Design and construction of a cylindrical GEM detector as Inner Tracker device at KLOE-2

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on behalf of the KLOE-2 IT subgroup

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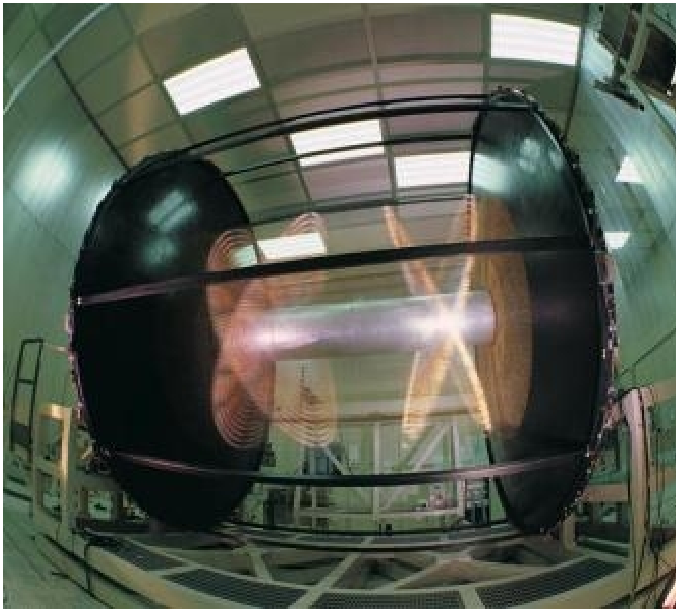
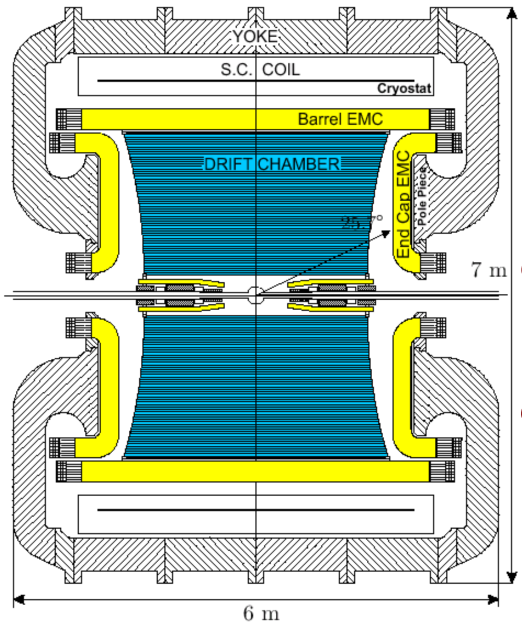
KLOE at upgraded DAΦNE Φ factory (1020 MeV)





Pb-Scintillating Fiber Calorimeter with excellent timing performance:

$\sigma_t = 54\ ps / \sqrt{E(GeV)} \oplus 100\ ps$

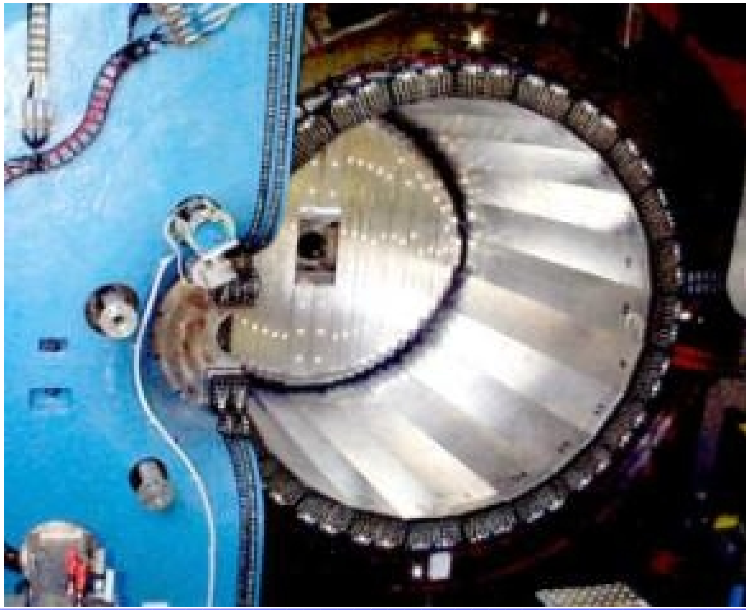
- Energy resolution:

$\sigma_E / E = 5.7\% / \sqrt{E(GeV)}$

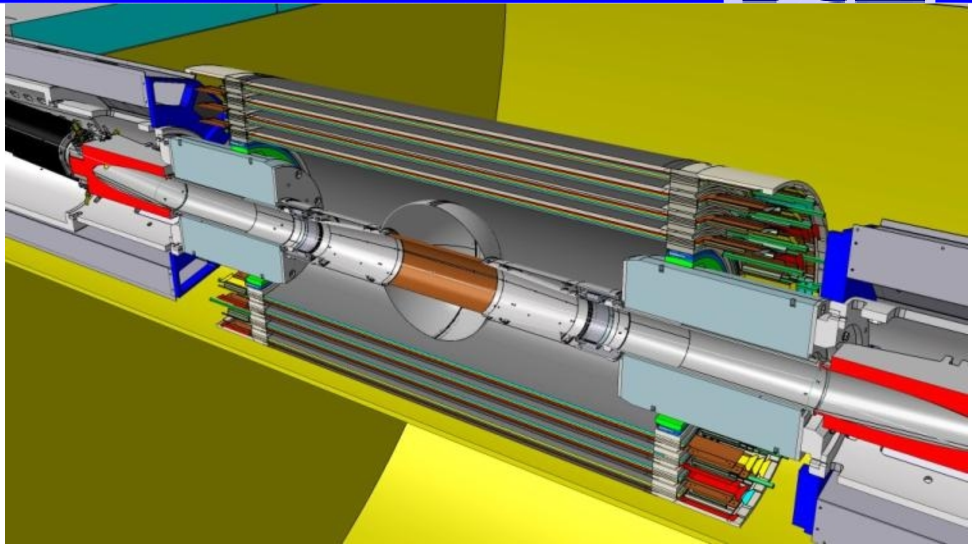
- 4 m long, 98% solid angle coverage

- Huge, transparent Drift Chamber in 5.2 kGauss field of a SC coil
- 2 m outer radius, 25 cm inner radius, 4 m long, He/iC_4H_{10} gas mixture, all-stereo geometry
- Momentum resolution: $\sigma(p_T)/p_T \sim 0.4\%$

  $<\vec{p}_K> \simeq 120\ MeV, <\vec{p}_\pi> \simeq 200\ MeV$
- Spatial resolution: $\sigma_{r\varphi} \simeq 150\ \mu m, \sigma_z \simeq 2\ mm$



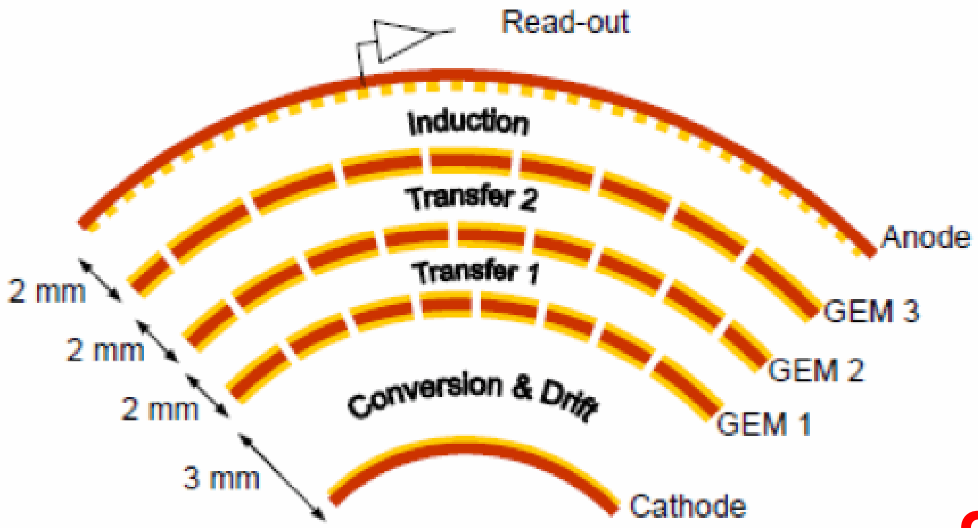
KLOE-2 Inner Tracker Upgrade



Improvement of the decay vertex reconstruction requires an IT with

- $\sigma_{r\varphi} \approx 200\ \mu m$ and $\sigma_z \approx 500\ \mu m$
- low material budget: < 2% X_0 (low momentum)
- 5 kHz/cm^2 rate capability

The requirements can be met using



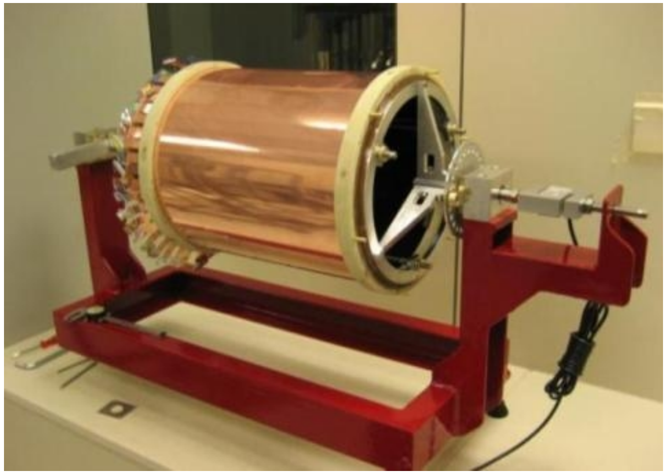
- 4 layers of cylindrical GEM with radii from 13 to 23 cm
- 700 mm active length
- X-V strips-pads readout
- 1.5 % X_0 radiation length with the carbon fibers support

Improvement of about a factor 3 on the $K_S \rightarrow \pi\ \pi$ vertex resolution

Present vertex resolution 6 mm

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

The steps leading to the final IT



- Construction and characterization of a CGEM prototype (test beam 2008) built using 3 GEM foils (354 x 330 mm^2) spliced together. Axial strips (single view).

NSS Conf. Rec. Vol. I, 2268 (2009)

- Construction of 100 x 100 mm^2 planar chambers equipped with new concept for X-V readout and study of their behaviour in magnetic field (test beam 2009).

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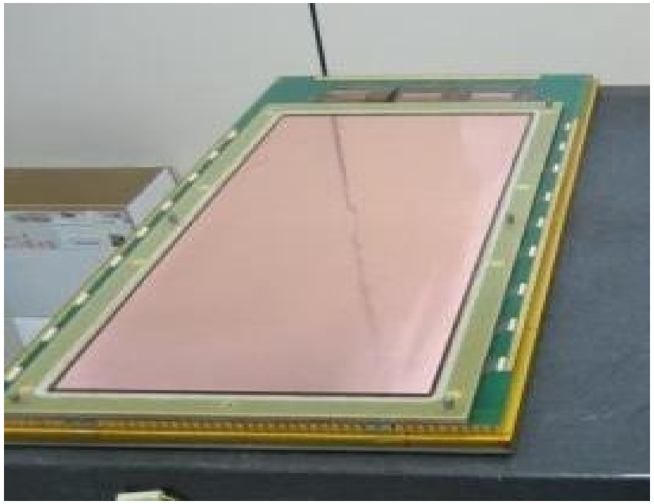
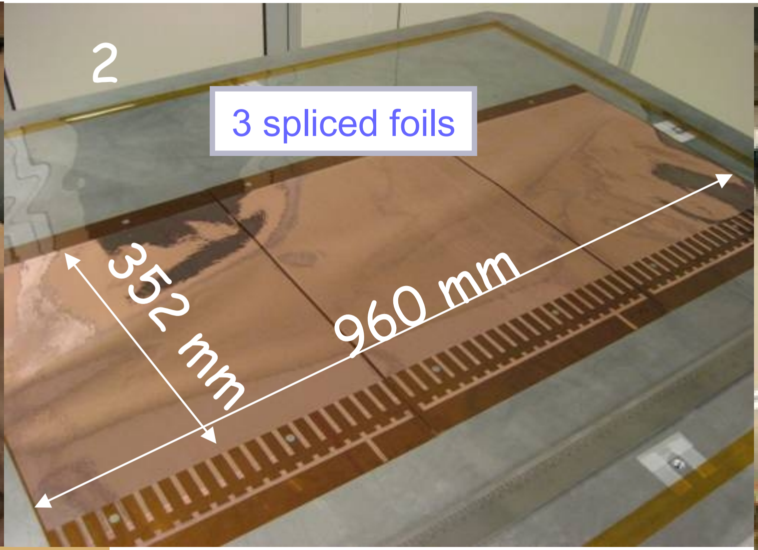
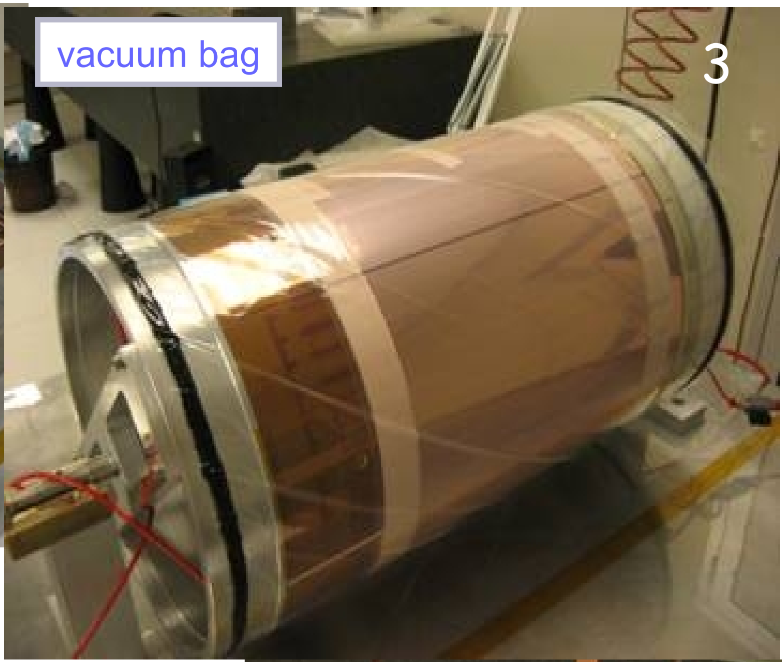


- Construction and characterization of two large planar chambers with the new single-mask photolitographic technique equipped with final X-V readout (test beam 2010).

The Cylindrical GEM prototype



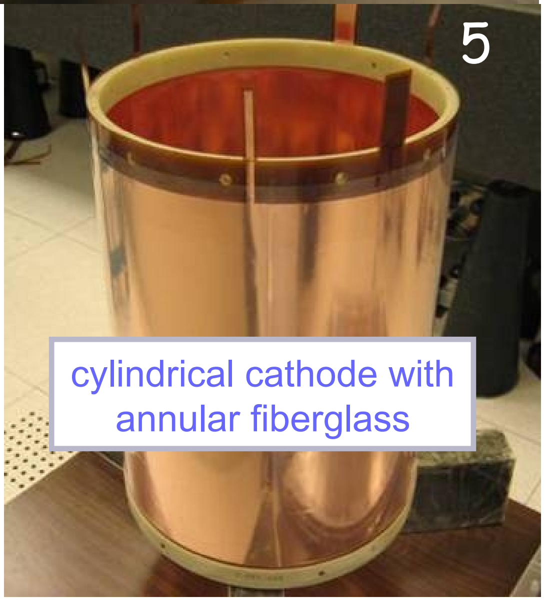


Proto01: Ø =300 mm, L=350 mm

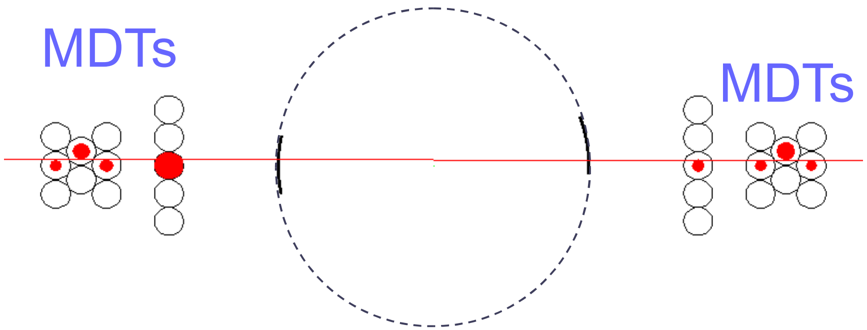
1538 axial strips, 650 μm strips

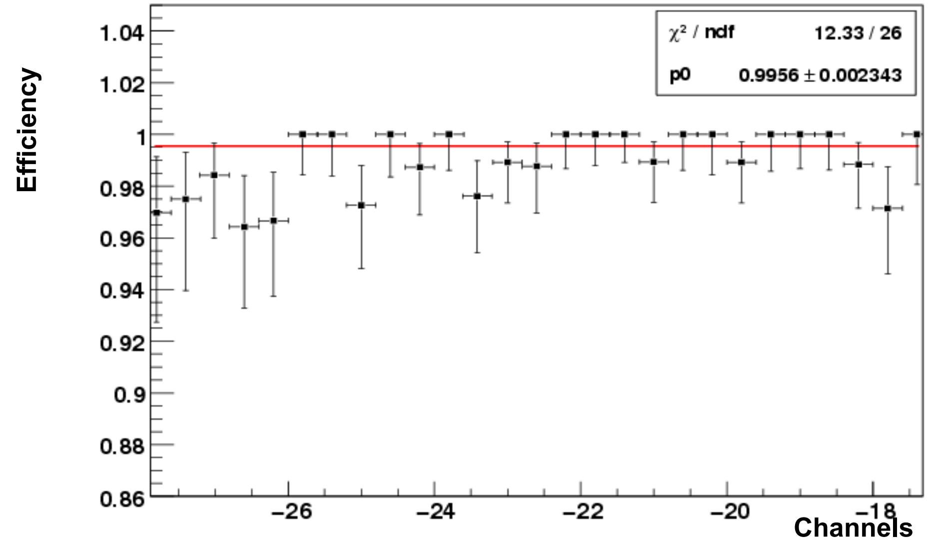
NO FRAMES IN THE ACTIVE AREA

THE FIRST CGEM DETECTOR EVER!



The test beam on the CGEM prototype (2008)





10 GeV pions beam CERN-PS T9 area

- GAS MIXTURE: Ar/CO_2 70/30
- GAIN: 2×10^4
- FEE: 16-channels GASTONE [NIMA 604 (2009)]
- Axial strips, 650 μm pitch
- External tracking: 2 MDT stations

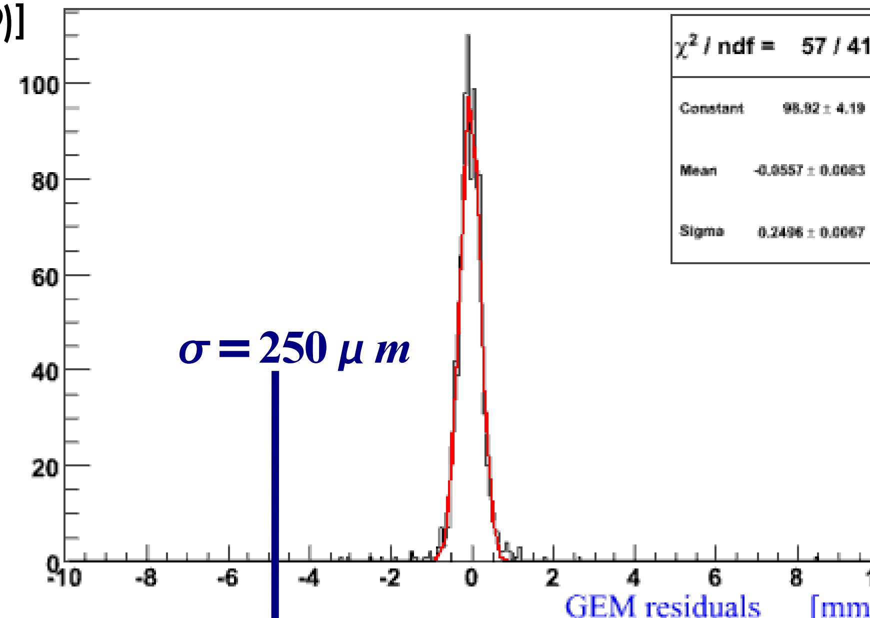
Detection efficiency ε = 99.6%

$$\sigma_{GEM} = \sqrt{(250\,\mu m)^2 - (140\,\mu m)^2} \simeq 200\,\mu m$$

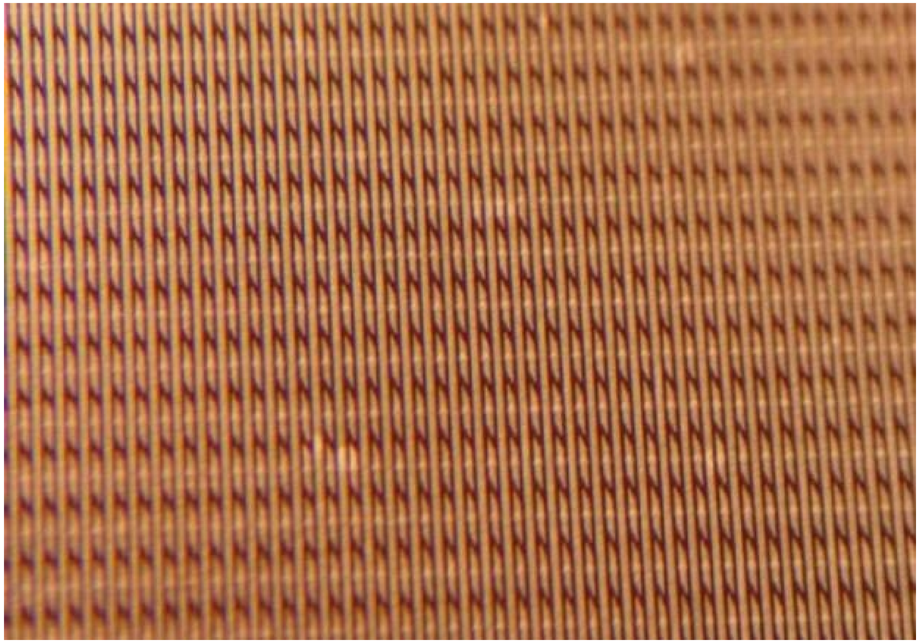
$650\,\mu m / \sqrt{12}$

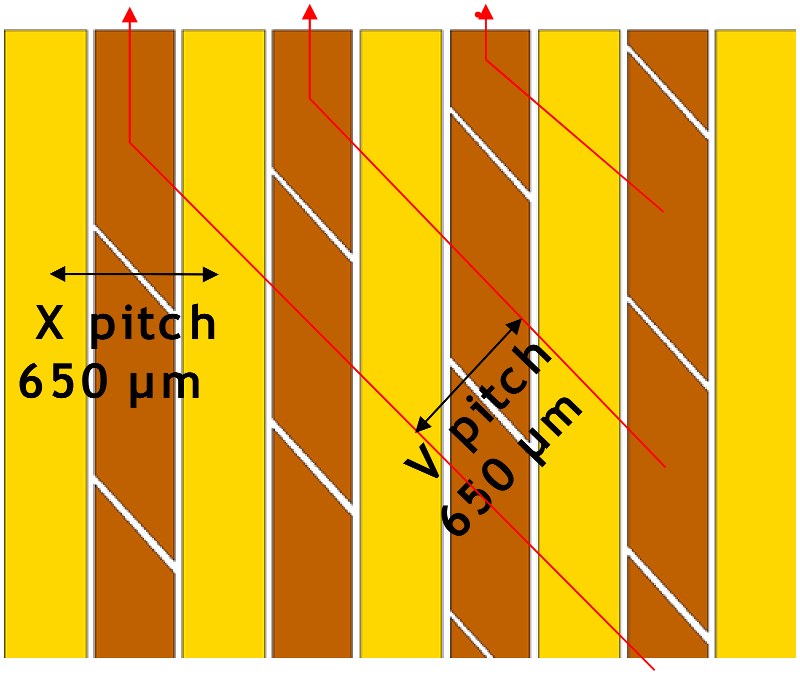
MDT spatial resolution

$\sigma = 250\,\mu m$



A new readout was drawn to fit the cylindrical shape of the IT anodes: a multilayer circuit with X-V pattern realized with strips (X) and pads (V) etched on the same kapton layer



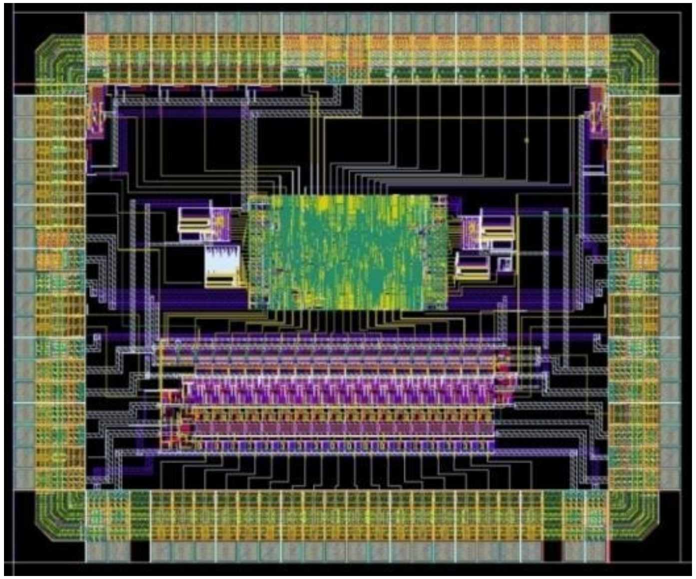


A dedicated test was performed in order to study the final readout configuration

The IT dedicated FEE chip: GASTONE

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

- 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)

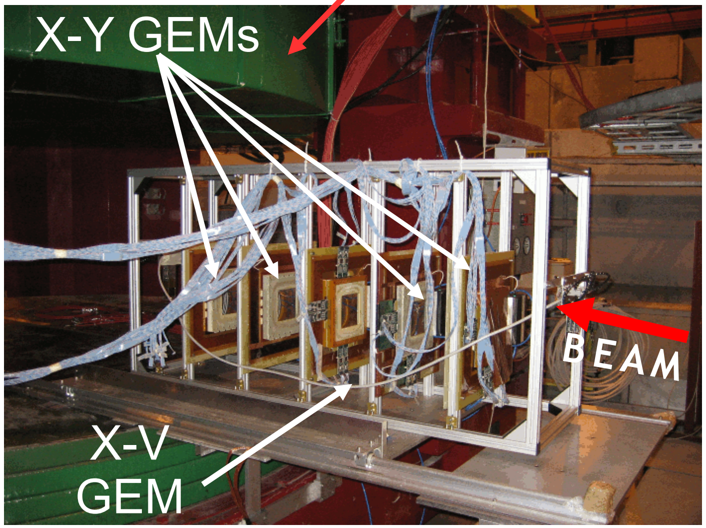


GASTONE 64 ch

TOTAL POWER CONSUMPTION for the 30000 chs ~ 200 W

The test beam in magnetic field (2009)

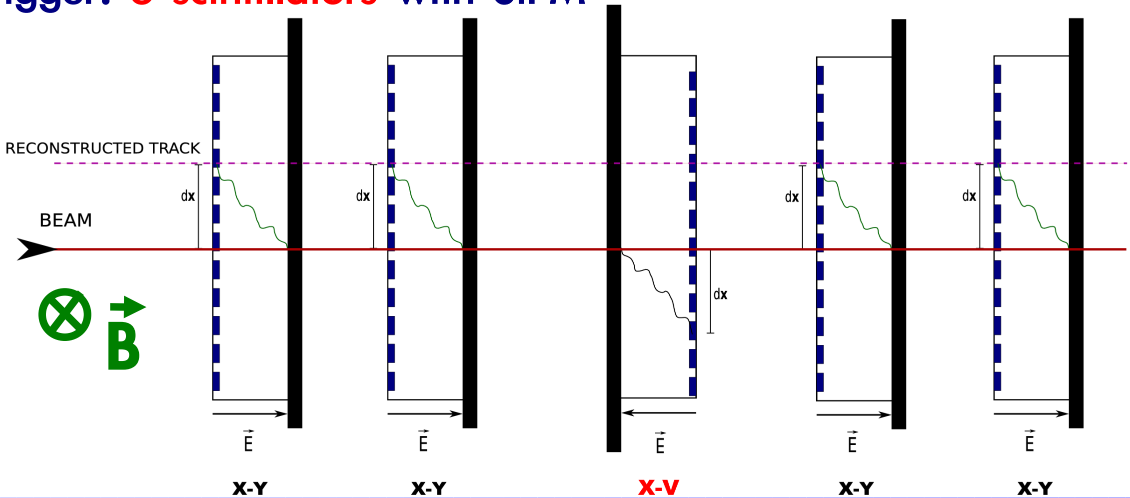
The behaviour of a GEM in magnetic field was studied at H4 beam-line (RD51 facility) at CERN-SPS with 150 GeV pions. The magnetic field was provided by the GOLIATH dipole magnet; it can be adjusted up to 1.5 T in a 3x3x1 m^3.



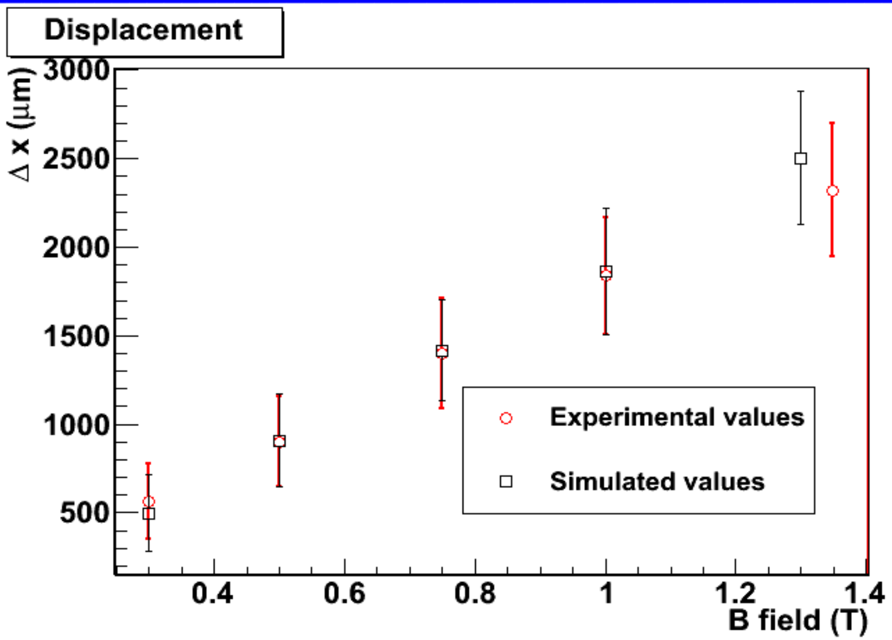
In this case the magnetic field has two effects: a shift of electrons with respect to the position of the track and a large spread of the charge.

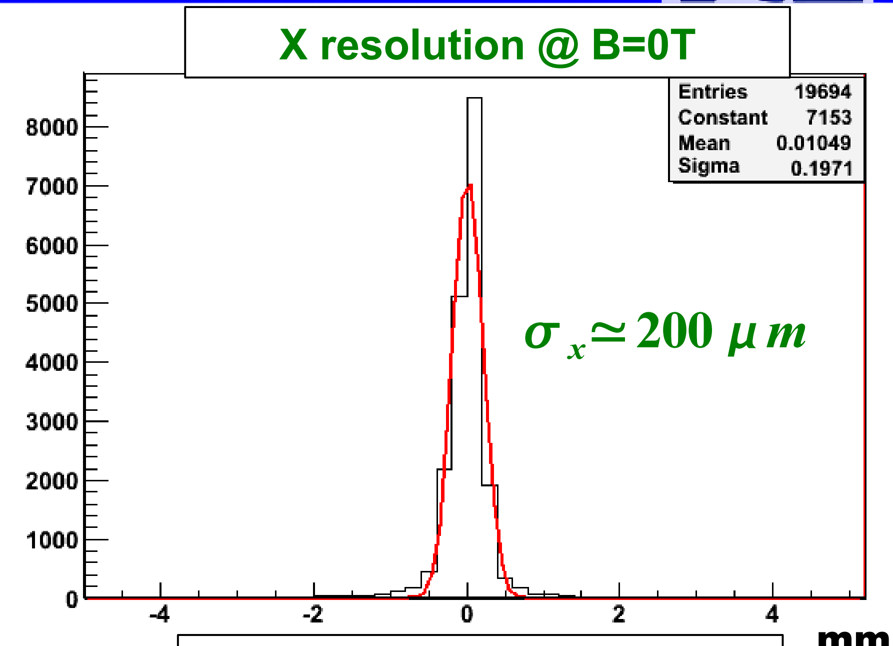
- GAS MIXTURE: Ar/CO_2 70/30
- GAIN: $2x10^4$
- FEE: GEMs partially equipped with 22 GASTONE boards
- External tracking: 4 planar GEMs, 650 µm pitch X-Y strips
- Trigger: 6 scintillators with SiPM

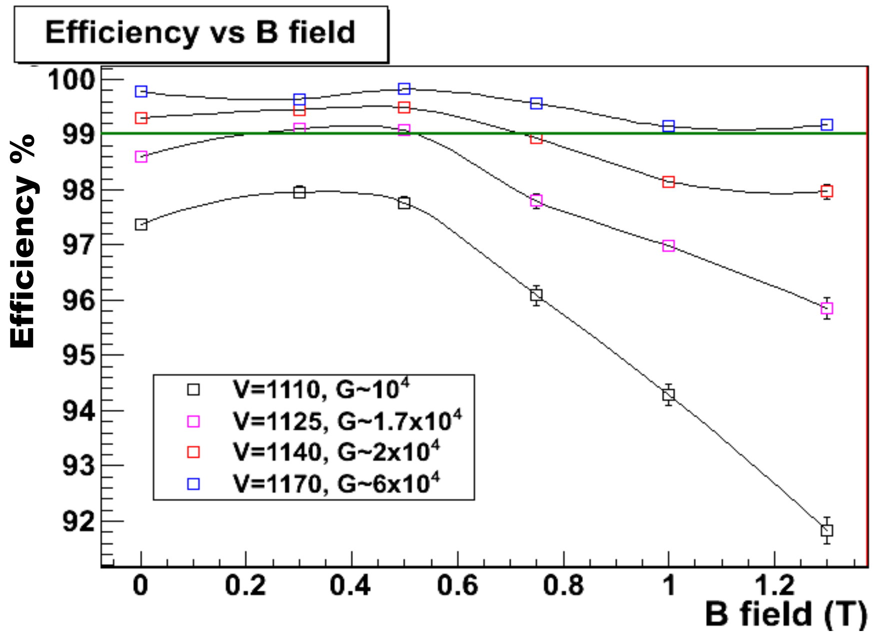
The setup was aligned at B=0. The **X-V chamber was reversed** with respect to the others: the distance between the X-V cluster and the reconstructed track was measured for different B values

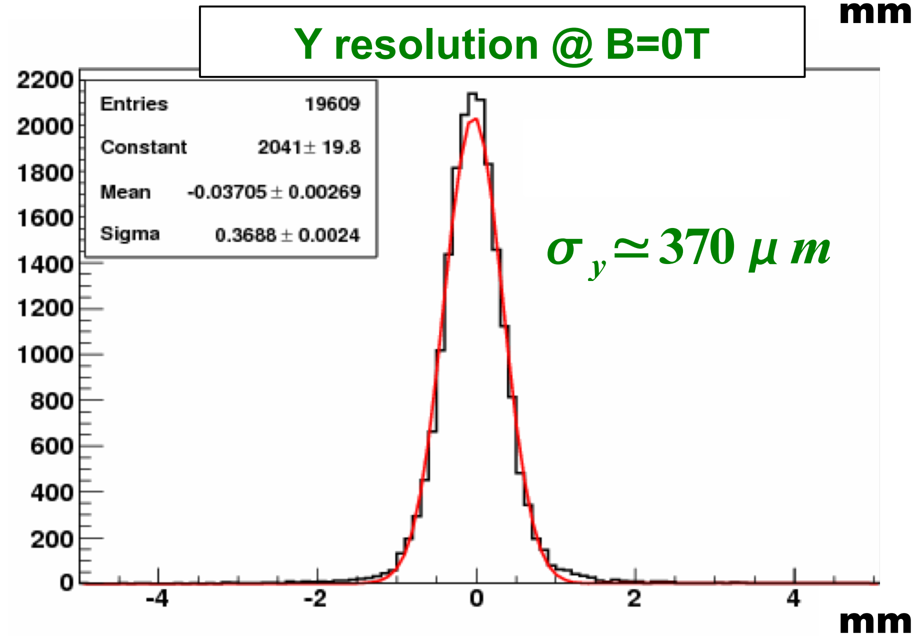


The test beam in magnetic field (2009)







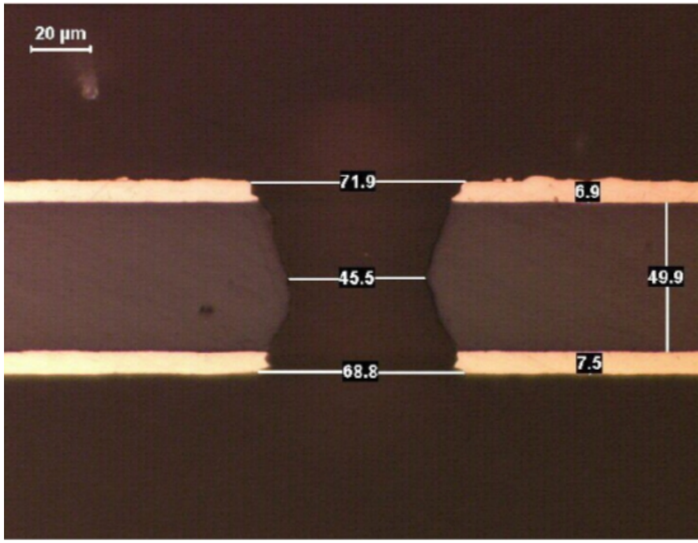


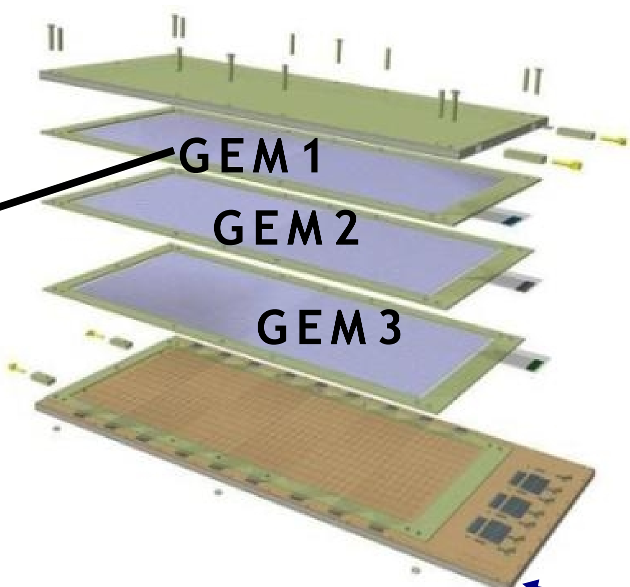
Large area GEM

The KLOE-2 Inner Tracker requires GEM foils with an area of 350 x 700 mm^2 (splicing 3 of them to obtain 1 electrode). This required a change in the GEM manufacturing:

the single-mask photolitographic technique

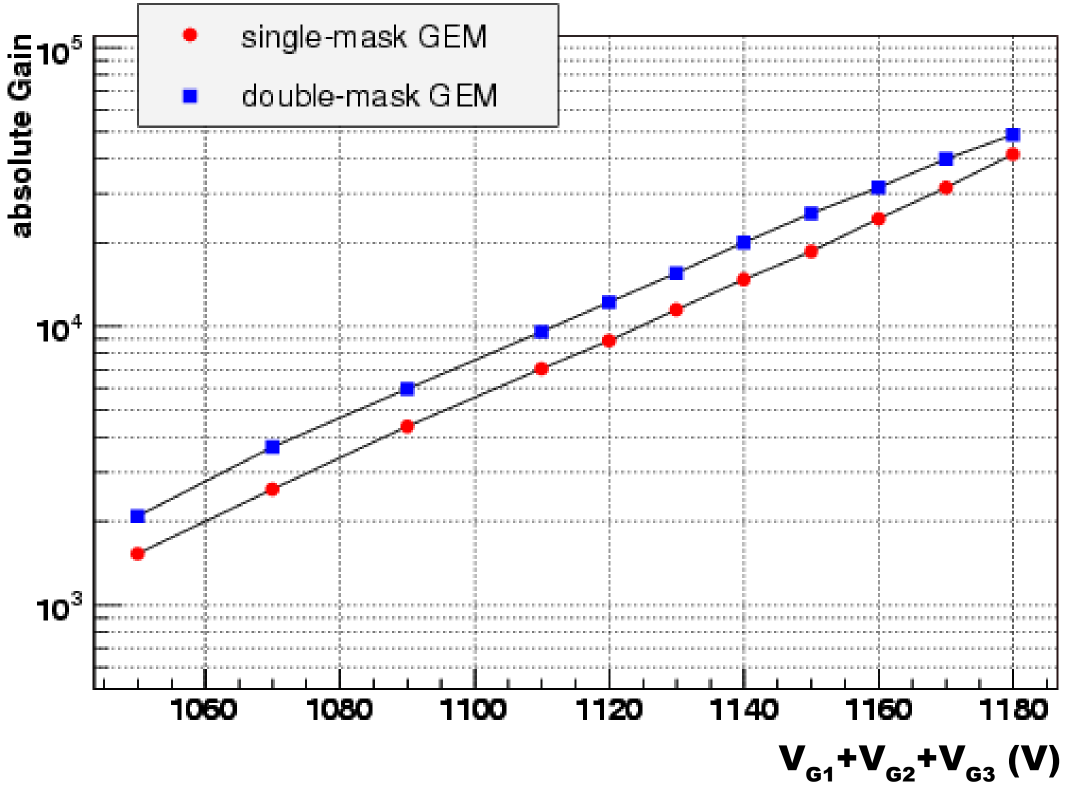
The foils are produced by the CERN TE-MPE-EM group





Pad readout PCB

Large area triple-GEM



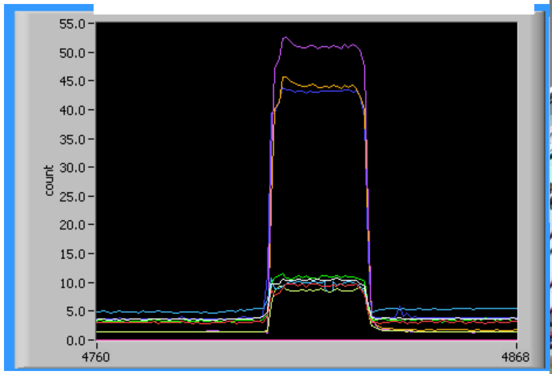
The detector was flushed with **Ar/CO_2 (70/30)** and tested in current-mode with a **^{137}Cs source** (660 keV photons). A 10x10 cm^2 chamber with double-mask foils was used as reference and normalization of performance

GAIN ~25% lower in single-mask GEM

A ~20 V difference between the two curves.

NO DISCHARGE OBSERVED DURING MEASUREMENTS

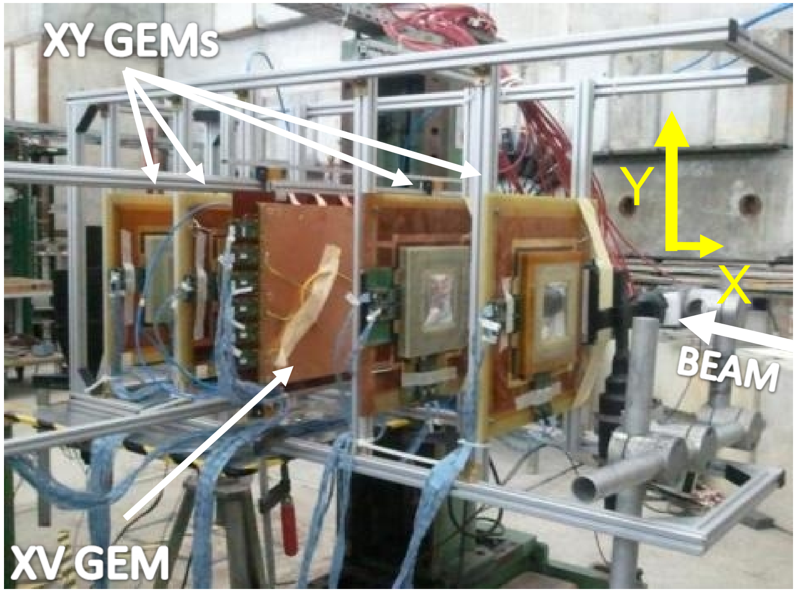
Electrode currents

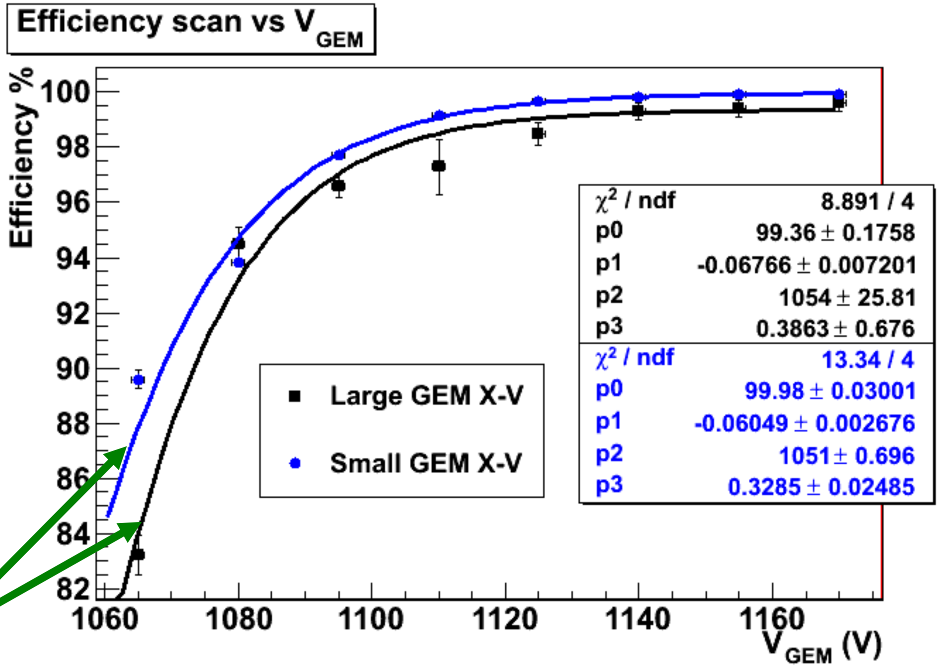


Large area prototype (test beam 2010)

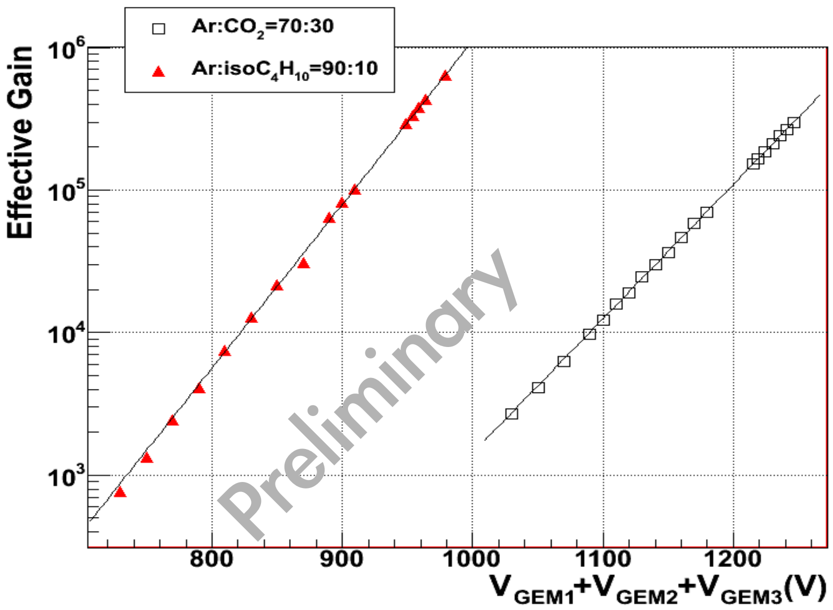
The Large area planar prototype was tested at CERN-PS T9, equipped with the final X-V readout strips-pads

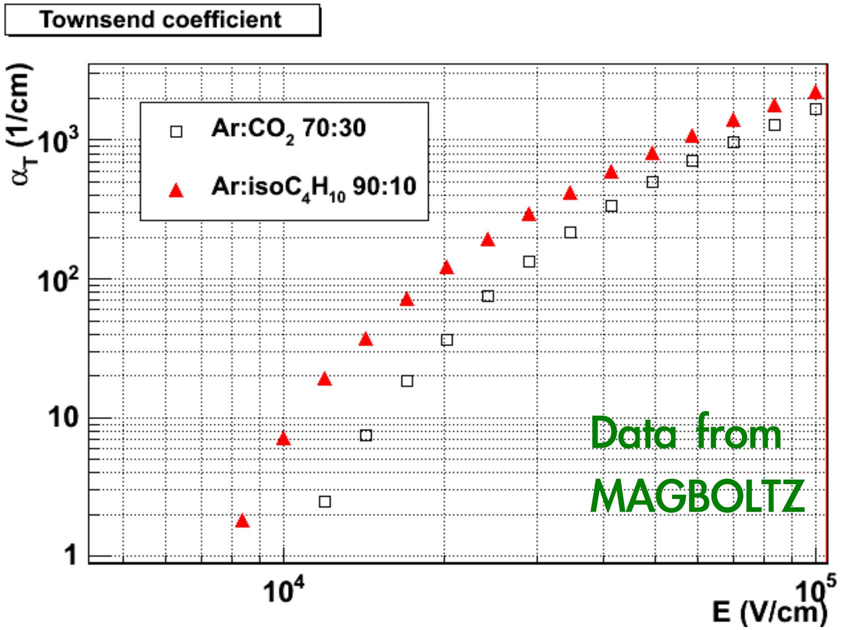
- GAS MIXTURE: Ar/CO_2 70/30
- GAIN : $2\cdot10^4$, $3\cdot10^4$
- Final DAQ+electronics chain test: GASTONE64 + Interface board + General Intermediate Boards (GIB) + Software Interface
- External tracking: 4 planar GEMs, 650 μm pitch X-Y strips
- Trigger: 4 scintillators (2 upstream, 2 downstream)

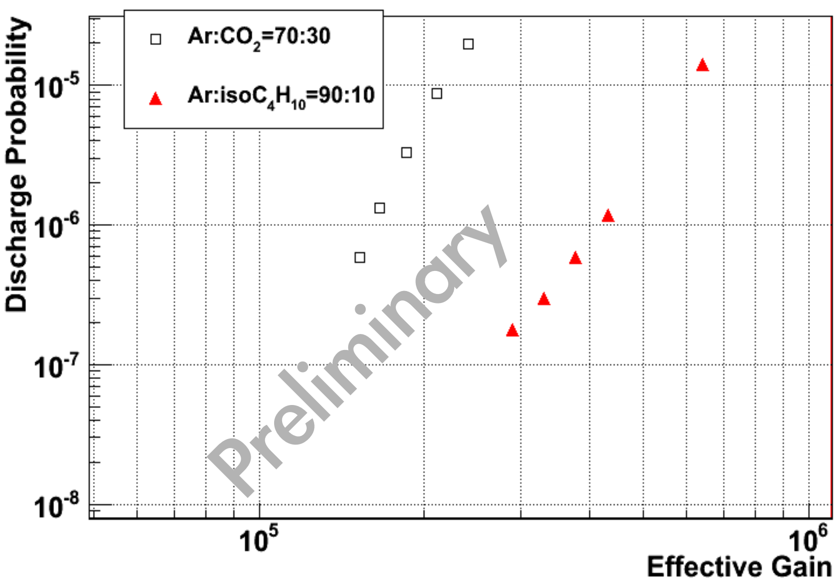




Fermi-Dirac functions



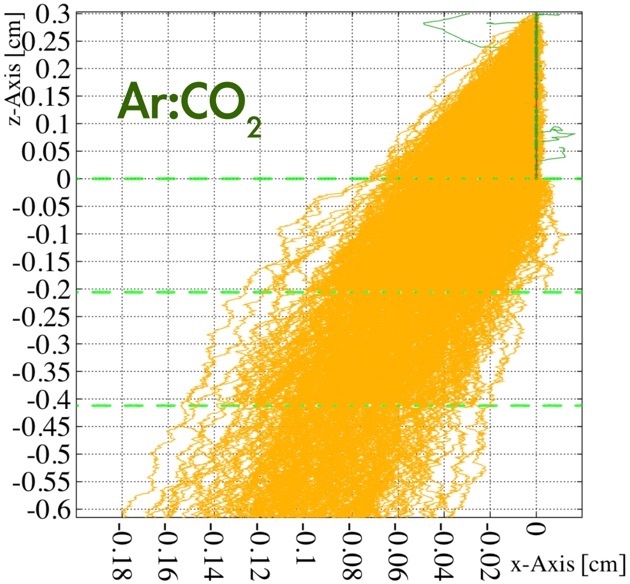


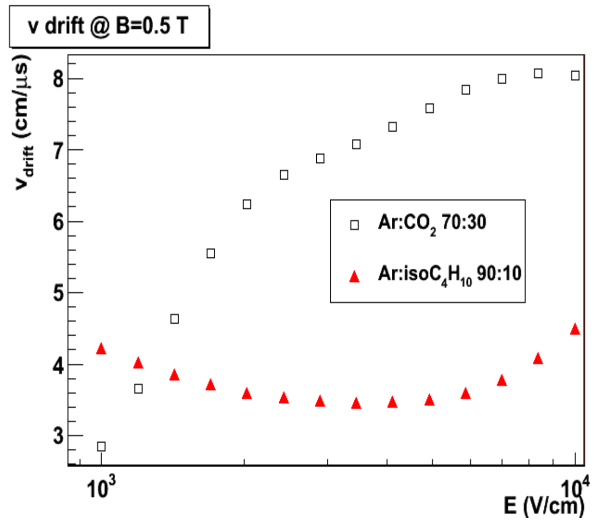


Gain measured with 6 keV X-rays. Discharge rate measured with α particles from ^{241}Am source. The isobutane knocks down the discharge rate thanks to its quenching power. Further parameters have to be taken into account for final decision (v_{drift}, diffusion, primary and total ionization)

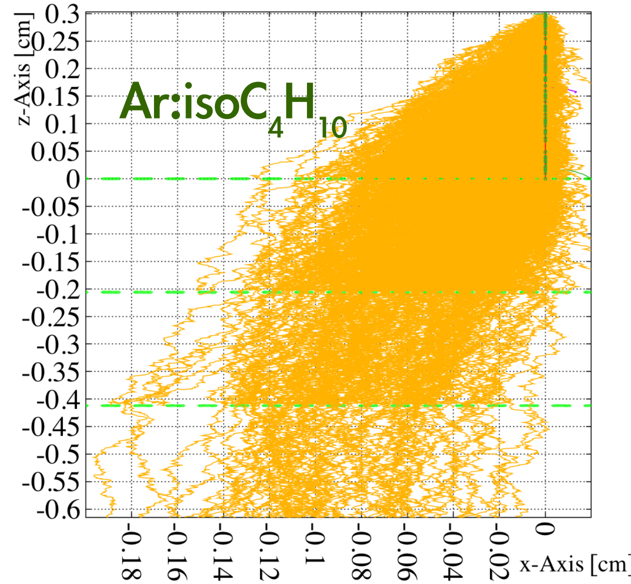
Gas mixture studies: GARFIELD simulations

Gas: CO_2 30%, Ar 70%, T=290 K, p=1 atm

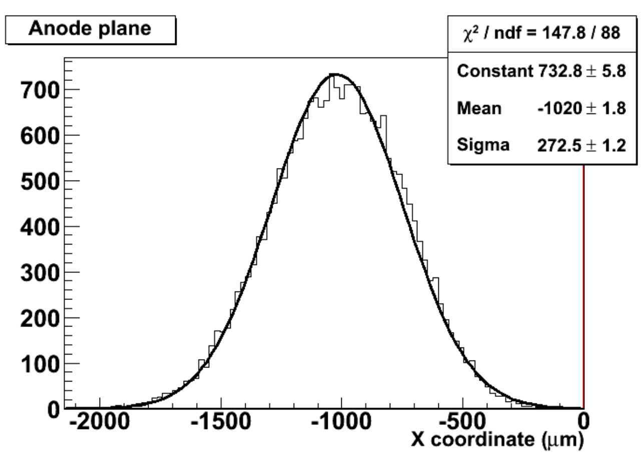


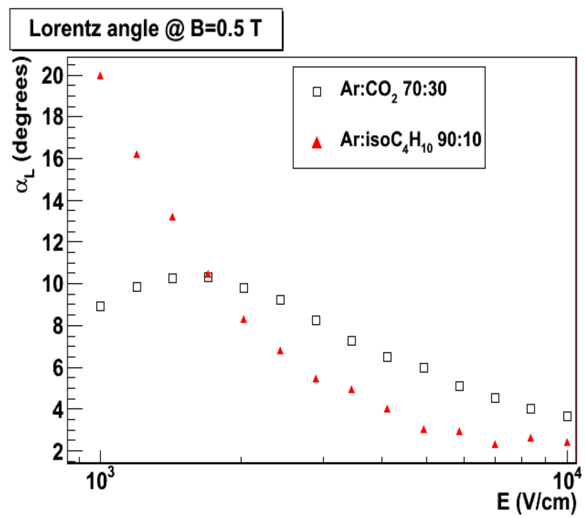


Gas: iC_4H_{10} 10%, Ar 90%, T=290 K, p=1 atm



⊗ B=0.5 T





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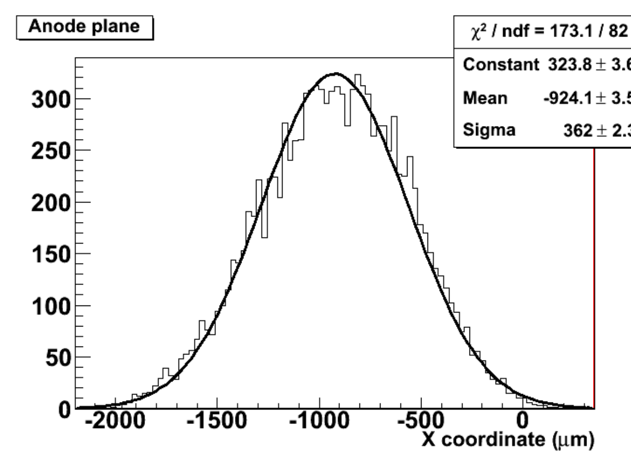
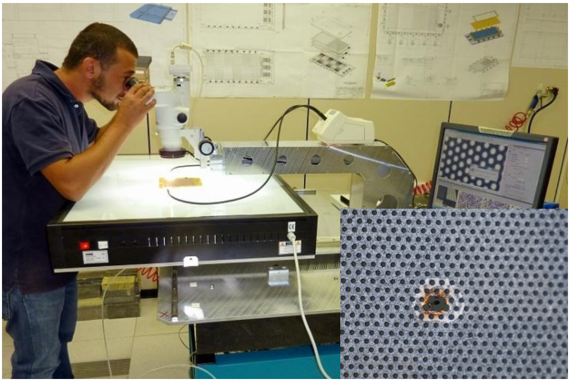
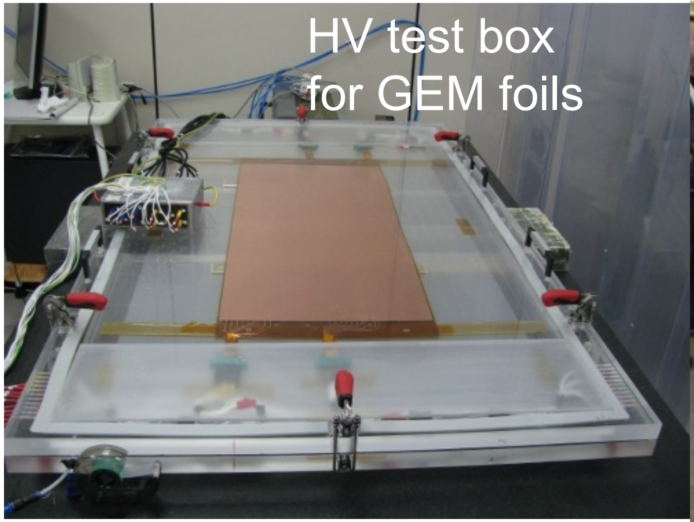




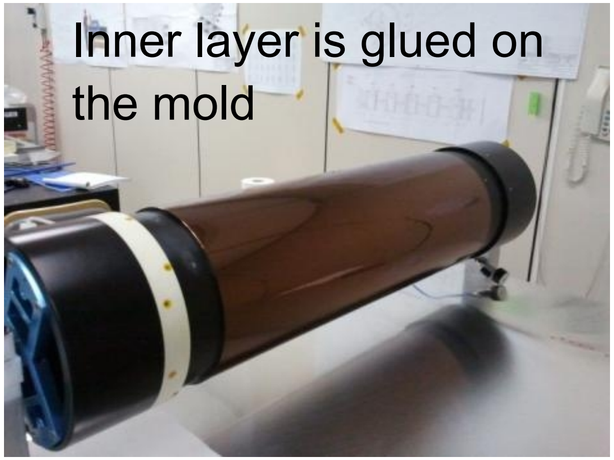
- Nikon microscope with ocular
- CCD
- Light source with optical fibers
- back-lighted inspection plane
- Mechanics and semi-automatic plane position handling
- Software for image editing

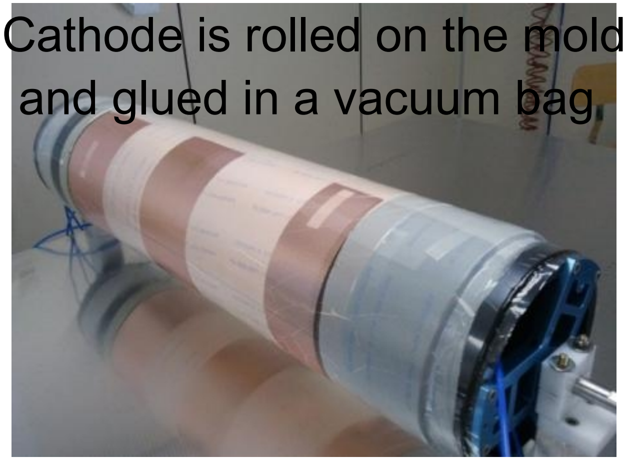
- Plexiglass box with O-rings and HV connectors to flow Nitrogen
- Relative Humidity (RH) probe
- CAEN SY2527 to test in parallel up to 40 sectors

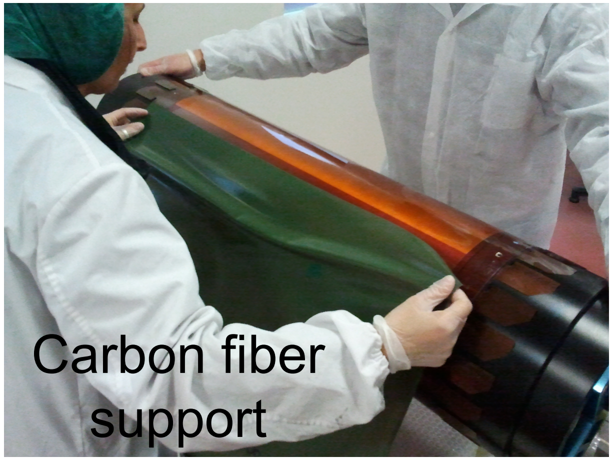


After the gluing on the molds, that have a 400 μm thick Teflon film, the cylindrical layers are inserted one into the other by a vertical insertion machine

IT: the construction has started!







Conclusions

- The cylindrical prototype validated the new idea of this innovative detector

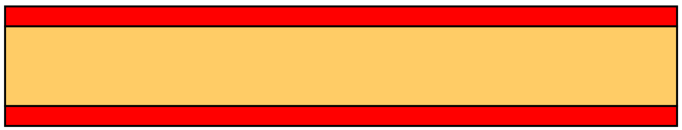
- The new concept for X-V readout was successfully tested in magnetic field with planar GEMs

- A Large area planar GEM was realized with the single-mask technique and tested with the final electronics chain

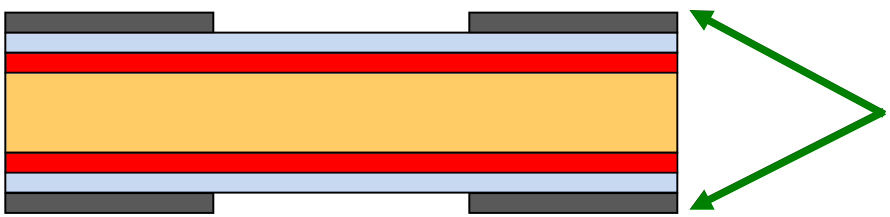
- The construction of the Inner Tracker for KLOE-2 experiment **HAS STARTED** **planning to complete the detector in about one year (summer 2012)**

Spare slides

Double-mask technique



Starting raw material 50 μm kapton foil with 5 μm copper clad



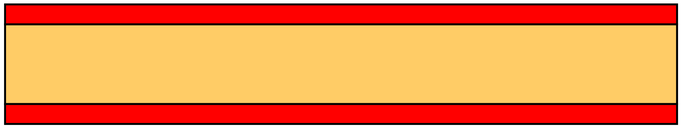
Photoresist coating: the masks are laid down and exposed to UV light

Double side metal etching

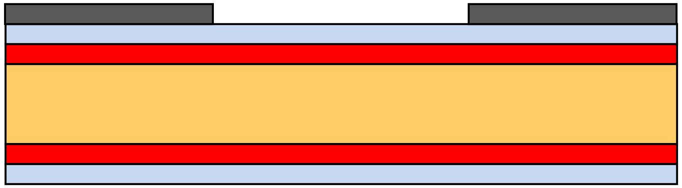
Double side kapton etching

Single-mask technique

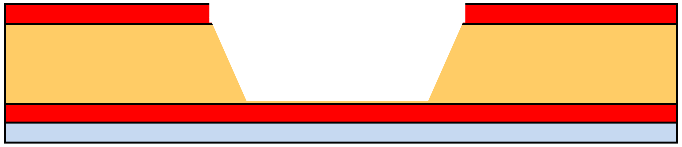
Starting raw material 50 μm kapton foil
with 5 μm copper clad



Photoresist coating: the mask
is laid down and exposed



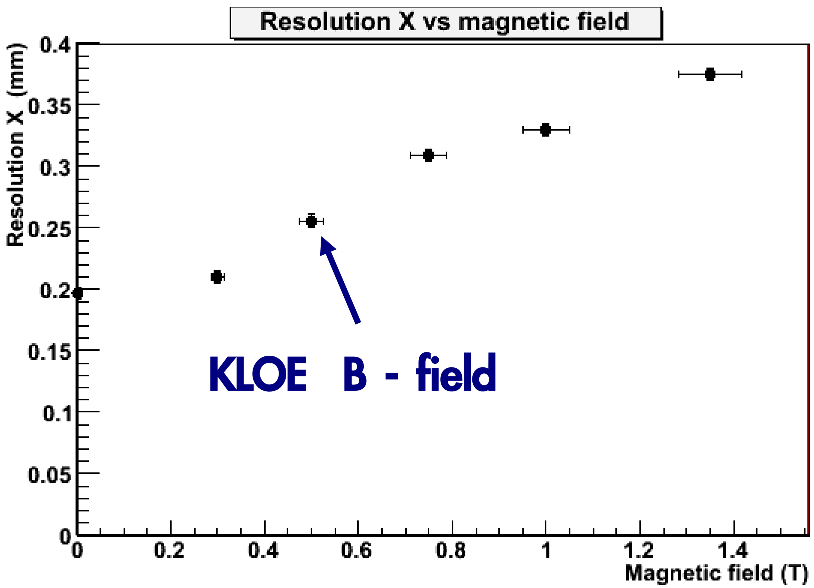
Metal and kapton etching

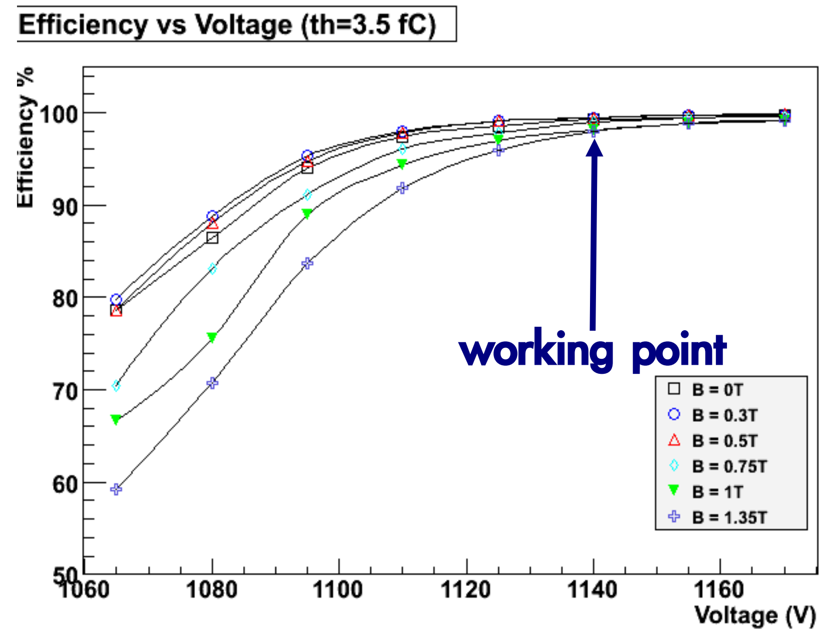


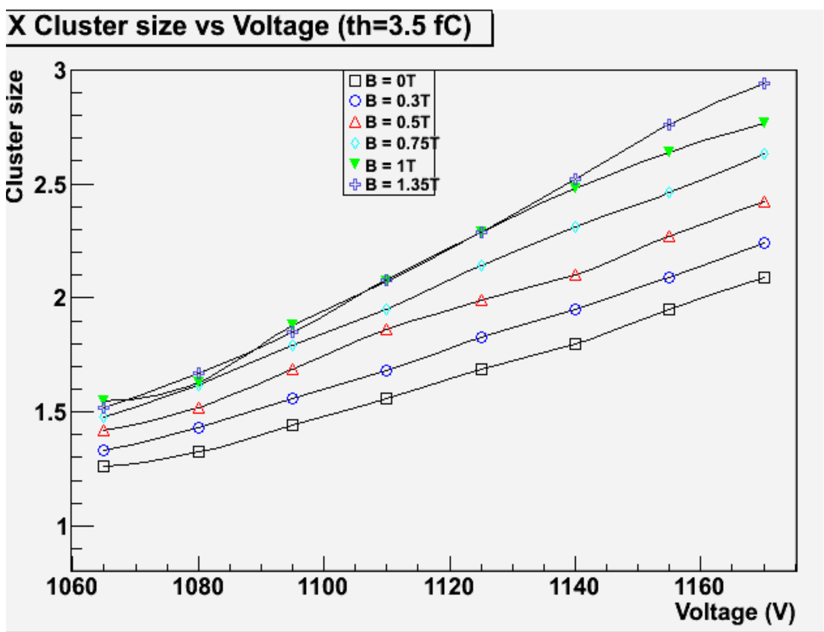
Bottom side metal etching. Top side metal is preserved with <u>**Cathodic Protection**</u> technique

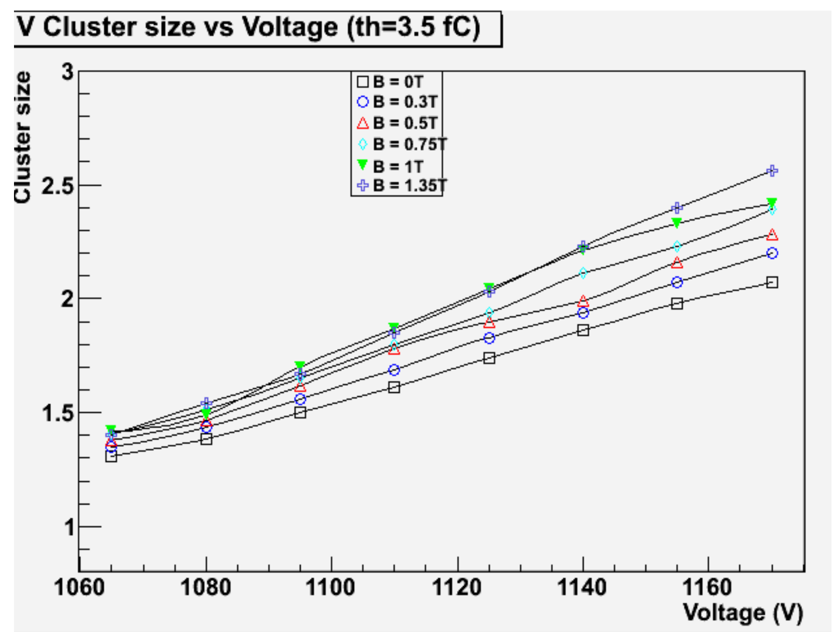
Back to kapton etching to get
final shape

The test beam in magnetic field (2009)

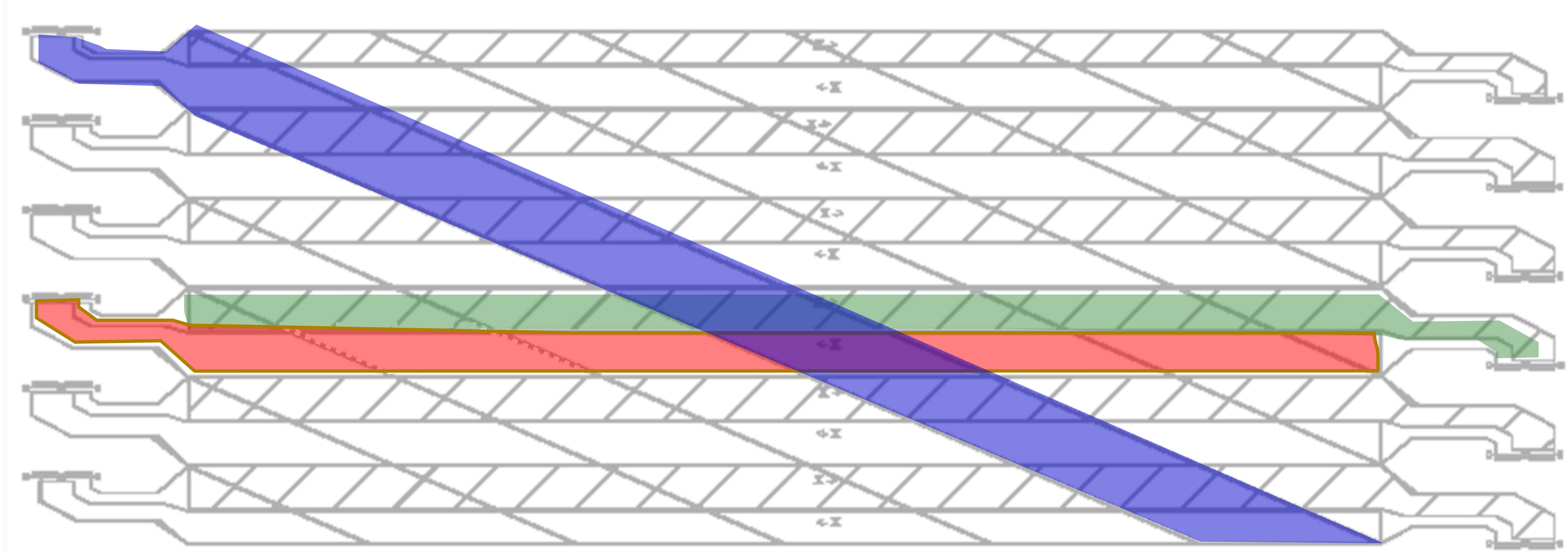


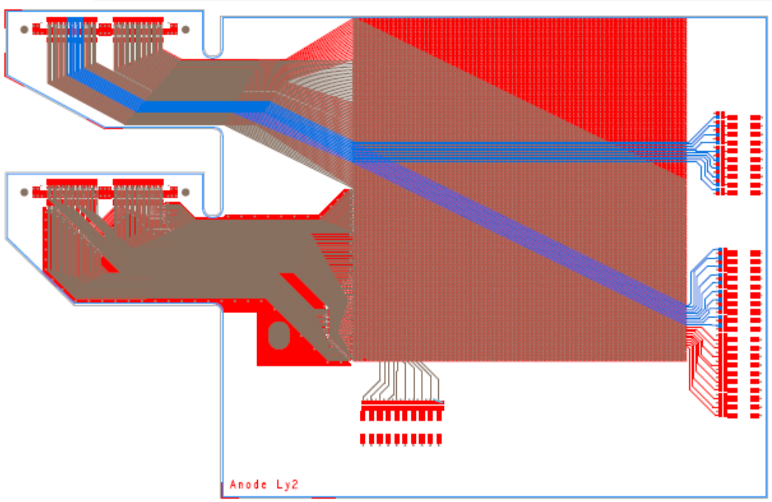




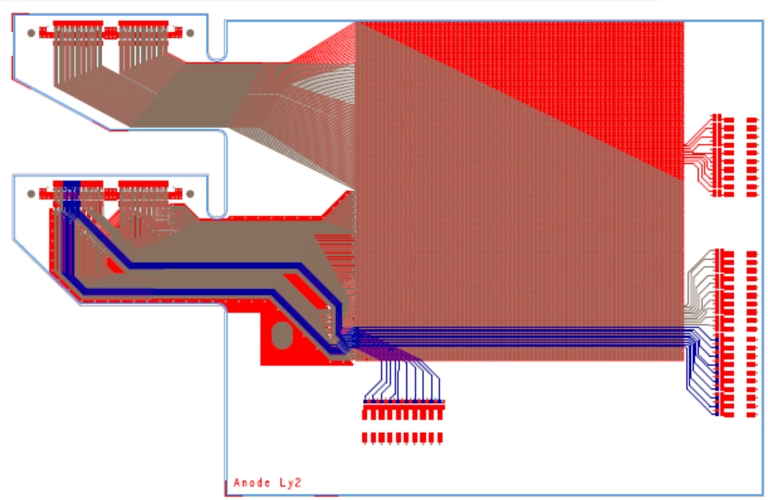


The final readout



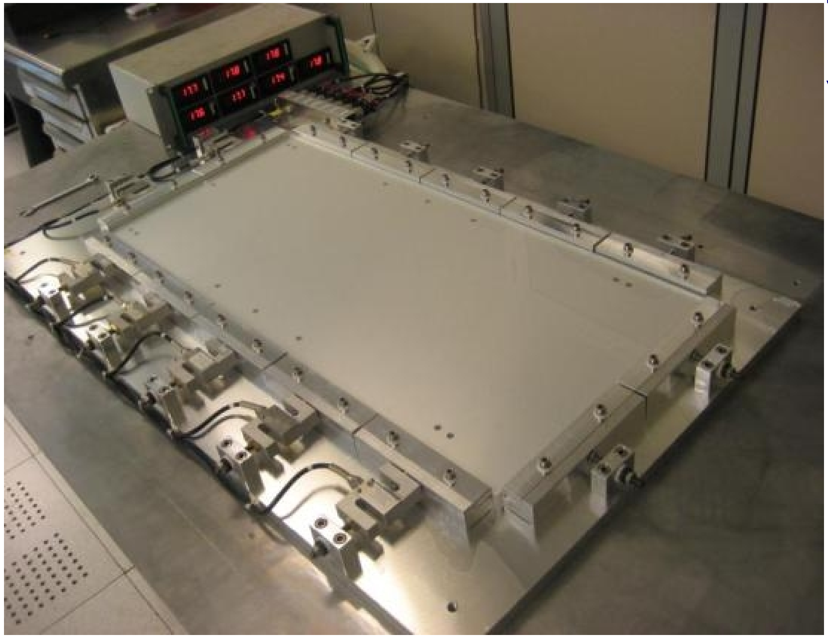


Old path for signal routing:
20% X-talk between X and V



New path for signal routing:
<1% X-talk between X and V

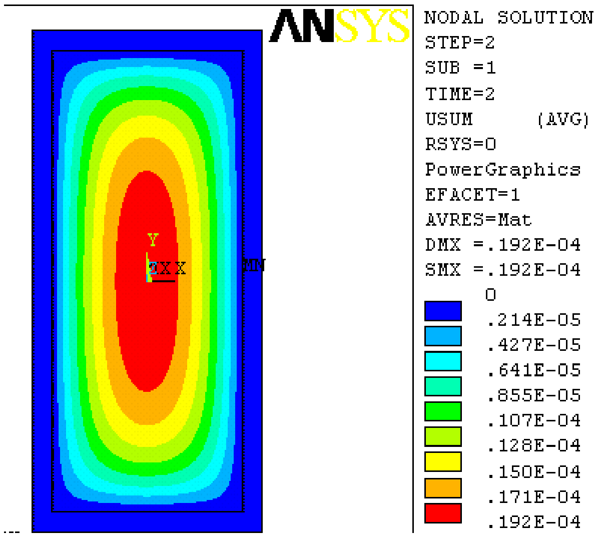
Large area prototype

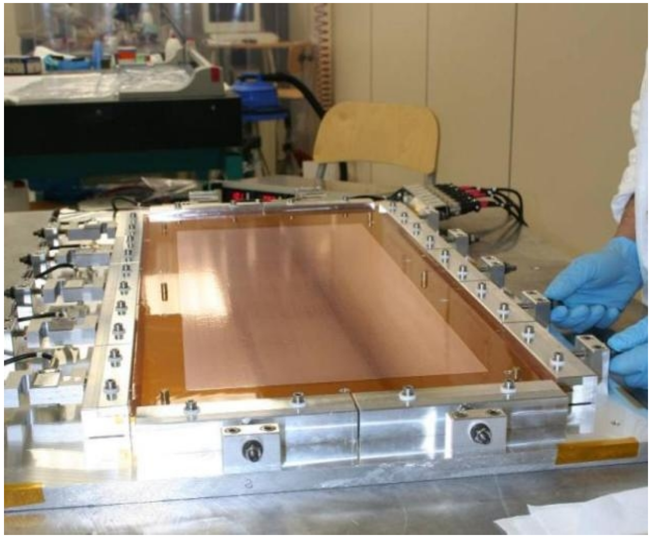


[NIMA doi:10.1016/j.nima.2009.06.063]

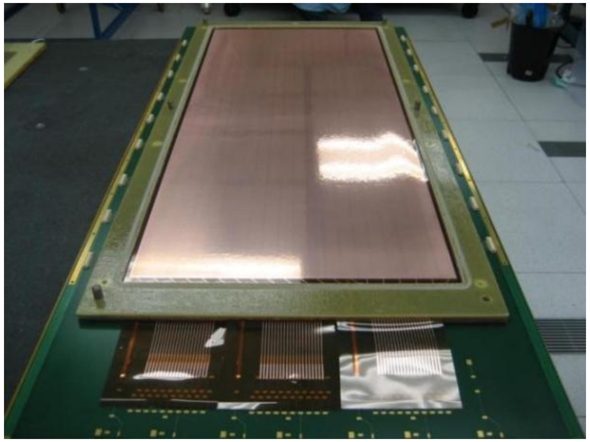
The foils are stretched on a custom-made machine with a tension of 1 kg/cm measured by load cells.

Finite element simulation (ANSYS) indicates a maximum gravitational+electro static sag of the order of **20 μm** (O(5 μm) electrostatic only).





The frame is glued on the GEM using the **vacuum bag** system already tested during the CGEM construction. The results is a planar foil with **no supports inside the active area**.

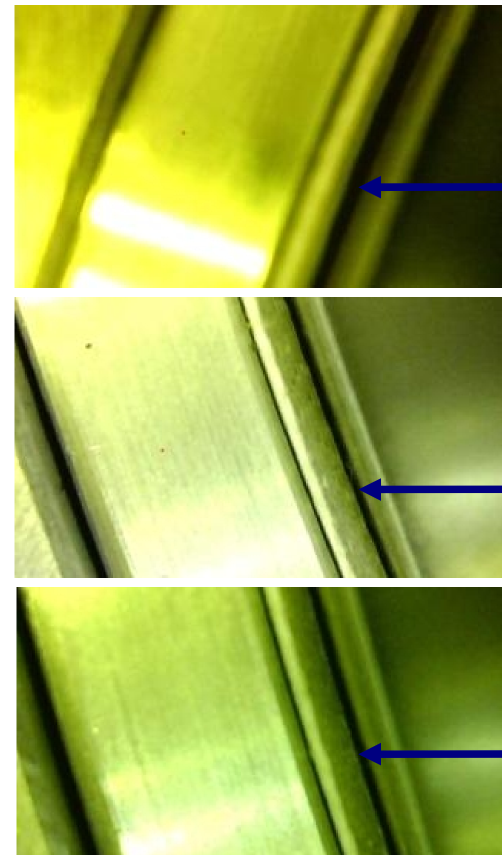


Large area prototype

Dedicated tool for HV test of Cylindrical Electrode

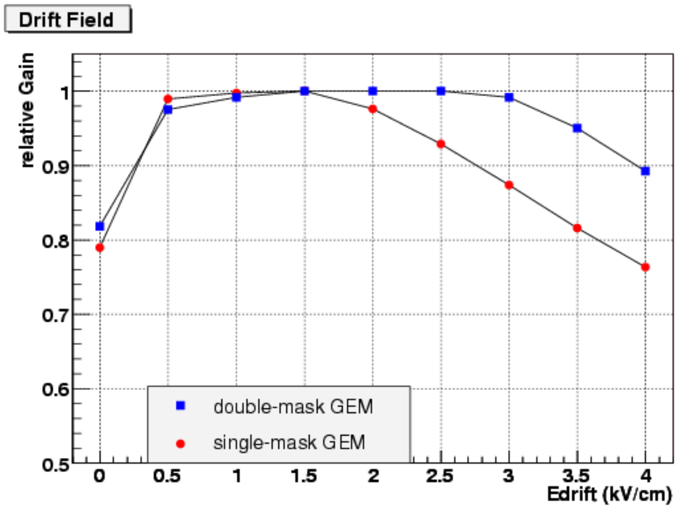
Dedicated tool to handle the molds

The tolerance of 150 μm between the rings has been met

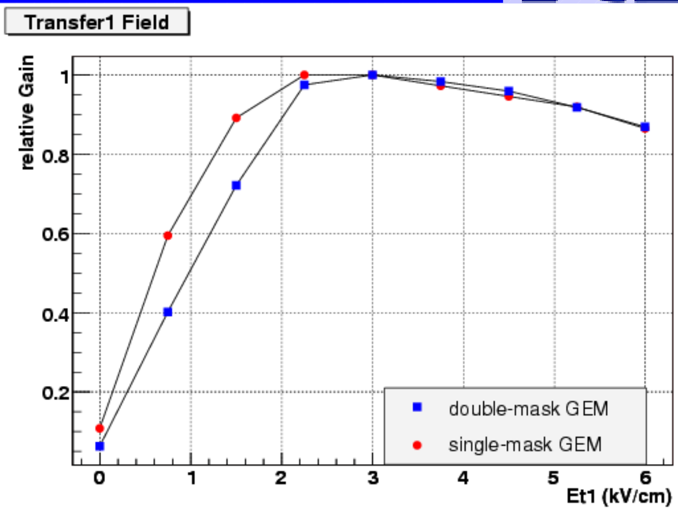


Durostone Fiberglass/Epoxy rings from RESARM

Large area GEM: optimization of the fields



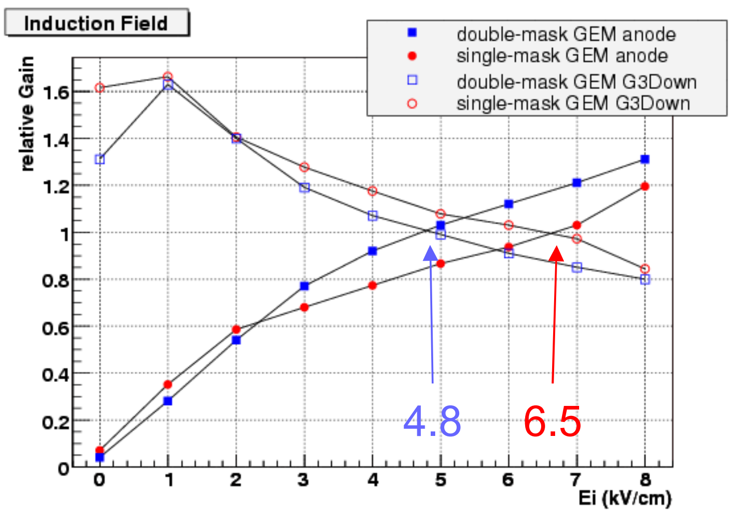
Only slight difference between the two GEM (due to different hole shapes?)



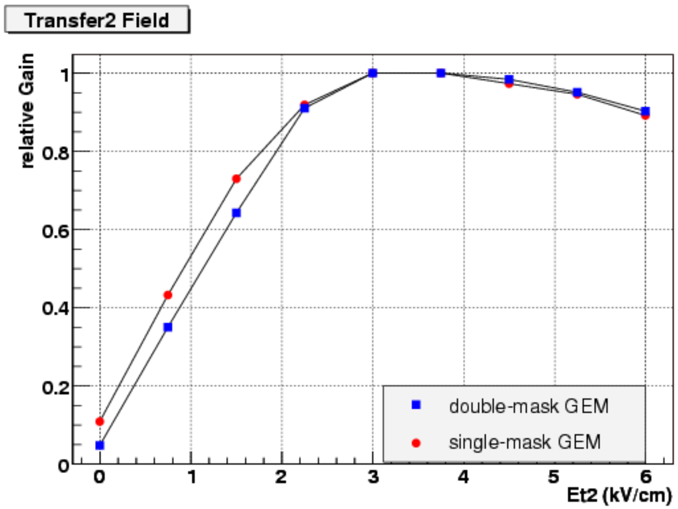
Final operating fields values:

1.0 - 3.0 - 3.5 - 6.5 kV/cm

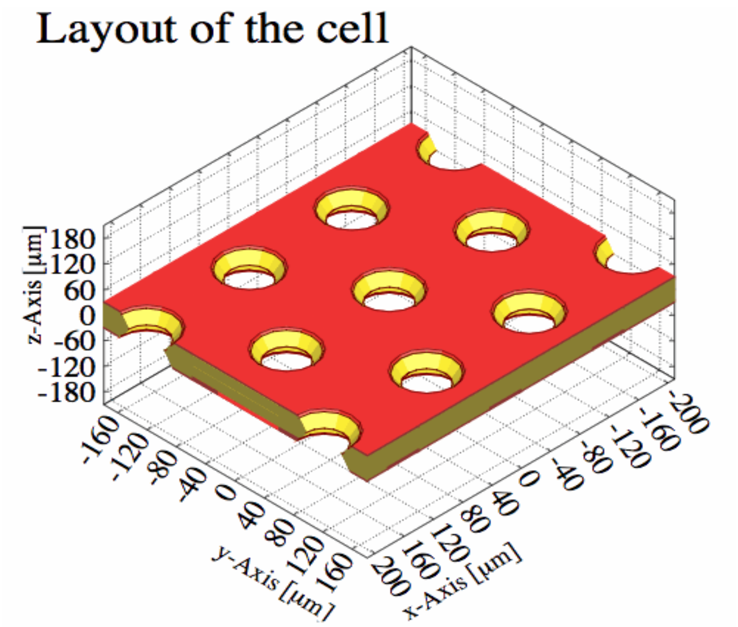
(Drift - Transf1 - Transf2 - Induction)

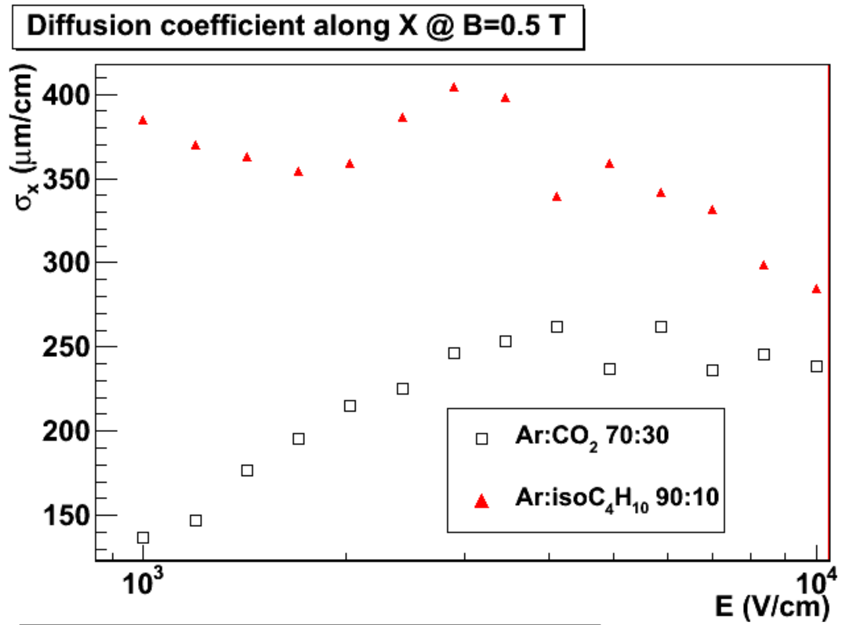


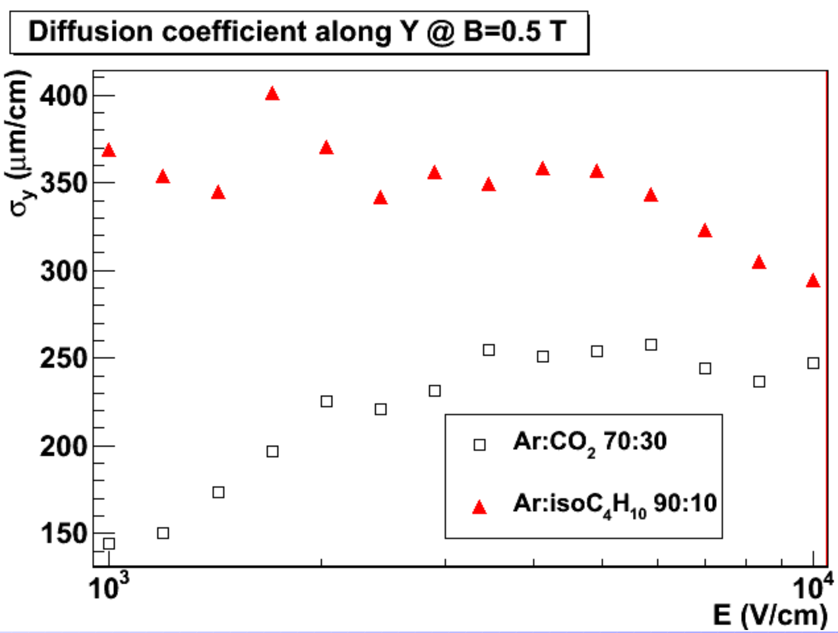
Equal charge sharing occurs at higher induction field in the single-mask

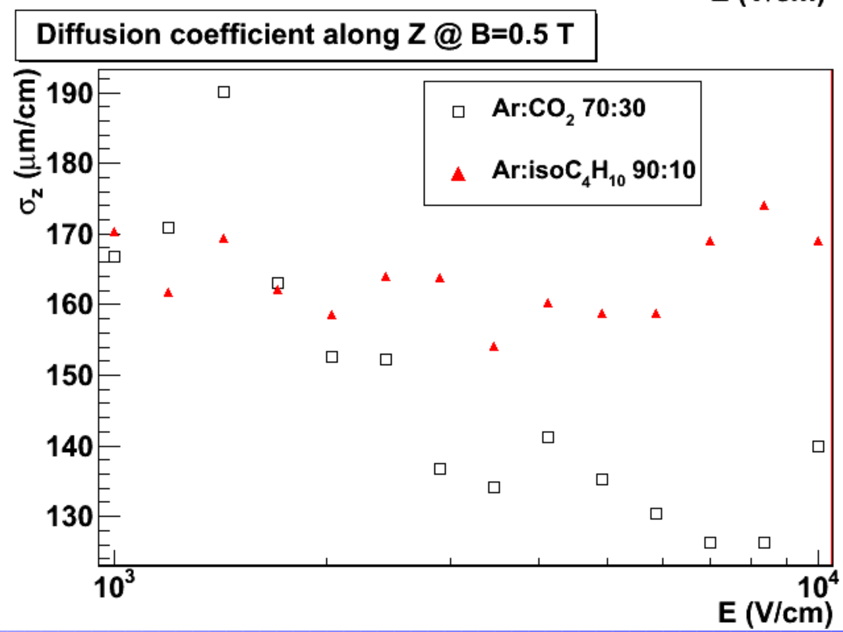


Gas mixture studies: GARFIELD simulations



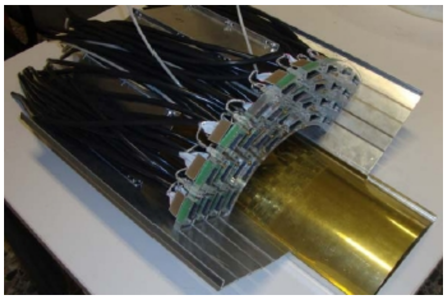


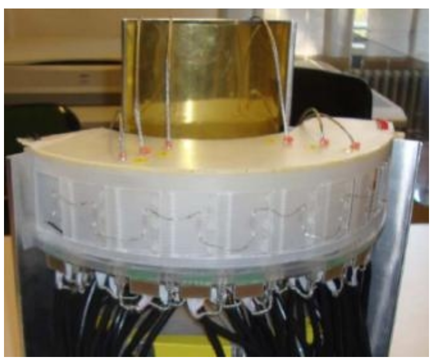


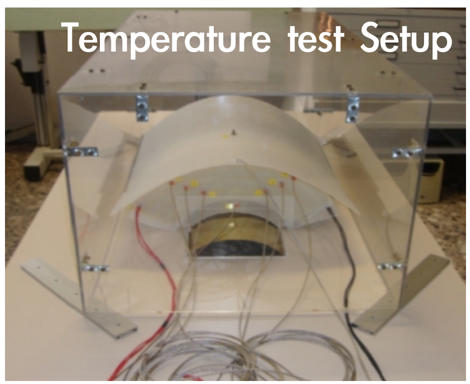


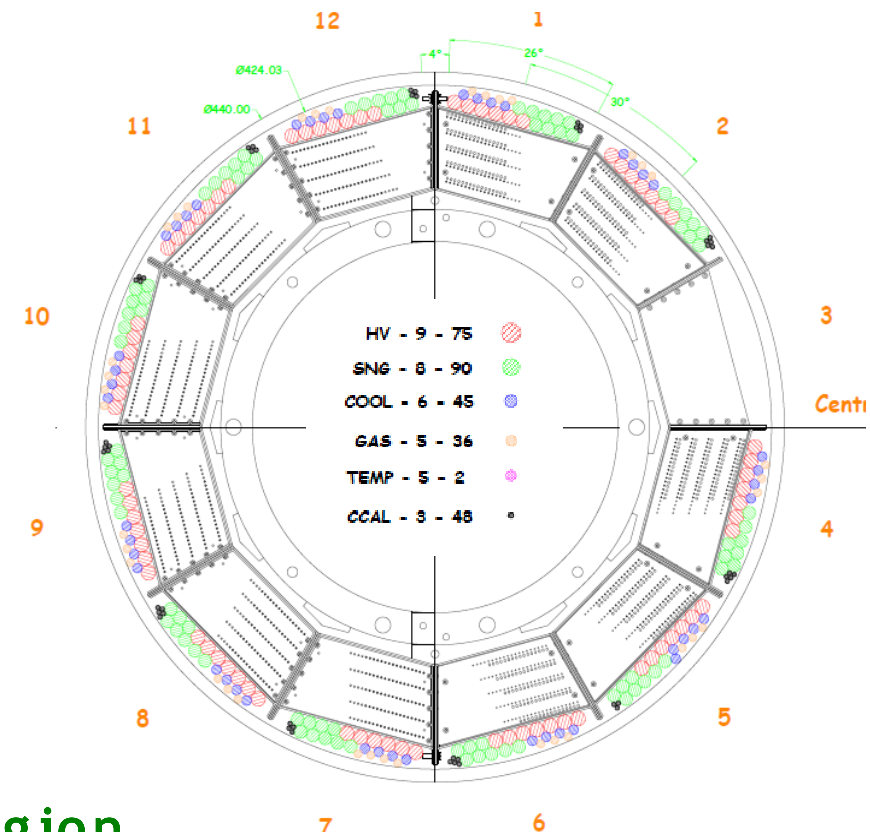
• Cable integration presently the most important issue

• Temperature test in IT Front-end region done using maquette for cables & board-flanges with resistors









Cooling needed in IT Front-end region

• **Mockup of beam-pipe(BP) + BP supports + detectors planned for beginning 2011**