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

FAIRNESS 2016 Garmisch-Partenkirchen

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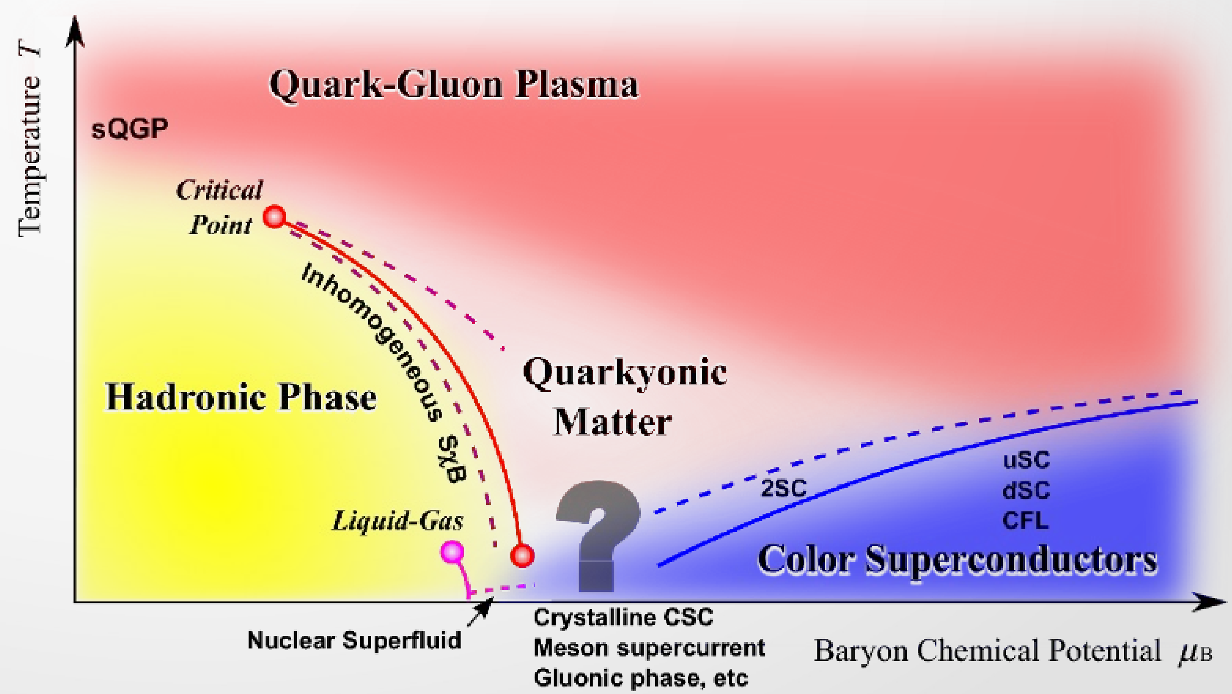
Outline

Introduction

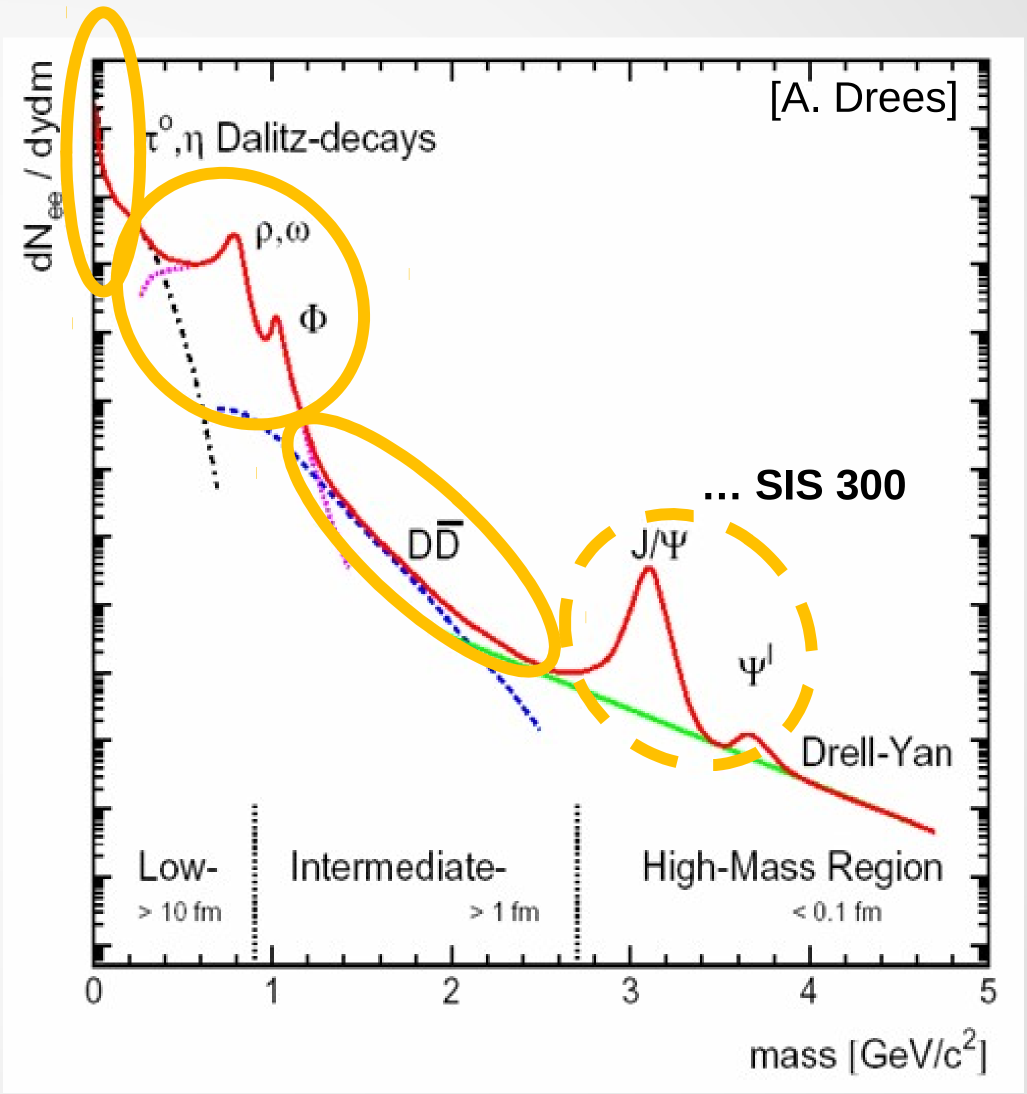
- CBM at FAIR: explore the QCD phase diagram in the region of high baryon density with A+A collisions
- Energy range (Au-Au) from 2 to 11 AGeV beam energy @SIS100 (up to 35 AGeV @SIS300)
- EM probes
  - Low mass vector mesons
  - J/Ψ
  - photons

⇒ **Identify electrons !**



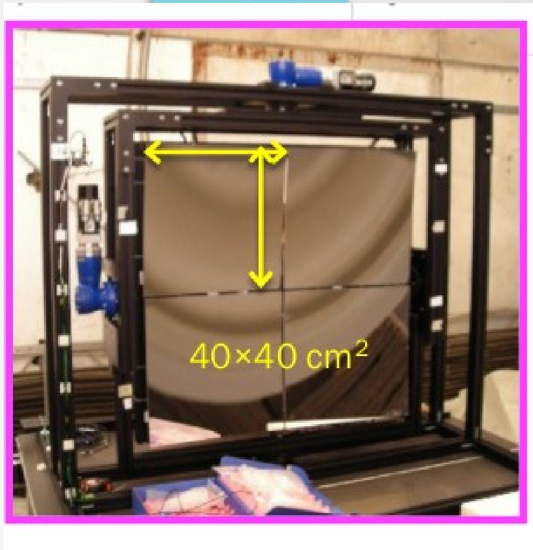
Introduction

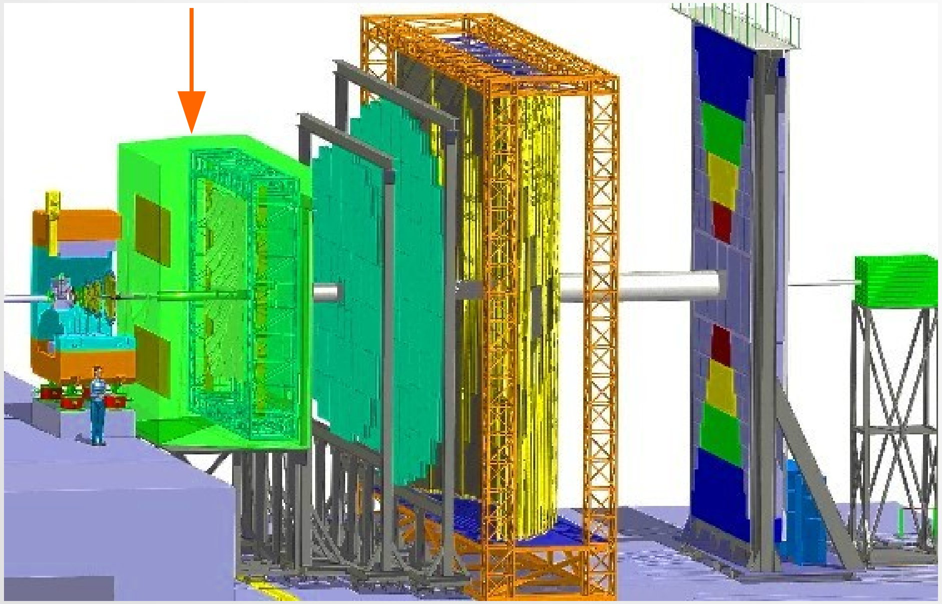
- Photons: access to early temperatures
  - Excitation function
- Low-mass vector mesons: in-medium properties of ρ
  - Strength due to coupling to baryons (in HADES)
  - Go to real dense matter
- Intermediate range: access to fireball radiation (in NA60): QGP, 4p- or r-a_1 chiral mixing
  - Quarkyonic phase
- J/Ψ: charm as a probe for dense baryonic / partonic matter
  - Propagation of charm
  - Distribution amongst hadrons

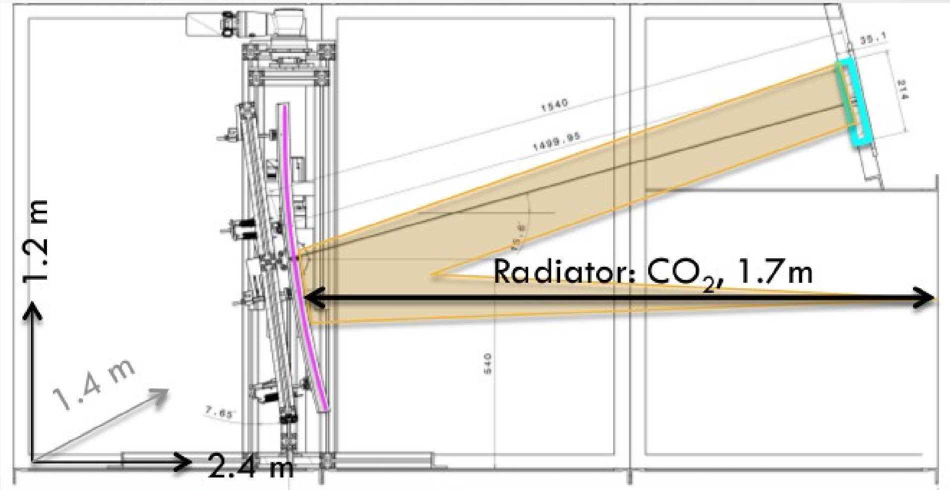


Introduction

- RICH detector for electron identification (CO_2 radiator, glass mirrors, MAPMT plane)
- laterally scaled prototype built and successfully tested in beamtests at CERN PS (2011, 2012, 2014)
- Four-mirror test setup within the prototype: The mirrors are remotely controlled, offering the possibility to induce misalignments

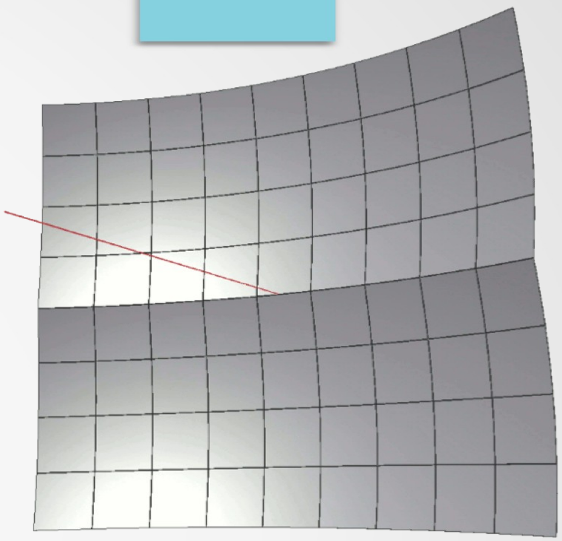


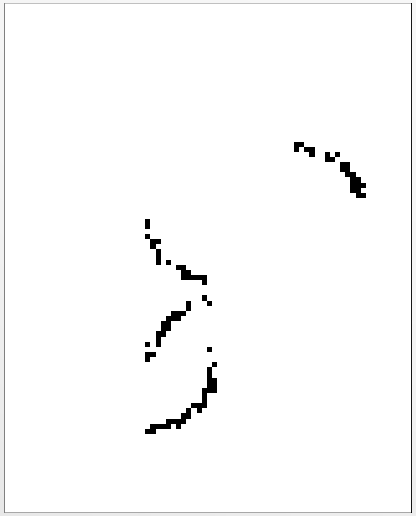


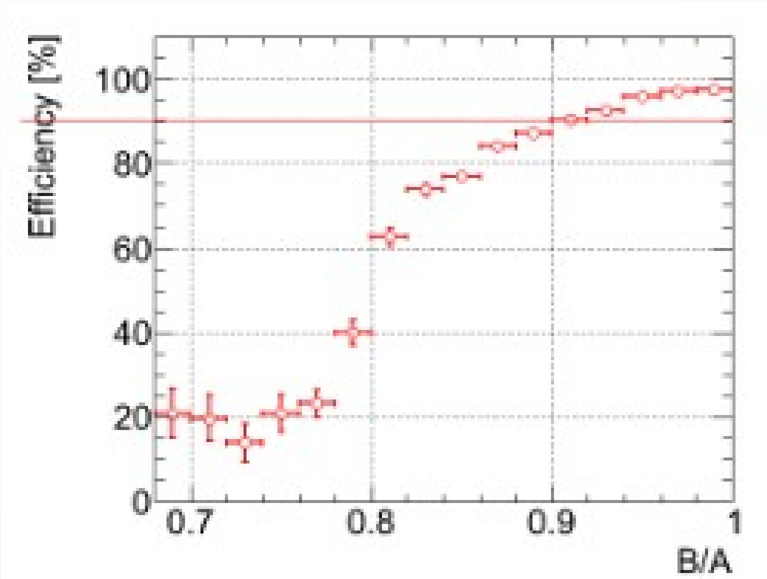


Introduction

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



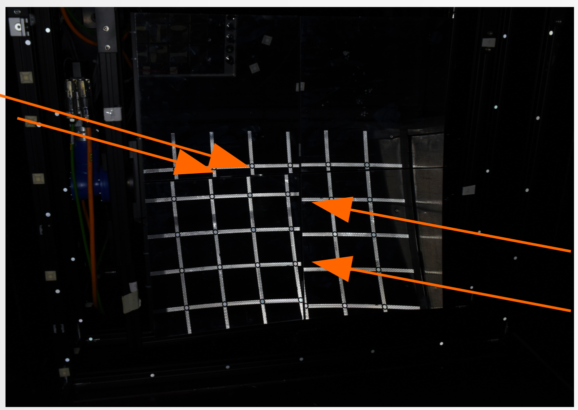




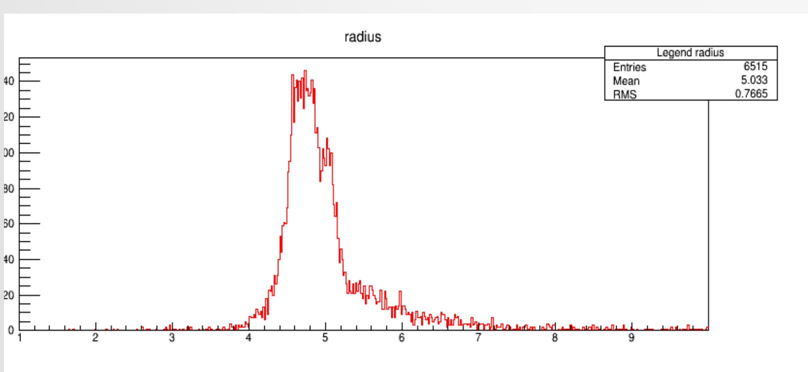
Introduction

Detect misalignment:
- CLAM method

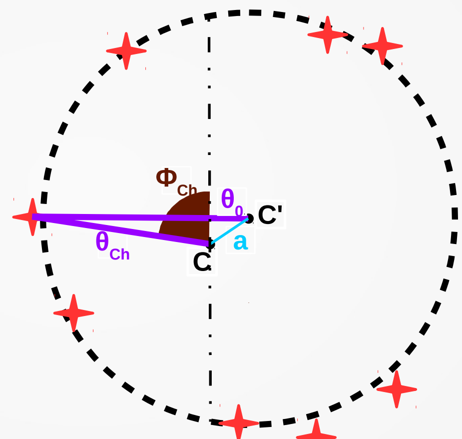
See effects on:
- A&B axes, B/A
- dR
- Radius

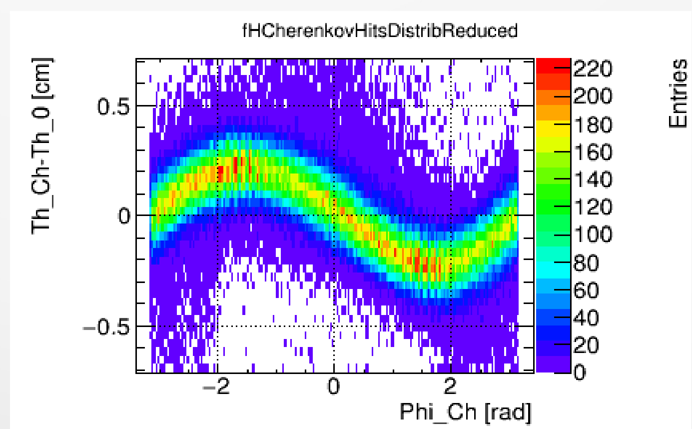


In case of misalignment, lines appear broken and the targets are now displaced, with regard to the external ones

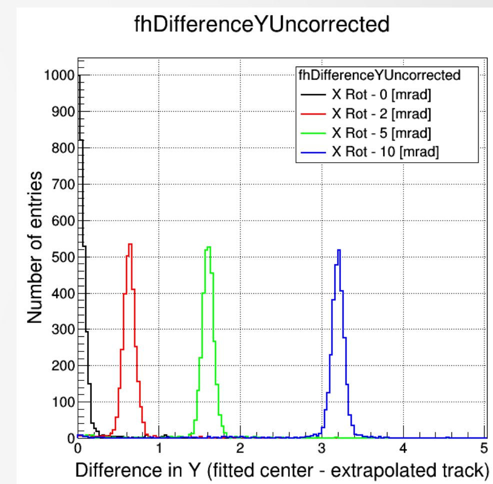


Quantitative determination of misalignment:
- Using data: HERA-b
- Hardware: CLAM





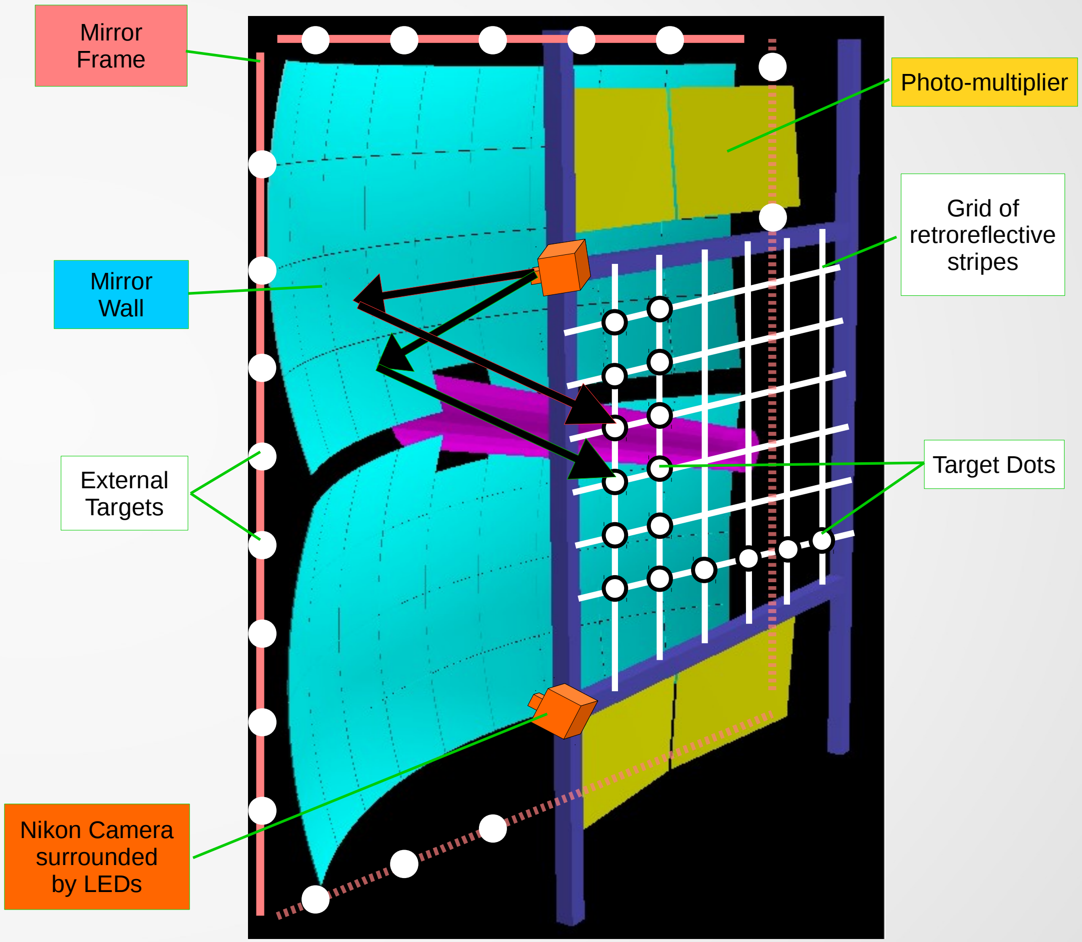
Correction routines:



Outline

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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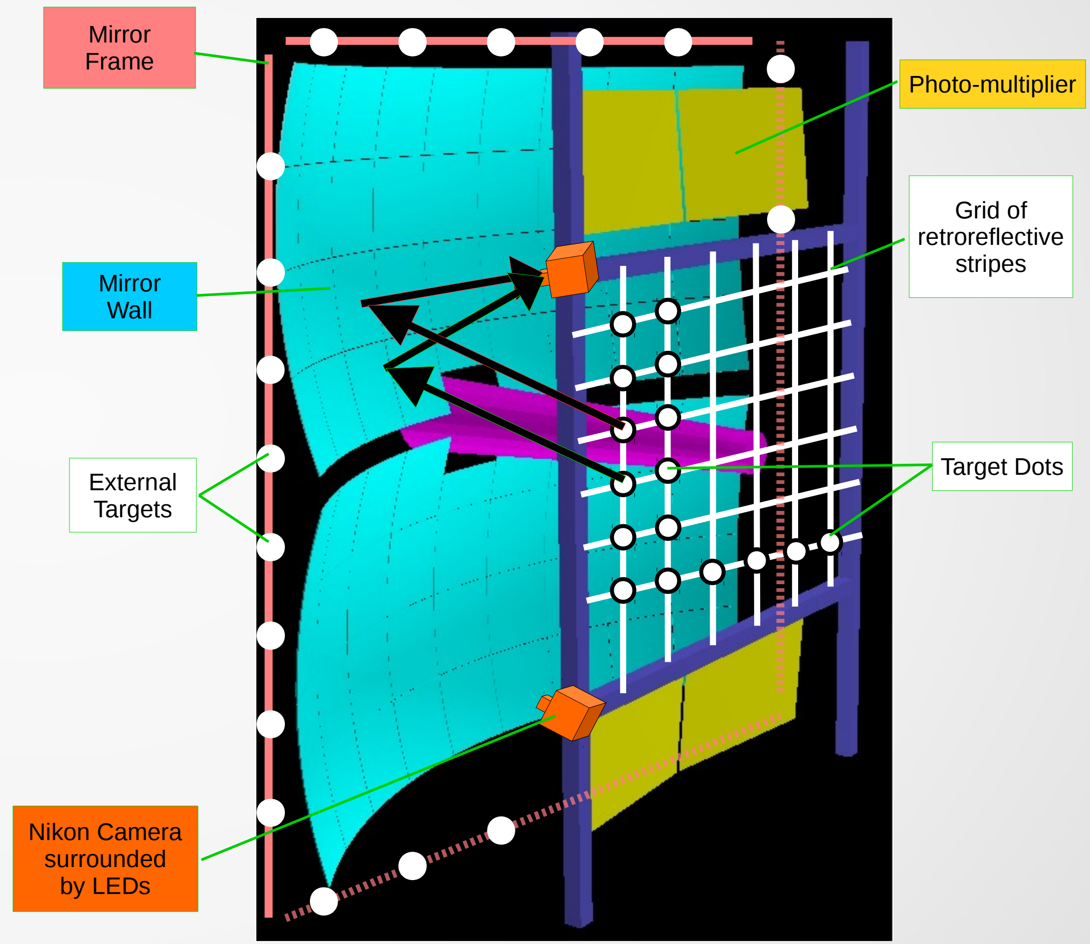
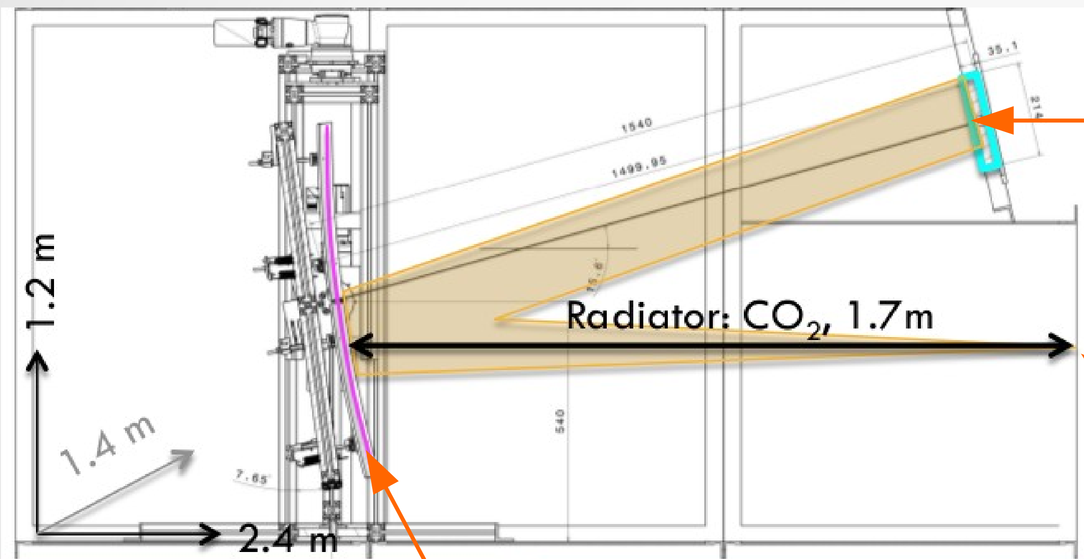


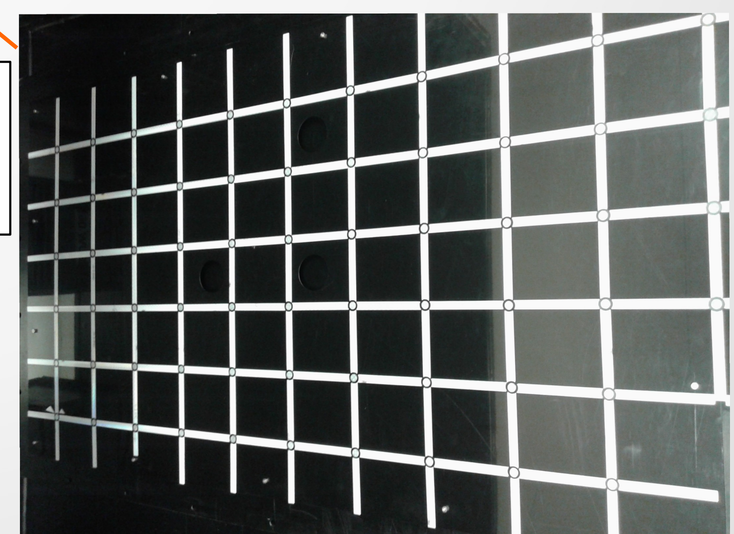
Prototype set-up and equipment

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

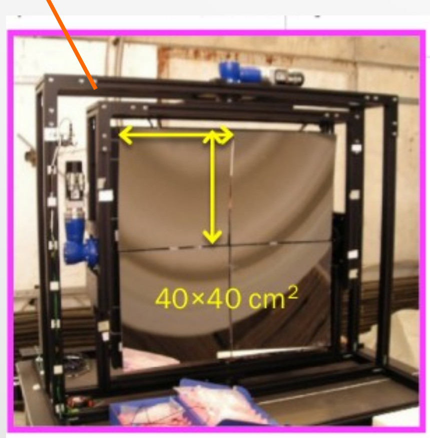


CLAM camera surrounded by 3 LEDs

Retro-reflective grid
&
Target dots at entrance

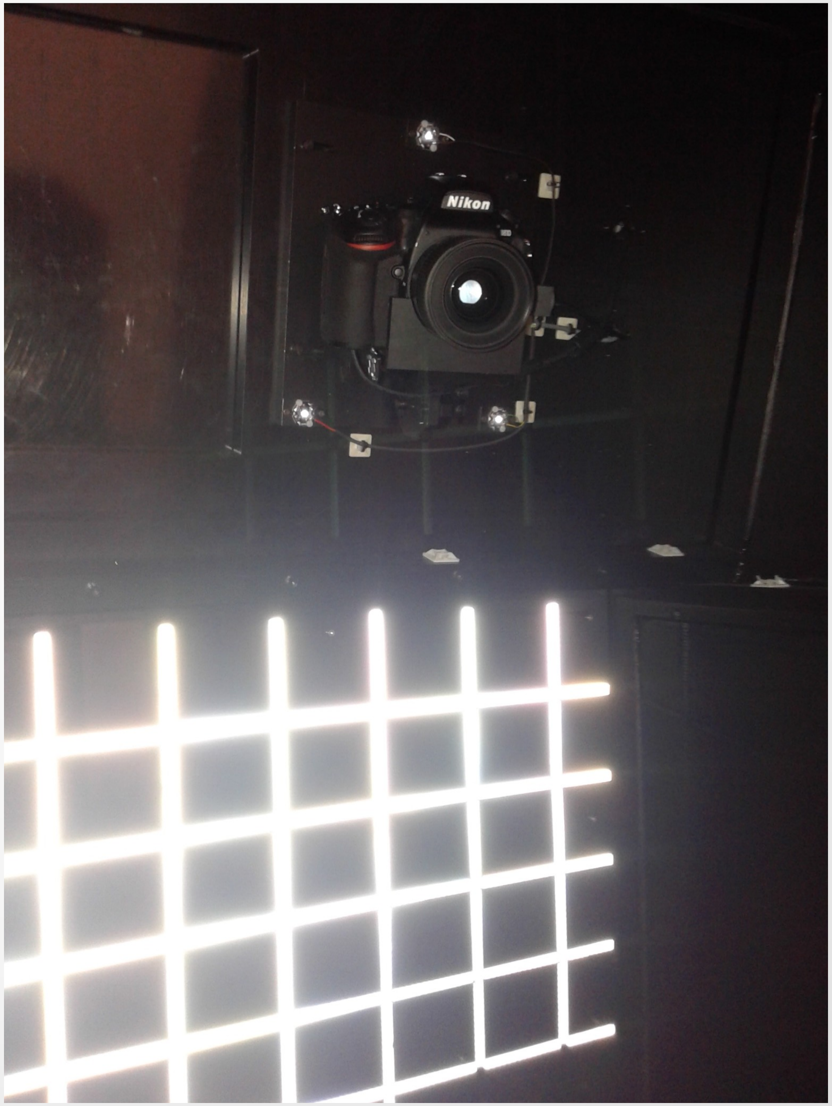


Four-mirror system remotely controlled



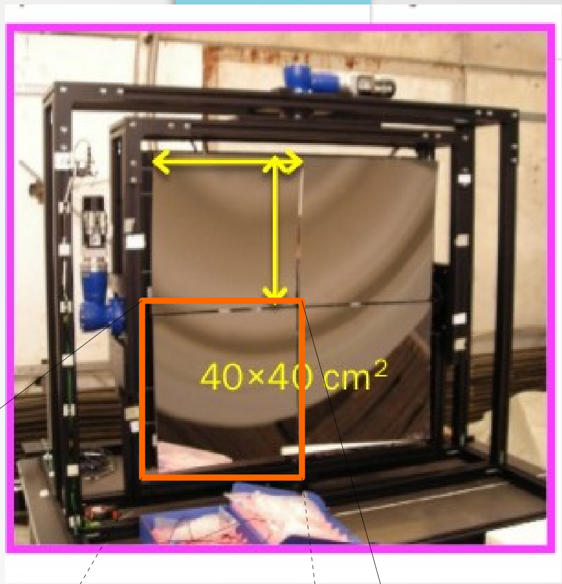
Prototype set-up and equipment

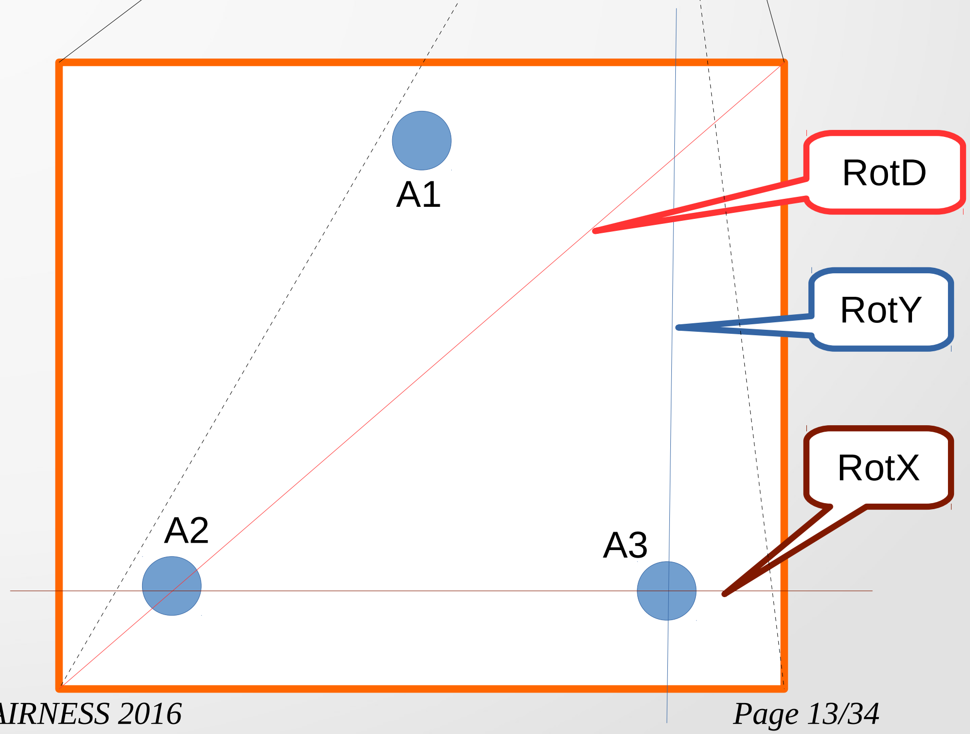
- View inside the prototype



Prototype set-up and equipment

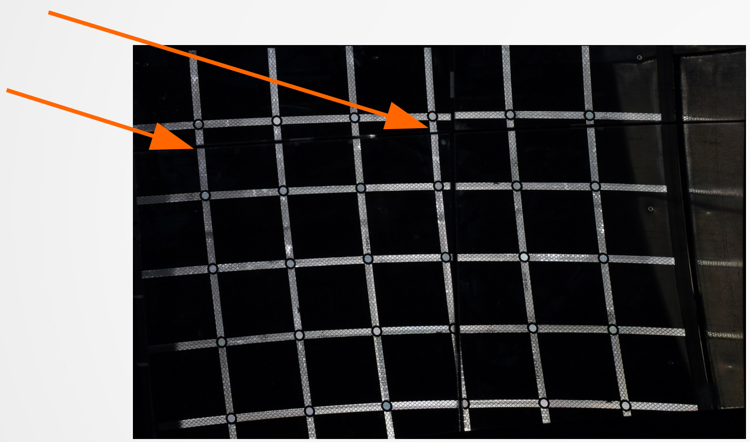
- 3 fixation points & 3 rotation axes
- 1, 2 and 4 mrad displacements induced for each measurement
- Event selection:
  - Beam (e^- and π^- @1-2 GeV) between mirrors not focussed
  - Approximate selection of events with beam passing right between two mirrors with finger scintillator detector

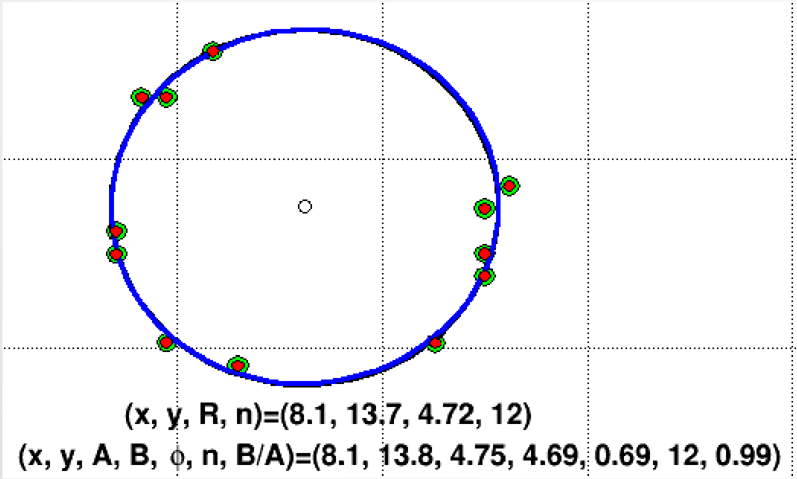




Qualitative misalignment study

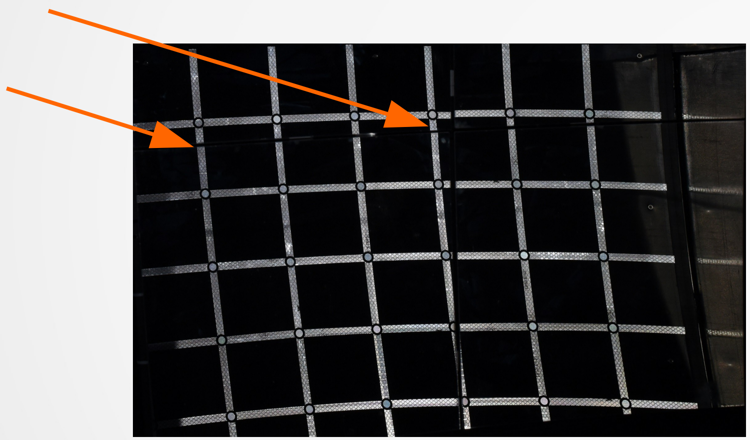
- Mirror system viewed by the CLAM camera and reconstructed rings
  - Left: right after the reference alignment

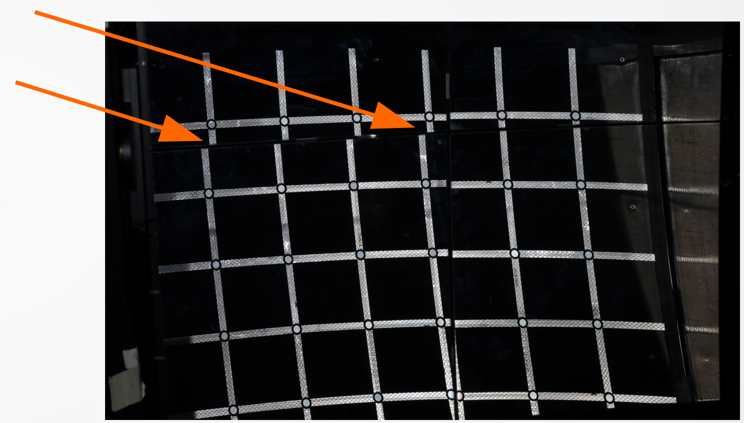


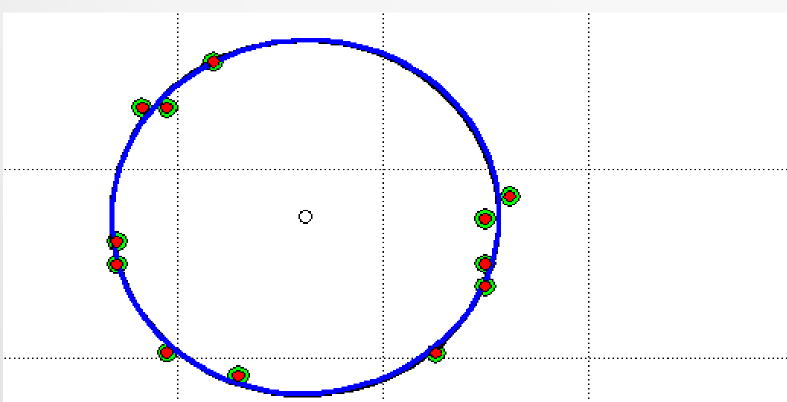


Qualitative misalignment study

- 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

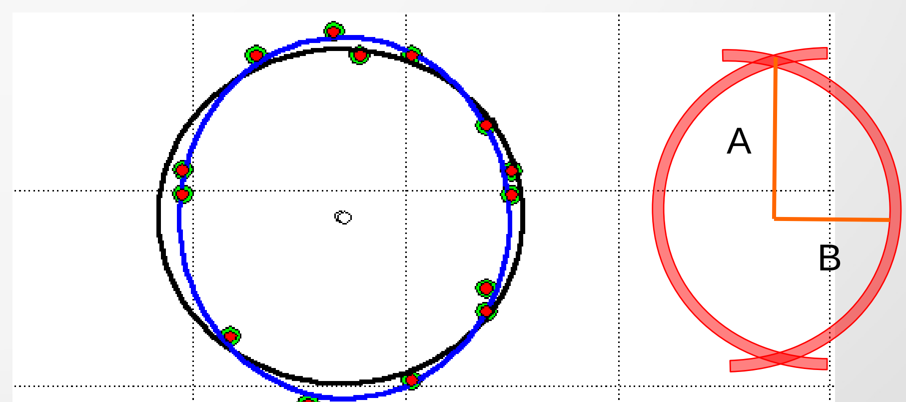






(x, y, R, n)=(8.1, 13.7, 4.72, 12)

(x, y, A, B, ϕ, n, B/A)=(8.1, 13.8, 4.75, 4.69, 0.69, 12, 0.99)

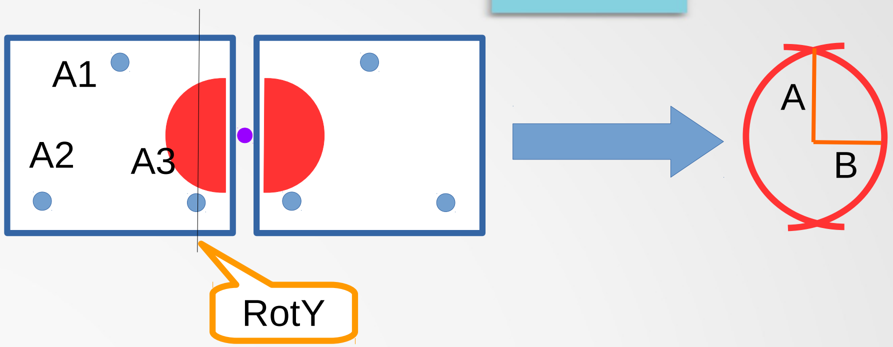


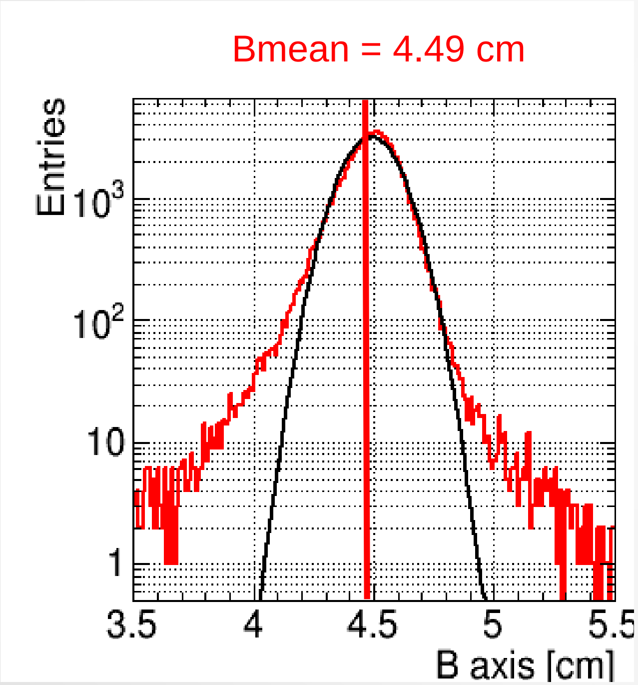
(x, y, R, n)=(8.5, 14.4, 4.30, 14)

(x, y, A, B, ϕ, n, B/A)=(8.6, 14.3, 4.65, 3.89, -1.55, 14, 0.84)

Qualitative misalignment study

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

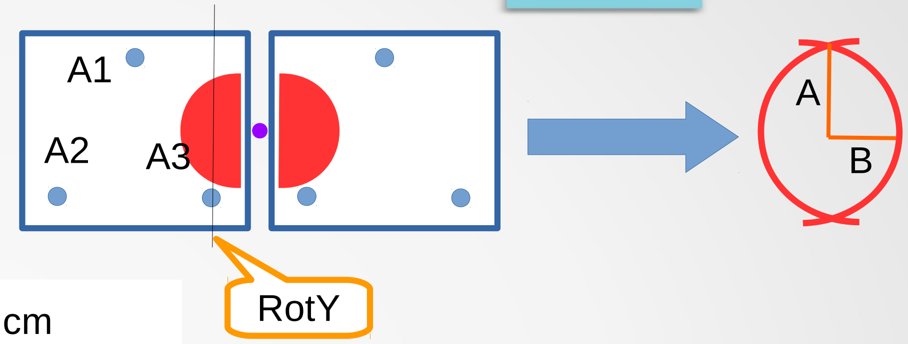


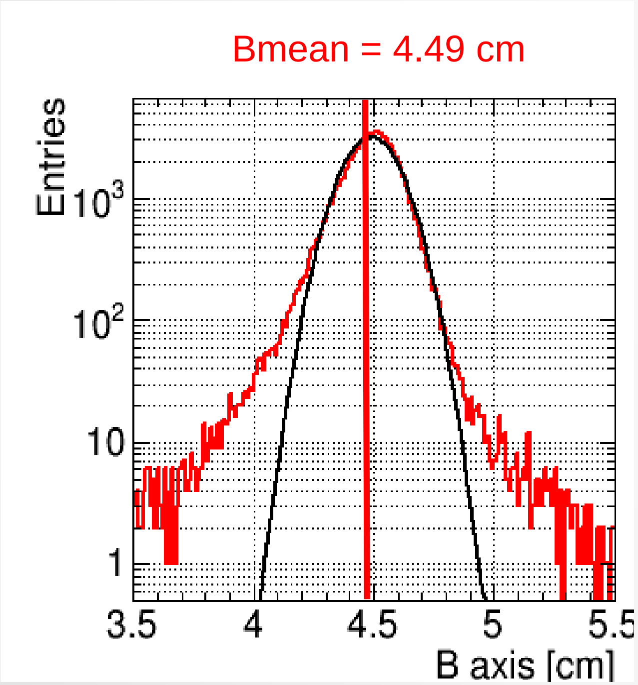


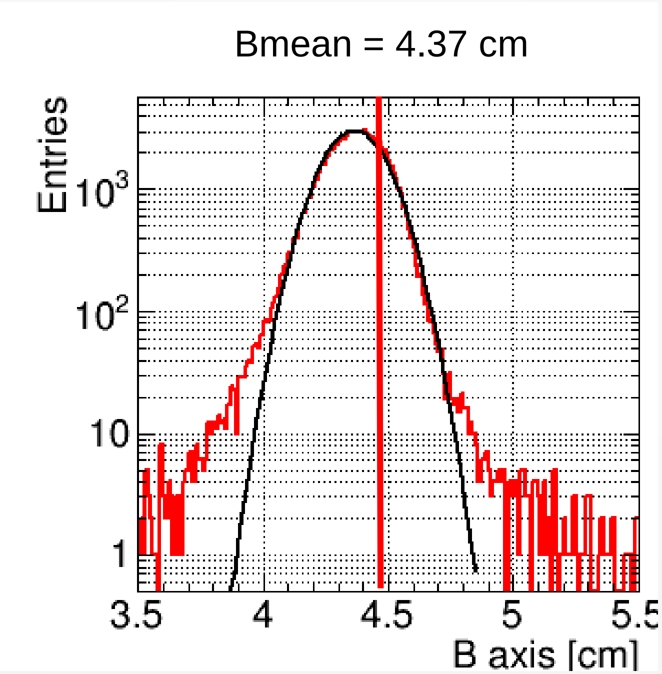
B axis distribution for reference data set

Qualitative misalignment study

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





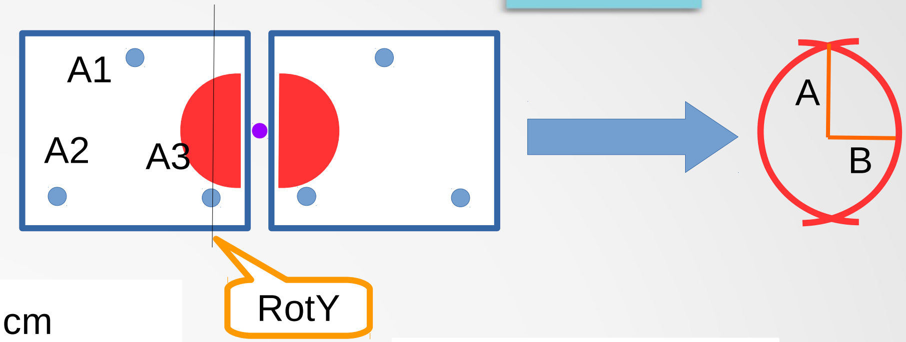


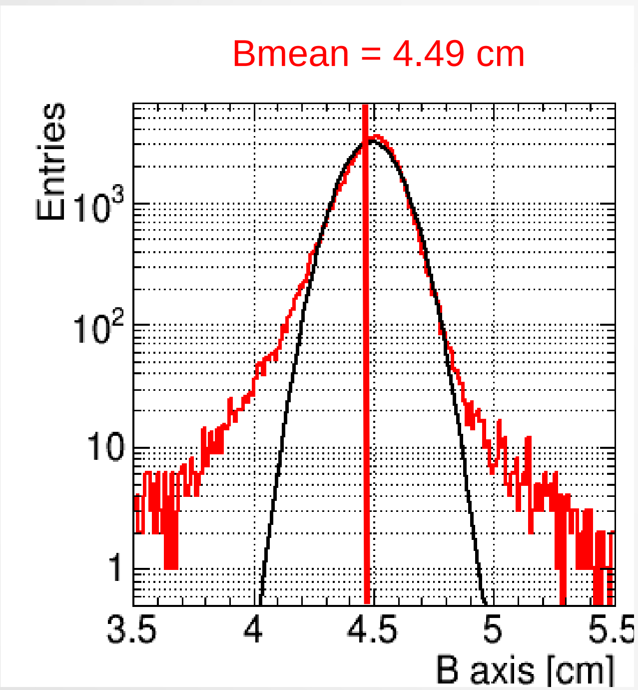
B axis distribution for reference data set

B axis distribution for 1 mrad misalignment around RotY axis

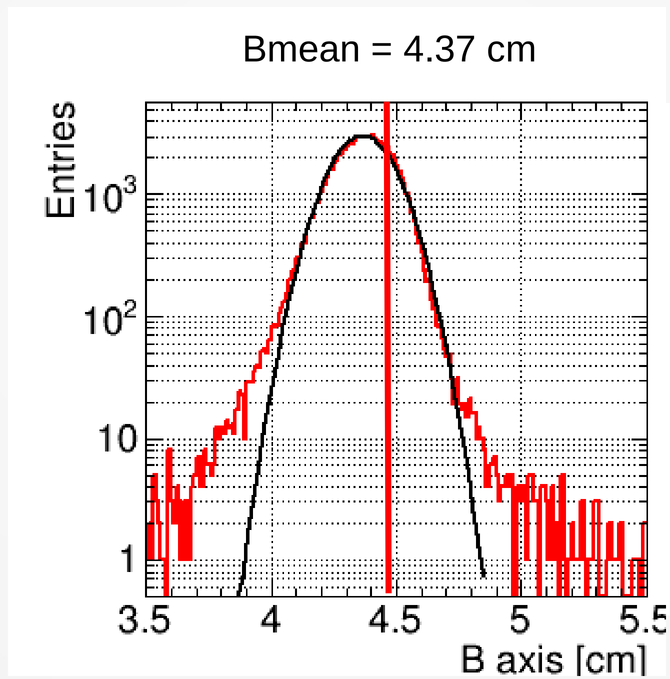
Qualitative misalignment study

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

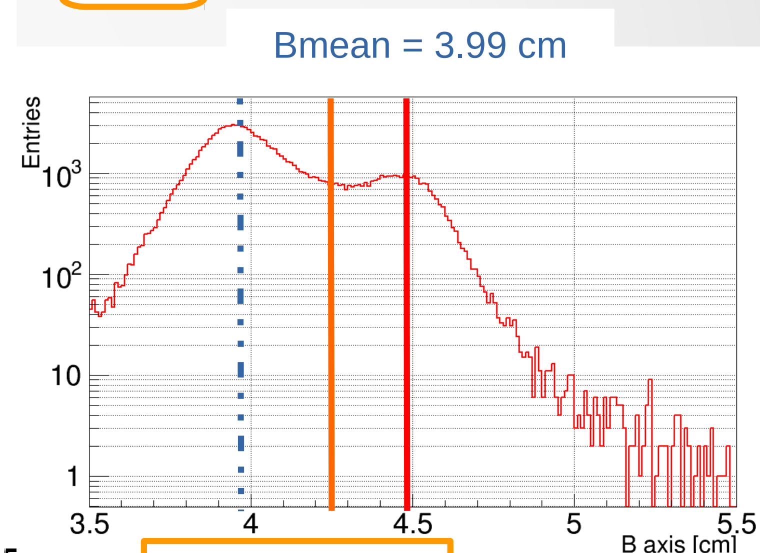




B axis distribution for reference data set



B axis distribution for 1 mrad misalignment around RotY axis

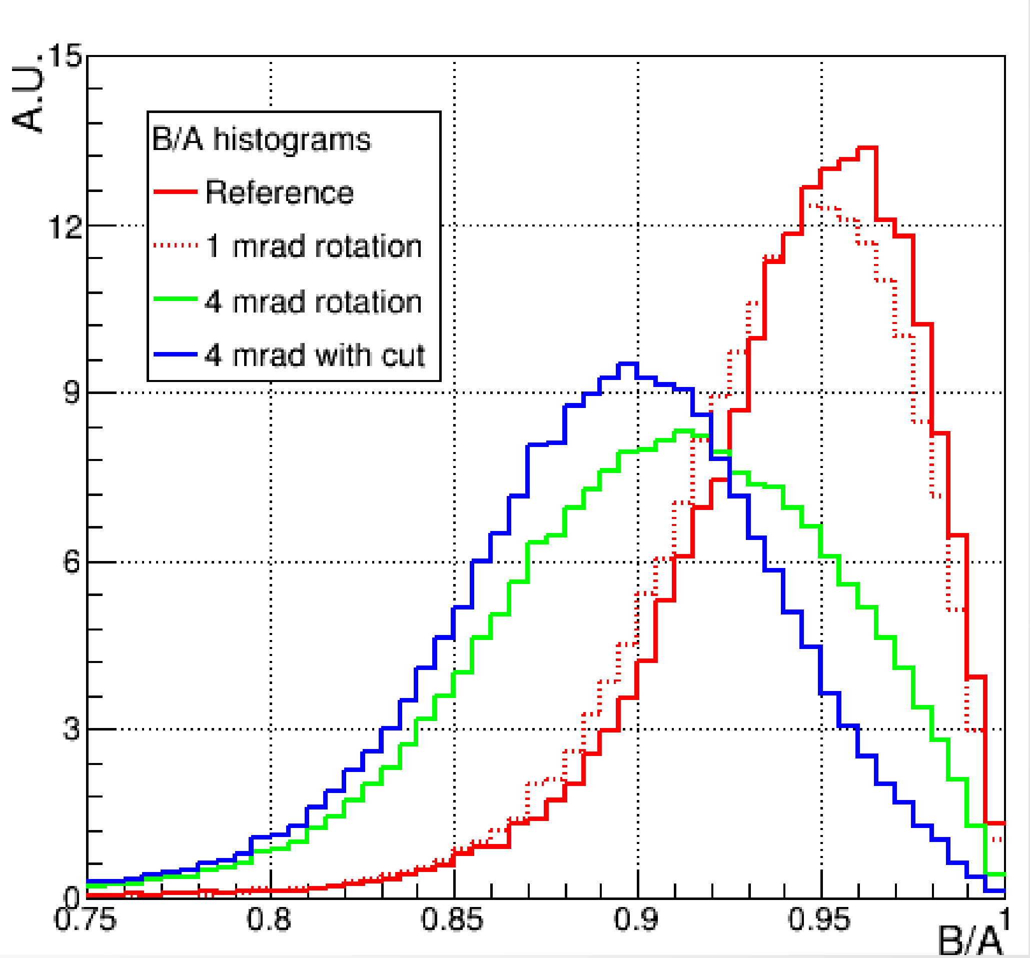


Limit at 4.25

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

Qualitative misalignment study

- Impact on ellipticity
  - Increasing ellipticity with increasing misalignment
  - Application of cut to separate distorted from undistorted data samples
- Ring distortion into elliptic shapes and lower radius:
  - Such rings are lost in later identification cuts!
- Keep distortions at minimum
- Be able to correct

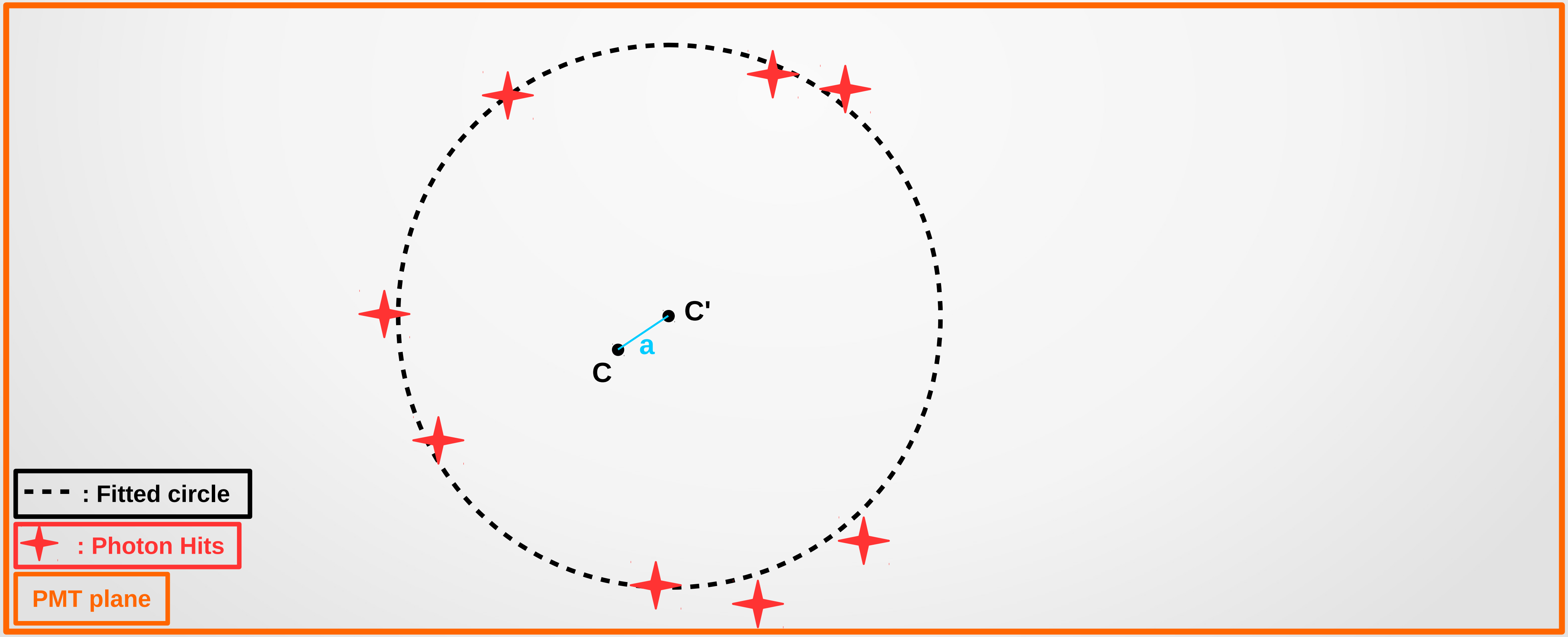


Outline

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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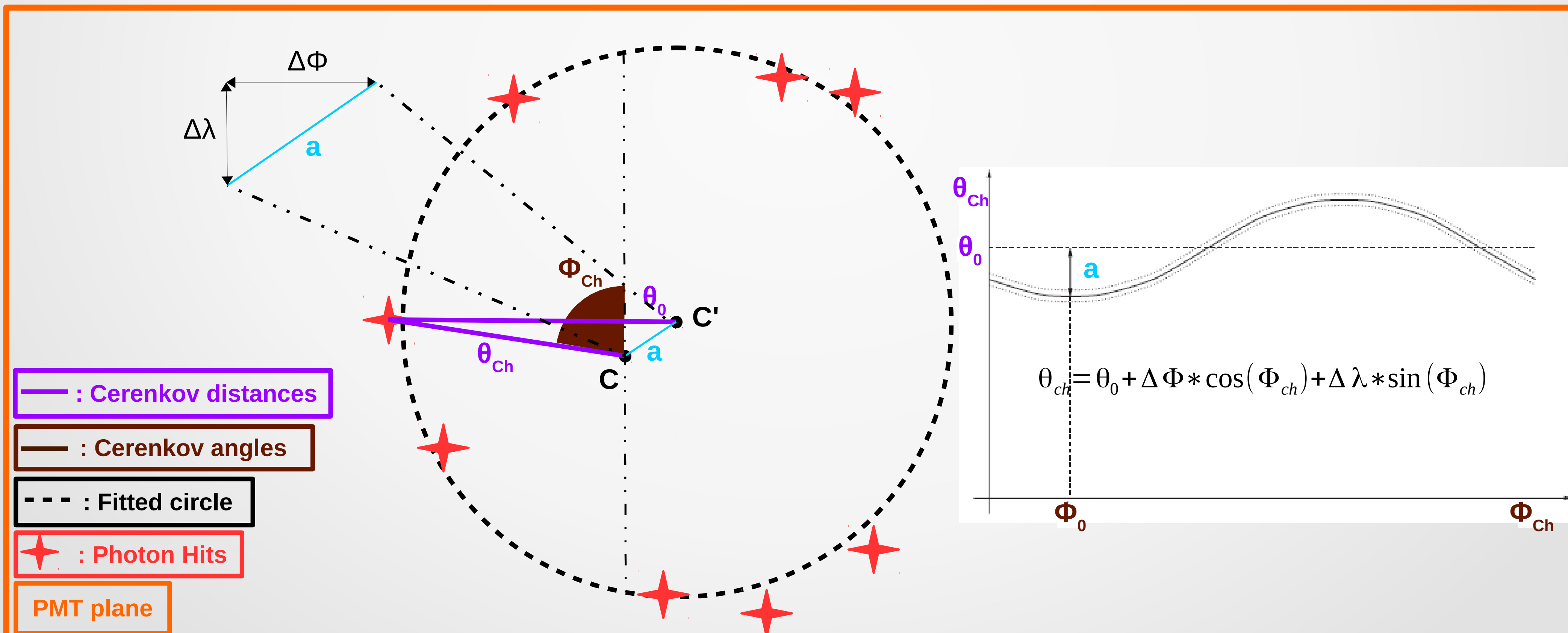
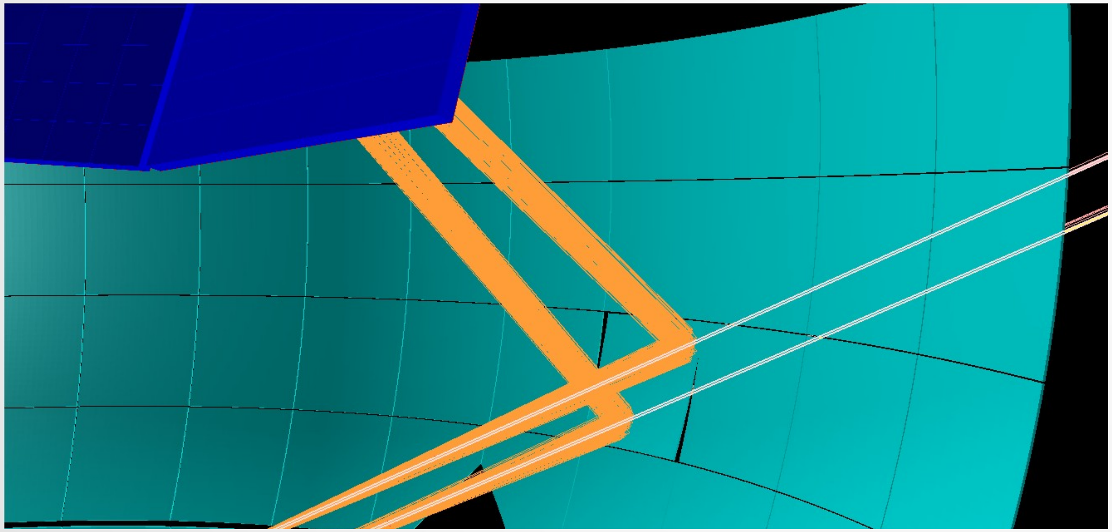
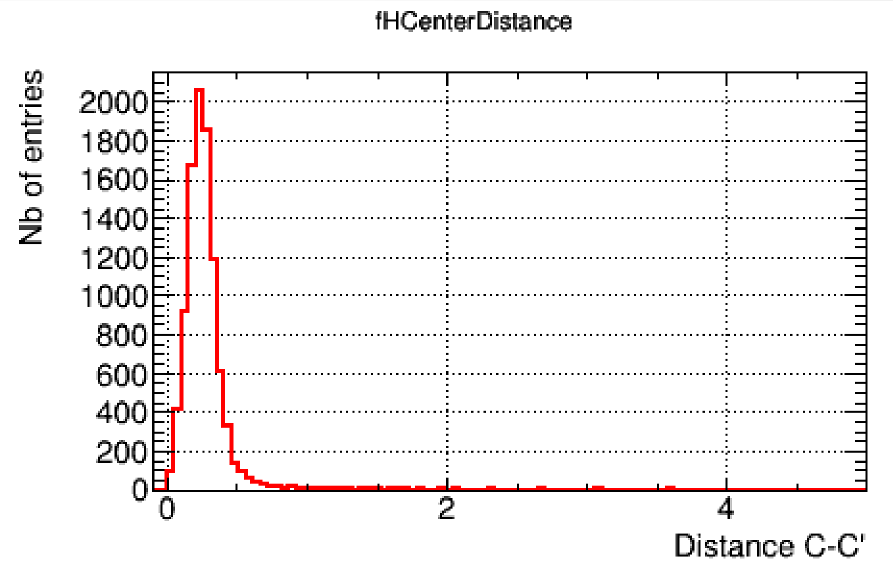
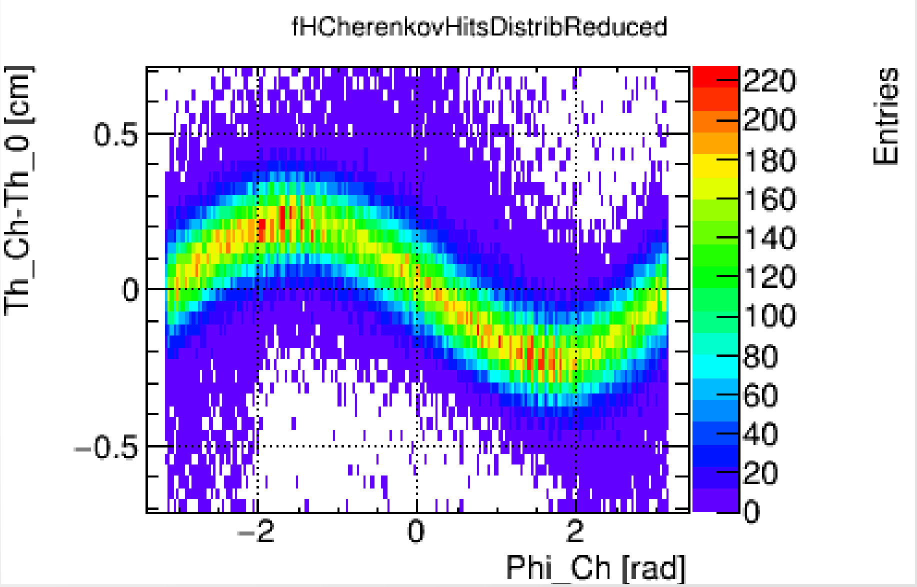


Simulation

- Input parameters of the study:
  - 1 e- per event є [9.9; 9.95] GeV
  - 10 000 events
- Misalignment of -0.75 mrad induced along Y axis

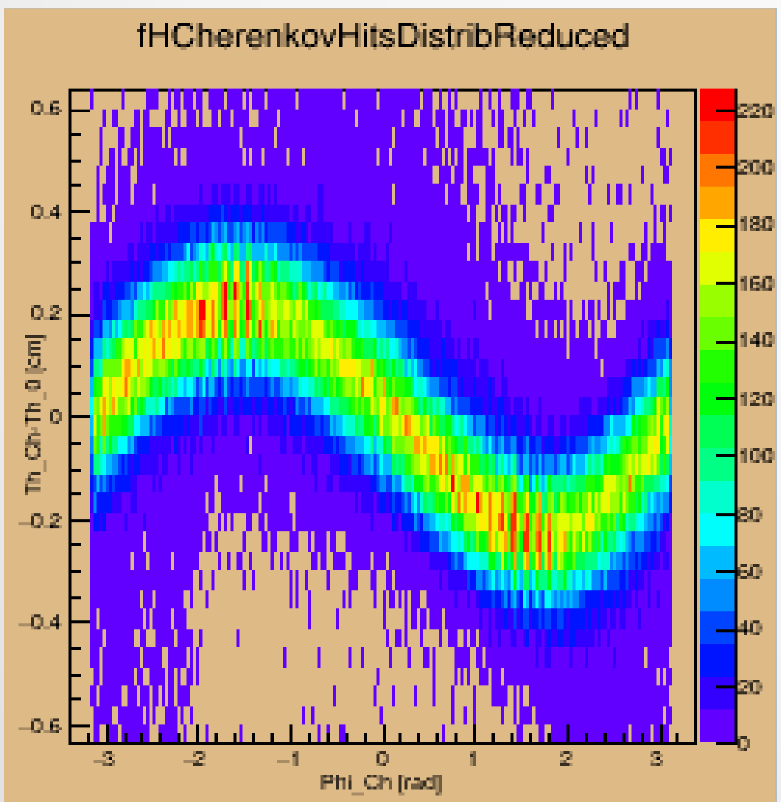


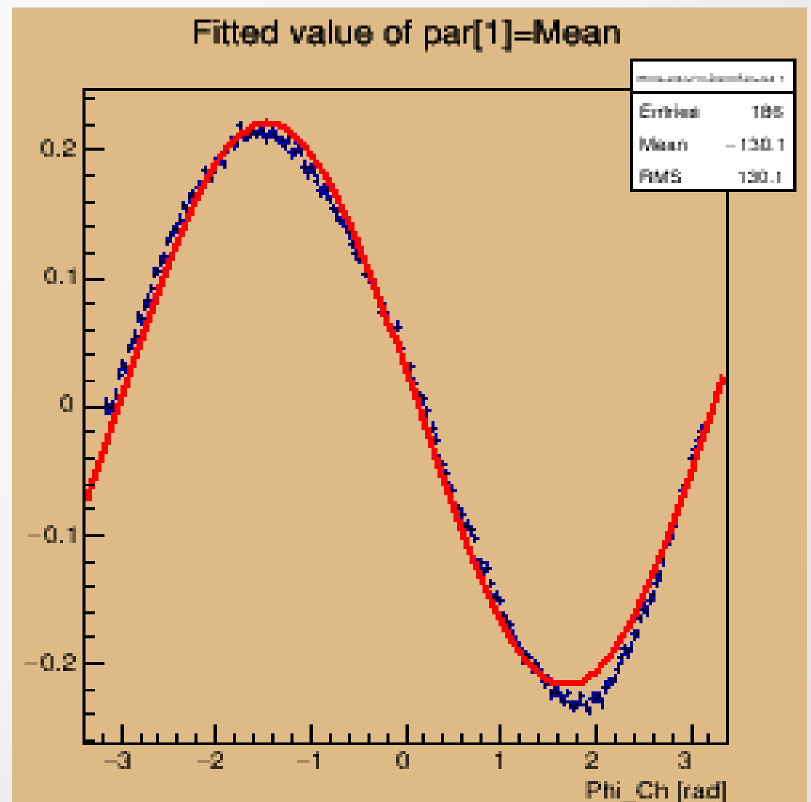




Quantitative measurement

- Fitted parameters:
  - $x_{misalignment} \equiv \arctan\left(\Delta\Phi / Focal-length\right)$
  - $y_{misalignment} \equiv \arctan\left(\Delta\lambda / Focal-length\right)$
  - => 0.085 mrad in X
  - => -0.724 mrad in Y



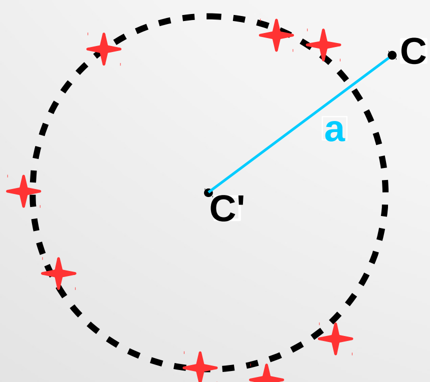


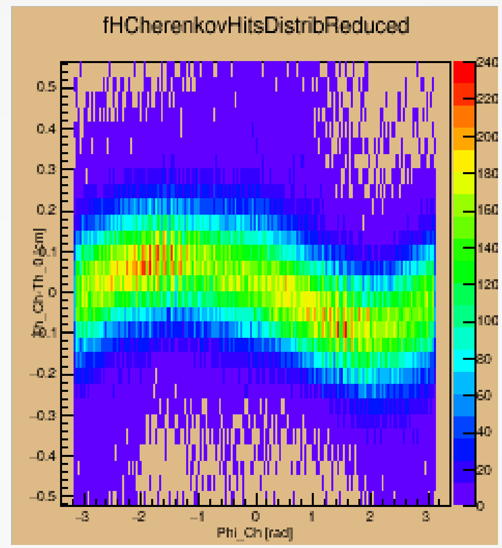
Limits of the method

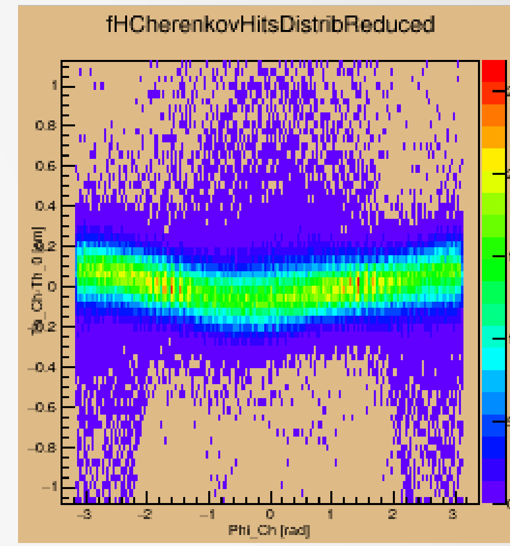
- Systematic analysis
  - Minimum detectable misalignment: 0.3 mrad
  - Maximum detectable misalignment: 12.22 mrad (≡ 0.7 deg)

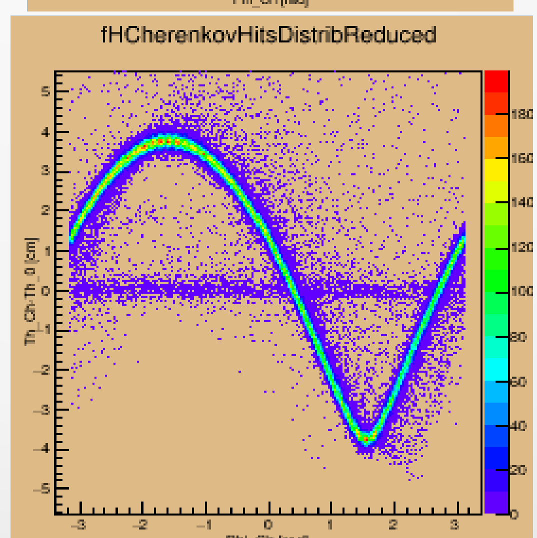
- ✓ Upper left: 0.3 mrad misalignment around Y axis
- ✓ Lower left: 12.2 mrad misalignment around Y axis
- ✓ Upper right: 0.3 mrad misalignment around X axis
- ✓ Lower left: 12 mrad misalignment around X axis

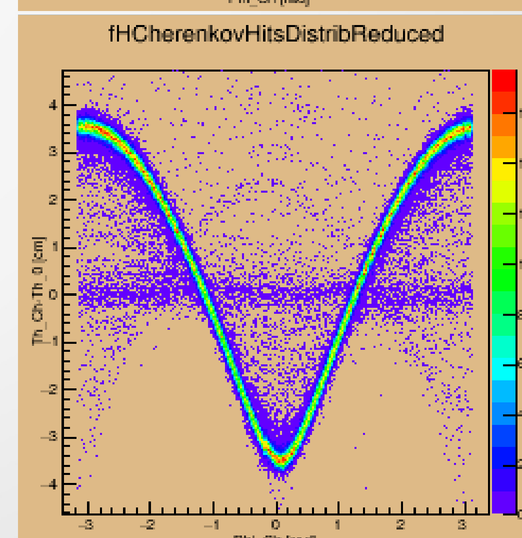
- Maximum reached, as difference between C and C' becomes larger than the ring radius





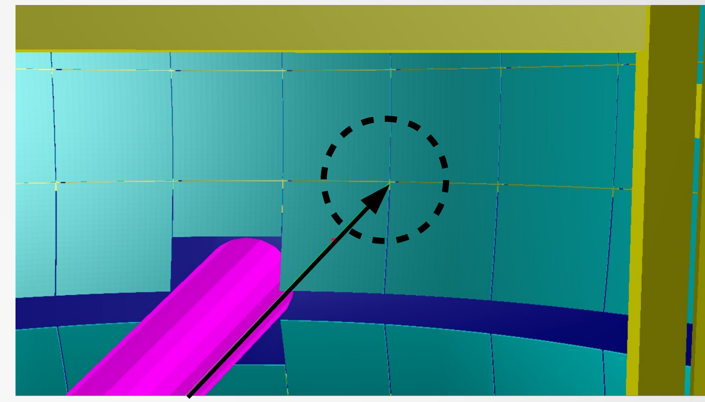


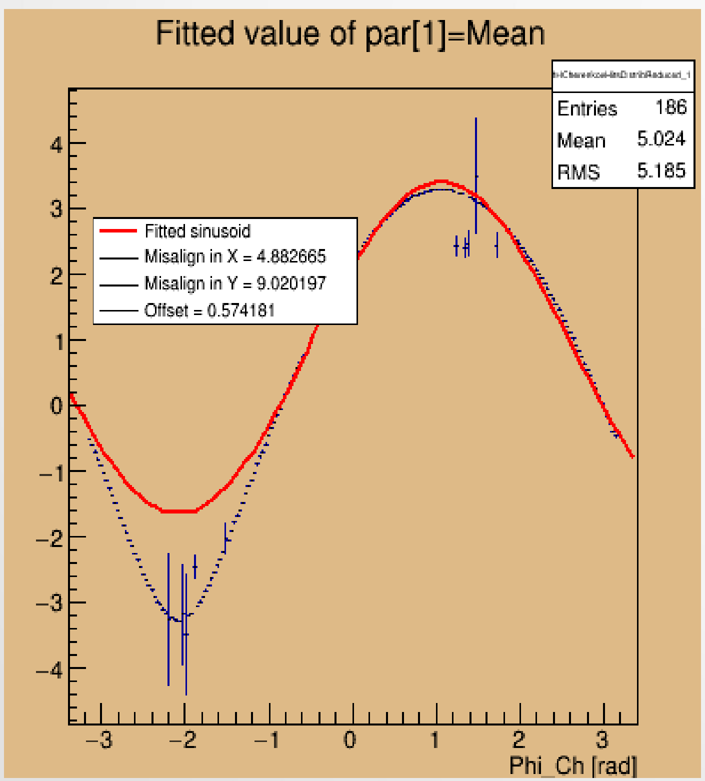


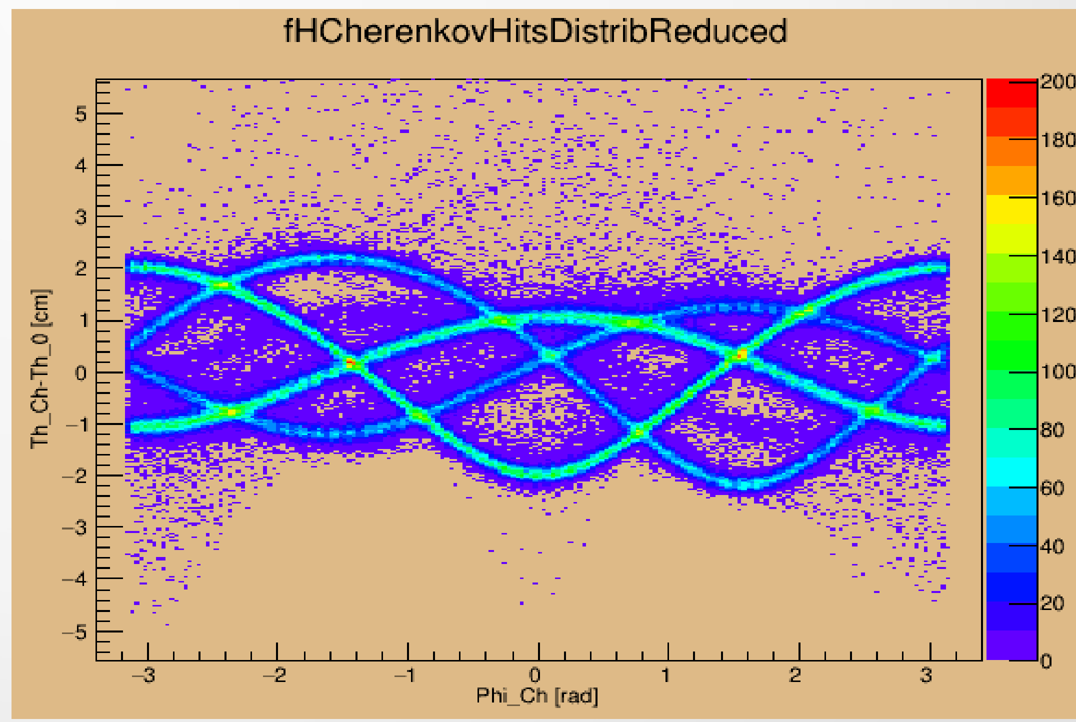


More results

- 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



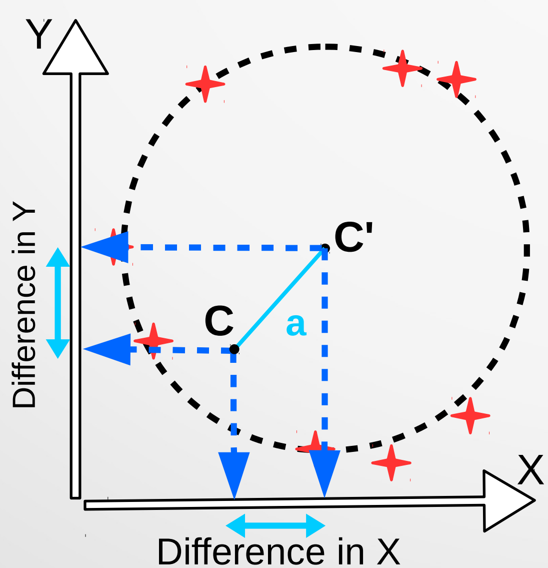


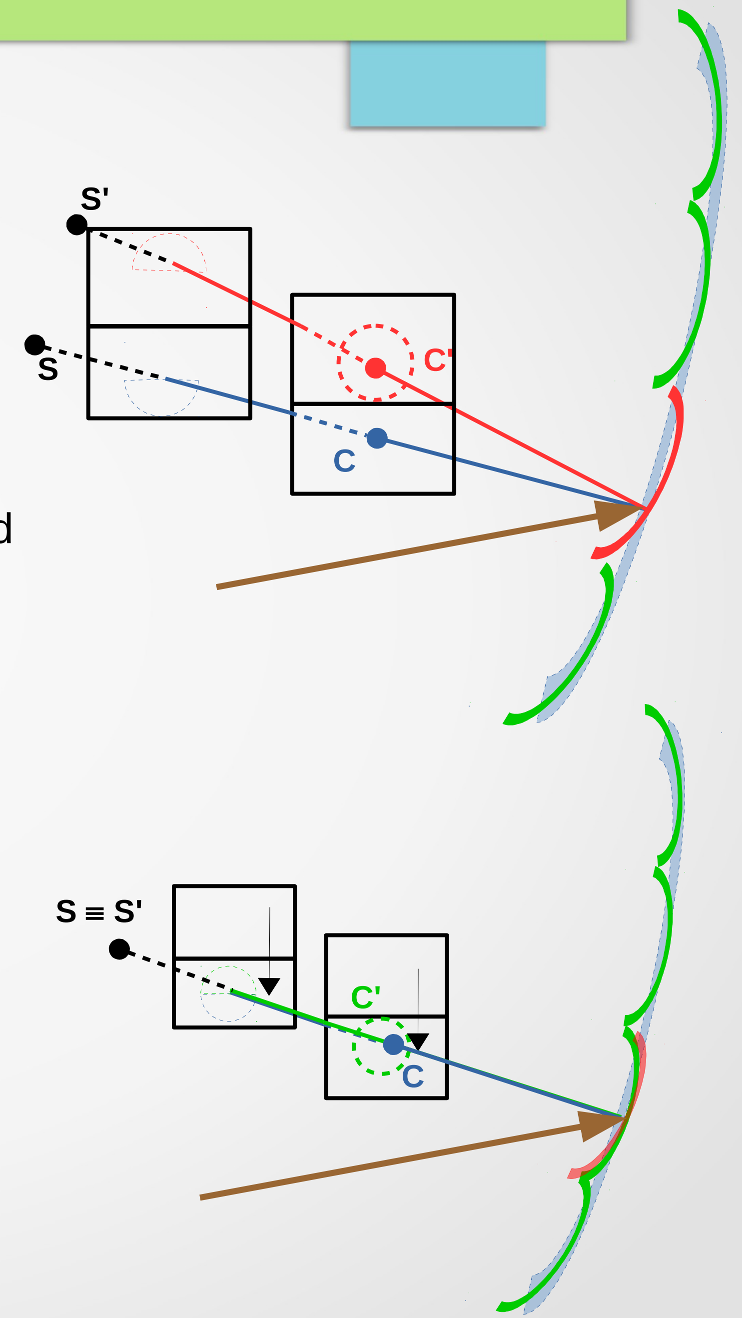


Outline

Correction routine

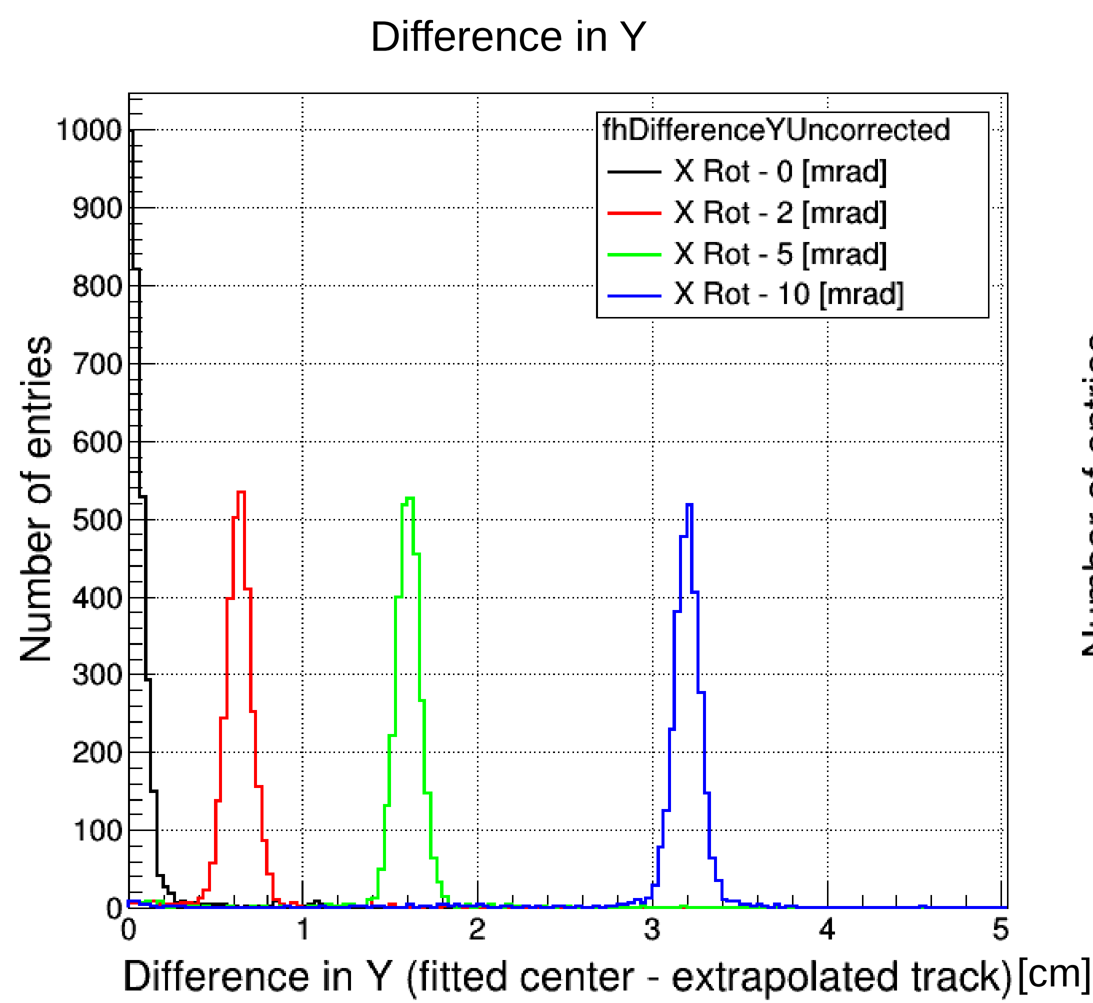
- Reconstruction sequence:
  - Simulation with mirror misalignment
  - Extract misalignment from data
  - Implement misalignment info in the geometry file
  - Run reconstruction with misalignment correction included
  - Compare without and with correction
- First step: work with rings located inside mirror (no edge effects are taken into account)

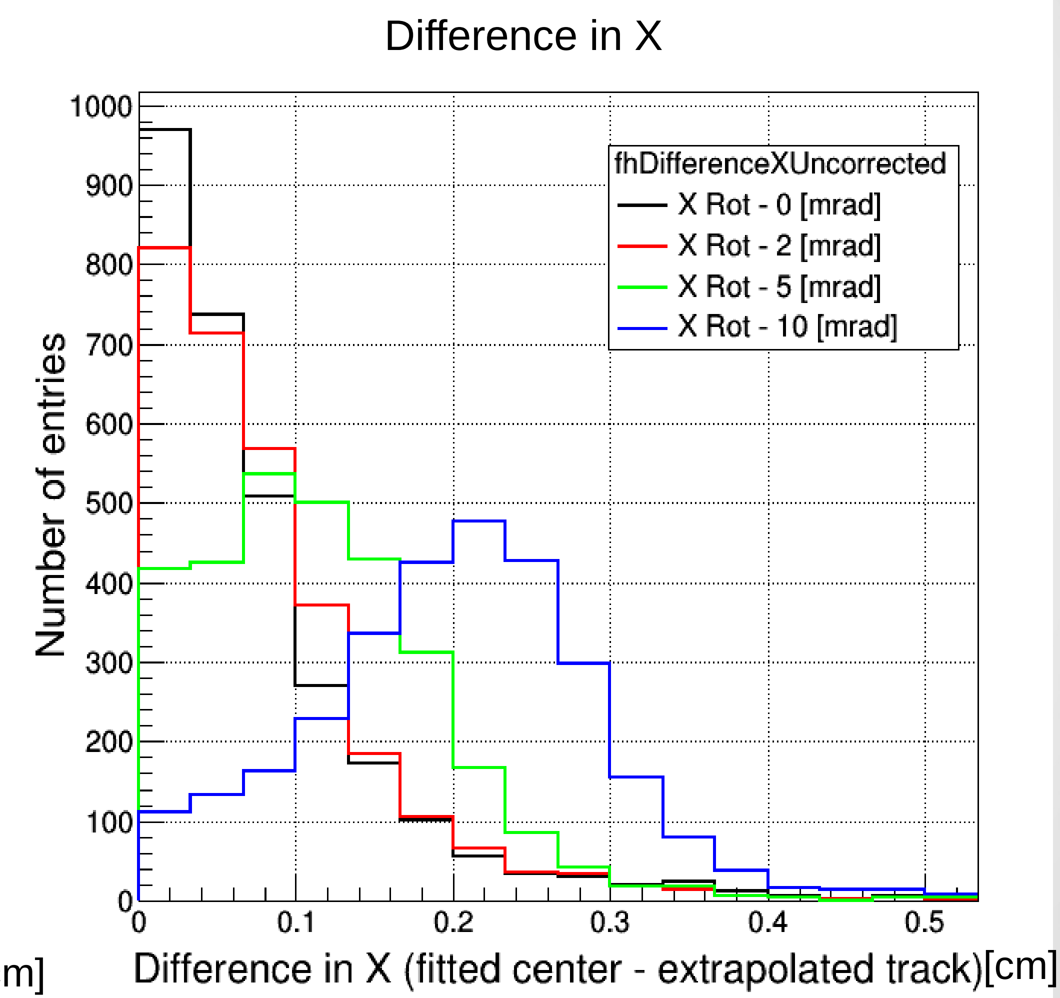




Correction routine

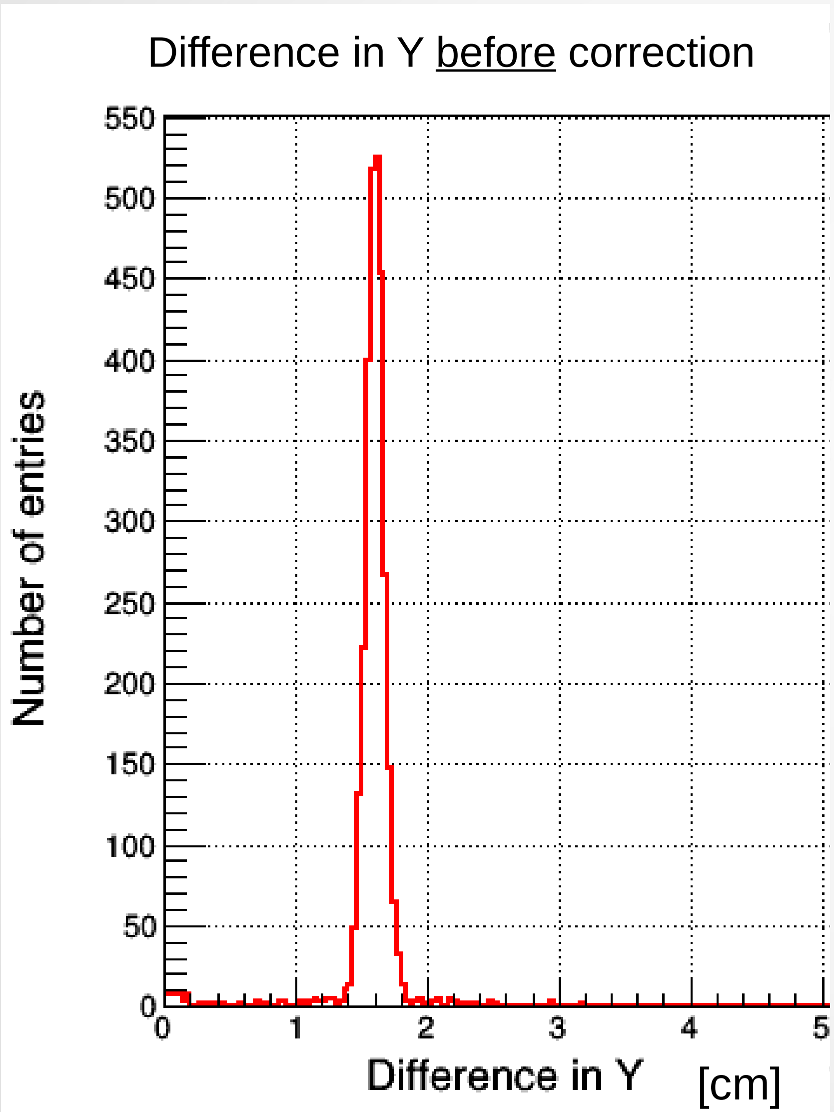
- Several rotations around X axis of the mirror tile:

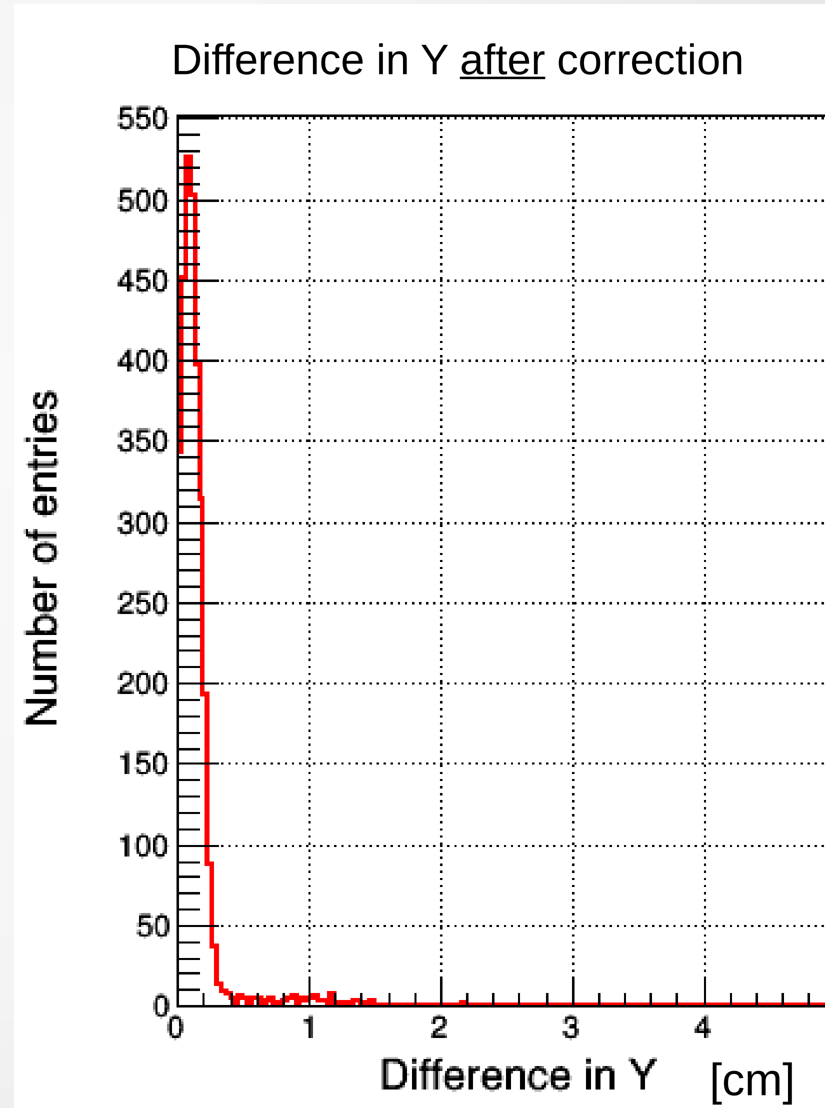




Correction routine

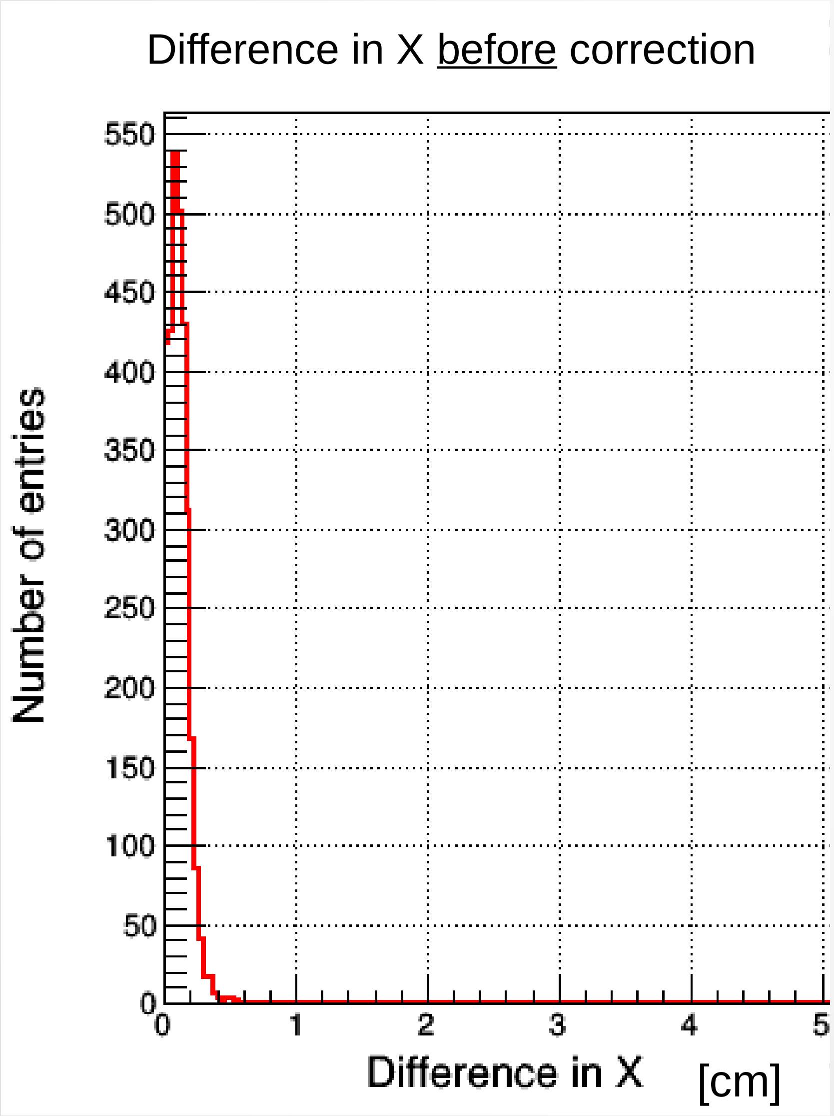
- Case of a 5mrad misalignment around X:

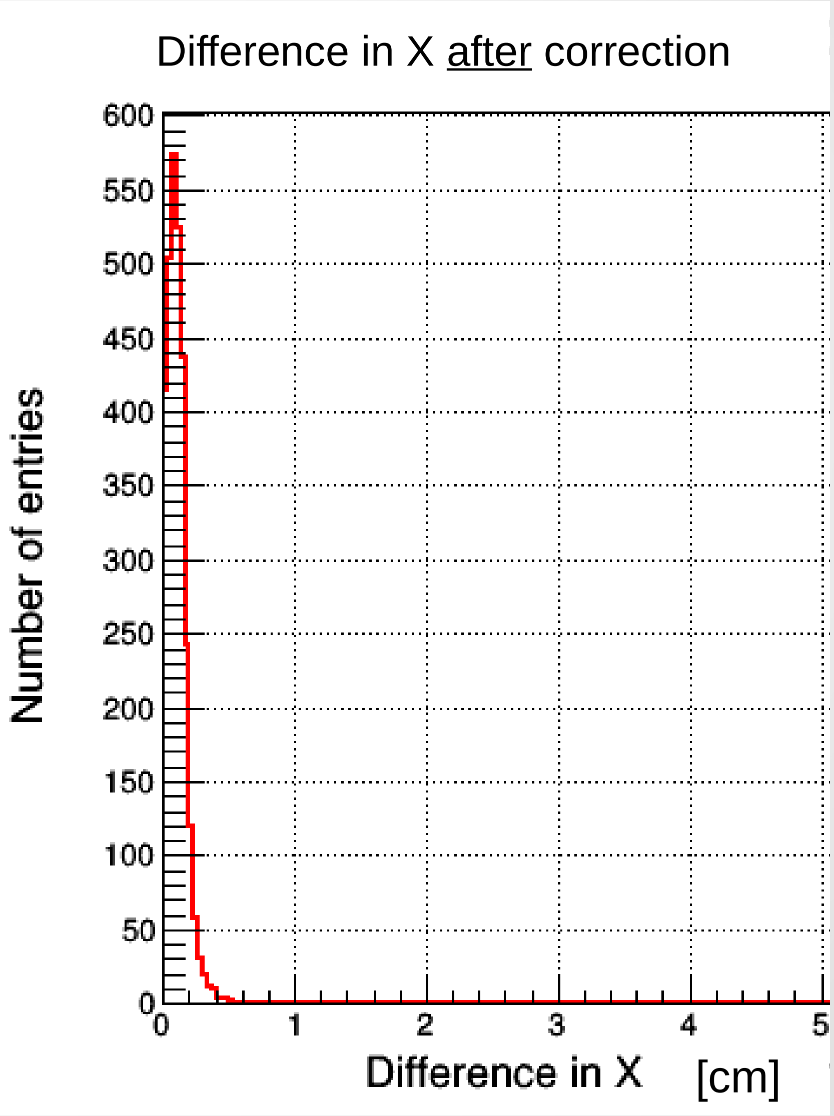




Correction routine

- Case of a 5mrad misalignment around X:

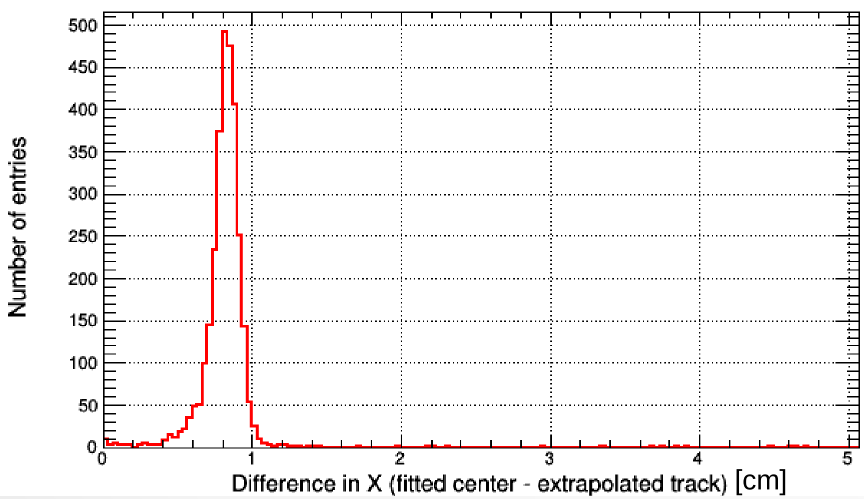




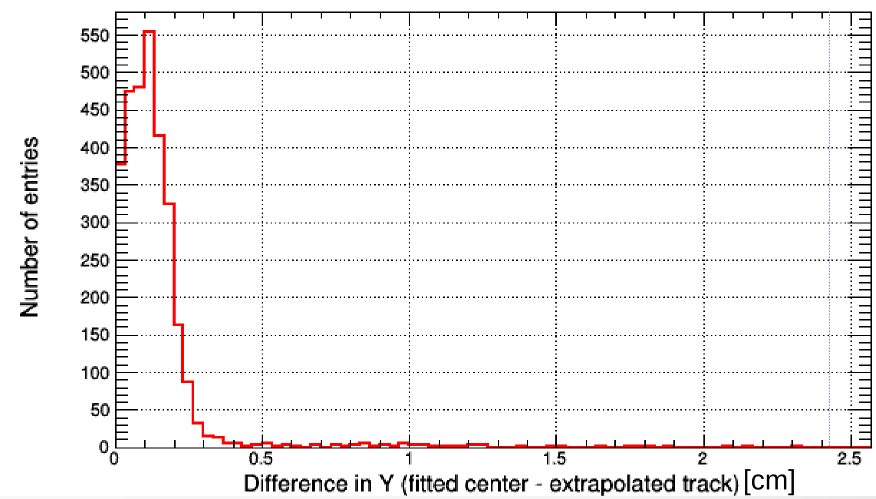
Correction routine

- Case of a 3mrad misalignment around Y:

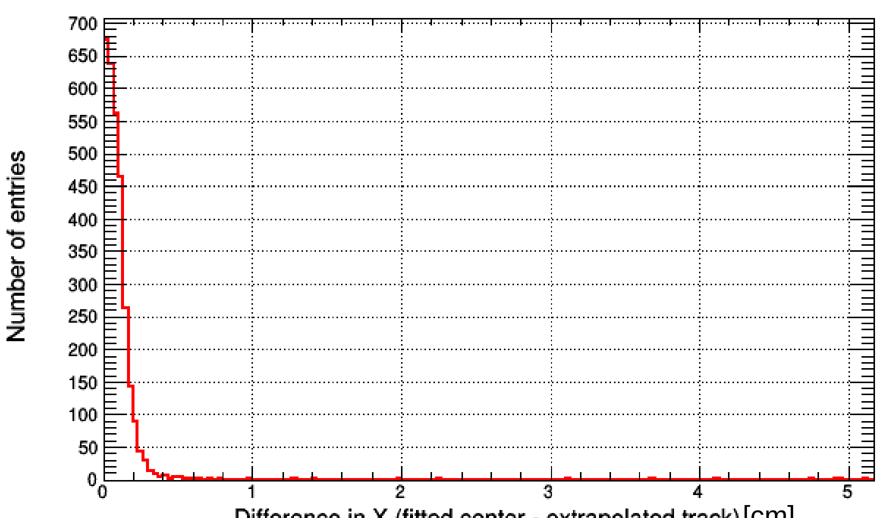
Difference in X <u>before</u> correction



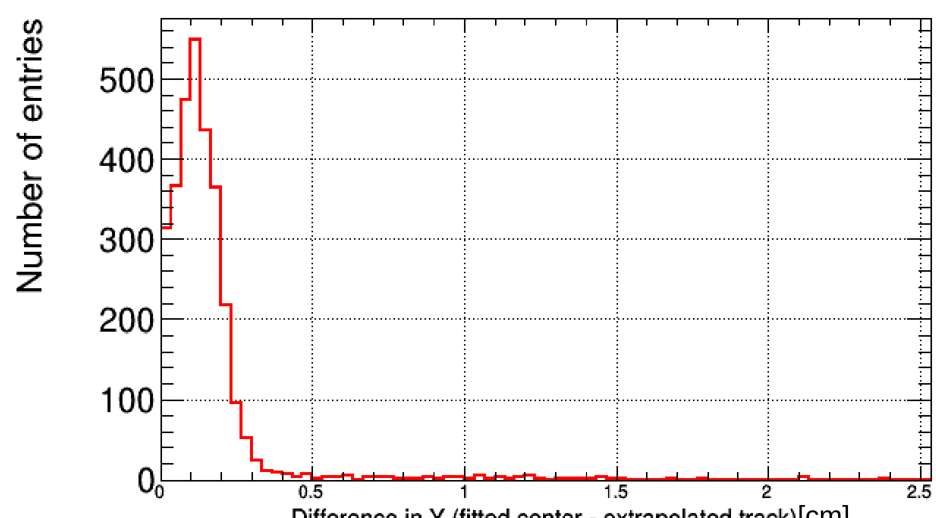
Difference in Y <u>before</u> correction



Difference in X <u>after</u> correction

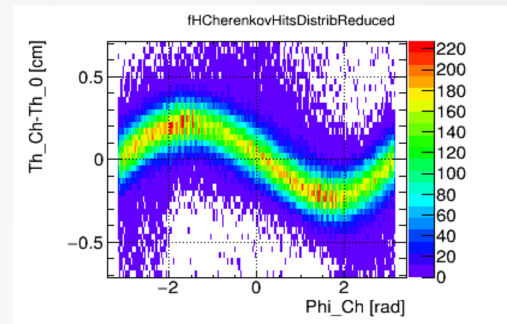


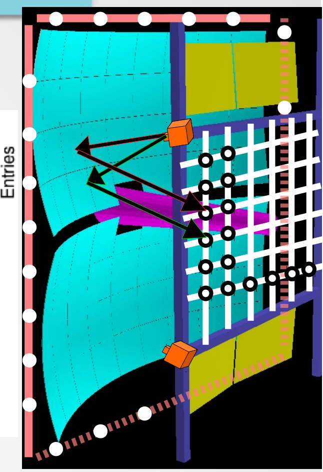
Difference in Y <u>after</u> correction

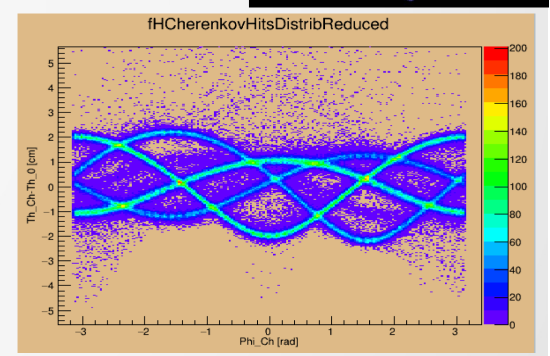


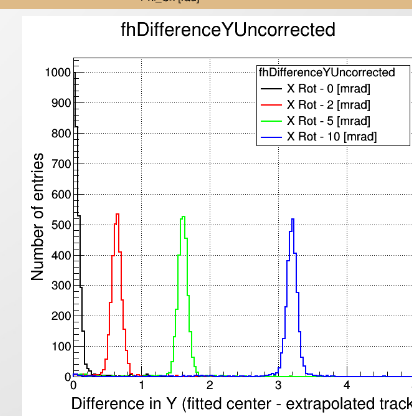
Summary

- Qualitative determination of misalignments using CLAM
  - Broken lines
  - Impact on ring parameters
- Quantitative determination of misalignment and correction
  - Performances of the technique
  - Presentation of a first correction cycle
- Solid ground from which expansion and addition of correction routines is possible
  - Include and compare reconstruction, track-ring matching efficiencies
  - Tests under different conditions
- Next: apply photogrammetry with CLAM algorithm to quantify misalignment and compare with results from shown technique









FAIRNESS

14 – 19 February 2016

Thank you for your attention !