PXD test beam performance

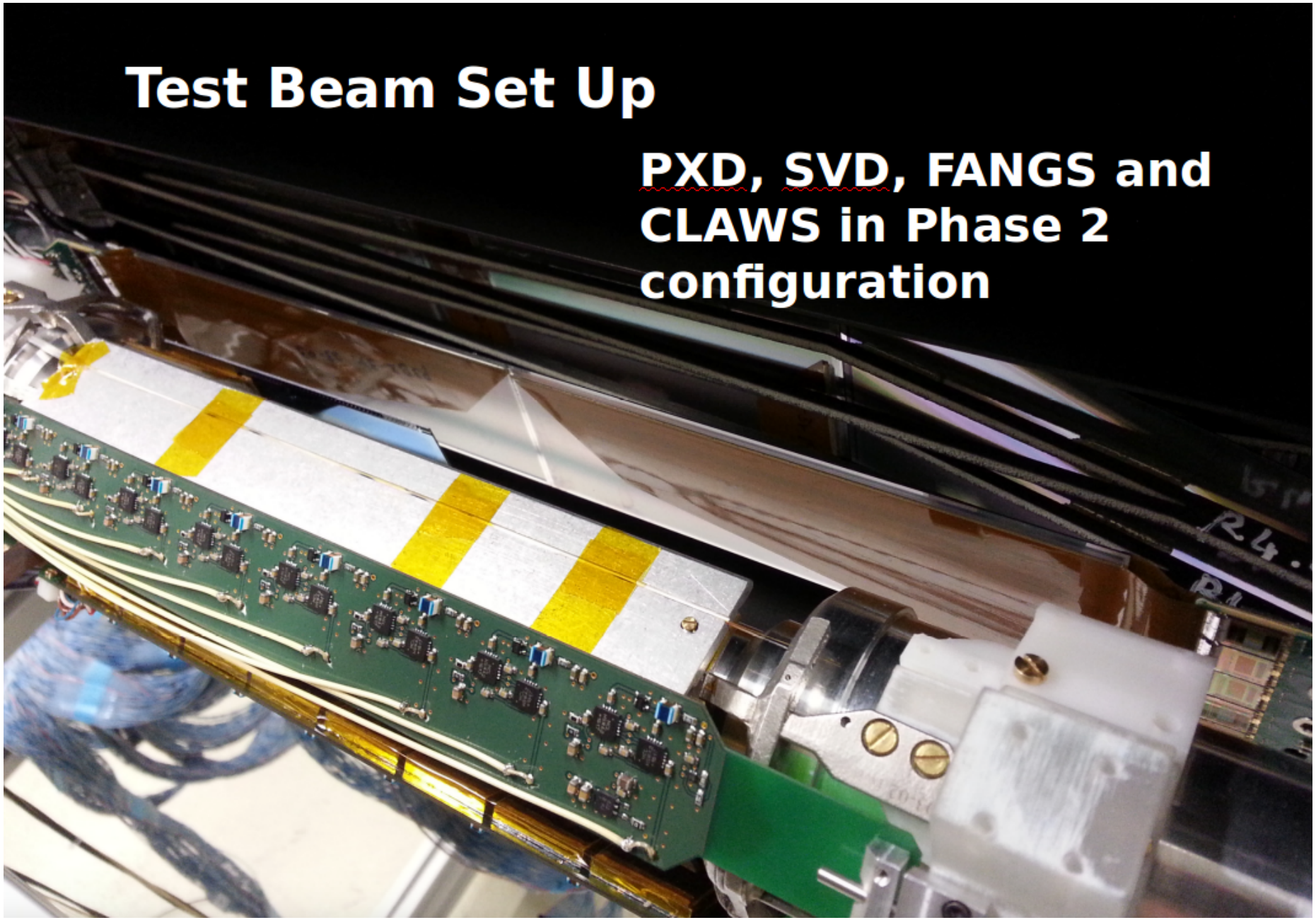
Benjamin Schwenker

II. Physikalisches Institut, Universität Göttingen

BPAC focused review on VXD

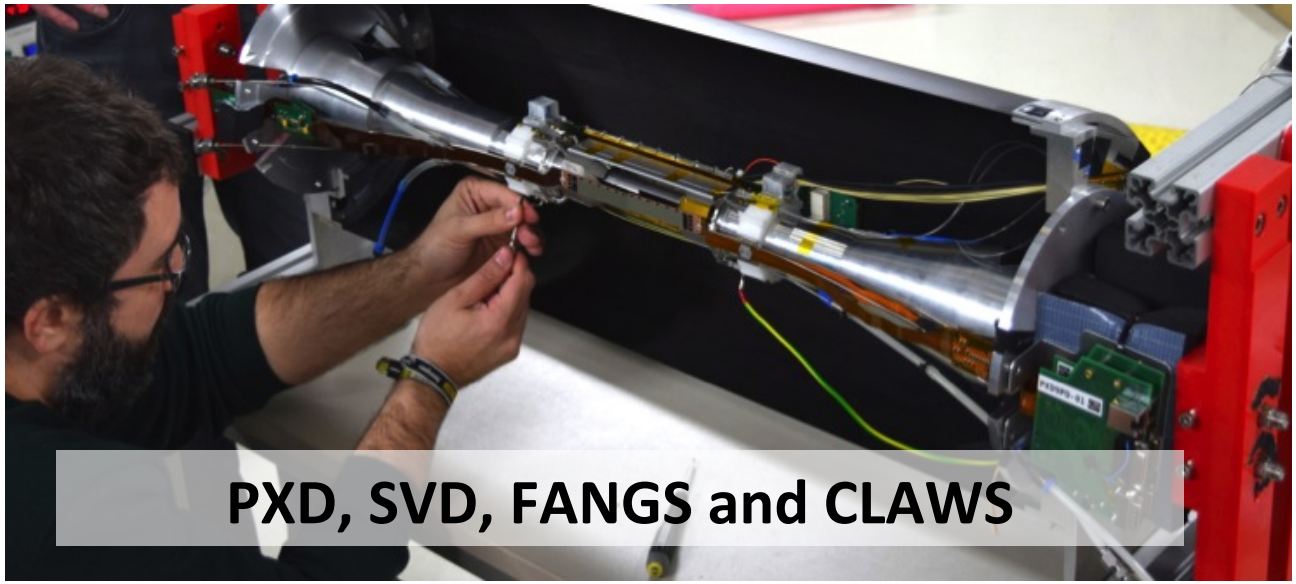
GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

Test Beam Set Up



VXD combined beam tests at DESY (2016+2017)

- **4 GeV electron beam**
- **4 SVD layers** + **2 PXD layers** in **1 T magnetic field**
- Full data acquisition chain
- Belle II slow control system
- CO_2 cooling



Combined Phase 2 operation successfully demonstrated during the beam test

Improvements on PXD DAQ in TB17

Achievement #1: Onsen running stable for 10^9 events, some runs up to 15h, ~1500 sroot files (3.5TB)
Few kHz trigger

Achievement #2: final ONSEN hardware used in test beam

Achievement #3: Almost final ONSEN firmware
(merger, selector, carrier board)
Missing: handling of hardware cluster from DHH

Achievement #3: Re-Mapping implemented, online decoding of DHP frames

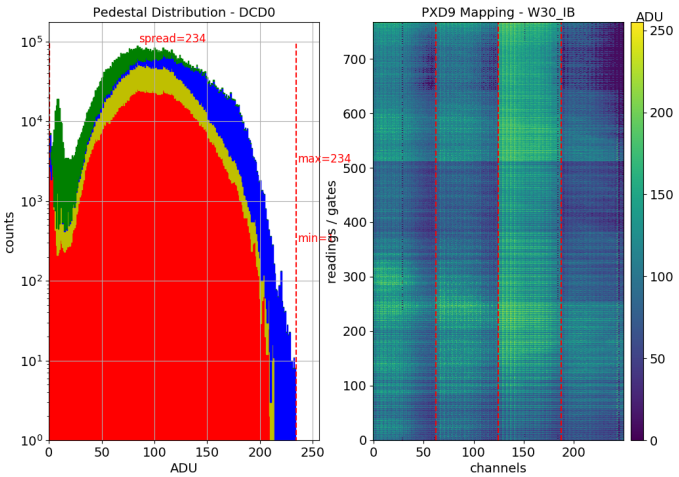
Mapping from cols → ucell is 2 x 'mirrored'

Re-Mapping allowed sending small ROIs and data reduction as default.

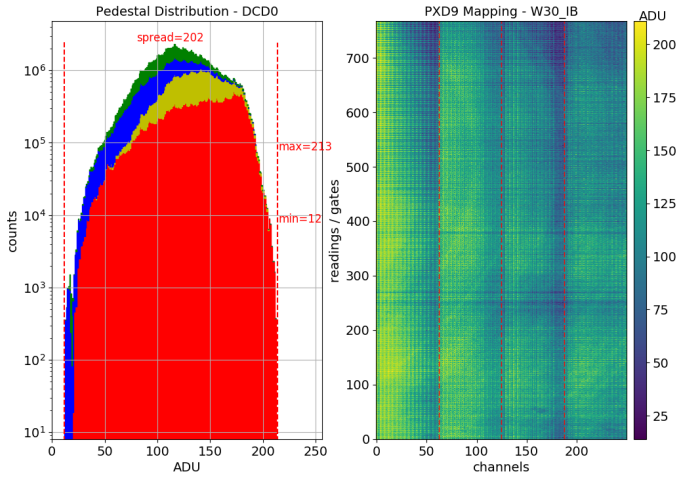
(S. Lange)

PXD calibration in local runs

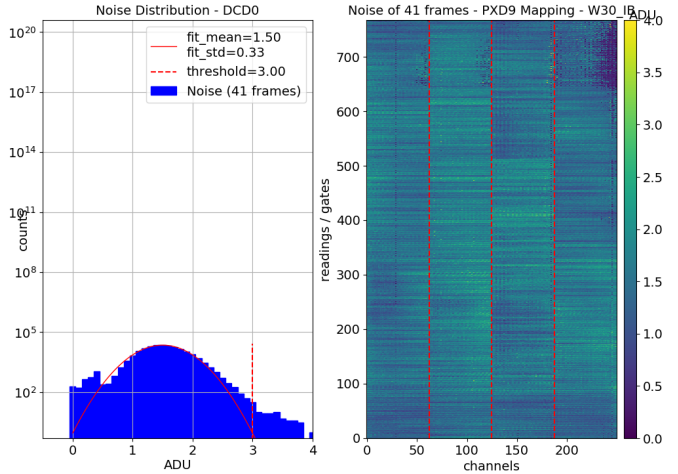
W35_0B1

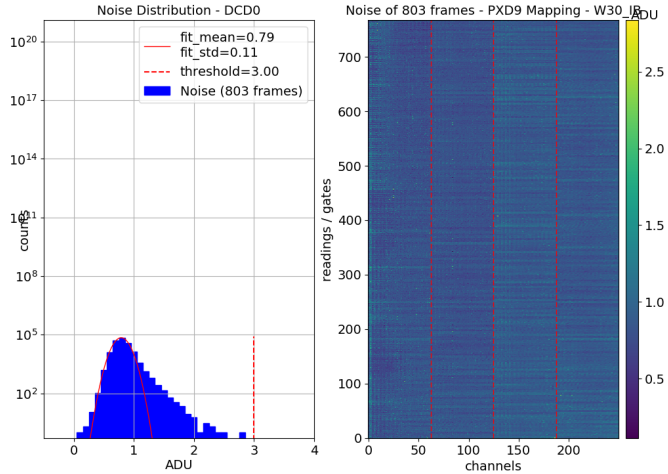


W30_IB



Compute pedestals/pixel masks in local runs (using BonnDAQ)
Upload constants to ConfigDB; then used for PXD configuration at run start

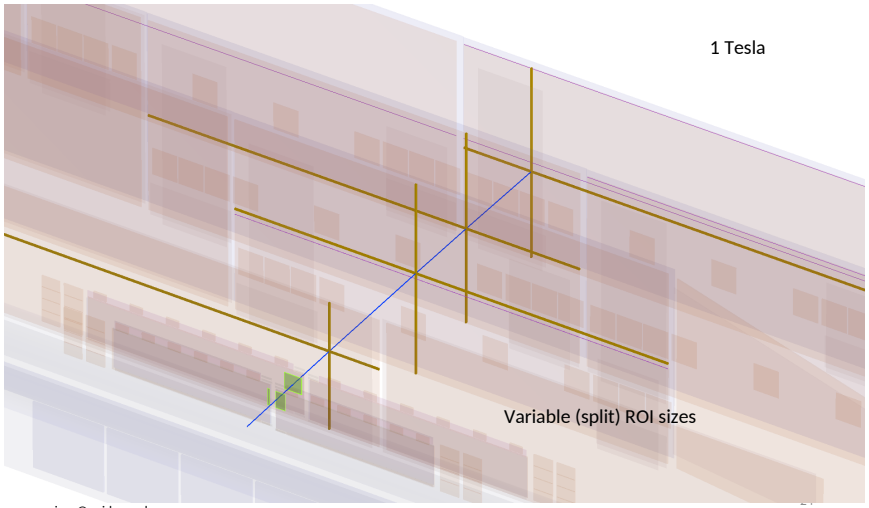




Track finding used for data reduction

- 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



PXD Hit efficiency after online data reduction

Detail of analysis

- Analysis done on master branch with up to date tracking code.
- basf2 path: Unpacker $\rightarrow$ RawHitSorter $\rightarrow$ Clusterizer $\rightarrow$ VXDTF1/2 $\rightarrow$ DAFRecoFitter $\rightarrow$ TrackCreator $\rightarrow$ PXDEfficiency.
- Use only runs with alignment included in *beamtest_vxd_april2017_rev1*, available since 27.06.17.
- All runs taken from the list of long, stable runs. Processed at least $1,000,000$ events.
- https://confluence.desy.de/display/VBTA/Description+of+runs

Uwe Gebauer, University of Göttingen

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 HLT 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

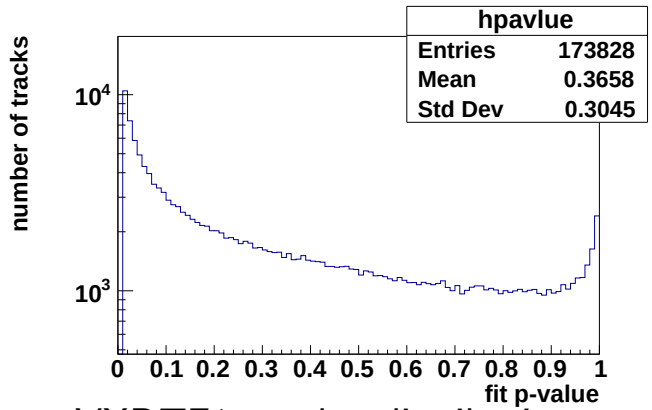
- Problems in PXD DAQ (data losses, event mixing, event mismatch etc.) always show up as bad efficiencies.
- Efficiency study for runs w/ small HLT ROIs sent to ONSEN and online data reduction ON.

Run 176

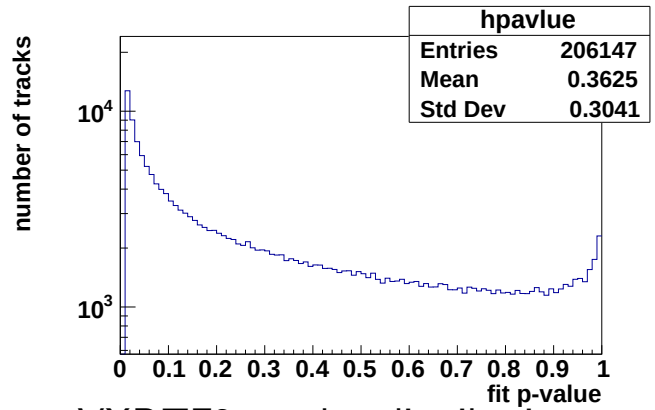
- Magnetic field 0.5T, beam energy 2.4 GeV
- Geometry 1 with sensors 1.1.2 (W30_IB) and 2.1.2 (W35_OB1) in the beam, the same as in TB16.

Comments

- Earlier analysis greatly hindered by alignment being available only with great delay.
- Quality of fitted tracks from VXDTF version 1 and 2 (SVD-only track finding)



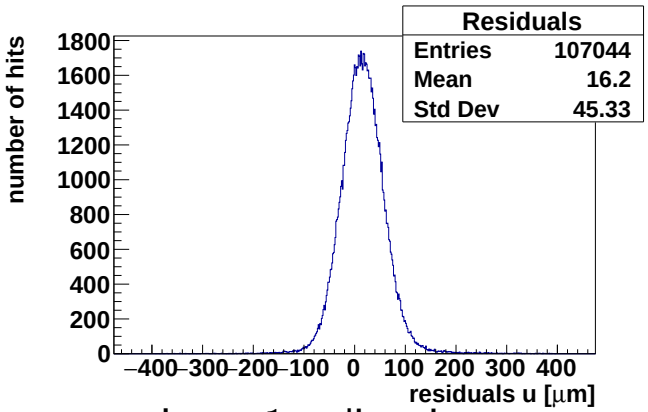
VXDTF1 p-value distribution



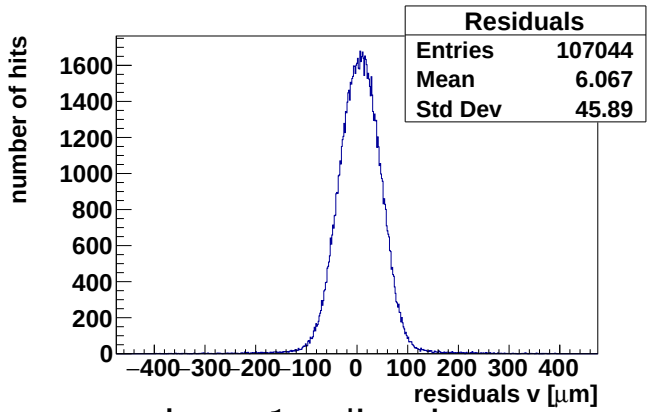
VXDTF2 p-value distribution

Run 176

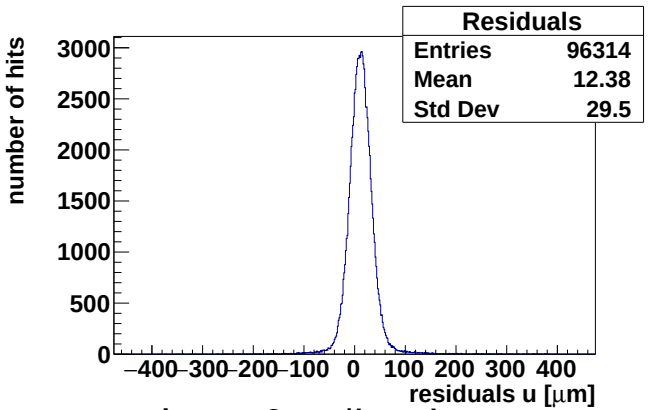
- Residuals from VXDTF2 tracking
- Offsets of the mean on the order of $5 - 20\mu\mathrm{m}$
- RMS values are roughly in the order of the pixel pitch



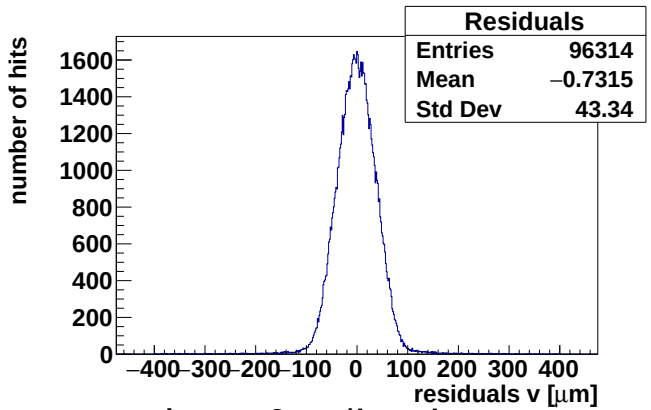
Layer 1 u-direction



Layer 1 v-direction



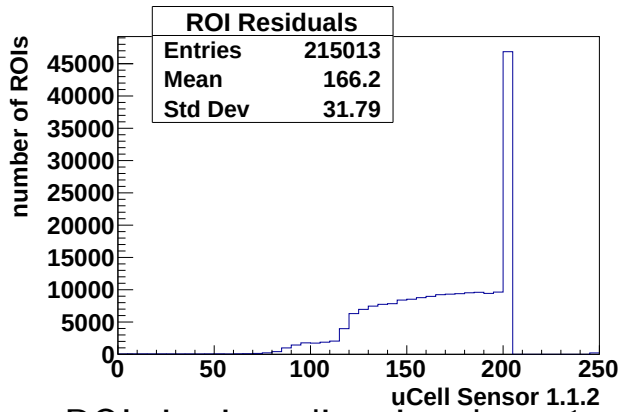
Layer 2 u-direction



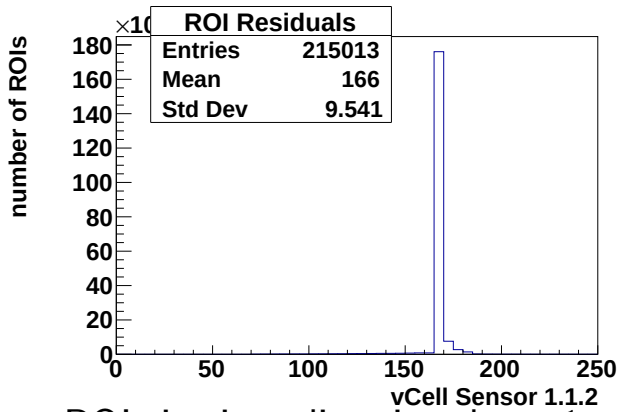
Layer 2 v-direction

Run 176

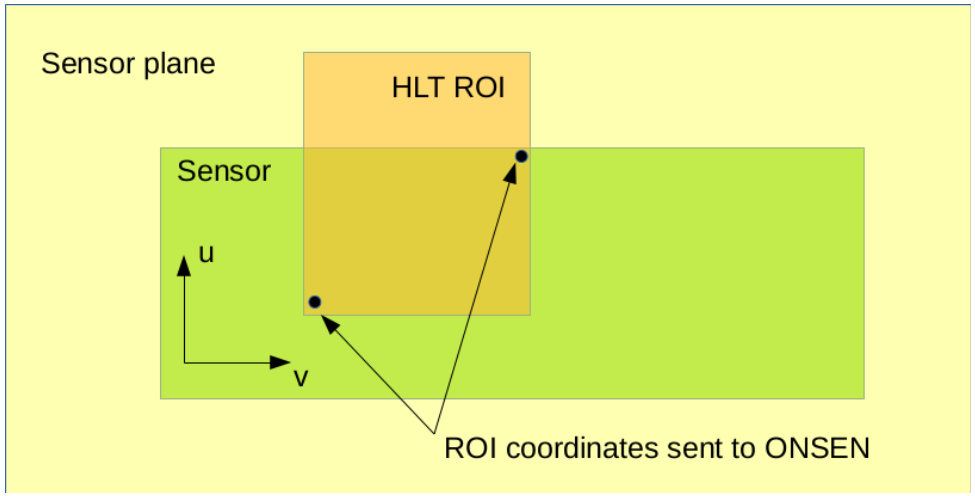
- In u-direction most ROIs lie partially outside the sensor, making the effective ROI smaller.
- For PXD efficiency study no ROIs with intercept outside the sensor area are accepted, limiting how small ROIs can be.



ROI size in u direction, layer 1

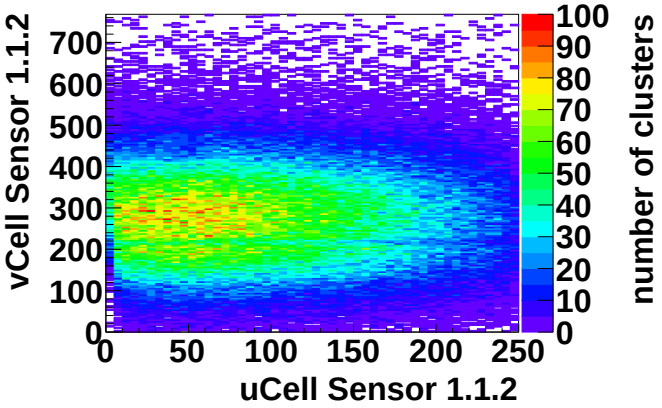


ROI size in v direction, layer 1

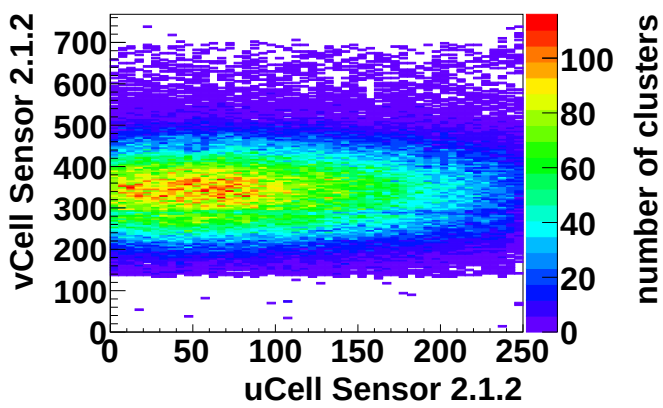


Run 176

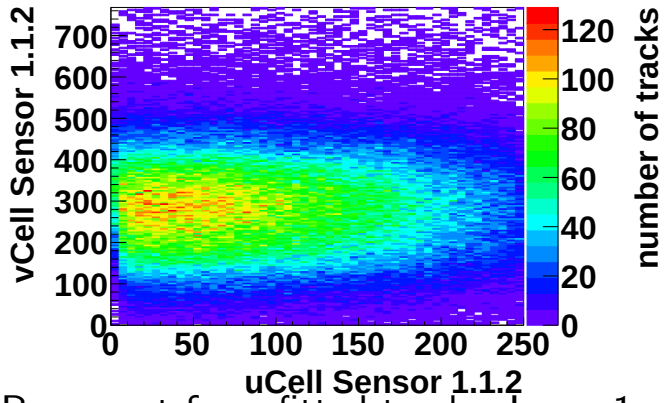
- Magnetic field 0.5T, beam energy 2.4 GeV, VXDTF2
- Beamspot from fitted tracks matches hitmap from sensor very well.



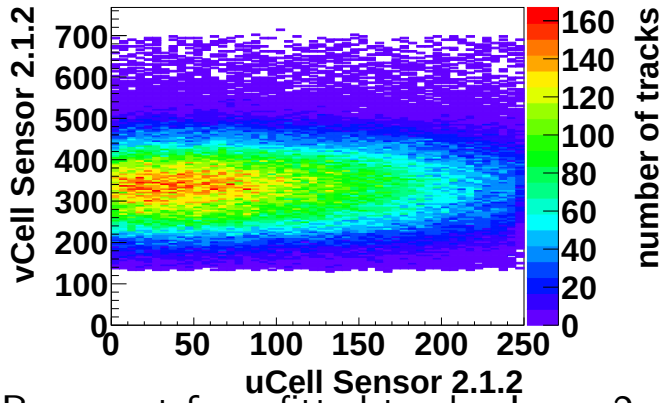
Hitmap of layer 1



Hitmap of layer 2



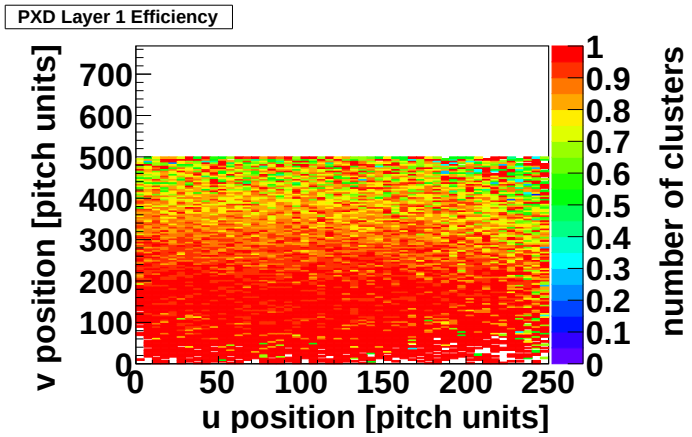
Beamspot from fitted tracks, Layer 1



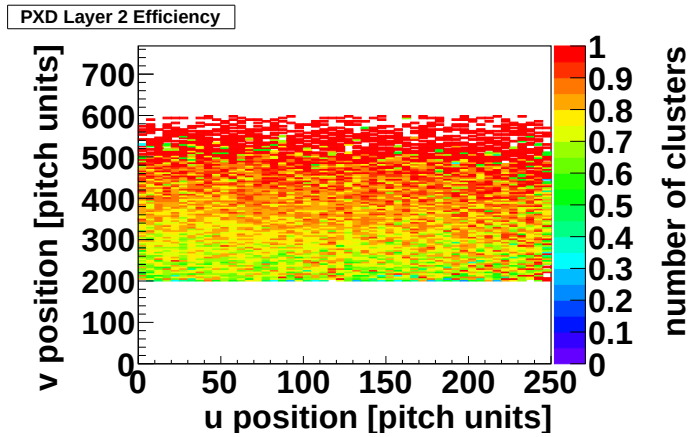
Beamspot from fitted tracks, Layer 2

Run 176

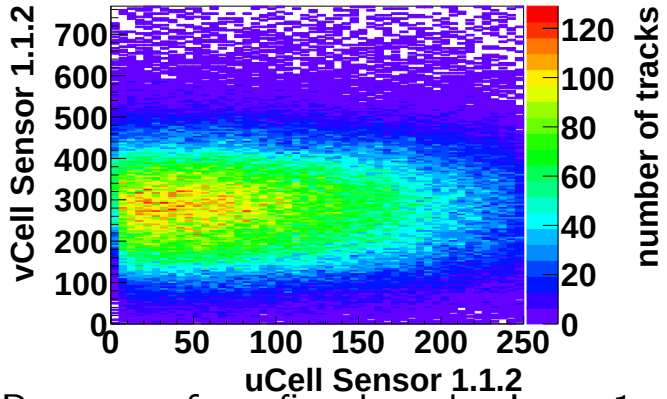
- Magnetic field 0.5T, beam energy 2.4 GeV, VXDTF2
- Efficiency shows gradient in v-direction
- Efficiency gradient swaps sign from layer 1 to layer 2



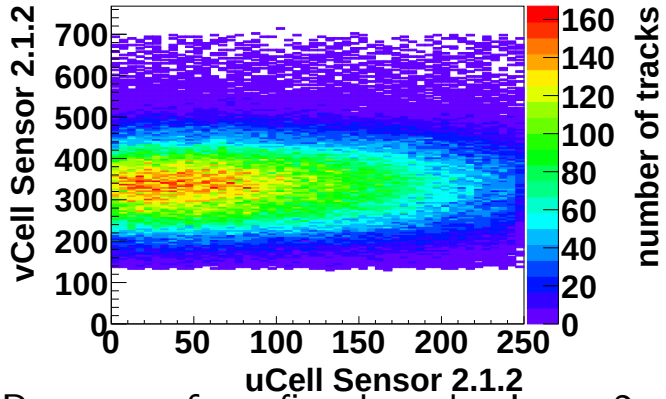
Efficiency on layer 1



Efficiency on layer 2



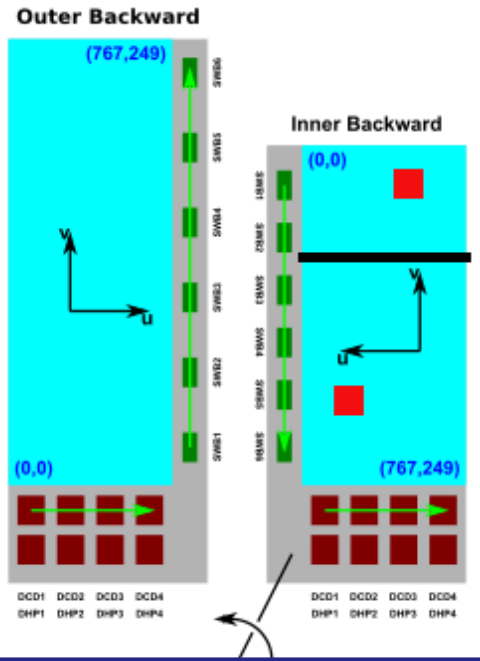
Beamspot from fitted tracks, Layer 1



Beamspot from fitted tracks, Layer 2

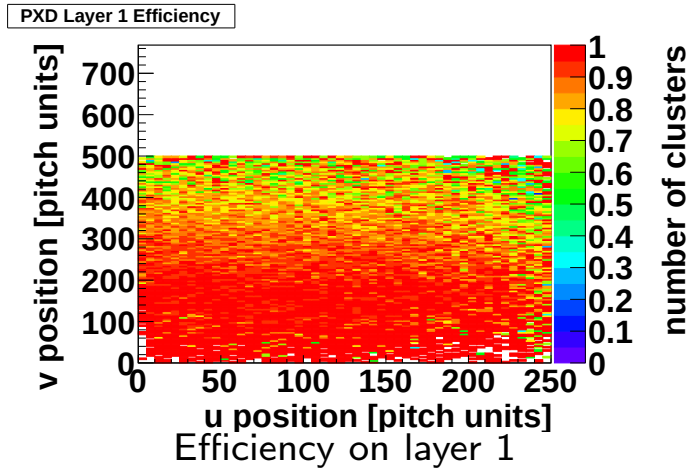
Run 176

- Efficiency gradients (sign swap) hard to explain from other sources than PXD itself (intense discussions)
- Current understanding: Gradient can appear if signal hits in 2nd readout frame get lost in DAQ.

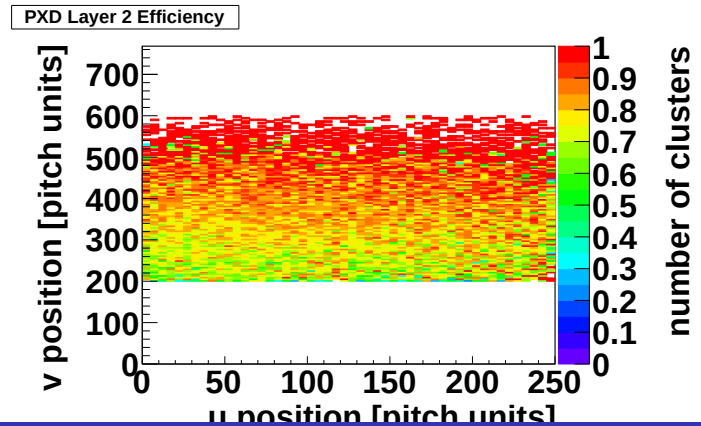


Possible explanation for gradient

- Due to rolling shutter, each event consists of two frames.
- If hits in 2nd frame get lost, the inefficiency is highest at row 0.

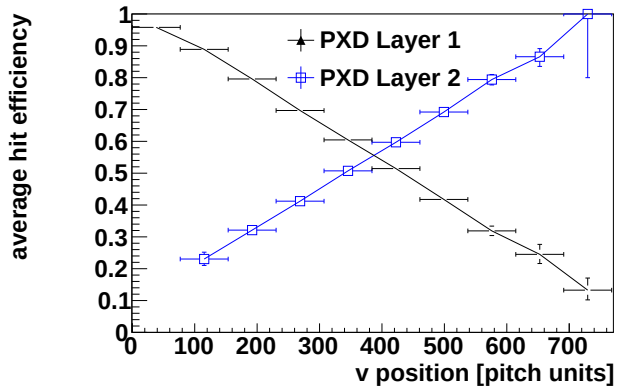


Efficiency on layer 1

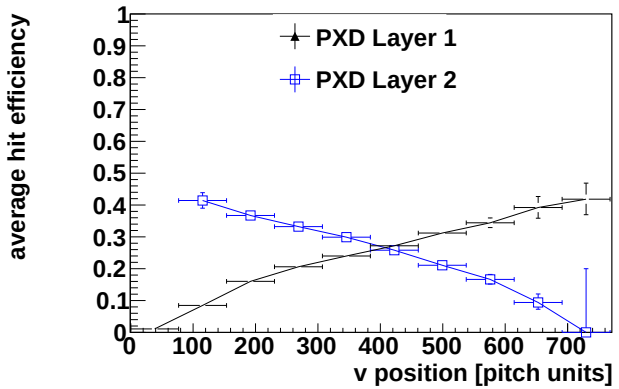


PXD DAQ

- Computing hit efficiency seperately for PXD hits in first/second frame.
- Efficiency for hits in first frame: Expect linear gradient between 0% at row=0 and 100% at row=768.
- Direction of shutter changes from inner to outer. Efficiency as function of v changes sign going from inner to outer layer.



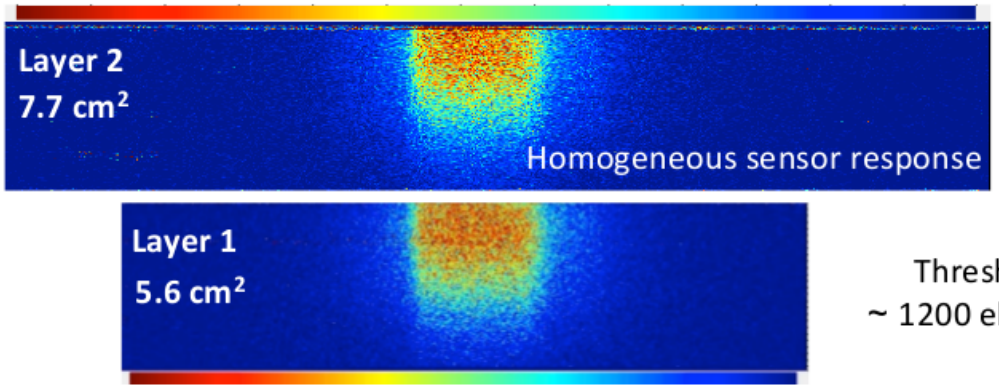
Matching only digits with frame number 0. As expected linear gradient 0% $\rightarrow$ 100%, but with some small offsets.



Matching only digits with frame number 1. The gradient reverses its direction as expected, but the slope is too small. Roughly half of the hits which should be in the second frame are missing.

Reminder: PXD performance TB16

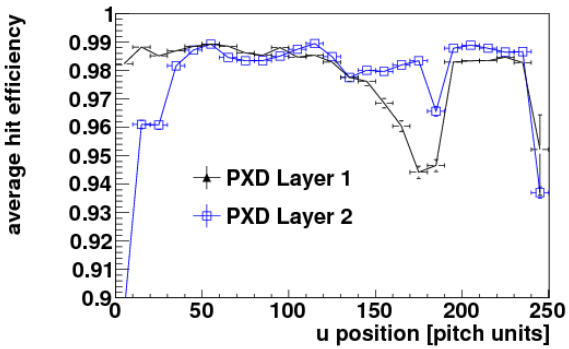
We used the very same sensors as in TB17 (run 176). Only difference are parts of (like FW) of PXD DAQ.



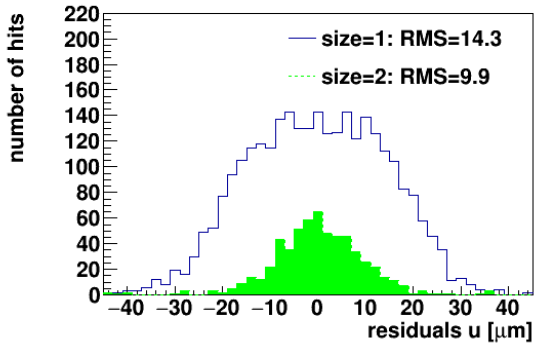
Threshold:
~ 1200 electrons

MIP, perpendicular incidence

Event mismatch fix on event builder



Using SVD+Tel hits as ref. track



Conclusion

- In TB16: Nice performance of PXD sensors. Sensor resolution and efficiency ok.
  - Important parts of PXD DAQ (data reduction) not fully tested ($\rightarrow$ re-mapping problem)
- In TB17: A DAQ integration test beam. Final ONSEN hardware and improved firmware used.
  - We used the very same PXD sensors as in TB16.
- Event number mismatch solved in TB17. But other problems likely related to PXD DAQ showed up.
  - It seems PXD DAQ drops some signal hits in the 2nd readout frame.
  - So far no final conclusion what has happend.
- Reasons which prevented us to spot problem earlier:
  - ExpressReco DQM modules did not produce PXDEfficiency plots.
  - Final alignment arrived very late (June 2017) .. and delayed efficiency studies.
  - Not all header fields filled by DHH .. prohibits more strict data format consistency tests.
- Final DAQ firmware for DHH not available in TB17. Development of firmware will address issues.

Backup