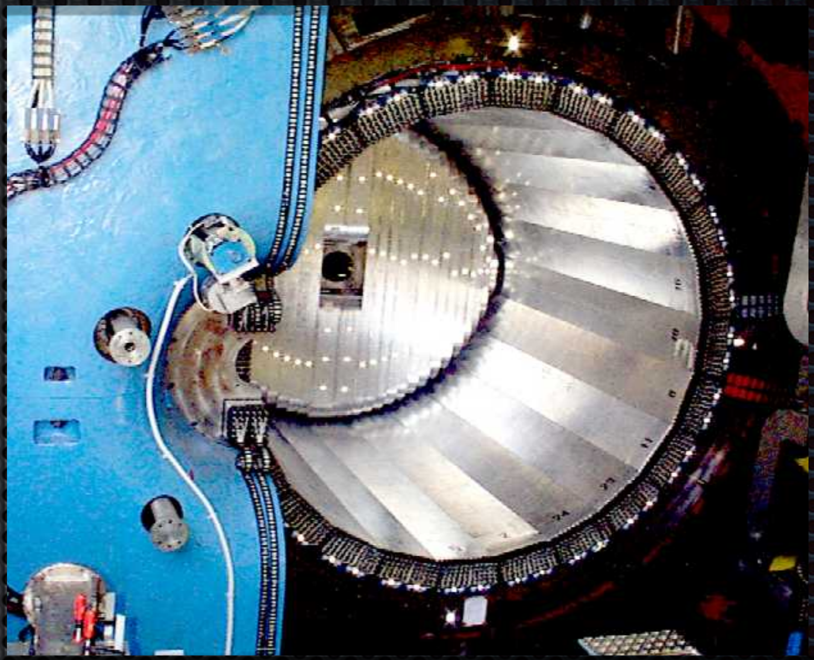
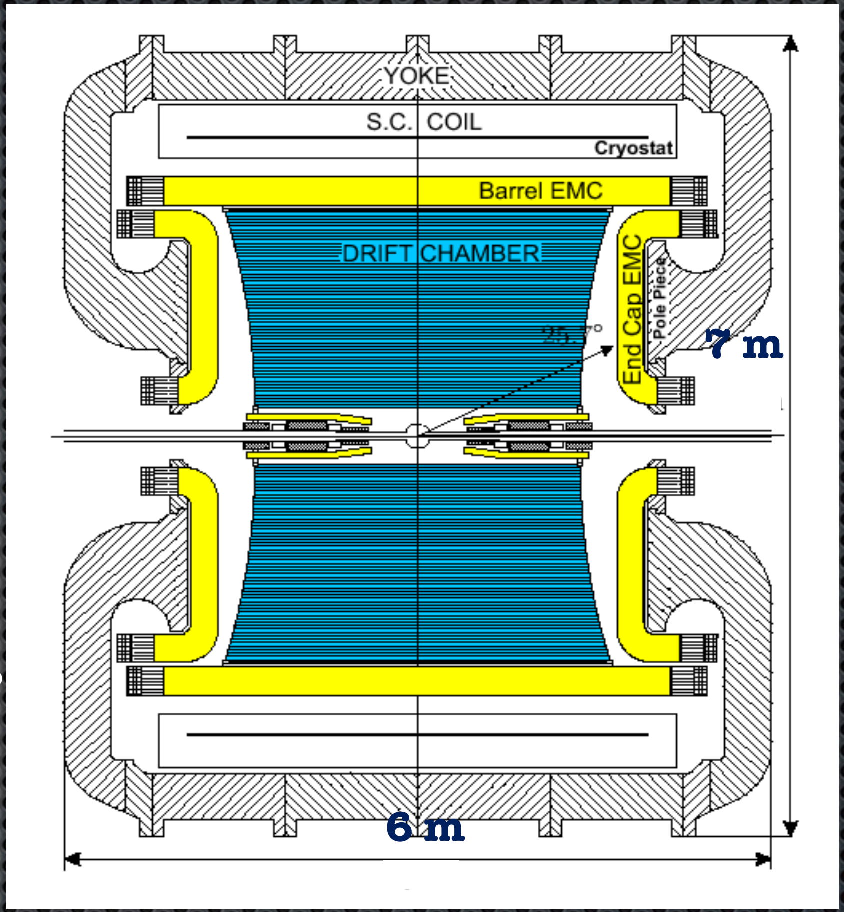
KLOE-2 CGEM-IT detector operation & performance

E. De Lucia
LNF- INFN
for the KLOE-2 Inner Tracker Group

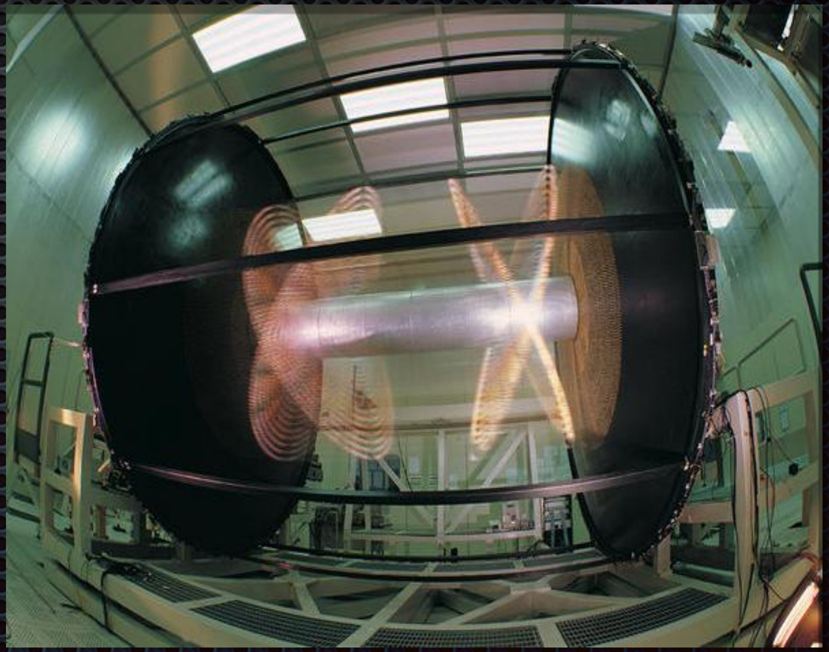
KLOE-2 at DAFNE

- Calorimeter System
  - EMC – Lead / Scintillating Fibers w PMT





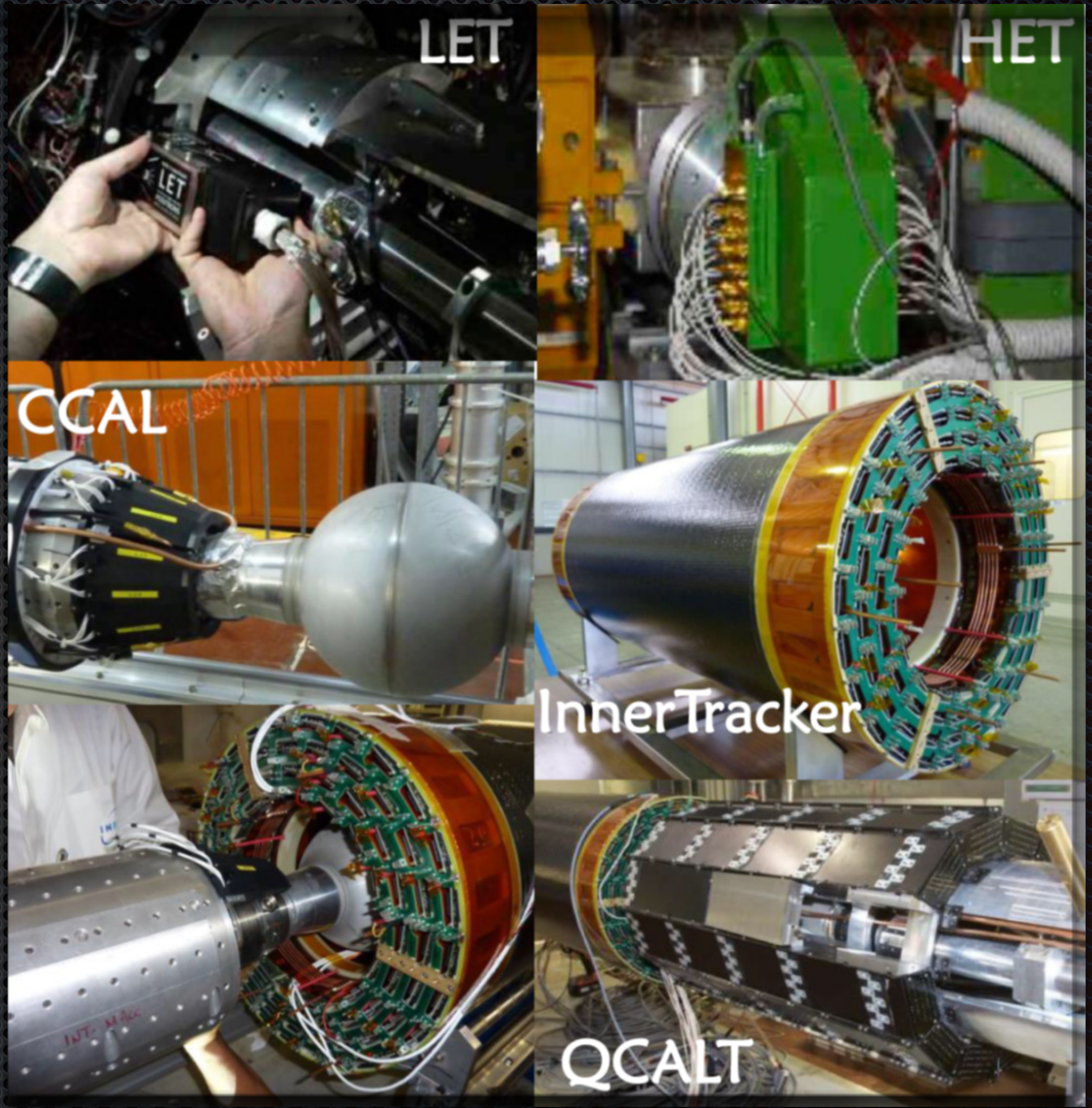
- Tracking System
  - DC – He-Iso 90-10
  3.7m x 4m Drift Chamber



- Superconductive Magnet
  - 0.52 T solenoidal field
- DAFNE φ-factory
  - $e^+ e^-$ at 1020 MeV
  - 1 fb^{-1} by Sep 2015

KLOE-2 at DAFNE

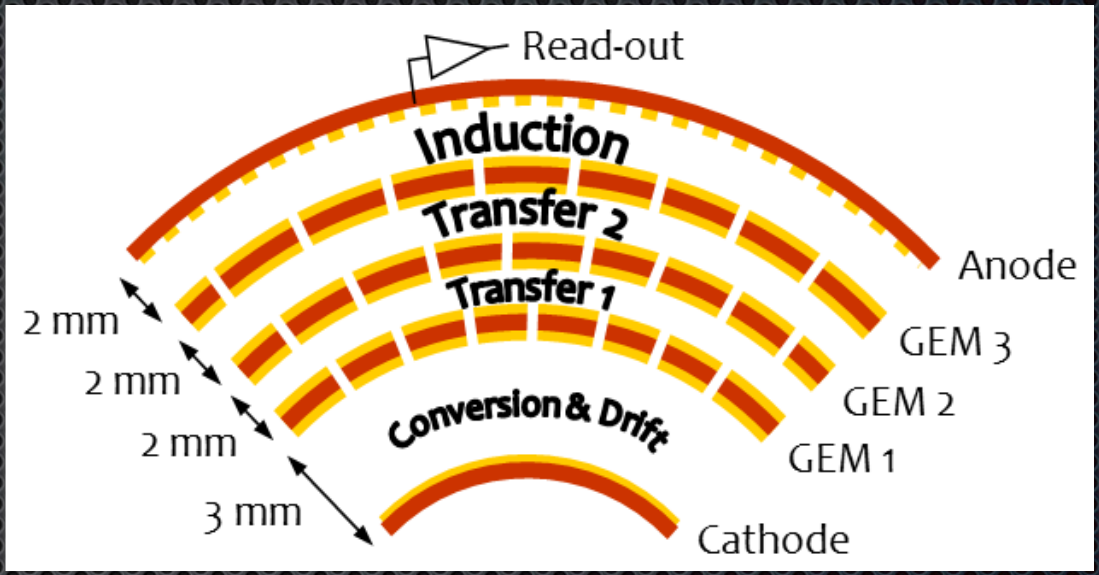
- Calorimeter System
  - EMC – Lead / Scintillating Fibers w PMT Barrel and Endcaps
  - LET / LYSO+SiPMs
  - HET / Scint+PMTs
  - QCAL – Tungsten / Scintillating Tiles w SiPM Quadrupole Instrumentation
  - CCAL – LYSO Crystal w SiPM – Low-beta
- Tracking System
  - DC – He-Iso 90-10
    3.7m x 4m Drift Chamber
  - Inner Tracker – 4 Cylindrical GEM detectors
- Superconductive Magnet
  - 0.52 T solenoidal field
- DAFNE φ-factory
  - $e^+ e^-$ at 1020 MeV
  - RunI ended in July 2015 with 1 fb^{-1}



- Physics program [EPJC 68 (2010)]
  - Ks, η, η_S rare decays
  - Quantum Interferometry
  - Dark photon search

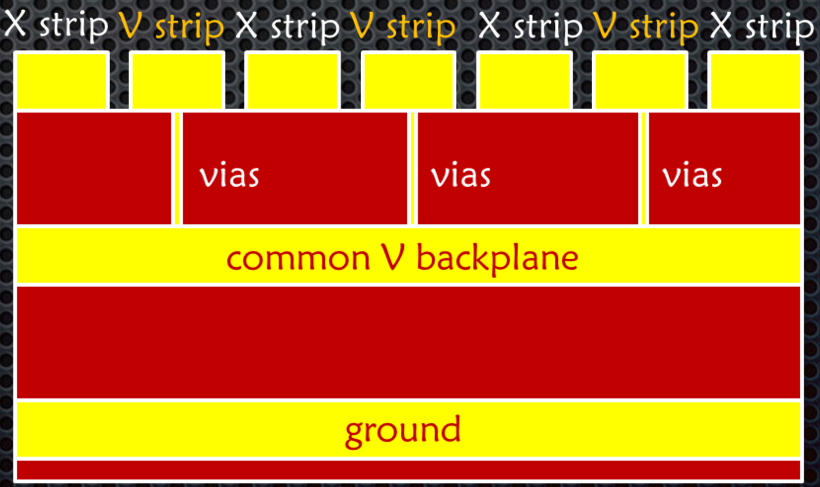
KLOE-2 CGEM Inner Tracker

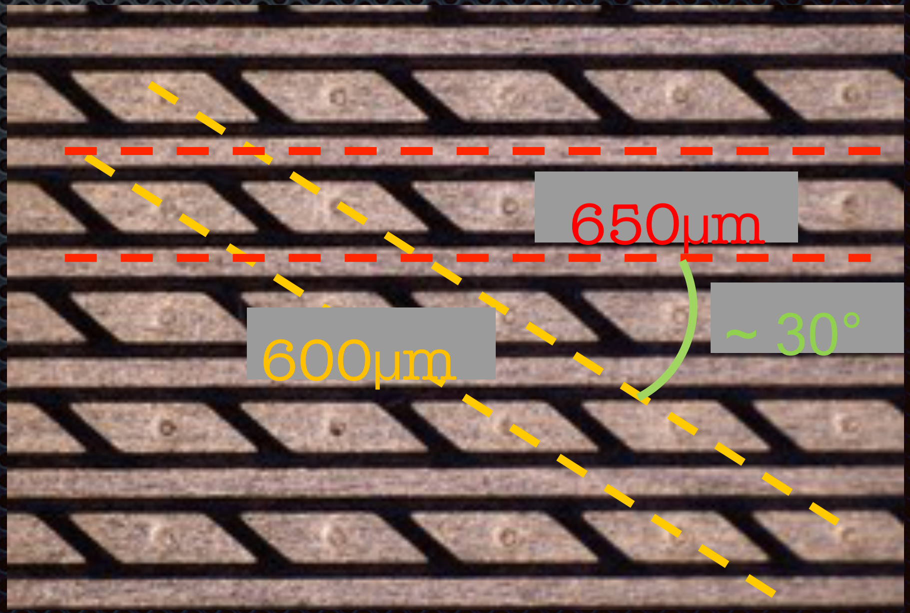
- First batch ever of GEM foils produced with a single-mask etching technique developed by CERN-TE-MPE-EM and RD51 to produce large area foils
- 70 cm active length
- 650 μm XV pitch strip readout
- 25k chan GASTONE FEE [NIM A 732 (2013)]
- 1600 HV channels
- FEE DAQ system [JINST 08 T04004 (2013)]
- 3/2/2/2 mm triple-GEM layout
- Ar/Iso:90/10 gas mixture
- 12000 gas gain
- 2% X_0 material budget



Kapton/copper multilayer flexible circuit built at CERN TE-MPE-EM (Tot thickness 300 μm)

- X-view: longitudinal strips
- V-view: connection of pads through conductive vias and a common backplane

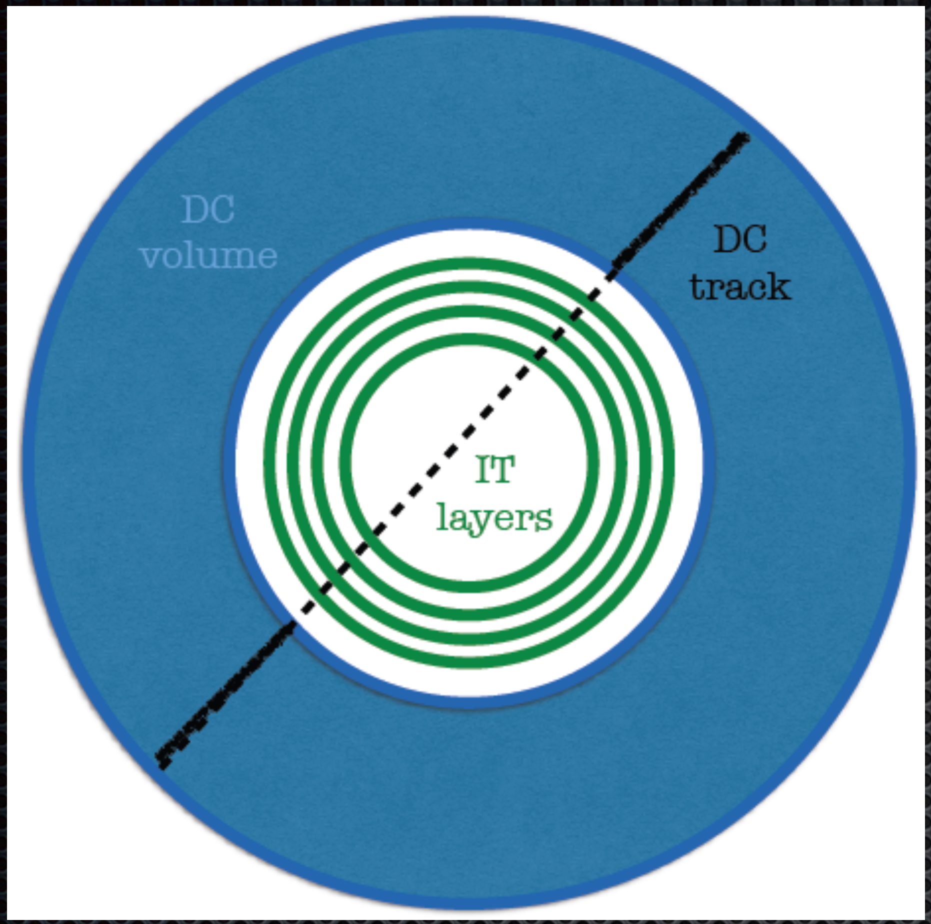




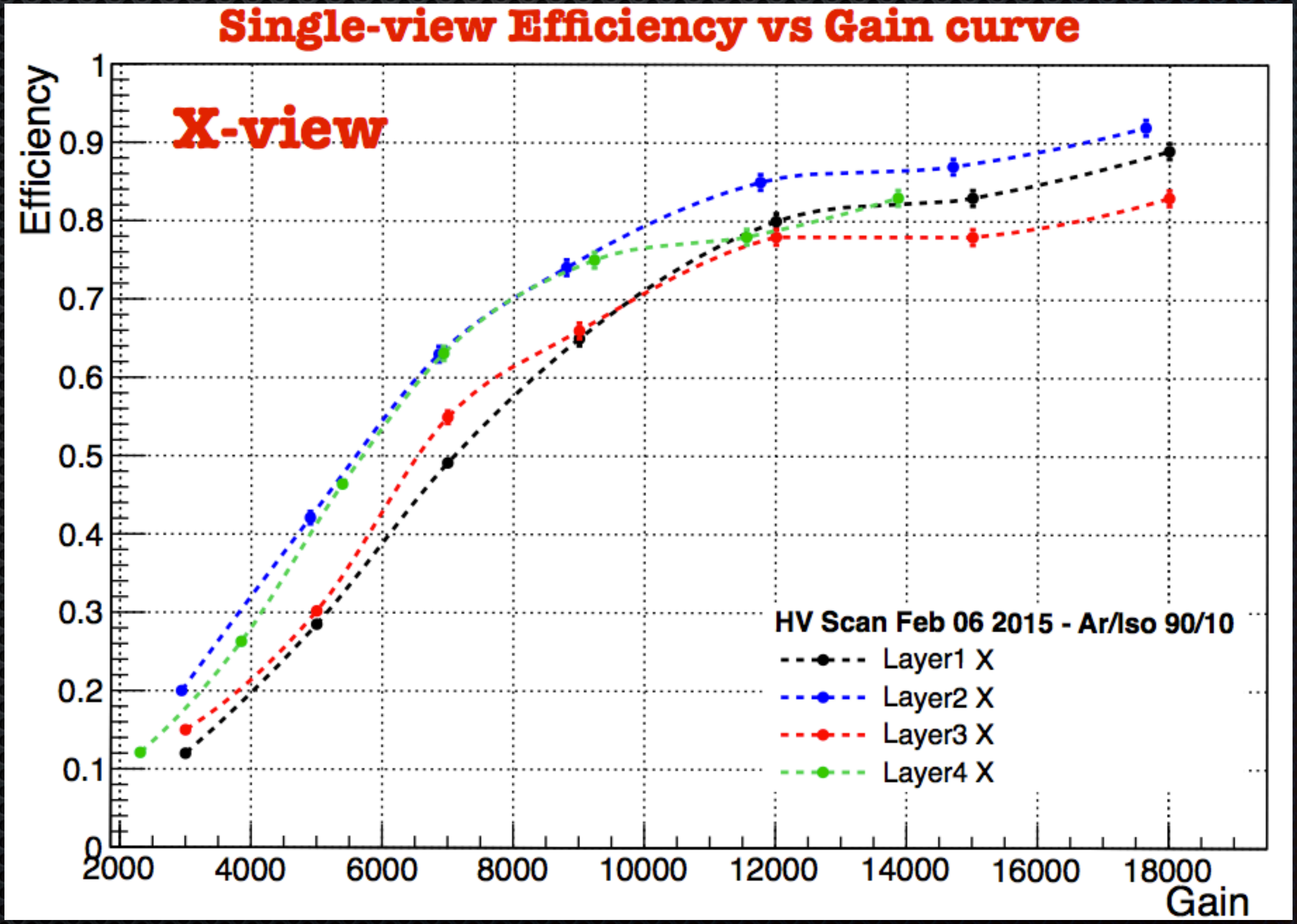
IT Operation point optimization (I)

Cosmic-ray muon data:

- Monitor detector noisy/dead channels situation and mask them in DAQ
- Extrapolate DC tracks to IT with straight-line approximation
- Look for reconstructed IT clusters close to expected positions from DC track

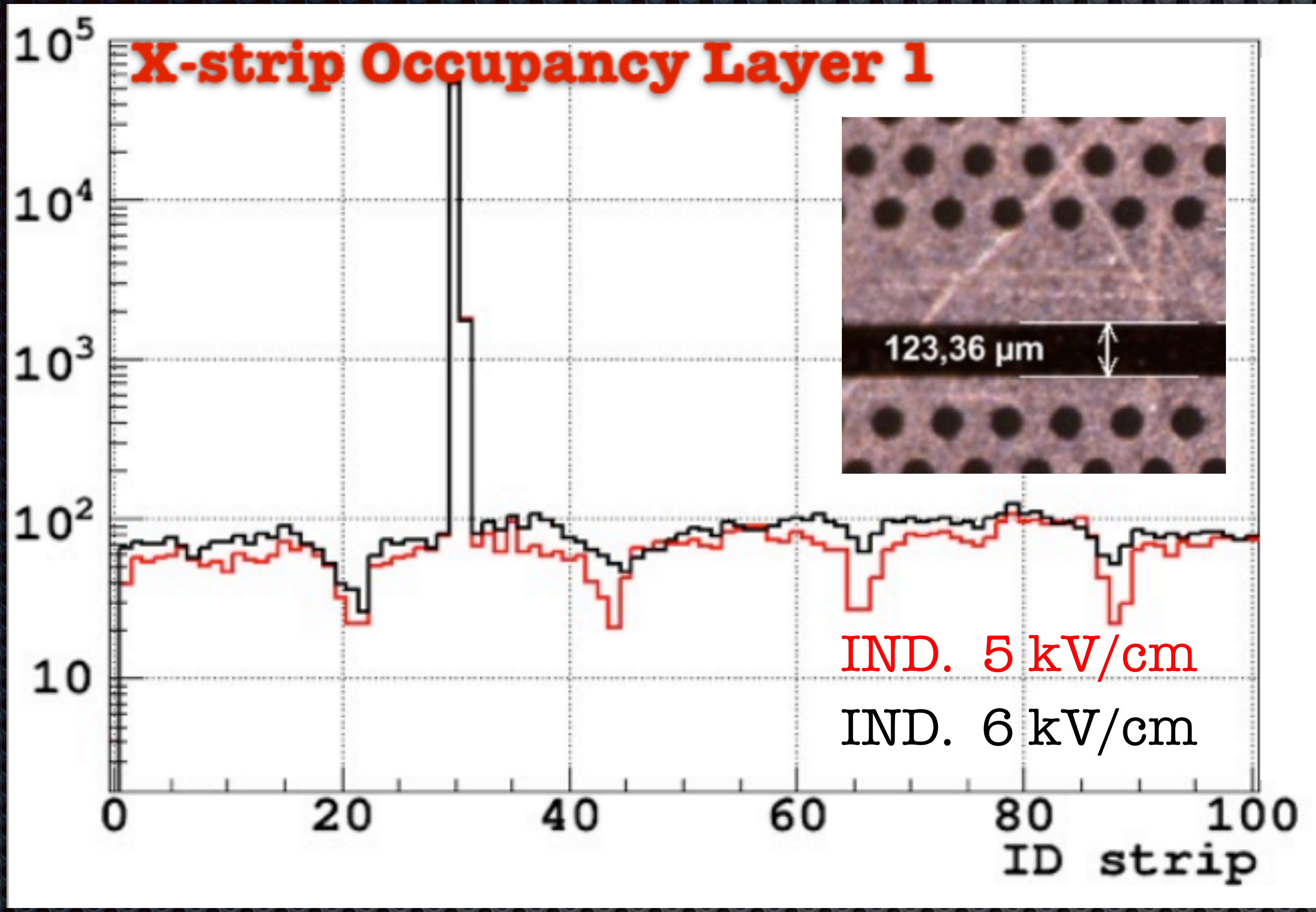


(kV/cm)				(V)		
Drift	T1	T2	IND.	G1	G2	G3
1,5	3	3	5	285	280	265



IT Operation point optimization (II)

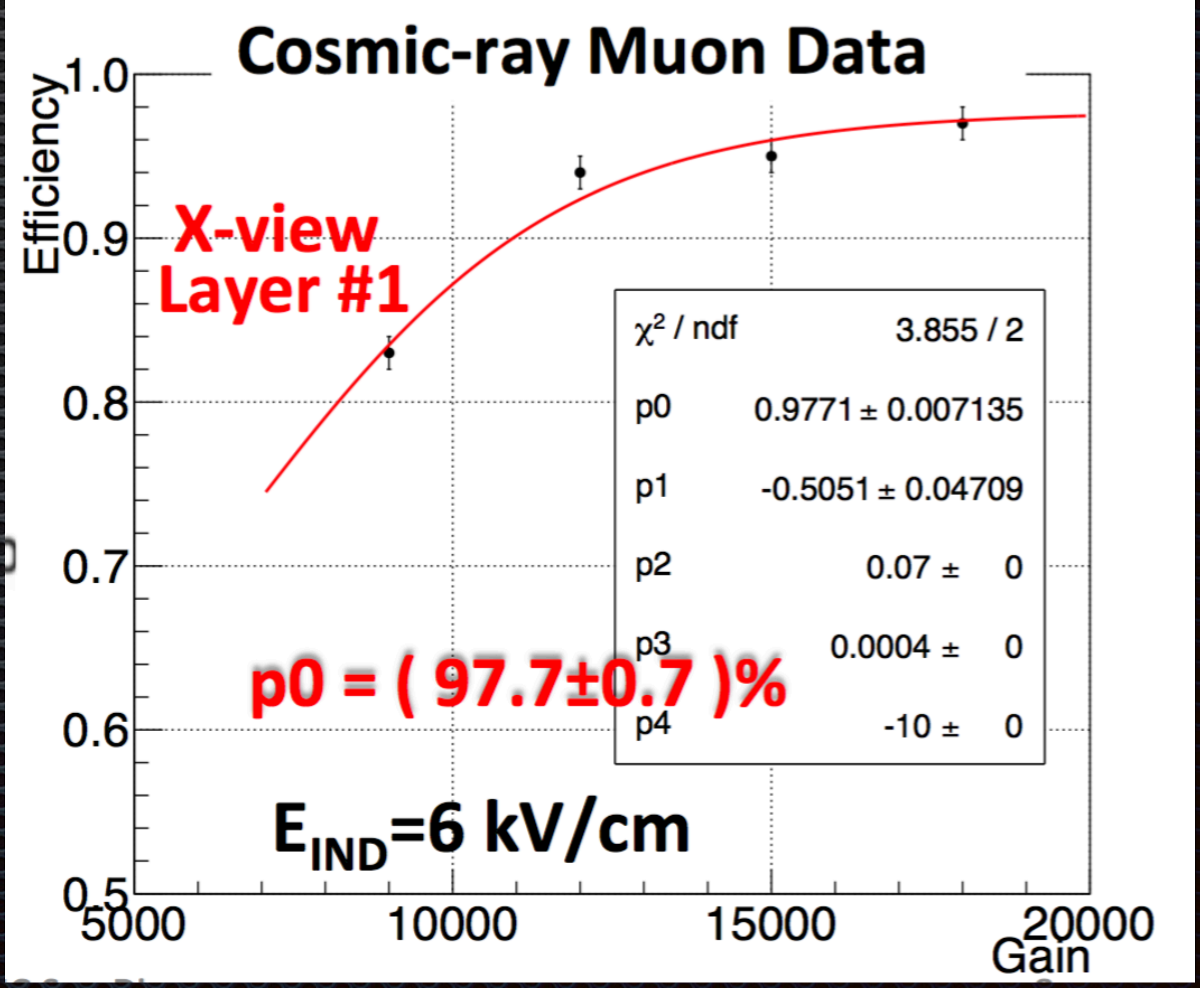
- Dips in the occupancy distribution show the micro-sector structure of GEM foils



Drift	T1	T2	IND.	G1	G2	G3
(kV/cm)				(V)		
1,5	3	3	5	285	280	265

- Induction field increased from **5 kV/cm** to **6 kV/cm**

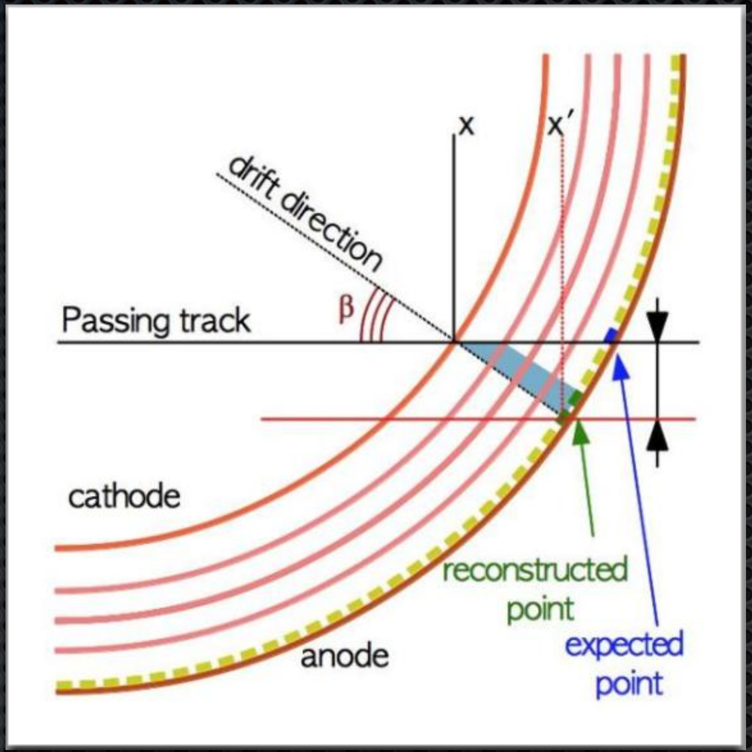
$\varepsilon_{(5\ kV/cm)} = 86\ \% \rightarrow \varepsilon_{(6\ kV/cm)} = 94\%$

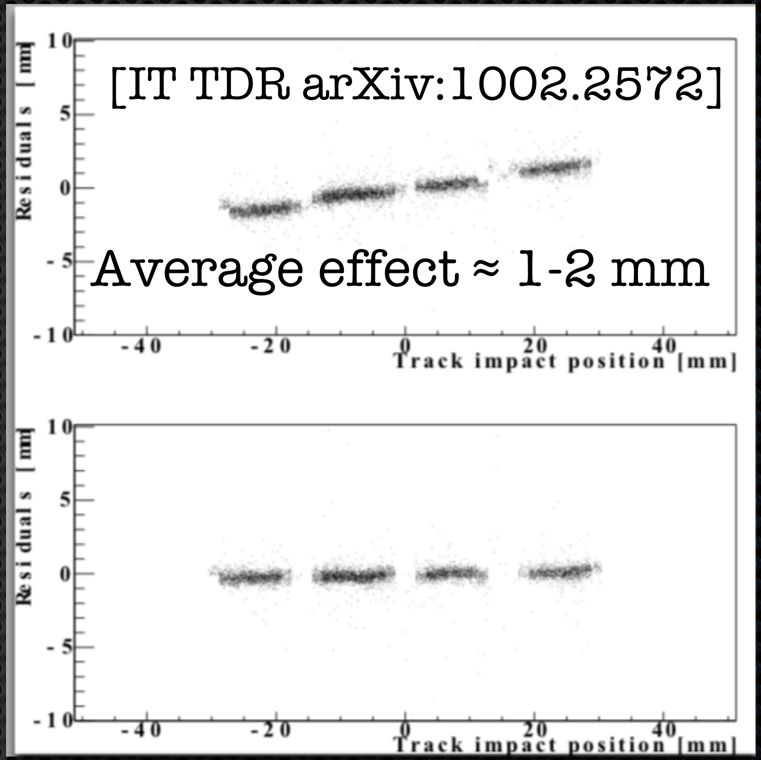


Alignment & Calibration strategy (I)

1. NON-RADIAL TRACKS

The angle formed by a track and the orthogonal to the cathode influences the reconstruction at two levels: **shift & spread**

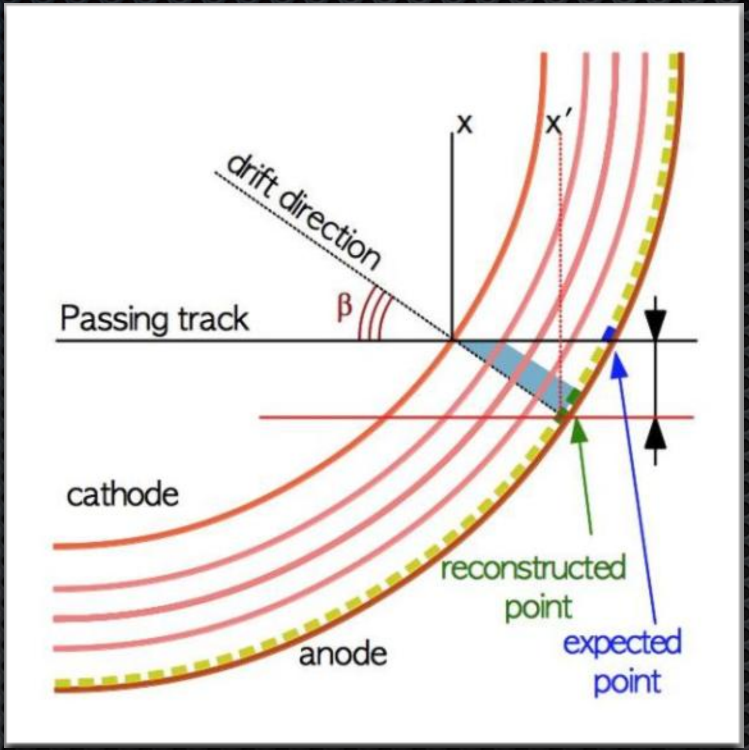


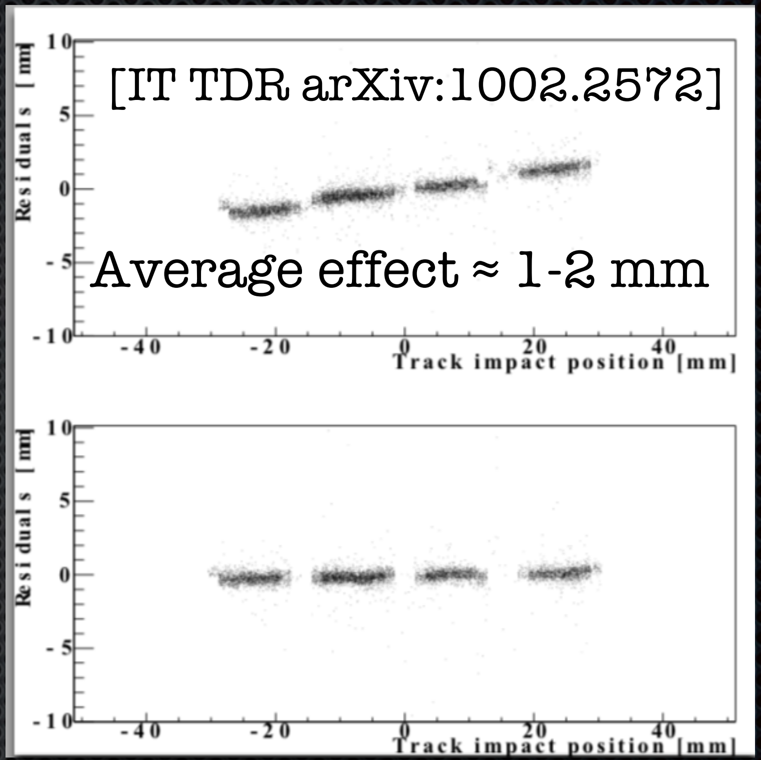


Alignment & Calibration strategy (I)

1. NON-RADIAL TRACKS

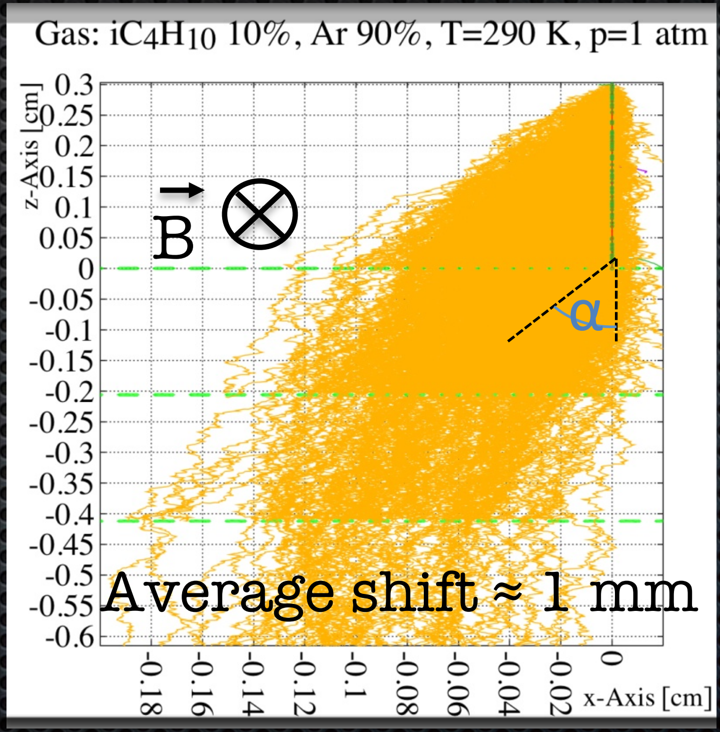
The angle formed by a track and the orthogonal to the cathode influences the reconstruction at two levels: **shift & spread**

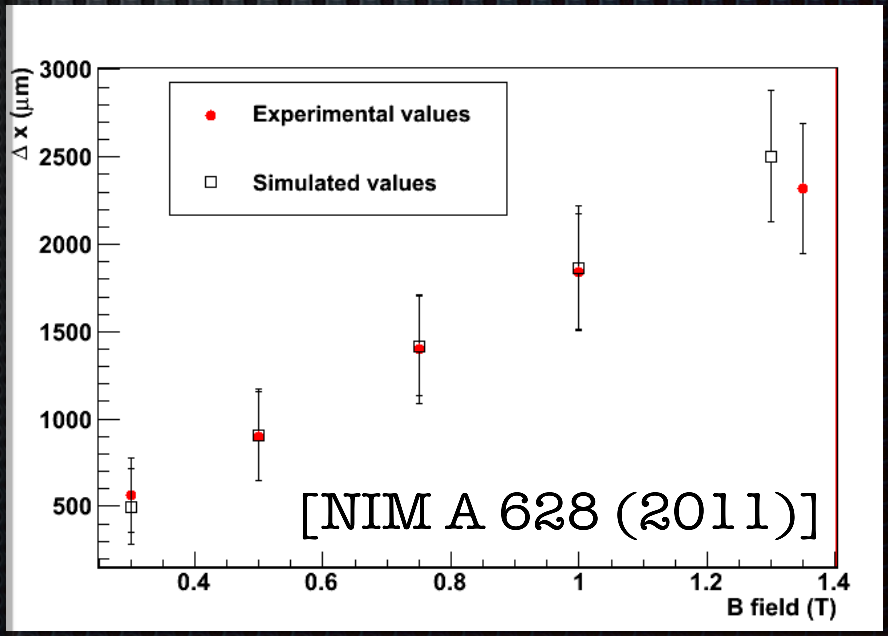




2. MAGNETIC FIELD

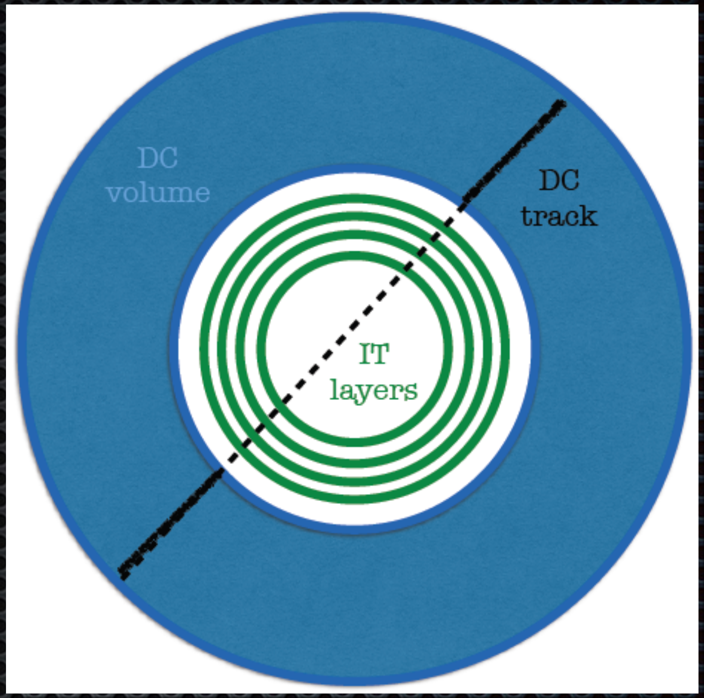
KLOE-2 0.52 T magnetic field is orthogonal to the electric fields of the triple-GEMs, introducing two effects: a **shift** $\Delta x(\alpha_L)$ and consequently a **larger spread of the electron cloud**.

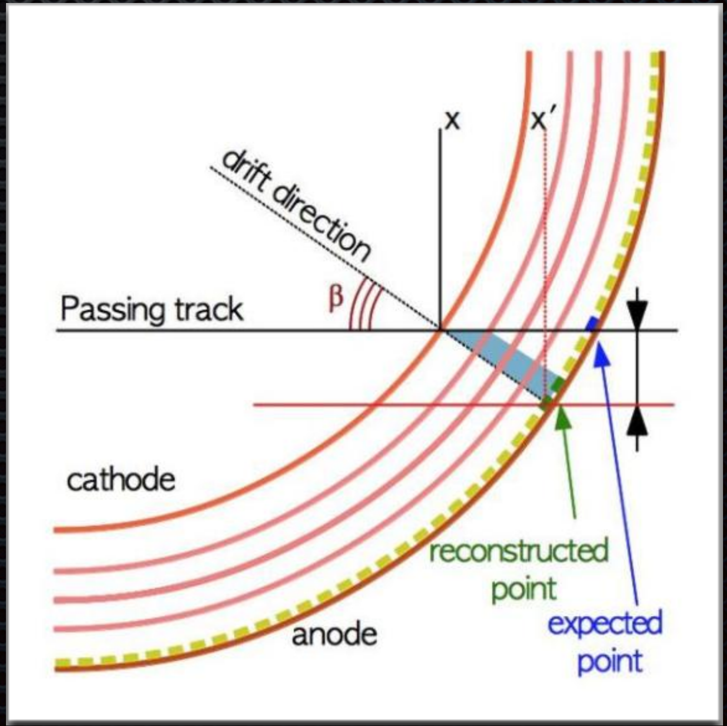




Alignment & Calibration strategy (II)

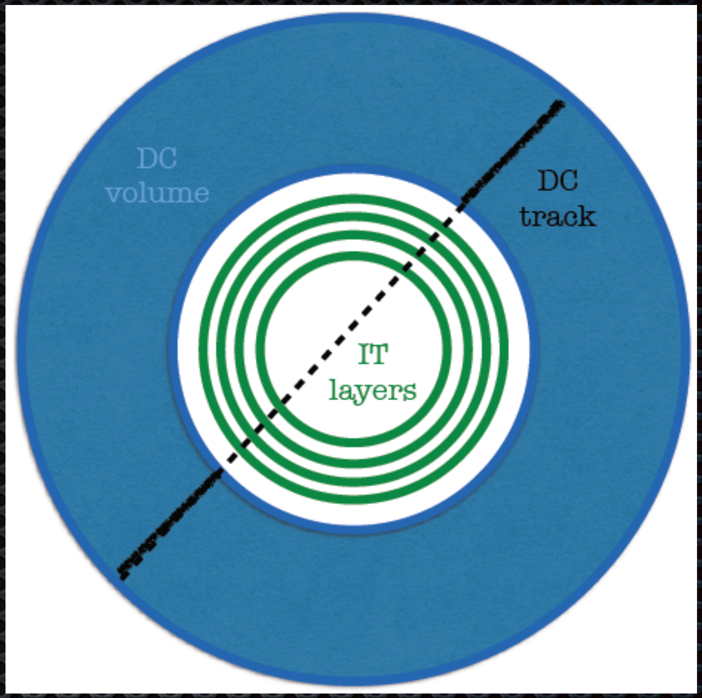
- Cosmic-ray muon data acquired with B-field OFF
  - Calibration of Non-radial track effect
  - Dedicated algorithm for DC straight track reconstruction
  - Select tracks crossing IT at 2 points
  - Corrections as a function of track parameters
  - Shifts and rotations to align the IT



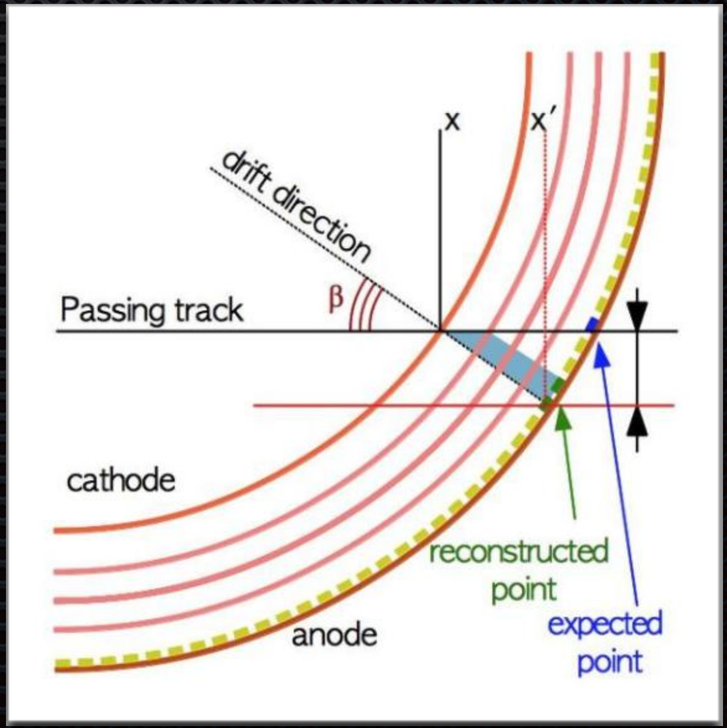


Alignment & Calibration strategy (II)

- Cosmic-ray muon data acquired with B-field OFF
  - Calibration of Non-radial track effect
  - Dedicated algorithm for DC straight track reconstruction
  - Select tracks crossing IT at 2 points
  - Corrections as a function of track parameters
  - Shifts and rotations to align the IT

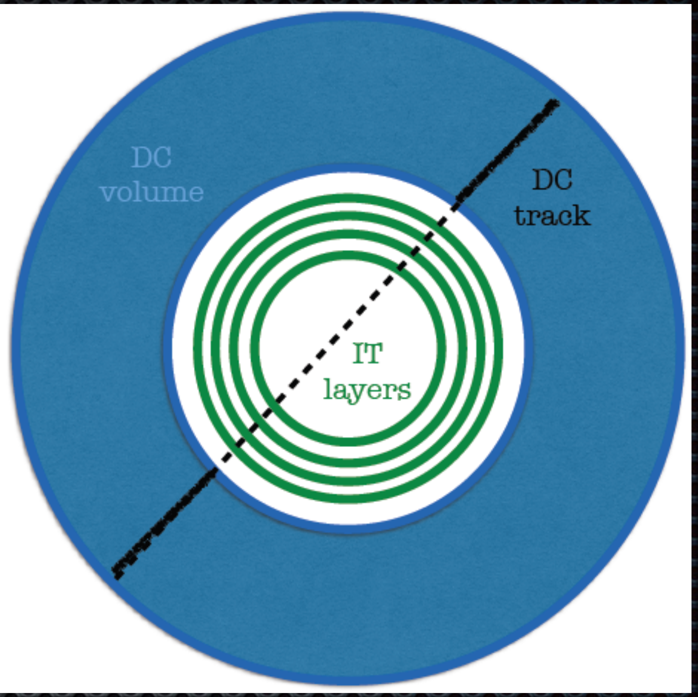


- Cosmic-ray muon data acquired with B-field ON
  - Calibration of Non-radial track & B-field effects
  - Official KLOE-2 DC track reconstruction
  - Select tracks crossing IT at 2 points
  - Apply corrections and Shifts and rotations from B-field OFF sample
  - Study and apply B-field effects corrections

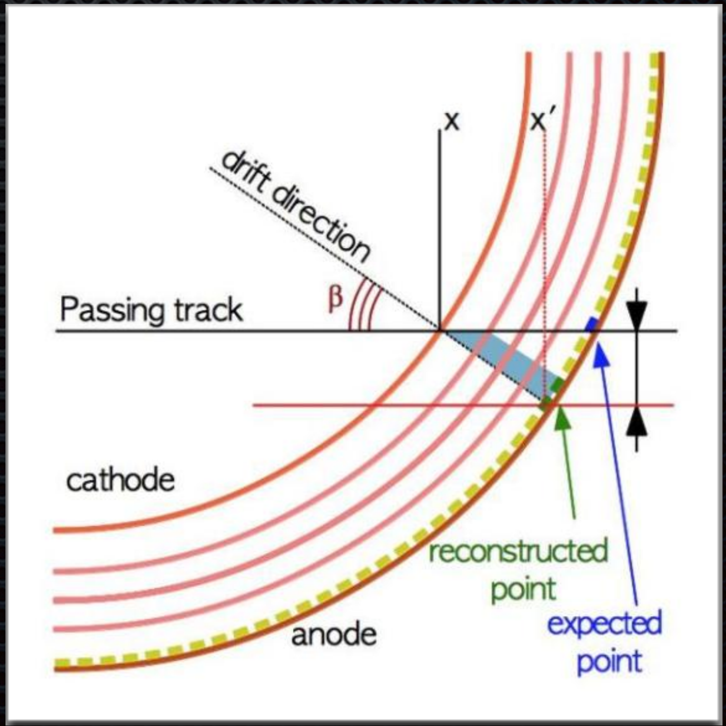


Alignment & Calibration strategy (II)

- Cosmic-ray muon data acquired with B-field OFF
  - Calibration of Non-radial track effect
  - Dedicated algorithm for DC straight track reconstruction
  - Select tracks crossing IT at 2 points
  - Corrections as a function of track parameters
  - Shifts and rotations to align the IT



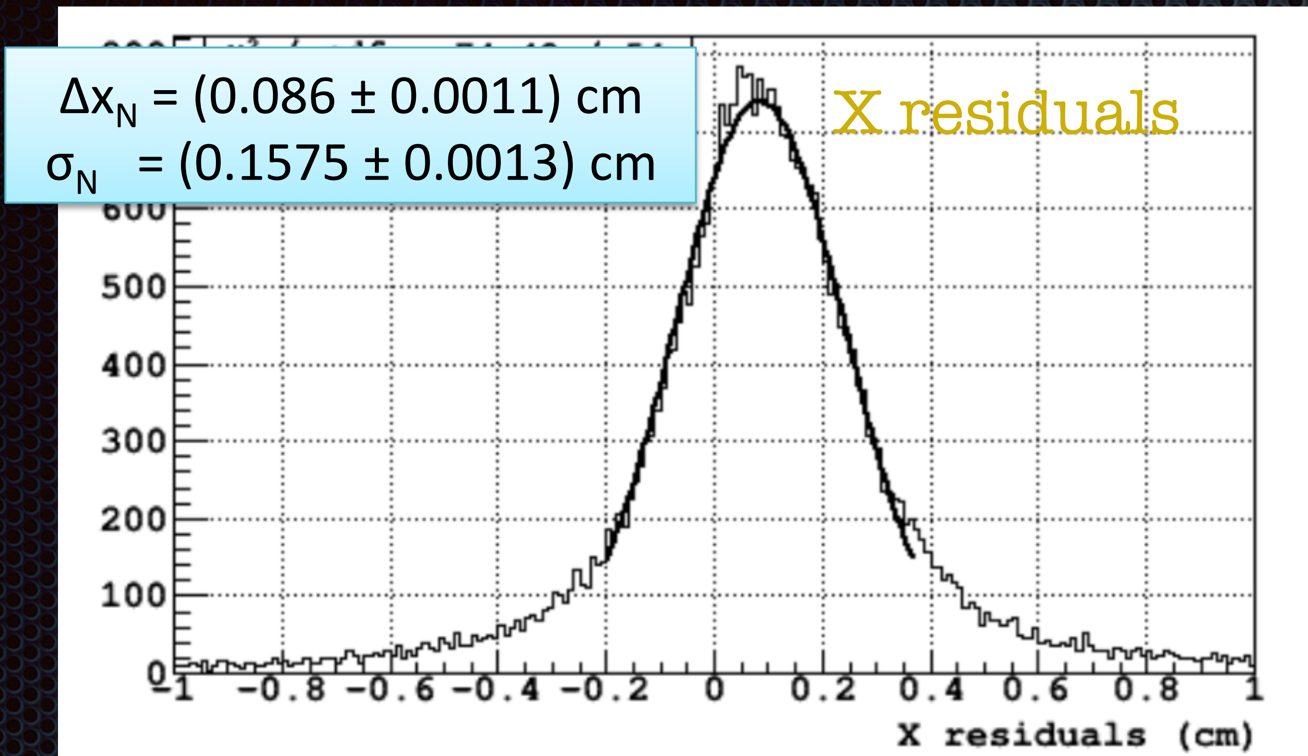
- Cosmic-ray muon data acquired with B-field ON
  - Calibration of Non-radial track & B-field effects
  - Official KLOE-2 DC track reconstruction
  - Select tracks crossing IT at 2 points
  - Apply corrections and Shifts and rotations from B-field OFF sample
  - Study and apply B-field effects corrections

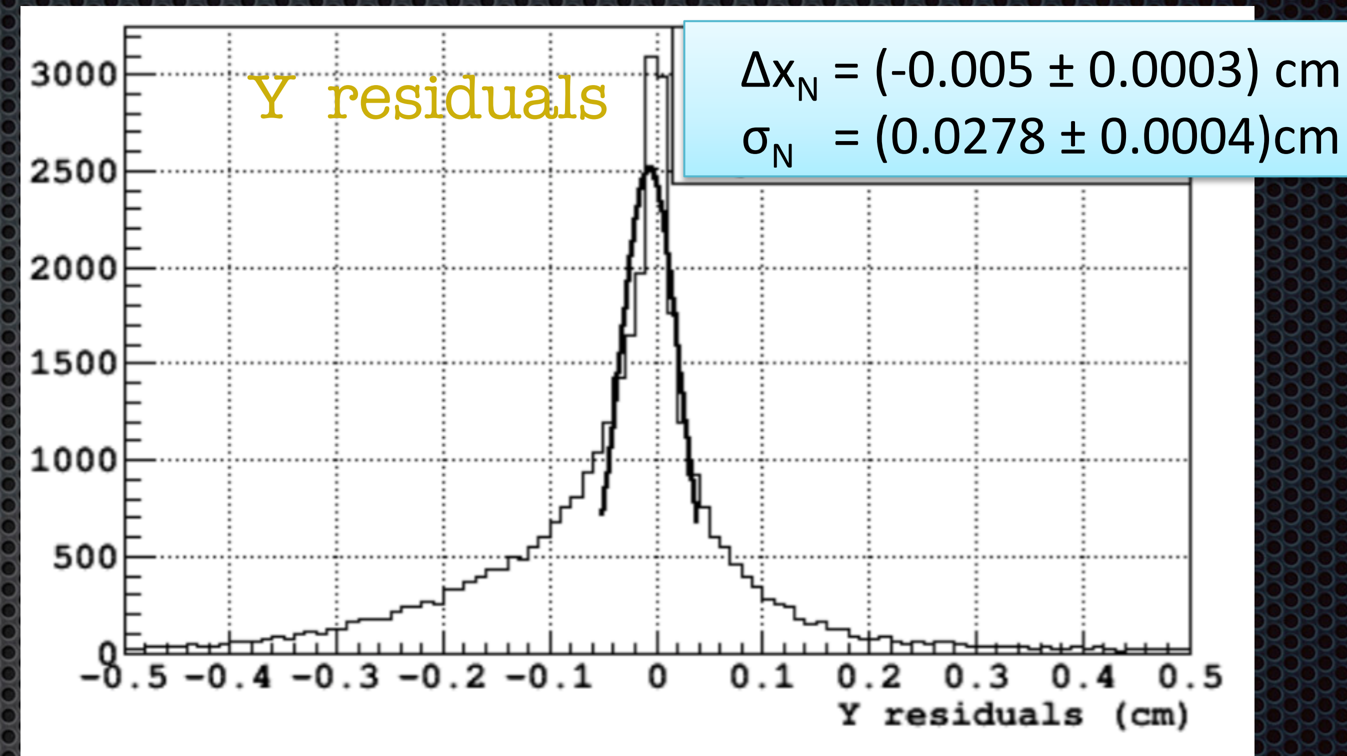


- Bhabha scattering events
  - Calibration of Non-radial track & B-field effects
  - Apply corrections and Shifts and rotations from cosmic-ray muons with B-field ON sample

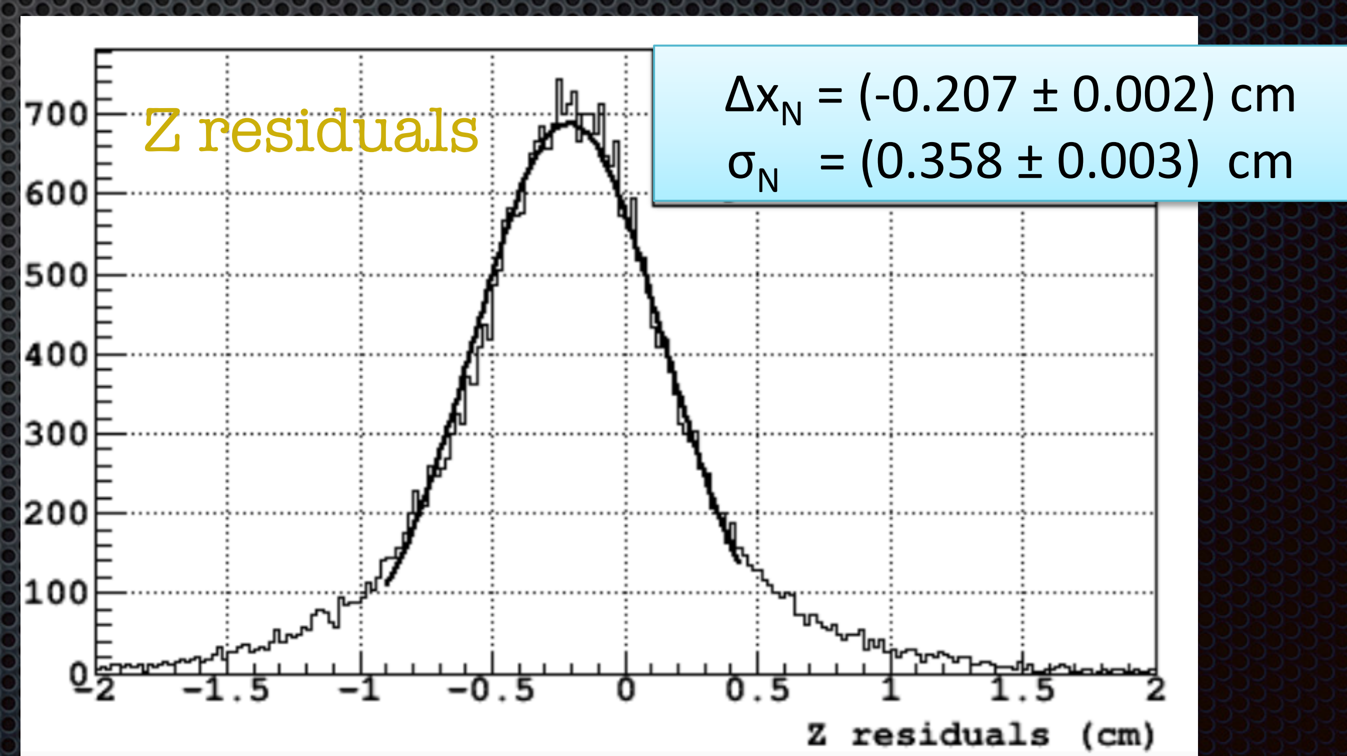
B OFF studies with cosmic-ray muons

Layer #4 residuals: starting point



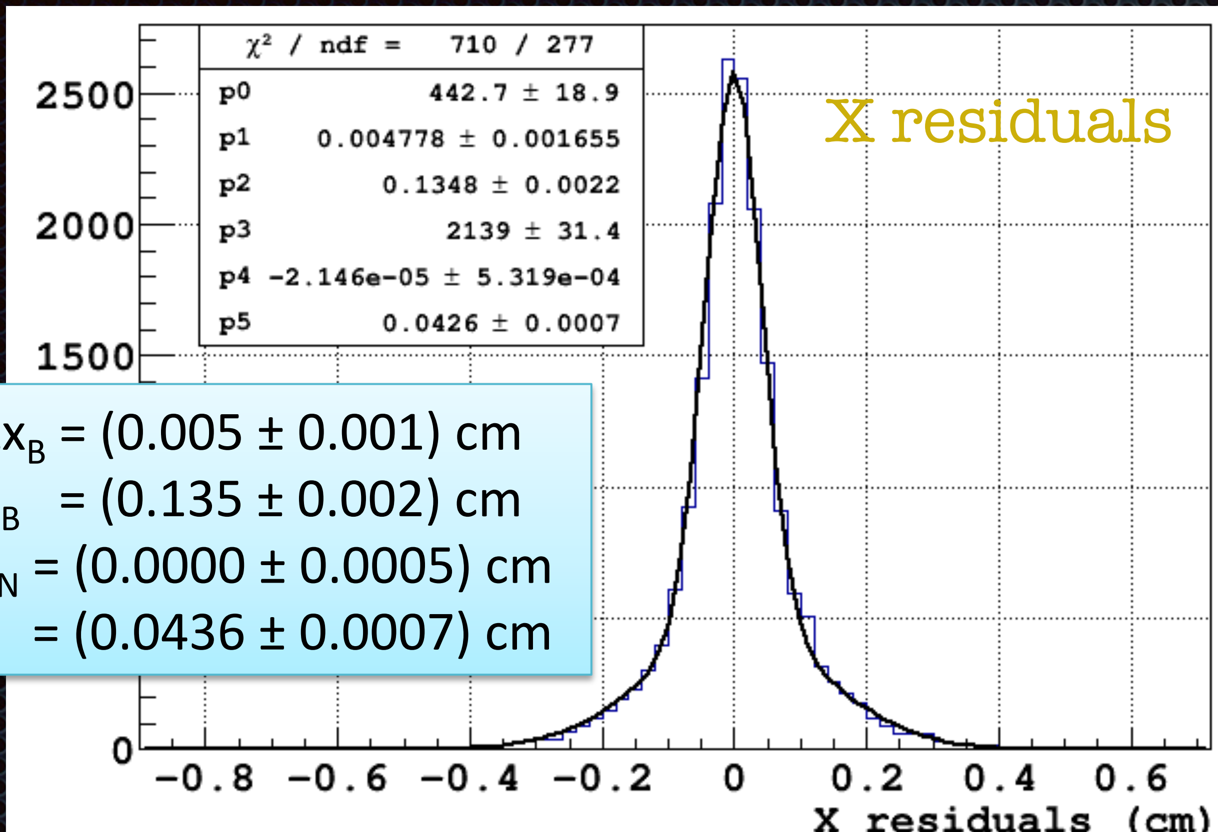


- Starting point before align & calib
  - Resx = 1.5 mm
  - Resy = 280 μm
  - Resz = 3.6 mm
  - Δx = 860 μm
  - Δy = - 50 μm
  - Δz = 2 mm

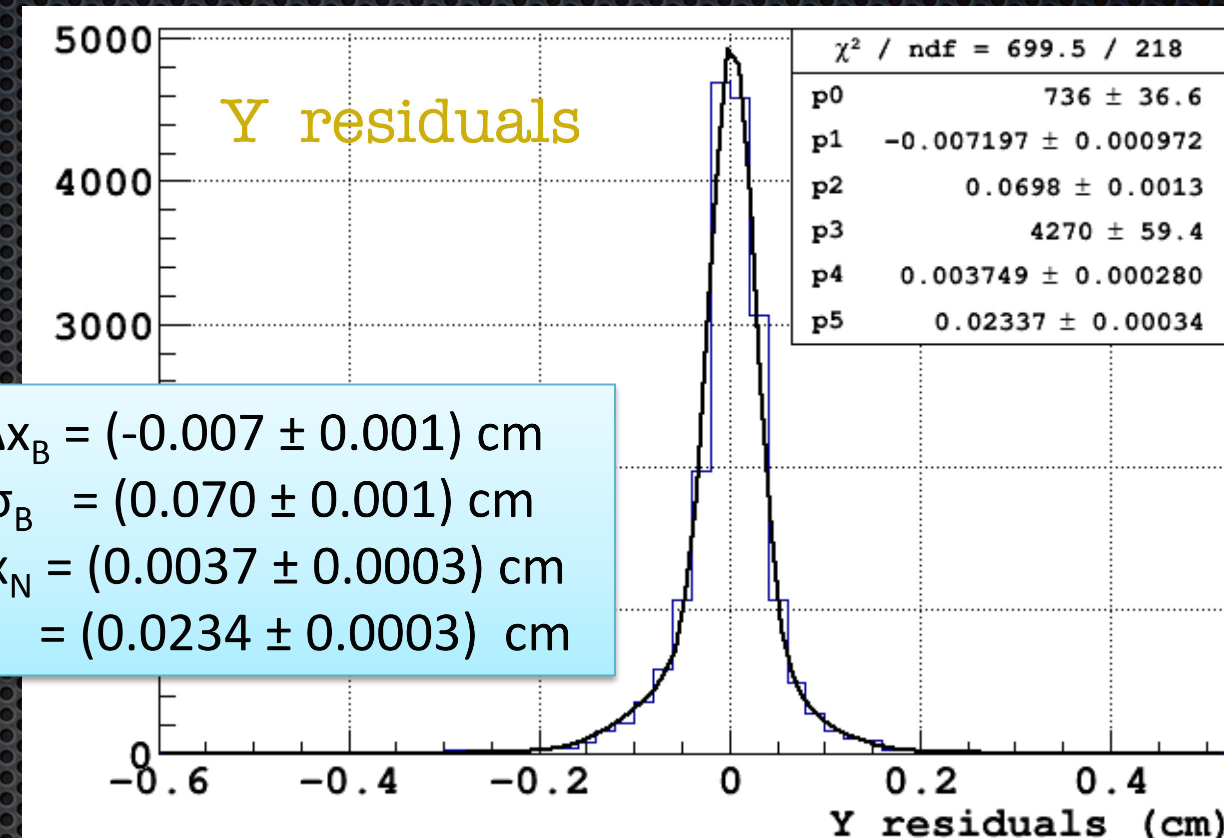


Convolution of DC + IT resolution

Layer #4: after 1st align & calib



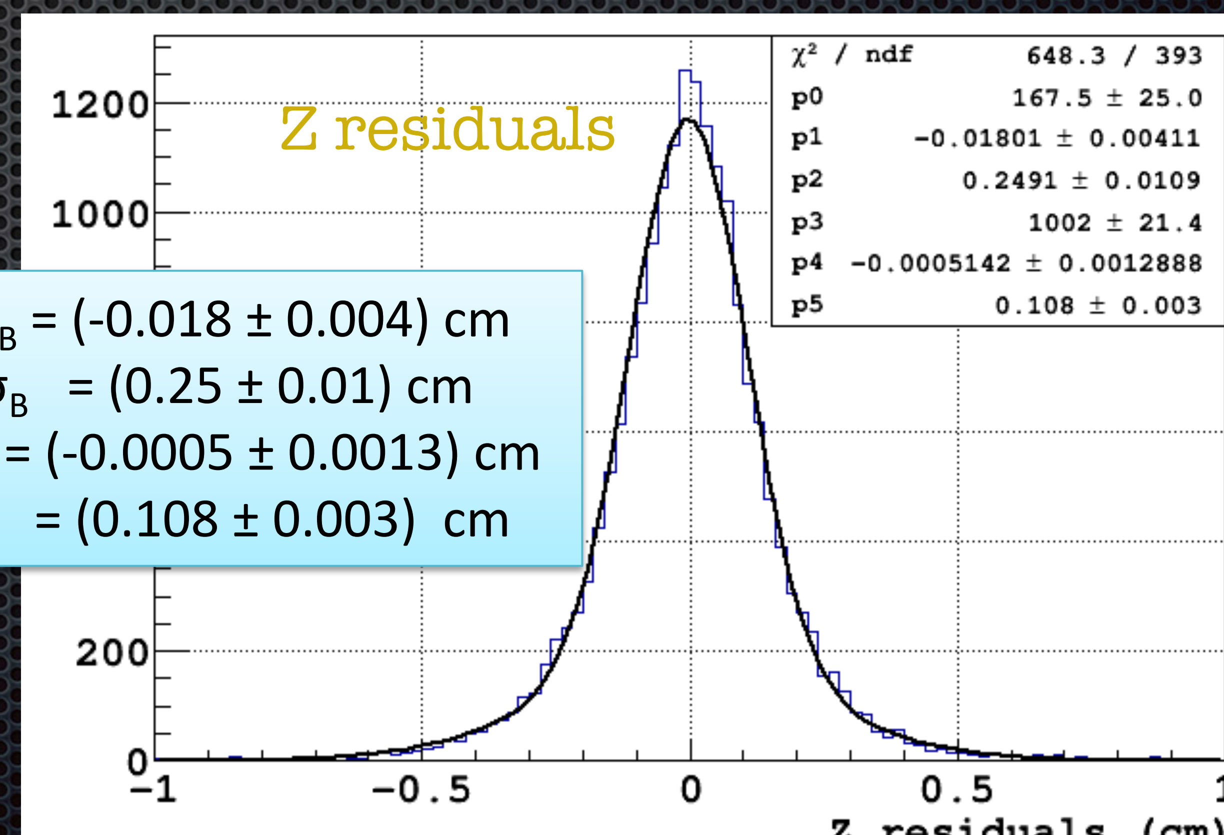
Δx_B = (0.005 ± 0.001) cm
σ_B = (0.135 ± 0.002) cm
Δx_N = (0.0000 ± 0.0005) cm
σ_N = (0.0436 ± 0.0007) cm



Δx_B = (-0.007 ± 0.001) cm
σ_B = (0.070 ± 0.001) cm
Δx_N = (0.0037 ± 0.0003) cm
σ_N = (0.0234 ± 0.0003) cm

- Improvement with 1st align & calib
  - Resx = 1.5 mm => 440 µm
  - Resy = 280 µm => 240 µm
  - Resz = 3.6 mm => 1.1 mm
  - Δx = 860 µm => 50 µm
  - Δy = - 50 µm => -50 µm
  - Δz = 2 mm => 5 µm

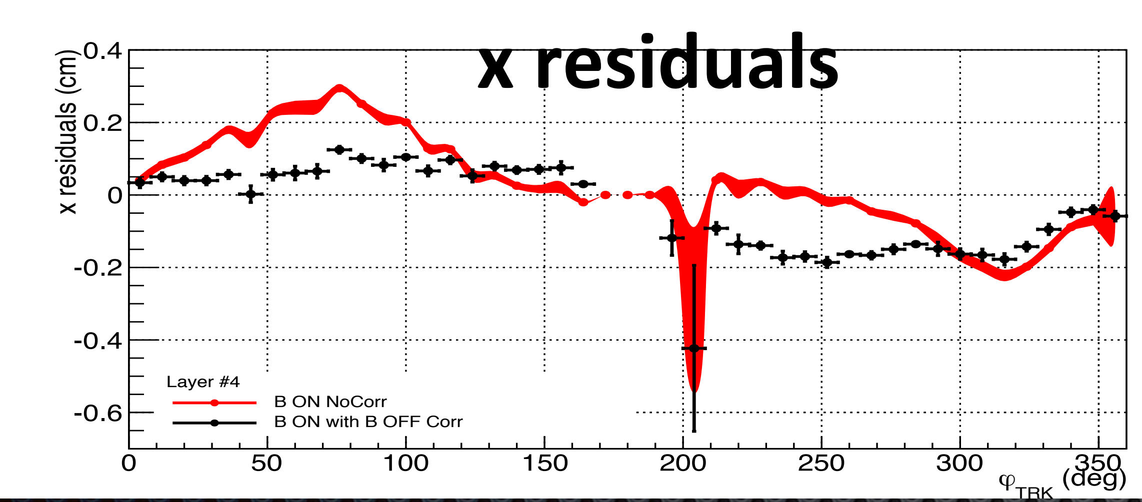
Convolution of DC + IT resolution



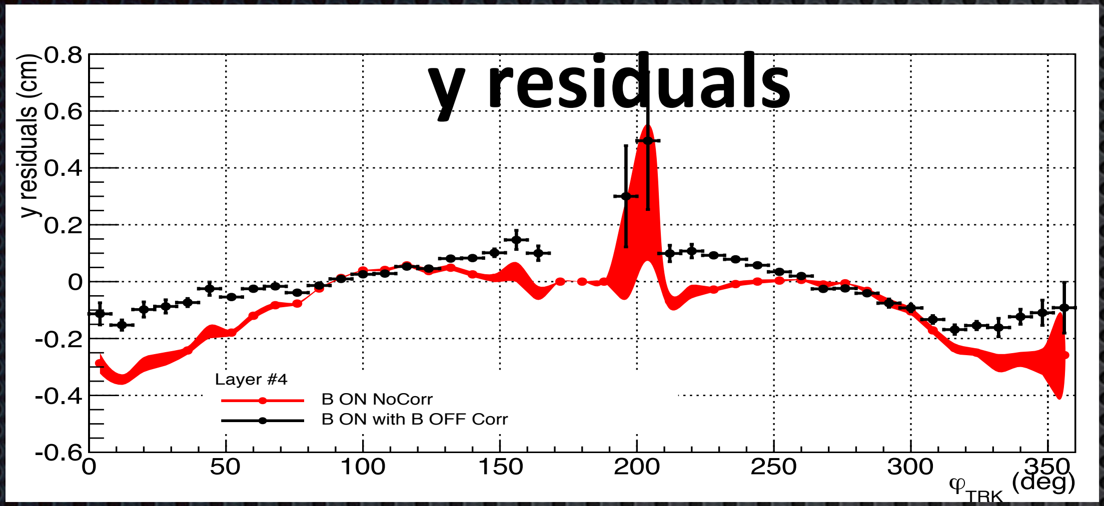
Δx_B = (-0.018 ± 0.004) cm
σ_B = (0.25 ± 0.01) cm
Δx_N = (-0.0005 ± 0.0013) cm
σ_N = (0.108 ± 0.003) cm

B ON studies with cosmic-ray muons

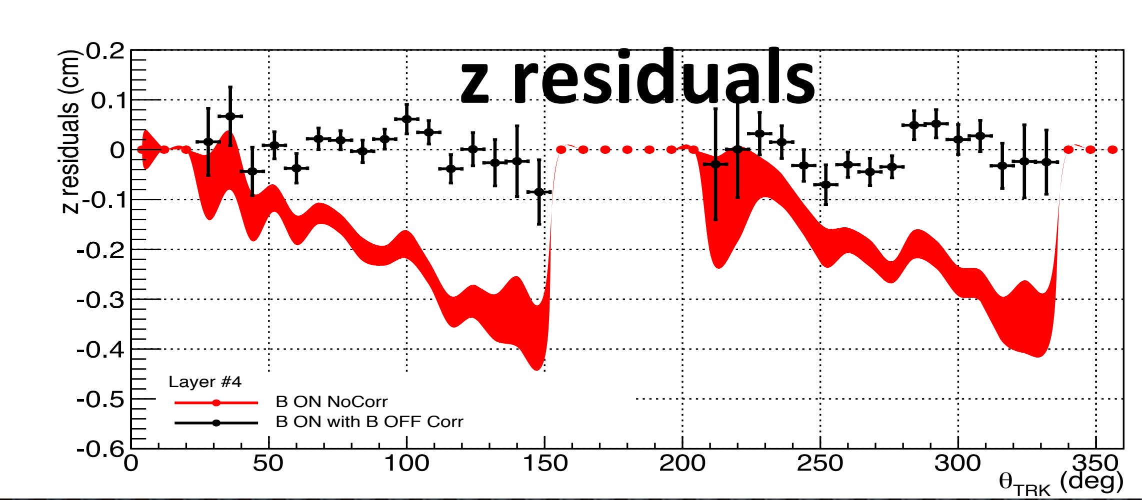
Layer #4 with corrections from B OFF

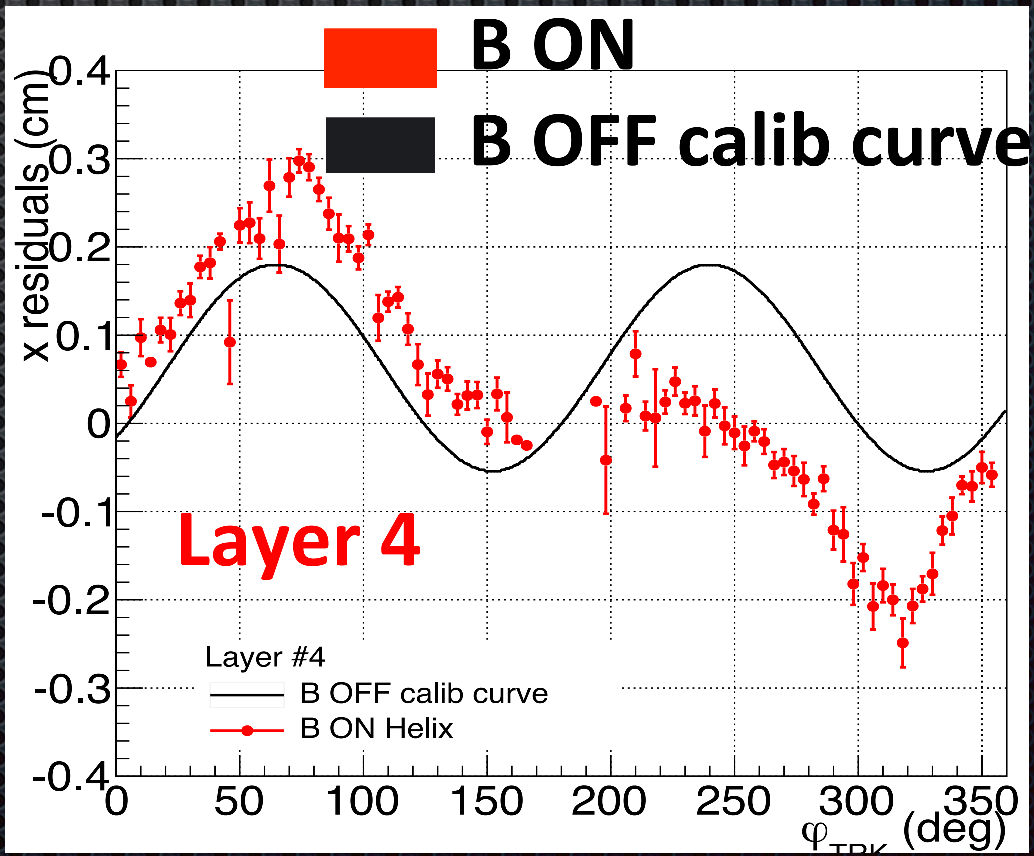


Layer4 cosmic-rays muons w B ON
Before BOFF corrections
After BOFF corrections



TOP/BOTTOM residual B-field effect in the transverse plane after BOFF corrections



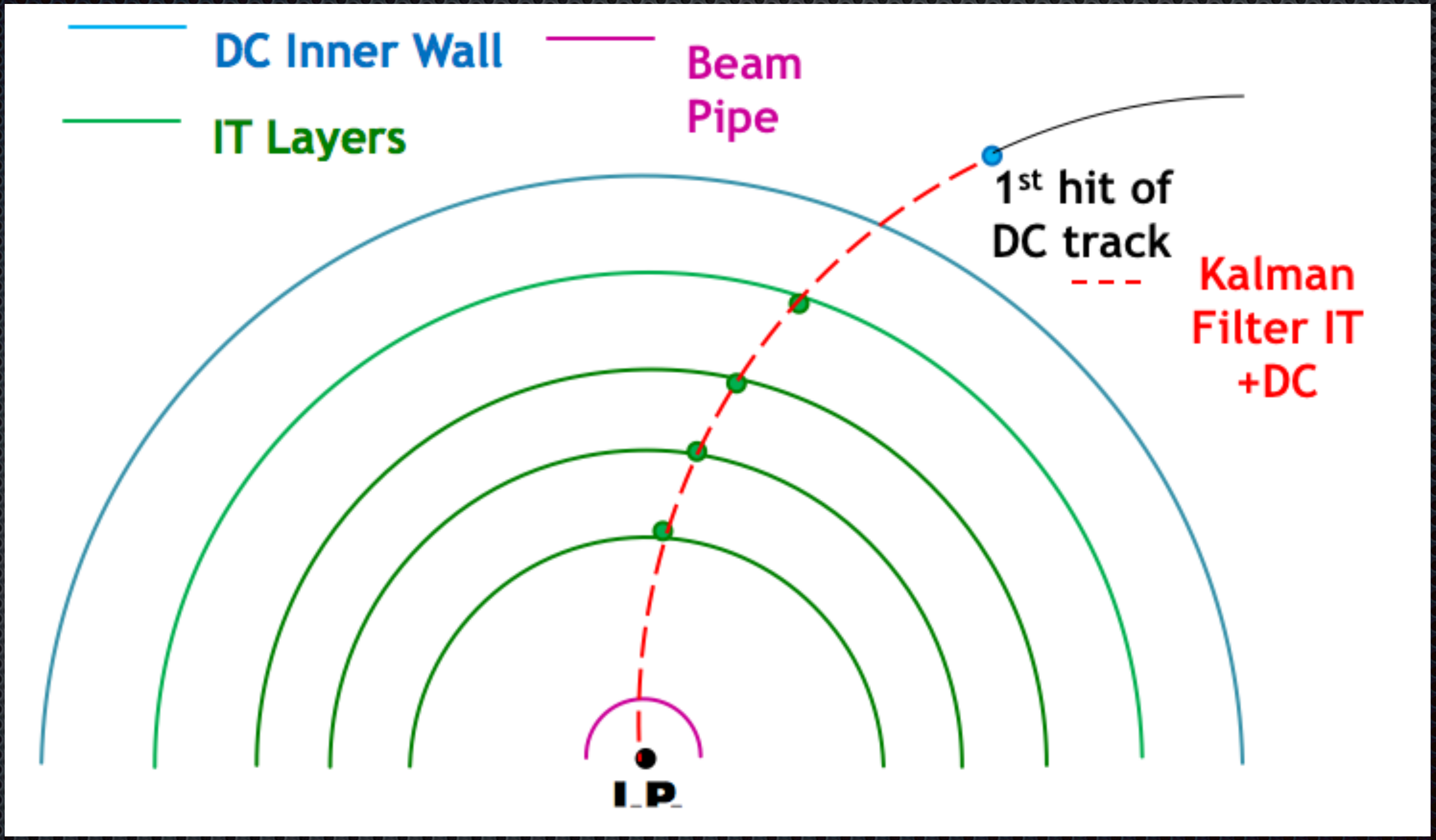


Convolution of DC + IT resolution

Tracking with the IT

IT tracking with Kalman & DC (I)

- Starting with DC tracks
- IT Clusters reconstructed are added
- IT+DC Kalman filter
- Reconstruction procedure developed and tested with MC samples

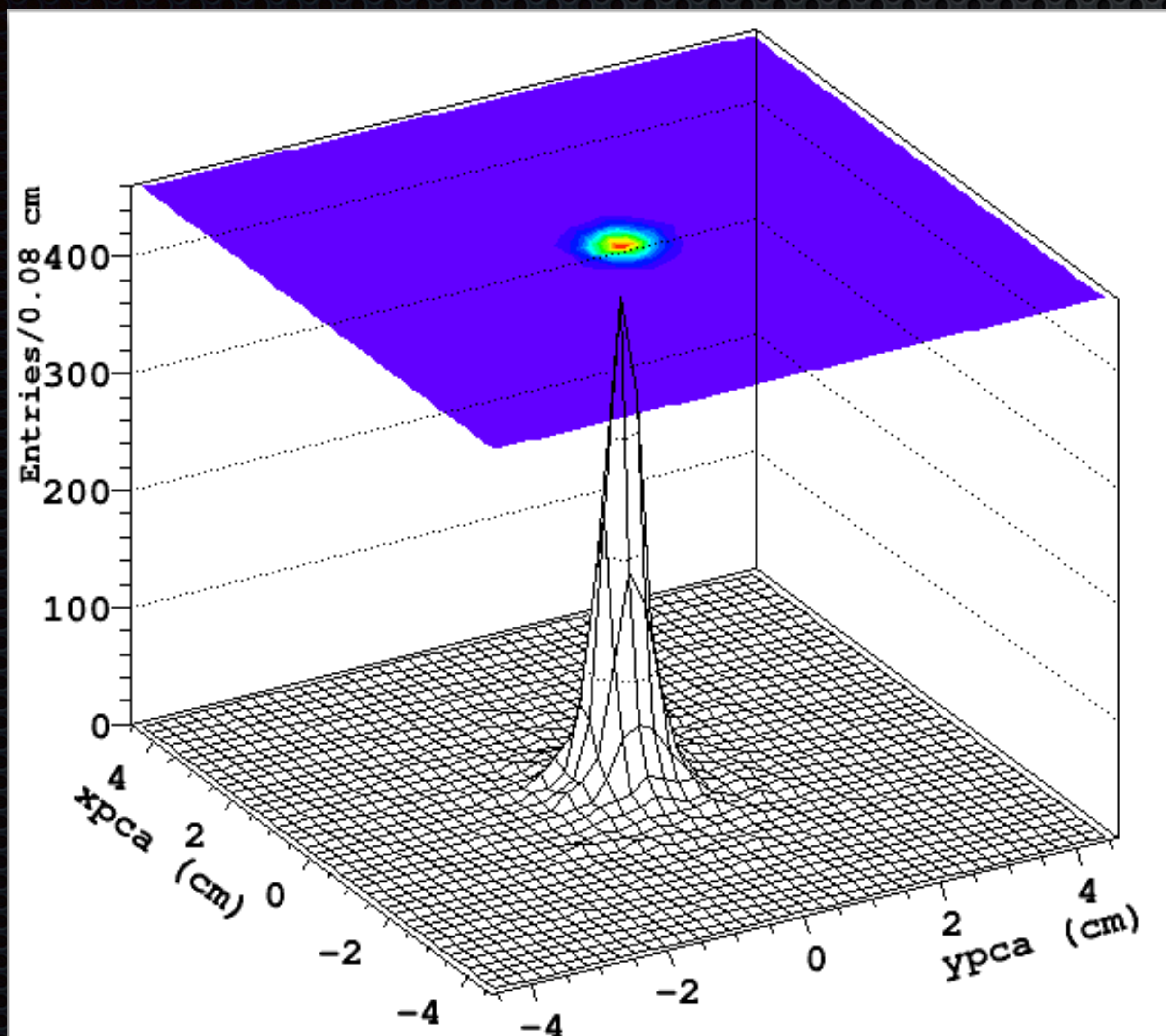


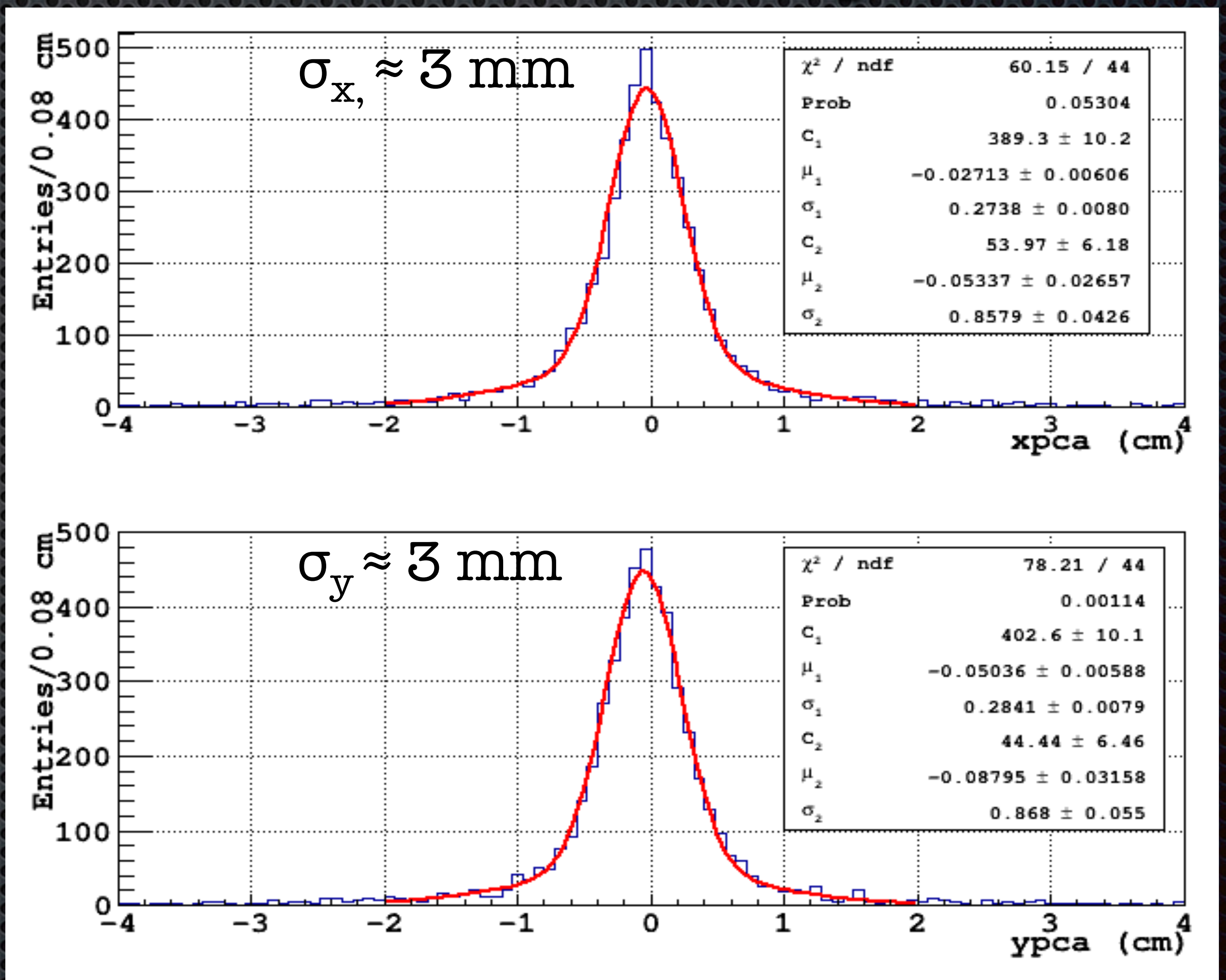
- Validation with cosmic-ray muon data & Bhabha scattering events
- Alignment and calibration parameters from B OFF/ON control samples

IT tracking with Kalman & DC (II)

- Preliminary Point of Closest Approach (PCA) of the track to beam-line without alignment and calibration for B-field & non-radial tracks

Bhabha scattering events





Conclusions

- **First CGEM detector used in high-energy physics experiment**

- **Operation working point set.**

Compromise between good efficiency and stable detector operation

- **Detector Alignment and calibration.**

Challenging. Never done before.

Control sample defined and clear path to final target set.

Resx ≈ 400 μm and Resy ≈ 250 μm preliminary results obtained with cosmic-ray muons with B-field Off

- **IT+DC tracking with Kalman filter**

Reconstruction procedure developed and tested with MC samples.

Validation with cosmic-ray muons and Bbhabha scattering events

SPARE SLIDES

IT Operation with collisions