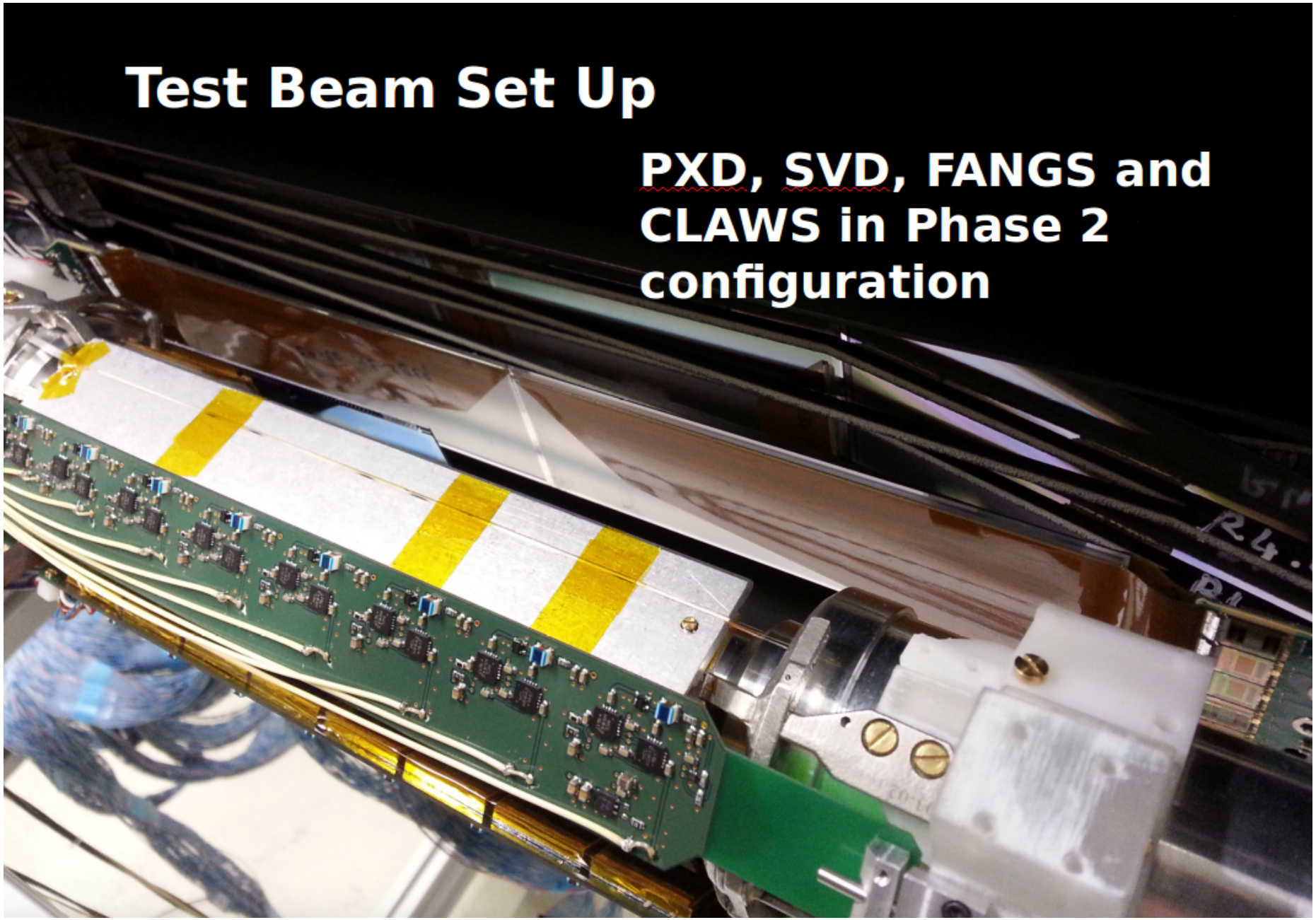
Outcome from DESY-TB February 2017

Benjamin Schwenker

II. Physikalisches Institut, Universität Göttingen

Belle II Trigger DAQ Workshop

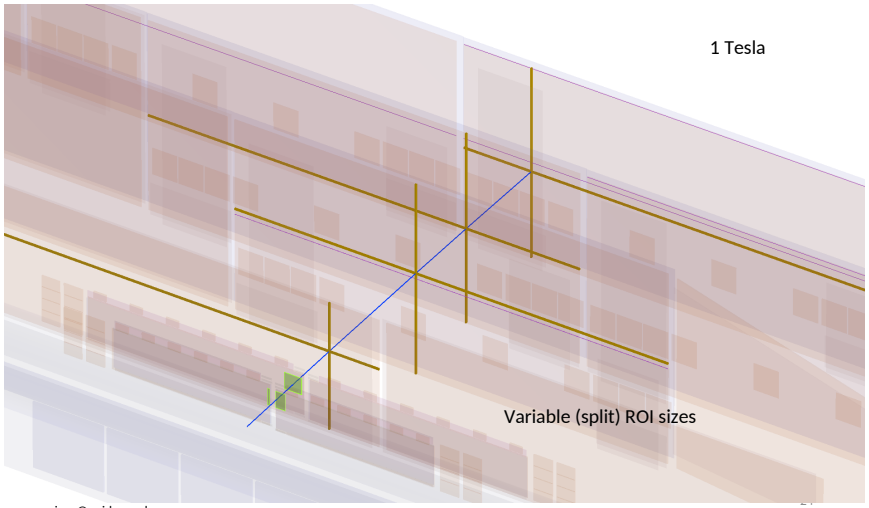
Test Beam Set Up



Track finding used for data reduction

- Belle II has two trigger stages:
  - hardware based trigger L1
  - High Level Trigger (HLT): software based trigger
- track finding algorithm will be used on the HLT to reduce the amount of data read out by the PXD
  - find tracks in the SVD
  - extrapolate found tracks to the PXD
  - define Regions Of Interest (ROI) on PXD sensors
  - read only PXD - hits found in ROI (data reduction factor $\approx 10\%$)

VXDTF2 Online ROI Selection



Definition of the Observables

➡ ***efficiency:*** *measurement of the fraction of Particles (with at least an associated RecoTrack and a PXDDigits) that have at least one PXDDigit inside and ROI*

$$\varepsilon_{PTD} = \frac{\text{\# Particles with at least one related RecoTrack and one related PXD Digit inside a ROI}}{\text{\# Particles with at least one related RecoTrack and one related PXD Digit}}$$

PTD = Particle with Track and Digit

➡ ***data reduction factor*** *(drf):* *measurement of the fraction of activated PXDDigits that are selected with ROI finding and that will be available for offline reconstruction*

$$\text{drf} = \frac{\text{\# PXDDigits inside the ROIs}}{\text{\# PXDDigits}}$$

PXDDigits are intended over threshold

➡ ***execution time:*** *time reported by the statistics at the end of the basf2 execution (ms/call)*

DRF with Run 111

Run number	RUN/TEST	Beam	Beam Energy [GeV]	Magnet	Magnet Field [T]	Cooling	Nominal C02 temperature [°C]	Geometry	Track finder	Trigger rate (in/out) [Hz]	Rotation [°]
111	COMBINED RUN	ON	5.0	OFF	NO	ON	-15	2 PXD	VXDTF	120	0

➡ *data reduction factor*

- choose a run with no ROI Finding running on HLT → Run111
- run tracking, ROI Finding and PXDDigit filtering *offline*

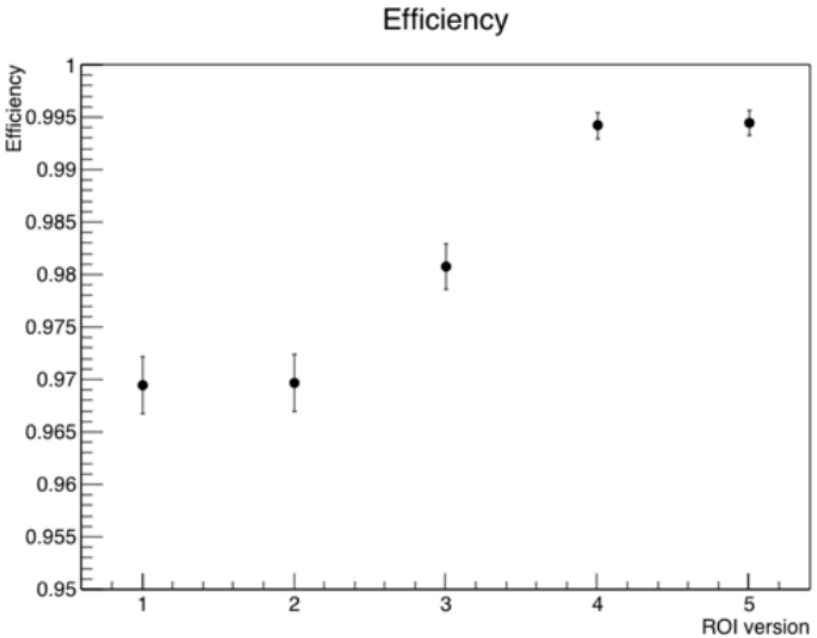
data → offline tracking → offline ROI finding

- 10k analysed events
- only PXD layer 1 data available
- average of 0.5 tracks per event
- average of ~1 intercepts per event (two per tracks)
- average of ~ 1 ROI per event, depending on ROI size

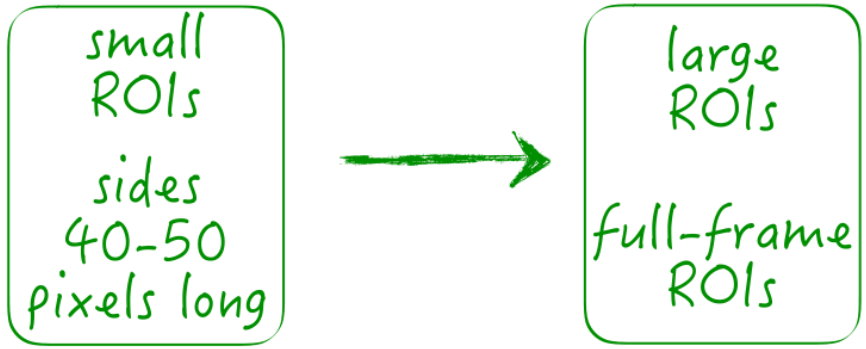
ROI Finding Efficiency at DESY

simulation

- Efficiency above 97% even for small ROIs
  - geometry is simple, high momentum tracks, low track multiplicity
  - inefficiencies due to:
    - lack of intercepts for v4, v5 (large ROIs)
    - too small ROIs for v1,v2,v3 (small ROis)



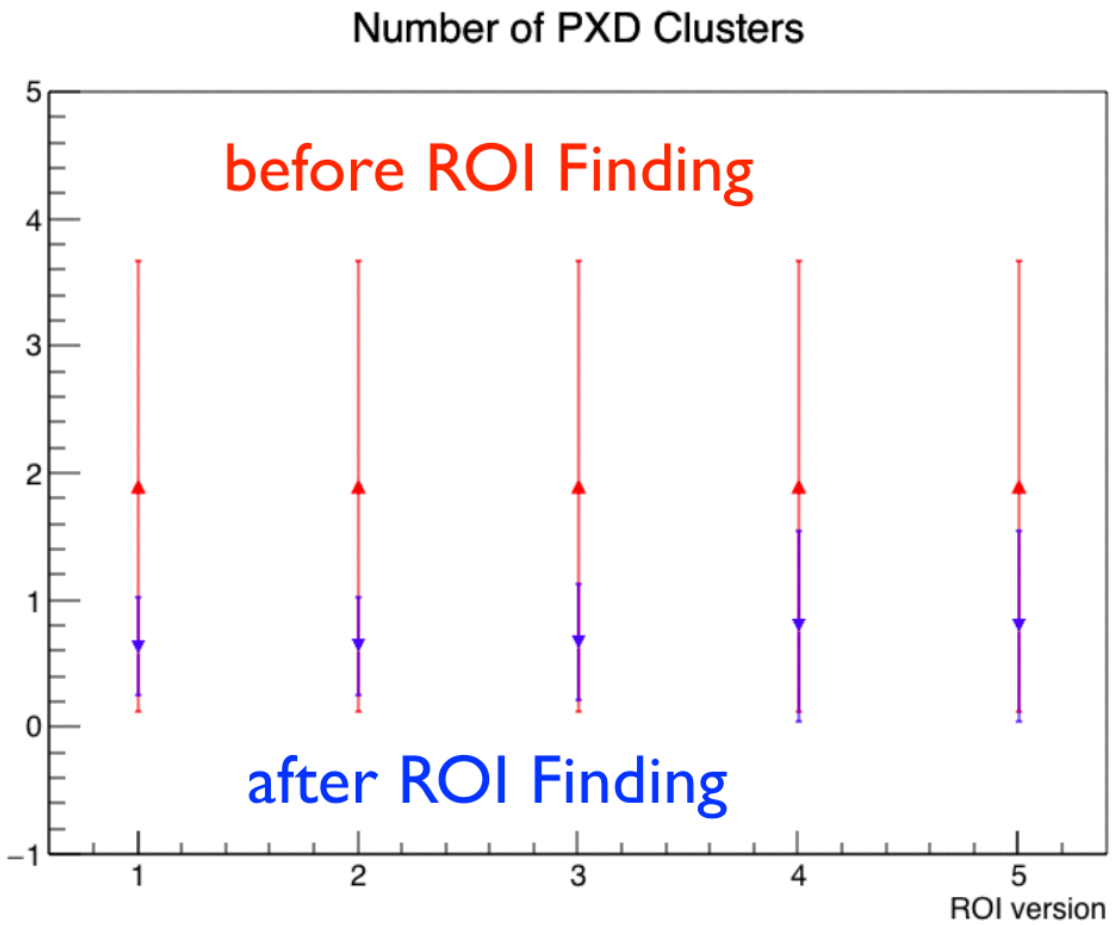
- Execution Time evaluated on simulated events at KEK, *not equivalent to the HLT*
- Tracking + PXD Data Reduction Execution time < 5ms/call, with large fluctuations (15ms/call)
  - included modules: pattern recognition (VXDTF1), track fitter, PXDDataReduction



Number of PXD Clusters

Run111

➡ Evaluated with testbeam data: the number of clusters is reduced, but most important the long tails of the umber of clusters distributions are cut away



PXD Hit efficiency after online data reduction

PXD Hit Efficiency

$$\varepsilon = \frac{\#\text{Matched track intersection inside ROI}}{\#\text{Track intersection inside ROI}}$$

Detail of analysis

- Analysis done on branch *feature/DESY_testbeam_Feb2017* forked from master at the beginning of the testbeam.
- Offline Analysis Chain: Unpacker → DigitSorter/RawHitSorter → Clusterizer → VXDTF1/2 → DAFRecoFitter → TrackCreator → PXDEfficiency.
- Use only runs with alignment included in *beamtest_vxd_april2017_rev1*, available since 27.06.17.
- Taking *ROIs* generated on HLT from the sroot-files.
- Analyzed runs before run 341, containing two PXD modules in the beam.
- All runs taken from the list of long, stable runs, processed the first $1,000,000$ events for each.
- https://confluence.desy.de/display/VBTA/Description+of+runs

Uwe Gebauer

PXD Hit Efficiency

$$\varepsilon = \frac{\#\text{Matched track intersection inside ROI}}{\#\text{Track intersection inside ROI}}$$

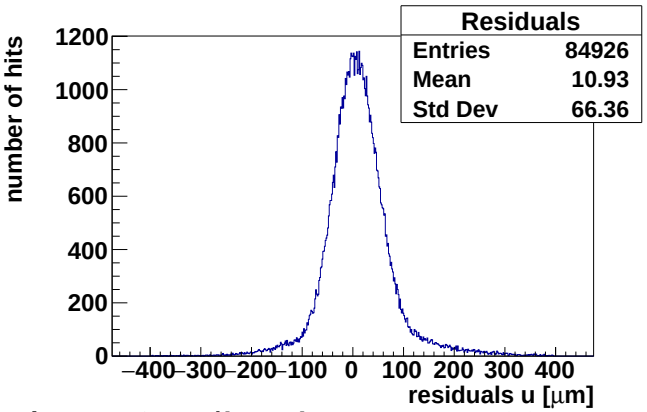
- Require events with exactly one fitted track with $1\ \mathrm{GeV} < |p_{fit}| < 8\ \mathrm{GeV}$ and fitted p-value $p > 0.01$.
- Require exactly one ROI on module in question, and require track intersection to lie inside.
- Match track intersections to hits with a distance of less than 400 $\mu\mathrm{m}$ on the PXD.

Comments

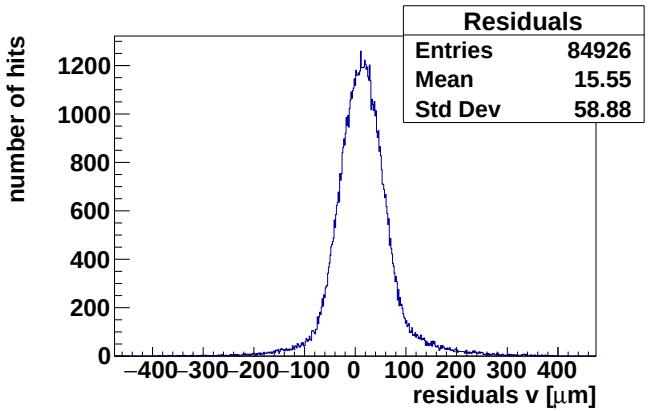
- Alignment used on HLT and during offline analysis different.
- Offline-tracking can produce more/different tracks than online-tracking. Ignore tracks outside ROIs.
- Outdated version of VXDTF2 in branch used. Plan to repeat study on current master.

Run 176

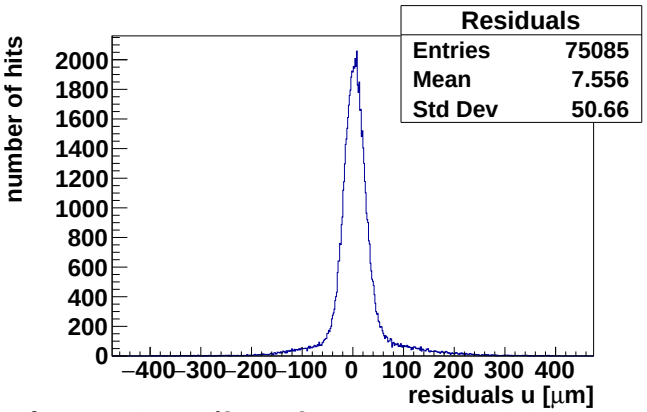
- Magnetic field 0.5T, beam energy 2.4 GeV
- Cross-check of alignment *beamtest_vxd_april2017_rev1*
- Residuals for VXDTF2



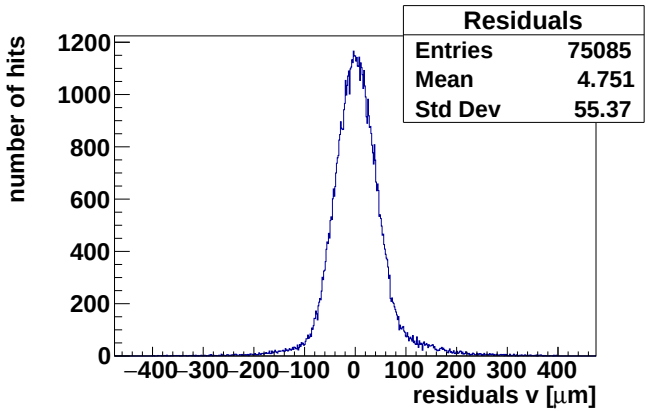
Layer 1 u-direction: $\sigma_{Fit} = 285\mu\mathrm{m}$



Layer 1 v-direction: $\sigma_{Fit} = 290\mu\mathrm{m}$



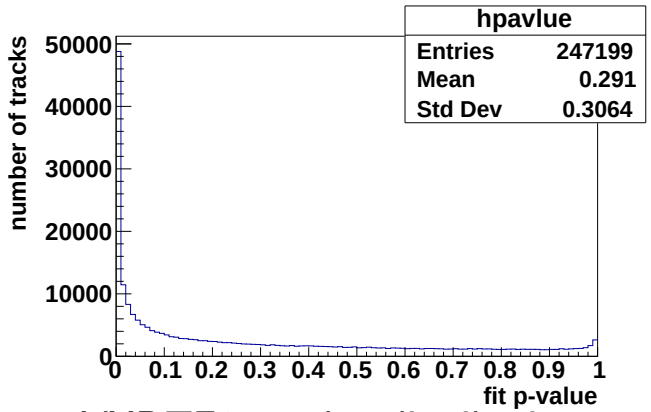
Layer 2 u-direction: $\sigma_{Fit} = 215\mu\mathrm{m}$



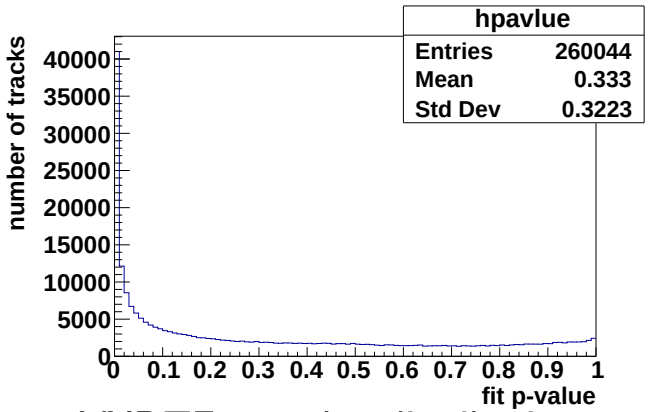
Layer 2 v-direction: $\sigma_{Fit} = 255\mu\mathrm{m}$

Run 176

- Magnetic field 0.5T, beam energy 2.4 GeV
- Cross-check of alignment *beamtest_vxd_april2017_rev1*



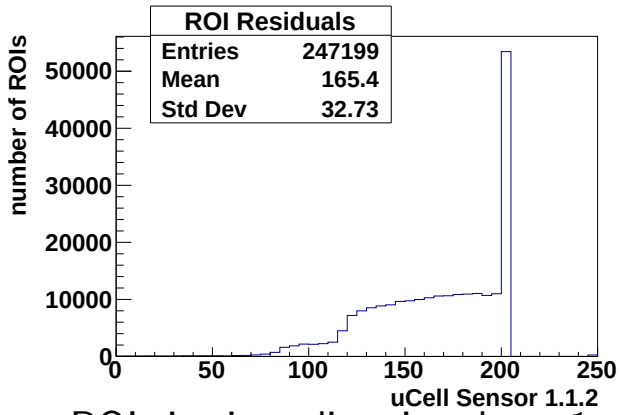
VXDTF1 p-value distribution



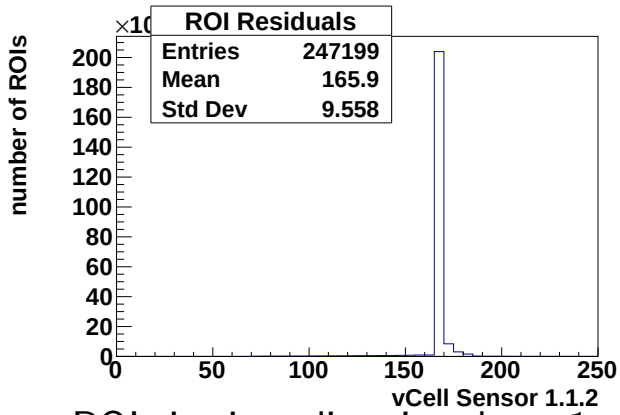
VXDTF2 p-value distribution

Run 176

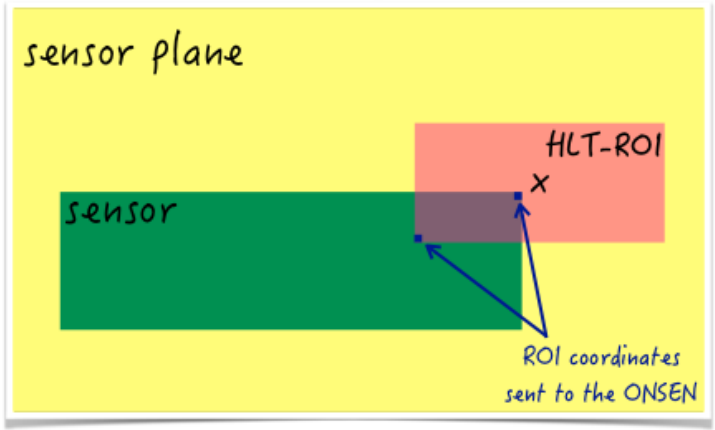
- In u-direction most ROIs lie partially outside the sensor, making the effective ROI smaller.
- For PXD efficiency study no ROIs with intercept outside the sensor area are accepted, limiting how small ROIs can be.



ROI size in u direction, layer 1

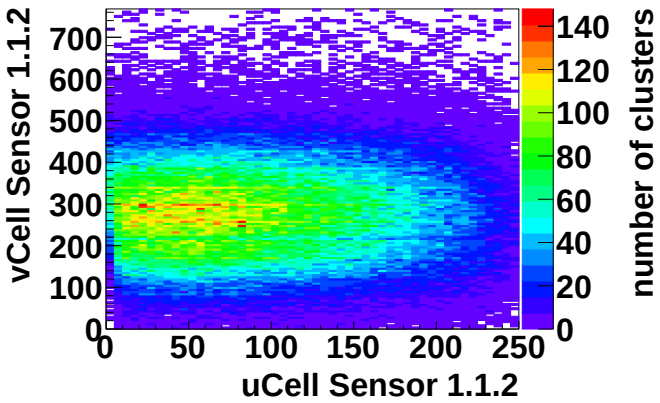


ROI size in v direction, layer 1

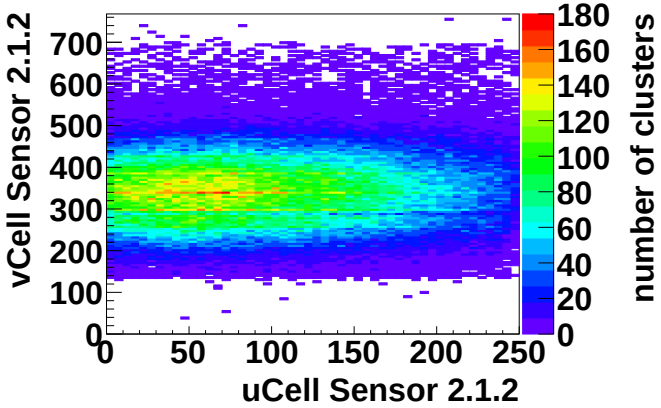


Run 176

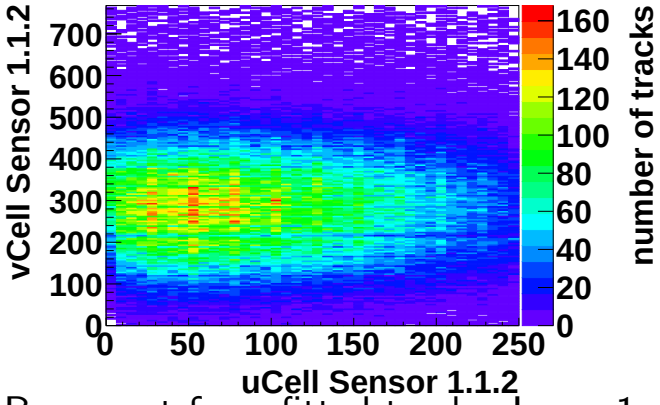
- Magnetic field 0.5T, beam energy 2.4 GeV, VXDTF1
- Beamspot from fitted tracks matches hitmap from sensor very well.



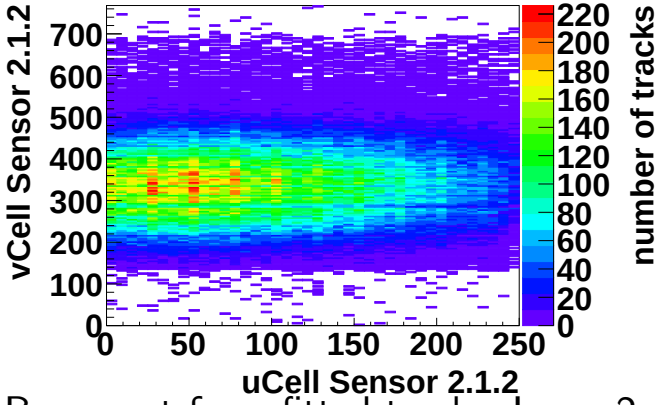
Hitmap of layer 1



Hitmap of layer 2



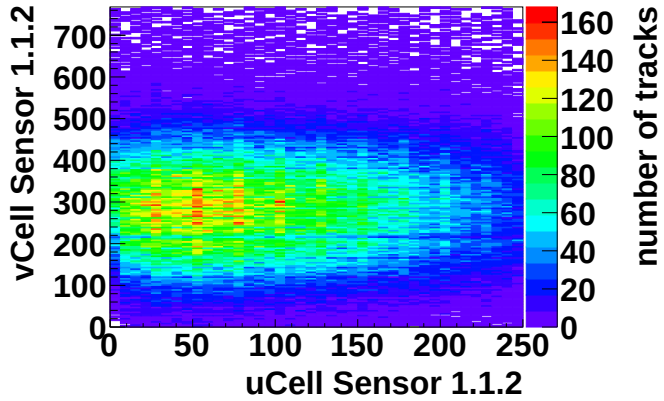
Beamspot from fitted tracks, Layer 1



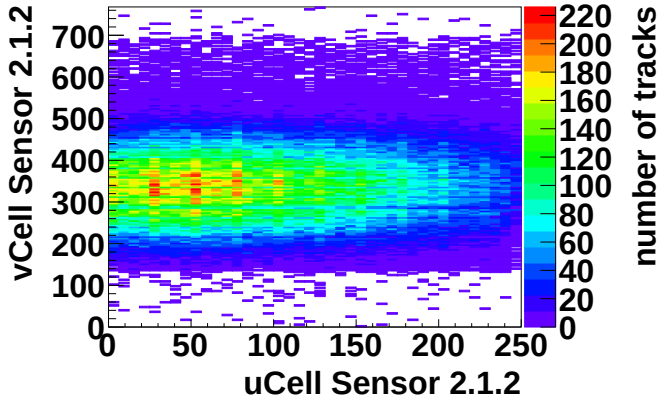
Beamspot from fitted tracks, Layer 2

Run 176

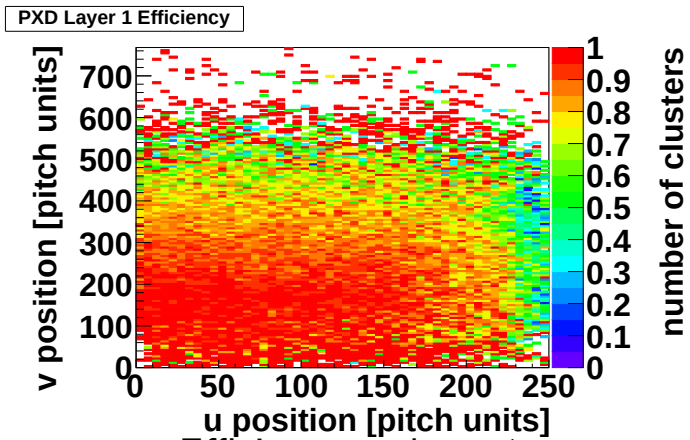
- Magnetic field 0.5T, beam energy 2.4 GeV, VXDTF1
- Area of maximal efficiency offset but similar in shape to beamspot



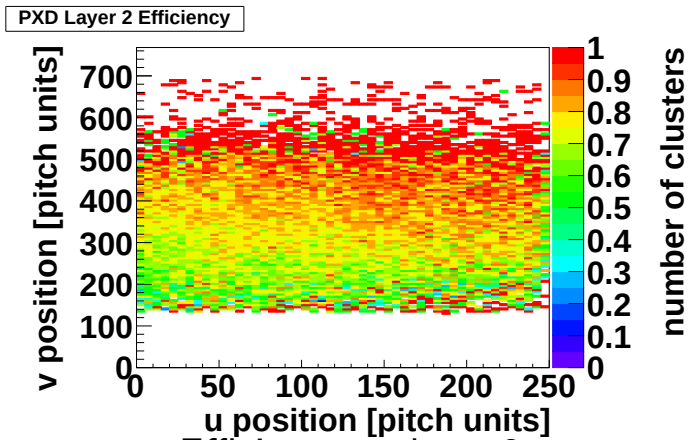
Beamspot from fitted tracks



Beamspot from fitted tracks



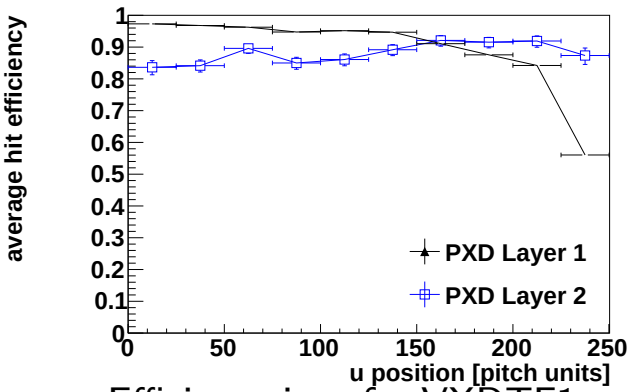
Efficiency on layer 1



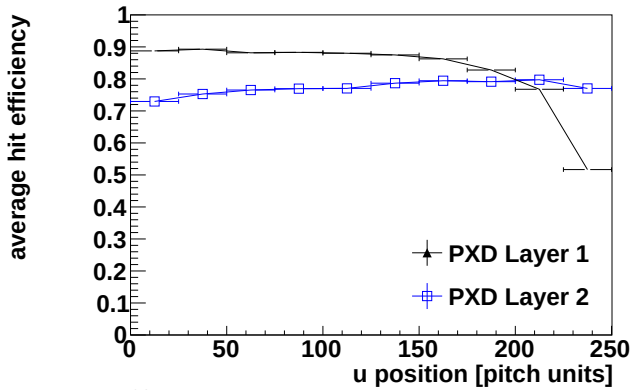
Efficiency on layer 2

Run 176

- Projecting the efficiency along the v-direction.
- Constraining the area to sub-range in v-direction:
- Layer 1: $100 < v < 200$
- Layer 2: $500 < v$



Efficiency in u for VXDTF1

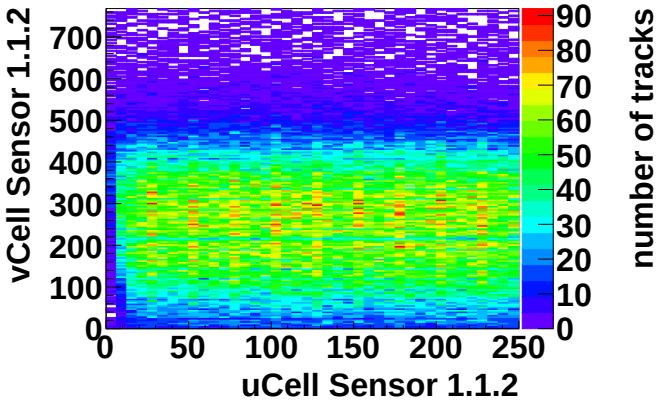


Efficiency without constraint

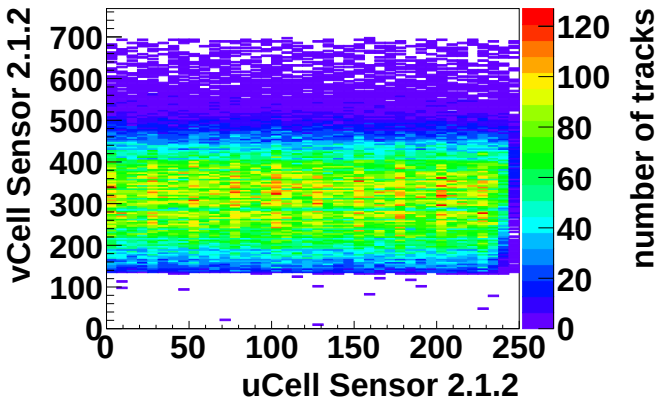
- Lower efficiency outside the selected v-region hard to explain from sensor side.
- Possible causes: Training of sector maps, misalignment, ...
- Open to suggestion for further investigations.

Run 195

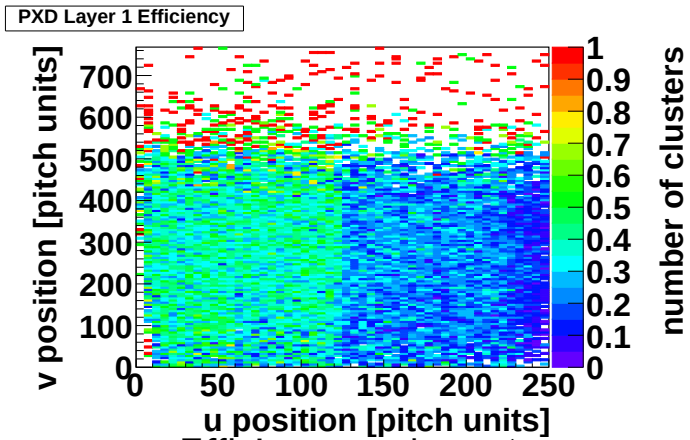
- Magnetic field 1T, beam energy 2.4 GeV, VXDTF1
- Many runs are like this: Efficiency much lower.
- Sharp edge with different efficiency: Problems during module operation?



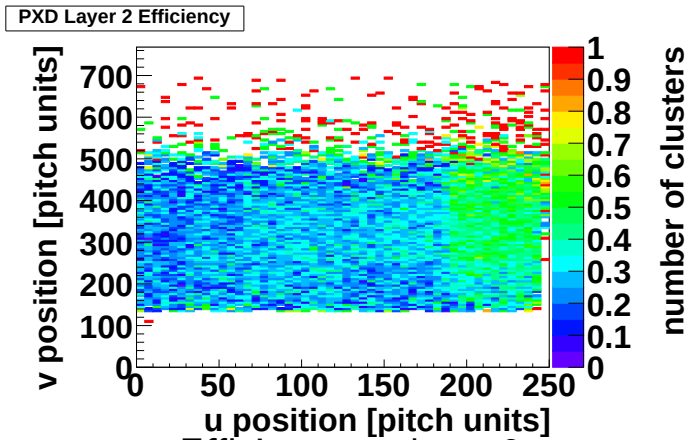
Beamspot from fitted tracks



Beamspot from fitted tracks



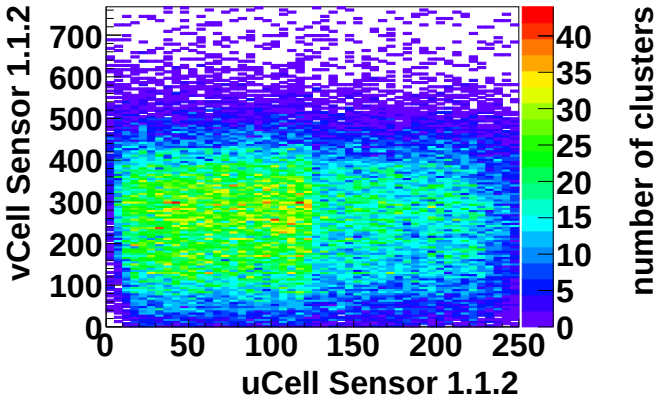
Efficiency on layer 1

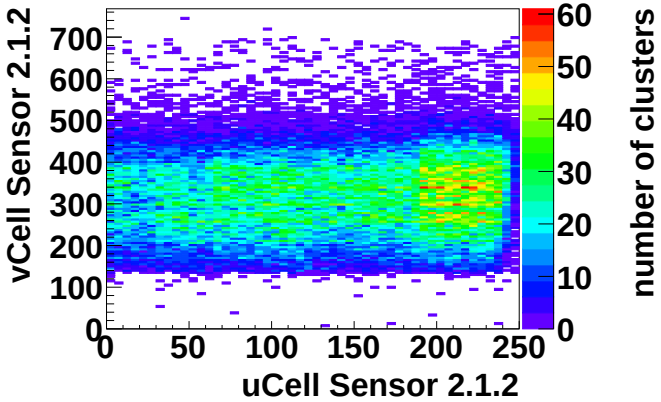


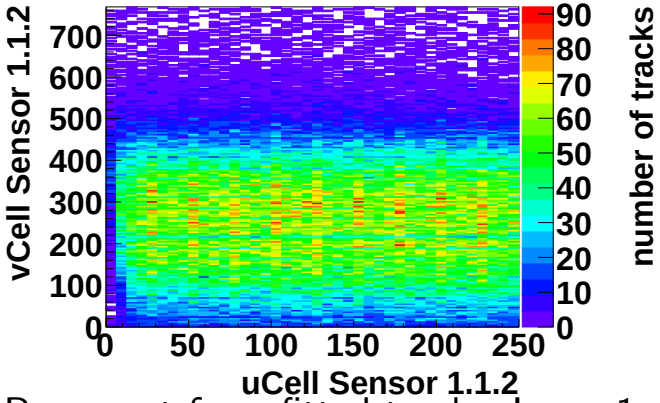
Efficiency on layer 2

Run 195

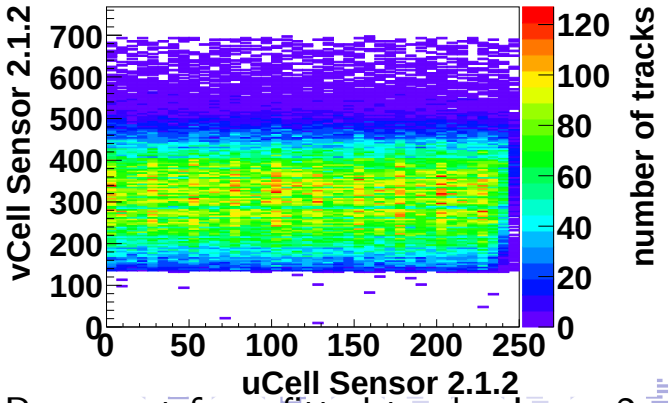
- VXDTF1
- Same effect observed on hitmap
- Some links died during operation on both modules during run, but logged information incomplete.







Beamspot from fitted tracks, Layer 1



Beamspot from fitted tracks, Layer 2

Conclusion

- ROI Finding software is in good shape, the algorithm has been tested on the main physics processes with complete machine background.
- The analysis of DESY testbeam data has been performed confirming results of past testbeams.
- Measured PXD efficiency is highly run-dependant. Hard to follow what changed between runs: Magnetic field, energy, HLT scripts, PXD configuration
- In selected runs with online data reduction, observe high PXD efficiencies ($> 97\%$)
- VXDTF2 (from testbeam branch) ran smoothly on HLT at the end of the testbeam.
- VXDTF2 (from testbeam branch) also usable for the offline scripts.

The End

Thank you for your attention!

Appendix

ROI Settings

➡ ROI Finding is run offline for this study → can change the parameters

- width = (# sigma) x $\sqrt{(syst^2 + stat^2)}$
- minimum width = # sigma x syst

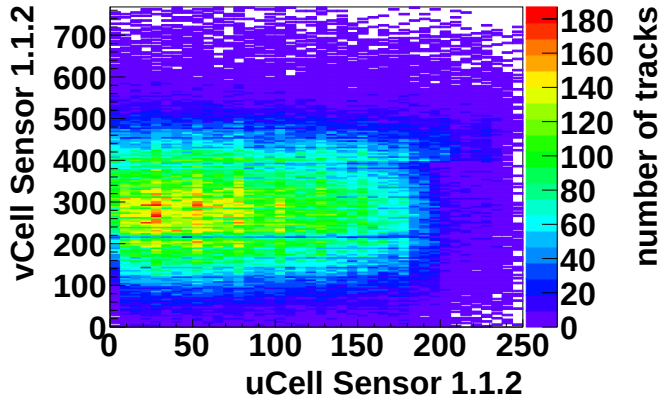
small ROIs

large ROIs

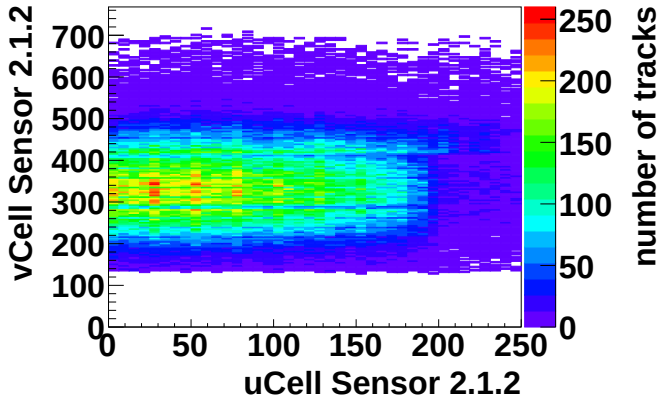
ROI	# sigma	syst	max width U	max width V	minimum width U&V
v1	10	0.25 mm	5 mm	1.5 cm	2.5 mm
v2	10	0.25 mm	1 cm	3 cm	2.5 mm
v3	10	0.5 mm	1 cm	3 cm	5 mm
v4	10	5 mm	10 cm	10 cm	5 cm
v5	10	5 mm	10 cm	30 cm	5 cm

Run 176

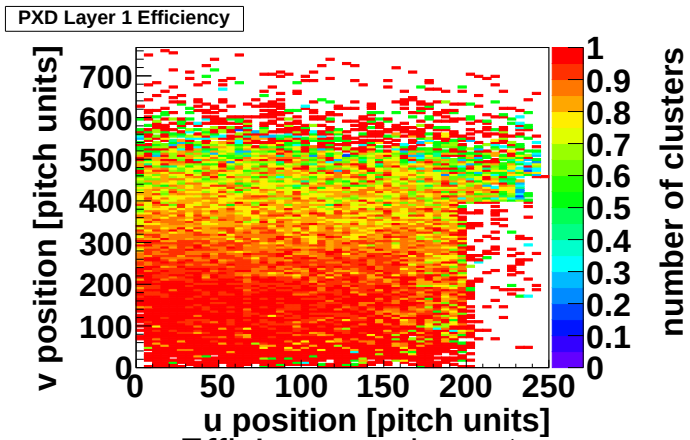
- Magnetic field 0.5T, beam energy 2.4 GeV, VXDTF2
- With VXDTF2 strange area of low efficiency in lower right corner



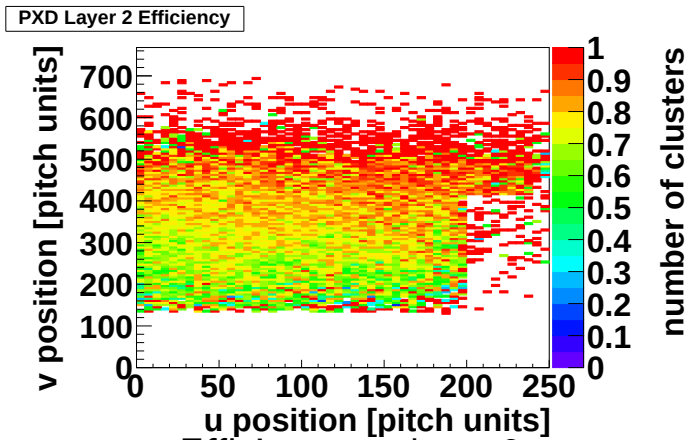
Beamspot from fitted tracks



Beamspot from fitted tracks



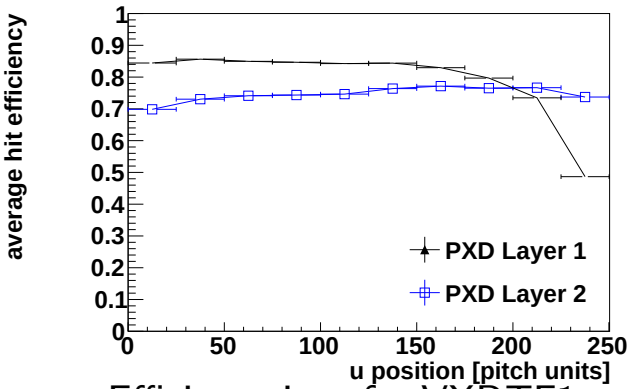
Efficiency on layer 1



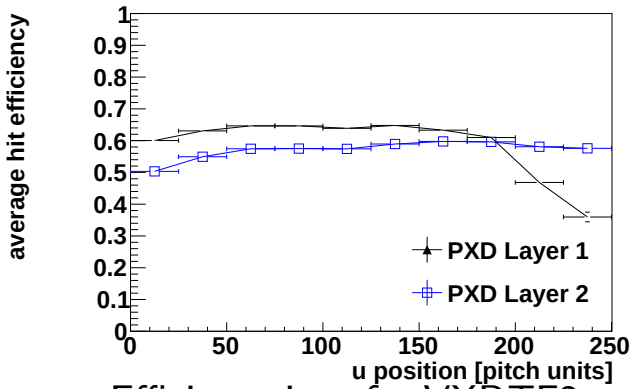
Efficiency on layer 2

Run 176

- When not requiring the fitted track to lie inside the ROI, measured efficiency with VXDTF2 drops drastically.
- Not applying constraint in v here.



Efficiency in u for VXDTF1

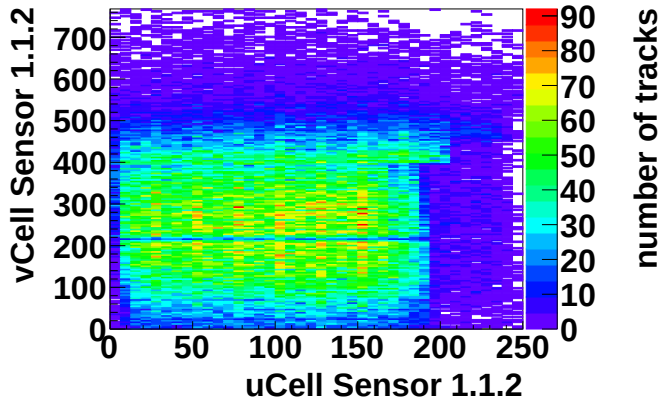


Efficiency in u for VXDTF2

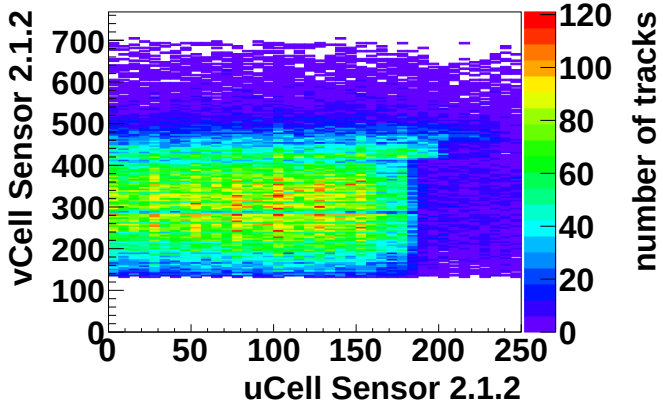
- Even if correct track found, if not passing through a ROI no hit information is saved.
- ROIs are determined with VXDTF1 on HLT, so finds mostly the same tracks as were used there.
- If VXDTF2 finds different tracks than VXDTF1, these will not pass through the ROI and have no chance of being matched.

Run 195

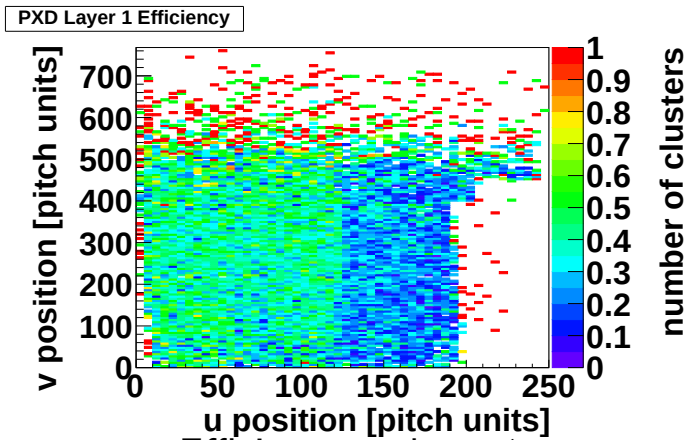
- VXDTF2
- Again observe lower right corner as much less efficient: Some sector-map effect?



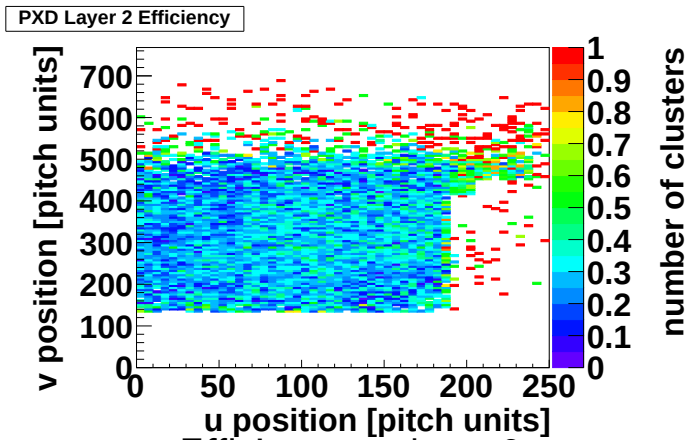
Beamspot from fitted tracks



Beamspot from fitted tracks



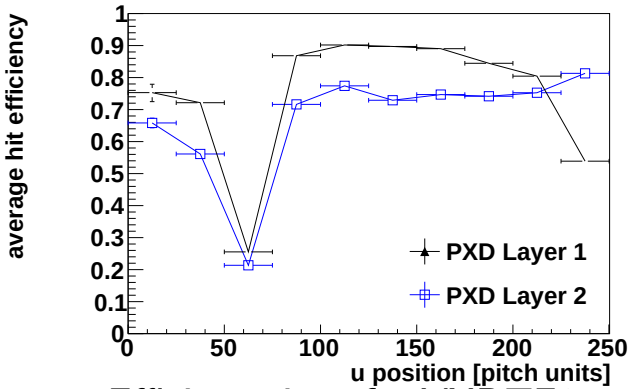
Efficiency on layer 1



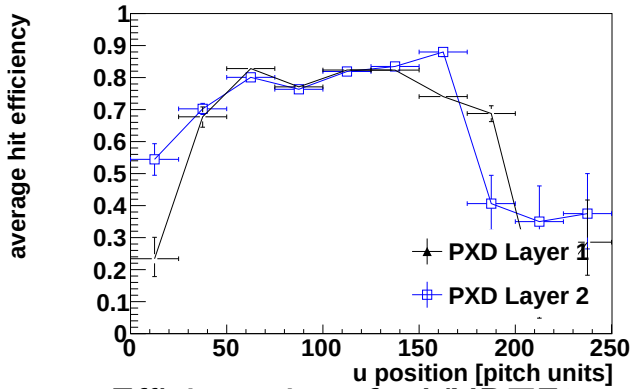
Efficiency on layer 2

Run 236

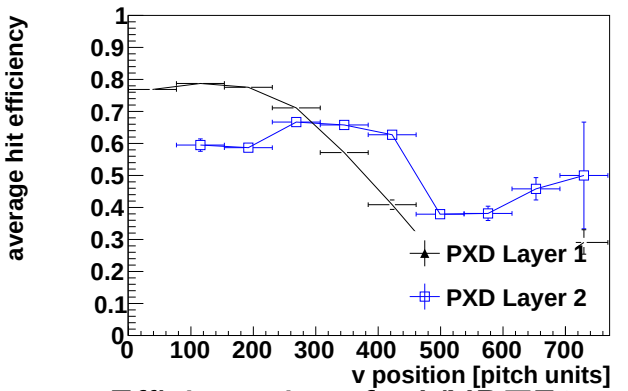
- Magnetic field 1 T, beam energy 1 GeV
- Minimal fitted momentum reduced to 0.5 GeV



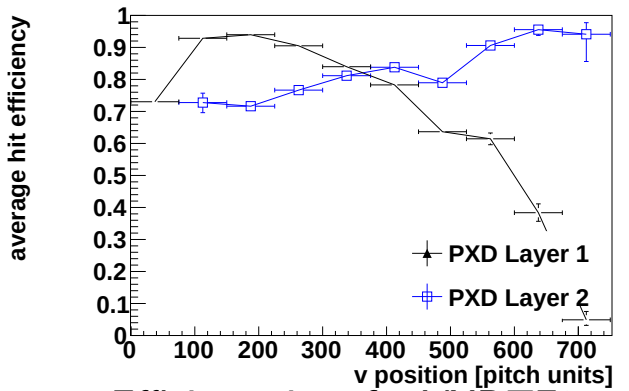
Efficiency in u for VXDTF1



Efficiency in u for VXDTF2



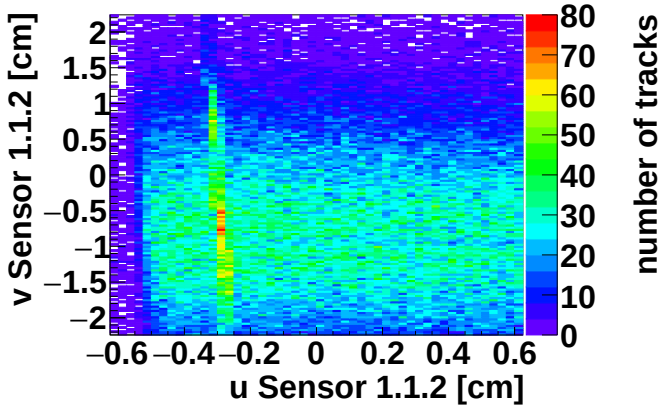
Efficiency in v for VXDTF1



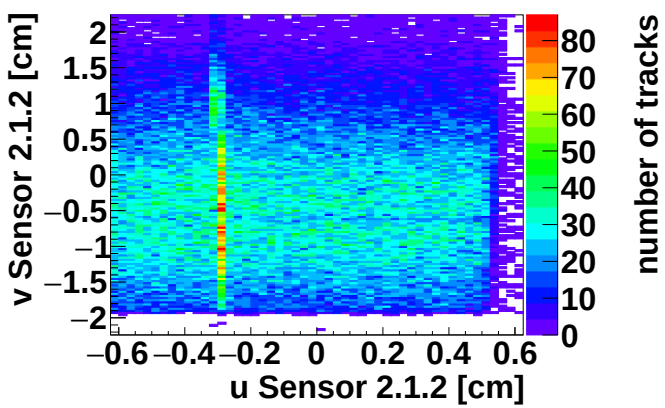
Efficiency in v for VXDTF2

Run 236

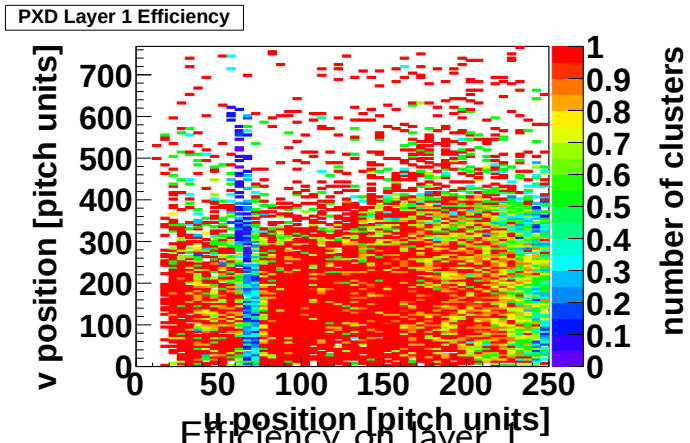
- VXDTF1



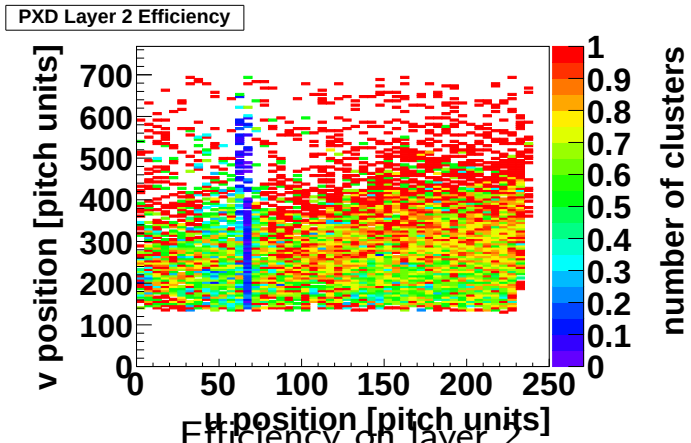
Beamspot from fitted tracks



Beamspot from fitted tracks



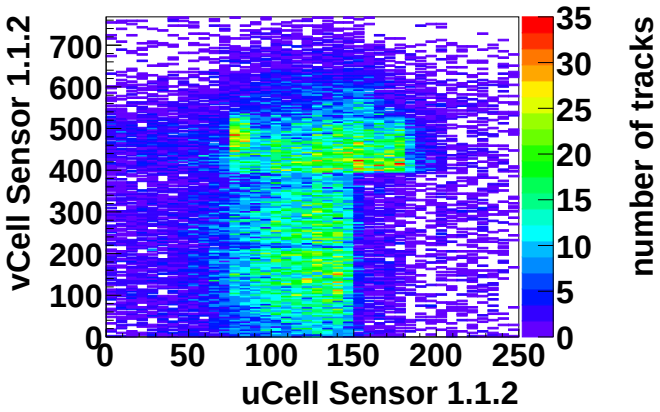
Efficiency on layer 1



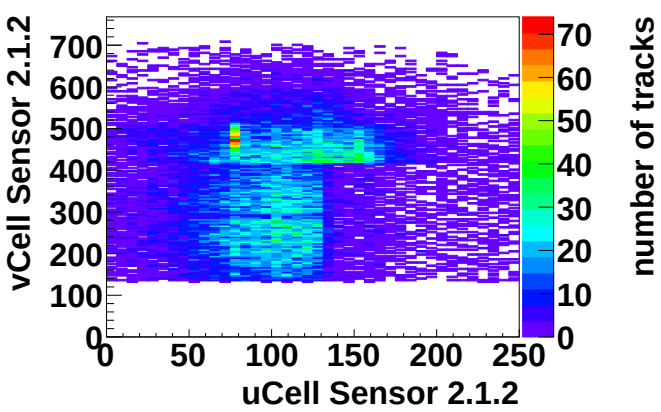
Efficiency on layer 2

Run 236

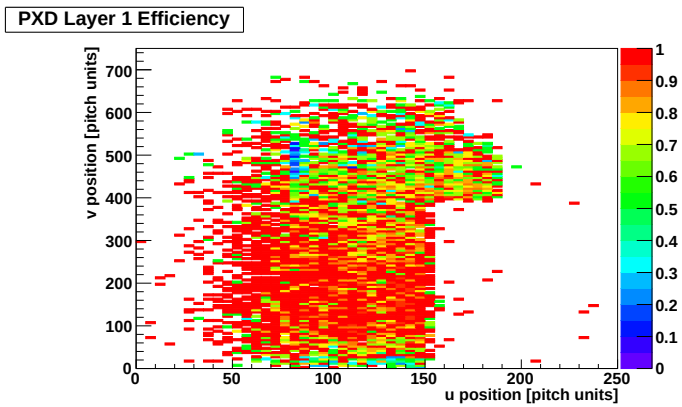
- VXDTF2



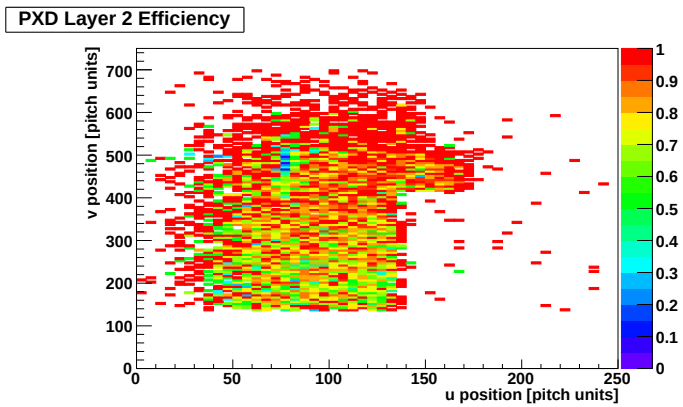
Beamspot from fitted tracks



Beamspot from fitted tracks



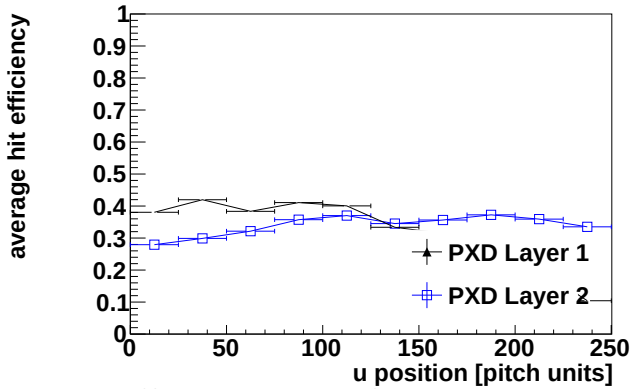
Efficiency on layer 1



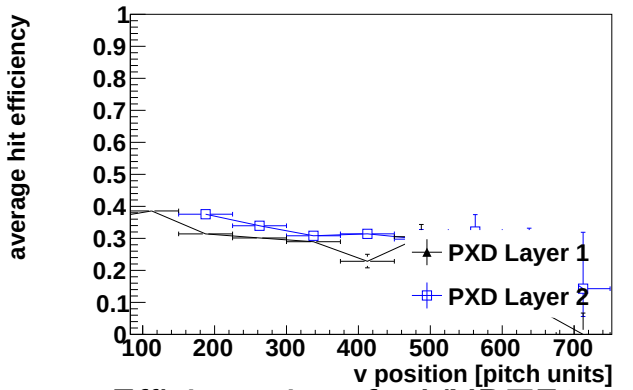
Efficiency on layer 2

Run 250

- Magnetic field 1 T, beam energy 2.4 GeV
- Analysis fails with VXDTF2



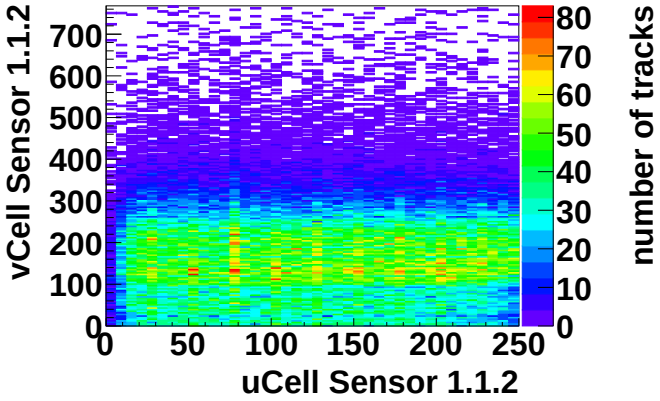
Efficiency in u for VXDTF1



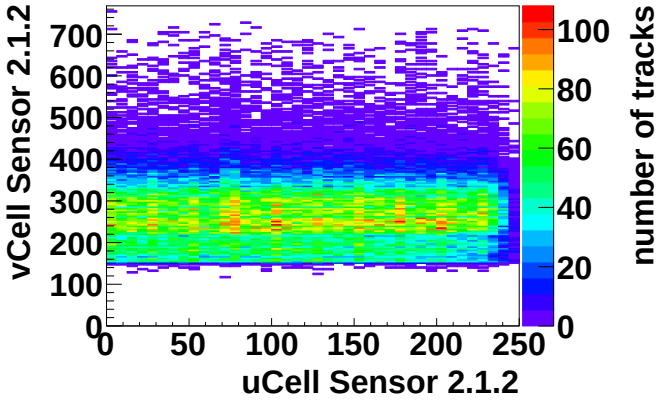
Efficiency in v for VXDTF1

Run 250

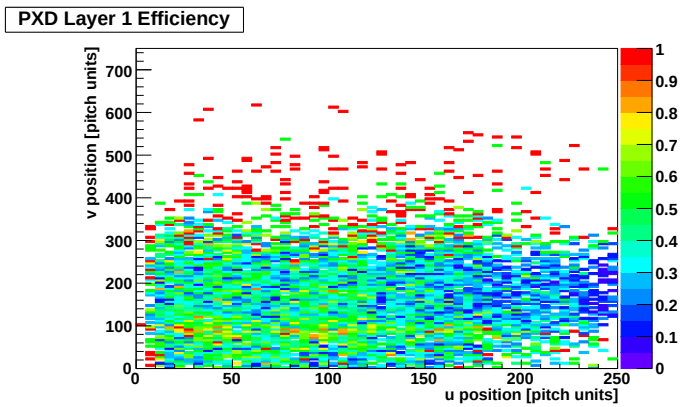
- VXDTF1



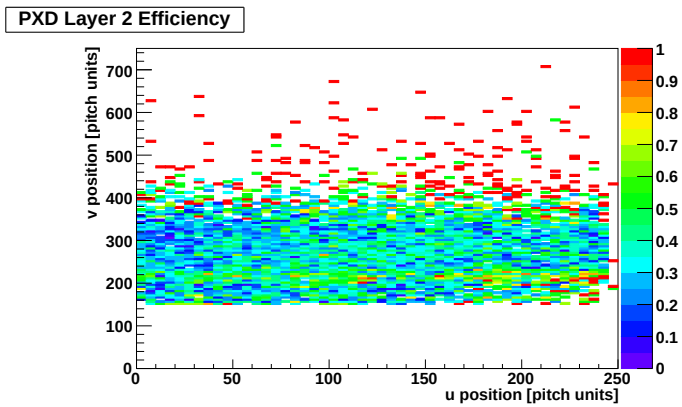
Beamspot from fitted tracks



Beamspot from fitted tracks



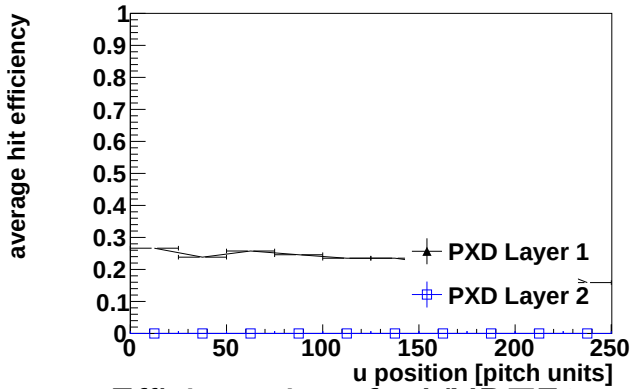
Efficiency on layer 1



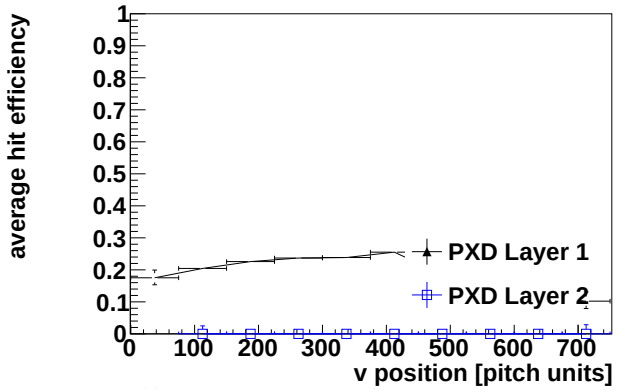
Efficiency on layer 2

Run 111

- No magnetic field, beam energy 5 GeV
- Only layer 1 taking data, full-frame dummy ROIs sent
- Analysis fails with VXDTF2



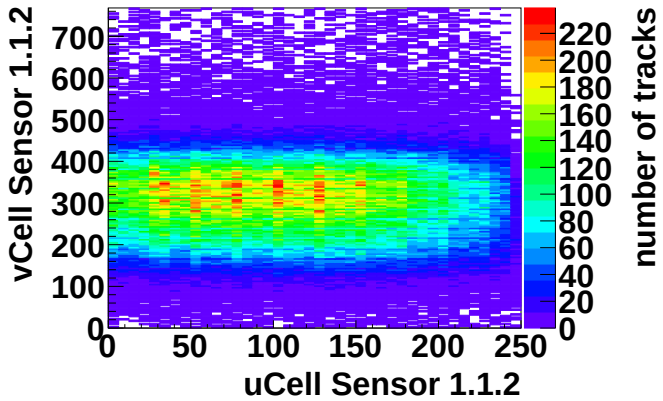
Efficiency in u for VXDTF1



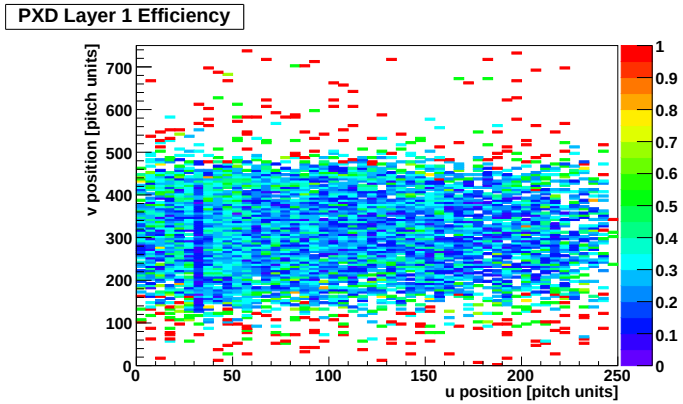
Efficiency in v for VXDTF1

Run 111

- VXDTF1



Beamspot from fitted tracks



Efficiency on layer 1