PXD software

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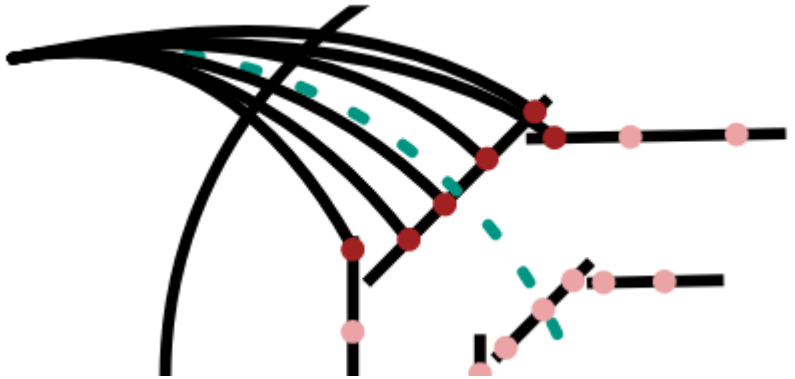
PXD Meeting, 23.1.18

Outline

- Online software: See talk by Björn
- VXD alignment: See talk by Peter
- DQM: see talk by Björn

- Focus here: Offline PXD software
  - Reconstruction: Cluster shape and track direction sensitive position estimation.
  - Application of cluster shape reconstruction to Phase 3 background simulation.
  - Calibration: Data base objects, interface to BonnDaq, results from TB17 data.

Motivations for looking into PXD hit reconstruction



CKF based track extrapolation into PXD (Nils Braun)

- You have extrapolation of hit position and angles.

- You can use angle information in two ways:

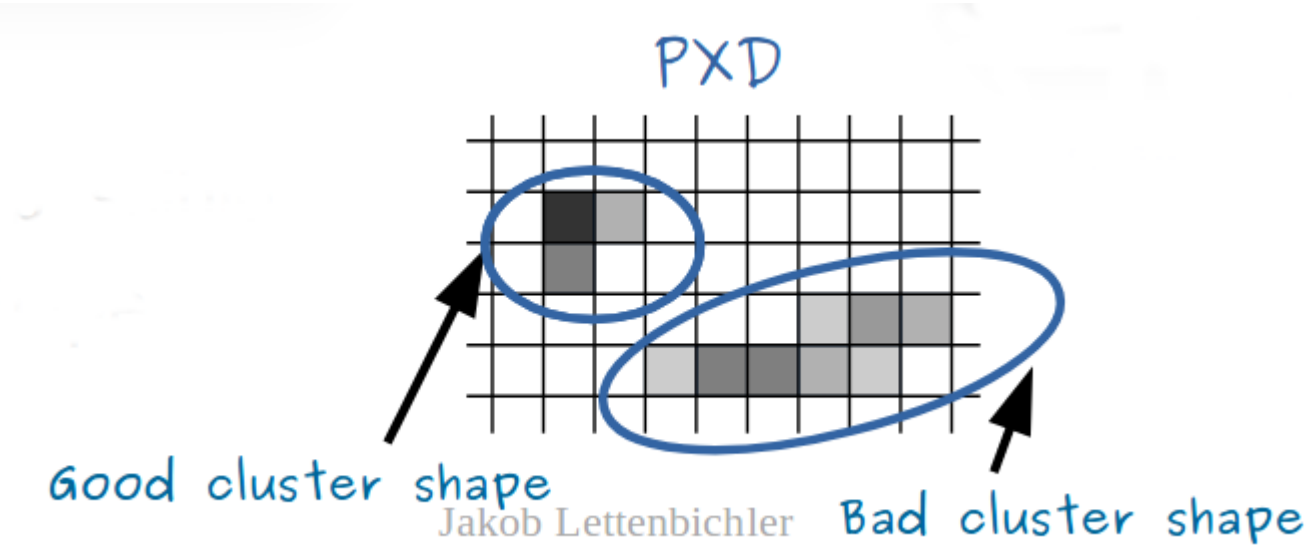
  a) Check of shape of close-by cluster is likely to be produced for given incidence angles.

  → here: quantify what likely means

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

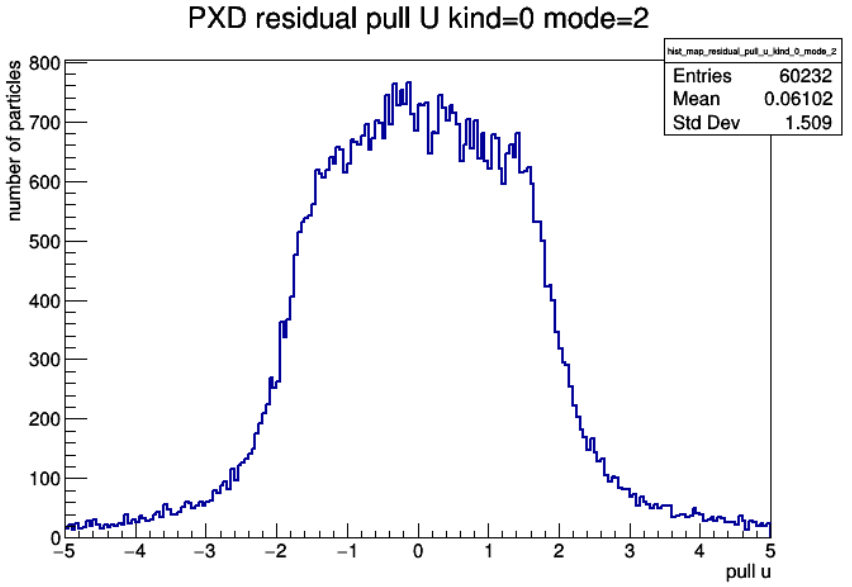
  → Continue work started by Prague group

Motivations for looking into PXD hit reconstruction



Pull Mean = 0.06
Pull RMS = 1.5!!

(z55 pixels, phase 3 setup)



Hit reconstruction (in clusterizer)

:- Problems/Issues:

- Biases in hit position observed.

- Inconsistent cluster covariance matrix.

→ Pull RMS ≠1

:- Attempt to improve the situation:

→Digitizer works well.

→ Bootstrap position estimates 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

1) Creation of training data in basf2:

:- Particle gun positioned just below a pixel with given pixel pitch (z55, z60, z70, z85)

:- Vertex smeared uniformly over the pixel area

:- Wide spectrum of directions Θ_u / Θ_v of particles into the sensor

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

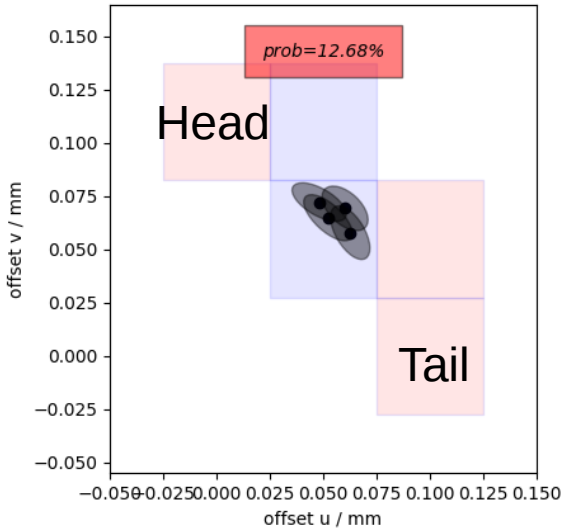
2) Training of lookup tables for hit reconstruction (separately for pixelkinds):

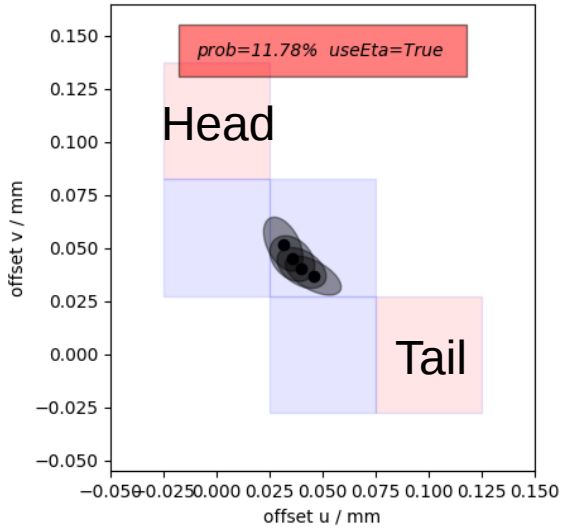
:- Sort training data into angular grid Θ_u / Θ_v

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

:- Classify true intersects based on simulated cluster shape and compute moments.

Brief look into details





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

- Lookup correction based on cluster properties:

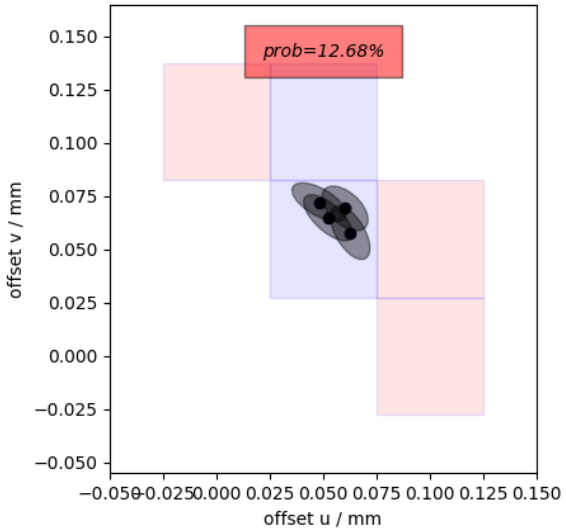
  - rel. positions of fired pixels (digital shape)
  - binned Eta=S_{head} / S_{head} + S_{tail}

- Pre-computed lookup tables providing

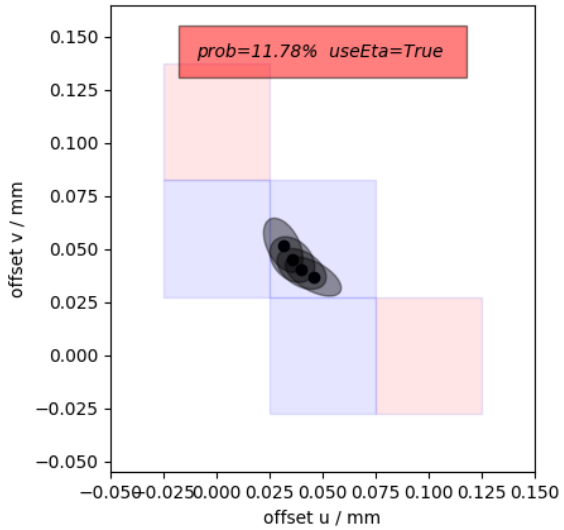
  - uOffset, vOffset (in cluster coordinates)
  - 2x2 covariance matrix
  - likelyhood for charged particle to cause such a shape; depending in binned incidence angles.

Brief look into details

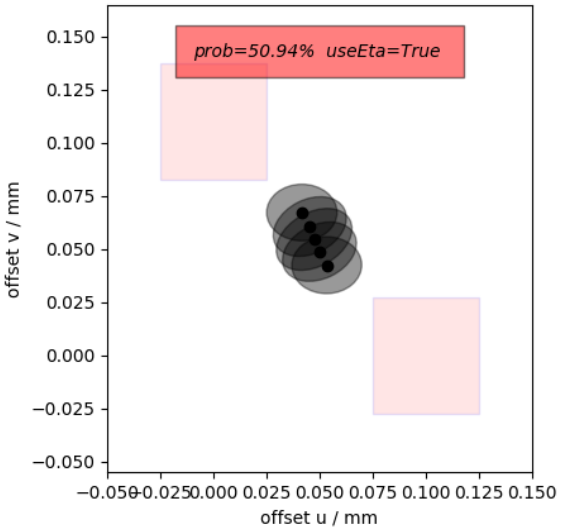
‘Fulldigital’ variant



- 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
- 4MB lookup table → cond. DB
- order of 18k corrections prepared
- order of 400 different digital shapes

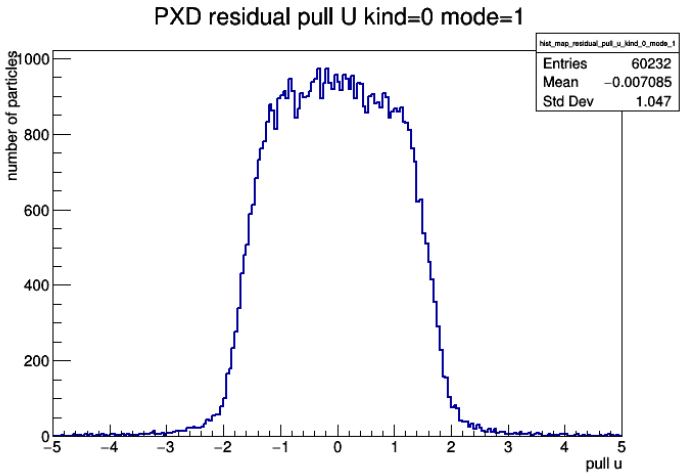
Testing of corrections

- 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

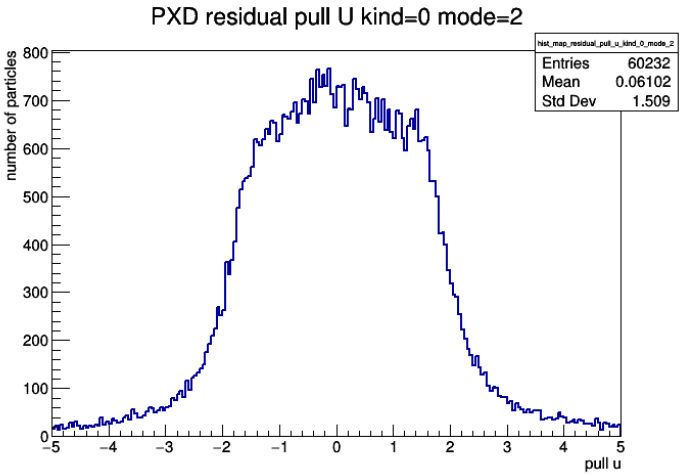
Pulls (Kind=0, u direction)

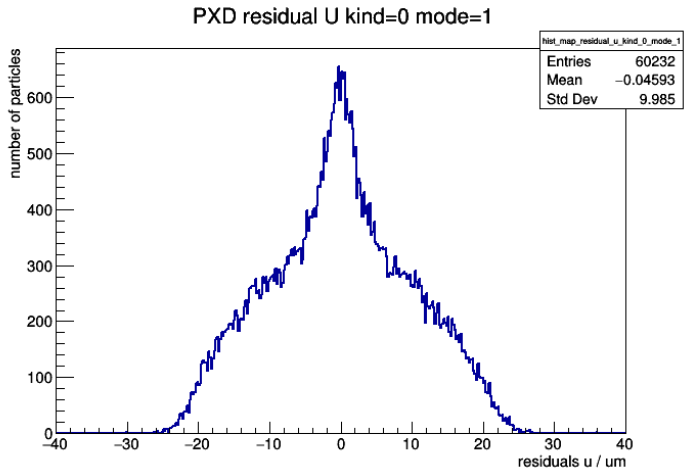
Cluster shapes,
fallback: clusterizer

Only clusterizer

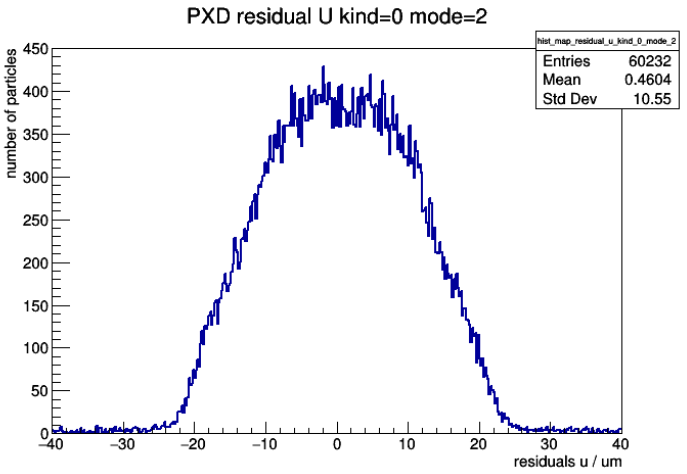


Consistent pulls:
→ correct cov. matrix



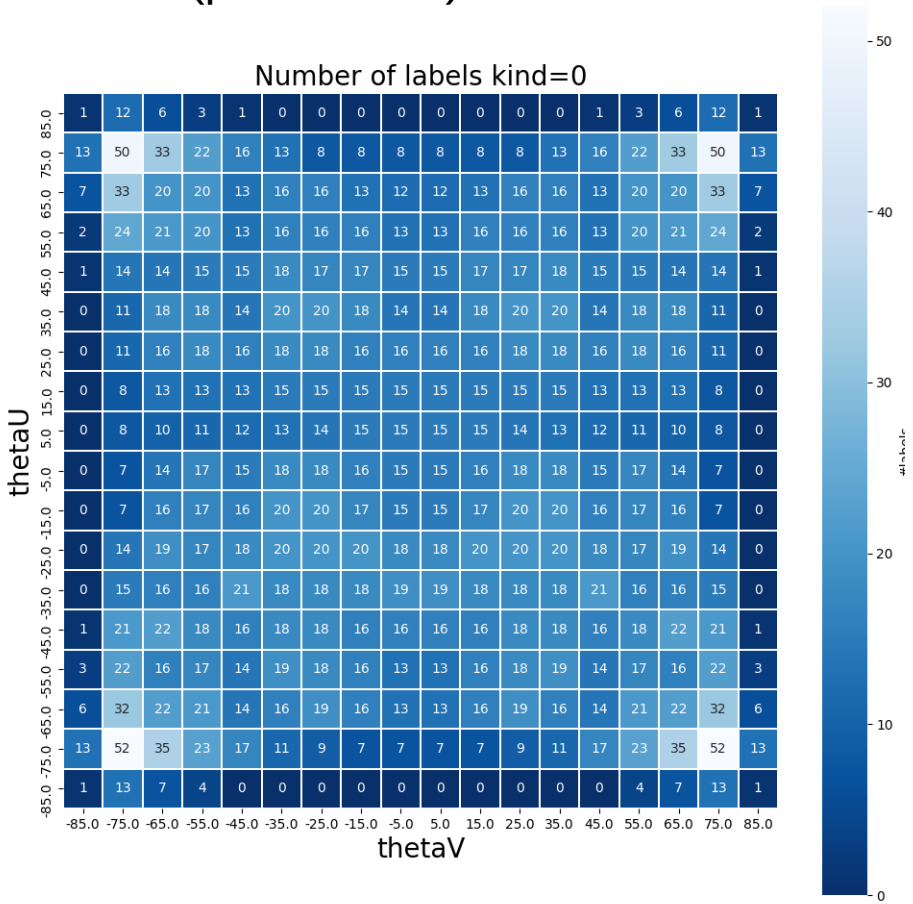


Narrow peak in residuals:
→ better positions for small multi pixel clusters.

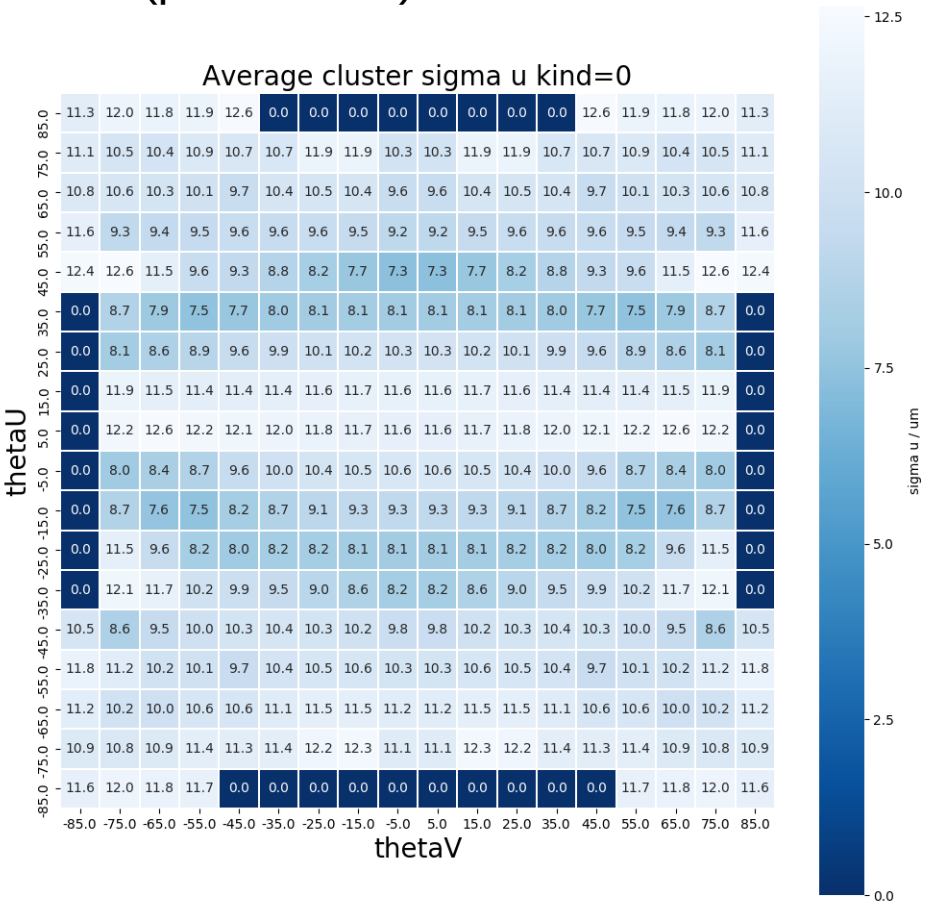


Some more results

Number of corrections per angle bin (pixelkind=0)



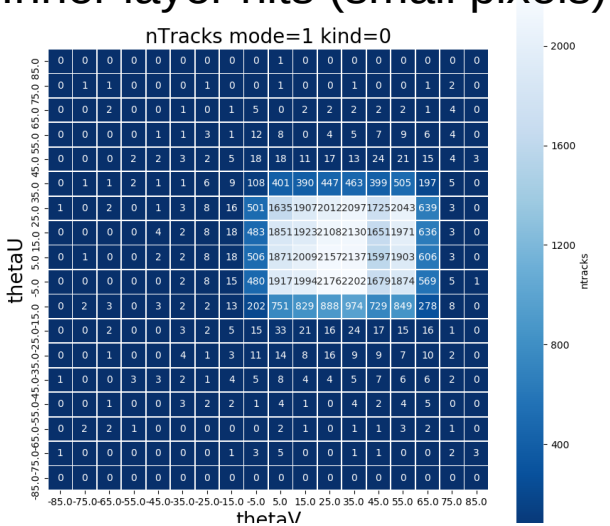
Average cluster sigmaU per angle bin (pixelkind=0)



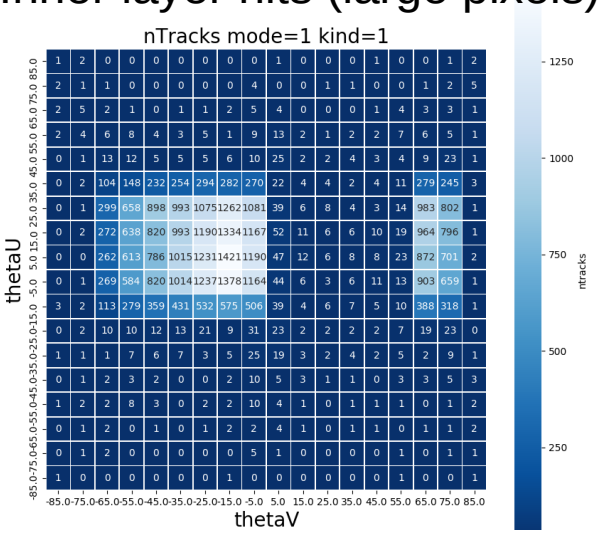
Would like to confirm these tables PXD standalone in DESY TB

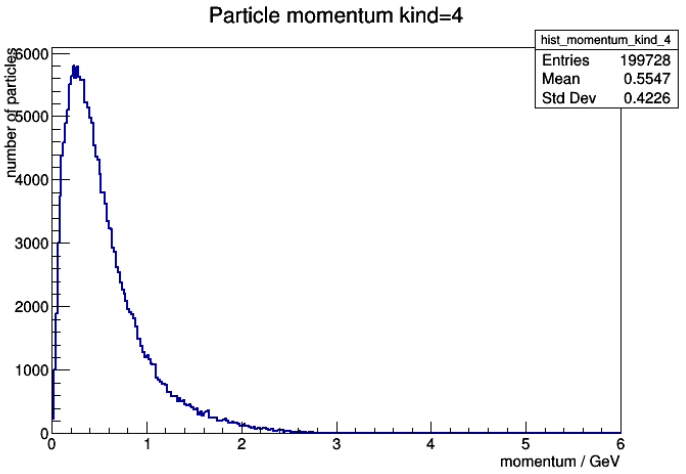
Hits from signal particles (BBBar) on PXD

Inner layer hits (small pixels)

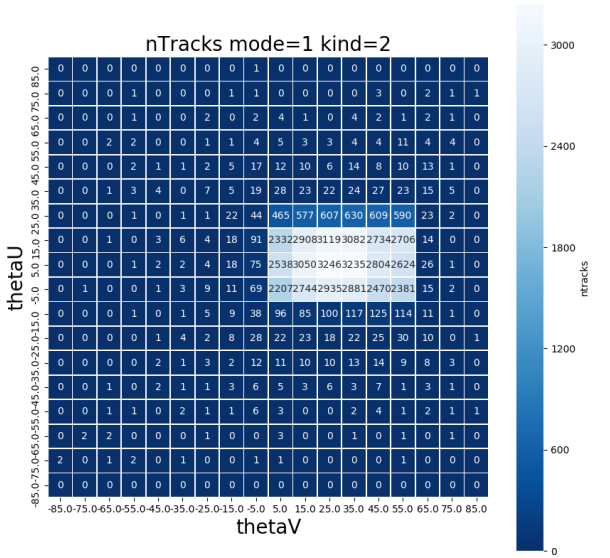


Inner layer hits (large pixels)

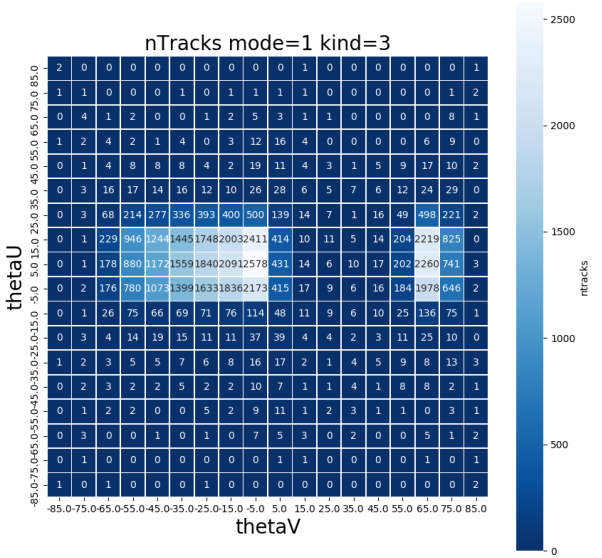




Outer layer hits (small pixels)



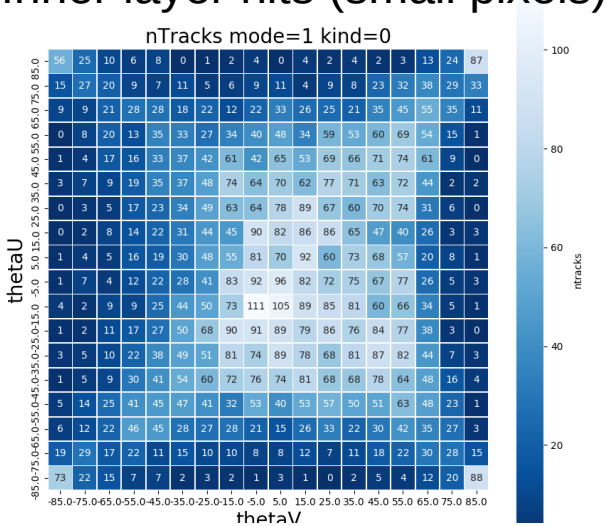
Outer layer hits (large pixels)



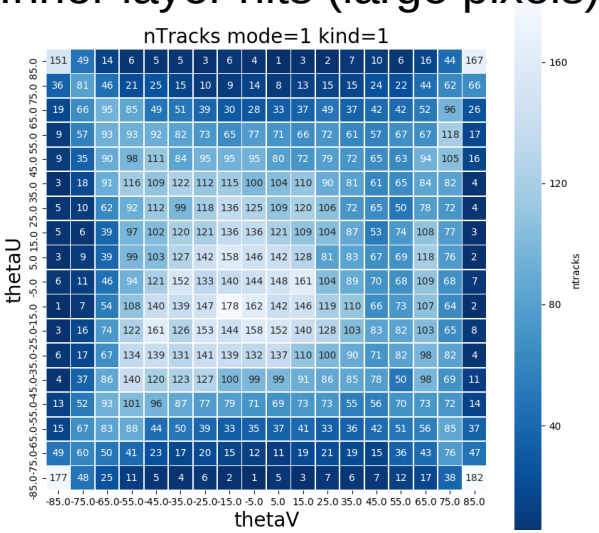
- Average momentum of ~550 MeV
- narrow angle range contains most signal hits
- for layer two even more narrow.

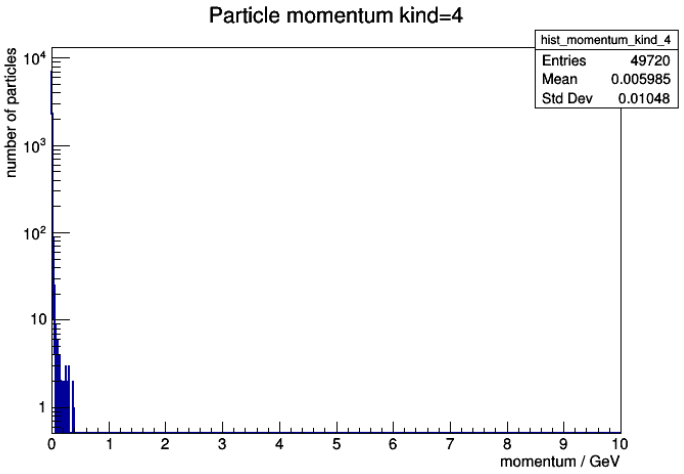
Hits from bg particles (two photons) on PXD

Inner layer hits (small pixels)

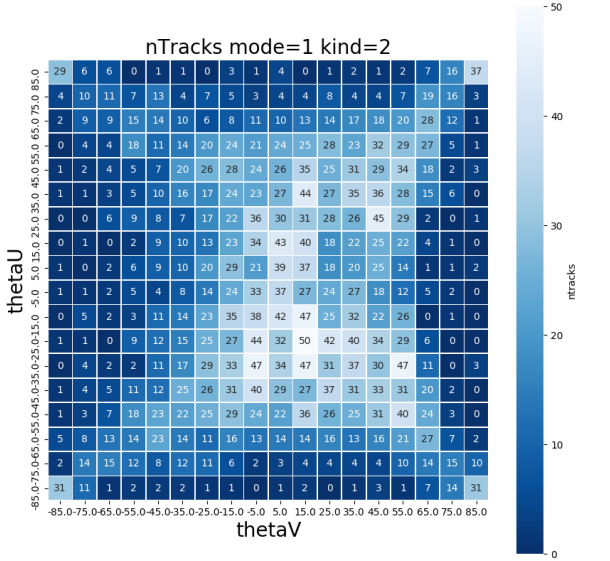


Inner layer hits (large pixels)

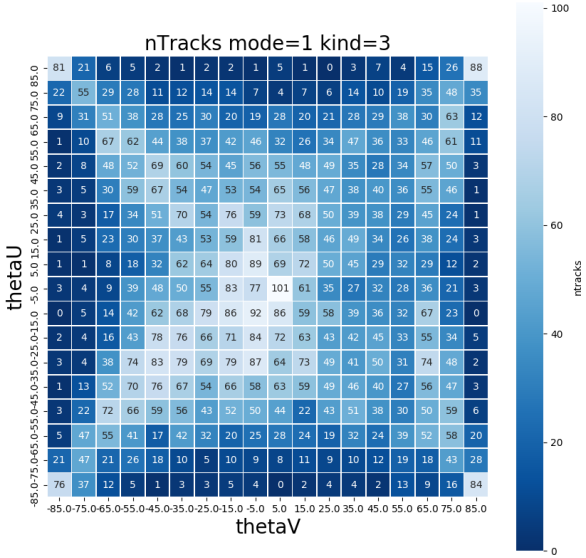




Outer layer hits (small pixels)



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 calibrations (remarks)

:- Apart from alignment, there are currently no data driven calibration constants in basf2 pxd reconstruction/simulation.

:- What can be done in next month?

- Add payloads for PXD cluster shapes (next 2 weeks):
- Add payloads for PXD simulation:

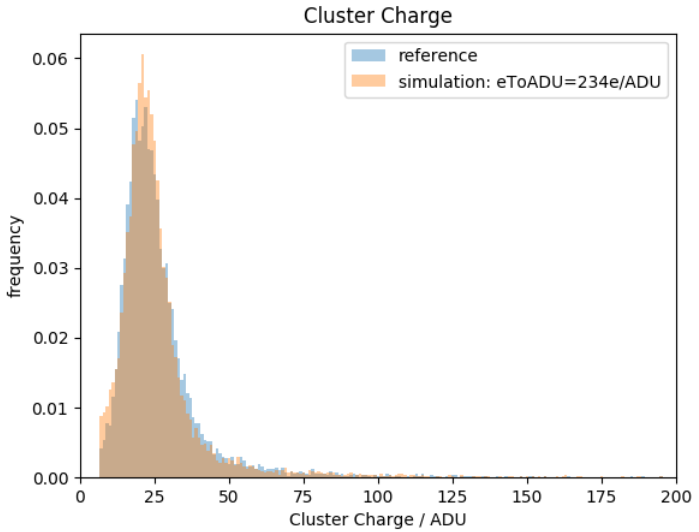
  a) pedestal maps per sensor (~8MB payload for phase3, negligible for phase2)
  b) dead pixel maps sensors (hopefully small payload)

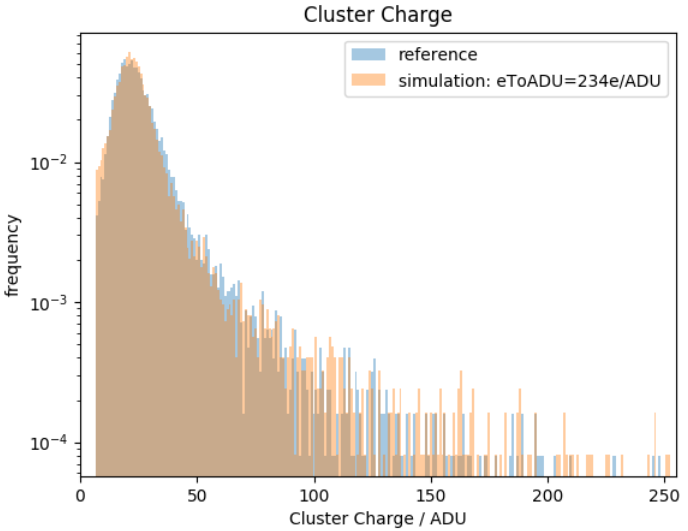
  → Available from local runs with BonnDAQ. Import to basf2 cond. DB can be done purely in python ;)

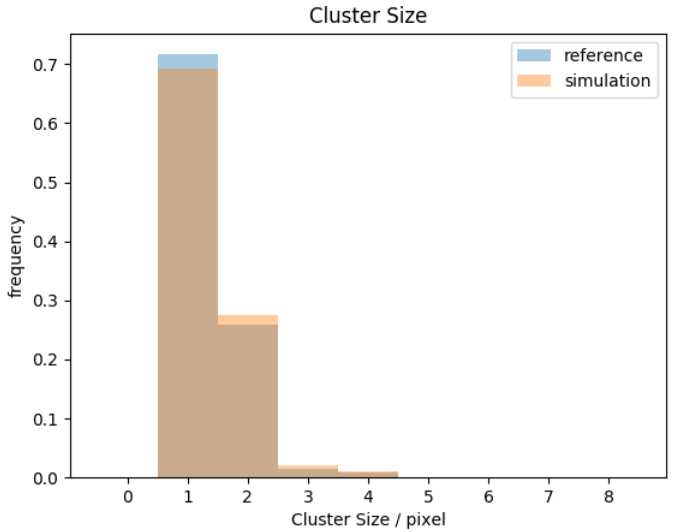
  c) Gains and border length parameters from beam data. Exercise fitting using TB17 data.

Calibration results: TB17

OB: 2.1.2







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

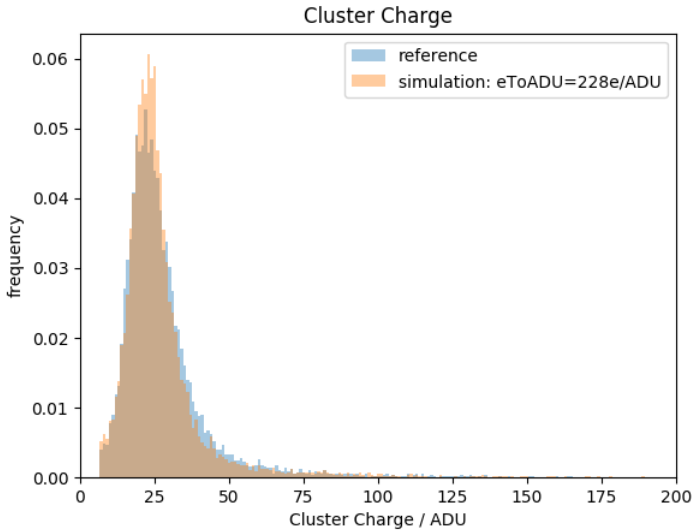
:- Fit variables: Gq, border lengths

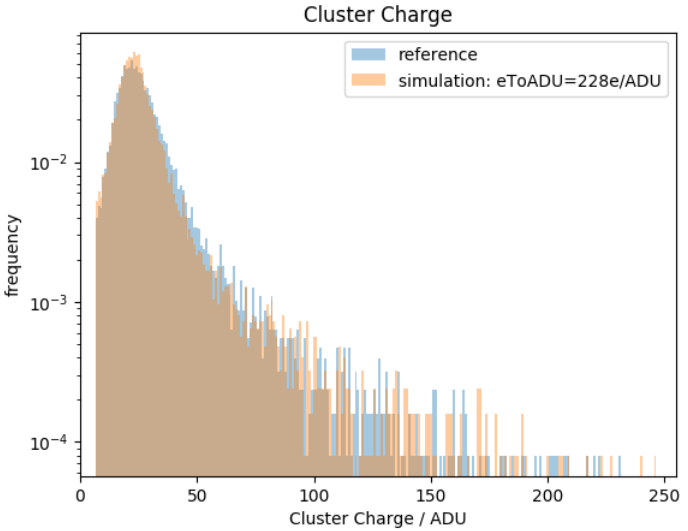
:- Fitted gain: eToADU=234e/ADU

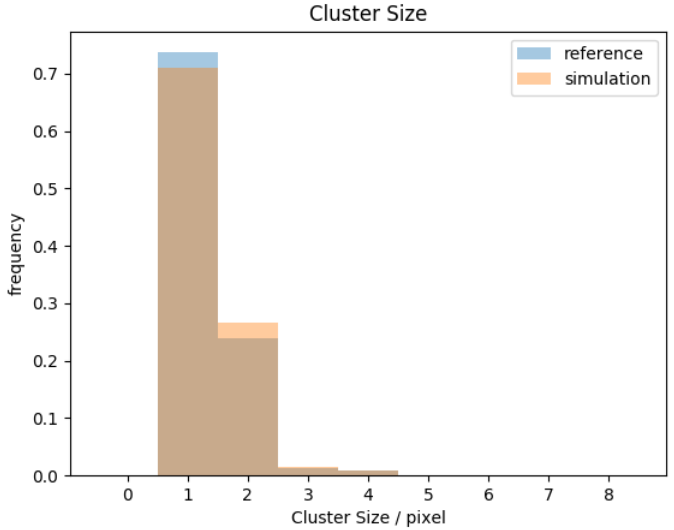
:- Cluster charge/sizes reasonably well described.

Calibration results: TB17

OB: 1.1.2







:- These calibration need beam data

→ Pairs of clusters matched to track
→ ~20k per correction

:- Granularity for gains (eToADU): per sensor (or DCD-SW)

:- For border lengths: Large/small pitch per sensor

Organization

- Request from Thomas Kuhr: Estimate amount of service tasks/shifts after commisioning:
  - Service task: 50 working day (8h)
  - Shifts: both remote and at KEK
  - We can define pre-requistes for shifts and tasks
  - Collect ideas after the talk → for software session at B2GM
- Proposal for pxd software meetings:
  - Pacemaker to steer progress and prepare for beams and BG studies
  - Discuss technical points on DQM, calibration, background studies
  - Bi-weekly format

Conclusions

- Finish work on cluster shape position estimation:
  - Move corrections into conditions DB
  - Use correction in during track fitting / pattern reco
  - Re-implement computation of correction in CAF
  - Finalize Belle2 note

- Plans: PXD calibration constants
  - Move pedestals, gains, and dead pixel maps for phase 2(3) in cond. DB
  - Initial values can be taken from lab testing
  - Updated values from local runs with BonnDAQ
  - Beam data needed for Gains and some digitizer parameters

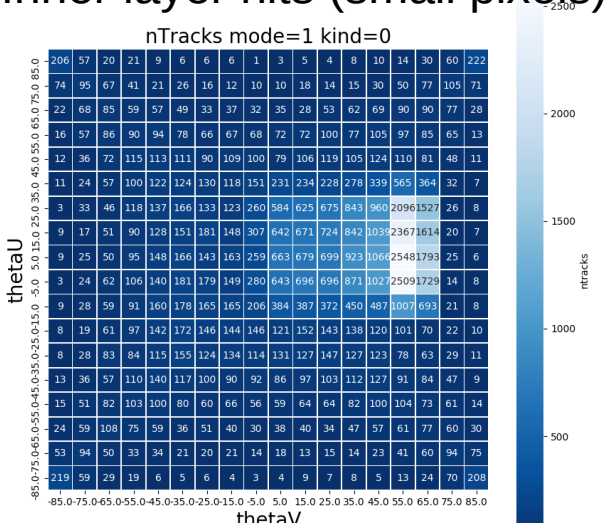
Conclusions

- Plans: Estimation of incidence angles from cluster shapes:
  - Separation of signal and background in angle (Θ_u / Θ_v) space.
  - Mainly because dominant bg components (like two photons) consist of low momentum (few MeV) particles that have wide range of incidence angles into PXD sensors.
  - Prototype implementation can be done quickly, because approach very similar to cluster shape position estimation
  - Potentially interesting for 6-layer tracking and BG studies

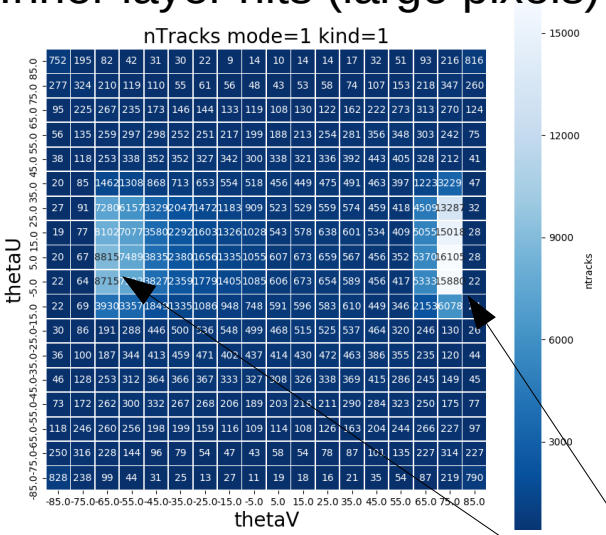
Backup

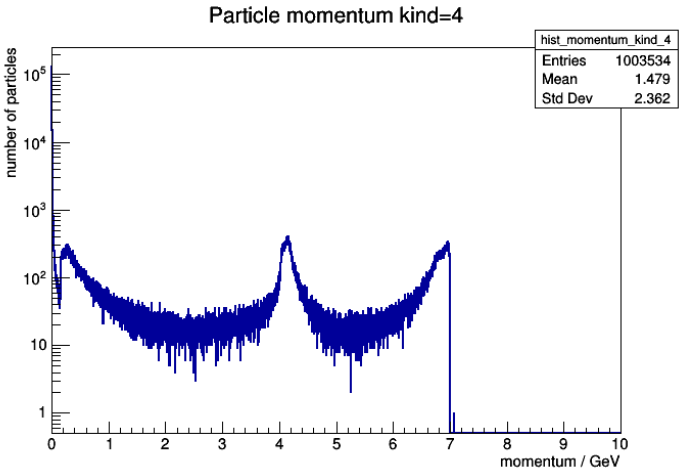
Hits from bg particles (BHWideLA) on PXD

Inner layer hits (small pixels)

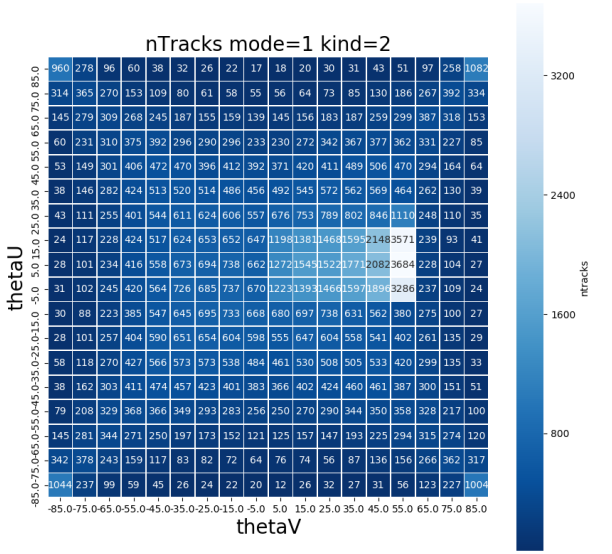


Inner layer hits (large pixels)

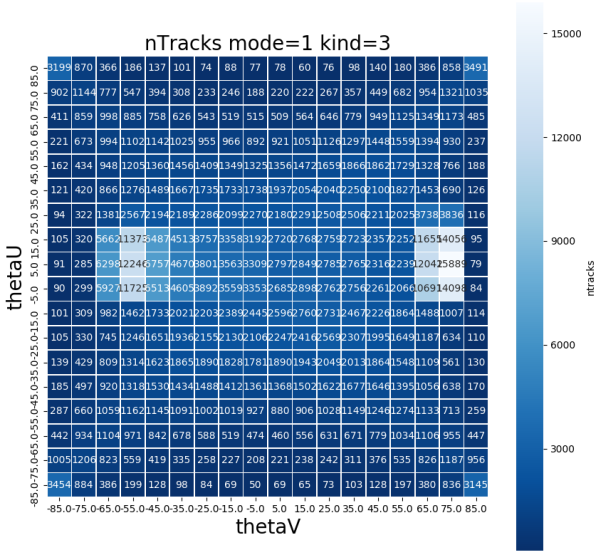




Outer layer hits (small pixels)



Outer layer hits (large pixels)



- Two components

a) High momentum e+e-

b) Low momentum particles

Residuals (z55 pixels, V direction) cluster shapes