Status report on Cylindrical GEM Detector

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on behalf of KLOE2
Bari-Cosenza-LNF collaboration

Outline

- Introduction
- Proto0.1: construction and test
- Short/Medium term programs
- Conclusions

KLOE2 - Inner Tracker

Main detector requirements:

- ❑ $\sigma_{r\varphi} \times \sigma_z \sim 200 \times 500\mu m$ single layer spatial **resolution** for fine vertex reconstruction of **Ks and η decays and interferometry measurements**
- ❑ 5 tracking **layers with low material budget** : ~1.5% X_0

The IT will cover the space from the beam pipe to the inner wall of the KLOE Drift Chamber: **150 mm to 250 mm radius, with an active length of about 700 mm** (very large GEM needed: up to 500x700 mm^2 !!!)

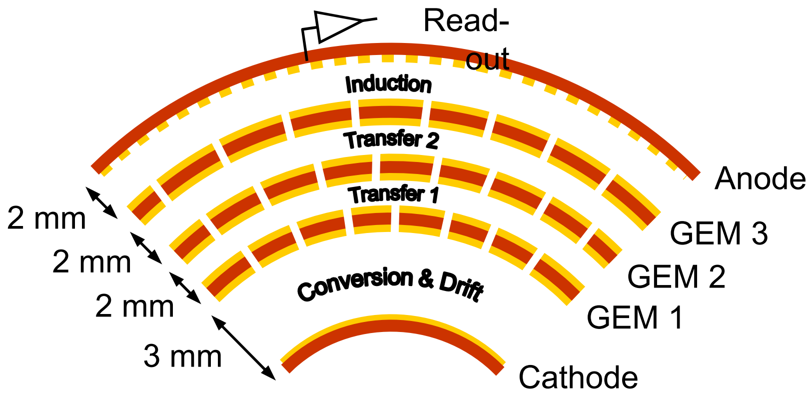
Each **CGEM is completely realized with polyamide**, and the final result is a very light detector: only **0.2% of X_0** per layer inside the active area

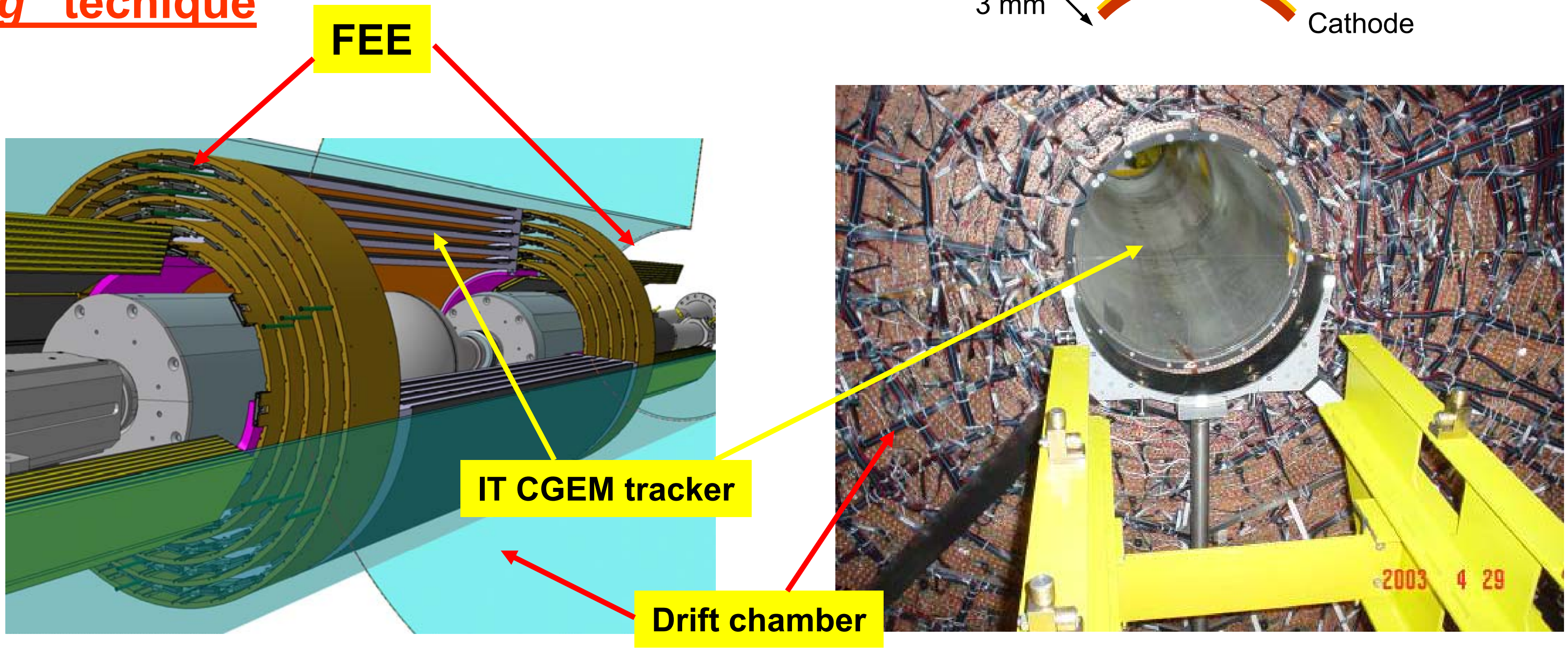
no support frame inside the sensitive volume !!!

KLOE2 IT- CGEM

Each CGEM is composed by **five concentric cylindrical structures**: ***each one realized with the "vacuum bag" tecnique***

Cylindrical Triple GEM





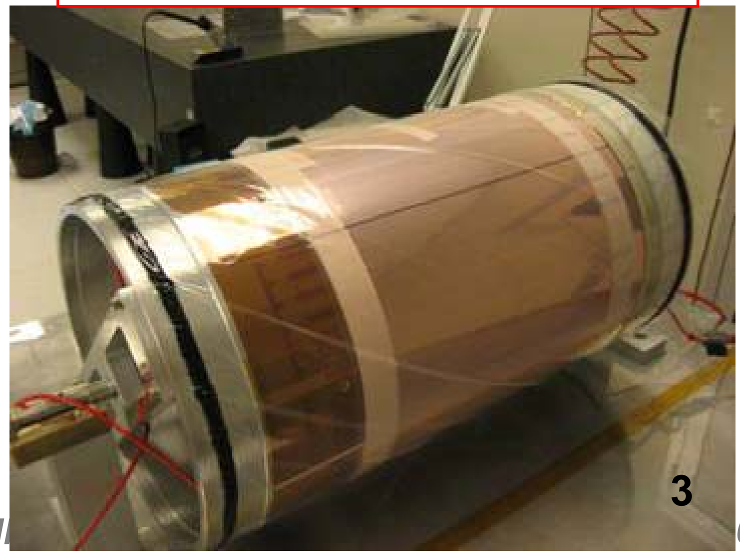
Proto0.1: Ø=300mm, L=350mm; 1538 longitudinal strips only, 650 µm pitch.

Full size CGEM prototype: construction and test

CGEM building procedure

1. An epoxy glue is distributed along the edge of the GEM foil (<3 mm)

2. The GEM foil is rolled on a Aluminum mould covered with a 400 µm thick machined Teflon film for a non-stick, low-friction surface

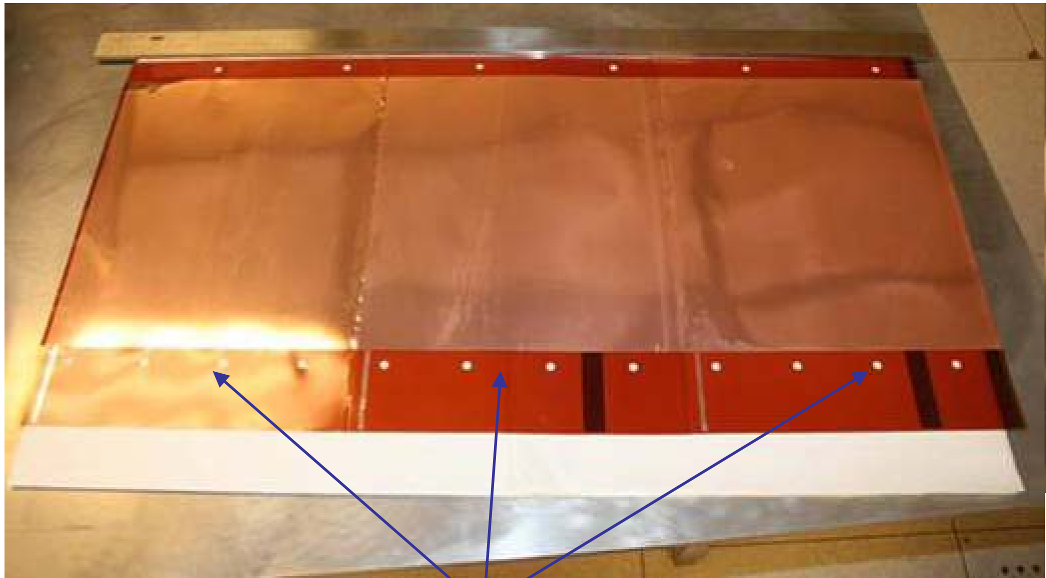


3. The cylinder is enveloped in a vacuum bag. Vacuum is applied with a Venturi system, providing a uniform pressure of 1 kg/cm^2

4. A perfectly cylindrical GEM is obtained

With the same procedure Anode and Cathode are obtained

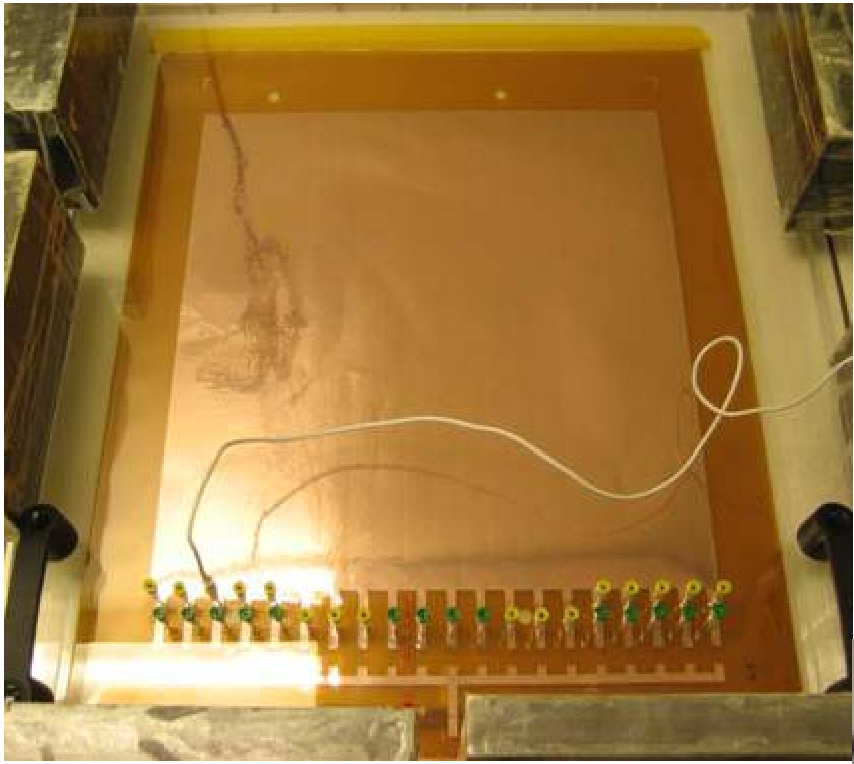
Cathode



3 foils joined together

Permaglass annular flanges outside the active area act as supports for the detector

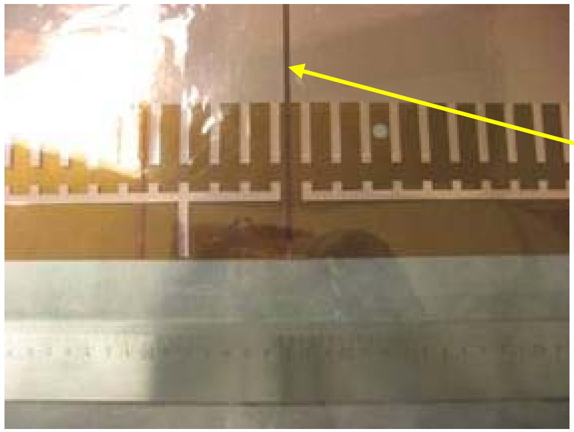
GEMs

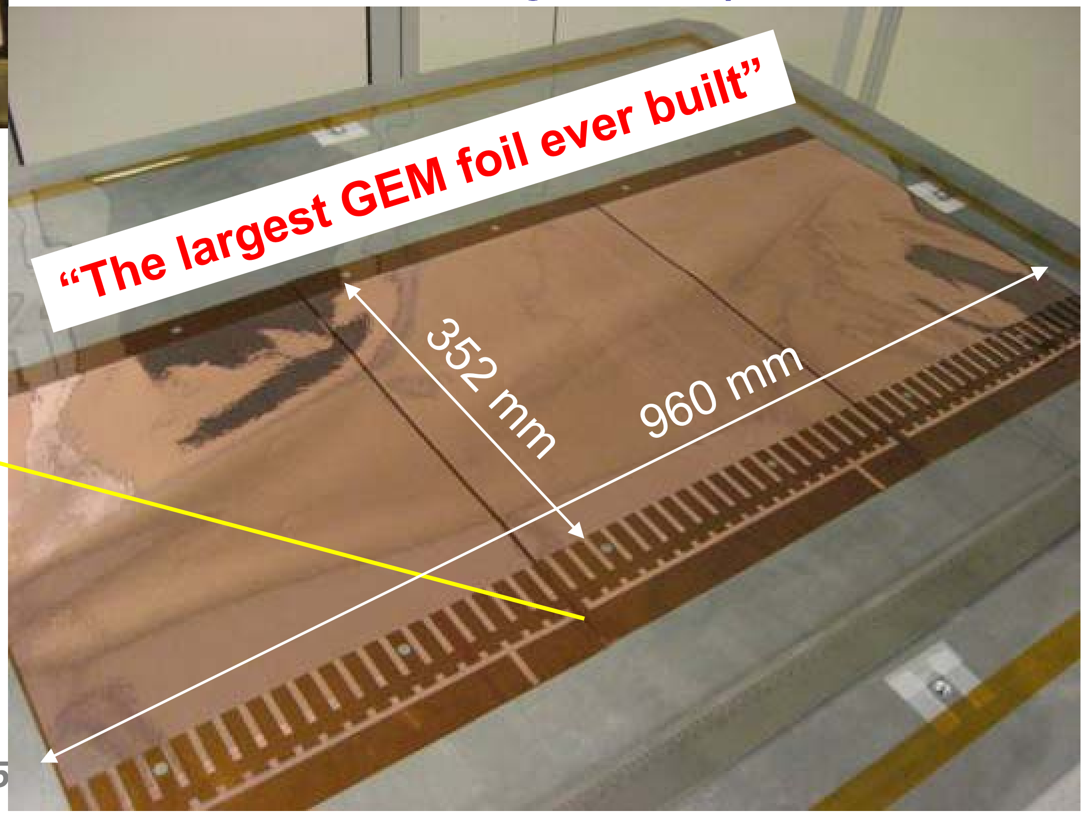


GEMs are preliminary tested, sector by sector, in a humidity controlled box. Each foil is divided 20 independent HV sectors, ~50 cm^2 area each.

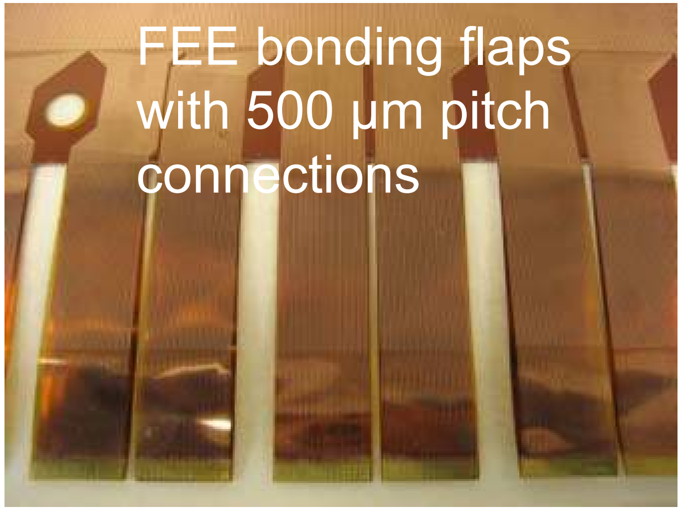
Three GEM foils are "planary" glued with the *vacuum bag tecnhique*

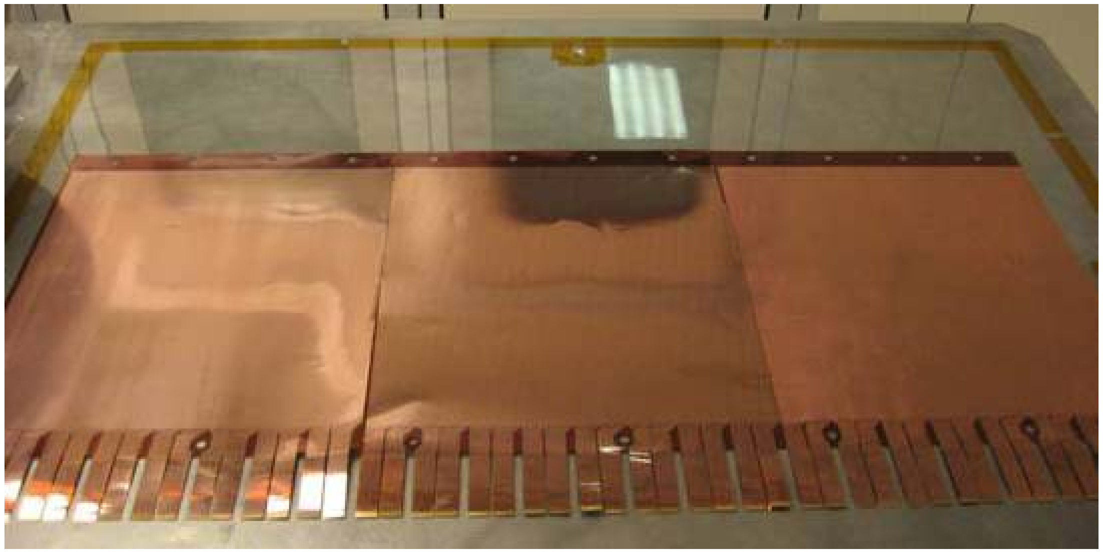
<3 mm overlap region

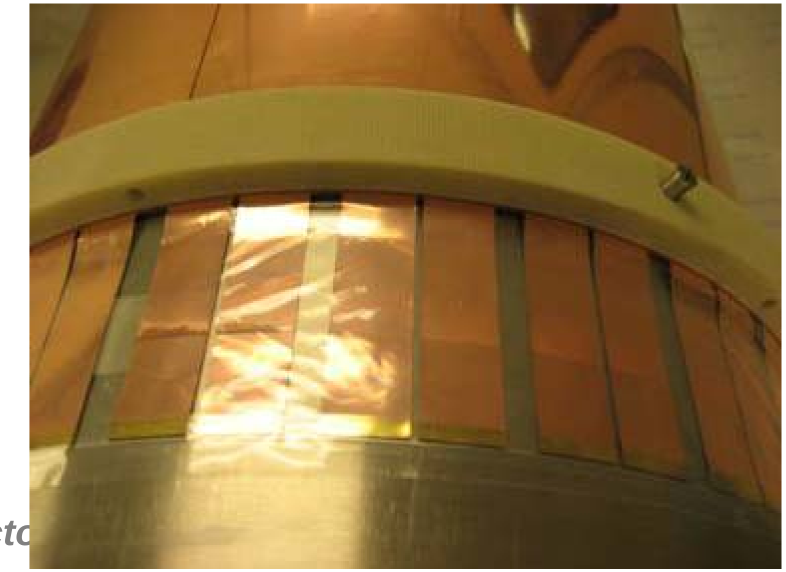




Anode read-out

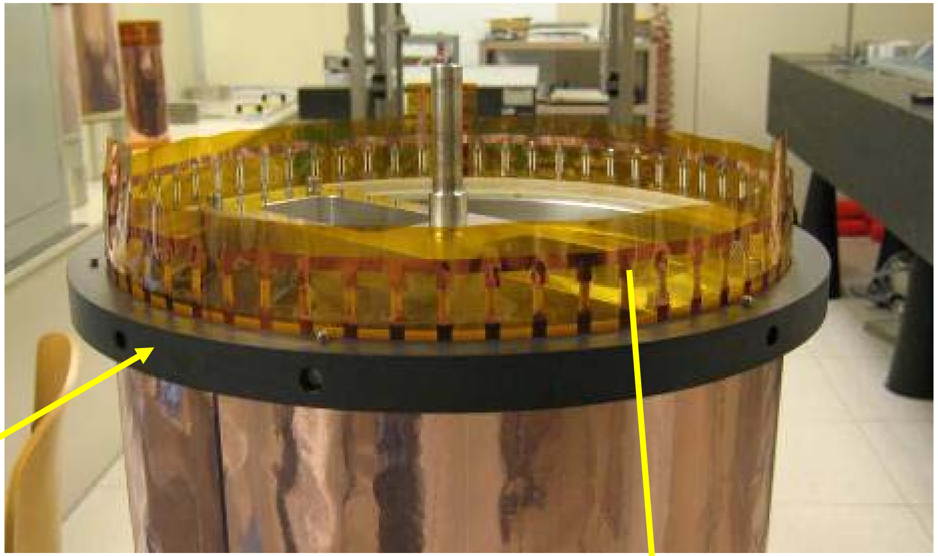


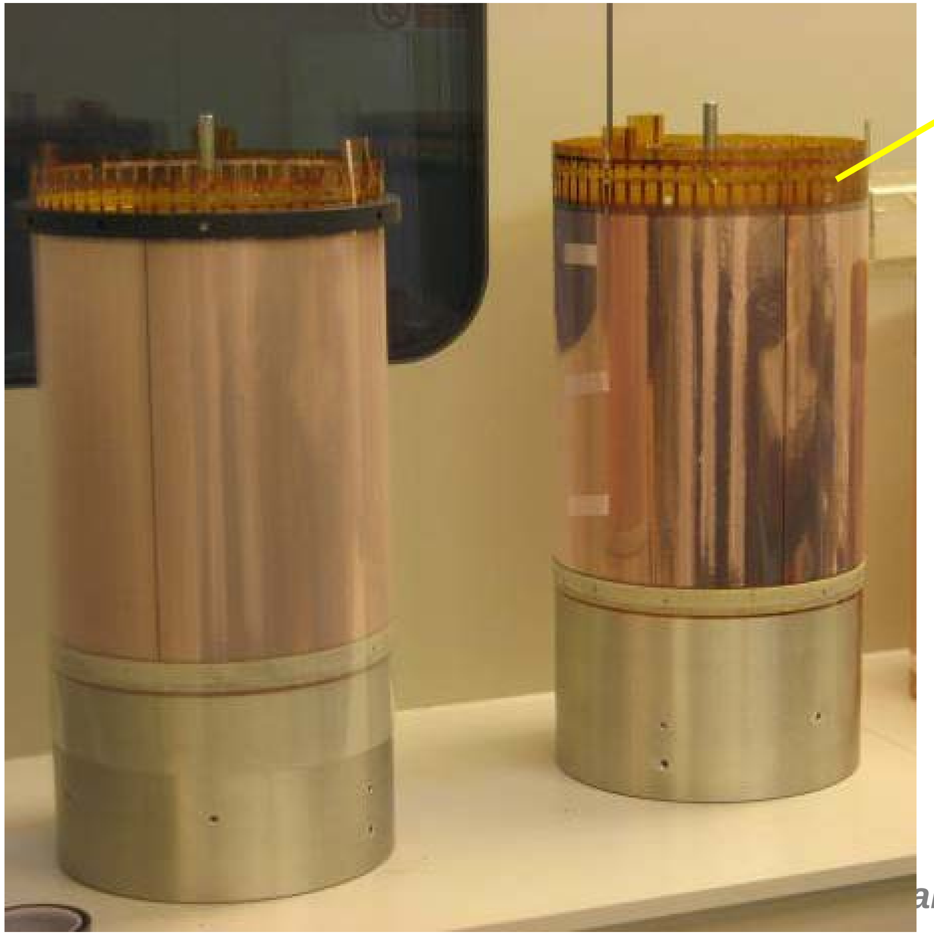


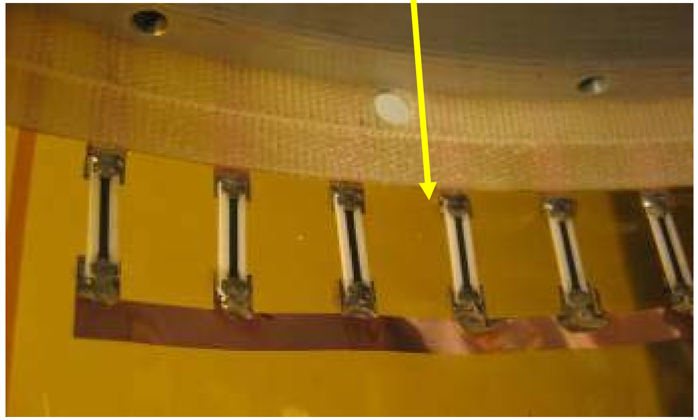


HV Resistors soldering

Then the cylindrical GEM electrodes are partially extracted from the mould for the soldering of 1MΩ limiting HV-resistors on the 60 HV sectors

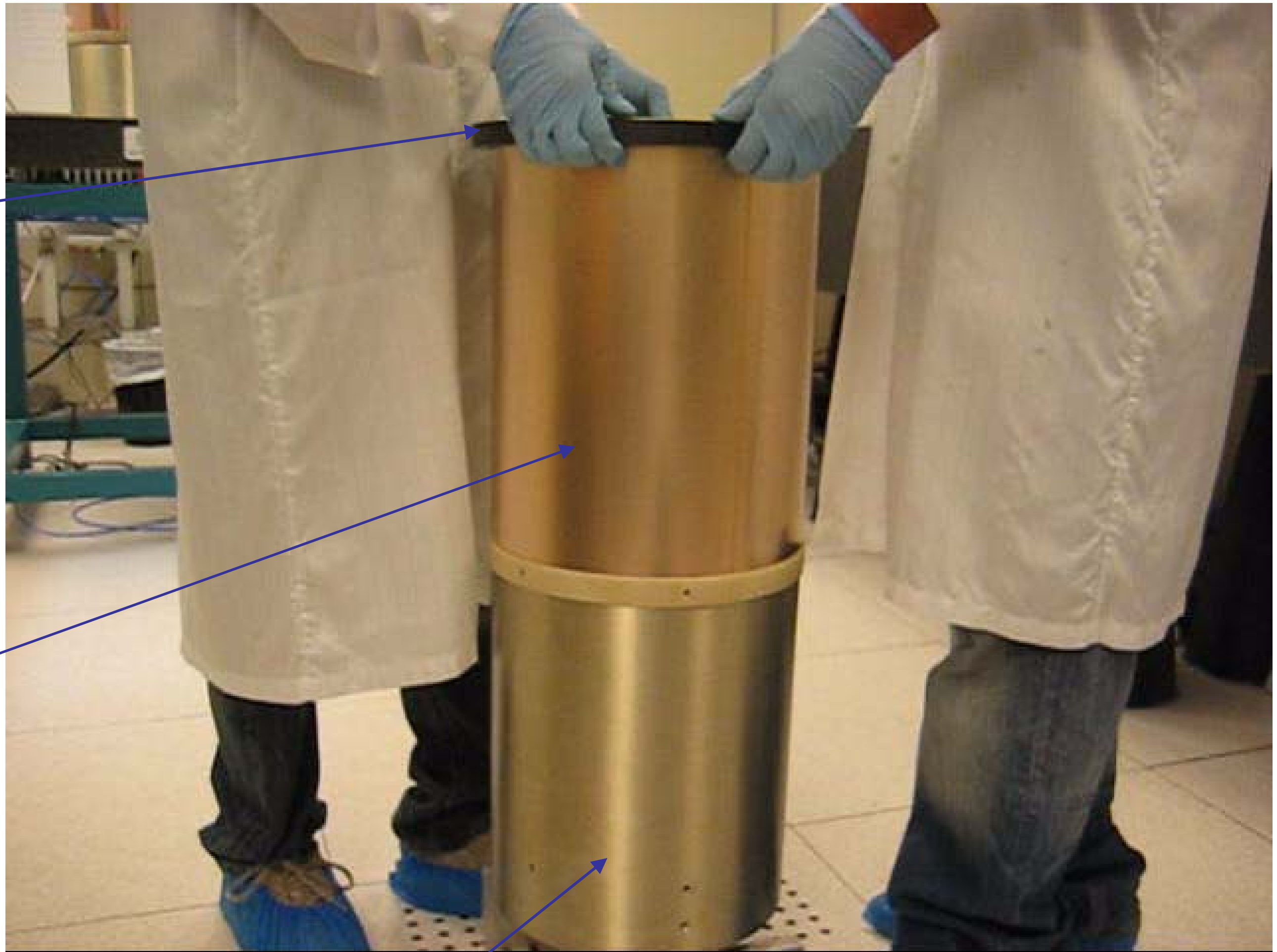






Electrode Extraction

PVC exctraction ring

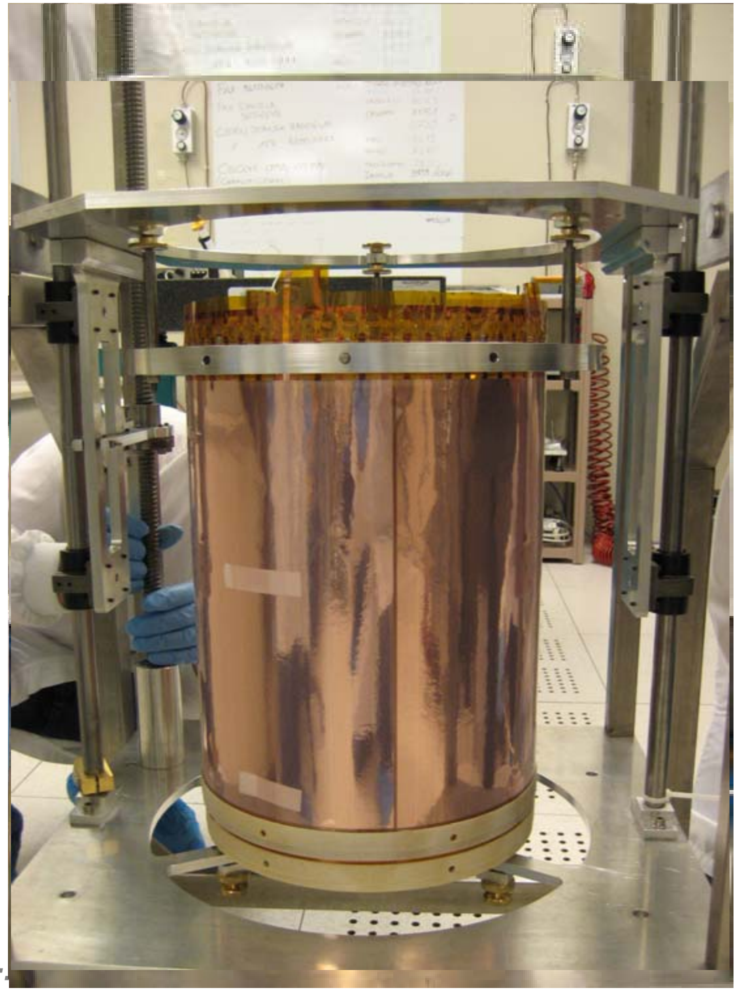


cathode

TEFLON coated mould

Vertical Insertion System

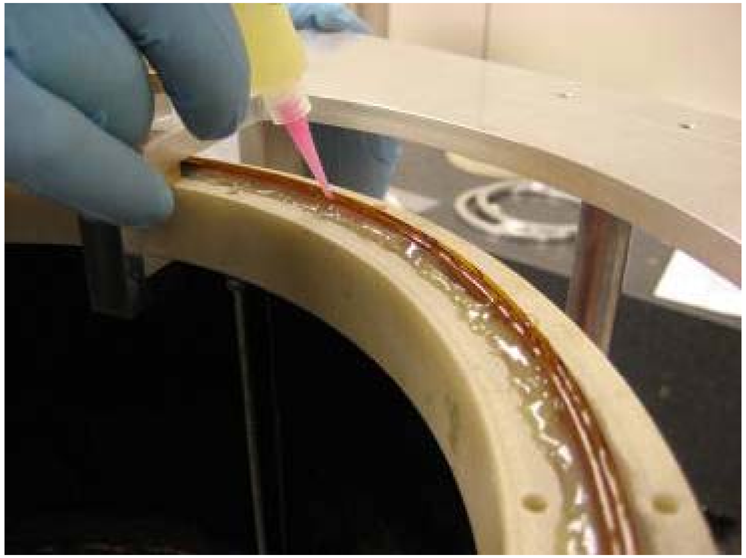
The Cathode is fixed on the bottom Al plate
The other electrodes are fixed on the top plate and are **pulled down slowly** with a precise linear bearing equipment



Detector Sealing

glue is dispensed just before the full insertion of the electrode

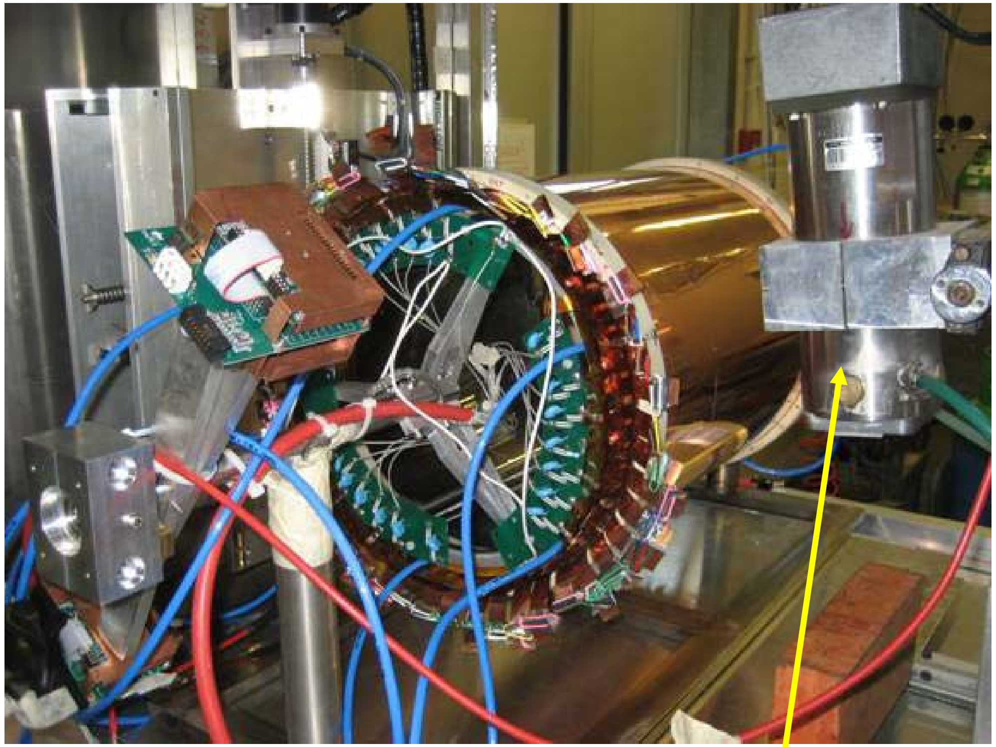
detector is sealed on one side with epoxy glue



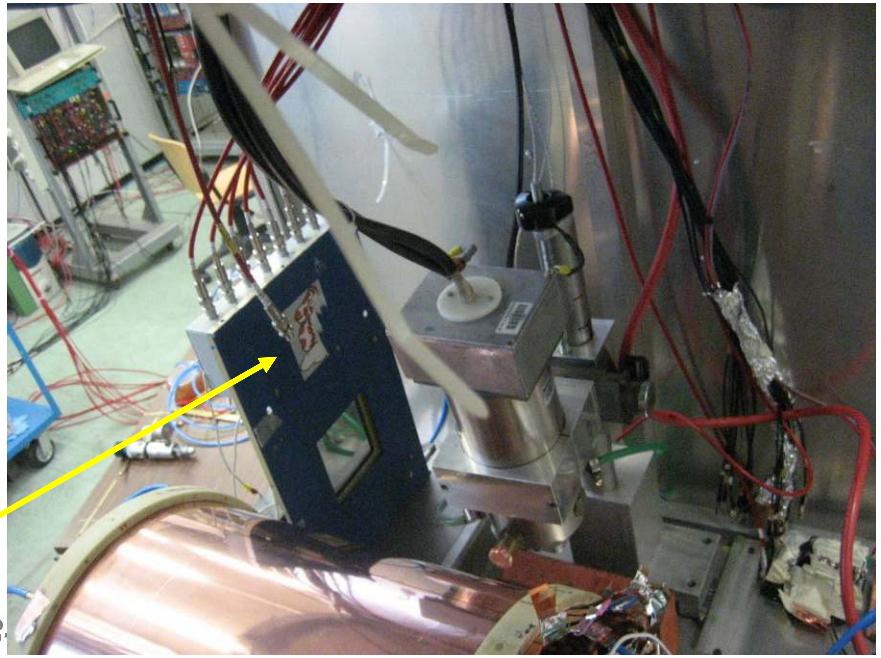
Once the detector is fully assembled the VIS can be rotated to allow the sealing of th other side… et voilà le jeux sont faites !!!

X-ray Test

X-ray Test



- ❑ CGEM tested in current mode
- ❑ 10x10cm^2 GEM used as reference (normalization for pressure/temperature effects …)
- ❑ Gain and electron transparency measurements
- ❑ Uniformity measurement throughout the whole CGEM surface



~ 6 keV X-ray gun

Reference Planar GEM

Gas Gain

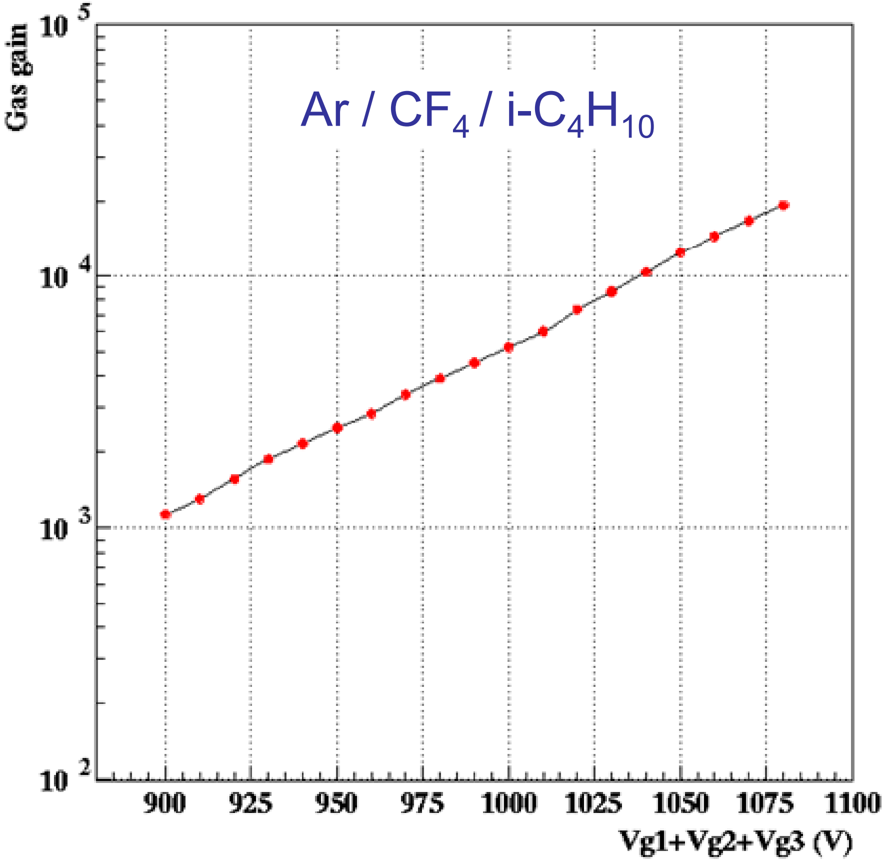
- The detector is being flushed with a $Ar/CF_4/i\text{-}C_4H_{10}$ = 65/28/7 gas mixture (previously characterized by us for the LHCb GEM)

  - CF_4 helps to match the fast electronics available in that moment (CARIOCA-GEM)

  - Isobutane allows a safer detector operation

- Gas gain measured up to 20000

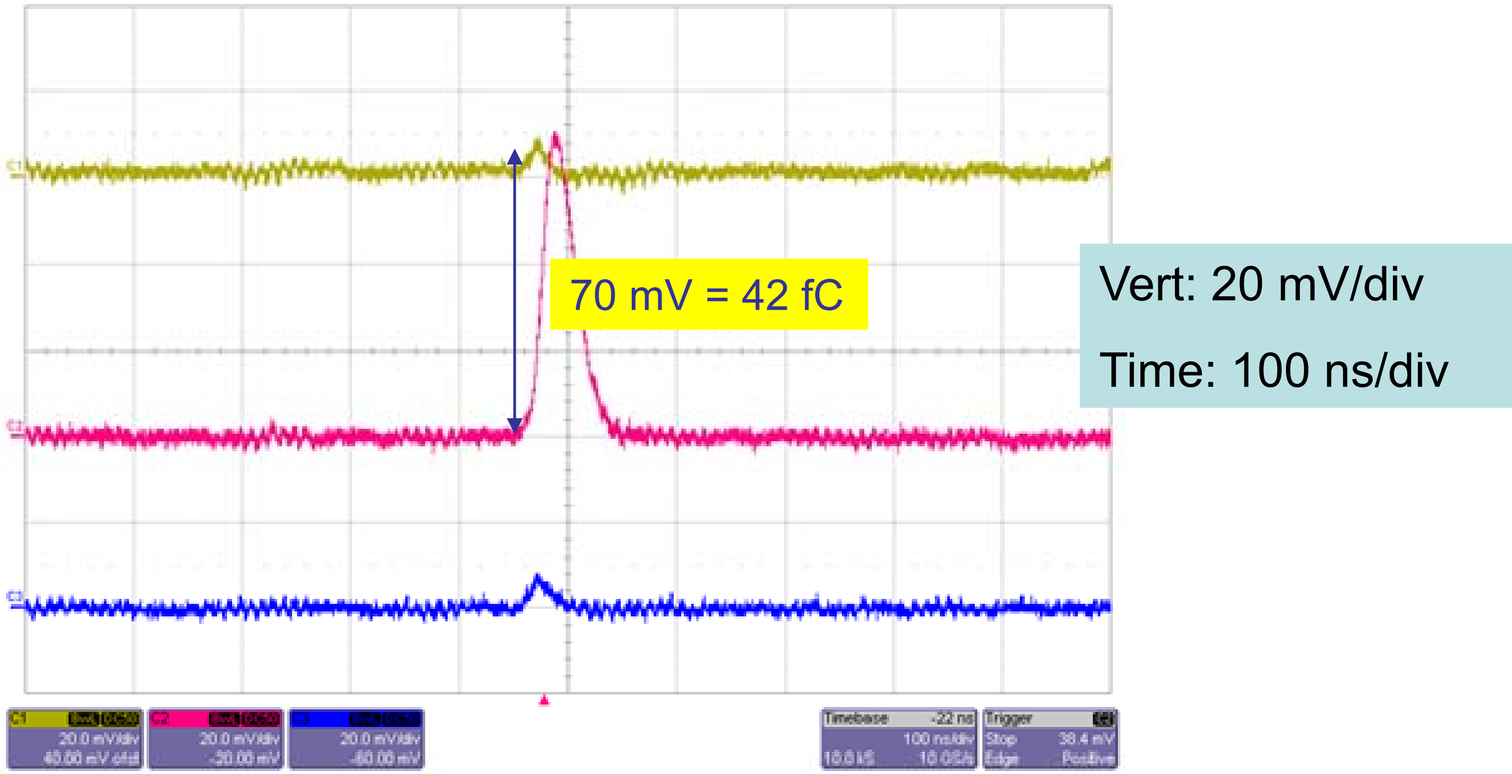
- **No discharges** or **leakage currents** observed



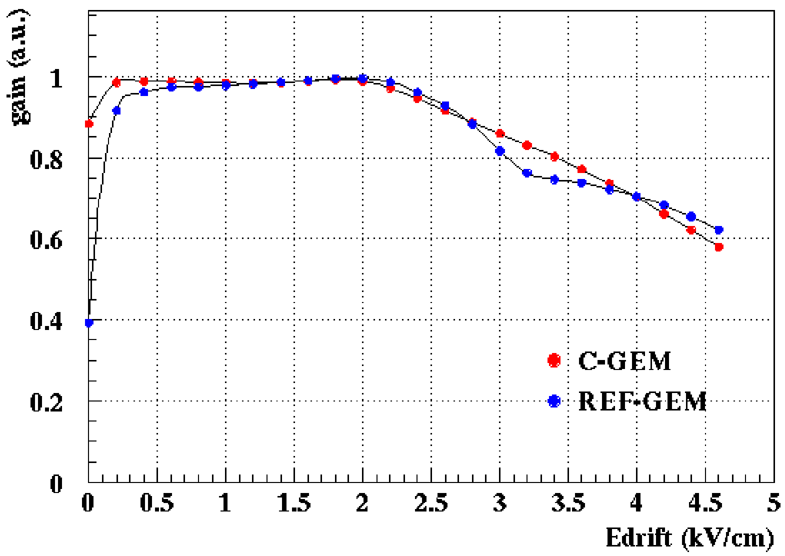
VTX signals with X-rays

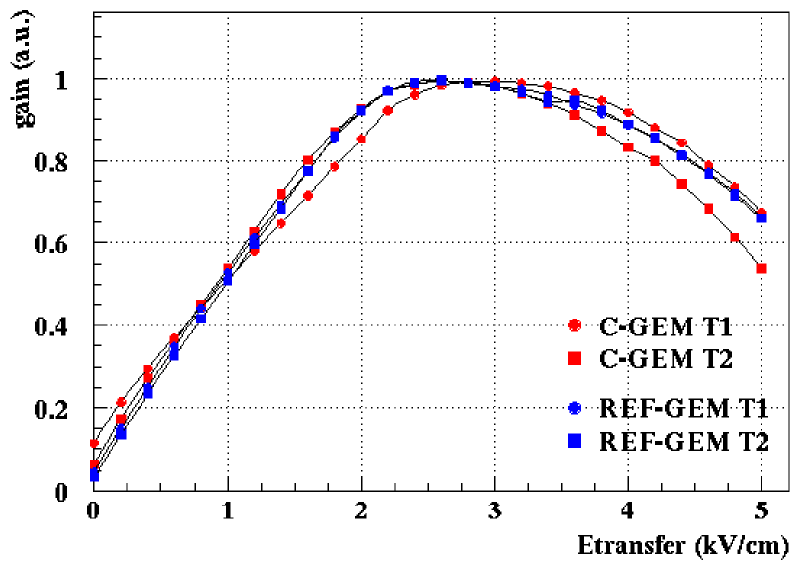
❑ Examples of signals on the readout strips equipped with VTX analog amplifier (VTX sensibility, with 15 pF C_{det} = 0.6 mV/fC)

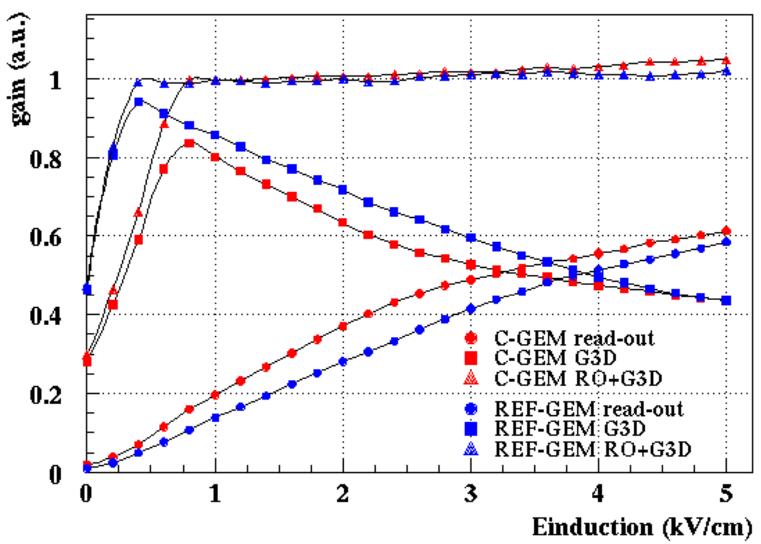
Charge induction on strips (650 µm pitch)



CGEM characterization with X-rays







$Ar/CF_4/i\text{-}C_4H_{10}$ = 65/28/7

GEM polarization: 375/365/355 V

Gain ~ 20000

GASTONE (GEM Amplifier Shaper Tracking ON Events)

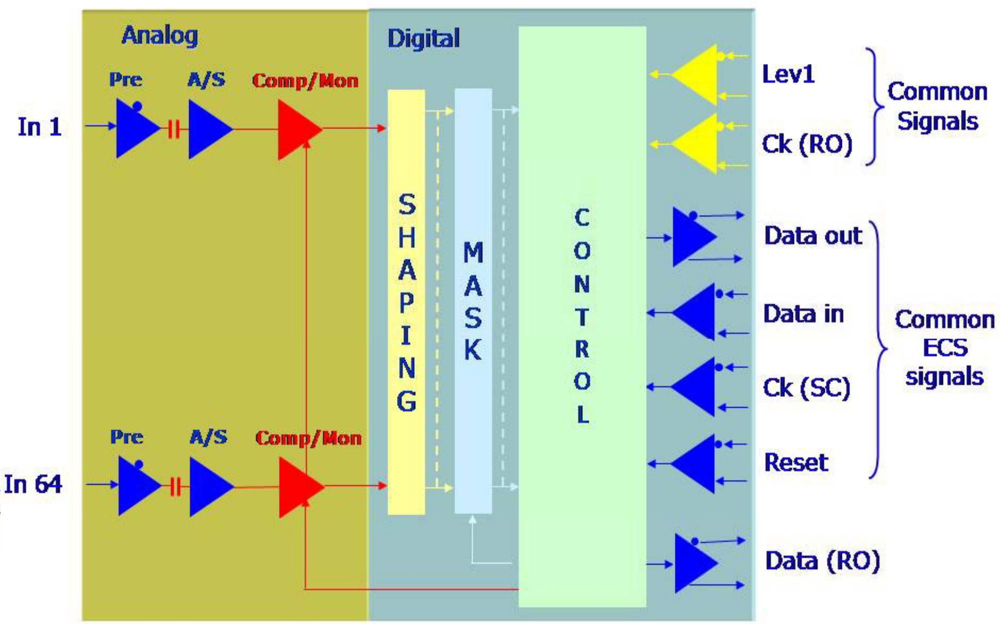
- **GASTONE** is a **low-noise, low-power,** mixed **analog-digital ASIC** designed in the **0.35μm CMOS AMS** process. It's designed to host, on its **final version 64 chs**, or the strips readout of the CGEM detector.

- The channel **architecture** foresees **four different blocks**: a **charge sensitive preamplifier, a shaping stage, a leading-edge discriminator** (with programmable thr.) and a **monostable circuit** to stretch the digital signal, waiting for Lev1 trigger generation.

- Digital **output data** are transmitted **via serial interface at 100 Mbit/s** data rate.

- A first **16 chs prototype** has been already produced and used to **instrument the CGEM** prototype tested with cosmics and a pion beam at CERN.

GASTONE block diagram



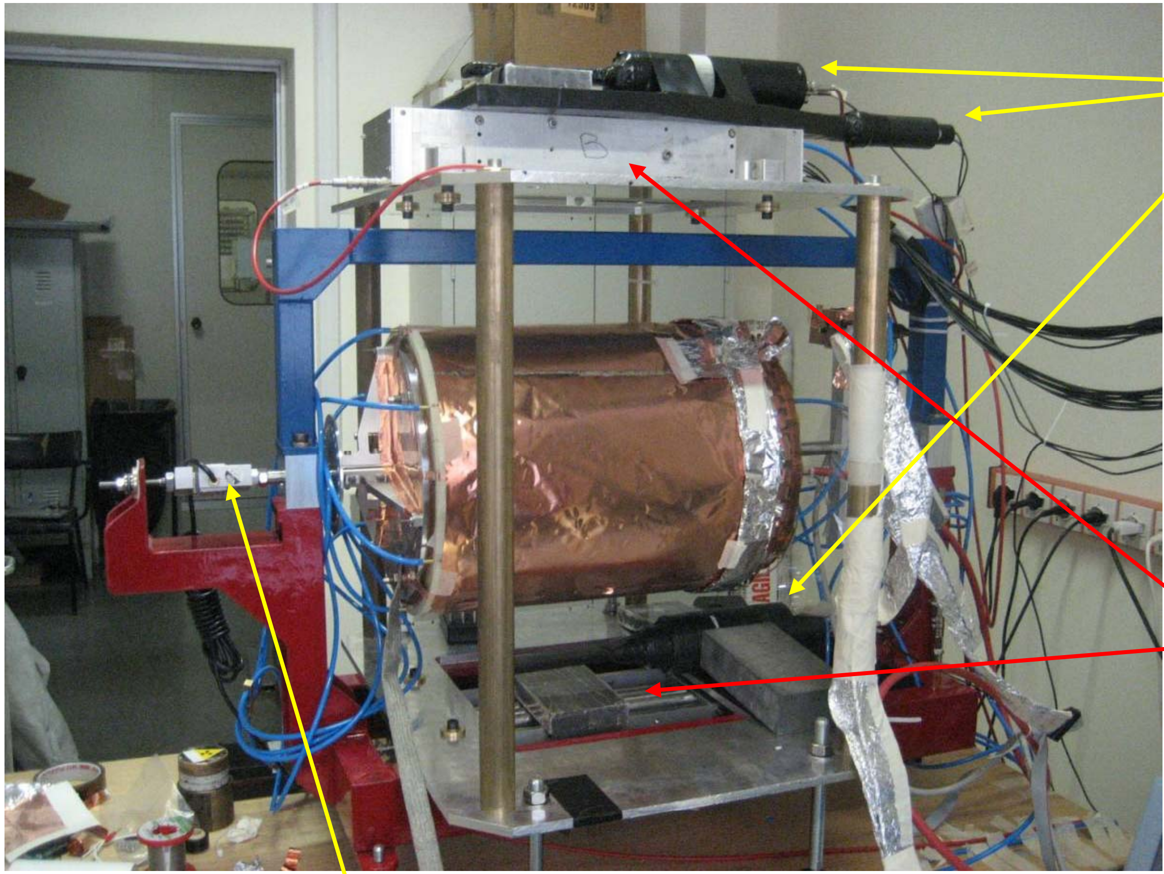
GASTONE parameters

	GASTONE	CARIOCA
Sensitivity (o pF)	20 mV/fC	14.5 mV/fC (pos) – 13.8 mV/fC (neg)
Z_{IN}	400 Ω (low frequency)	< 50 Ω
C_{DET}	1 – 50 pF	10 – 200 pF
Peaking time	90 – 200 ns (1 -50 pF)	10 – 15 nS
Noise (erms)	974 e^- + 59 e^-/pF	416 e + 35.9 e/pF
Baseline restorer	no	yes
Channels/chip	64	8
Readout	Digital/Serial	LVDS (8 chs)
Power consumption	≈ 0.6 mA/ch	≈ 19 mA/ch

GASTONE	
Threshold sensing/setting	8 bits ADC/DAC (16 chs modularity)
Single channel monostable for Digital/Serial	

Cosmic ray setup

Study of the performance of peculiar regions (< 1% of the whole surface)



Triple coincidence of **scintillators** for trigger (with fingers parallel to the GEM strips

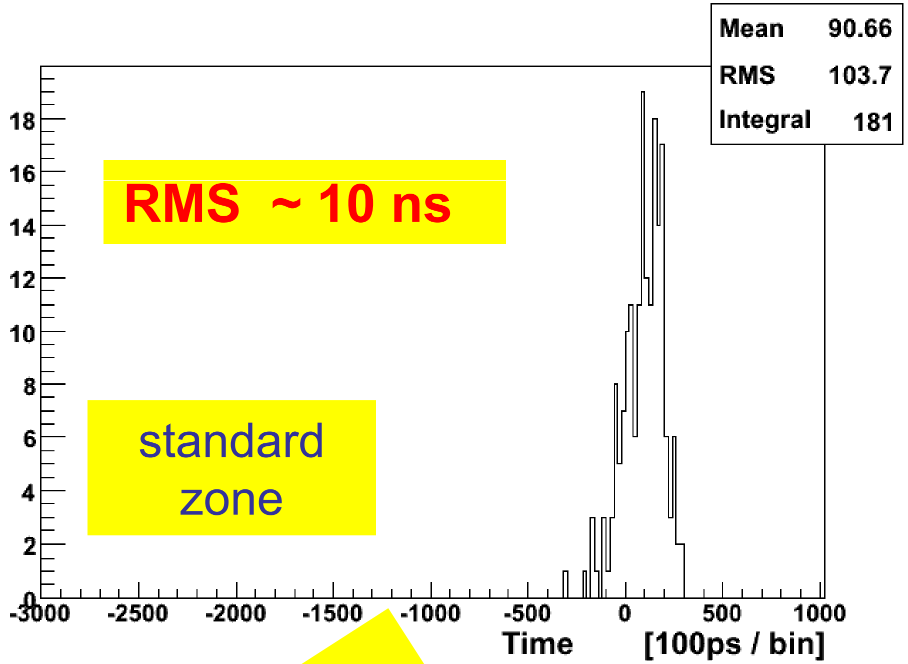
2 sets of drift tubes, in streamer mode, for tracking (only X coordinate along GEM strips)

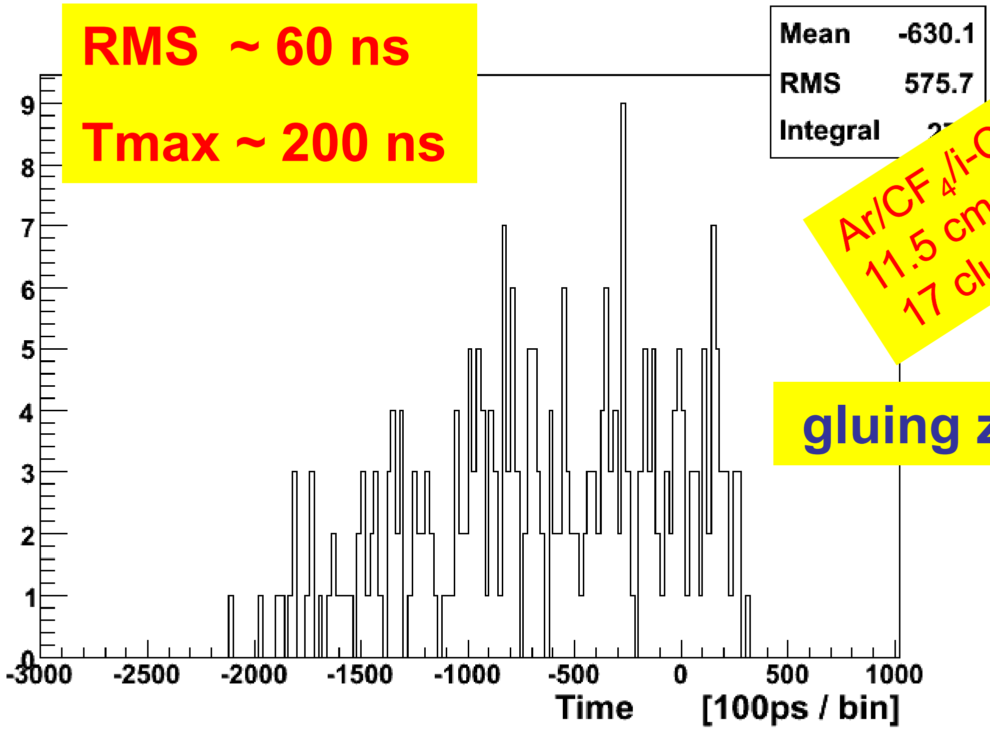
Load cell for CGEM mechanical tensioning

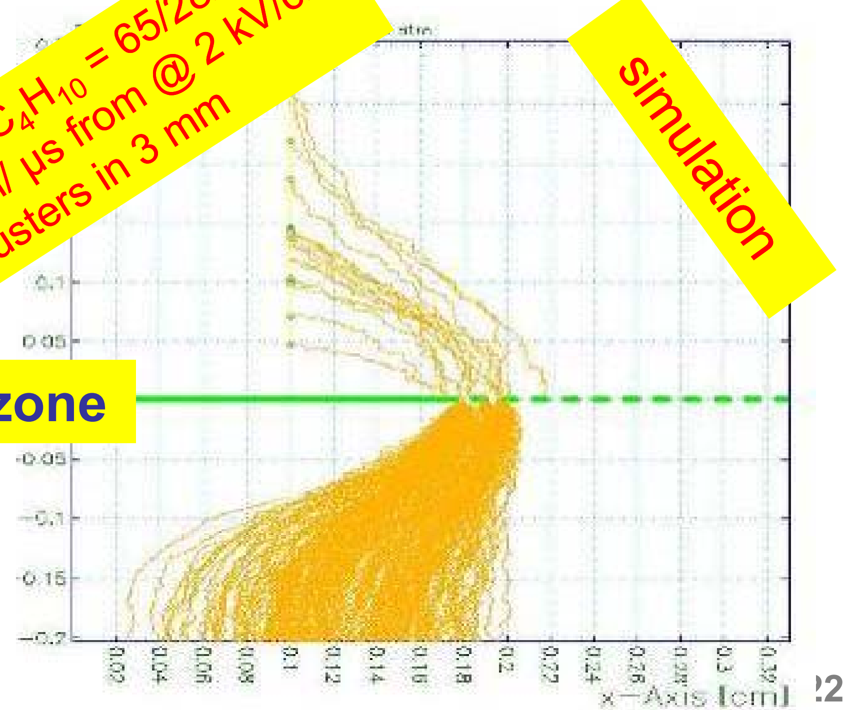
2 opposite zones were equipped with FEE

CGEM time spectra

- GEM channels near gluing joints show peculiar time spectrum due to the distortion of field lines
- effect already simulated and taken into account for the GASTONE design







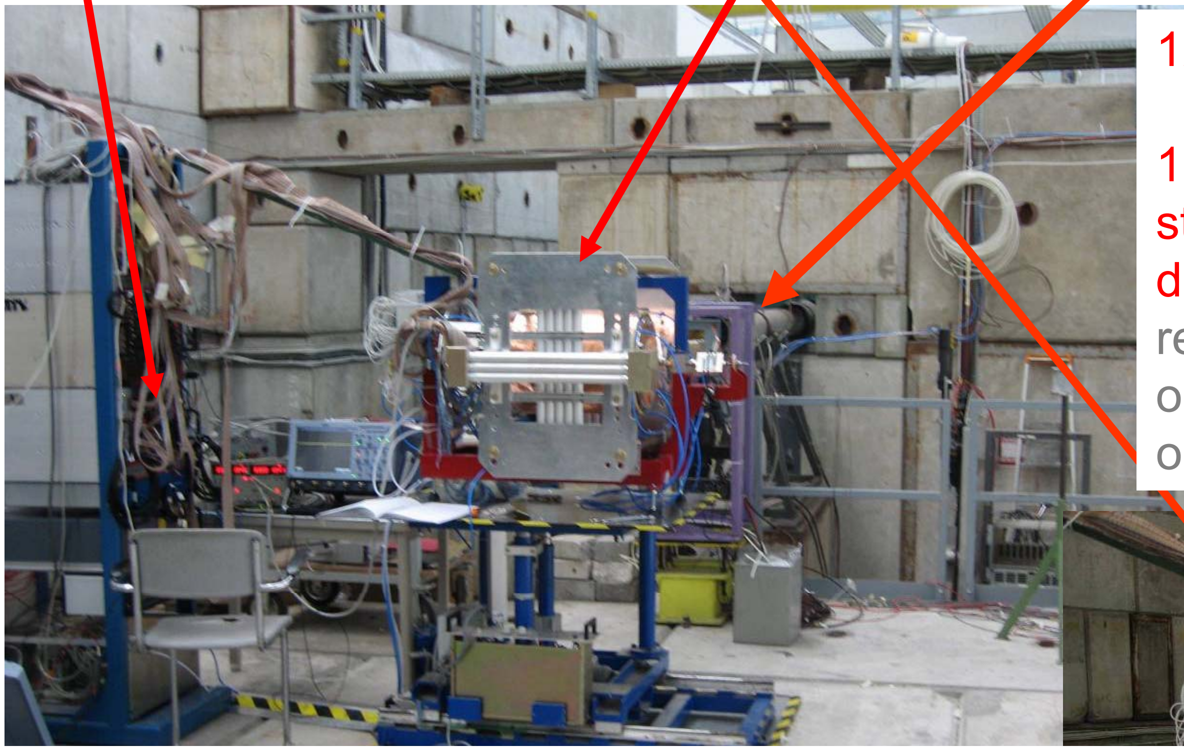
CGEM Test Beam at CERN PS-T9

Test beam at the CERN PS-T9

electronics rack

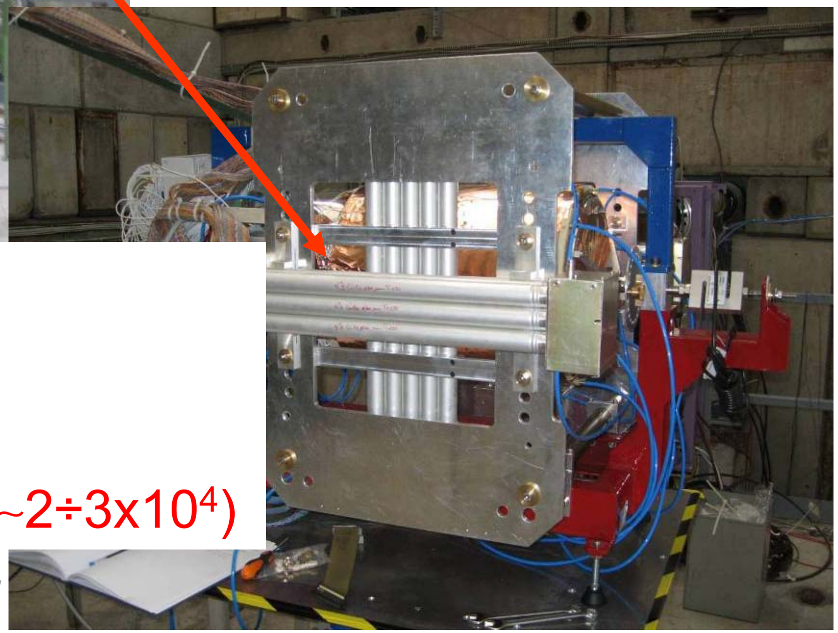
detectors

beam line: 10 GeV pion beam



128 chs of GASTONE: 1 Mtrigg.

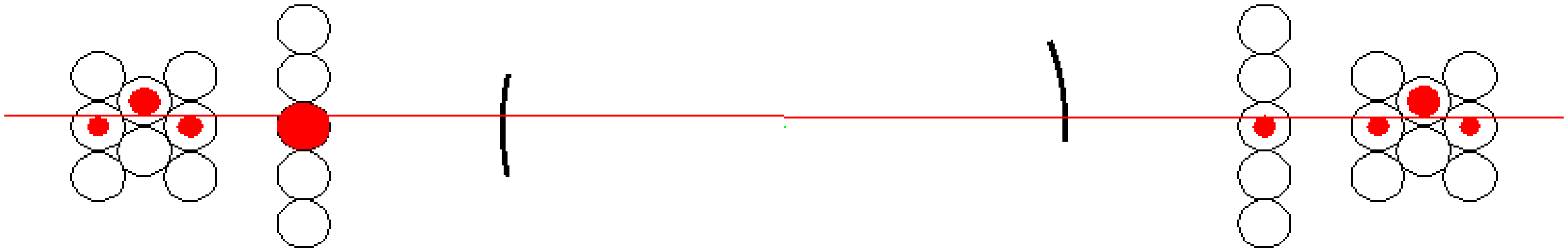
192 chs Carioca-GEM FEE, to study time chacteristics of the detector (too fast electronics with respect Ar/CO_2 detector operation … so some instability observed)

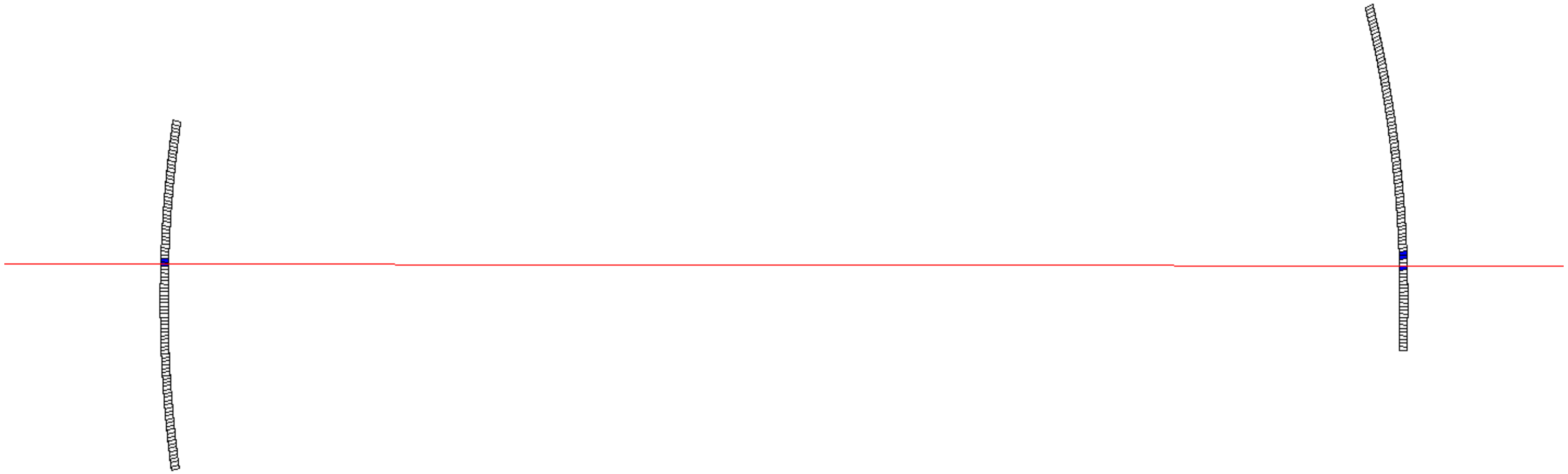


Detector operation conditions:

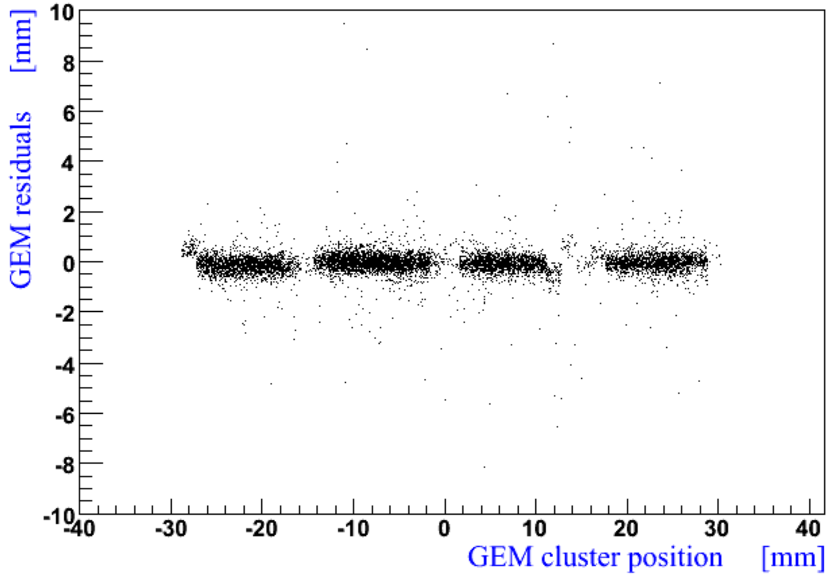
- ❑ Ar/CO_2 = 30/70
- ❑ V_{fields} = 1.5/2.5/2.5/4 kV/cm
- ❑ V_{GEM} = 390/380/370 V (ΣV_G = 1140V → G ~2÷3x10^4)

TB events

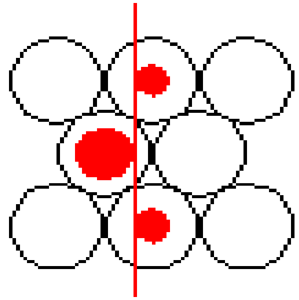


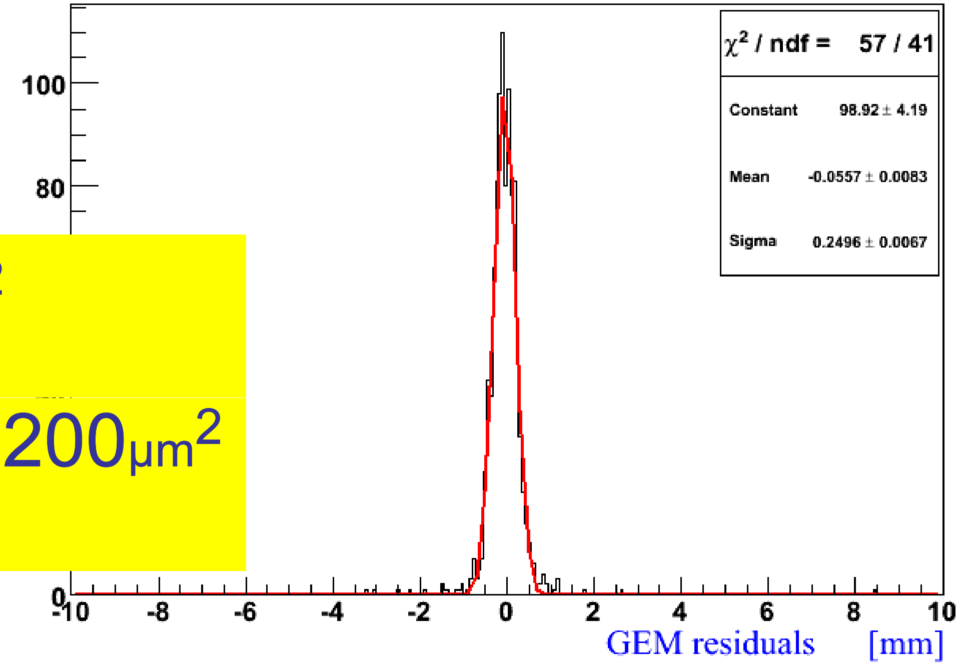


Test beam results



GEM residuals with respect to the track reconstructed by the external drift tubes

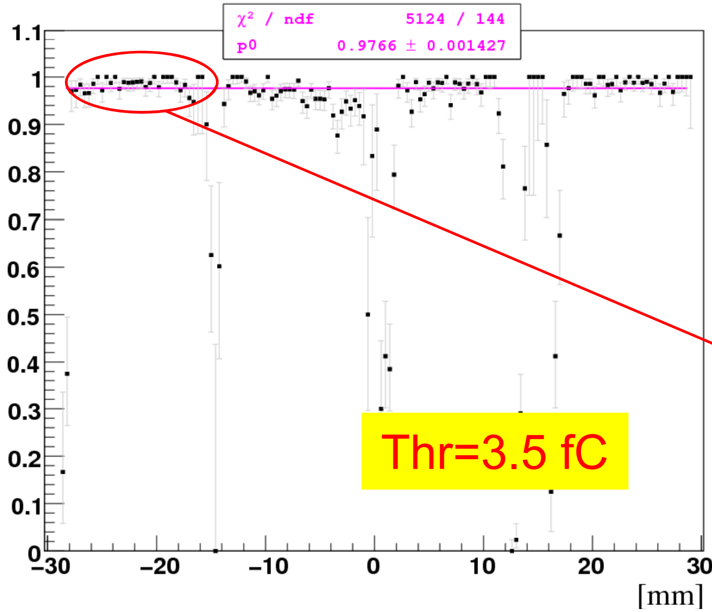


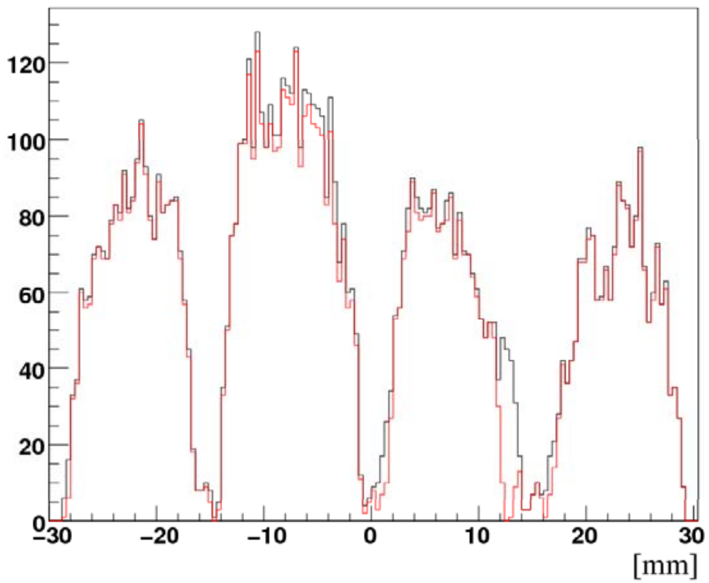


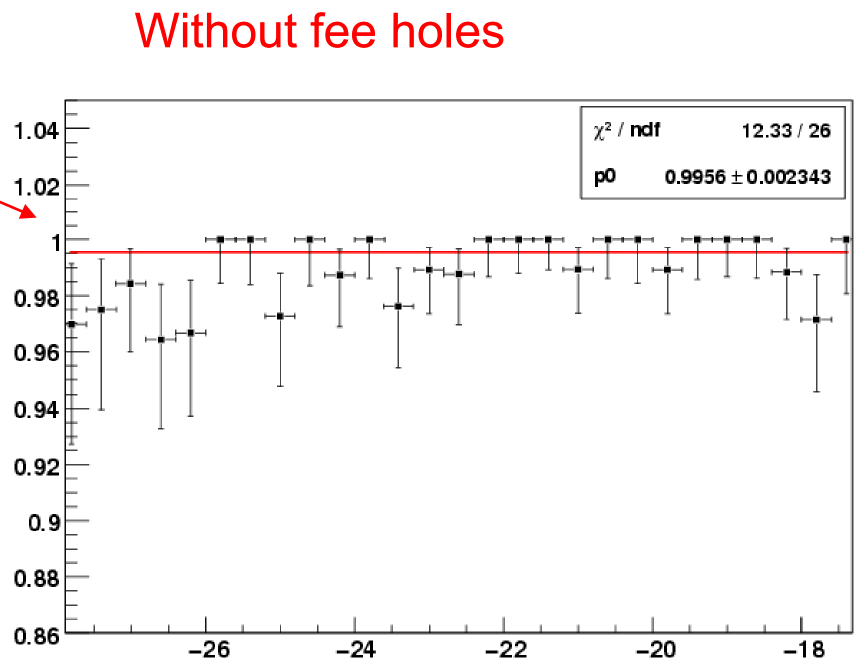
$\sigma(\text{global})^2 = \sigma(\text{GEM})^2 + \sigma(\text{tracker})^2$

$\sigma(\text{GEM})^2 = 250_{\mu m}{}^2 - 140_{\mu m}{}^2 \sim 200_{\mu m}{}^2$
(compatibile with <pitch>/$\sqrt{12}$)

Efficiency in standard GEM zone

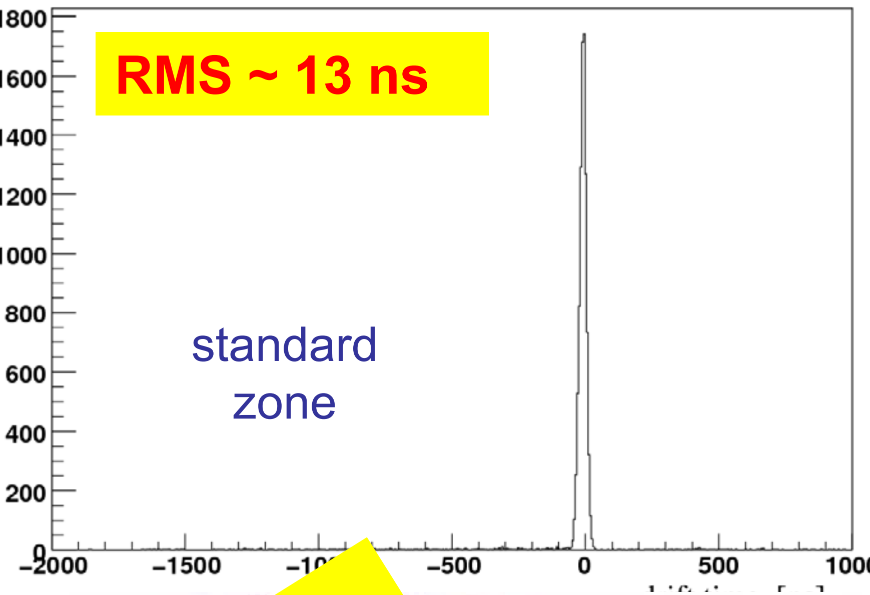






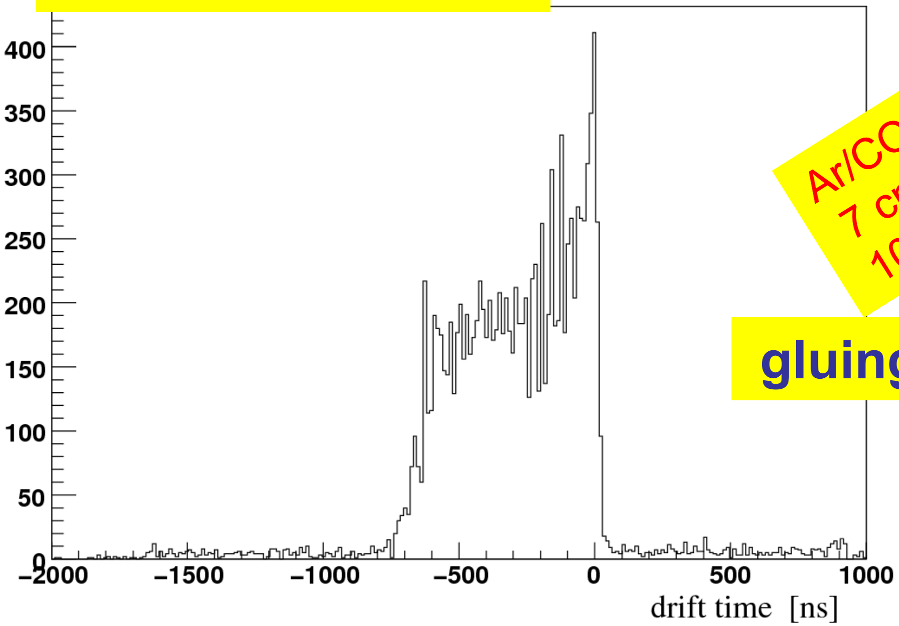
CGEM time spectra

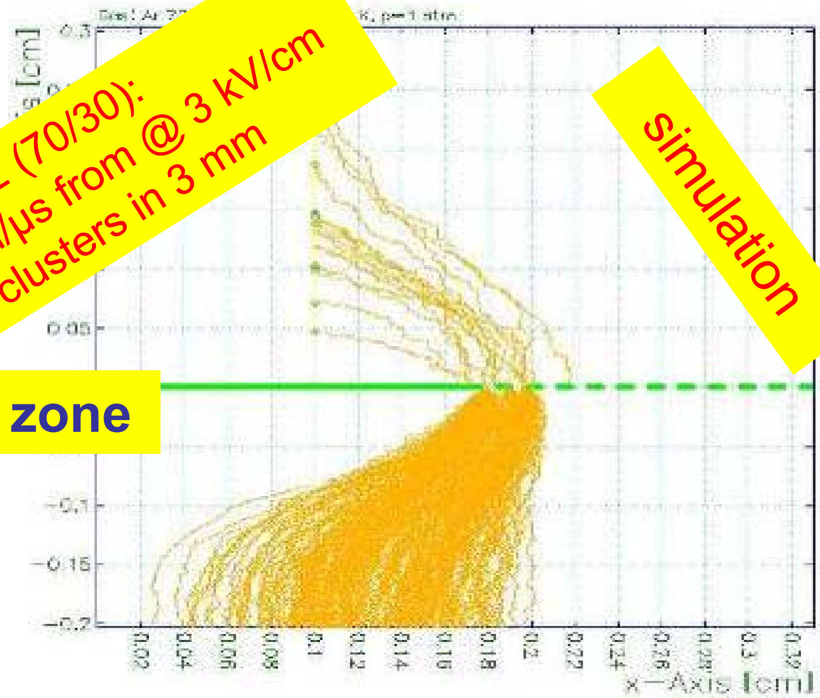
Time spectra with Ar/CO_2 = 30/70 gas mixture, obtained with CARIOCA-GEM



RMS ~ 200 ns

Tmax ~ 750 ns





What we learnt from Proto0.1

Validated (or almost validated) items/procedures:

- planar gluing: OK
- construction technique of cylindrical electrodes and construction materials: OK
- gluing region (<3 mm wide): OK (final measurement needed !!!)
- cylindrical insertion system: OK
- mechanical stretching: no high mechanical tension seems to be required for detector operation (but final detector length ~ 700 mm !!!); encouraging/interesting results from ANSYS simulation: ~ 5 μm sag for 10 kg of overall stretching load;
- gas mixture Ar/CO_2=70/30: <u>require small adjustment</u> (probably too slow with respect to the electronics: a 0.8 μs tail has been observed around the gluing region …)

Non validated items:

- HV distribution on GEM sectors: we have to recover the modularity of the detector. A short circuit MUST be "masked" disconnecting a very small part of the detector (~1.5 cm x L)
  → NEW GEM DESIGN + HV distribution needed (about 180÷200 HV chs per layer !!!) + HV connectors + cabling + …
- FEE-strip connection: for P0.1 we used the ZIF connectors, but we would like to change it with soldering connector

- CLEAN ROOM : we had too many shorts in the detector:
  ≥ 11 shorts (5% area) in ~ 1.2 m^2 of GEM foils (to be compared with)
  0 shorts in ~ 4.5 m^2 of GEM foils for LHCb

Open problems

Large-GEM: for final detector GEM foil **500x700mm²** wide are needed, while standard technology produce GEM of about **400x400mm²**.

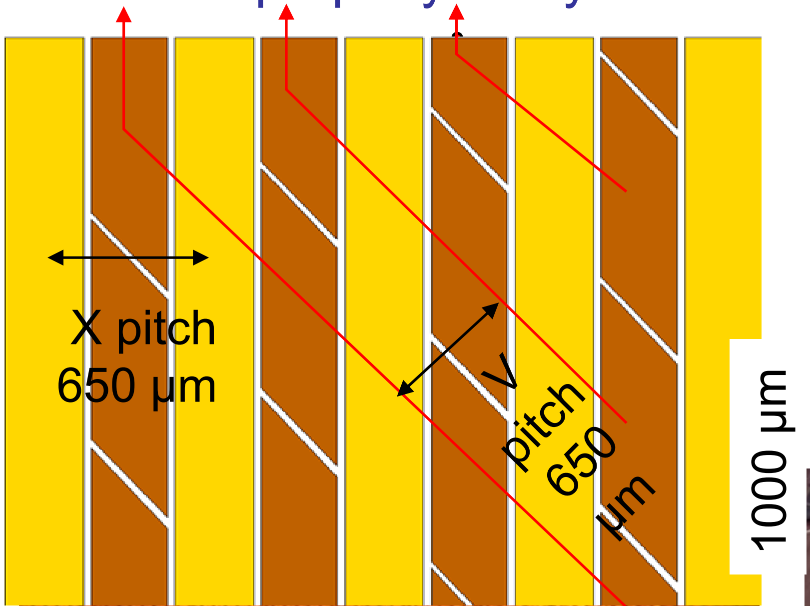
XV-readout: P0.1 has been realized only with X-view; the problems correlated with double XV readout (charge sharing, grounding, cross-talk…) will be studied first with a 100x100mm² proto (step1- next months), then with a full size planar proto (500x700 mm² – step2 → next year)

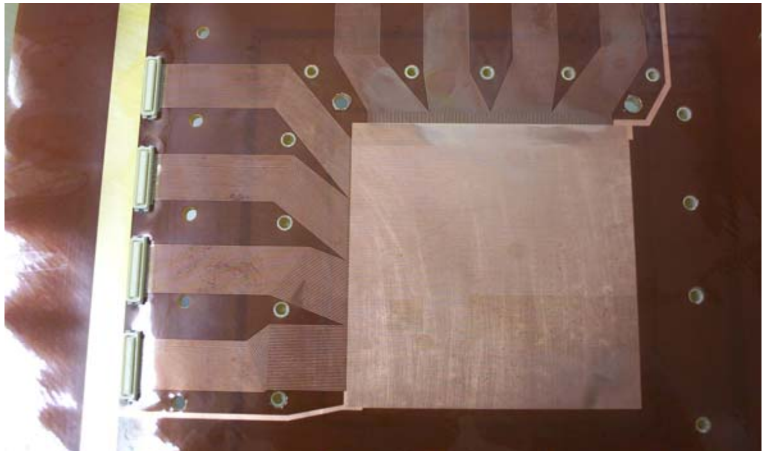
"CF" cylinder: foreseen as a mechanical support of the whole detector and in particular of the readout electrode.
Each "CF cylinder" is realized as a sandwich of 2x200μm CF slides interleaved by ~5mm NOMEX honeycomb (0.16% X_0 per CF cylinder, 0.8% X_0 for the whole IT – X_0(CF)=250 mm)

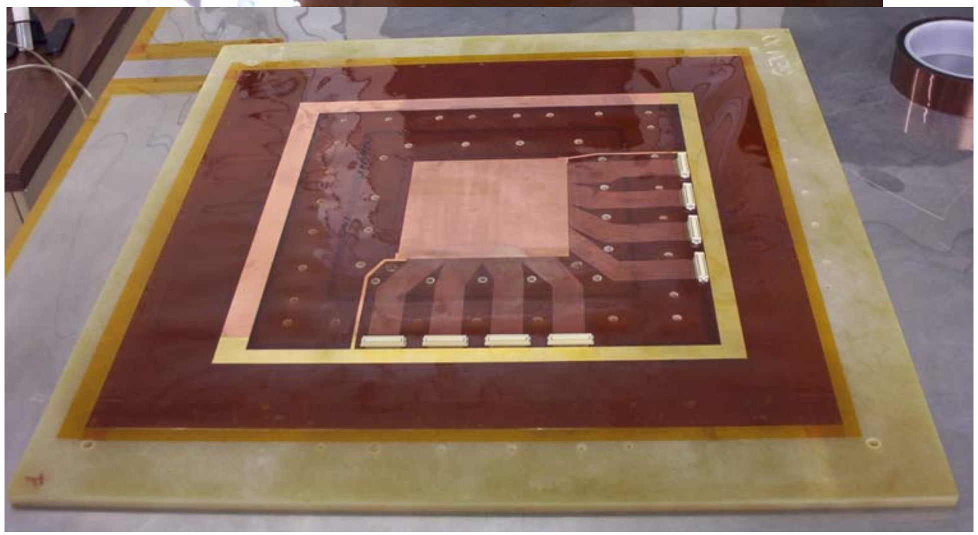
XV Readout Studies

- Readout circuit with XV strips engraved on a single Kapton substrate

- The readout prototype will be mounted on dedicated 10x10cm^2 GEM detectors to properly study and finalize the readout of the IT





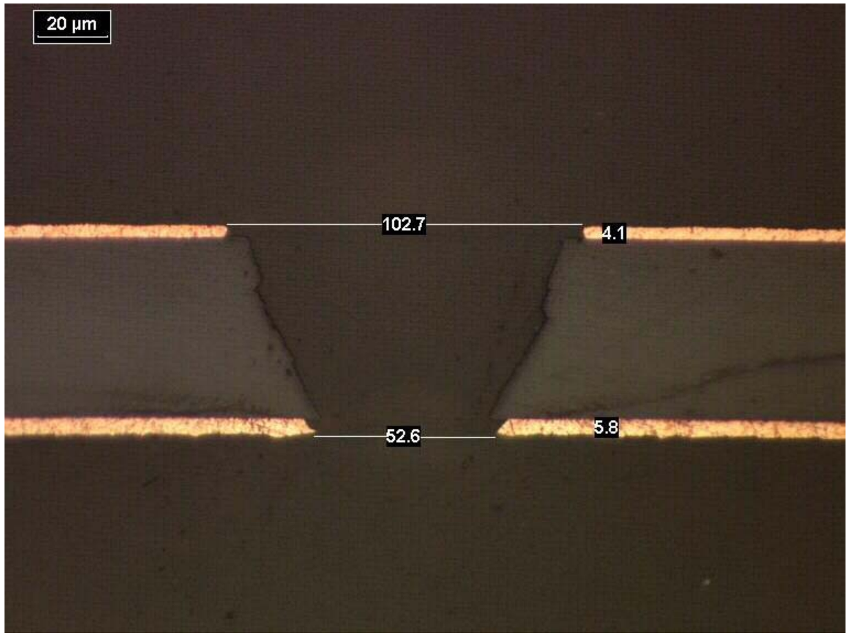


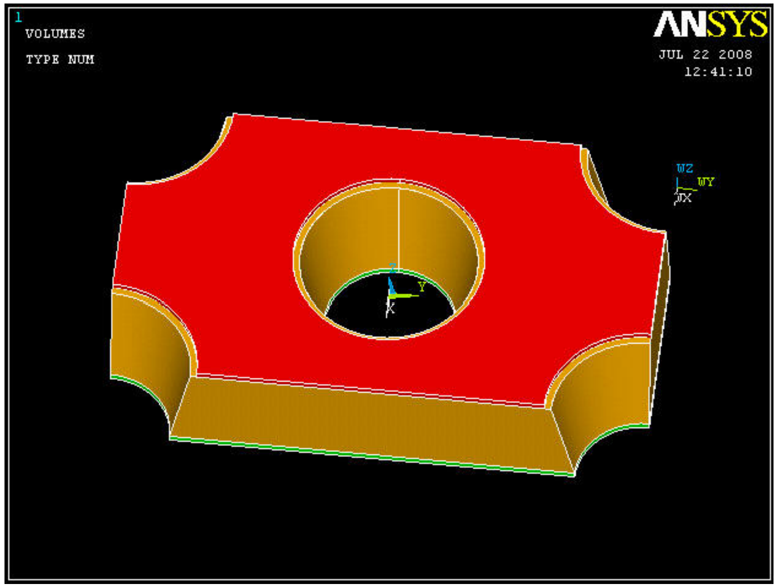
Detector simulation

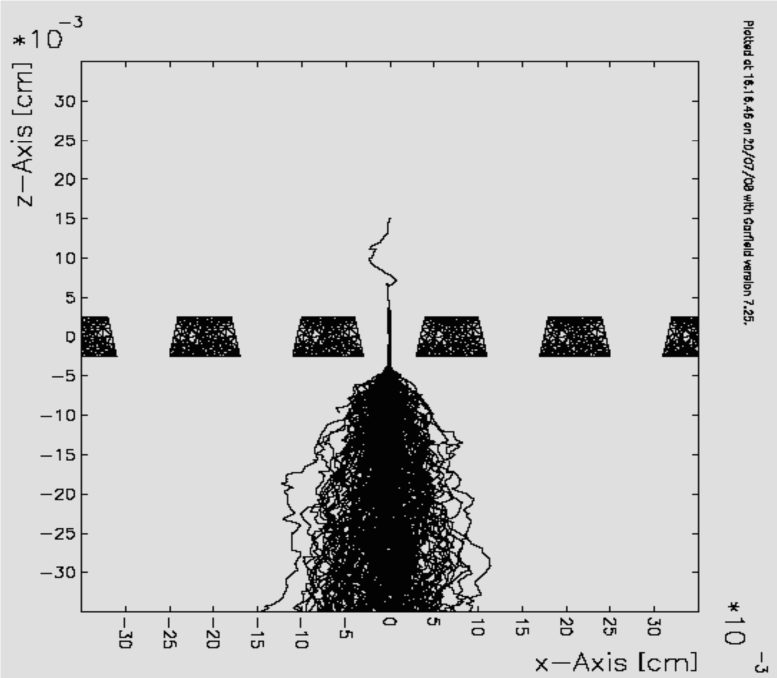
A simulation of single gluing region (3 mm wide) with the standard bi-conical hole structure, 70-50-70 μm, on a substrate Cu-Kapton-Cu, 5-50-5 μm , with standard Ar/CO_2 gas mixture (without magnetic field) has been performed.

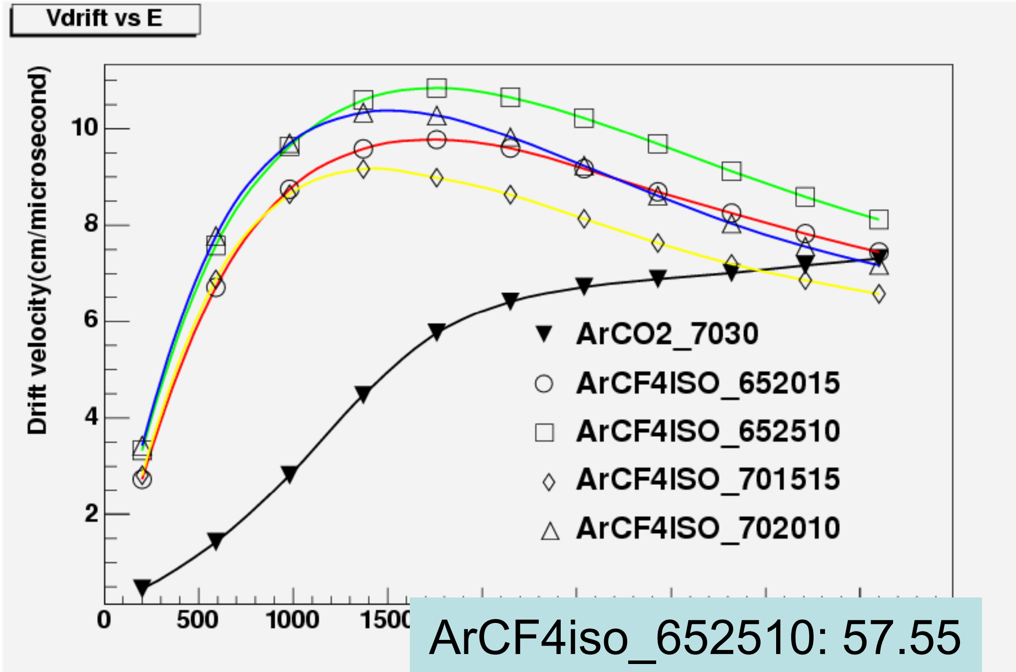
We need a complete simulation of the detector:

- new GEM geometry for large GEM (CERN R&D): conical 100-50 μm on a substrate Cu Kapton-Cu, 2-50-2 μm
- one vs three gluing regions
- magnetic field (especially around the gluing zone)
- new “more fast” and dense gas mixtures (primary ionization & drift velocity)

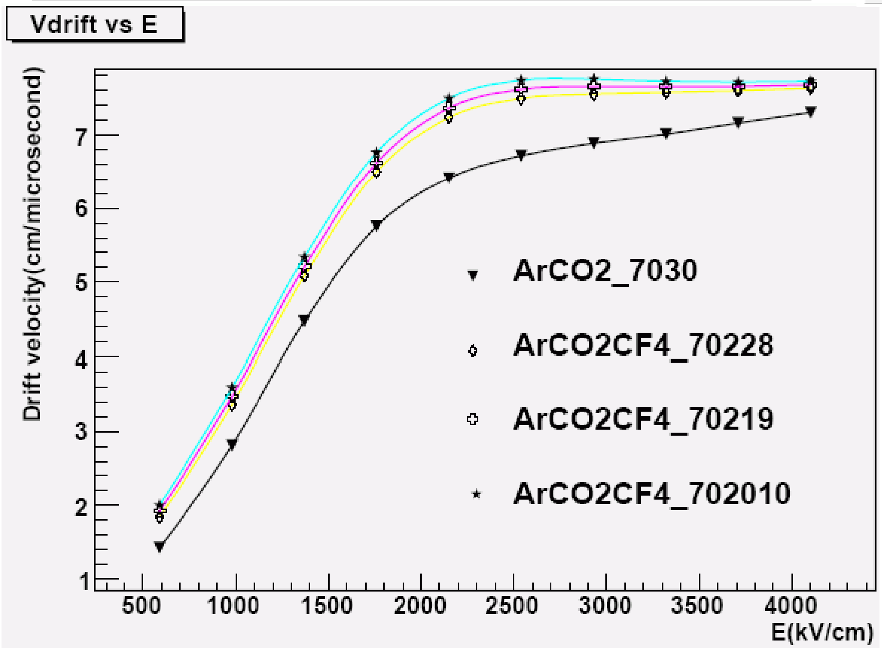








ArCF4iso_652510: 57.55
ArCF4iso_652015: 56.01
ArCF4iso_702010: 55.69
ArCF4iso_701515: 53.57



gas mixture	primary ionization(mean)
ArCO2_7030	38.85
ArCO2CF4_70282	39.61
ArCO2CF4_70255	40.61
ArCO2CF4_70237	41.14
ArCO2CF4_70228	42.15
ArCO2CF4_70219	42.27
ArCO2CF4_702010	42.5

Detector mechanics simulation

We started a finite element simulation (ANSYS) of the static behaviour of the detector mechanics:

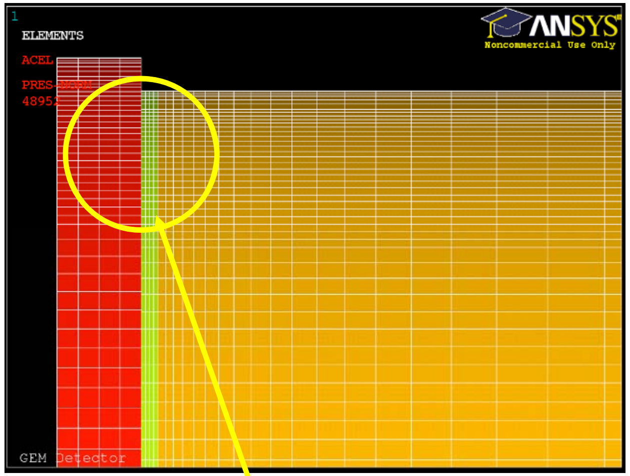
step 0 – measurement of the Young module of the different material + global load behaviour of the proto0.1

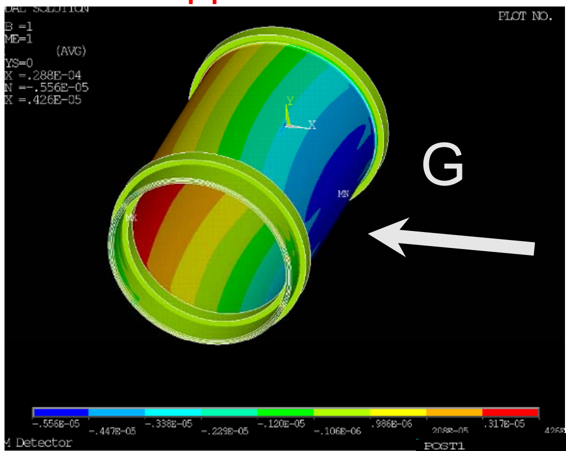
step 1 – simulation of the static behaviour of the proto0.1 (L360) in the linear/non-linear zone, and comparison w/measurements

step 2 – simulation of the static behaviour of the full size CGEM (L700)

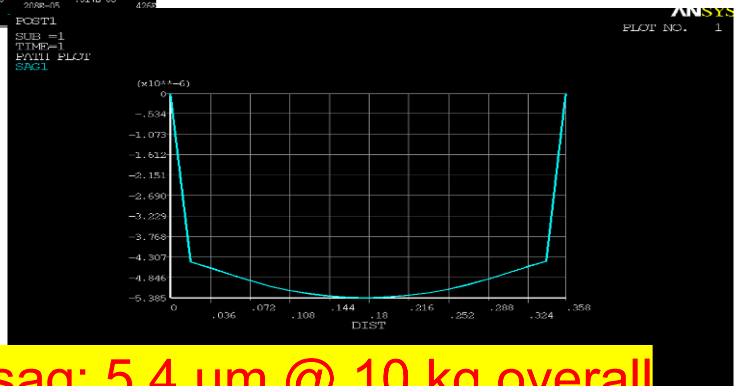
step 3 – introduction of the CF cylindrical support structure

Assembly	ΔL[mm]-calcolato	ΔL[mm]-misurato
100N	0.0287	0.03
300N		0.12
400N		0.15
500N		0.15



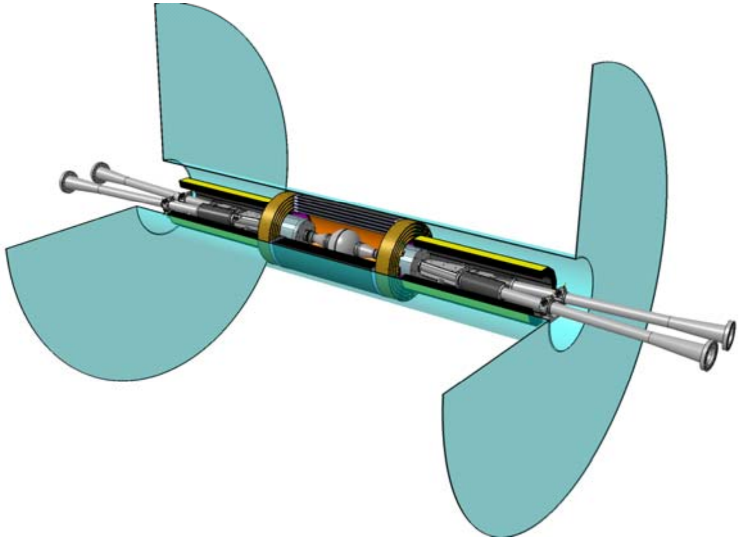


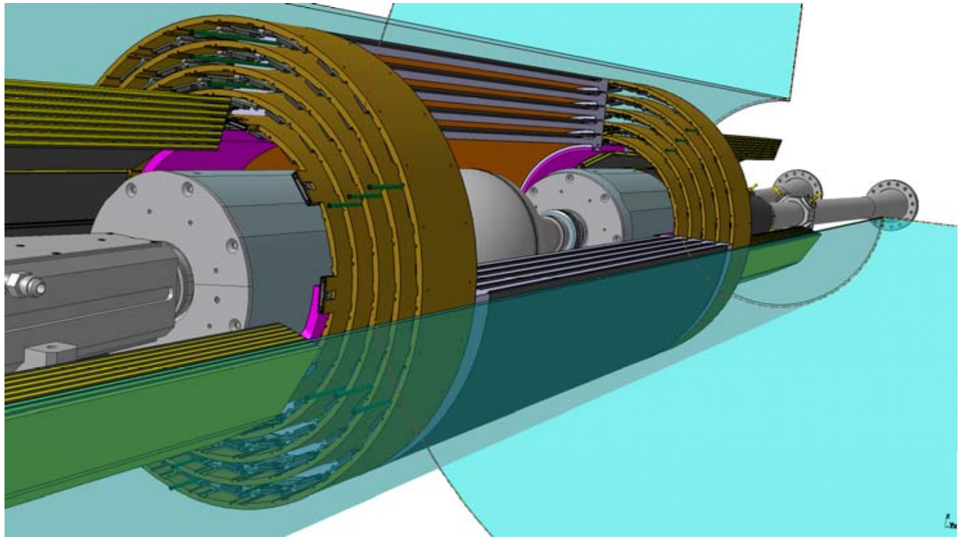
Mesh non uniforme, infittita dove ci si aspetta maggiori gradienti di tensione
(5 mm solo Kapton vicino al permaglass)

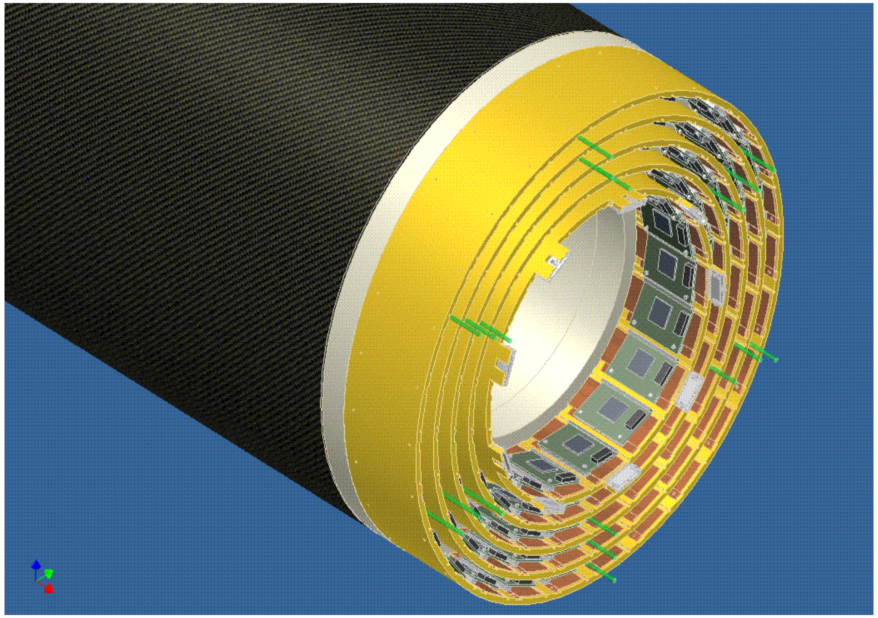


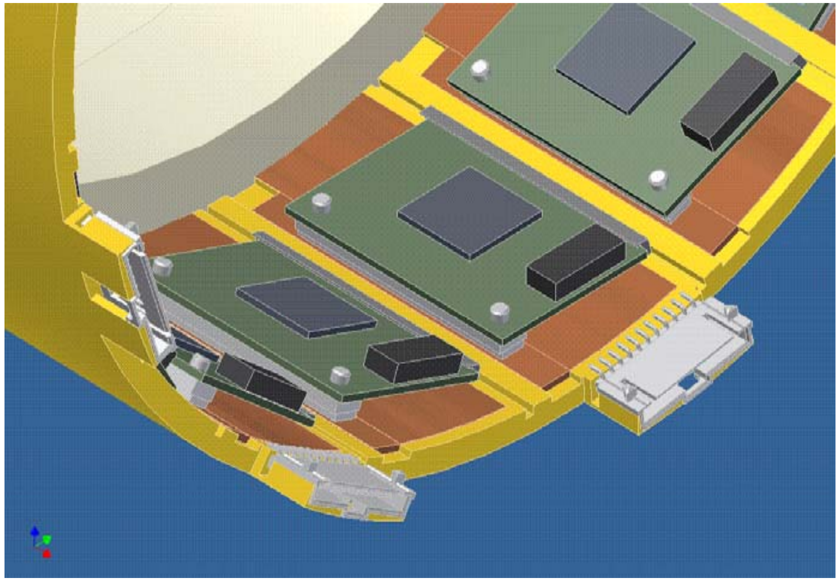
max sag: 5.4 μm @ 10 kg overall

Detector design









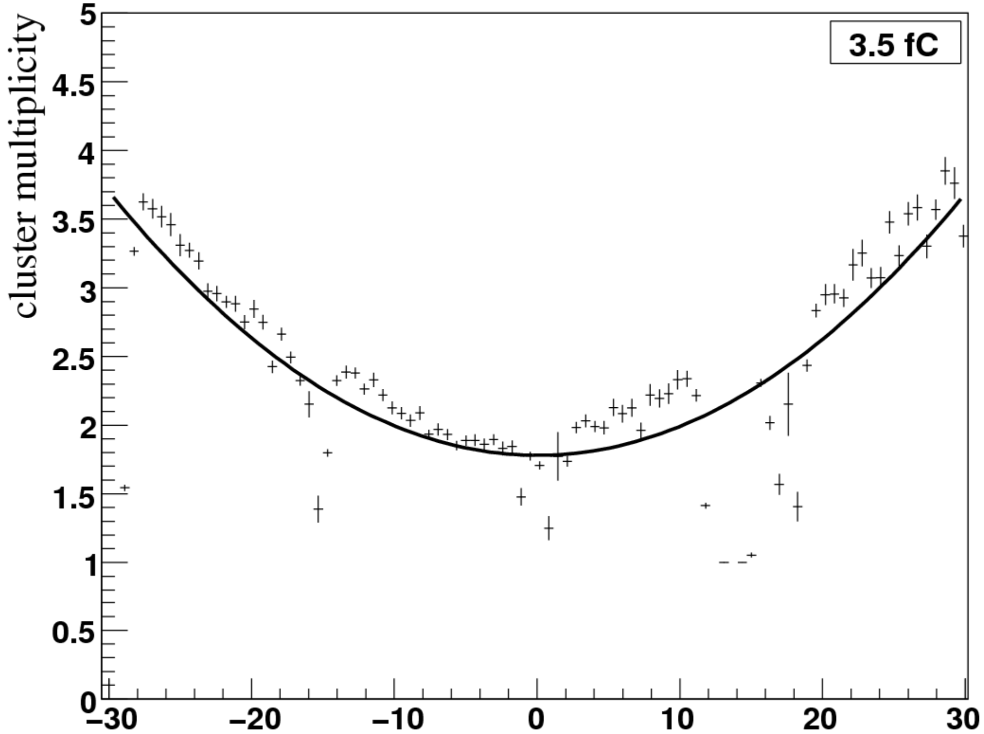
Short/medium term programming

Activity	date	resp.ty
Design & construction of the full size prototype (P0.1)	12/2007	LNF
Tests: X-rays, cosmics & test beam	7/2008	LNF
XV readout study with 100x100 mm^2 planar GEMs	**12/2008**	**LNF/Ba**
Design, construction & test of large size, 300x700mm^2 , single mask GEM	**12/2008**	**LNF**
Stress tests of CF cylinders (0.1% X_0) used as detector supports	**12/2008**	**LNF**
Construction test of a CF cylinder with "embedded" readout anode	**12/2008**	**LNF**
Full detector simulation (operation in magnetic field -0.3 T- included)	**3/2009**	**Cs**
test beam w/B-field of the 100x100mm^2 planar XV-protos at CERN	**6/2009**	**LNF**
Design/construction/test of full size XV readout on planar configuration	**5/2009**	**Ba**
Construction of the front-end mechanical support in composite material	**5/2009**	**Ba**
Global design of the IT detector and construction tools	**7/2009**	**LNF**
TDR	**9/2009**	**LNF/Ba/Cs**

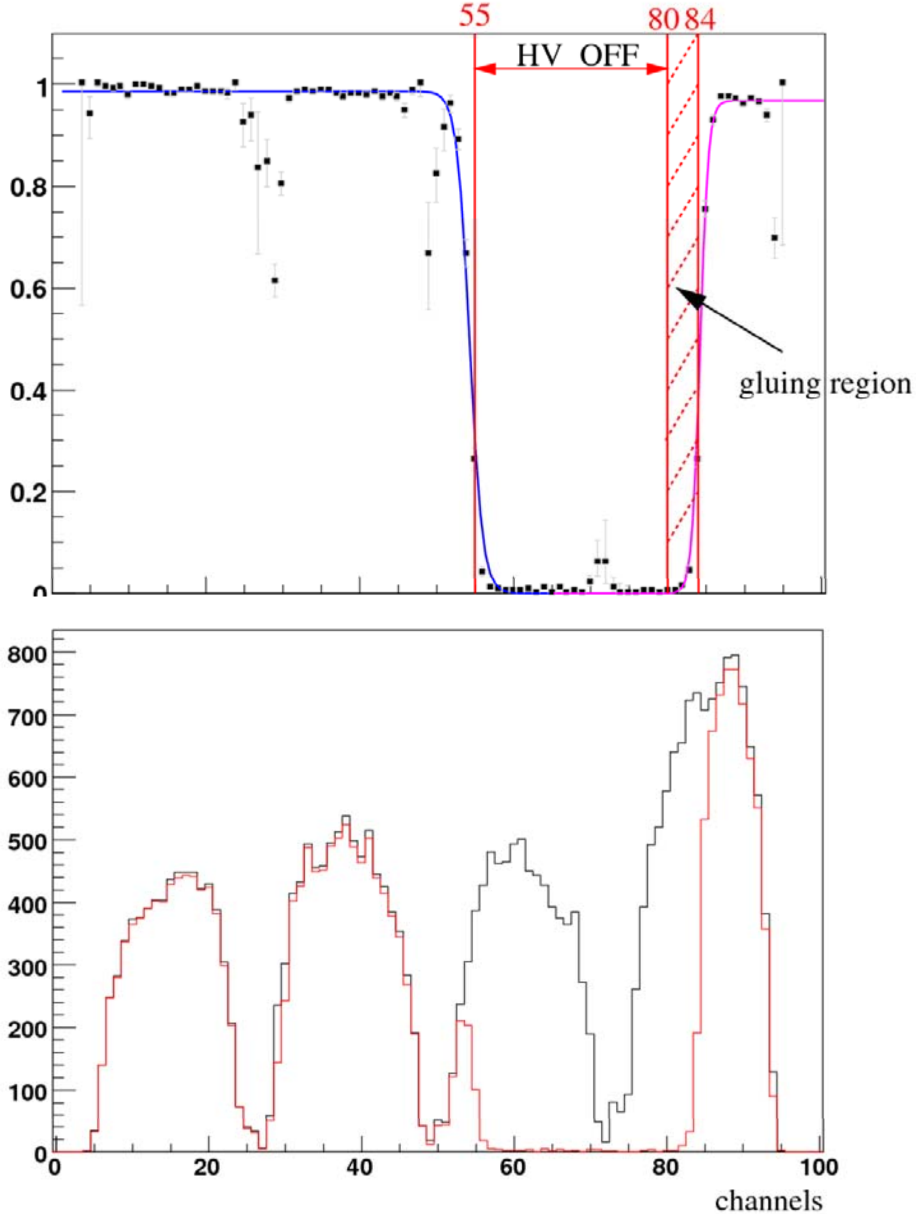
Conclusions

- Proto0.1 demonstrated the feasibility of the **CGEM** and then we **can start the engineering** of a part the detector & construction tools, even though **several crucial R&D** must be still done:
    - **Large-GEM**
    - **XV-readout (step1, now; step2, next year)**
    - **Mechanics tests (CF cylinder, "embedded" anode)**
    - **B-field operation**

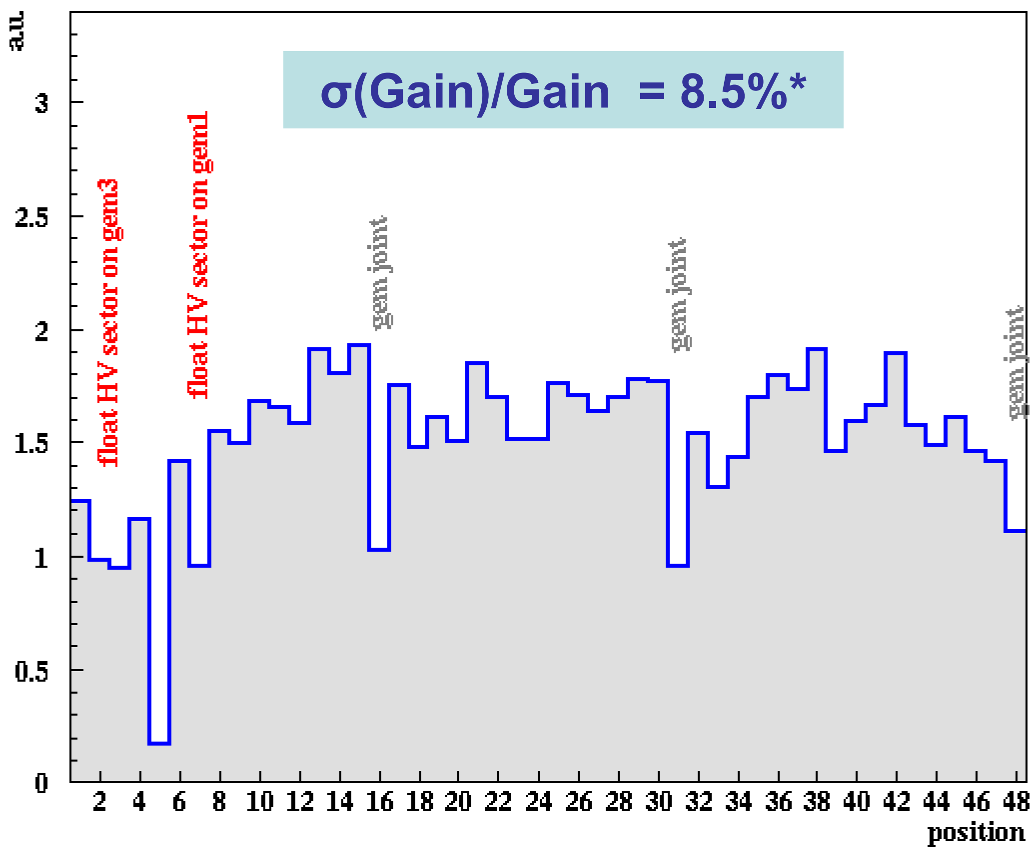
Spares


cluster multiplicity
3.5 fC
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
−30
−20
−10
0
10
20
30

Efficiency in a gluing GEM zone (very preliminary)



CGEM characterization with X-rays



Gain uniformity

* Not considering the following zones:

- *Gem joints:* overlaps of GEM foils cause a decrease of gain
- *HV float sectors:* not polarized GEM sectors due to sc (see next slides)

Each position corresponds to 1/48th of surface (~7.5° ~20 mm)