PXD reconstruction

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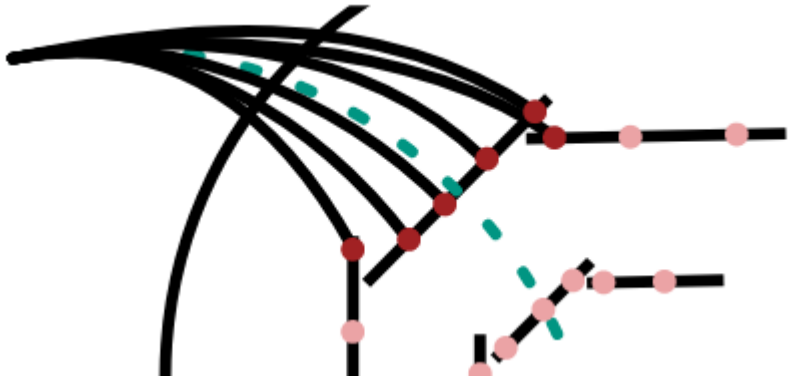
PXD reconstruction

- Focus here: Offline PXD software
  - Reconstruction: Cluster shape and track direction sensitive position estimation.
  - Application of cluster shape reconstruction to Phase 3 background studies
  - Calibration studies: Database objects and results from TB17.

Motivations for looking into PXD hit reconstruction



CKF based track extrapolation into PXD (Nils Braun)

- You have extrapolation of hit position and angles at PXD sensors.

- You can use angle information in two ways:

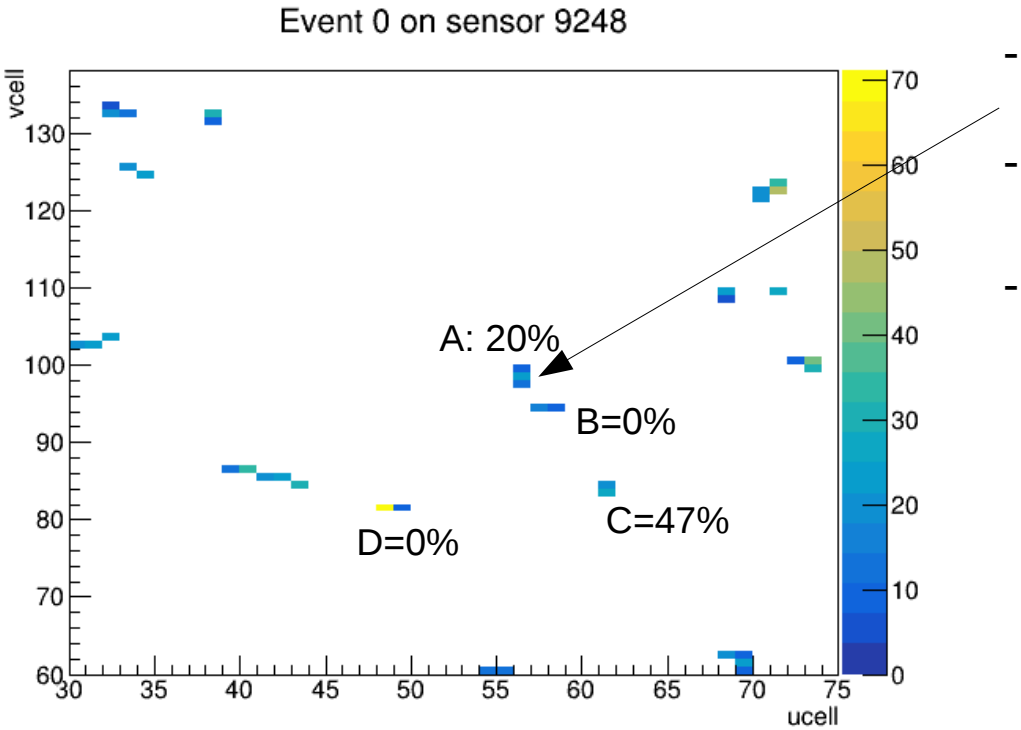
  a) Check if **shape** of close-by cluster is likely to be produced for given incidence angles.

  → Here: quantify what **likely** means

  b) Estimate cluster position and cov. Matrix using extrapolated angles.

  → Continue work started by Prague group

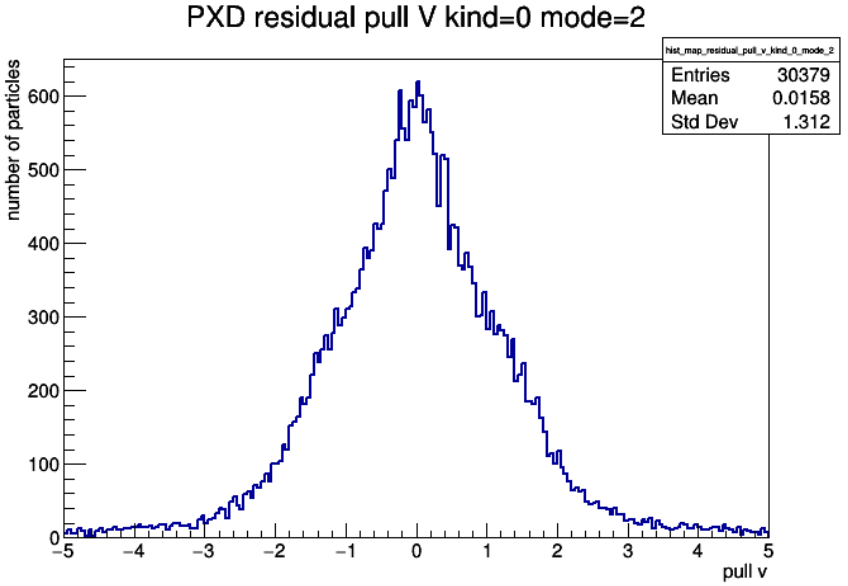
Motivations for looking into PXD hit reconstruction

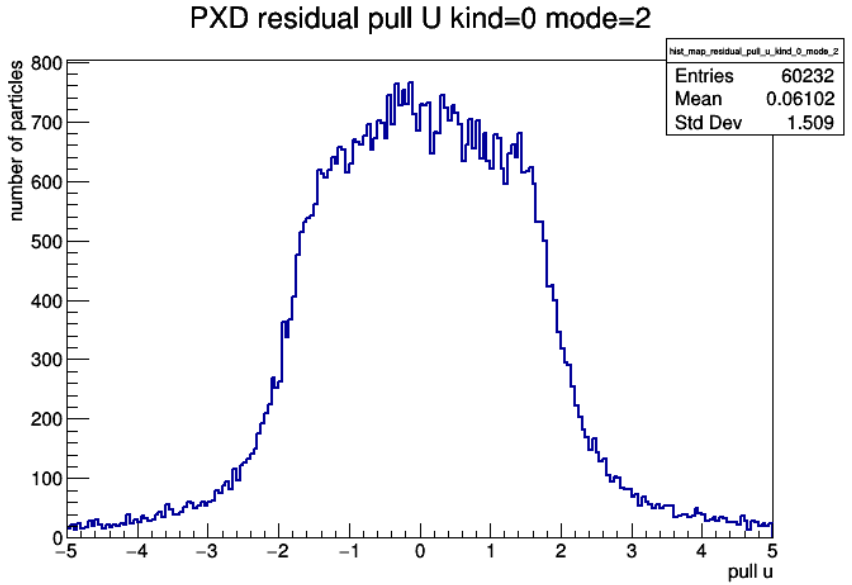


Sim+Rec of generic Bbbar + bgoverlay

- cluster A at ui/vi = 57/98 related to truehit
- true incidence angles Θ_u/Θ_v = -3° / 54°
- Lookup likelyhood to create close-by clusters:
  - likelyhood(A) = 20% (correct match)
  - likelyhood(B) ~ 0% (unlikely shape)
  - likelyhood(C) = 47% (likely shape)
- In some cases, clusters can be ruled out because of their shape.

Motivations for looking into PXD hit reconstruction





- Residuals pulls from clusterizer hit positions not very convincing
    - example: z55 pixels, phase3
    - Pulls are much to broad
    - RMS (u pulls) = 1.5
    - RMS (v pulls) = 1.3
- Position estimation done in clusterizer leaves headroom for improvement.

Hit reconstruction (in clusterizer)

:- Problems/Issues:

- Biases in hit position observed

- Inconsistent cluster covariance matrix.

→ Pull RMS ≠1

:- Attempt to improve the situation:

→PXD digitizer works well.

→ Bootstrap position corrections and cov. matrix from samples of simulated clusters.

*Turchetta, R. : Spatial resolution of silicon microstrip detectors. NIM A335 (1993) 44-58

Hit position: (u_c, v_c)	Hit position error $\begin{pmatrix} \sigma_u^2 & \rho\sigma_u\sigma_v \\ \rho\sigma_u\sigma_v & \sigma_v^2 \end{pmatrix}$
Positions and their errors are calculated separately from cluster projections to each direction. The correlation coefficient is calculated as $\rho = \frac{\sum_{pixels} S_i (u_i - u_c)(v_i - v_c)}{\left(\sum_{pixels} S_i [(u_i - u_c)^2 + \epsilon_u^2]\right)^{1/2} \left(\sum_{pixels} S_i [(v_i - v_c)^2 + \epsilon_v^2]\right)^{1/2}}$	(u_i, v_i) pixel positions S_i pixel signals $\epsilon_u = \frac{p_u}{\sqrt{12}}$ in-pixel spread $\epsilon_v = \frac{p_v}{\sqrt{12}}$ in-pixel spread
size in u = 1 Center of pixel	$\sigma_u = p_u \frac{(n_v+2)S_{thr}}{S+(n_v+3)S_{thr}}$ n_v cluster size in v S_{thr} 0-supp. threshold
size in u = 2 $u_c = \frac{S_1 u_1 + S_2 u_2}{S}$	$\sigma_u = p_u \frac{(n_v+2)S_{thr}}{S+(n_v+3)S_{thr}}$ n_v cluster size in v S_{thr} 0-supp. threshold
size in u > 2 $u_c = \frac{u_h+u_t}{2} + p_u \frac{S_h - S_t}{2S_0}$, $S_0 = \sum S_i$	$\sigma_u = \frac{p_u}{2}\left[2\left(\frac{S_{thr}}{S_0}\right)^2 + \frac{1}{2}\left(\frac{S_h}{S_0}\right)^2 + \frac{1}{2}\left(\frac{S_t}{S_0}\right)^2\right]^{1/2}$

The same formulas are used for v

Cluster shape hit reconstruction

0) Bootstraping:

:- Sort true position corrections into classes based on pixel type, binned incidence angles and discrete cluster shape.

:- Compute mean and covariance. Compute likelyhood for cluster shape given pixel type and incidence angles.

1) Creation of training data in basf2:

:- Separate samples for different pixel pitches (pixelkinds: z55, z60, z70, z85)

:- Uniform vertex smearing, wide angle spectrum into sensor

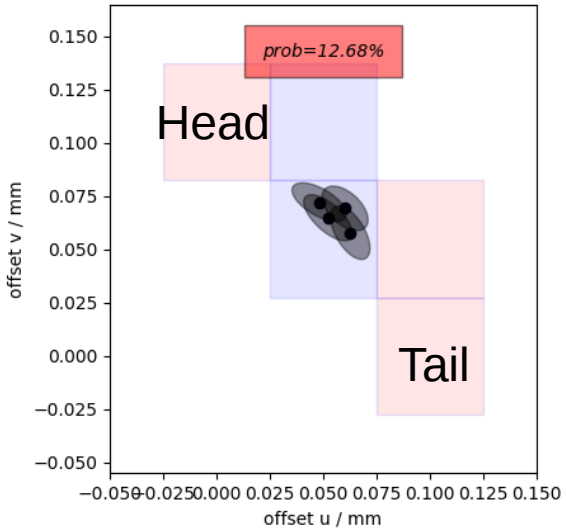
:- Training data: 10 million pairs of true hits from 1GeV pions and related clusters.

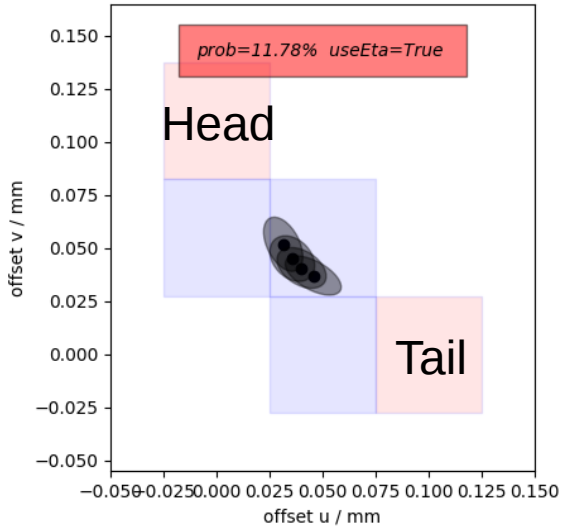
2) Training of lookup tables for hit reconstruction (separately for pixelkinds):

:- Sort training data into angular grid Θ_u / Θ_v

:- Angular grid: 10°x10° covering full angular range -90°,…,+90°

Brief look into details





- Example corrections for angle bin (-55°,55°) at pixelkind=0 (z55)

- Lookup correction based on cluster properties:

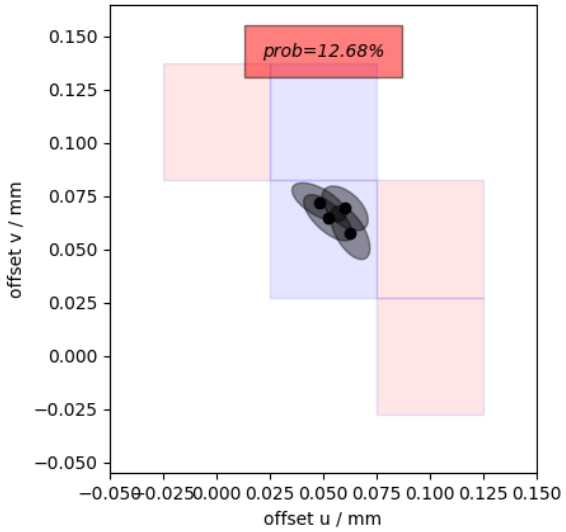
  - rel. positions of fired pixels (digital shape)
  - binned Eta=S_{head} / S_{head} + S_{tail}

- Pre-computed lookup tables providing

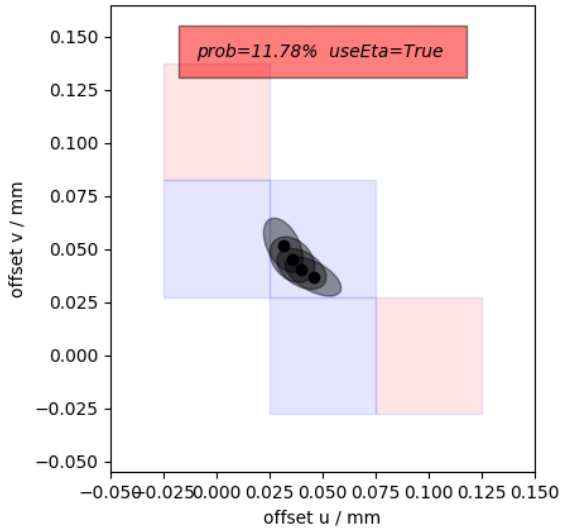
  - uOffset, vOffset (in cluster coordinates)
  - 2x2 covariance matrix
  - likelyhood for charged particle to cause such a shape; depending in binned incidence angles.

Brief look into details

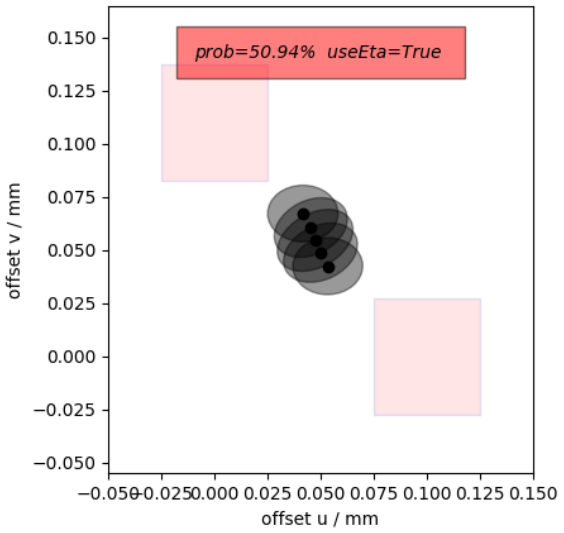
‘Fulldigital’ variant



- Different possibilities to define the cluster properties for lookup:
  - ‘fulldigital’: rel. positions of all fired pixel + binned eta
  - ‘head-tail’: only use relative position of head-tail pixels + binned eta



‘Head-tail’ variant



Corrections for full PXD in phase 3:

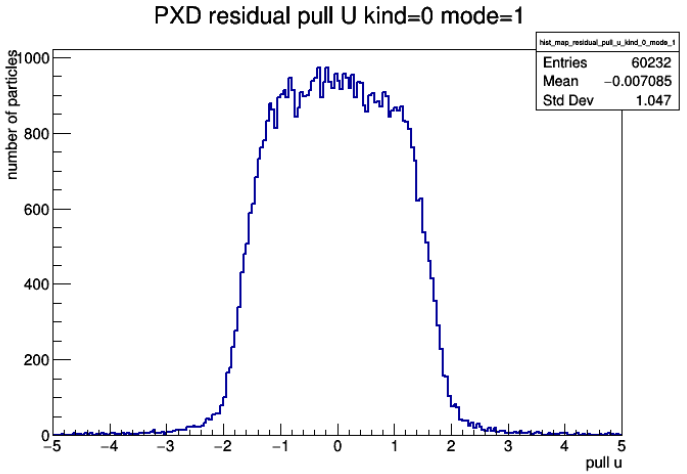
- time: ~2days on my laptop
- <1MB lookup table →cond. DB
- order of 18k corrections prepared
- order of 400 different digital shapes

Testing of corrections

- Simulate 10k events of generic BBbar with overlaid bg digits in basf2 (phase 3).
- Match true hits in PXD from BBbar events against PXD clusters.
  - Ignore clusters touching sensor edge, having different pixel kinds.
  - Use lookup correction if possible. Otherwise, use position from clusterizer.
  - Compute u/v residuals and u/v pulls.
- In 93% of hits in PXD, a position corrections could be found in lookup table.
  - Most fails from cases where signals from different particles overlap
  - Interesting way to identify candidates for overlap clusters

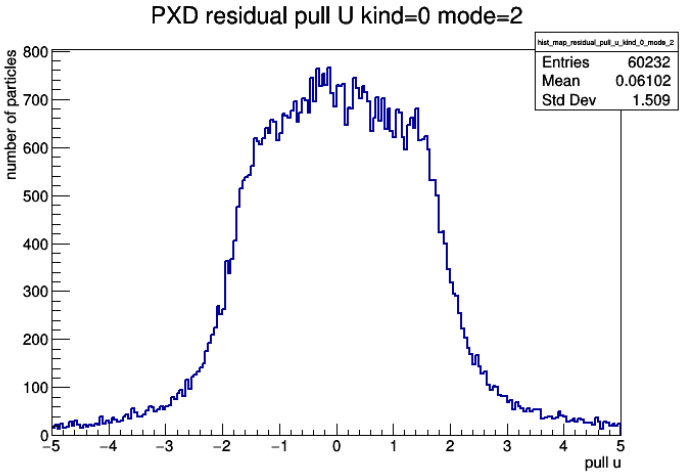
Pulls/residuals (z55 pixels, u-direction)

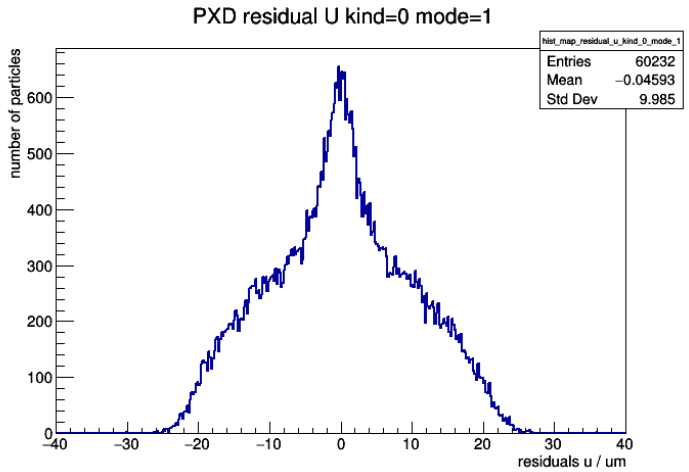
Cluster shapes,
fallback: clusterizer



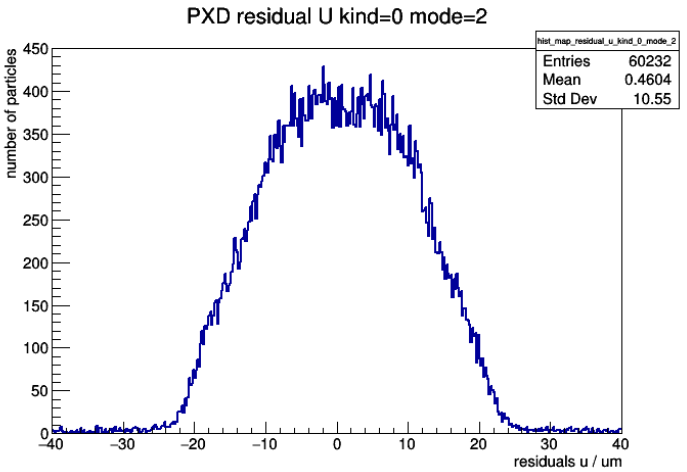
Consistent pulls:
→ correct cov. matrix

Only clusterizer



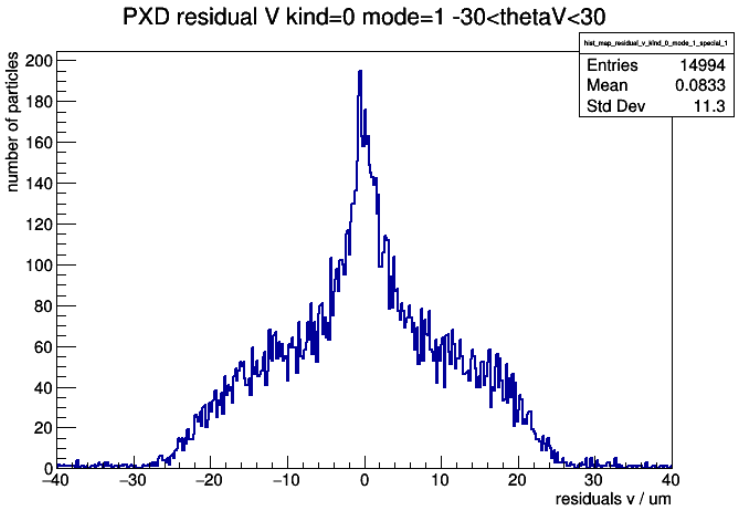


Narrow peak in residuals:
→ better positions for small multi pixel clusters.

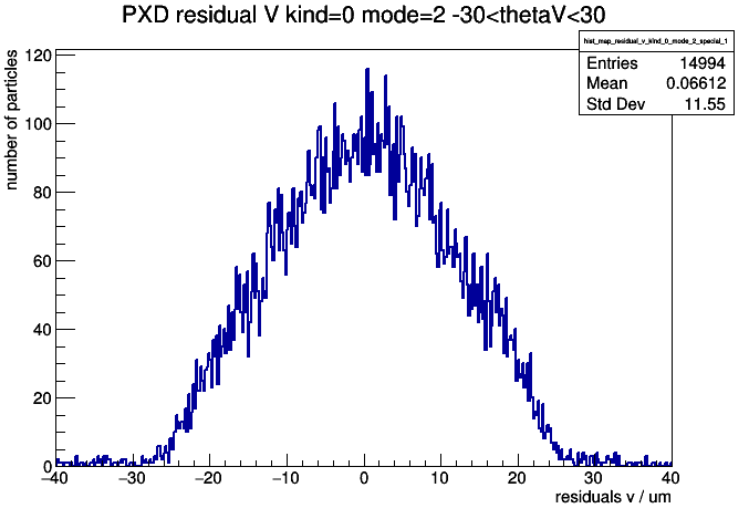


Residuals (z55 pixels, V direction) cluster shapes

Cluster shapes,
fallback: clusterizer



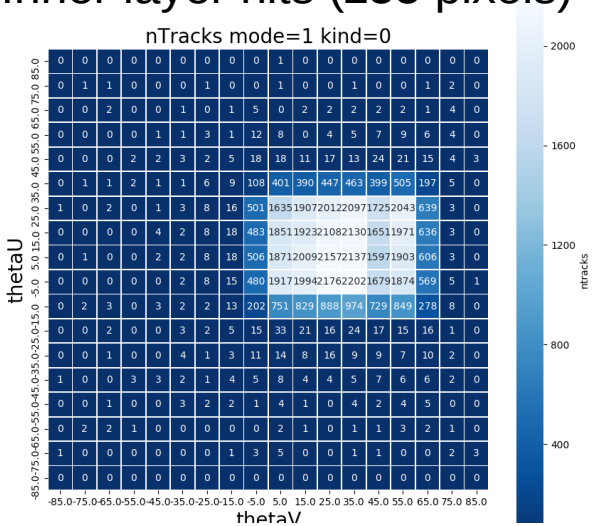
Only clusterizer



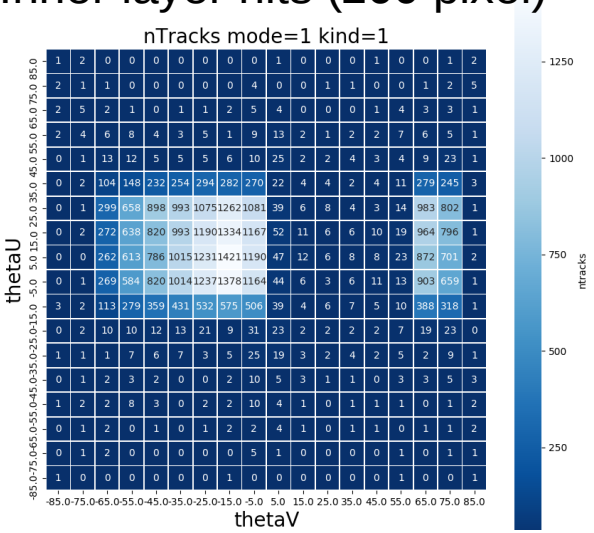
:- Improvement in residuals visible for small multi-pixel clusters at not too large incidence angles (expected)

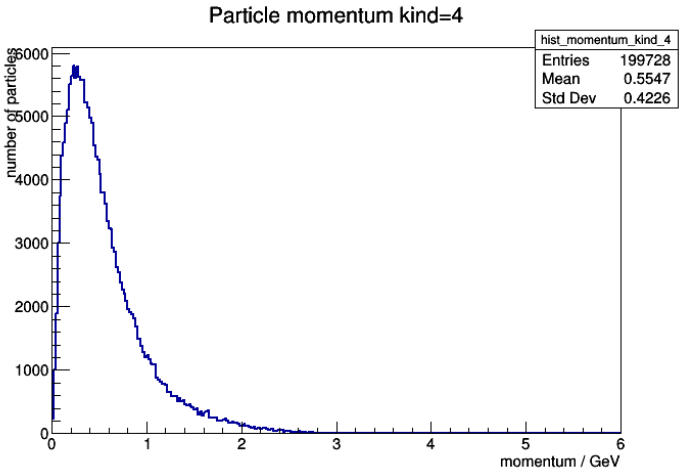
Hits from signal particles (BBBar) on PXD

Inner layer hits (z55 pixels)

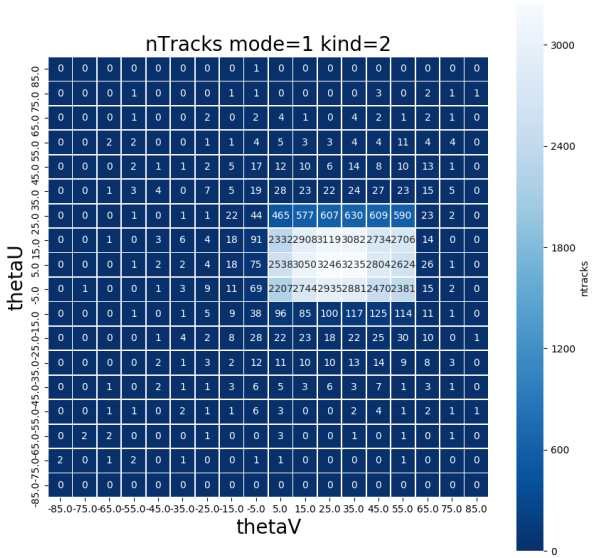


Inner layer hits (z60 pixel)

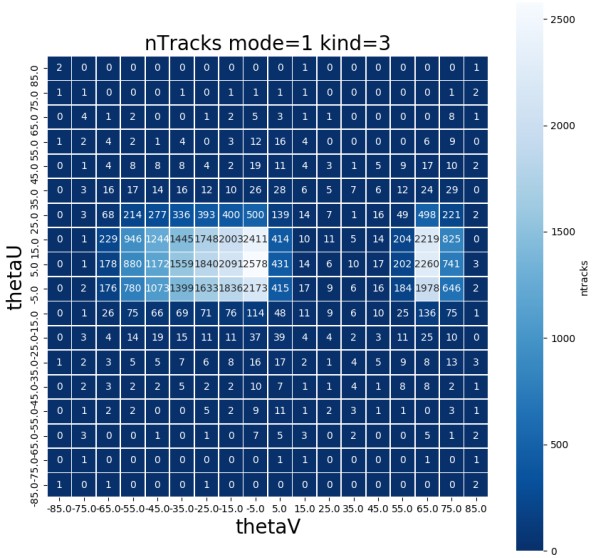




Outer layer hits (z70 pixels)



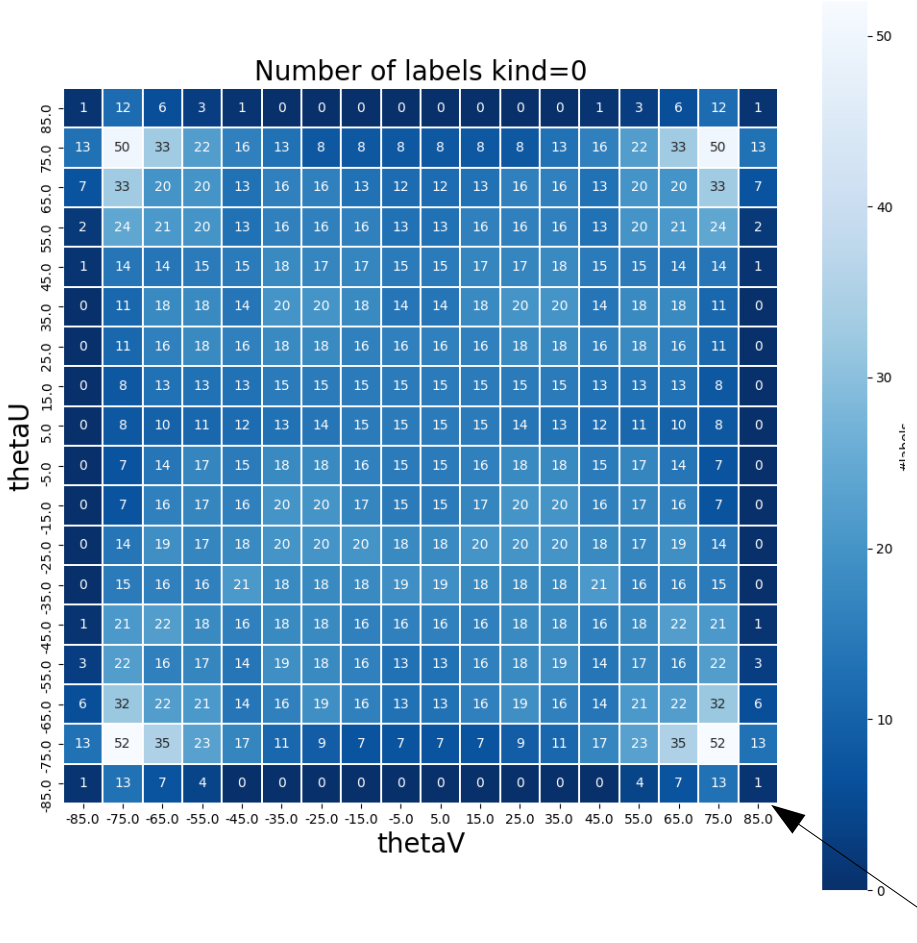
Outer layer hits (z85 pixels)



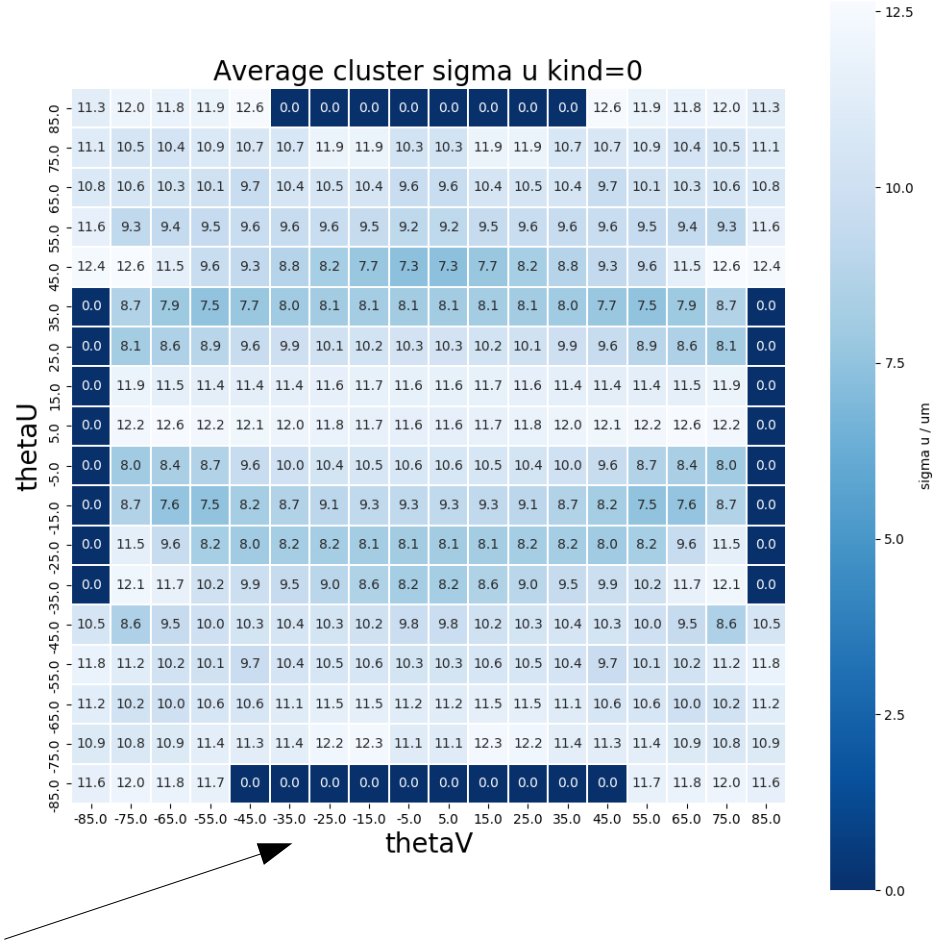
- Average momentum of ~550 MeV
- narrow angle range contains most signal hits
- for layer two even more narrow.

Some more results

Number of corrections per angle bin (pixelkind=0)



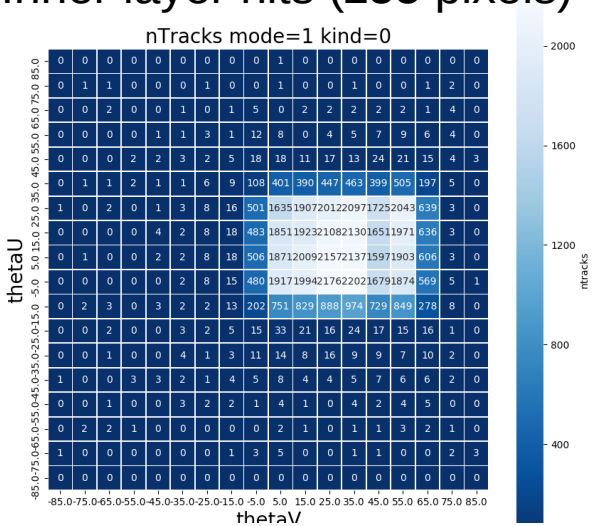
Average cluster sigmaU per angle bin (pixelkind=0)



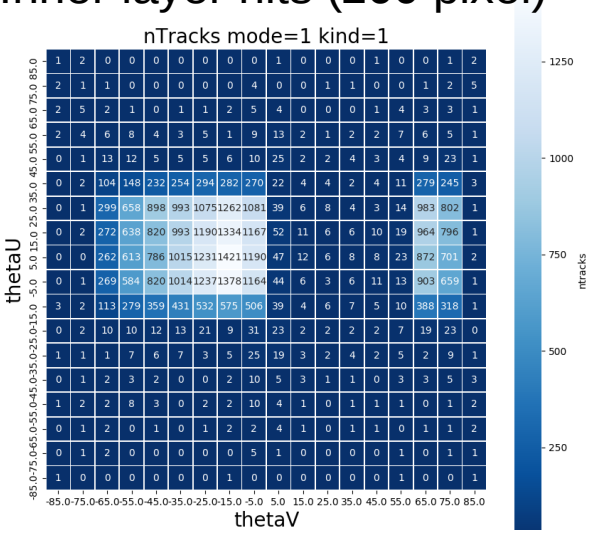
Statistical limitations in outermost bins (need some fine tuning of sample sizes)

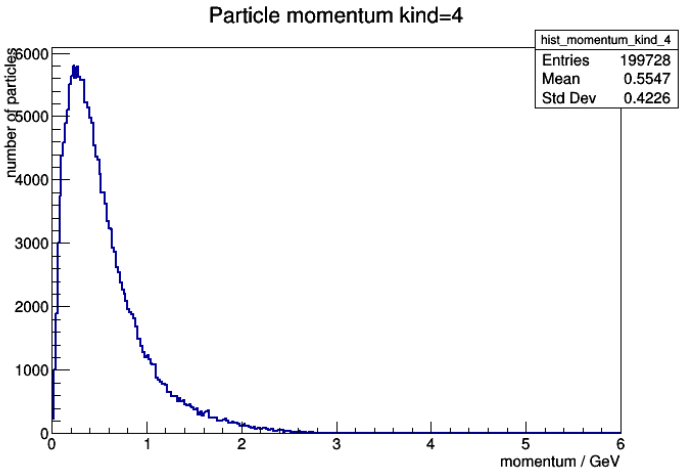
Hits from signal particles (BBBar) on PXD

Inner layer hits (z55 pixels)

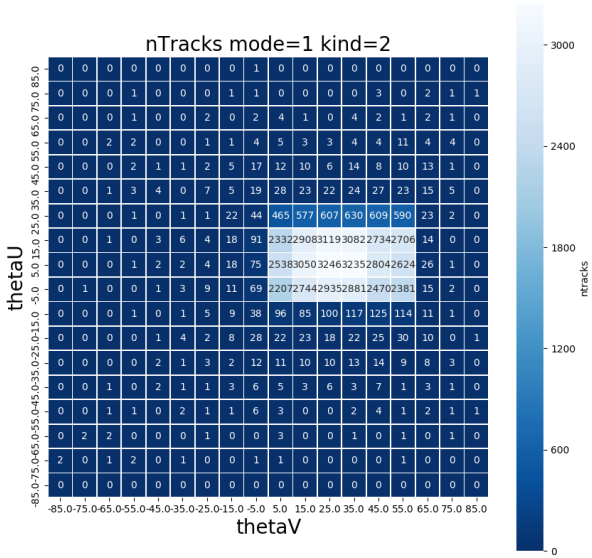


Inner layer hits (z60 pixel)

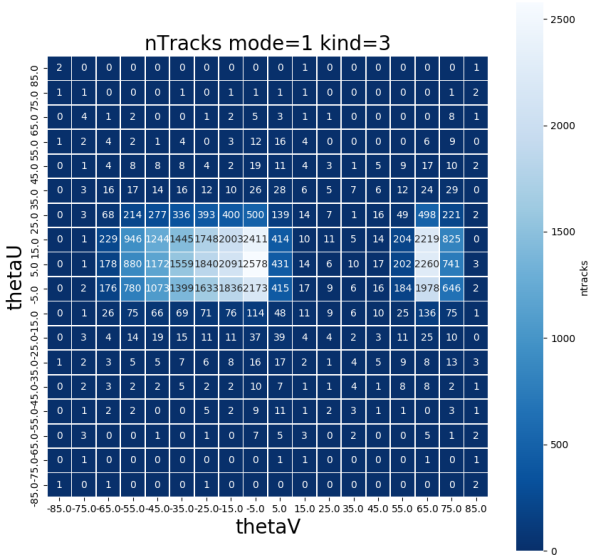




Outer layer hits (z70 pixels)



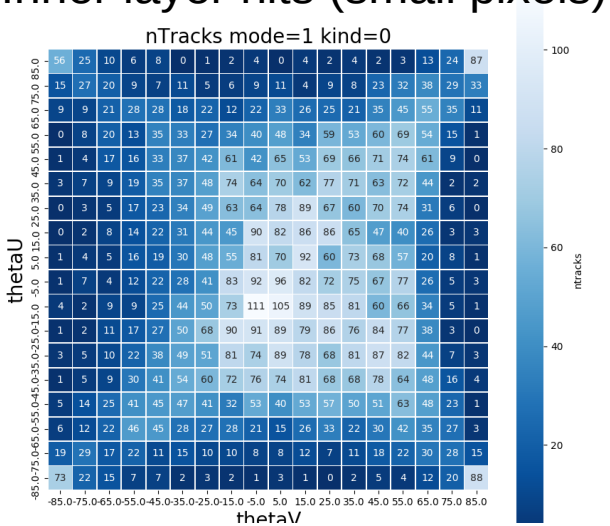
Outer layer hits (z85 pixels)



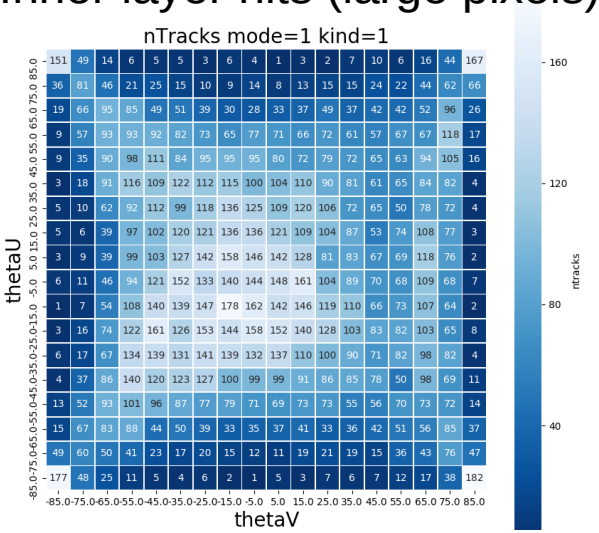
- Average momentum of ~550 MeV
- narrow angle range contains most signal hits
- for layer two even more narrow.

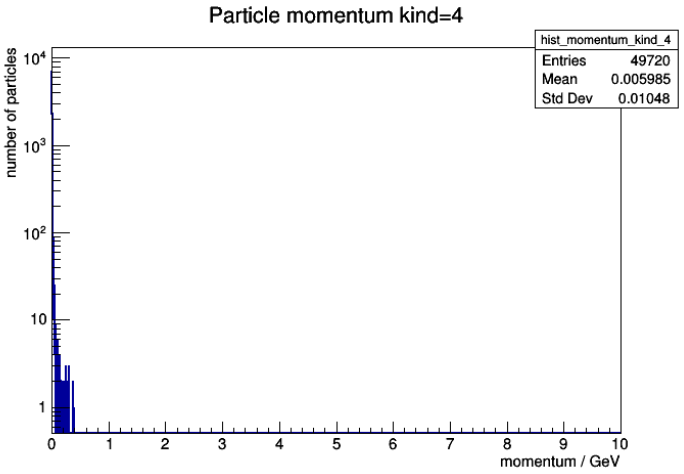
Hits from bg particles (two photons) on PXD

Inner layer hits (small pixels)

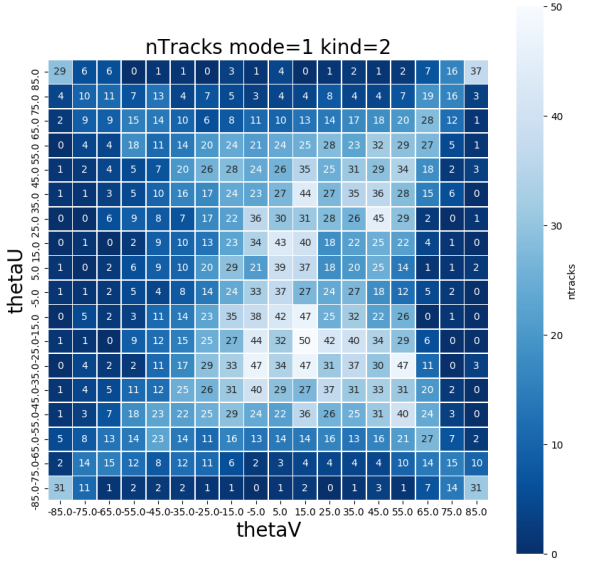


Inner layer hits (large pixels)

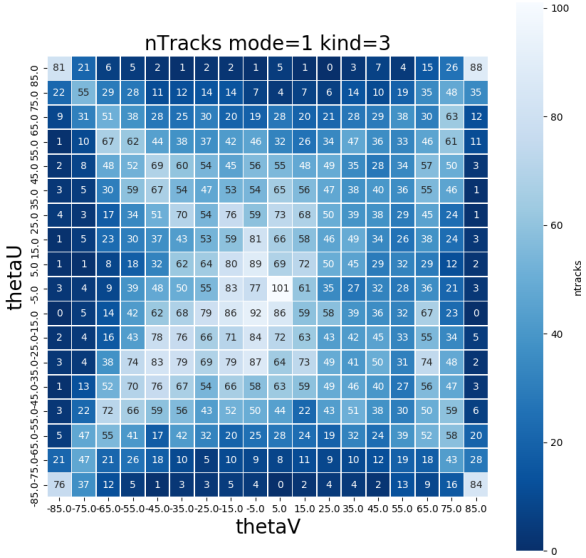




Outer layer hits (small pixels)



Outer layer hits (large pixels)



- Average momentum of ~6 MeV
- broad range of incidence angles into PXD sensors.
- seems cutting on thetaV/thetaV can separate signal/bg clusters.

PXD calibration studies (using TB17 data)

:- Use TB17 data to study which PXD constants need calibration from real beam data?

:- Run 176 in magnetic field (0.5T) in 2.4GeV electron beam has data from sensors 1.1.2 and 2.1.2.

:- Following Digitizer constants (per sensor) were fitted against real data:

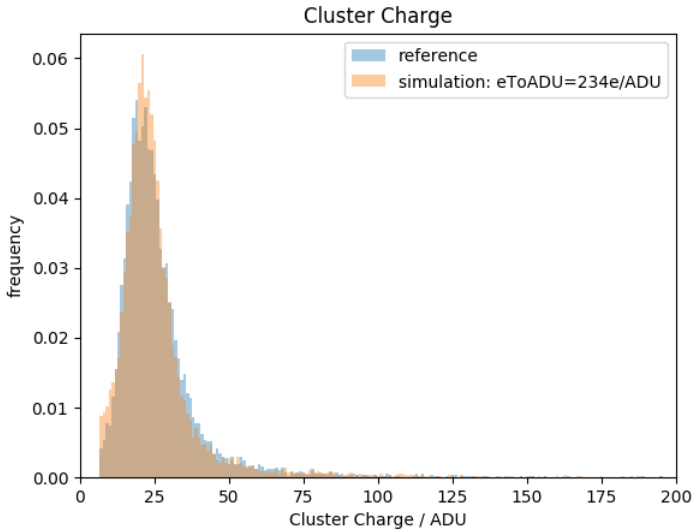
- A) Digitizer gain (eToADU)
- B) Border length in u/v (size of pixel area with weak drift fields)

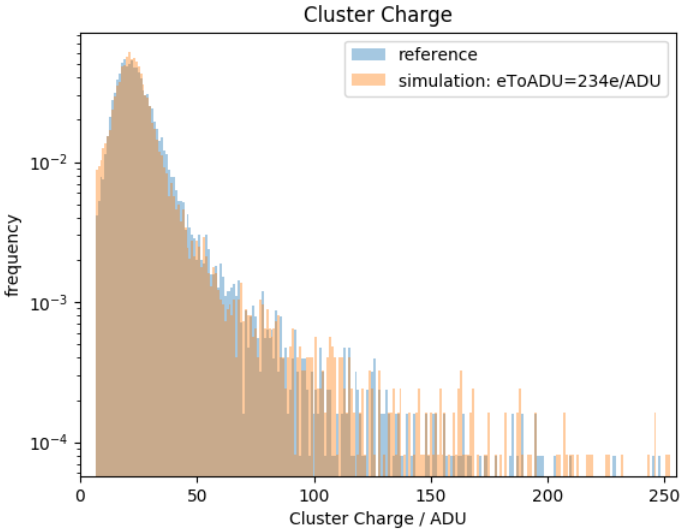
:- Iterative least square fit, minimizing residuals between shape likelyhoods.

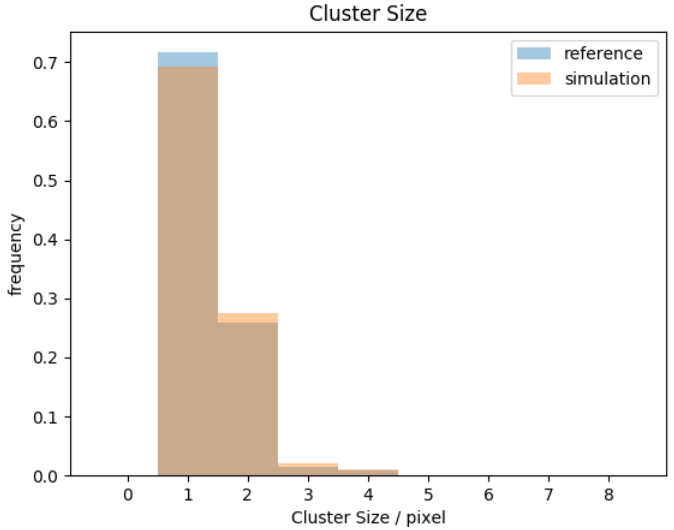
:- Requires ~20k clusters matched to tracks per sensor.

Calibration results: TB17

Sensor 2.1.2 (run 176)







:- Least squares fit of digitizer parameters to TB17 data:

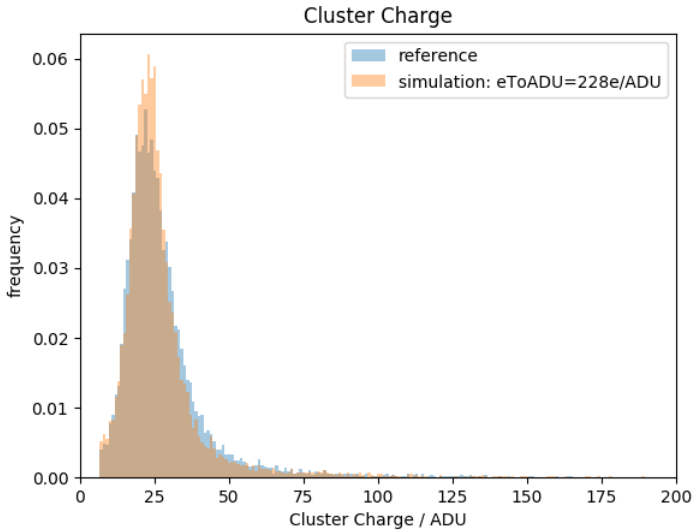
:- Fit variables: Gq, border lengths

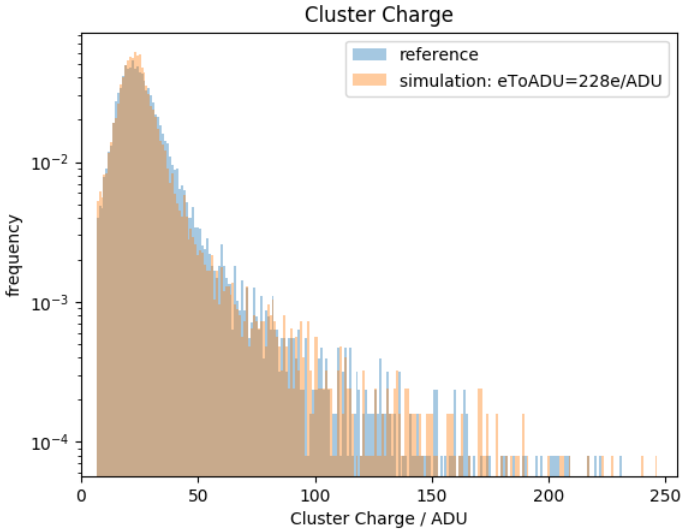
:- Fitted gain: eToADU=234e/ADU

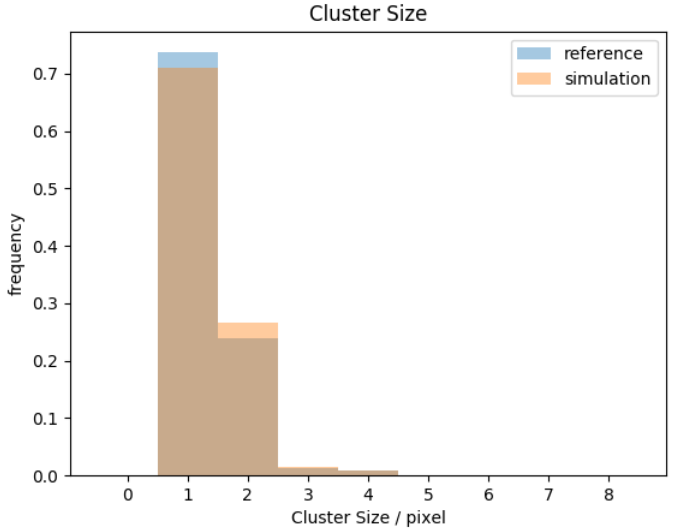
:- Cluster charge/sizes reasonably well described.

Calibration results: TB17

Sensor 1.1.2







:- Overall similar results

:- Gain (1.1.2): eToADU=228e/ADU
:- Gain (2.1.2): eToADU=234e/ADU

:- Homogenize gains of sensors by tweaking Depfet bias voltages (gate-ON) and DACs of Drain-Current-Digitizer (DCD) chip.

Conclusions

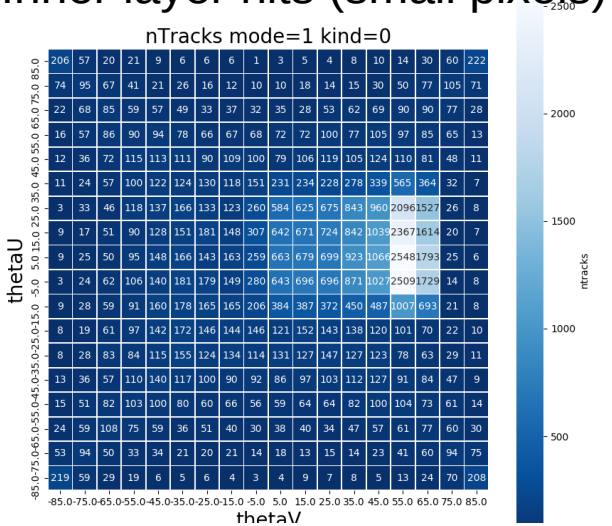
- Status of cluster shape corrections in basf2:
  - Initial implementation not fully integrated into basf2
  - Fill C++ dbobjects with correction tables (done)
  - Retrieve corrections constants in reco modules (half-done)
  - Computation all corrections in CAF (to be done)

- Plans: PXD calibration constants (for February)
  - Move pedestals, gains, and dead pixel maps for phase 2(3) in cond. DB
  - Initial values can be taken from lab testing
  - Expect to be faster after experience with shapes.
  - Update calibration requirements for PXD

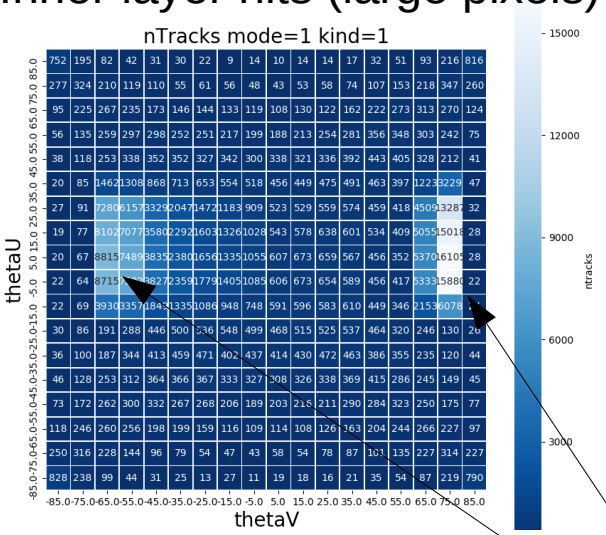
Backup

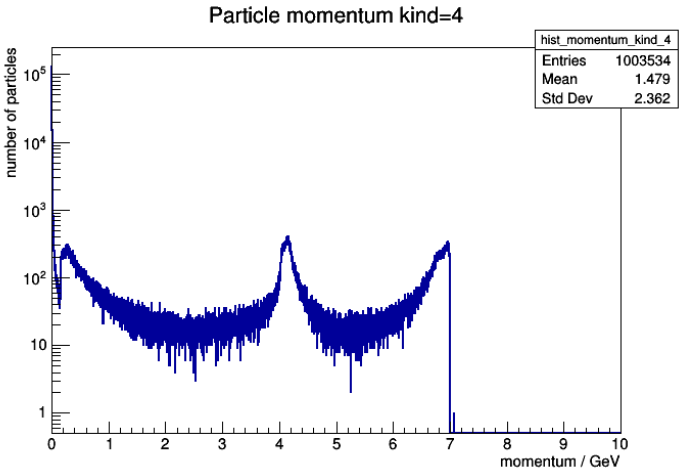
Hits from bg particles (BHWideLA) on PXD

Inner layer hits (small pixels)

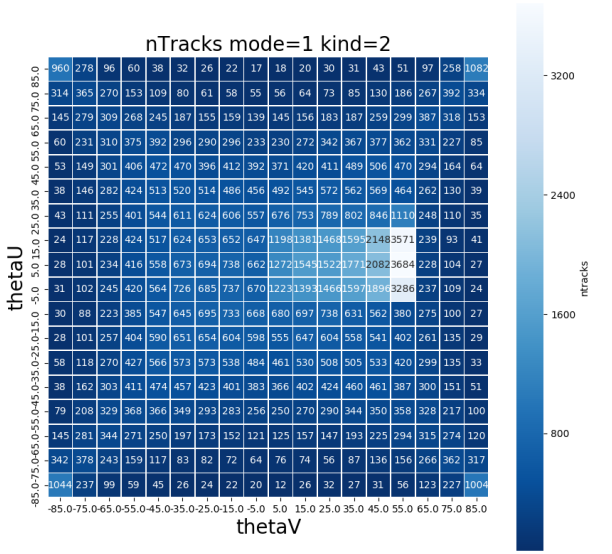


Inner layer hits (large pixels)

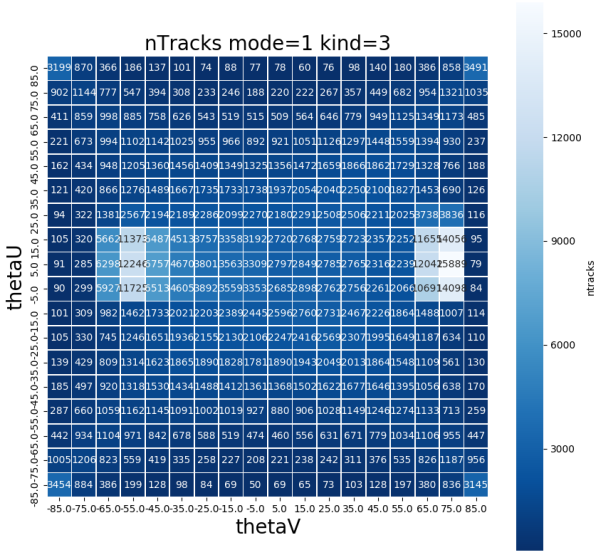




Outer layer hits (small pixels)



Outer layer hits (large pixels)



- Two components

a) High momentum e+e-

b) Low momentum particles