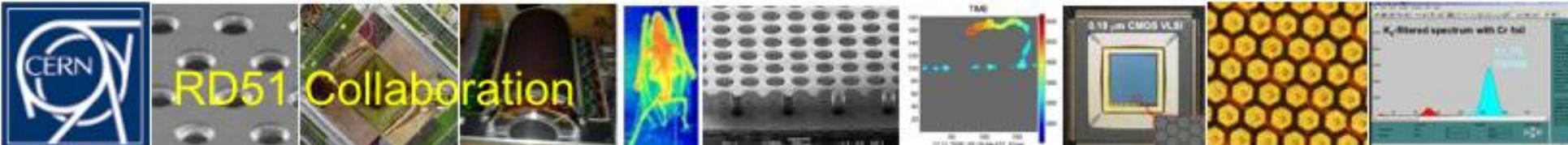


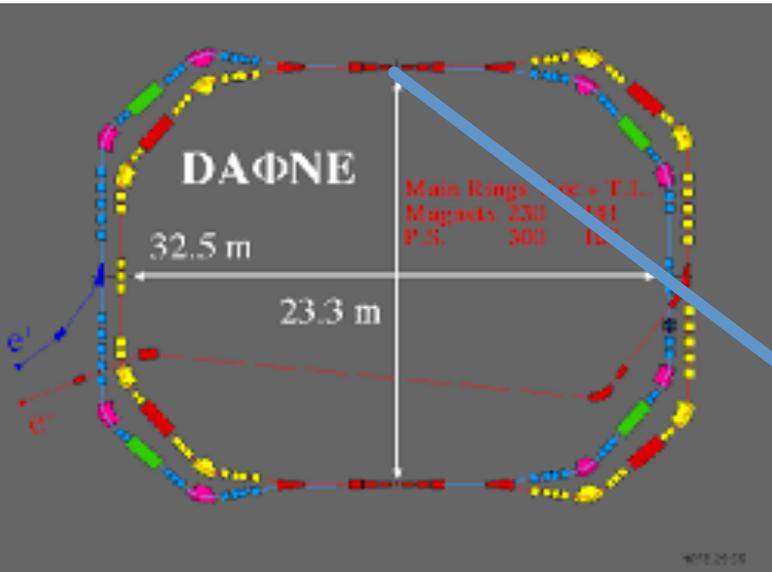
# The KLOE-2 Inner Tracker: detector commissioning and operation

G. Morello on behalf of KLOE-2 Inner Tracker group

14<sup>th</sup> Vienna Conference on Instrumentation  
February 17<sup>th</sup>, 2016

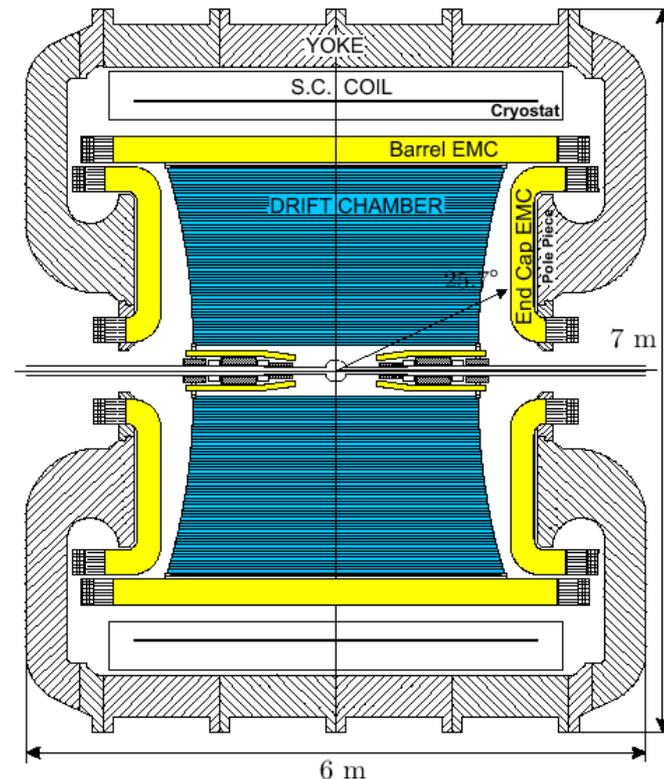


# KLOE @ DAΦNE



- e<sup>+</sup>e<sup>-</sup> collider at Laboratori Nazionali di Frascati
- E<sub>cm</sub> = 1.02 GeV (φ factory)
- $\mathcal{L} \sim 10^{32} \text{ cm}^{-2}\text{s}^{-1}$

- **Huge Drift chamber:**
  - $\sigma(p_t)/p_t = 0.4\%$
  - $\sigma_{r\phi} = 150 \mu\text{m}, \sigma_z = 2 \text{ mm}$
- **EMC:**
  - $\sigma_t = 54 \text{ ps}/\sqrt{E(\text{GeV})} \oplus 100 \text{ ps}$
  - $\sigma_E/E = 5.7\%/\sqrt{E(\text{GeV})}$
  - **98%** solid angle covered
- **0.52T axial magnetic field**



# KLOE-2 @ DAΦNE

## New calorimeters:

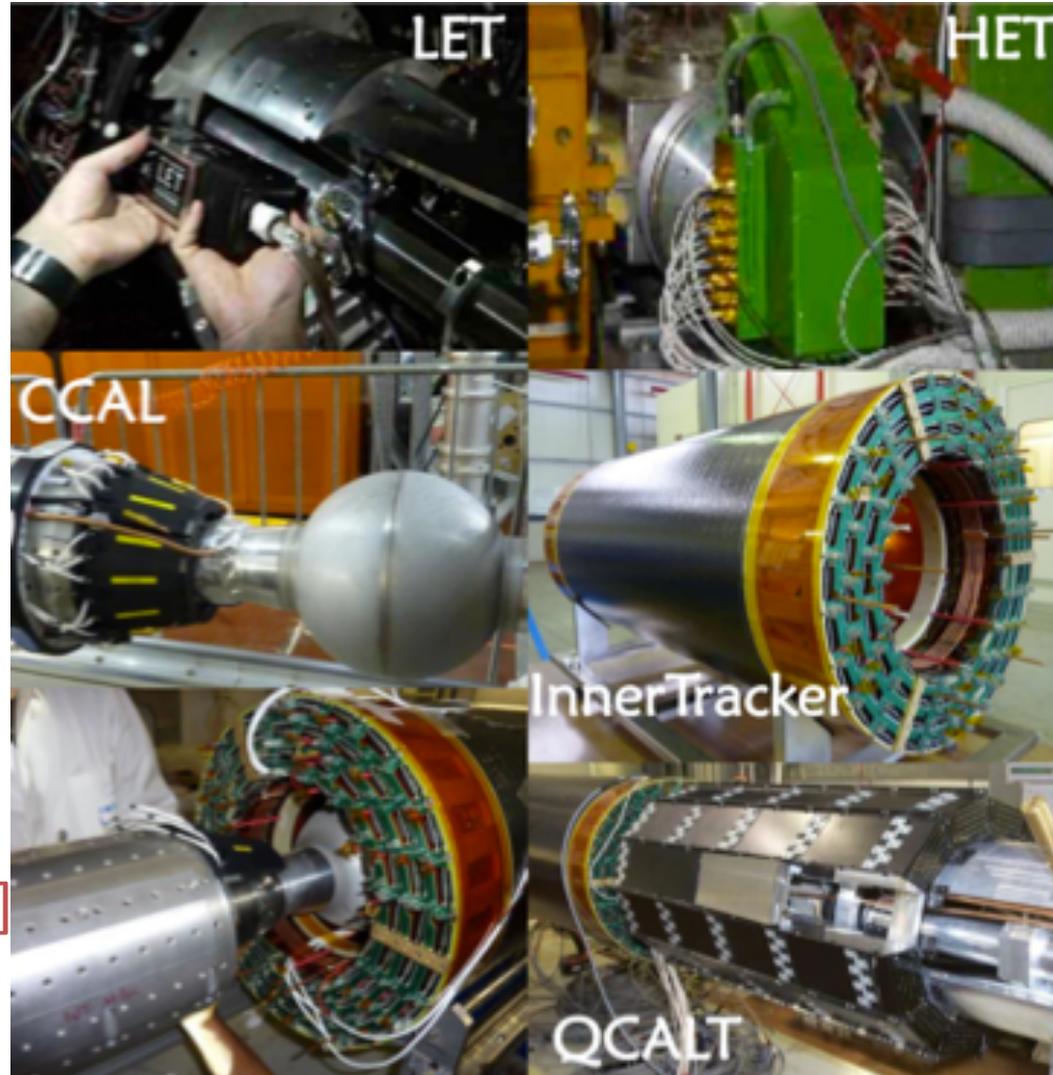
- **LET** – LYSO + SiPM
- **HET** – Scint + PMTs
- **QCALT** – Tungsten + Scintillating Tiles with SiPMs (quadrupole)
- **CCAL** – LYSO + APDs Low- $\beta$  insertions

## New tracker:

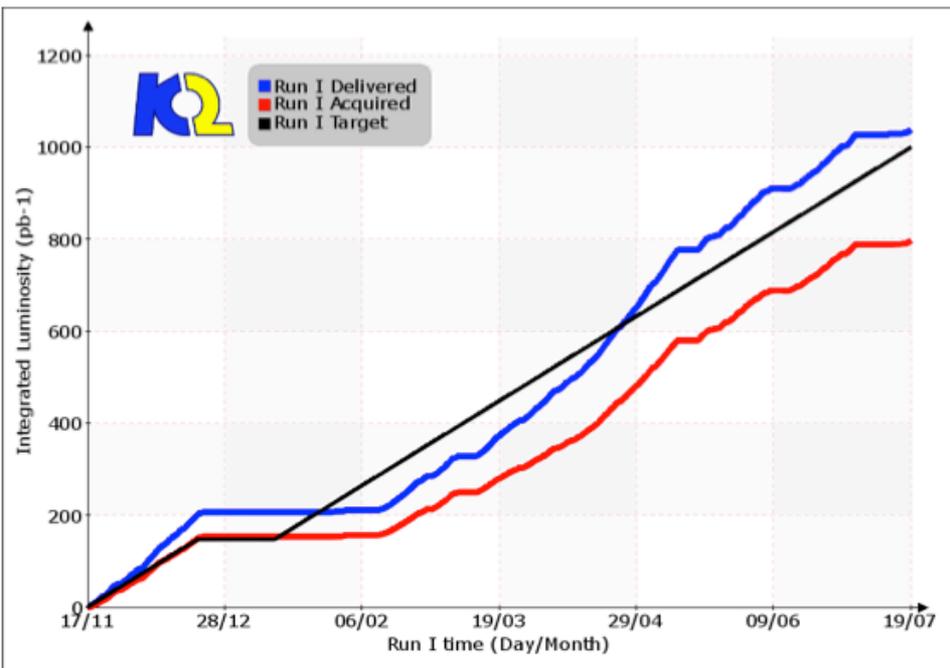
- **Inner Tracker** – 4 CGEM detectors

## Physics Program [EPJ C68 (2010)]

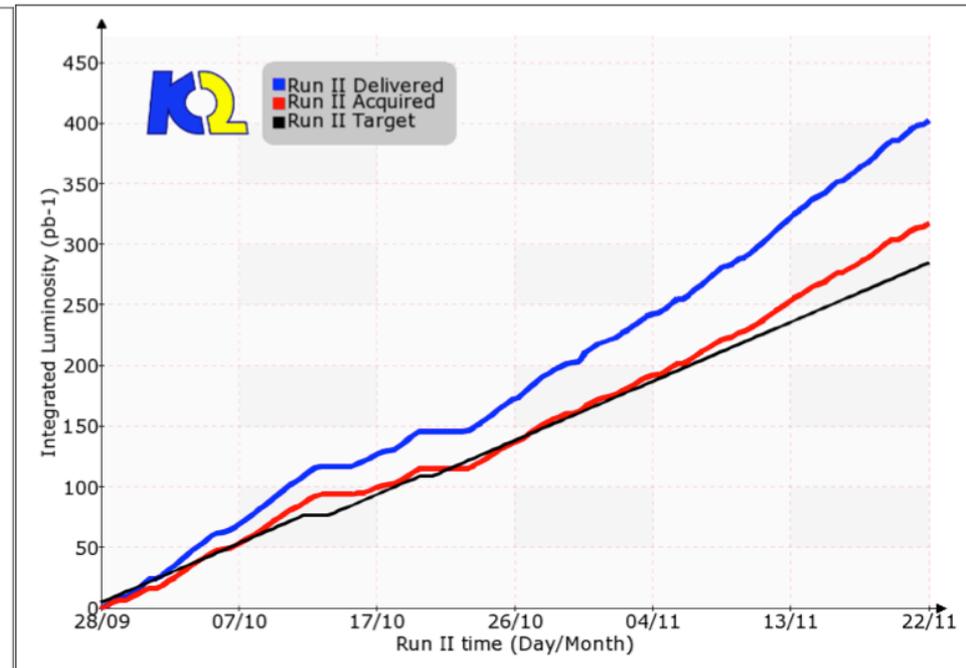
- $K_S$ ,  $\eta$ ,  $\eta_S$  rare decays
- Quantum interferometry
- Dark Photon searches



# KLOE-2 integrated luminosity



KLOE-2 data taking period started on 17 November 2014 and successfully reached the goal of  $1 \text{ fb}^{-1}$  by July 2015 (Run-I)



Run-II started in November 2015 with  $2.5 \text{ fb}^{-1}$  by July 2017 milestone

# The CGEM @ KLOE-2

The Inner Tracker has been inserted to improve the precision on the vertex reconstruction.

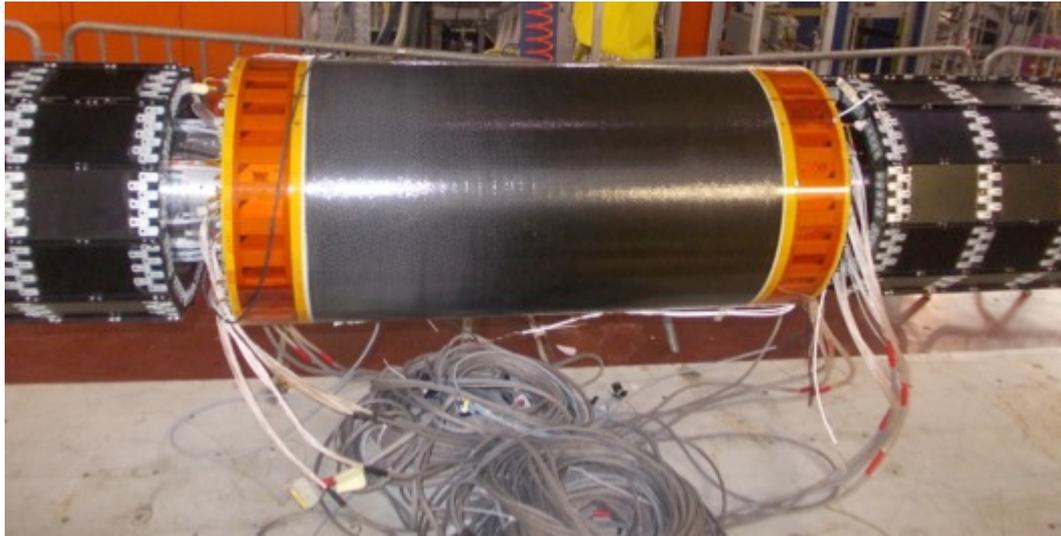
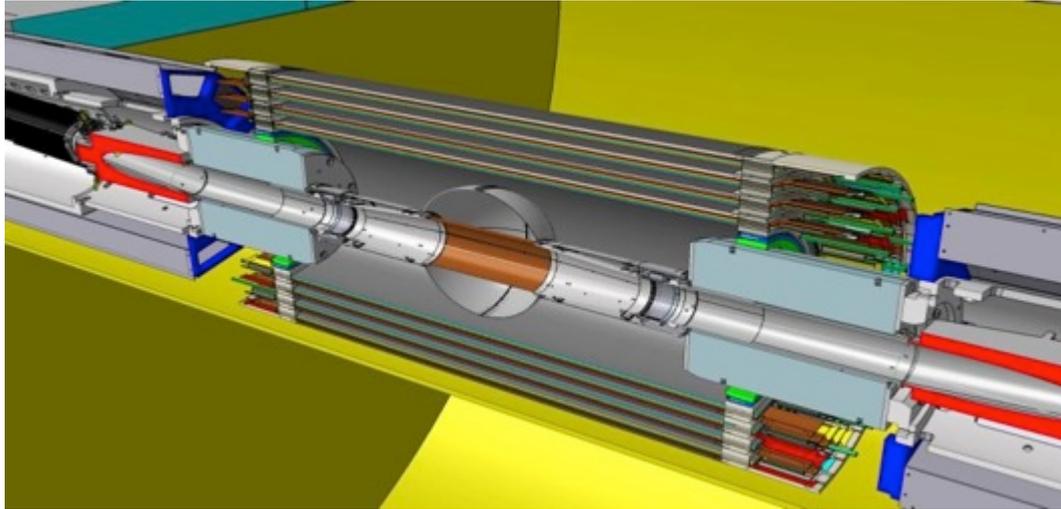
Requirements:

- **200  $\mu\text{m}$**  on r- $\phi$  plane (transverse plane), **500  $\mu\text{m}$**  along the beam line
- **$\sim 2\%$   $X_0$**  radiation length
- **5 kHz/cm<sup>2</sup>** rate capability

The detector:

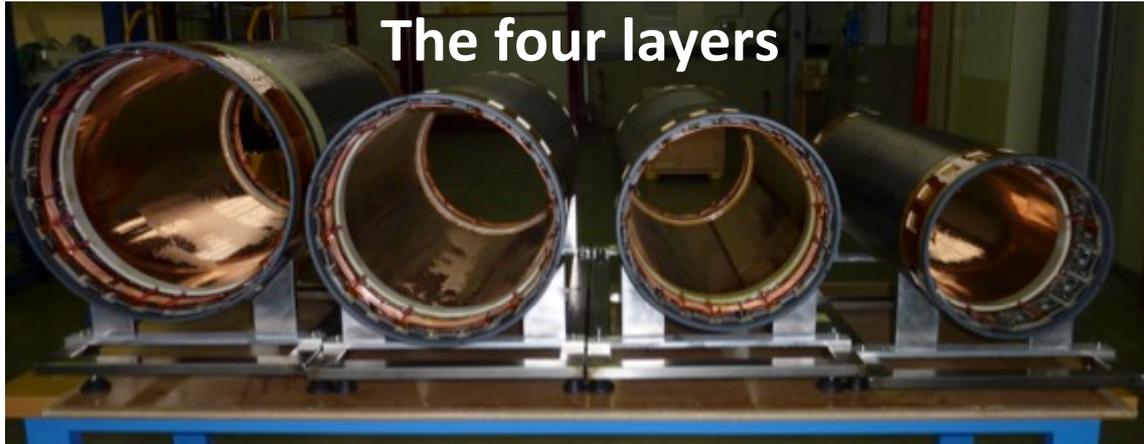
- **4 Cylindrical GEMs** have been realized with radii between **130** and **205 mm**
- Active length: **700 mm** (large GEM foils, single-mask technique)
- **X-V** stereo readout (kapton/Cu flexible multilayer circuit)

# The KLOE-2 Inner Tracker



# Intermediate steps...

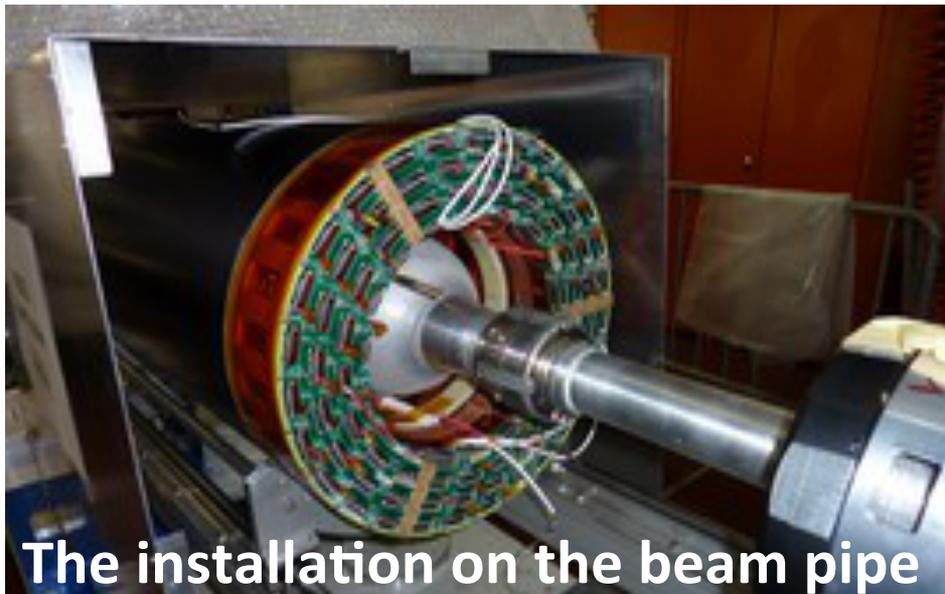
The four layers



The IT



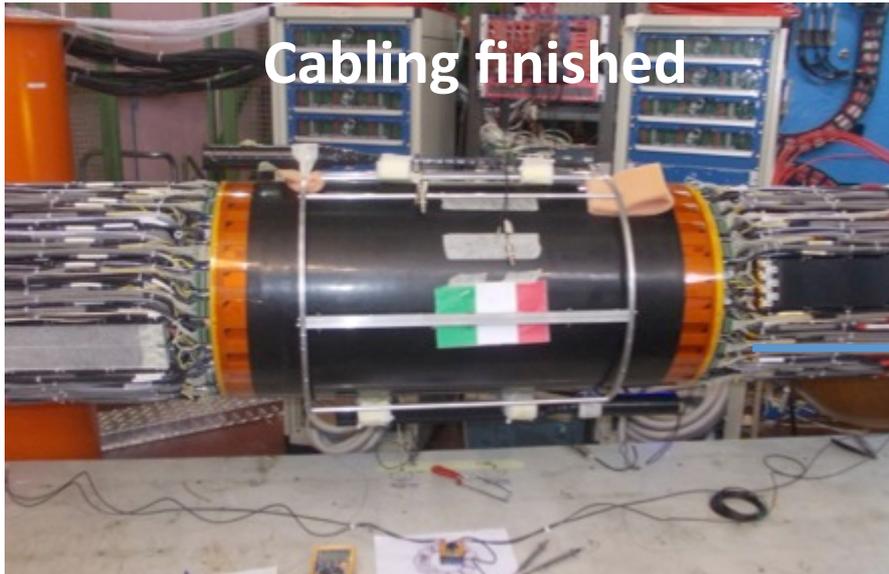
The installation on the beam pipe



Soldering the beam pipe



# Inner Tracker integration



A detail of the cabling



A copper shield completes the Faraday cage

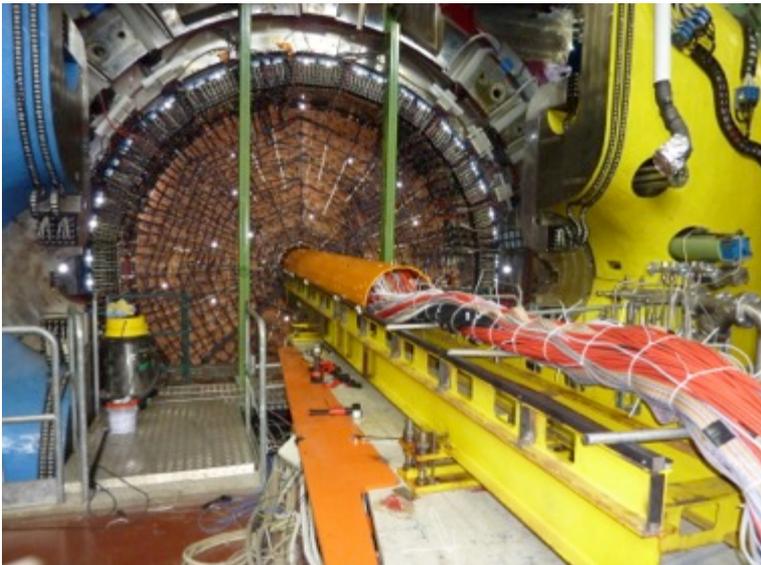
# Inner Tracker integration



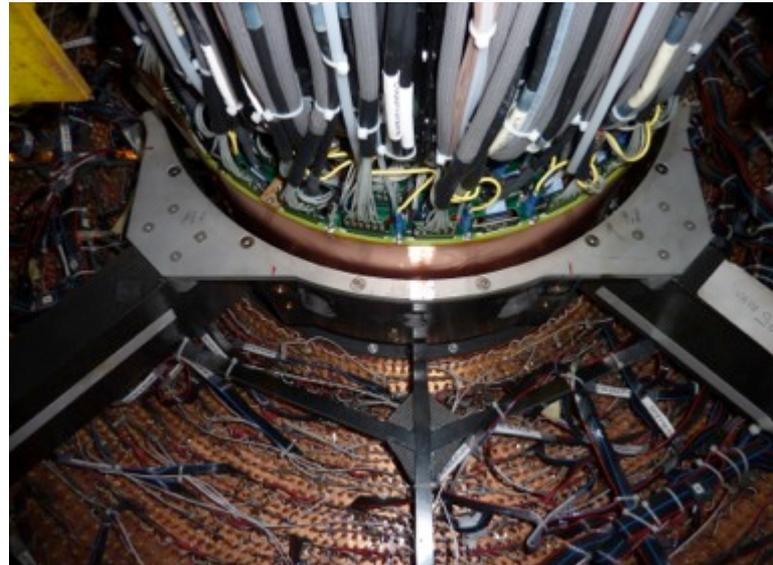
Protection shell installation



Kapton protection of the HV boards

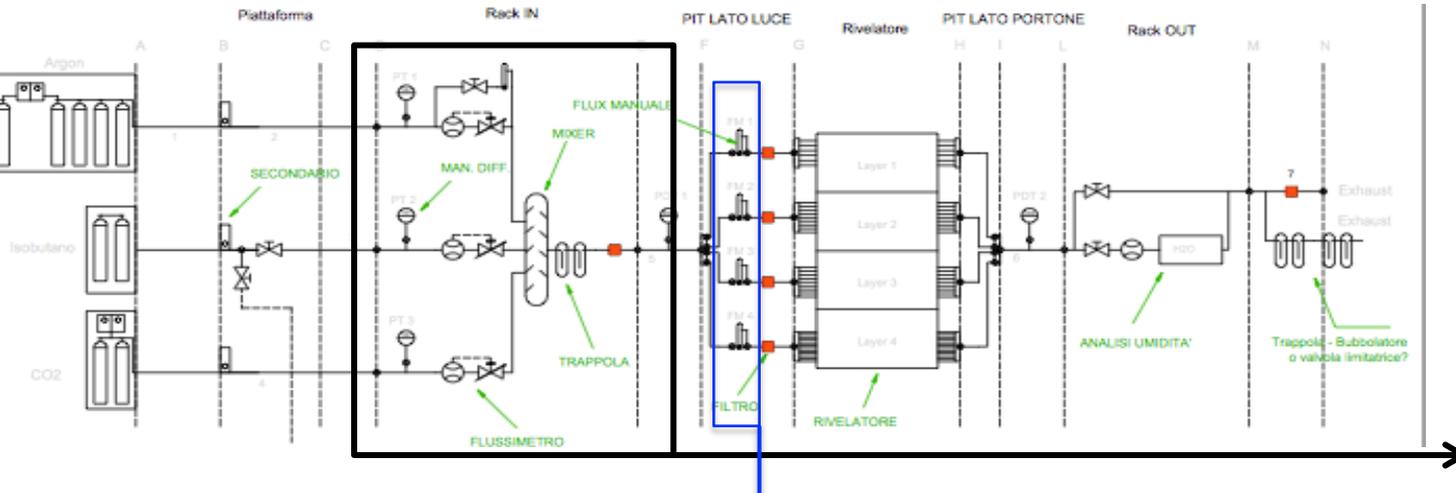


IR positioning

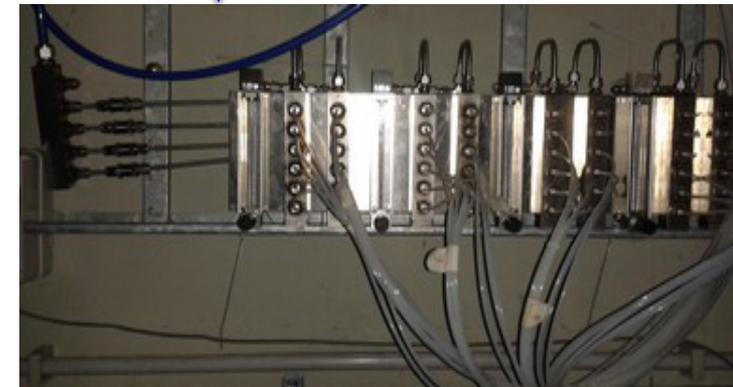


Detail of the IT insertion

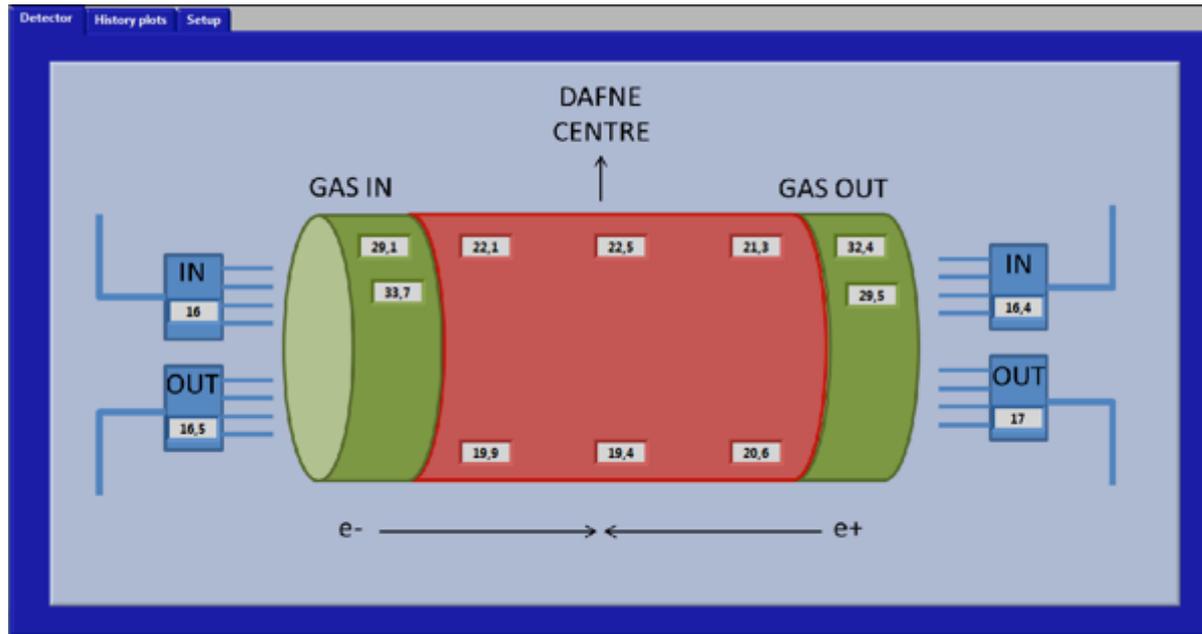
# Inner Tracker gas system



- The IT is flushed at **30 l/h**
- Filters present along the inlets of each layer
- Isobutane sniffer close to the IT to detect gas leakage
- We can set the flux for each layer and monitor the overpressure of the line
- Data transmission to slow control for alarm

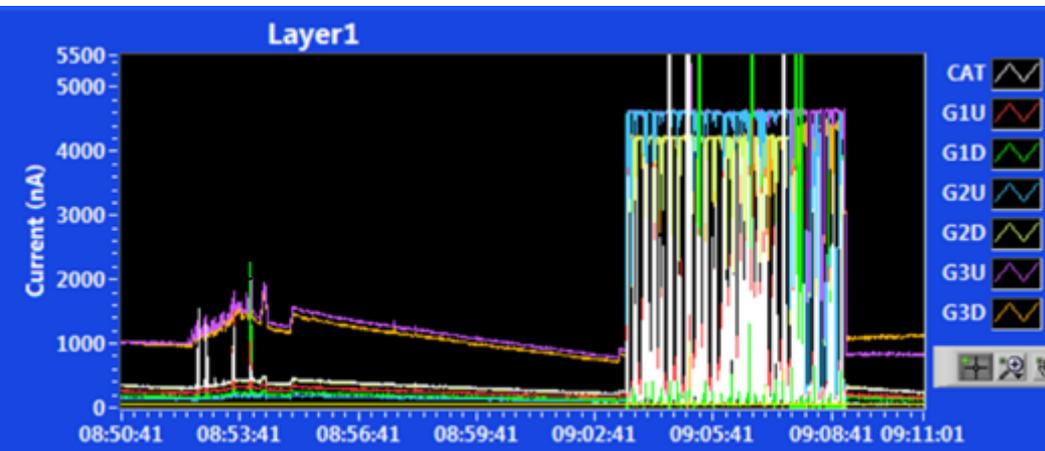
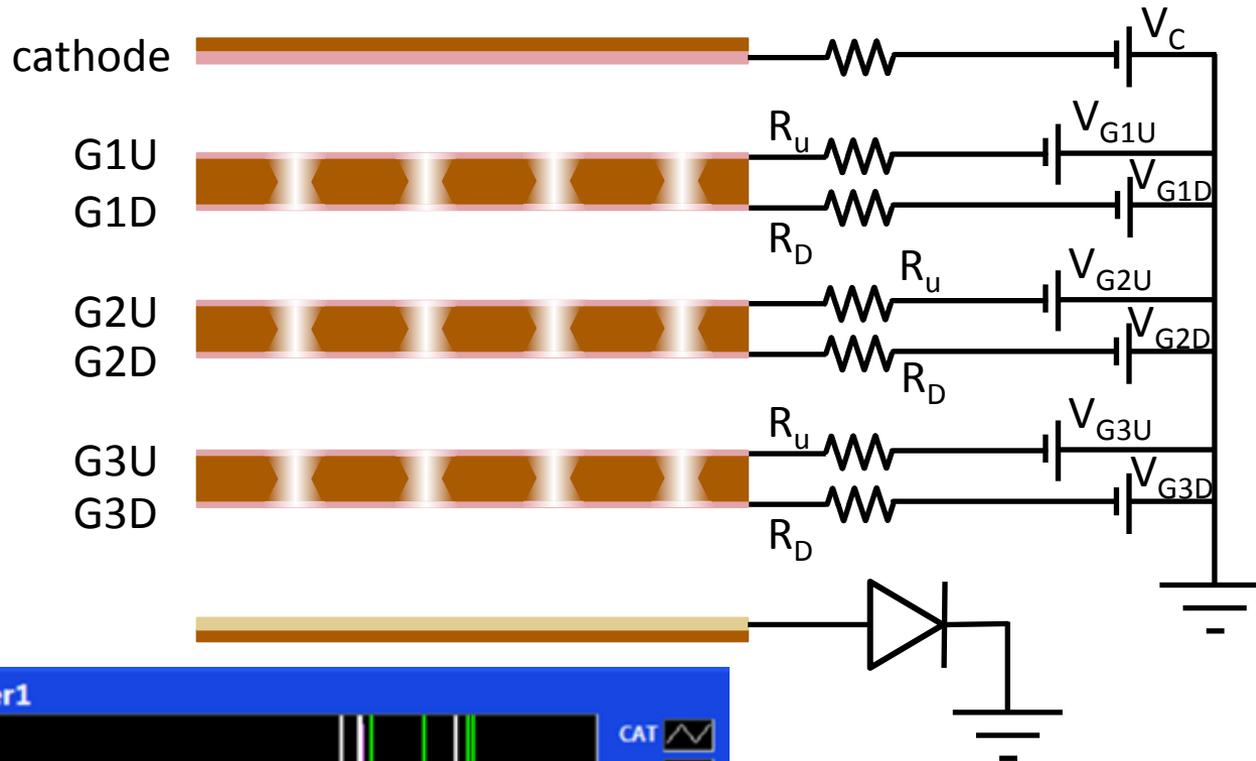


# Inner Tracker temperature slow control



- **6 probes** on the innermost surface of the IT
- **4 probes** on the FEE
- **4 probes** on the water cooling circuit for the GASTONE boards

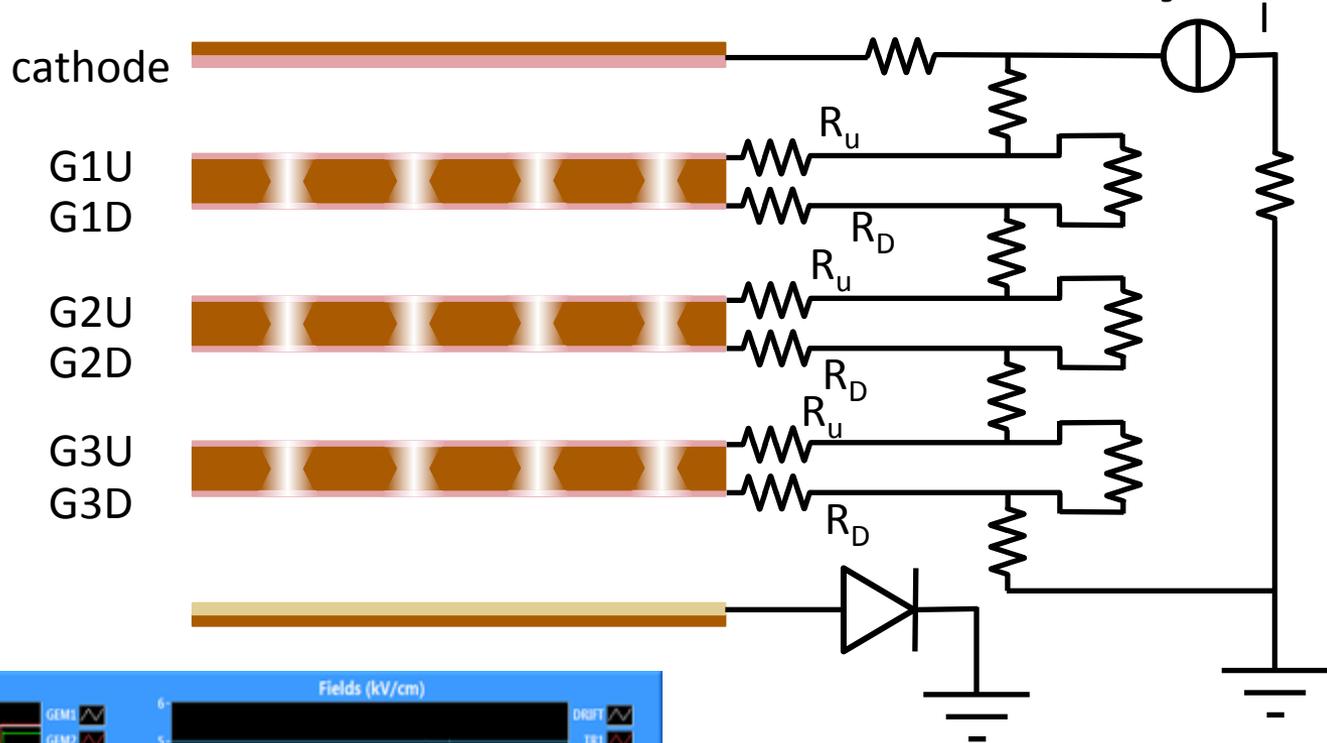
# Inner Tracker HV distribution system



## OLD DISTRIBUTION SYSTEM (RUN I)

- 7 independent channels for each layer
- Voltage settings (effective gain) adjustable
- Very sensitive to discharges, causing shorts in some HV sectors

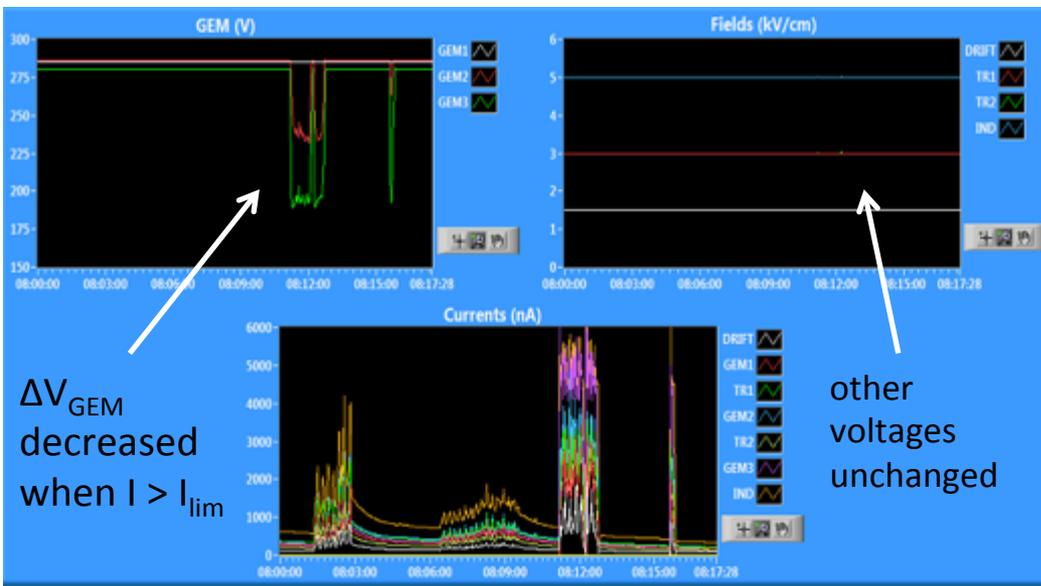
# Inner Tracker HV distribution system



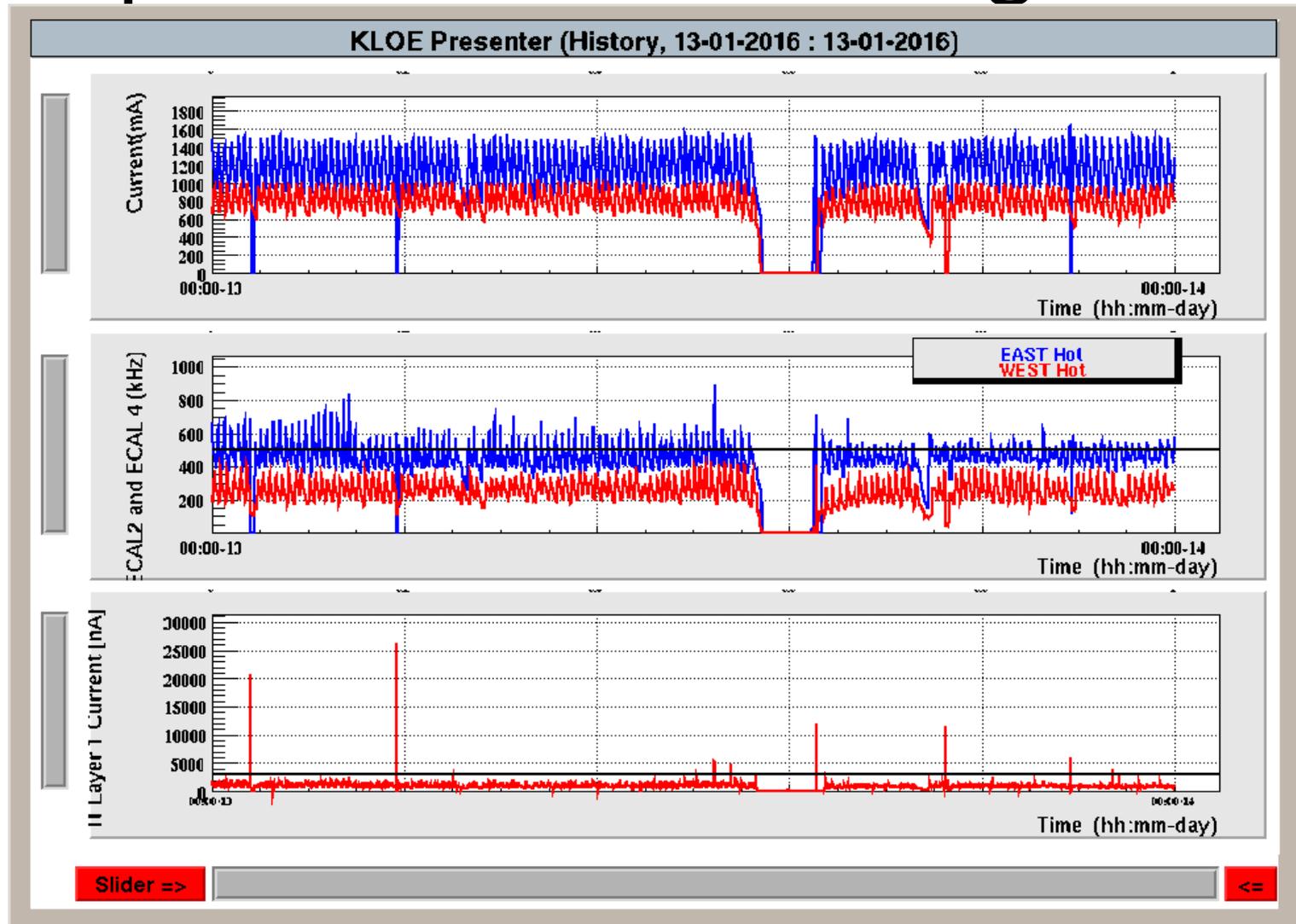
## NEW DISTRIBUTION SYSTEM (RUN II)

- **1 channel only**
- Dedicated board developed by CAEN with common floating channels

**Dividers installed for all the Layers**

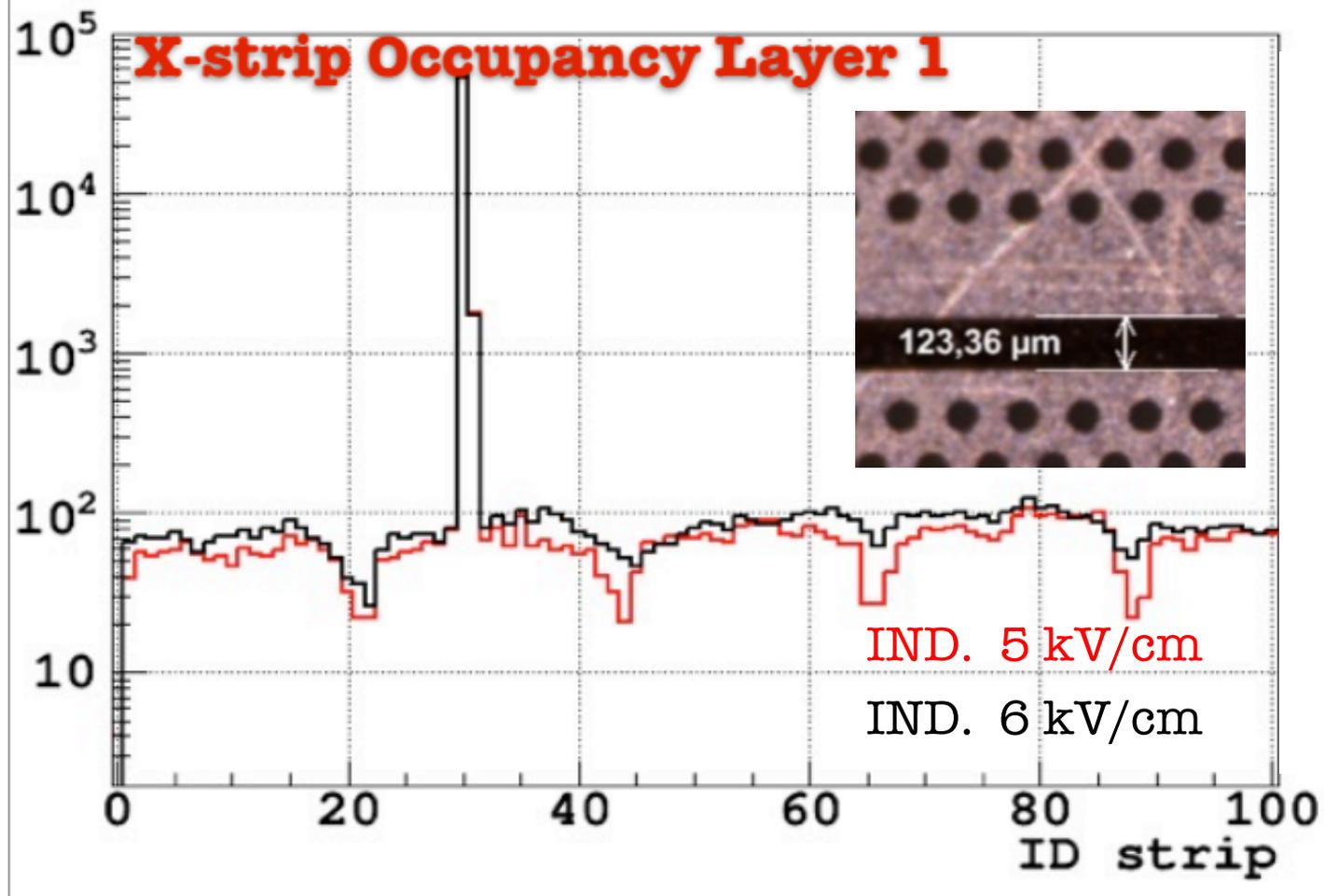


# IT operation with colliding beams



IT Layer 1 currents most of the time below the safety limit 14

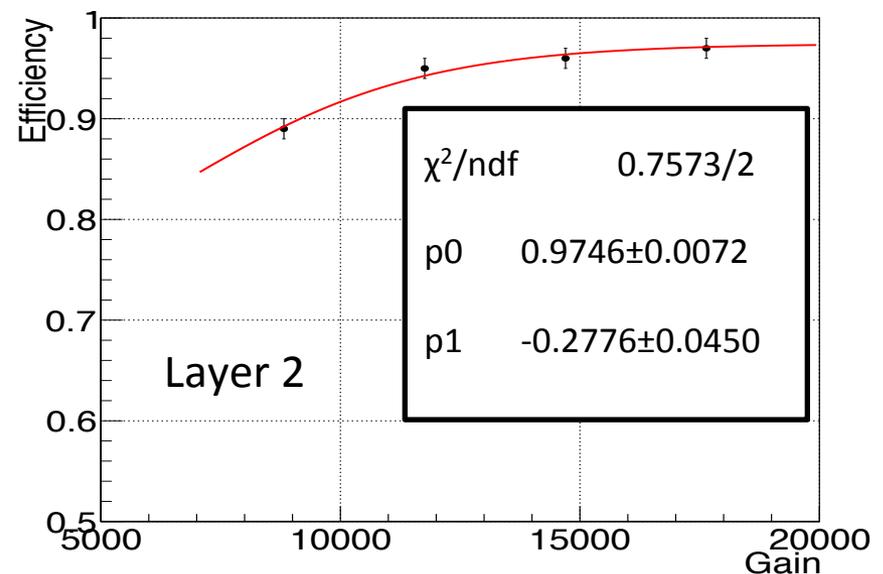
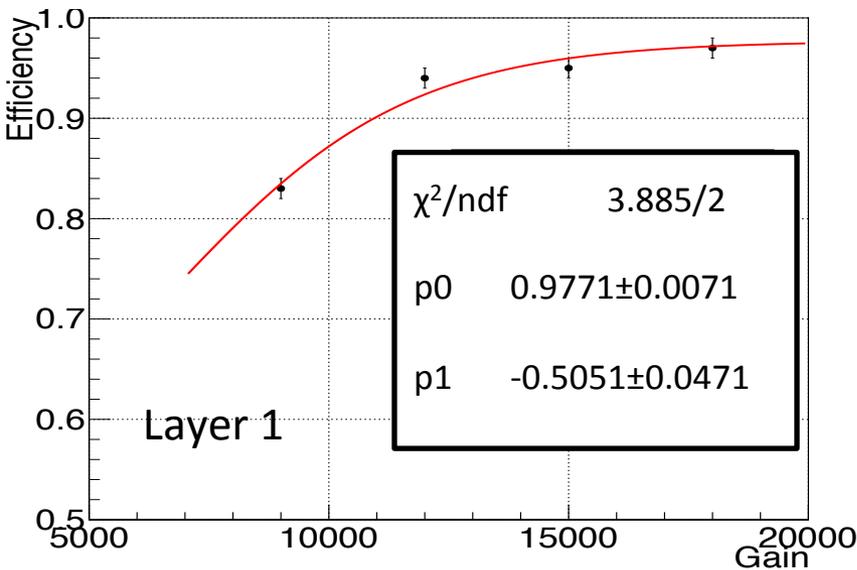
# IT Operation point optimization



- Dips in the occupancy show the micro-sector structure of GEM foils
- Induction field increased from 5 kV/cm to 6 kV/cm

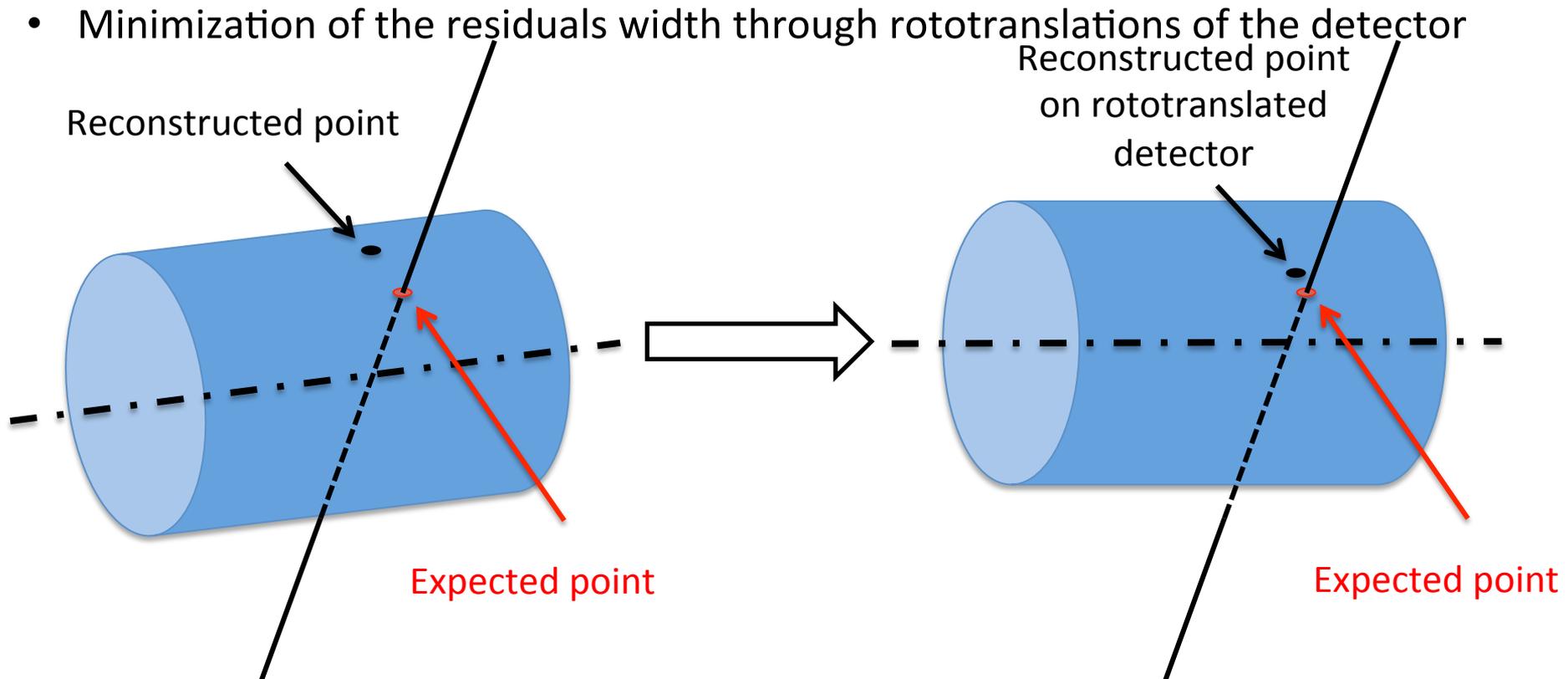
# IT HV test(gain scan @ $E_{ind} = 6$ kV/cm)

- Efficiency computed with tracks reconstructed in the Drift Chamber and extrapolated on the IT
- Ar: $iC_4H_{10}$  90:10 gas mixture
- Fit using a Fermi-Dirac function, imposing 3 parameters



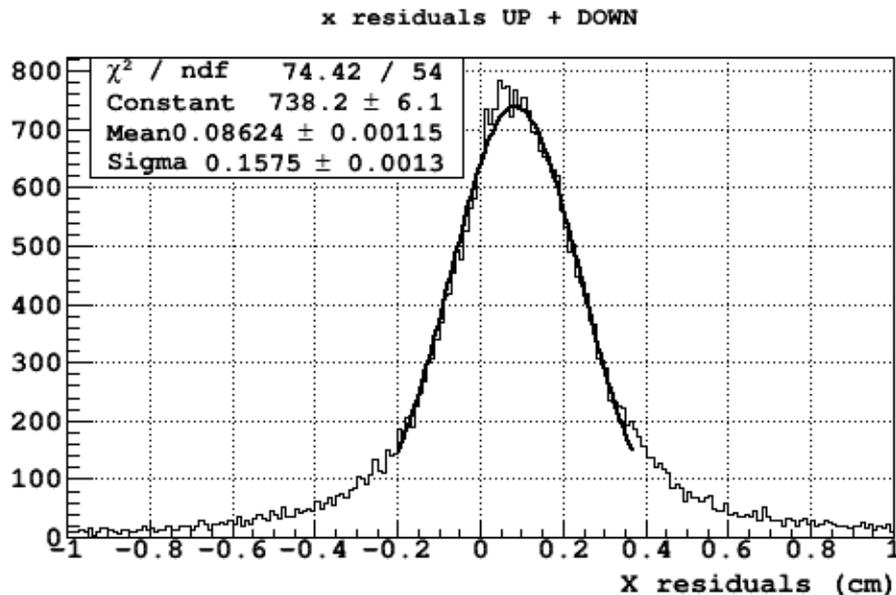
# Inner Tracker alignment

- Based on residuals distributions: different datasets (cosmic-ray muons at  $B=0$ ,  $B=0.52T$  and Bhabha events)
- Residuals are defined as the difference between the expected DC tracks position on the IT and the reconstructed position
- Minimization of the residuals width through rototranslations of the detector

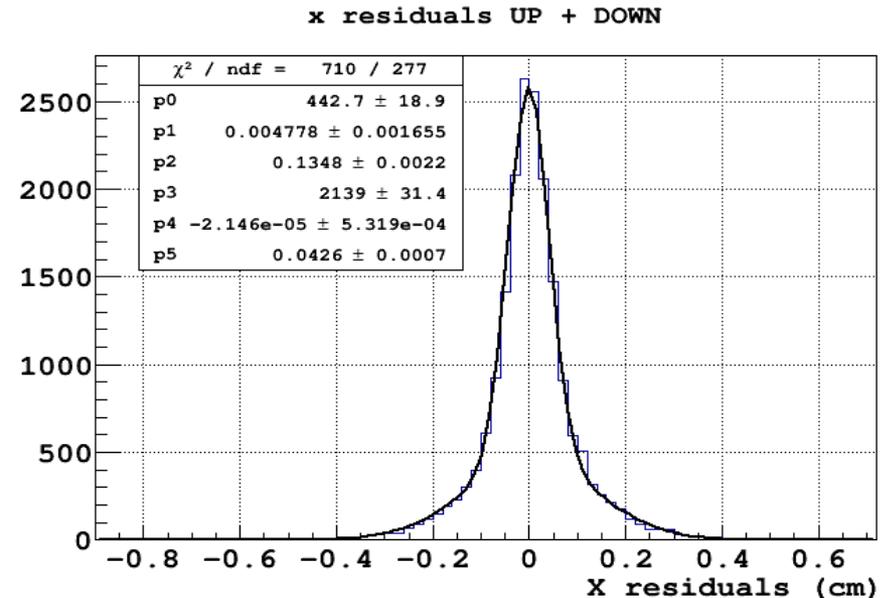


# Inner Tracker alignment

A first look with cosmic-ray muons without magnetic field and without calibration of the detector response



Cosmic-ray muons without magnetic field and with a 1<sup>st</sup> alignment and calibration of the detector response



## Convolution of DC and IT resolutions

$$\Delta x: 0.086 \pm 0.001 \text{ cm}$$

$$\Delta y: -0.005 \pm 0.003 \text{ cm}$$

$$\Delta z: -0.207 \pm 0.003 \text{ cm}$$

$$\text{RES}_x: 1.57 \text{ mm} \rightarrow 440 \text{ } \mu\text{m}$$

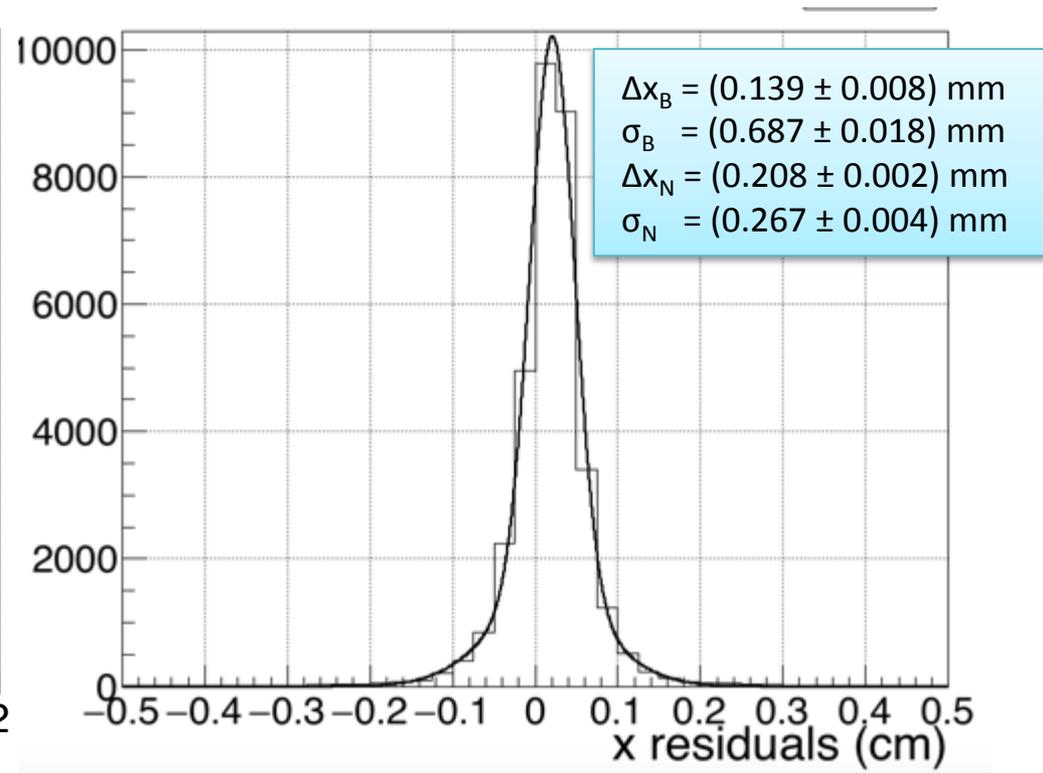
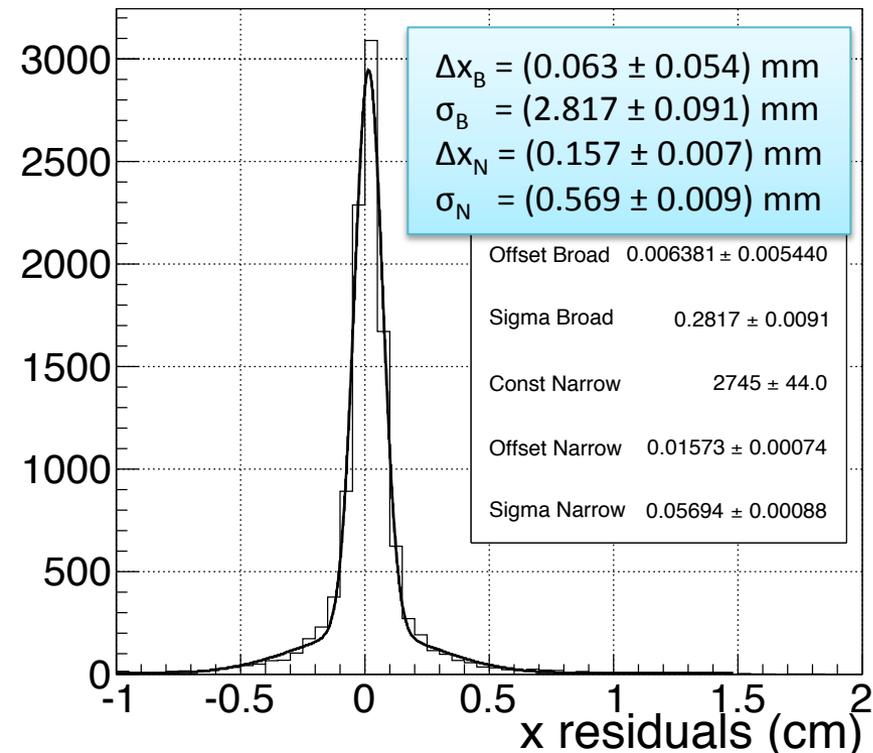
$$\text{RES}_y: 280 \text{ } \mu\text{m} \rightarrow 240 \text{ } \mu\text{m}$$

$$\text{RES}_z: 3.58 \text{ mm} \rightarrow 1.1 \text{ mm}$$

# Inner Tracker alignment

Cosmic-ray muons: B on and applying calibrations of non-radial effect

Bhabha scattering: B on and applying calibrations of non-radial effect



# Conclusions

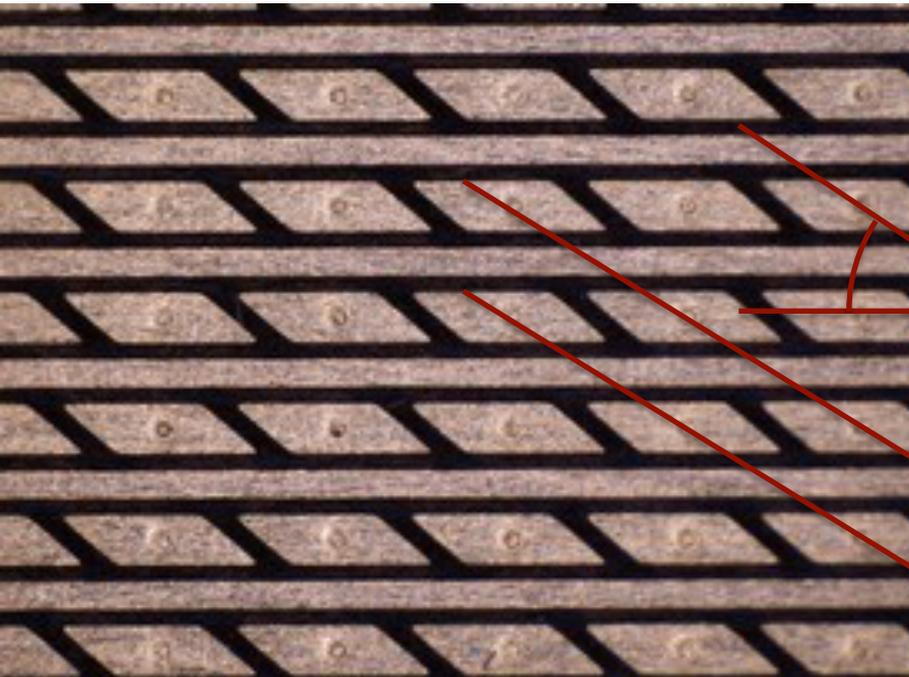
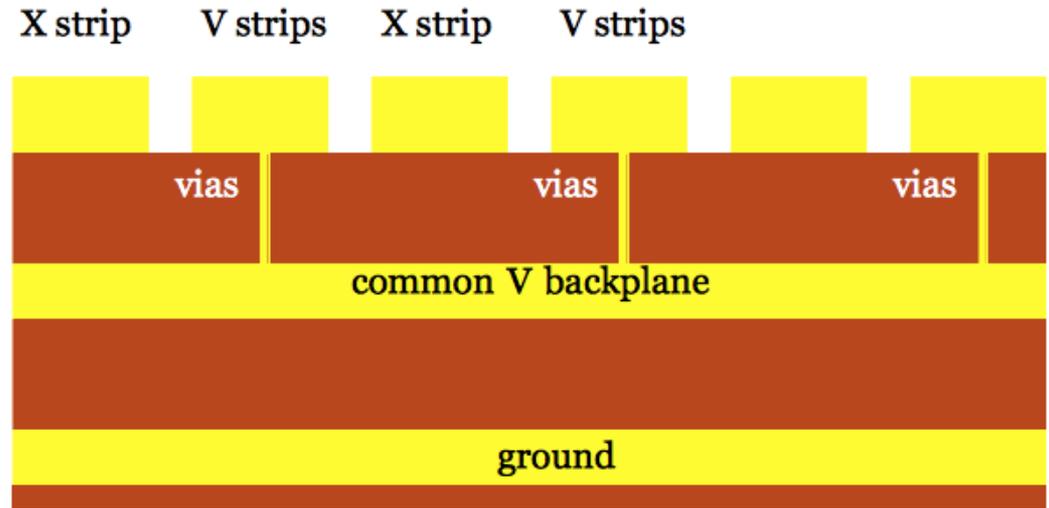
- The Inner Tracker has been integrated on the DAΦNE beam pipe
- IT safe operation with a new HV distribution system
- The detector has been aligned with cosmic-ray muons
- Calibration of detector response performed with data at  $B=0$  and  $B\neq 0$
- $\sigma_{\text{res } \chi} = 570 \mu\text{m}$  with cosmics and  $\sim 270 \mu\text{m}$  with Bhabha

**SPARE**

# The readout of the IT

The readout of the IT is a flexible kapton/copper circuit.

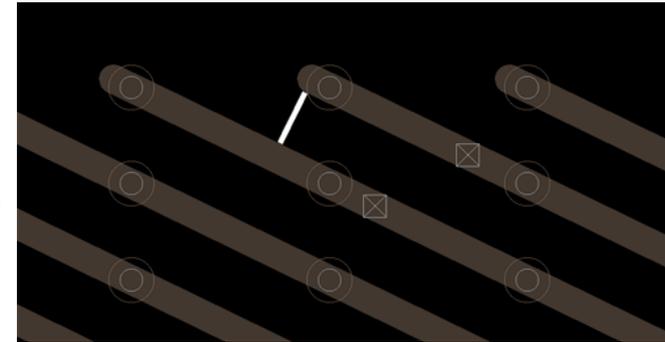
The 2-dimensional reconstruction is given by the X strips (parallel to the axis of the CGEM) and V pads connected by vias to a common backplane



$$\alpha = 32.75^\circ$$

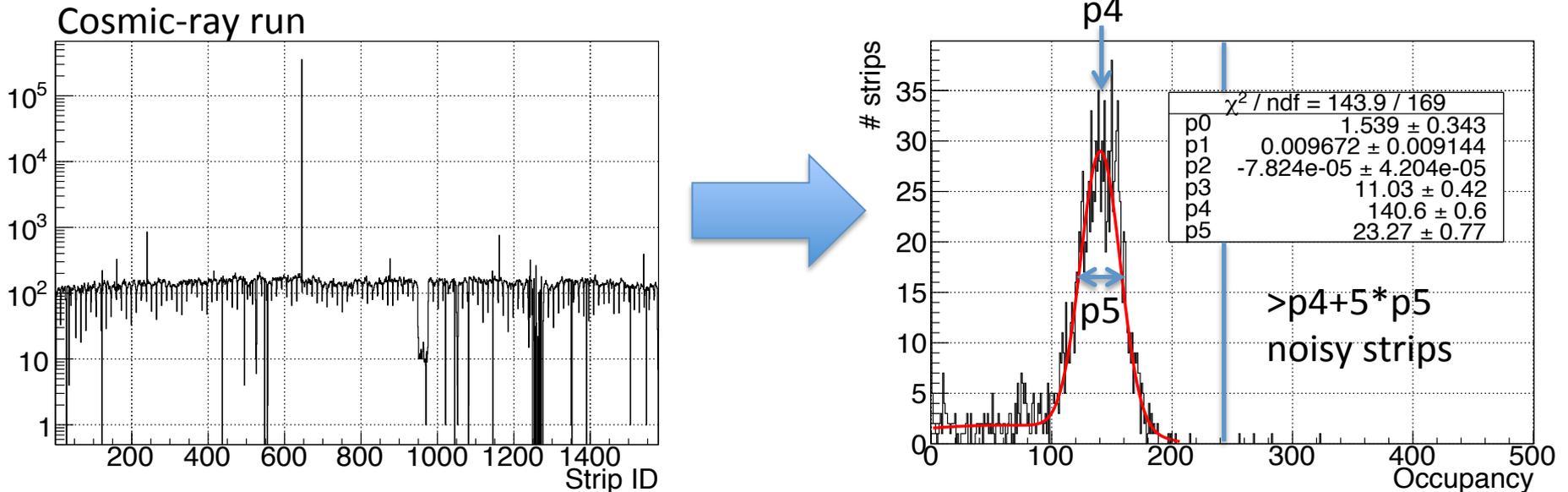
$$\text{X pitch} \approx 650 \mu\text{m}$$

$$\text{V pitch} \approx 600 \mu\text{m}$$



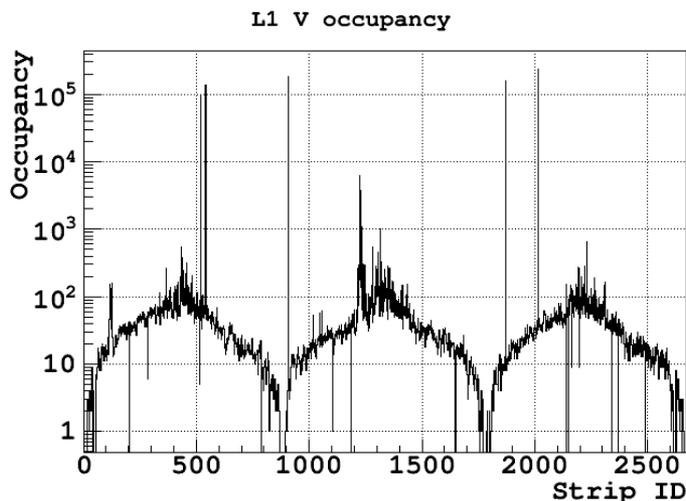
# Noisy strips detection

- A software tool is necessary to detect noisy channels among the  $\sim 25000$  strips
- The agreed solution is to use the 8 occupancies distribution (4 layers  $\times$  2 views)
- The profile of the distributions for the X view is fitted with a gaussian function whose sigma is used to classify the strips.

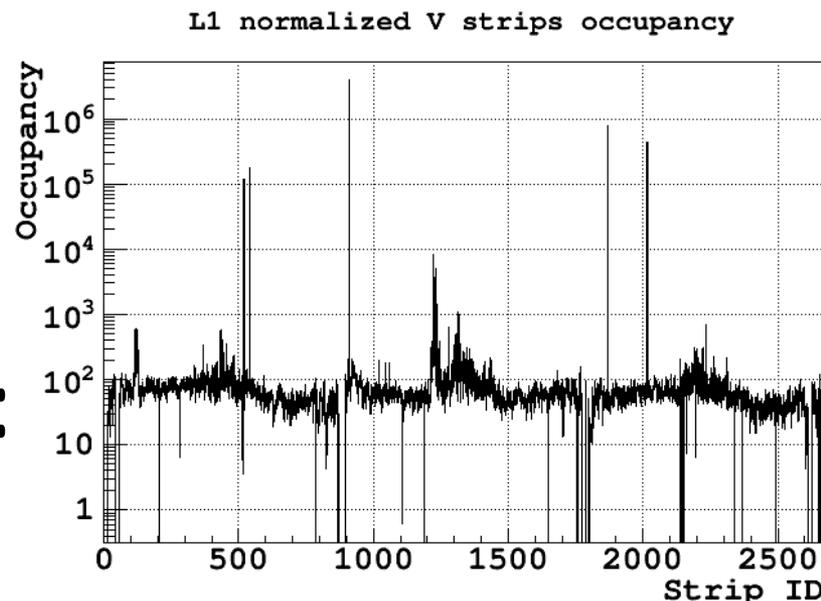


# Noisy strips detection

For the V view it's necessary an intermediate step, with the normalization of the occupancy to the length of each strip

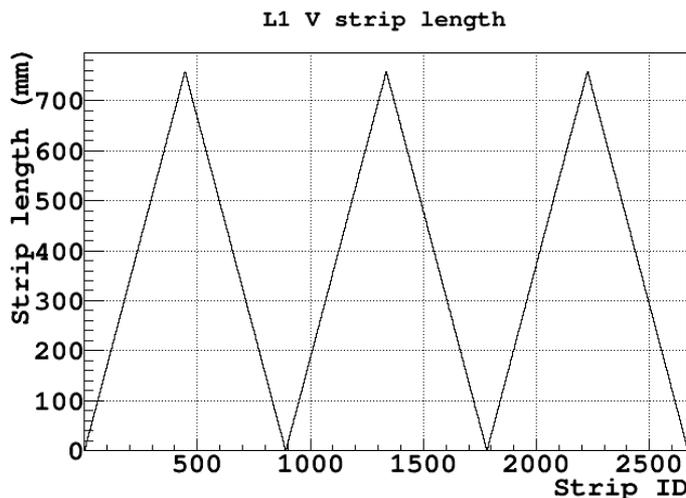


Run 69265



700

\*



=

$\cos(\alpha_1)$

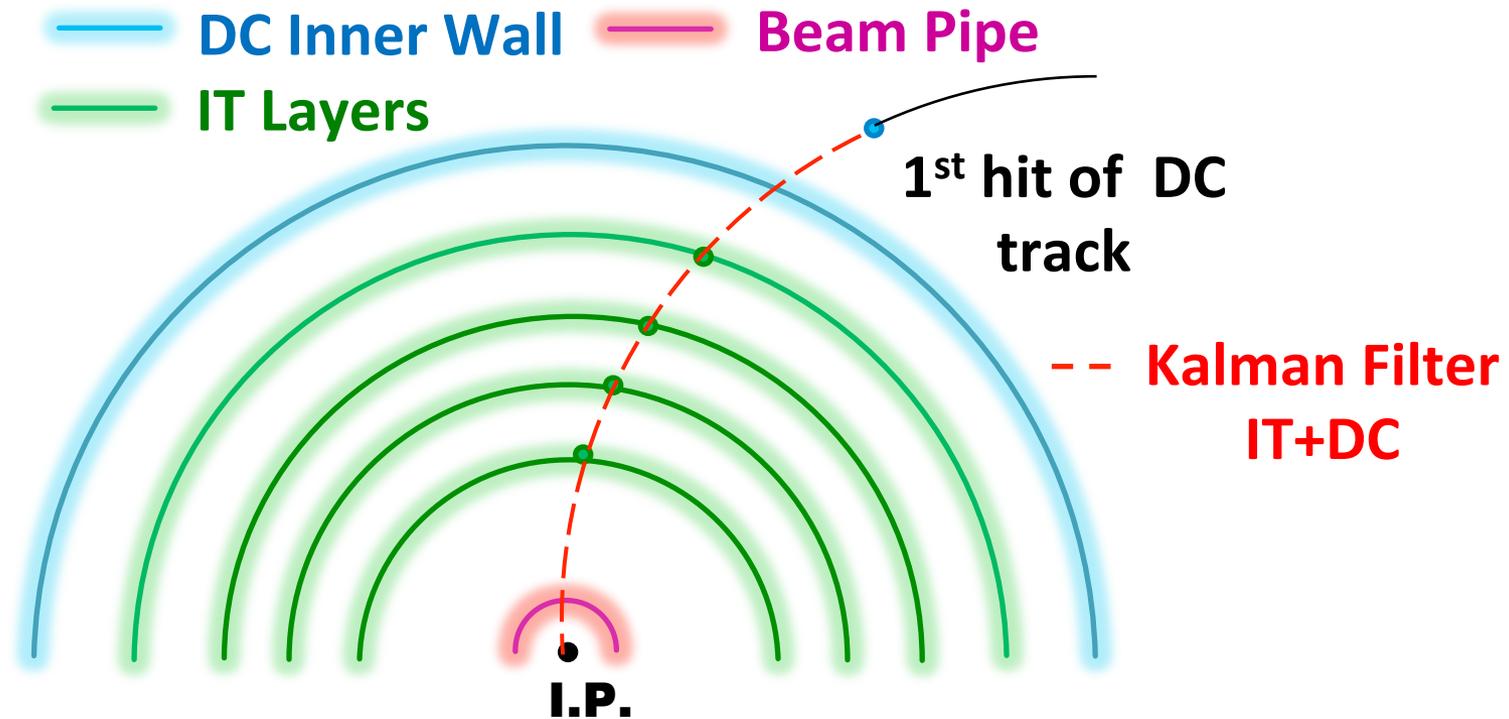
$$l(i, j) = 0.363 + \frac{[\bar{s}_j - |\bar{s}_j - (i \bmod 2\bar{s}_j)|]}{\bar{s}_j} \cdot \frac{700}{\cos(\alpha_j)}$$

$\bar{s}_j$  is the ID of the first longest strip (diagonal one) of the j-th layer

THE ID of the noisy strip is then written in the DB

# Track reconstruction

- The tracking procedure is based on a **Kalman filter** where the points reconstructed in the Inner Tracker. Track parameters are recomputed at each step.

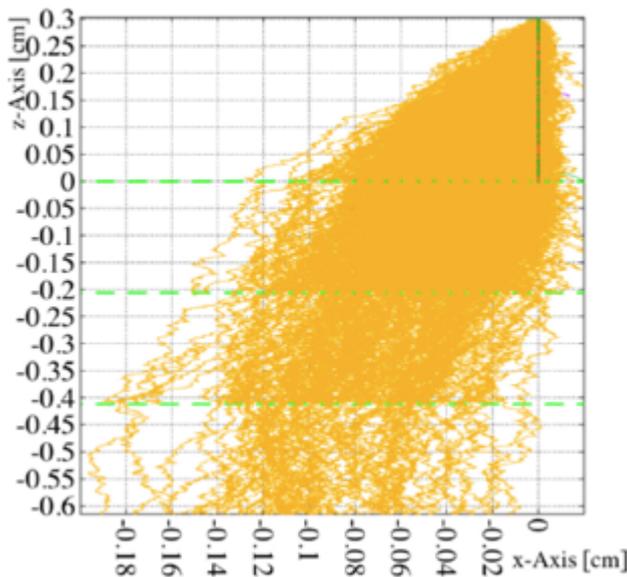


# First runs: need for calibration

## MAGNETIC FIELD

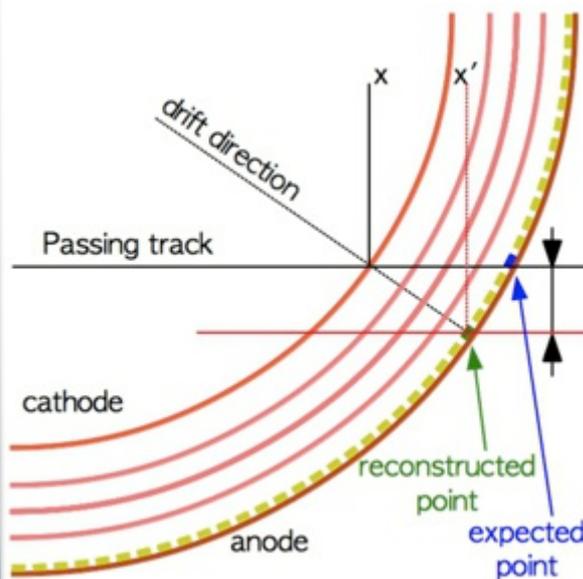
The KLOE-2 magnetic field is orthogonal to the electric fields of the triple-GEMs, introducing two systematic effects: a **shift**  $\Delta x(\alpha_L)$  and consequently a **larger spread of the electron cloud**.

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



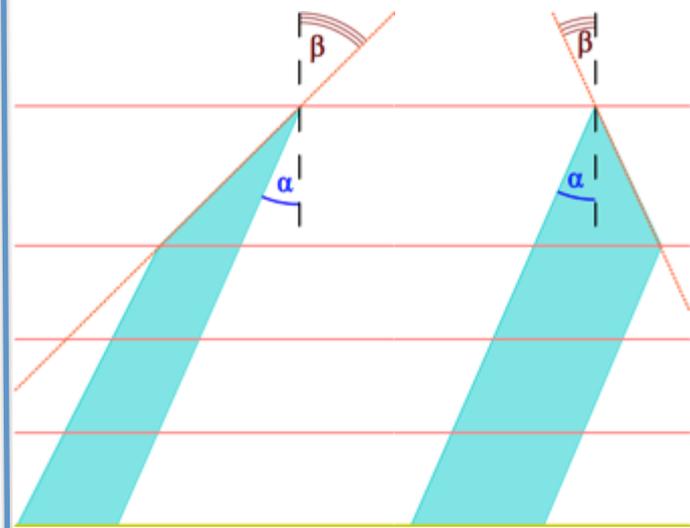
## NON-RADIAL TRACKS

The angle formed by a track and the orthogonal to the cathode influences the reconstruction.



## COMBINED EFFECTS

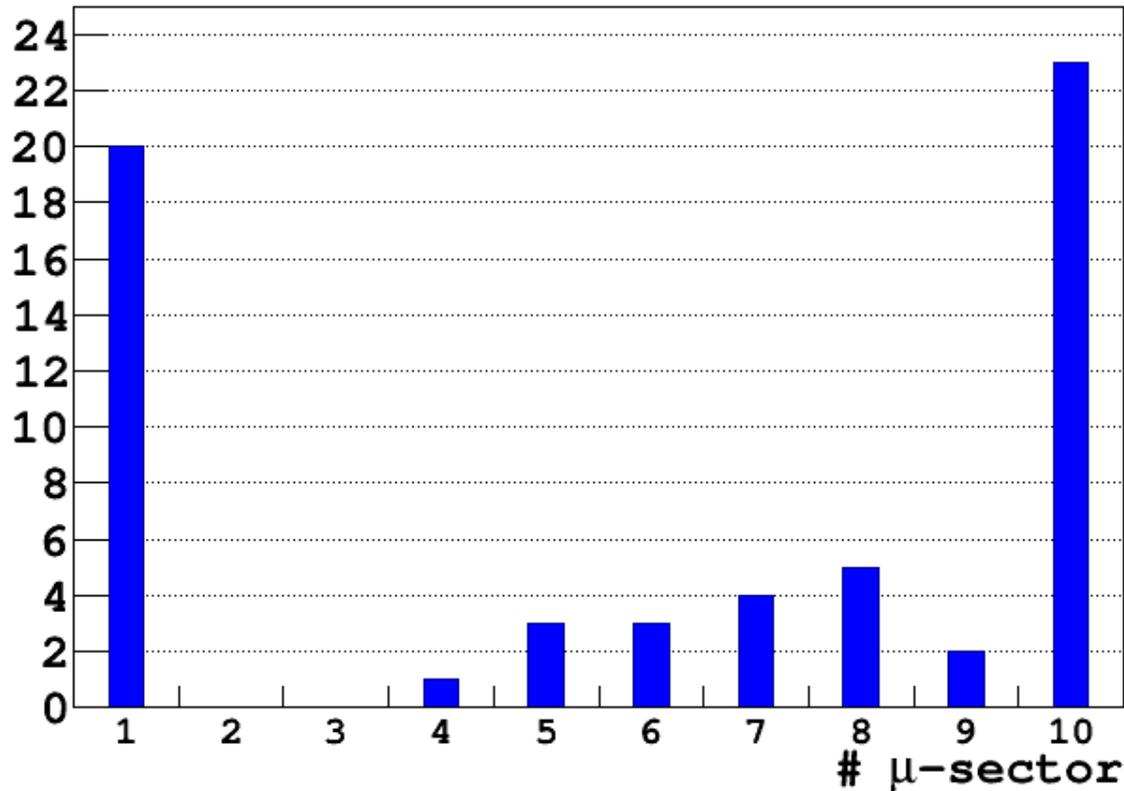
The total contribution of the two effects is simplified in the picture: the electrons are focused or defocused if the angles  $\alpha_L$  and  $\beta$  have the same sign



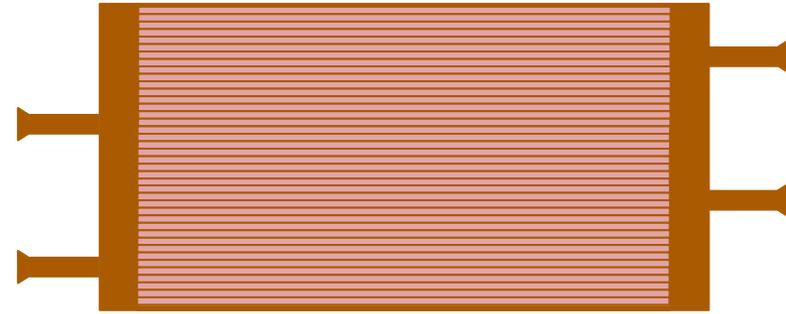
**Dedicated runs are scheduled with cosmic-ray muons, w/wo B field and Bhabha scattering events to separately evaluate the two effects**

# IT Operation point optimization

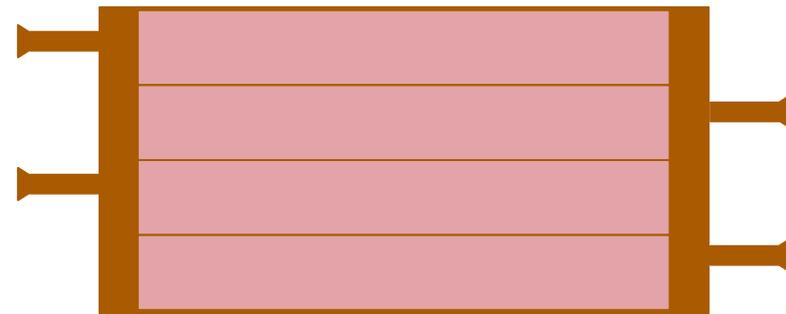
Short-circuit distribution vs  $\mu$ -sector number



GEM UP: 40 HV sectors



GEM DOWN: 4 HV sectors



- “Shorts” occurrence enhanced by the relatively high gas gain at which the detector is operated
- Mainly triggered by DAΦNE injections or beam losses
- Each GEM foil is divided in 4 macro-sectors, respectively divided in 10 microsectors
- **EDGE effect:** sectorization creates distortion of electric field resulting in higher effective gain
- **RECENTLY OBSERVED BY ALICE, COMPASS-THGEM,** solved increasing hole diameter