The CGEM-IT of the BESIII experiment

Project update and test results in magnetic field

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Outline

BESIII Experiment (details in Cui Li, Petterson, Boger, Wencheng Yan talks)

Aging of the MDC Inner Tracker (MDC-IT)

The Project

- Gas Electron Multipliers (GEM) Detector
- Status

Test Beam

- Preliminary results in magnetic field
- μTPC studies

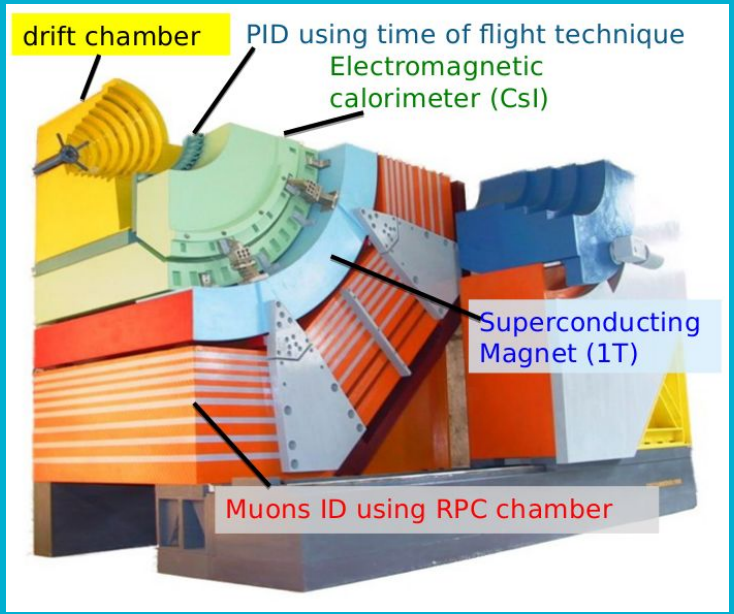
Bird view of BEPCII

BESIII physics

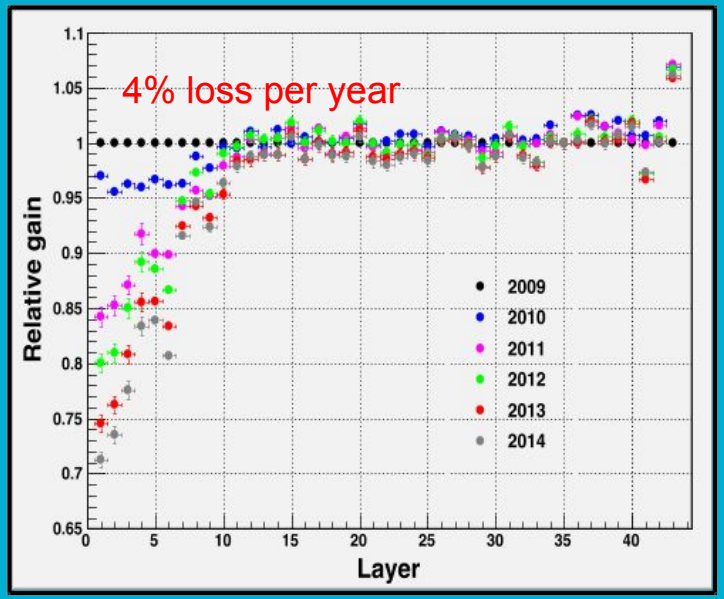
- Charmonium(-like) physics
- Light hadron spectroscopy
- Charm physics
- τ physics

Aging Problem

Aging of the DC-IT



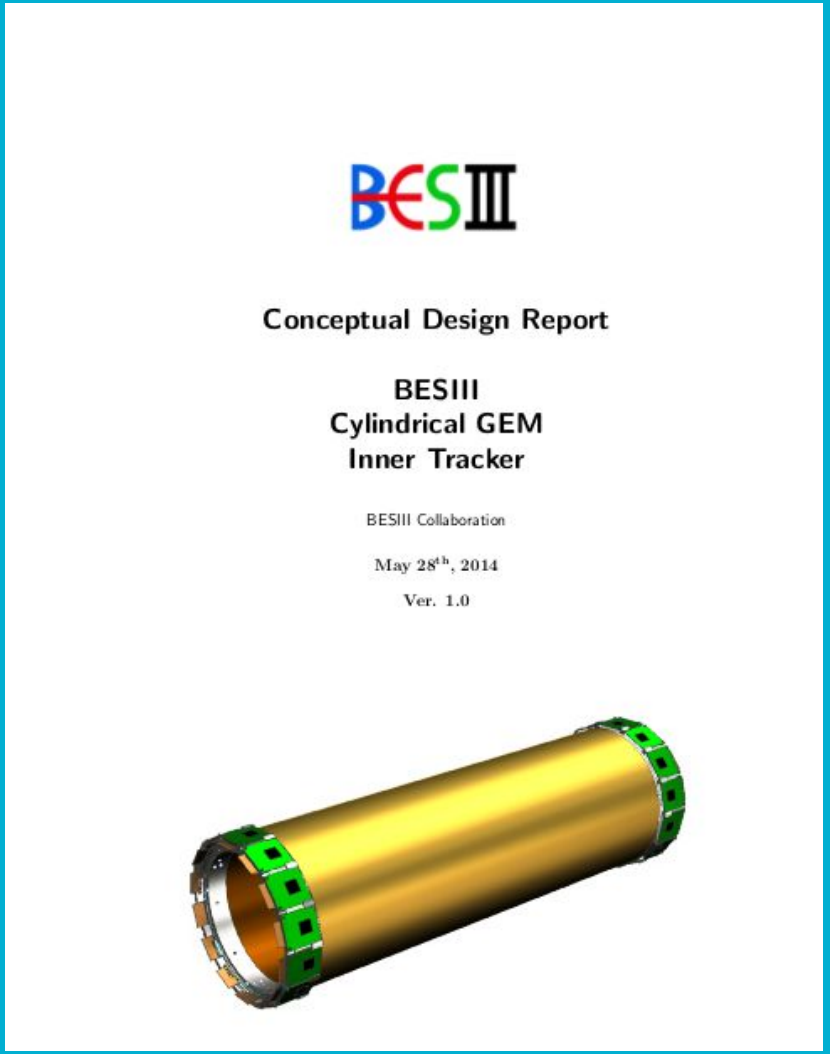
I. Juric and J. Kadyk, LBL-21170 (1986)141



Inner drift chamber is showing aging effect

If loss continues, replacement needed by 2018

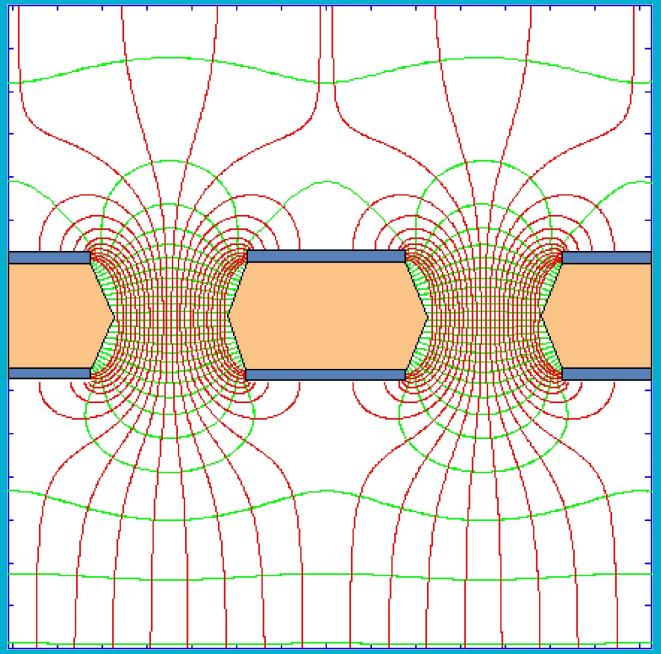
A proposed solution to match the experimental requirements



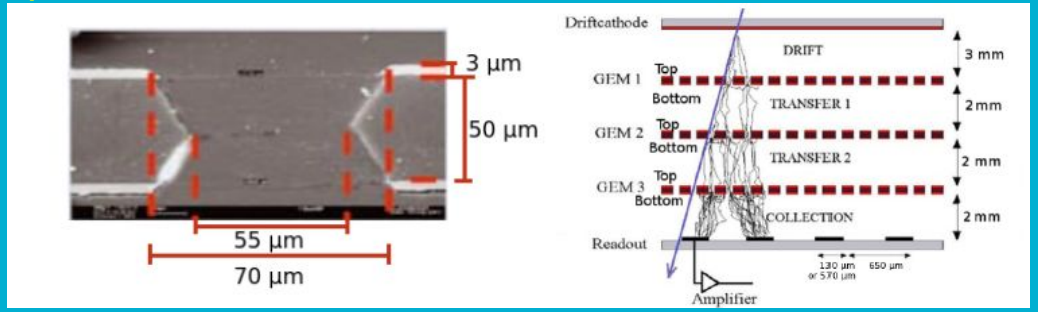
CGEM-IT Project

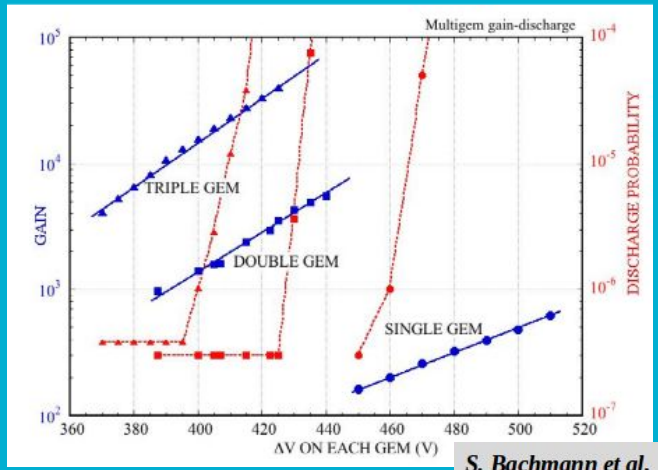
Gas Electron Multipliers (GEMs)

Micro Pattern Gas Detector based on thin (50 μm) metal-coated polymer foil with high density of holes



F. Sauli, Nucl. Instr. and Meth. A386(1997)531





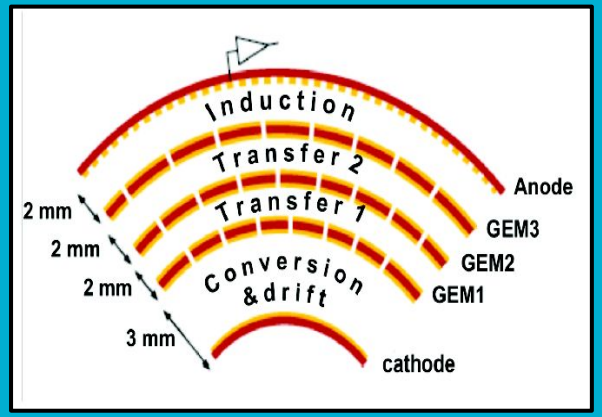
discharge rate on a 5 MeV α

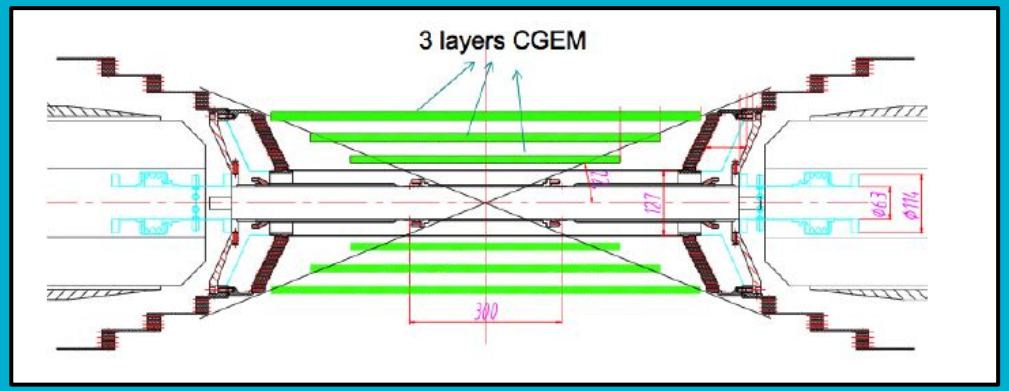
S. Bachmann et al, Nucl. Instr. and Meth. A479 (2002) 294

CGEM-IT project

Requirements for BESIII new IT:

- 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 %
- Trigger rate ~ 10^4 Hz/cm^2





Ministero degli Affari Esteri e della Cooperazione Internazionale

"Significant Research Project"
MAECI-MOST 2013-2015

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

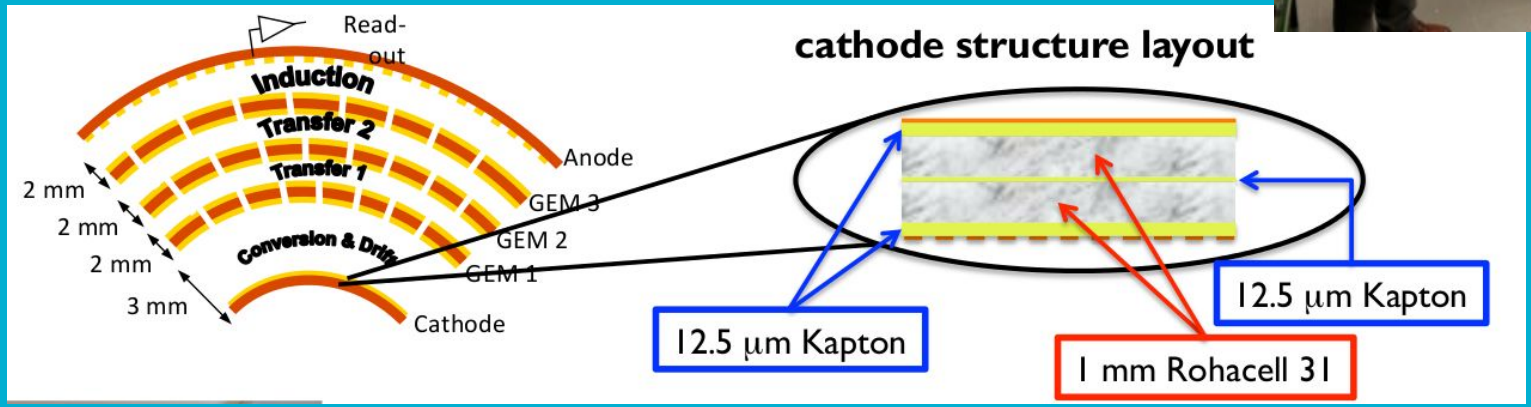
BESIIICGEM project involves Uppsala, Mainz, INFN-Fe, INFN-LNF, INFN-To and IHEP

Features
Rohacell structure

To match the requirements of budget material, idea to use Rohacell to give mechanical rigidity to anode and cathode.

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

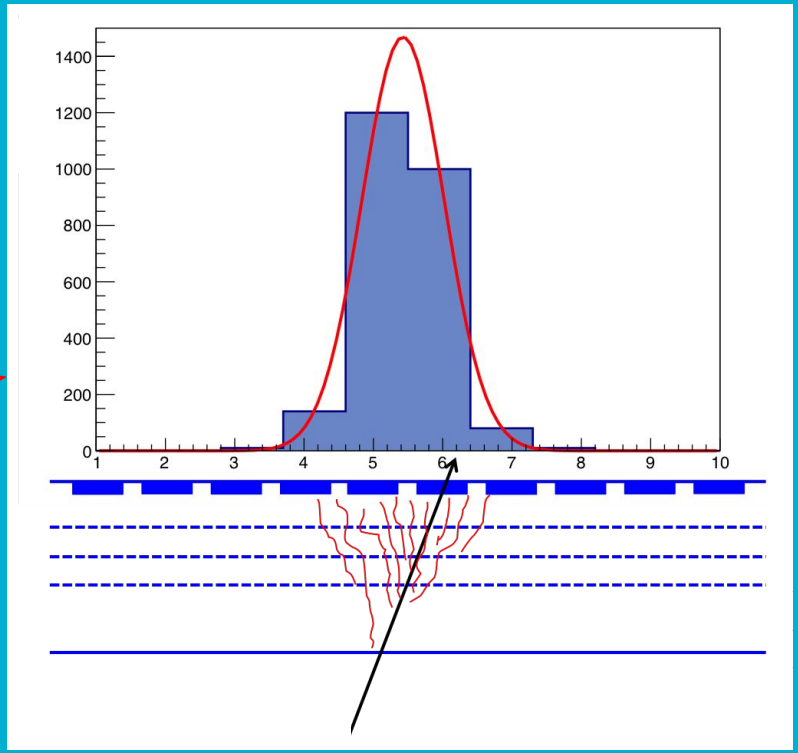
Expected X_0 (per layer) = 0.33%



Features
Analog readout

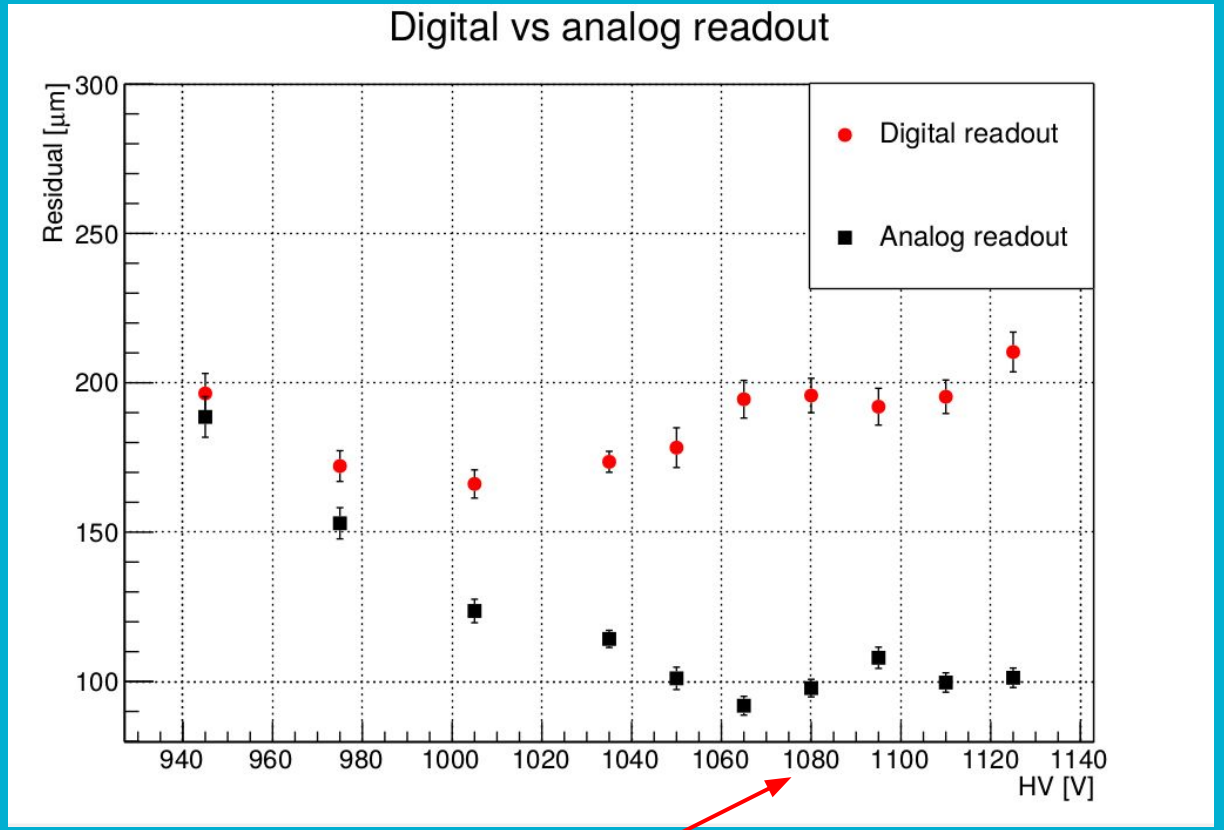
Analog readout best compromise between number of readout channel and spatial performances

To achieve desired resolution charge centroid method was implemented



Features
Analog readout

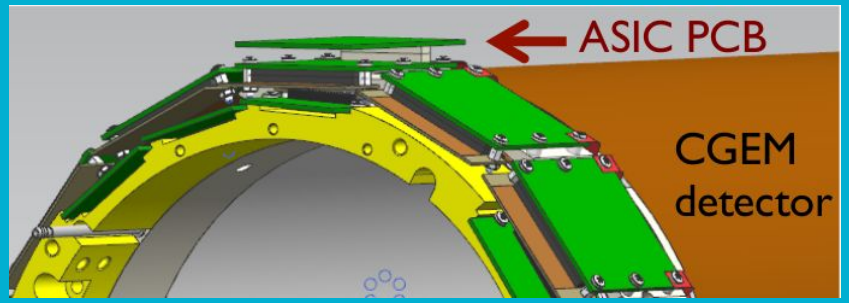
Comparable results with state-of-art planar GEM in absence of magnetic field



Gain ~ 10K

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

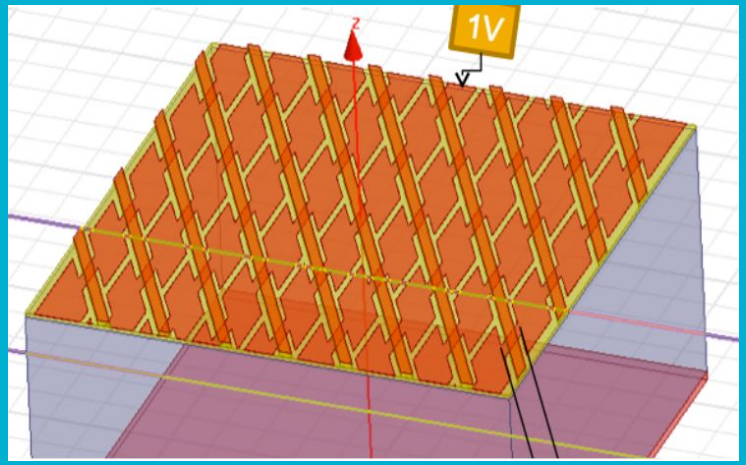


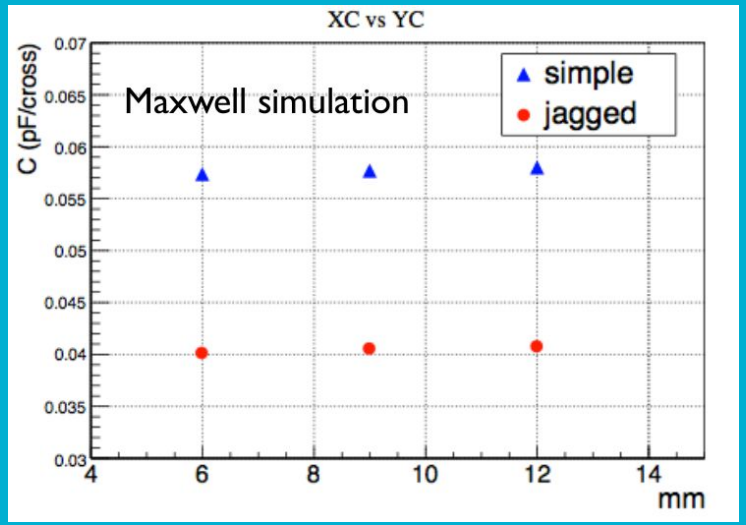
Features
Jagged anode

BESIII will deploy a readout plane produced by TS-DEM department at CERN

- large strip capacitance
- stereo angle
- ground plane at 2mm from readout

Jagged anode aims to reduce inter-strip capacitance up to 30% with respect to simple configuration





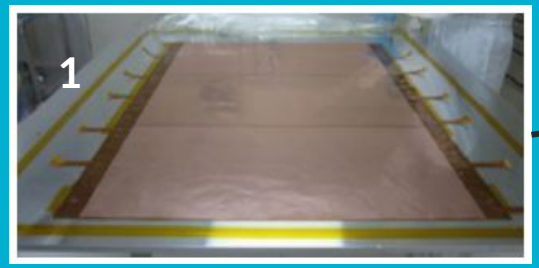
More than a new technology detector:

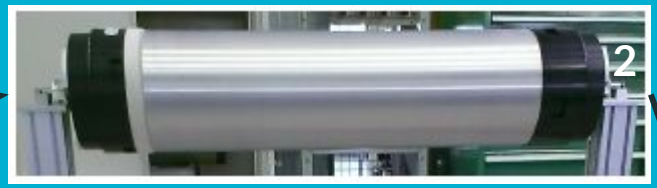
- ➔ Improved resolution along the beam direction -> Better resolution on secondary vertex with respect to MDC-IT
  - Better Background rejection
  - Reconstruction efficiency improves for rare decays with complex topology

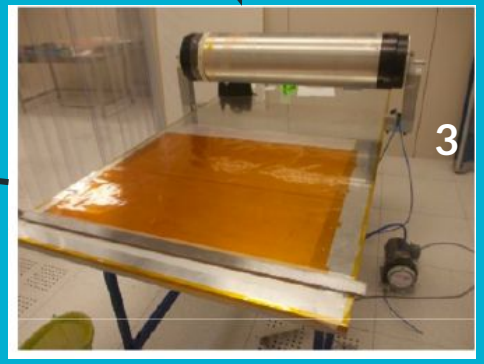
- ➔ Without losing momentum resolution:
  - Precise information on high momentum particle to be sensible at golden channel for BESIII (Charm decays, XYZ studies)

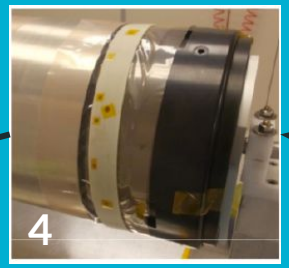
- ➔ Long reliability:
  - BESIII will run until 2022, possible extension to 2024

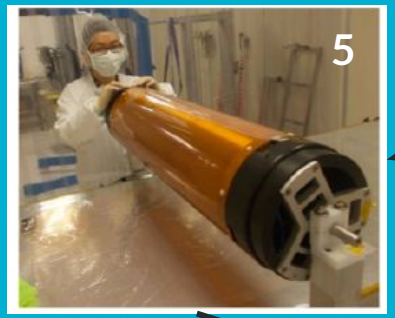
Assembly procedure

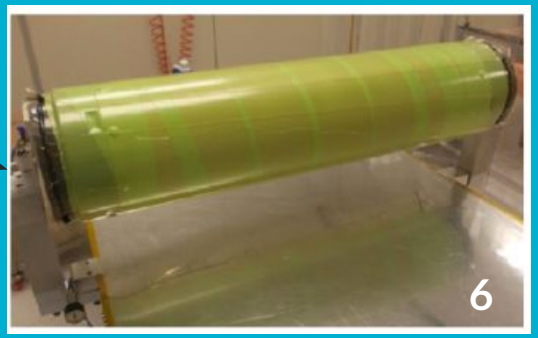










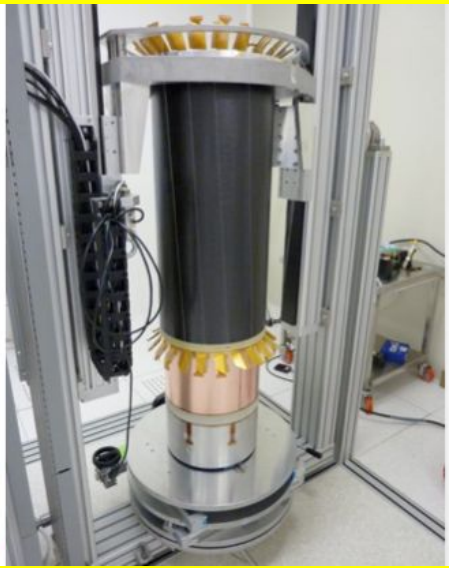


Assembly procedure

The first cylindrical prototype is being finally assembled in these days in Laboratori Nazionali di Frascati

Special vertical insertion technique with micrometric system allows perfect control and keep cylindrical shape safe

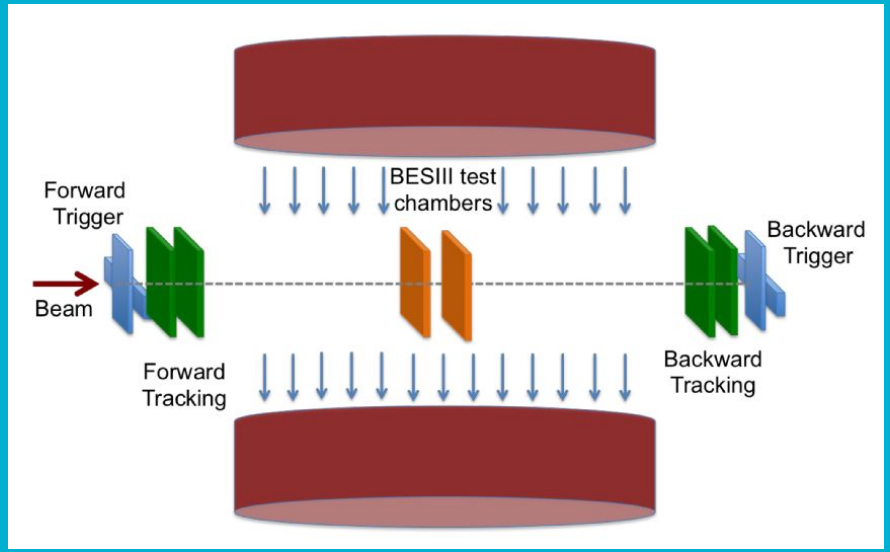
(photos courtesy of KLOE-II)



Test Beam studies with planar prototypes

Setup

- Performed last June at H4 line @ SPS at CERN
- Tested two different planar 10x10 cm^2 planar prototypes:
  1. Jagged anode with XV strip
  2. Linear anode with XY strip



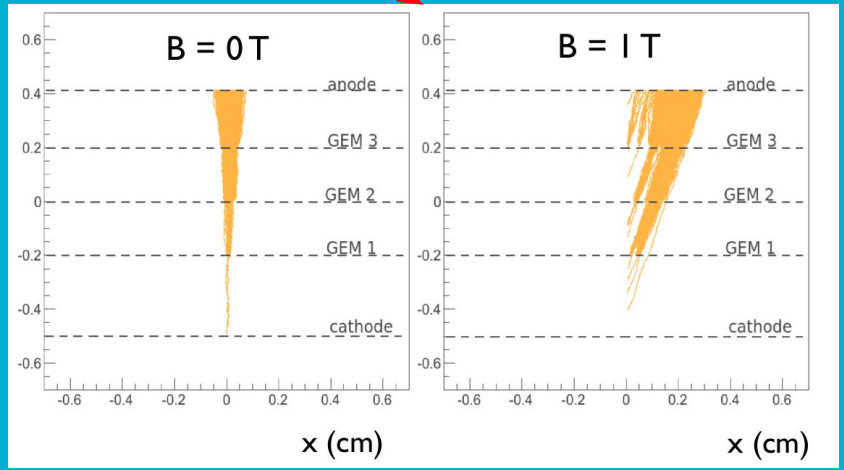
- Magnetic field provided by GOLIATH
  - Only prototypes influenced by magnetic field
- Several gas mixtures and electric field configuration tested

Effect of the Magnetic Field

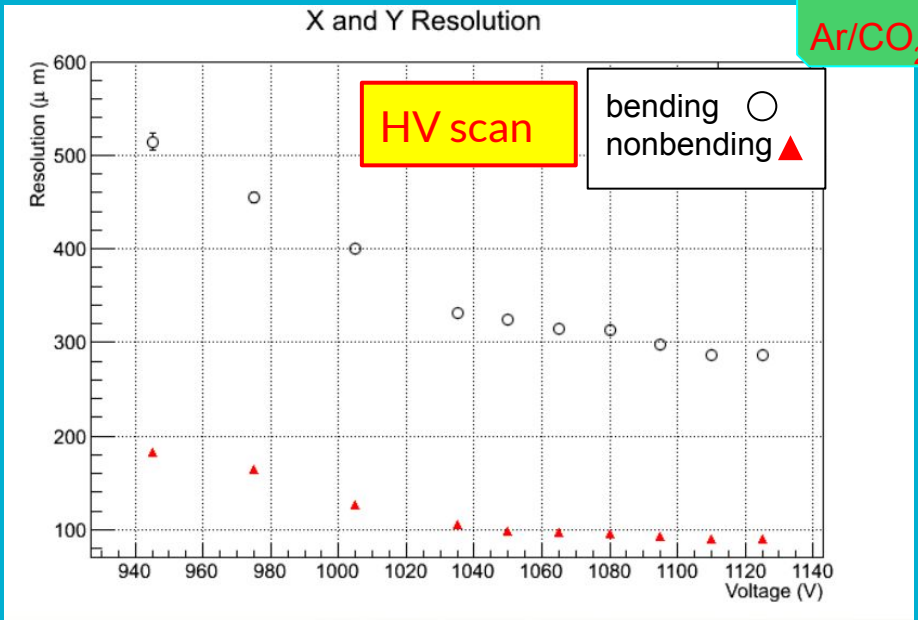
Two main effects occur:

1. Bending of the particle trajectory in the lab -> correction to alignment (TRIVIAL)
2. Broadening of charge distribution -> Lorentz angle

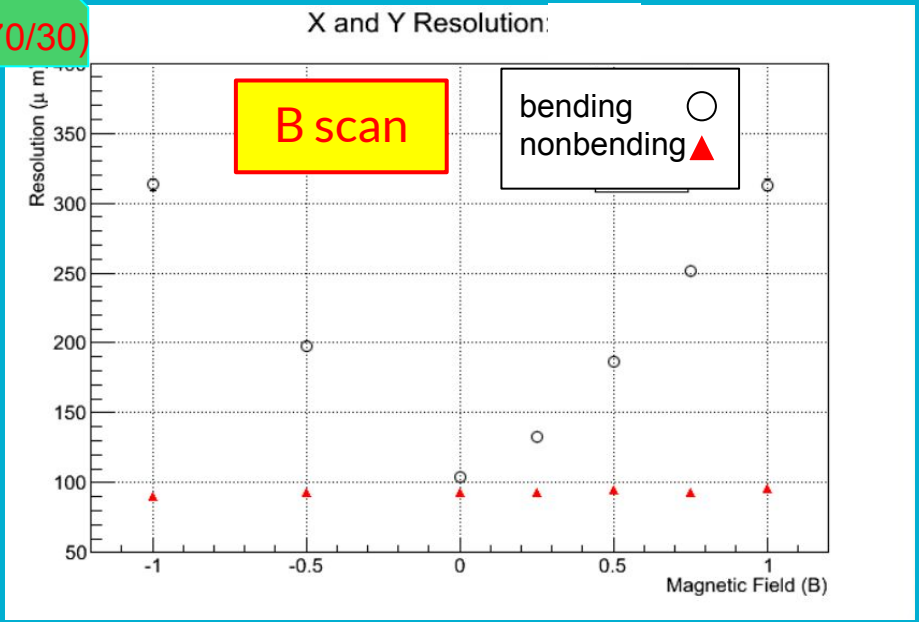
Charge distribution no longer gaussian. Expected worsening of the charge centroid method performances



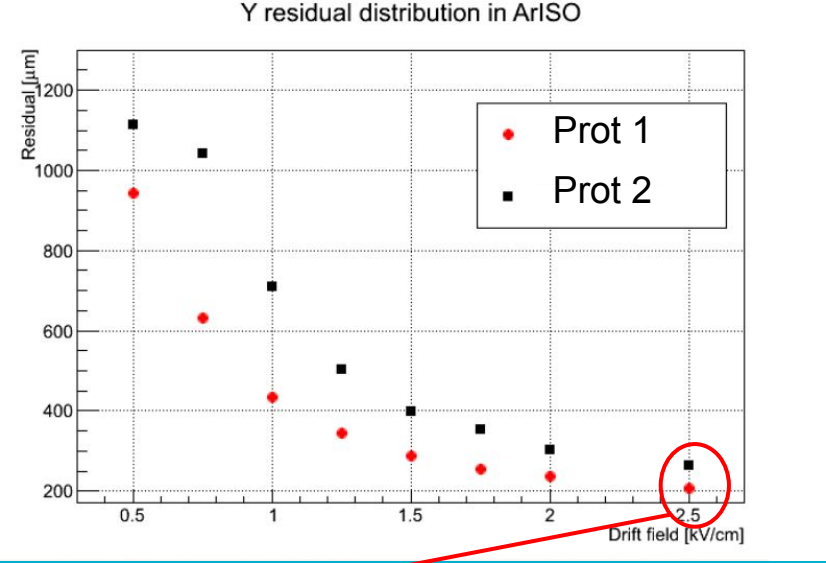
Preliminary Results - Magnetic Field



Ar/CO_2 (70/30)

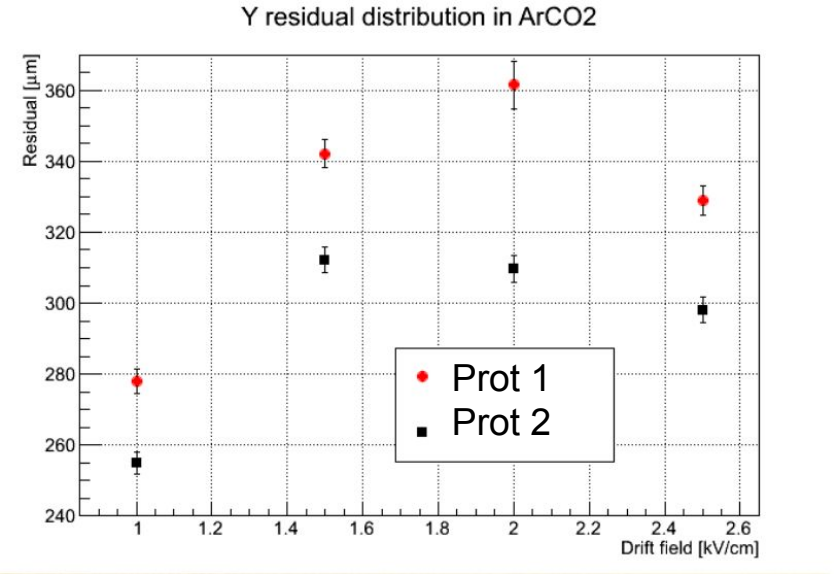


Preliminary Results - Magnetic Field



Drift field scan

Resolution close to 200 µm
Best result with GEM in high magnetic field



Residual distribution follows behaviour of Lorentz angle wrt to drift field

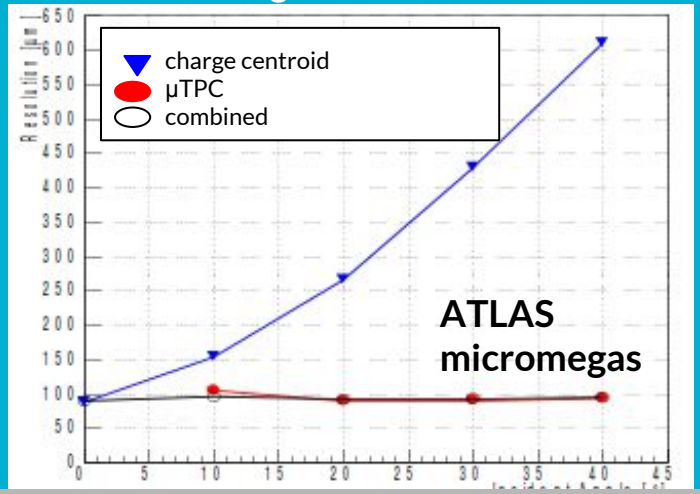
μTPC readout

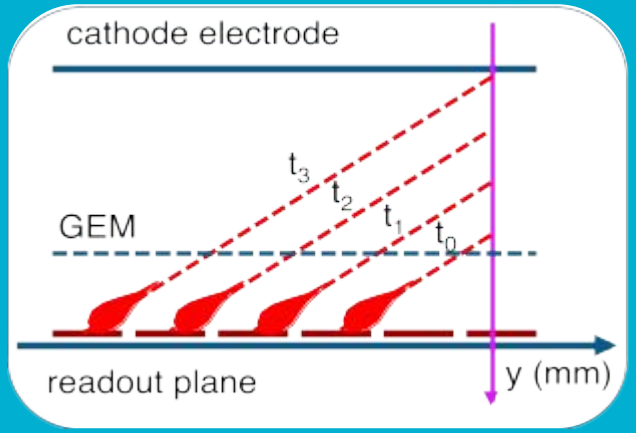
Principles of μTPC readout

Time information of the hit can be used to identify the track path inside the gap

Operate the GEM as a small TPC (i.e. μTPC)

Due to the charge spread, at large angles or with high magnetic field, time measurement is more precise than charge centroid



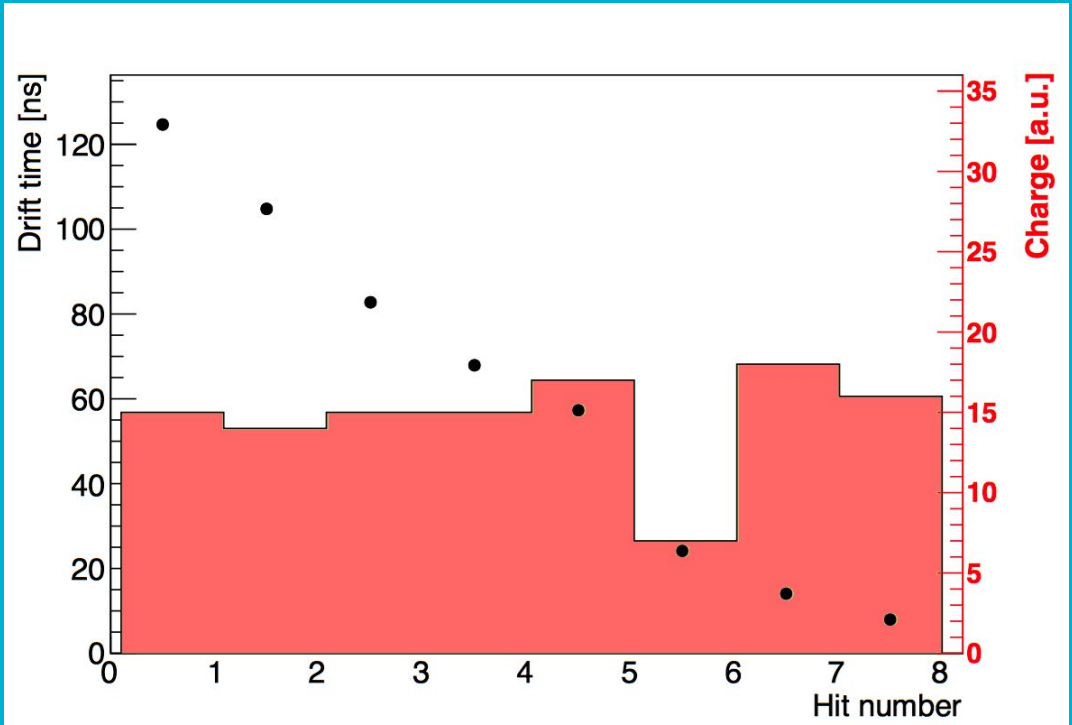


Technique has been successfully tested for ATLAS small wheel upgrade with MicroMegas

Also proposed to improve space resolution for GEM based neutron detectors

μTPC vs Charge Centroid

In red the charge distribution, black dots represents the reconstructed hit from the μTPC



Ar/Isobutane (90/10) gas mixture
45° particle incident angle

Summary and Outlook

- The present Inner Tracker of the BESIII experiment is showing aging effects

- A proposal for a new IT, based on CGEM technology was discussed
  - Innovative features (Rohacell, analog readout, jagged anode) will be deployed
  - With the same momentum resolution, improve the resolution along the beam direction

- First layer is being built in these days
  - Cosmic rays run
  - Beam test before of the end of the year

Summary and Outlook

- Preliminary results of a 10x10 cm^2 prototype shows state-of-art resolution without magnetic field

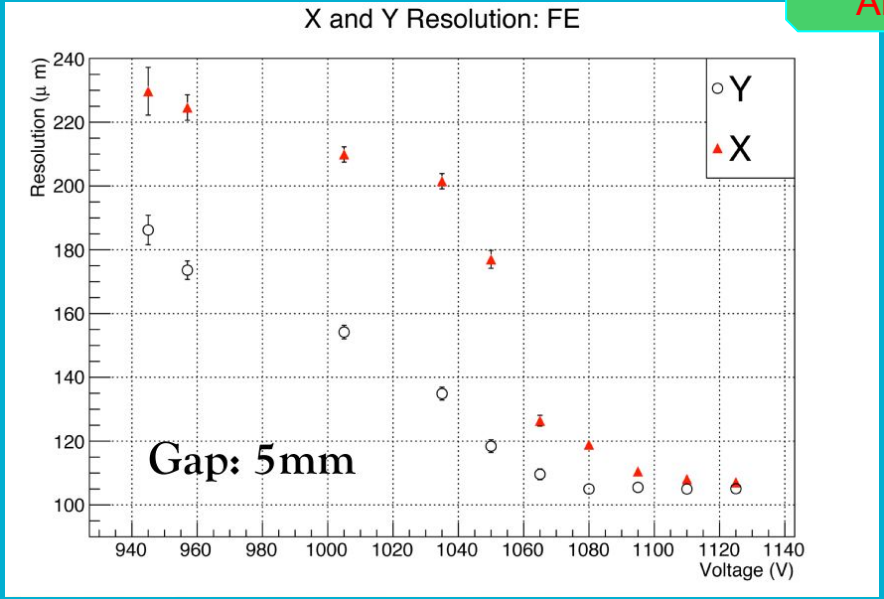
- With magnetic field, charge centroid method is not optimal
  - Lorentz angle broadens the charge distribution
  - Optimization of gas mixture and drift field allow to find resolution ~ 200 µm

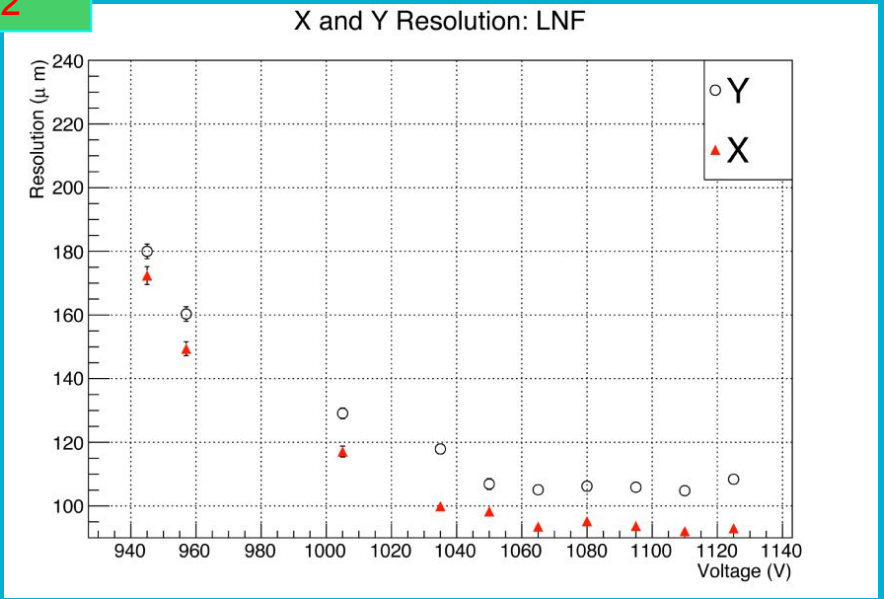
- A new readout mode, based on a µTPC mode, is being developed
  - First results very soon!

BACKUP

Preliminary Results - No Magnetic Field

ArCO2





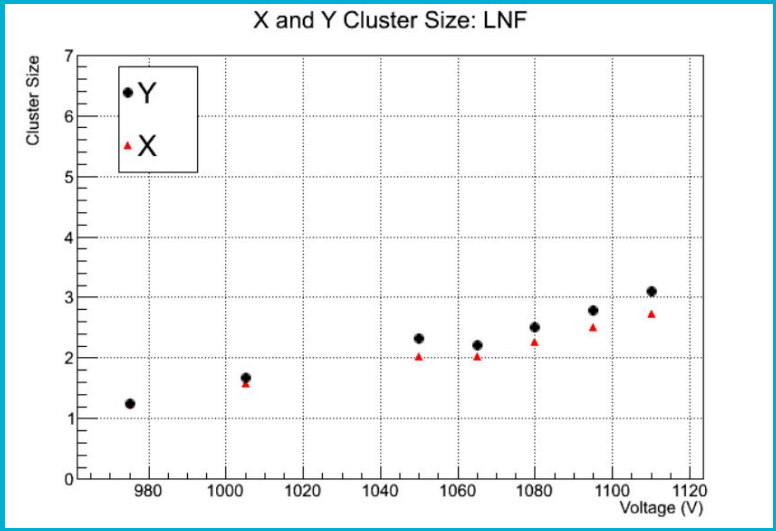
Results compatible with state-of-art planar GEM detector

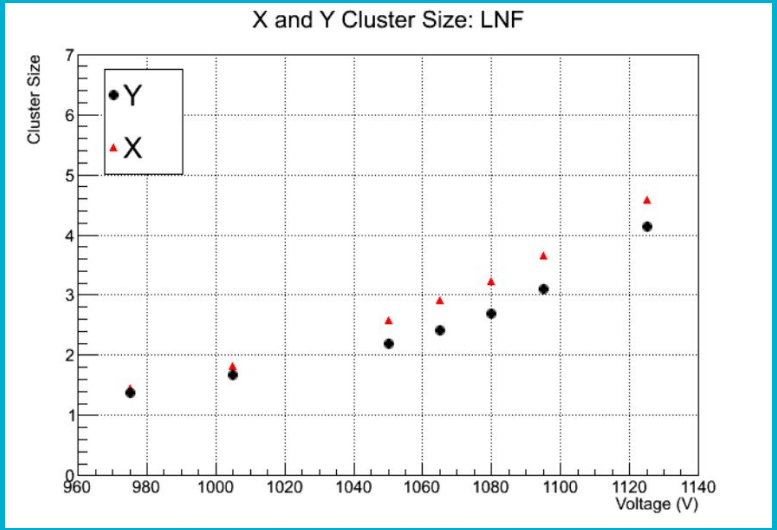
Effect of the Magnetic Field

B = 0

ArCO2

B = 1



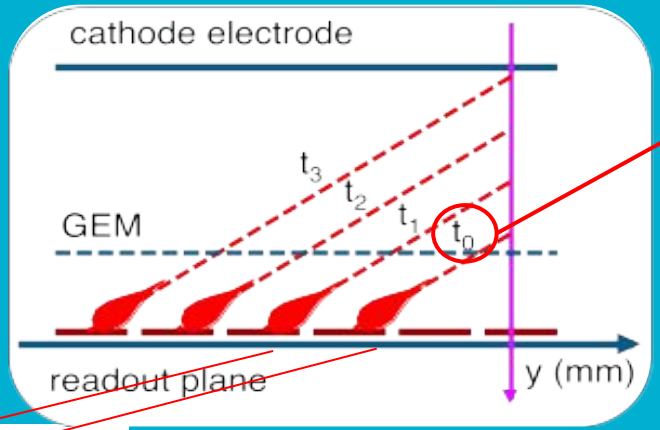


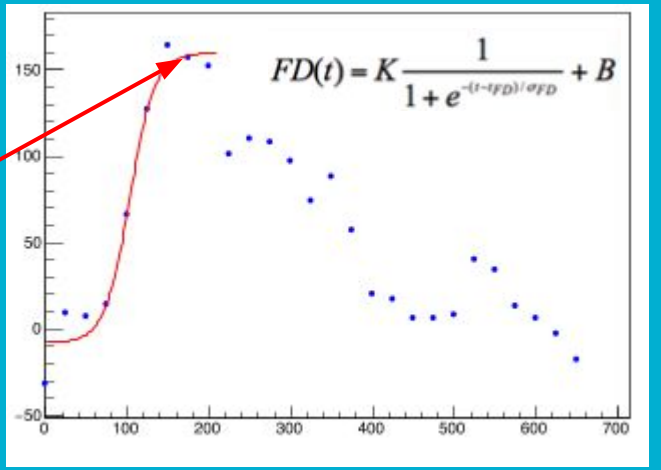
Larger clustersize in magnetic field.
Can it become a benefit?

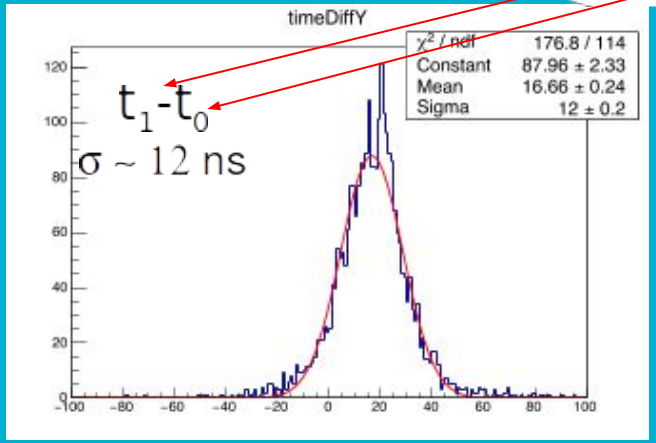
μTPC feasibility studies

For diagonal tracks and/or in high magnetic field

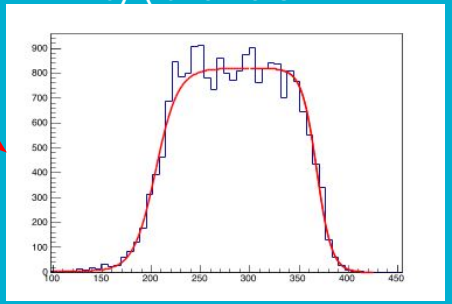
Use the projection of the track to improve the spatial resolution





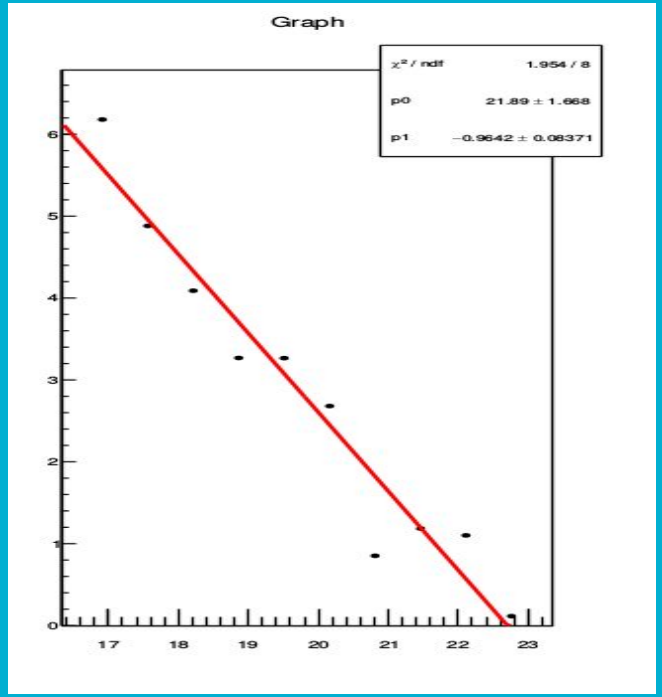


1. Fit the charge sampling to extract time of arrival
2. From Garfield simulation, drift velocity (it can also be estimated from data)



μTPC feasibility studies

3. **Extract the position in the conversion gap**



First results will be ready soon! Stay tuned!

4. **The cluster position (X,Y) is set halfway in the gap**