25 are almost terminated and the performance of the triple-GEM fulfill the BESIII requirements
- A dataset with TIGER and triple-GEM has been collected with a setup closer to the BESIII setup
- Three Cylindrical triple-GEM has been produced and now will be tested with the TIGER electronics