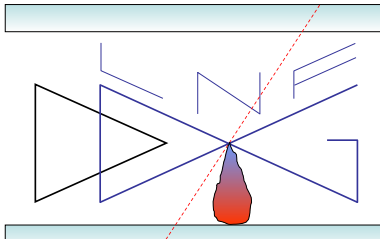


An innovative tracker for precision measurements at KLOE-2

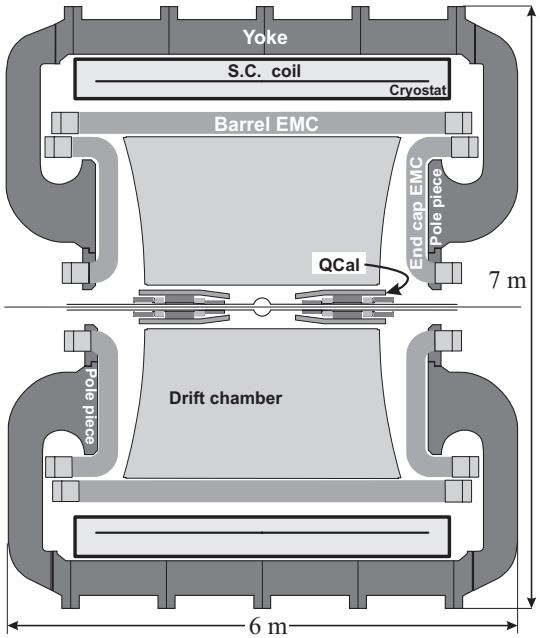
G. Morello for the KLOE-2 collaboration

April 9, 2010

IFAE 2010

2 The KLOE experiment

The KLOE experiment collected an integrated luminosity $\int \mathcal{L}dt \sim 2.5\ fb^{-1}$ at the DAΦNE collider at LNF. It consists of a large volume drift chamber surrounded by an electromagnetic calorimeter and it operates in a magnetic field $B = 0.52\ T$.



The experiment achieved several precision results in

- **Kaon physics**: measurements of all significant branching ratios of K_S, K_L, $K^{\pm}$.
- **Hadron physics**: study of the properties of scalar and pseudoscalar mesons and measurement of the $e^+e^- \longrightarrow \pi^+\pi^-$ cross section giving the main contribution to the error of muon anomaly.

3 KLOE-2

At KLOE-2 enhanced interest on physics from the interaction region:

- $K_S - K_L$ interference
- K_S decays
- η, η' decays
- multi-lepton events

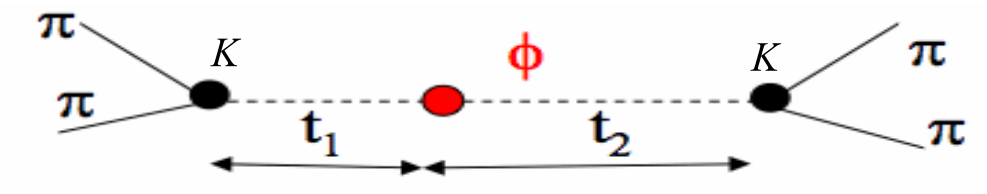
The insertion of the Inner Tracker between beam pipe and DC inner wall will improve detection performance and capabilities close to the IP:

- reducing the track extrapolation length and improving the decay vertex reconstruction capability
- increasing the geometrical acceptance for low momentum tracks, presently limited by the KLOE magnetic field and by the distance of the DC first layer and optimizing their detection
- improving the track momentum resolution

4 KLOE-2

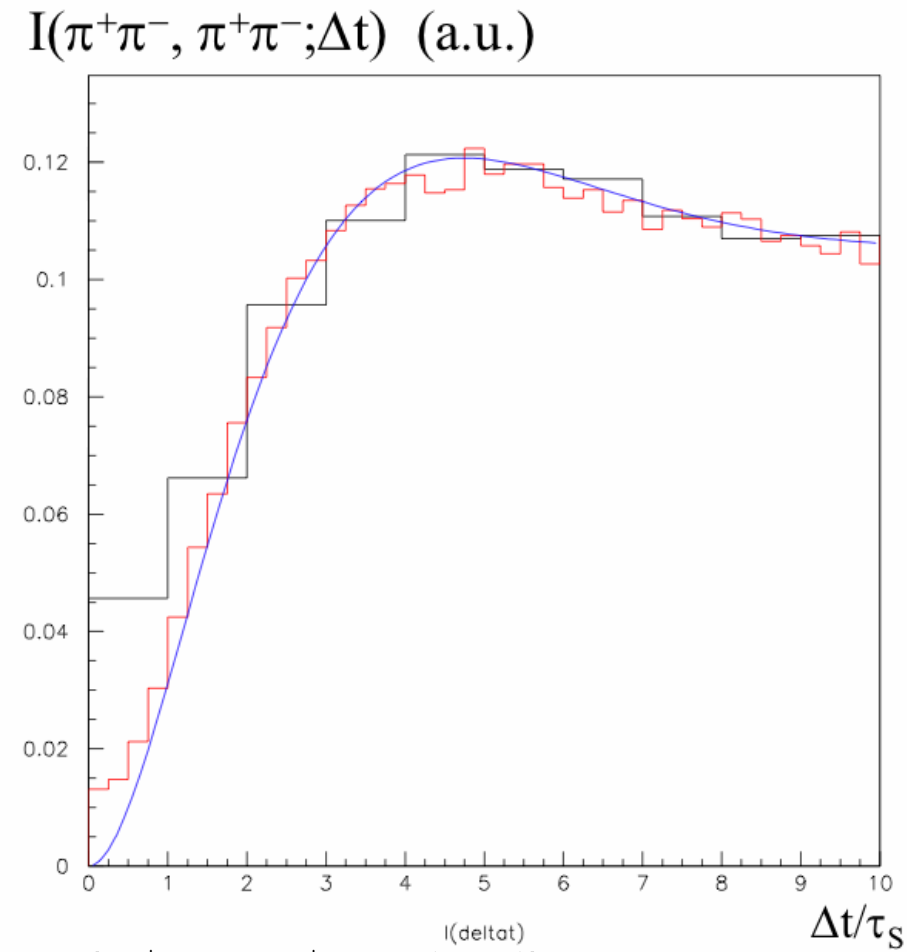
- The most precise measurement of $K_S \rightarrow \pi e \nu$ BR, very important to test CPT symmetry, has been obtained by KLOE. The total uncertainty is $\sim 1.3\%$, having a systematic contribution of 0.7% related to the precision of the distribution of the tracking-related quantities. With a target integrated luminosity of $10 - 20\ fb^{-1}$, the contribution to the total uncertainty is dominated by systematic effects that can be reduced at few per mil level with the IT.
- The internal structure of η meson can be studied by its radiative decays with a virtual photon converting into a lepton pair. The statistical uncertainty on the BR of $\eta \rightarrow \pi^+\pi^- e^+ e^-$ is 3.4% while the systematic one is 2.6%. The IT will improve the detection efficiency for low momentum tracks and the rejection of the background.
- Multi-lepton events could be a signature for a secluded gauge sector weakly coupled with SM. Since these leptons have low momentum, the insertion of the IT will help to fully reconstruct these events.

5 Neutral Kaon Interferometry



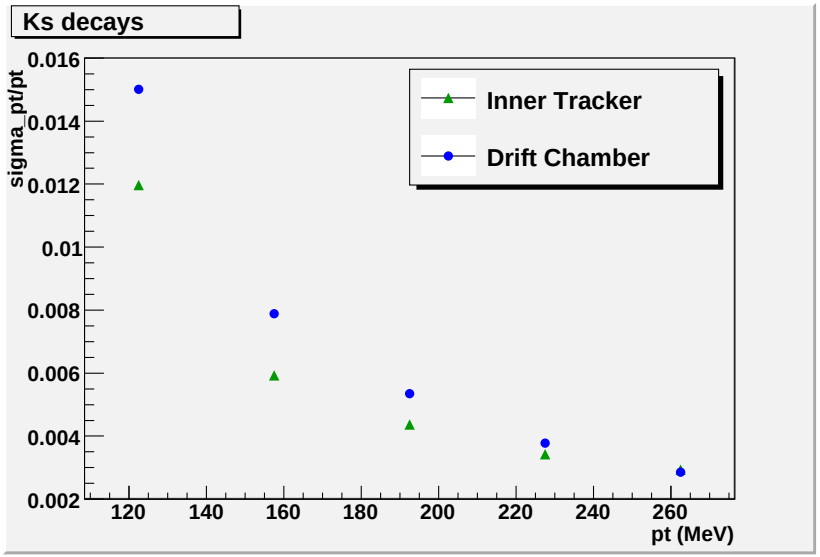
$$\Delta t = |t_1 - t_2|$$
$$I(\pi^+\pi^-, \pi^+\pi^-; \Delta t) \propto$$
$$\left[e^{-\Gamma_L \Delta t} + e^{-\Gamma_S \Delta t} - \right.$$
$$\left. -2(1-\zeta_{SL})e^{-(\Gamma_S+\Gamma_L)\Delta t/2}\cos(\Delta m \Delta t)\right]$$

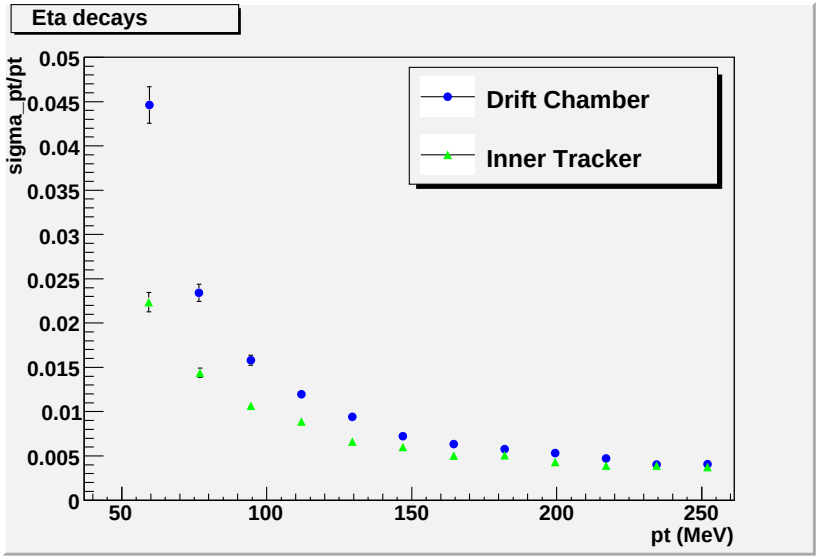
$\zeta_{SL} = 0$ Q.M.
$\zeta_{SL} = 0.003 \pm 0.018 \pm 0.006$
Experimental sensitivity improved by a factor ~ 2 using the Inner Tracker.
A. Di Domenico and KLOE Coll.
J. Phys. Conf. Ser., 171, 012008, **2009**



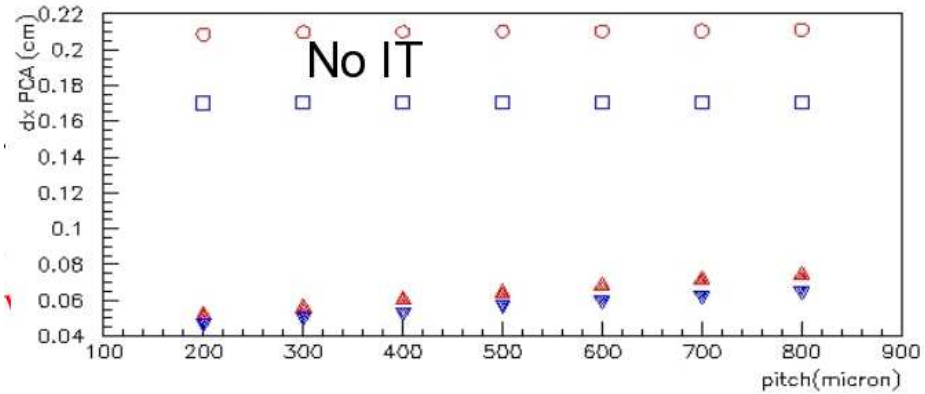
The $I(\pi^+\pi^-, \pi^+\pi^-; |\Delta t|)$ distribution as function of $|\Delta t|$ with the present KLOE resolution $\sigma_{|\Delta t|} \approx \tau_S$ (wide bins), with $\sigma_{|\Delta t|} \sim 0.3\tau_S$ (narrow bins) and the ideal case (blue line).

6 MC Simulation results





Resolution σ_{p_T}/p_T on the transverse momentum measurements as function of p_T for $K_S \longrightarrow \pi^+\pi^-$ (Left) and $\eta \longrightarrow \pi^+\pi^- e^- e^+$ (Right) decays.

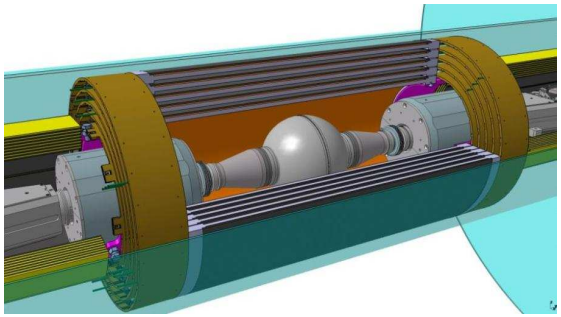


Resolution on the PCA to the decay vertex in the $r-\phi$ plane obtained for reconstructed tracks $K_S \longrightarrow \pi^+\pi^-$ (blue triangles) and $K_S \longrightarrow \pi^+ e^- \nu$ (red triangles).

7 The Inner Tracker

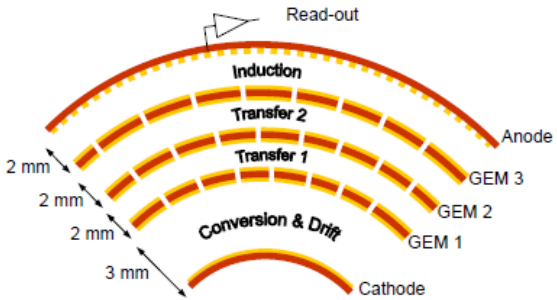
The Inner Tracker must satisfy the following requests:

- $\sigma_{r\phi} \sim 200\ \mu m$ and $\sigma_z \sim 500\ \mu m$
- material budget: $\sim 2\% X_0$
- 5 kHz/cm^2 rate capability



The cylindrical GEM detector is the proposed solution

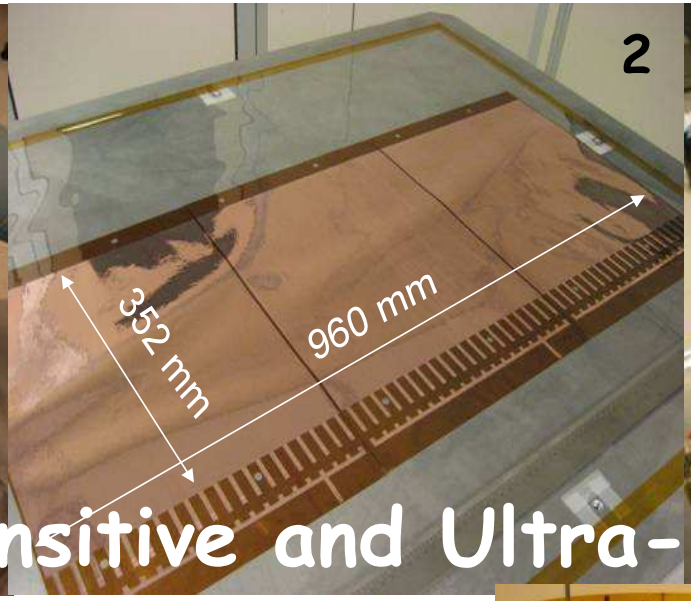
- 5 CGEM layers with radii between 13 *cm* and 23 *cm* (from the beam pipe to inner wall of the Drift Chamber)
- 70 *cm* active length
- *XV* strips-pads readout: the stereo angle is 40°
- 1.5% X_0 total radiation length in the active volume including Carbon fibers support

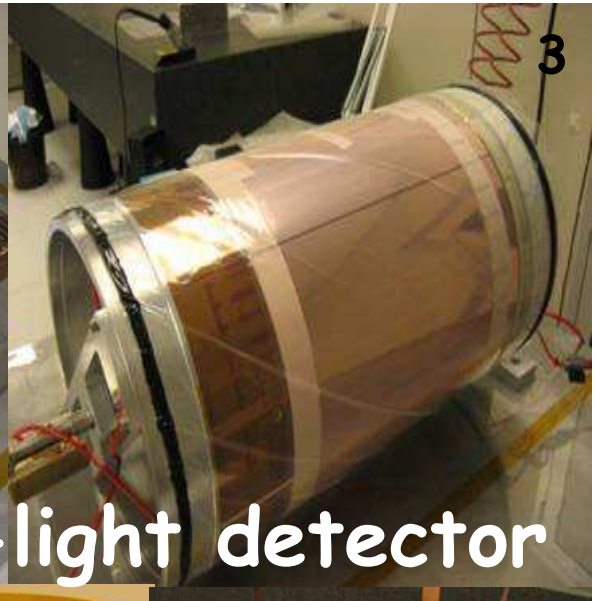


The present vertex resolution (6 *mm*) of the $K_S \to \pi\pi$ will improve of a factor 3

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

8 The Construction of the IT

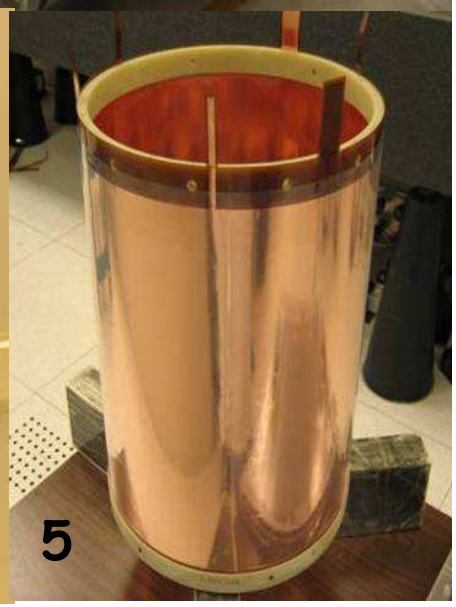




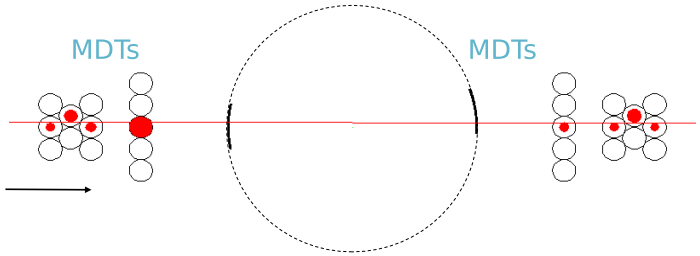
Full sensitive and Ultra-light detector

1. Distribution of epoxy on foil edge
2. 3 spliced foils ~1000mm long
3. Cylindrical mould in vacuum bag
4. Cylindrical GEM foil
5. Cylindrical Cathode with annular fiberglass support flanges

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

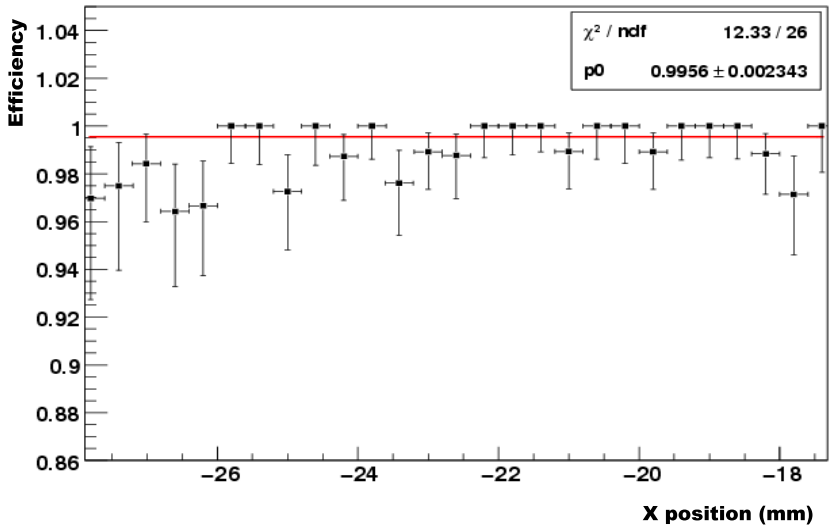


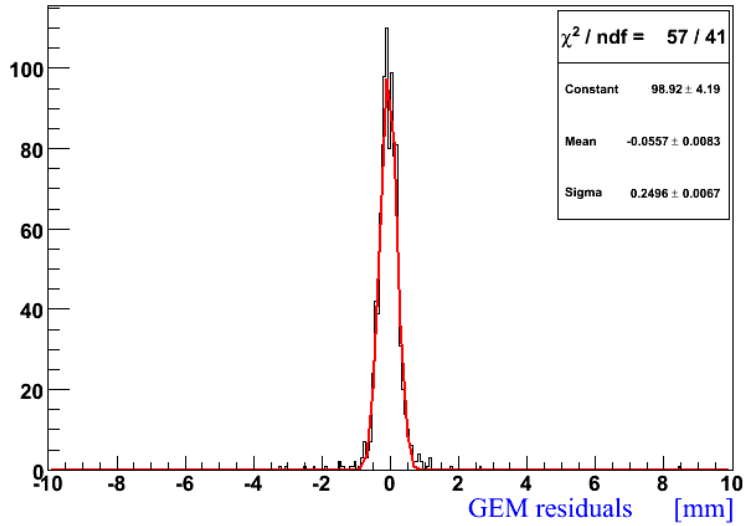
Construction and test of the first CGEM full-size prototype validated the new detector idea. The prototype, equipped with 650 μm pitch longitudinal strips was tested at CERN-PS T9 beam area.



- Gas: Ar:CO_2 70 : 30
- Fields: $1.5/2.5/2.5/4\ kV/cm$
- V_{GEM}:
  $390 - 380 - 370 = 1140\ V$
- FEE: 16-channels GASTONE
- Trigger: 2×8 MDT stations.

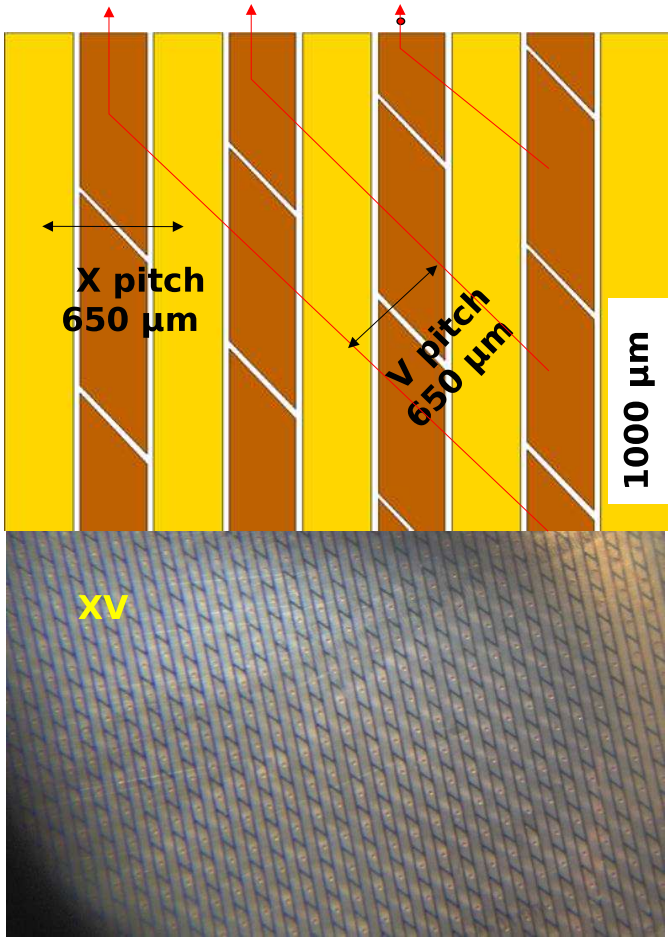
The spatial resolution was $\sigma_{GEM} = \sqrt{(250\ \mu m)^2 - (140\ \mu m)^2} \sim 200\ \mu m$
NSS Conf. Rec. **2009**





10 The final readout

The final detector will be equipped with XV readout. Dedicated planar prototypes were built and tested to check performance of these readout patterns. The readout was tested in magnetic field at H4 area at CERN-SPS beam line.



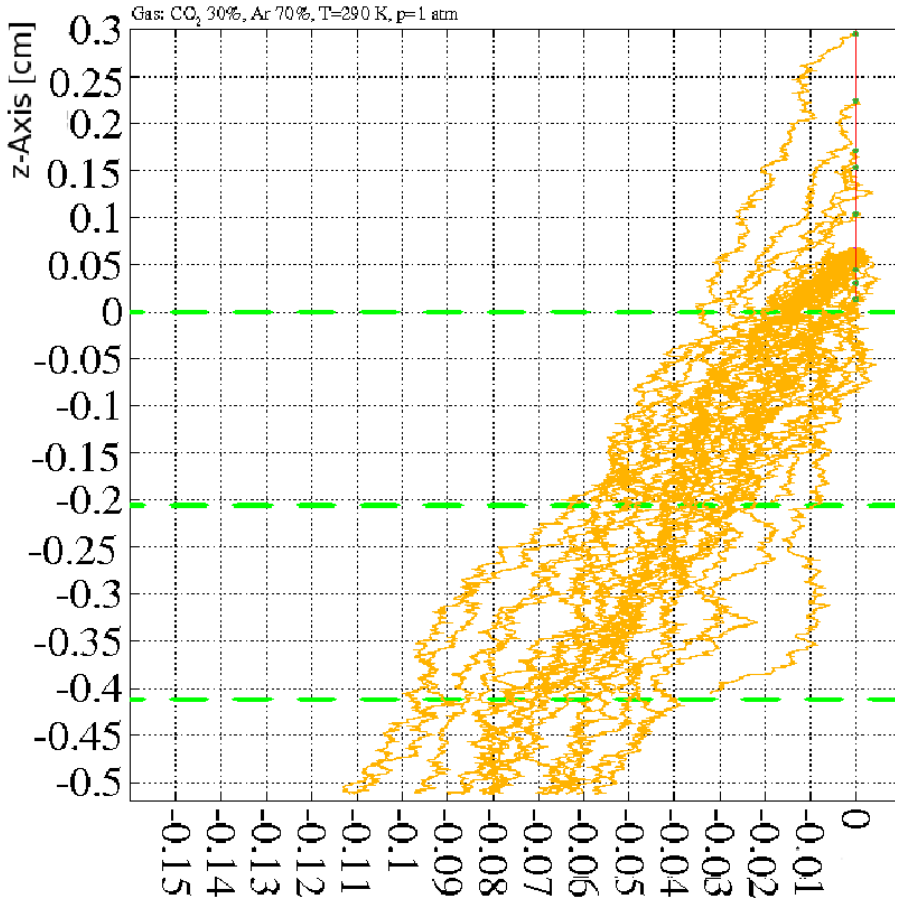
The V view is made of pads connected by internal vias and with a stereo angle of $\sim 40°$. The FEE is provided by GASTONE chips.

Sensitivity (pF)	20 mV/fC
Z_{in}	400 Ω (low frequency)
C_{det}	$1 - 50$ pF
Peaking time	$90 - 200$ $ns(1 - 50$ $pF)$
Noire (erms)	$800e^- + 40e^-/pF$
Channels/chip	64
Readout	LVDS/Serial
Power consum.	≈ 0.6 mA/ch

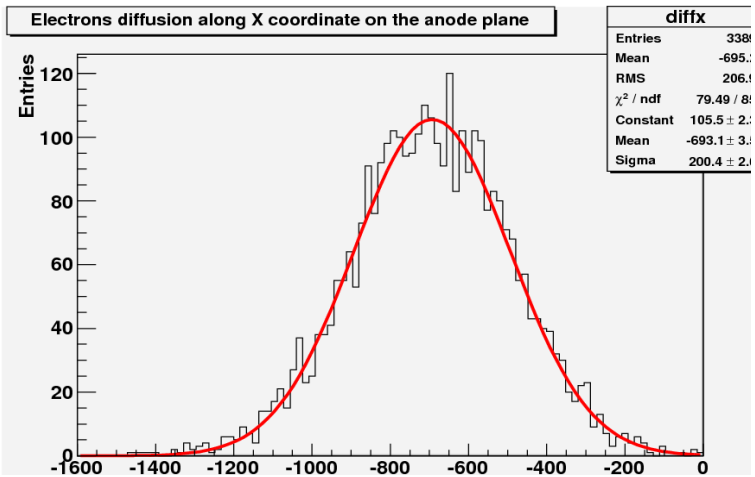
NIMA 604 **2009**

11 Magnetic field effects

The magnetic field affects the drift motion of electrons: they move towards the anode experiencing the Lorentz force. The results are a systematic shift between the actual track and the reconstructed one and a larger spread of electrons.



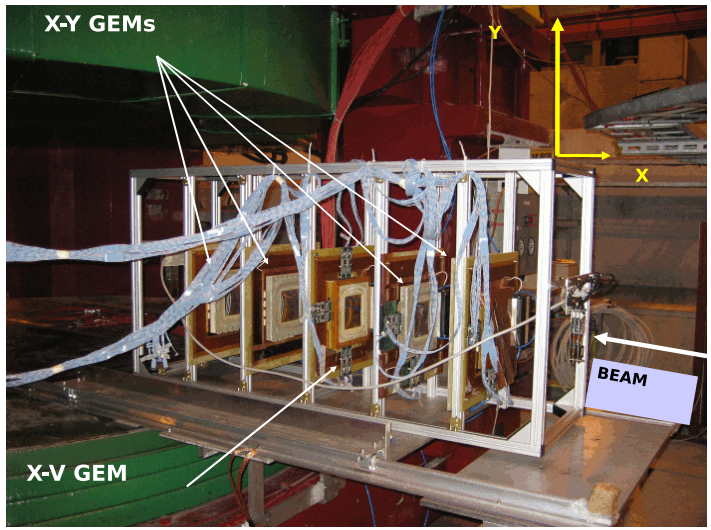
Garfield simulation

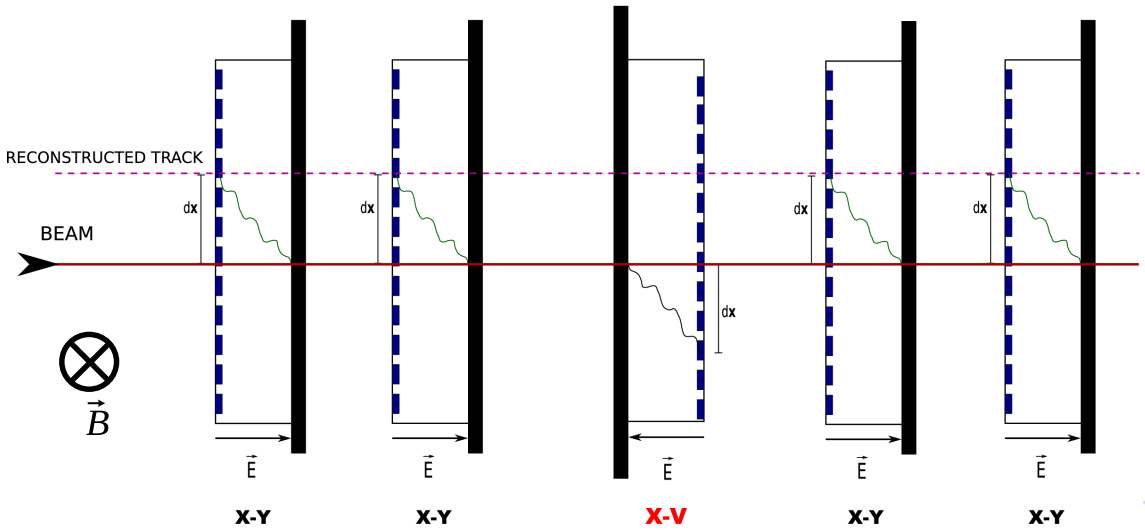


$\Delta x \simeq 700\ \mu m$

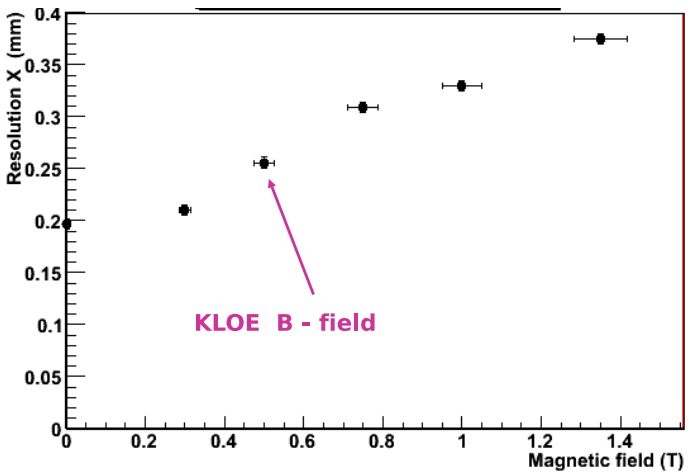
$\sigma_x \simeq 200\ \mu m$

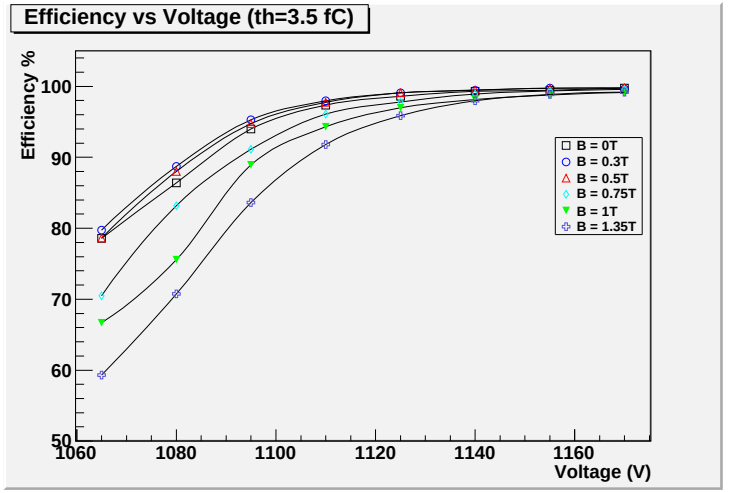
- Goliath Magnetic field up to 1.5 T in $3 \times 3 \times 1$ m^3
- Gas mixture used for GEM: Ar:CO_2 70 : 30
- Fields: $1.5 - 3.0 - 3.0 - 5.0$ kV/cm
- V_{GEM}:$390 - 380 - 370 =$ 1140 V, gain$\sim 2 \cdot 10^4$
- FEE: GEMs partially equipped with 22 GASTONE chips
- Trigger: 6 scintillators with SiPM



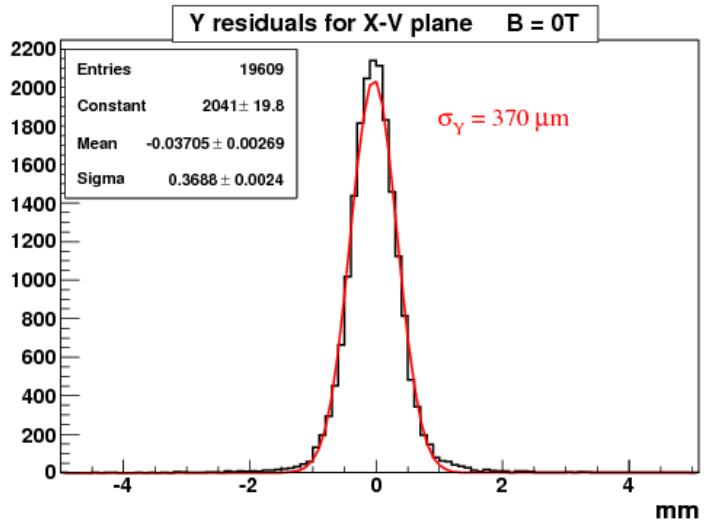


- External trackers: 4 planar GEMs with XY readout (650 μm pitch)

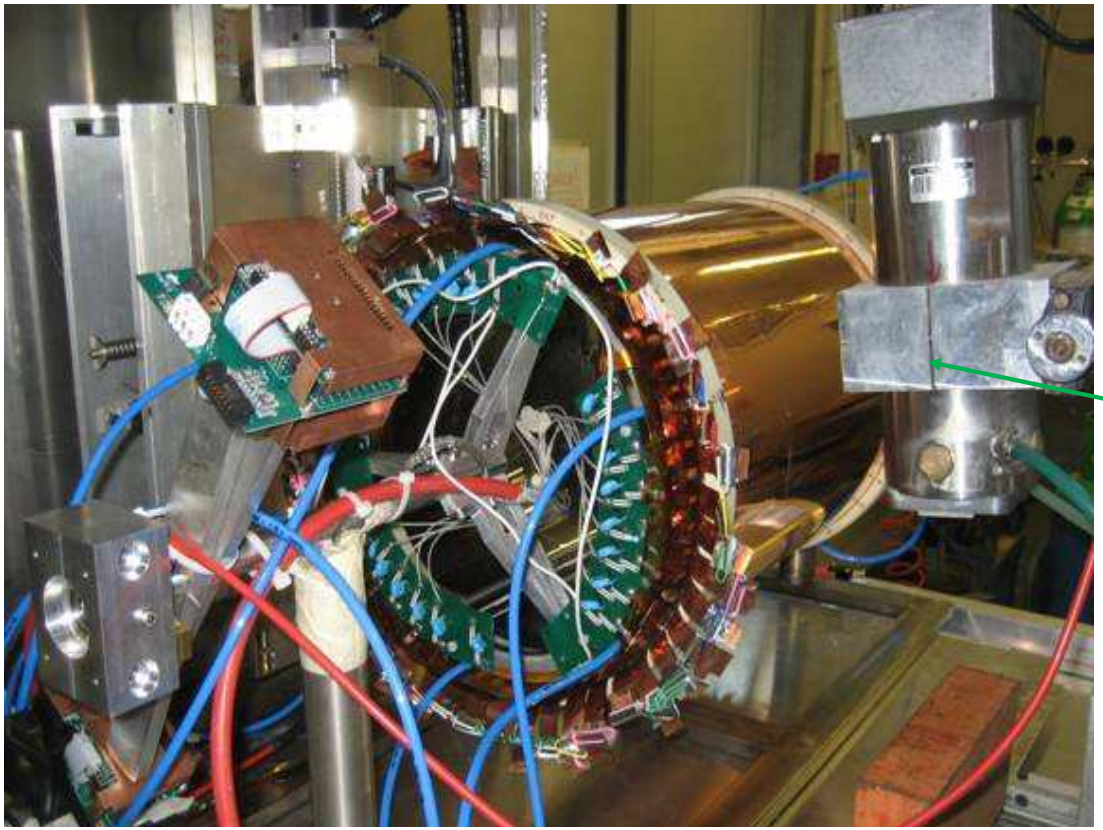




At working point the efficiency drop is negligible for $B < 0.5\ T$. Increasing the magnetic field, efficiency drops. This effect can be reduced setting higher gain even if a higher gain means a bigger cluster size. Measurements showed identical response of both X and V readout views.



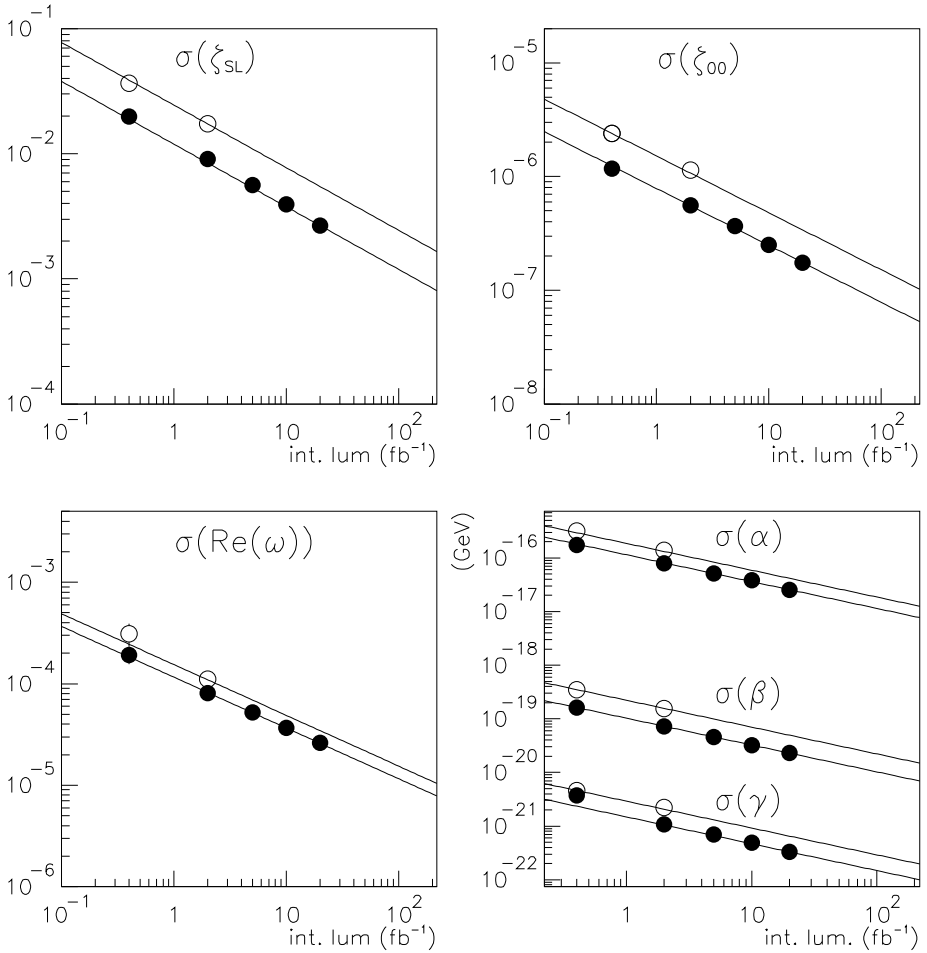
Conclusions



- The CGEM full-size prototype was built and tested
- The final *XV* readout was successfully tested in magnetic field

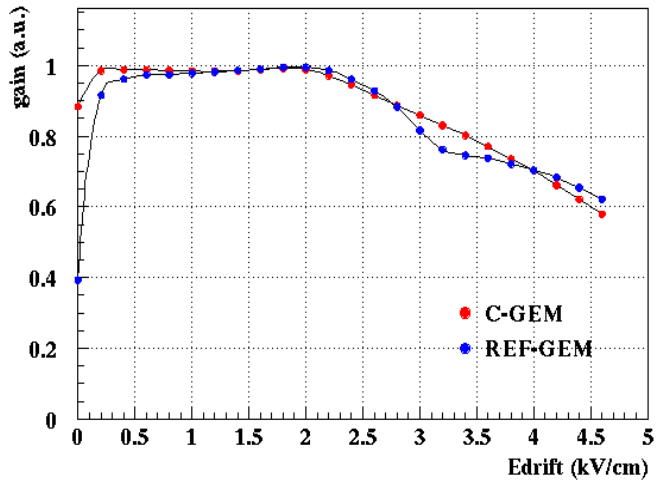
- **The project of the KLOE Inner Tracker has been recently approved and its construction has started**

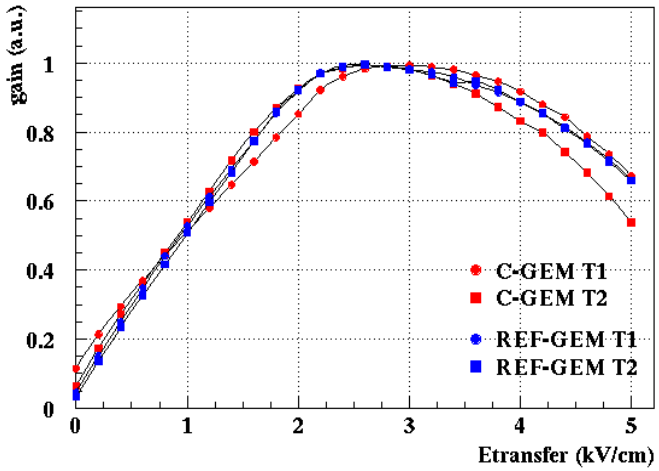
Spare slides

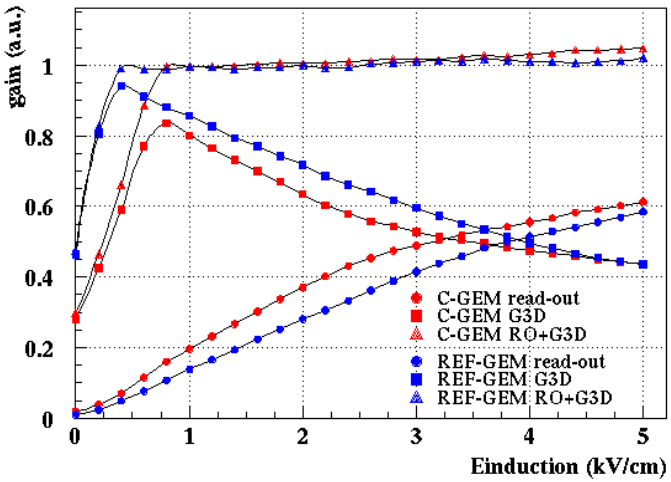


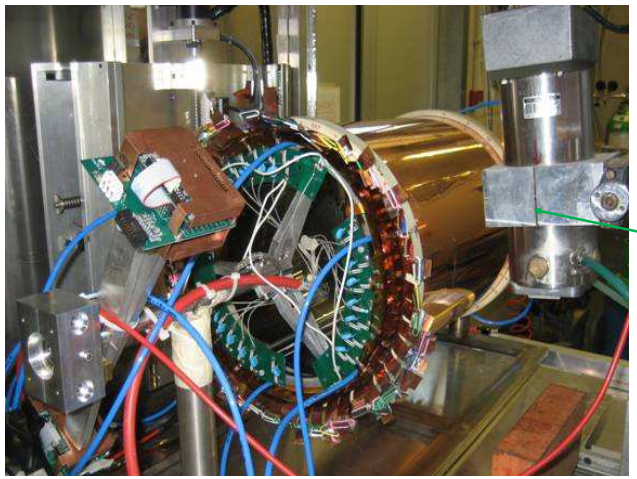
The statistical sensitivity to the parameters ζ_{SL}, $\zeta_{0\bar{0}}$, $\Re\omega$, α, β, γ. The open circles represent the present KLOE resolution, the full circles represent the improved one $\sigma_{|\Delta t|} \sim 0.3\sigma\tau_S$.

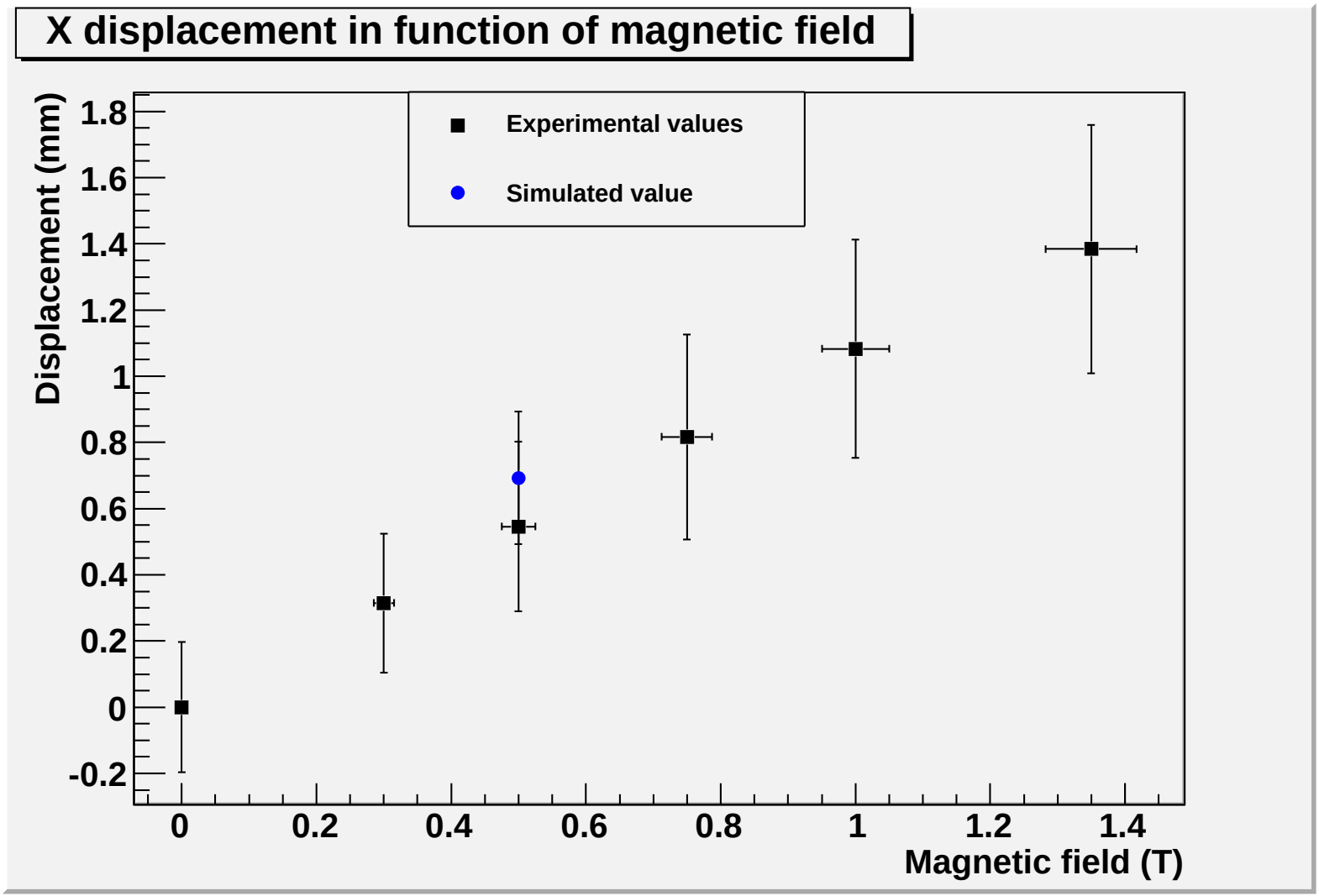
In 2007 an almost full-size prototype was built at LNF. A characterization with X-rays was performed using a planar GEM ($10 \times 10\ cm^2$) as reference. The gas mixture was Ar:CO_2 70 : 30. **No discharges or leakage currents were observed.**










X displacement in function of magnetic field
Experimental values
Simulated value
Displacement (mm)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Magnetic field (T)