Misalignment in the TPC simulation and reconstruction

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ALICE offline week

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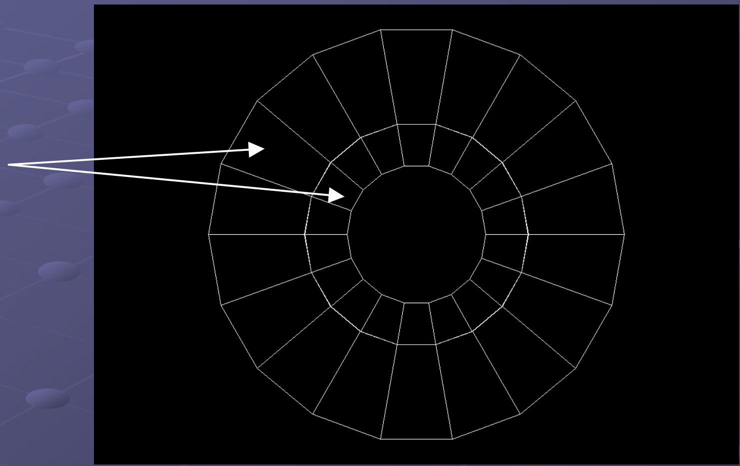
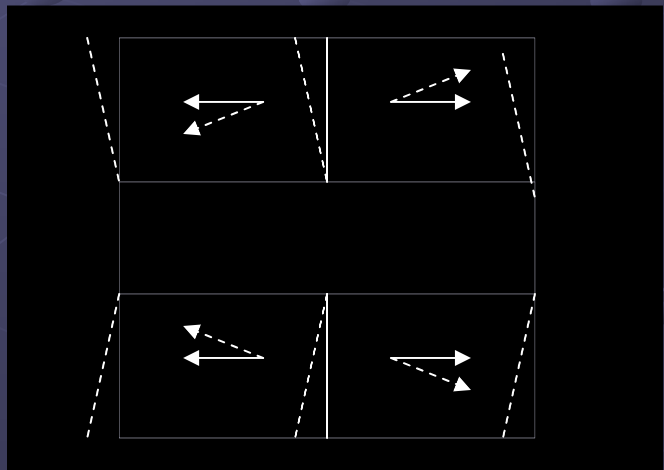
Introduction – TPC alignment model

- In TPC we consider 'alignable' only the 72 readout chambers:
  - 3 rotation angles + 3 translations per chamber



- For the moment, the electric field in the drift volume is assumed to be exactly orthogonal (and uniform) to the chambers plane

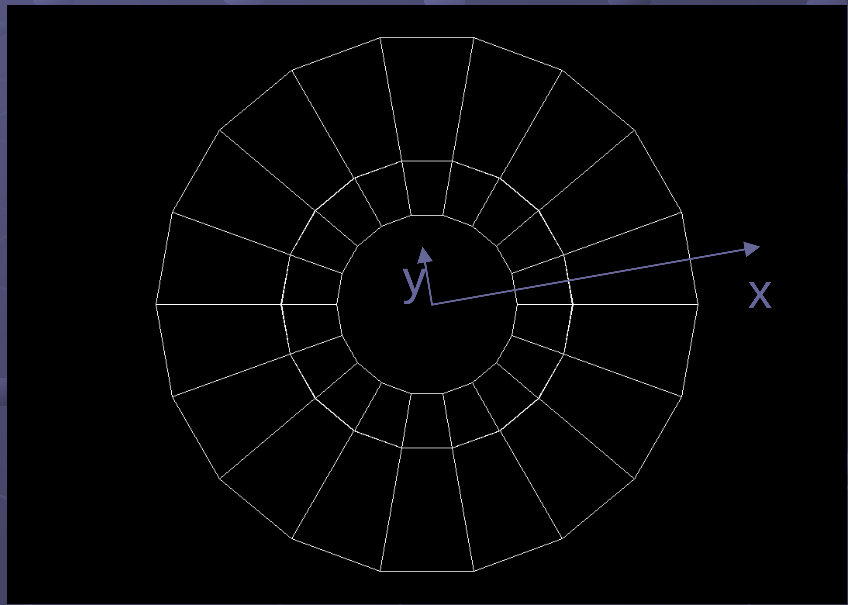


Coordinate system definitions

- ‘Sector’ (or ‘ideal’) coordinate system:
  - Origin and Z axis coincide with the origin and Z axis of the global coordinate system
  - In XY plane it is rotated by

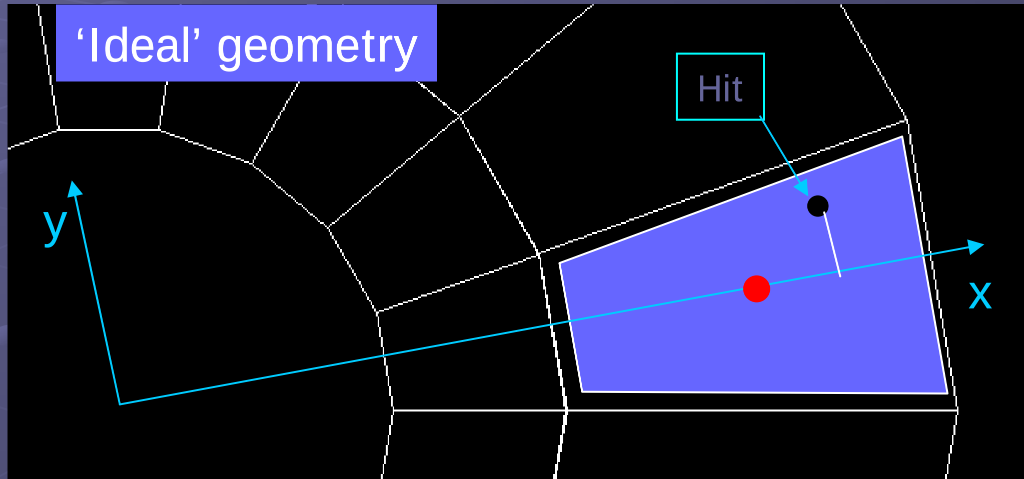
    $\alpha = 10^{\circ} + i \times 20^{\circ}$

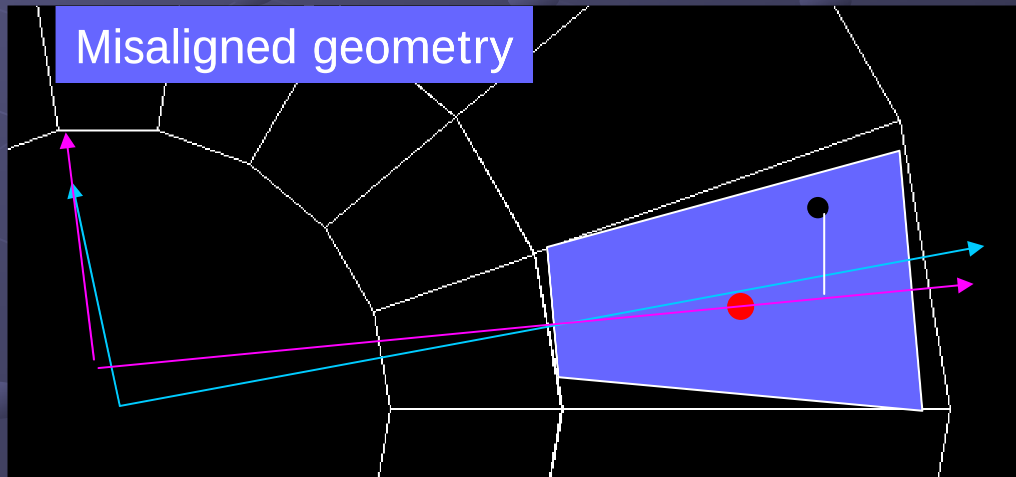
    where ‘i’ is the sector index
- The magnetic field is parallel to the X axis!



Coordinate system definitions

- 'Chamber' coordinate system:
  - Connected to actual (misaligned) position of readout chambers
  - X axis orthogonal to pad rows
  - Z axis orthogonal to chamber plane
  - Chamber center position is fixed
- In case of 'ideal' geometry 'sector' and 'chamber' systems coincide





Misalignment data from TGeo

- In case one loads the geometry from file:
  - Inside AliMC::InitGeometry() call new method of AliModule - ReadParsFromTGeo()
  - In case of TPC - inside this method call AliTPCParam::ReadParsFromTGeo()
    - Retrieve the position and orientation of the chambers from TGeoManager (‘TIRC’ & ‘TORC’ volumes) as TGeoHMatrix’es
    - Transform them to the ‘sector’ coordinate system
    - Store the differences to the ideal positions and orientations as TGeoHMatrix array inside AliTPCParam

Misalignment in TPC simulation

- In case the transport MC uses TGeo, the misaligned geometry is used correctly up to the production of Hits
- In case of TPC the MC is used to produce hits along the track trajectories

  ⇒ Misalignment should be introduced also at the digitization level:
  - During the digitization of the hits, the ionization electrons are transported ‘by hand’ to the surface of the readout chambers
  - The misalignment data from AliTPCParam are loaded and used to put the electrons into the local coordinate system of the readout chambers
- The rest of the digitization is not affected
- We assume that the misalignment is relatively small

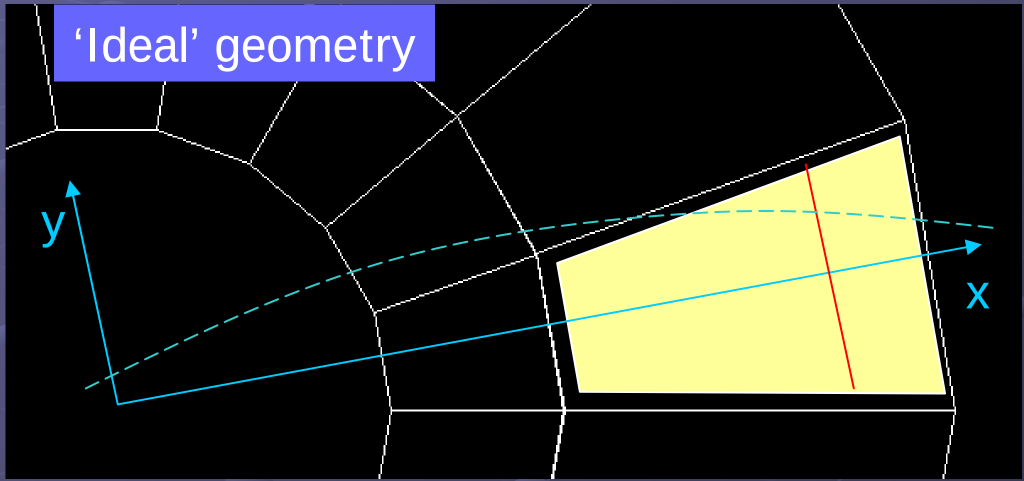
  ⇒ No flipping of electrons between neighbor sectors

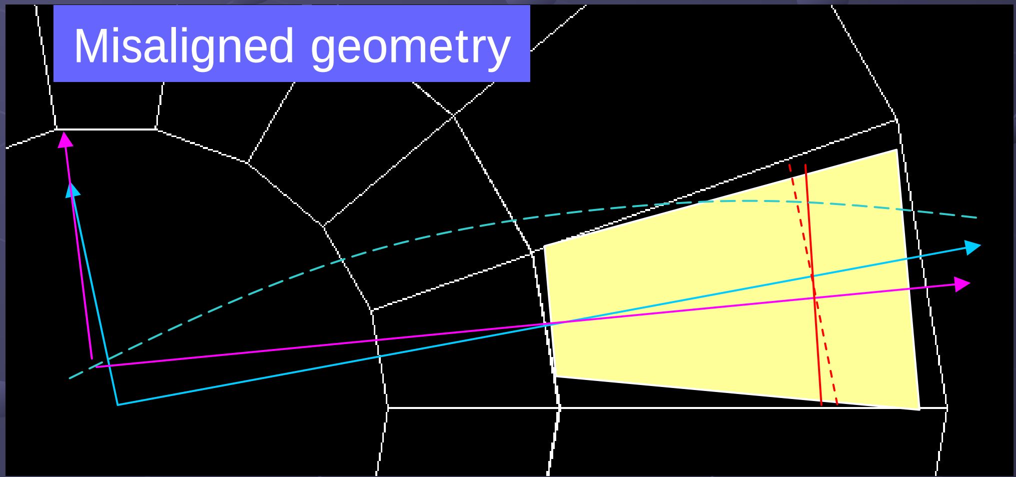
TPC tracking using alignment data

- Main problem – the choice of the 'tracking' coordinate system:
  - 'Sector' ('ideal') coordinate system
  - 'Chamber' coordinate system
  - 'Mixing' of 'Sector' and 'Chamber' coordinate systems

Definition of the tracking coordinate system

- 'Sector' ('ideal') coordinate system
  - Transform the clusters from the 'chamber' to 'ideal' system
  - Tracks are untouched
  - Need to redefine track propagation method:
    - Pad row – time bin plane is no longer orthogonal to the X axis
    - Propagation not to a fixed X reference plane but to X(Y,Z)

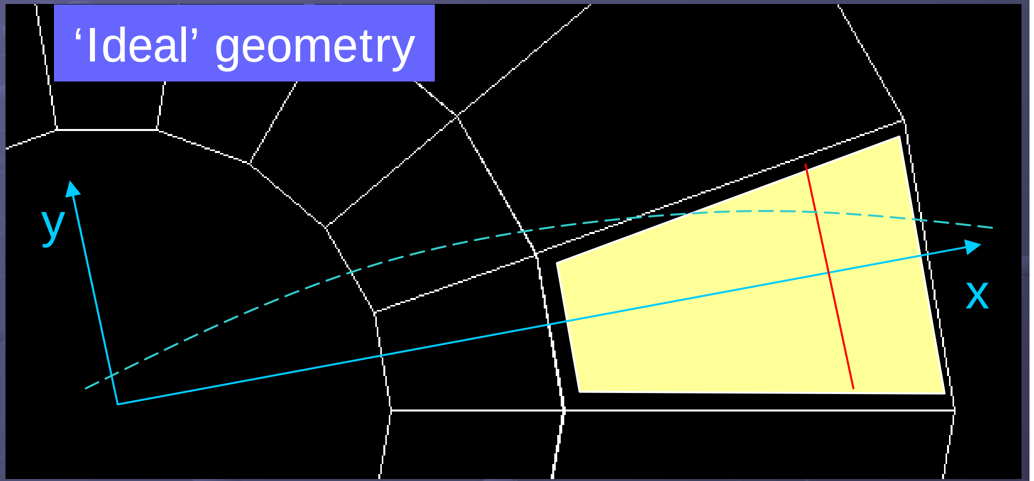


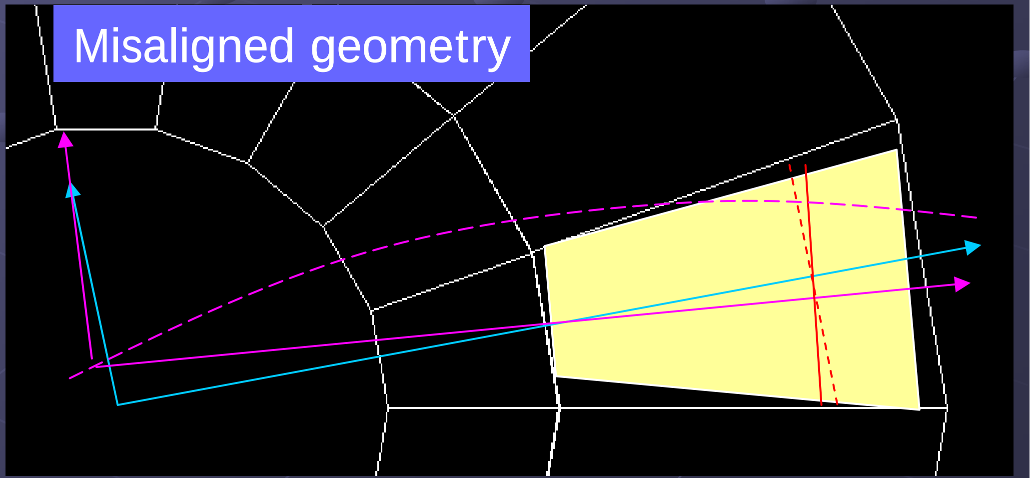


Definition of the tracking coordinate system

- 'Chamber' coordinate system
  - Clusters are untouched
  - Propagation is on a fixed X reference plane
  - Each time track enters new sector it is transformed into the 'chamber' coordinate system
  - Magnetic field is no longer parallel to the Z axis

    ⇒ Tracks are not helices!

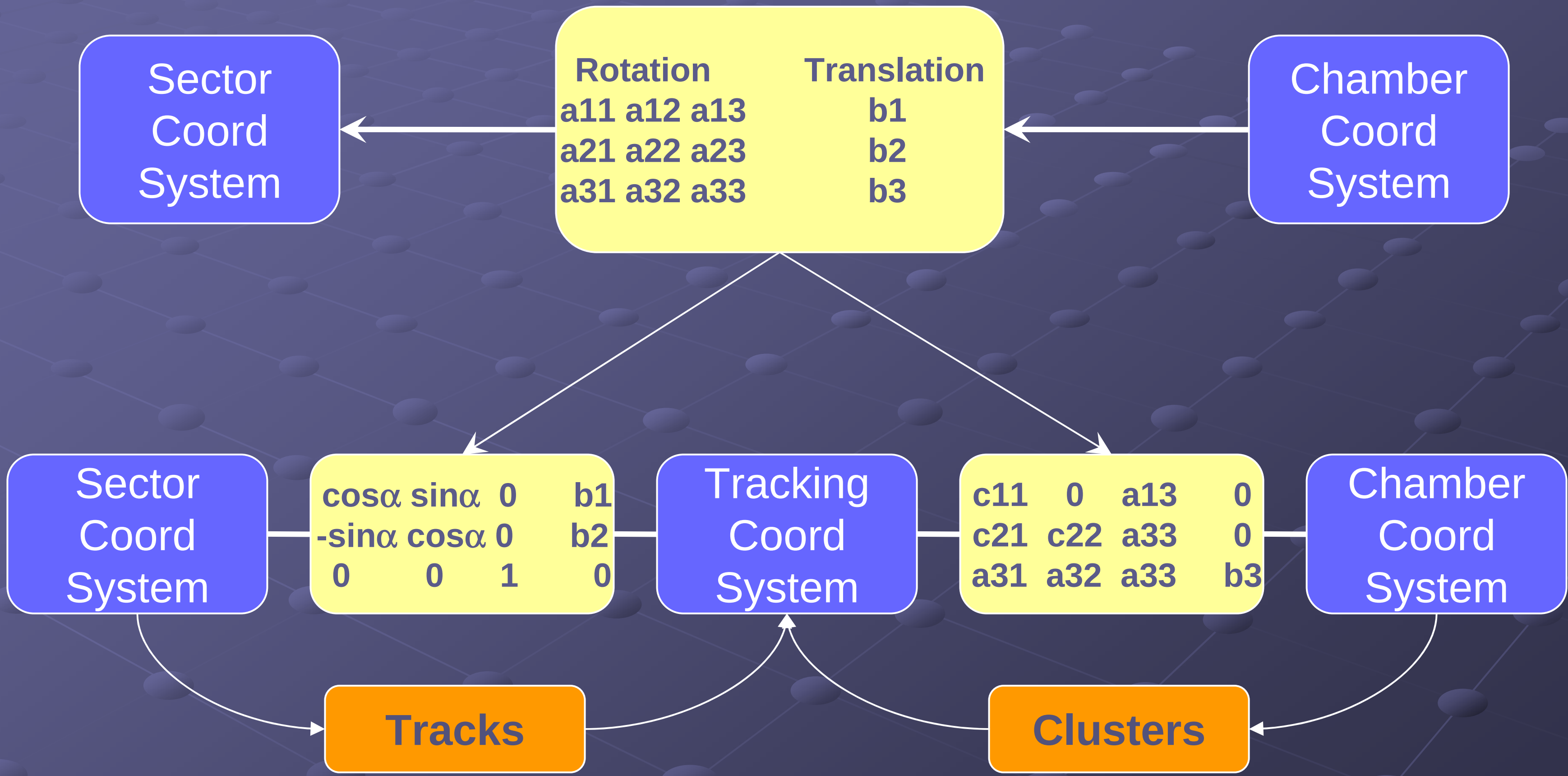




Definition of the tracking coordinate system

- Proposal for the ‘tracking’ coordinate system:
  - Use ‘sector’ (‘ideal’) coordinate system rotated in XY so that the X axis is orthogonal to the pad rows
  - We are preserving our helix track model
  - Track propagation to X(Z)

Tracking coordinate system



Tracking coordinate system

- Misalignment TGeoHMatrix is decomposed into 2 parts:
  - Rotation in XY plane + translations in X&Y
  - Rotation in XZ&YZ planes + translation Z
- Tracks and clusters are transformed to the same tracking coordinate system in which the track propagation and cluster association is being done
- Track transformation just few times per tracking pass
- The new propagation method is rather fast (linear approximation

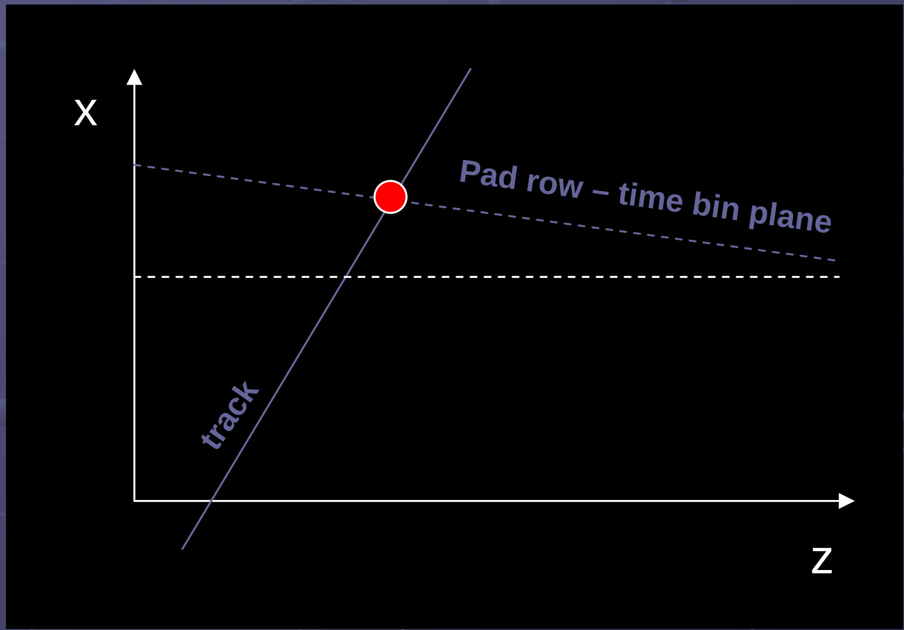
Track propagation

- The propagation X position is found assuming straight track:

  Z~X*Tan(λ)

- Usually we propagate by <= couple of cm
- The expected misalignment is at the order of mrad

  ⇒the linear approximation works to microns precision



Implementation inside TPC tracker code

- For the moment the misalignment matrices are taken from AliTPCParam stored in gAlice (in future should be loaded from CDB – either stand-alone or inside AliTPCParam object)
- The Y&Z cluster positions are transformed to the 'tracking' coordinate system while loaded into the tracker (AliTPCtracker::TransformCluster())
- In order to transform tracks between 'ideal' and 'tracking' coordinate systems:
  - New AliTPCtrack::Translate() method is added
  - Already available AliTPCtrack::Rotate() is used

Implementation inside TPC tracker code

- The calls to PropagateTo() and Rotate() methods of AliTPCtrack were replaced by new methods PropagateSeed() and RotateSeed() of the tracker:
  - Check if the track is to enter in a new sector
  - If yes then:
    - Take from the misalignment matrices the X&Y positions and XY angle of the current and the next readout chamber
    - Transform the track into the 'ideal' coordinate system
    - Rotate the track (in RotateSeed() method)
    - Transform the track into the next 'chamber' coordinate system
    - Propagate the track (in PropagateSeed() method)

Implementation inside TPC tracker code

- Coordinate system (chamber index) of the track is identified by:
  - index of the last pad row on which track is propagated
  - azimuthal angle of 'sector' coordinate system $(10^{\circ} + i \times 20^{\circ})$
  - z position of the track
- At entrance/exit of the three tracking passes (Clusters2Tracks, PropagateBack and RefitInward tracker methods), the tracks are transformed to 'chamber'/'sector'('ideal') coordinate system, respectively.
- The ESD tracks are always stored in the 'sector'('ideal') coordinate system

Results

- The method was tested with misalignment configuration where all the inner chambers were randomly rotated and translated within 10mrad and 0.5cm
- The efficiency and resolution is restored back to the 'ideal' case
- The effect on multiple found tracks rate and kink finding to be further investigated
- No visible effect on the timing:
  - Tracks are transformed between 'sector'⇔'tracking' coordinate systems are called ~3.5/track
  - New propagate method uses linear approximation
  - Clusters are transformed to 'tracking' coordinate system only once

Barrel tracking with alignment data

- Define the 'alignable' objects in the detector's geometry
- Implement method to retrieve the misalignment data from TGeo and store it as array of TGeoHMatrix
- Define an appropriate 'tracking' coordinate system
- Implement methods of the tracker which:
  - Transform clusters and tracks to the 'tracking' coordinate system
  - Calculate the X position for propagation
  - Propagate and rotate the tracks in the 'tracking' coordinate system

Conclusions & Outlook

- **The code for the simulation and reconstruction with misaligned TPC geometry is almost ready to be committed**
- **Check the tracking performance on higher statistics**
- **Finalize the way we access TGeo geometry (see Raffaele's talk)**
- **Further develop our TPC alignment (and calibration) model – introduction of ExB, space charge, drift velocity, central membrane misalignment, …**
- **Develop procedures for alignment and calibration**