Tracking for Alignment

Fitting with GBL | Alignment with Millepede

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Overview

❑ Current status

- VXD alignment in basf2
- MC tracking for EUDET telescopes
- Example for full Belle II VXD
- Example for VXD testbeam

❑ Ongoing development

- New features
- GBL for CDC

❑ Implementation issues

- Extending GENFIT for alignment
- GBL integration into GENFIT

❑ Conclusion

Current status | VXD alignment in basf2

❑ General Broken Lines (GBL)

- Track model / fast refit with proper description of multiple scattering
- Adds multiple scattering effects to initial trajectory as additional fit parameters
  https://www.wiki.terascale.de/index.php/GeneralBrokenLines

- **GBLfit** module in basf2 → production of alignment data files for Millepede
  - Basic track selection (point Chi2, track p-value, minimum degrees of freedom)
  - genfit::TrackCand → genfit::Track → gbl::GblTrajectory → Mille binary

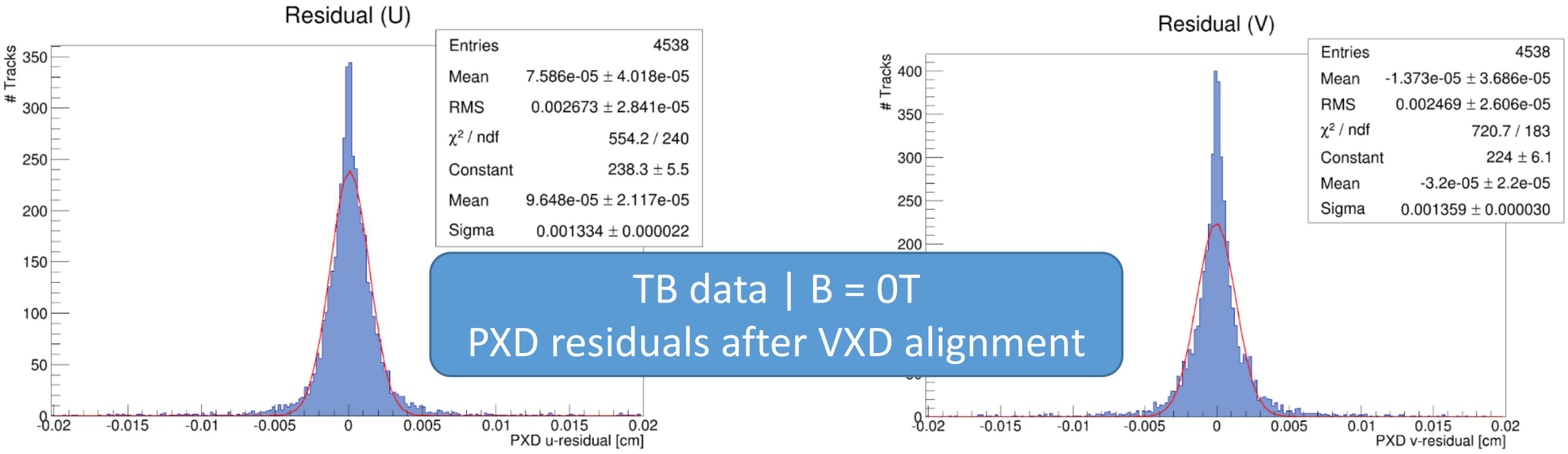
❑ Millepede II

- Implementation of the Millepede algorithm for global alignment
  https://www.wiki.terascale.de/index.php/Millepede_II
- Linear least squares fit for *very* large number of parameters

- **MillepedeIIalignment** module in basf2 → can compute (basic) constraints, run Pede and analyse results → xml with alignment
  - Python ***alignment_tools*** (in testbeam package)… allow to sum alignment in two xmls or sum alignment in txt (from Pede) with xml

Current status | Progress in basf2 since last F2F meeting in Prague

- ❑ GBL fit working with both TrueHits/Clusters
- ❑ Material treatment using thin/thick scatterers
- ❑ Alignment procedure for testbeam and Belle II VXD (fully working in MC)
- ❑ Telescopes supported (except real track finding)
- ❑ Basf2 modules for GBL fitting + Millepede alignment
- ❑ Testbeam geometry reflects the experiment
  - Local coordinates, sensor positions …
  - Note that PXD is shifted by almost 5mm from nominal position!



TB data | B = 0T

PXD residuals after VXD alignment

Current status | MC tracking for EUDET telescopes

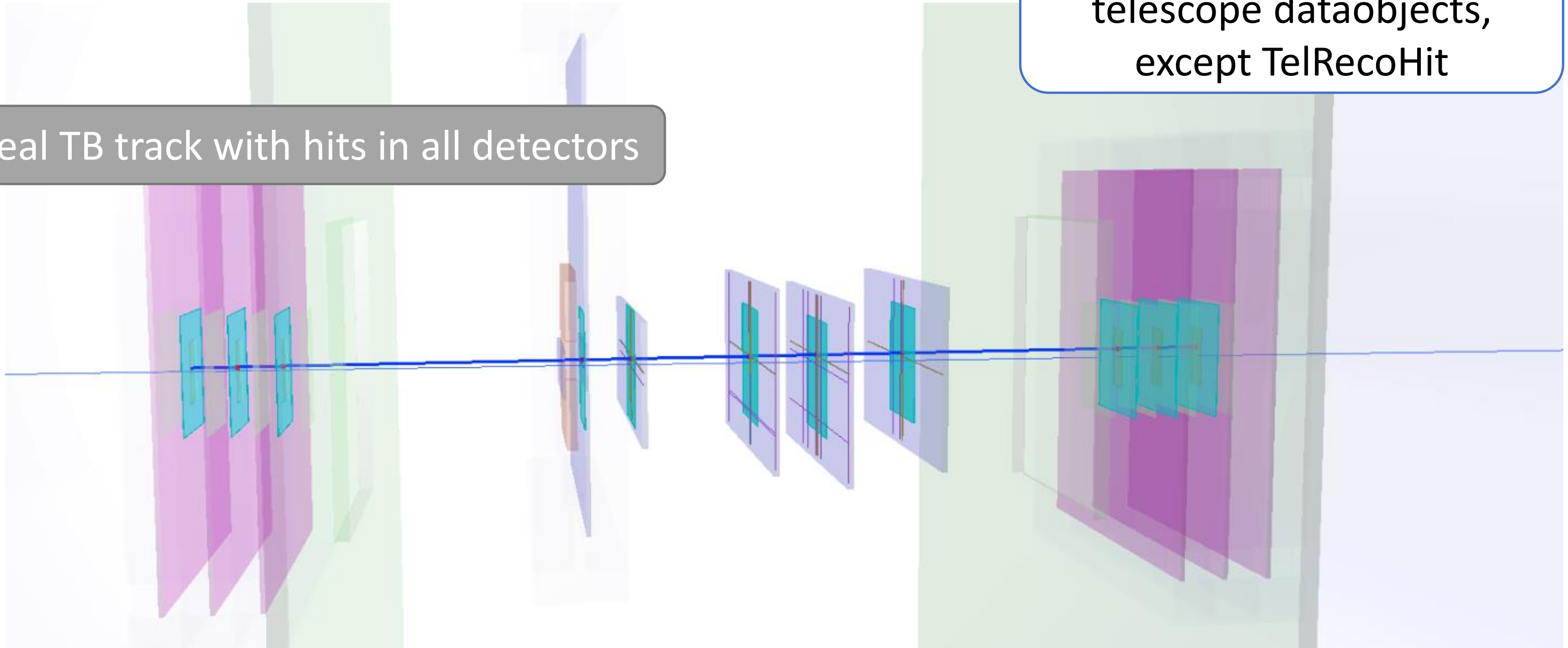
- ❑ Cloned modules with support for telescopes added
  - EUDET telescope detector: Const::TEST
  - EUDET dataobjects: TelSimHit, TelTrueHit, TelCluster, TelRecoHit

✓ **TrackFinderMCVXDTB** … MC telescope + VXD track finding

✓ **GenFitterVXDTB** … fitting for telescopes + VXD

✓ No changes necessary for alignment

✗ Display does not support telescope dataobjects, except TelRecoHit



Real TB track with hits in all detectors

Current status | Full Belle II VXD alignment

❑ Basic example available in release

❑ See alignment/examples

- Step 1 a/b … generates ip/cosmics sample
- Step 2 a/b … uses misaligned geometry to fit sample and produce data for alignment
- Step 3 … alignment with Millepede on combined sample
- Step 4 a/b … fit samples again with alignment parameters from step 3

❑ Only misalignment in geometry at reconstruction level

- 100µm in U/V, 1 mrad in gamma
- Available as xml in svn
- Official version does not fully support slanted SVDs (solved locally)

❑ On following slides: results of single alignment procedure iteration

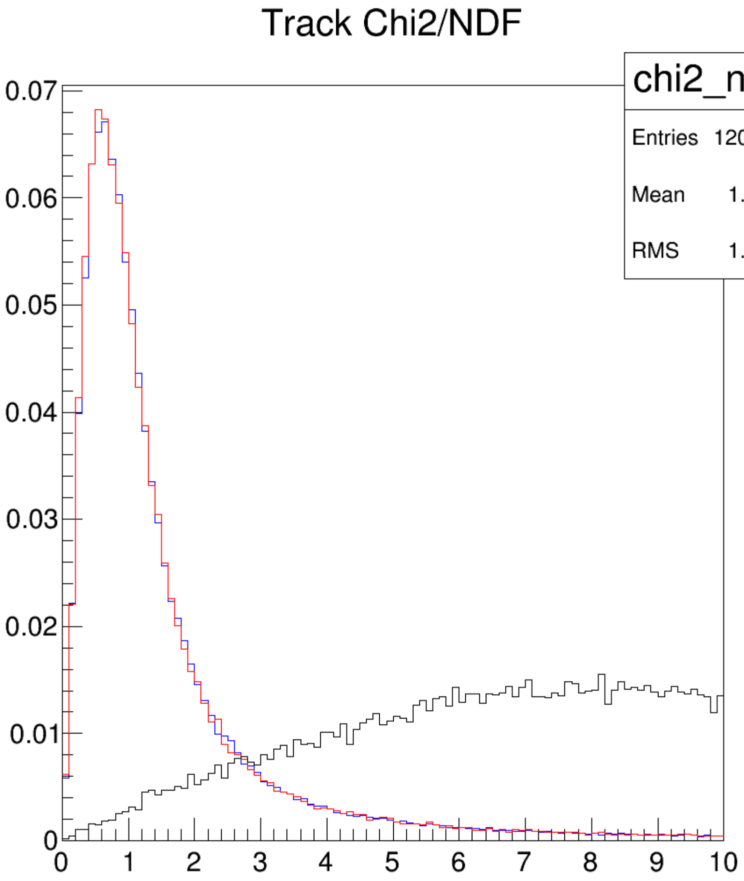
- > 1000 alignment parameters fitted (around 200 000 tracks)
- Takes < 1min

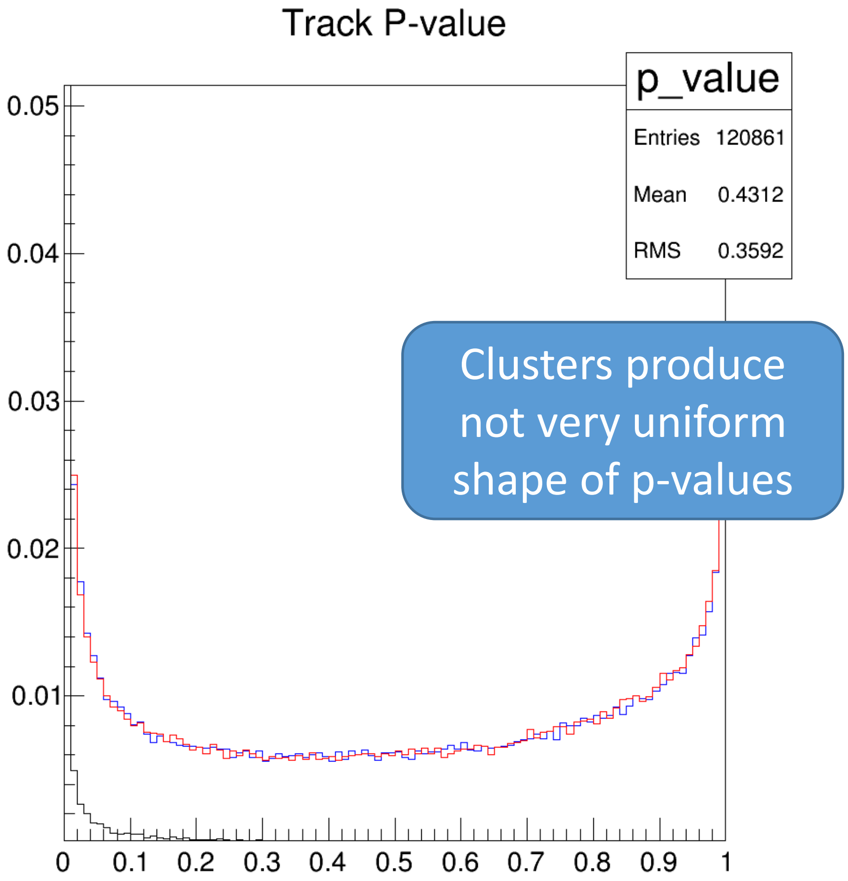
❑ Known issue: Need to remove TracksToMCParticles relations from input in steps 2 and 4

Current status | Full Belle II VXD alignment

- ❑ > 100k muons from IP + > 100k cosmic muons (field off)
- ❑ Generated average misalignment 100um in u, v; 1mrad in gamma
- ❑ Plots for B=0 (cosmic muons)

Ideal geometry | misaligned | after alignment (using constraints)



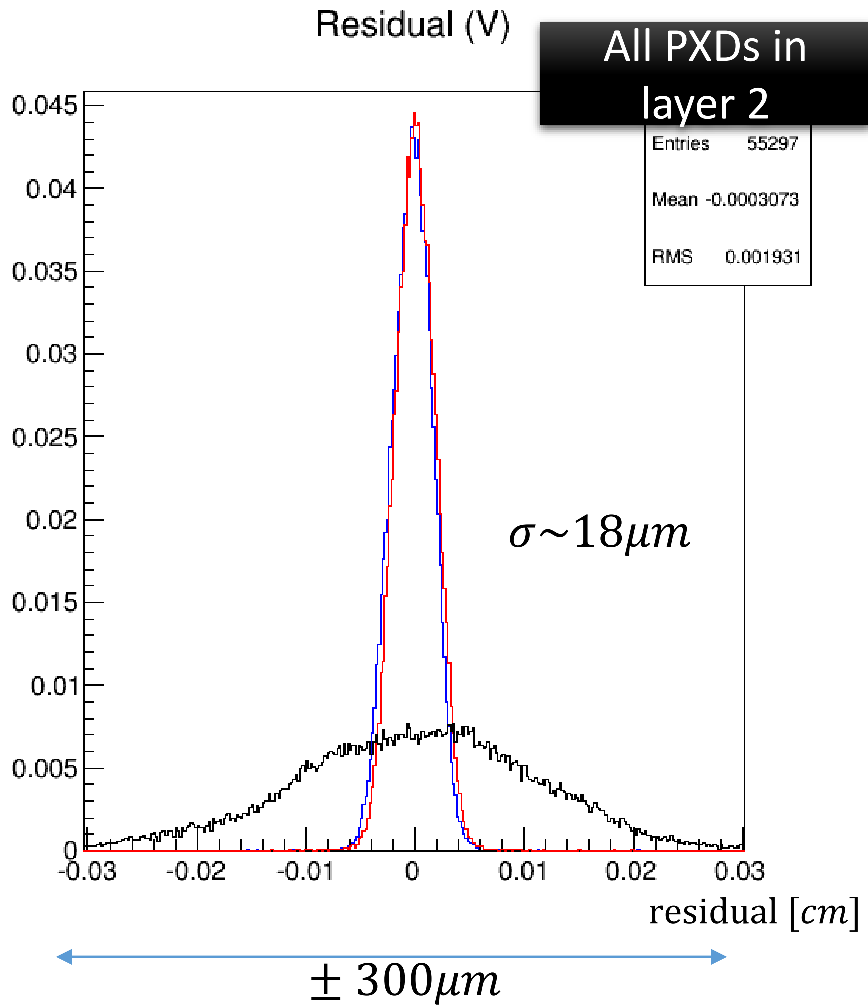


Clusters produce not very uniform shape of p-values

Current status | Full Belle II VXD alignment

- ❑ Residuals in ***Z*** in layer 2 (PXD) and layer 6 (SVD)
- ❑ Plots for *B = 0T* (cosmic muons)

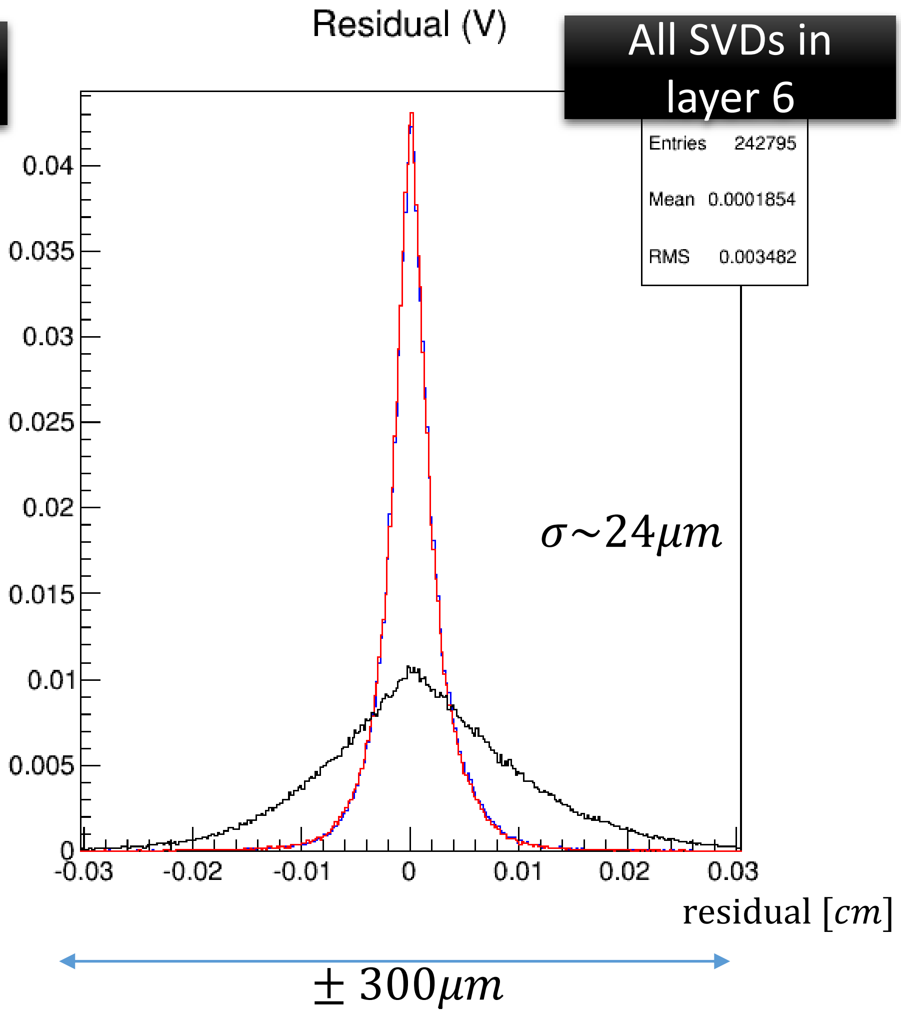
Ideal geometry | misaligned | after alignment



All PXDs in layer 2

$\sigma{\sim}18\mu m$

$\pm\,300\mu m$



All SVDs in layer 6

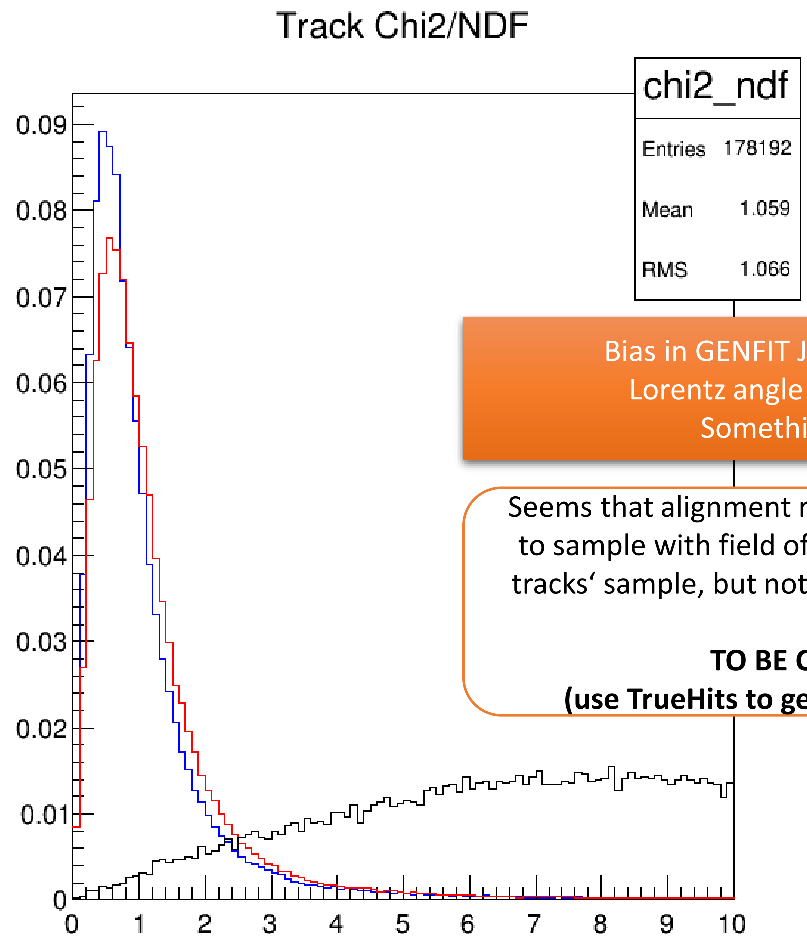
$\sigma{\sim}24\mu m$

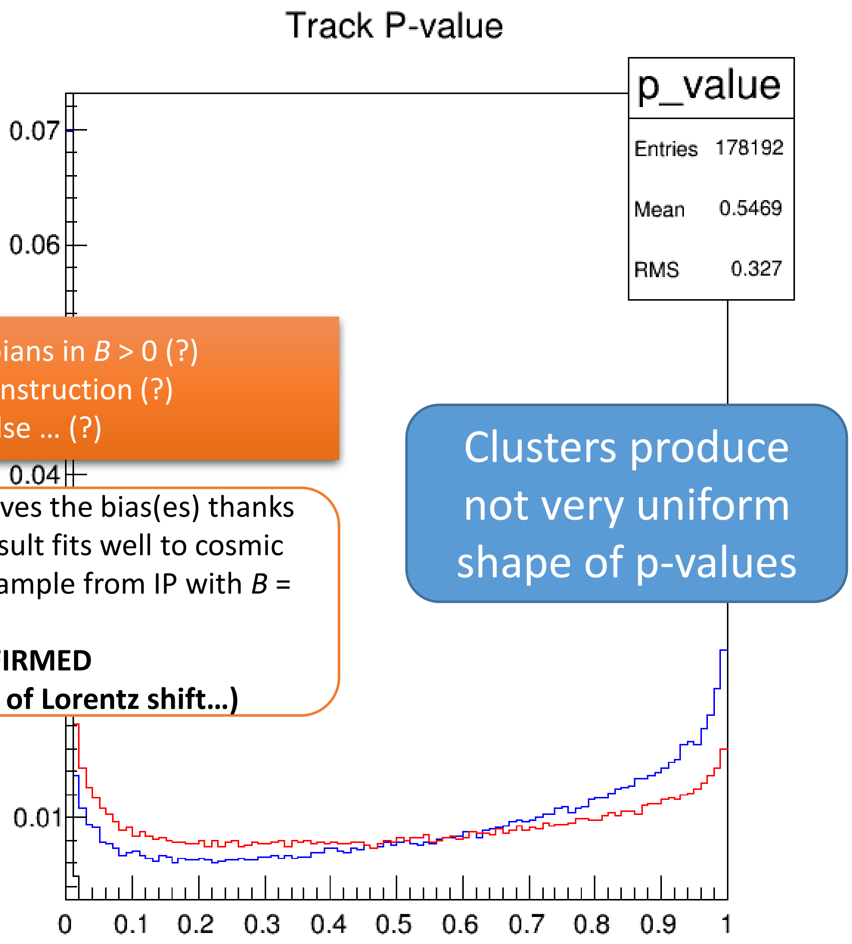
$\pm\,300\mu m$

Current status | Full Belle II VXD alignment : Issues with magnetic field

- ❑ Chi2/NDF and P-values. Plots for B=1.5T

Ideal geometry | misaligned | after alignment





Bias in GENFIT Jacobians in $B > 0$ (?)
Lorentz angle reconstruction (?)
Something else … (?)

Seems that alignment removes the bias(es) thanks to sample with field off. Result fits well to cosmic tracks' sample, but not to sample from IP with B = 1.5T

TO BE CONFIRMED

(use TrueHits to get rid of Lorentz shift…)

Clusters produce not very uniform shape of p-values

Current status | VXD testbeam example

❑ Simulate digits or get real data in form of merged digits

- *SimulateDigits.py* (eutel/MergerTest3.py)

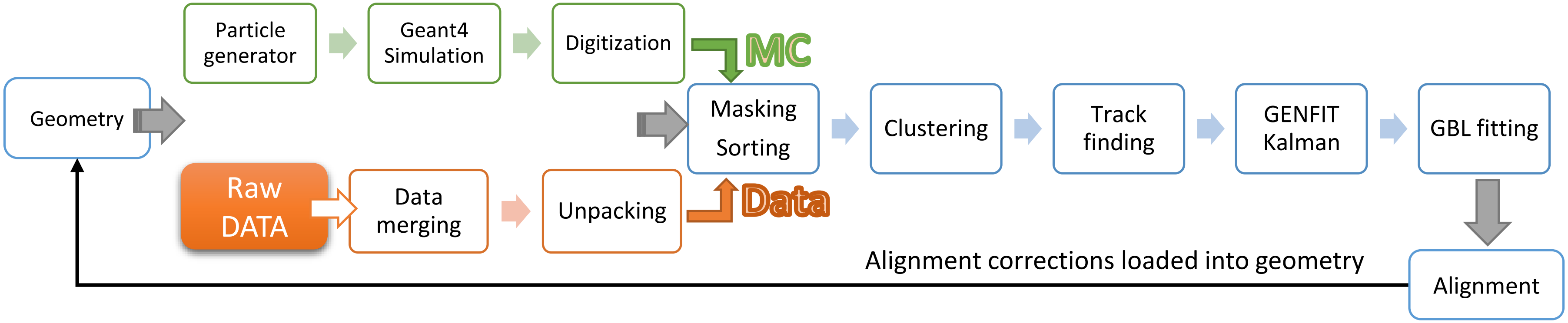
❑ Clusterize, mask, find tracks, fit with Kalman, output alignment data

- *Digits2Tracks.py*

❑ Plug in computed alignment

- *FitForAlignment.py* (2 step script)

❑ Not very nice (but automatic) manipulation with xml files for changing alignment parameters using python *alignment_tools* (in TB package) … will be gone after misalignment stuff is added



Ongoing development | New features

❑ Combination of SVD clusters in genfit::Track (correct errors for slanted SVDs)

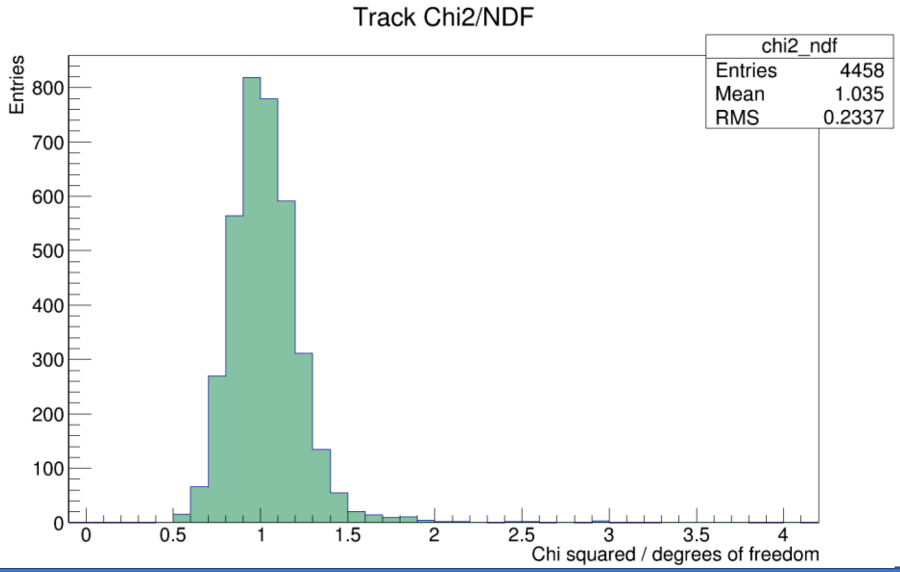
❑ Trajectories with arbitrary combination of 1D and 2D hits supported

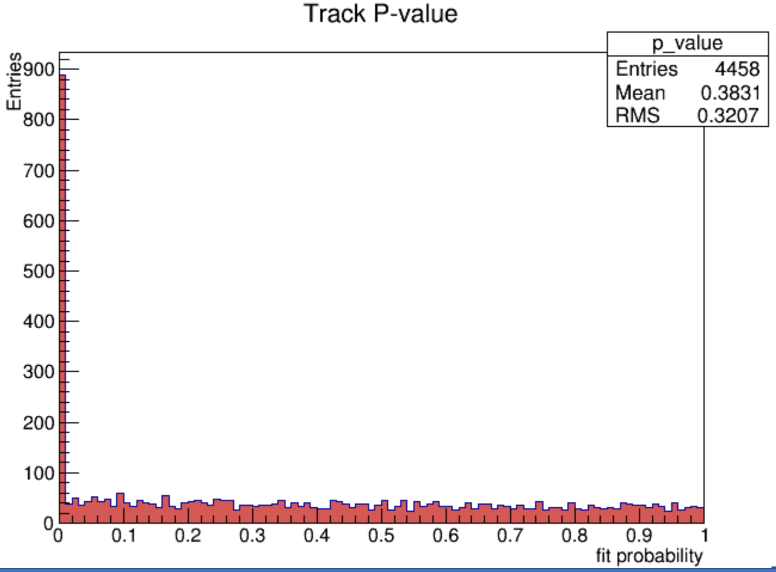
❑ Hierarchical alignment (experimental)

- = production of derivatives w.r.t. parameters of composite structures (ladders, layers) and corresponding constraints
- First testing version privately available
- Highly depends on misalignment stuff – it needs matrices for transformation between subcomponents
- Numbering scheme? Currently structures identified by string, but for Millepede, we need 1:1 map between this string and its integer label (for each parameter)

Ongoing development | GBL fit for VXD + CDC

- ❑ First attempt to add CDC to GBL trajectory
  - Extended MCFitting.py (uses TrueHits)
  - Seg. Fault in standard MCFitting.py for TrueHits & RootOutput | clusters OK
    - No comparison to GENFIT
  - CDC measurement with highest weight taken; *thin* scatterers used
- ❑ Problems with hit sorting in long tracks (over 100 hits)
  - I cut the track before the point extrapolation steps back
- ❑ Alignment / calibration for CDC ?
  - „Just“ add derivatives and their labels





Ongoing development | Issues

❑ Issue: Bias in GENFIT numerical Jacobians in magnetic field → destroys Chi2 invariance and influences parameter propagation in GBL

- Tobias recently updated Jacobian stuff, not yet fully tested by me if this issue is gone

❑ Issue: Package dependency

- GBLfit allows telescopes only after uncommenting some stuff and changing SConscript file
- Scons ignores undefined blocks in dependency check → false missing dependecies
- Add compilation switch for TB? Can it be automatic? E.g. TB package presence would switch telescopes on itself?
- What about Display module? Dependency to TB in library, not the module

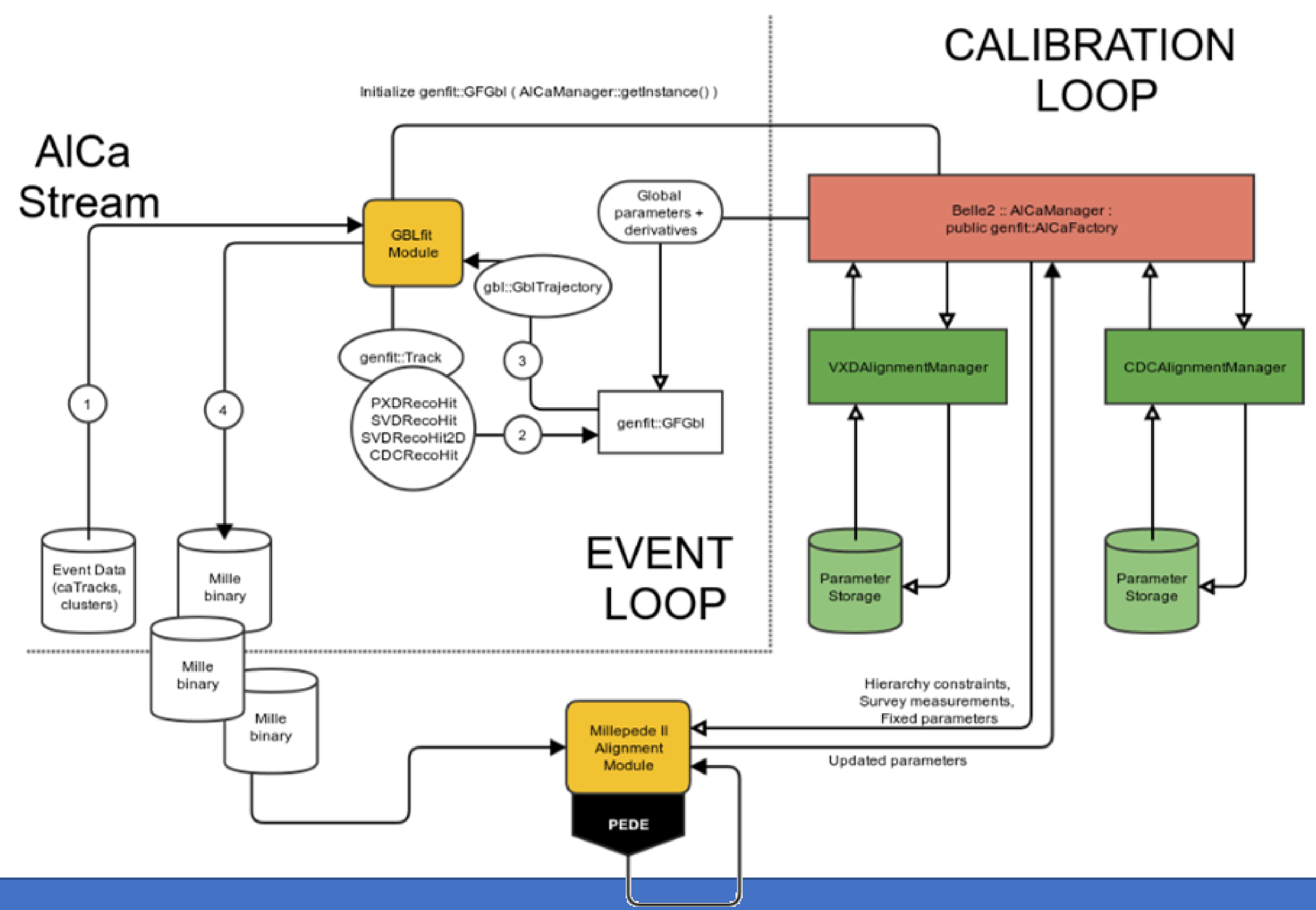
❑ Interfaces

- Labels and derivatives are highly experiment dependent … common interface between GBL in genfit and derivatives computation and labeling
- One interface class or extend all RecoHits??

Implementation issues | Interfaces: Option 1

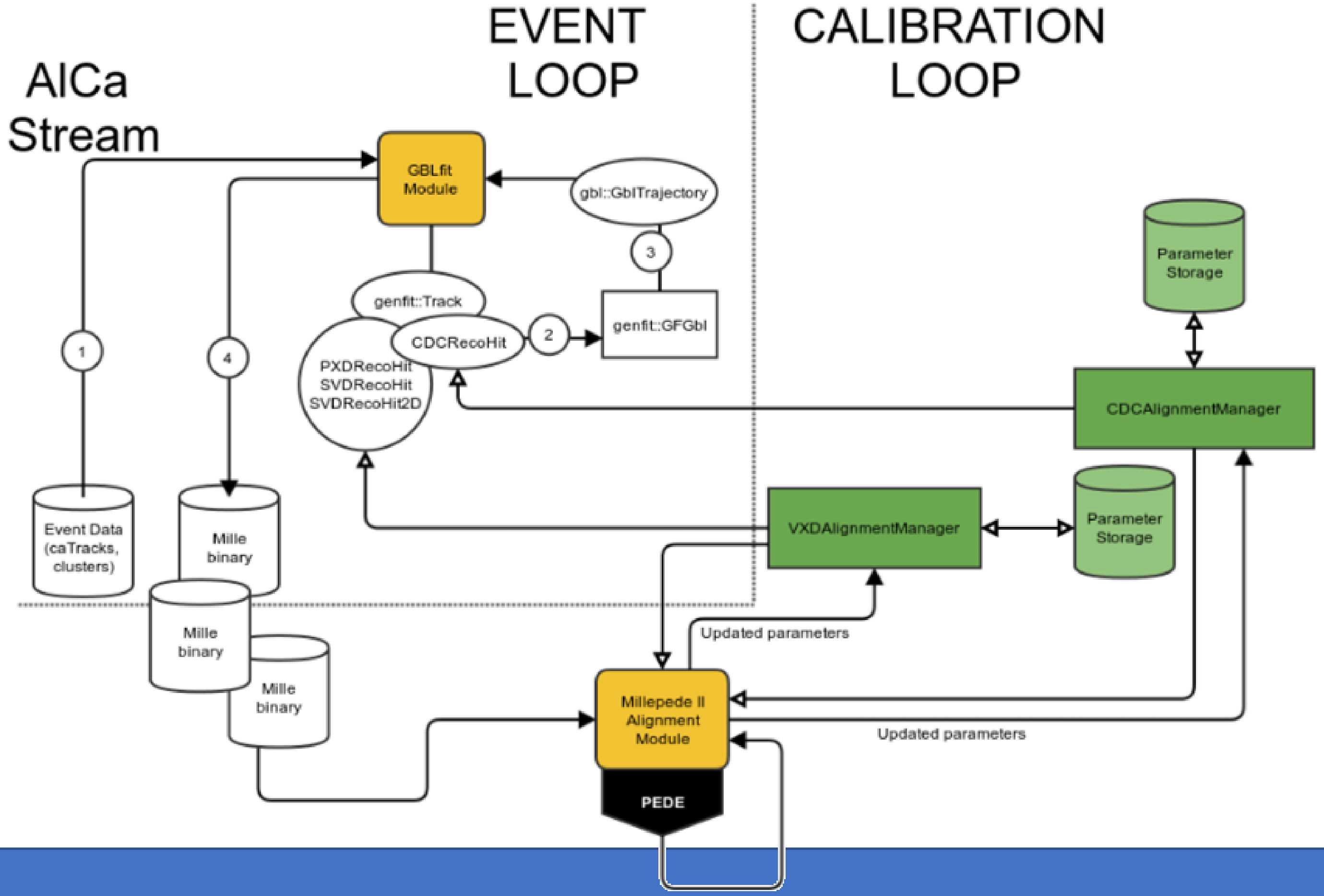
❑ All in one: Interface between GENFIT and derivatives through single class

- Only GBL part of GENFIT affected
- Construct GFGbl with pointer to AlCaManager


CALIBRATION LOOP
Initialize genfit::GFGbl (AlCaManager::getInstance())
AlCa Stream
GBLfit Module
Global parameters + derivatives
Belle2 :: AlCaManager : public genfit::AlCaFactory
gbl::GblTrajectory
genfit::Track
3
VXDAlignmentManager
CDCAlignmentManager
1
4
PXDRecoHit SVDRecoHit SVDRecoHit2D CDCRecoHit
2
genfit::GFGbl
Event Data (caTracks, clusters)
Mille binary
EVENT LOOP
Parameter Storage
Parameter Storage
Mille binary
Mille binary
Hierarchy constraints, Survey measurements, Fixed parameters
Millepede II Alignment Module
Updated parameters
PEDE

Implementation issues | Interfaces: Option 2

- ❑ Extending RecoHits: Each RecoHit has to provide derivatives for itself
  - Makes whole GENFIT alignment – friendly
  - 2 possible solutions:
    - XXXRecoHit: public *AbsMeasurementWithDerivatives* | *AbsMeasurementWithDerivatives* : public AbsMeasurement
    - XXXRecoHit: public AbsMeasurement, public *IAlignmentDerivatives* (interface only) … multiple inheritance (!?)



Implementation issues | GBL integration into GENFIT

❑ Current status

- GBL inside GENFIT
- GFGbl (AbsFitter) takes genfit::Track, propagates it to account for material and creates gbl::Trajectory
- Output to Mille Binary hidden in GFGbl
- GBLfit module: starts from genfit::TrackCand, but also possible to start from genfit::Track with reference state (previously fitted by KalmanRefTrack)

❑ Not neccessary to fit GBL trajectory for alignment

- GBL used to construct linear equation system
- Millepede performs last (in fact only) iteration of trajectory fit itself

❑ Full GBL integration ?

- Non – measurement points … ThinScatterer should only have variance + plane (position on arc-length)
- GblFitterInfo ? Or re-use Kalman stuff?
- How to attach constructed trajectory to the track (GblFitStatus ?)
- Iterations? Re-propagation of track or only update the states (→derivatives) ?

Conclusion

- □ Working example with Belle II VXD alignment in release
  - More studies needed, but the procedure works
- □ Working example for TB
  - Fully working in MC
  - Real data processing requires to take care of masking, track candidates…
  - Attempt to add telescopes without VXDTF using cluster combiner from Peter Kodys → additional studies needed
- □ Additional interface for global derivatives and labels needed
  - Especially because of hierarchical alignment (for each hit needs to somehow figure out all its parent structures and corresponding transformations)
  - Option with AlCaManager partly implemented including hierarchical alignment
- □ CDC experimentally added to GBL trajectory
  - I am still not sure about some details in CDC, but fitting performs „well“
- □ Testbeam package dependency
  - Not possible to make just a clone of Display module for testbeam (dataobjects added in a library, not in the module)

Thank you for your attention!

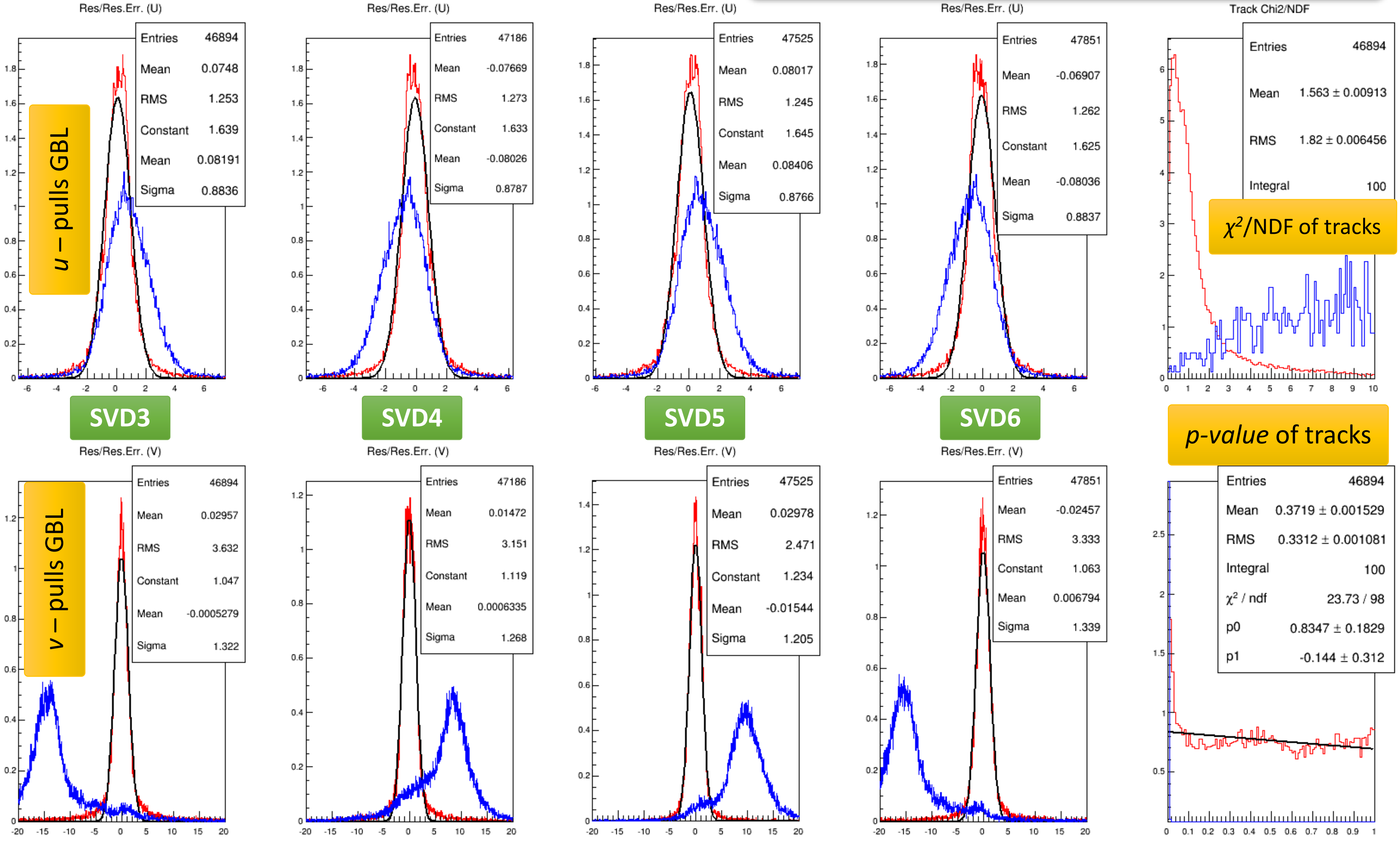
TB alignment. Pulls

RUN 507 | Full tracks with 4 x 2 x 1D measurements

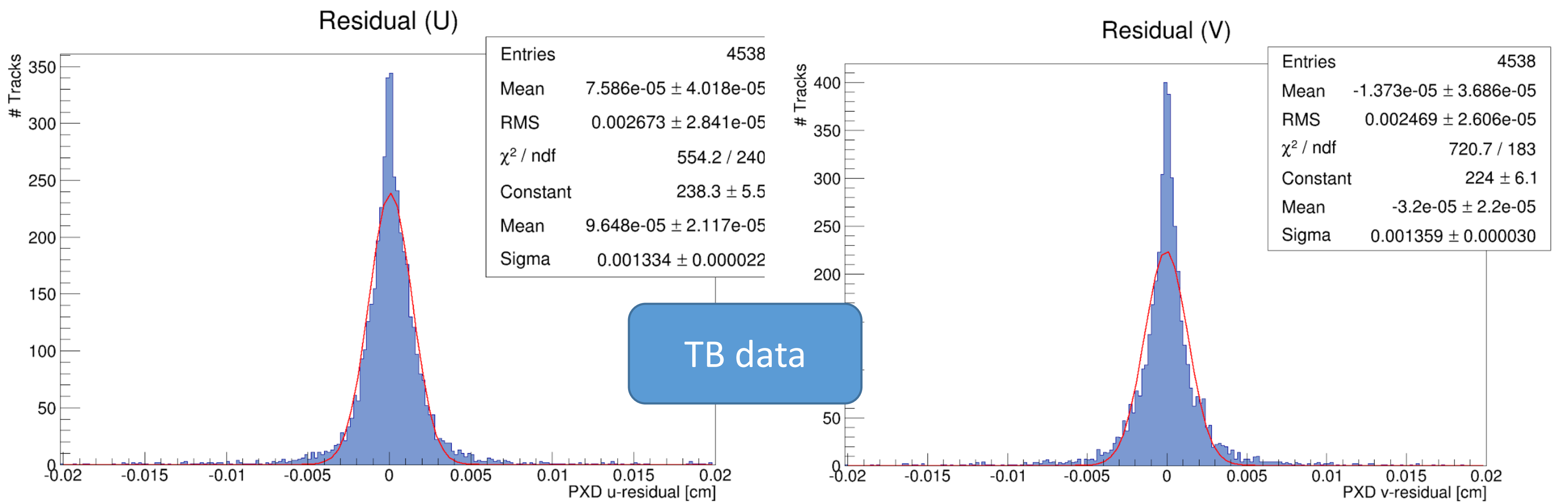
B=**1T** E=**4GeV**

Combined alignment data: **500**(4GeV)+**507**+**508**(5GeV)
SVD3 fixed, SVD6 fixed shifts. SVD5 fixed v.
Shifts and in-plane rotations only.

❑ **Before** and **after** Millepede alignment



PXD residuals in *B* = 0T after alignment



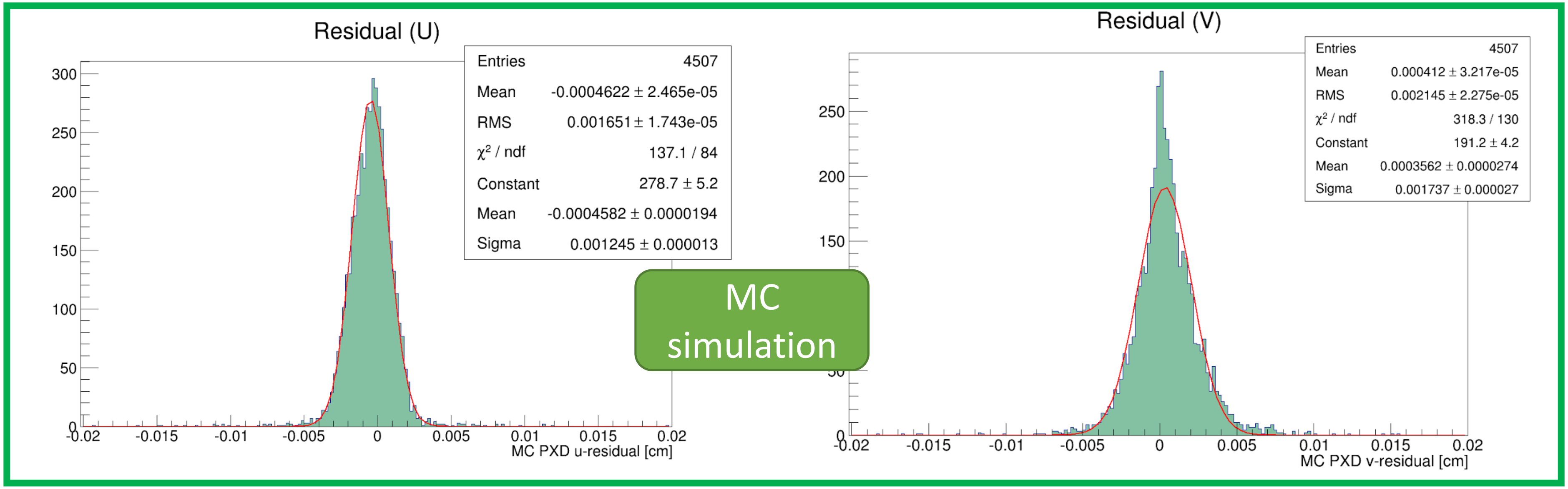
Residual (U)

Entries	4538
Mean	7.586e-05 ± 4.018e-05
RMS	0.002673 ± 2.841e-05
χ^2 / ndf	554.2 / 240
Constant	238.3 ± 5.5
Mean	9.648e-05 ± 2.117e-05
Sigma	0.001334 ± 0.000022

Residual (V)

Entries	4538
Mean	-1.373e-05 ± 3.686e-05
RMS	0.002469 ± 2.606e-05
χ^2 / ndf	720.7 / 183
Constant	224 ± 6.1
Mean	-3.2e-05 ± 2.2e-05
Sigma	0.001359 ± 0.000030

TB data



Residual (U)

Entries	4507
Mean	-0.0004622 ± 2.465e-05
RMS	0.001651 ± 1.743e-05
χ^2 / ndf	137.1 / 84
Constant	278.7 ± 5.2
Mean	-0.0004582 ± 0.0000194
Sigma	0.001245 ± 0.000013

Residual (V)

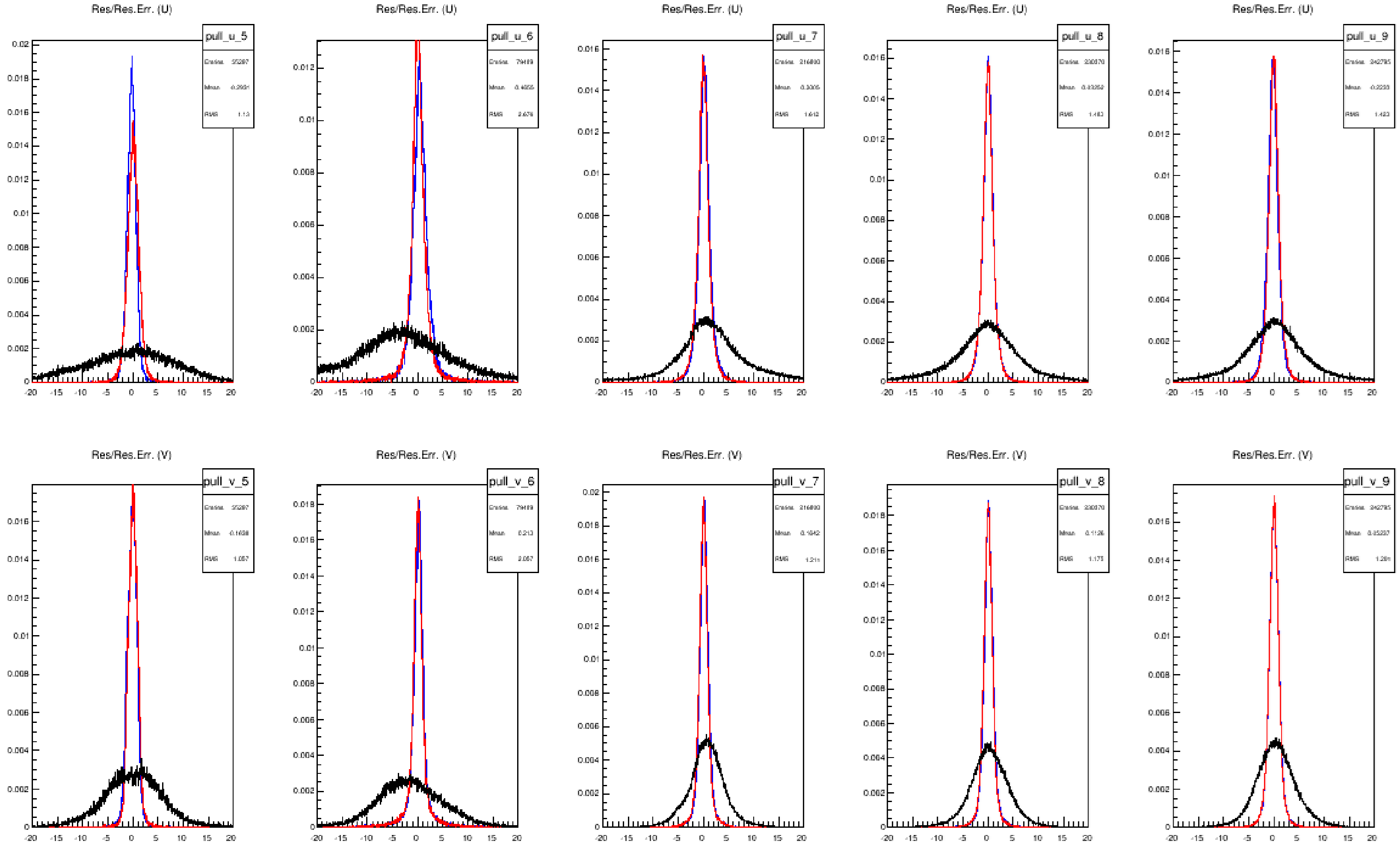
Entries	4507
Mean	0.000412 ± 3.217e-05
RMS	0.002145 ± 2.275e-05
χ^2 / ndf	318.3 / 130
Constant	191.2 ± 4.2
Mean	0.0003562 ± 0.0000274
Sigma	0.001737 ± 0.000027

MC simulation

Backup: Belle 2 VXD alignment

- ❑ Pulls per layer. Plots for B=0T

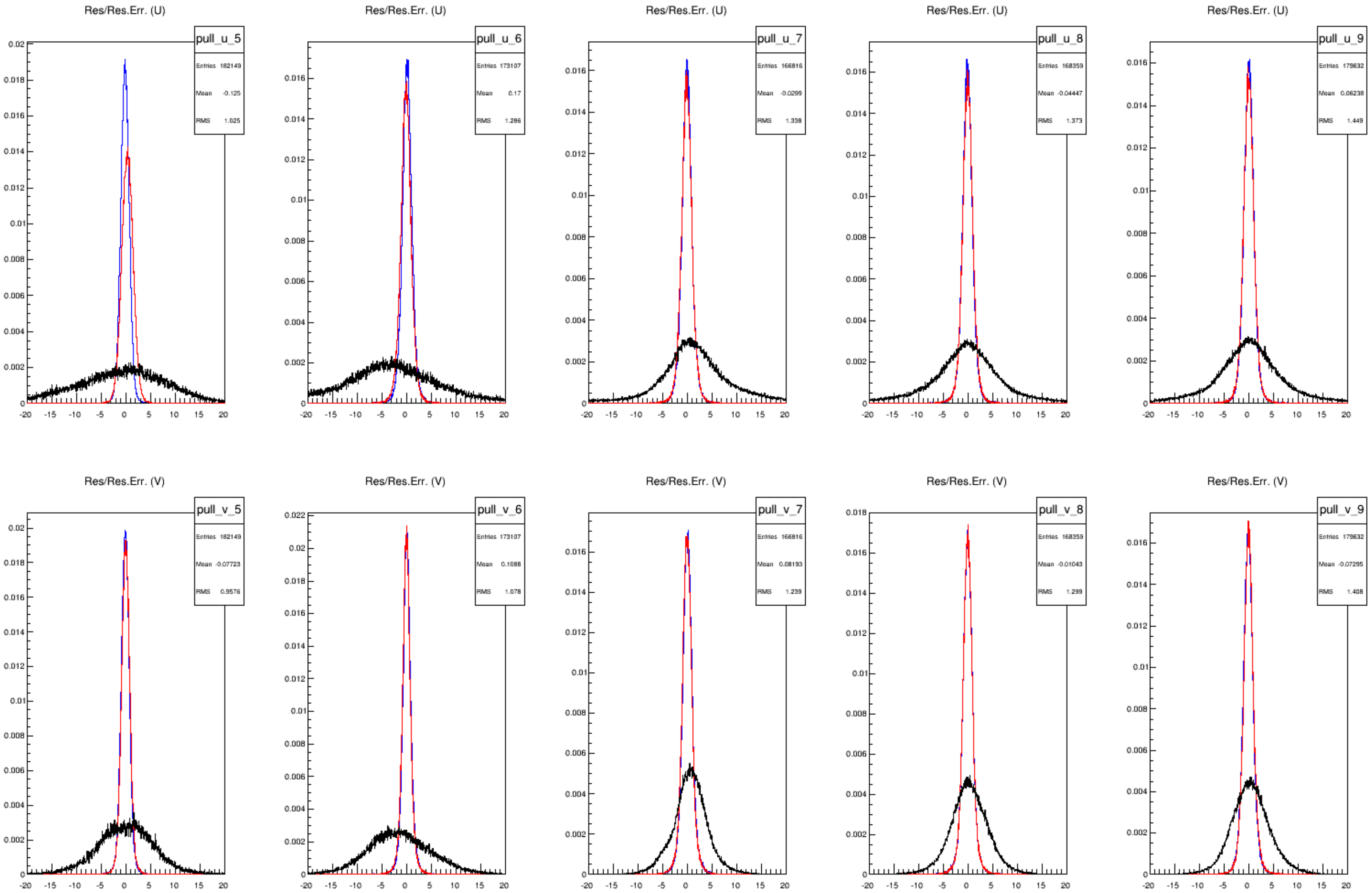
Ideal geometry | misaligned | after alignment



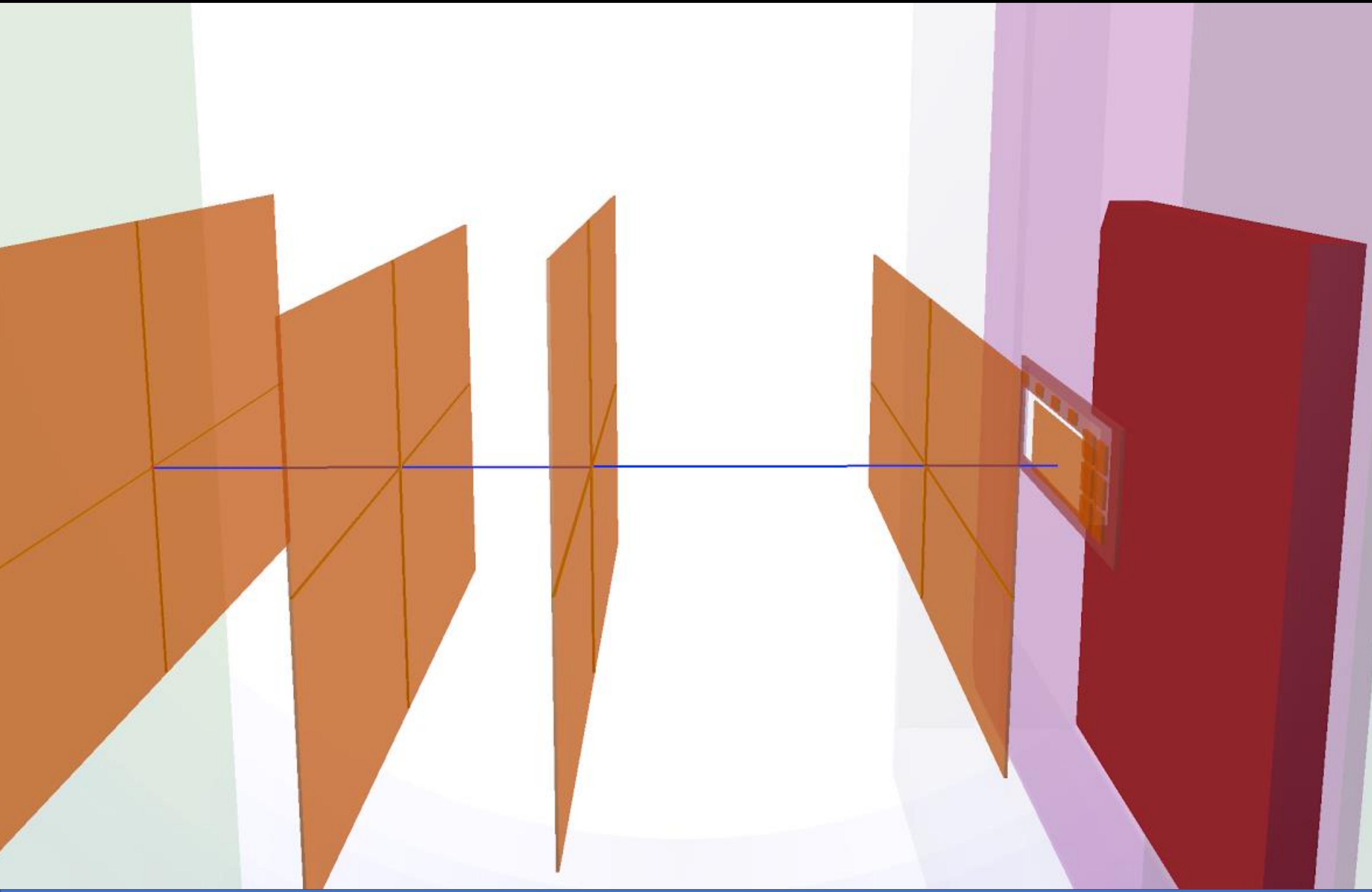
Backup: Belle 2 VXD alignment

- ❑ Pulls per layer. Plots for B=1.5T

Ideal geometry | misaligned | after alignment



Reconstructed VXD track in B = 0T

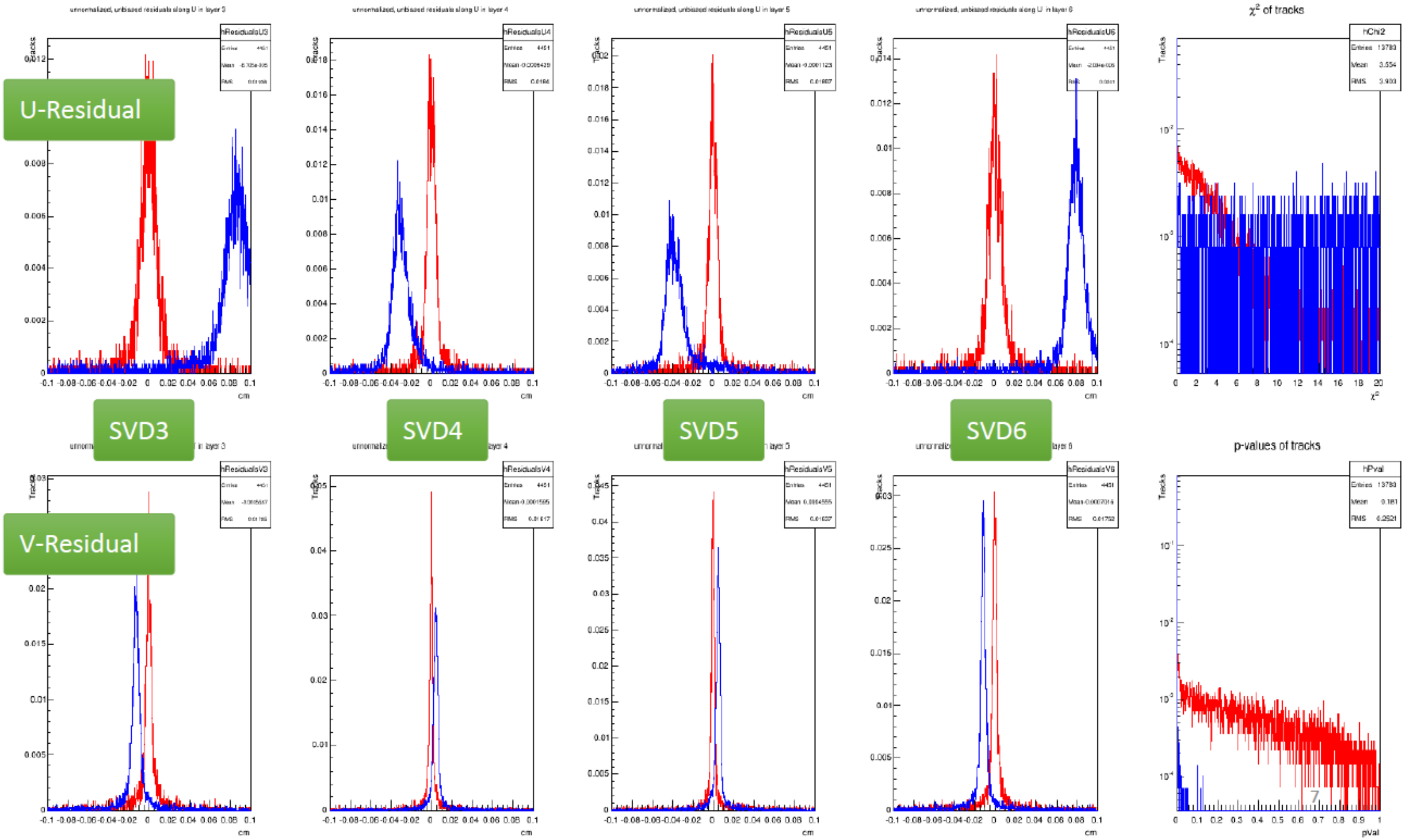


TB alignment in *B* = 0T

RUN 104
B=0T E=5GeV
Alignment data: 104

DESY TB Results PRELIMINARY

Before and after



U-Residual

V-Residual

SVD3

SVD4

SVD5

SVD6