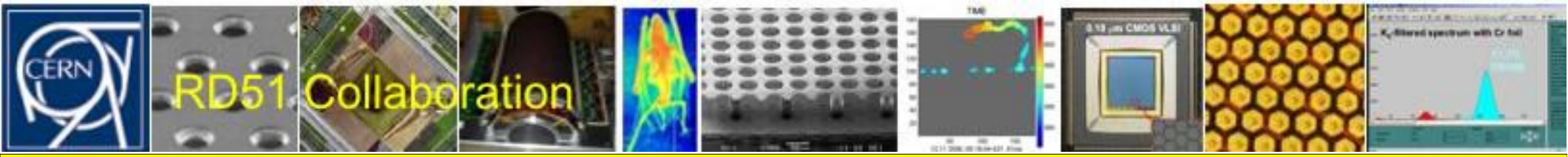
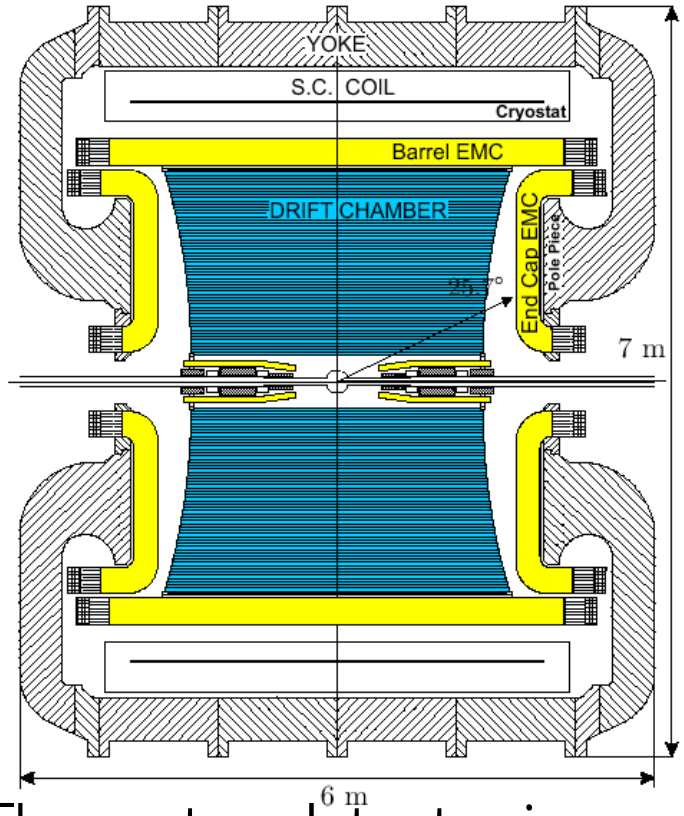
The Cylindrical GEM detector for the KLOE-2 Inner Tracker

G. Morello on behalf of the KLOE-2 IT group

MPGD2013, July 1st, Zaragoza (E)

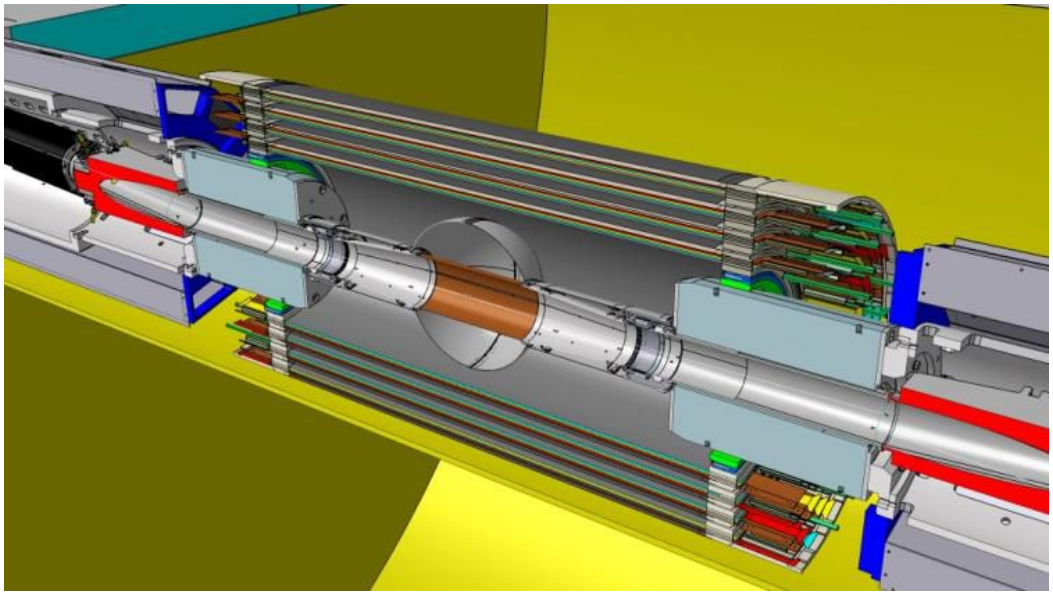


The KLOE-2 Inner Tracker



The KLOE apparatus, consisting of a huge Drift Chamber and a Electromagnetic Calorimeter working in a 0.5 T axial magnetic field, has been upgraded with new subdetectors (including a vertex detector) for a new data taking campaign.
The required vertex detector performances are:

- 200 μm spatial resolution on the transverse plane and 500 μm along the beam line
- material budget less than 2% X_0
- 5 kHz/cm^2 rate capability



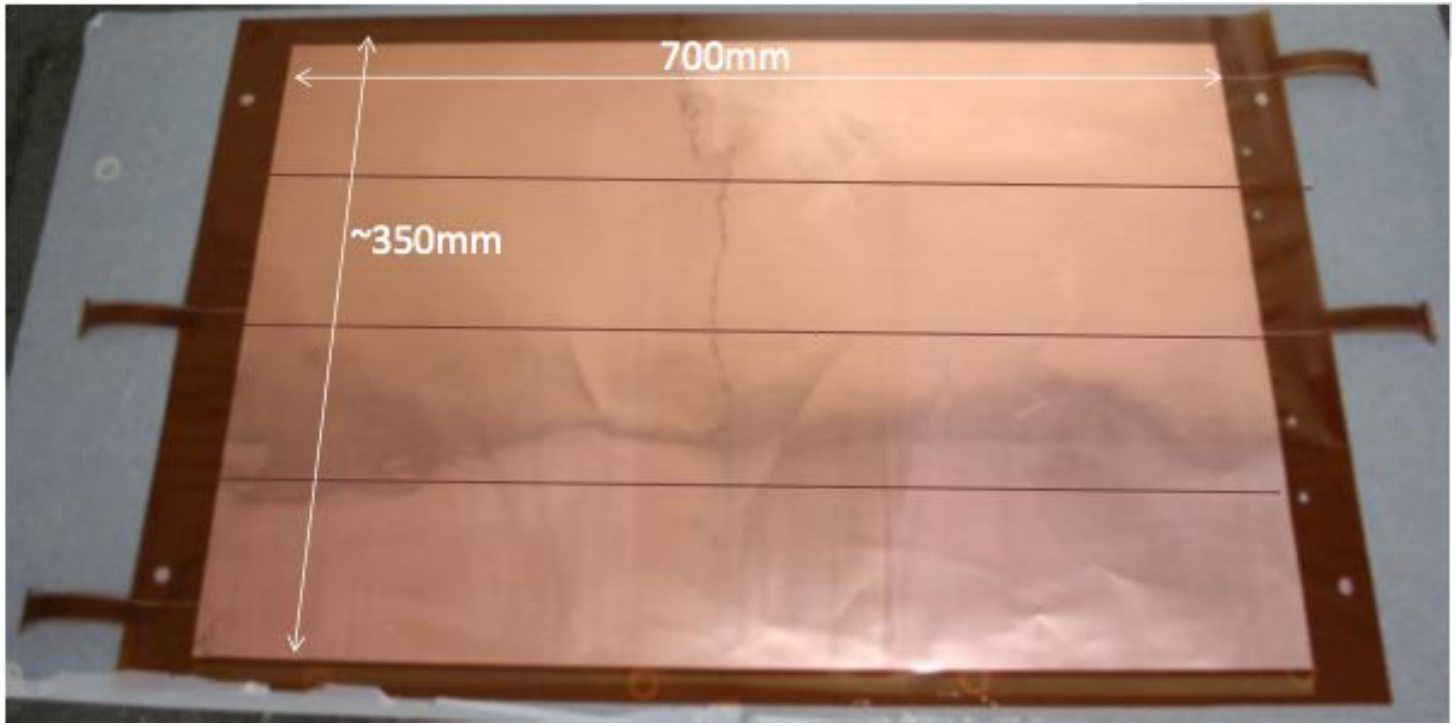
The vertex detector is composed by 4 coaxial cylindrical GEMs with

- 700 mm active length
- radii from 130 to 205 mm
- X-V strips-pads readout (25°- 32° stereo angle)

Very low-mass detector

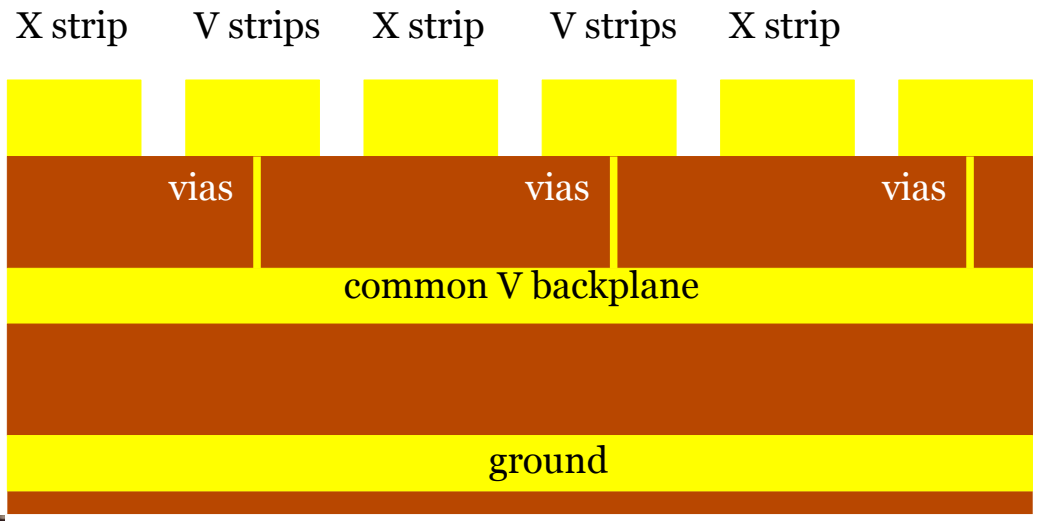
The electrodes of the IT

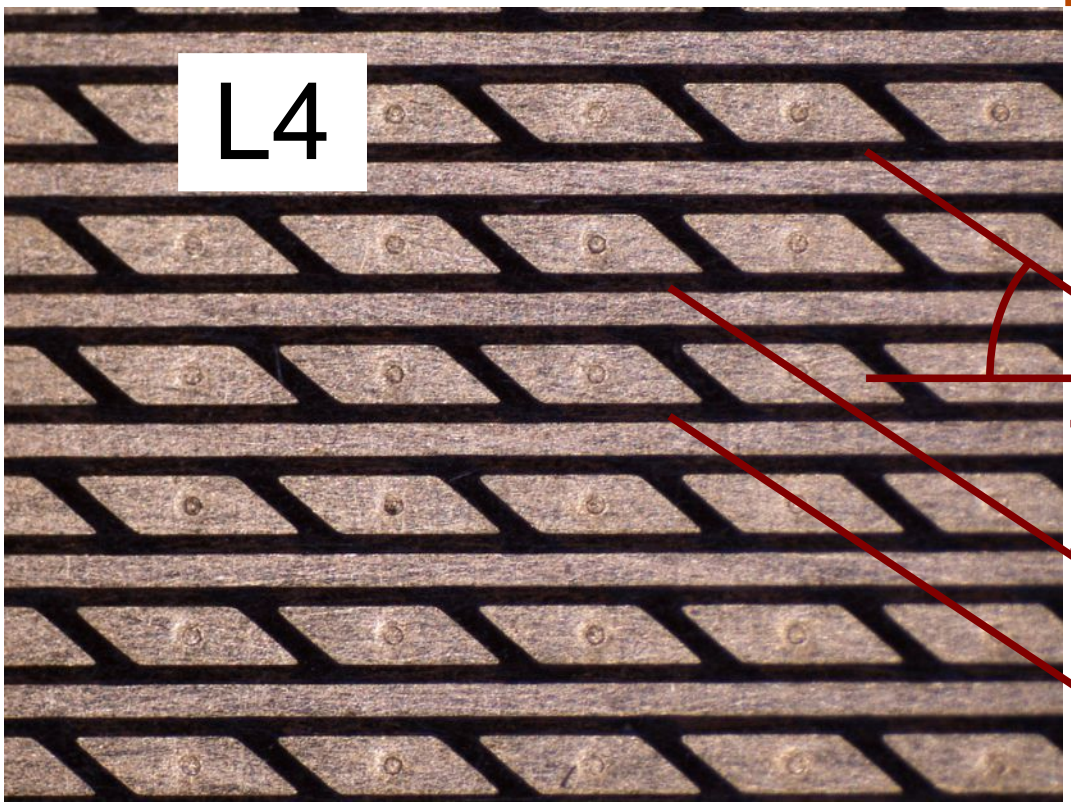
- Every layer of the Inner Tracker is a triple-CGEM composed by a cylindrical anode, 3 CGEM and a cylindrical cathode
- The dimensions of the electrodes required a new production technique
- The CERN TE-MPE-EM workshop (Rui de Oliveira) produced large area GEM foils (up to 350 x 700 mm^2) using the single-mask technique (**first time for an experiment**)
- Every GEM foil is divided in 40 HV sectors (1.5 x 70 cm^2) on the top side and 4 HV sectors on the bottom side in order to reduce the energy of discharges
- Each cylindrical electrode is composed by three foils and it's realised with the wrapping technique developed by us

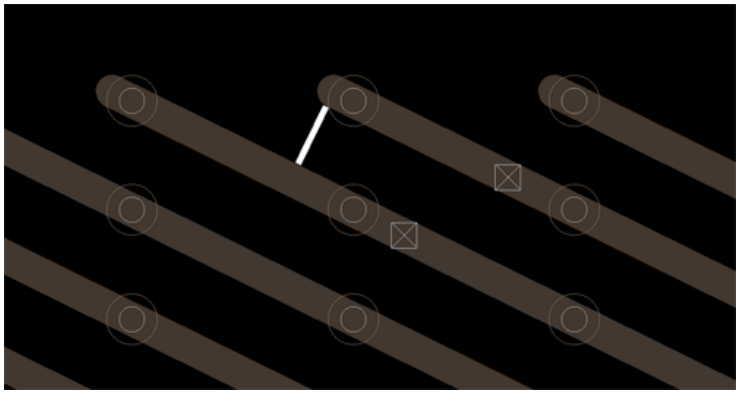


The readout of the IT

The readout of the IT is a flexible kapton/copper circuit.
The 2-dimensional view is given by the X-strips (parallel to the axis of the CGEM) and V pads connected by vias to a common backplane







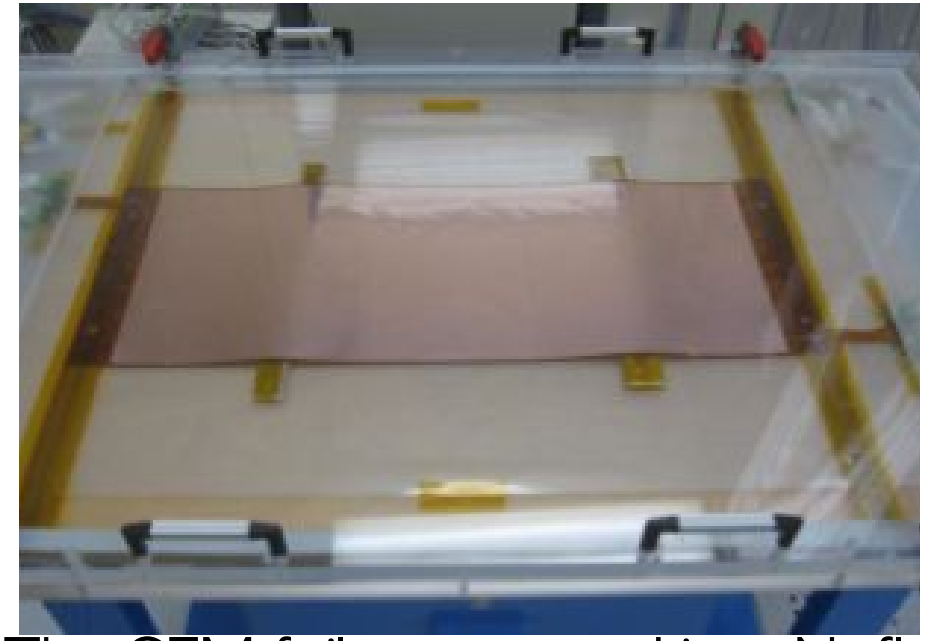
GASTONE: the FEE for the IT

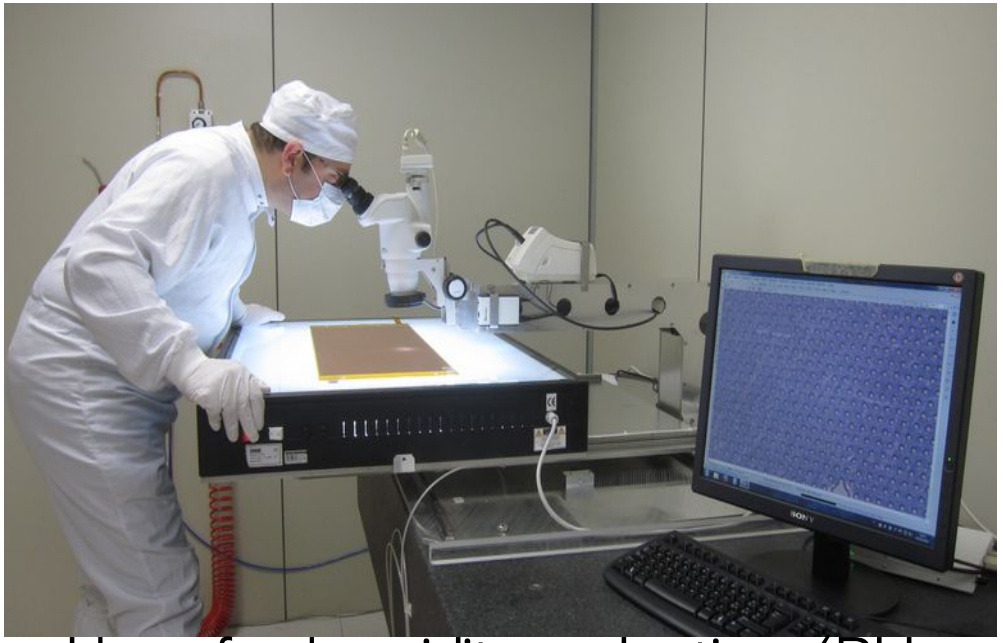
- Mixed analog-digital circuit
- Low input equivalent noise, low power consumption and high integrated chip
- 4 blocks:
  - charge sensitive amplifier
  - shaper
  - leading-edge discriminator (programmable threshold)
  - monostable (stretch digital signal for trigger)

Sensitivity (pF)	**20 mV/fC**
Z_{IN}	**400 Ω** (low frequency)
C_{DET}	**1-50 pF**
Peaking time	**90-200 ns (1-50 pF)**
Noise (erms)	**800 e^- + 40 e^-/pF**
Channels/chip	**64**
Readout	LVDS/Serial

Developed by INFN Bari and LNF

Quality check





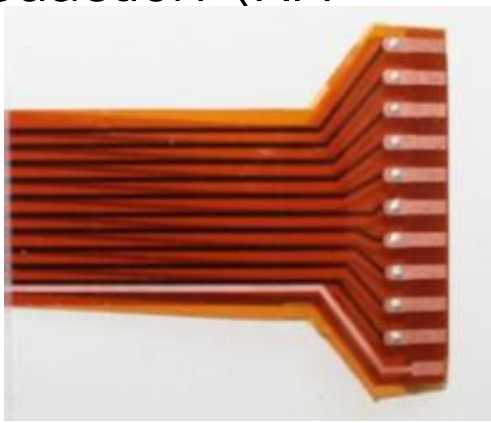
The GEM foils are tested in a N_2 flushed box for humidity reduction (RH below 10%)

Each sector of the foil is supplied with up to 600 V

Discharge rate ($O(1)\ h^{-1}$ @ 600 V) and current leaks (<1nA) are monitored

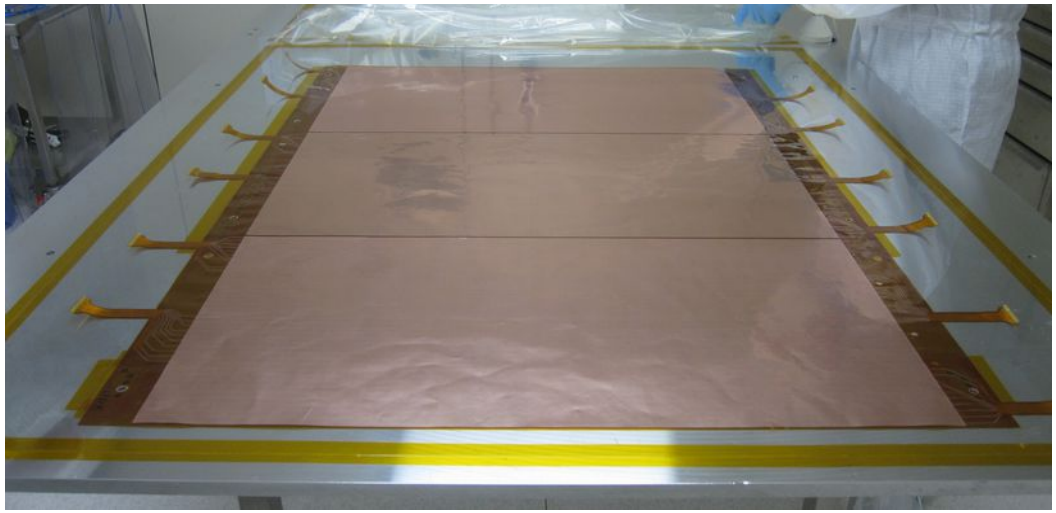
HV connections are checked to have $R < 2\ \Omega$

A complete test takes ~ 4 h

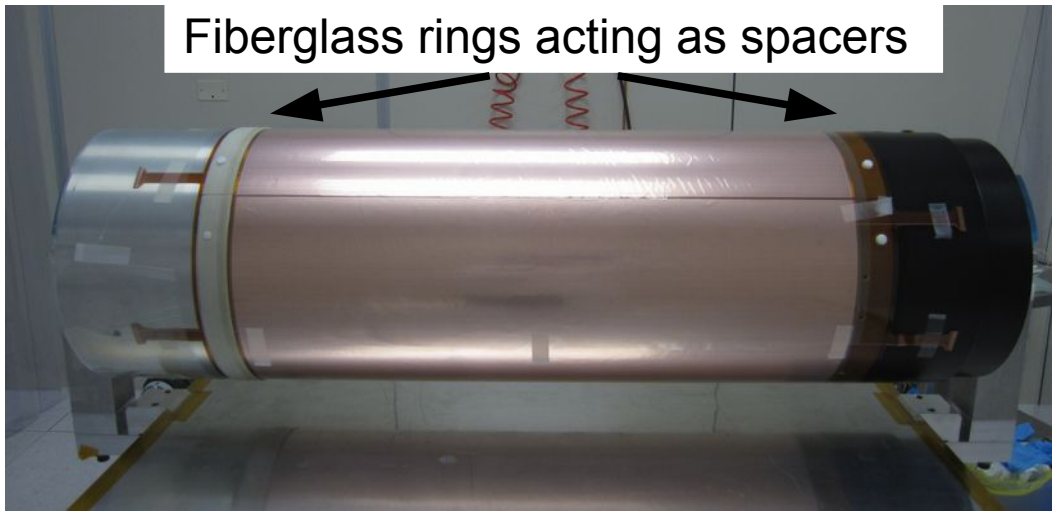


On a total of **50** GEM foils, **41** (**82%**) were OK (**5** of them recovered by Rui), **9** were BAD (large current leaks, short, continuous discharge)

Construction details



Three foils are spliced together along the kapton frame

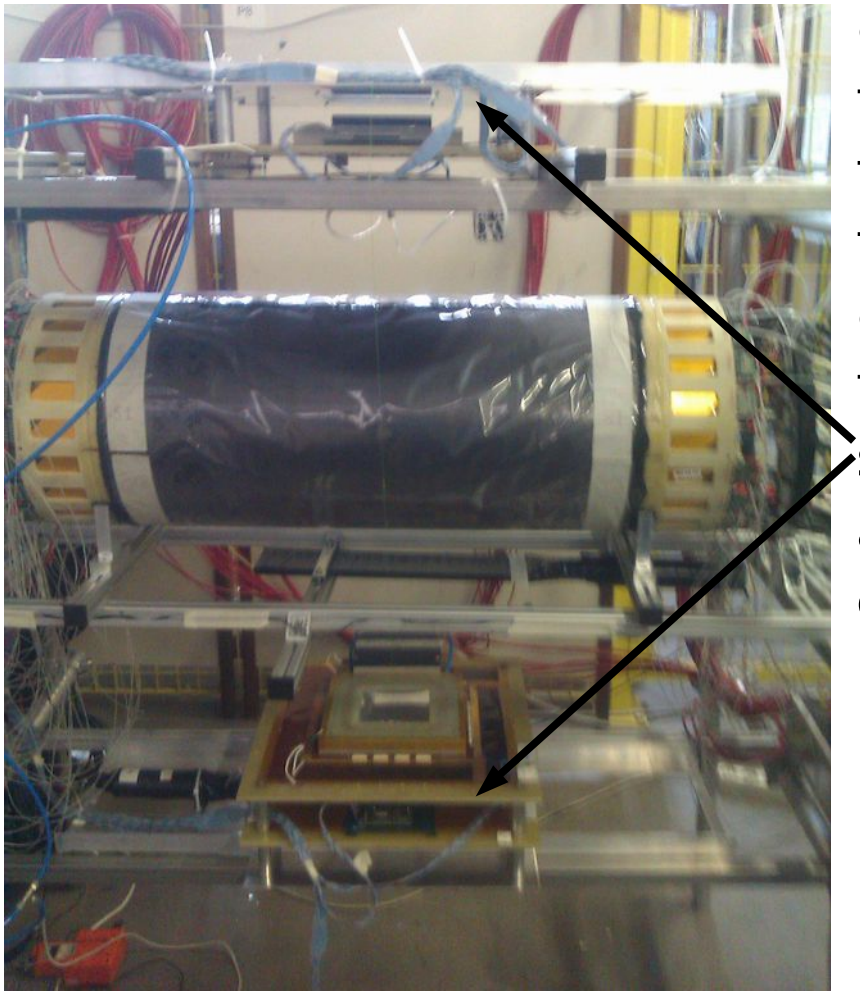


The large electrode is then rolled on a Teflon machined mould, glued and polymerized with the vacuum bag technique

The cylindrical GEM is ready to be extracted from the mould: the very low friction of the Teflon reduces the mechanical tensions on the foil

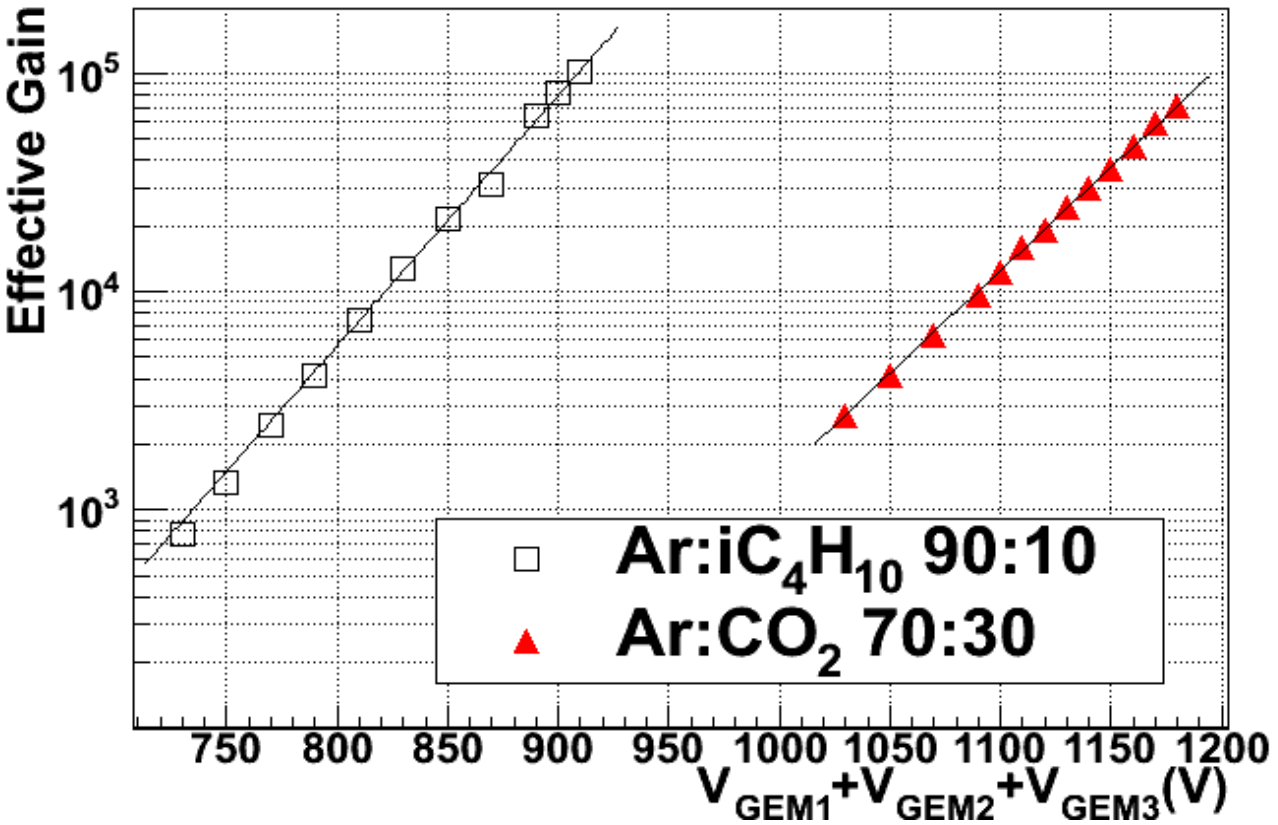
Assembly and test

The Vertical Insertion System provides the insertion of all the cylindrical electrodes one into the other ensuring a distance between the axis less than 100 μm over 1 m length

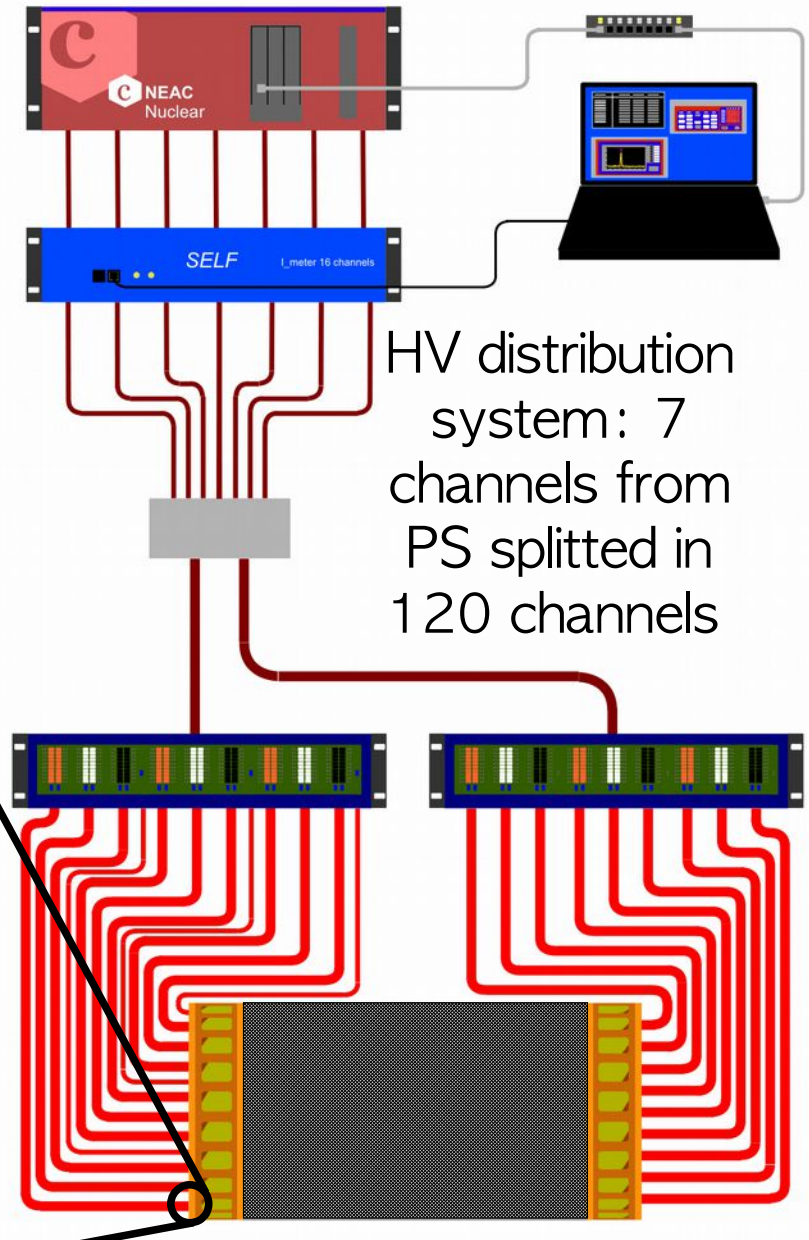


- ^{90}Sr source test to check the functioning along the φ angle
- Cosmic rays test with scintillators trigger and 3 PGEMs as external trackers

Operational parameters



standard non-floating CAEN HV modules



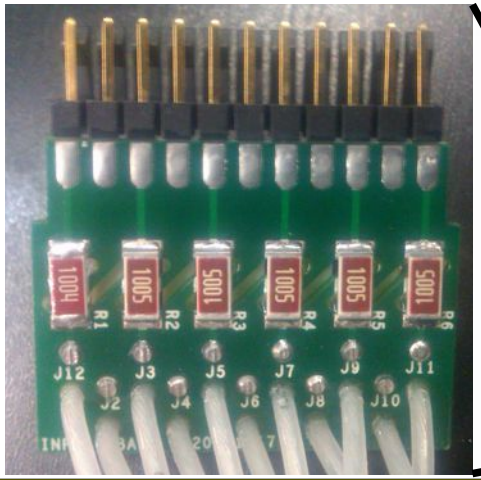
Gas mixture: Ar:iC$_4$H$_{10}$ 90:10

e$^-$/ions pair (3 mm): 10 $\pi^{\pm}$, 100 K$^{\pm}$ (at DAΦNE)

Fields: 1/1.5/1.5/5 kV/cm

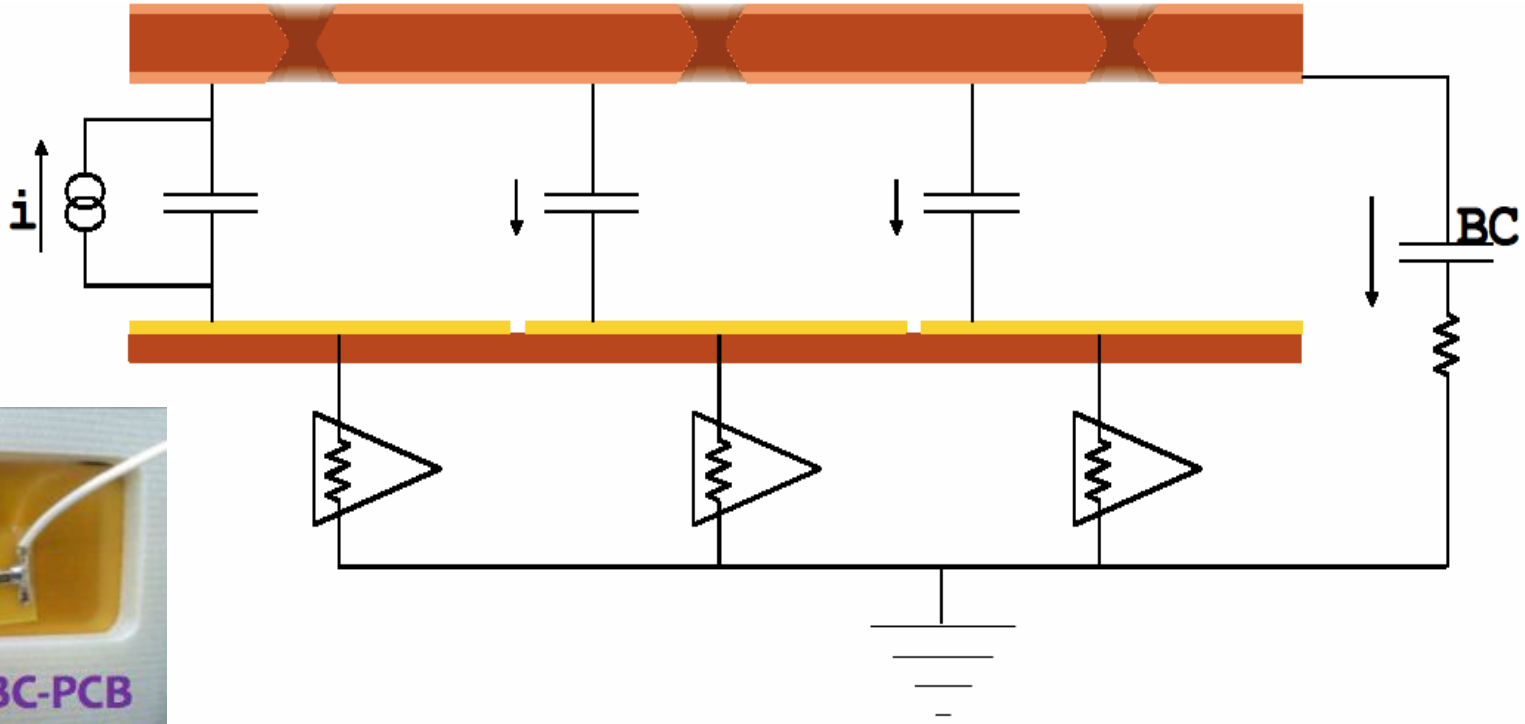
GEM voltages: 295/285/280 V

Gain: O(10^4)

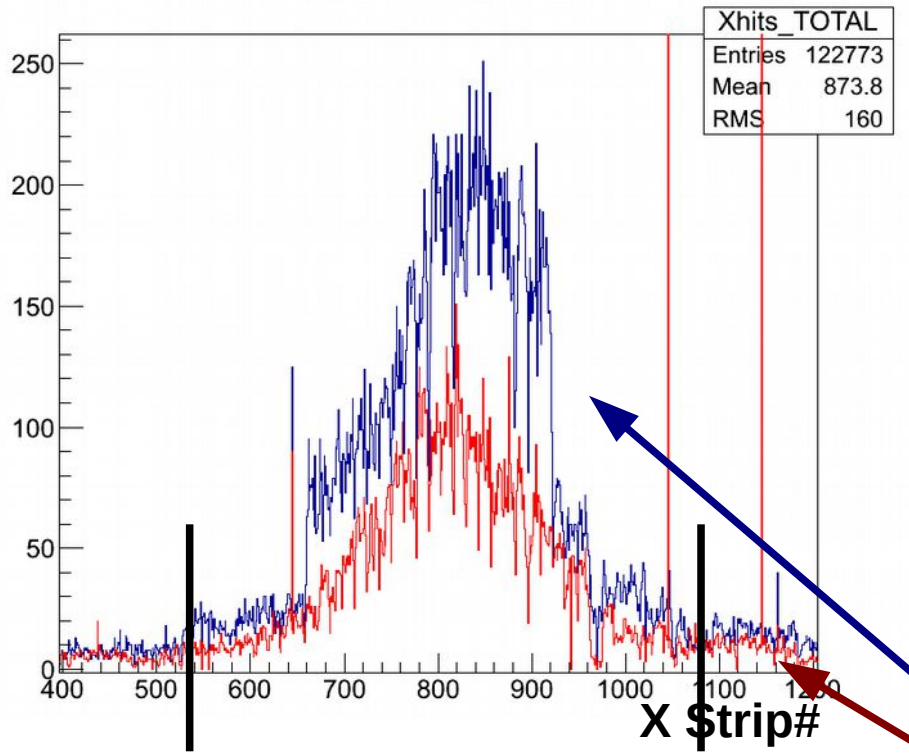


HV Network on the 3rd GEM foil

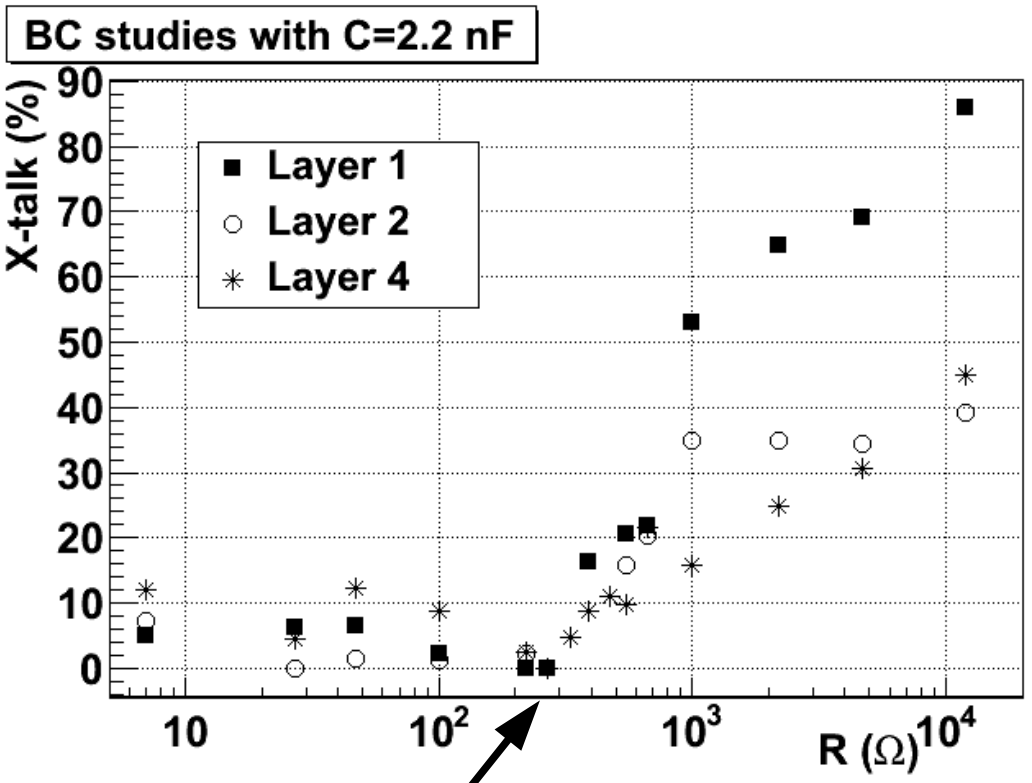
- Correlated noise observed on the CGEM
- This effect can be explained with a capacitive coupling between G3 bottom and the Readout plane. A large charge deposit on the G3 bottom can induce signals on all the strips/pads facing the HV macrosector giving rise to Large Hits Multiplicity Events
- These events can be strongly reduced installing a RC circuit (from LHCb experience) between the G3 bottom and the strips/pads ground plane.



Blocking Capacitor optimization



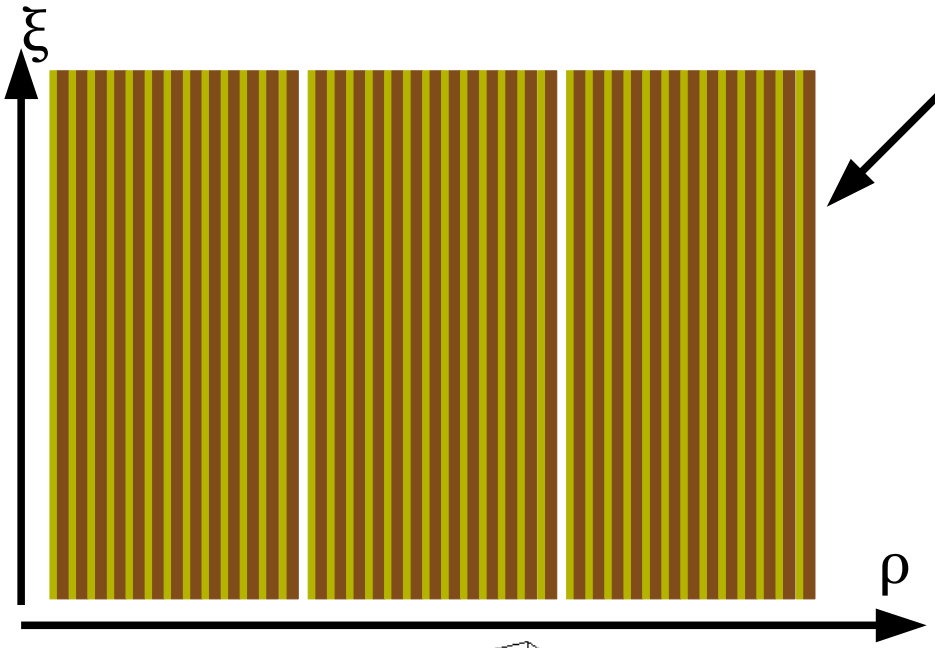
Strips range of integration



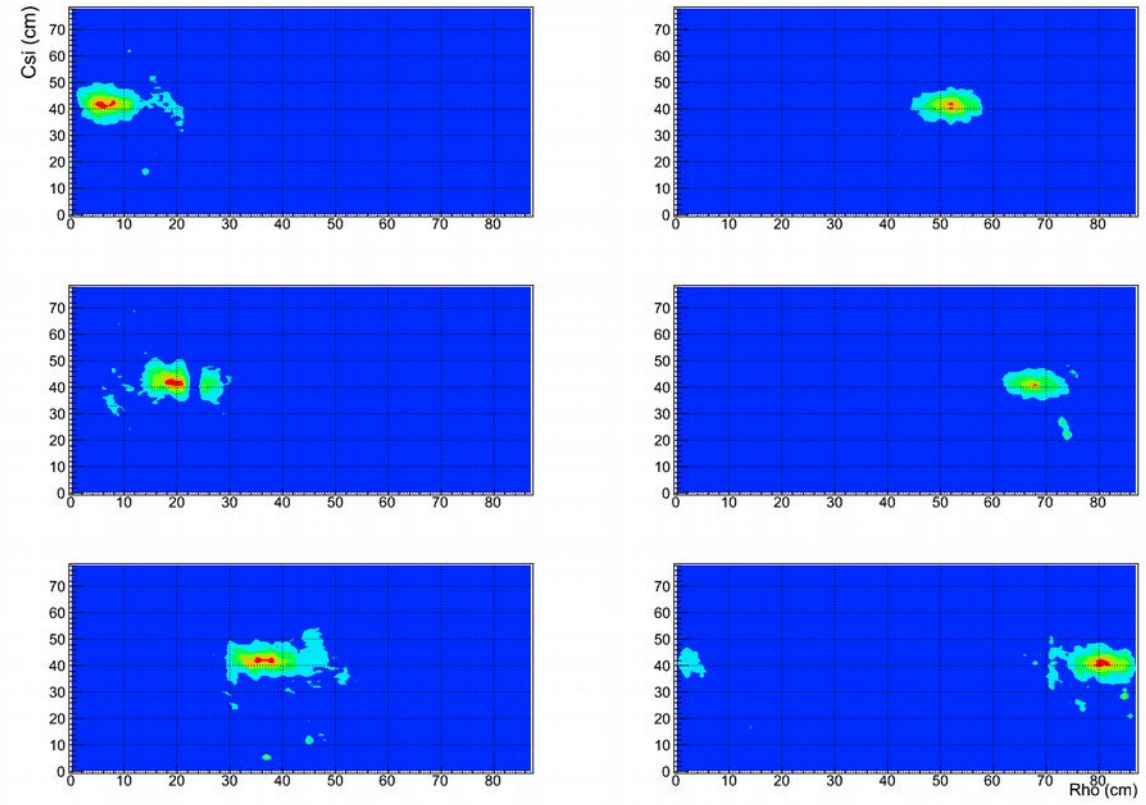
assuming R_{min} the value minimizing the integral of the entries we defined:

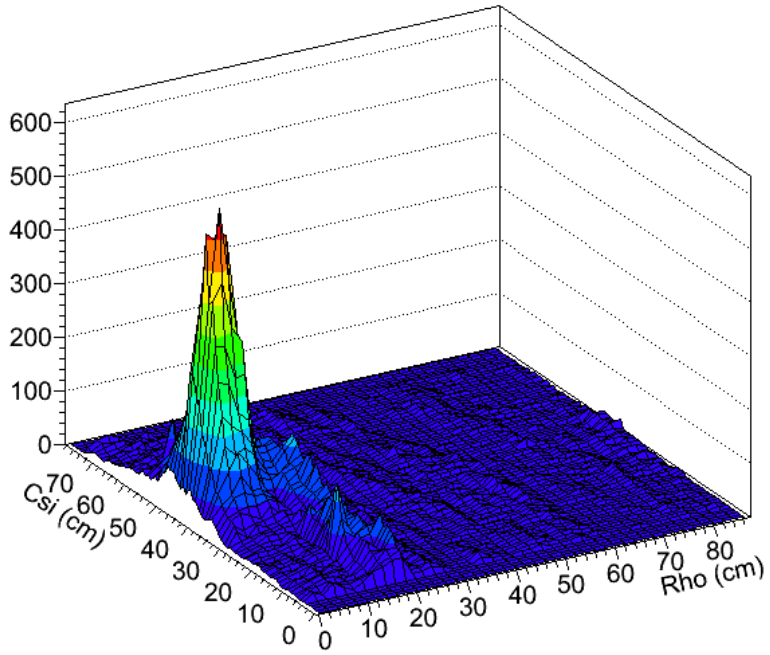
$$X-talk(R)=\frac{\int_{Strips\ range} Entries(R) - \int_{Strips\ range} Entries(R_{min})}{\int_{Strips\ range} Entries(R_{min})}$$

Test results from ^{90}Sr source



Unrolled anode



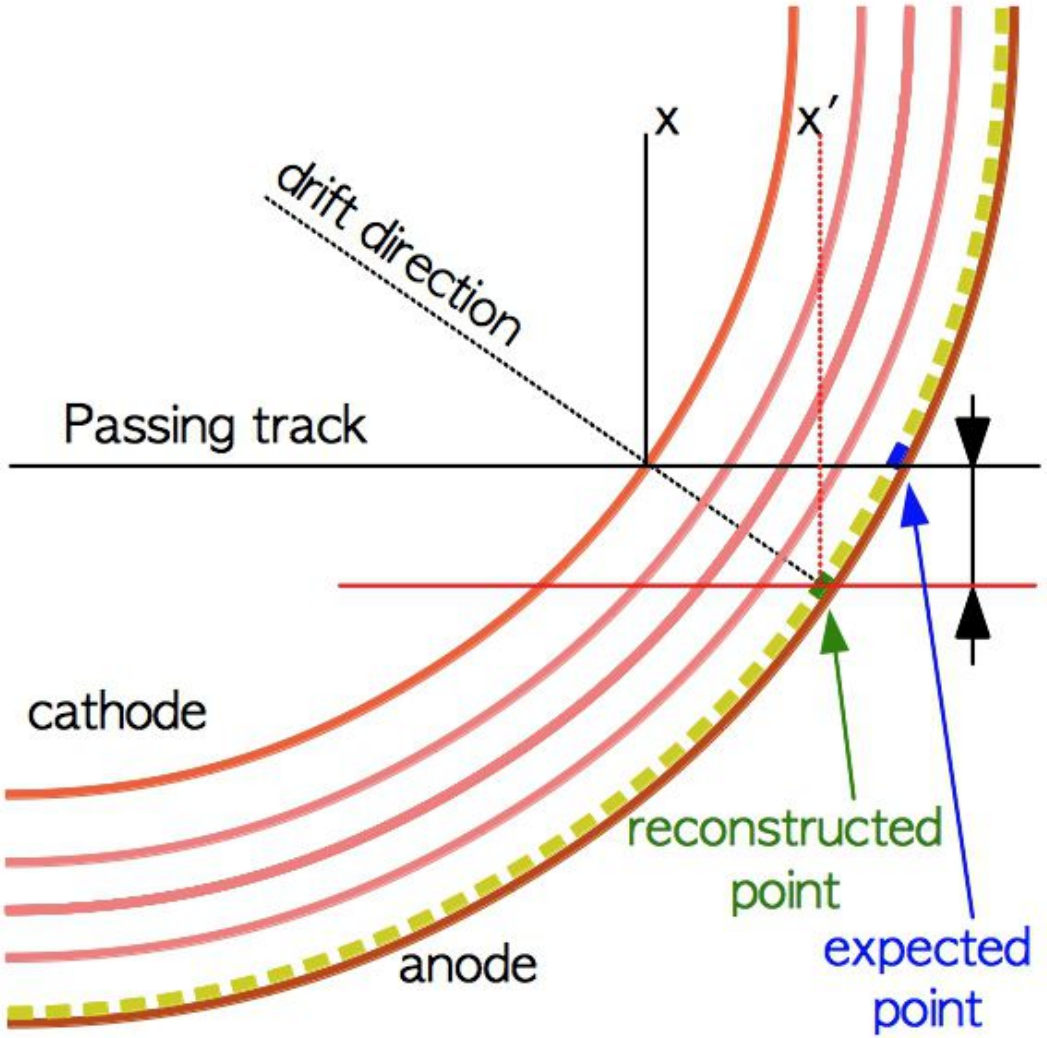


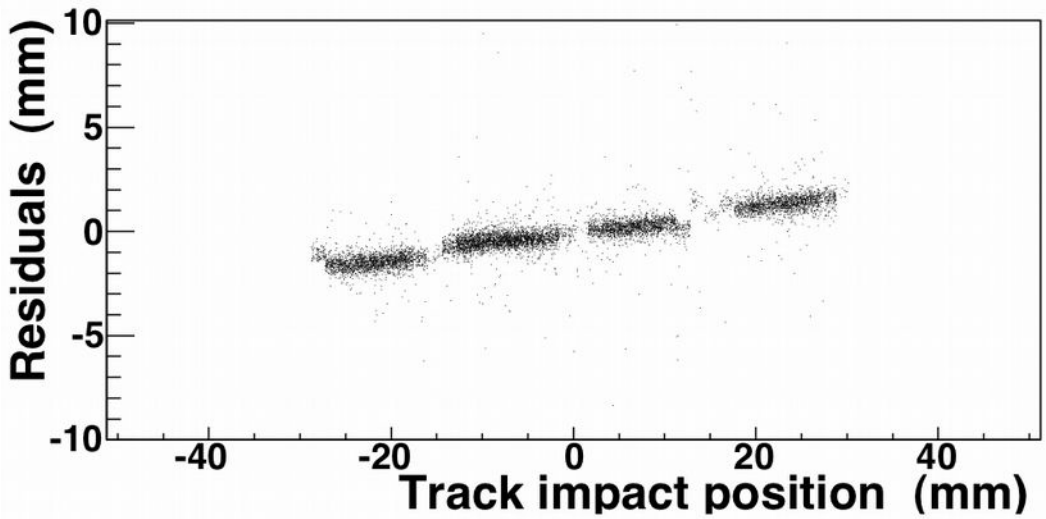
The profile of the source in 6 different positions is reconstructed by triggering the DAQ with a clock signal

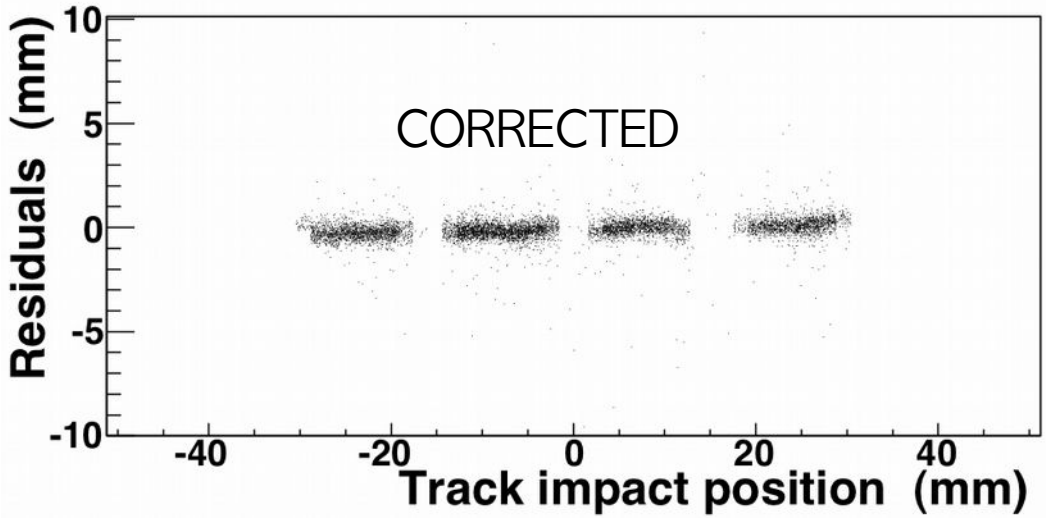
This fast test allows to check the cabling

A peculiar feature from R&D

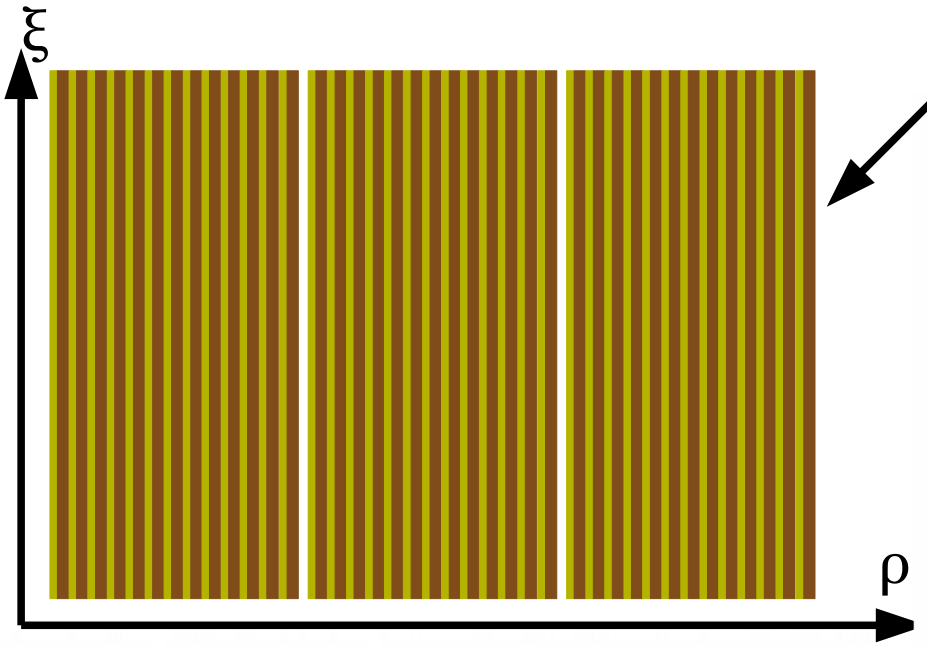
The tracks usually don't cross the detector along a diameter, so according to its impact parameter with respect to the centre, due to the radial drift of the ionization, a correction on the reconstructed position must be applied



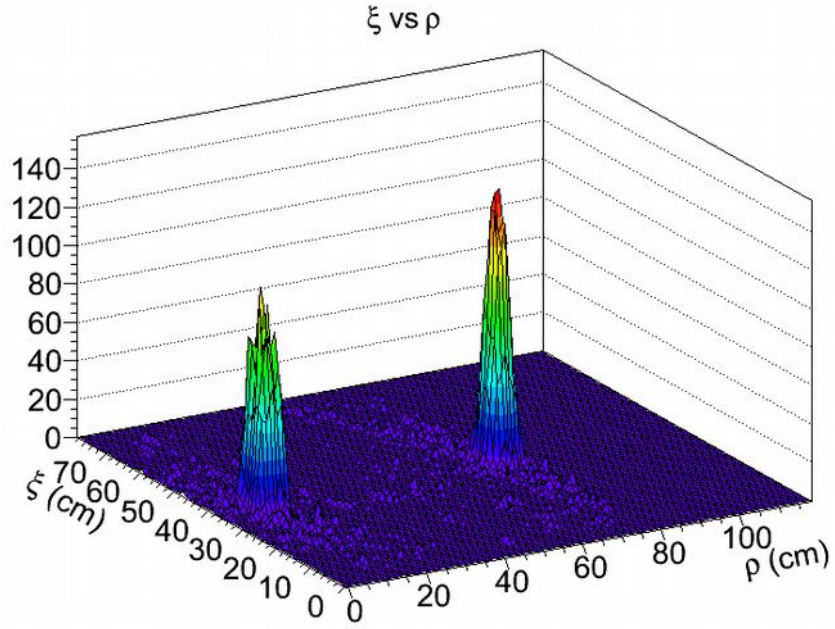


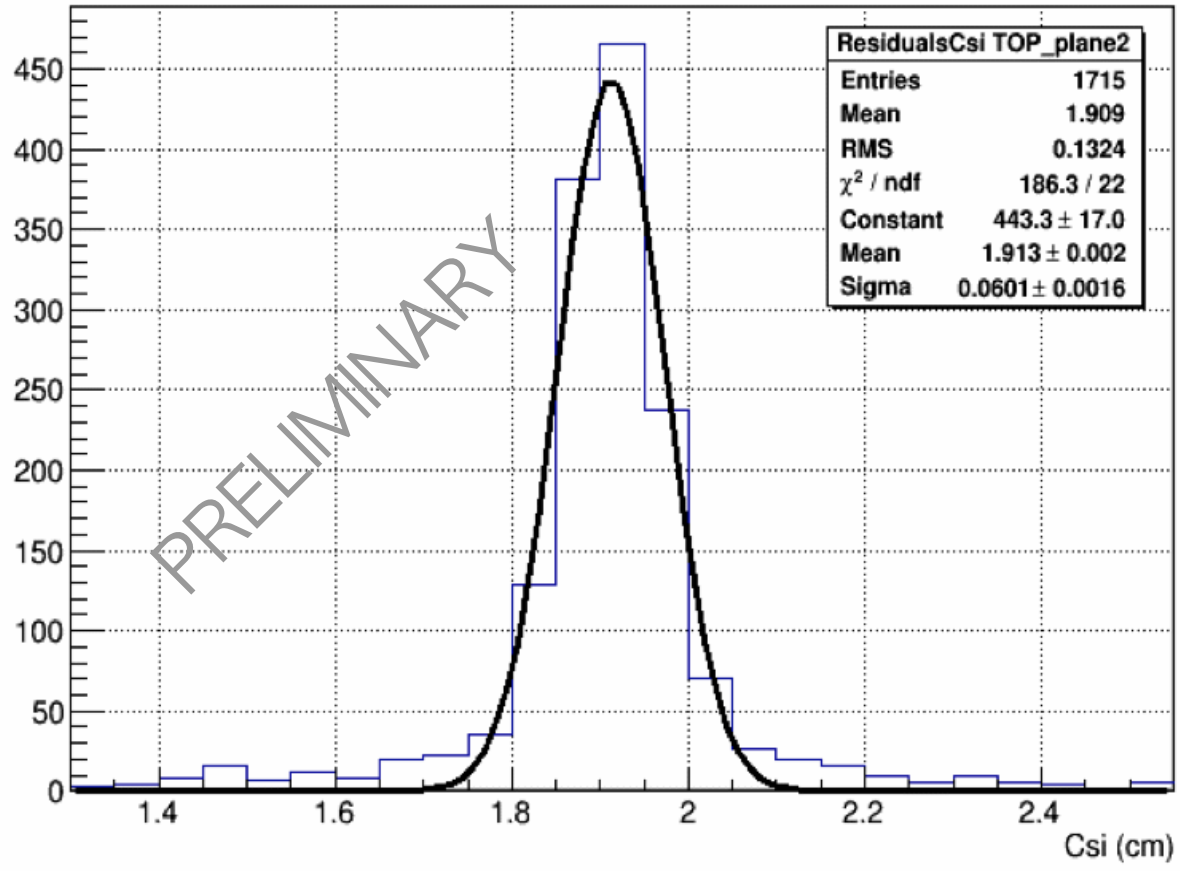


Test results from cosmic rays events



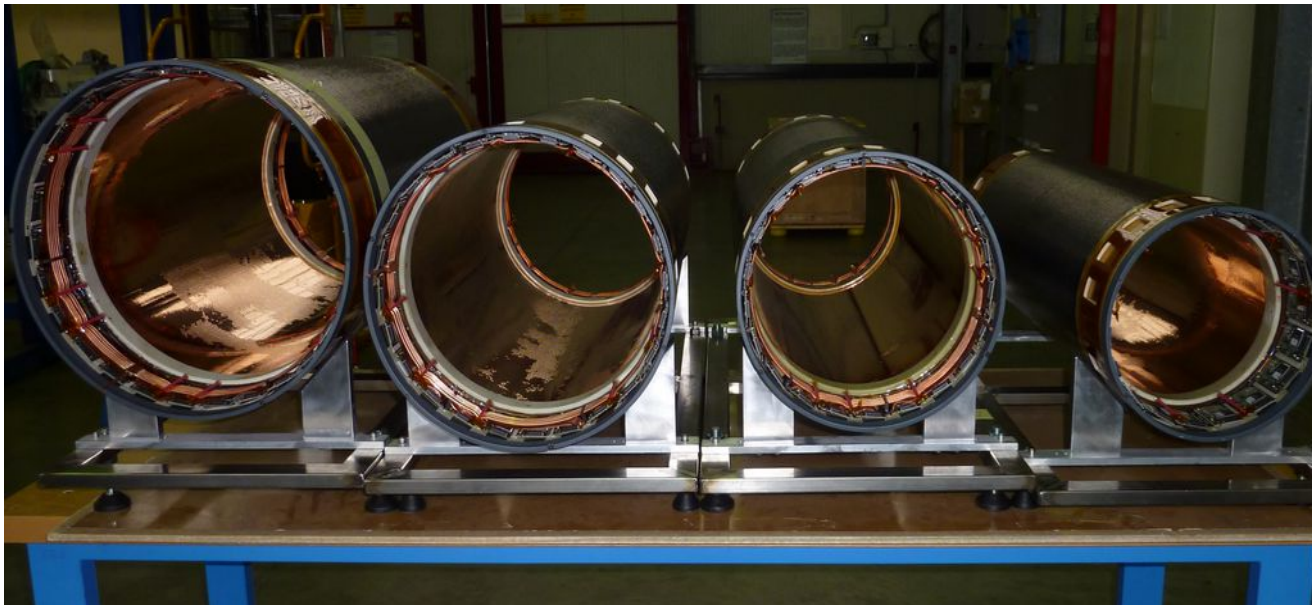
Unrolled anode

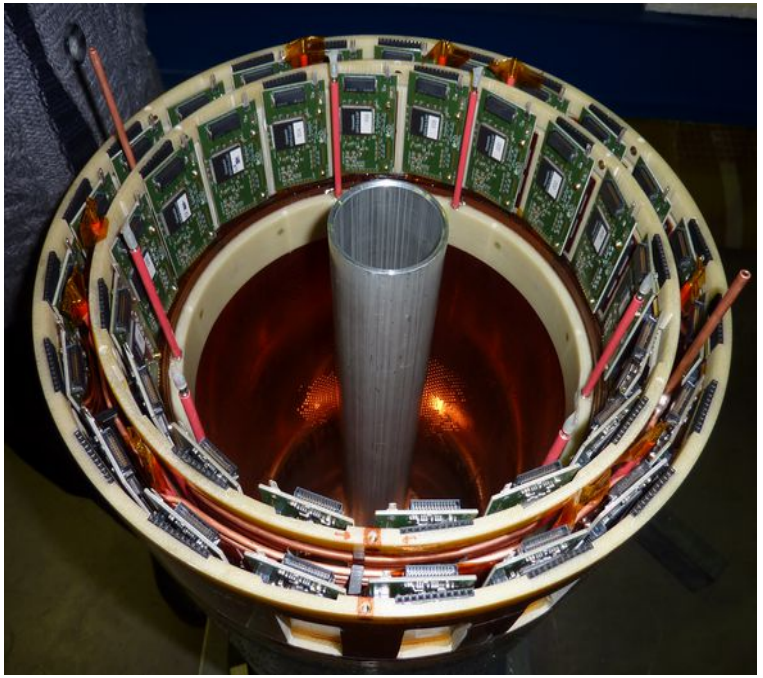


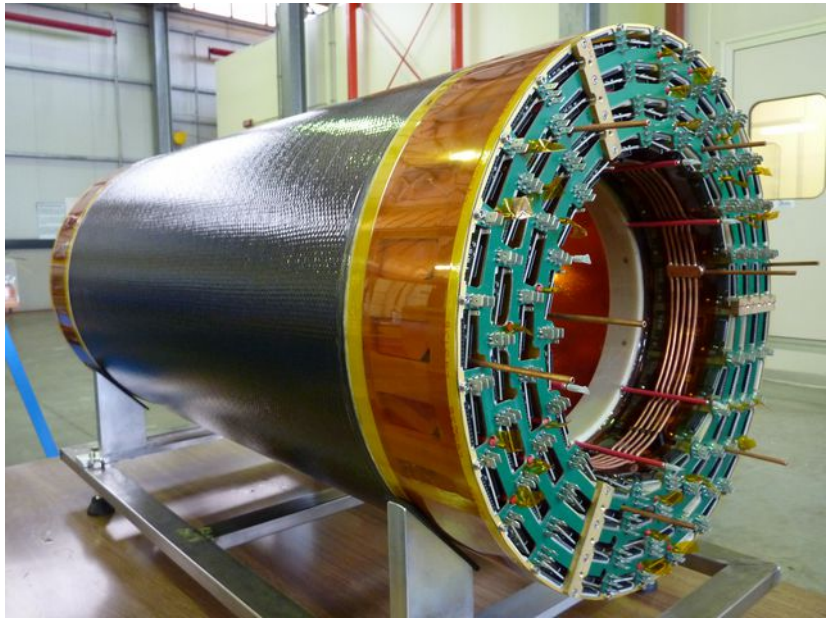


Events selected using External Tracking provided by 3 Planar Triple-GEM

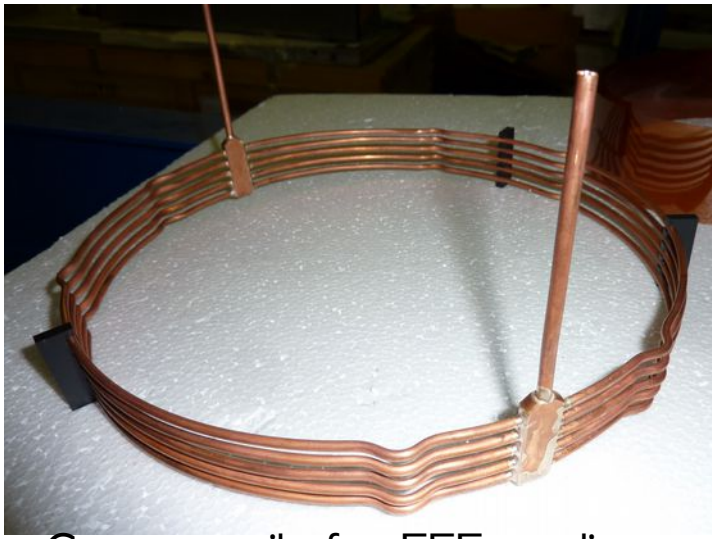
IT final assembly





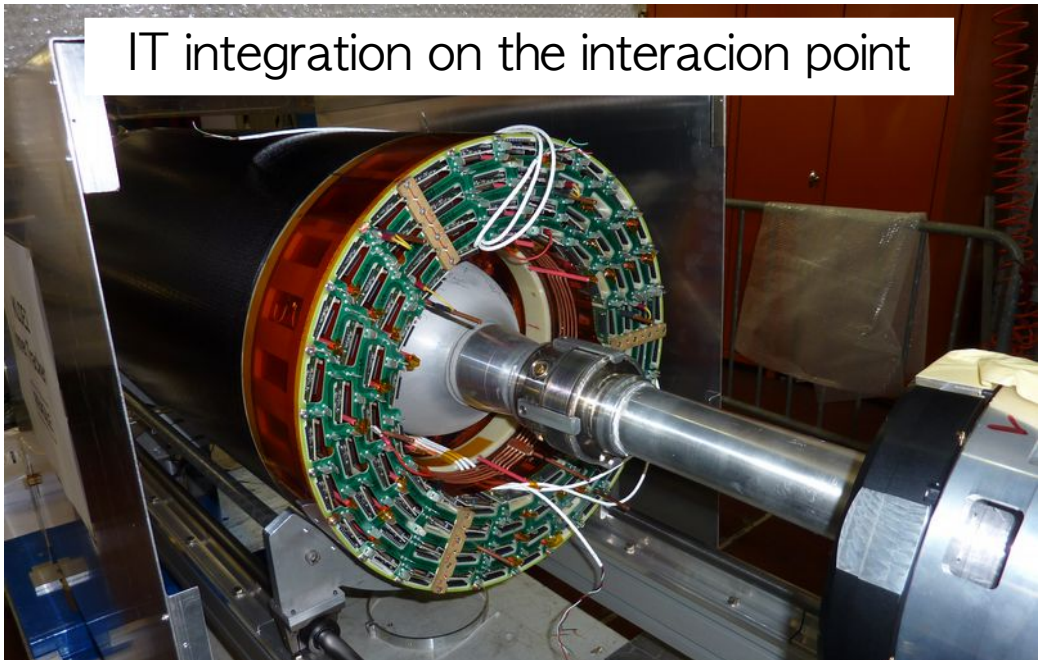


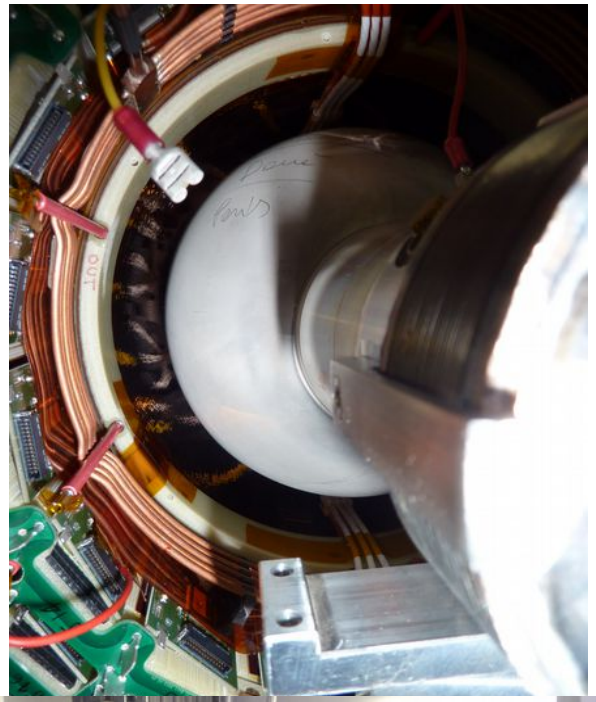
The final assembly of the KLOE-2 Inner Tracker, with the insertion of all the triple-CGEMs one into the other took place in March 2013



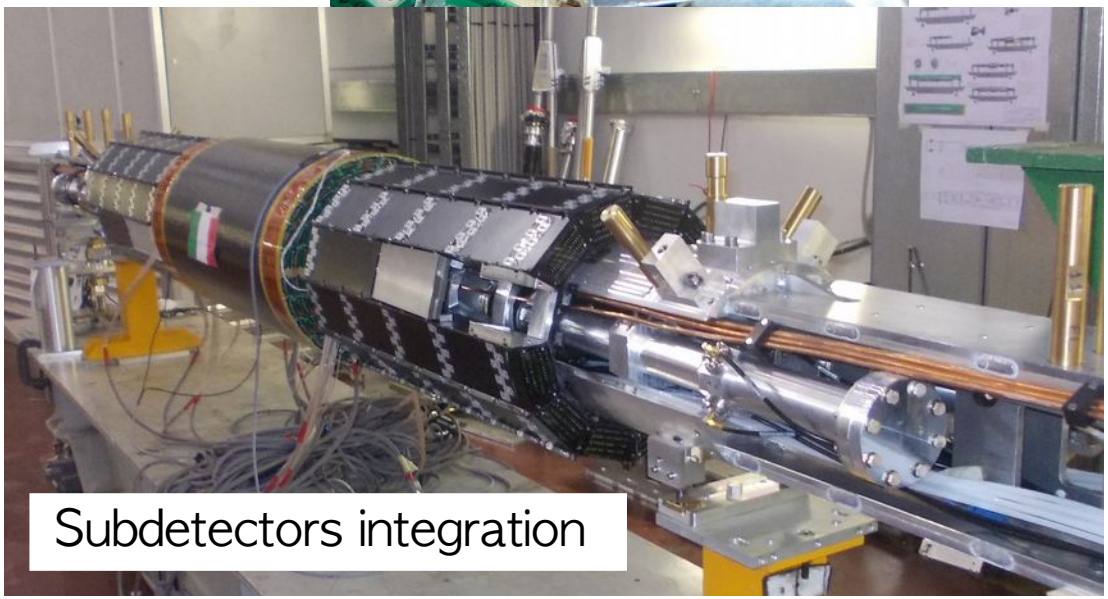
Copper coils for FEE cooling

IT integration


IT integration on the interacion point

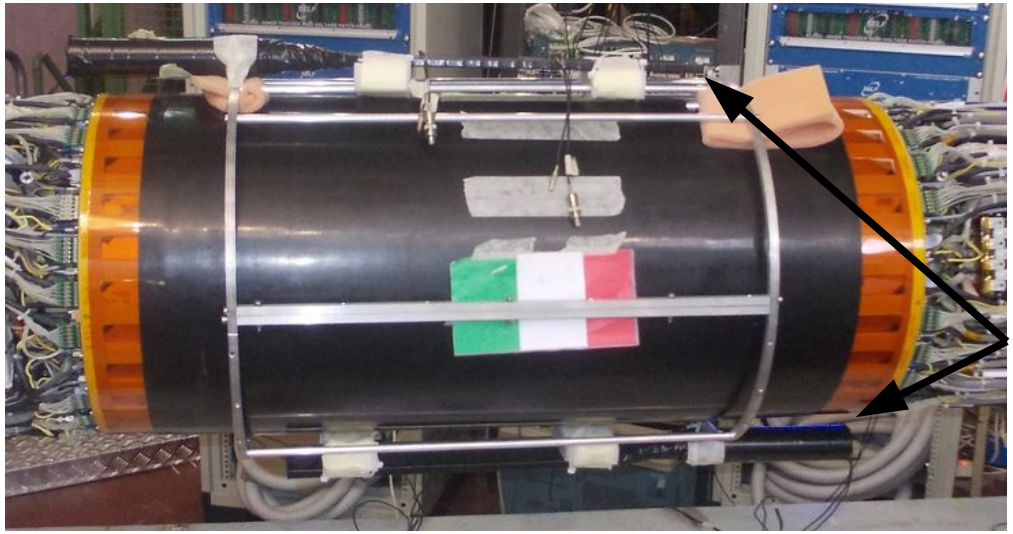


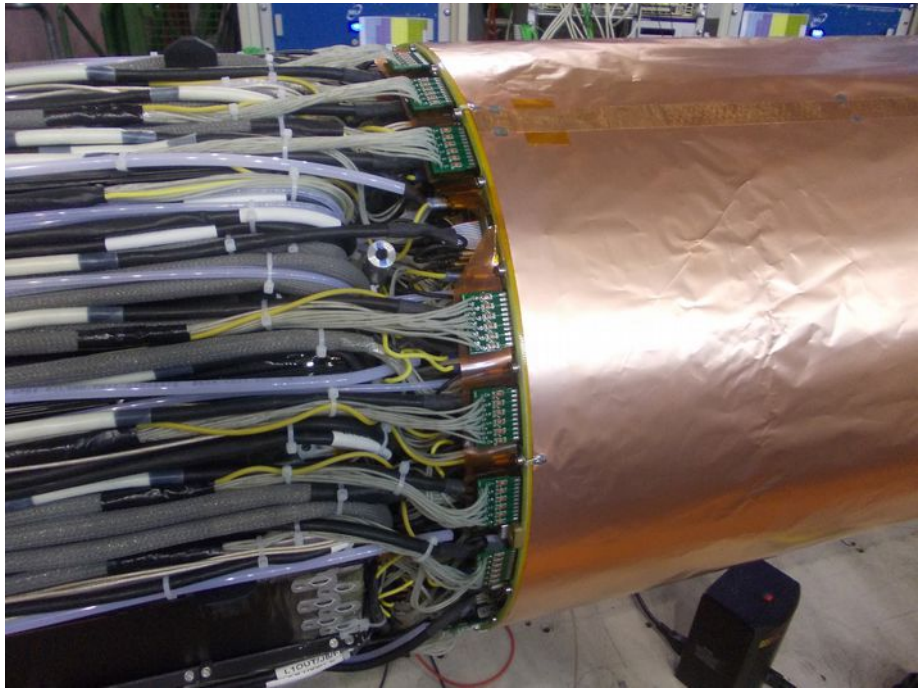
IP soldering


Subdetectors integration

IT integration

Faraday cage completed with a **18 µm** shield connected to the PCB end caps

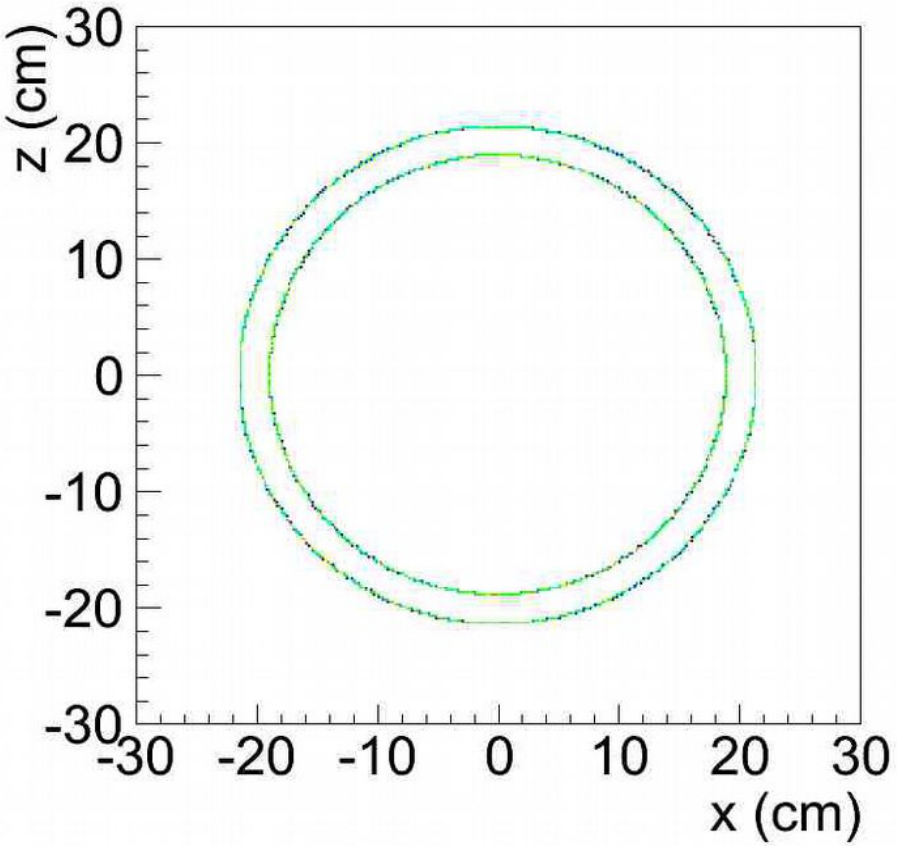




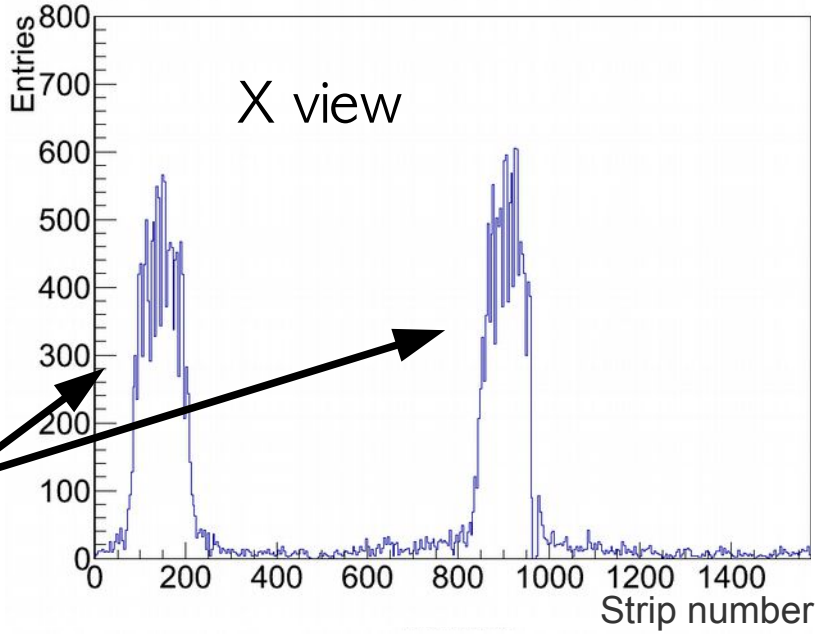
Scintillators for cosmic rays trigger mounted on a cylindrical rotating support for acquisition on different sectors of the Inner Tracker

Pre-insertion test

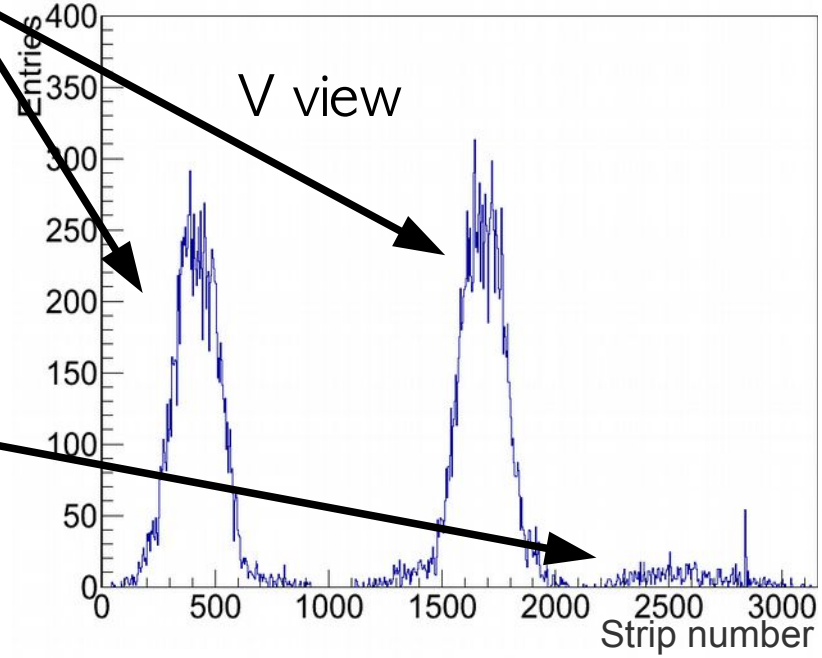
After the final cabling each layer was tested



Noise run with Layer 3 & 4



peaks related to cosmic rays



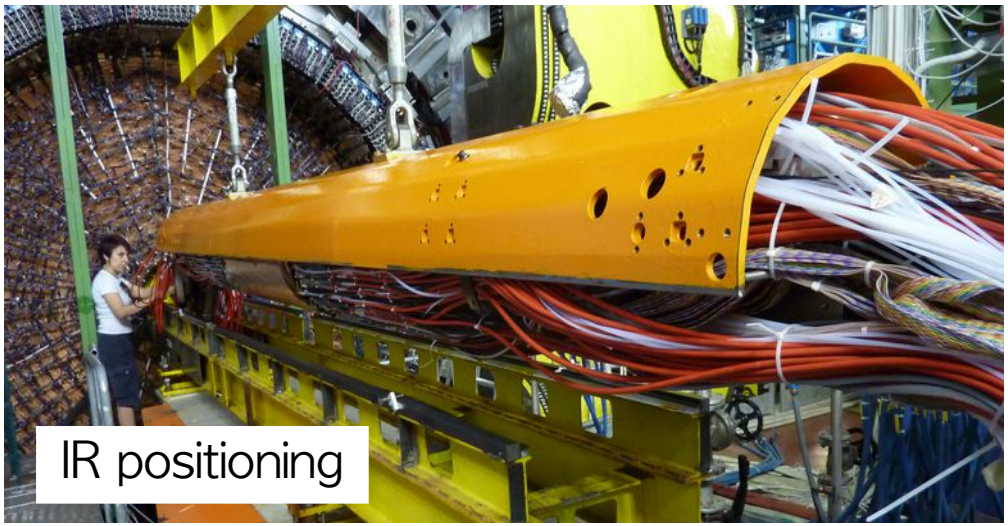
noise correlated to the V strips length

IT integration

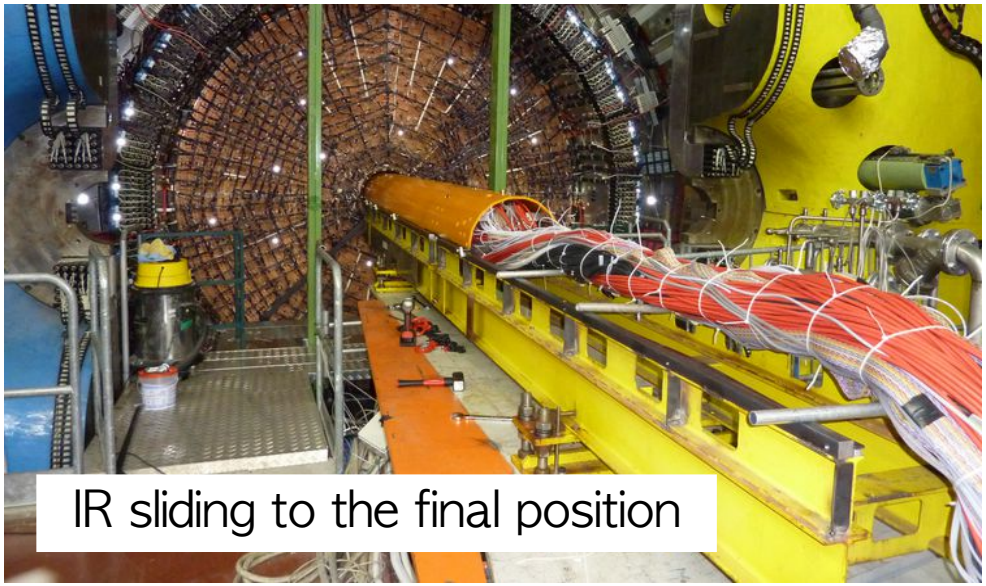

Protection shell installation


Interaction region movement

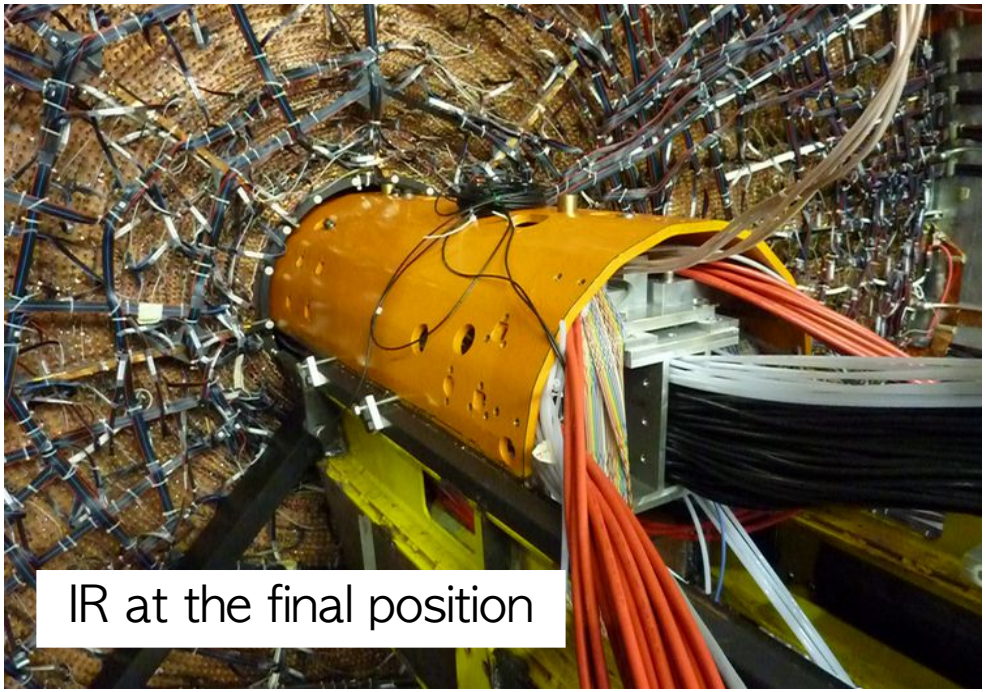

Kapton protection on the HV boards


IR positioning

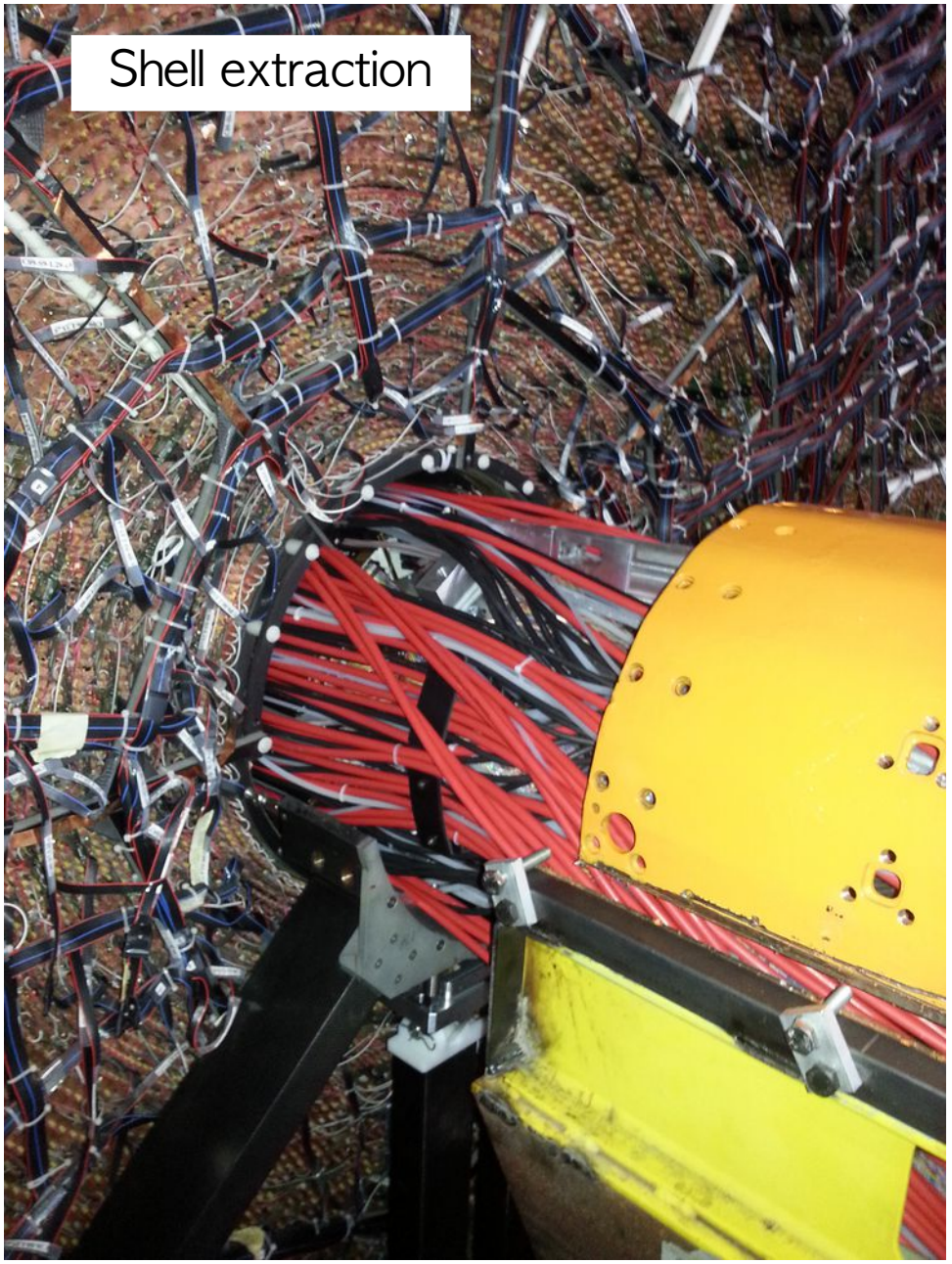
IT integration



IR sliding to the final position



IR at the final position



Shell extraction

Summary and outlook

- The Inner Tracker has been completed and installed and cabled on DAΦNE
- Optimization of the operating parameters
- Calibration and alignement runs with the KLOE DC w/o magnetic field
- Calibration runs in magnetic field
- Physics runs by the end of the year

References

- TDR of the Inner Tracker for the KLOE-2 experiment [arXiv:1002.2572]

- D. Domenici, G. Morello et al., *"Status of the cylindrical-GEM project for the KLOE-2 Inner Tracker"*, COMO 2009, Astroparticle, particle and space physics, detectors and medical physics applications, 839-844

- M. Alfonsi, G. Morello *et al.* *"Activity of CERN and LNF Groups on Large Area GEM Detectors"*, Proceeding of the 11th Pisa Meeting on Advanced Detectors, Nucl. Instr. Meth.A 617 (2010)

- E. De Lucia, G. Morello *et al.* *"Status of the cylindrical-GEM project for the KLOE-2 Inner Tracker"*, Proceeding of the 12th Vienna Conference on Instrumentation (2010), Nucl. Instr. Meth. A 628 (2011) 194-198

- G. Morello for the KLOE-2 Collaboration, *"An innovative tracker for precision measurements at KLOE-2"*, Proceeding of the IFAE 2010, Il Nuovo Cimento 33 C (2010) 221

- A. Balla, G. Morello et al., *"Design and construction of a cylindrical GEM detector as Inner Tracker in KLOE-2"*, NSS/MIC, 2011 IEEE 1002-1005

- A. Balla, G. Morello et al., *"Design and construction of a cylindrical GEM detector as the Inner Tracker device of the KLOE-2 experiment"*, Proceeding of TIPP 2011, Phys. Proc., 37 (2012) 522-529

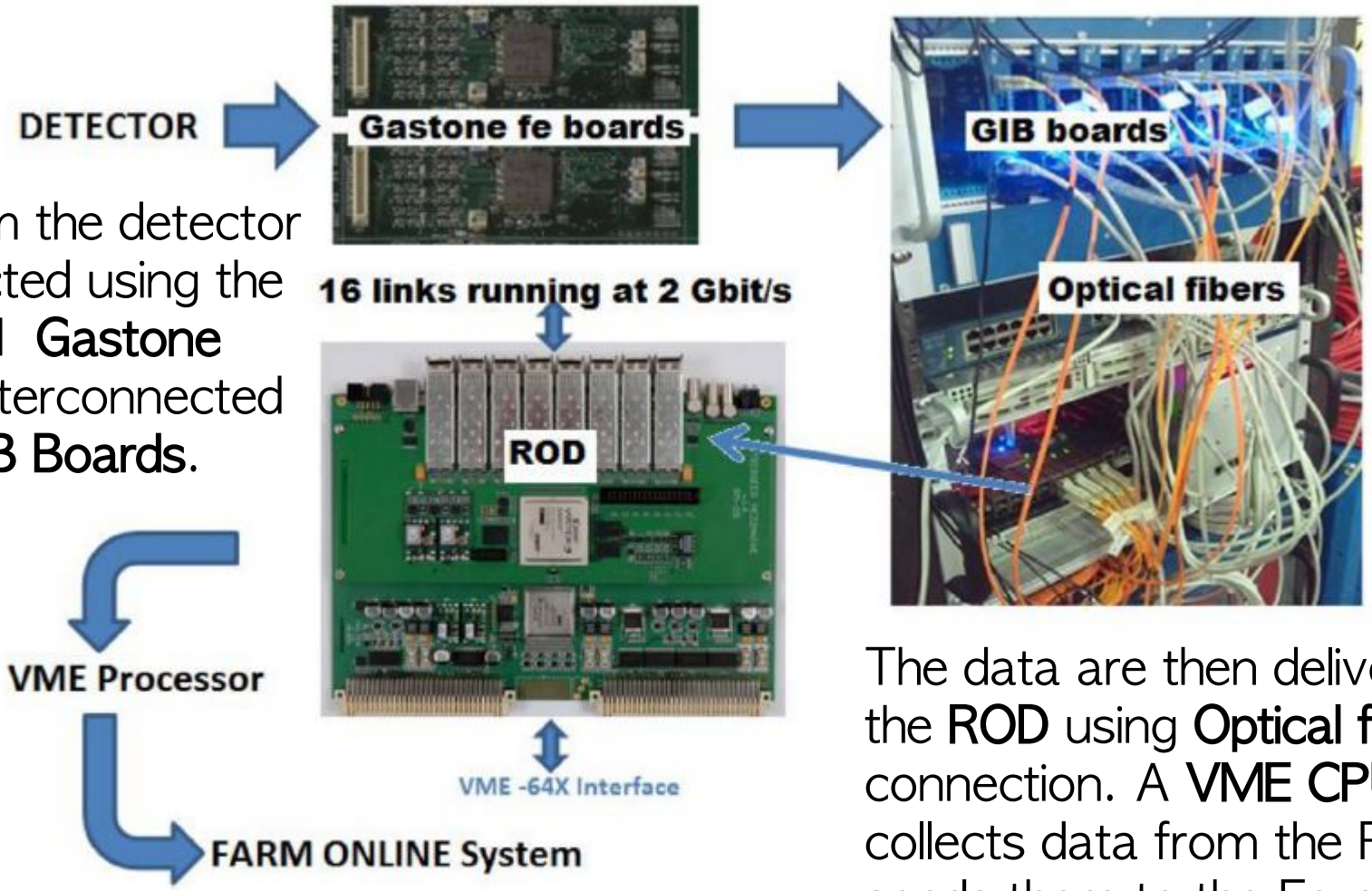
- G. Morello for the KLOE-2 Collaboration, *"Design and construction of a cylindrical GEM detector as the Inner Tracker device of the KLOE-2 experiment"*, Proceeding of STORI' 2011, PoS STORI11 (2011) 071

- A. Balla, G. Morello et al., *"A new cylindrical-GEM Inner Tracker for the upgrade of the KLOE experiment"*, Nucl. Phys. Proc. Suppl. 215 (2011) 76-78

- E. De Lucia, G. Morello et al., *"Production and test of the first two layers of the KLOE-2 Inner Tracker"*, NSS/MIC, 2012 IEEE 754-758

Spare slides

DAQ system



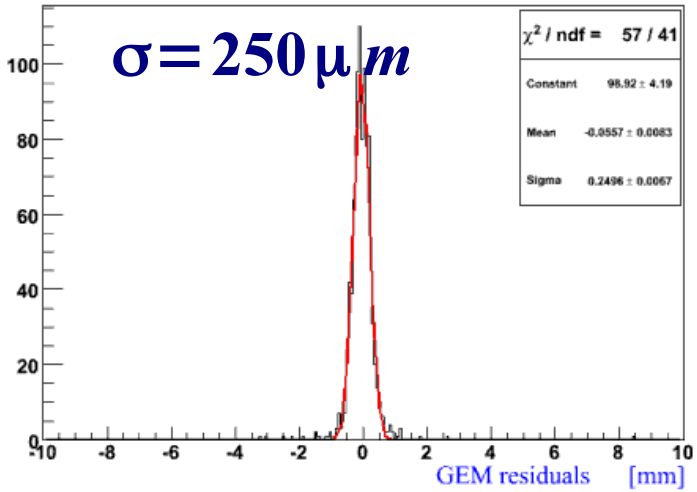
Data from the detector are collected using the front-end **Gastone boards** interconnected to the **GIB Boards**.

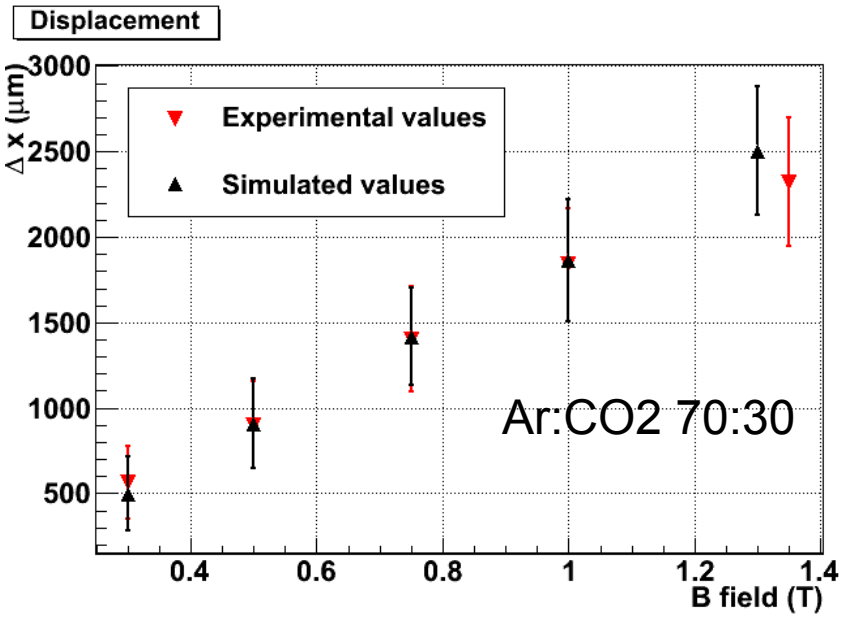
The data are then delivered to the **ROD** using **Optical fiber**s connection. A **VME CPU** board collects data from the ROD and sends them to the Farm on-line system through TCP/IP

Finally, the data are written to the storage disks.

The R&D of the Inner Tracker

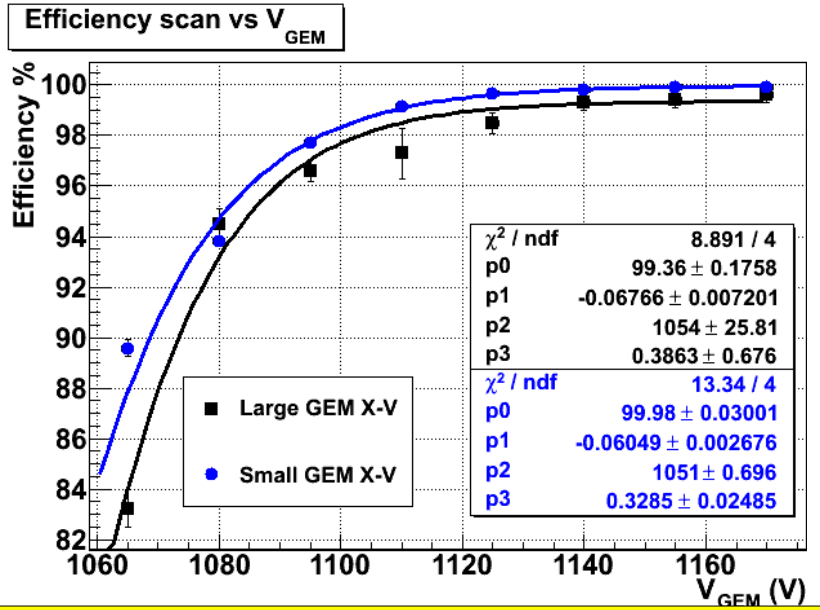
Construction and characterization of a CGEM prototype (test beam 2008) built using 3 GEM foils (**354 x 330 mm²**) spliced together. Axial strips (single view).





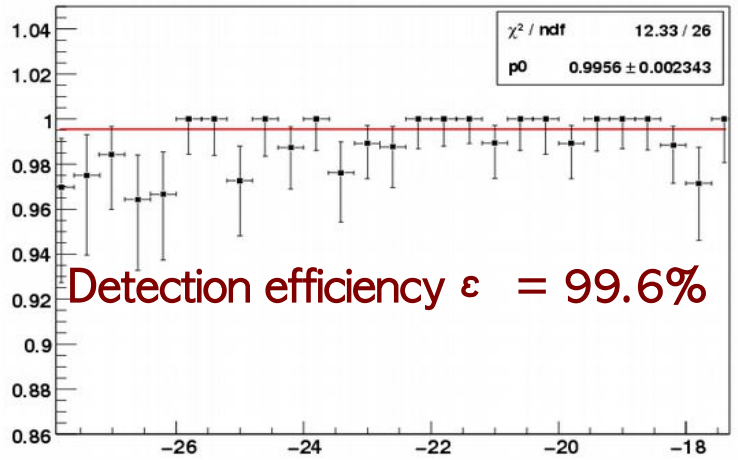
Construction of **100 x 100 mm²** planar chambers equipped with new concept for X-V readout and study of their behaviour in magnetic field.

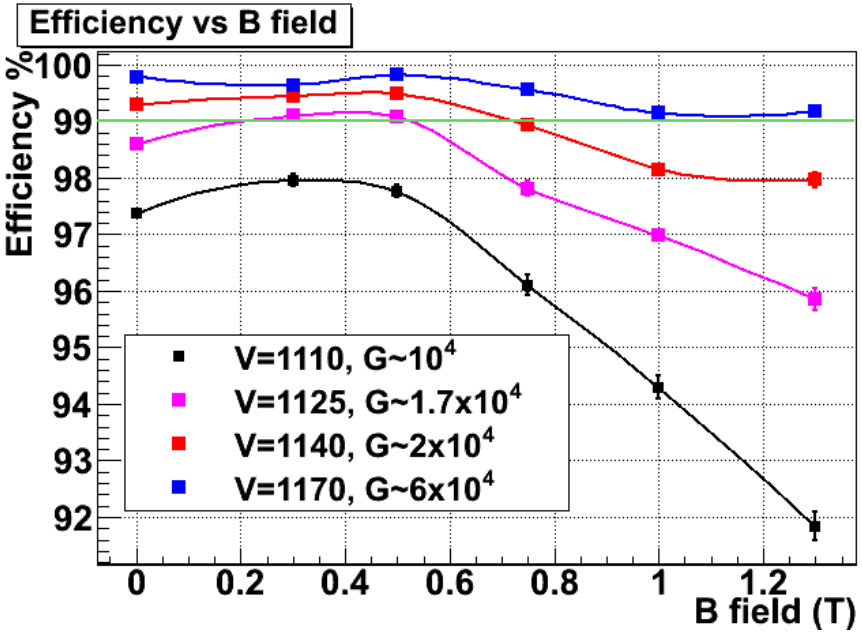
Construction and characterization of two large planar chambers with the new single-mask photolitographic technique equipped with final X-V readout (test beam 2010).



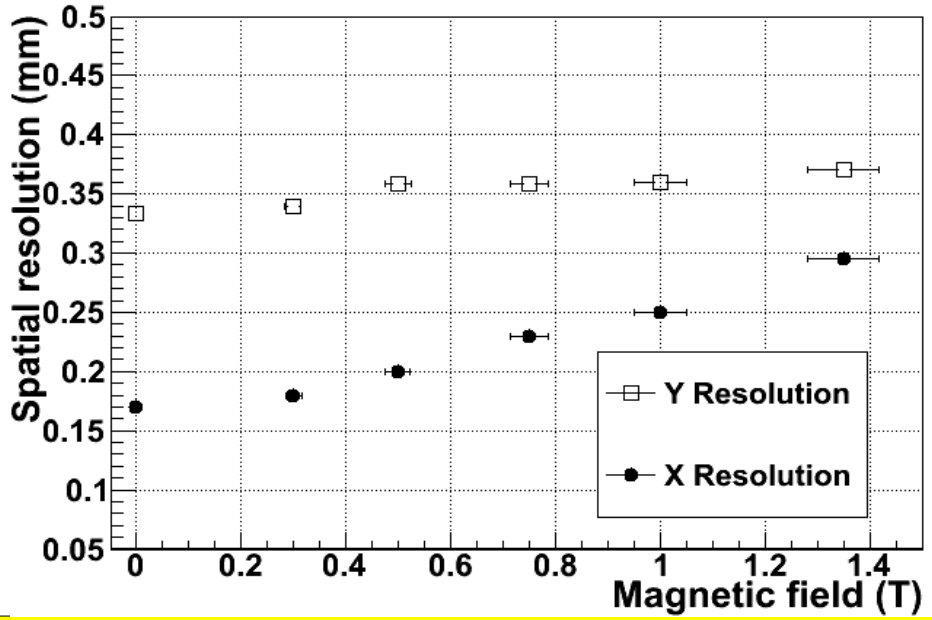
The R&D of the Inner Tracker

Construction and characterization of a CGEM prototype (test beam 2008) built using 3 GEM foils (**354 x 330 mm²**) spliced together. Axial strips (single view).

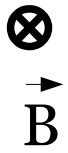


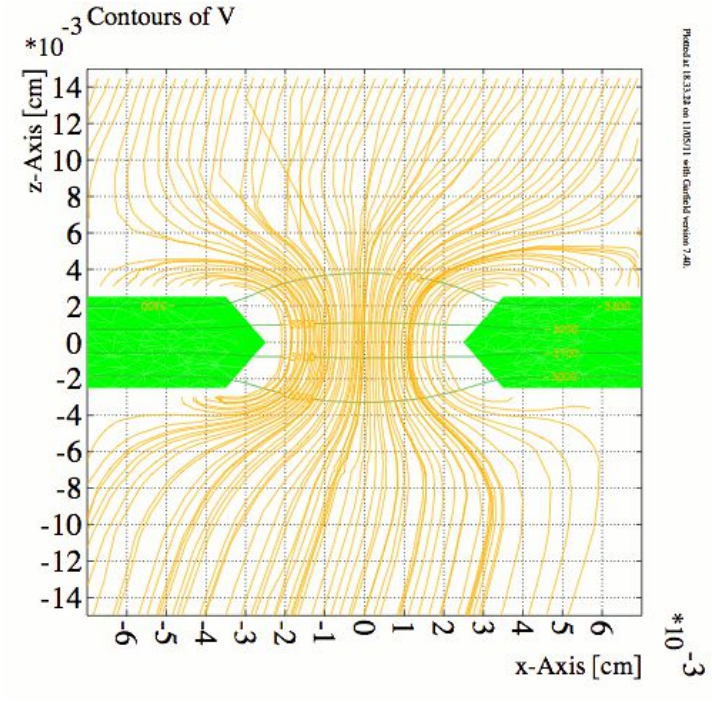


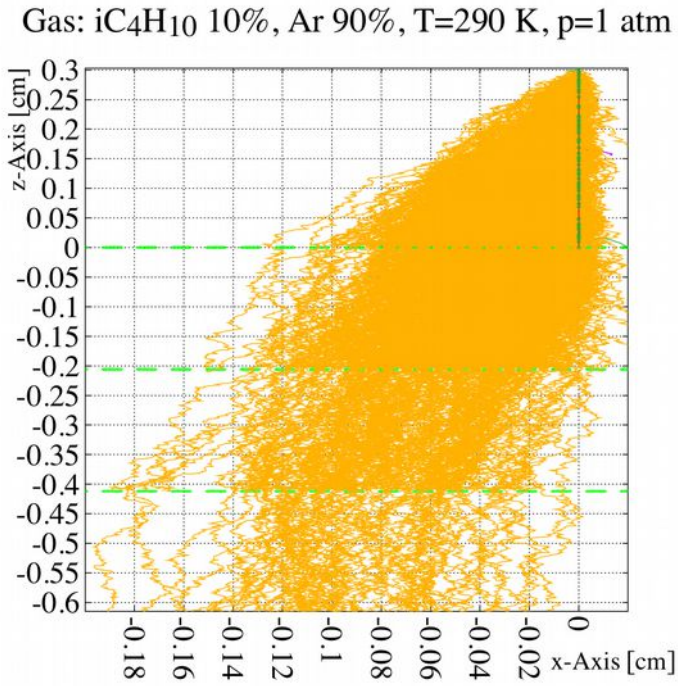
Construction of **100 x 100 mm²** planar chambers equipped with new concept for X-V readout and study of their behaviour in magnetic field.

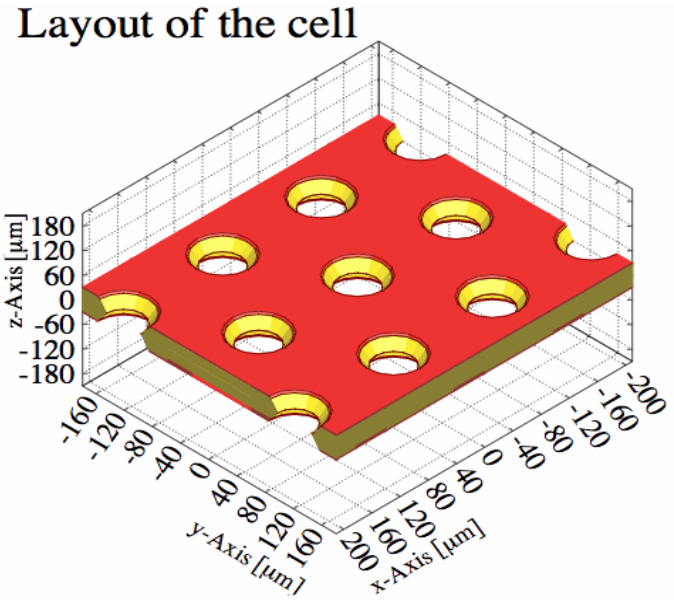


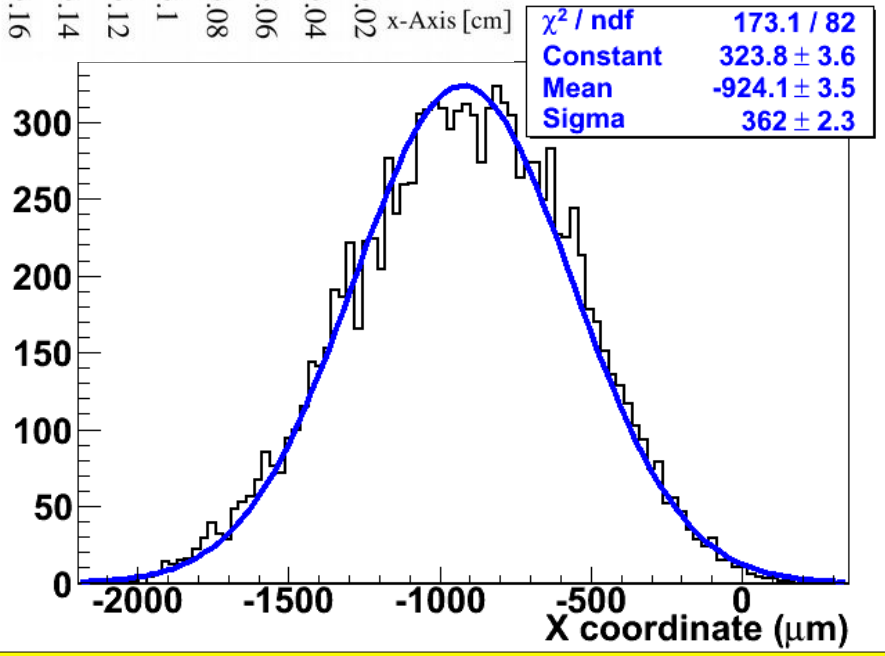
GEM in magnetic field (simulations)



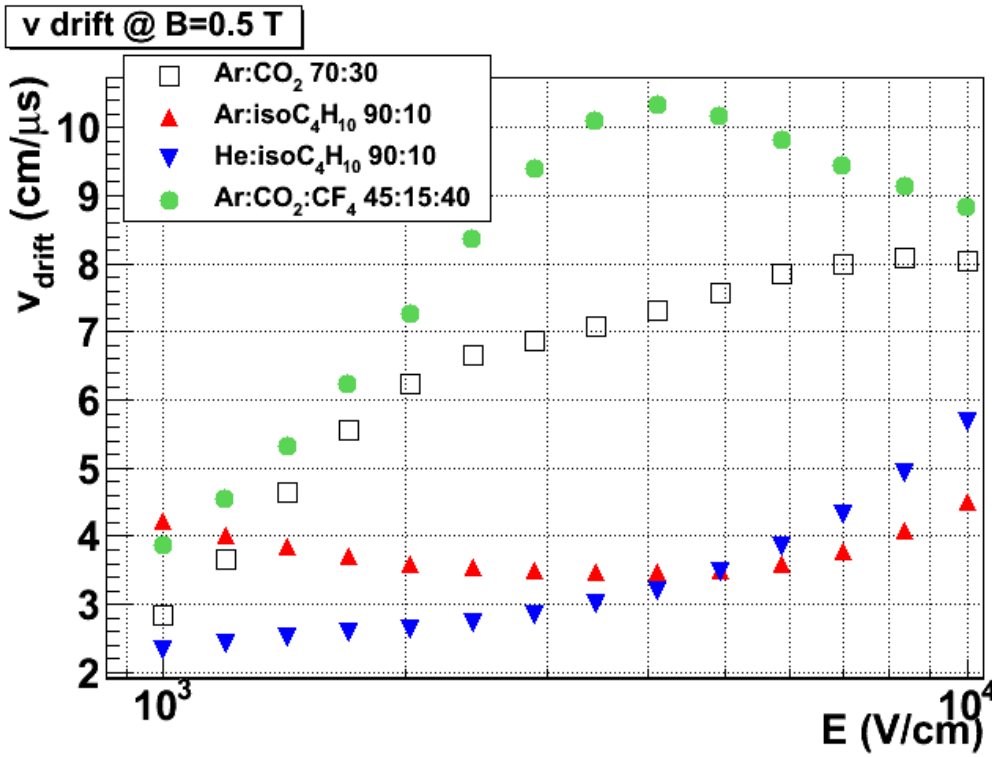


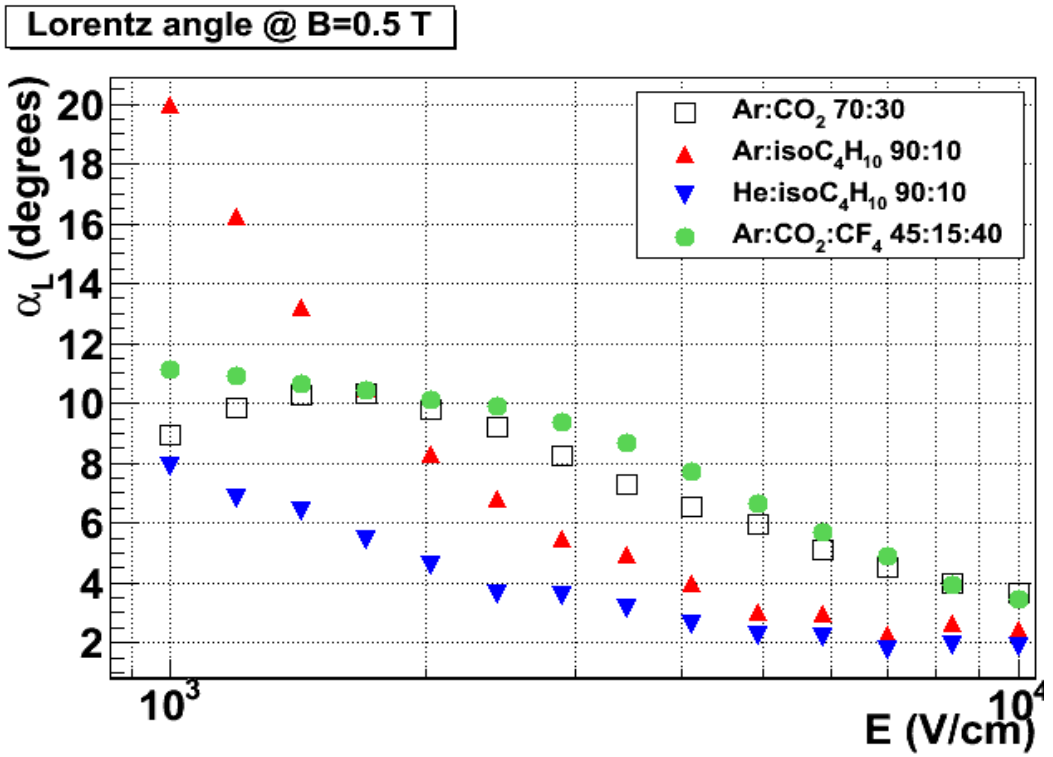






MAGBOLTZ values in 0.5 T

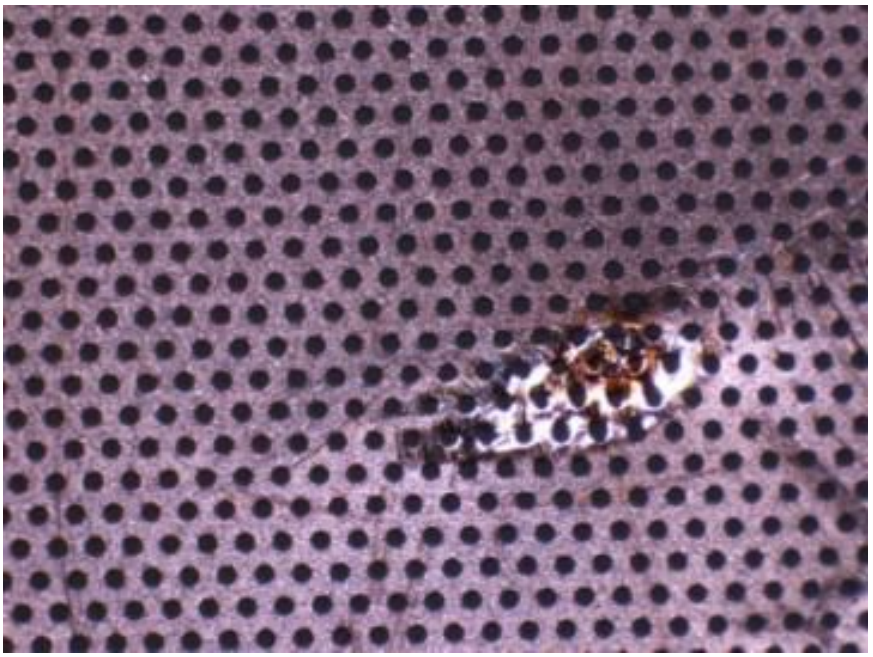


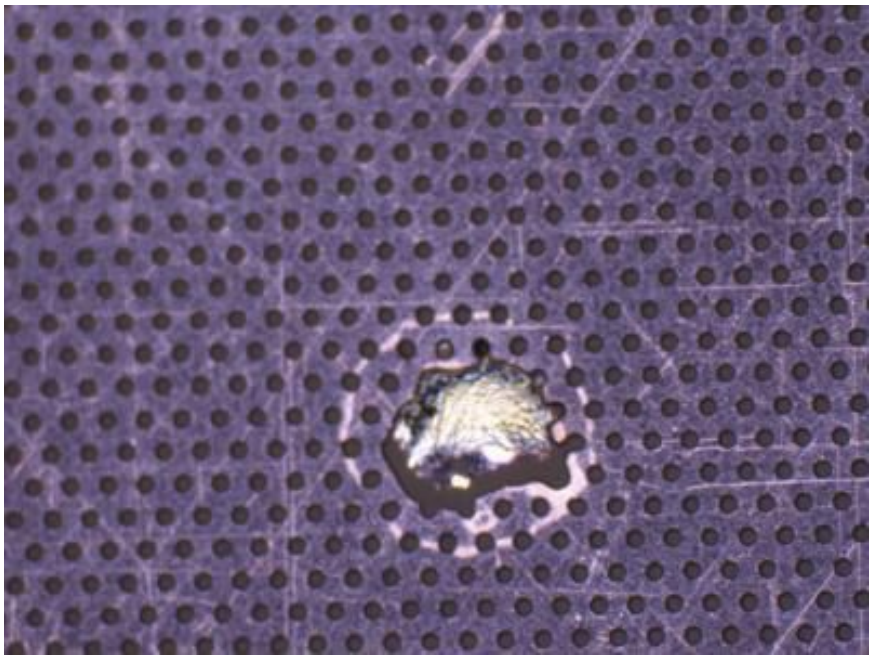


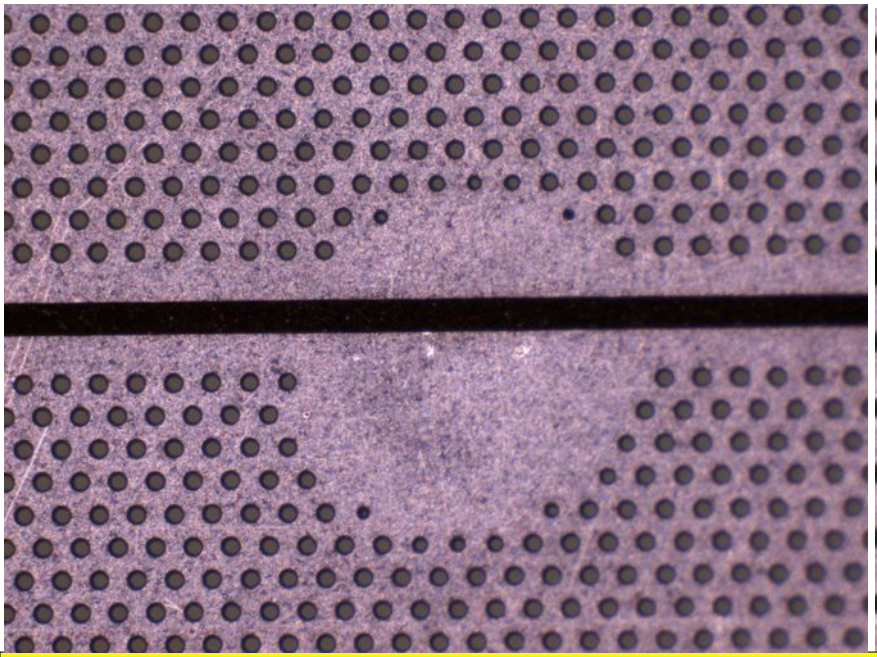
	GAIN	<n of cl.>	<e⁻/cl.>	<tot. e⁻/trk>
$Ar:CO_2$	$3 \cdot 10^4$	9.08	2.19	$5.9 \cdot 10^5$ e⁻ = 94 fC
$Ar:iC_4H_{10}$	$2.76 \cdot 10^4$	10.53	2.12	$6.1 \cdot 10^5$ e⁻ = 98 fC
$Ar:CO_2:CF_4$	$6 \cdot 10^3$	12.79	2.87	$2.2 \cdot 10^5$ e⁻ = 35 fC

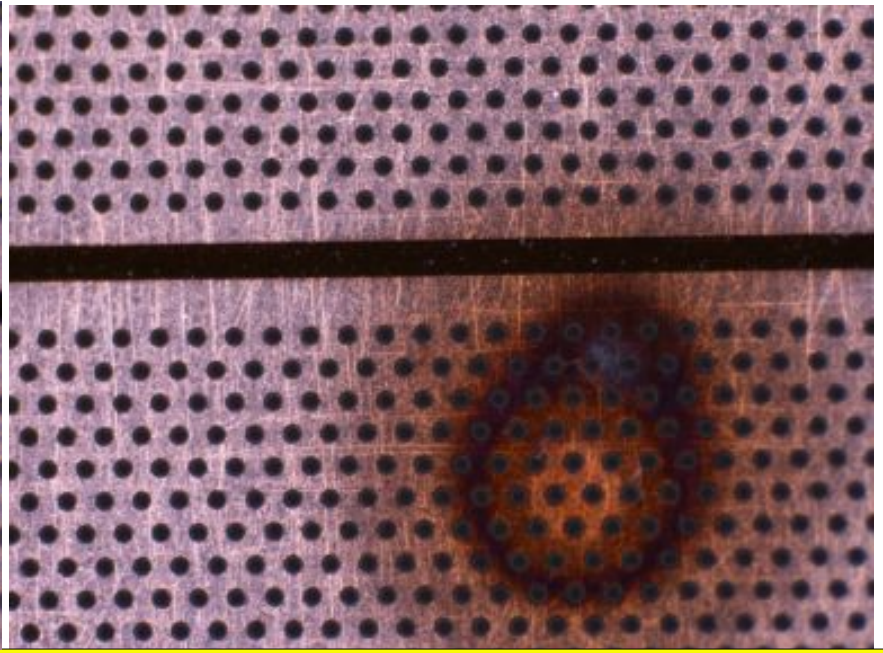
π^-; E_k=200 MeV; $\beta\gamma$=2.21

Quality check details









9 GEM foils bad: over-etching with discharges, leakage currents, roughly defined sectors

3 foils with high resistance on HV vias connections