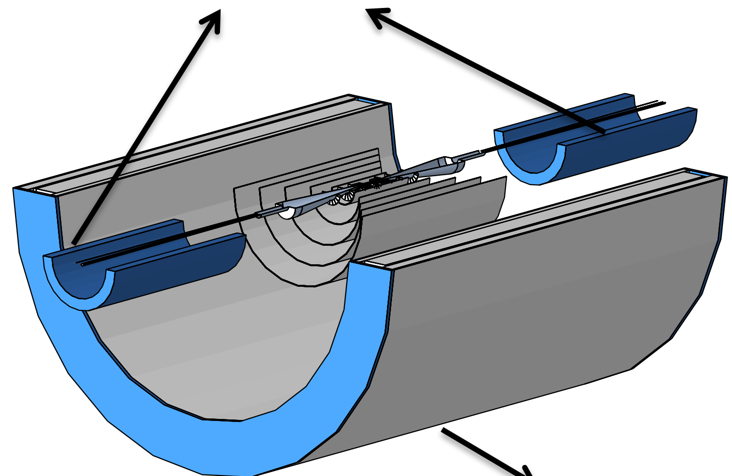
Impact of non-uniform B field on tracking performance

Rosa Simoniello
Supervisor: Konrad Elsener

Outline

- Brief introduction + workflow
- Non-uniform B-field cases studied:
  - 1% variation along z direction
  - 10% variation along z direction
- Comparison of the tracking performance
- Comparison with the CMS case
- Conclusions and next steps

Magnetic system overview



- Central solenoid + 2 forward anti-solenoid superconducting magnets
  - Main functions of the anti-solenoids:
    - to protect QD0 (final focusing quadrupole) from demagnetization
    - to reduce the local central solenoid magnetic field in order to limit perturbation of the incoming particles
- Effects of the magnetic field to be considered:
  - Field outside detector is important because it can cause *perturbation in other magnetic fields*
  - Beam crossing angle of 20 mrad → particles see also a perpendicular field component => *distortion of the trajectory and luminosity loss*
  - Distortion of the field is important because it can distort particles trajectories => *tracking performance are affected* (like the the track resolution and the track efficiency reconstruction)
    → no calo performance are studied at the moment

Workflow

1) Geometry definition: compact.xml + GeomConverter

→ ***Non-uniform*** *B field introduced by a map with position coordinates and field values*

2) Simulation: SLIC (based on Geant4 → interaction of particle in matter)

→ *Tracker hits are simulated according* ***the non-uniform*** *B field*

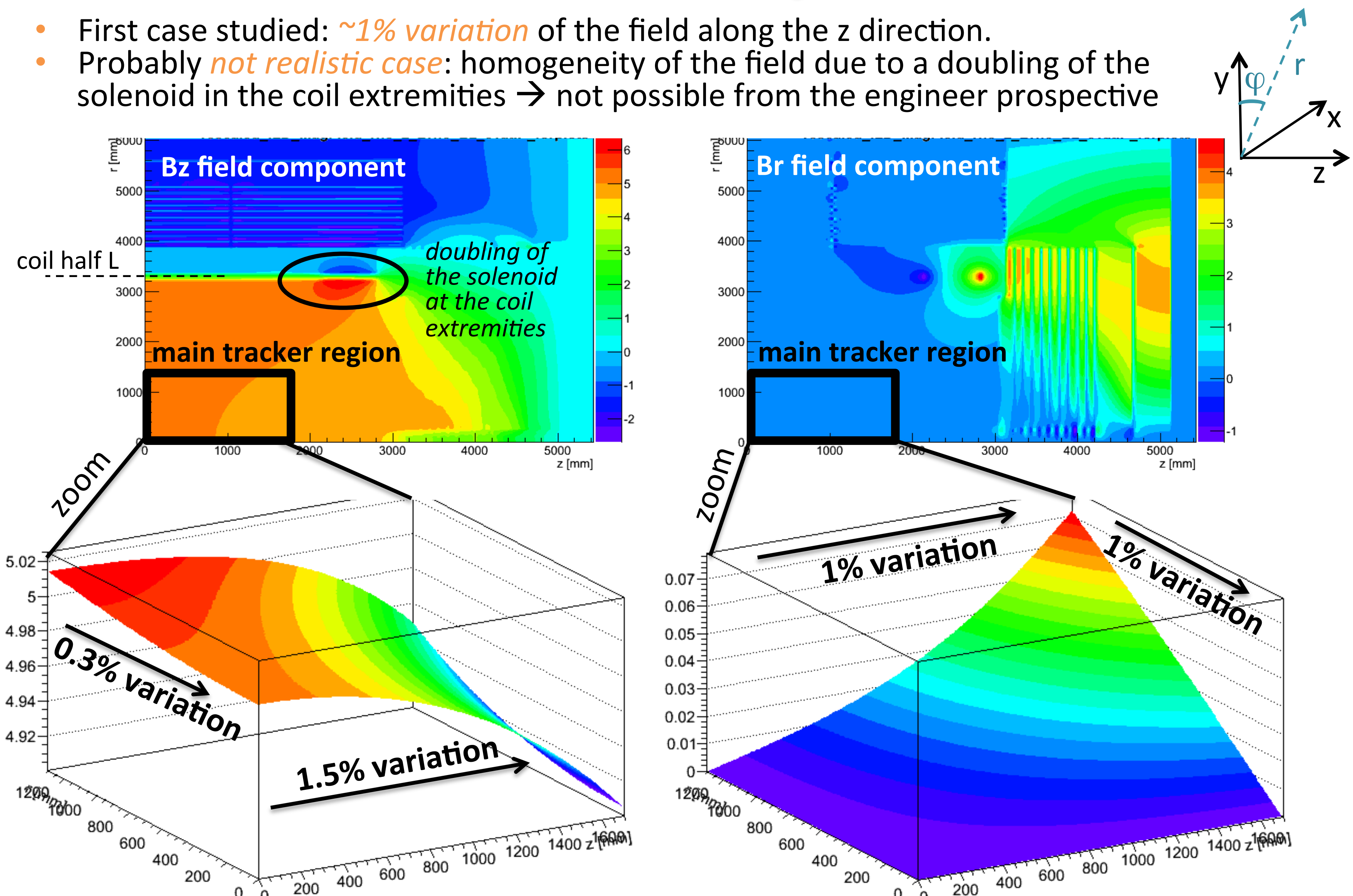
3) Reconstruction: LCSim

→ ***Uniform*** *B field assumed (value at the IP):*

- CPU usage + no tracking reconstruction code available for non-uniform B field (also CMS choice)

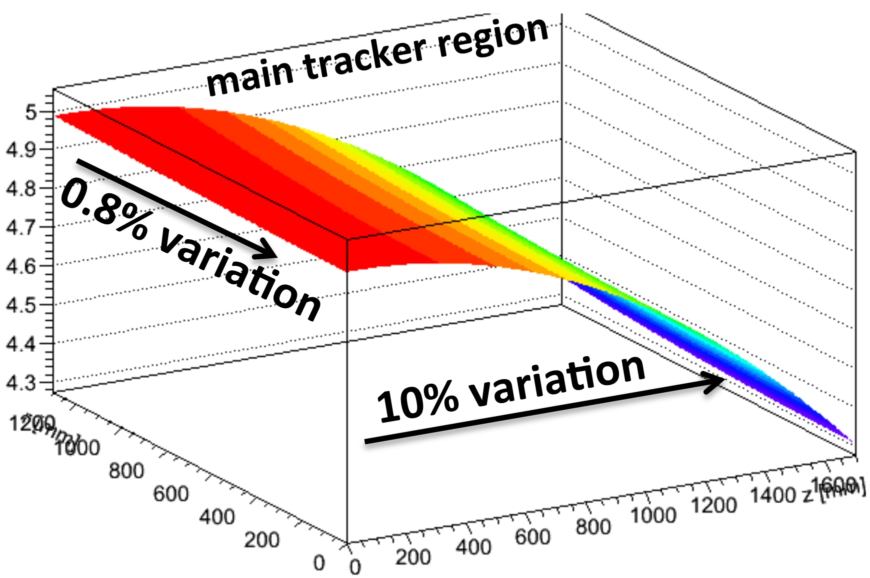
Non-uniform B-field map: ~1% variation

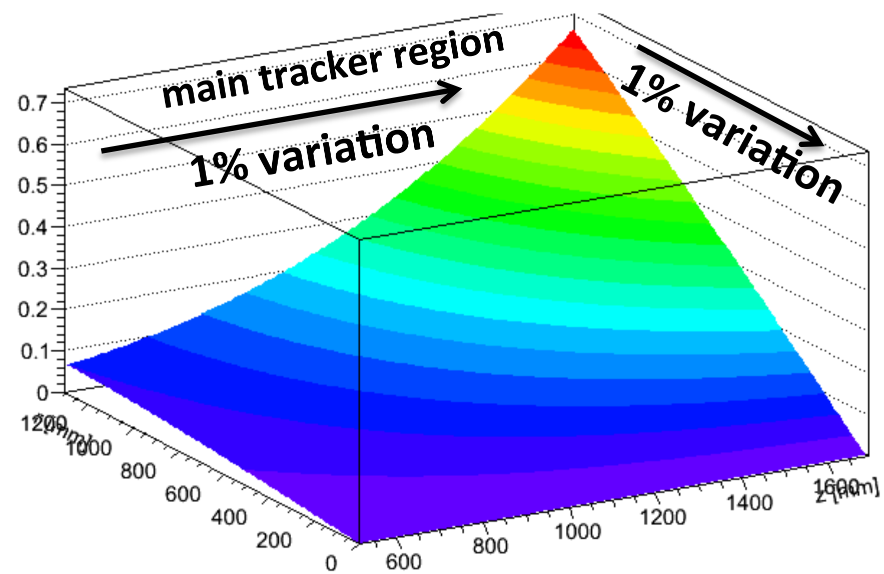
- First case studied: *~1% variation* of the field along the z direction.
- Probably *not realistic case*: homogeneity of the field due to a doubling of the solenoid in the coil extremities → not possible from the engineer prospective



Non-uniform B-field map: 10% variation

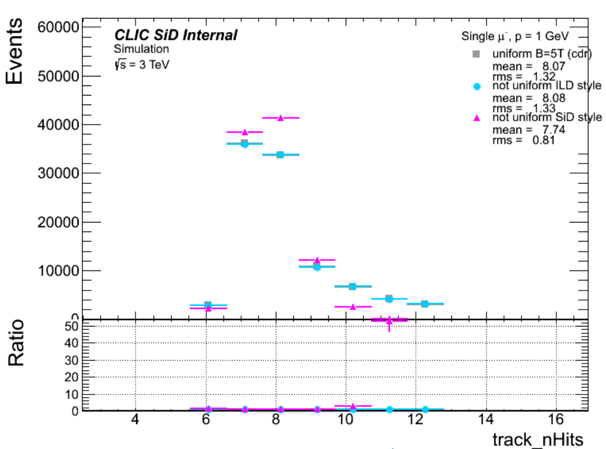
- From beam line studies, expected a *10% variation* of the B-field along the beam line direction (20 mrad)
- More realistic expectation
- *Preliminary results* obtained imposing a 10% variation of the Bz component independently from the Br component inside the main tracker region
  - *A proper map for the SiD detector concept is under derivation (thanks to Benoit Cure)*



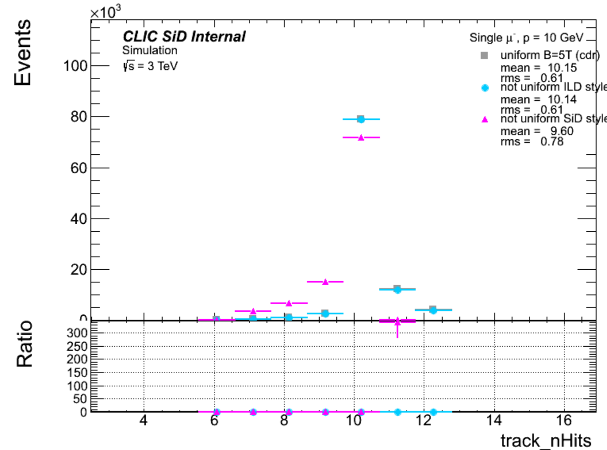


Tracking performance – number of hits

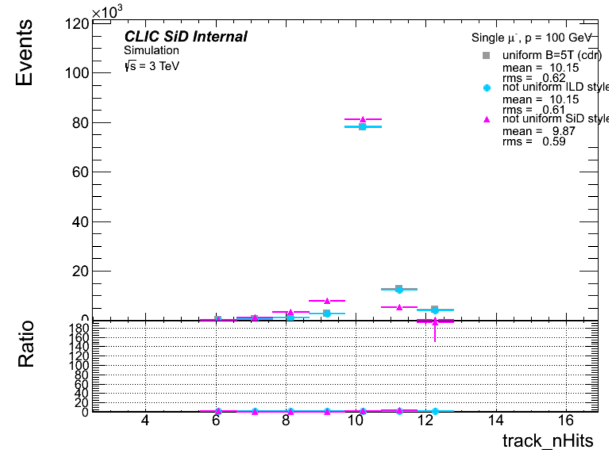
μ⁻, p = 1 GeV



μ⁻, p = 10 GeV

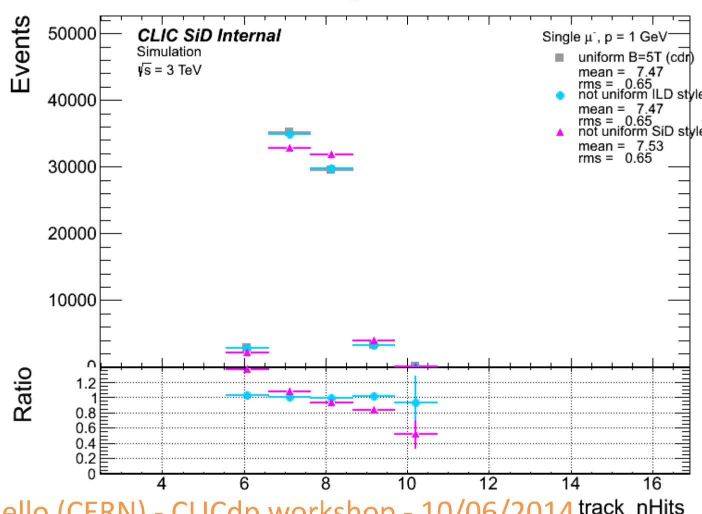


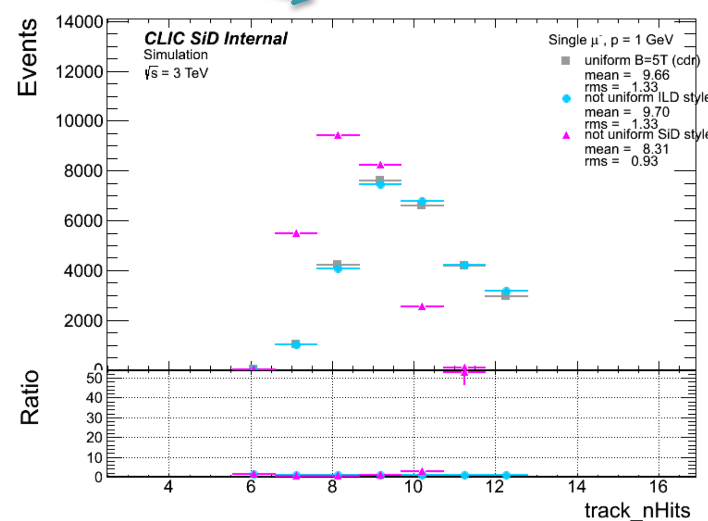
μ⁻, p = 100 GeV



"central region"
45°<|θ|<90°

"forward region"
|θ|<45°



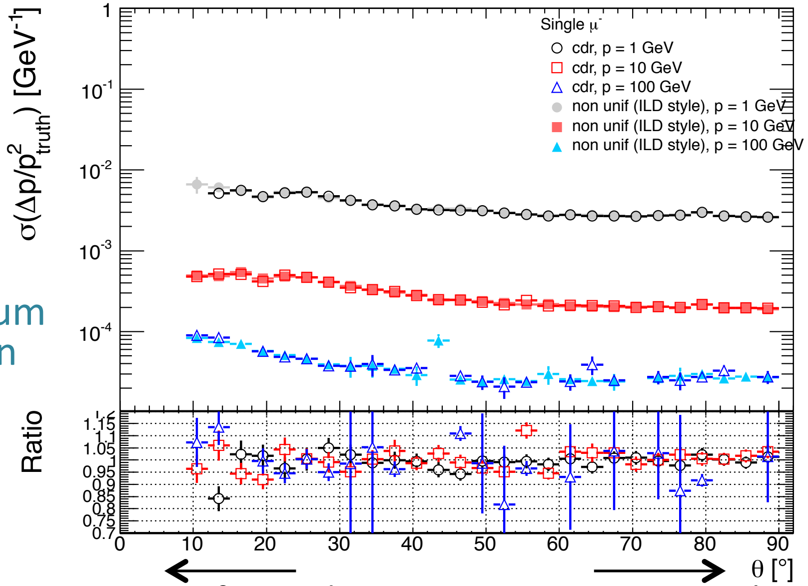


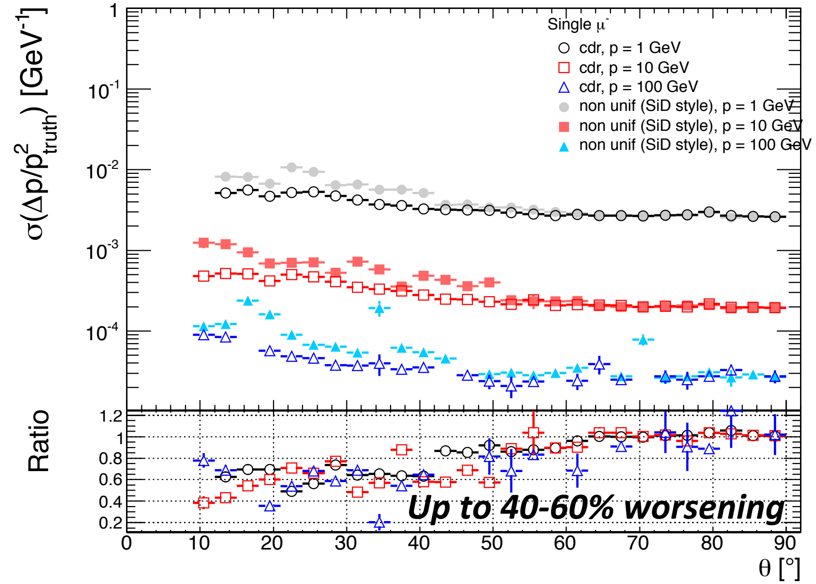
Tracking performance – momentum resolution

↓ 1% non-uniform B-field

↓ 10% non-uniform B-field

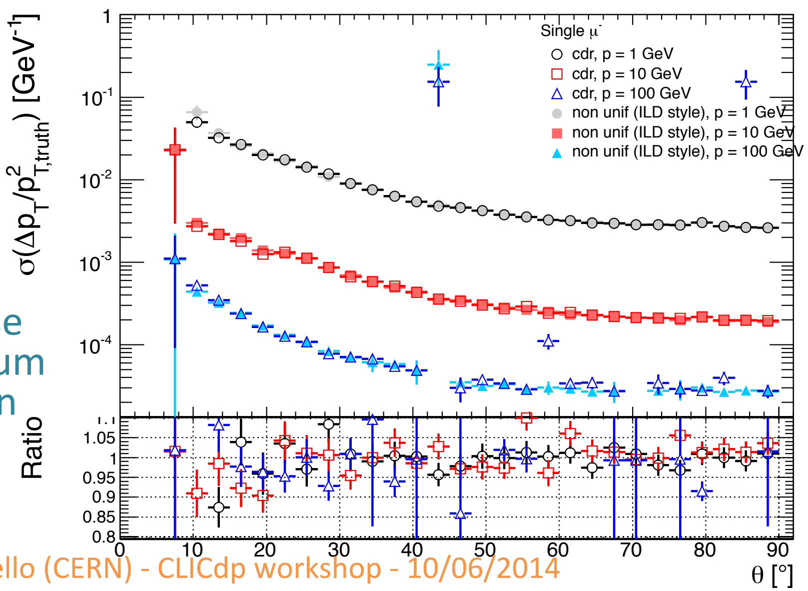
→ momentum resolution

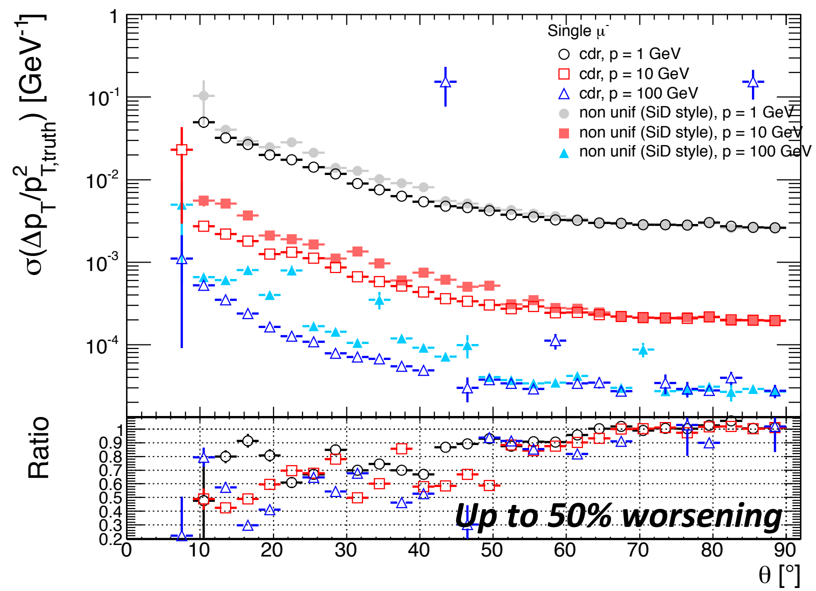




← *more forward*   *more central* →

→ transverse momentum resolution



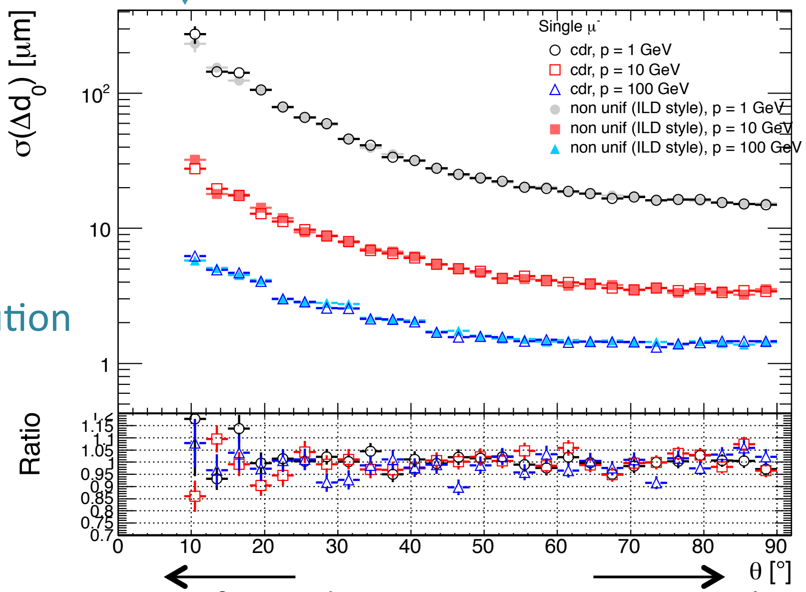


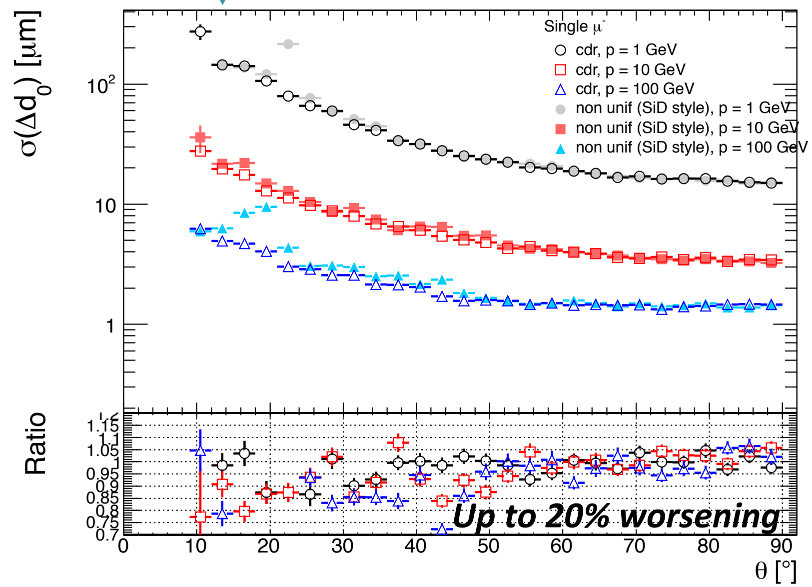
Tracking performance – d_0, z_0 resolution

1% non-uniform B-field

10% non-uniform B-field

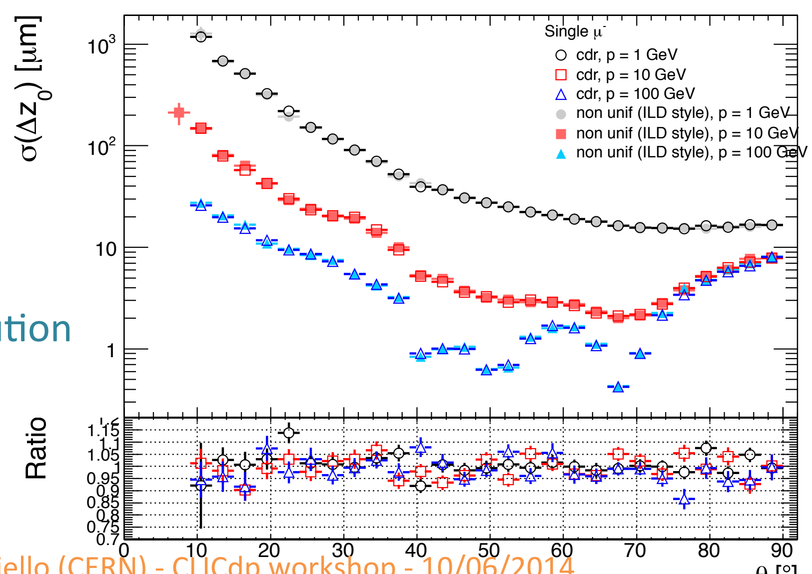
d_0 resolution

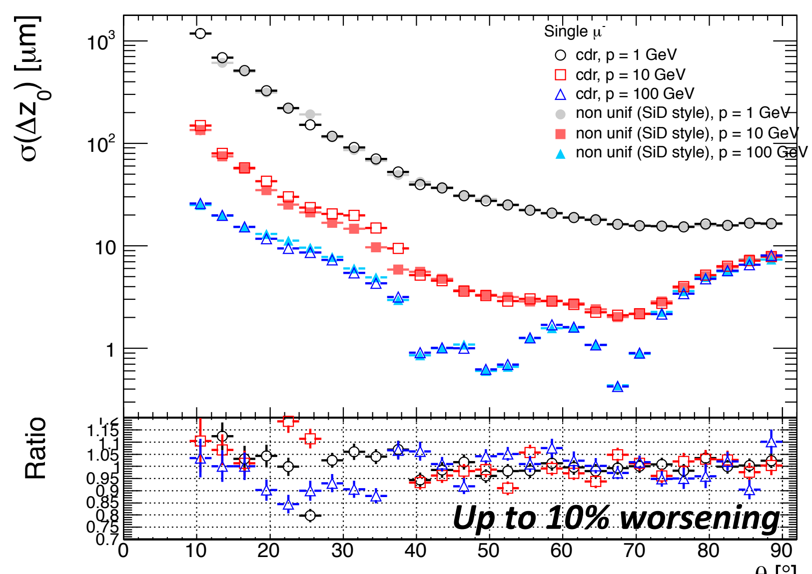




more forward *more central*

z_0 resolution

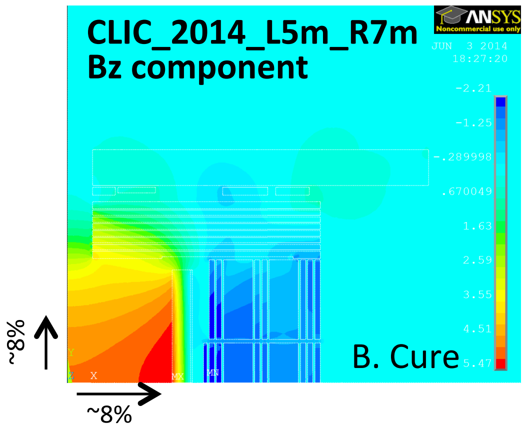


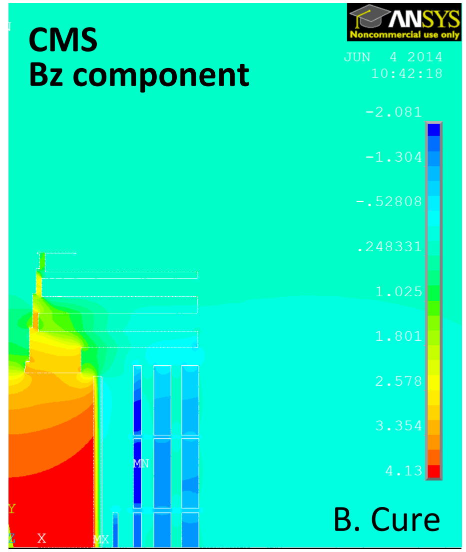


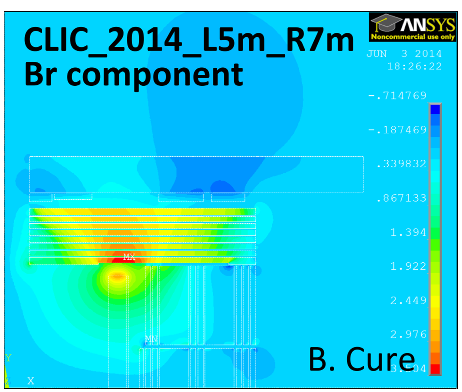
Comparison with CMS

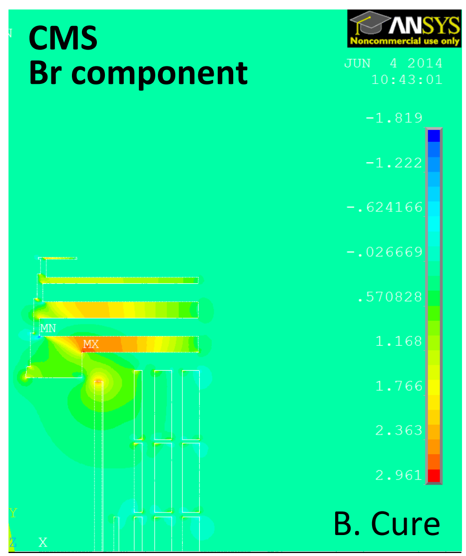
Thanks to Benoit Cure and Nicola Amapane

SiD with reduced iron yoke in the endcap will be used (CLIC_2014_L5m_R7m)→ expected a bit more non-uniform field => more relevant for these studies









- CMS pays a lot of attention to field in the yoke (arXiv:0910.5530) → less critical for CLIC
- Field inside the tracker region *pretty uniform* (long solenoid)
  - Main non from non-symmetry in z (different number of spires in the coil)
- Tracker field mapped with an *accuracy <0.1%* → important for physical analysis:
  - measurements of track parameters near the interaction vertex
  - to limit bias in the momentum scale (w.r.t. the momentum resolution)

	CMS	SiD
B [T]	3.8	5.0
L [m]	12.5	6.4
R [m]	3.0	5.4

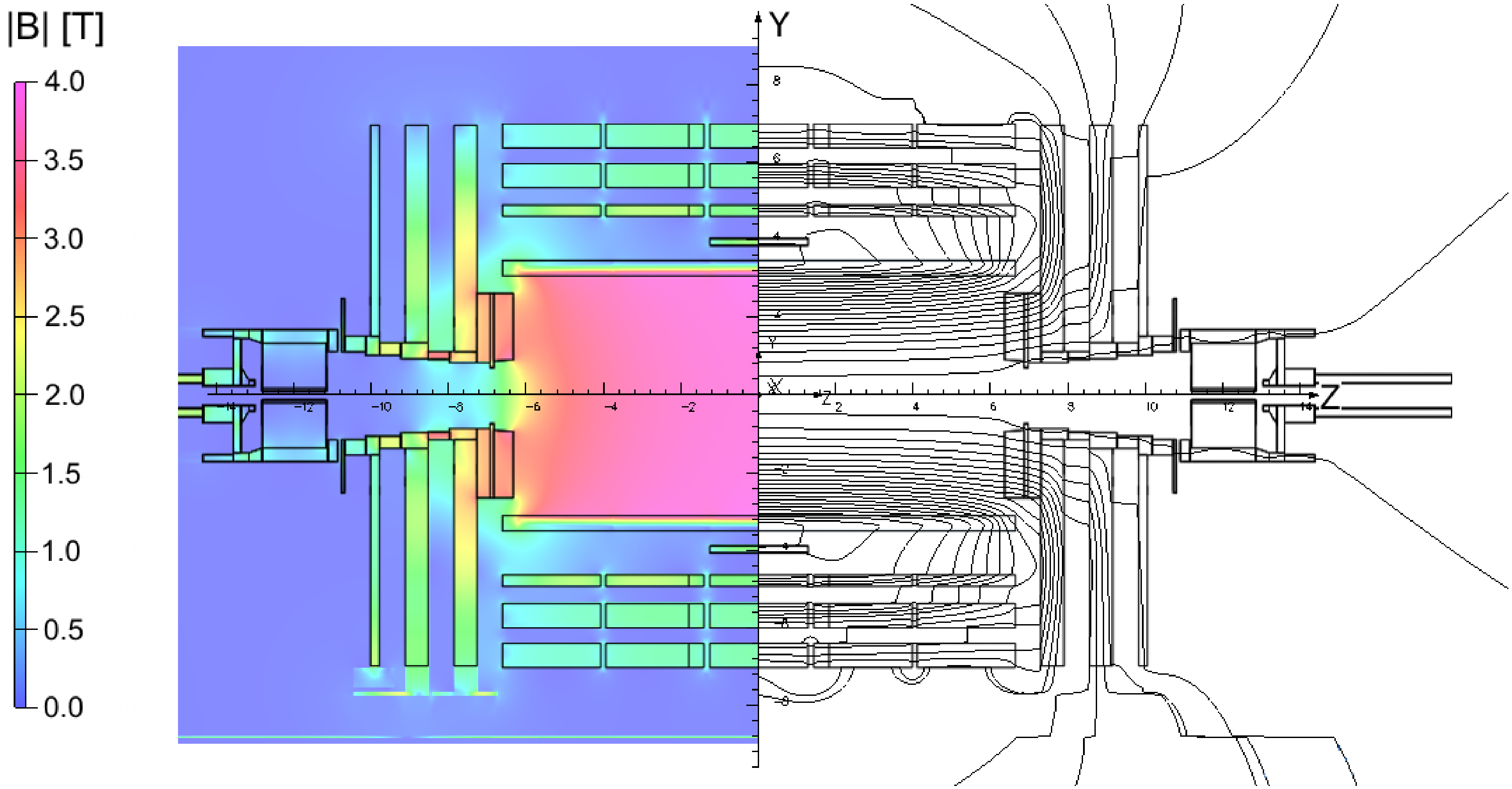
Conclusions and next steps

- *Non-uniform B-field* is an important aspect to take into account during the design of the detector
- Distortion of the particle trajectory → *effects on the tracking performance*
    - Not negligible effects are observed for B-field non-uniformities of 10%, in particular for the momentum resolution performance
      → variation of the B-field of 5-10% looks as a realistic expectation
    - Work on-going to have a proper B-field map for SiD

- CMS benefits of a more uniform B-field in the tracker region thanks to the longer solenoid
- Important to study the case of the new geometry (with the longer tracker) → the longer dimension of the solenoid could provide a more uniform field as well

BACK-UP

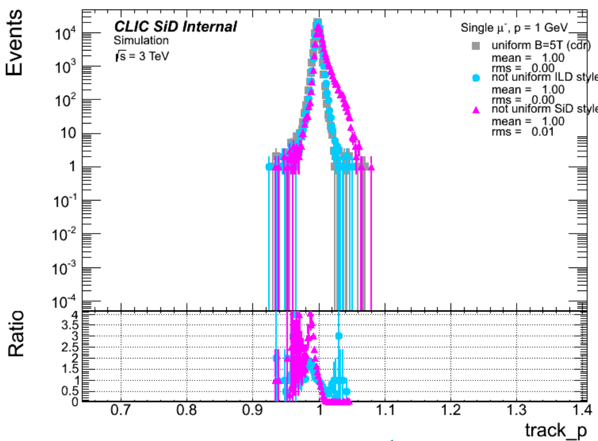
B field in CMS



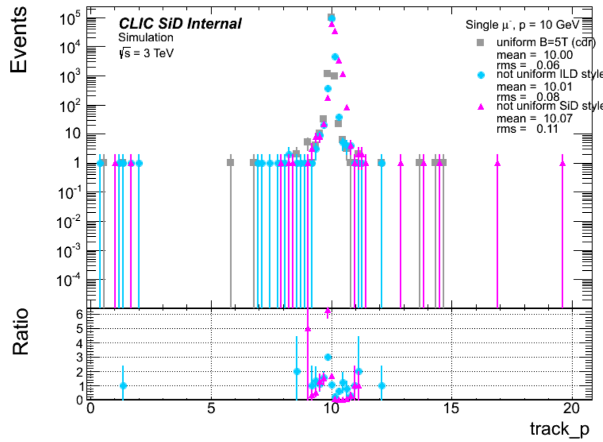
Tracking performance – reconstructed p

Log y scale

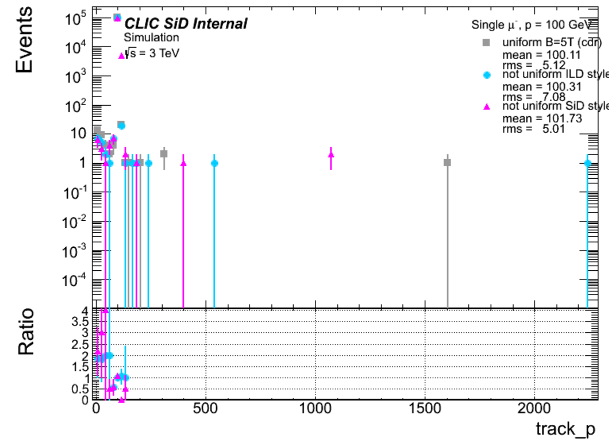
μ^-, p = 1 GeV



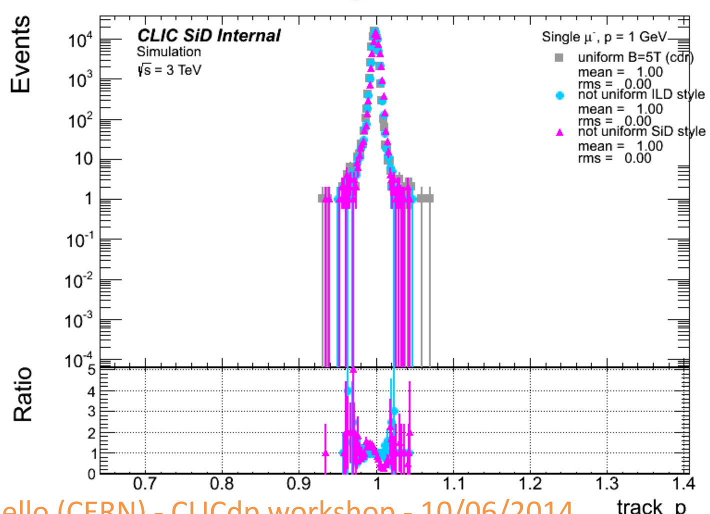
μ^-, p = 10 GeV



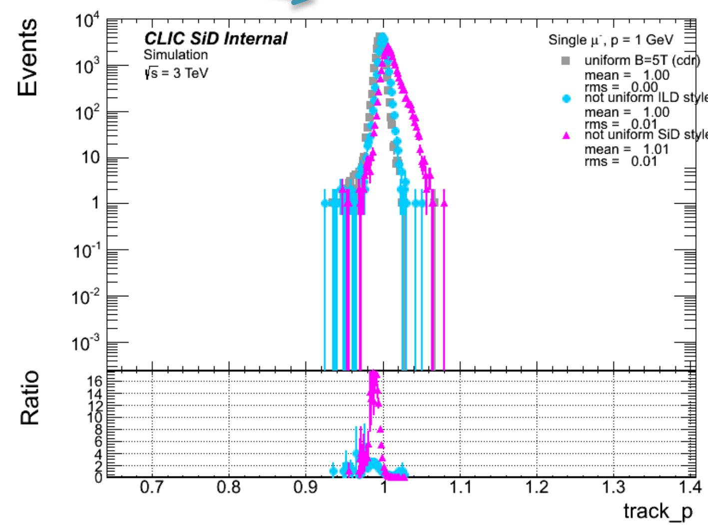
μ^-, p = 100 GeV



"central region"
45°<|θ|<90°



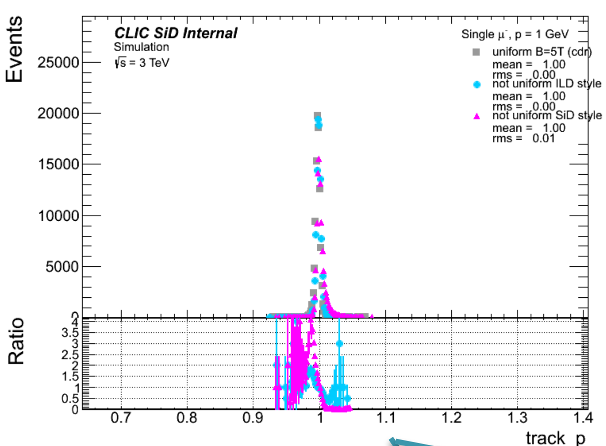
"forward region"
|θ|<45°



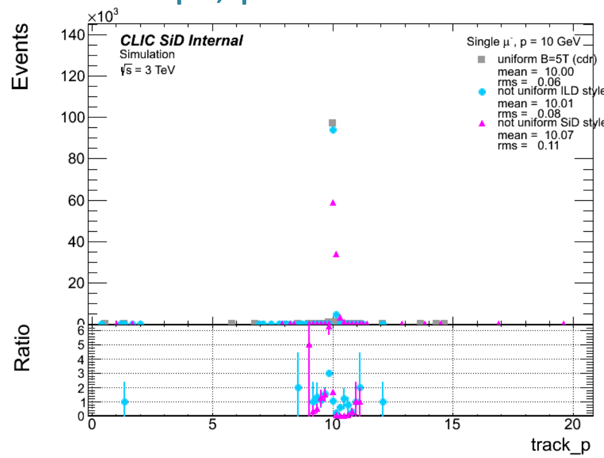
Tracking performance – reconstructed p

Linear y scale

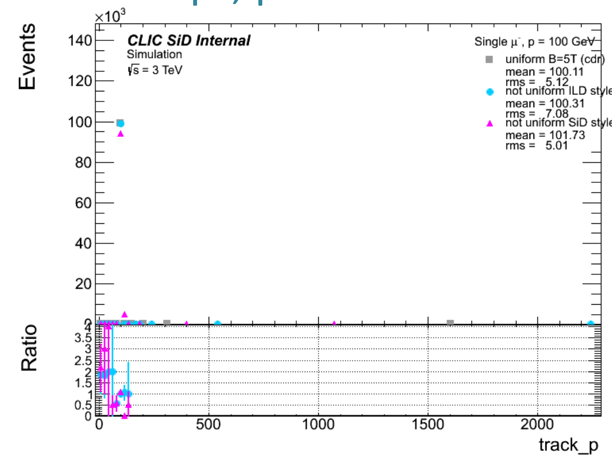
μ⁻, p = 1 GeV



μ⁻, p = 10 GeV

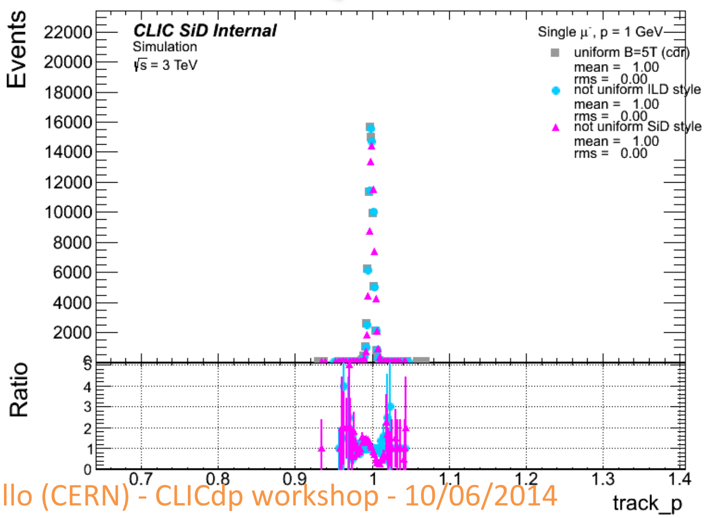


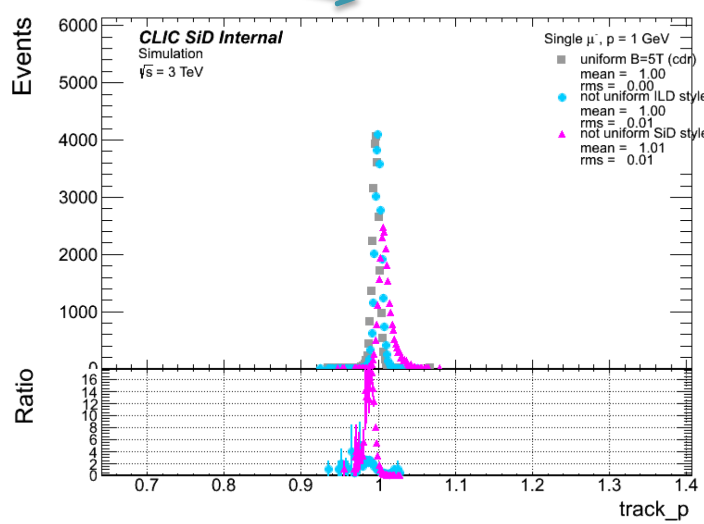
μ⁻, p = 100 GeV



"central region"
45°<|θ|<90°

"forward region"
|θ|<45°



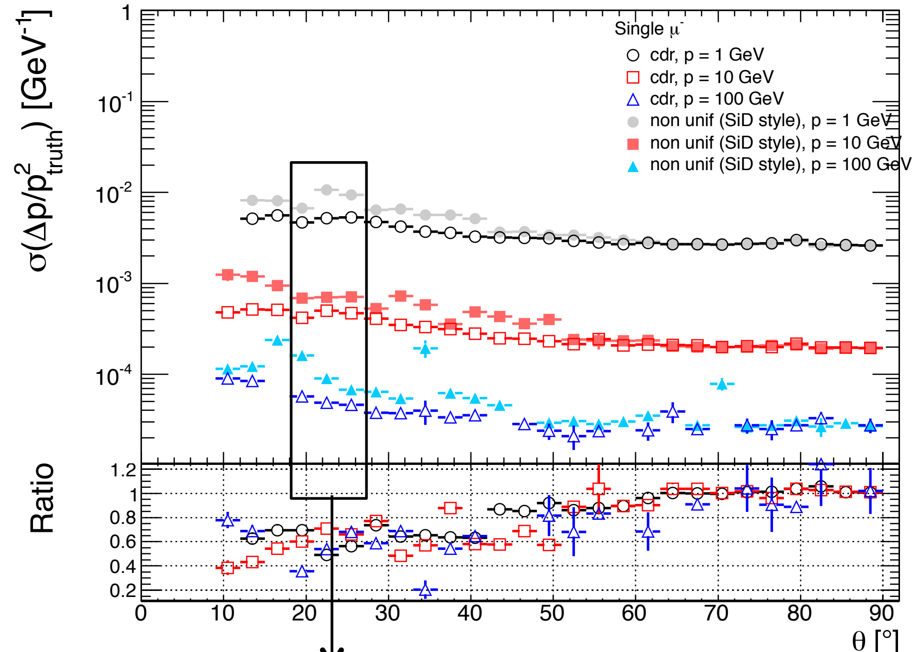


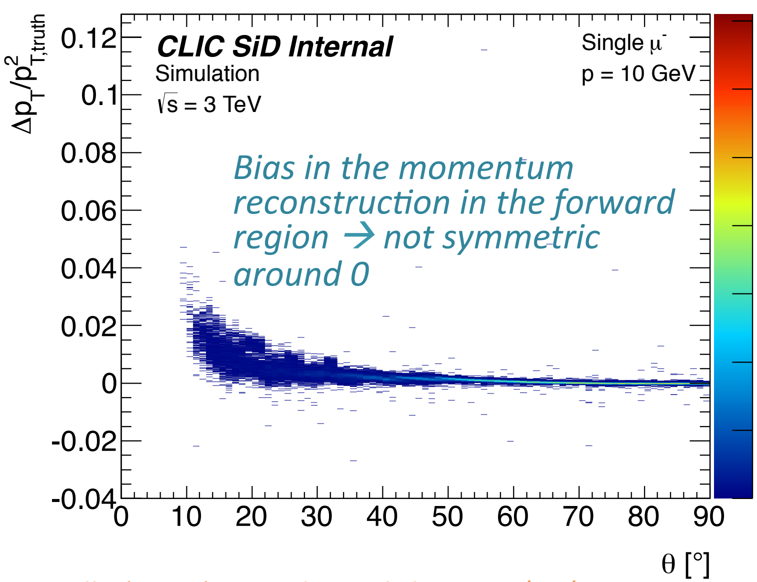
Tracking performance – p resolution

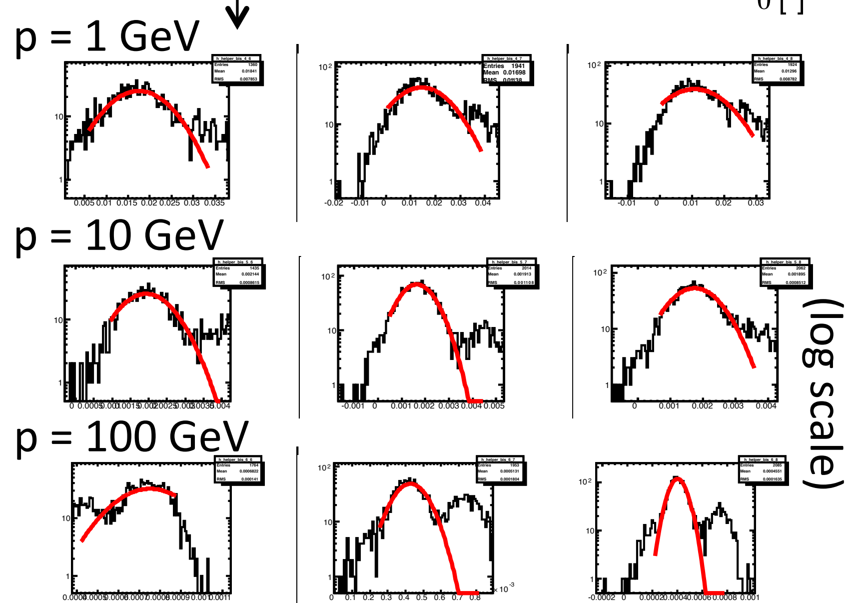
In the forward region beyond the worse resolution it seems to be also a *bias in the momentum reconstruction* (not centered at 0)

→ Some *double peak distributions* (more evident at high p where the better resolution allows to distinguish the peaks)

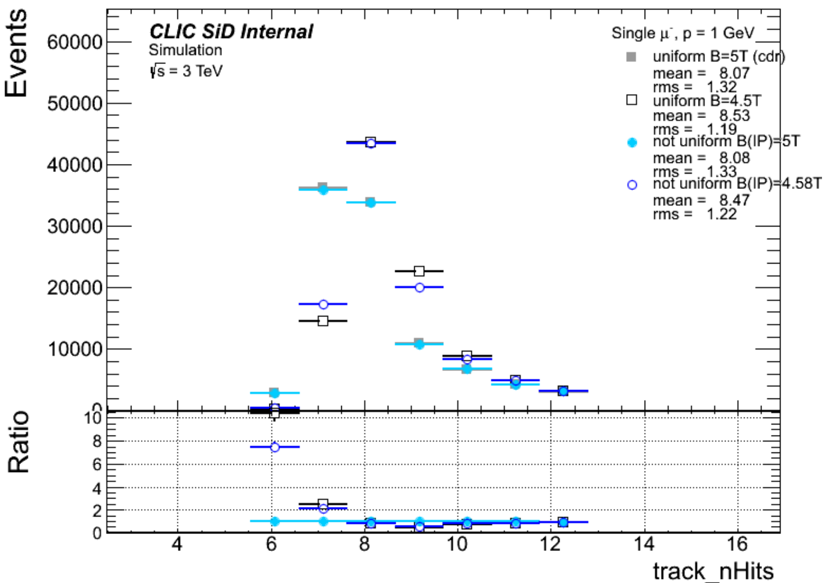
→ The performance are actually worse than what it looks like

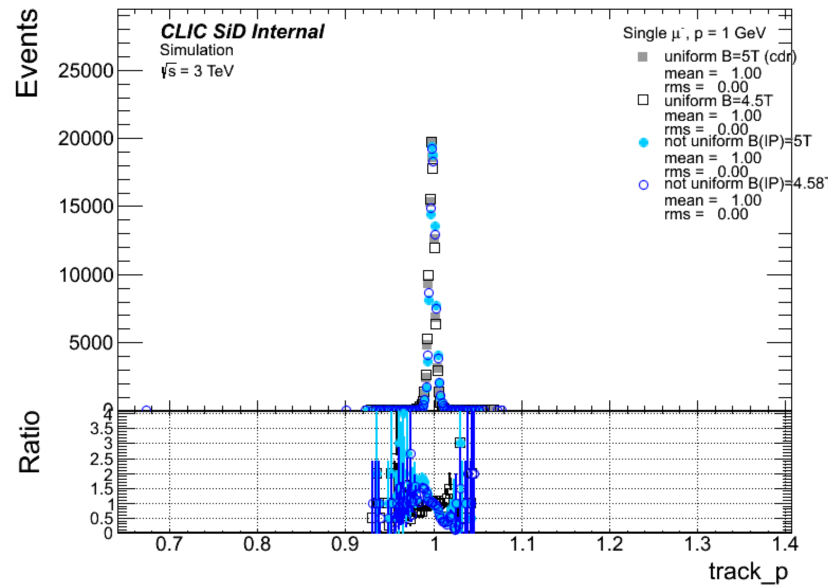


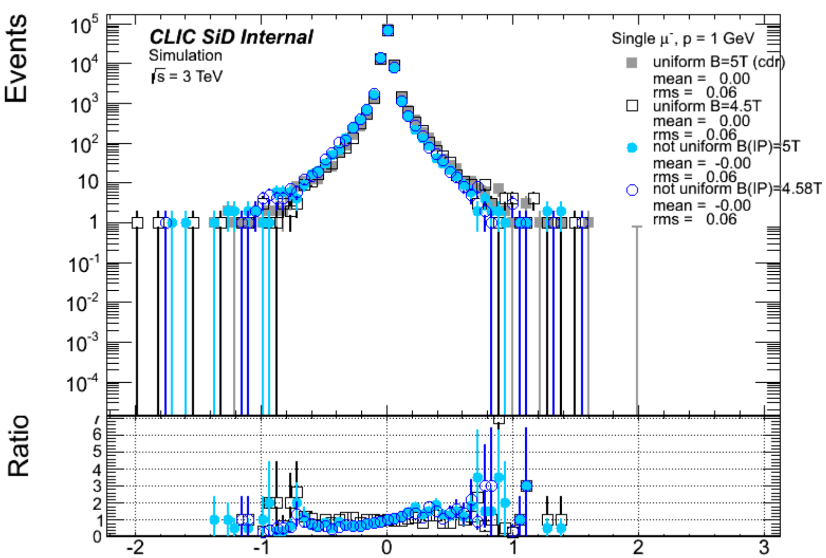


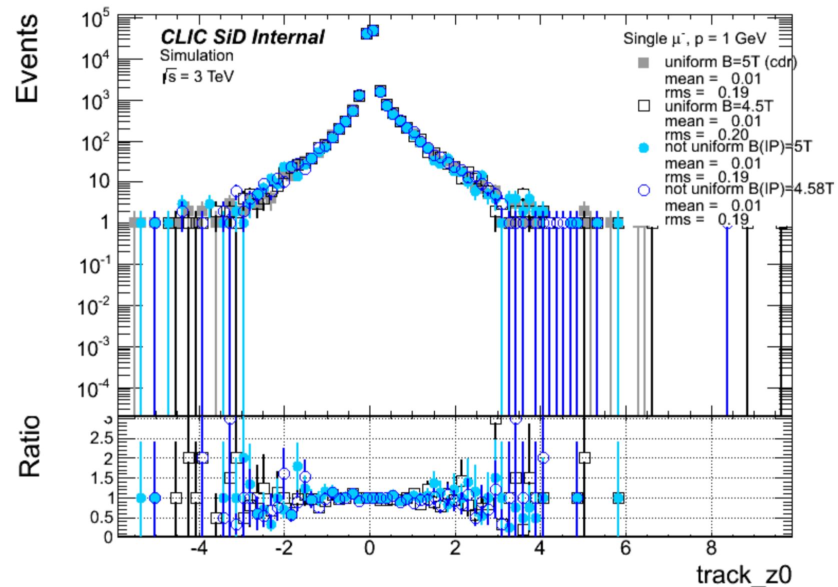


Comparison between 5 T and 4.5 T B field, uniform and non-uniform

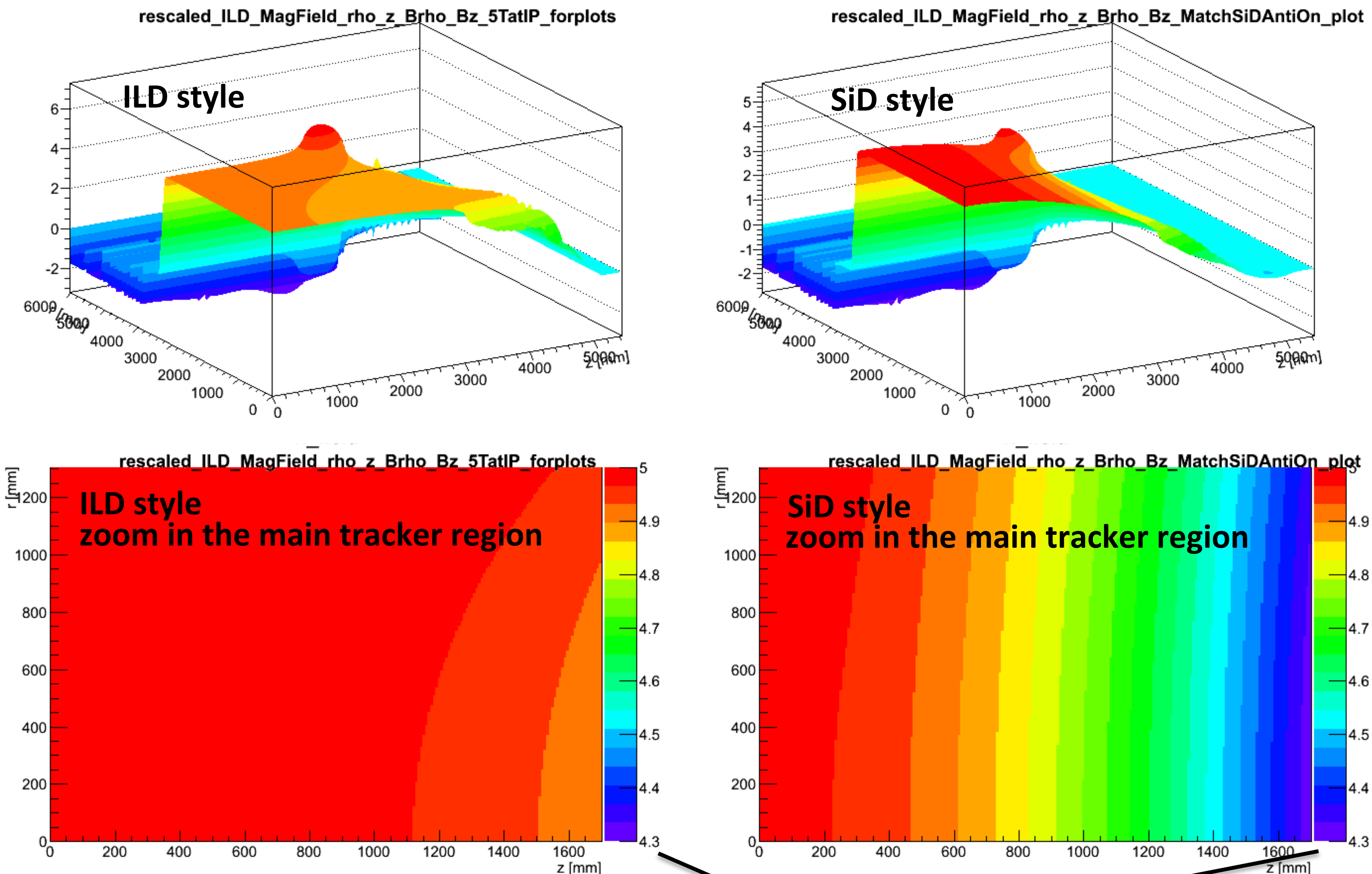








Comparison between rescaling methods



same color scale

Rescaling function for ILD map to match SiD expectation

- The ILD and SiD Bz and Br field projection are fitted with a parabolic function:

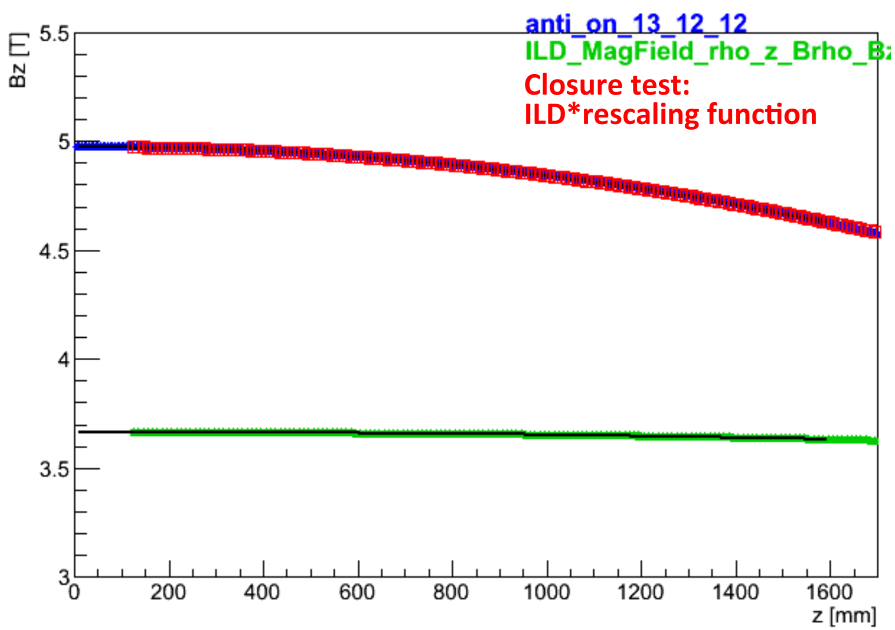
$$f(x) = a + bx + cx^2$$

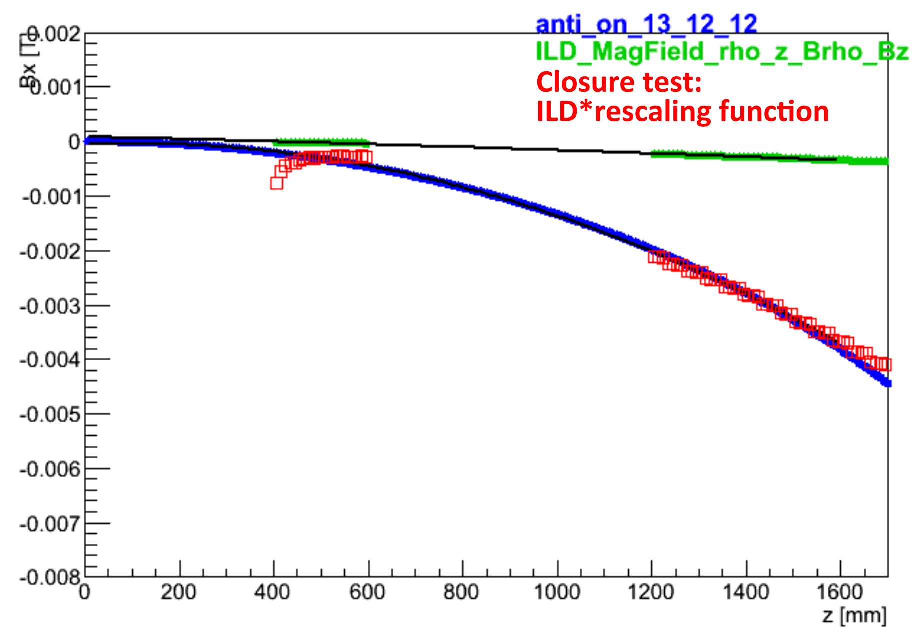
- The rescaling function obtained as the ratio of the two fitted functions

$$F_{Bz,Br}^{rescaling}(\vec{x}) = f_{Bz,Br}^{SiD}(\vec{x}) \Big/ f_{Bz,Br}^{ILD}(\vec{x})$$

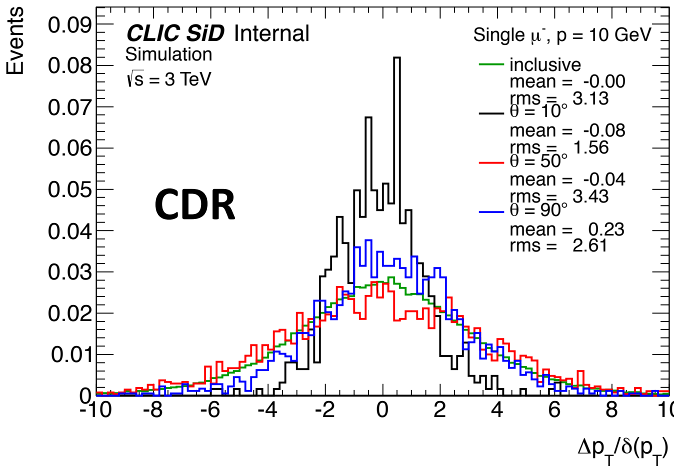
and then applied to rescaled ILD field to SiD expectation

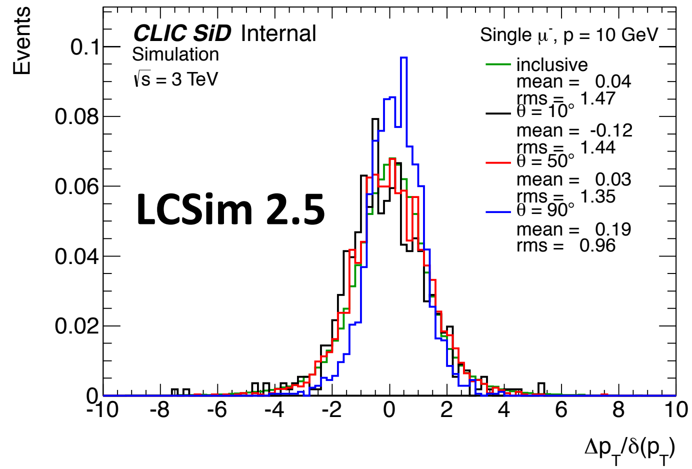
$$B_z^{rescaled} = B_z^{ILD}(\vec{x}) F_{Bz}^{rescaling}(\vec{x}), \qquad B_r^{rescaled} = B_r^{ILD}(\vec{x}) F_{Br}^{rescaling}(\vec{x})$$



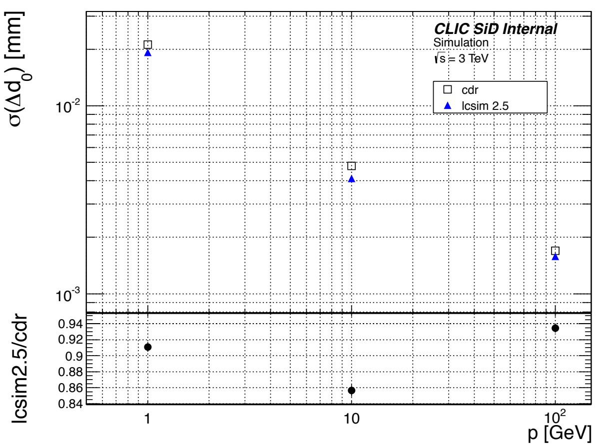


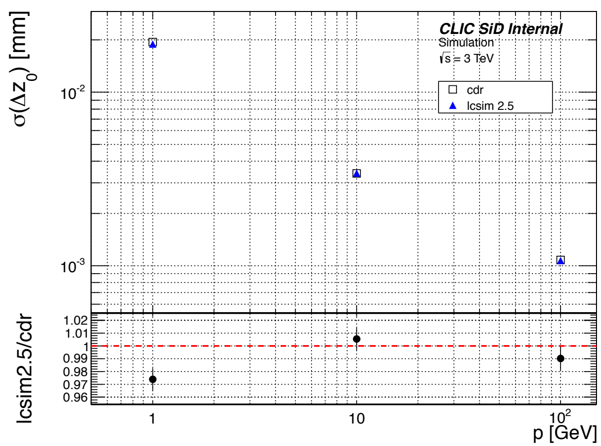
Choice of LCSim 2.5 and not CDR version

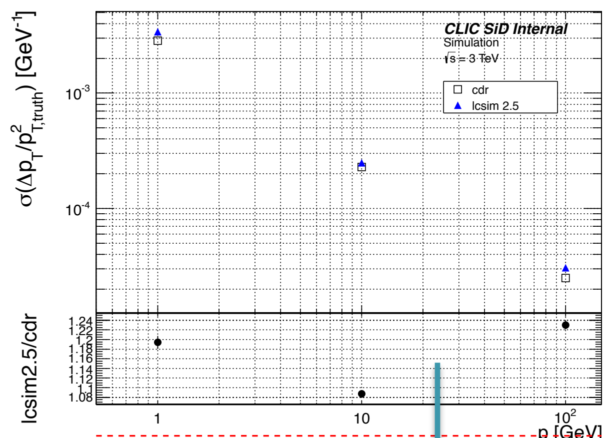




Better tracking uncertainties performance for LCSim 2.5 → pull distribution more centered at 0 and with rms closer to 1 across different theta → Probably due to underestimation of multiple scattering in CDR version







Better resolution for CDR version. But CDR version gives results better than expectation too…