Design of a control and monitoring system for the mirror alignment of the CBM RICH detector

DPG 2016 Darmstadt

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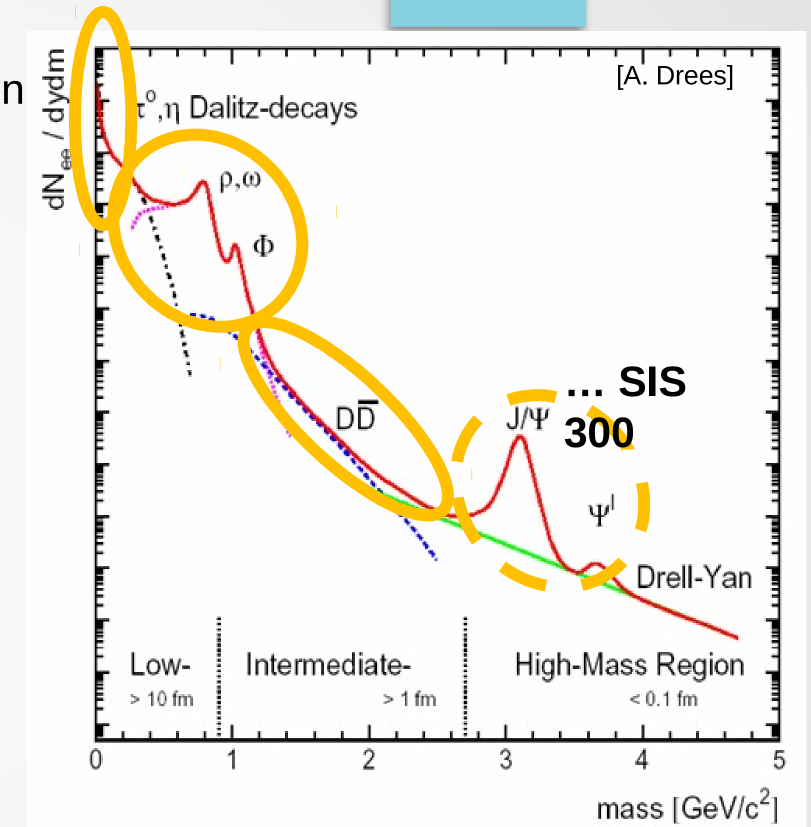
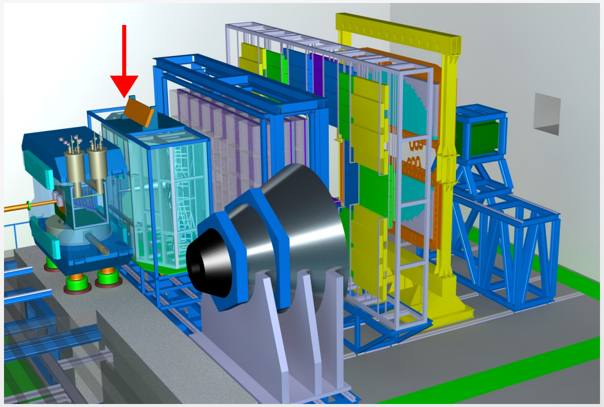
Introduction

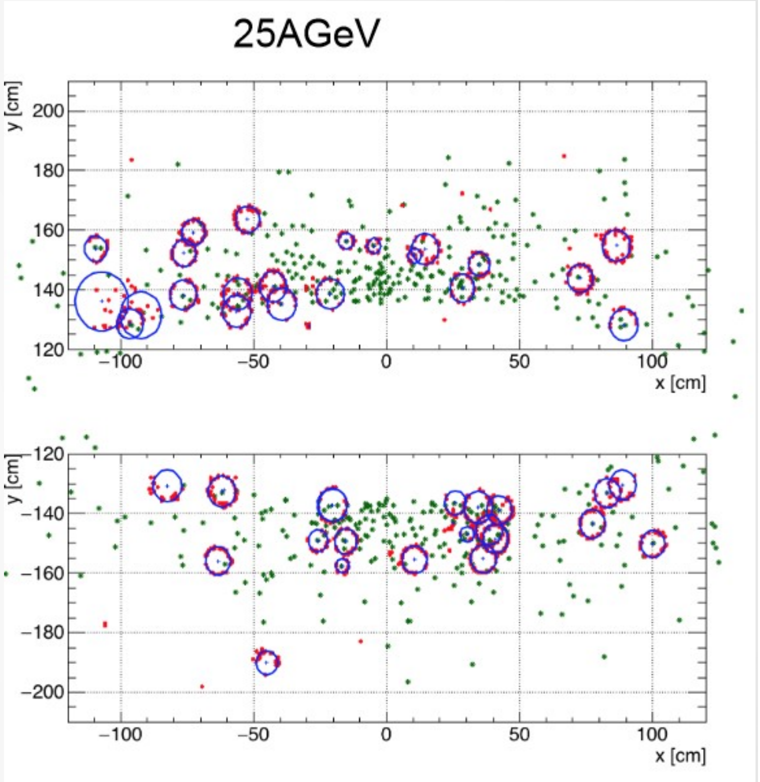
- CBM at FAIR: explore the QCD phase diagram in the region of high baryon density with A+A collisions
- Energy range (Au-Au) from 2 to 11 AGeV beam energy @SIS100 (up to 35 AGeV @SIS300)
- EM probes
  - In low-mass region
    Photons: early temperatures of the fireball
    Low mass vector mesons: hadron dynamics
  - Intermediate-mass region
    Slope: indicates thermal radiation of the fireball
    Also hints for a quarkyonic phase?
  - High-mass region (SIS 300)
    J/Ψ: investigation of the charm quark propagation
- Identify electrons with RICH detector

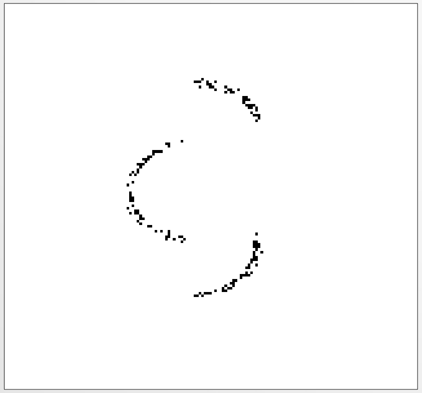


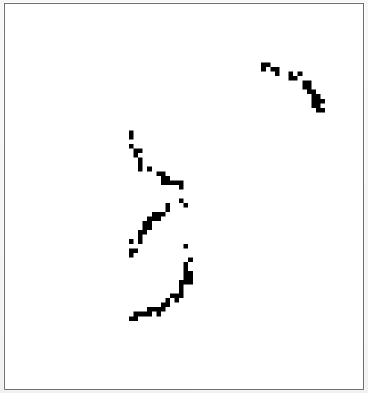


Introduction

- CBM: high ring density environment & RICH will be moved
- In case of misalignment:
  - Efficiency losses in ring reconstruction: ring splitting, ring distortion, double rings, ring-track mismatches
  - Misidentification due to distorted ring parameters
- Perfectly aligned and stable mirror system is required for accurate and highly efficient ring reconstruction
- Development of an alignment correction cycle



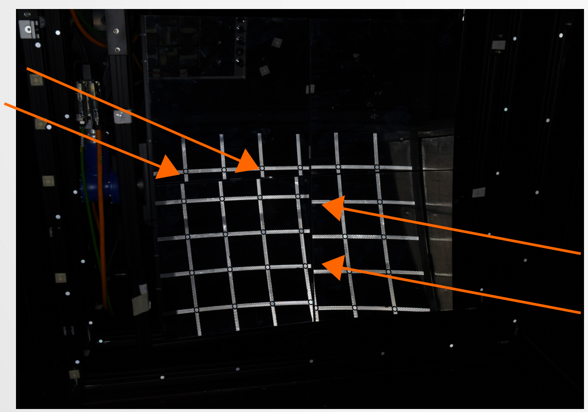




Outline

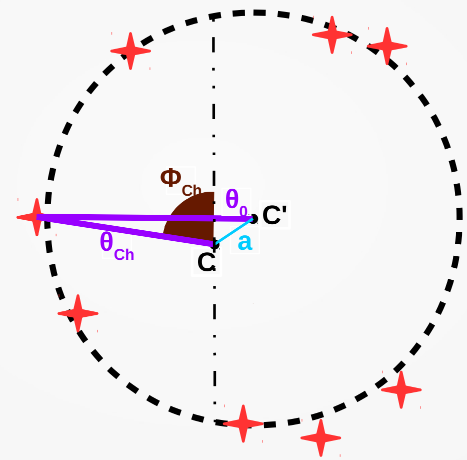
I. Qualitative control of mirror misalignments
- CLAM method

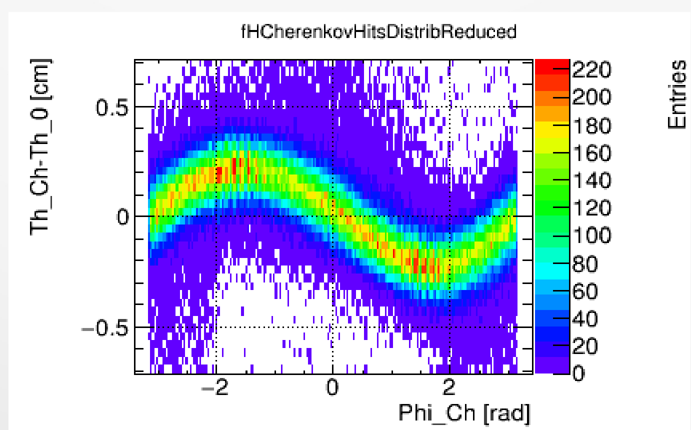
Impact on ring parameters:
- A&B axes, B/A
- dR
- Radius



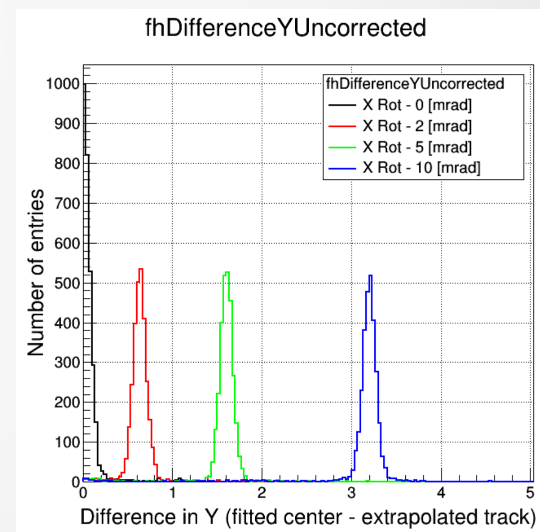
In case of misalignment, lines appear broken and the targets are now displaced, with regard to the external ones

II. Quantitative determination of mirror misalignments
- Using data: HERA-b
- Hardware: CLAM



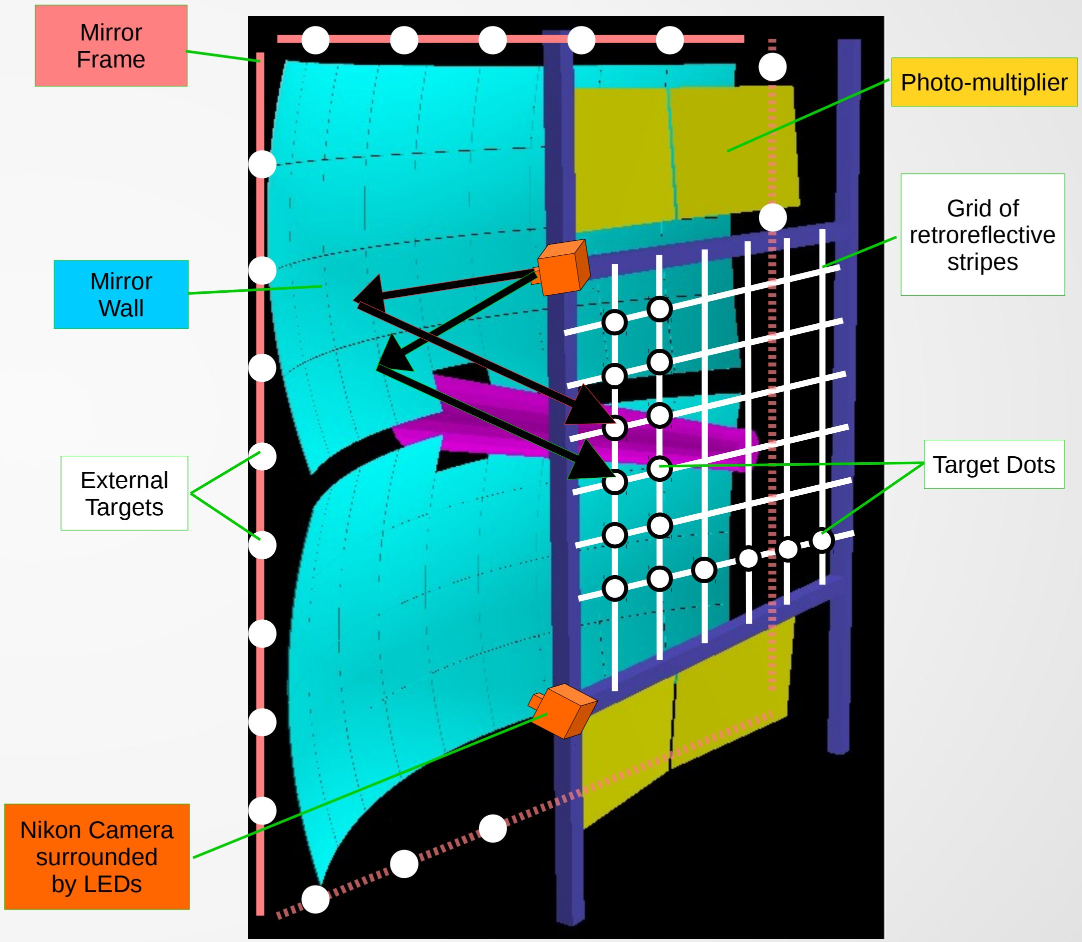


III. Correction of misalignments in data
- Impact of misalignment
- Comparison with and without corrections



CLAM principle*

- Qualitative control measurement
  - Grid of retro-reflective stripes
  - Illuminate grid with LEDs
  - Record grid reflection through the mirrors
    - Perfect grid → alignment
    - Broken lines → misalignment
- Quantitative position measurement
  - Target dots on grid crossings
  - Target dots on external frame



* Developed by the COMPASS experiment – Nucl. Instr. Meth. Phys. Res. A 553 (2005) 135

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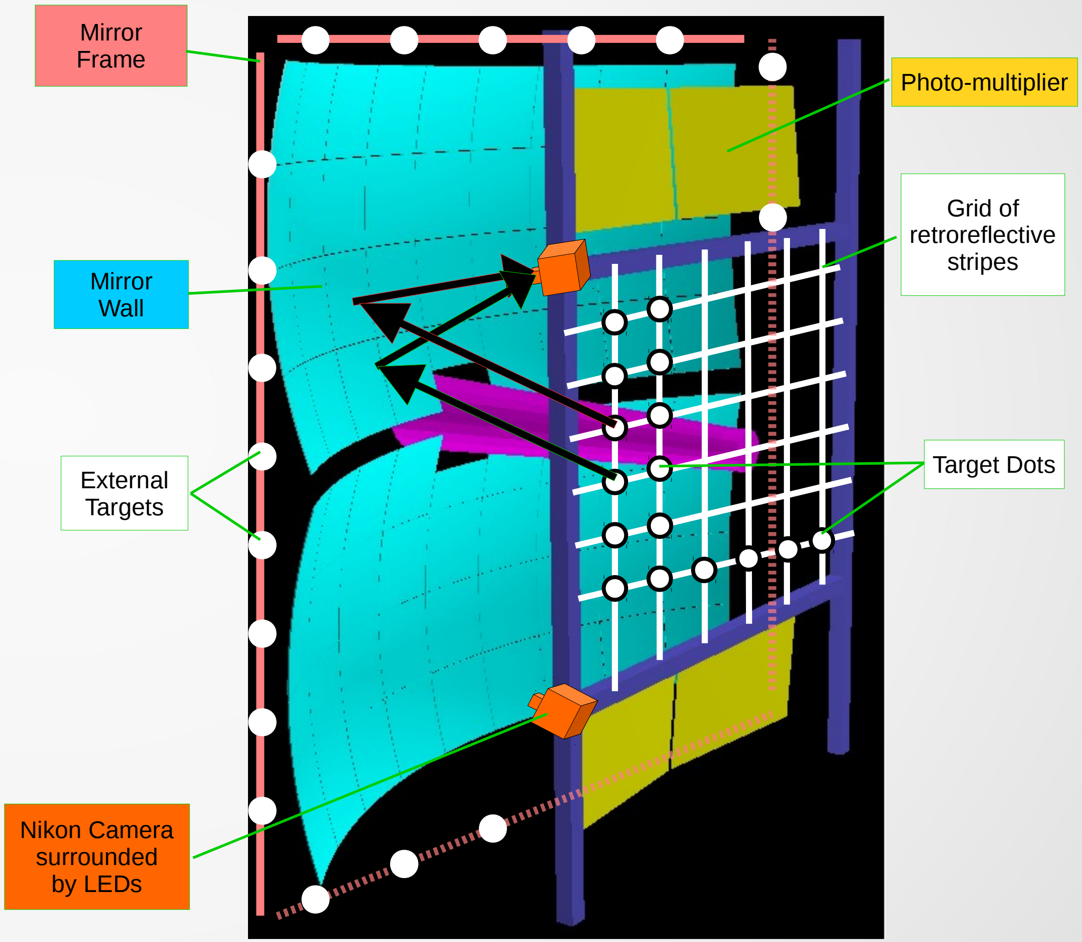
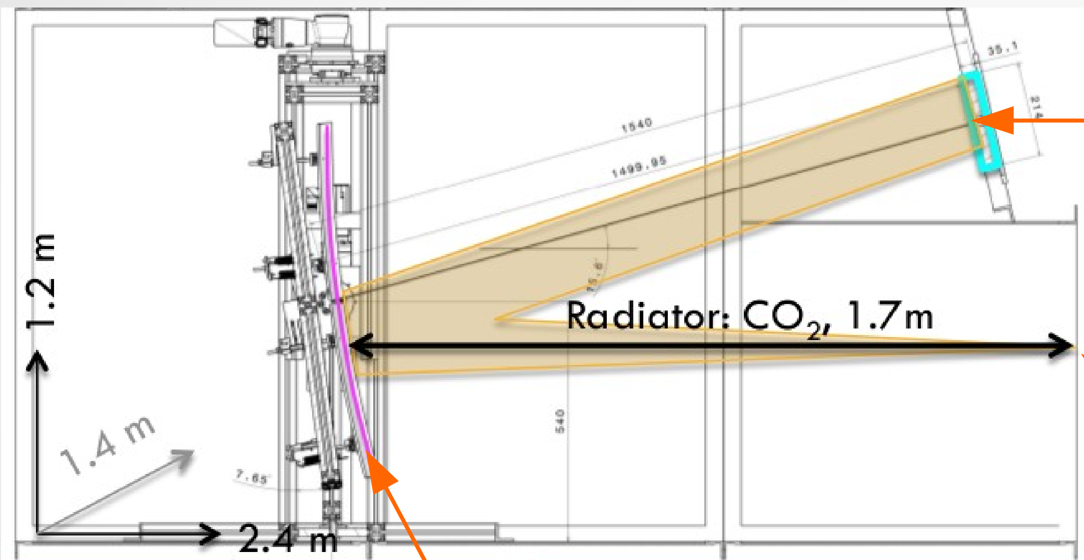


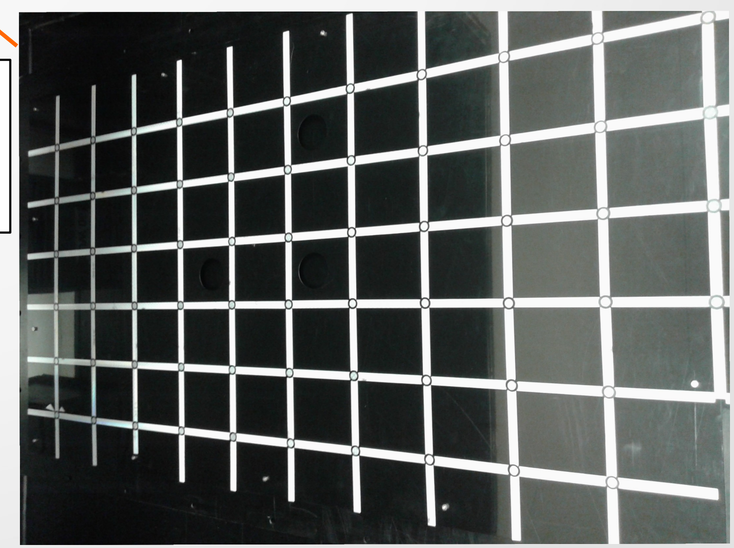
Prototype set-up and equipment

- Test setup in RICH prototype for beamtest at CERN Nov 2014

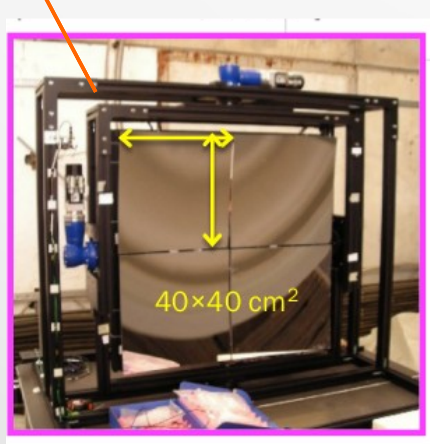


CLAM camera surrounded by 3 LEDs

Retro-reflective grid
&
Target dots at entrance

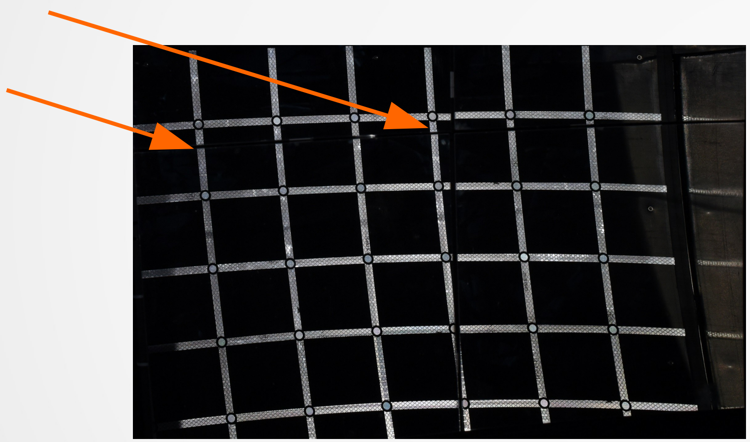


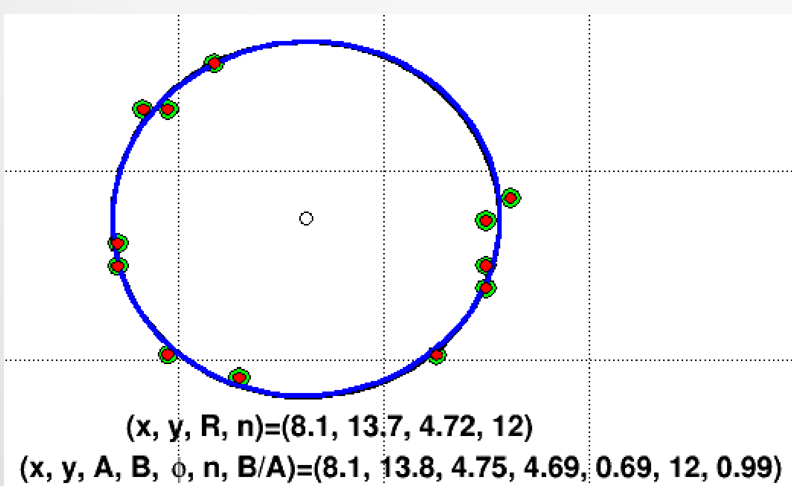
Four-mirror system remotely controlled



Qualitative misalignment study

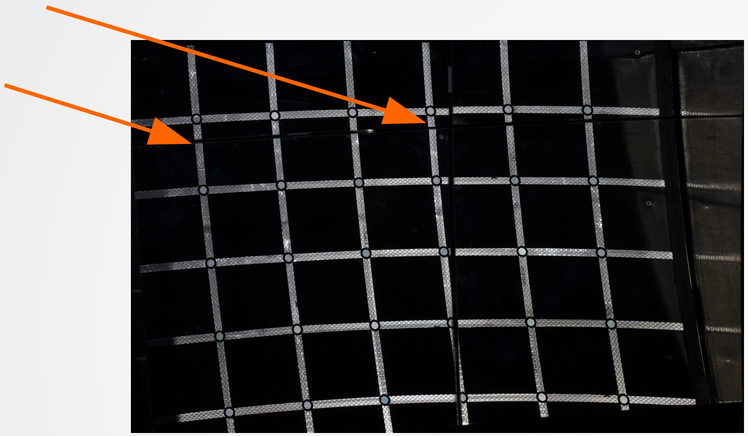
- Mirror system viewed by the CLAM camera and reconstructed rings
  - Left: right after the reference alignment

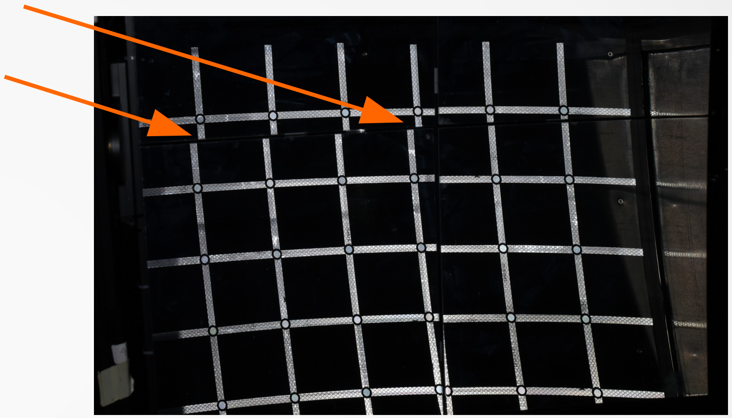


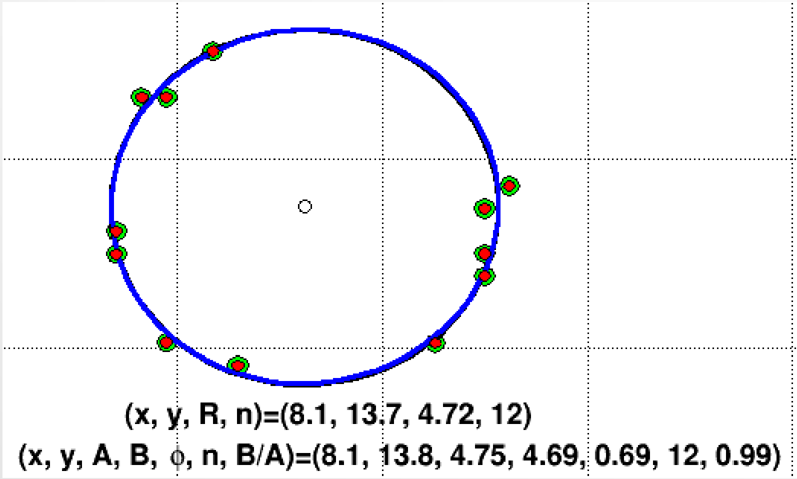


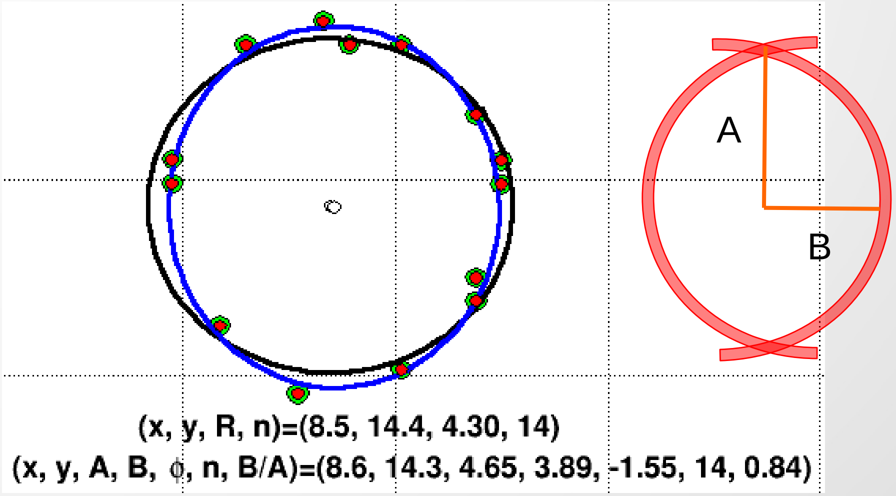
Qualitative misalignment study

- Mirror system viewed by the CLAM camera and reconstructed rings
  - Left: right after the reference alignment
  - Right: lower left mirror rotated by 4 mrad Backwards around Y axis







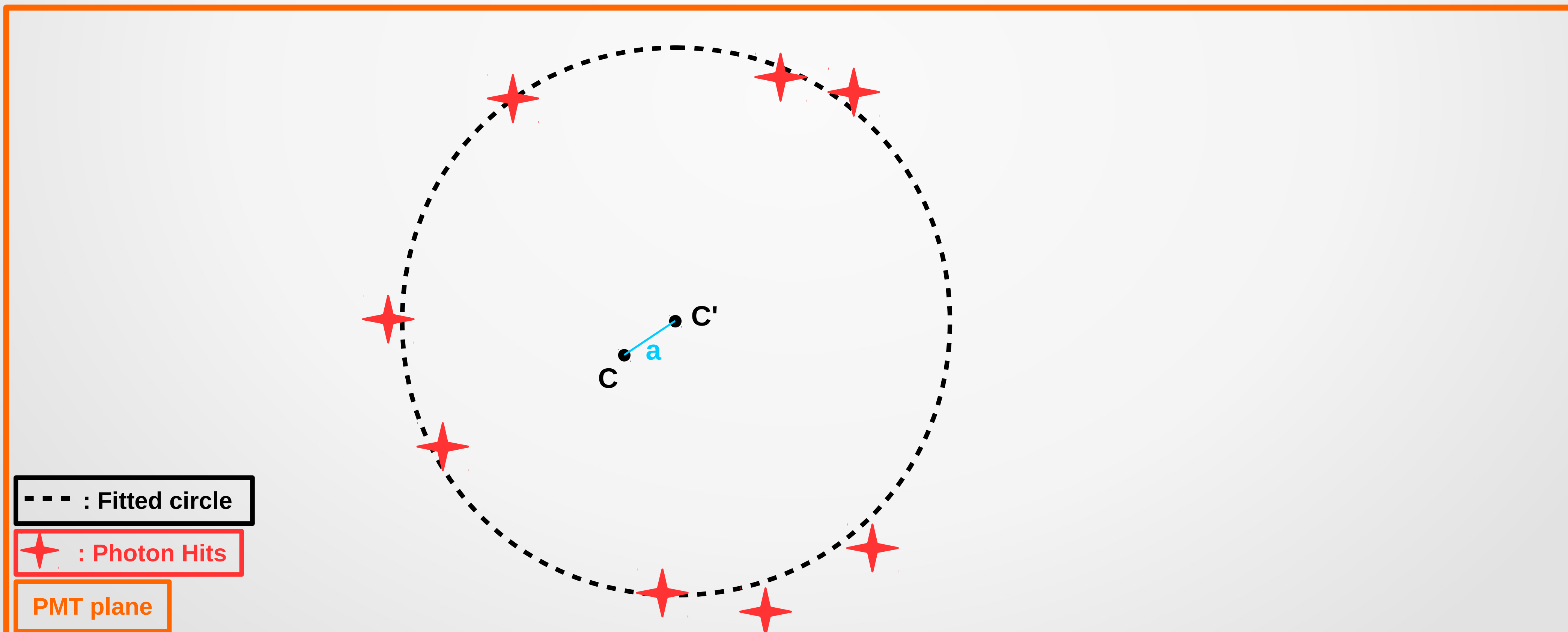


➔ Data have been recorded and a detailed analysis on the impact of misalignment on ring parameters has been conducted

Principle of the correction with data*

- Fitted ring center C' and extrapolated track hit C
- Calculation of Cerenkov distances θ_{ch} and angles Φ_{ch}
- Sinusoidal behaviour: $\theta_{ch} = \theta_0 + \Delta\Phi * \cos(\Phi_{ch}) + \Delta\lambda * \sin(\Phi_{ch})$

* Developed by the HERA-B experiment – Nucl. Instr. Meth. Phys. Res. A 433 (1999) 408



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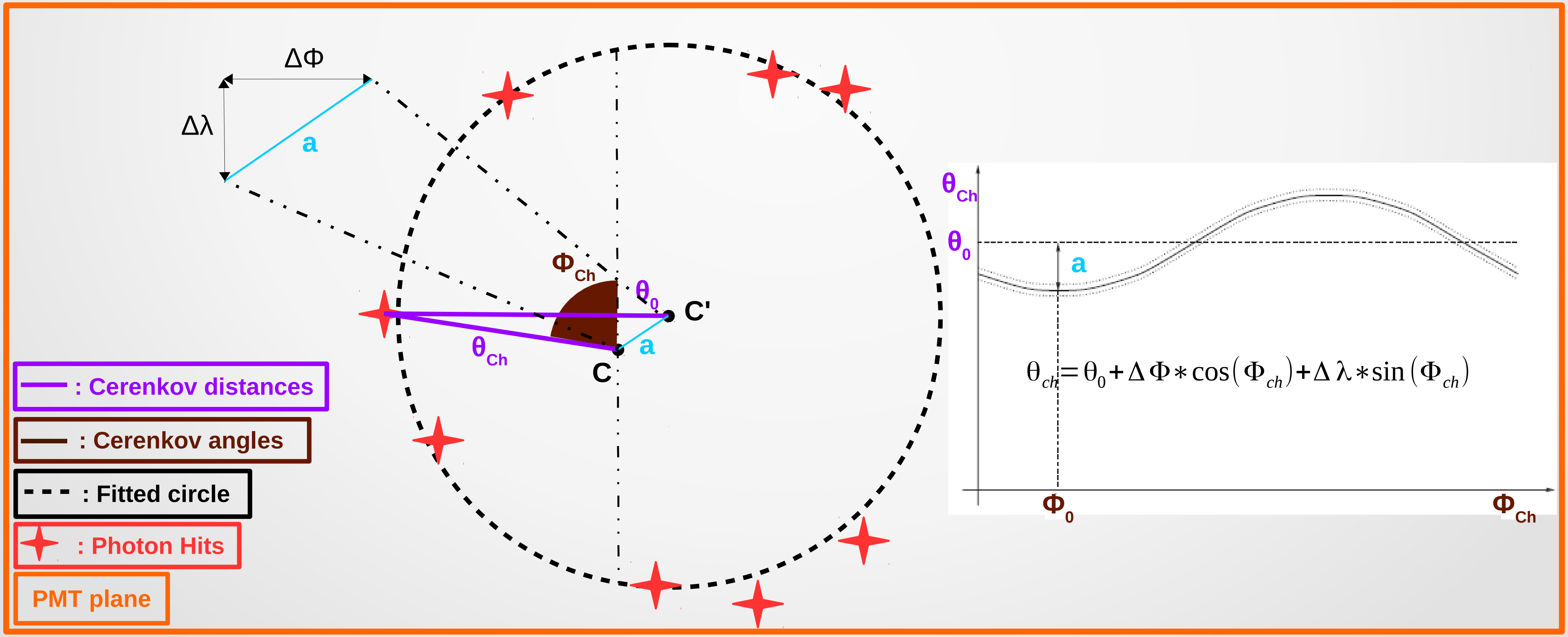
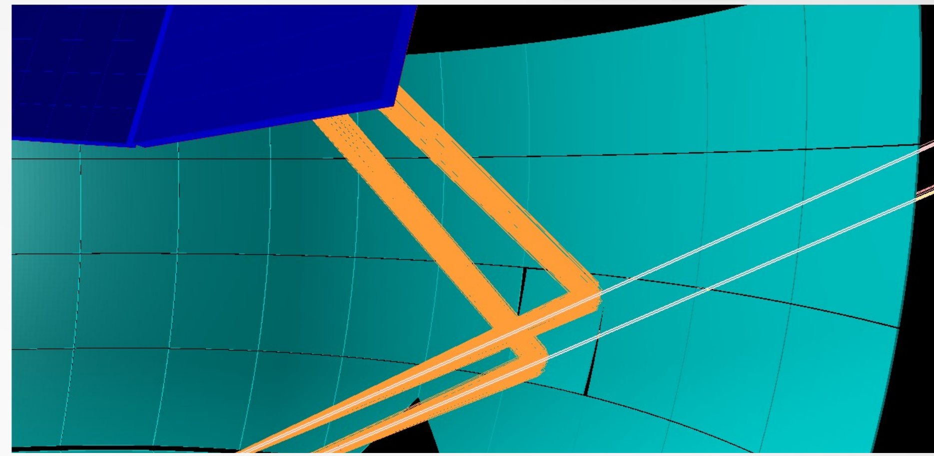
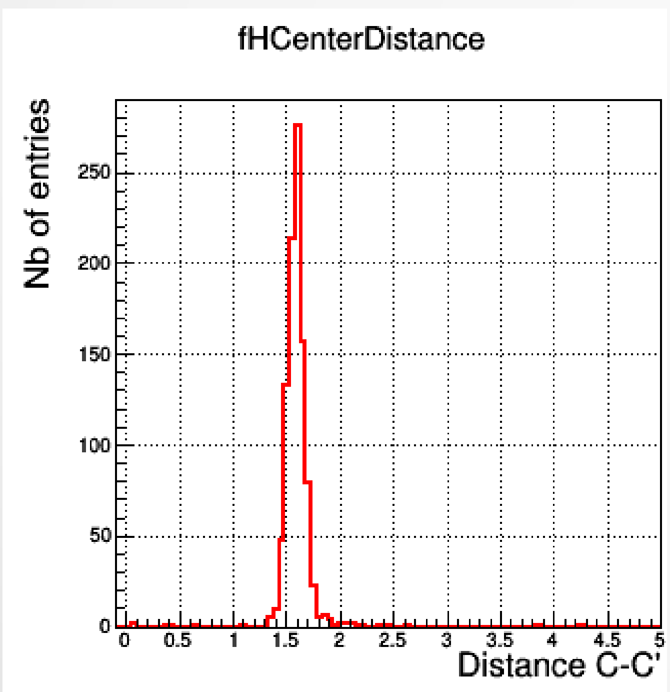
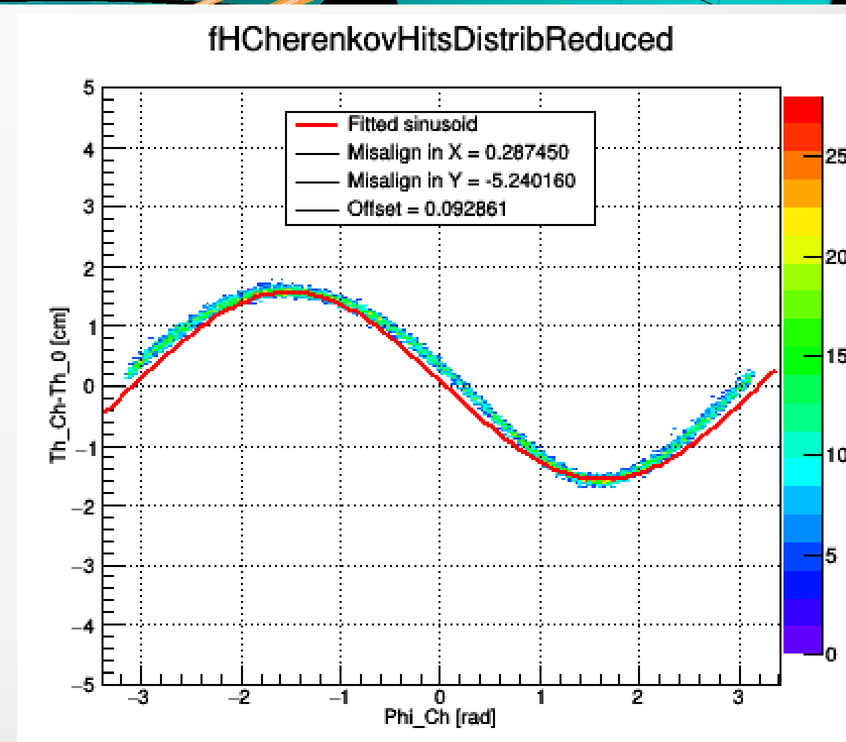


Quantitative measurement

- Misalignment of 5 mrad induced around X axis
- Fitted parameters:
  - $x_{misalignment} \equiv \arctan(\Delta\Phi / Focal-length)$
  - $y_{misalignment} \equiv \arctan(\Delta\lambda / Focal-length)$
  - ✔ 0.287 mrad in X
  - ✔ 5.240 mrad in Y



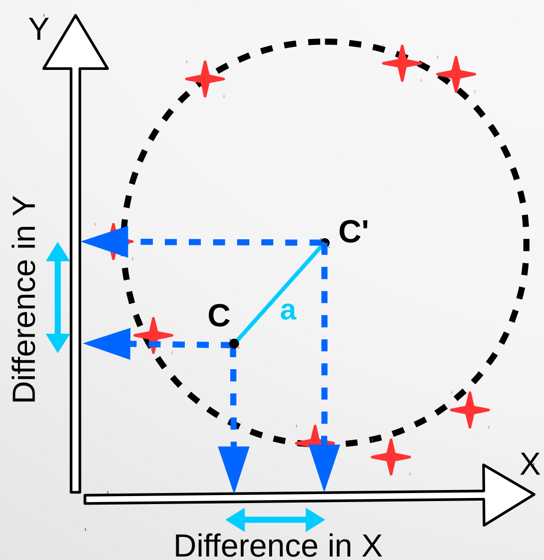


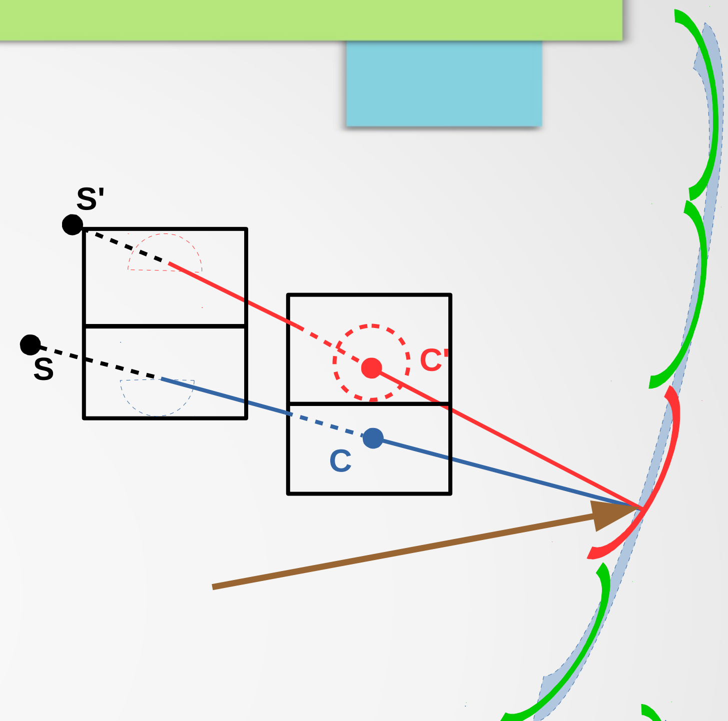


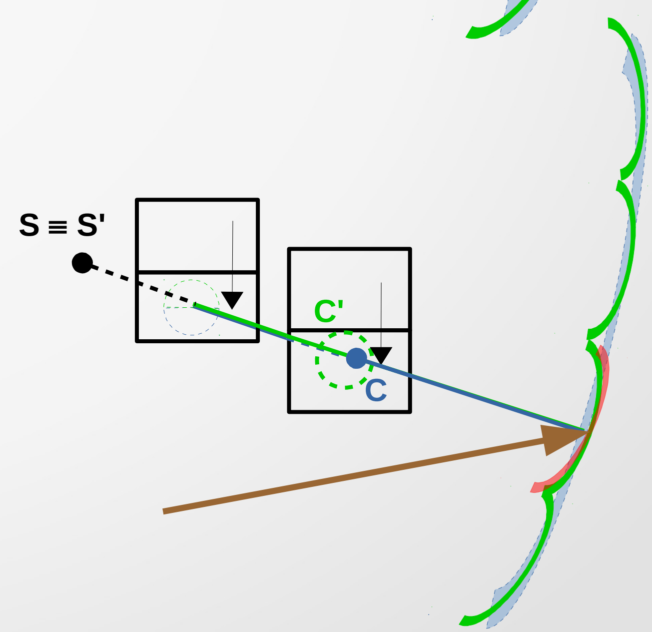
- Minimum detectable misalignment: 0.1 mrad
  & Maximum detectable misalignment: 12 mrad

Correction routine

- Reconstruction sequence:
  - Simulation with an artificially misaligned geometry
  - Extraction of misalignment info using the presented method
  - Run correction routine, for three different cases:
    - Without misalignment corrections
    - With corrections included
    - Using ideal corrections
- First step: work with rings located inside mirror (no edge effects are taken into account)

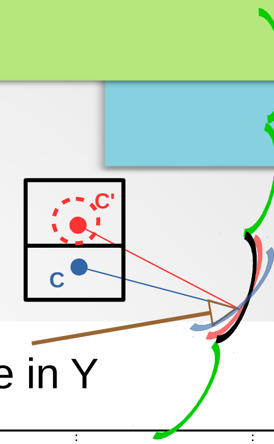


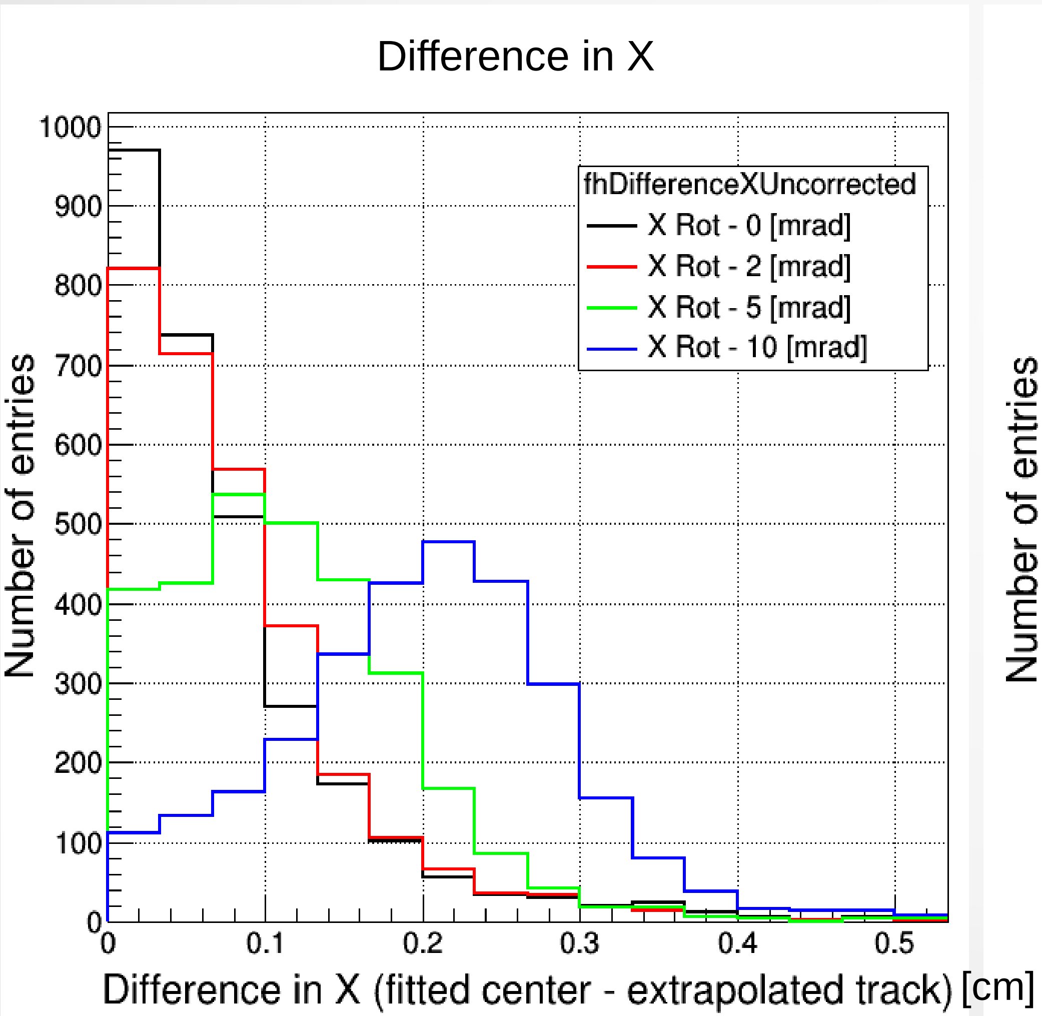


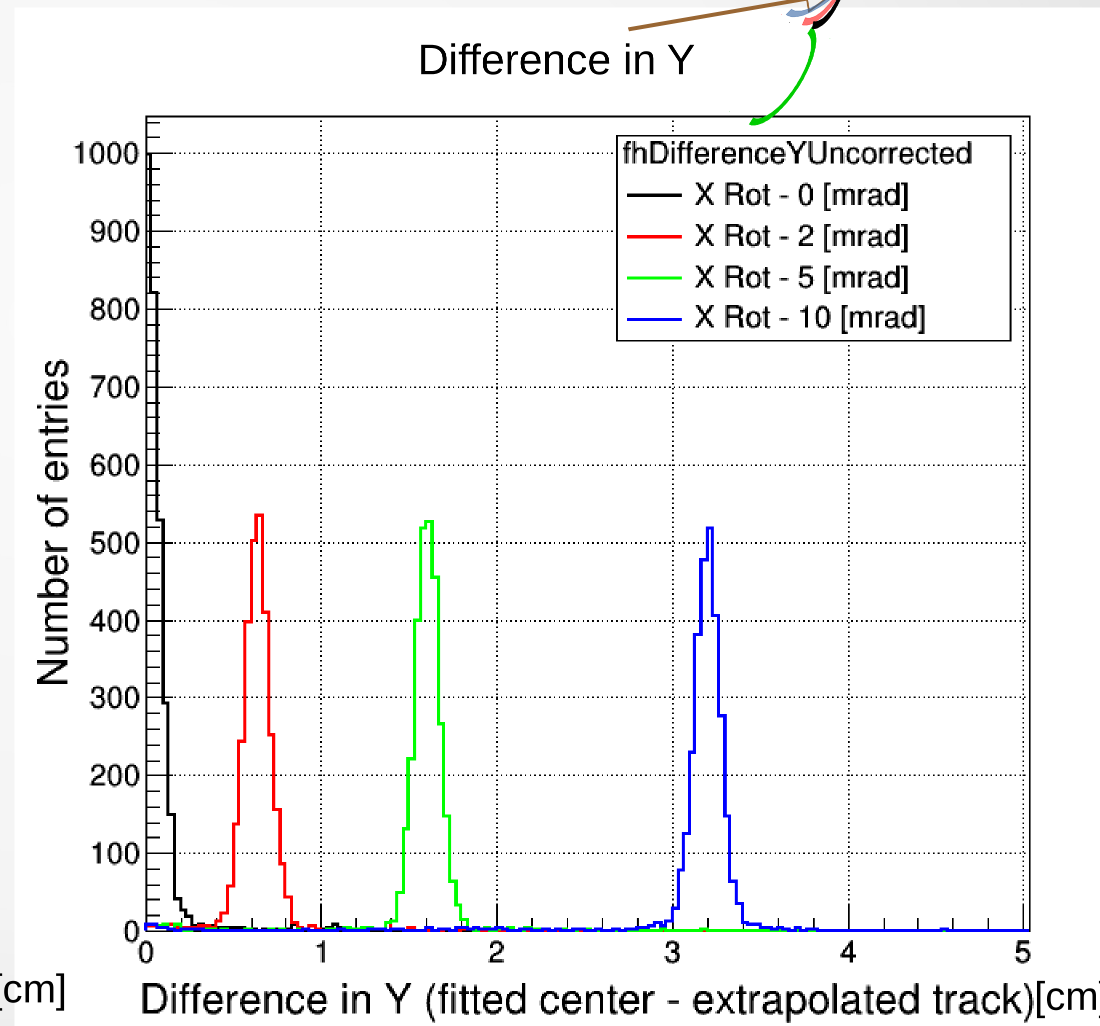


Correction routine

- Several rotations around X axis of the mirror tile:
  Black: 0 mrad ; red: 2 mrad ; green: 5 mrad ; blue: 10 mrad rotations

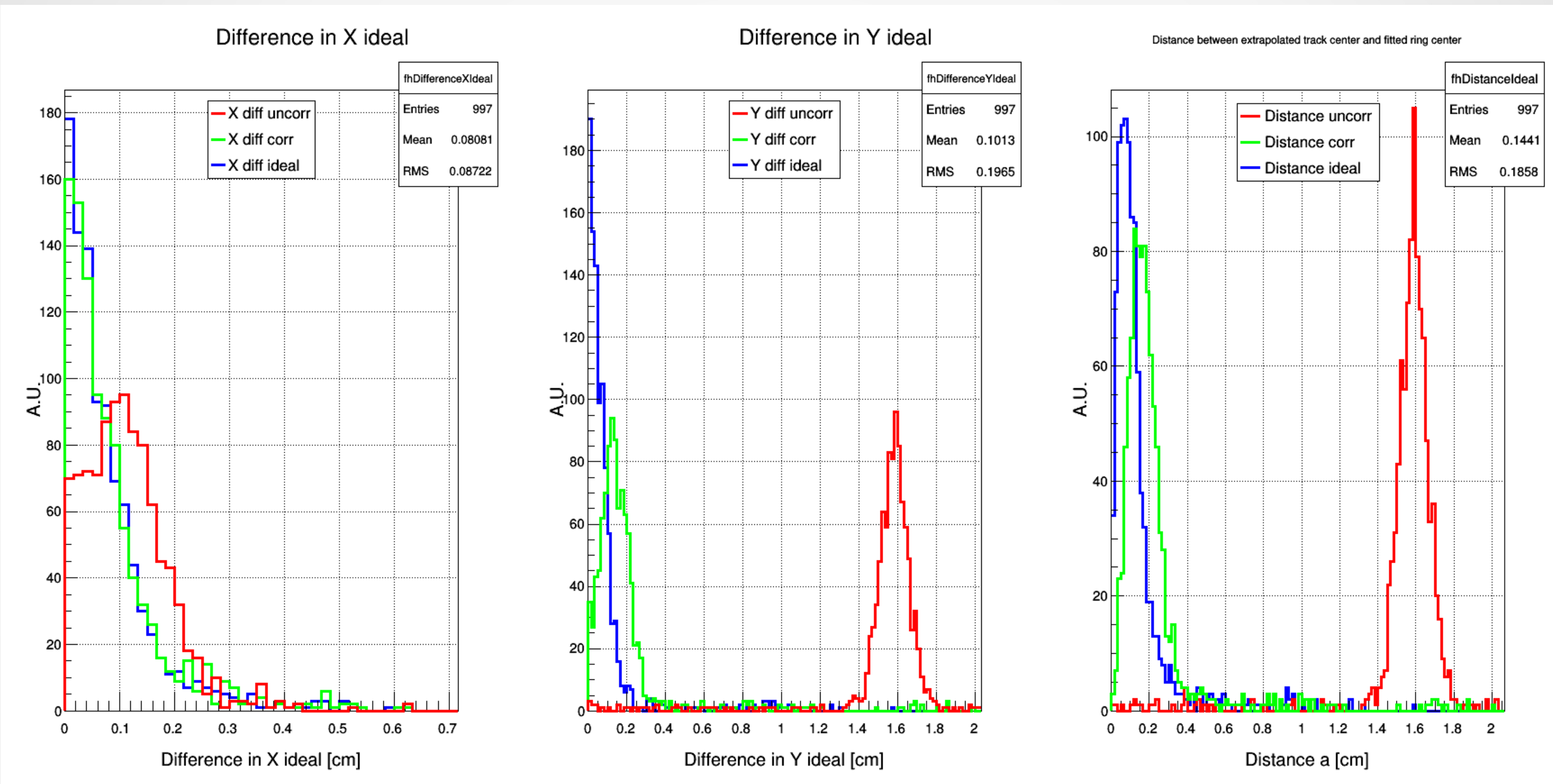






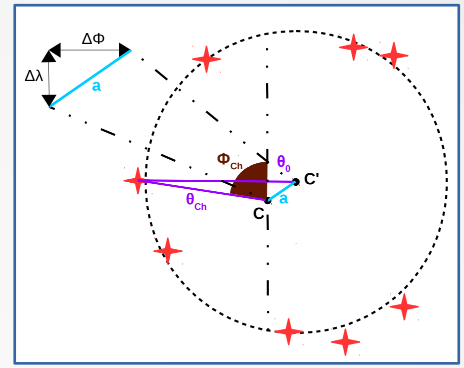
Correction routine

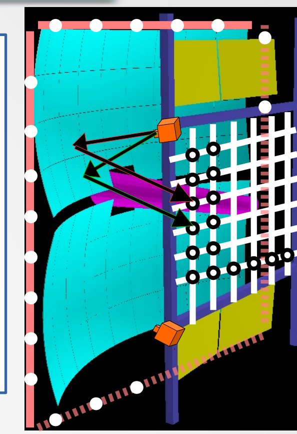
- Back to the 5 mrad misalignment example:
  Red: uncorrected geometry ; Green: corrected geometry ; Blue: ideal correction

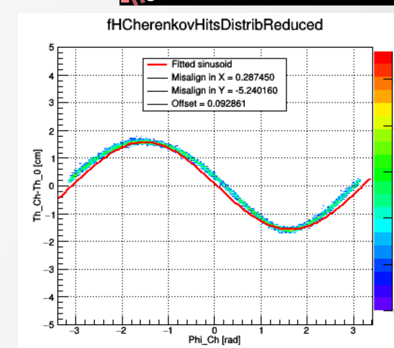


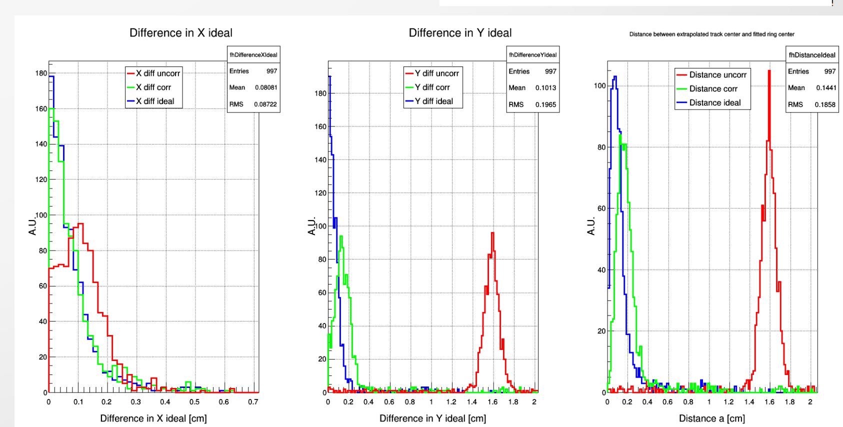
Summary

- Qualitative determination of misalignments using CLAM
  - Broken lines
  - Impact on rings
- Quantitative determination of misalignment and correction
  - Performances of the technique
  - Presentation of a first correction cycle
- Next steps:
  - Include and compare reconstruction and track-ring matching efficiencies without and with corrections
  - Study method for rings reflected on edges of mirrors
- Next: apply photogrammetry with CLAM algorithm to quantify misalignment and compare with results from shown technique







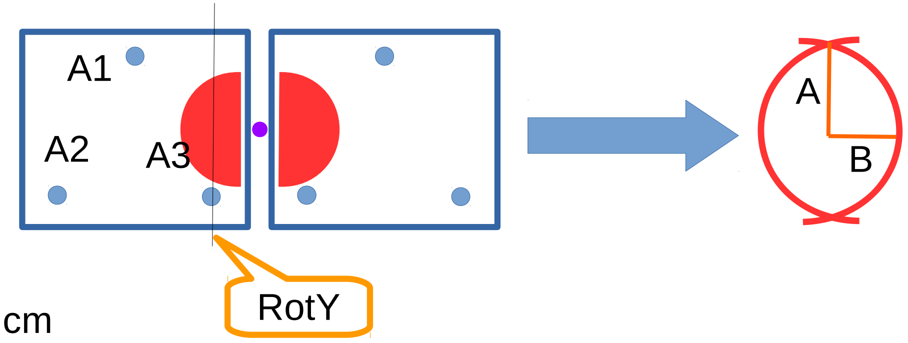


Thank you for your attention !

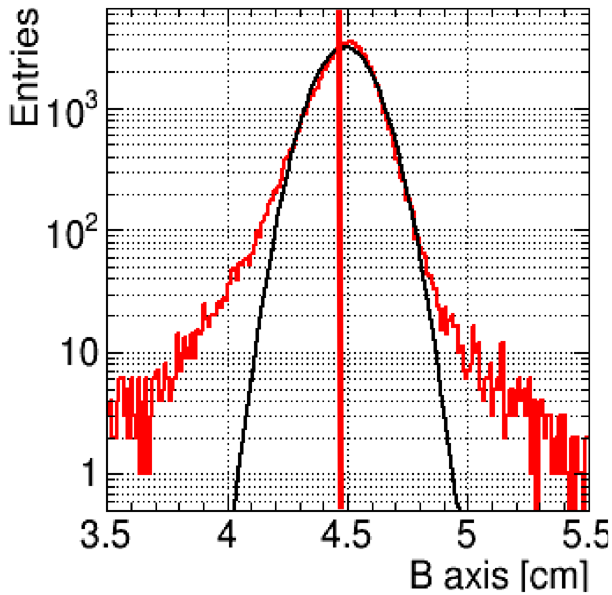
Backups

Qualitative misalignment study

- Rotation of 1, 2 and 4 mrad backwards, around Y axis. Foreseen impact on rings:
- Comparison

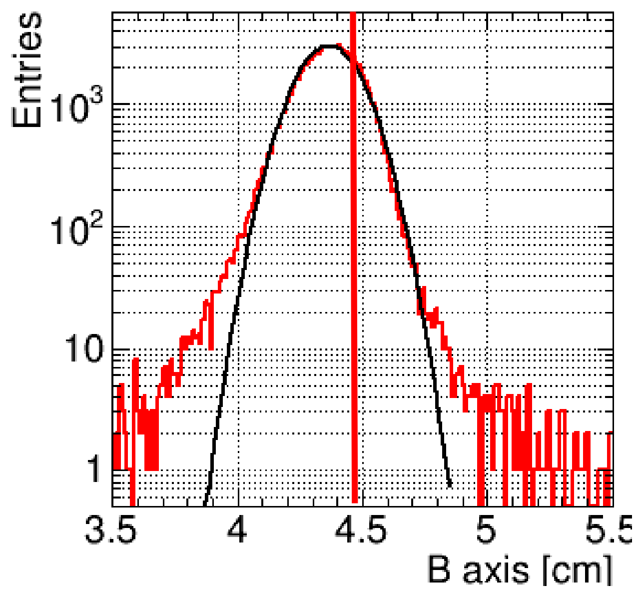


Bmean = 4.49 cm



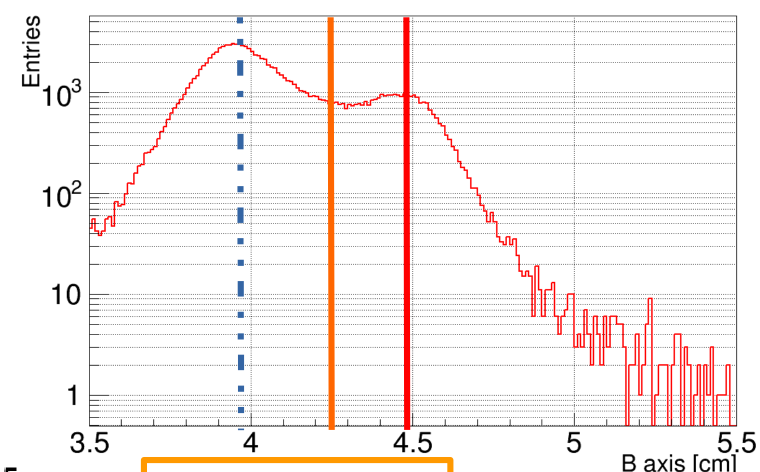
B axis distribution for reference data set

Bmean = 4.37 cm



B axis distribution for 1 mrad misalignment around RotY axis

Bmean = 3.99 cm



Limit at 4.25

4 mrad displacement: Apply B axis cut to enhance distorted rings sample, as it turns out the finger scintillator had not properly selected the events

More results

- Systematic analysis
  → Minimum detectable misalignment: 0.1 mrad
  → Maximum detectable misalignment: 12 mrad
- Misalignment of 0.3 deg on X axis and 0.5 deg on Y axis
  → 4.88 mrad ≡ 0.28° in X
  → 9.02 mrad ≡ 0.52° in Y
- Beam between four mirrors
  → Lower left: -0.2 deg along Y, lower right: 0.2 deg along X
  → Upper left: -0.4 deg along X, upper right: 0.4 deg along Y