Performance of a triple GEM prototype in magnetic field for the BESIII experiment

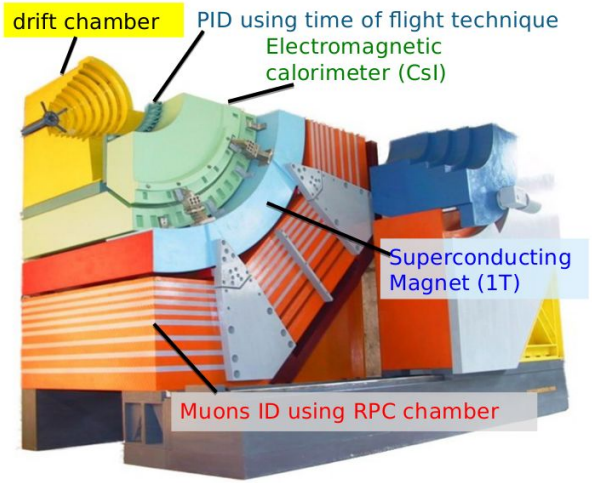
Giulio Mezzadri
INFN Ferrara & University of Ferrara

RD51 Miniweek - Meyrin

Outline

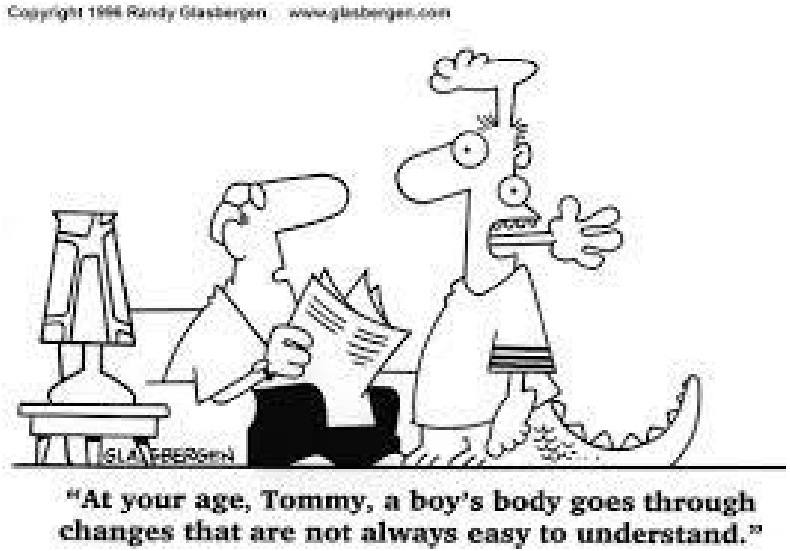
- Intro
  - Aging of the drift chamber
- The CGEM Inner tracker
  - Status of the project
- Study of triple GEM: the peformance in magnetic field
  - Charge centroid
  - μTPC
- Outlook and Summary

Intro


drift chamber
PID using time of flight technique
Electromagnetic
calorimeter (CsI)
Superconducting
Magnet (1T)
Muons ID using RPC chamber

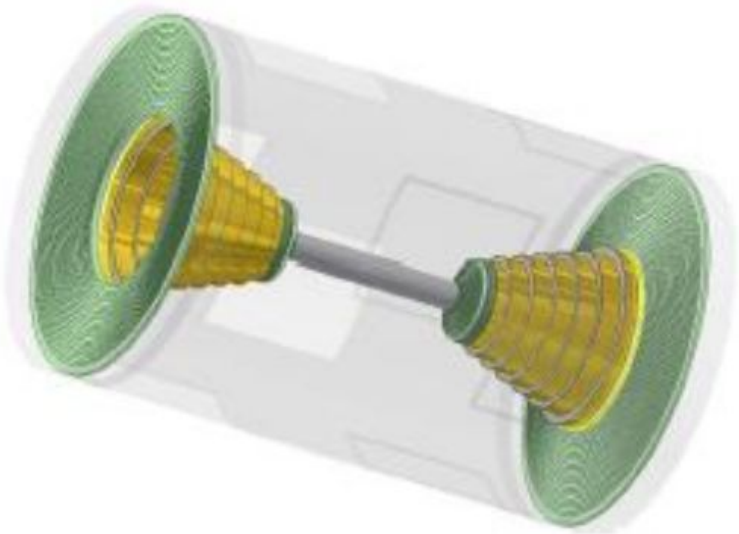

Bird view of BEPCII
Linac
Storage ring
2004: start construction
2008: test run
2009-now: data taking
BESIII at BEPCII
BESIII physics
Charmonium(-like) physics
Light hadron spectroscopy
Charm physics
τ physics

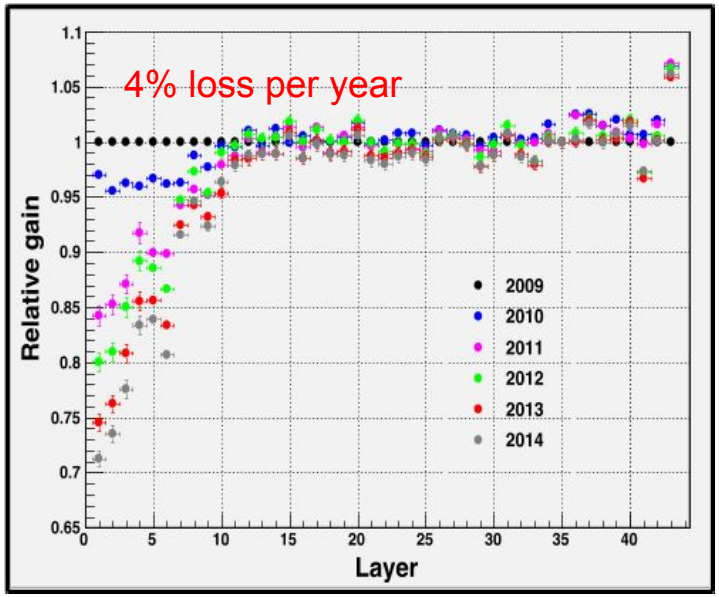
Aging problems



"At your age, Tommy, a boy's body goes through changes that are not always easy to understand."

Aging of the inner drift chamber



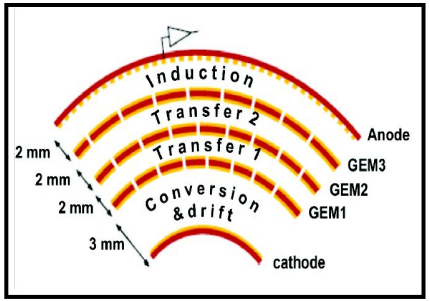


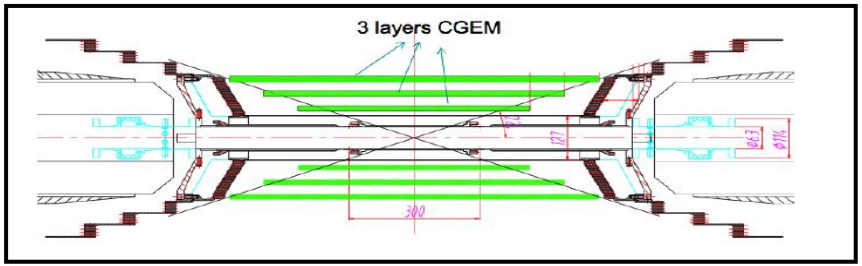
Substitution is scheduled for 2018 with a new inner tracker based on Cylindrical Gas Electron Multipliers

A cylindrical GEM Inner Tracker for BESIII

Experimental requirements to be matched:

- inner radius: 78 mm (min)
- outer radius: 179 mm (max)
- 93% of 4π solid angle
- σ_{xy} ~ 130 μm (per layer)
- σ_z < 1 mm (per layer)
- X_0 < 1.5 %
- Particle flux ~ 10^4 Hz/cm^2



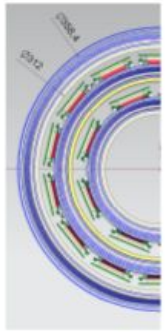


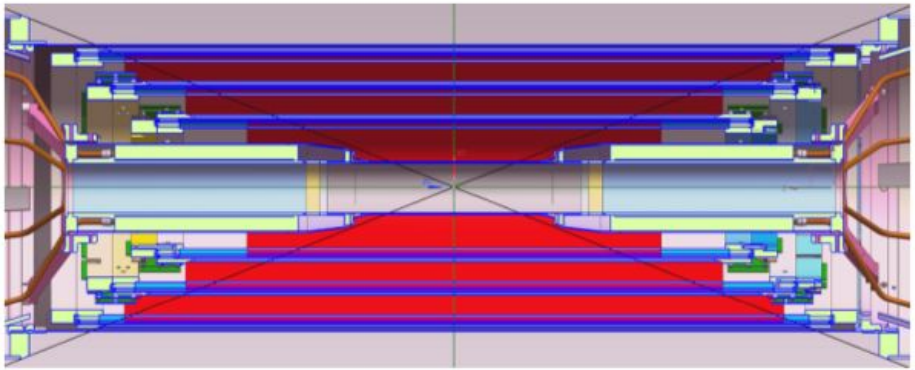
BESIIICGEM funded by the European Commission within the call H2020-MSCA-RISE-2014

Status update

- Design
- Electronics
- Assembly

Design - overview



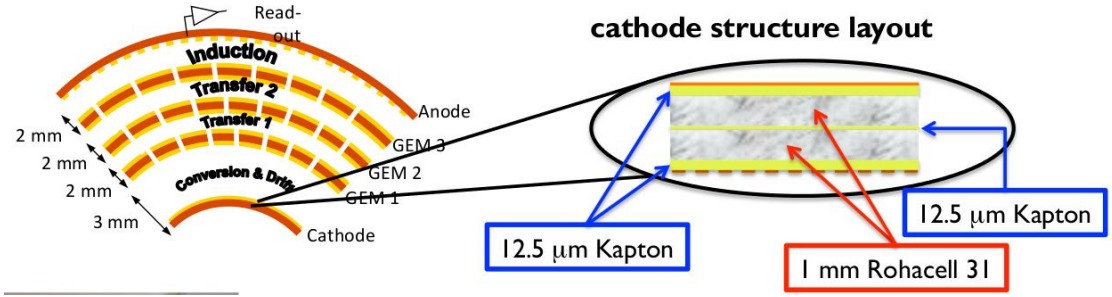


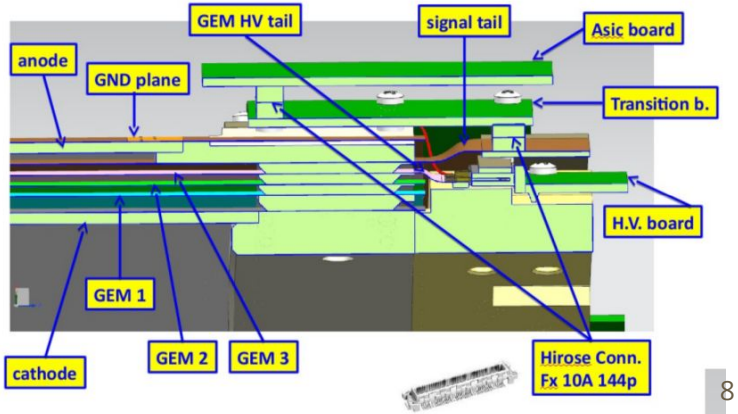
Design of the first two layers completed
Third under discussion

Choices of

- Compact structure
- Electronics to the ends
- Rohacell support

driven by strong space requirements

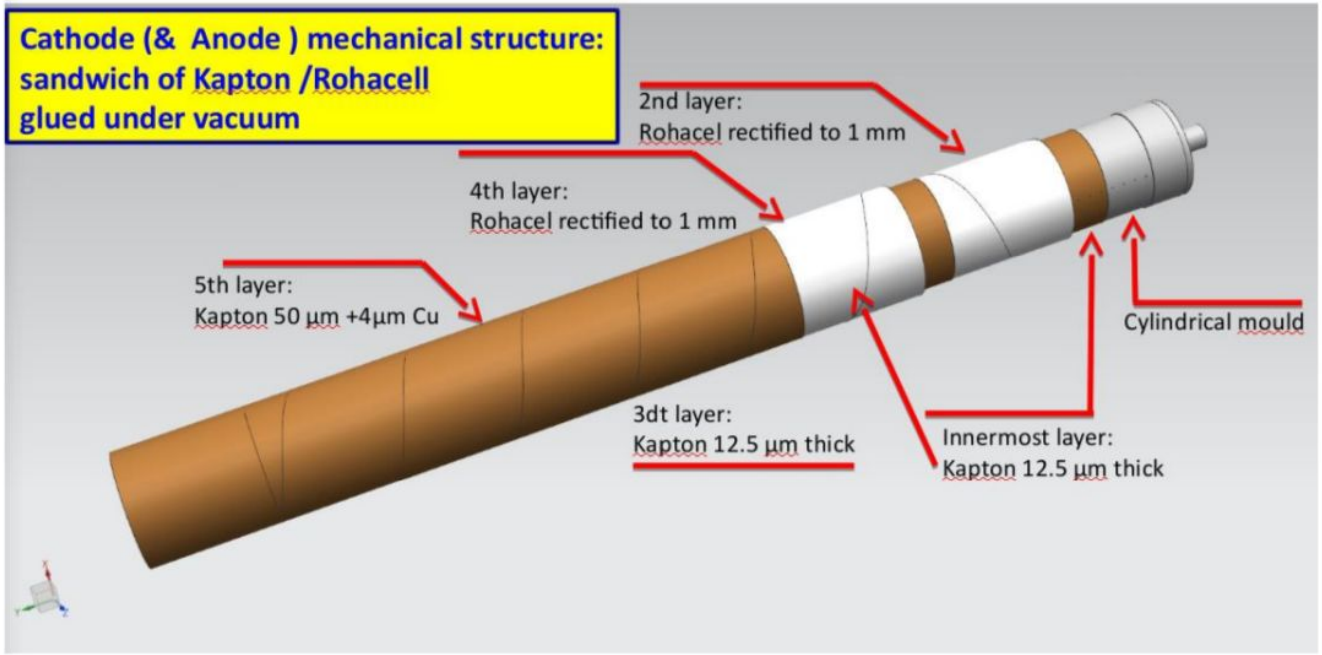




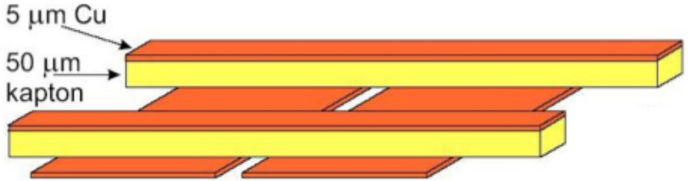
Light structure Rohacell

PMI-based structural foam, extremely light (31 kg/m^3)

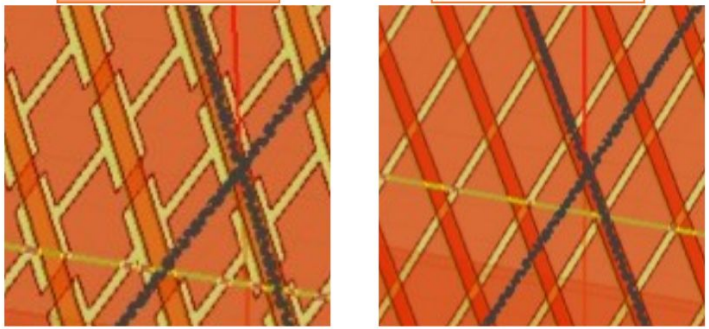
Expected X_0 (per layer) = 0.33%



Anode design



general anode layout



Reducing coupling capacitance

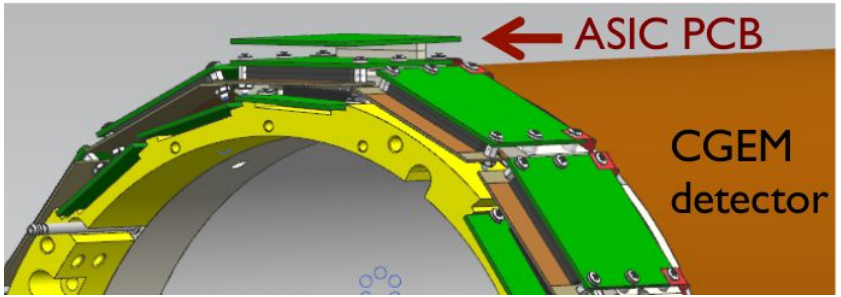
	Layer1	Layer 2	Layer 3
# ch. x	846	1281	1692
# ch. stereo	1176	2193	2838
Stereo angle	45,9	- 33.1	33.0

Large stereo angles impact on the expected resolution along the beam axis

Factor between 4 and 6 of improvement of the resolution wrt the present drift chamber

Asic Design

- UMC 110 nm technology
  - Limited power consumption (< 10 mW/channel)
- Input charge: 3-50 fC
- Sensor capacitance up to 100-150 pF
- Input rate (single strip): up to 60 kHz/ch
- Time and Charge measurements
- Time resolution: 2 ns
  - TDC based on Time Interpolator
- ADC to measure the charge
  - ADC resolution: 10 bit

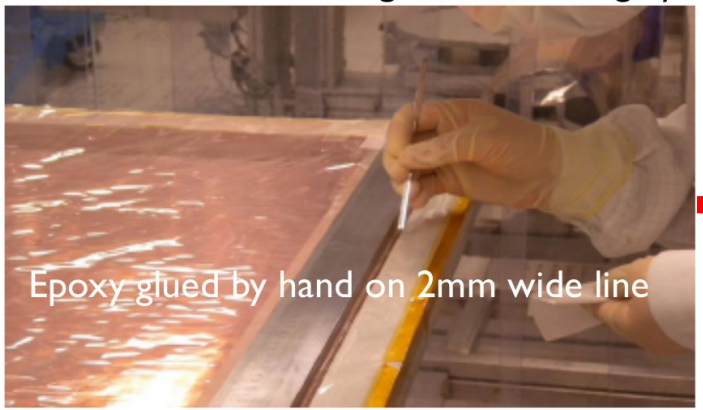


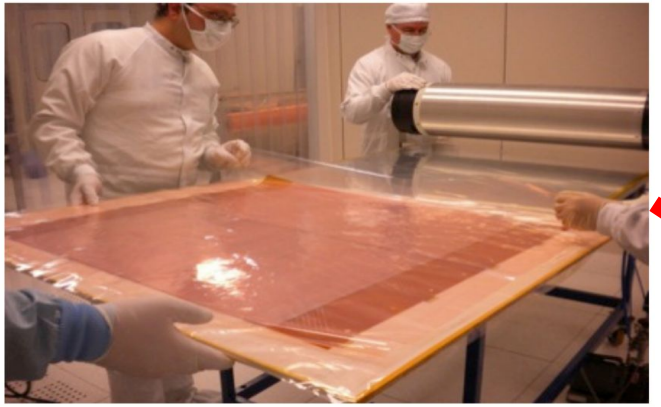
1st prototype submitted to foundry

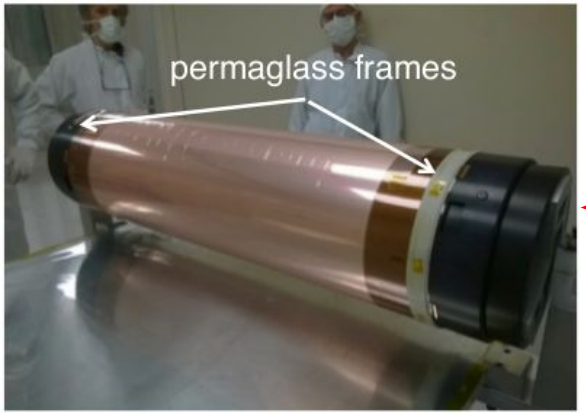
1st test in August 2016

Asic test with detector in October 2016

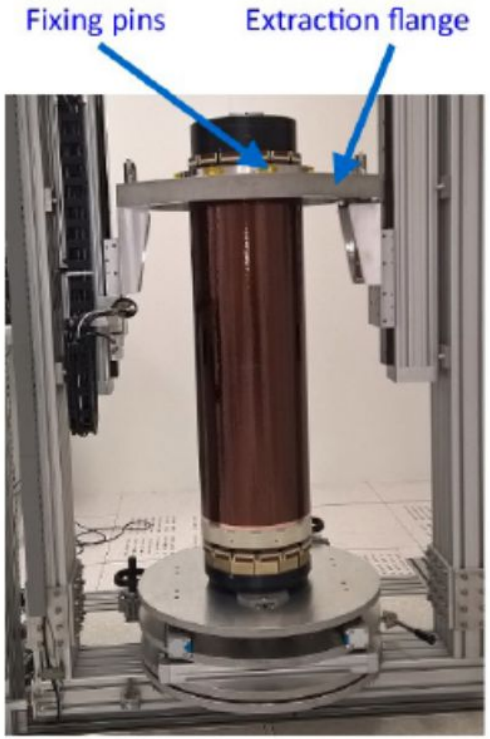
Electrode Assembly



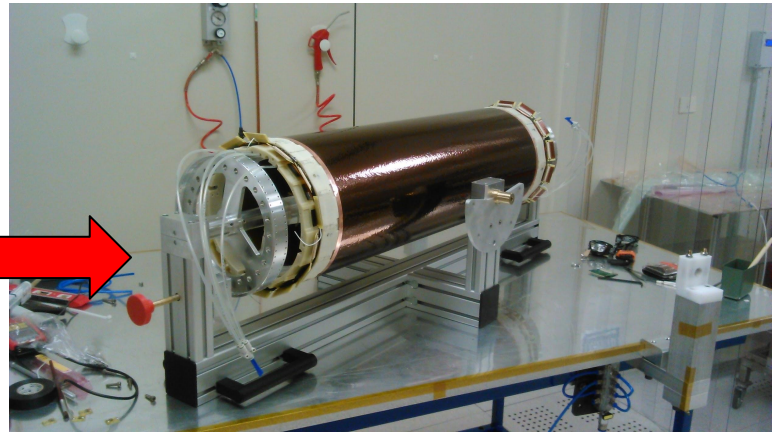




Layer Assembly

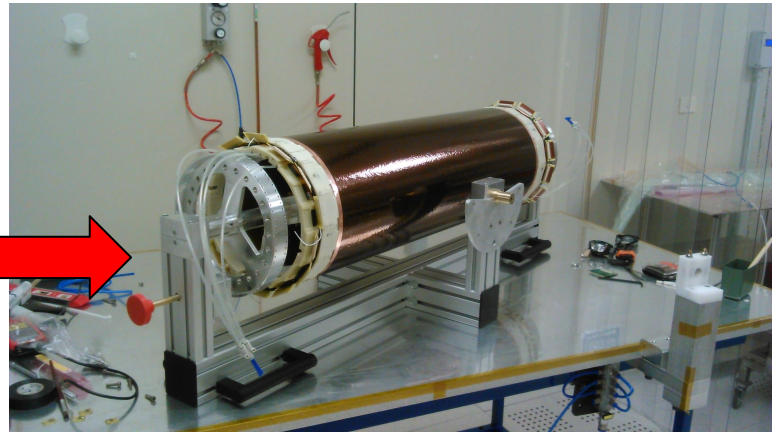


Layer Assembly - II



Final look after the 5 electrodes glueing

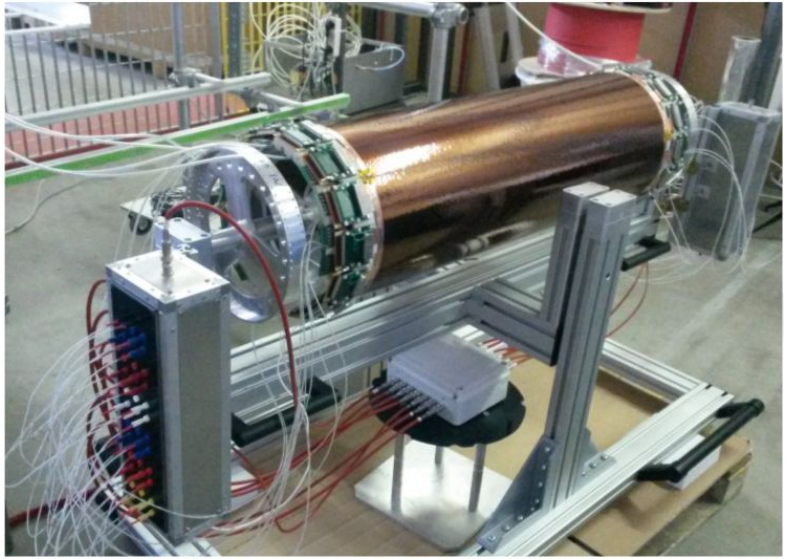
Layer Assembly - II



Final look after the 5 electrodes glueing

First HV test was good!

Next step



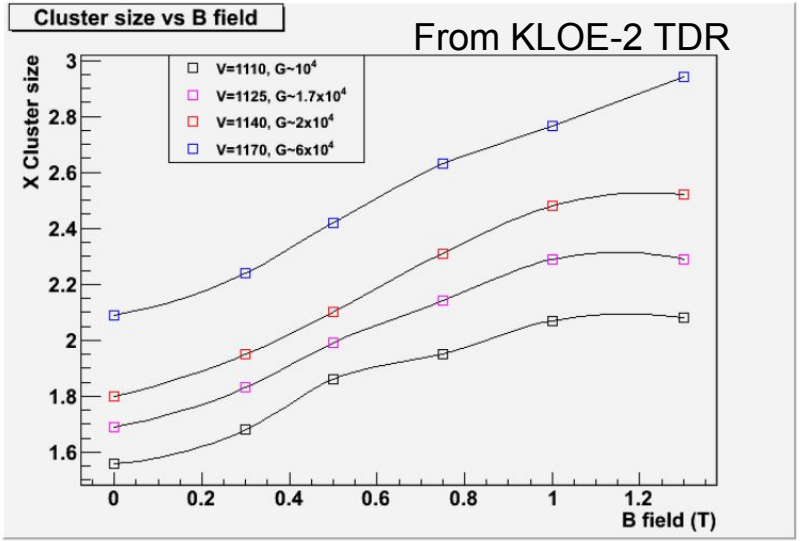
Cosmic rays test @ LNF

Beam test @ H2 in August

Test beam results in magnetic field

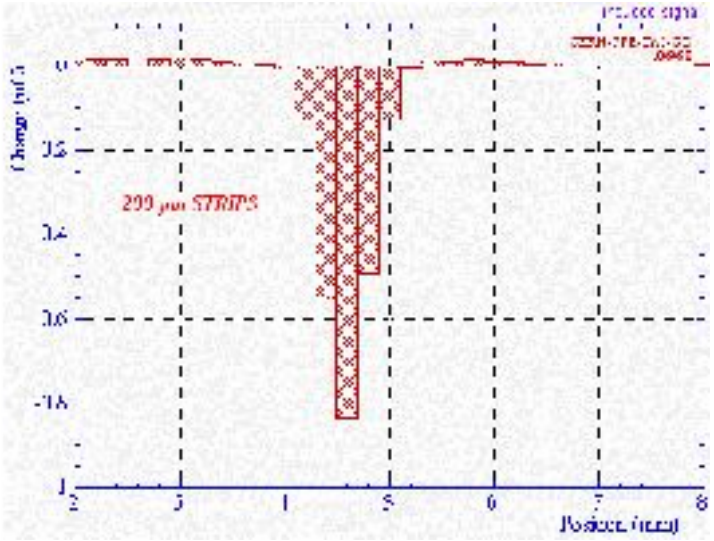
- Test beam setup
- Center of gravity
- µTPC readout

Measuring the spatial resolution



Digital readout degrades with magnetic field

Analog readout with charge centroid reconstruction was chosen



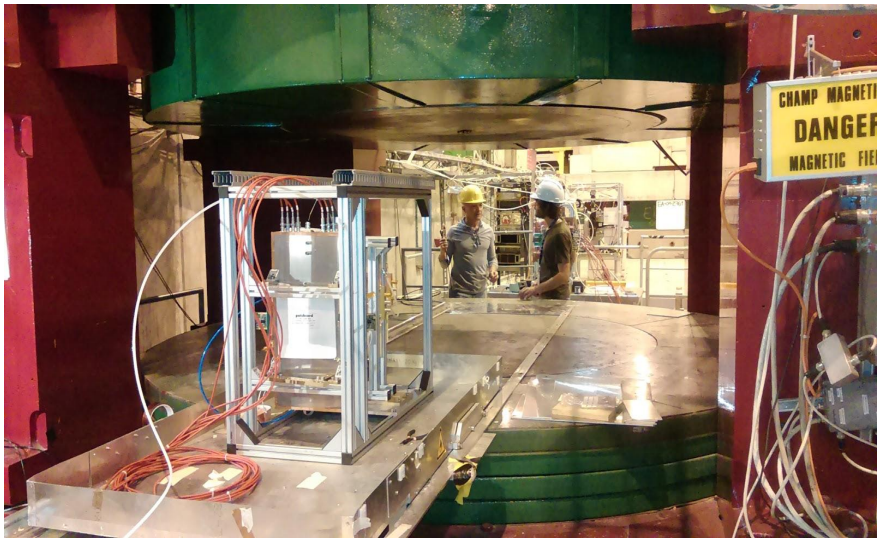
Idea was discussed inside the MPGD community....

A Cylindrical GEM Detector with Analog Readout for the BESIII Experiment

Gianluigi Cibinetto
(INFN Ferrara)
on behalf of the BESIIICGEM consortium

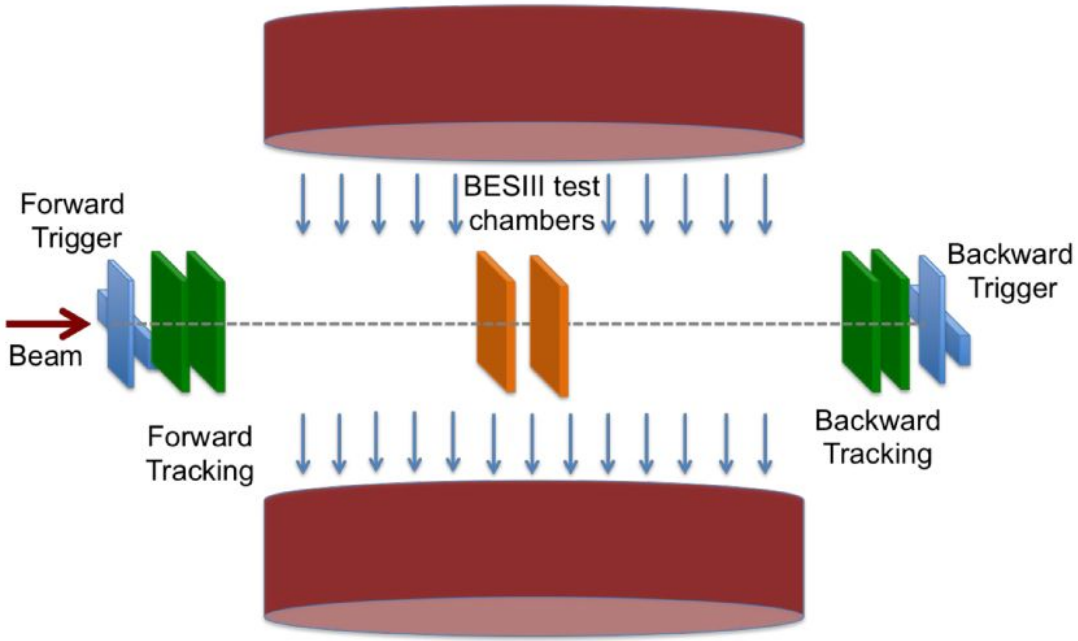
...and tested in 2 test beams

December 2014



June 2015

2015 Test beam setup

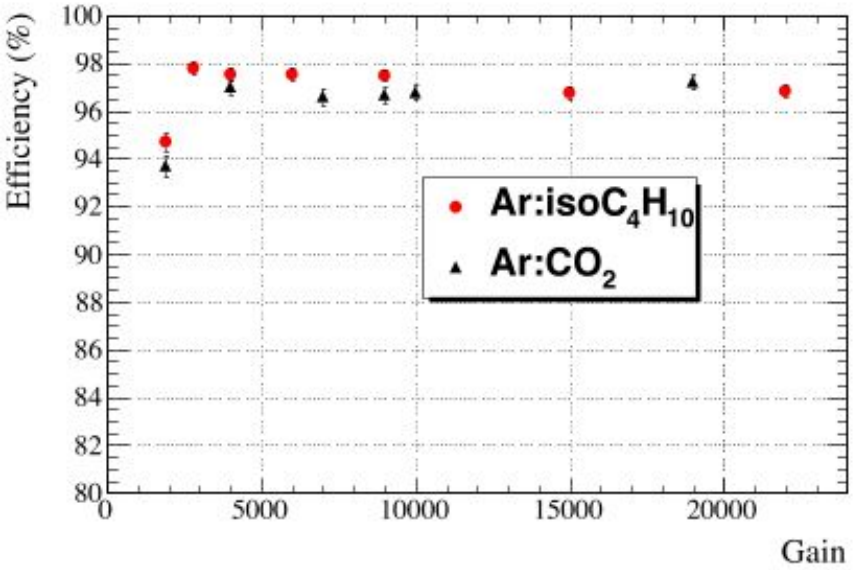


Tested 2 planar 10x10 cm^2 planar prototypes up to 1 Tesla

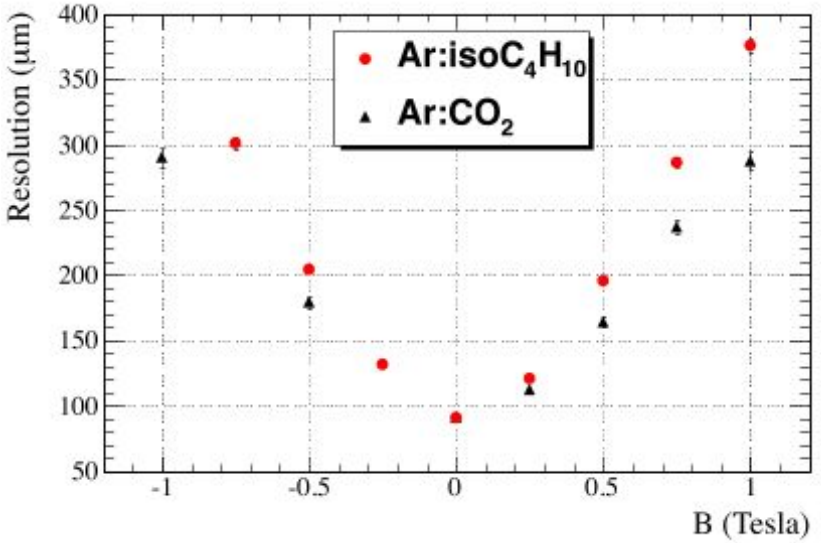
with different gas mixtures ArCO2(70/30) and ArISO(90/10)

And drift gaps (3 mm and 5 mm)

Charge centroid method



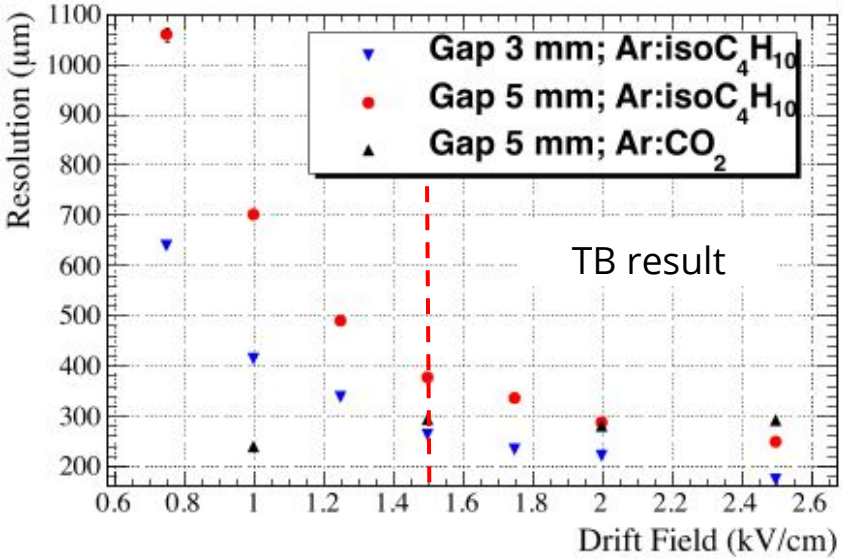
We were able to measure 90 μm resolution with gain of 6K with no magnetic field

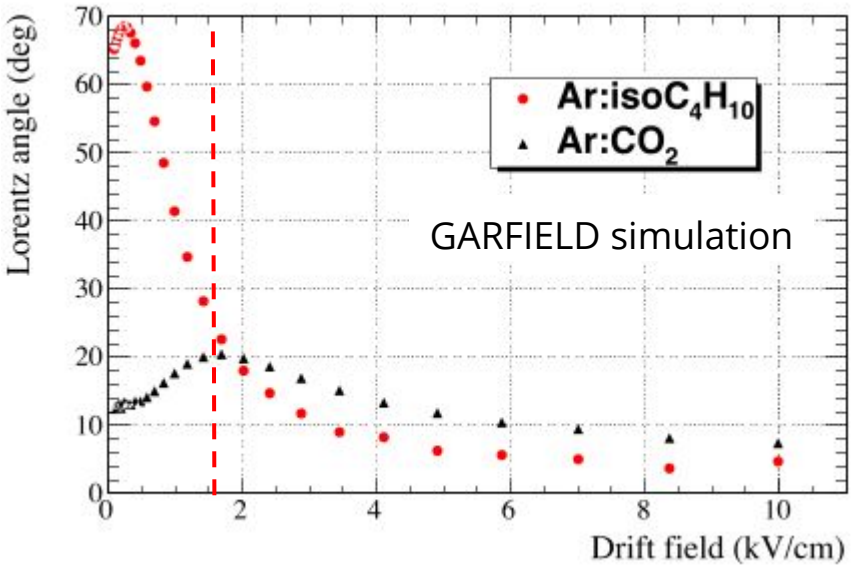


With strong B field, distortion of the avalanche from the gaussian shape

Charge centroid method - Drift field scan

Resolution follows the lorentz angle behaviour

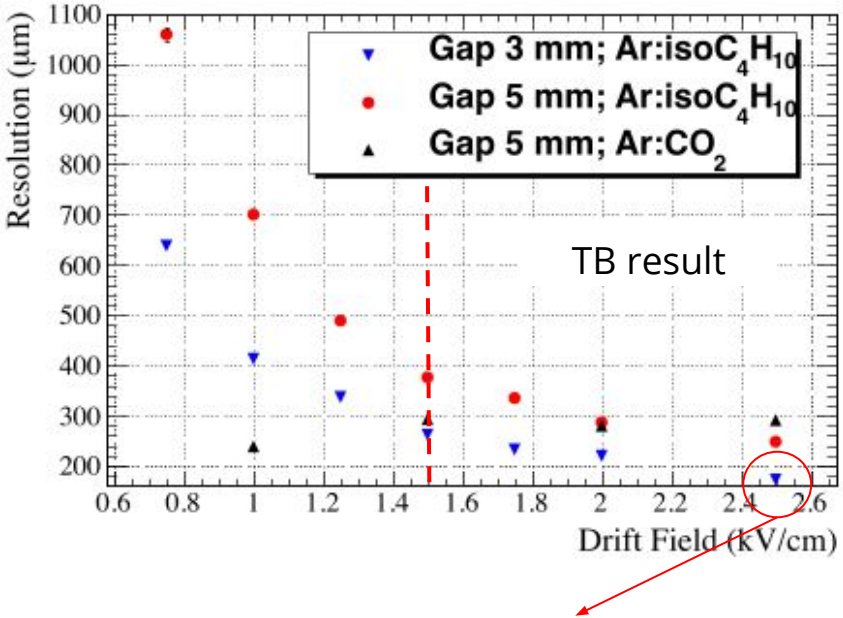


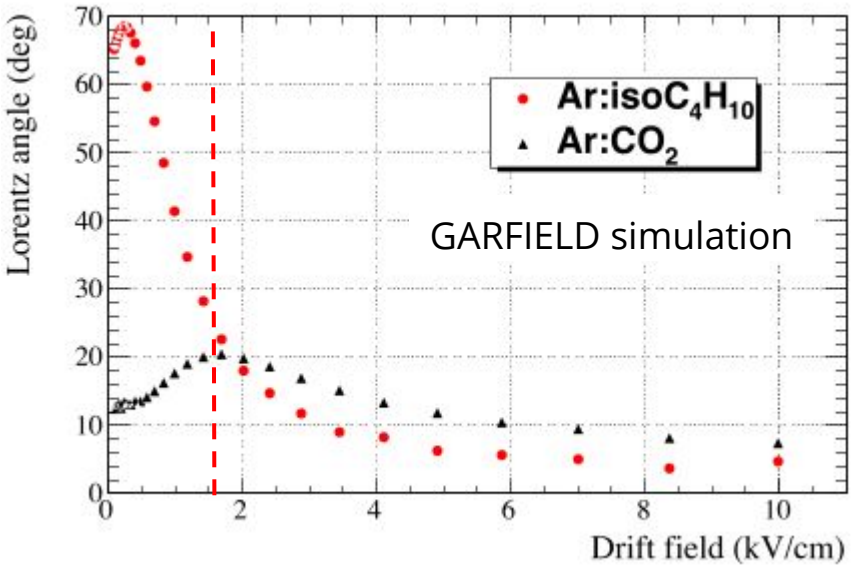


Red dashed line standard drift field (1.5 kV/cm)

Charge centroid method - Drift field scan

Resolution follows the lorentz angle behaviour



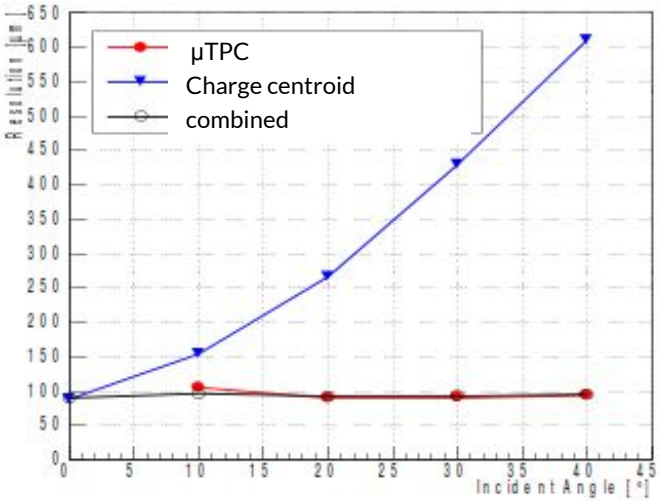


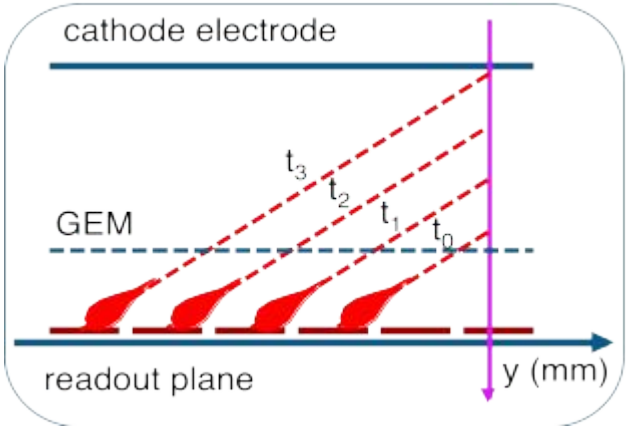
Resolution with magnetic field lower than 200 μm

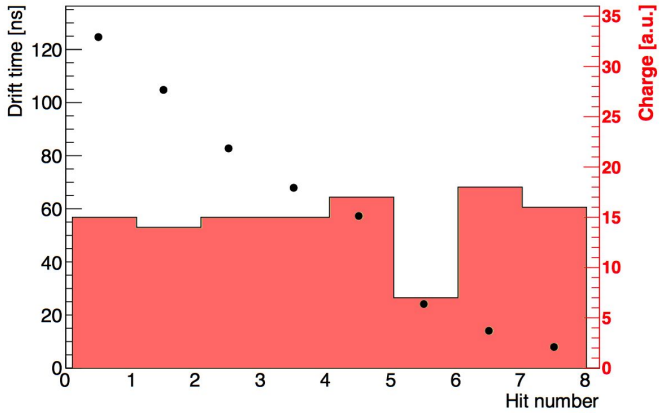
Principles of μTPC readout

Technique that allows to use time information to reconstruct cluster position

Our ASIC is able to cope with both readout method







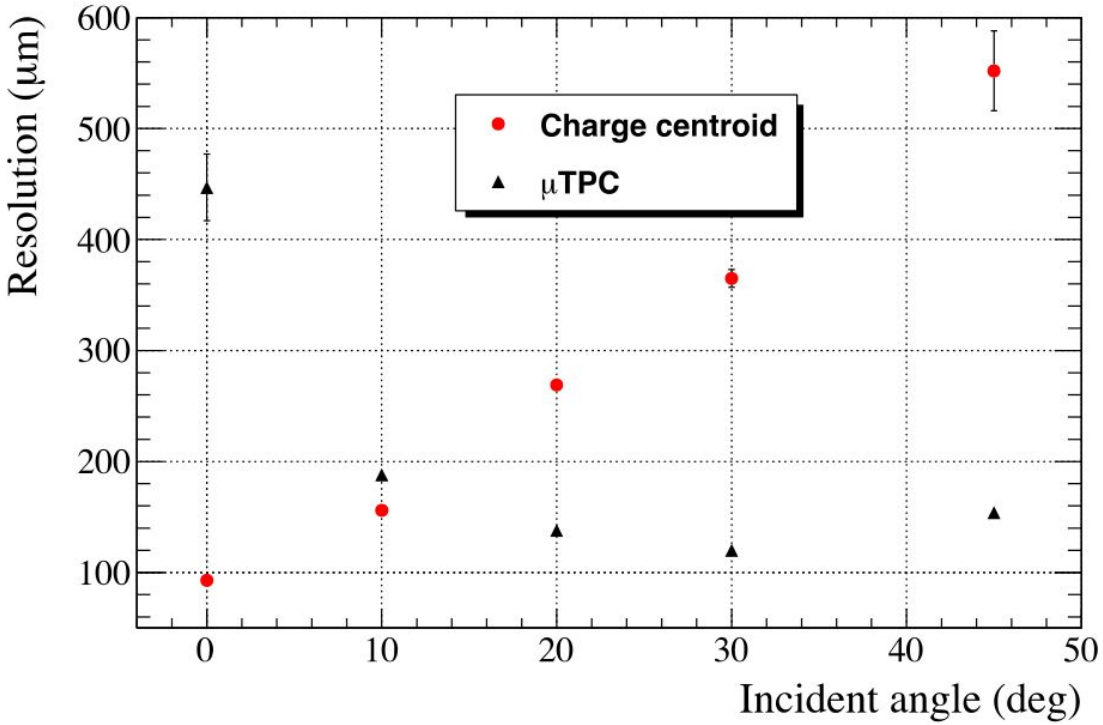
Features of μTPC readout

- Larger drift gap: from 3 mm to 5 mm implies better track reconstruction
  - More point for the time projection position estimation

- Spatial resolution limited by time resolution
  - Statistic of the ionization
  - Detector feature
  - Electronics

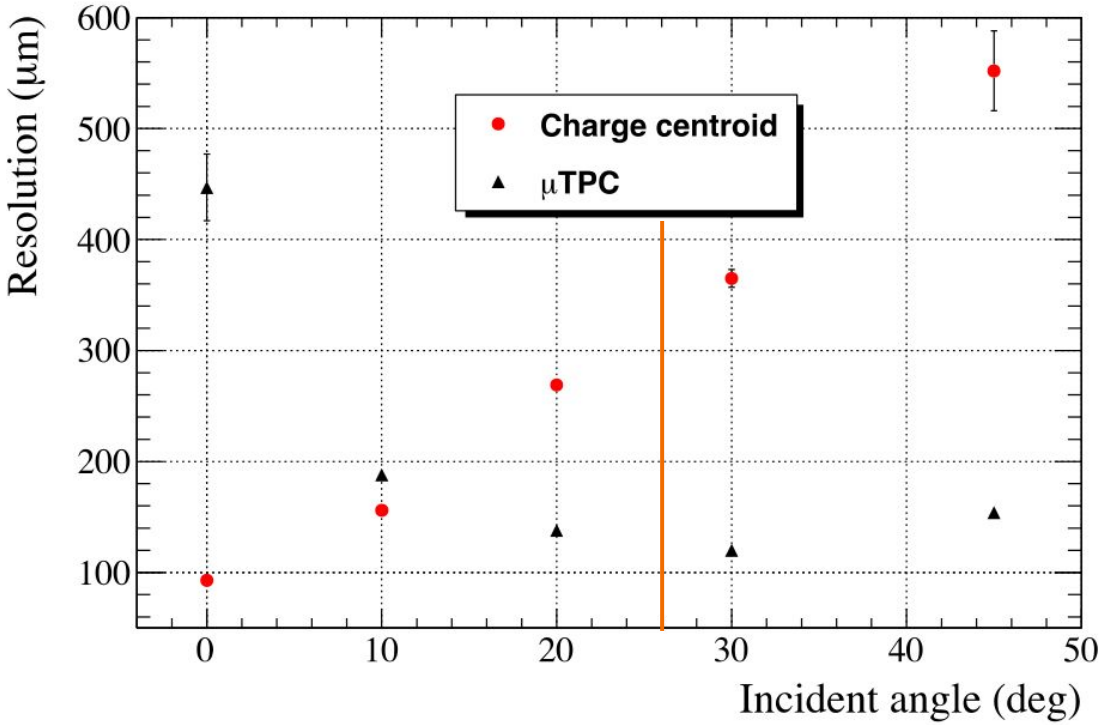
- More complicated reconstruction, but provides more information on the track
  - Idea for the future: global tracking with μTPC

μTPC results with no magnetic field



- First implementation of μTPC readout for triple GEMs
- Best spatial resolution results with incident tracks

μTPC results with no magnetic field



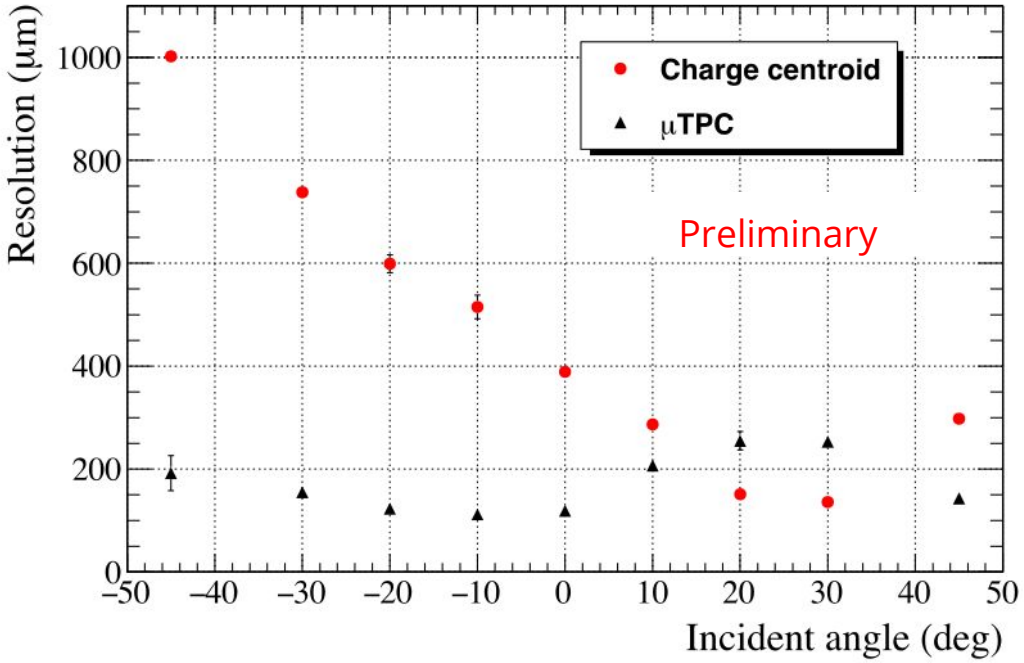
- First implementation of μTPC readout for triple GEMs
- Best spatial resolution results with incident tracks

From GARFIELD:
- Lorentz angle ~ 26°

In data:
- Expected resolution with B=1T ~ 130 μm

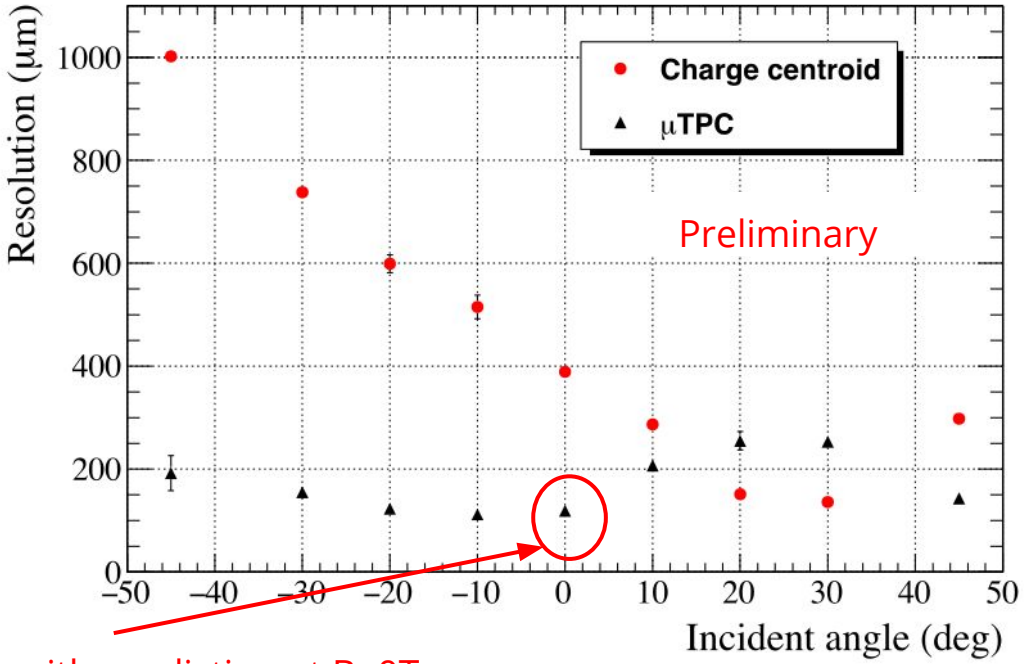
μTPC results with magnetic field

First implementation of μTPC readout on a tripleGEM with magnetic field



μTPC results with magnetic field

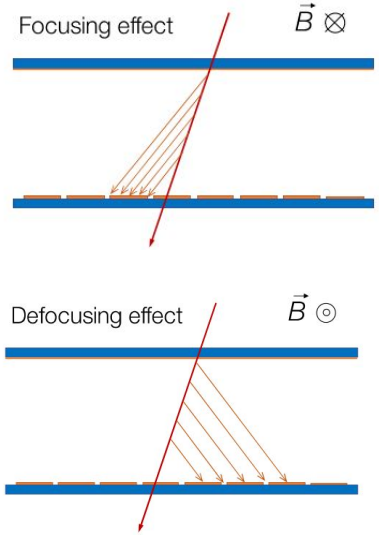
First implementation of uTPC readout on a tripleGEM with magnetic field

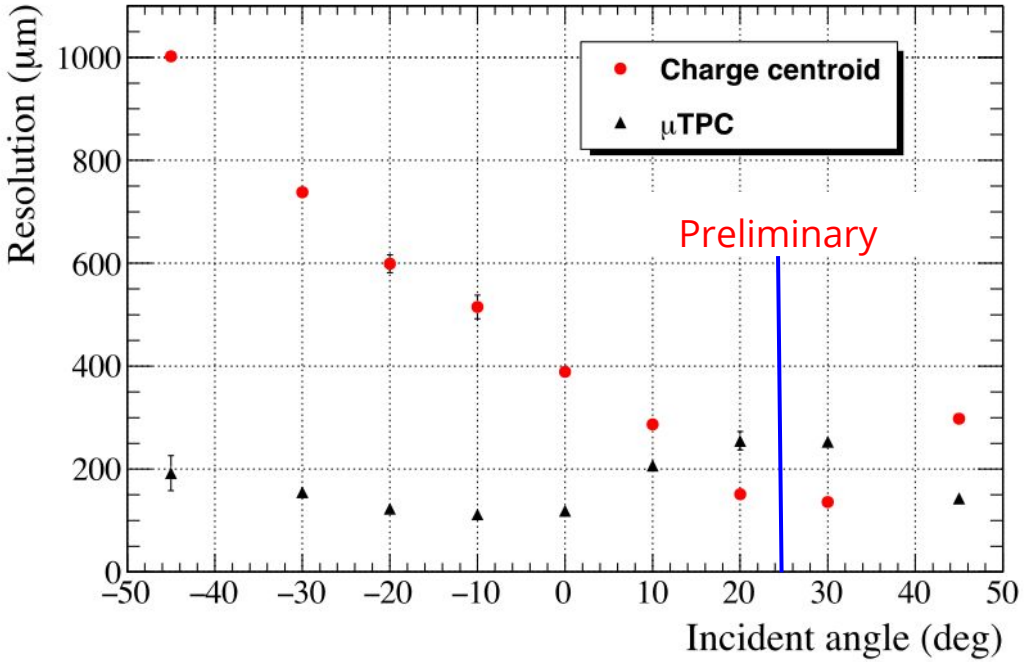


Compatible with prediction at B=0T

μTPC results with magnetic field

First implementation of uTPC readout on a tripleGEM with magnetic field





In correspondence of the lorentz angle

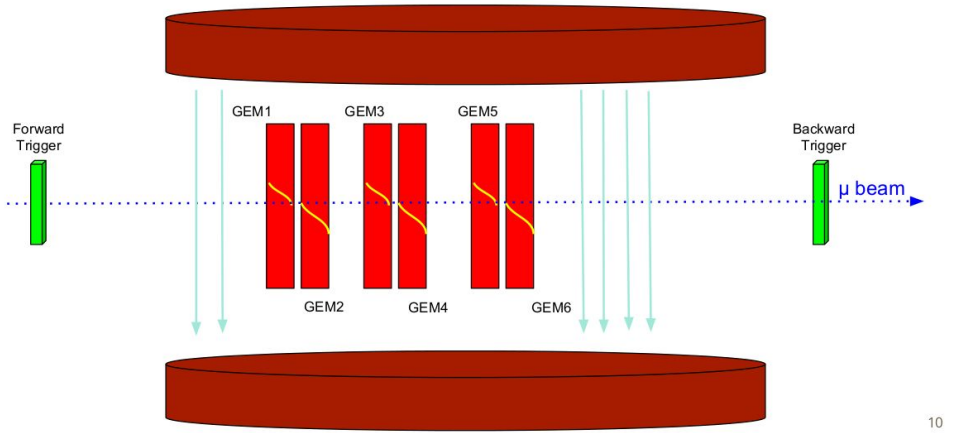
maximum focusing effect

Charge centroid resolution improves

Further Studies on μTPC

Test beam with 6 planar prototype back-to-back (finished yesterday):

Exploit the full potentiality of μTPC readout with different drift fields and angles



Tomorrow during WG7 there will be a presentation by R. Farinelli! **Stay tuned!**

Final outlook

- Due to aging problems, BESIII DC-IT needs an upgrade
- CGEM-IT will deploy several new features and innovation with respect to the state-of-art Cylindrical GEM detector
  - Rohacell
  - Analog readout
  - Jagged Anode
- 1st ASIC prototype has been submitted
  - Tested before the end of the year
- The first cylindrical prototype is ready
  - Construction technique validated
  - Test in August in H2 beam line

Final outlook

- Analog readout allows charge centroid method and uTPC readout
- With the charge centroid method
  - In B = 0T, state-of-art performances in spatial resolution
  - In B = 1T, resolution degrades due to avalanche shape distortion
    - With gas, drift gap and field optimization resolution better than 200 μm
- First implementation of uTPC readout for tripleGEM detector with
  - Incident angles different from zero
  - Magnetic field
- Preliminary studies show that spatial resolution largerly improves
- A new test beam has just finished
  - Goal: Exploit the full potential of uTPC readout.


Thanks!