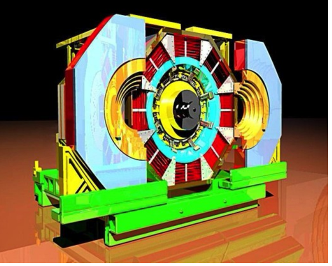
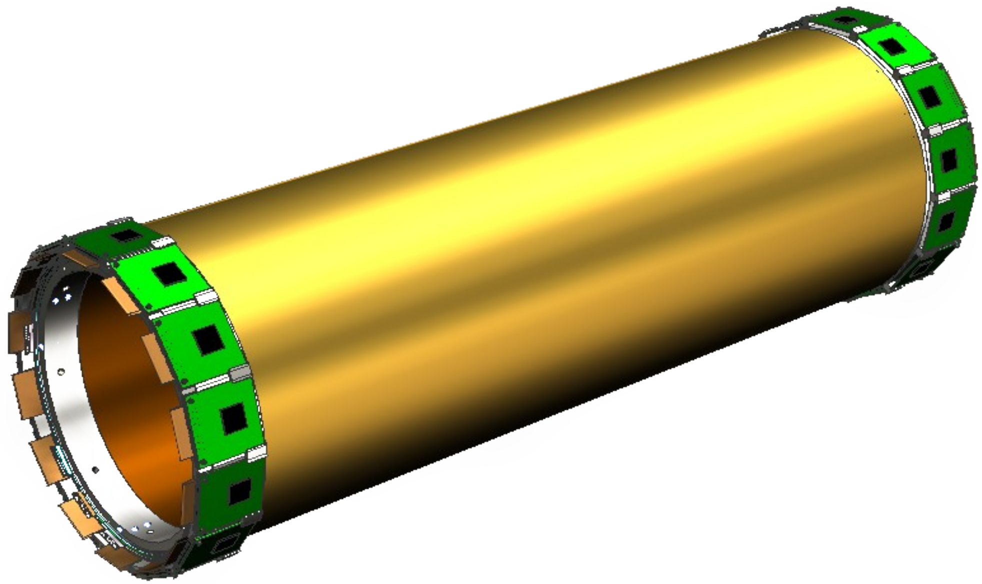




Introduction to the Workshop CGEM FEE, trigger and DAQ for the BESIII experiment

Riccardo Farinelli
INFN Ferrara – University of Ferrara
on behalf of the BESIIICGEM consortium

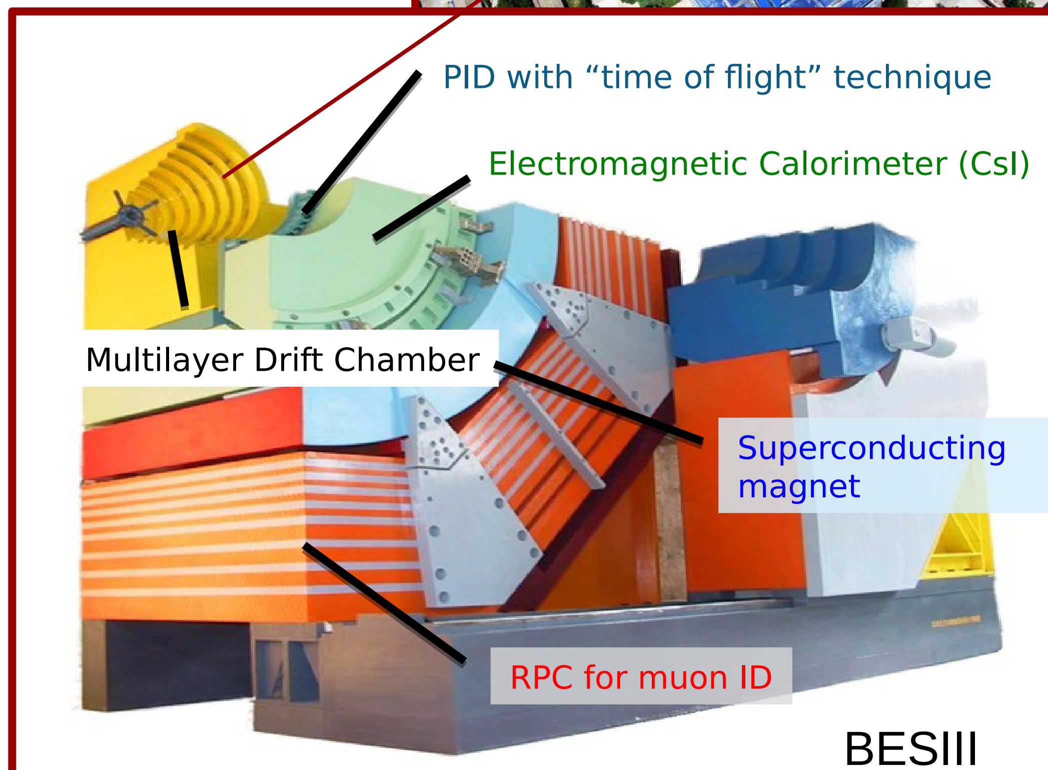
Turin – 13-14 April, 2016

Outline

- The BESIII experiment
- The Cylindrical GEM-Inner Tracker
- Status of the project
  - Assembly of the first cylindrical layer
  - Measurement of the performance with a test beam
  - Status of electronics (not shown in this introduction)

BESIII @ IHEP

- The Beijing Electron-Positron Collider BEPCII and the Beijing Spectrometer BESIII work at from 2 to 4.6 GeV
- → E_{cm} = 2 – 4.6 GeV
- → $L_{design} = 10^{33}$ $cm^{-2}s^{-1}$
- At least 7 more years of data taking
- 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
  - 12 countries and 58 institutions



The BESIII detector

A multipurpose magnetic spectrometer with an effective geometrical acceptance of 93% of 4π is built up by a series of subdetectors

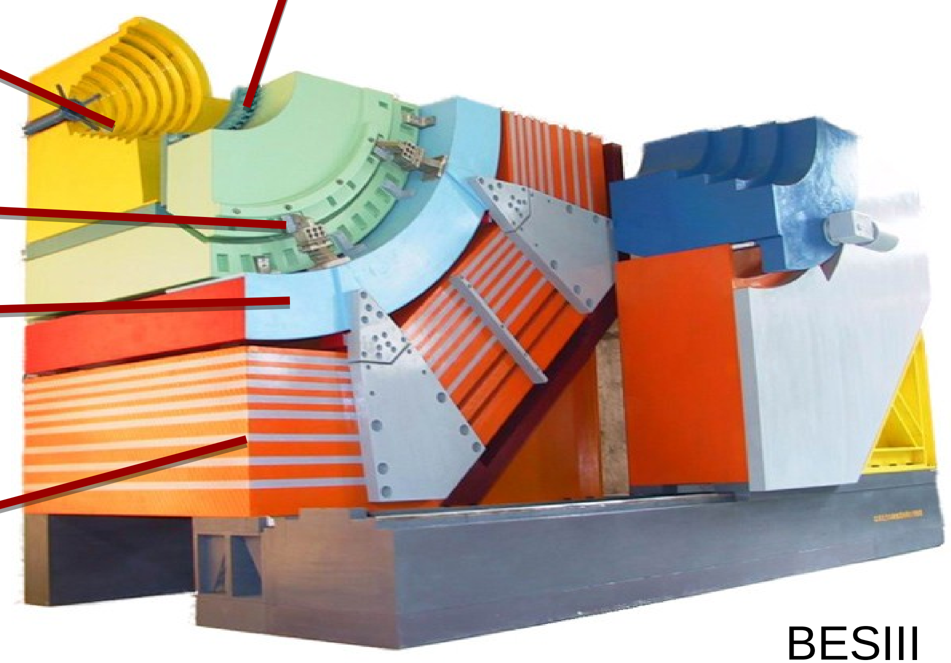
Time Of Flight
90 ps time resolution for PID

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

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

Superconducting magnet
magnetic field = 1 Tesla

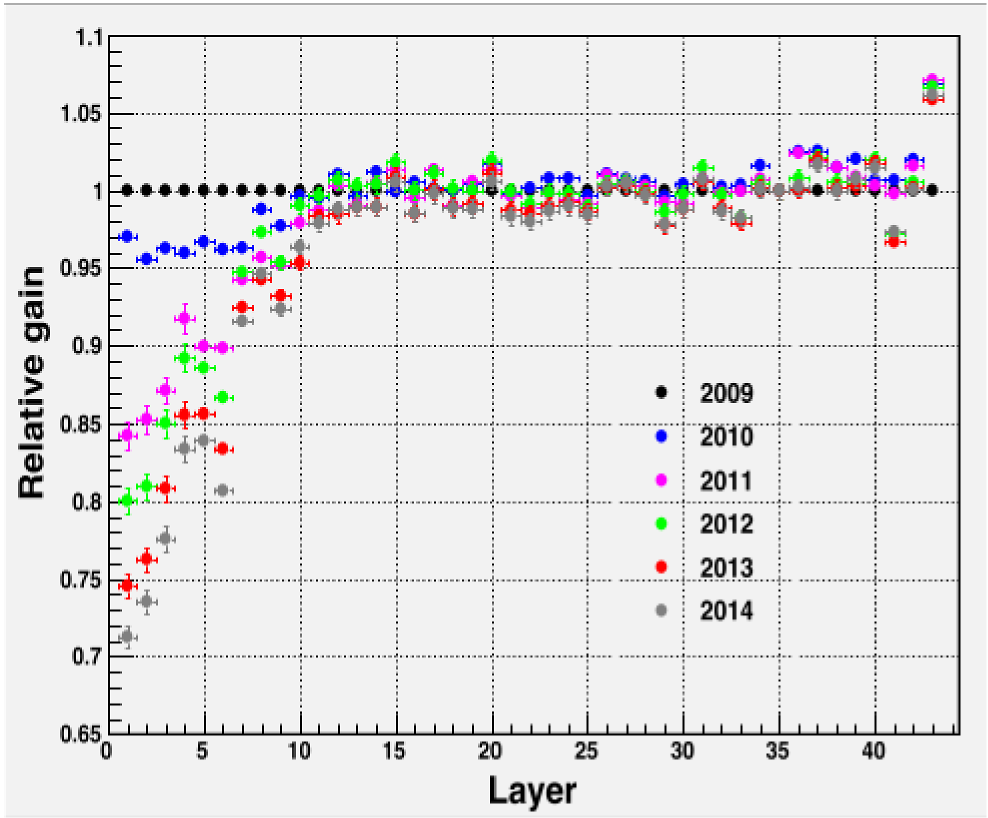
RPC for muon ID



BESIII

MDC aging

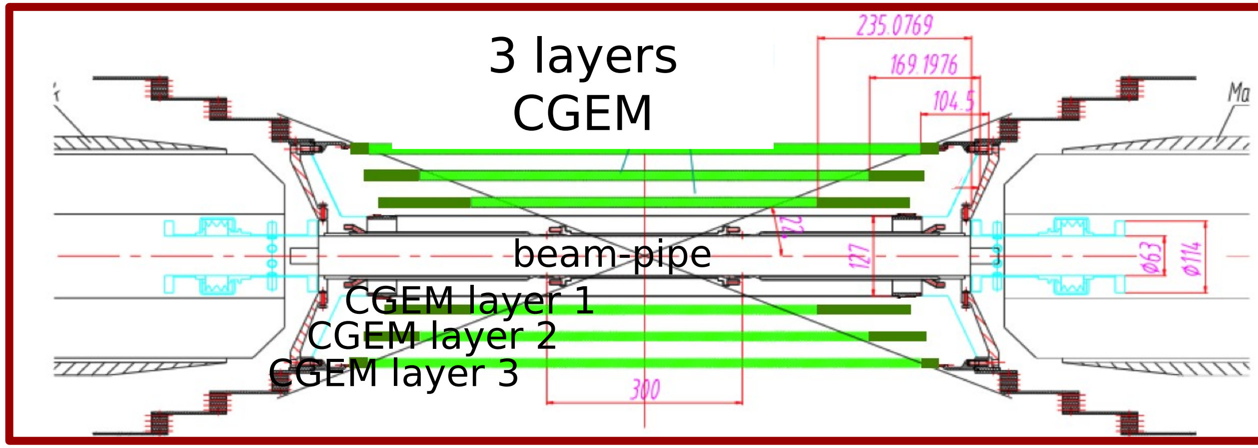
- The Multilayer Drift Chamber is built up by 43 layers and it shows a significant aging in the inner part
- The HV values of hte MDC have been lowered to keep the current under controll. This has worsen the reconstruction efficiency
- BESIII is an experiment that will taken data until 2022 or more and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

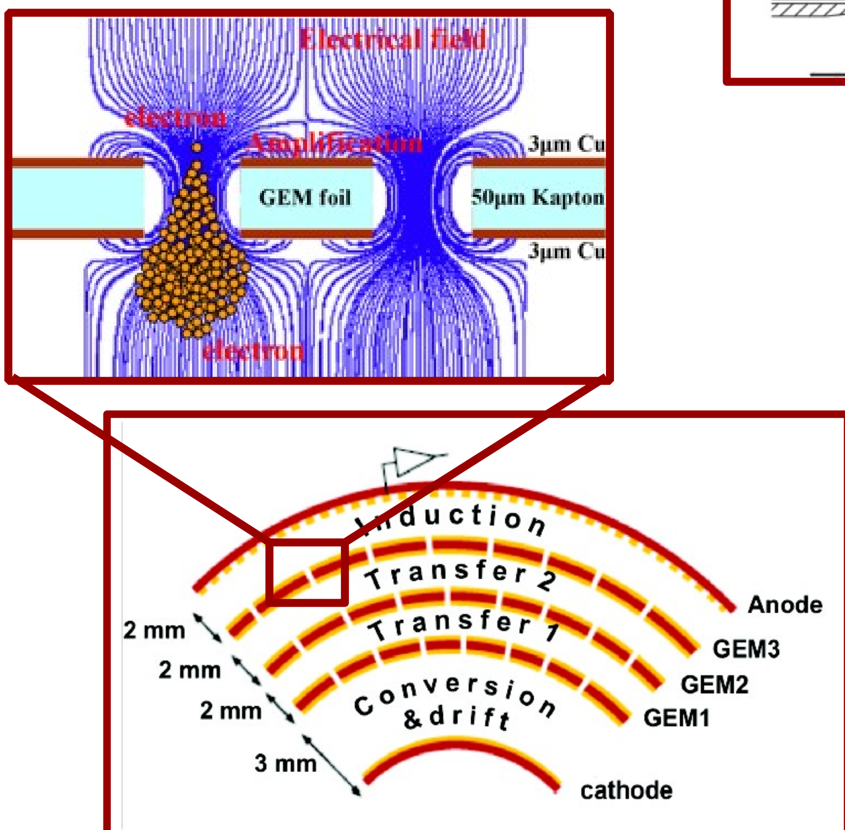


The Cylindrical GEM-IT

The project has been funded by the Foreign Affairs Ministry(MAE) and it received funded by the European Commision within the H2020-MSCA-RISE-2014

German, Swedish and Chinese collaborators joined the group and a CDR has been approved by the Executive Board in 2014





Requirements

- Workability in a magnetic field of 1 Tesla
- Rate capability: ~10^4 Hz/cm^2
- Spatial resolution: s_{xy} =~120µm : s_z=~1 mm
- Momentum resolution:: σ_{Pt}/P_t =~0.5% @1GeV
- Efficiency = ~98%
- Material budget ≤ 1.5% of X_0 all layers
- Coverage: 93% 4π
- Operation duration ~ 5 years

Installation planned for 2018

KLOE2 and improvement

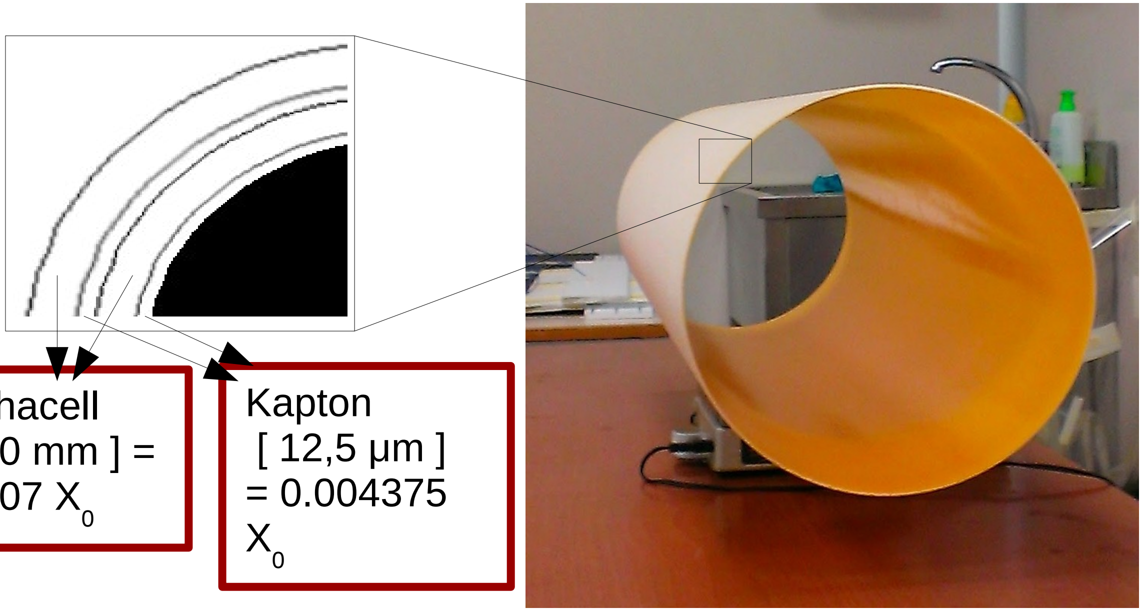
- The KLOE-2 CGEM detector is the first one built and now it is normally taking data in the running experiment
- Respect to the state of the art the CGEM-IT for BESIII will take advantage of these improvements:
  - Rohacell
  - Anode design
  - Analog and µTPC readout

    ➔ development of a dedicated ASIC

Operational enviroment difference:

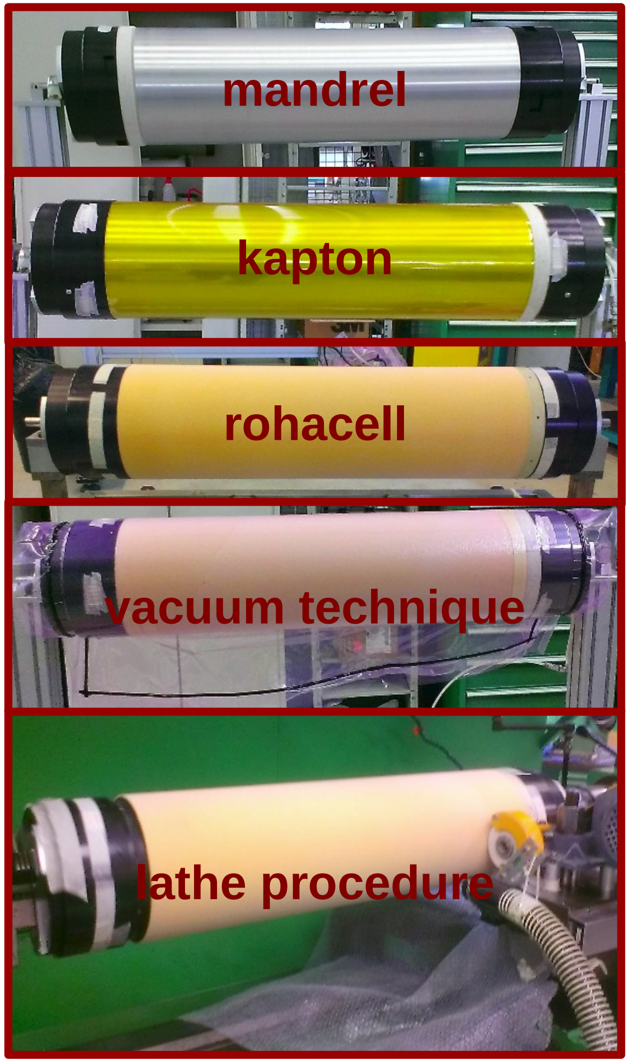
KLOE-2 → B = 0.5T / digital r.o. / s_{xy} = 200 µm
BESIII → B = 1.0T / analog r.o. / s_{xy} = 120 µm

Anode and cathode construction



Rohacell
[1,0 mm] =
0.007 X_0

Kapton
[12,5 μm]
= 0.004375
X_0

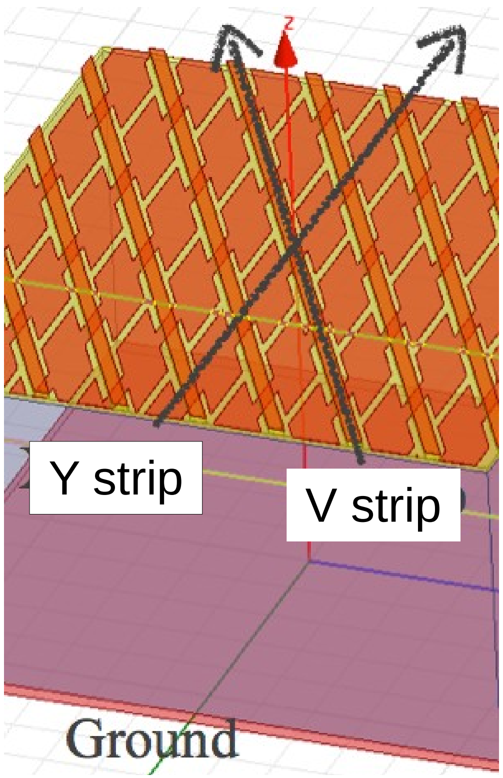


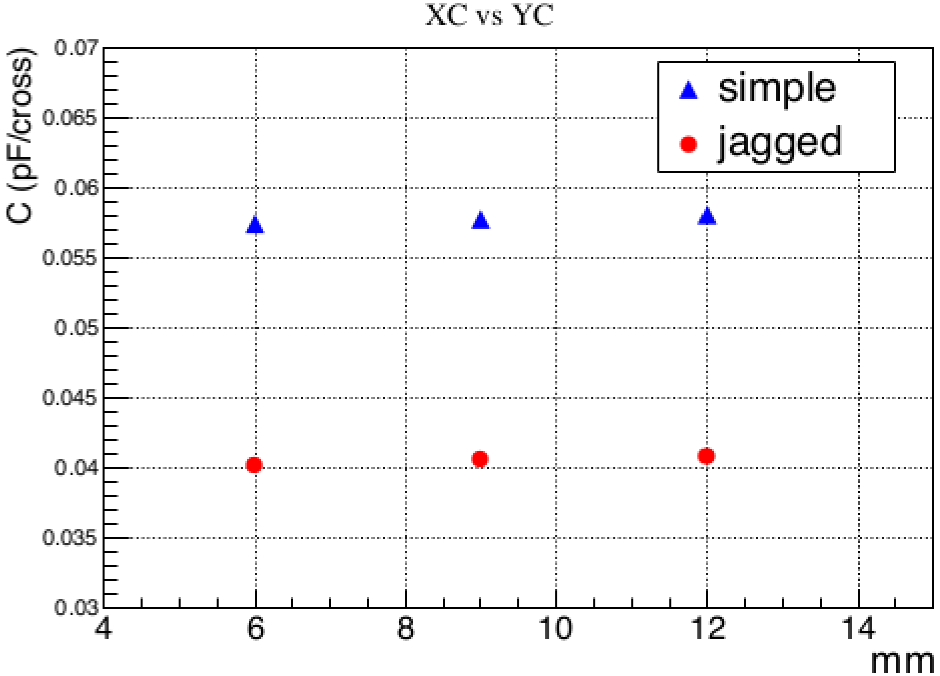
- Structure weight (without electrode) weight 180 g and 0.02275 X_0
- The full CGEM-IT material budget willl be ~ 1% X_0
- Cathode electrode and anode circuit are build similarly and are glued onto a kapton - rohacell double sandwich
- The mechanical support is performed by annular flanges of permaglass placed on the edges of the cylinder

Readout plane design and features

BESIII will deploy a readout with two set of strips and a stereo angle produced by TS-DEM department at CERN

- large strip capacitance up to 100-160 pF
- stereo angle depending on the layer geometry: about + 45°, - 30°, + 30°
  - different stereo angles will help reducing the combinatoric
- strip geometry is 650/570/130 μm
- (pitch, Y wide, V wide)
  - about 10'000 electronics channels
- ground plane at 4 mm from the readout
- jagged strip layout studied to minimize the strip capacitance

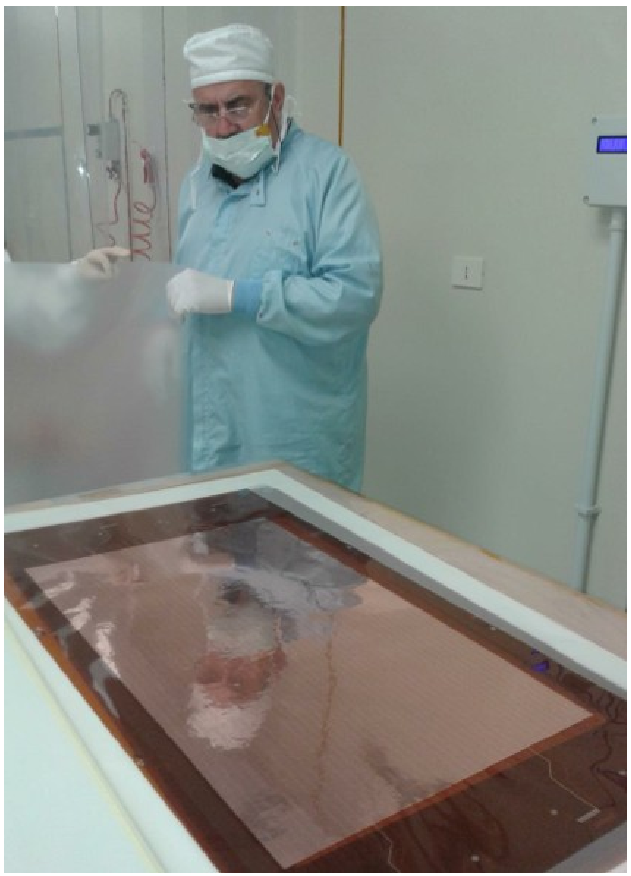


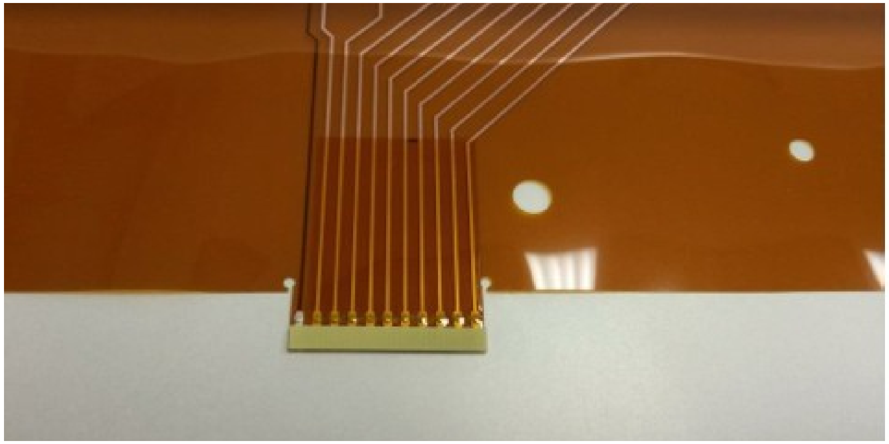


Construction of the first cylindrical layer

GEM test

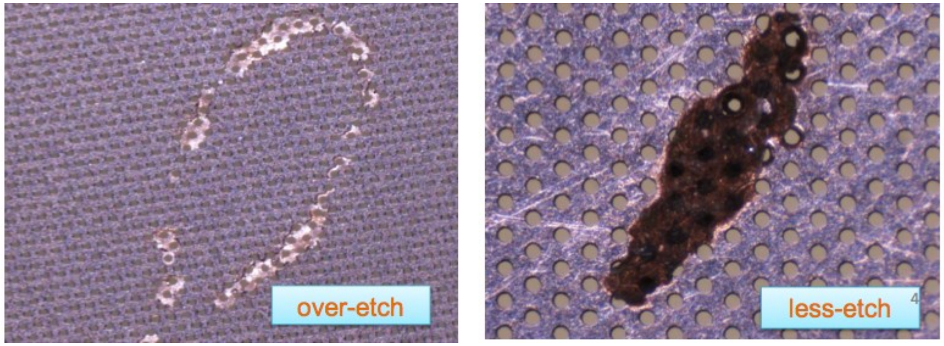
GEM foils arrived from CERN and have been tested in the clean room.



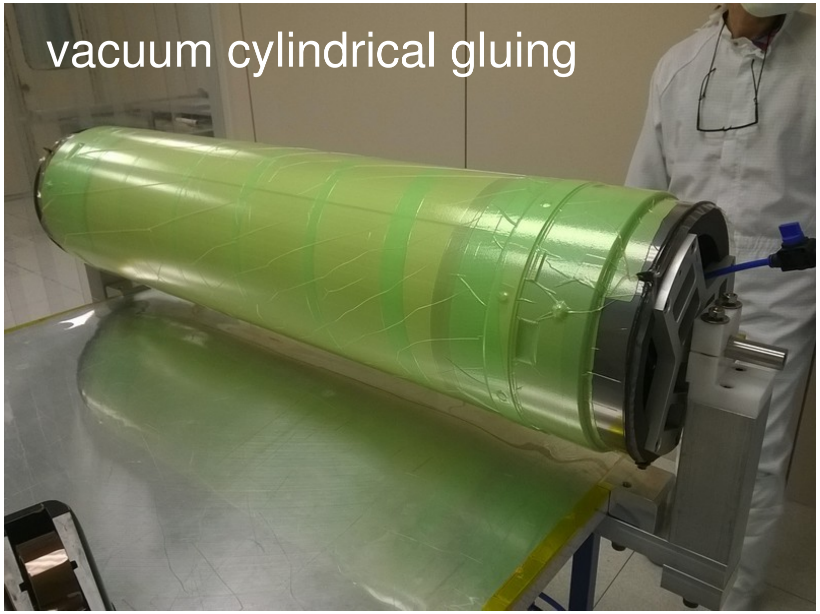


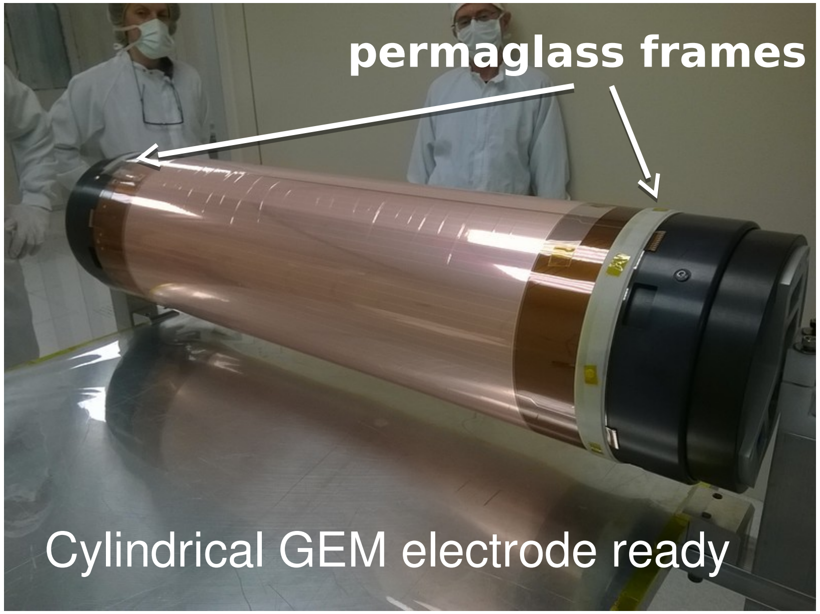
GEM production quality test.
Before gluing, a HV test is performed on the GEM foils.
Good GEM must satisfy both:

- <1 nA @ 600 V
- <2 discharges/30mins



GEM assembly





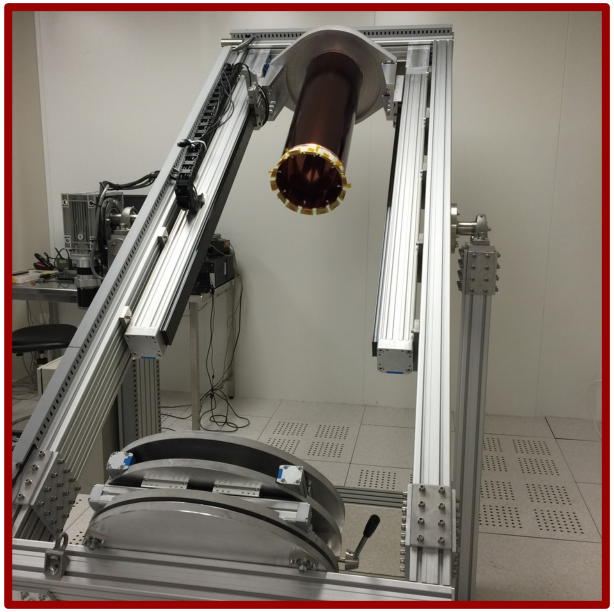
- The mechanical precision of all the item involved is critical for the detector assembly.
- Main issue of the gluing procedure is the mechanical tolerance of the reference holes used for the foils alignment.

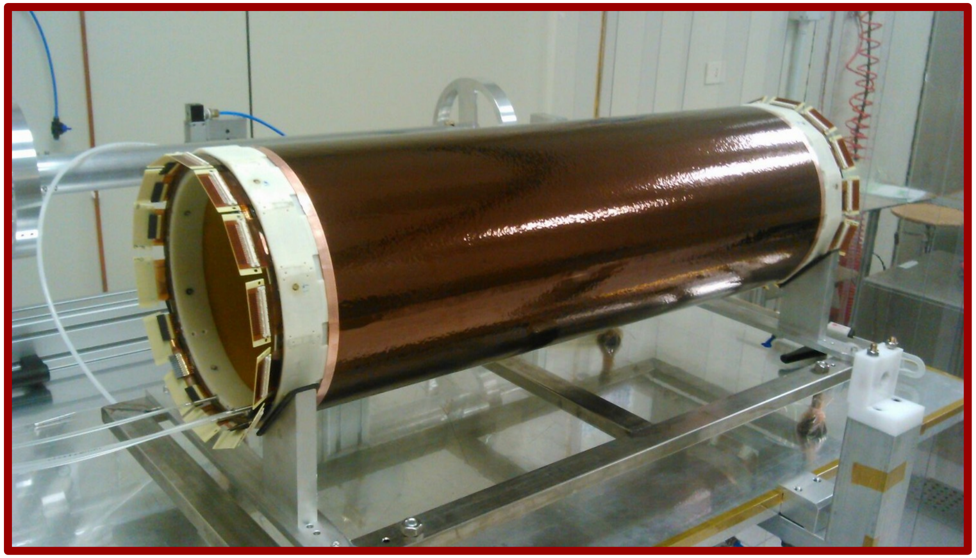
Cathode and anode test and assembly

- Several deformation test on the mechanical structure have been performed:
  - axial compression before and after an irradiation test
  - internal pression variation
- Cathode and anode electrodes are glued to the rohacell/kapton structure and thanks to the glue and the vacuum technique the cylindrical form is fixed

Assembly

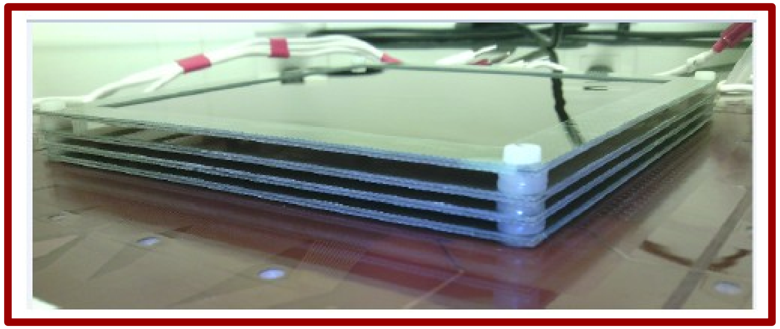
- Once the 5 electrodes (3 GEM, cathode and anode) have been built, they are assembled concentrically
- Axial alignment has a precision of 100µm along the operational length of 1.5m
- A dedicated assembling machine has been designed and realized to perform the insertion of the electrodes
- The structure can rotate by 180° around its central horizontal axis
- The first Cylindrical prototype of triple-GEM has been successfully assembled and now is under test

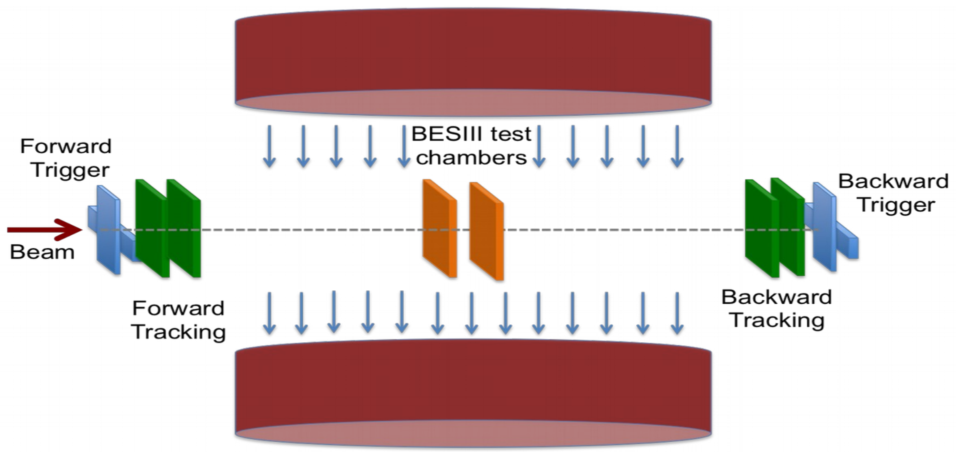




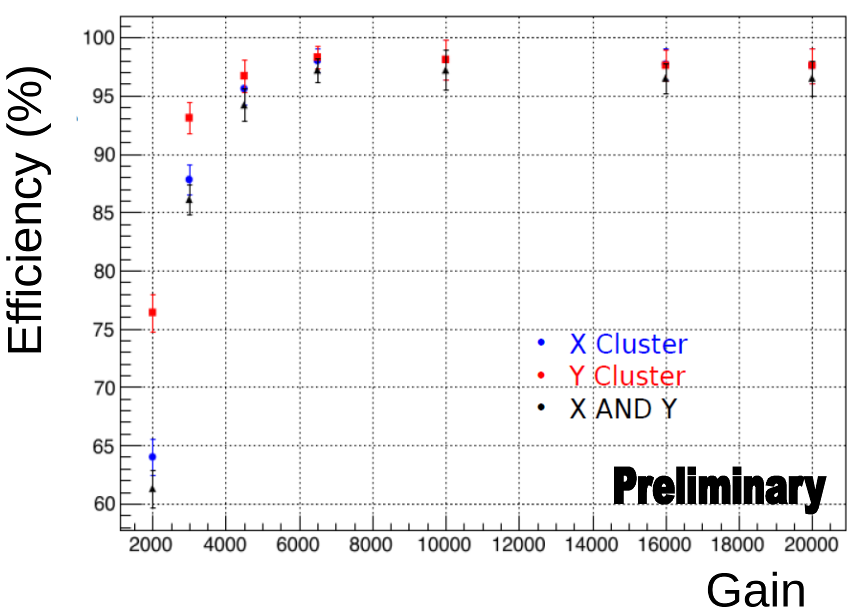
Measurement of the performance

TestBeam of a planar triple GEM prototype





Efficiency (%) vs gain



Several planar triple-GEM prototypes have been tested in a testbeam @ H4-CERN to:

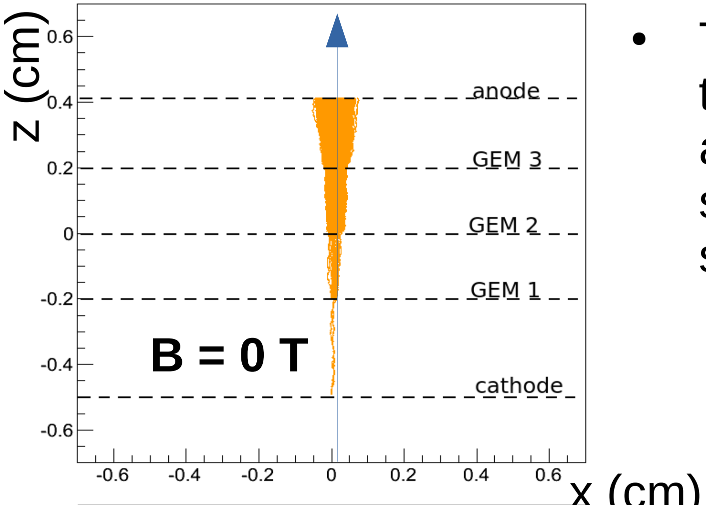
- Validate analogue and µTPC readout
- Validate Garfield simulations
- Test different gas mixtures and geometries

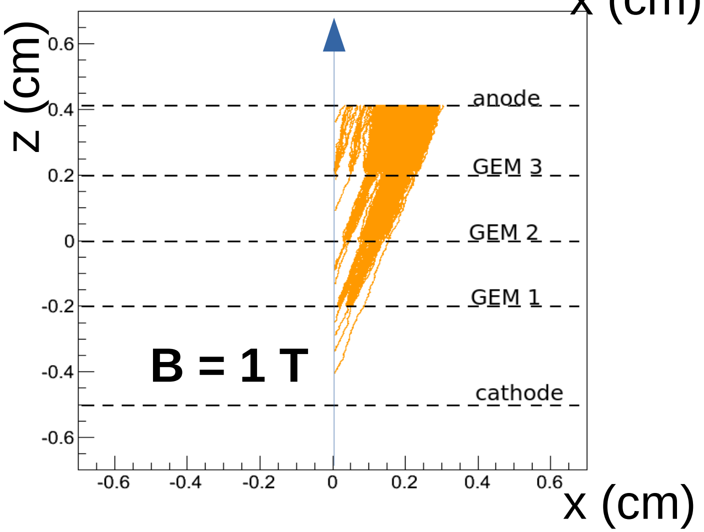
Efficiency plateau starts at ~ 6000. The effieciency on both the view is ~ 97%.

A pitch of 650µm has been used with a gas mixture of Argon-Isobutane (90/10) and Ar-CO_2 (70/30).

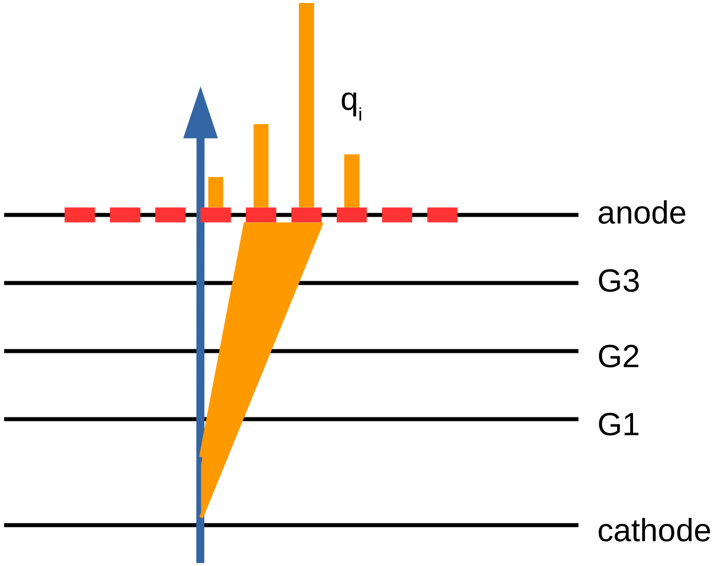
The spatial resolution reached without magnetic field is below of 100µm with the charge centroide method.

Magnetic field effect on the electron avalanche

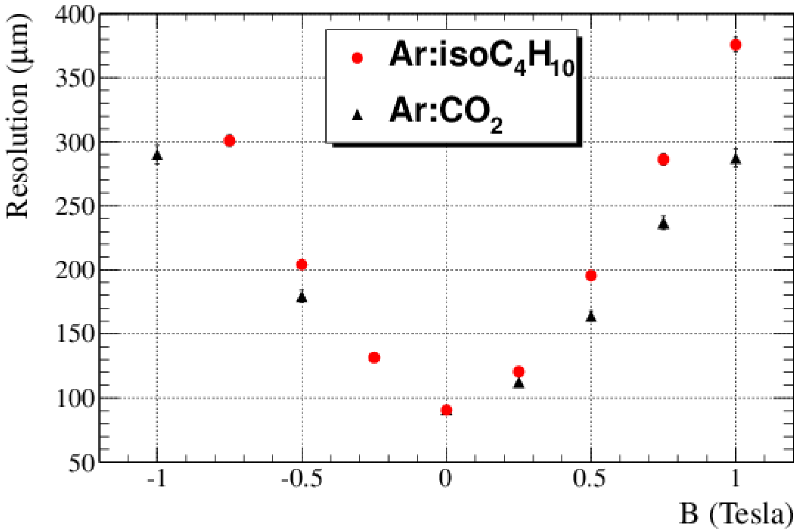




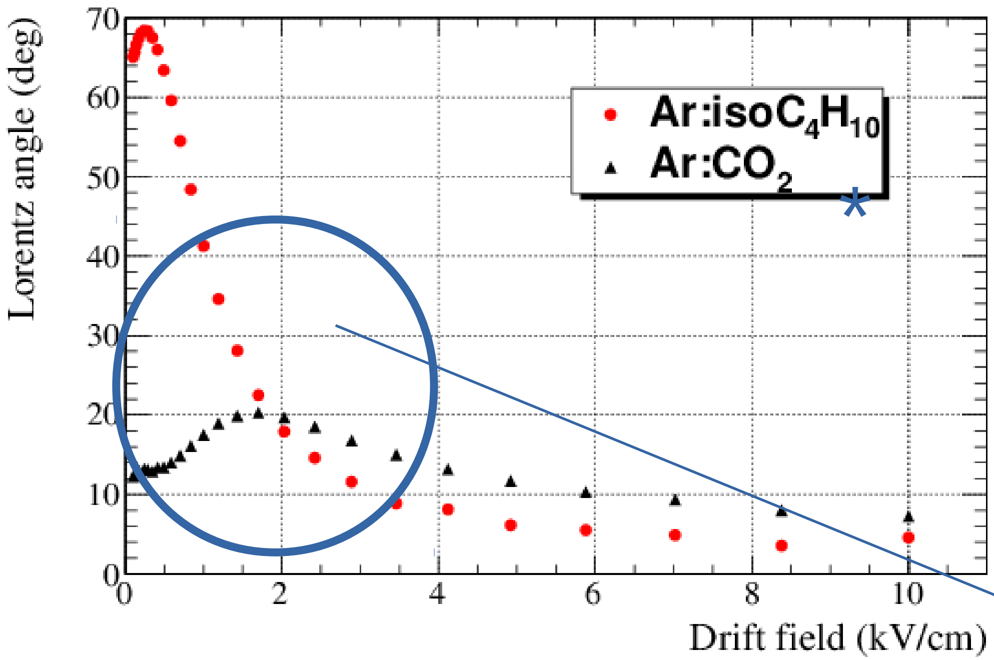
- The magnetic field acts on the electron avalanche and its effect has been studied with Garfield simulation
  - The Lorentz force shifts the avalanche,
  - Additionally the magnetic field B enlarge the charge distribuion collected at the anode;
  - The shape of the charge distribution is no longer gaussian and the charge centroide.



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

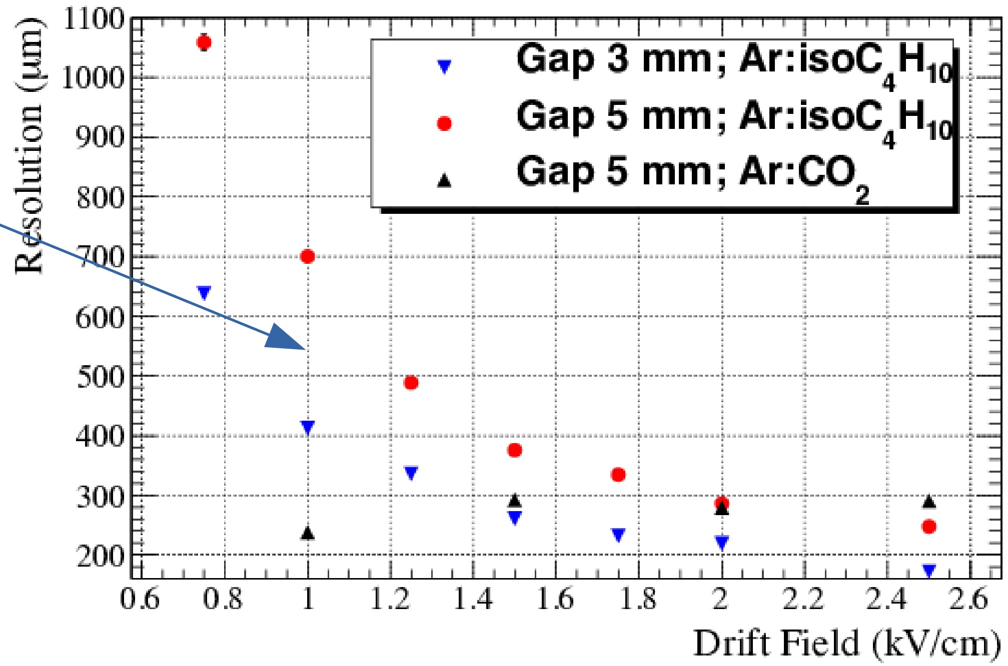


Optimization of the prototype @ 1 Tesla



- The behavior of the spatial resolution and the Lorentz angle are similar.

➔ The lose of the charge centroid performance is mainly due to the increasing of the Lorentz angle

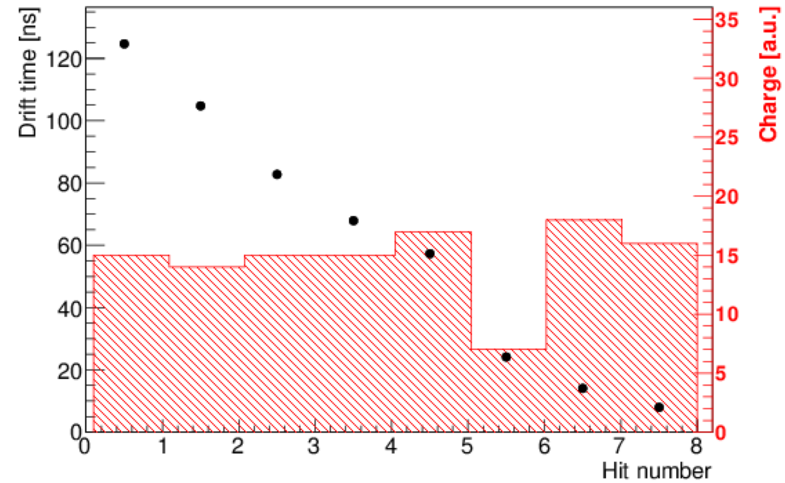


- The prototype with Argon-Isobutane (90/10) gas mixture and high drift field reachs the spatial resolution of ~ 190µm with a magnetic field of 1T

- The effiency is constant if this range of field values

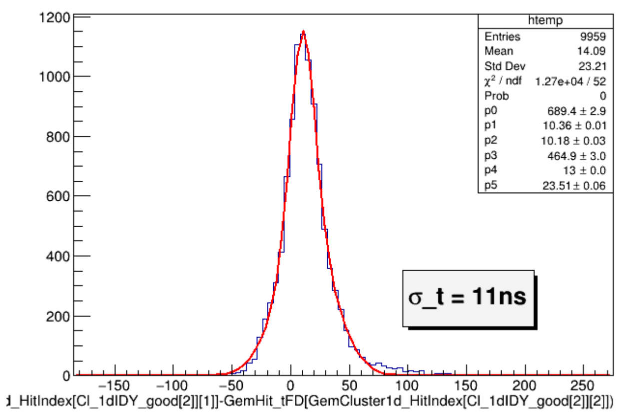
Data from Garfield simulations

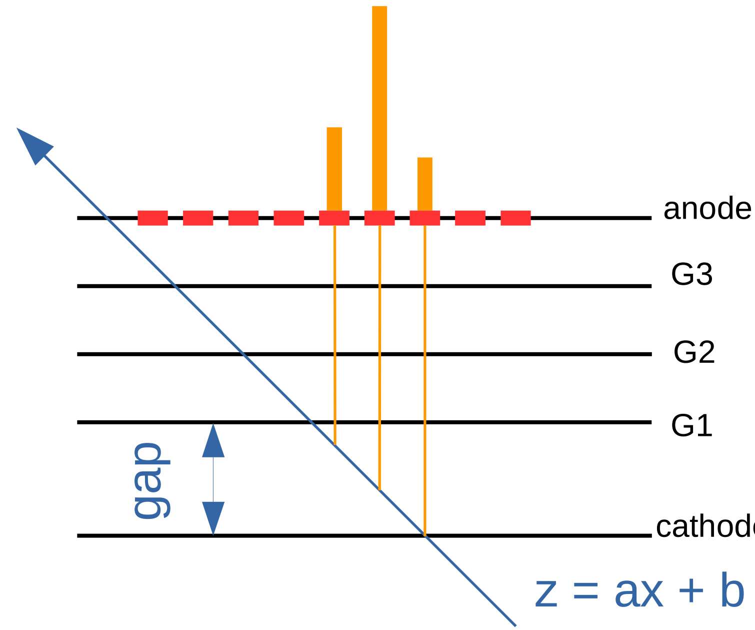
µTPC method



- 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.
- The new ASIC has to have good timing performance.
- 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
- The method is initially tested with angled tracks and without magnetic field

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





µTPC results

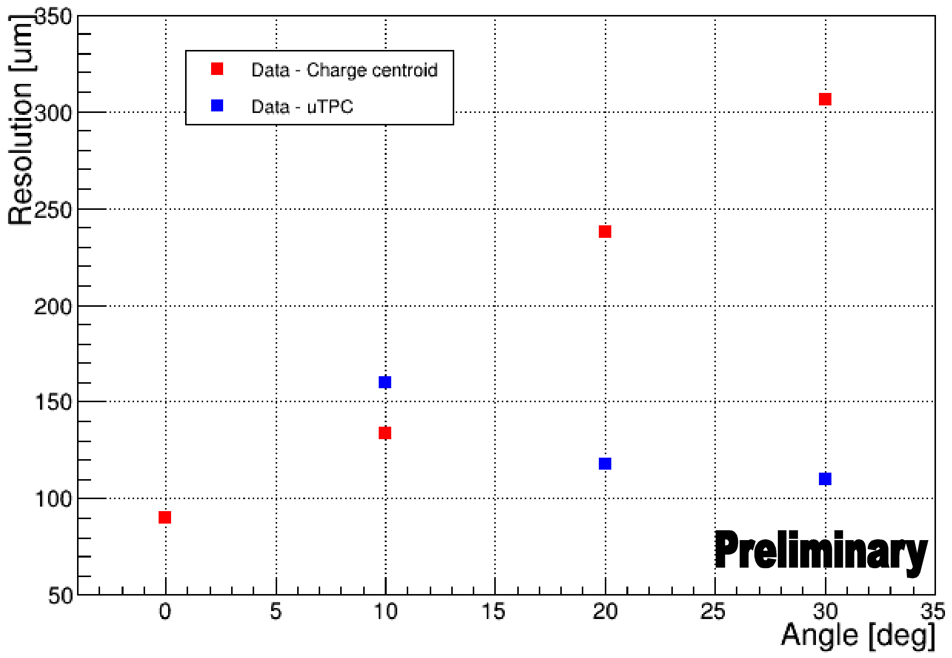
The charge centroid resolution increases linearly with the incident angle of the track because the number of fired strips increases and the charge distribution as well

The µTPC allows to reconstruct angled tracks without lose of performance:

- At angles greater that 10° the resolution is flat around ~ 130µm
- At angles smaller that 10° the number of fired strip is too small to apply successfully this method

The incident angle of the track is reconstructed in µTPC and the angular resolution improve at the increasing of the angle

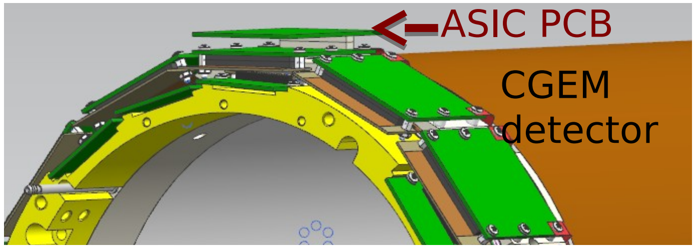
The shown results are measured without magnetic field and with angled tracks
→ we expect a similar behavior in magnetic field because the Lorentz angle is ~26° (Ar/Iso)



Some numbers about the ASIC

Frontend electronics

- The analog readout is mandatory to limit the number of electronics channels. The charge measurements is performed by a dedicated ASIC chip.
  - with moderate strip pitch (650 μm) ~10000 electronics channels
    64 channels per ASIC → 2 ASIC in each frontend PCB → 80 PCB
  - ASIC PCBs will be located on the detector to preserve the S/N ratio



- Design of CGEM ASIC (UMC .11μm) starting from existing design (IBM .13 μm)
  - BackEnd design shared by several projects
  - BackEnd porting to UMC .11 μm in progress
  - Different input stage (suited for CGEM) to increase signal sensitivity and SNR

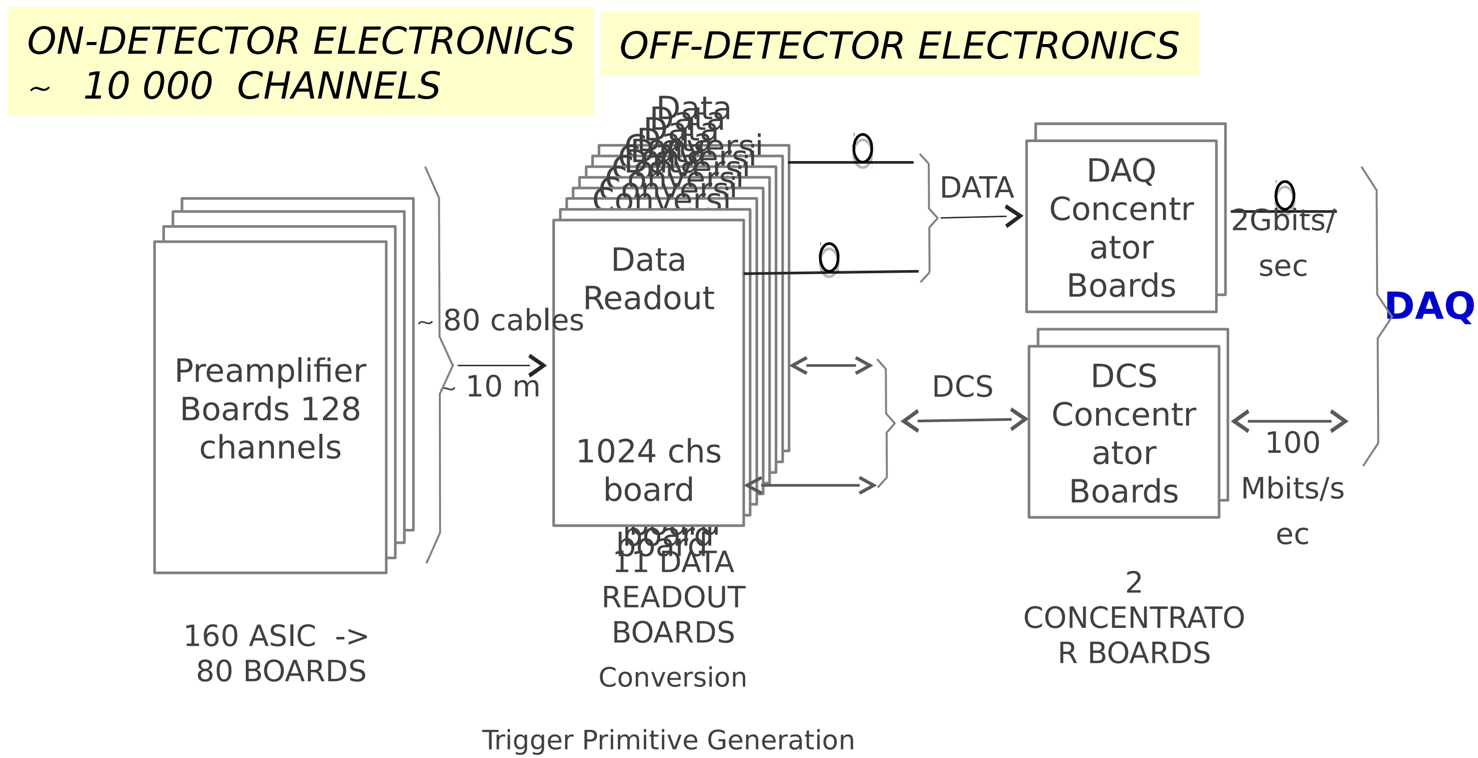
- FrontEnd Optimization
  - input stage optimized to handle capacitance in the range 20pF-100pF

Main feature of the ASIC design

- UMC 110 nm technology (limited power consumption, to be tested for radiation tolerance)
- Input charge: 1-50 fC
- Maximum sensor capacitance 100 pF
- Input rate: 60 kHz/channel
- Time and Charge measurements by independent TDCs
- TDC time binning > 50 ps
- Time resolution: 4-5ns **⇒ CGEM needed time resolution ~ 5 ns**
- Double threshold discrimination
- Anolog to Digital Converter (ADC) to measure the charge
- Power consumption ~ 10 mW p/channel feasible **⇒ about 100W in total**

CGEM electronics

FEE Architecture inherited by KLOE-2 experiment



- **ON-DETECTOR electronics**
  Preamp boards located on the detector to preserve the S/N ratio
- **OFF-DETECTOR electronics**
  Readout boards and Concentrator boards as close as possible to the detector

CGEM electronics

FEE BLOCK DIAGRAM

ON-DETECTOR ELECTRONICS
~ 10 000 CHANNELS

OFF-DETECTOR ELECTRONICS

Preamplifier Boards 128 channels

~ 80 cables
~ 10 m

Data Readout

1024 chs board

48 chs board

DATA

DAQ Concentrator Boards

2 Gbits/sec

DCS

DCS Concentrator Boards

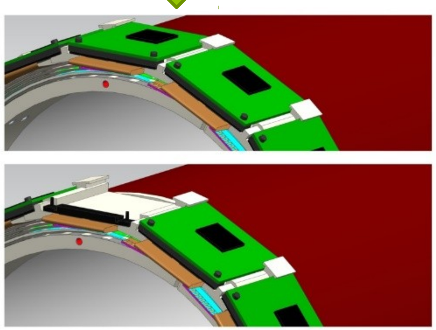
100 Mbits/sec

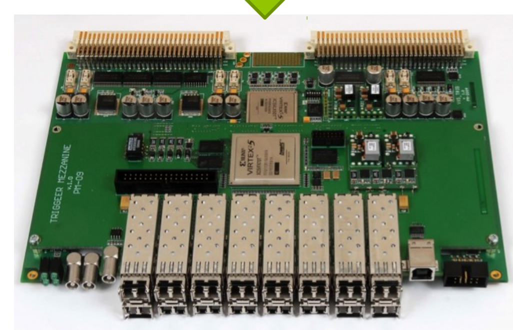
DAQ

160 ASIC -> 80 BOARDS

11 READOUT BOARDS

2 CONCENTRATOR BOARDS





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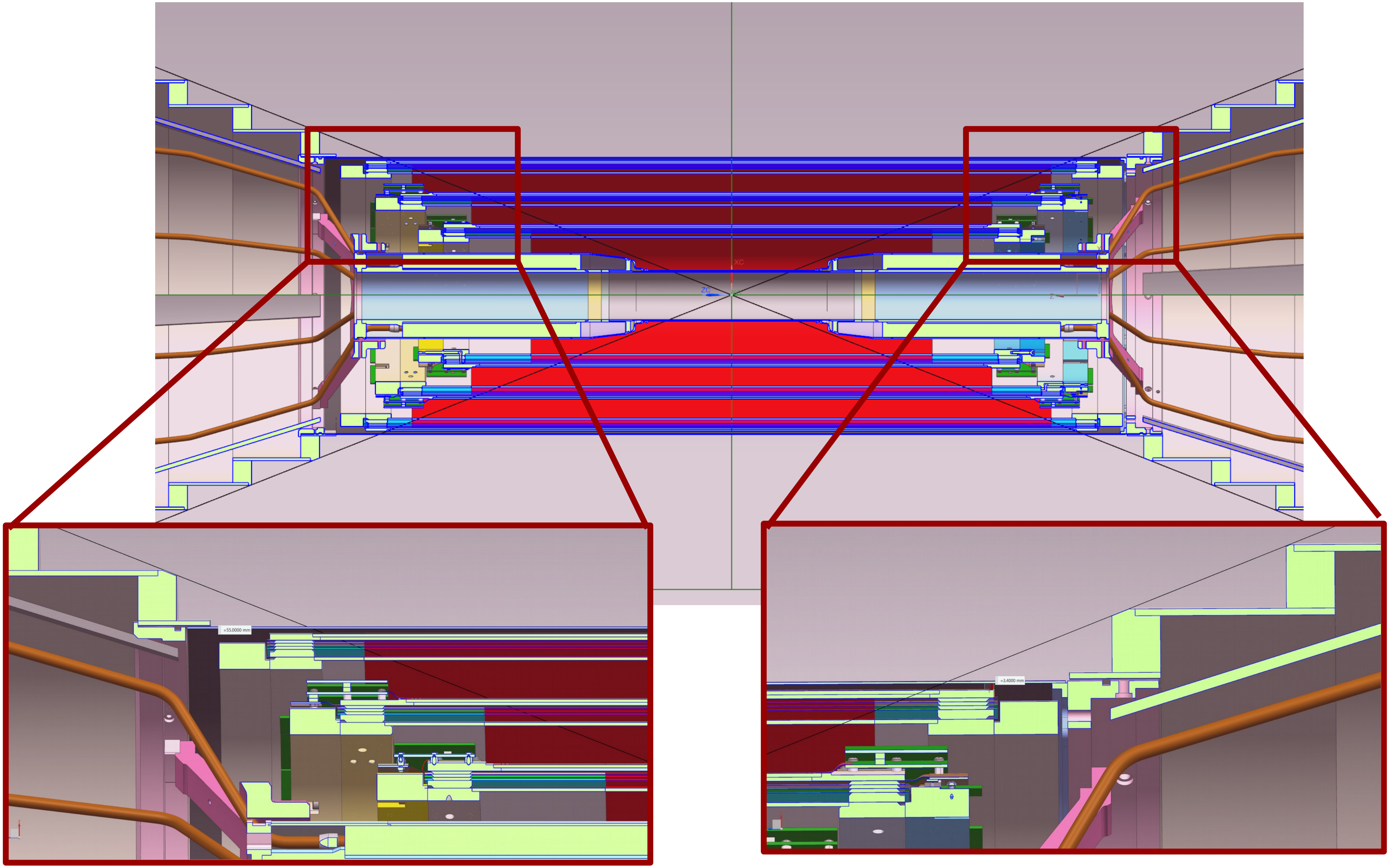
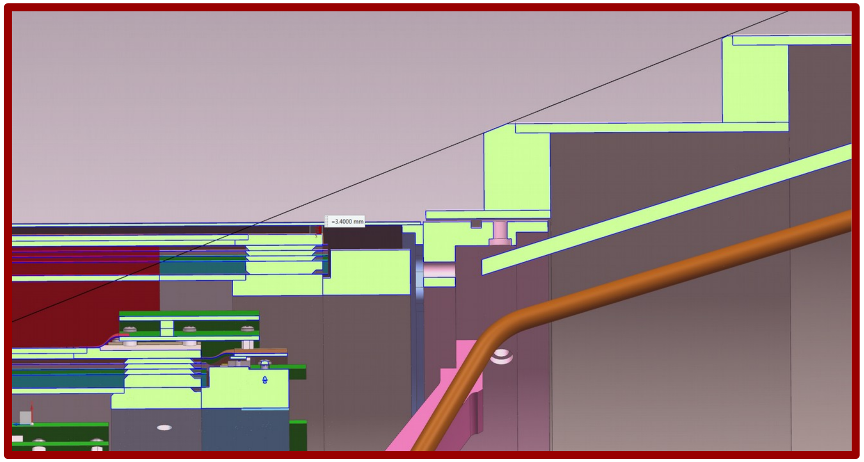
Free space

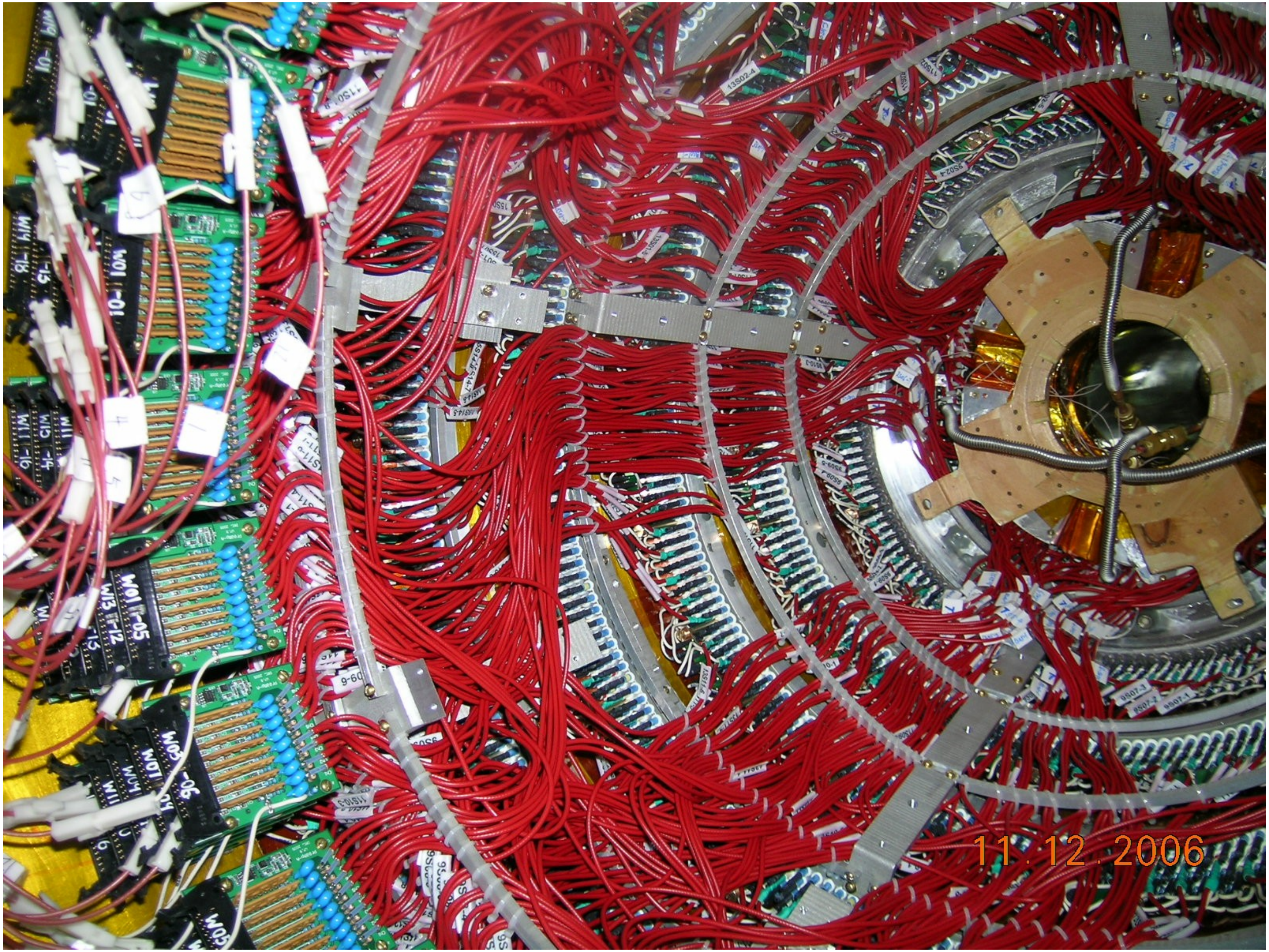


Layer 3 issue

- The layer 3 readout system is inside the active region
- At the current design the beam radiation would destroy the electronics and an alternative solution occurs
- Four possibile solutions must are propoped here:
  - Re-make the flange
  - Increase the strip lenght and move the electronics away from the beam
  - Reduce the size of the electronics
  - Exchange the cathode plane with the anode



Rooting cable



Conclusion and future plans

- A prototype of triple-GEM with charge centroid method has been optimized to work @ 1 Tesla and it reaches a spatial resolution of ~190µm: the best results in literature for GEM detector in magnetic field of 1 Tesla
- A first implementation of the µTPC readout system without magnetic field allows to reaches the BESIII requirement for angled tracks
- The feasibility of the µTPC in magnetic field is under development but preliminary results (not showed) confirm this tendency
- The first Cylindrical triple-GEM for BESIII has been successfully assembled and it will be tested in a testbeam after the gas and HV tests
- A new electronics for the CGEM-IT is under development. The BESIII geometry gives the main constrain while the reconstruction method feasibility impose its requirement

Thanks