Alignment & Vertexing

Advanced Trajectories in Alignment & Calibration

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Motivation

- Global distortions of VXD in alignment
  - Opposite phases in half-shelves
- Phi asymmetry of cosmic rays

Vertex – Constrained Decays in basf2

- Any vertex-constrained decay (also with IP profile) can be used in alignment

- GBL/Millepede will keep the tracks coming from single point (within IP profile) in the global fit

- Multi – body decays supported

- Global alignment with broken trajectory – vertex, measurements, kinks in all tracks in decays, all decays + other broken trajectories + all alignment and calibration parameters → all fitted simulatenously
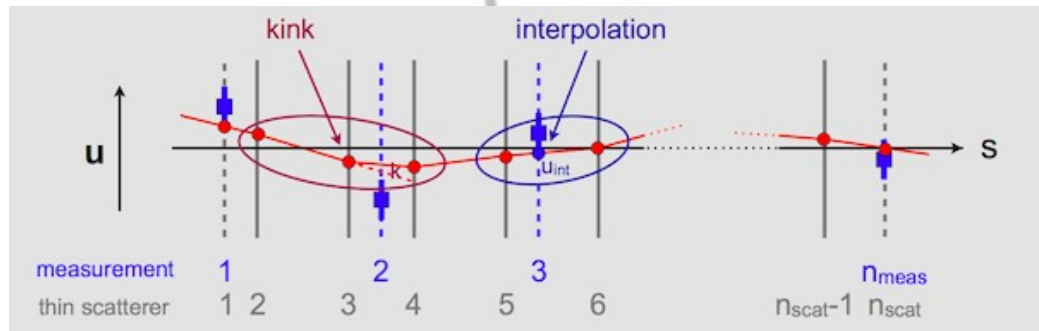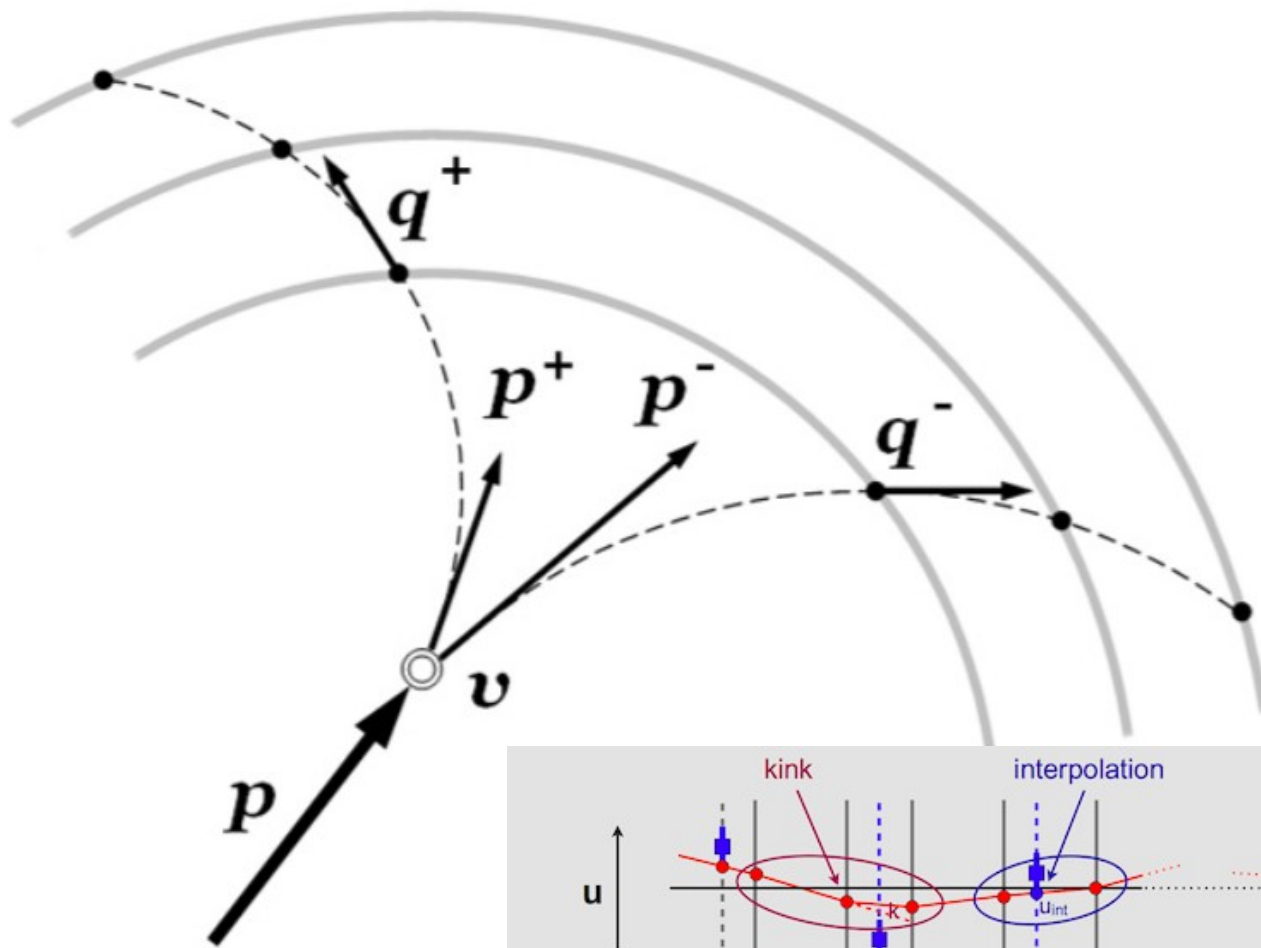
$$\chi^2\left(\Delta\mathbf{p},\Delta\mathbf{q}\right)=\sum_{j}^{\text{tracks}}\sum_{i}^{\text{hits}}\frac{1}{\sigma_{ij}^2}\left(\mathbf{m}_{ij}-\mathbf{f}_{ij}\left(\mathbf{p}_0,\mathbf{q}_{j0}\right)-\frac{\partial\mathbf{f}_{ij}}{\partial\mathbf{p}}\Delta\mathbf{p}-\frac{\partial\mathbf{f}_{ij}}{\partial\mathbf{q}_j}\Delta\mathbf{q}_j\right)^2$$

4

Combined GBL Trajectories

- Global GBL fit of multiple trajectories

- Define common set of parameters (vx,vy,vz)

- Changes propagated via d(q/p,u',v',u,v)/d(x,y,z) to local systems at first point of each daughter

  - Code for trafo taken from RKTrackRep

- Exact constraint (no Lagrange multipliers)

- Possibility of external measurement at the common system

Workflow 1/2

- Standard MC reconstruction
  - Weights in CDC
- Decay reconstruction (Rave)
  - With daughters update
  - Vertex or vertex + IP profile constraint
- Update daughters' TrackCands
  - Seed from vertex fit (+ remove CDC, BKLM)
  - Update of CDC weights?

Workflow 2/2

- Add vertex measurement at seed

  - Construct vertex virtual plane (local system – common to all daughters) with full measurement

  - „Cov < 0", does not contribute to Chi2

  - Material between vertex and 1st measurement as thick scatterer (beam pipe)

- Extrapolate seed and prepare GBL points

- Collect GBL points from all daughters (+ transformation at vertex)

- Add external IP profile measurement (optional)

- Construct, fit and write out combined trajectory

Impact of e+e-→mu+mu-

- KKGenInput generator
- BeamParameters(Y(4S)) → IP profile
- 2 other samples
  - Cosmic rays
  - Upsilon(4S) → … → fitted charged tracks
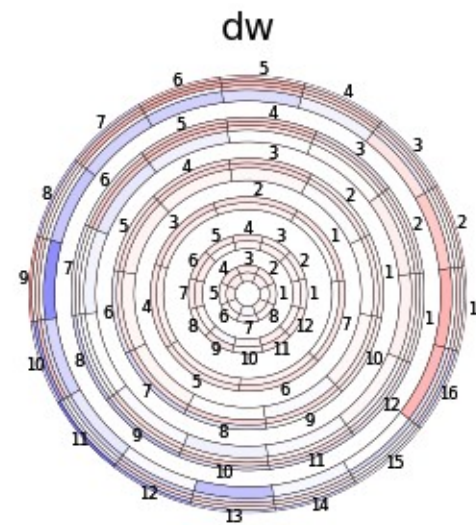
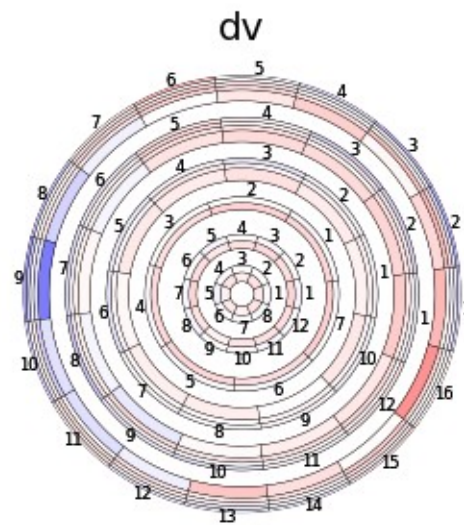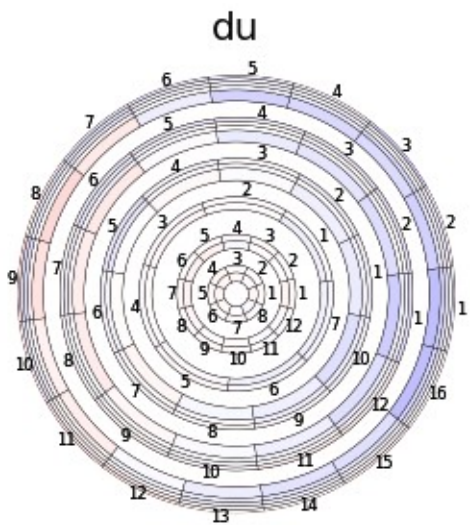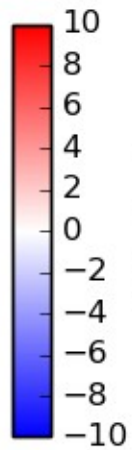# Upsilon + Cosmics (TrueHits + constraints), almost 1 + 1 M tracks
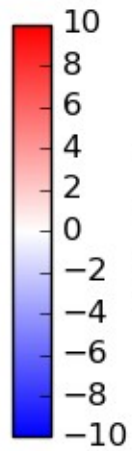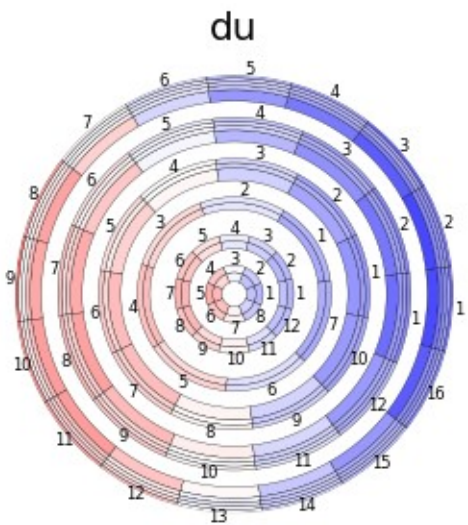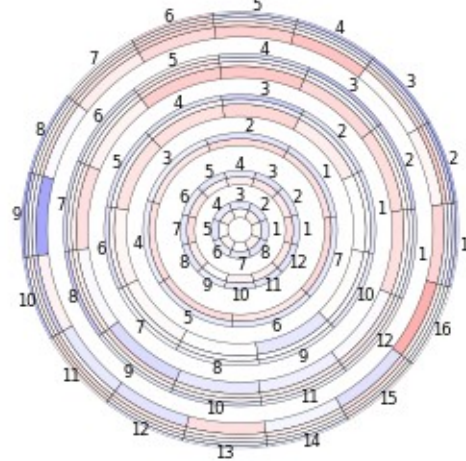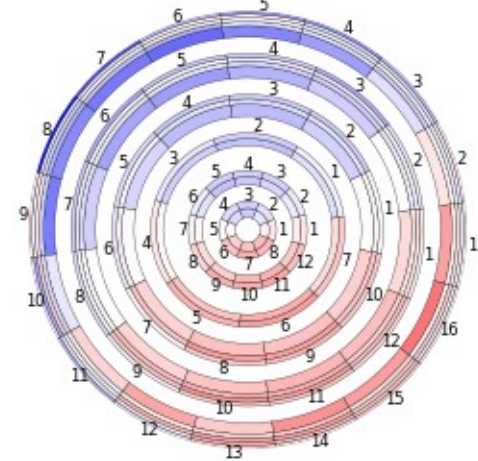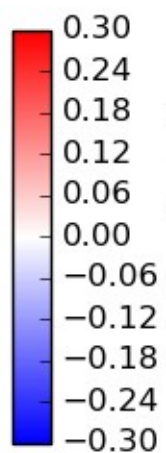
9
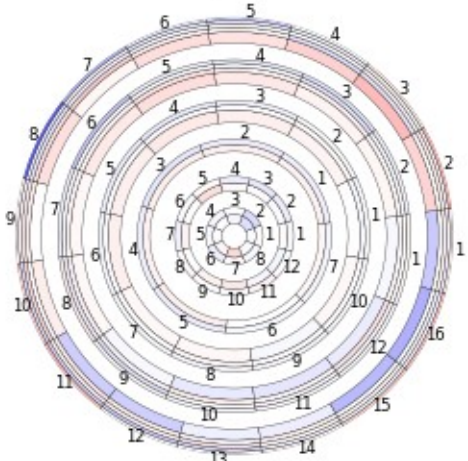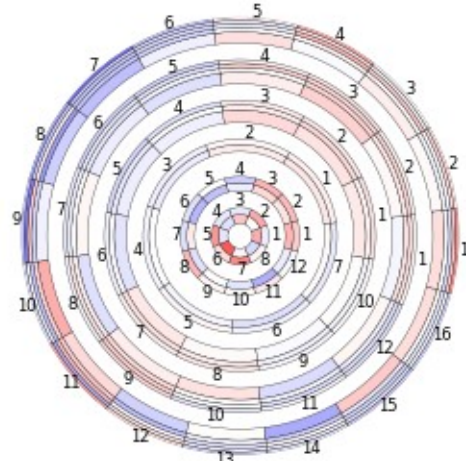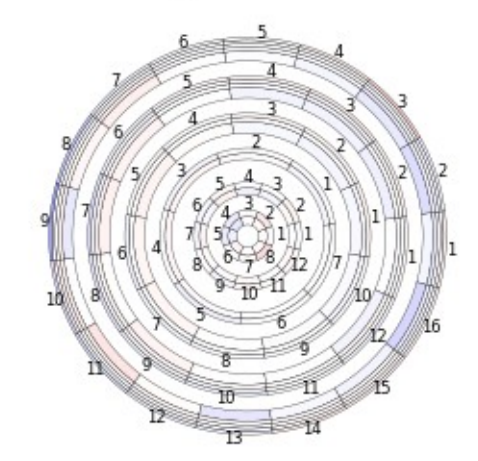
Upsilon + Cosmics (TrueHits + constraints), almost 1 + 1 M tracks
+ 50k e+e- → mu+mu-
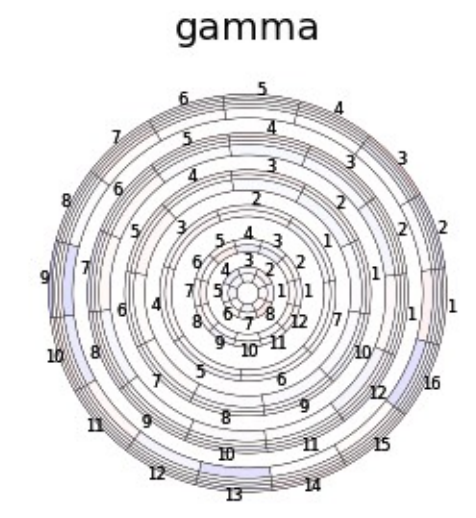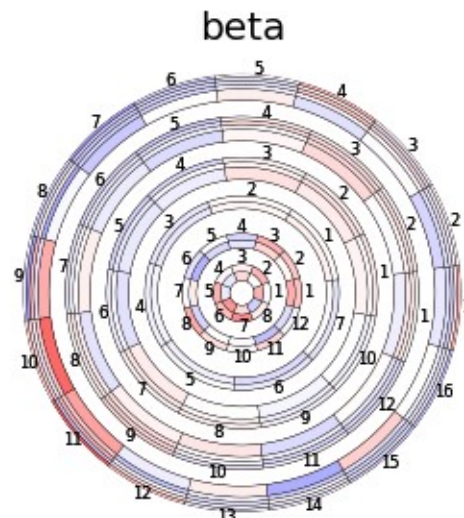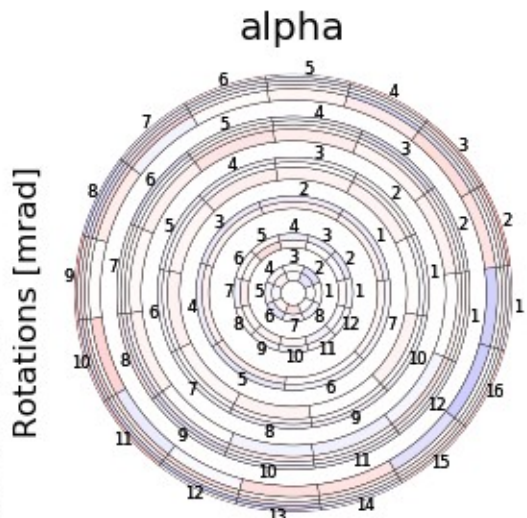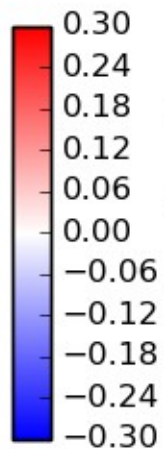
Upsilon + Cosmics (TrueHits + constraints), almost 1 + 1 M tracks
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Scale zoom
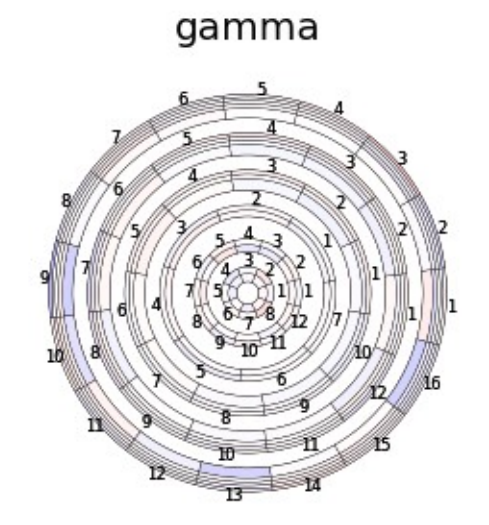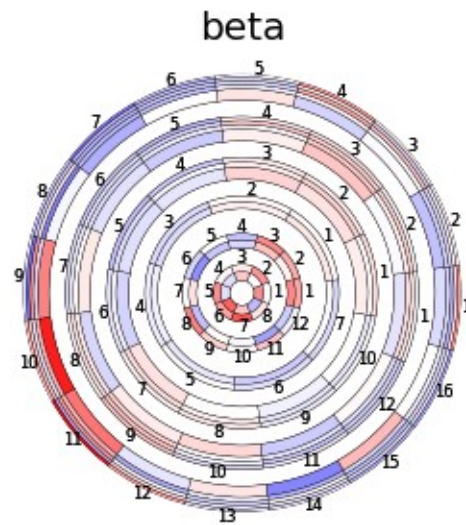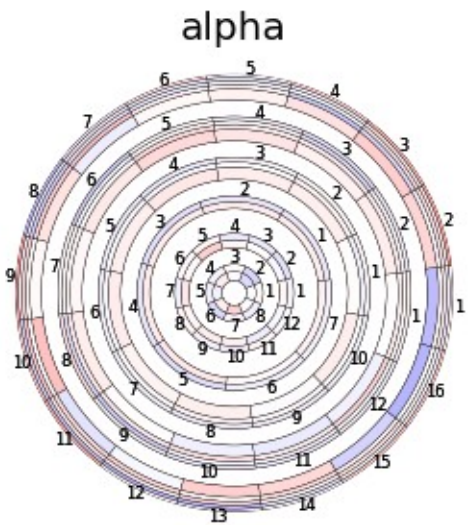
Kinematic Constraints

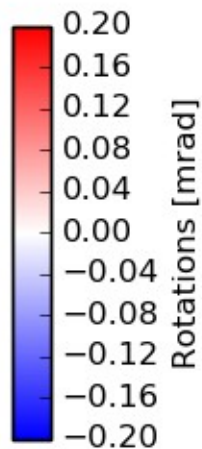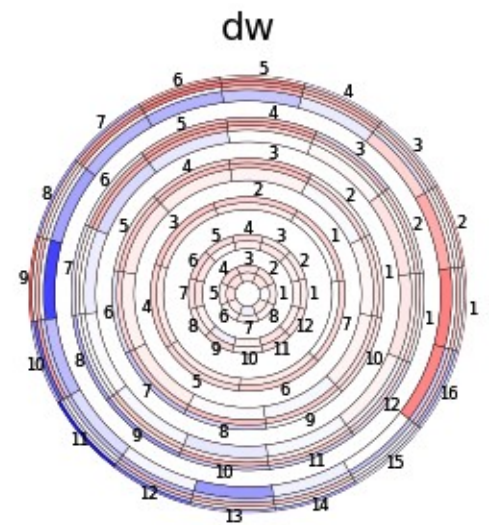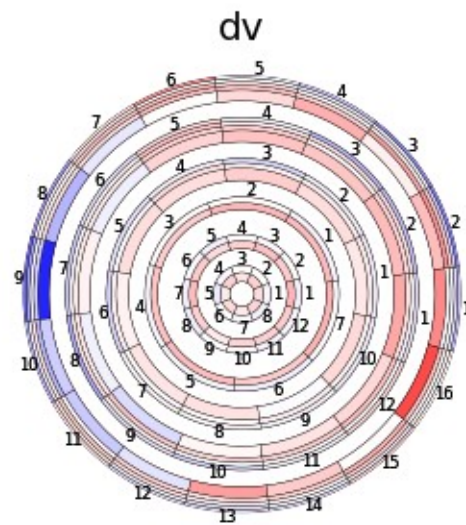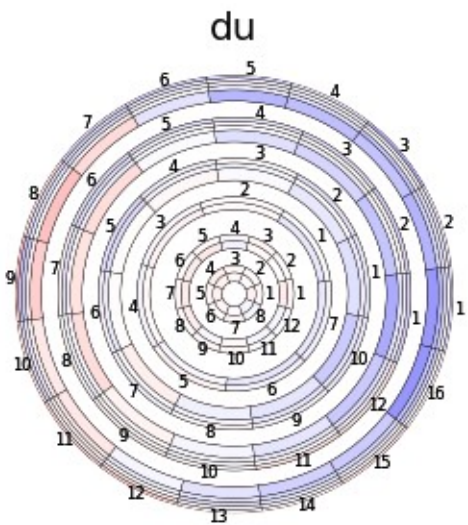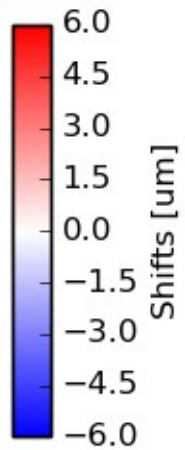- All logic/workflow same, just different transformation matrix
    - Only 2-body decays
    - Most work to write the matrix (derivative of decay model)
- Possible external (virtual) measurements (constraints):
    - Full beam kinematics or beam invariant mass (BeamParameters) → calibration?
    - Mother invariant mass
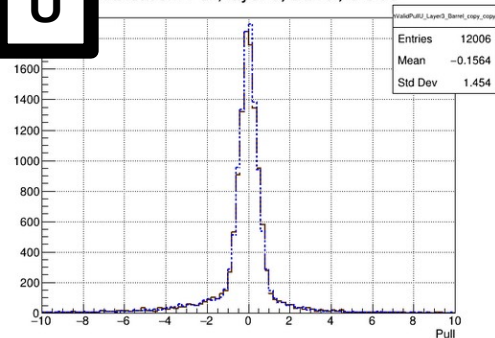- Expected to be more usefull with CDC in tracks – momentum resolution

Limitations

- Standard reconstruction does not (yet) see misalignment/alignment

- Update of Tracks after combined trajectory fit

  – Also no external iterations

  – Would be nice for diagnostics

- Clusters should be used

  – Can use TrueHits, but has to switch standard MC reconstruction to truehits too

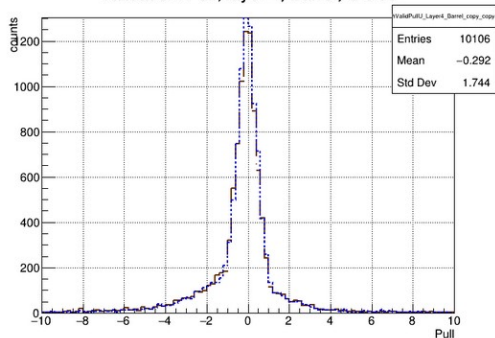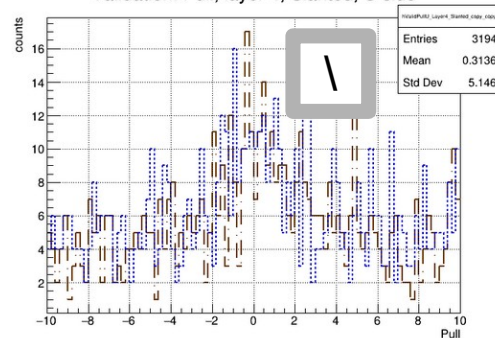 – Clusters have issues: just see validation plots...
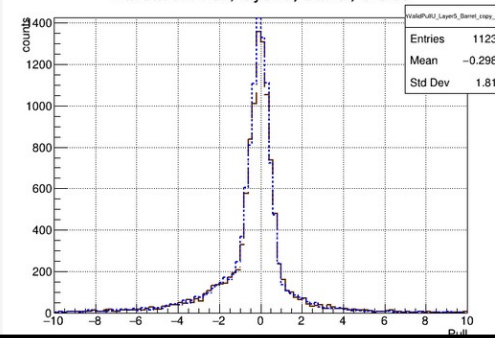
U

Validation: Pull, layer 3, Barrel, U side
Entries 12006
Mean -0.1564
Std Dev 1.454

Validation: Pull, layer 4, Barrel, U side
Entries 10106
Mean -0.292
Std Dev 1.744

Validation: Pull, layer 4, Slanted, U side
Entries 3194
Mean 0.3136
Std Dev 5.146

Validation: Pull, layer 5, Barrel, U side
Entries 11239
Mean -0.2988
Std Dev 1.819

Validation: Pull, layer 5, Slanted, U side
Entries 1854
Mean -0.5272
Std Dev 5.201

Validation: Pull, layer 6, Barrel, U side
Entries 12230
Mean -0.278
Std Dev 1.724

Validation: Pull, layer 6, Slanted, U side
Entries 1594
Mean -0.006339
Std Dev 4.745
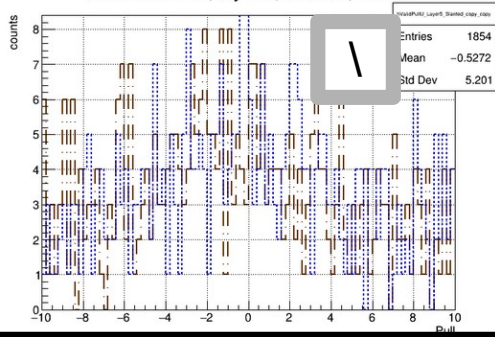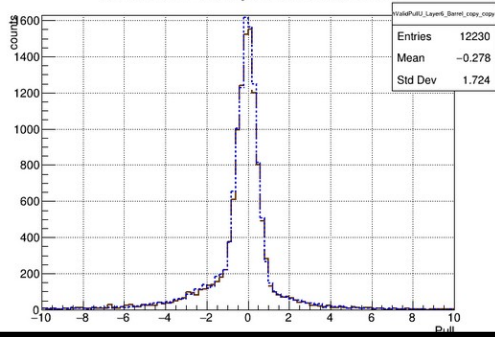
Validation: Pull, layer 3, Barrel, V side
Entries 11884
Mean -0.4697
Std Dev 1.661
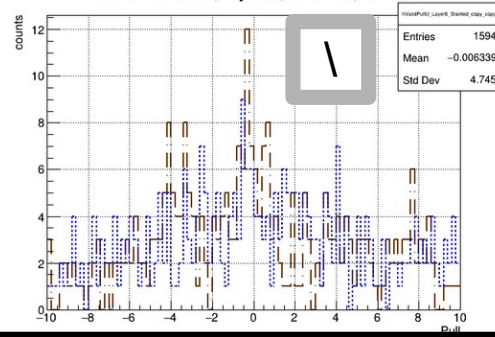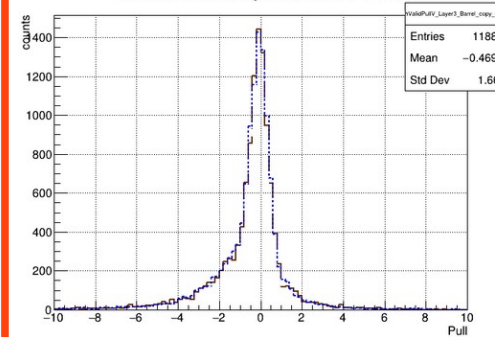
V

Validation: Pull, layer 4, Barrel, V side
Entries 10011
Mean -0.901
Std Dev 1.864
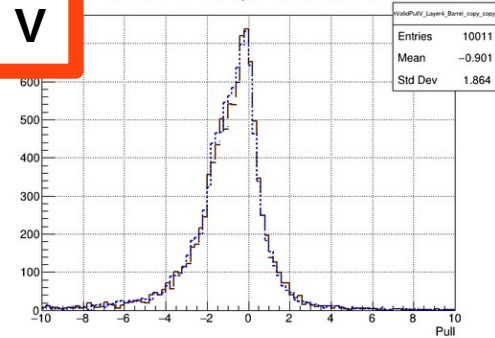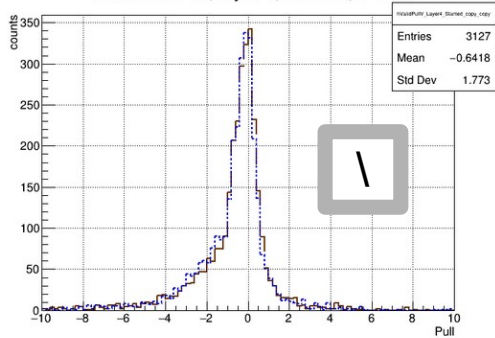
Validation: Pull, layer 4, Slanted, V side
Entries 3127
Mean -0.6418
Std Dev 1.773

Validation: Pull, layer 5, Barrel, V side
Entries 11084
Mean -0.8384
Std Dev 1.887

Validation: Pull, layer 5, Slanted, V side
Entries 1791
Mean -0.6425
Std Dev 1.817
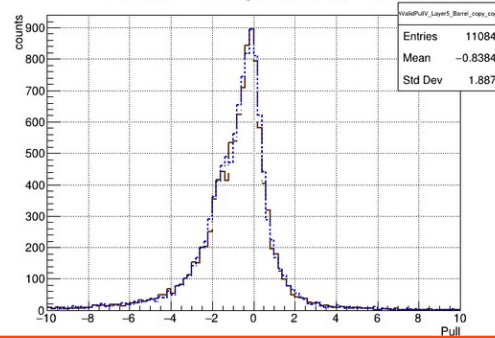
Validation: Pull, layer 6, Barrel, V side
Entries 12095
Mean -0.8386
Std Dev 1.846
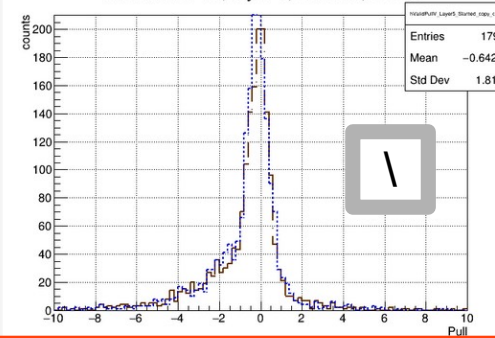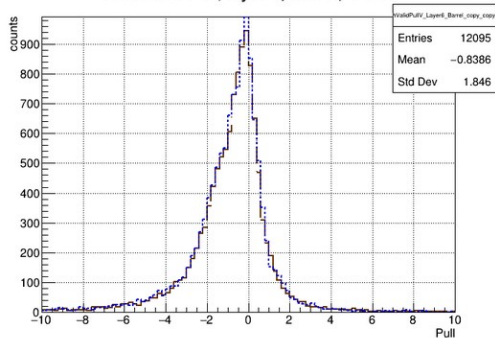
Validation: Pull, layer 6, Slanted, V side
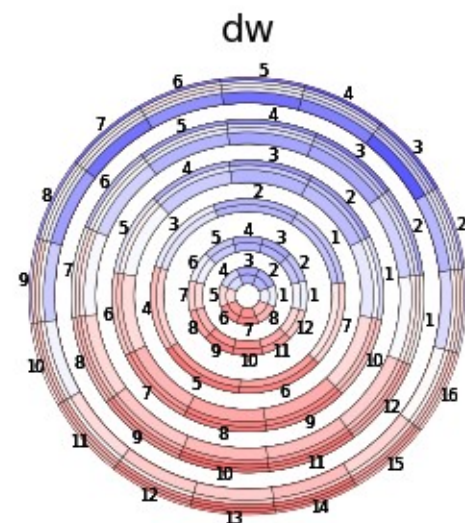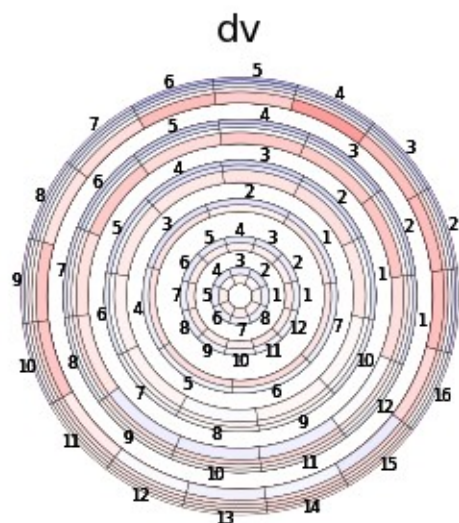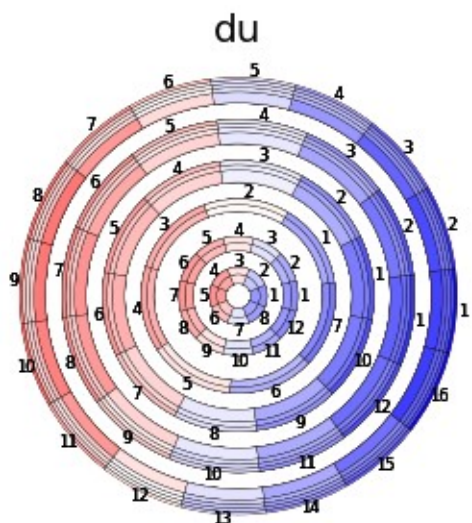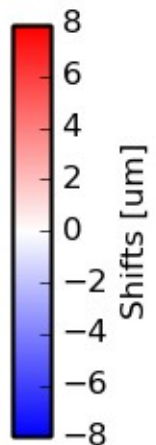Entries 1561
Mean -0.6502
Std Dev 1.799
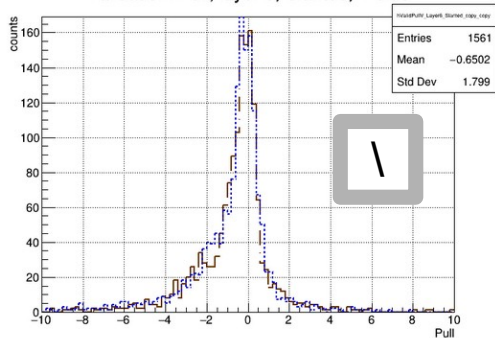
- On V side, the bias reaches -0.9 sigma on layer 4.
- All biases have the same sign
- Alignment will „fix" this by shifting the sensors!

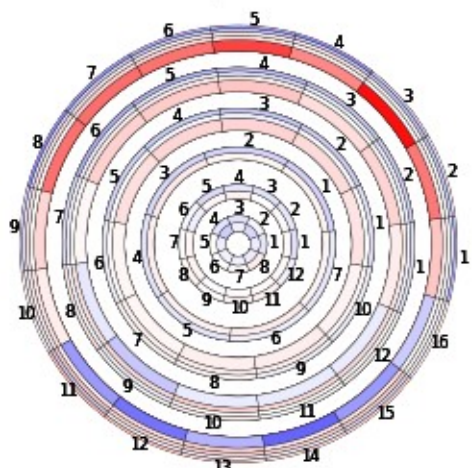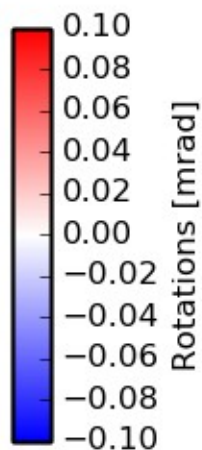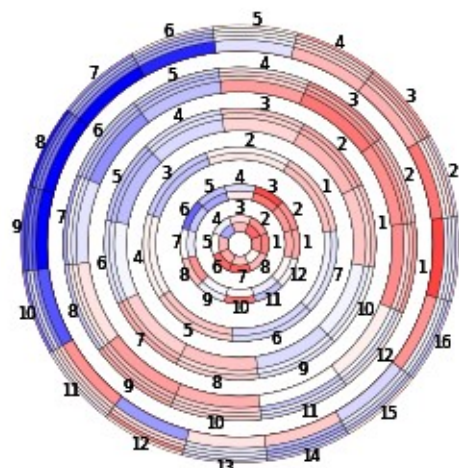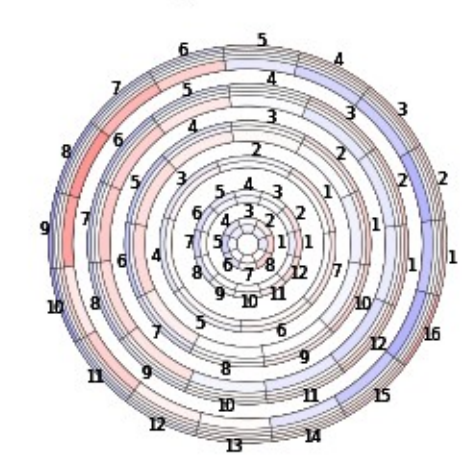TrueHits (Cosmic rays + Particle Gun; with constraints)

Clusters (Cosmic rays + Particle Gun; with constraints)
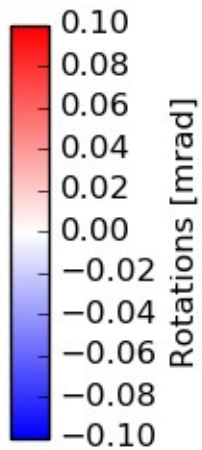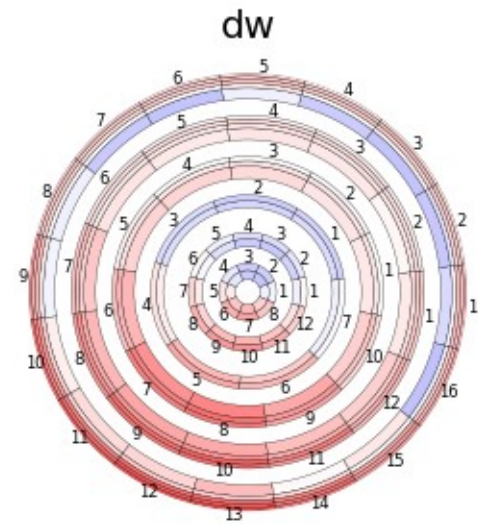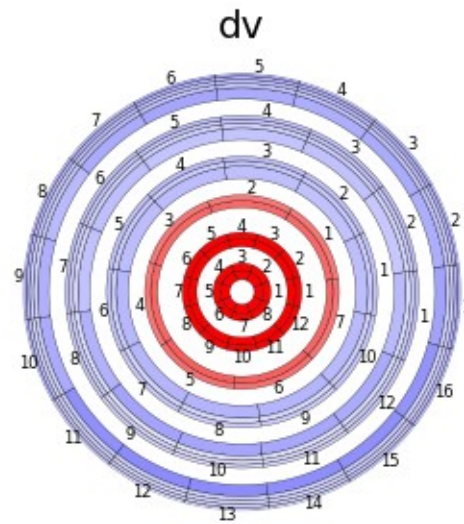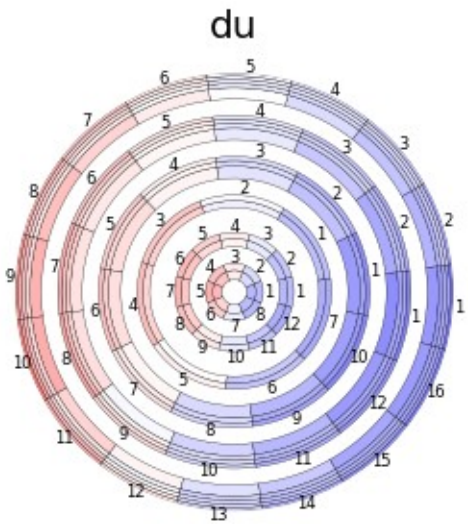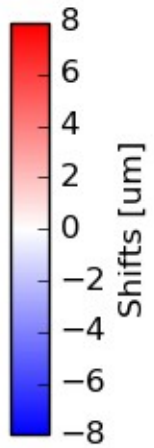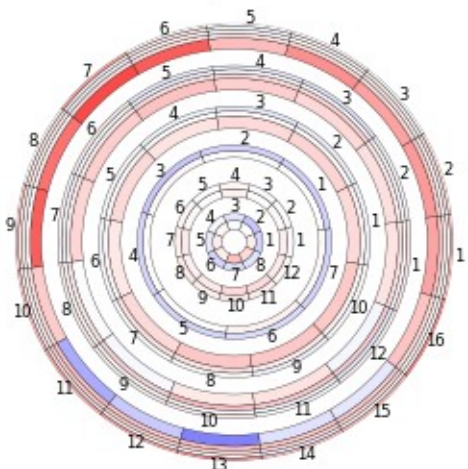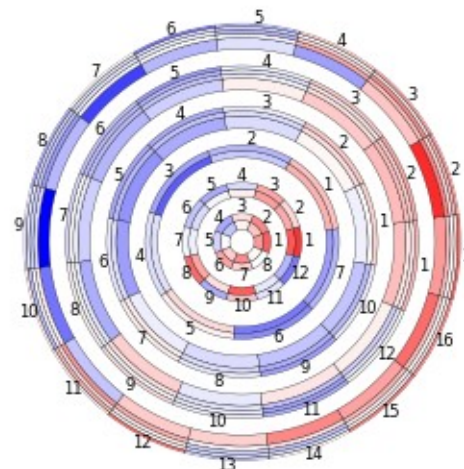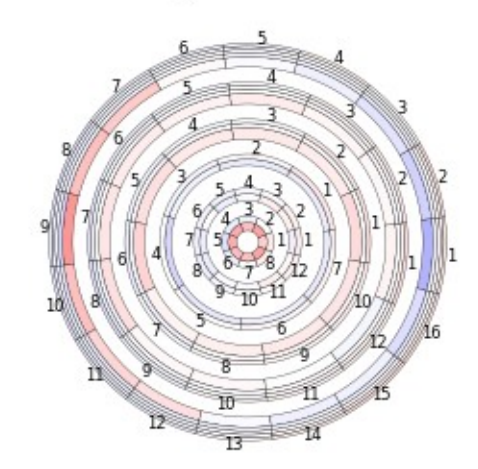
Issues in Hit Reconstruction

- We are very sensitive in alignment

- Issues in hit reconstruction directly propagated to alignment

- Examples

  - SVD – clusters

  - CDC – bias in drift velocity/time

  - BKLM – hits reconstructed in wrong plane

- We should do a detailed review of residual distributions per each measurement element (sensor, module...)

  - Any significant bias has to be removed to do reasonable alignment

- A long term task, but we are already doing testbeams and thus combining our reconstruction algorithm biases with corrections (calibrations) to real data

Some Notes

- Clusters are a disaster for alignment :(
  - I will switch all alignment to truehits until this is solved (Testbeam!!!)
- Vertex covariance is non-diagonal
  - GBL wants diagonalized precisions
  - Attempt to diagonalize and hide the transformation (eigenvector matrix) into external measurement derivative (otherwise unity)
  - Unsure if I did it right, but now it produces reasonable results → still experimental
- Decays far from IP seem to have large Chi2 (without IP profile constraint), needs more checks

Input of alignment: Analysis

- Select high quality tracks and reconstruct decays even in presence of misalignment (we are now cheating)

- Could analysis group help to define and trigger/select input samples?

- MillepedeCollector input = ParticleList(s)

  - trajectories ... single tracks

  - vertices, primaryVertices (= + IP profile) … lists of reconstructed mothers – input are daughters' tracks

  - In future: twoBodyDecays, primaryTwoBodyDecays …

  - Still possible to use „raw track candidates" (analysis for cosmics and B=0 ???)

Outlook (Short Time)

- Long lived particles' decays (K short, Lambda)
  - Already under tests (some issue with Chi2)
  - Some computing – cheap way of generation?
  - Should help in outer SVD layers
  - CDC probably useful (additional hits)
- Multi – body decays
  - Not yet tested, but should work out of the box
- Study of impact of different decays

Conclusions

- We have vertex (+ ip profile) constrained decays in alignment

- Opens large landscape of possible alignment inputs

- Expected reduction of systematics shown for mu+mu-

- I want to try as much as possible before we add kinematic constraints (probably needs CDC)