# Magnetic field effects in the TPC

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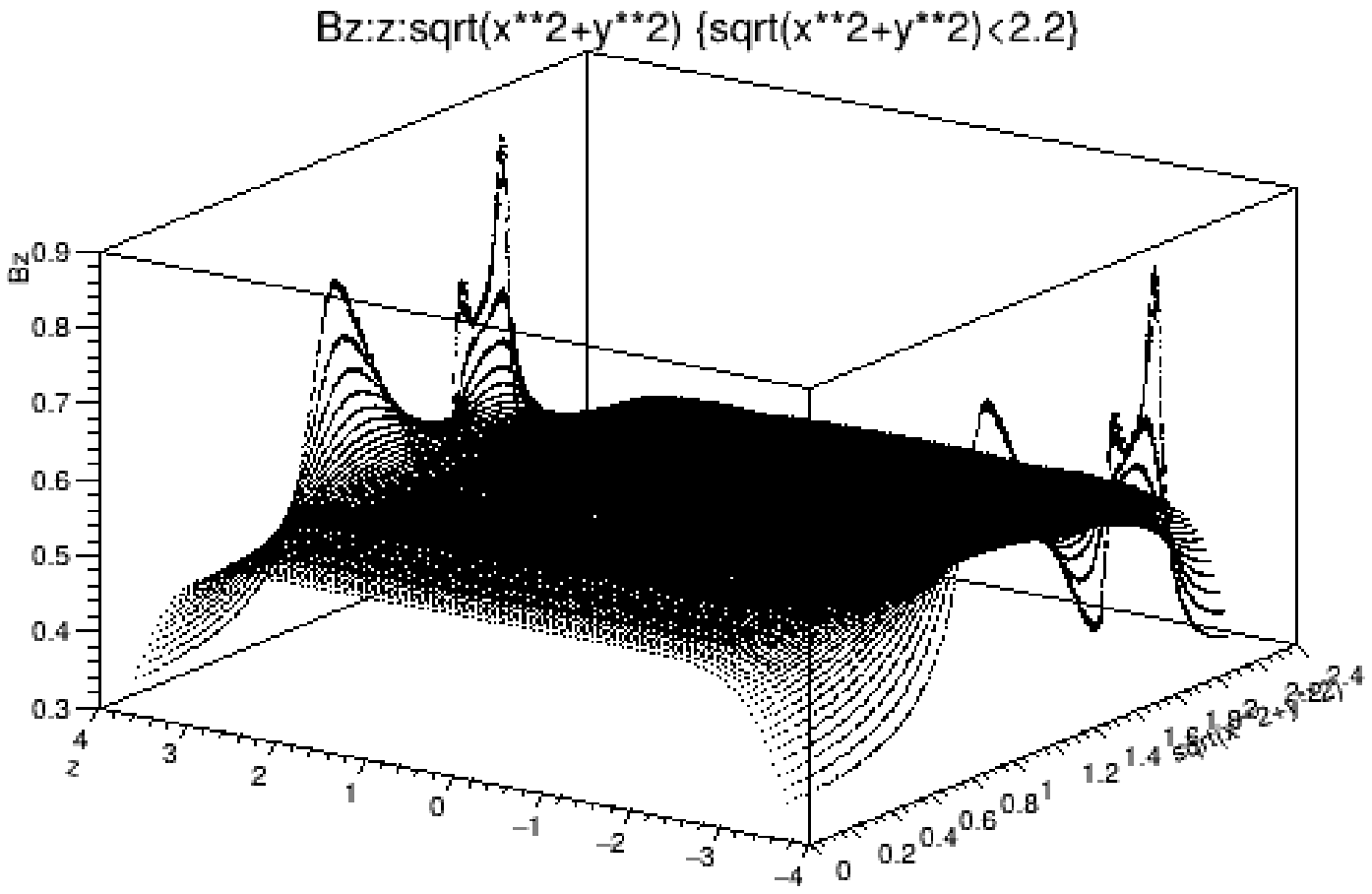
# Field map: 0.5 T by Novosibirsk INP

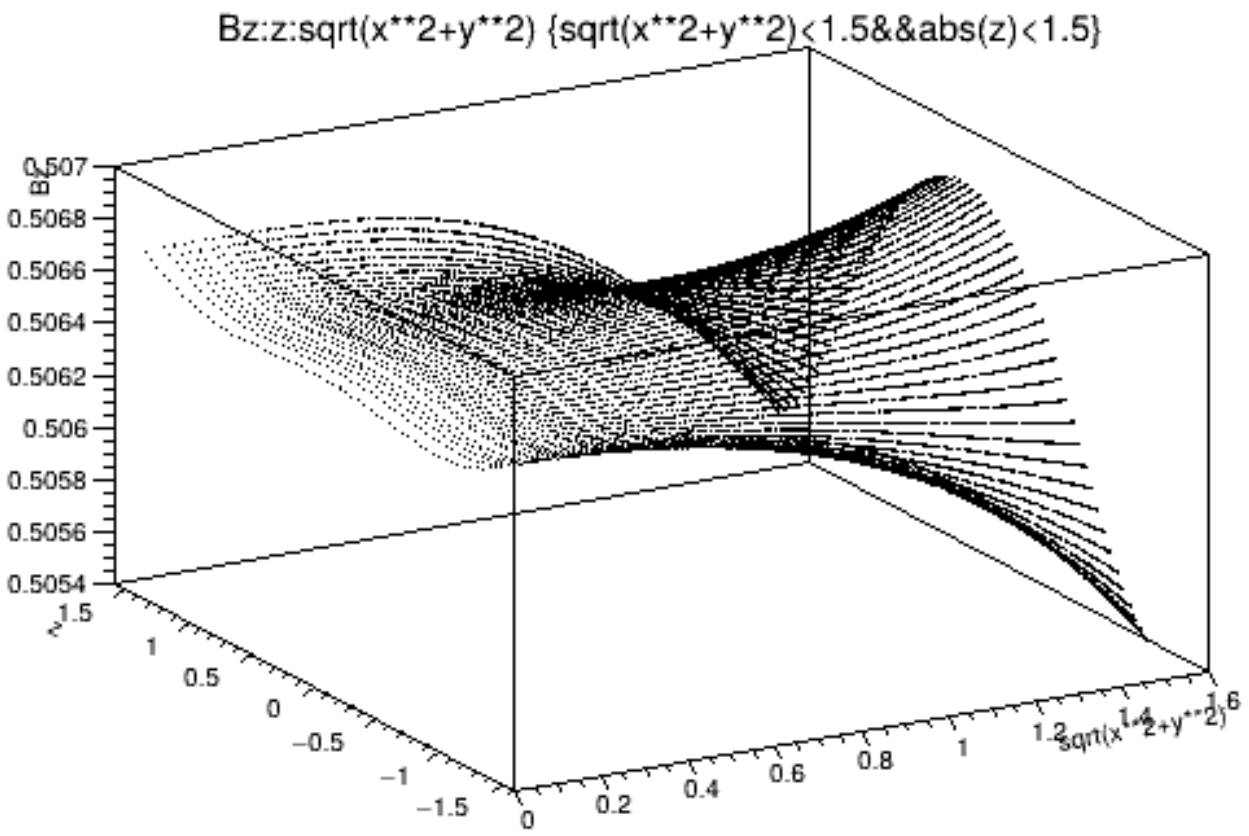
- *Bz* component as a function of *zed* and *radius* in the entire volume of the solenoid




Some unavoidable and large distortions on the edges

# Field map: 0.5 T by Novosibirsk INP

- *Bz* component as a function of *zed* and *radius* in the TPC volume




*Bz* component is responsible for momentum measurements, symmetric wrt. to *zed*=0

Maximum distortion (0.5069 - 0.5055) / 0.5064 ~ $2.8 \cdot 10^{-3}$, observed at large radii

The distortion of $3 \cdot 10^{-3}$ is negligible compared with the momentum resolution of $2 \cdot 10^{-2}$

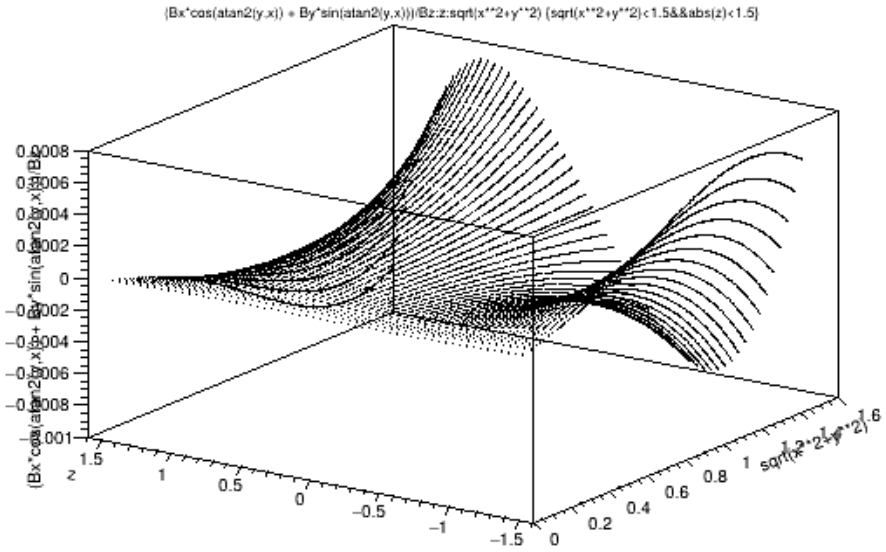
→ track distortions due to field non-uniformities are negligible

→ constant field map is good approximation for momentum measurements (curvature → momentum)

# Field map: 0.5 T by Novosibirsk INP

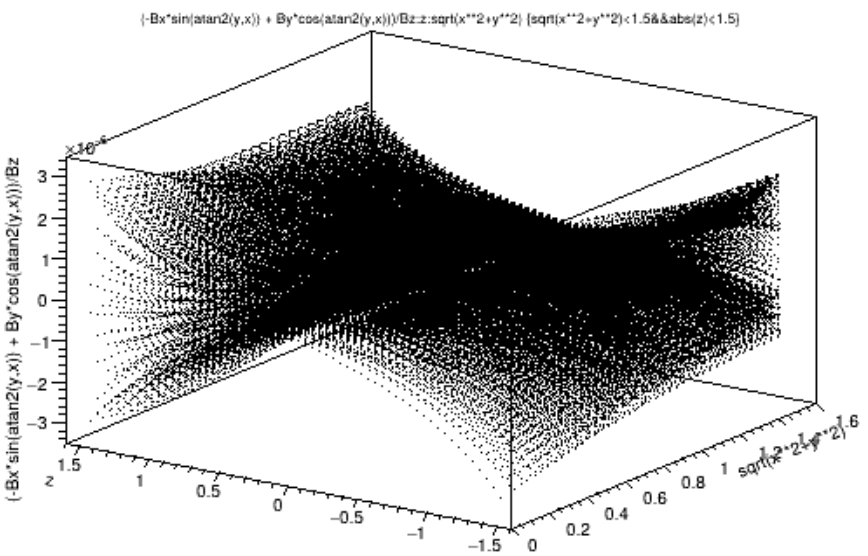
- Why field uniformity is of importance then?

***Br/Bz* in the TPC volume**




**may be important ~ $10^{-3}$ -$10^{-4}$**

***Bphi/Bz* in the TPC volume**



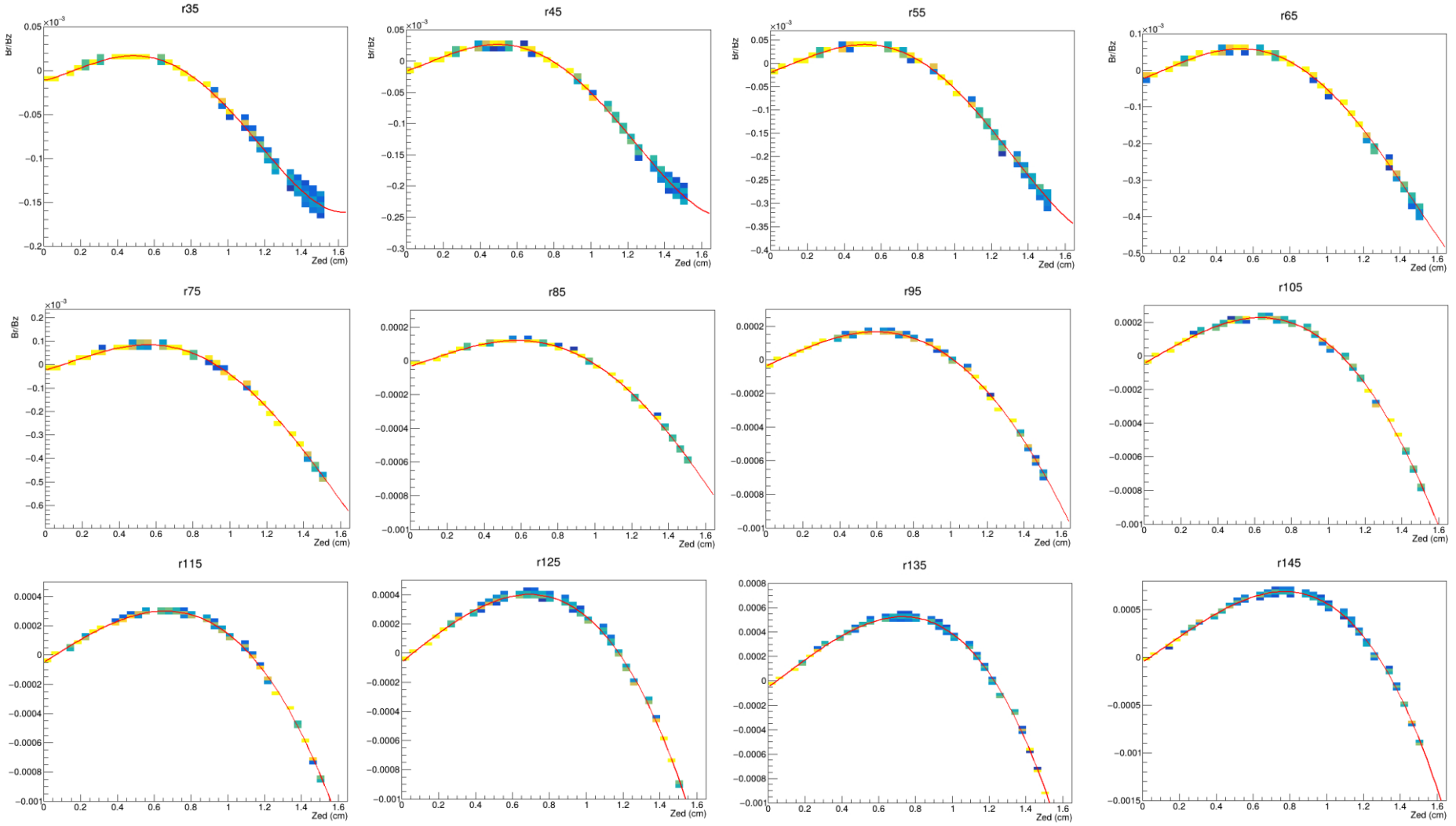

**negligible < $10^{-5}$**

- In TPC, electrons drift over a long distance of ~ 1.5 m. If the magnetic field is not perfectly parallel to the electric field, a force arises that deflects the electrons sideways. The magnitude of this displacement ($\Delta phi$, $\Delta r$) depends on the integral of the transverse field components along the entire drift path: $\Delta phi \approx \int_{z_hit}^{z_ROC} \frac{Br}{Bz} dz \qquad \Delta r \approx \int_{z_hit}^{z_ROC} \frac{Bphi}{Bz} dz$
- If *Br/Bz* ~ $10^{-4}$ → maximum $\Delta phi \approx 150$ cm · $10^{-4}$ = 150 μm → comparable to resolution

→ Let's try to estimate the effects using the B-field map

# Field map: 0.5 T by Novosibirsk INP

- Parameterized *Br/Bz* vs. *zed* for different radii at *zed* > 0 with pol5: anti-symmetric wrt. *zed* = 0

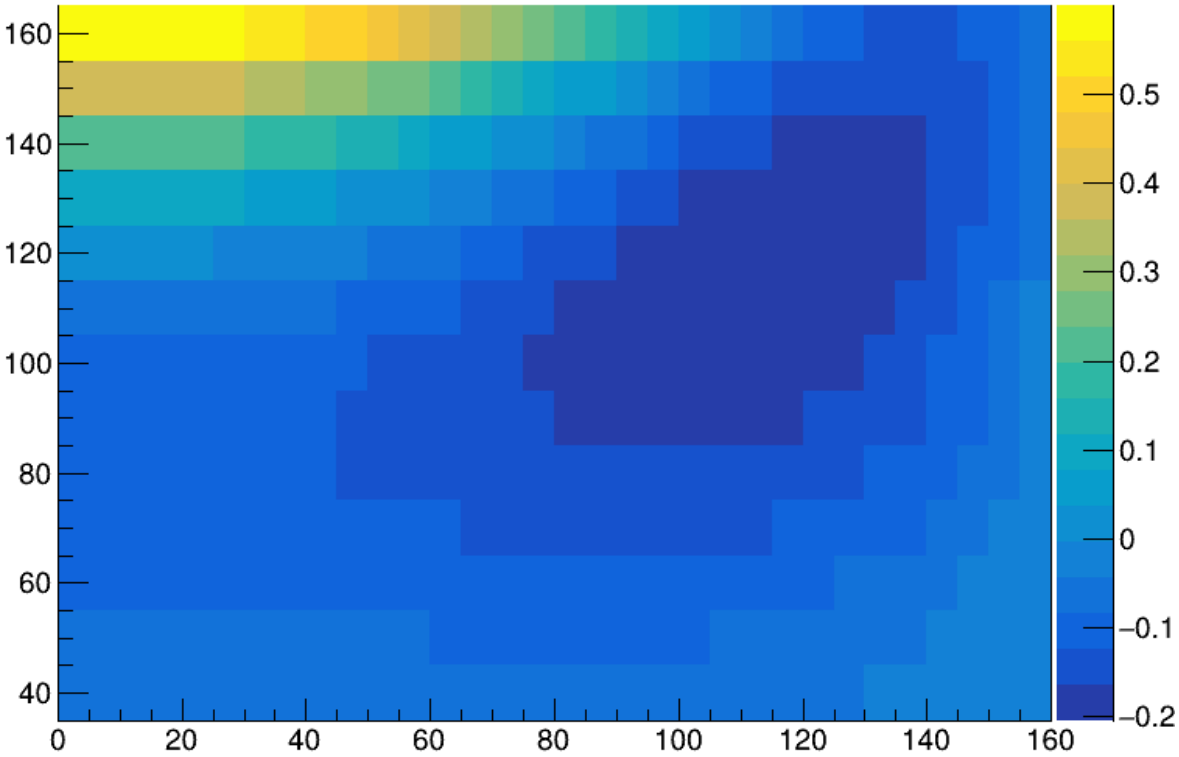



MAP: linear interpolation for different *radii* and functional forms for *zed* dependence

# Field map: 0.5 T by Novosibirsk INP

- Using the B-field parameterization from the previous slide, calculate $\Delta phi \approx \int_{z_hit}^{z_ROC} \frac{Br}{Bz} dz$ integrals for all possible TPC hit positions in terms of [*zed, radius*]

**Shift of TPC hits in *dphi* (mm) due to the magnetic field vs. hit *zed* (cm) and *radius* (cm)**

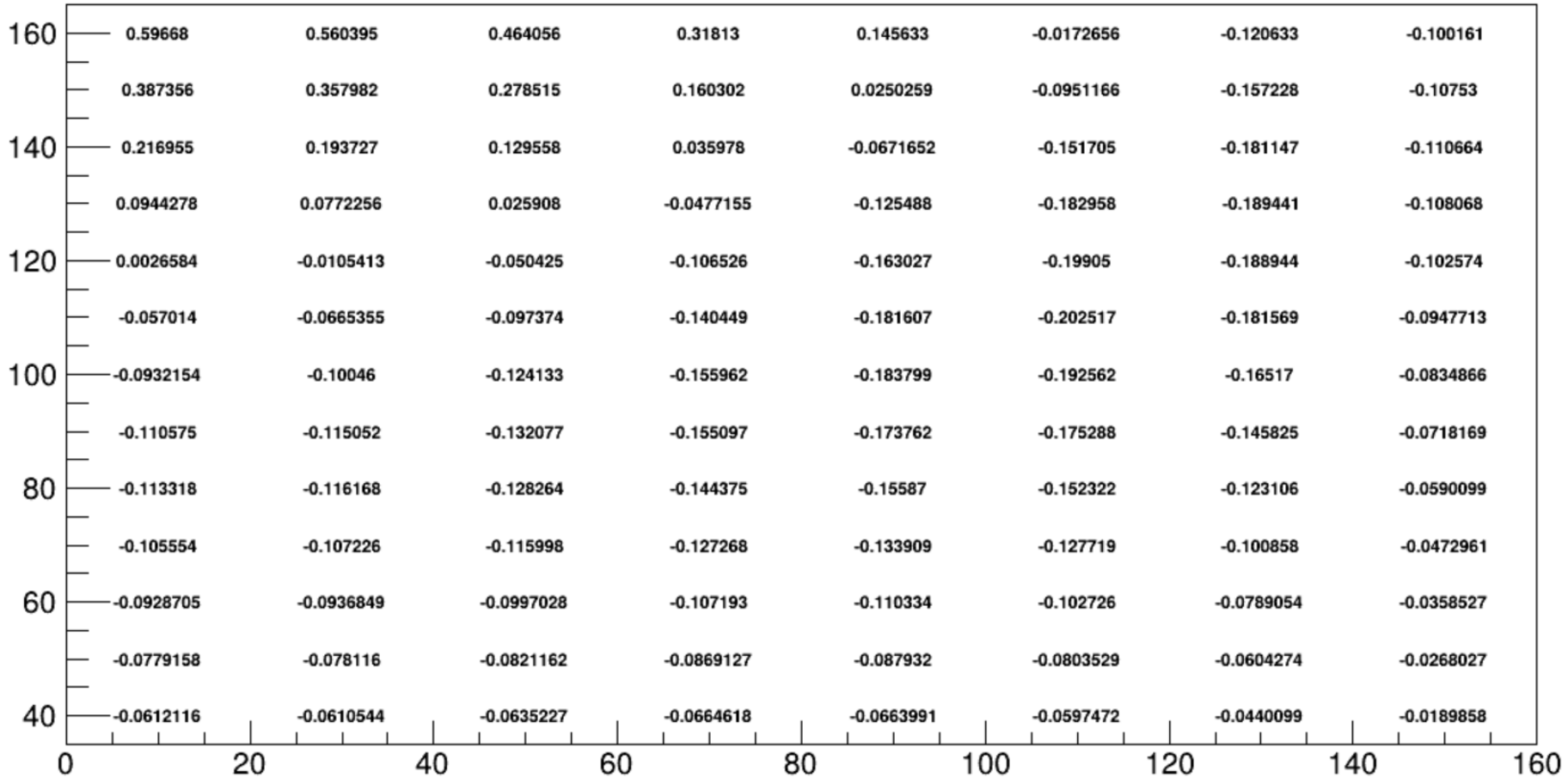



Distortions due to magnetic field are noticeable (hundreds of microns) but do not change much with *zed* → all hits in the tracks tend to shift by the same amount → reduced effect on the momentum resolution compared to stochastic smearing

# Field map: 0.5 T by Novosibirsk INP

- Same map in text format

**Shift of TPC hits in *dphi* (mm) due to the magnetic field vs. hit *zed* (cm) and *radius* (cm)**



# Simulations

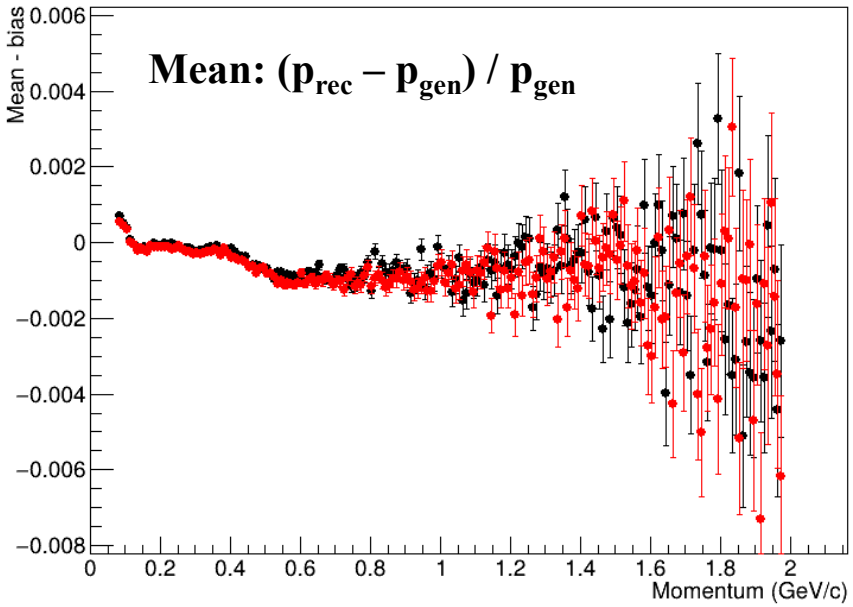
- UrQMD, BiBi@9.2 GeV
- Same detector settings as for the “Second collaboration paper” simulations
- Full event reconstruction
- Tasks:
  - ✓ Incorporate the magnetic field map in Geant → runMC.C
  - ✓ Incorporate shifts of the TPC hits depending on their production coordinates (*zed*, *radius*) → reco.C

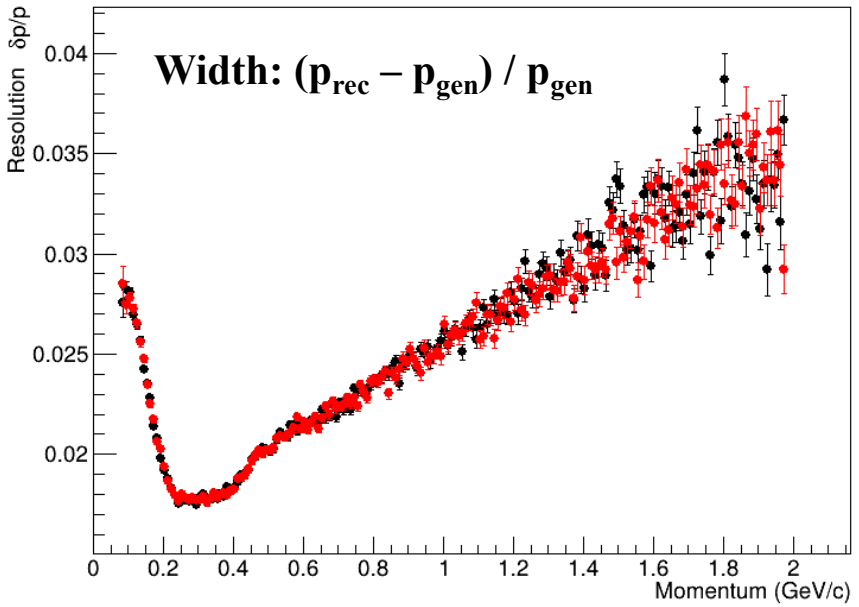
# Magnetic field map in Geant

- The field map is provided as (x,y,z,Bx,By,Bz) map with 5 cm grid size
- The field map is read-out, magnetic field is calculated (GetBx(), GetBy(), GetBz()) by interpolating field values between adjacent grid nodes
- The code was written by E.Kryshen, inspired by PandaRoot → thanks !!!
- So far track reconstruction in MpdRoot is possible only with a constant field
  → the field was fixed to (0, 0, 5.064) kG

# Momentum resolution with/without the map

- Tracks simulation:
  - ✓ **Constant field** (0, 0, 5.064) kG
  - ✓ **Field map** (slides 2-3)
- Tracks reconstruction:
  - ✓ Constant field (0, 0, 5.064) kG
- Distortions in electron drift directions are not simulated in MpdRoot



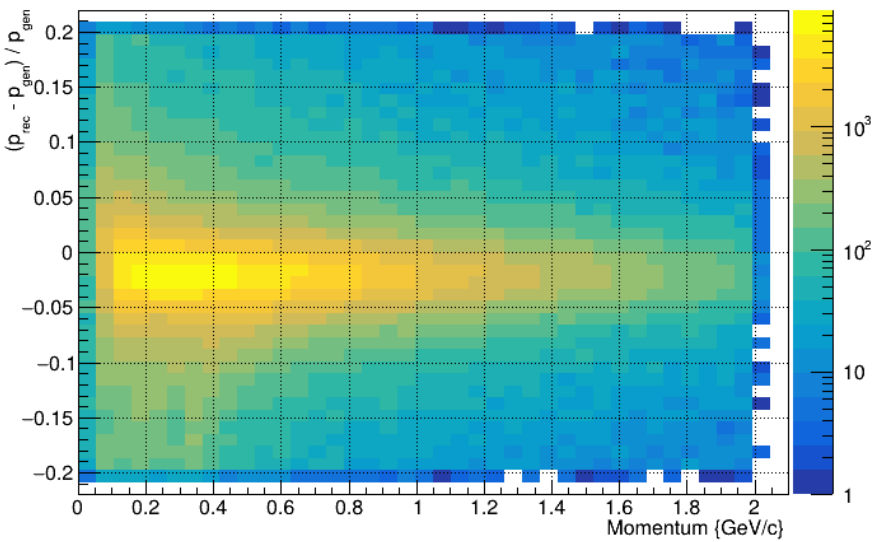




As could have been expected, the track reconstruction and the momentum resolution are not affected → the field non-uniformity is too small to play any role

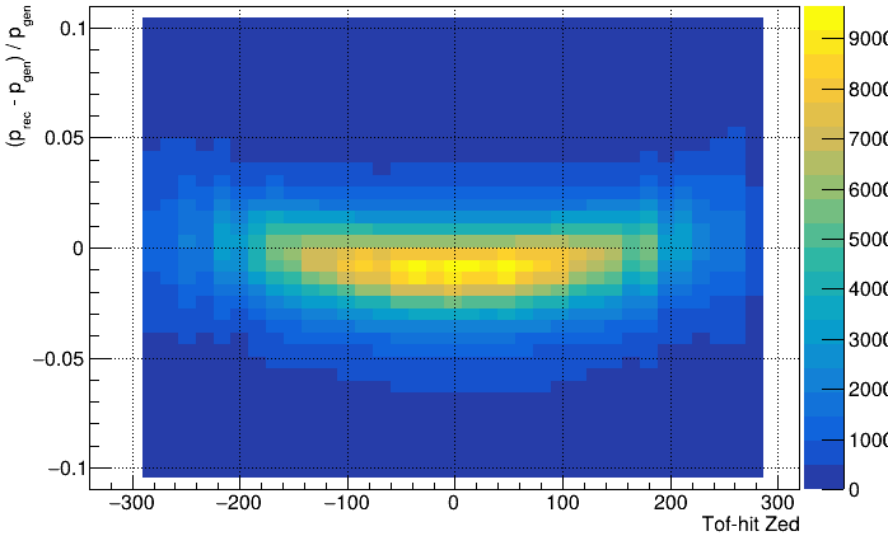
# Sanity check

- Voluntary varied the field map to see the effect

Scaled the field map by 1%




Scaled the field map to vary vs. zed by ±1%

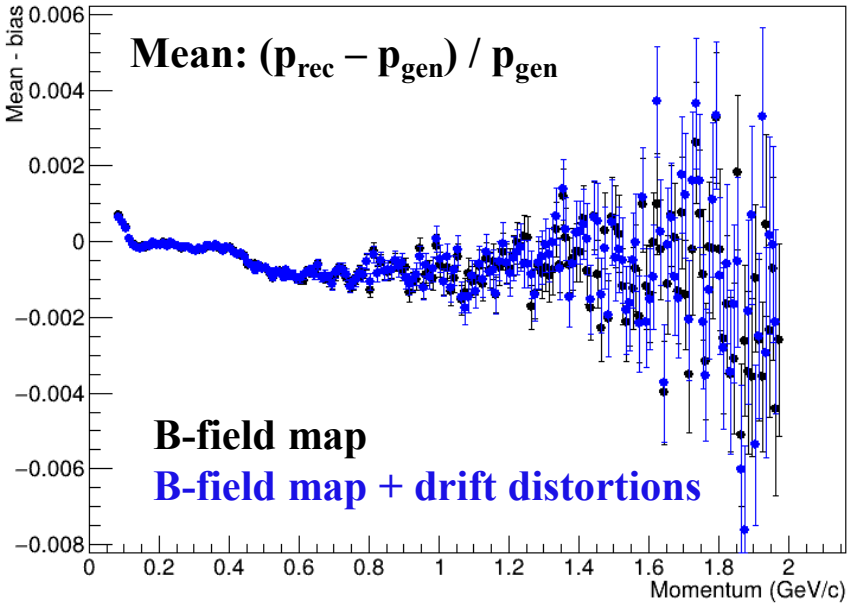


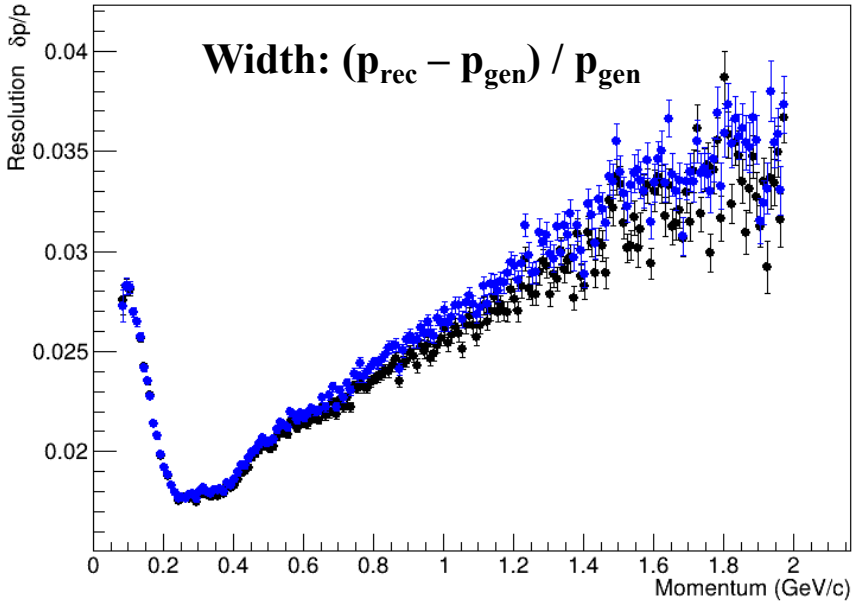

Reconstructed momentum is sensitive to the field map variations

However field variations should be significant ~$10^{-2}$ to be noticeable

# Electron drift distortions

- Made private modifications to MpdRoot:
  *mpdroot/detectors/tpc/clusterHitFinder/mlem/TpcClusterHitFinderMlem.cxx(h)*
- The modifications shift the reconstructed TPC hits in *phi* according to the map (from slide 6)
- Track reconstruction proceeds as usual



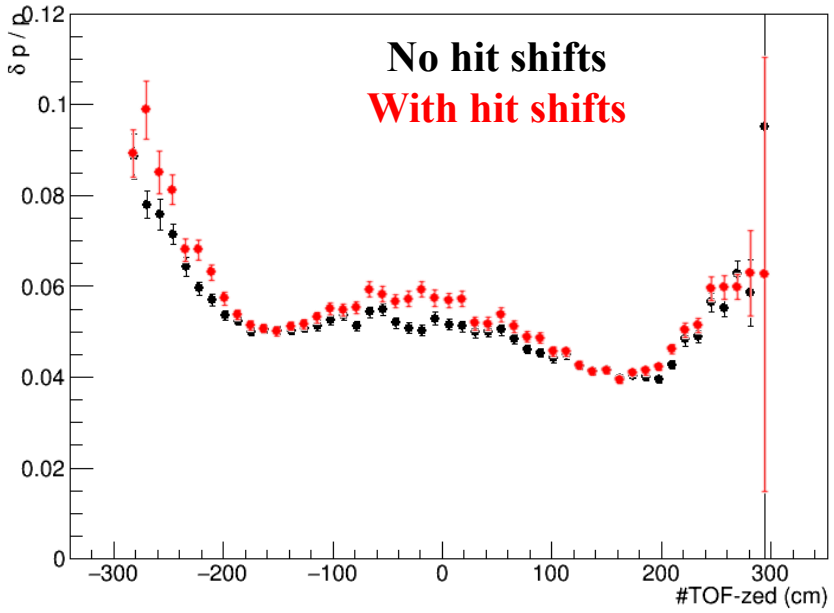




Very modest effect on momentum resolution, mostly at high $p_T$

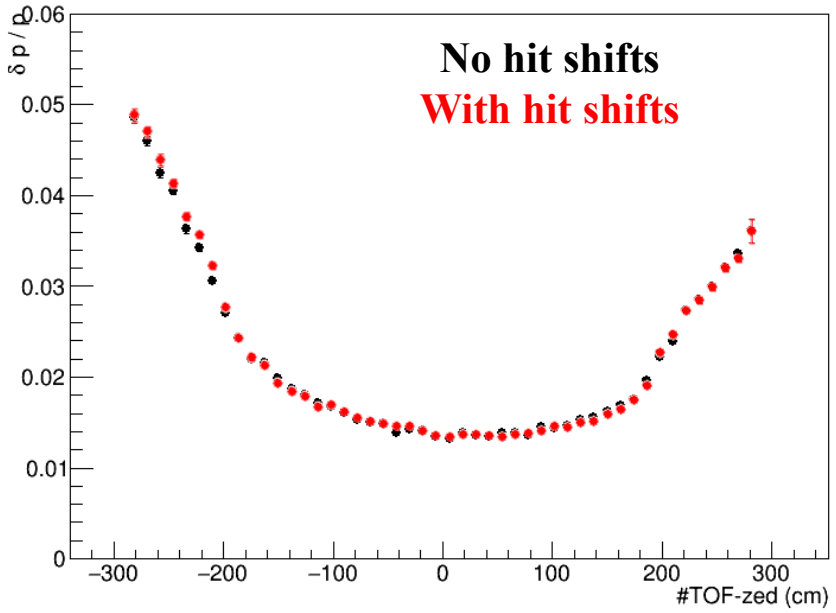
# Momentum resolution vs. zed

- Compare differential momentum resolution

**p > 0 GeV**




**p > 1 GeV**



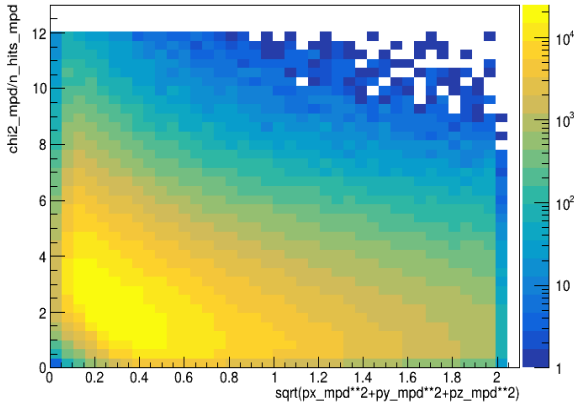

Very modest differential difference

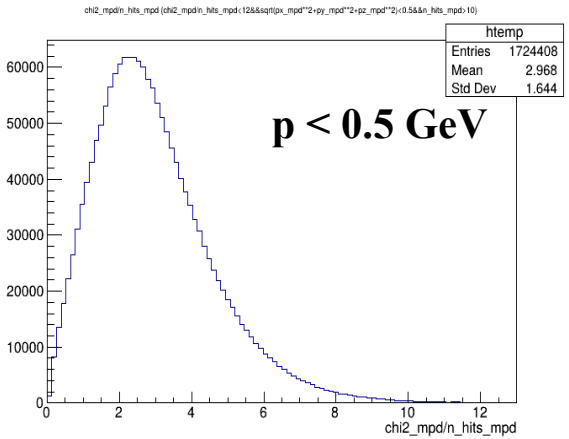
# Track quality cmparison

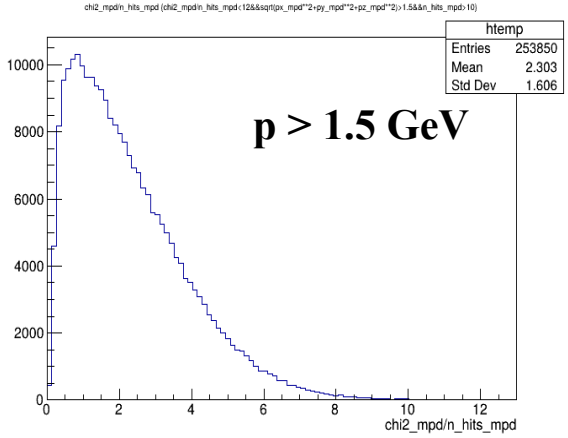
- Comparison of Chi2/NDF vs. momentum

**No hit shifts**

**Chi2/NDF vs. p**

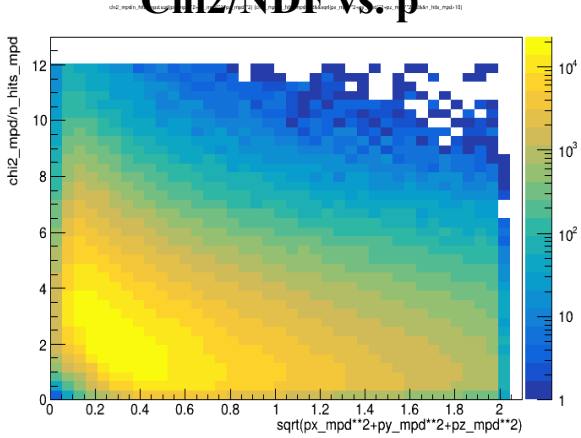


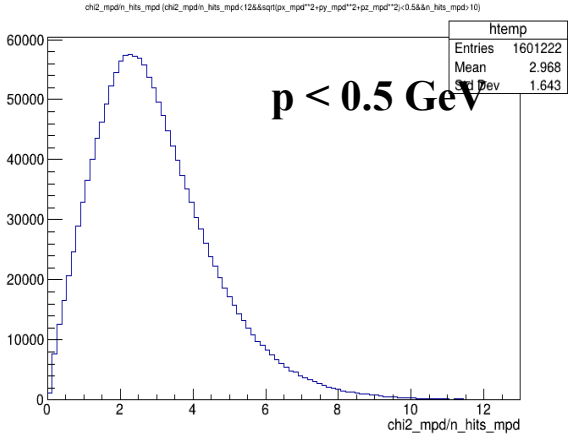



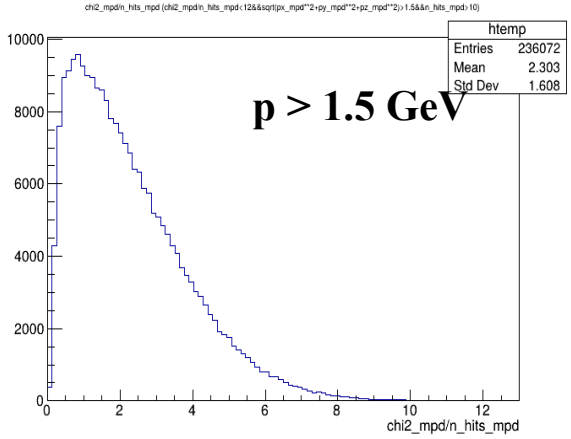

**With hit shifts**

**Chi2/NDF vs. p**



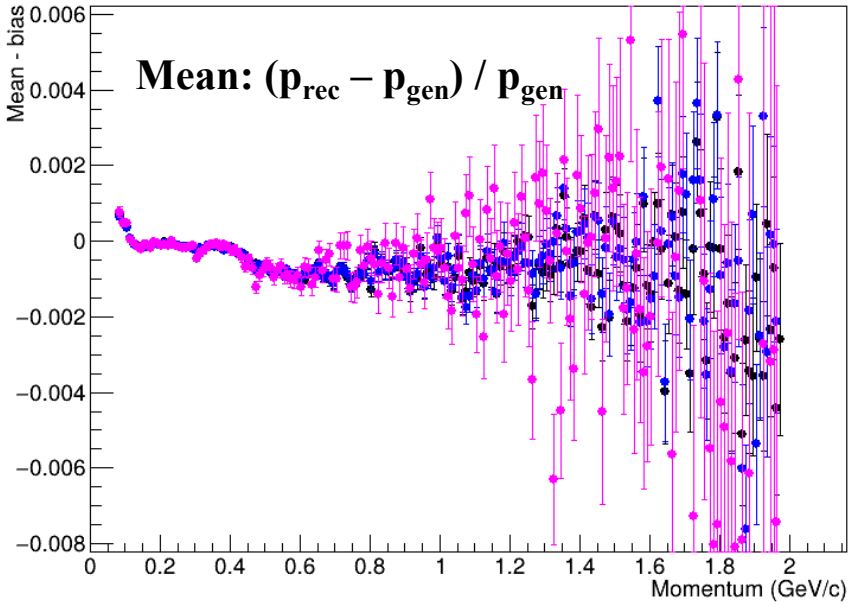

**With hit shifts**

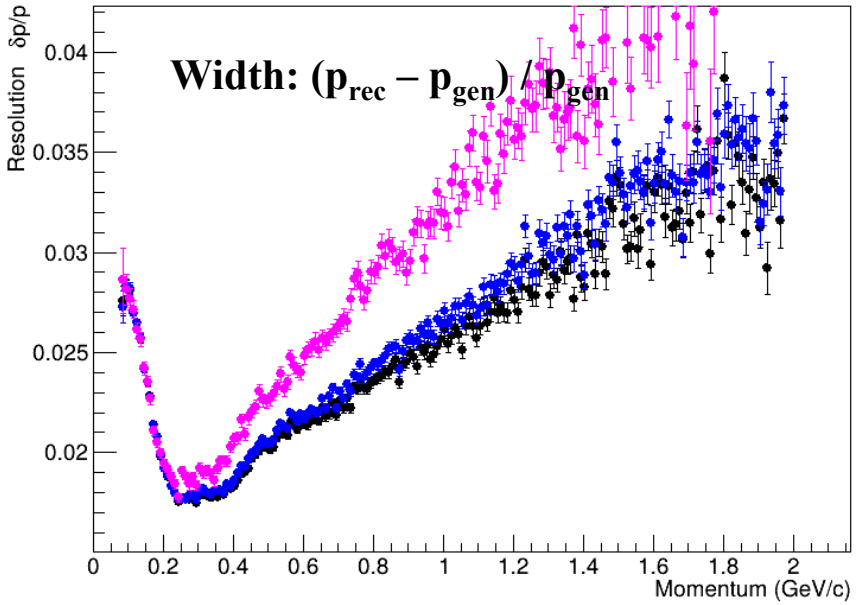



No visible difference in Chi2/NDF for reconstructed tracks

# Are we sensitive to the shifts at all?

- What if we blow the distortions by x3?




**B-field map**

**B-field map + drift distortions**

**B-field map + drift distortions x 3**

Distortions mostly affect high momenta (~ 50% of tracks)

Mean momentum remains the same → track curvature is not biased

# Conclusions

- Code to run Geant with external magnetic field map is ready
- Need to add field-map functionality to track reconstruction (KalmanFilter)
- The main effect of the magnetic field non-uniformity is in distortion of the electron drift directions → shifts in hit coordinates can be comparable to spatial resolution
- Estimates provided indicate that field non-uniformity in the calculated map is sufficiently small to be ignored
- Calculated field map is a good alternative?

However magnetic field calculations should be validated by real measurements,
may be not in the whole volume, may be not in all regimes …