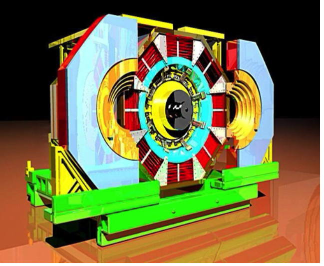
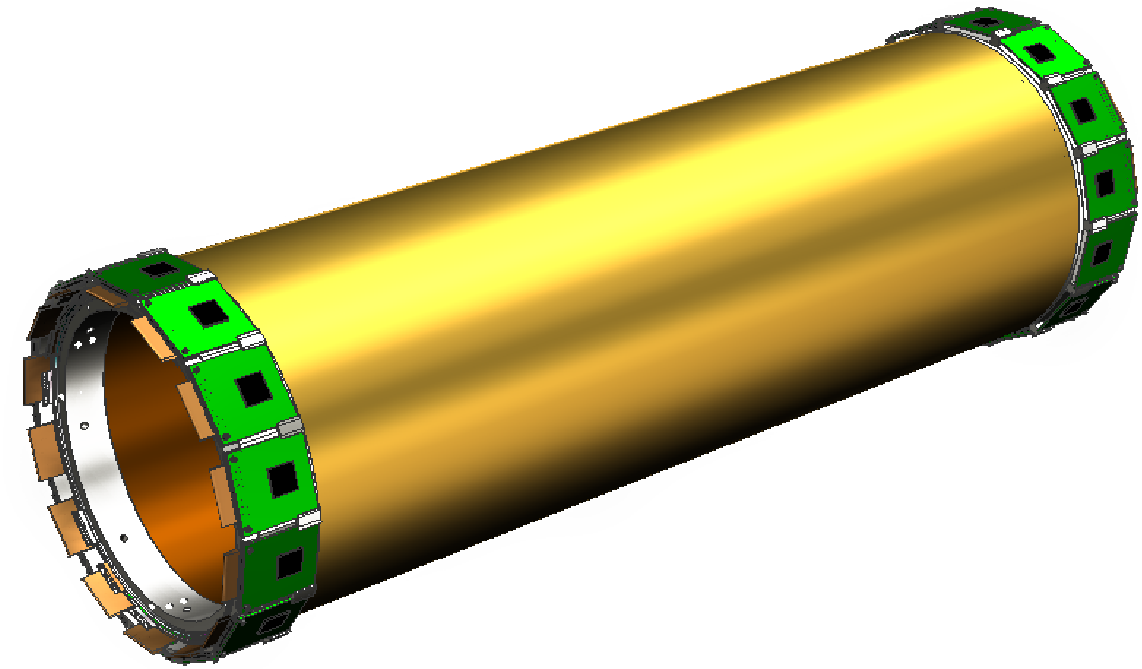


TIPP'17

BESIII



A Cylindrical GEM Inner Tracker for the BESIII experiment at IHEP

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University of Ferrara – INFN Ferrara
on behalf of the BESIII-CGEM group

INFN

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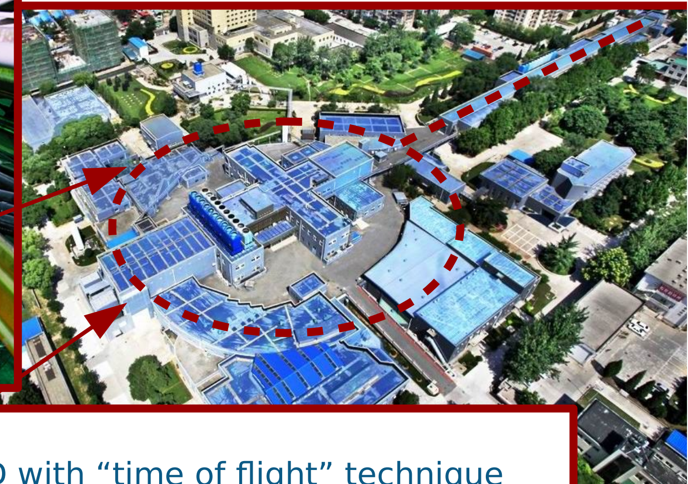
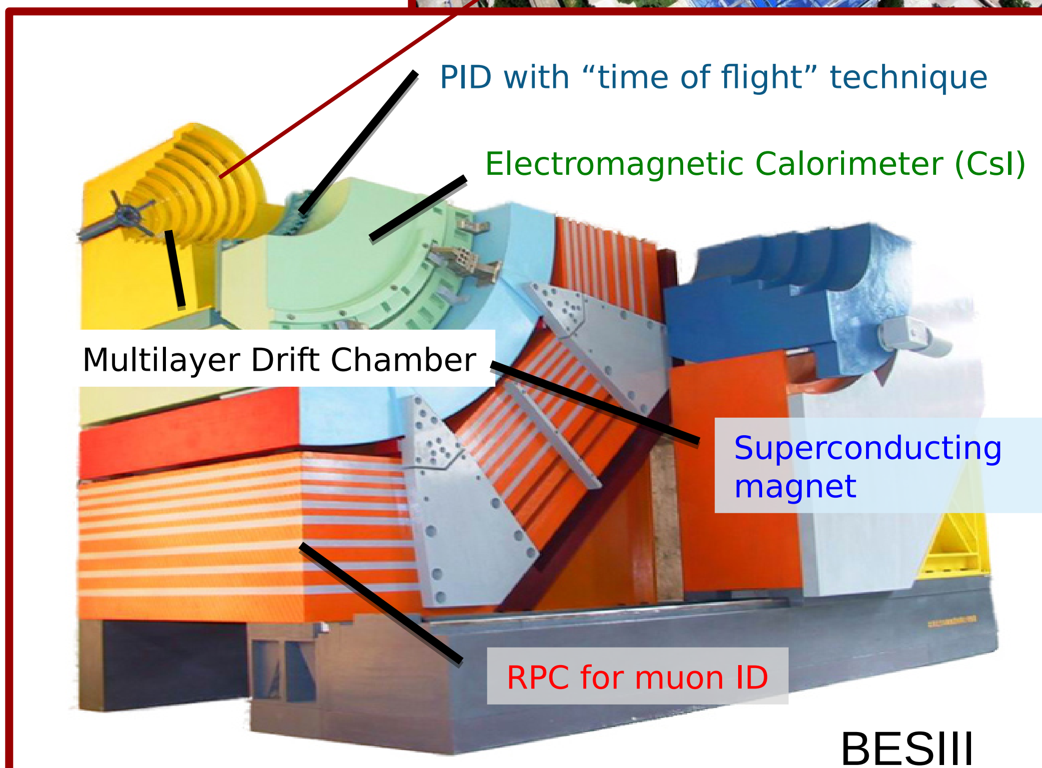
Outline

- The BESIII experiment: motivation, aims and gains
- The Cylindrical GEM project
- The GEM technology and R&D
- GEM & CGEM Test Beam results

BESIII @ IHEP

- The Beijing Electron-Positron Collider BEPCII and the Beijing Spectrometer BESIII are τ-charm factory.
- $E_{cm} = 2 – 4.6$ GeV
- $\mathscr{L}_{\text{achieved}} = 10^{33}\ \text{cm}^{-2}\text{s}^{-1}$
- Data taking until 2022 with the chance to continue up to 2027
- The physics program includes:
  - High precision test of EW interaction
  - High statistic studies of light hadron spectroscopy
  - Studies of charm physics
  - Studies of τ physics





The BESIII detector

A multipurpose magnetic spectrometer with an effective geometrical acceptance of 93% of 4π is composed of a series of sub-detectors

Multilayer Drift Chamber
120 μm spatial resolution
dp/p ~ 0.5% @ 1 GeV/c

Time Of Flight
90 ps time resolution
for PID

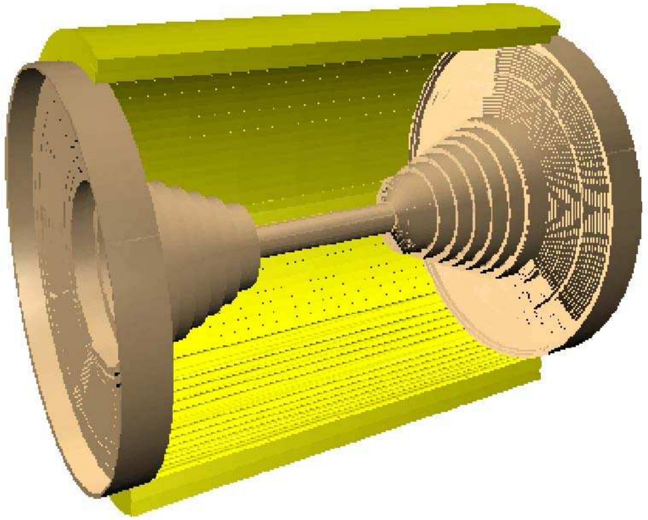
Electromagnetic Calorimeter (CsI)
dE/E ~ 2.5 % @ 1 GeV/c

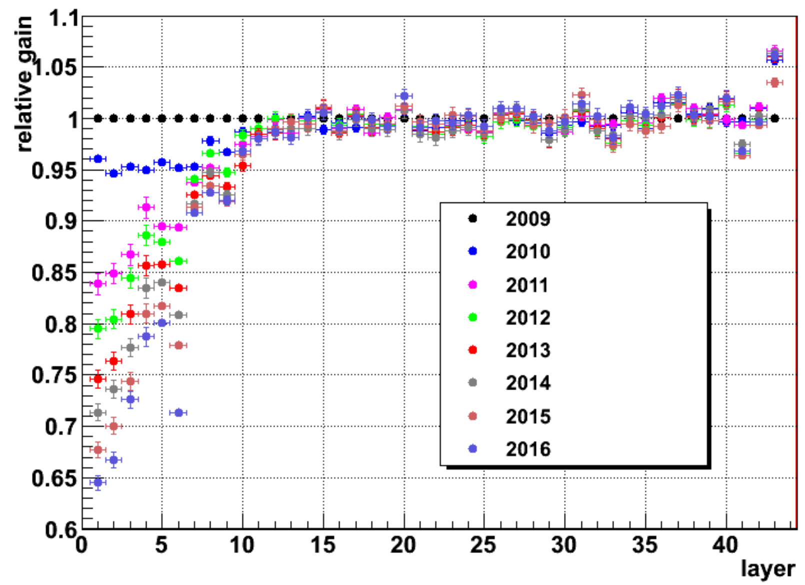
Superconducting magnet
magnetic field = 1 Tesla

RPC for muon ID

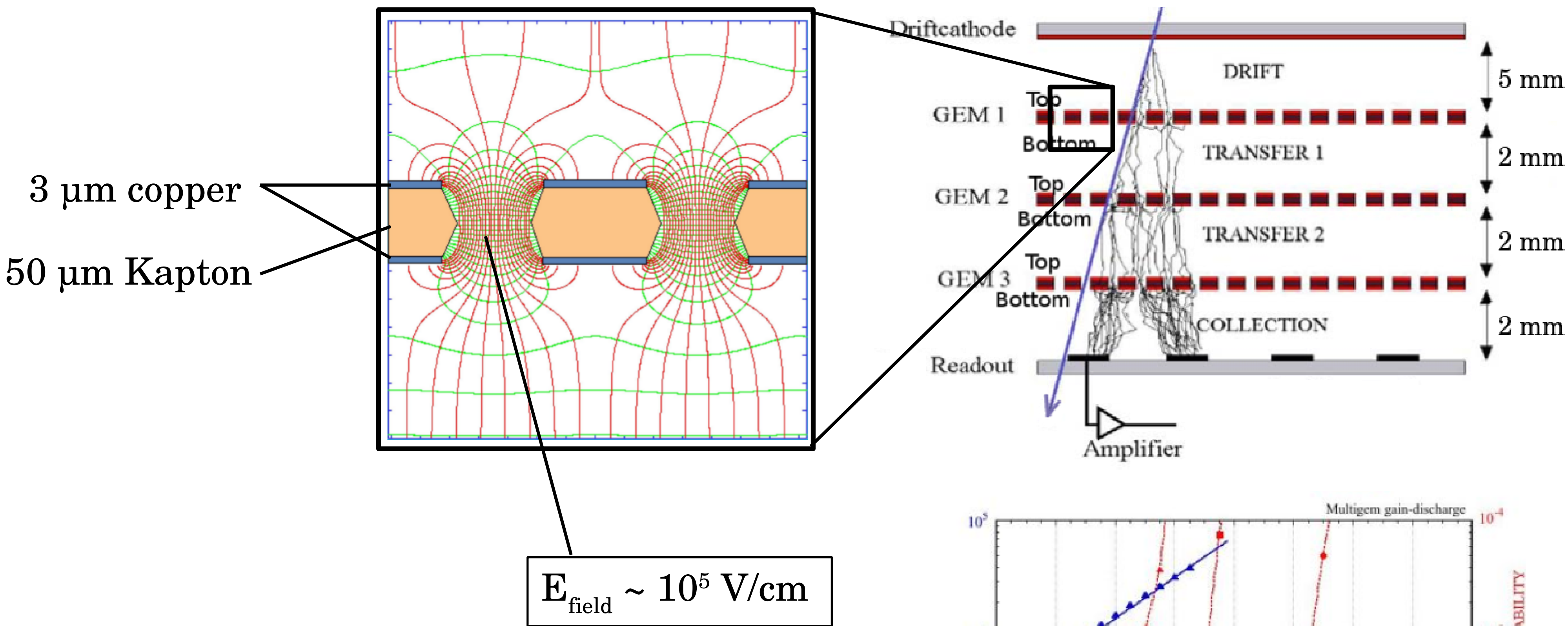
MDC aging

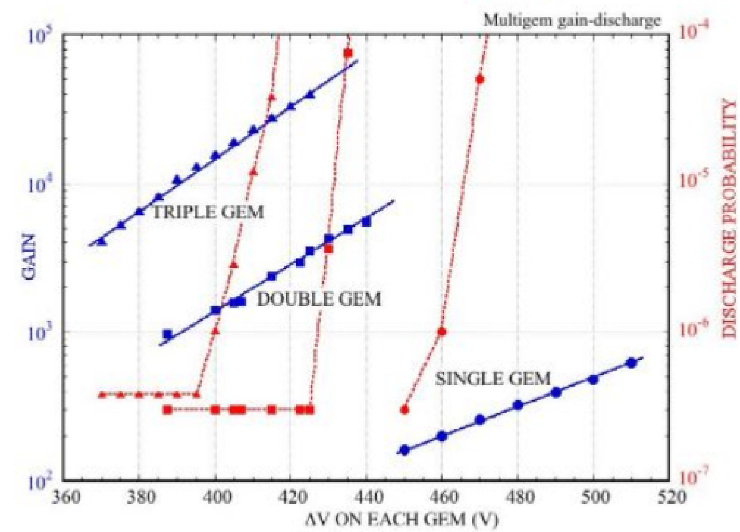
- The Multilayer Drift Chamber is composed by 43 layers and it shows a significant aging in the inner part
- The HV values of the MDC have been lowered to keep the current under control. This has worsen the reconstruction efficiency
- BESIII is an experiment that will take data until 2022 or more and it needs a new IT. The Italian group proposed to replace the inner part of the MDC with 3 independent layers of CGEM





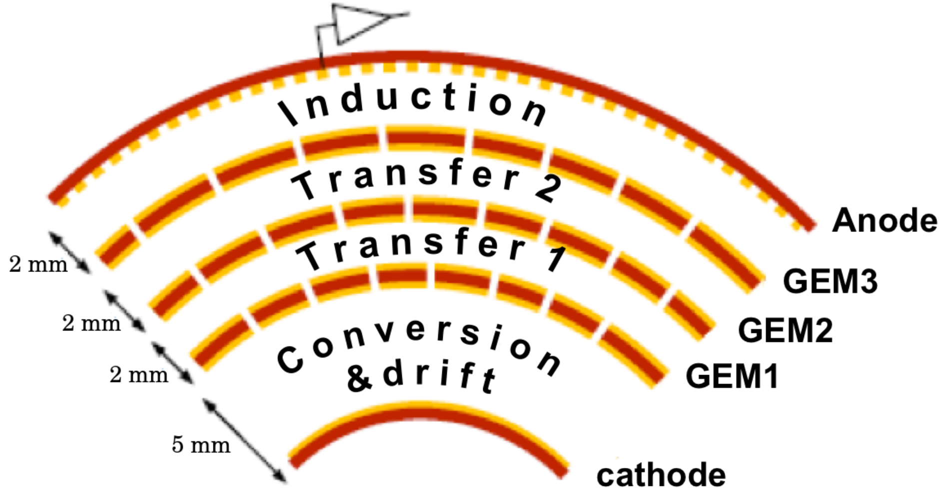
The GEM technology

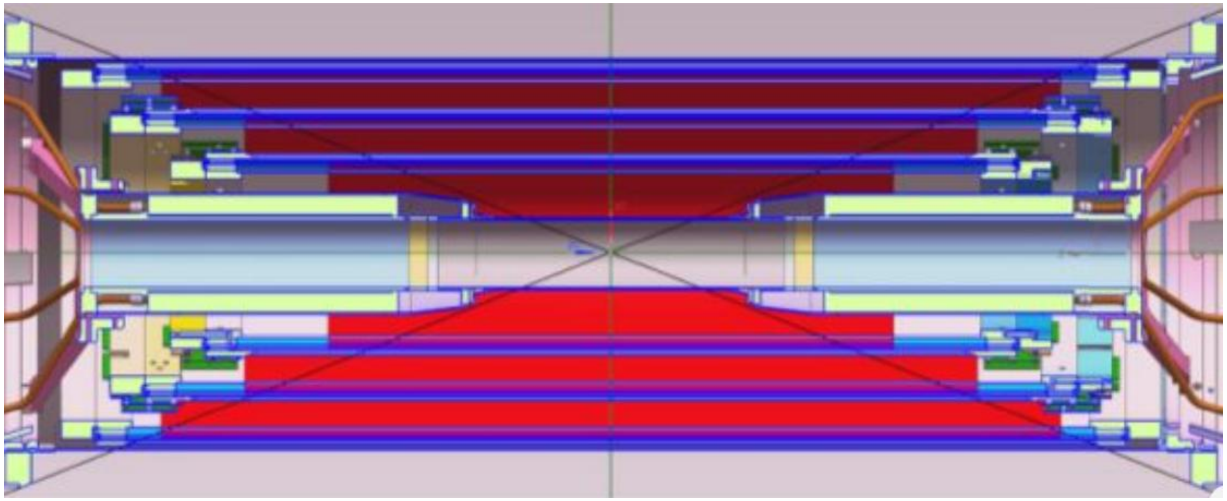




- High efficiency needs a gain of ~ 10^3-10^4 while safety standard imposes a discharge probability below 10^{-5}
- The signal depends by the gas mixture, the geometries and the involved fields.

A CGEM based Inner Tracker



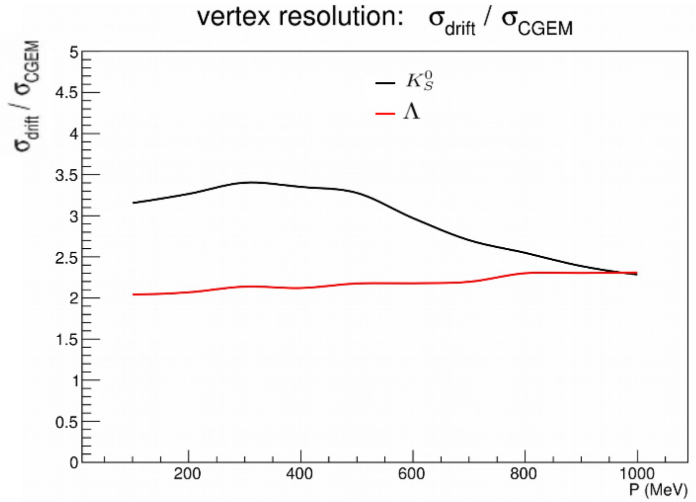


BESIII requirements

- Rate capability ~ 10^4 Hz/cm^2
- Spatial resolution: $\sigma_{r\text{-}\phi} \sim 130\ \mu m$, $\sigma_z \sim 1$ mm
- Momentum resolution: $\sigma_{pt}/P_t \sim 0.5\ \%$ @ 1 GeV/c
- Efficiency ~ 98 %
- Material budget ≤ 1.5 % X_0 in total
- Coverage: 93 % 4π
- 1 Tesla magnetic field

BESIII physics benefits

- XV readout on the anode largely improves the spatial resolution along z coordinate
- Analysis with final state including short living particles or precise secondary vertex will profit of the upgrade
- The vertex resolution of the K_s^0 and Λ particles will improve between 2 and 3 times w.r.t. the drift chamber
- Triple-GEM technology shows lower aging effect and it has an higher resistence to high particles flux



State of the art and innovations

Previous experiment:

– KLOE 2 experiment built the first CGEM that works inside a magnetic field of 0.5 T and reaches a spatial resolution about 350 µm

Innovations:

➔ The mechanical support of the detector is made of Rohacell instead of the Honeycomb

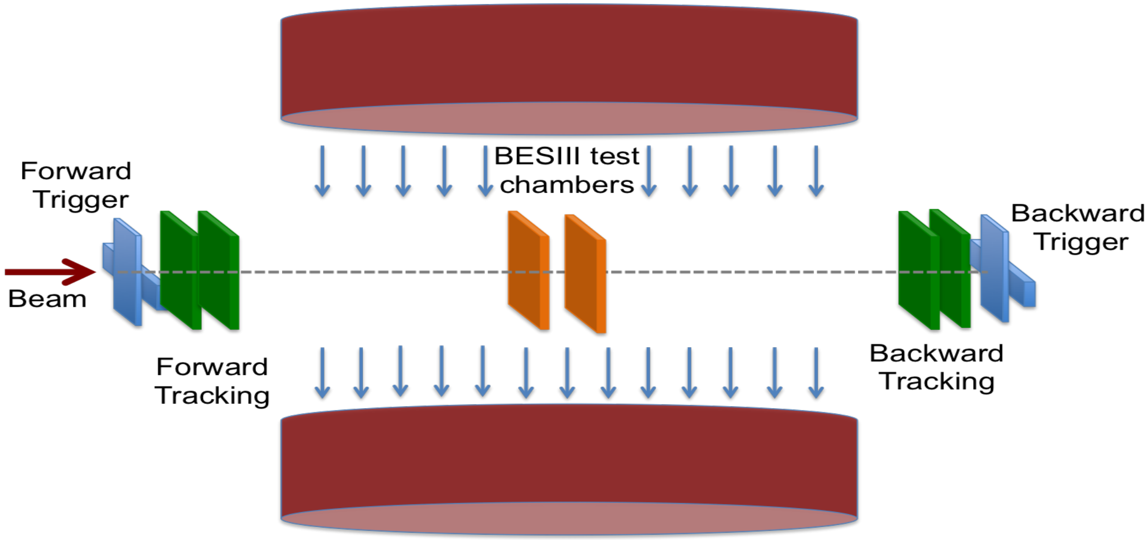
➔ A new anode design with a jagged layout reduces the interstrip capacitance of about 30 %

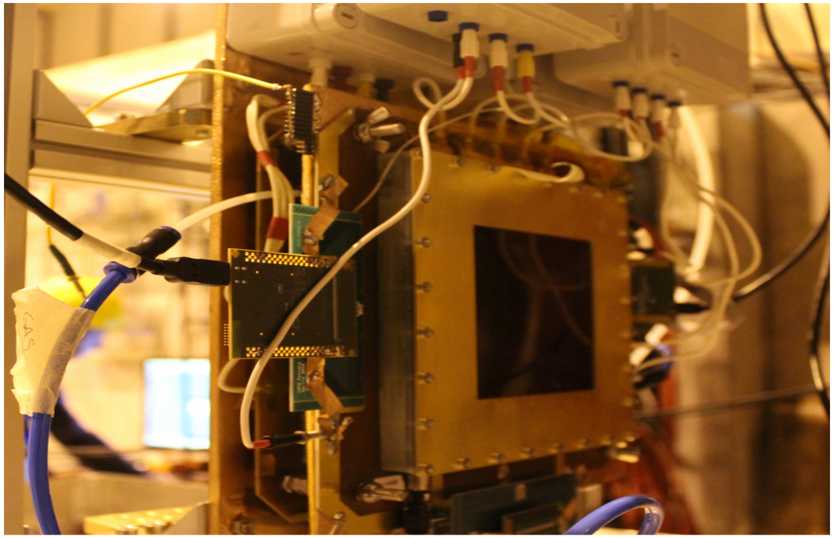
➔ Charge and time information will be used to reconstruct the position inside a 1 T magnetic field

➔ A dedicated ASIC on detector, named TIGER, performs time and charge measurement with a TDC, an ADC and ToT technique

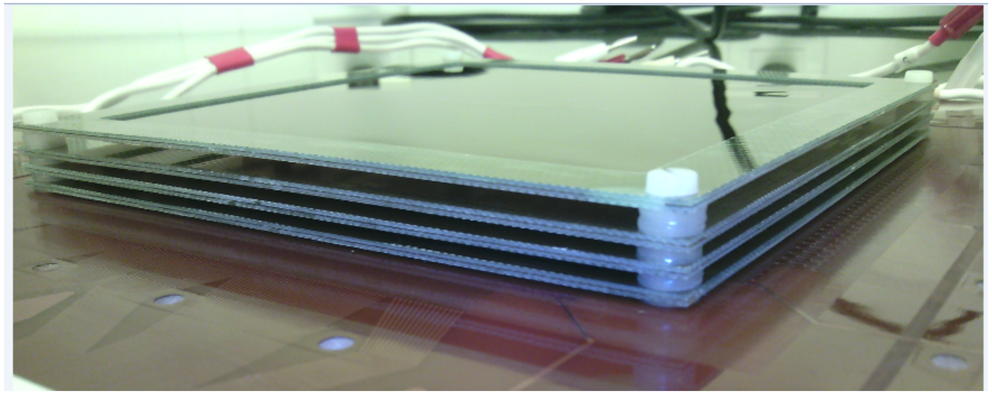
Gas Electron Multiplier characterization

Planar triple-GEM @ test beam





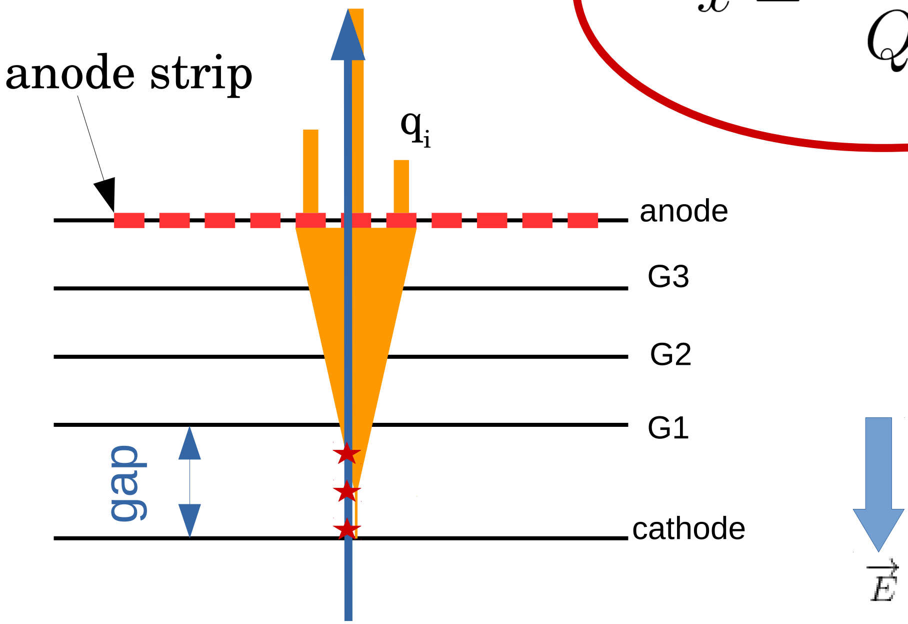
- Planar prototypes of triple-GEM have been tested on a muon/pion beam @ H4-CERN.
- The plateau efficiency on the two views reaches ~97% at a gain of ~ 6000
- Performance measured with different geometries, gas mixtures and electric fields.



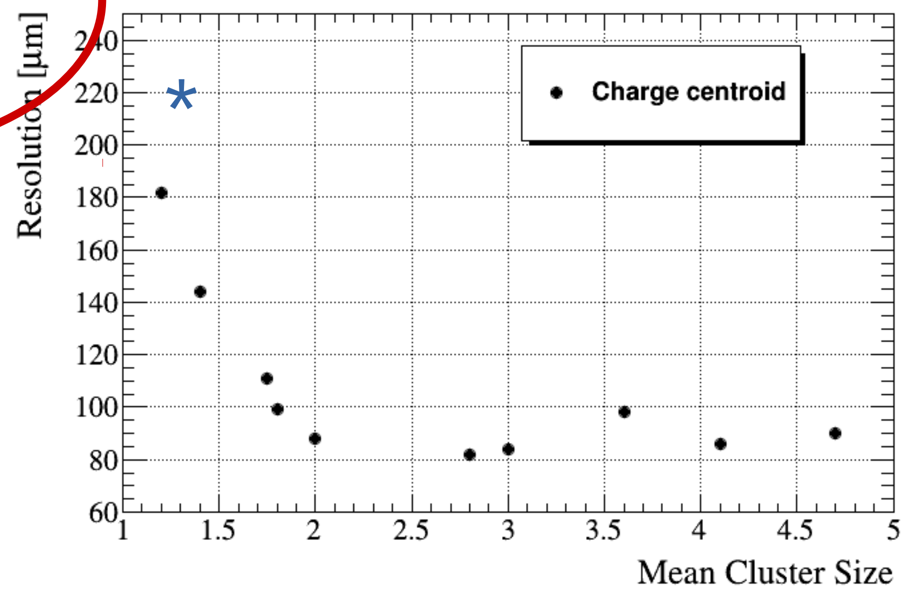
The charge centroid method

- The avalanche dimension depends on the gas diffusion that is affected by the electric field and the gas mixture
- A weighted average position is measured from the fired strip and its performance goes beyond the digital readout that is constrained to the strip pitch
- The best performances of the charge centroid are achieved when the number of the fired strips is higher than 2

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



* Data with $Ar:CO_2$ (70:30) gas mixture

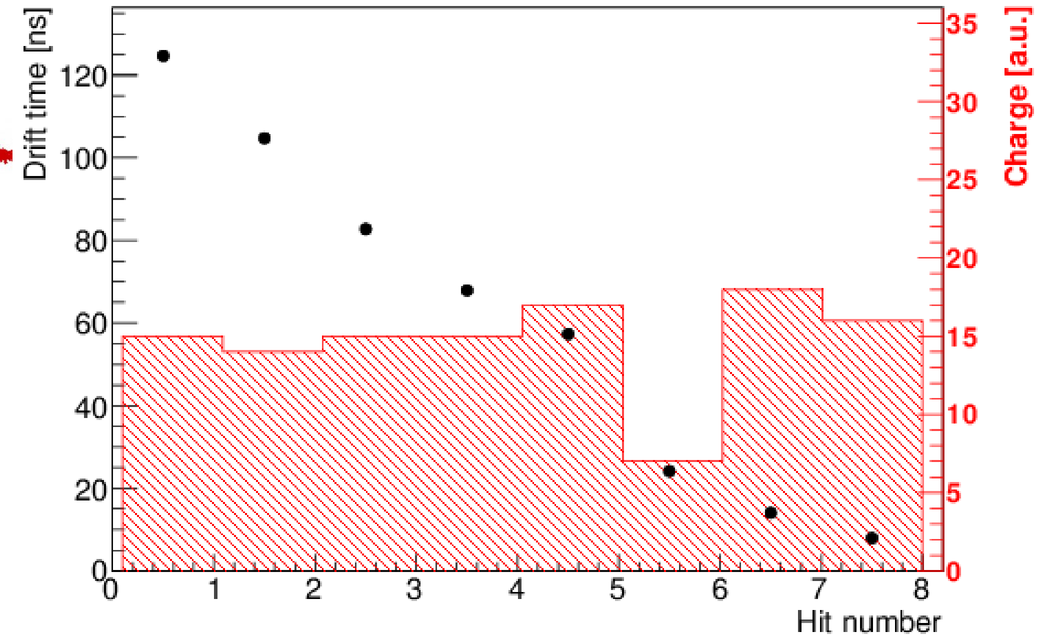


COMPASS has implement at first the charge reconstruction without magnetic field for triple-GEM detector

μTPC method

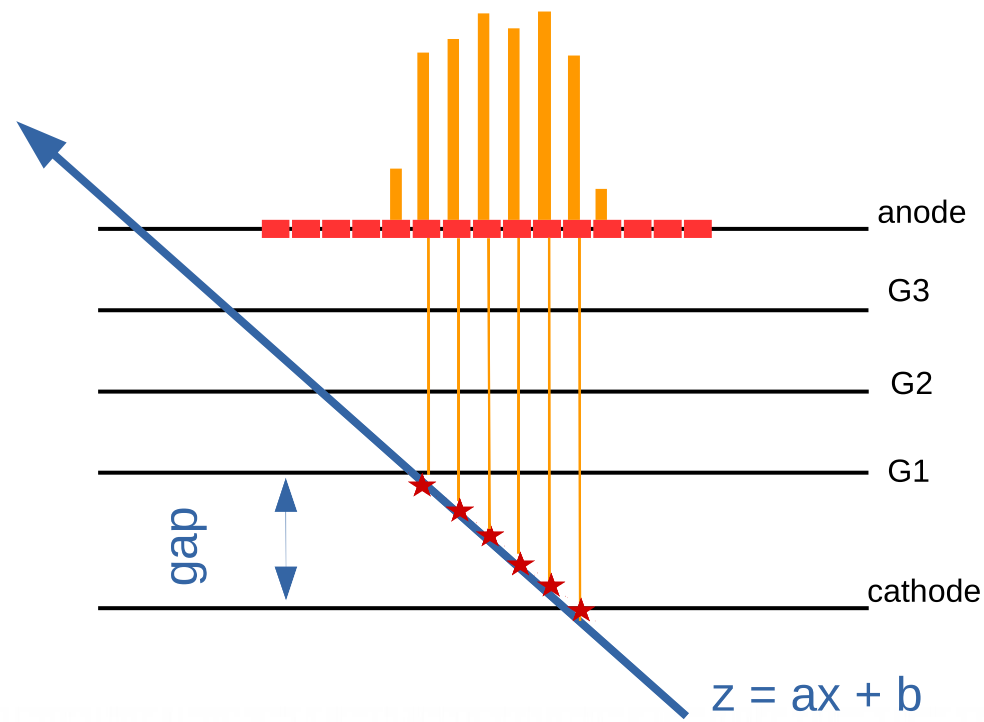
- The time information can be used to improve the spatial resolution in magnetic field and in case of non-perpendicular tracks.

$$x = \frac{\frac{gap}{2} - b}{a}$$



- Known the drift velocity from Garfield simulation, it is possible to assign to each fired strip a bi-dimensional point. These points are used to reconstruct the track in the conversion region

- A linear fit is used to reconstruct the path and to measure the particle position



ATLAS has implement at first the time reconstruction in B = 0.2 T for MicroMegas detector

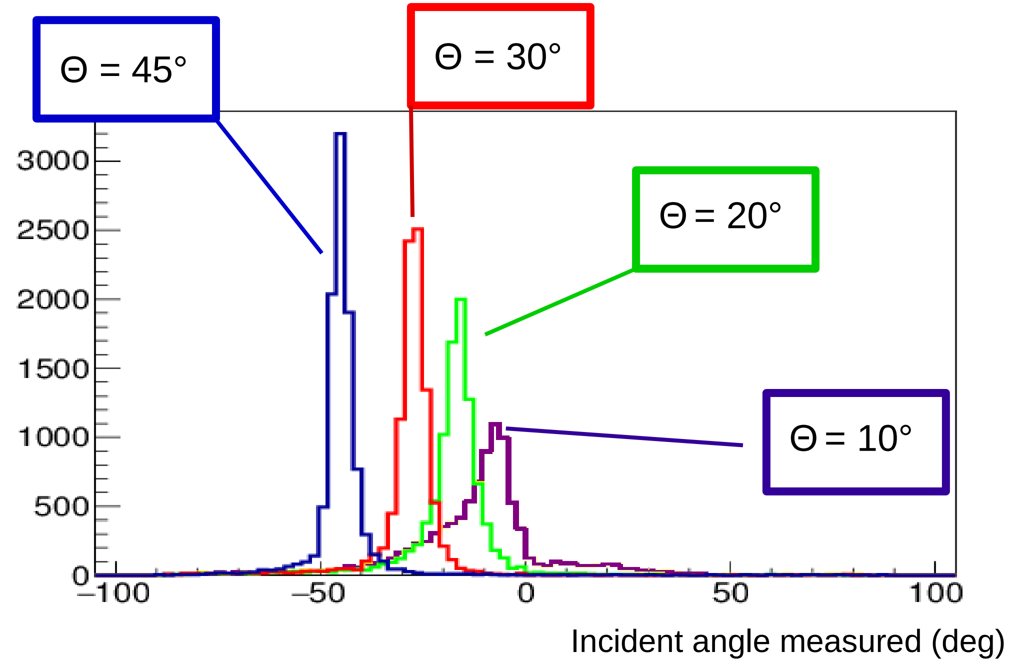
μTPC method

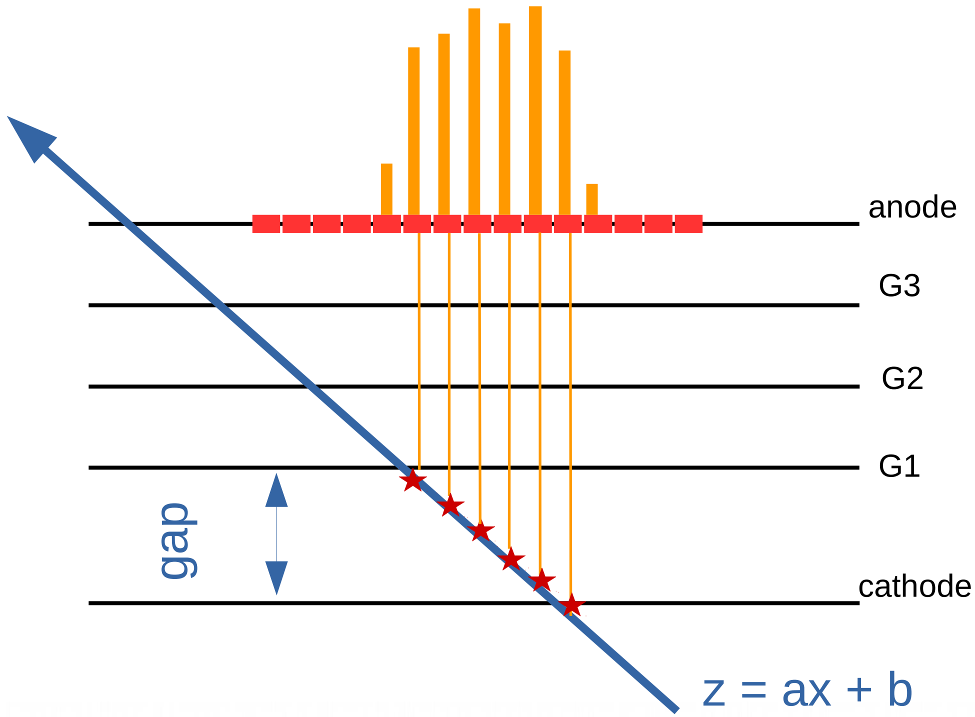
- The time information can be used to improve the spatial resolution in magnetic field and in case of non-perpendicular tracks.

$$x = \frac{\frac{gap}{2} - b}{a}$$

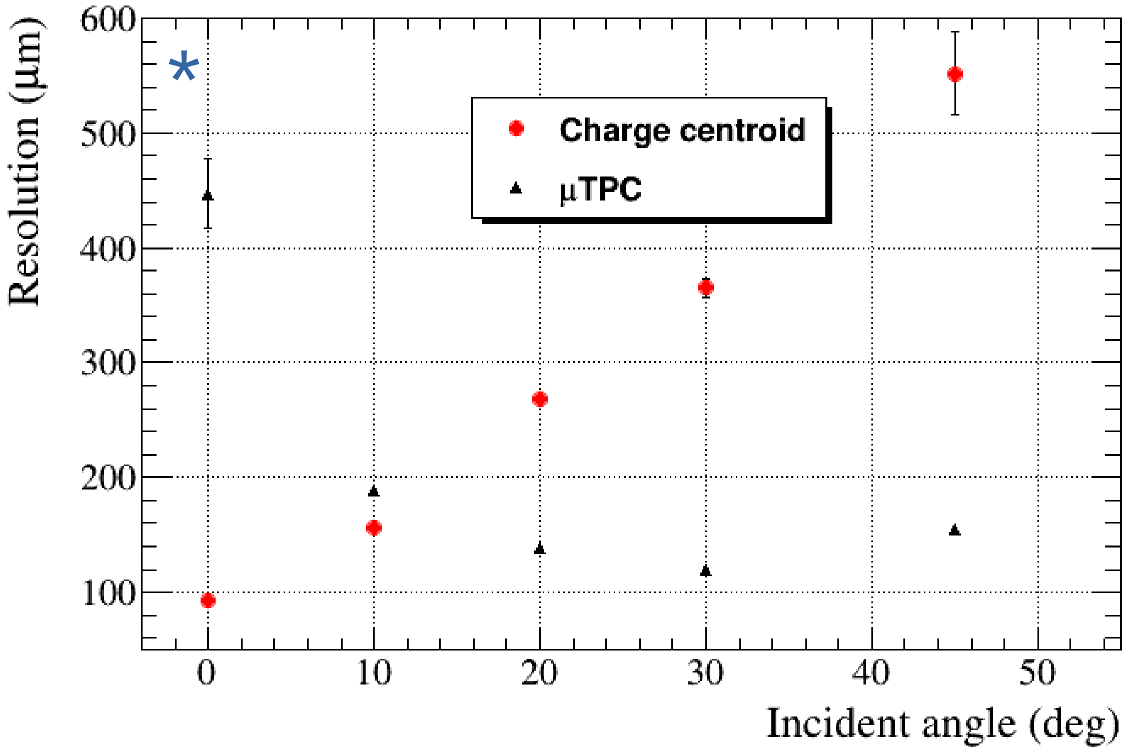
- Known the drift velocity from Garfield simulation, it is possible to assign to each fired strip a bi-dimensional point. These points are used to reconstruct the track in the conversion region

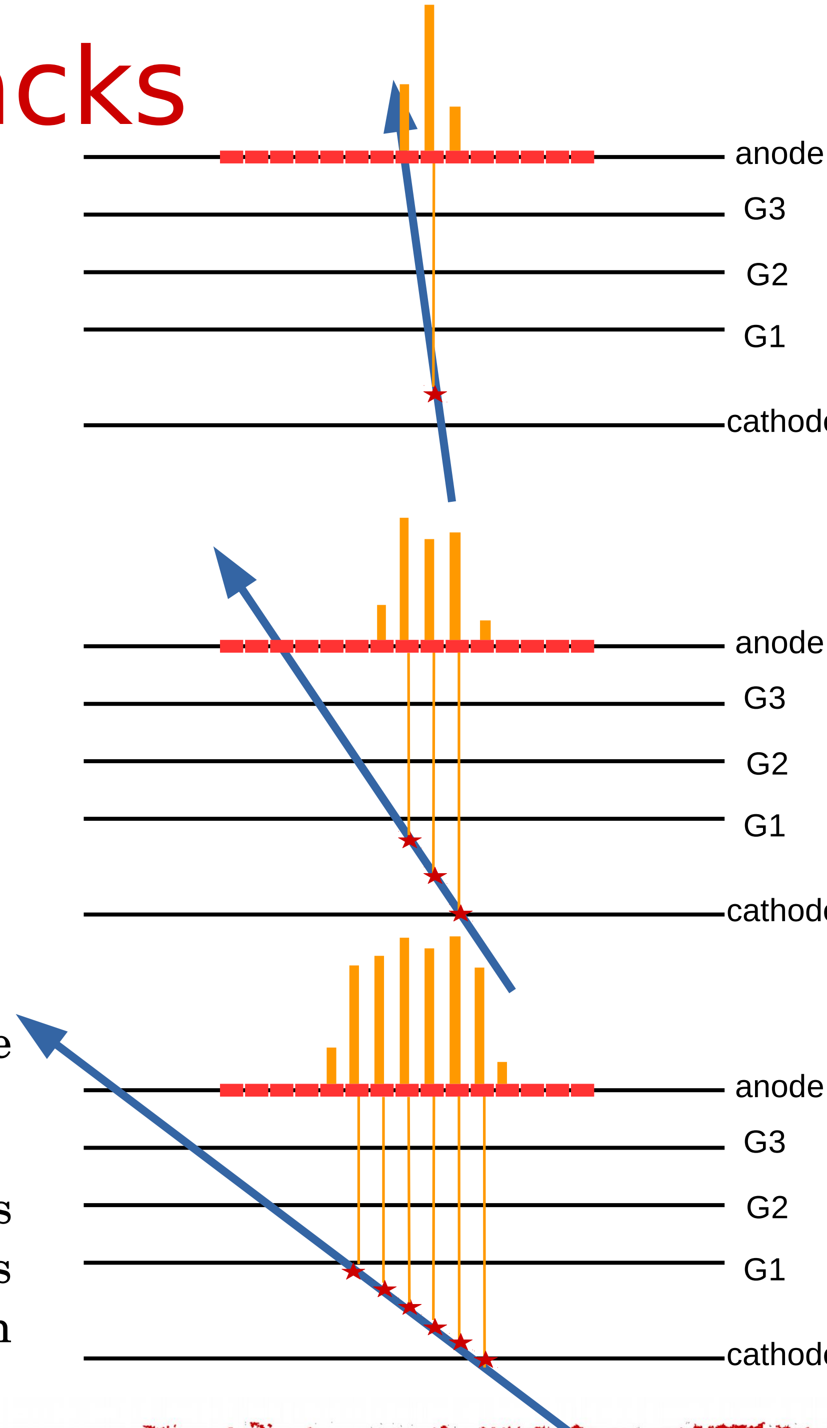
- A linear fit is used to reconstruct the path and to measure the particle position





CC & µTPC: angled tracks





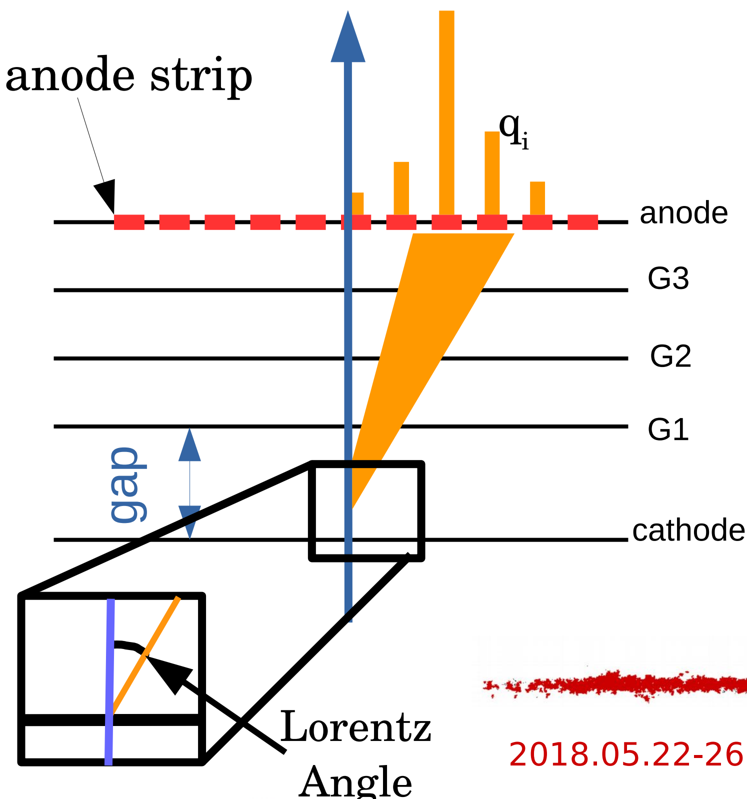
- As the incident angle departs from the perpendicular one, the cluster size increases:

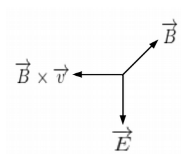
➔ this improves the µTPC performance but it degrades the CC because the 3 GEMs amplify the electrons and the diffusion increases the avalanche size with a shape that it is not Gaussian.

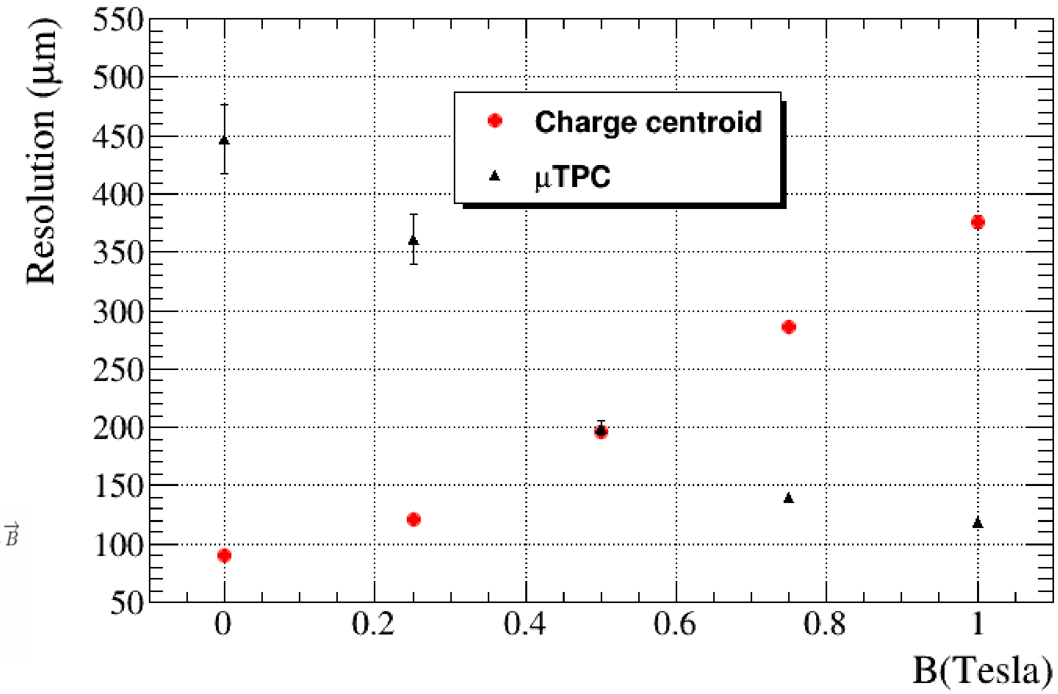
* Data with $Ar:iC_4H_{10}$ (90:10) gas mixture

CC & μTPC: magnetic field

- The magnetic field affects the electronic avalanche:
  - the Lorentz force drifts the electrons,
  - the magnetic field enlarges the charge distribution at the anode and the multiplicity largely increases,
  - ➔ the charge distribution of the charge is no longer Gaussian and the charge centroid performance degrades
  - ➔ μTPC reaches its best performance when the multiplicity is sufficiently large



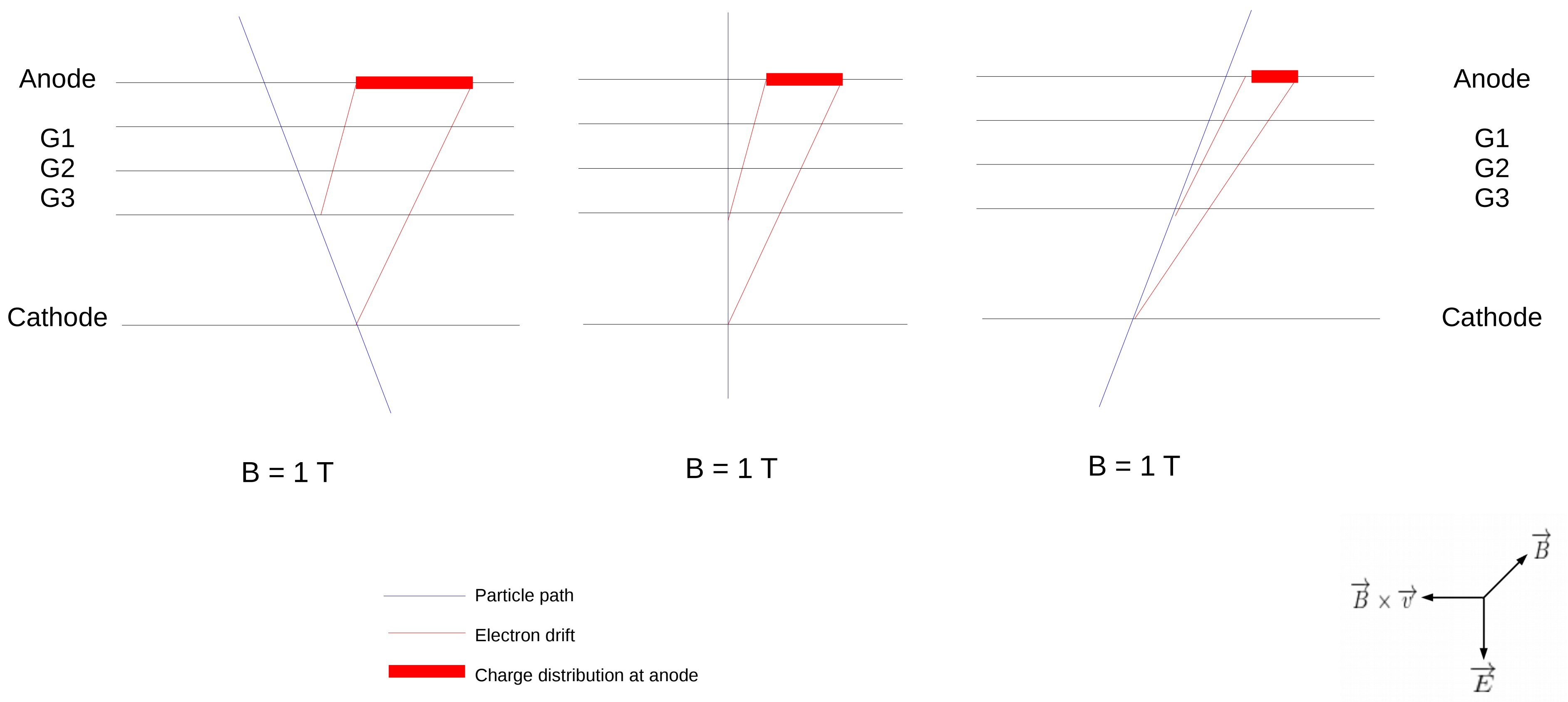




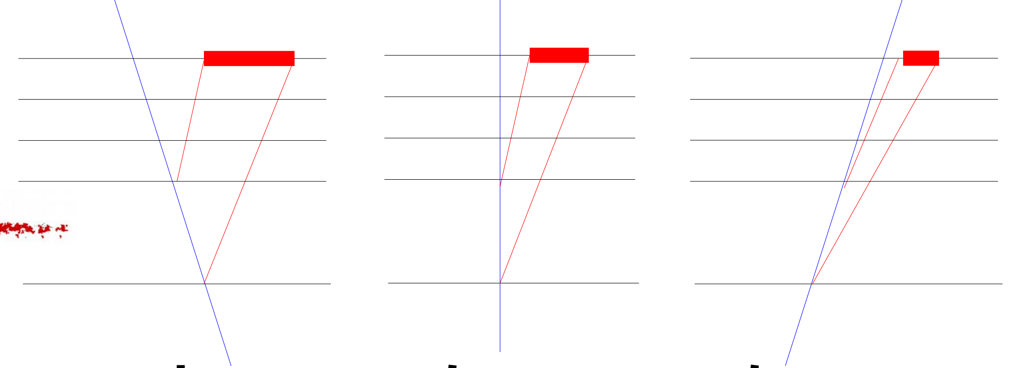
What if we combine $\overline{B}$ and angle tracks?

Defocusing configuration

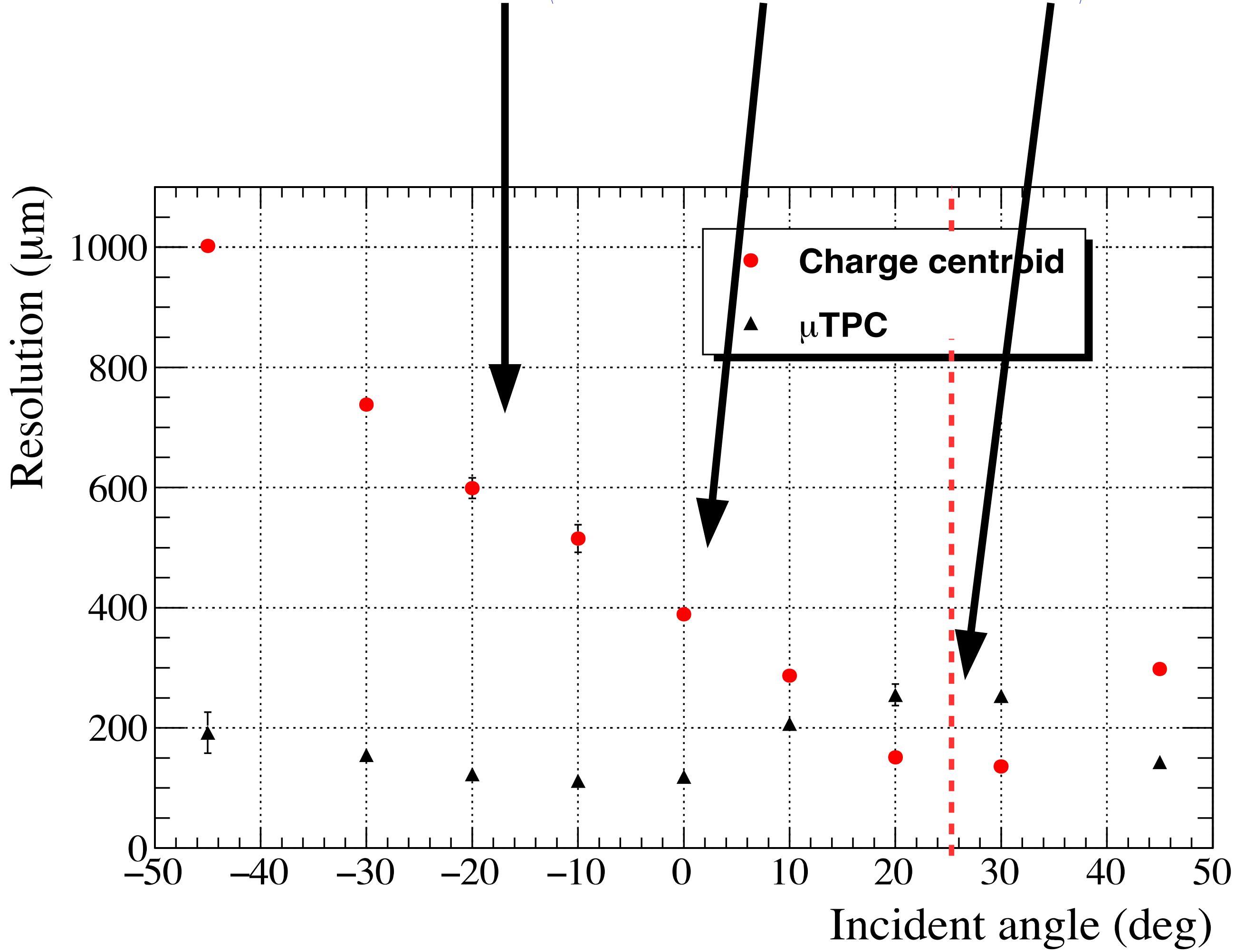
Focusing configuration



Scan angle w. B and Ar:iC_4H_{10}



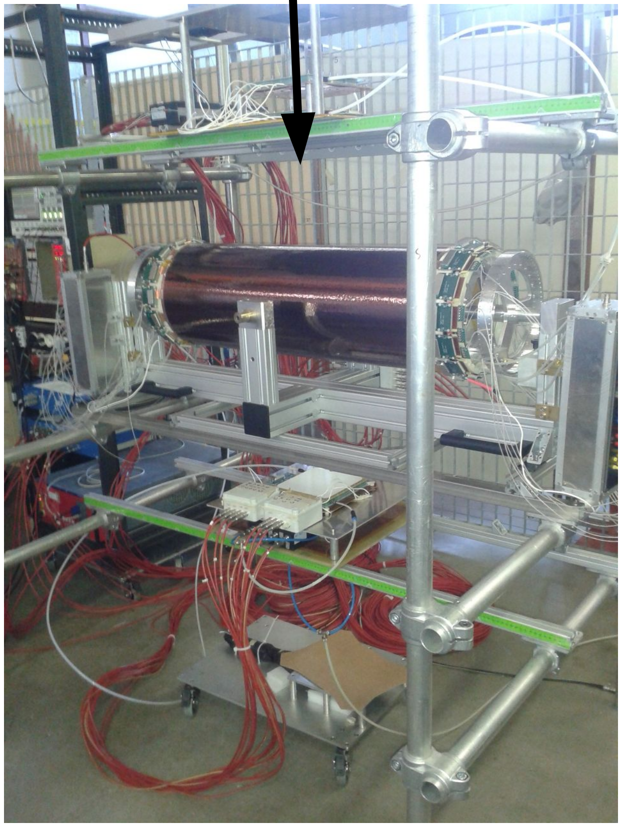
- μTPC has to take into account the Lorentz angle to reconstruct the tracks with the magnetic field. That angle is calculated with simulations.
- The Lorentz angle with Ar:iC_4H_{10} @ 1.5kV/cm drift field is ~ 26°. In this region CC is more efficient. In the other regions μTPC is flat around a resolution of ~130μm
- A combination of the two methods should keep the resolution stable in the full range of incident angles

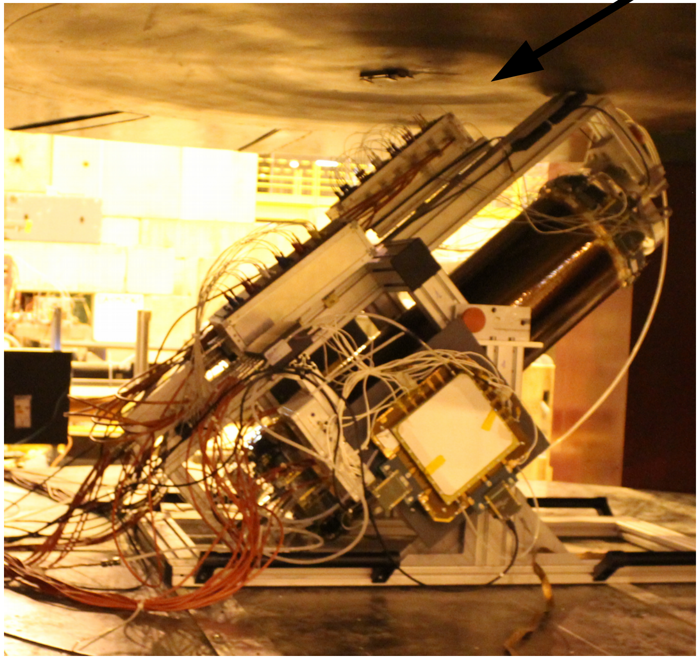


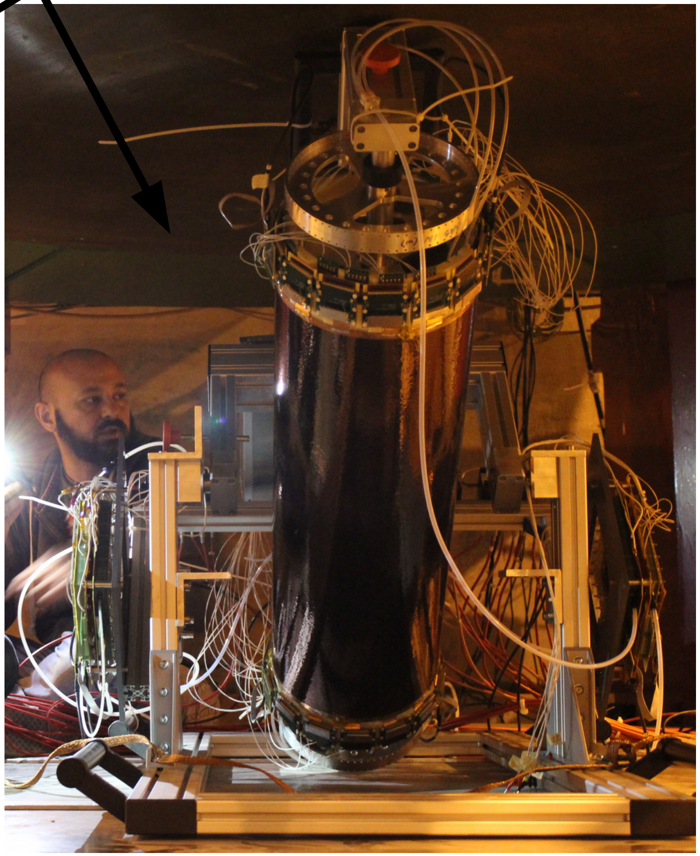
CGEM characterization

Cylindrical GEM Test Beam

Cosmics **Test Beam**



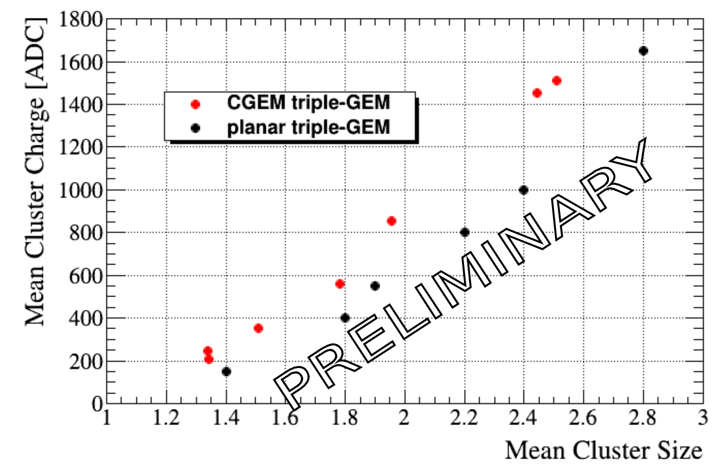


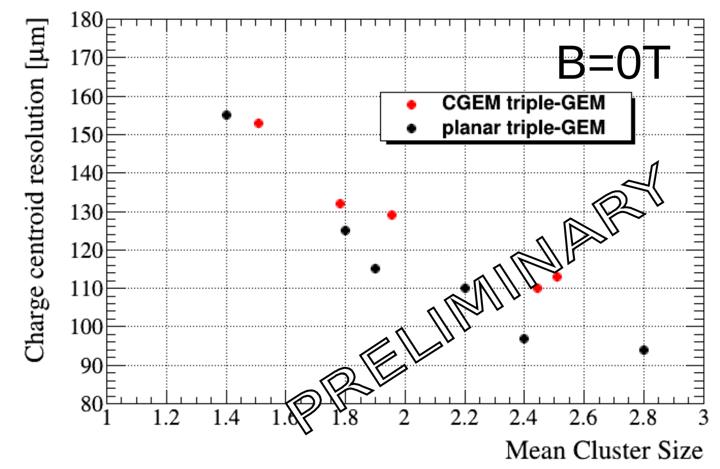


The aim of the cosmics run and the TB is to measure the performance of the CGEM and to compare it with the results obtained with the planar GEM

Matching planar and cylindrical geometry

- In order to compare the behaviour of the GEM and the CGEM an analysis as function of the cluster size has been performed
- These results have been acquired with orthogonal pion tracks and no magnetic field
- The cluster size shows the number of the fired strips. This is related to the signal dimension then to the gain and the drift properties of the electrons
- Charge centroid resolution behaviour indicates that the CGEM performance within tens of μm are compatible with the planar GEM





Conclusion

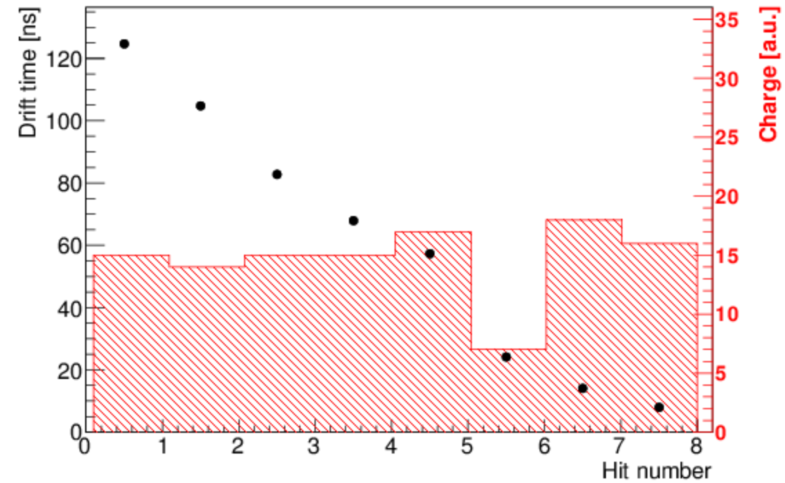
- A performance measurement and optimization of a planar GEM detector is performed with several test beam.
- The spatial resolution is stable and the results that combine charge centroid and μTPC are beyond the state of the art for this technology in magnetic field.
- A cylindrical GEM has been tested and the performance shows a similar behaviour to the planar GEM and the results obtained in these conditions, w/o magnetic field, are close to planar GEM
- BESIIICGEM project is funded by the European Commission within the RISE-MSCA-H2020-2014 call. It involves INFN (Ferrara, Torino and Frascati), Uppsala Univ., Mainz Univ. and IHEP

Thanks

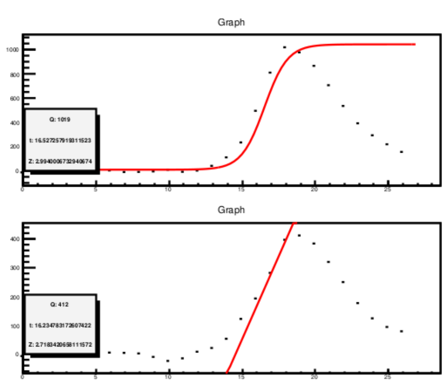
Backup slide

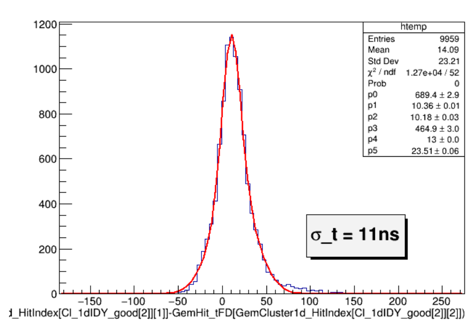
μTPC method

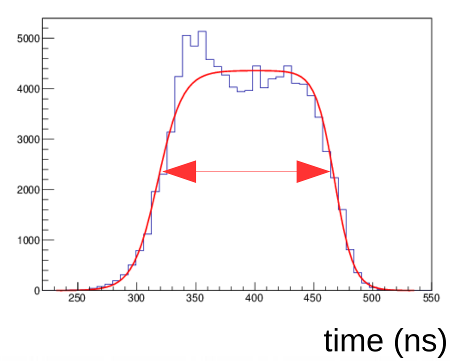
- The time information can be used to improve the spatial resolution in magnetic field and in case of non-perpendicular tracks.
- The time resolution measured is 11 ns. This take into account the contribution of the detector and electronics.
- Known the drift velocity, it is possible to assign to each fired strip a bi-dimensional point. These points are used to reconstruct the track in the conversion region

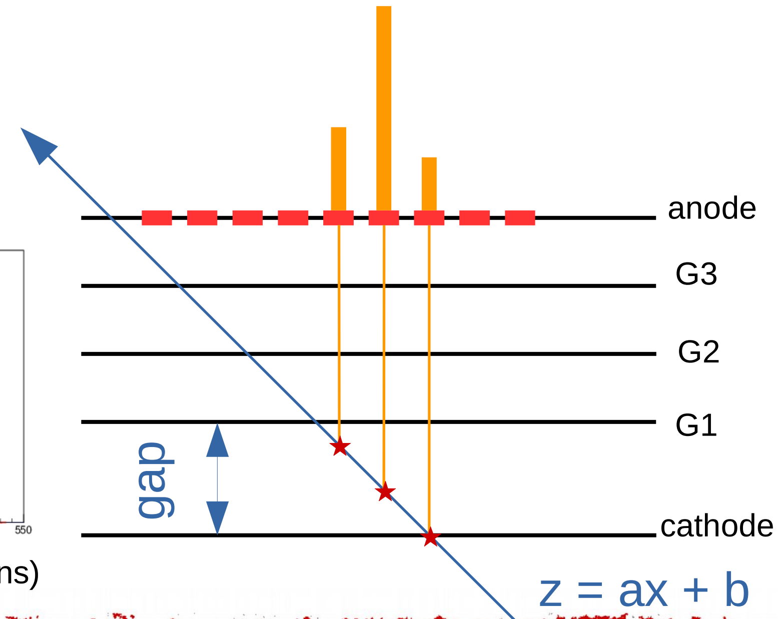


$$x = \frac{\frac{gap}{2} - b}{a}$$







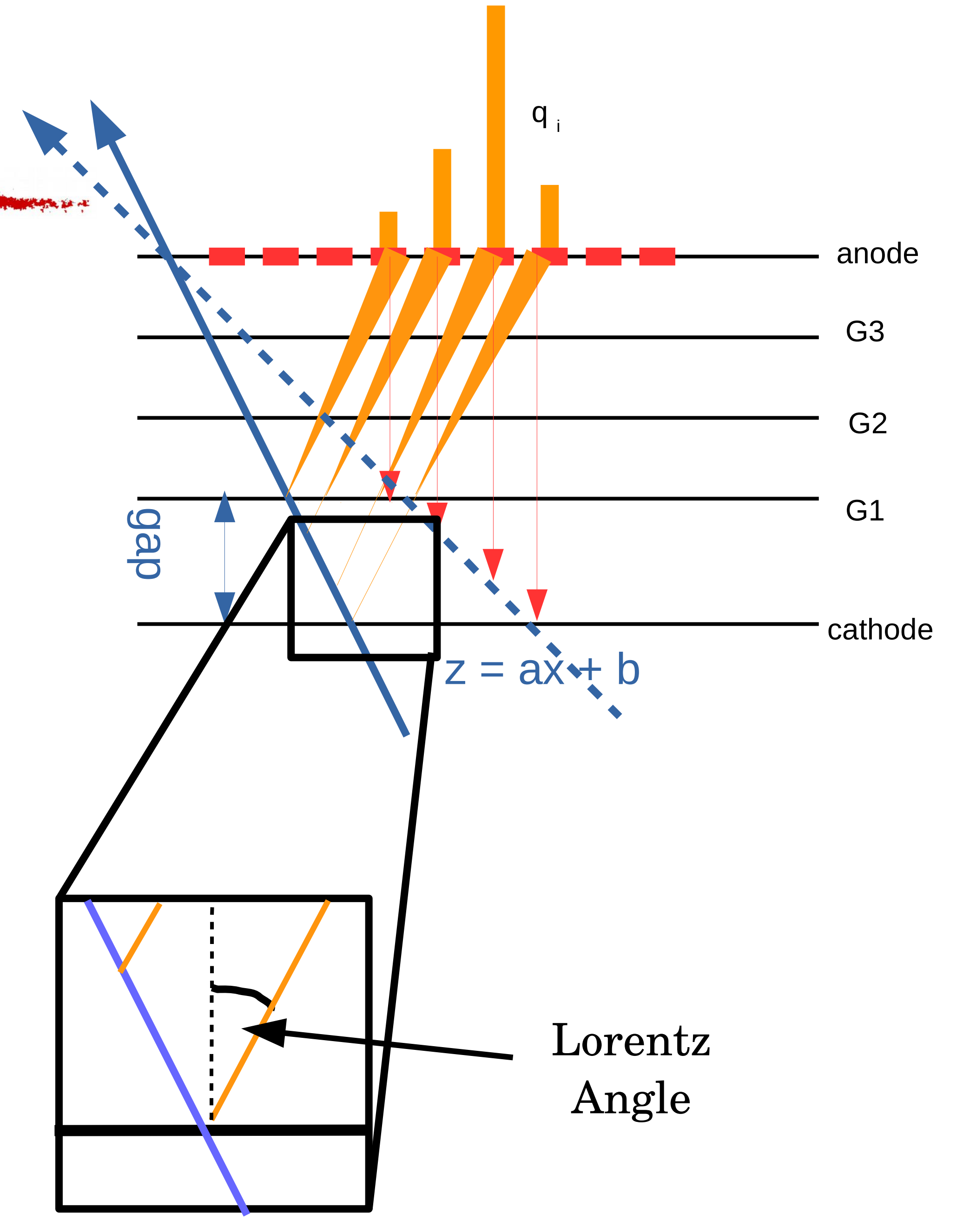


µTPC in magnetic field

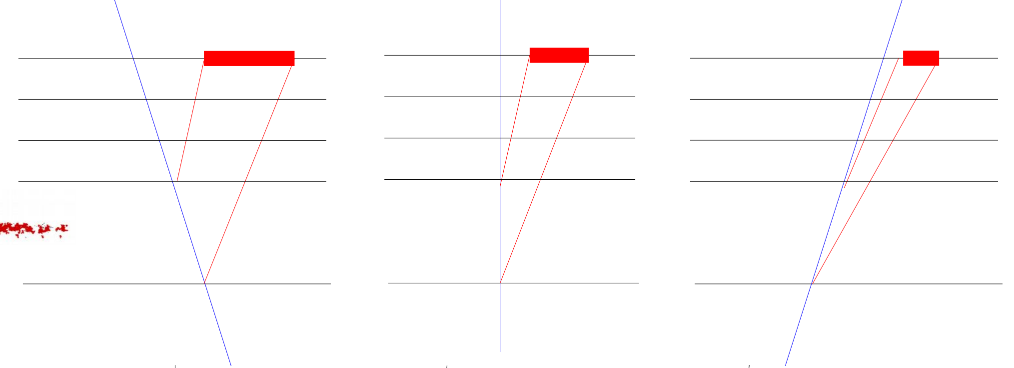
- The magnetic field shifts the electron avalanche

$$x = \frac{\frac{gap}{2} - b}{a}$$

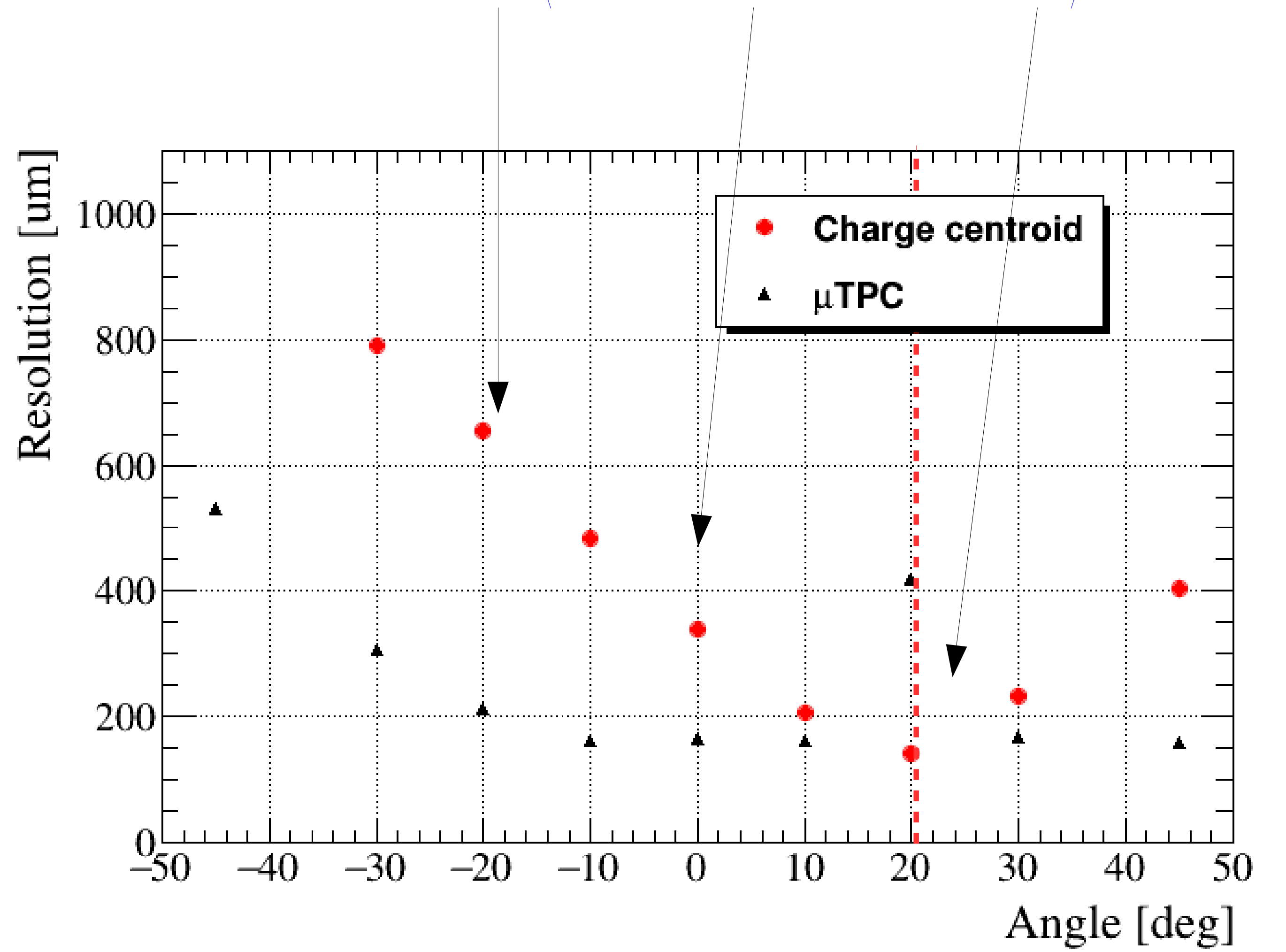
- The path of the electrons is not perpendicular w.r.t. the anode plane
- The parameter that describes this effect is the Lorentz angle
- The drift velocity and the reconstruction of the µTPC point has to take into account this effect



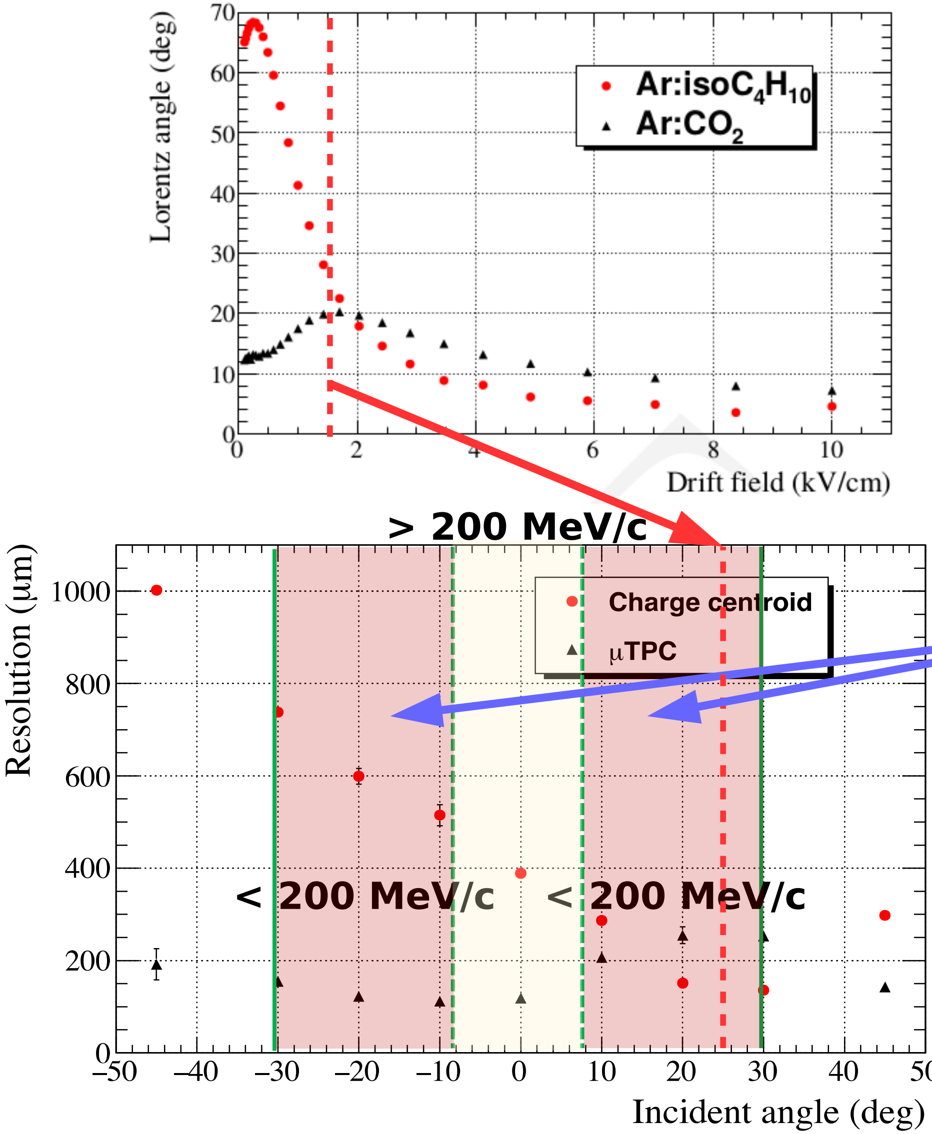
Scan angle w. B and Argon:CO_2



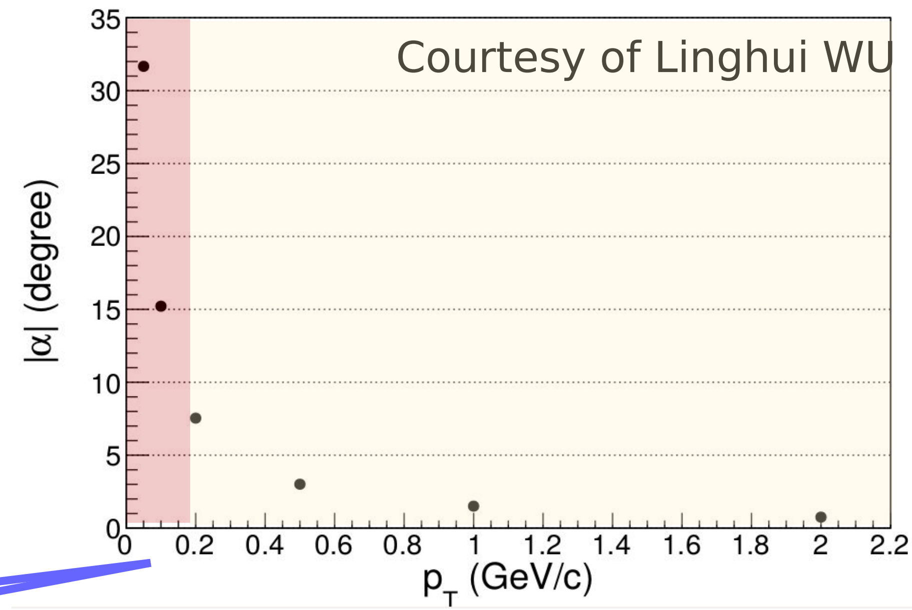
- This is the first implementation of the µTPC algorithm for GEMs in high magnetic field
- The Lorentz angle with Ar:CO_2 @ 1,5kV/cm drift field is ~ 20°. In this region CC is more efficient. In the other regions µTPC is flat around a resolution of ~150µm up to high defocussing angle
- A combination of the two method should keep the resolution stable



The µTPC optimization



Expected entrance angle at the outer radius of CGEM-IT (primary vertex particles)



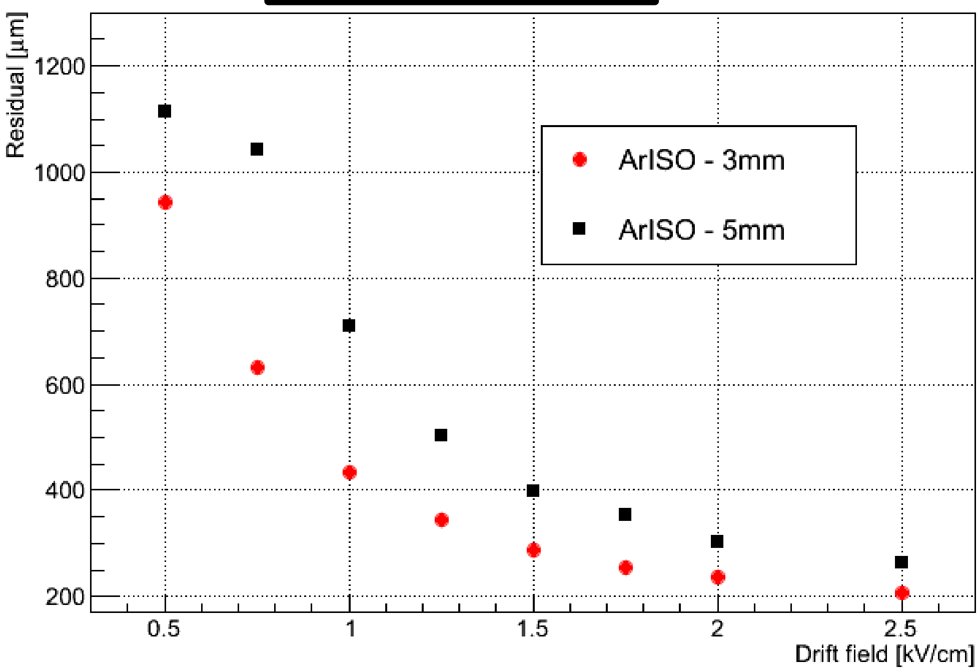
The incident angle of the majority of the BESIII tracks is between -15° and 15°, we have to reach the best resolution in this angular range

Optimization

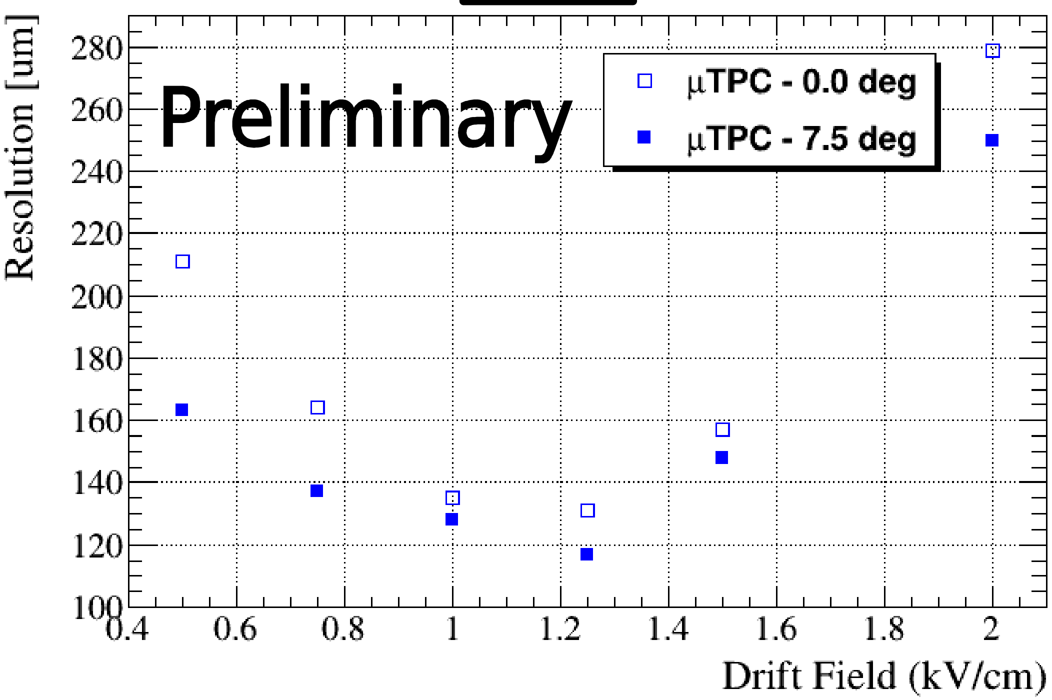
Both reconstruction methods can be optimized varying the field between the cathode and the first GEM

- CC reaches 190μm w/ perpendicular tracks
- μTPC reaches ~120μm w/ angled tracks

Charge centroid



μTPC



CGEM TB Setup

- A CGEM and 4 planar GEMs have been used
- The CGEM geometry is 3/2/2/2 mm between the gaps
- We instrumented only a portion of the detector
- The CGEM and the GEM have the same reference system
- The CGEM has a 42° angle rotation to test the performance of the CGEM with 1T magnetic field along the longitudinal strip