

Update VXD beam test results

Benjamin Schwenker

Göttingen University

Santander VXD workshop 2016

Outline

- Majority of beam test results from april 2016 already shown during June 2016 B2GM
- Updates/activities since then:
 - Fixed issue with 50% “matching” efficiency → due to a software bug in basf2 module (“PXDTriggerShifter”)
 - Studies of PXD noise occupancy in 'beam-less' runs with BonnDAQ (Julian Soltau)
 - Work on updating PXD / SVD resolution studies (Thomas, Benjamin, Felix) → planned for Vertex 2016
 - Studies on estimating SVD hit time (Peter Kvasnicka, planned for next B2GM)

The 50% “matching” efficiency

- A full documentation can be found here (thanks to Björn):
<https://confluence.desy.de/display/VBTA/Event+%28Number%29+Shifting>
- Problem: Event numbers and therefore data are shifted between HLT, PXD and SVD.
 - Related to B2TT firmware (beyond the scope of this talk)
- The event builder matches the data by event number (and ONSSEN is only sending out data matching the HLT event number), the PXD data is send one event too early.
- From run 262 on, a workaround has been implemented on the HLT and event builder. (Detail: HLT send "wrong" event number to ONSSEN to trigger sending out the correct data. Event builder skip check for event number match.)
- For runs before 262, we can correct for this by basf2 software module called “PXDTriggerShifter”.
- The original implementation of the “PXDTriggerShifter” had a bug;
 - This buggy version of the PXDTriggerShifter was used also for runs > 262.
 - For runs >262 this bug had a probability (~50%) to disorder PXD and SVD data again
 - The bug was found and fixed shortly after the B2GM in June.

Solution to 50% efficiency issue

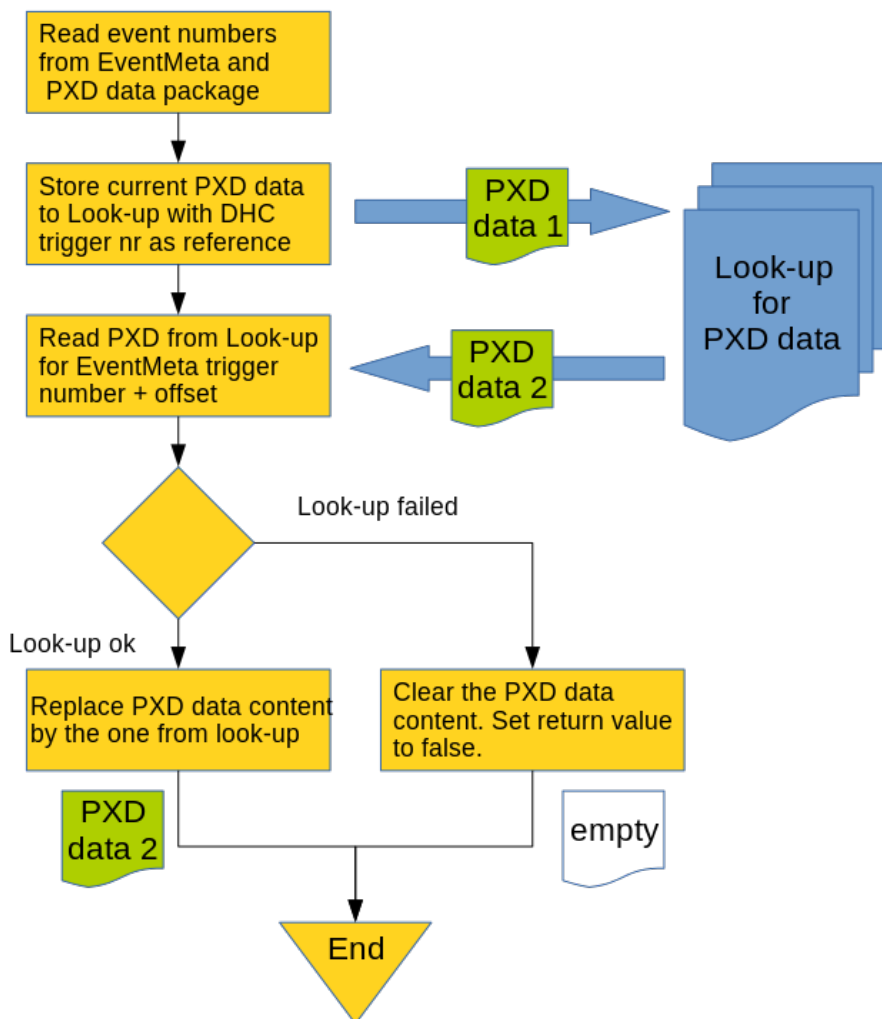
- For runs 262 and later:
 - PXDTriggerShifter module is not needed, best to remove it from your path.
- For runs before 262:
 - Add PXDTriggerShifter to your basf2 scripts:

```
triggershift=main.add_module(register_module('PXDTriggerShifter'))
```

```
triggershift.if_false(create_path()) # stop processing if the correct PXD data has not been found
```

We all expect there will be no event number mismatch in next beam test;)

The bug-fixed “PXDTriiggerShifter”



Two trigger numbers involved in lookup:

- 1) Trigger number from EventMetaData (the official trigger number)
- 2) Trigger number in PXD data stored in DHC header.

The look up may fail, if the correct PXD data was not yet added to table.

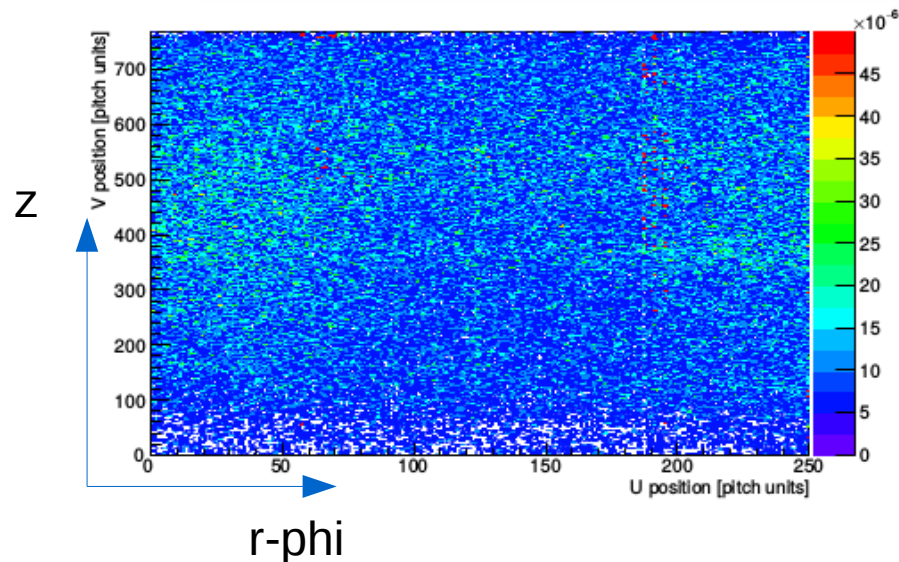
- remember that HLT can change order in which events are sent to onsen.
- Simple solution: ignore events with failing look up in analysis.

PXD noise occupancy study

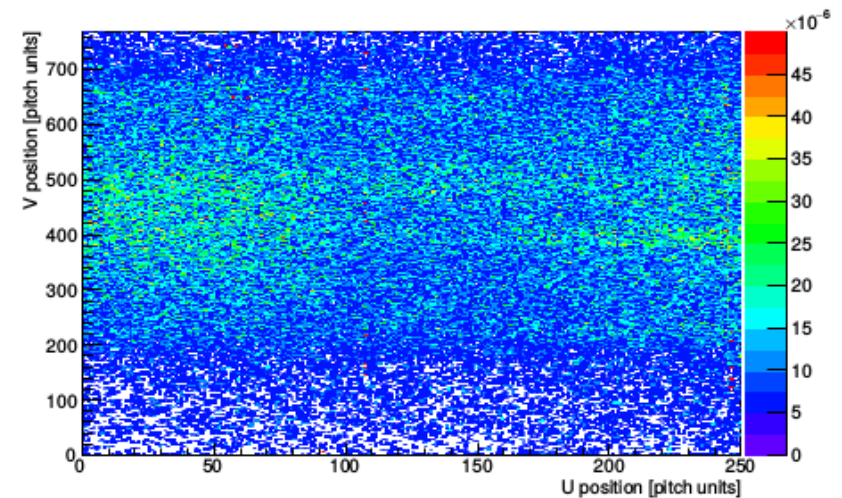
Define PXD occupancy of a single pixel as a normalized hit rate:

$$\text{occupancy (pixel)} = \text{hits (pixel)} / \text{events}$$

In a run with beam on, the occupancy (10^{-5} to 10^{-6}) is dominated by real particles
→ this is around one particle per event.



(a) Layer 1



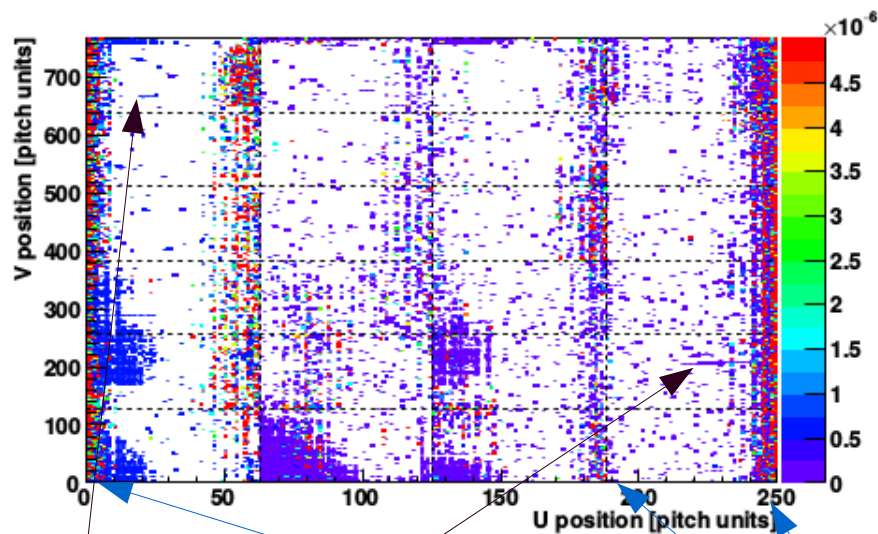
(b) Layer 2

The occupancy from real particles will be very different at Belle II → wait for Beast II

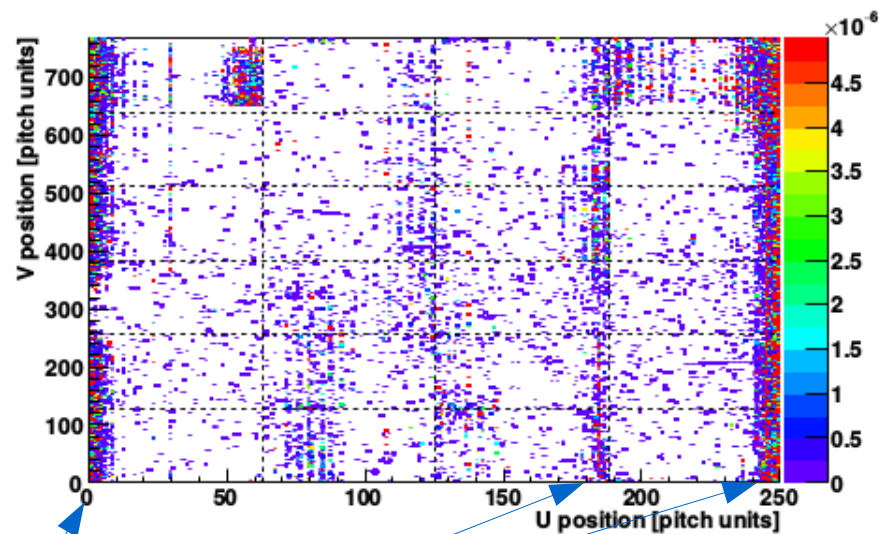
The occupancy coming purely from detector noise can be studied using TB data ;)

PXD noise occupancy study

Occupancy ($<10^{-6}$) from a long run w/o beam; data recorded with BonnDAQ



(a) Layer 1



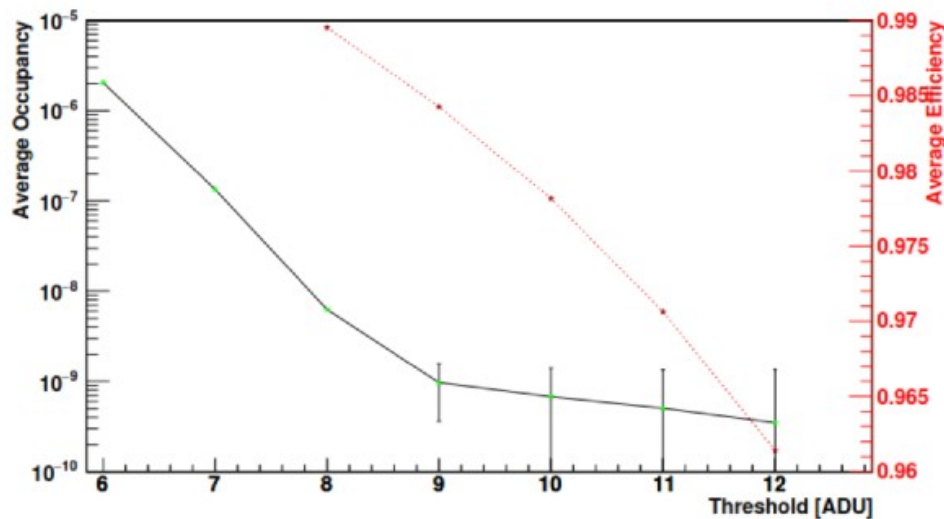
(b) Layer 2

Due to long integration time of PXD, you can see clusters from cosmics

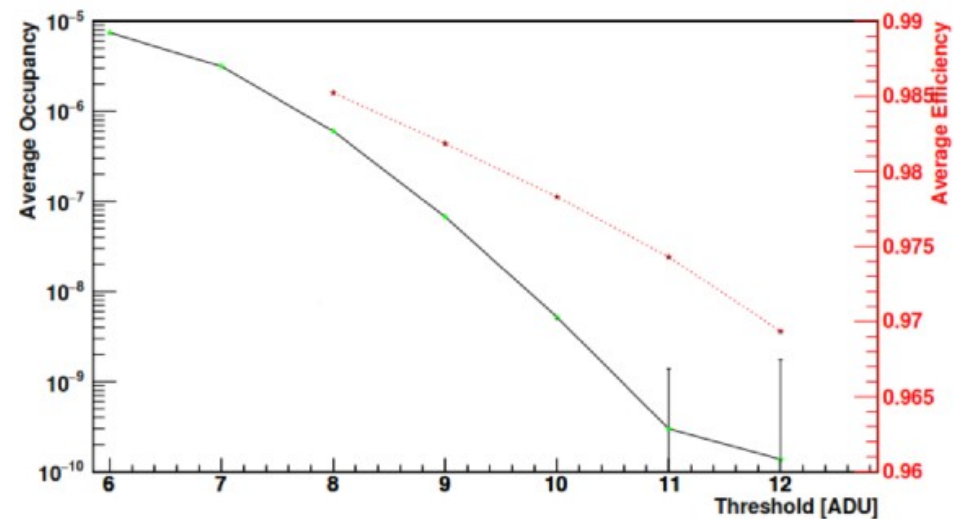
Noise hits appear to cluster in groups of adjacent physical columns.

Always groups of 8 very noisy columns, i.e. same column pair in DCD ASIC.

PXD threshold scans



(a) Layer 1



(b) Layer 2

:- Combining data from run w/ beam (Belle 2 DAQ) and run w/o beam (BonnDAQ)

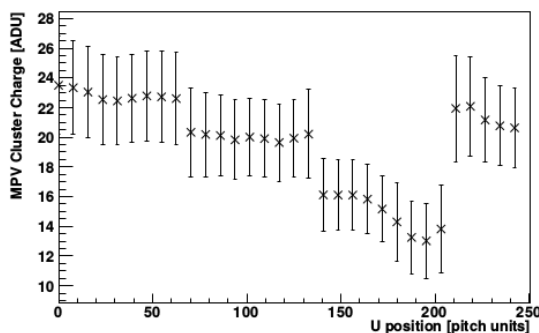
:- Minimum thresholds different for runs; defined by online zero-suppression.

:- Lowest threshold was 6ADU ($\sim 10\sigma$) [detailed characterization pending]

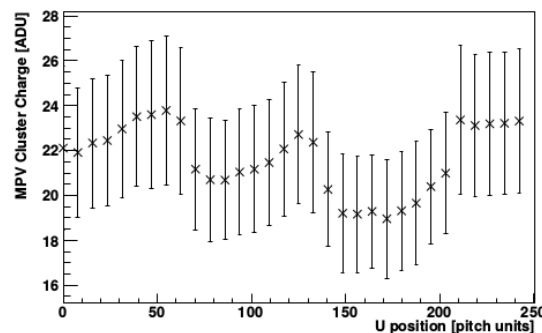
:- Average noise occupancy $< 10^{-5}$ (@ thr. 6ADU)

:- Average efficiency 98.5% (L1) and 99% (L2)

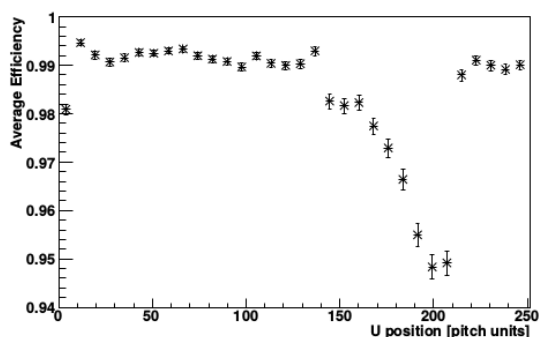
Signal homogeneity



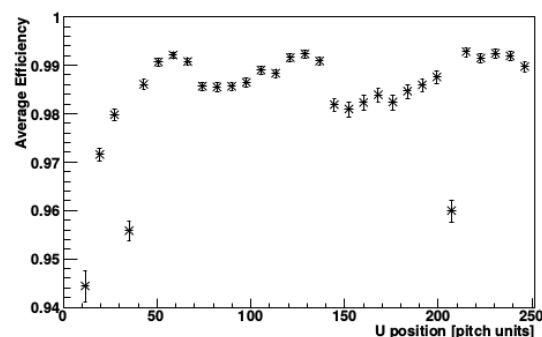
(a) MPV distribution on Layer 1



(b) MPV distribution on Layer 2



(c) Efficiency distribution on Layer 1



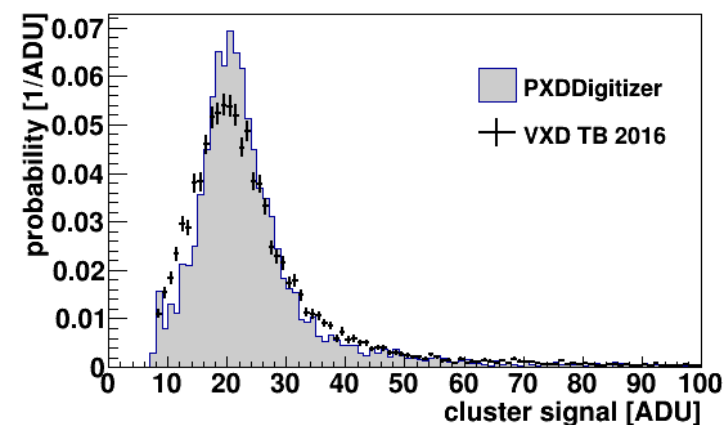
(d) Efficiency distribution on Layer 2

:- MPV cluster signal varies between DCD chips.

:- also varies inside DCD (among column pairs)

:- Clustering threshold of ~8ADU cut into signal.

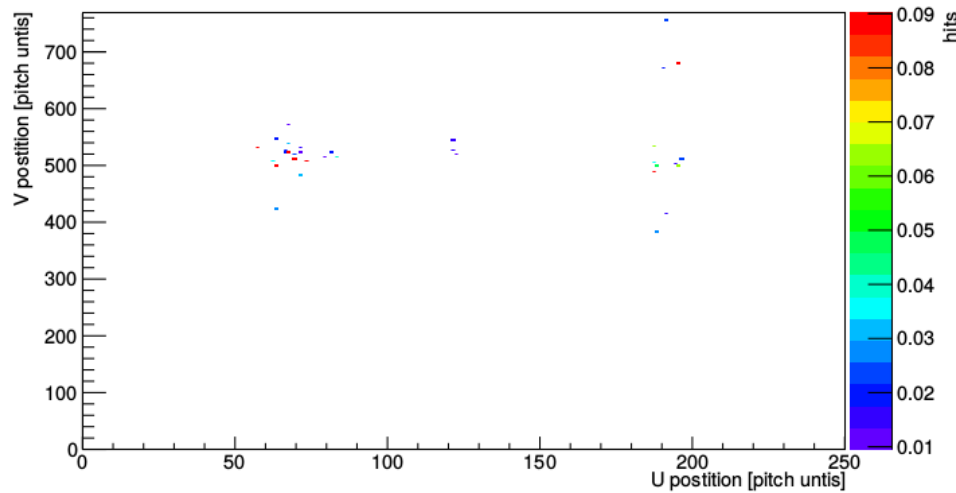
:- Need to work on gain homogeneity.



Conclusion and outlook

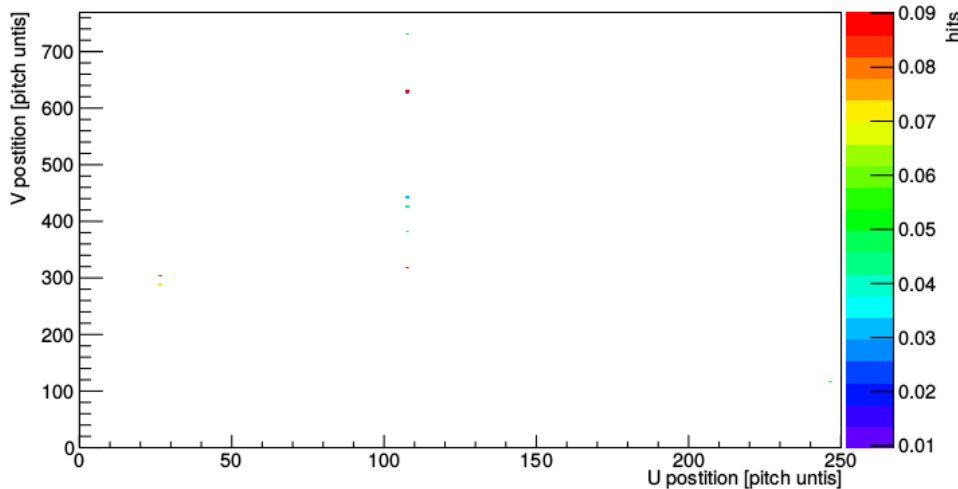
- Work on test beam analysis from april 2016 is mostly finished
 - Update on resolution studies for SVD+PXD (Vertex/B2GM)
 - Update on SVD hit time reconstruction on data (B2GM)
- From PXD side, a detailed characterization of the April PXD modules is missing:
 - Understand reason for columns with high occupancy
 - Improve signal homogeneity over large sensors
 - This is planned at DESY permanent setup (October 2016)
- Activities on software/analysis side should concentrate on preparing the next test beam.
 - Tracking → see next talk by Thomas

PXD noisy pixels – @threshold 7ADU (~1500e)



Inner half-ladder:

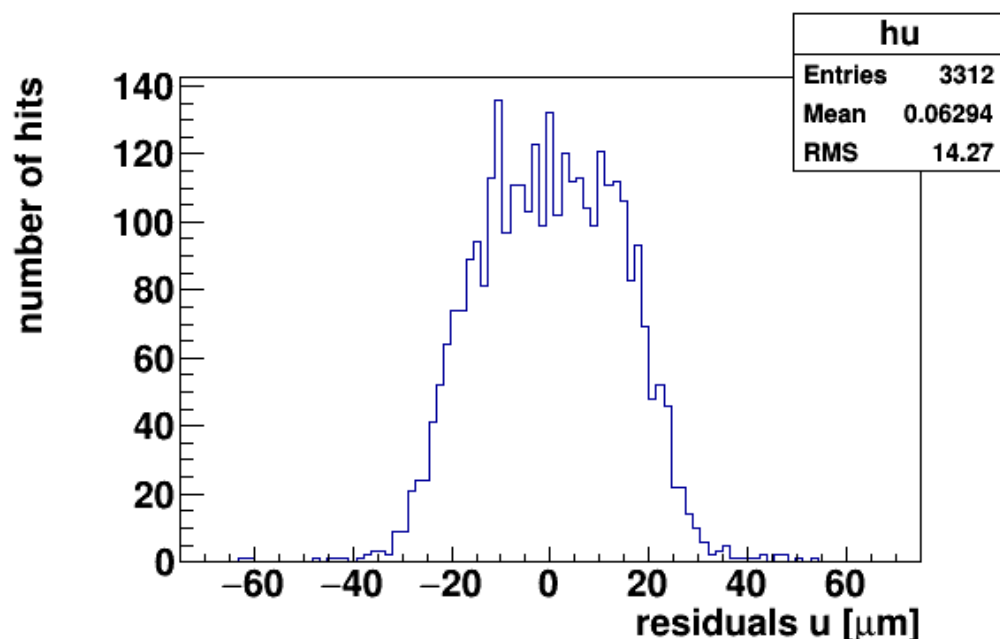
34/19200 pixels masked noisy



Outer half-ladder:

10/192000 pixels masked noisy

Residuals on inner PXD half-ladder



Extrapolation of 5GeV track with SVD+Tel to inner half-ladder:

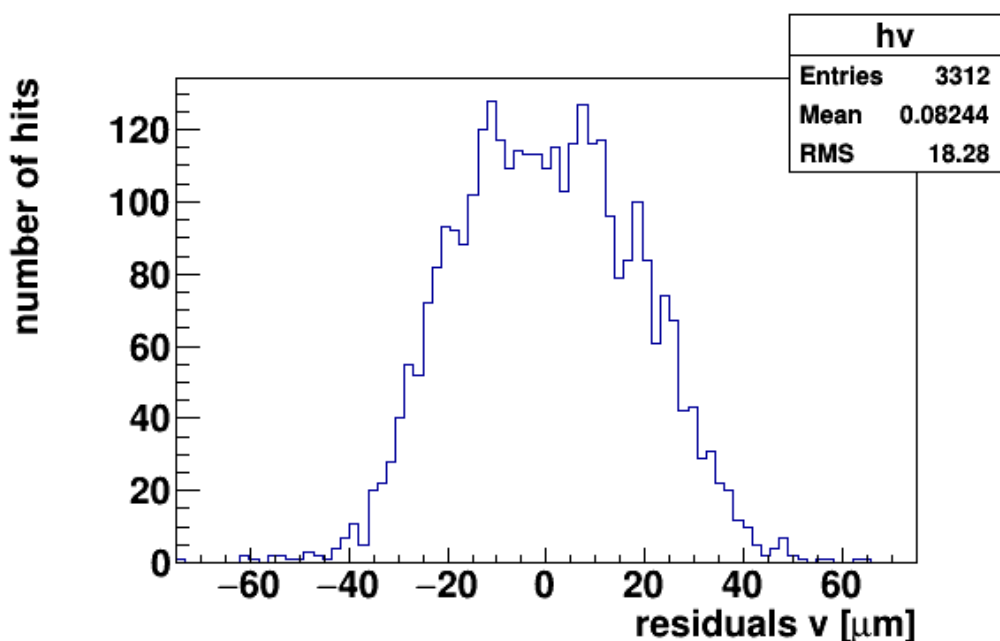
- Fit sigma U: $\sim 4\text{-}5\mu\text{m}$
(M26 hits + SVD rphi-strips)

- Fit sigma V: $\sim 6\text{-}7\mu\text{m}$
(M26 hits + SVD z-strips)

Unbiased residuals in U:

- **RMS: $14.3\mu\text{m}$ (pitch $50\mu\text{m}$)**

- Digital: $50\mu\text{m}/\text{Sqrt}(12)=14.3\mu\text{m}$



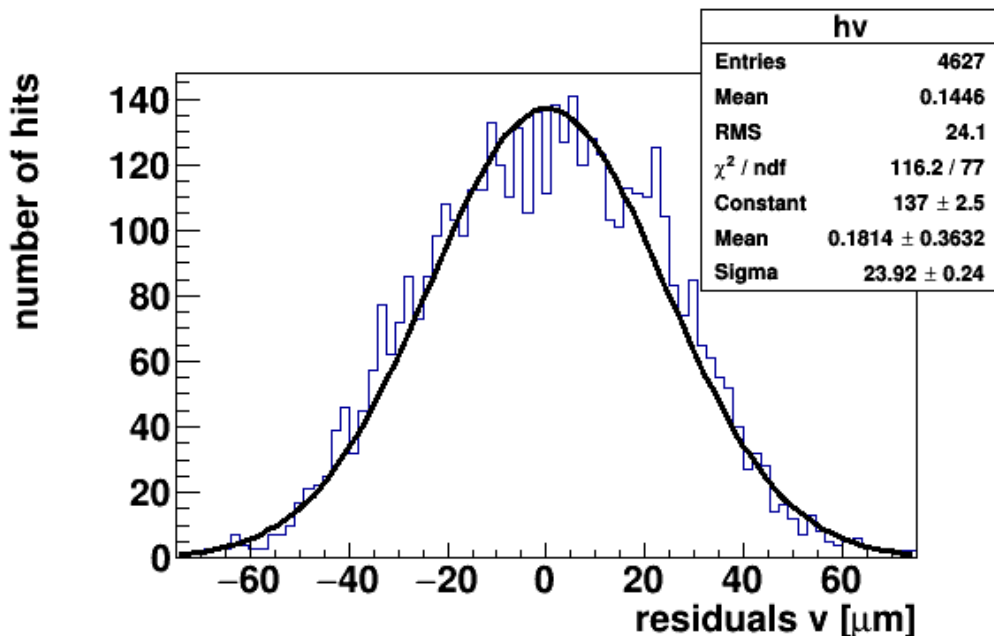
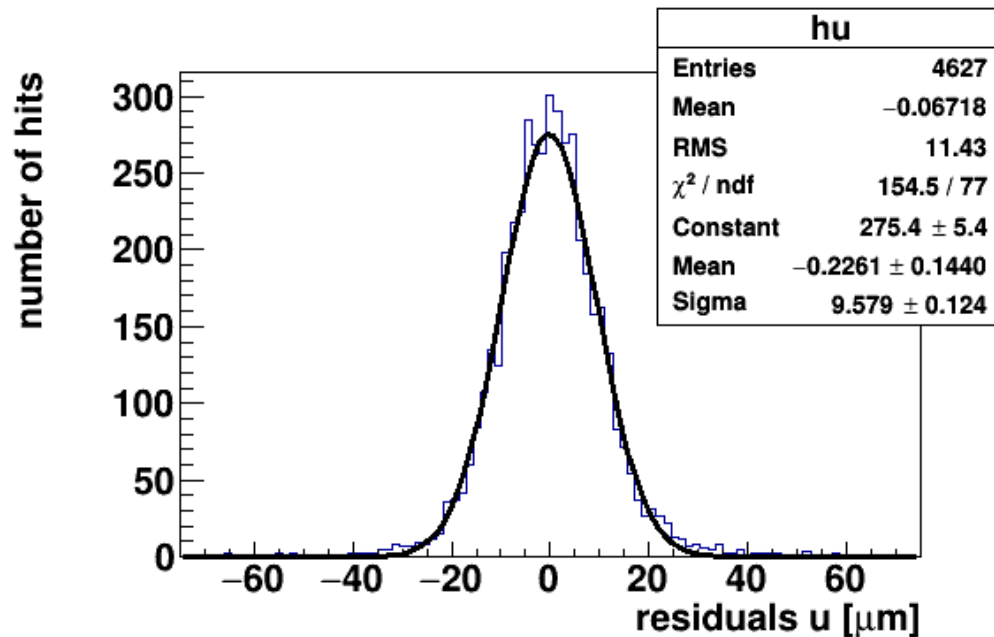
Unbiased residuals in V:

- **RMS: $18.3\mu\text{m}$ (pitch $60\mu\text{m}$)**

- Digital: $60\mu\text{m}/\text{Sqrt}(12)=17.3\mu\text{m}$

Unbiased residual is dominated by spatial resolution of PXD.

Residuals on SVD Sensor 3.1.2



Uncertainty for extrapolating track to layer 3.1.2

:- Fit sigma U is ~6-7 μm

:- Fit sigma V is ~8 μm

Unbiased residuals in U:

:- **Sigma = 9.6 μm (pitch 50 μm)**

:- Digital error is $50\mu\text{m}/2 \times \text{Sqrt}(12) = 7.2\mu\text{m}$

Unbiased residuals in V:

:- **Sigma = 23.9 μm (pitch 160 μm)**

:- Digital error is $160\mu\text{m}/2 \times \text{Sqrt}(12) = 23.1\mu\text{m}$

Run 96; 5GeV electrons

Summary of resolutions

SVD:

side	sensor	pitch	pitch/2 $\sqrt{12}$	measured res.
n-side	3.1.2	160um	23.9um	23.1um
p-side	3.1.2	50um	7.2um	9.6um

Ok

Ok; res. is ~ sum
of 7um (fit sigma)
and pitch/2 $\sqrt{12}$

PXD:

side	sensor	pitch	pitch/ $\sqrt{12}$	measured res.
u-side	1.1.2	50um	14.3um	14.3um
v-side	1.1.2	60um	17.3um	18.3um

Ok

Ok

Conclusion:

- 1) Tel. hits help to measure the resolution of PXD/SVD
- 2) Measured residuals very close to digital resolution
- 3) Of course, spatial resolution of perp. tracks is worst case (small charge sharing → small clusters)