Track reconstruction for the Jülich STT prototype

Susanna Costanza

(University of Pavia & INFN Pavia)

XLIX PANDA Collaboration Meeting

Darmstadt, 10-13 June 2014

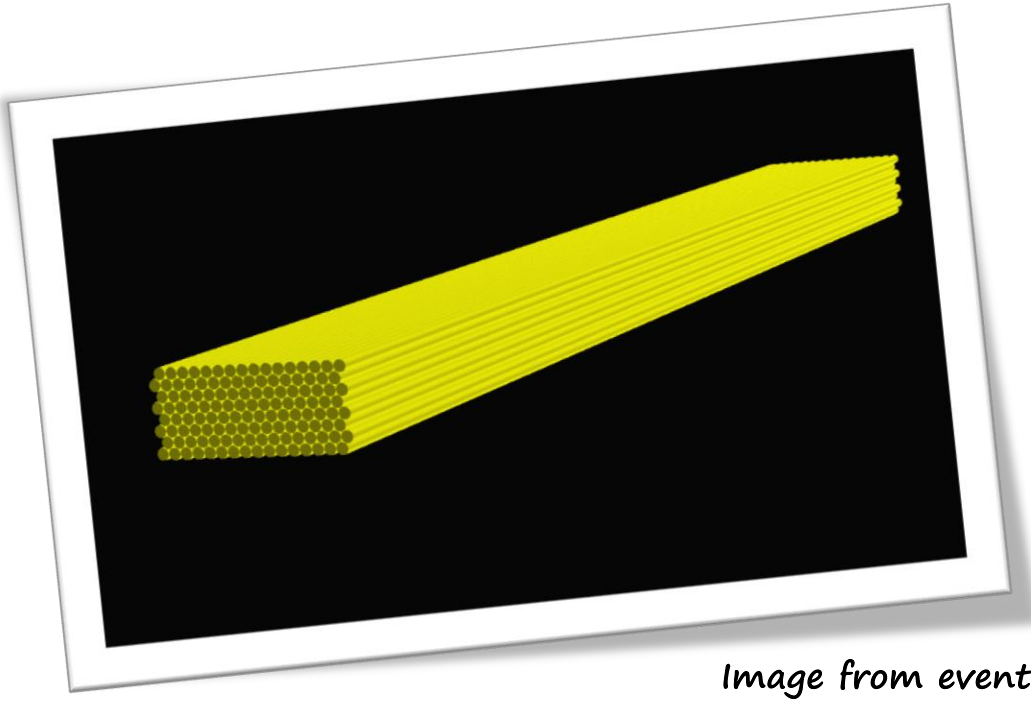
INFN Istituto Nazionale di Fisica Nucleare

Overview

State of the art of the track reconstruction code for the STT Jülich prototype

- Geometry implementation
- Description of the track finding/fitting software
- Screenshots from the event display
- Tracking results (residuals, efficiency, ...)
- Summary & Outlook

Geometry implementation



IMPLEMENTED IN PANDAROOT!!!!

Image from eventDisplay

- .geo file in geometry folder, as the usual STT geometry, created via C macro
- 8 layers of 16 tubes each, parallel to the x axis
- 150 cm long tubes, filled with $ArCO_2$ 90/10, operating at 2 bar pressure

Geometry implementation

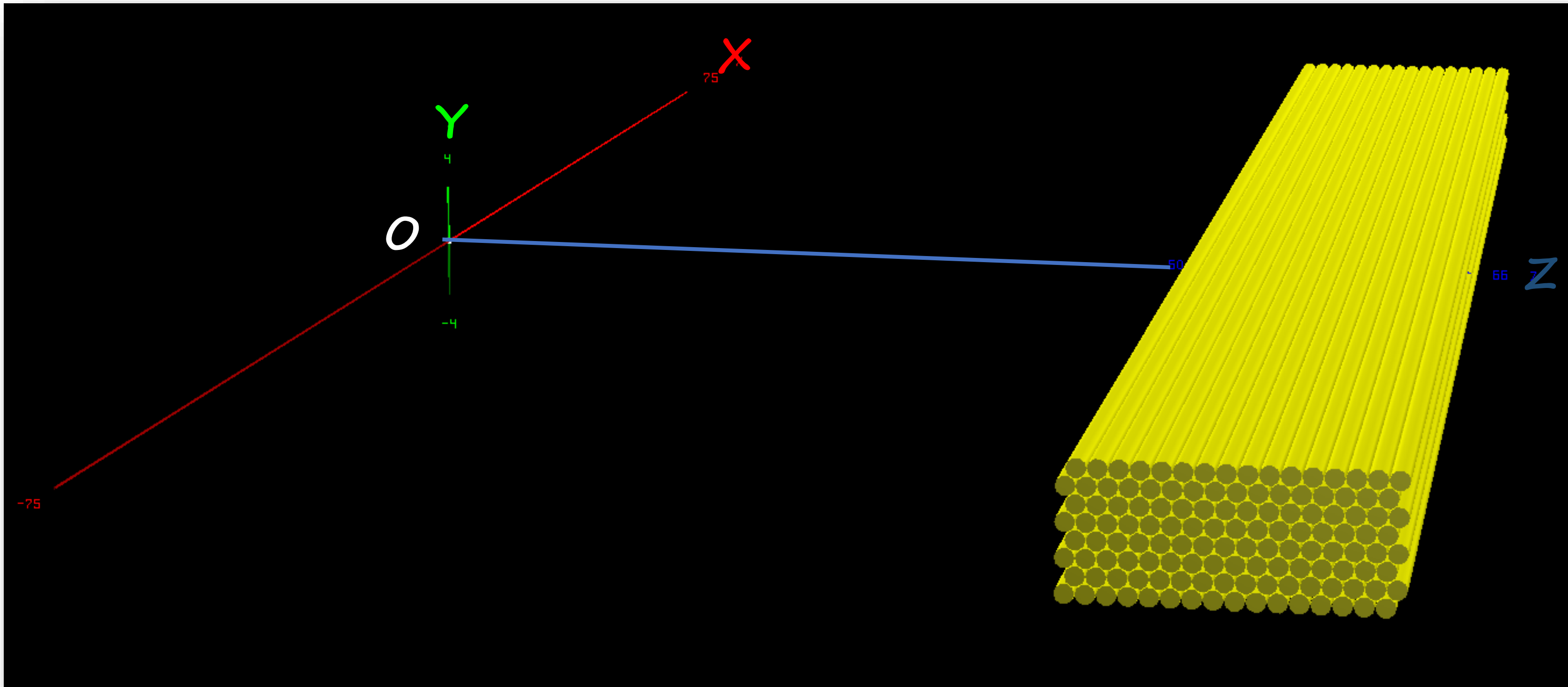


Image from eventDisplay

- Prototype placed at 50 cm distance from (0, 0, 0)
- Beam along z axis (as in standard PandaROOT)
- Geometry can be easily modified (i.e. rotation in case of analysis of cosmic data)

Analysis software

Implementation of an algorithm for track reconstruction and dE/dx determination

In PandaROOT:

- New folder in the tracking directory:
  - **tracking/prototype**
- New class for track reconstruction:
  - **PndTrkPrototype**
- Changes in STT classes (PndSttGeometryMap, PndSttMapCreator) for methods «geo type specific»
  - **GeoType2** for the new .geo file
- Standard PandaROOT objects and parameters used
- Integrated **event display** (on/off with a flag in the reco macro)

Analysis software

Implementation of an algorithm for track reconstruction and dE/dx determination

ALGORITHM STEPS:

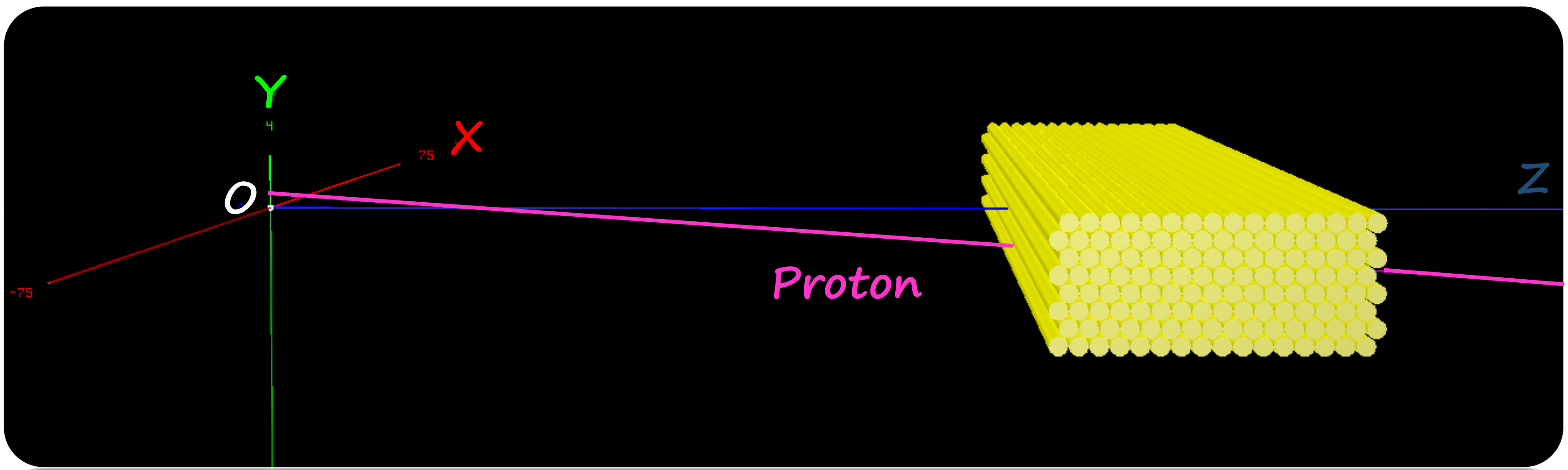
- **Track reconstruction**:
  - Track finding (pattern recognition)
  - Track fitting:
    - Prefit using points (centers of tubes)
    - Fit using isochrones
    - Fit using points (intersections on isochrones)
    - [Refit]
- **dE/dx determination**:
  - Track length calculation

MonteCarlo simulation

SIMULATION SETUP:

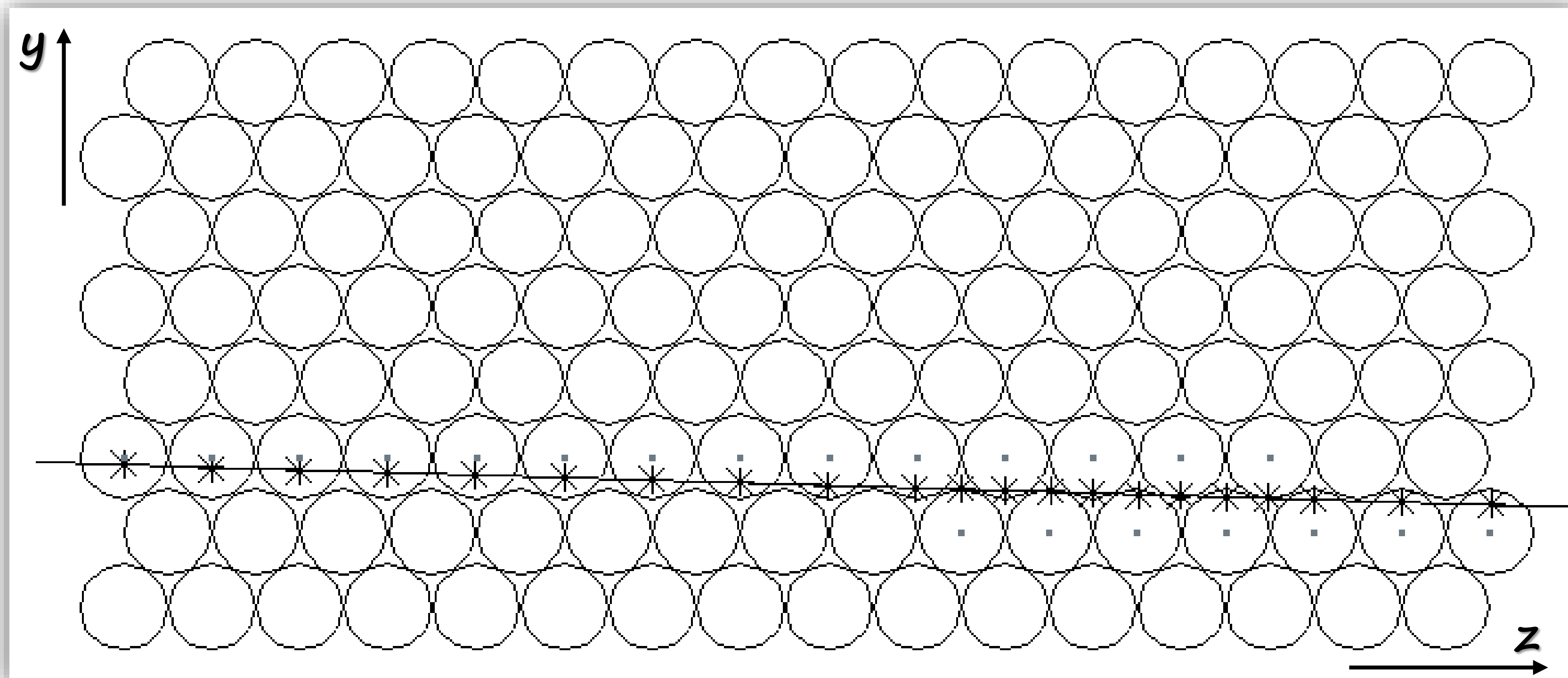
- 10^5 single and double track events
- Protons and deuterons @ 0.6, 1 and 3 GeV/c
- Tracks generated:
  - in the range ([-1.5,1.5] cm, [-1.5,1.5] cm, 0 cm)
  - uniformly in ϕ (0, 360°)
  - $\theta \in$ (-4.57°, 4.57°)
- No magnetic field

Image from eventDisplay



MonteCarlo simulation

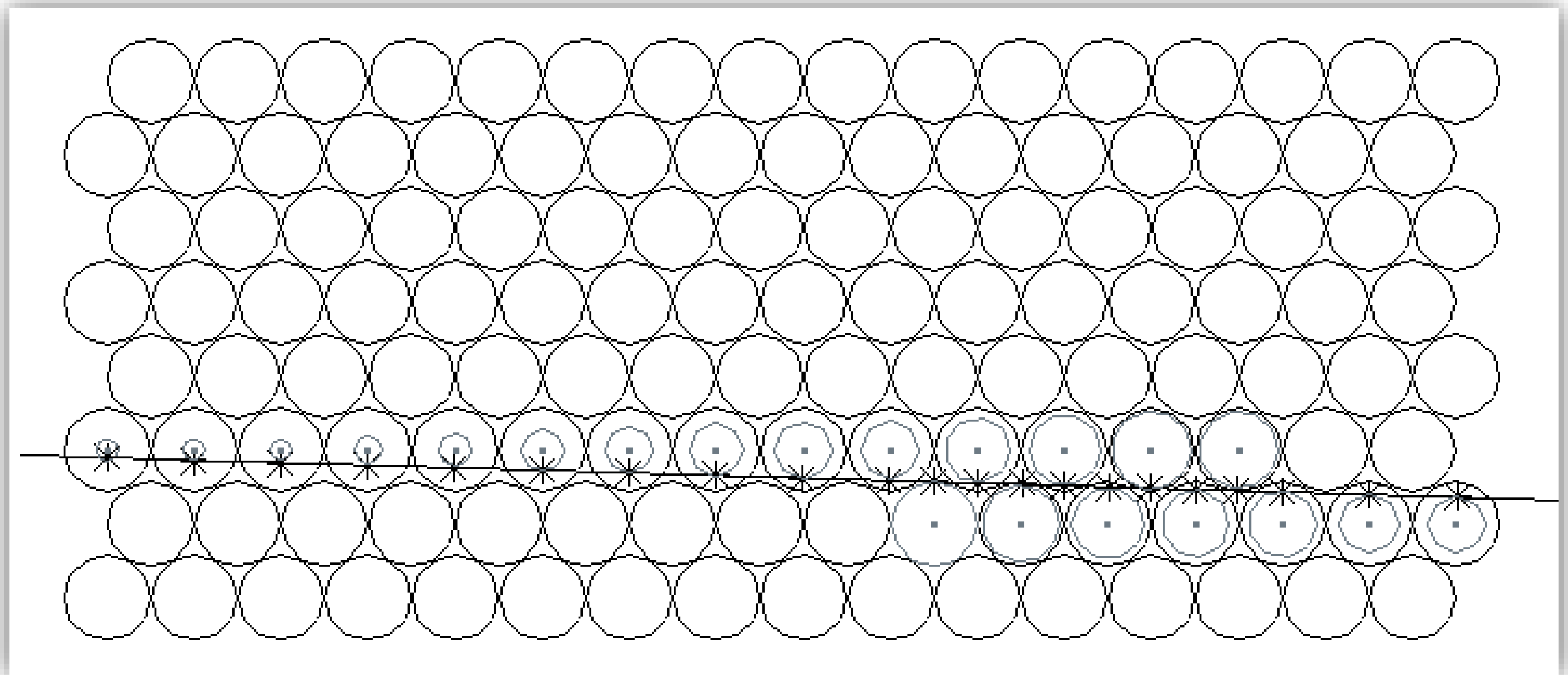
Sample event:
1 track/event, protons @ 1 GeV/c



MC points (x) and track; *centers of the hit tubes*

Track finding algorithm

CLUSTER FORMATION:
starting from a «border» tube, all the neighbouring tubes which have been hit are added to the cluster
At least 3 hits required

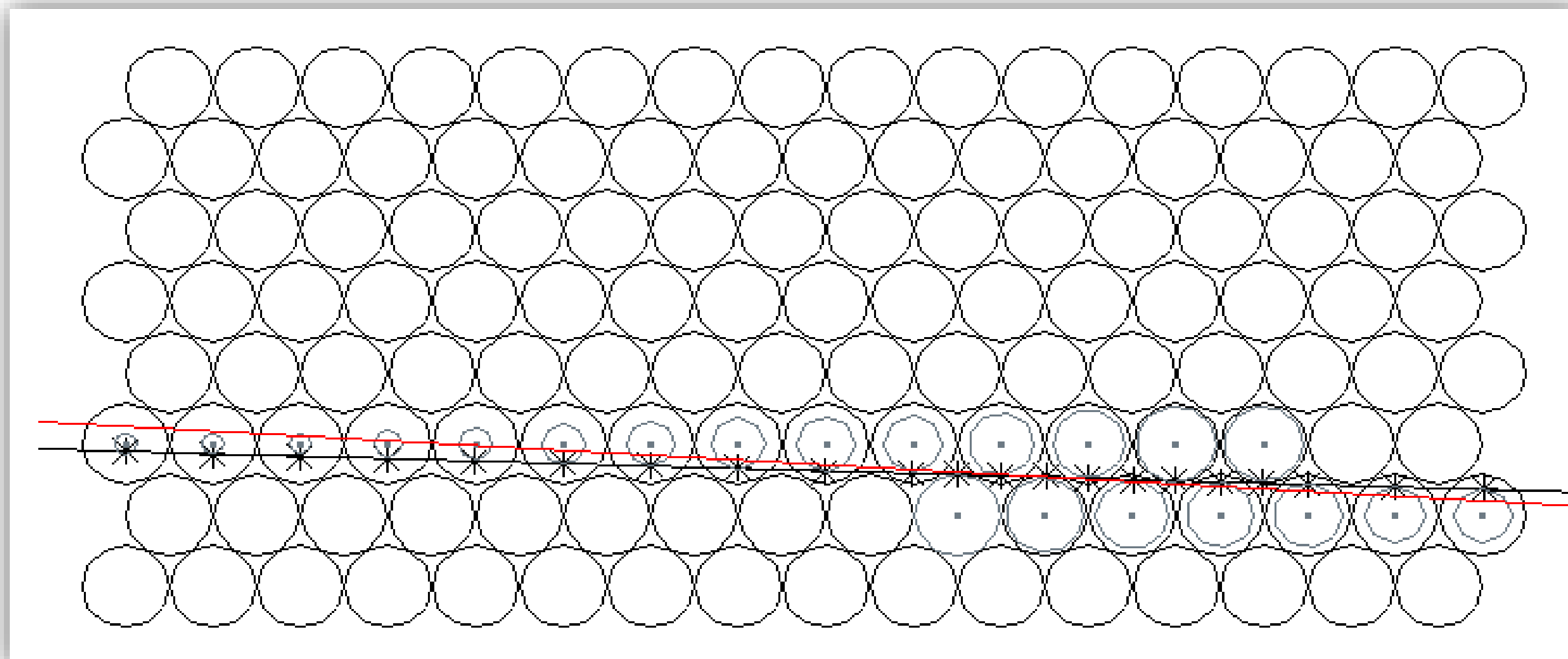


MC points and track; *isochrone curves of the hits tubes*

Track fitting algorithm

PREFIT: minimization of the perpendicular distance of the tube centre coordinates (z_i, y_i)

$$R_{\perp}^2 = \sum_{i=1}^{N} d_i^2 = \sum_{i=1}^{N} \frac{[y_i - (a + bz_i)]^2}{1 + b^2}$$



MC points and track; *isochrone curves*; prefit result

Track fitting algorithm

PREFIT: minimization of the perpendicular distance of the tube centre coordinates (z_i, y_i)

$$R_{\perp}^2 = \sum_{i=1}^{N} d_i^2 = \sum_{i=1}^{N} \frac{[y_i - (a + bz_i)]^2}{1 + b^2}$$

CheckDistance:

For each tube, if the distance $d_i(a,b) > 0.8$ cm, the hit is discarded

⇩

New cluster of «fake hits» is created/updated

Track fitting algorithm

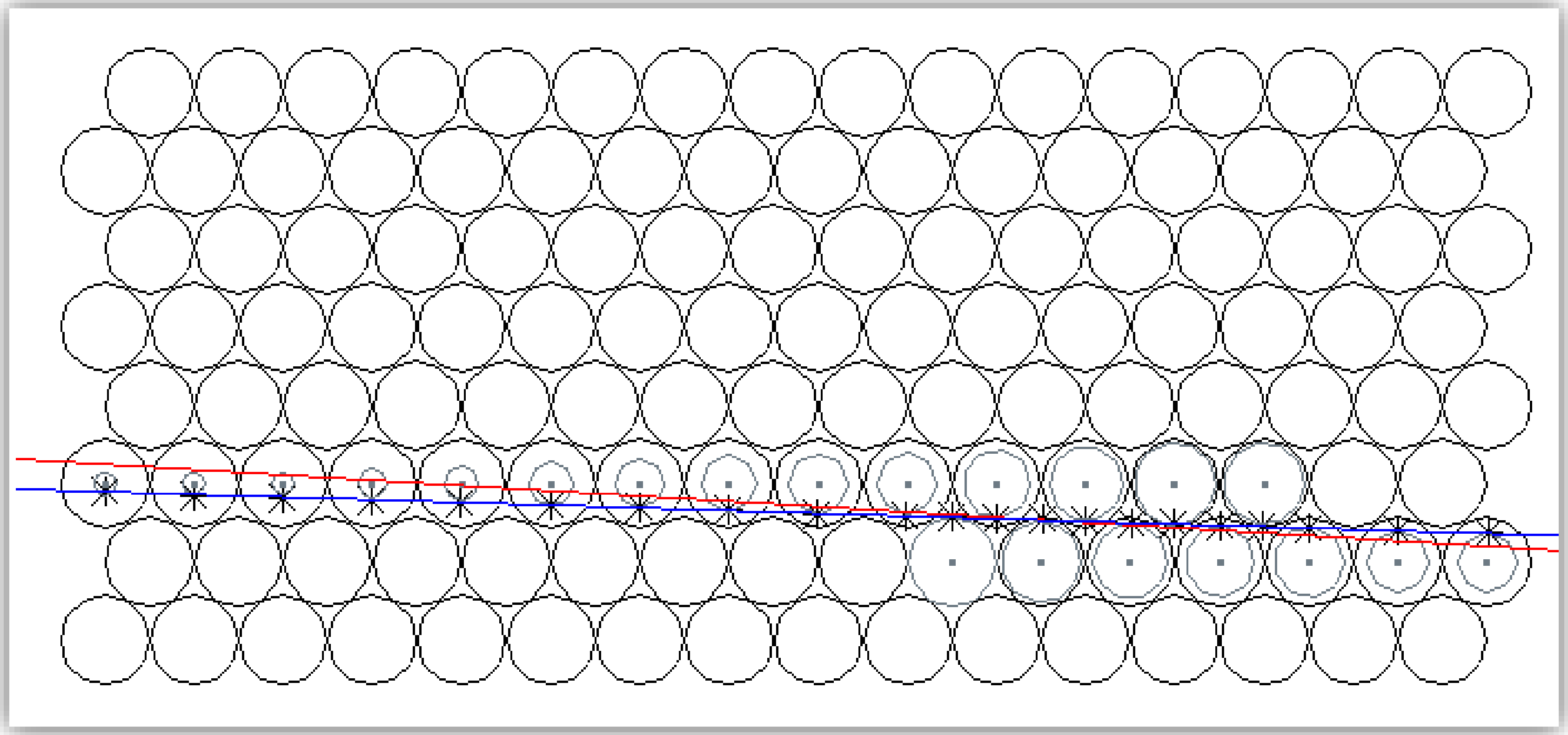
MINUIT FIT: χ^2 minimisation

$$\chi^2 = \frac{1}{N-2} \sum_{i=1}^{N} \left(\frac{\Delta r_i(a,b)}{\sigma_{r_i}} \right)^2$$

- $\Delta r_i(a,b)$ are the residuals: $$\Delta r_i = \frac{|y_i - (a + b z_i)|}{\sqrt{1+b^2}} - r_{i,MC}$$
- (z_i, y_i) are the centre coordinates
- (a, b) are the fit line parameters
- σ_{r_i} are the errors on the drift radii (from input resolution curve)
- $r_{i,MC}$ are the drift radii from simulation (digi); with exp data, they will be the raw drift radii from the r-t_{drift} relation
- NOTE: this is a **non linear minimisation** (it's not the sum of standard gaussian variables, parameter b in the denominator)

Track fitting algorithm

MINUIT FIT with isochrone radii: $$\chi^2 = \frac{1}{N-2}\sum_{i=1}^{N}\left(\frac{\Delta r_i(a,b)}{\sigma_{r_i}}\right)^2$$



MC points and track; isochrone curves; prefit result; fit result

Track fitting algorithm

MINUIT FIT: χ^2 minimisation

$$\chi^2 = \frac{1}{N-2}\sum_{i=1}^{N}\left(\frac{\Delta r_i(a,b)}{\sigma_{r_i}}\right)^2$$

CheckResiduals:

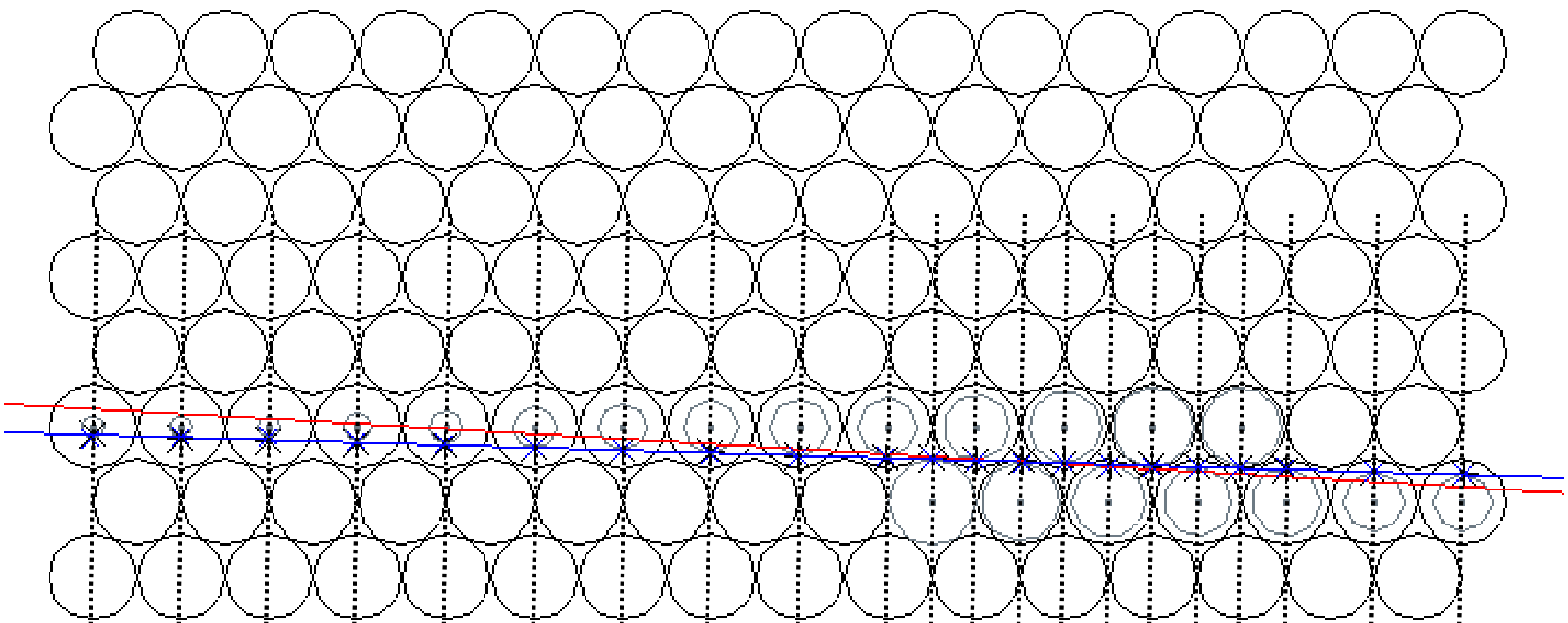
For each hit, if the residual $\Delta r_i(a,b) > 2$ mm, the hit is discarded

⇩

New cluster of «fake hits» is created/updated

Track fitting algorithm

INTERSECTION FINDER:
finds the intersection points between the orthogonal to the fit line (through the wire coordinates) and the drift circle; the closest to the fit track is the track point



MC points and track; isochrone curves; prefit result; fit result

Track fitting algorithm

MINUIT FIT
with intersection points:

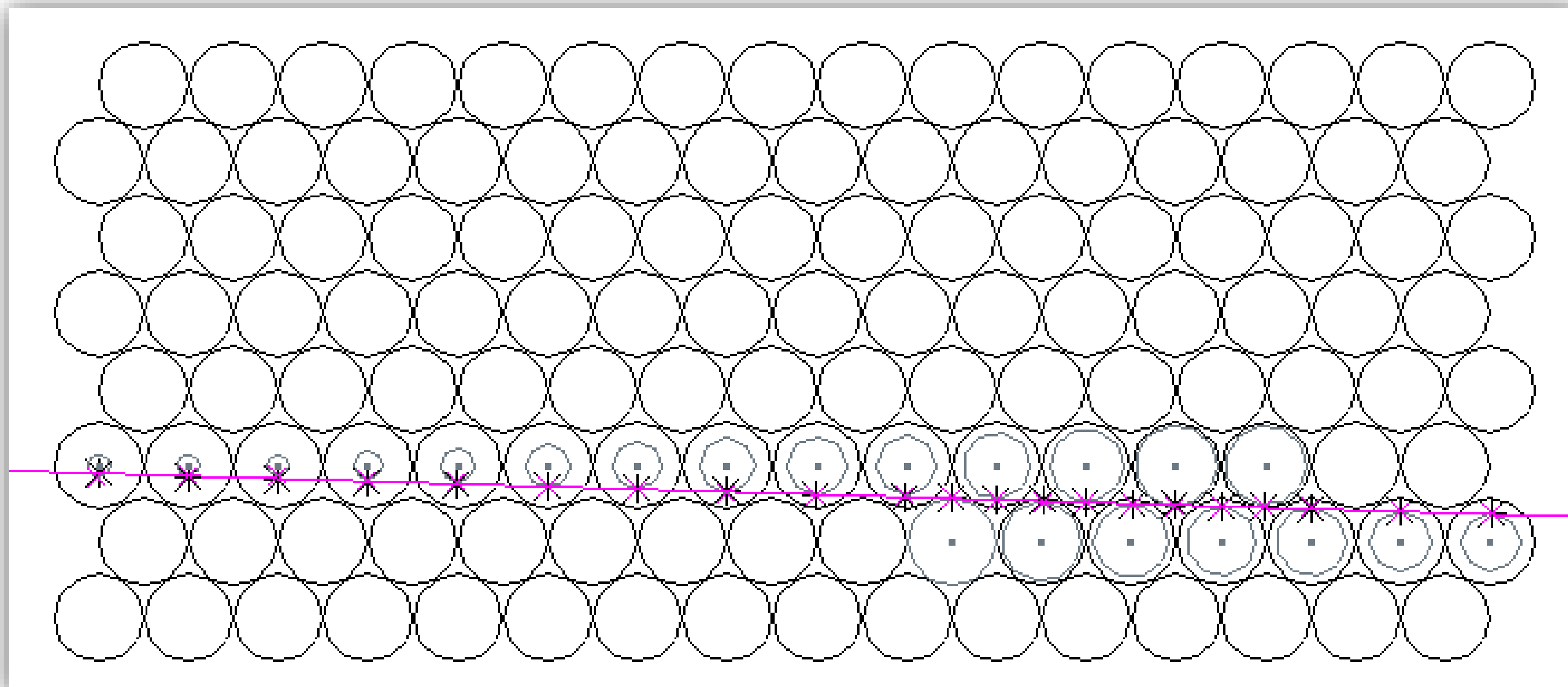
$$\chi^2 = \sum_{i=1}^{N} \frac{d_i^2}{\sigma^2_{d_i,tot}}$$

- d_i are the distances (to be minimised) of the «intersection points» to the fit track
- σ_{d_i} are the errors on the distances d_i: $\sigma^2_{d_i,tot} = \left(\frac{1-b^2}{1+b^2}\right)^2 \sigma_r^2$
- b is one of the fit line parameters
- NOTE: this is again a **non linear minimisation** (parameter b in the denominator) but it is closer to a standard χ^2

Track fitting algorithm

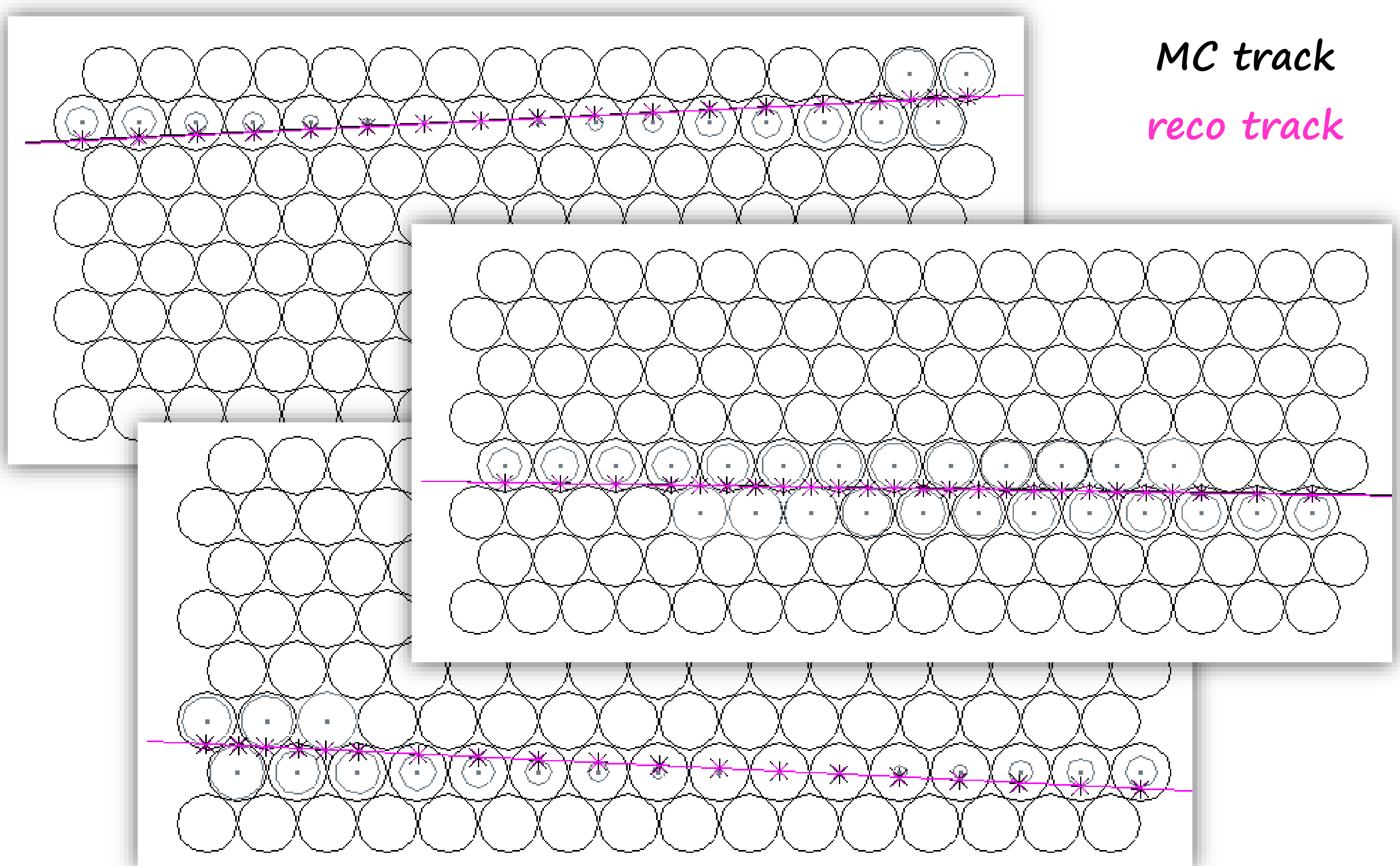
MINUIT FIT
with intersection points:

$$\chi^2 = \sum_{i=1}^{N} \frac{d_i^2}{\sigma_{d_i,tot}^2}$$



MC points; isochrone curves; reconstructed track and hits

Examples of reco tracks

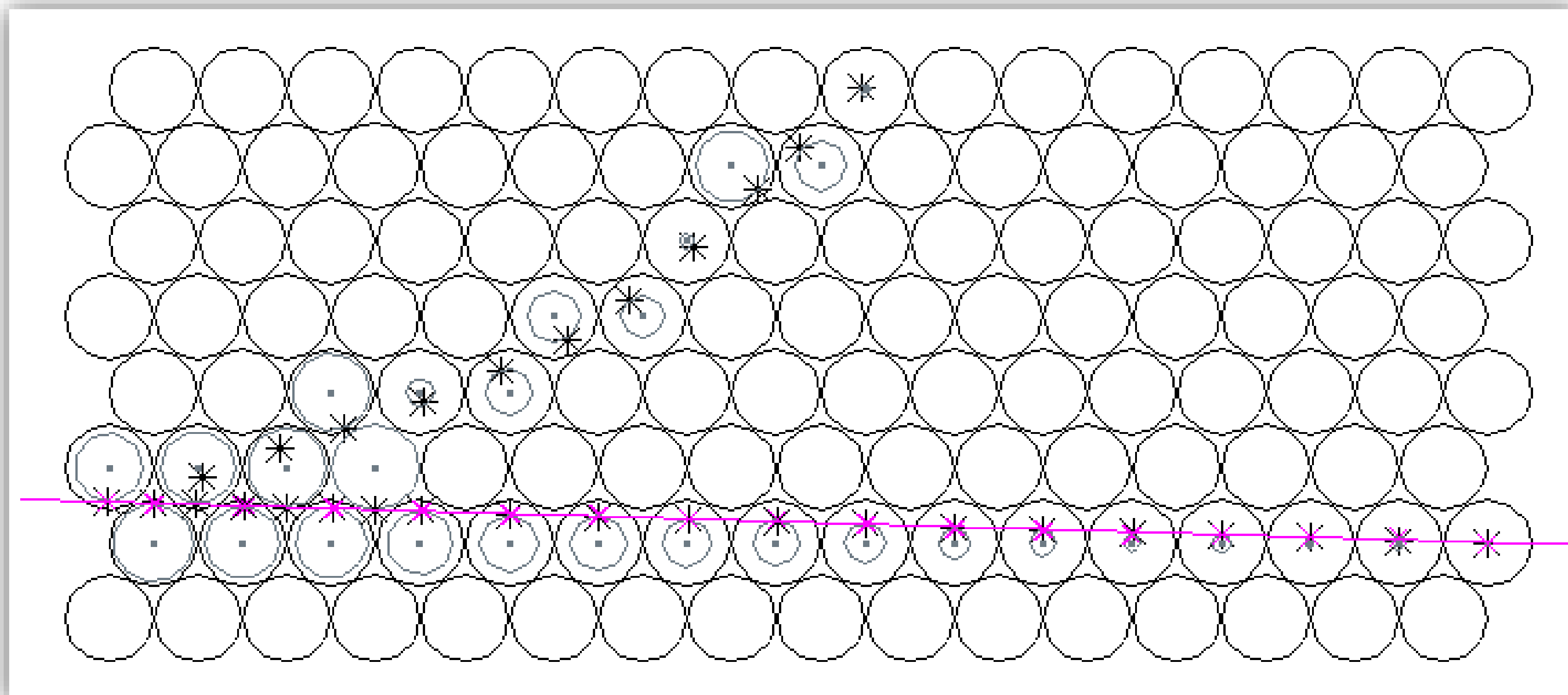


MC track

reco track

Examples of reco tracks

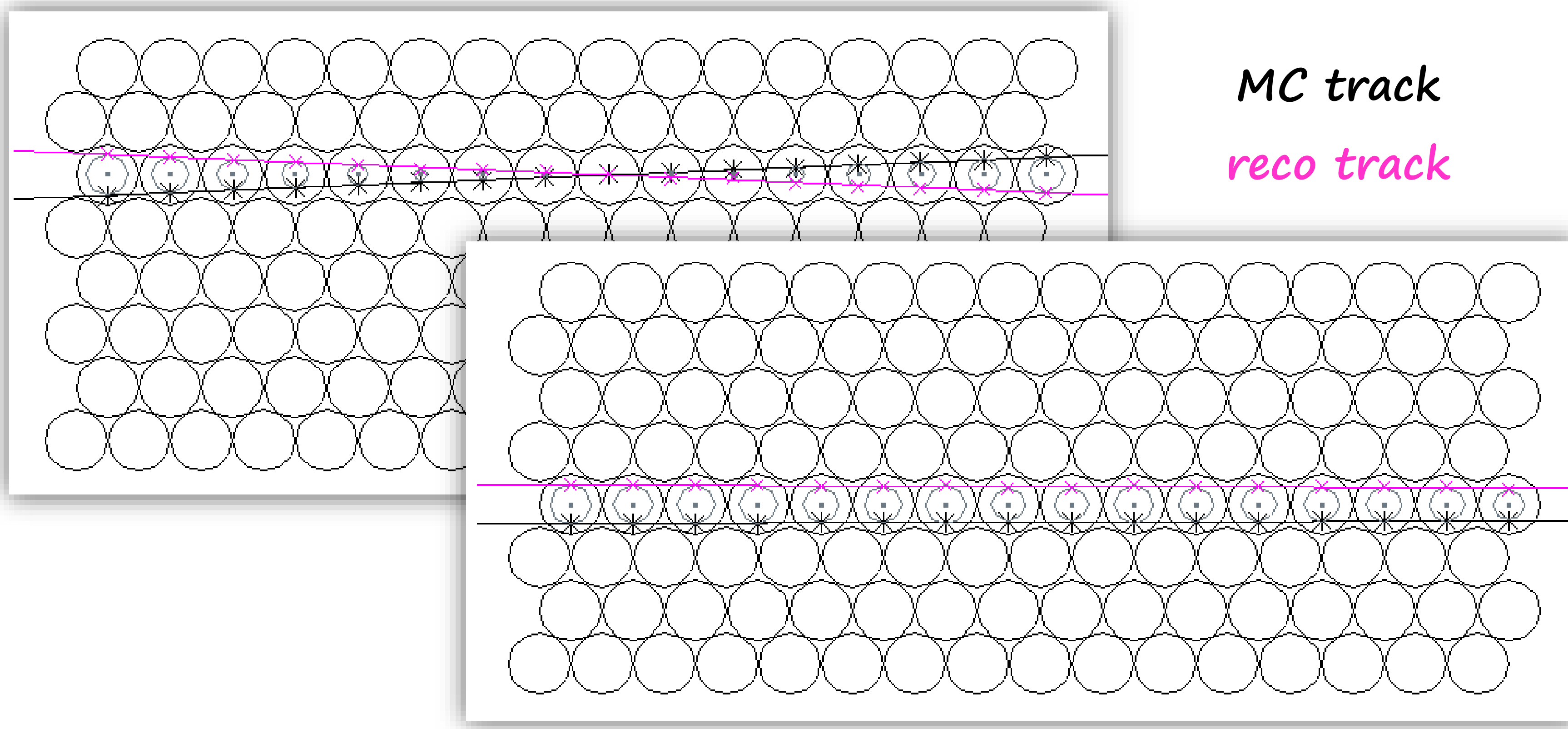
Example of event with secondary production
(electron not reconstructed)



MC track; reco track

Left/right ambiguity

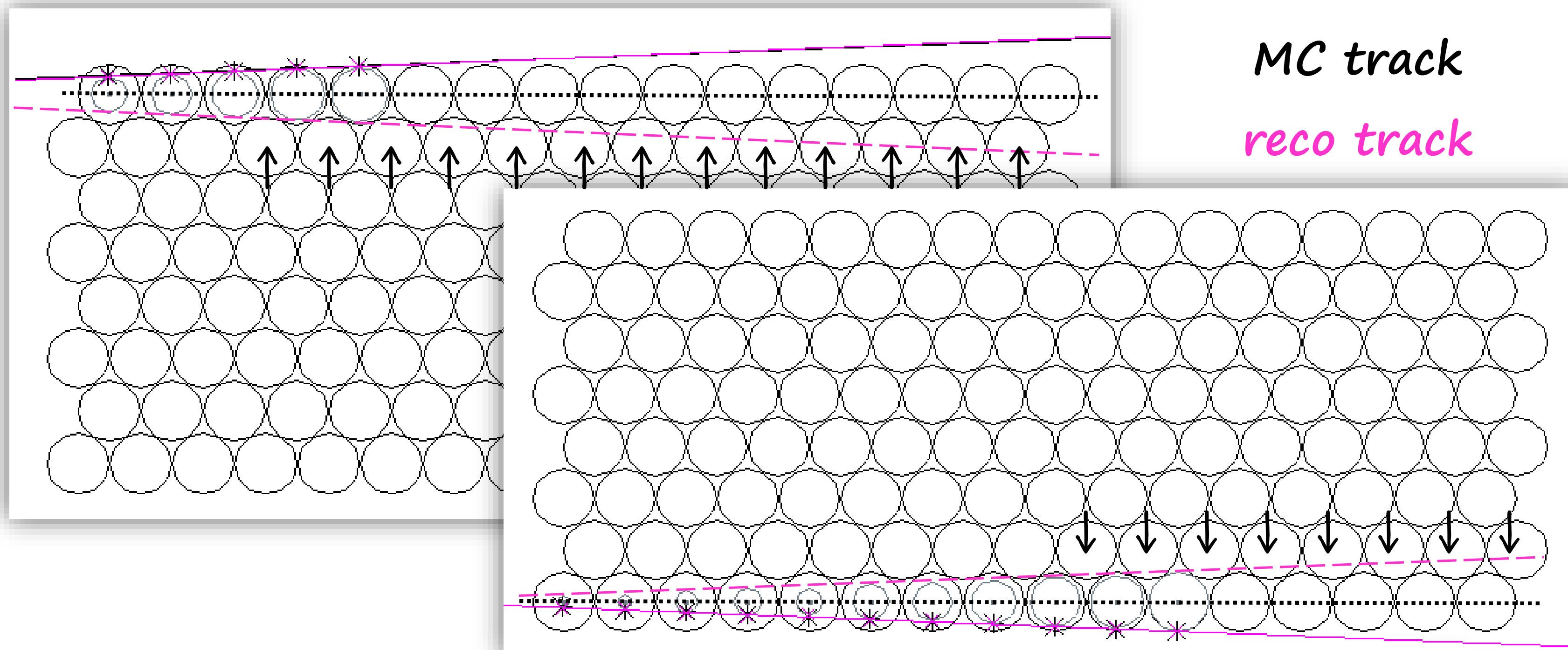
NO CHANCE to solve left/right ambiguity for tracks transversing only one «middle» layer



Same tracklength (→ dE/dx) for both tracks!!!

Left/right ambiguity

IMPORTANT to solve left/right ambiguity for «border» tracks: different tracklengths (→ dE/dx)!!!



Check on the tubes hit by the reconstructed track:
If (# new hits - # init hits) > 2, the correct solution is the straight line symmetric with respect to the layer axis

Reconstruction efficiency

SINGLE TRACK EVENTS

PROTONS:

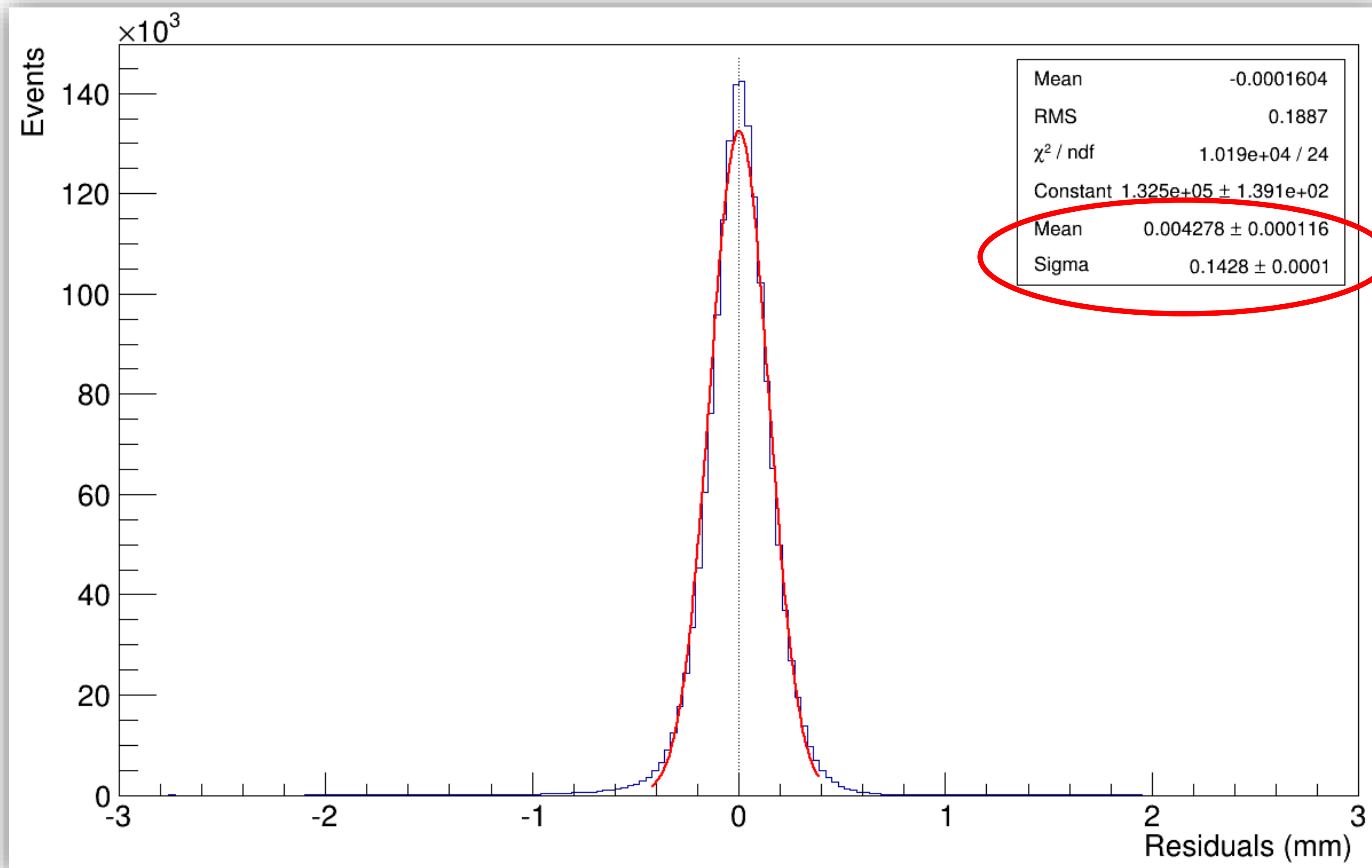
- @ 0.6 GeV/c: **99.7%** (98.8% if tracks with <2 hits are counted)
- @ 1.0 GeV/c: **99.7%** (98.6% if tracks with <2 hits are counted)
- @ 3.0 GeV/c: **99.7%** (98.7% if tracks with <2 hits are counted)

DEUTERONS:

- @ 0.6 GeV/c: **99.9%** (98.9% if tracks with <2 hits are counted)
- @ 1.0 GeV/c: **99.8%** (98.8% if tracks with <2 hits are counted)
- @ 3.0 GeV/c: **99.7%** (98.8% if tracks with <2 hits are counted)

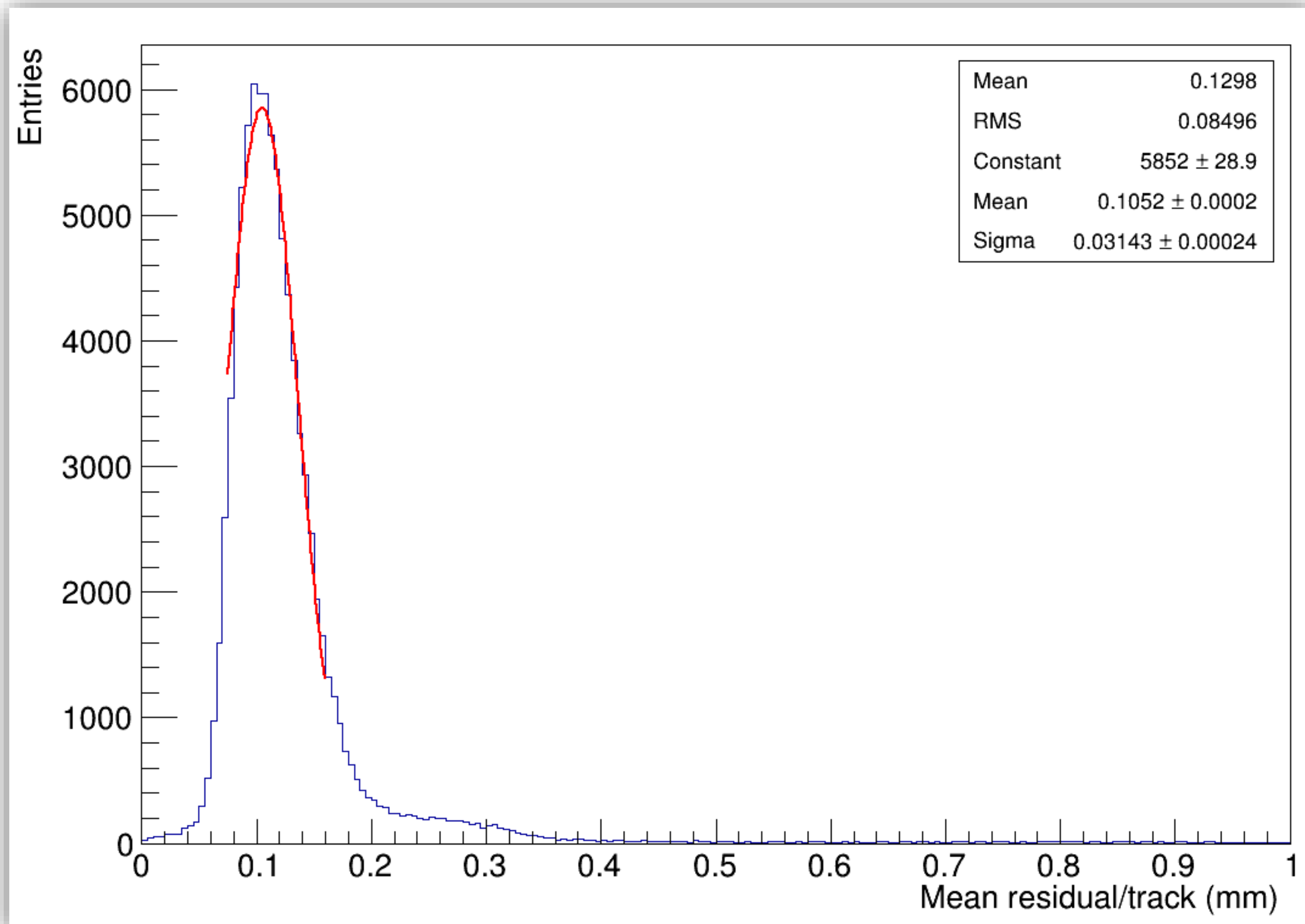
Residual distribution

$$\Delta r = r_{fit}(a,b) - r_{raw}$$

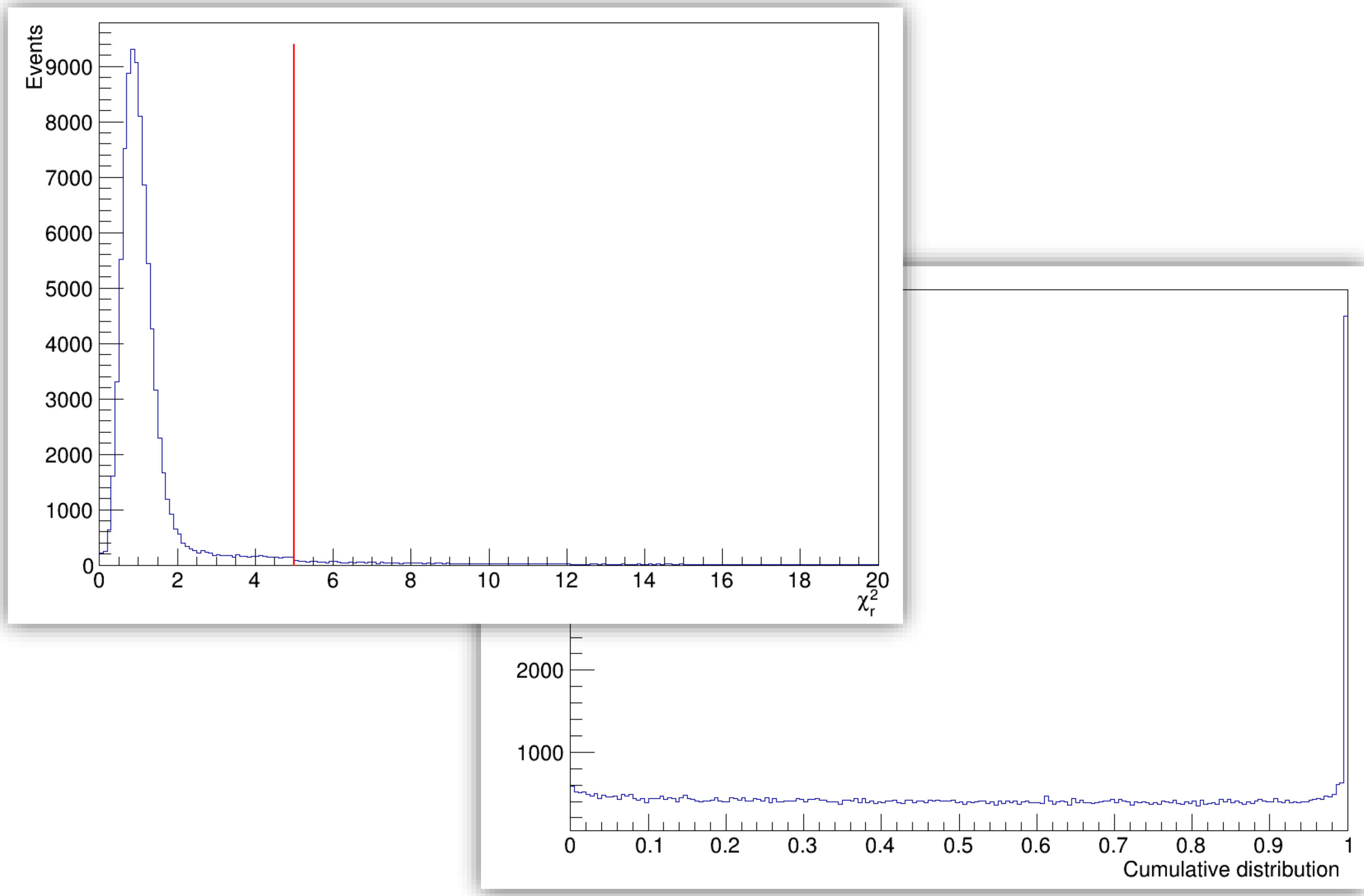


Mean residuals/track

$\Delta r_{mean} = \Sigma r_{hit}(a,b) \,/\, (\#hits/trk)$



χ^2 and cumulative distributions



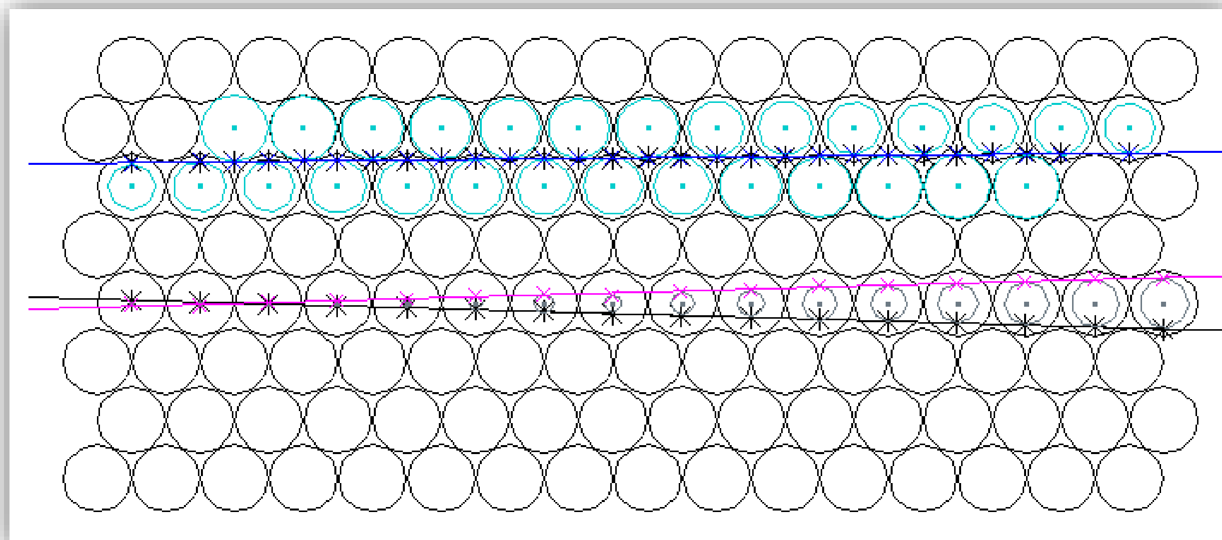
Double track events

EVENT «TOPOLOGY»

- 2 separate tracks 
- 2 «overlapping» tracks, with double hits in some tubes 
- 2 very close tracks, traversing usually 3 neighbouring layers 

Examples of reco events

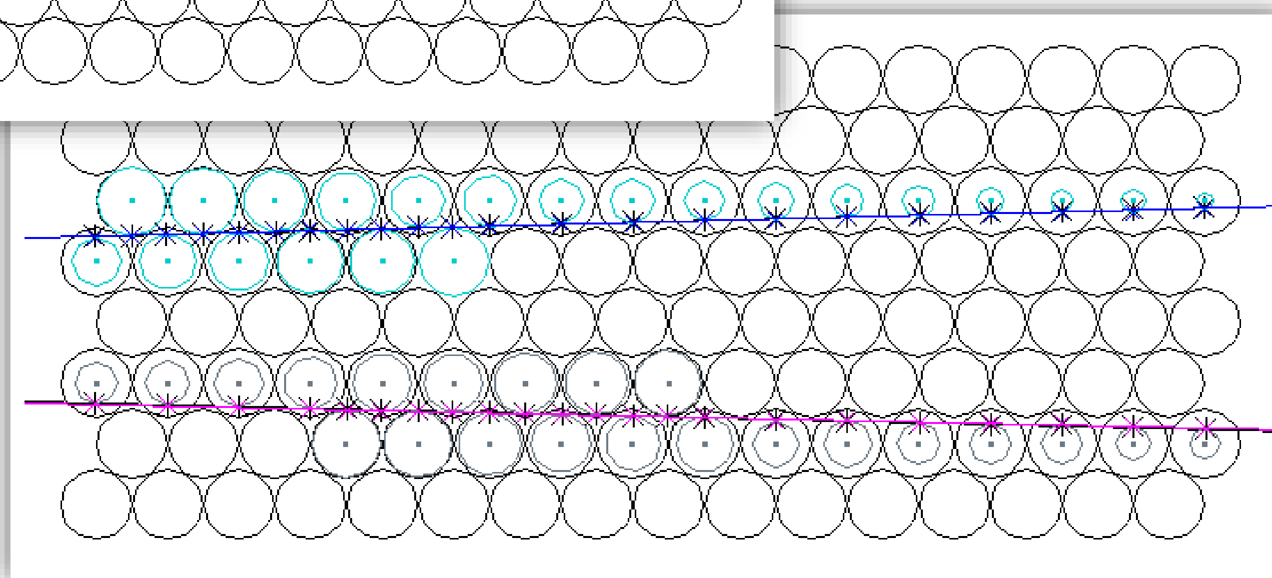
Examples of events with «separate» tracks



MC tracks;

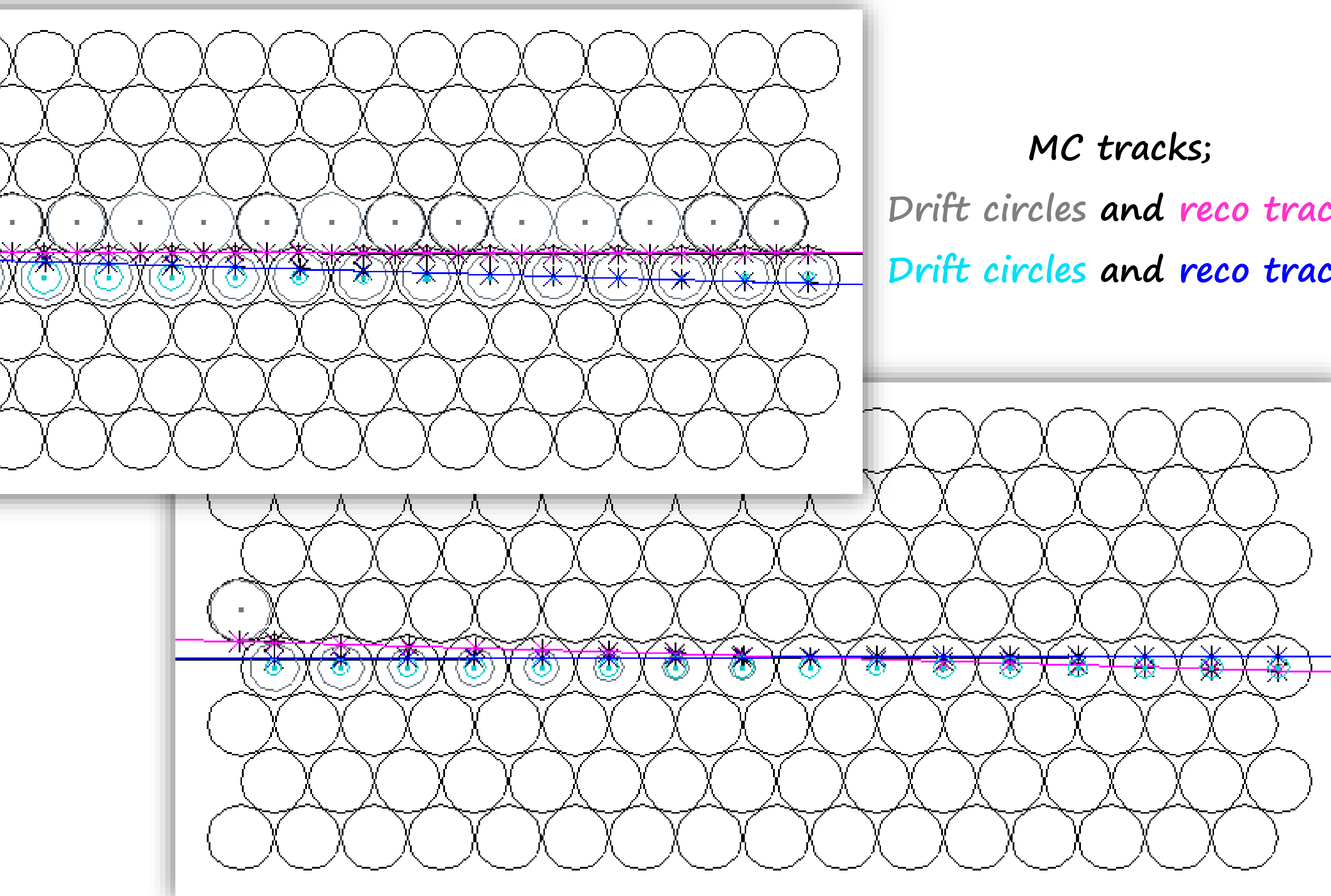
Drift circles and reco track

Drift circles and reco track



Examples of reco events

Examples of events with «overlapping» tracks



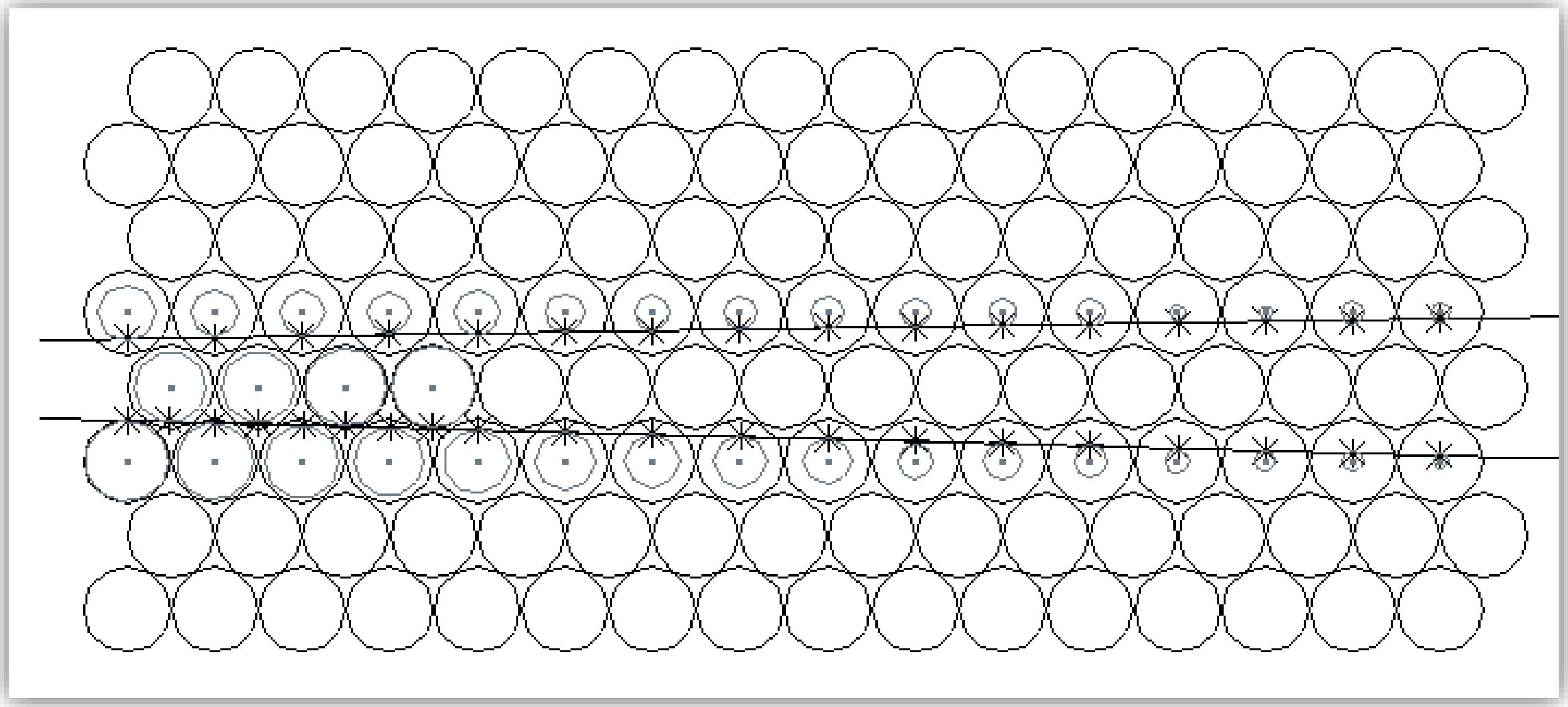
MC tracks;

Drift circles and reco track

Drift circles and reco track

Example of reco events

Examples of events with «close» tracks



Only 1 big cluster is created…

→ From 1 to more than 2 tracks reconstructed!!

Reconstruction efficiency

SINGLE TRACK EVENTS

PROTONS:

- @ 0.6 GeV/c: **99.7%** (98.8% if tracks with <2 hits are counted)
- @ 1.0 GeV/c: **99.7%** (98.6% if tracks with <2 hits are counted)
- @ 3.0 GeV/c: **99.7%** (98.7% if tracks with <2 hits are counted)

DEUTERONS:

- @ 0.6 GeV/c: **99.9%** (98.9% if tracks with <2 hits are counted)
- @ 1.0 GeV/c: **99.8%** (98.8% if tracks with <2 hits are counted)
- @ 3.0 GeV/c: **99.8%** (98.7% if tracks with <2 hits are counted)

Summary & Outlook

- The track finding and fitting code for the STT prototype is in progress
- The class is implemented in PandaROOT and available on svn (pandaroot/development/scostanza/trunk/tracking/prototype and pandaroot/development/scostanza/trunk/macro/stt/sttexp)
- Code testing with simulation (protons and deuterons):
  - Very good results for single track events
  - Good but improvable results for multiple track events

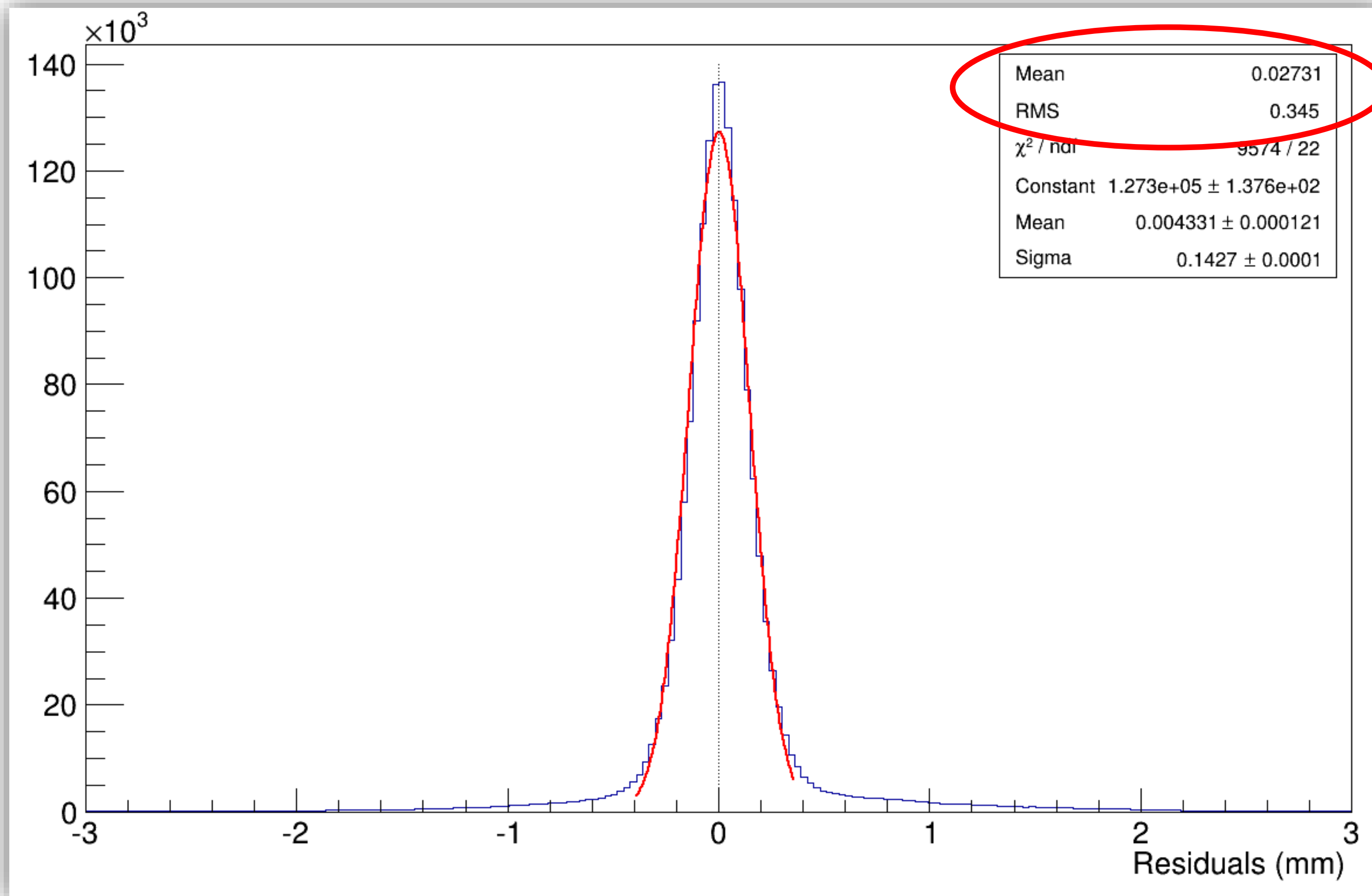
- Implementation of the raw data interface to PandaROOT
- Tests on PID (p/d separation power) and dE/dx calculation
- Tests with experimental data (from cosmics and beam)

Thank you!

Backup slides

Residual distribution after 1st fit

$\Delta r = r_{fit}(a,b) - r_{raw}$



Coordinate residuals

$$\Delta z = z(y)_{fit(a,b)} - z(y)_{MC}$$