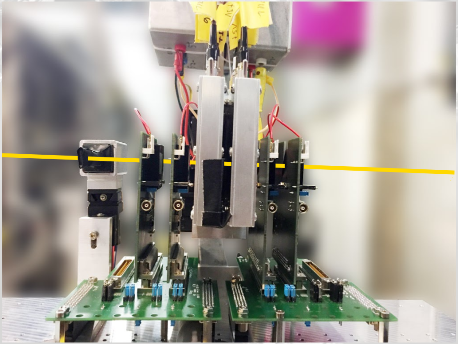


Results of High Rate Tests of Diamond Pad Detectors at PSI

Michael Reichmann

Table of contents I

Section 1

Introduction

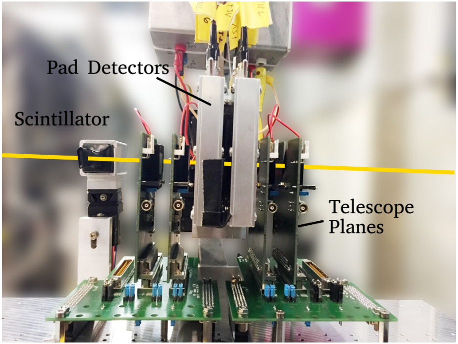
Goals of the beam test in August 2016:

- commissioning of the new setup ($\rightarrow$ Christians talk)
- confirming previous results $\rightarrow$ reproducibility
- investigating the high rate behaviour of higher irradiated diamonds
- testing a silicon diode as pad detector as reference

Measurements:

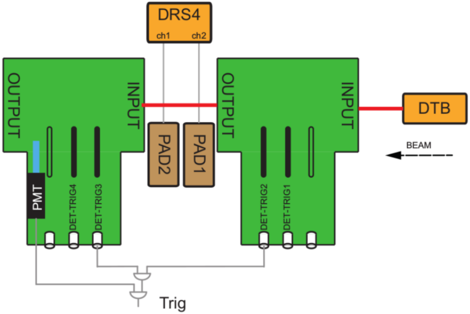
- tests of several diamond pad detectors and a silicon diode with a 260 Mev/c pion beam at Paul Scherrer Institute (PSI)
- sizes:
  - diamonds $\approx 5\,\mathrm{mm} \times 5\,\mathrm{mm}$
  - Si diode $1.71\,\mathrm{mm} \times 1.23\,\mathrm{mm}$
- irradiations: up to $1 \cdot 10^{15}$ neutrons/cm^2
- diamond brands:
  - Element Six (single and poly-crystal)
  - II-IV Inc. (poly-crystal
- flux range: from 1 kHz/cm^2 up to 3 MHz/cm^2 (at beam line pim1)

Setup



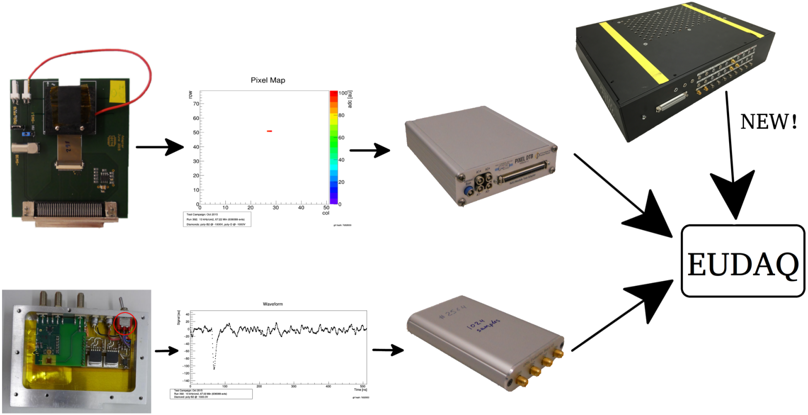
- 4 tracking planes with analogue CMS pixel chips
- 2 diamond pad detectors
- scintillator for precise trigger timing: sigma of 1.3(1) ns

Schematic Setup



- using PSI DRS4 Evaluation Board as digitizer for the pad waveforms
- using Digital Test Board (DTB) and pXar software for the telescope readout
- global trigger as coincidence of fastOR self trigger and scintillator signal
- EUDAQ as DAQ framework

DAQ

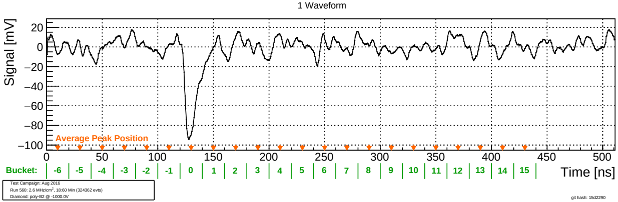


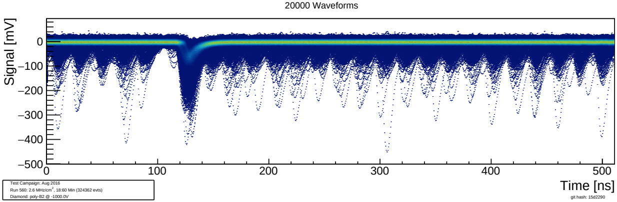
- EUDAQ saves event based data stream as binary file
- → conversion into ROOT-TTrees

Section 2

Analysis

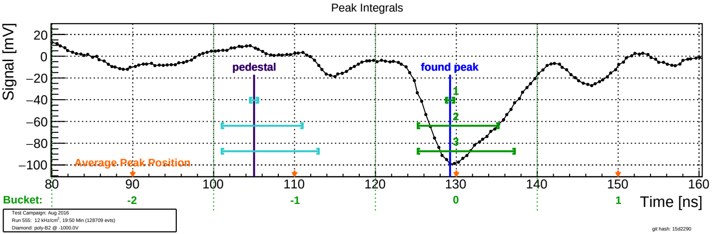
Waveforms





- most frequented peak ($\approx$130 ns): triggered signal
- other peaks originate from other buckets ($\rightarrow$ resolve beam structure of $\approx$19.7 ns)
- system does not allow signals in pre-signal bucket due to fastOR trigger deadtime

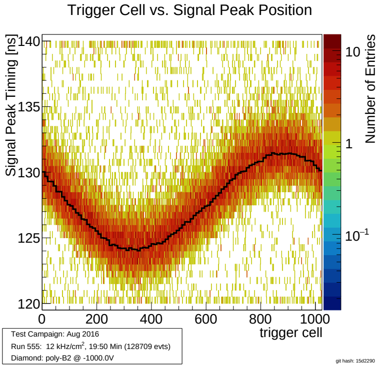
Pulse Height Calculation



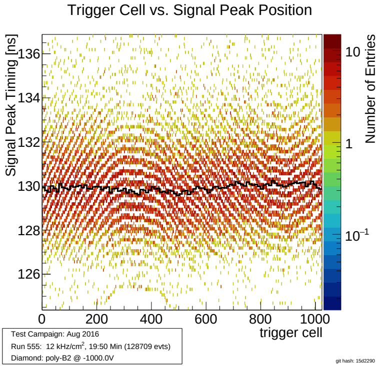
- finding the peak in the signal region (bucket 0)
- integrating the signal in given intervals around the found peak
- integrating the pedestal (base line $\rightarrow$ noise)
  - using same intervals as for the signal in fixed position in bucket -1 (signals forbidden!)
- optimizing the final interval by highest SNR (Integral / Pedestal Sigma)
- subtracting the pedestal from the signal integral on event-wise basis

Timing Correction

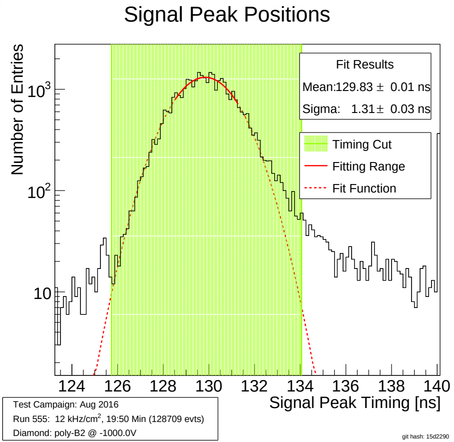
- ring buffer cells of the digitizer have different sizes ($\approx (0.50 \pm 0.15)$ ns)
- effective timing depends on starting cell of the buffer (=trigger cell)
- use trigger cell and measured cell length to get precise timing



Timing Correction
$\longrightarrow$



Corrected Timing of the Signal Peaks



- timing follows Gaussian distribution with $\sigma = (1.31 \pm 0.03)\,\mathrm{ns}$
- use cut $(4\,\sigma)$ based on this distribution to discard events with wrong timing
  - overlay of different buckets

Event Cuts

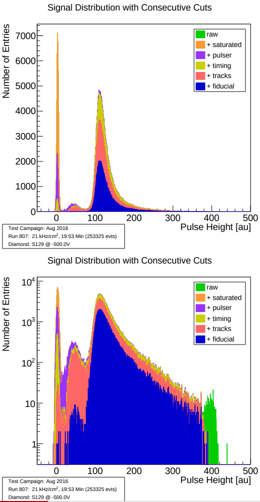
Exclude events:

- saturated: with saturated waveforms
- pulser: reference events
- tracks: with incomplete tracks
- timing
- fiducial: track not in selected area of the diamond

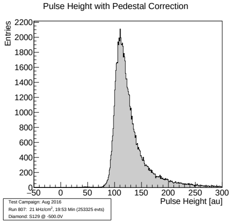
Also cuts on:

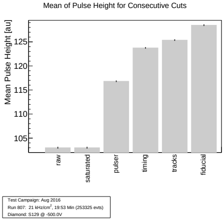
- χ^2 in x and y, track angle, event range, pedestal sigma

S129

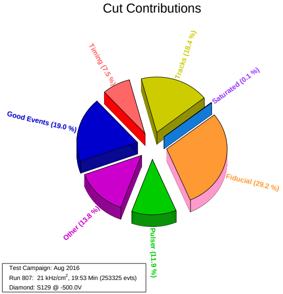


Pulse Height Distribution





- pedestal almost completely gone after application of the cuts
- mean of the pulse height increases significantly due to cuts (pedestal goes away)

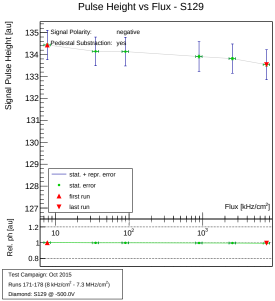


Section 3

Preliminary Results

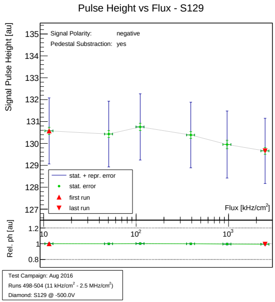
S129 @ $-500\,\mathrm{V}$ - unirradiated

October 2015



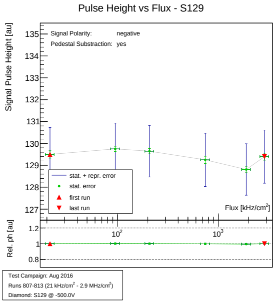
noise $\sigma \approx 2.6\,\mathrm{au}$

August 2016 - begin



noise $\sigma \approx 2.6\,\mathrm{au}$

August 2016 - end

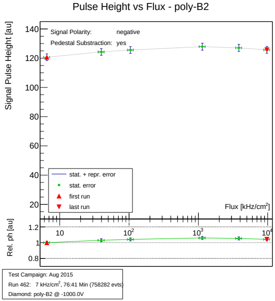


noise $\sigma \approx 2.6\,\mathrm{au}$

- measurements taken under the same conditions
- noise stays the same
- pulse height very stable

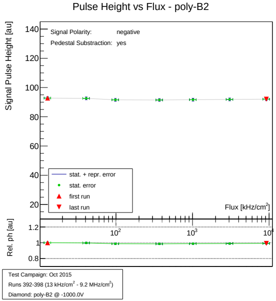
II6-B2 @ $-1000\,\mathrm{V}$

August 2016 - unirradiated



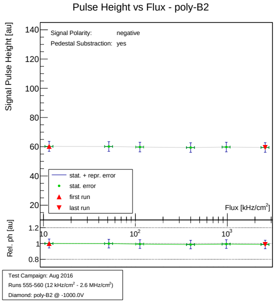
noise $\sigma \approx 4.9\,\mathrm{au}$

October 2015 - $5 \cdot 10^{14}\,\mathrm{n/cm^2}$



noise $\sigma \approx 4.9\,\mathrm{au}$

August 2016 - $1 \cdot 10^{15}\,\mathrm{n/cm^2}$

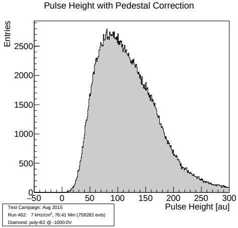


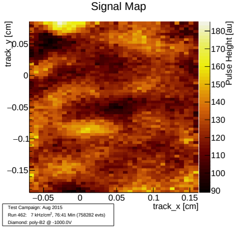
noise $\sigma \approx 4.9\,\mathrm{au}$

- pulse height very stable after irradiation
- noise stays the same

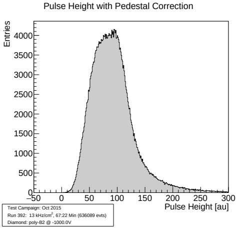
II6-B2 (II-VI - poly crystal)

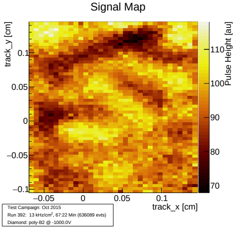
August 2016 - unirradiated



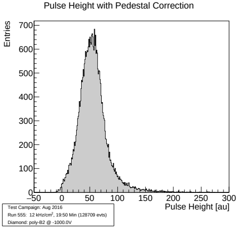


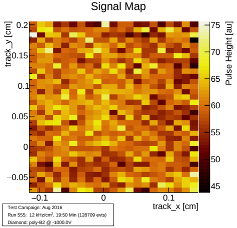
October 2015 - $5 \cdot 10^{14}\ \mathrm{n/cm^2}$





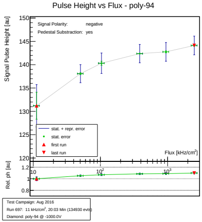
August 2016 - $1 \cdot 10^{15}\ \mathrm{n/cm^2}$



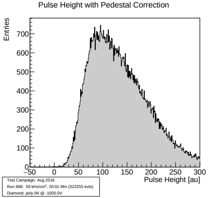


II6-94 and II6-95 @ $-1000\,\mathrm{V}$

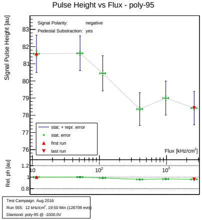
II6-94 - unirradiated



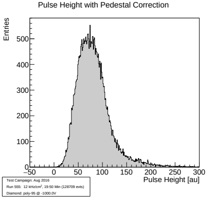
noise $\sigma \approx 5.7\,\mathrm{au}$



II6-95 - $5 \cdot 10^{14}\,\mathrm{n/cm^2}$

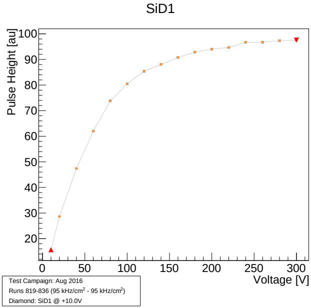


noise $\sigma \approx 4.7\,\mathrm{au}$

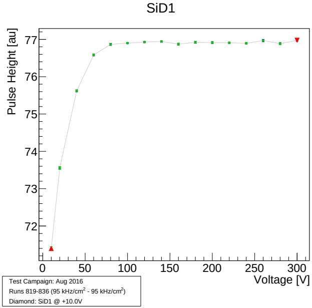


SiD1

Signal Pulse Height

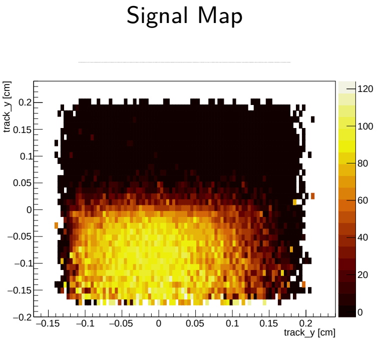


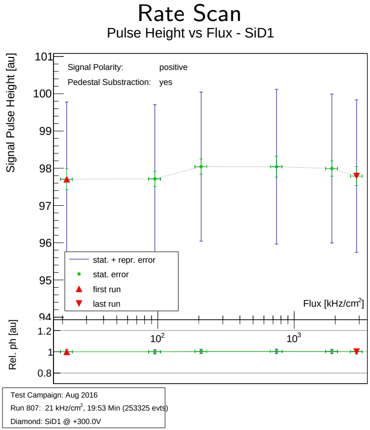
Pulser Pulse Height



- signal supposed to saturate at ≈80 V
- pulser saturates at expected value
- try to use it as calibration to extract CCD of diamonds did not succeed (deviation of ≈15 %)

SiD1 (PSI - silicon diode





- pulse height very flat with rate → no rate dependence

Section 4

Conclusion

Conclusion

- very good timing resolution with scintillator allows for precise integration and separation of the signals
- tests in August 2016 are compatible with the beam test before
- unirradiated single crystal shows almost no rate dependence
  - good reference
- behaviour of silicon diode not yet understood
  - yet very stable with rate

Section 5

Outlook

Outlook

- irradiate II6-B2 further
- find other stable poly-crystalline diamonds
- investigate behaviour of silicon diode
- build and test further silicon diode