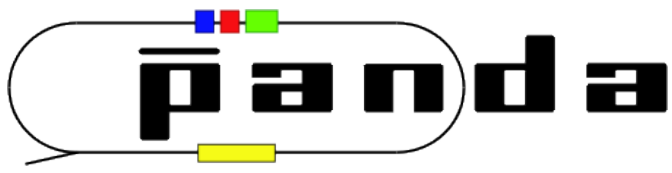
Frontend electronics for the backward calorimeter

Luigi Capozza

for the Mainz EMC group



PANDA DAQ/FEE Meeting 2016
Groningen, 31/3/2016

Outline

- Setup description
- Test data and performances
- Current and future activities

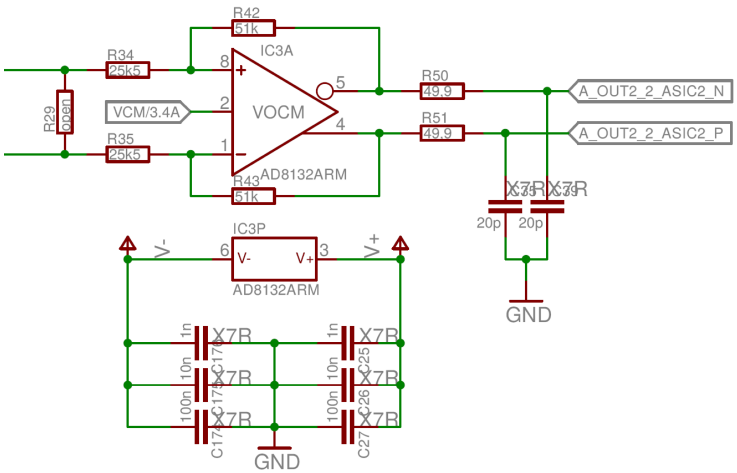
Setup Overview

Readout chain:

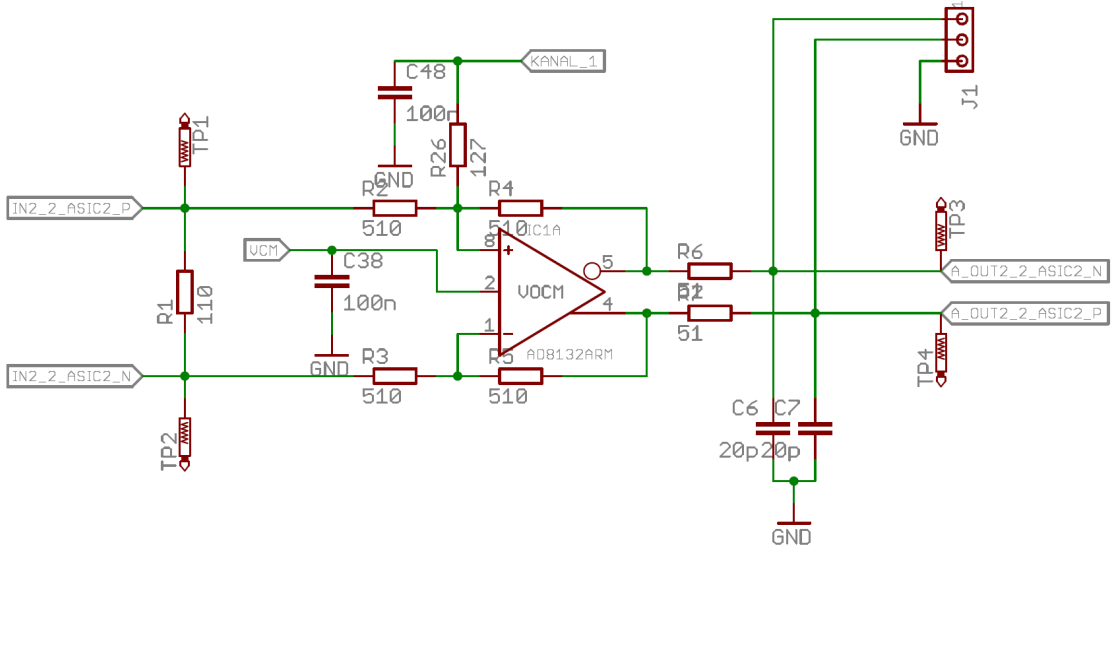
- Large Area Avalanche Photodiodes (Hamamatsu)
- APFEL ASIC (GSI)
- Distribution board (Mainz)
  - APD bias voltage
  - APFEL power supply and programming
  - Line drivers
- Sampling ADC
  - Until now for testing: FEBEX (GSI)
  - Near future: Uppsala SADC
- Read-out system
  - Until now for testing: PEXOR/TRIXOR + Multi-Branch System – MBS (GSI)
  - Near future: SODANET on TRB

Line Drivers

Sender

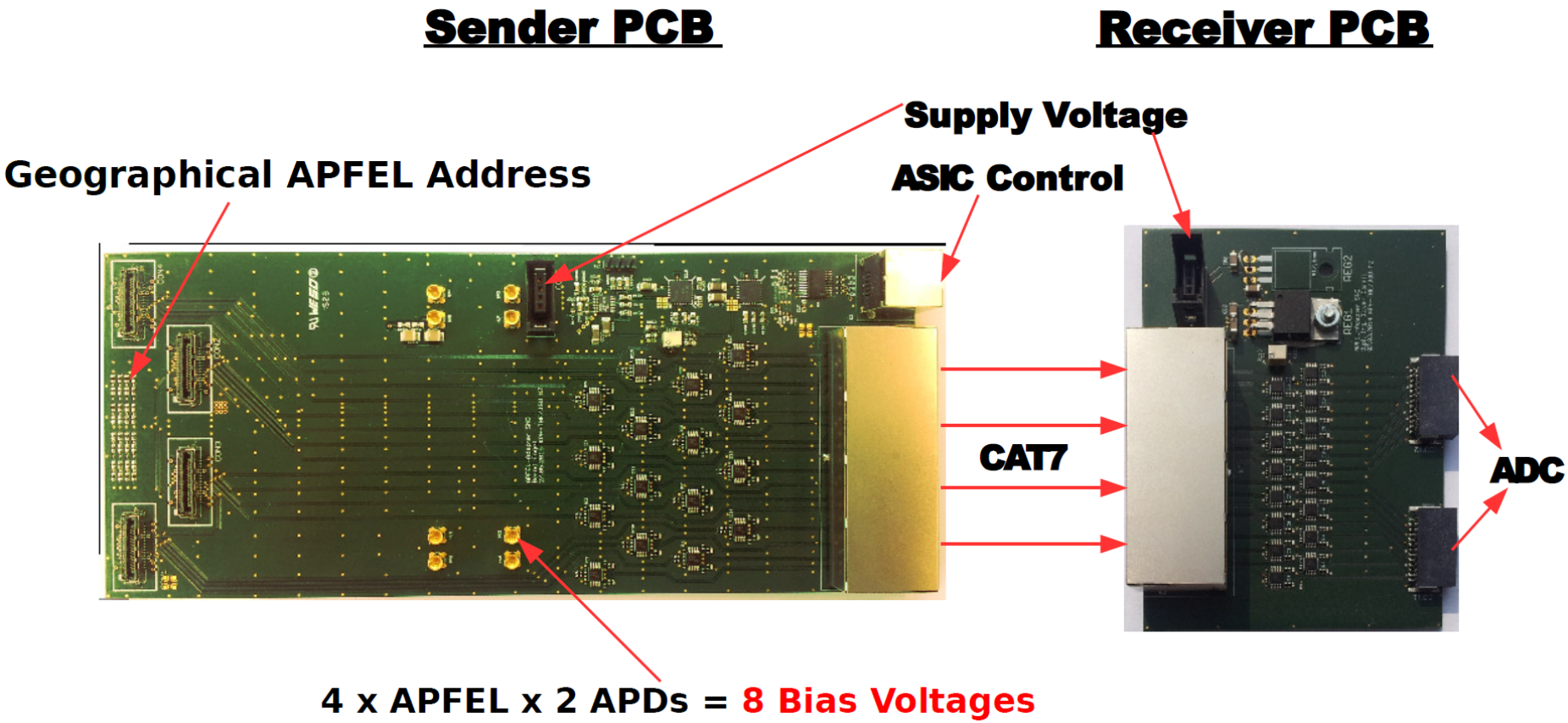


Receiver

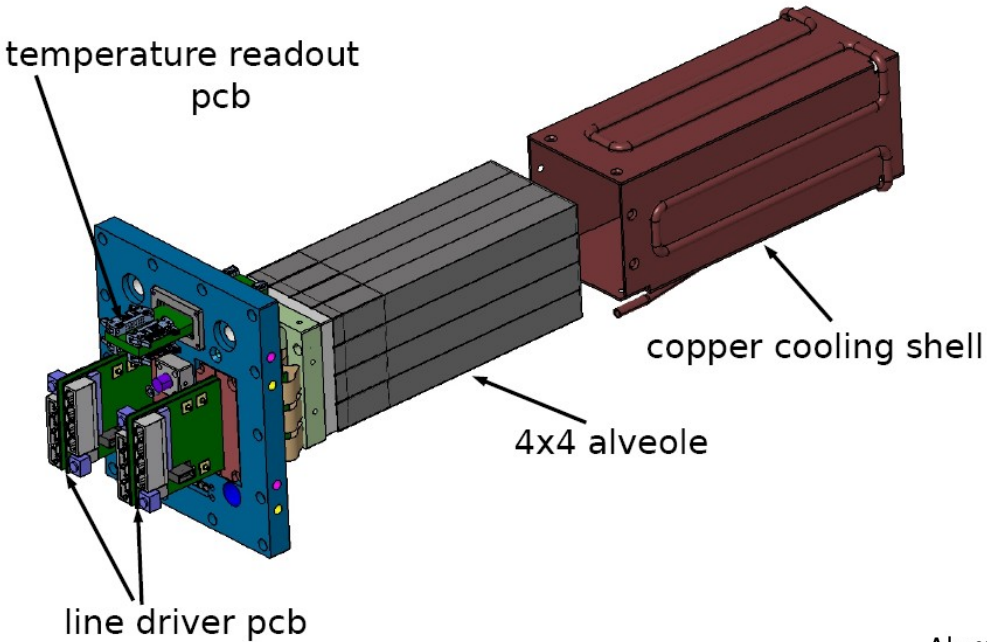


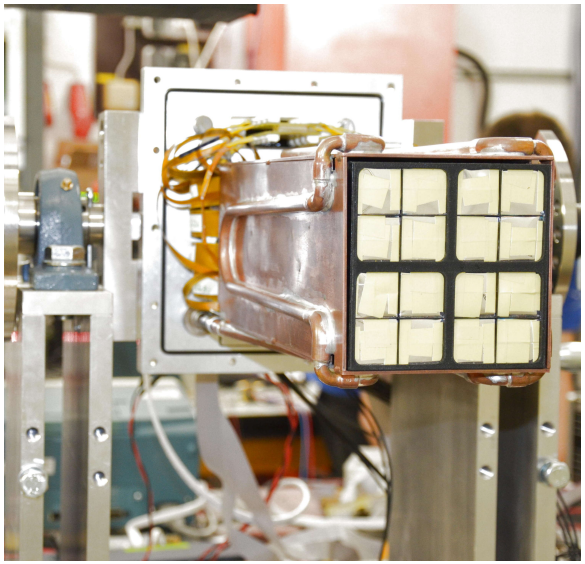
- High impedance on ASIC side
- Receiver will be implemented in the ADC input buffer
- Differential voltage setting at ADC input is useful

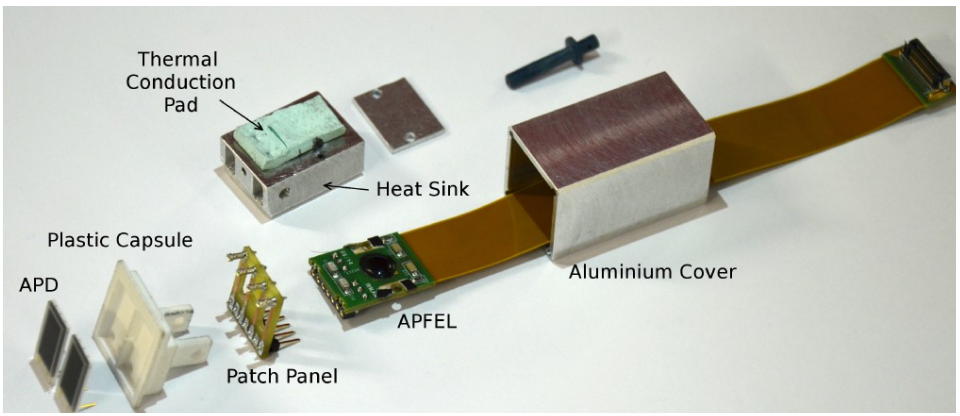
Line Drivers

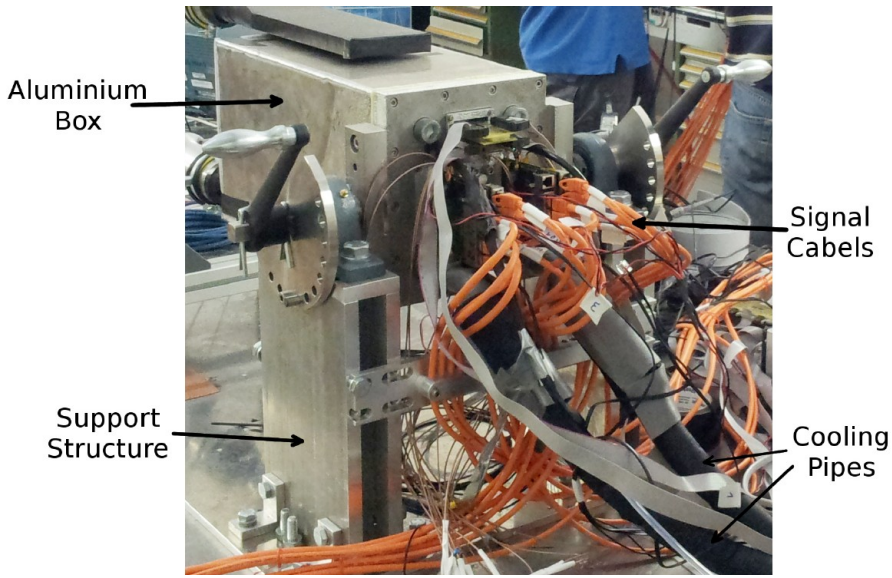


Prototype “Proto16”



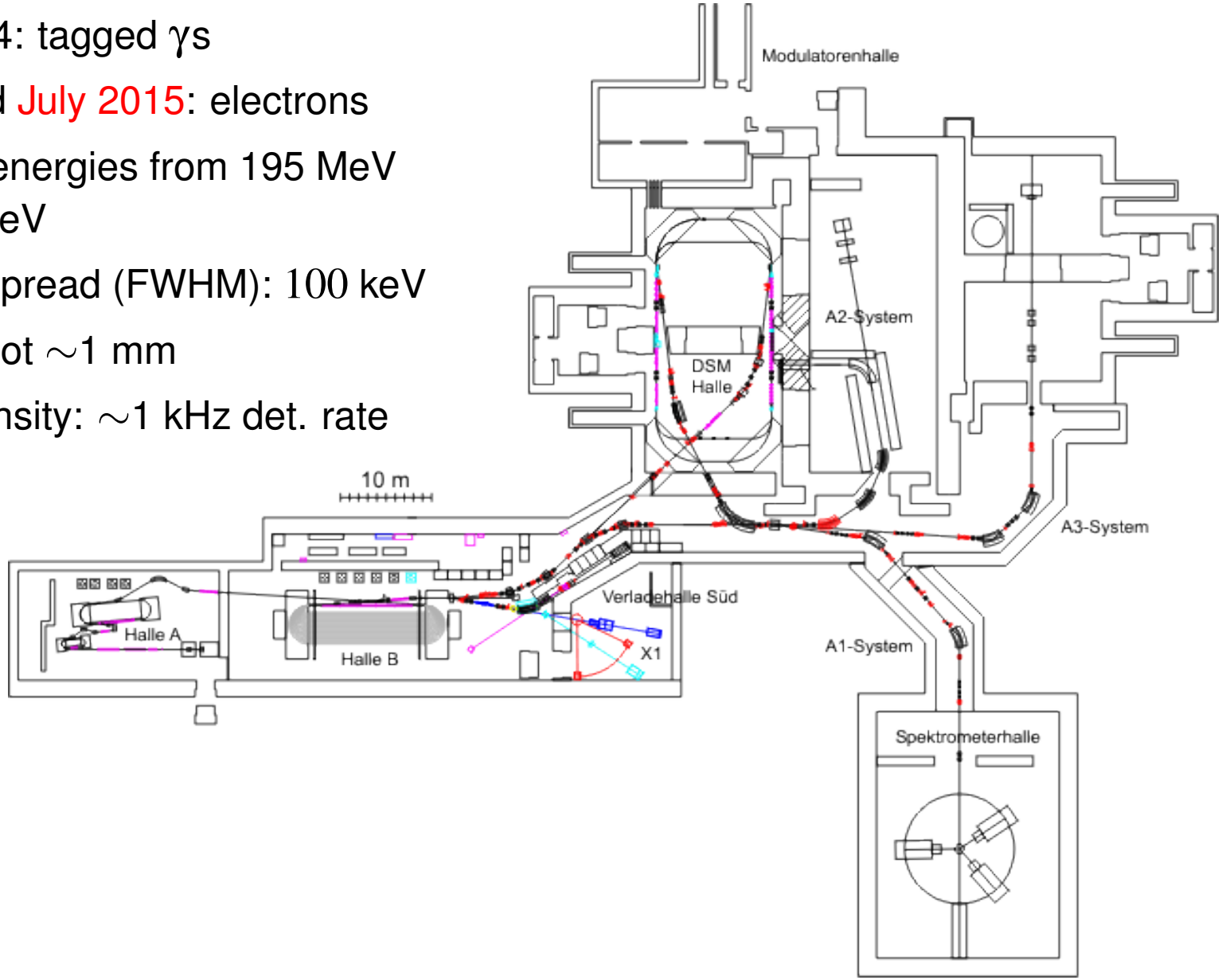






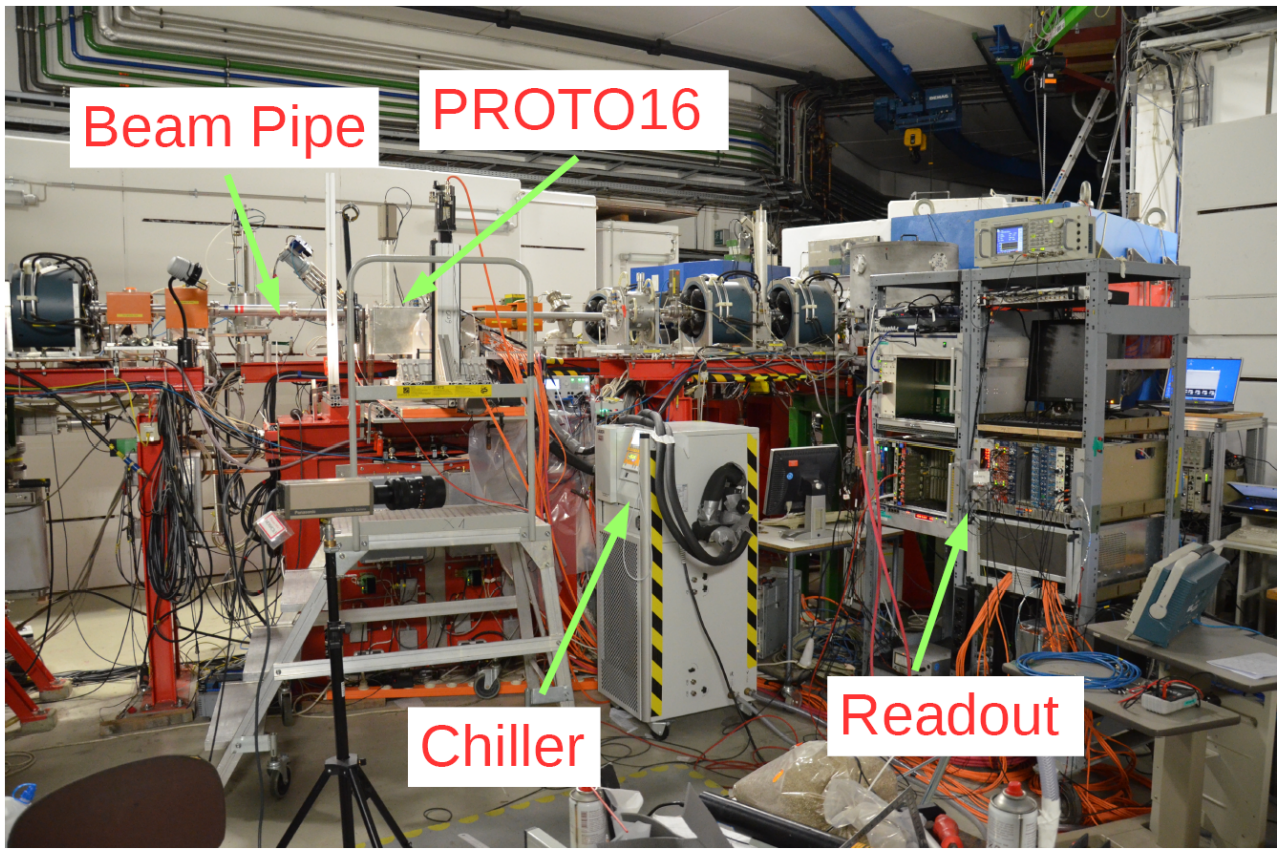
Beam tests at MAMI

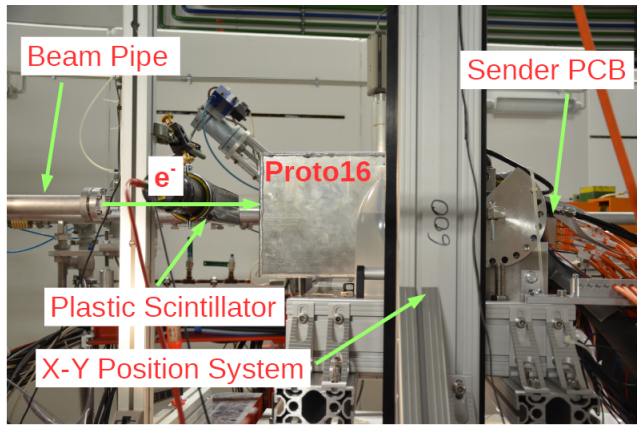
- July 2014: tagged γs
- June and July 2015: electrons
- 5 beam energies from 195 MeV to 855 MeV
- Energy spread (FWHM): 100 keV
- Beam spot $\sim$1 mm
- Low intensity: $\sim$1 kHz det. rate

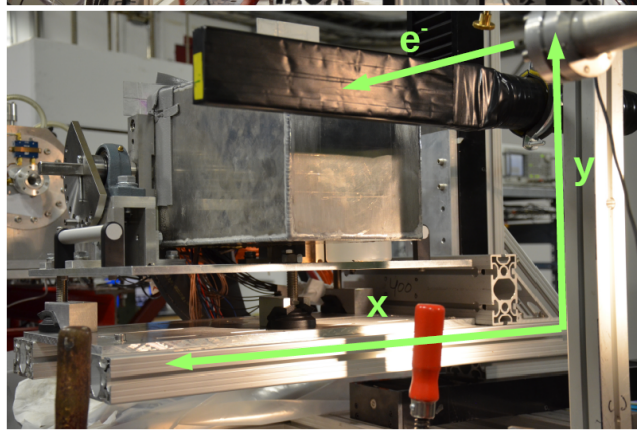


Beam tests at MAMI

- XY-table for centering each crystal on beam
- Plastic scintillator for coincidence event triggering

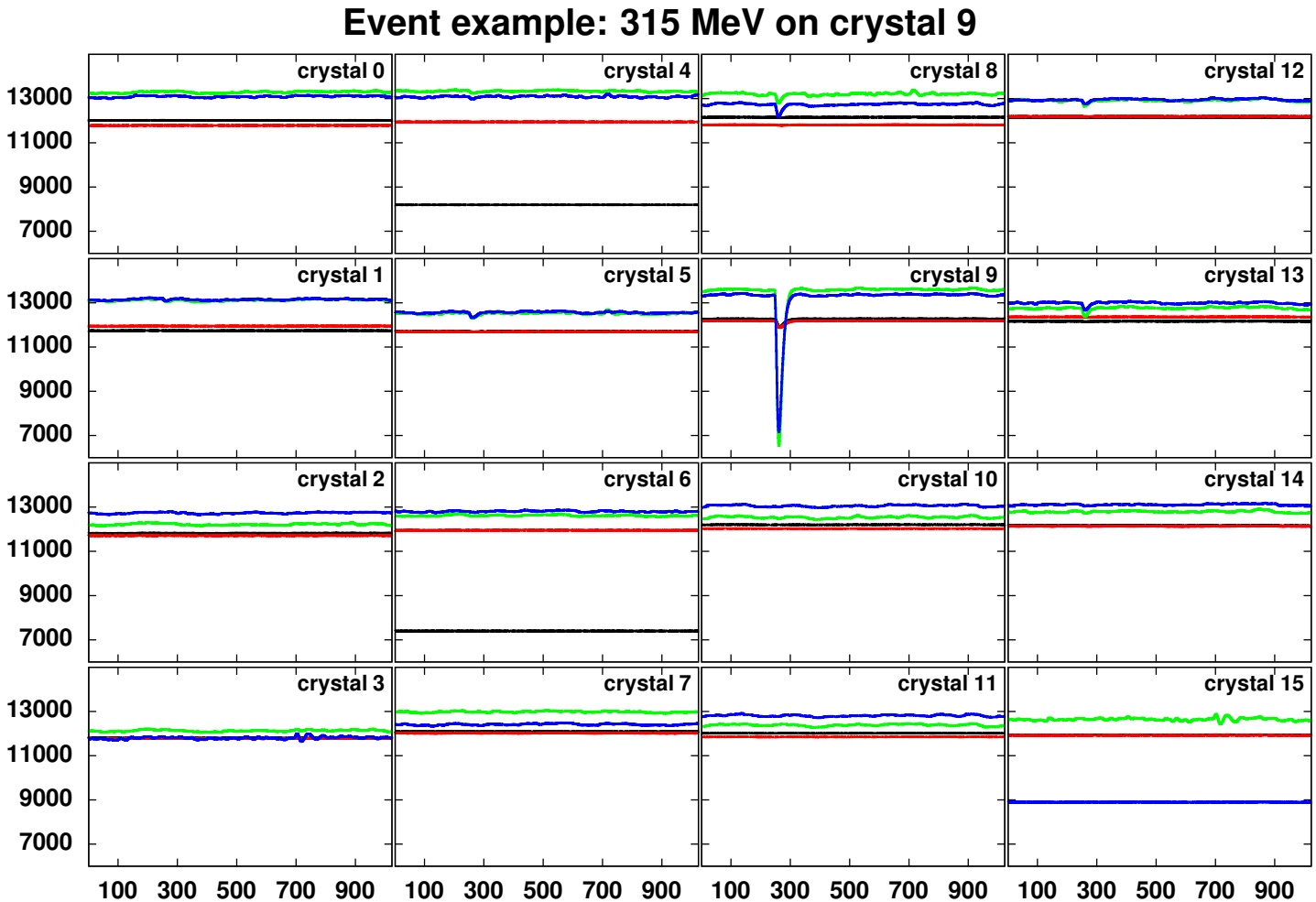






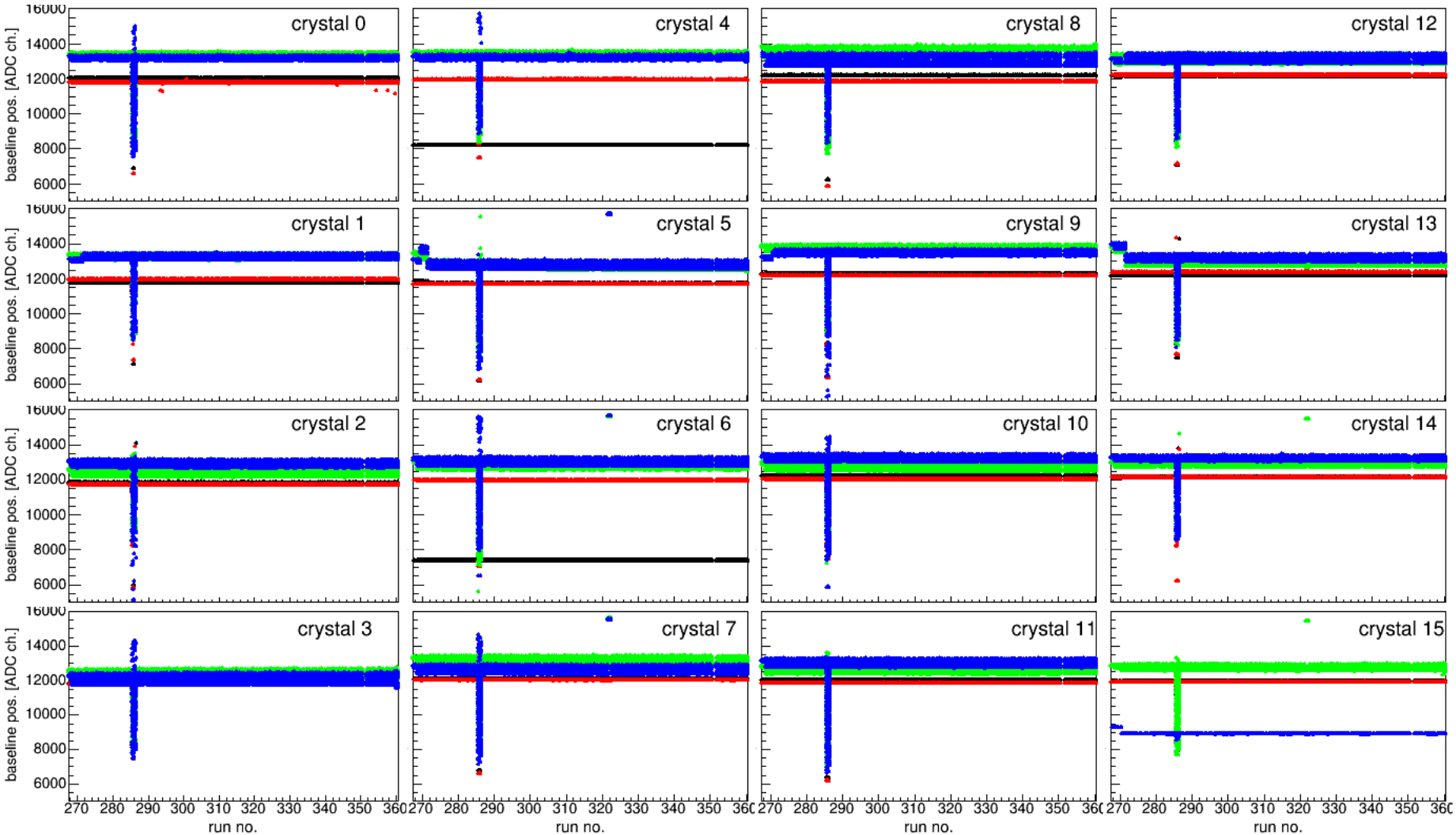
Raw data

- 64 traces pro event (16 crystals$\times$2 APD$\times$2 amplifications)
- Trace length: 20 μs (1024 samples)
- Event recording rate up to 1.4 kHz
- Amount of data per beam test: $\sim$1 TB



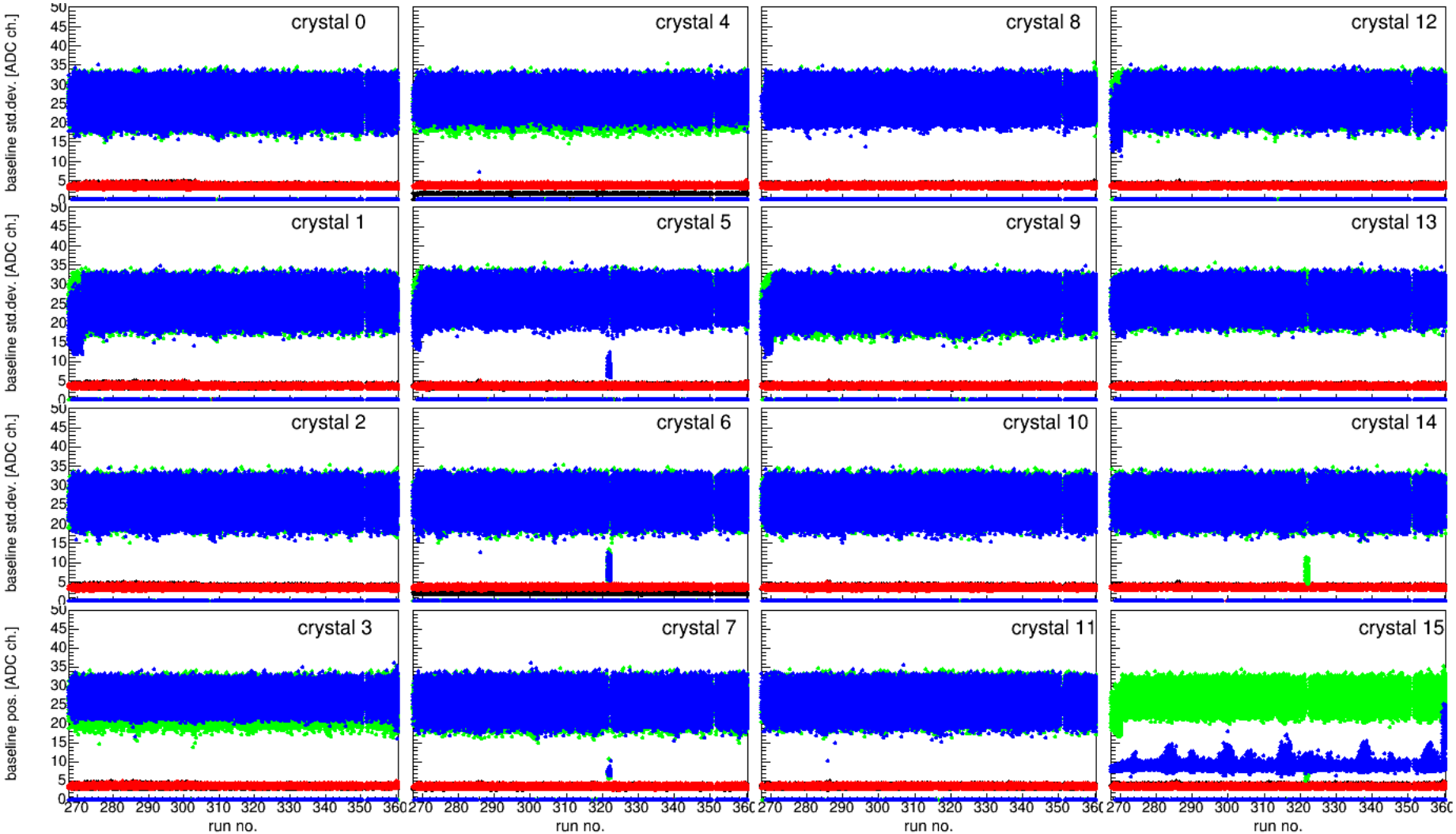
Detector stability

Baseline position

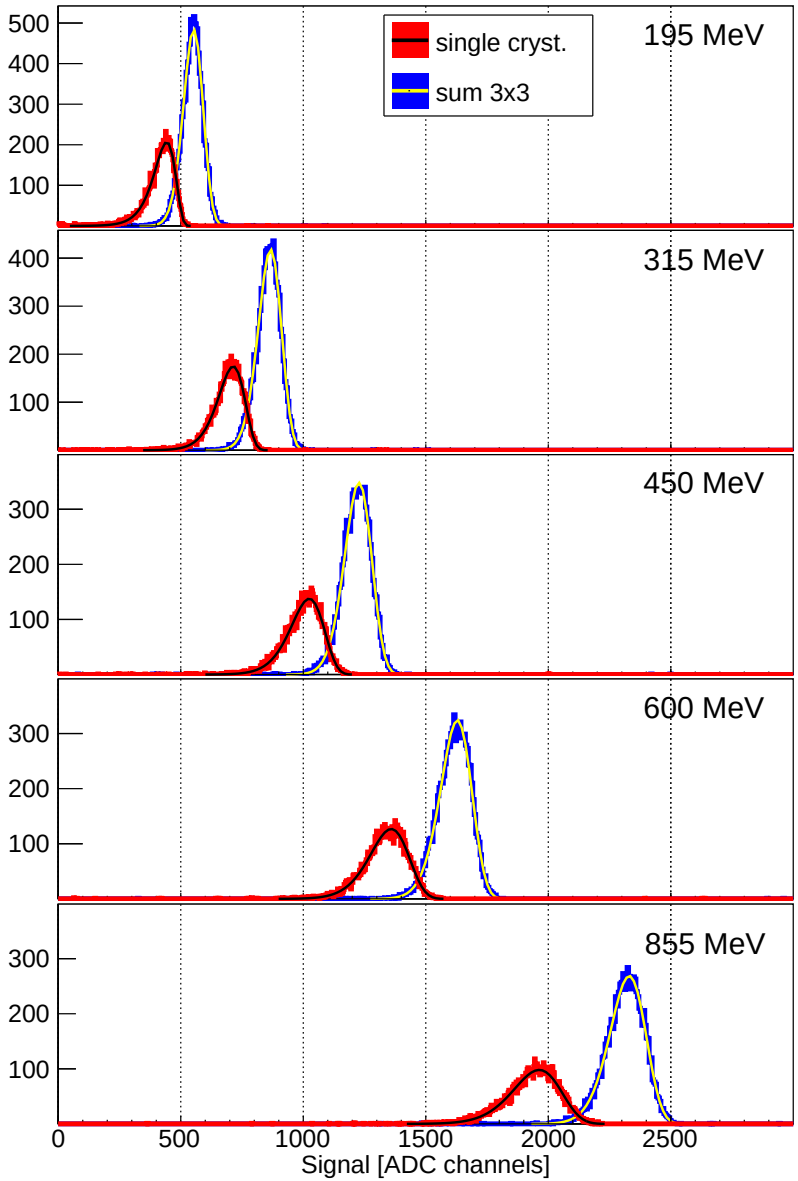


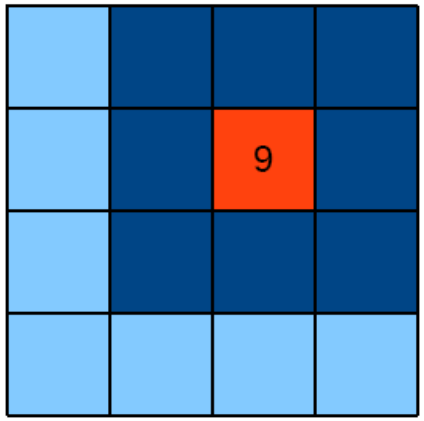
Detector stability

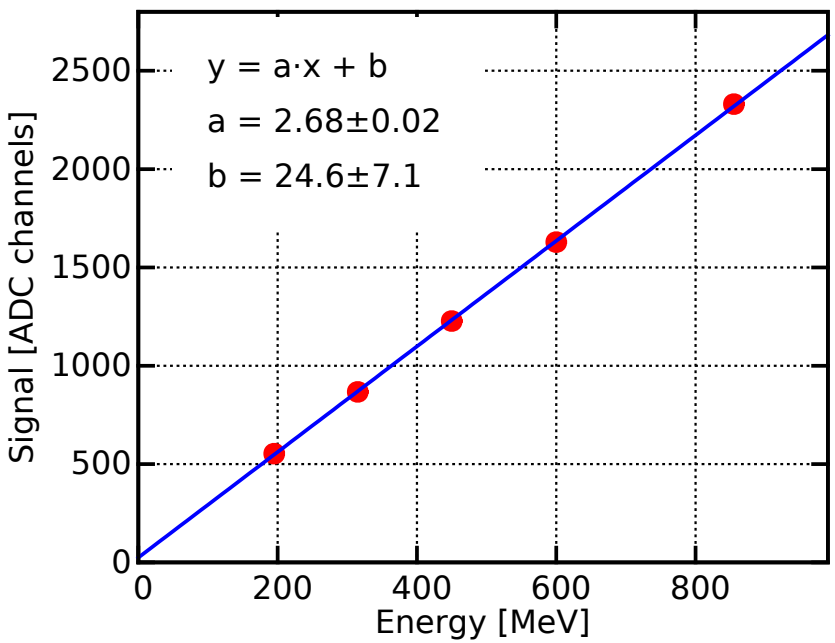
Baseline standard deviation



Detector response







Performance requirements

Relative energy resolution

$$\frac{\sigma_E}{E} = a \oplus \frac{b}{\sqrt{E/\mathrm{GeV}}} \oplus \frac{c}{E}$$

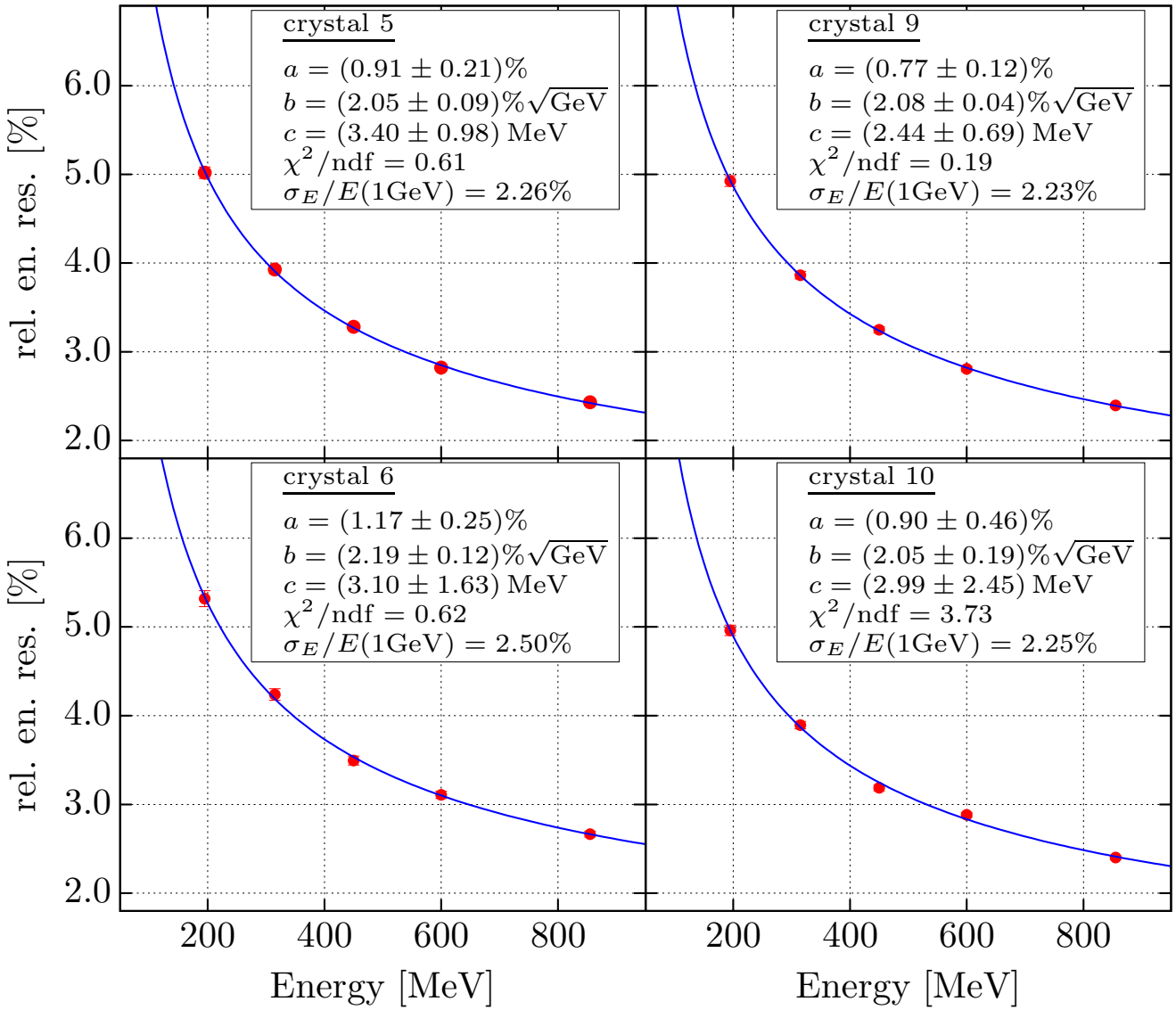
- Relevant here: electronic noise contribution c/E
- TDR requirement: $c = 1\ \mathrm{MeV}$

Single crystal energy threshold (E_{xtl})

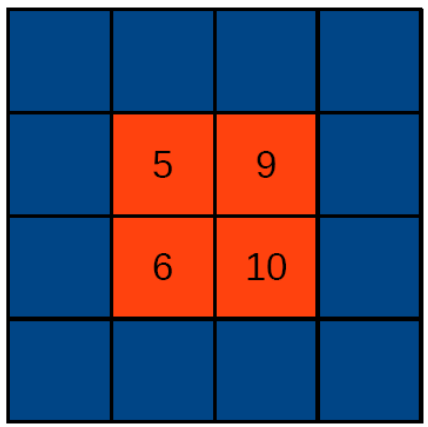
- Lowest energy distinguishable from noise
- Below E_{xtl}: contribution shower leakages
- TDR requirement: $E_{\mathrm{xtl}} = 3\ \mathrm{MeV}$

Energy resolution

Only low gain:



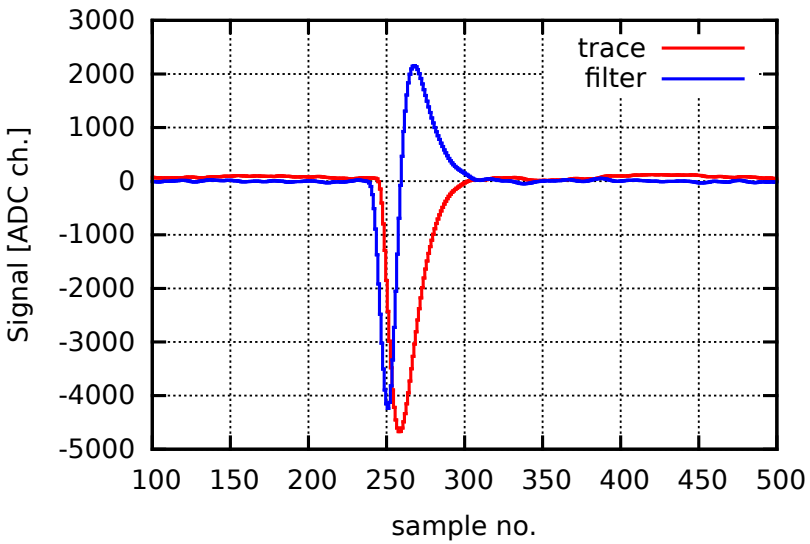
$$\frac{\sigma_E}{E} = a \oplus \frac{b}{\sqrt{E/\text{GeV}}} \oplus \frac{c}{E}$$



Single crystal energy threshold

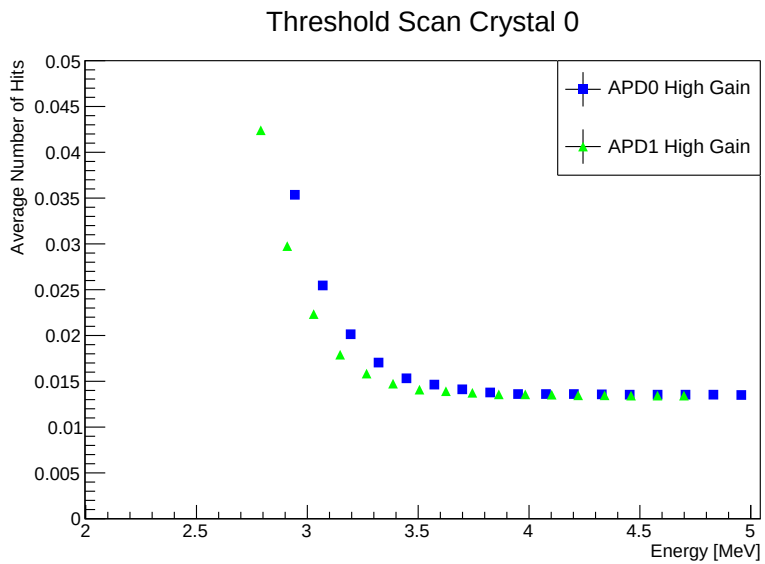
Hit detection filter

- Simple moving average + first derivative
- Robust, effective and simple
- Easy threshold conversion into energy
- Not yet implemented: time over threshold



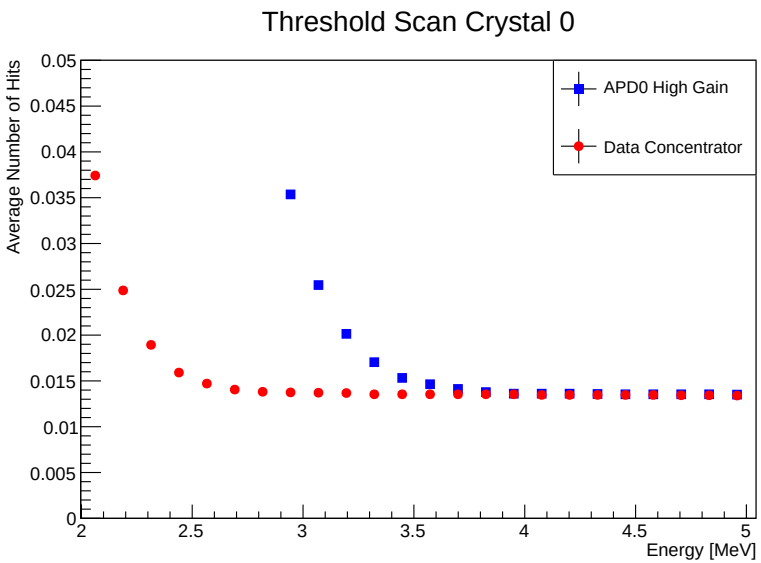
Threshold scan

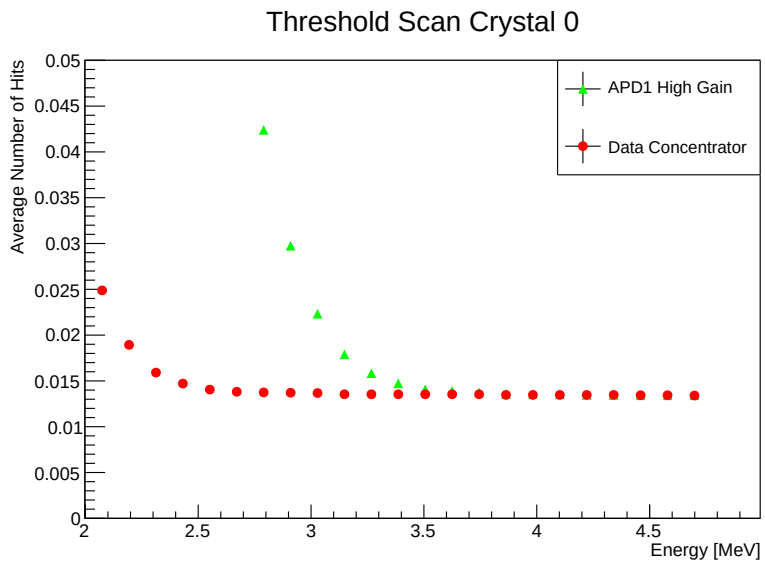
- Setting threshold on filtered trace
- Varying threshold
- Counting off-trigger hits
- Expected probability: Rate$\times$trace time $\sim$ 800 Hz$\times$17 μs = 1.36%
- Noise hit rate ($E_{\mathrm{xtl}} = 3$ MeV) ≤ 1.3 kHz



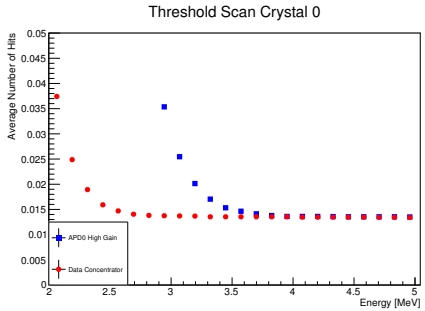
Single crystal energy threshold

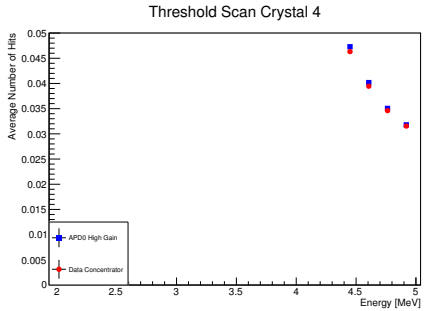
- Logic processing after feature extraction (DC level)
- Check if both APD see a hit at the same time
- Improvement of E_{xtl} by ~ 1 MeV

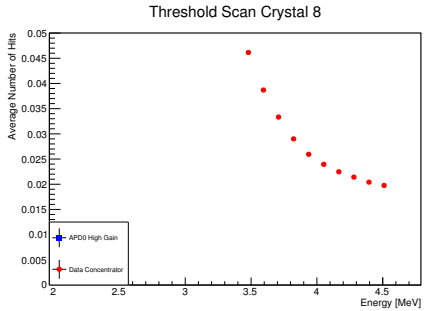


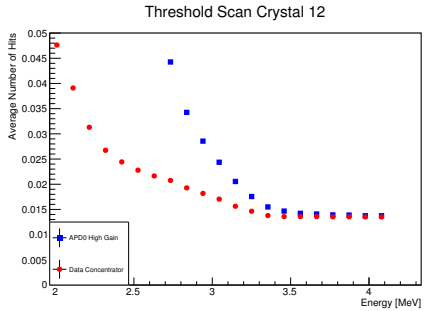


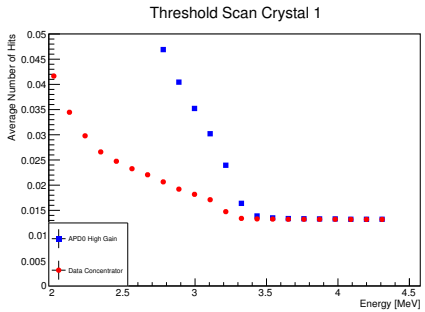
Single crystal energy threshold

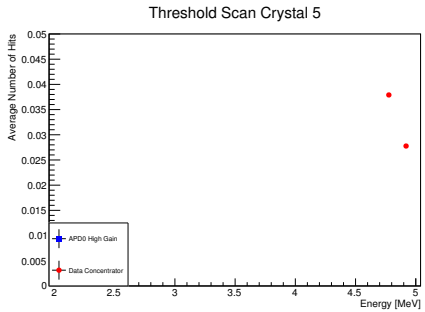


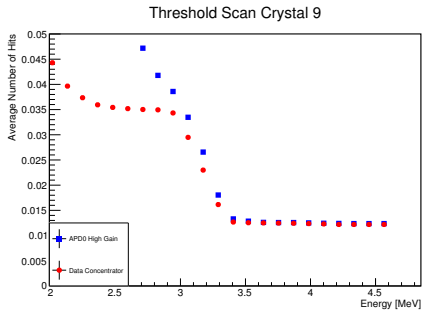


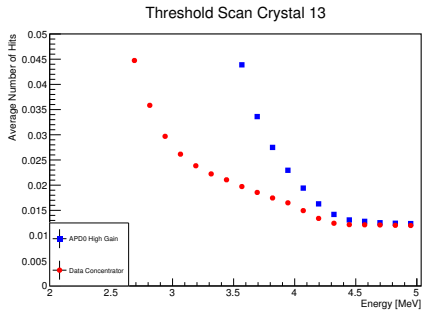


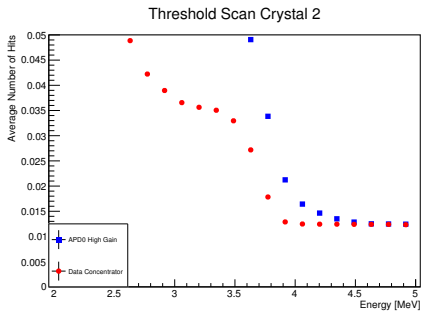


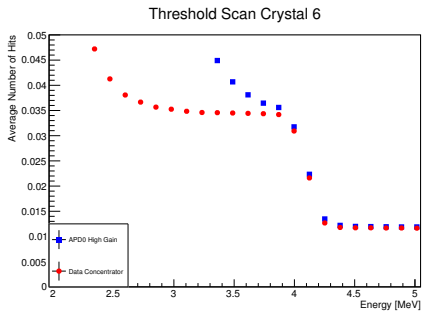


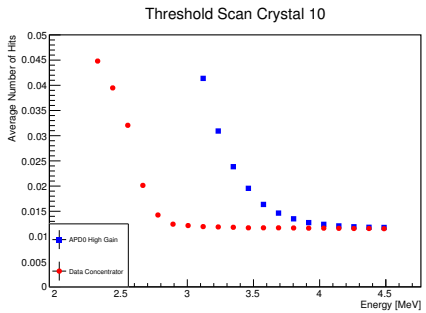


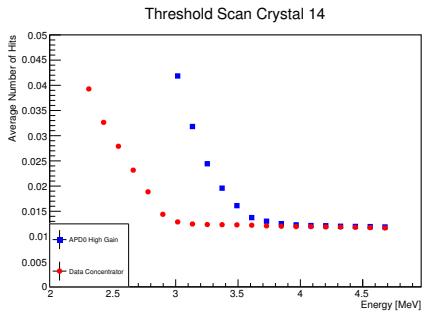


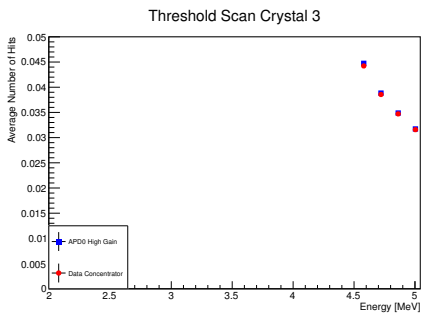


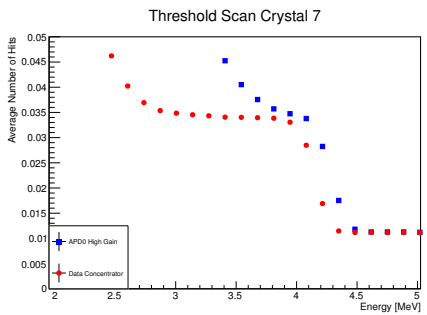


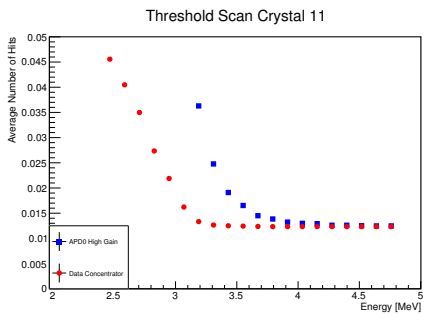


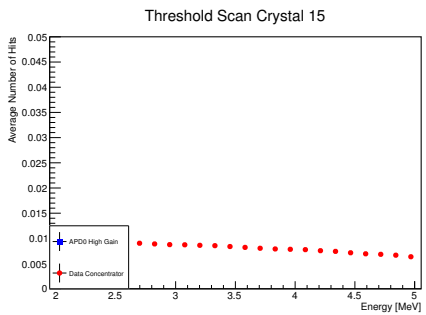






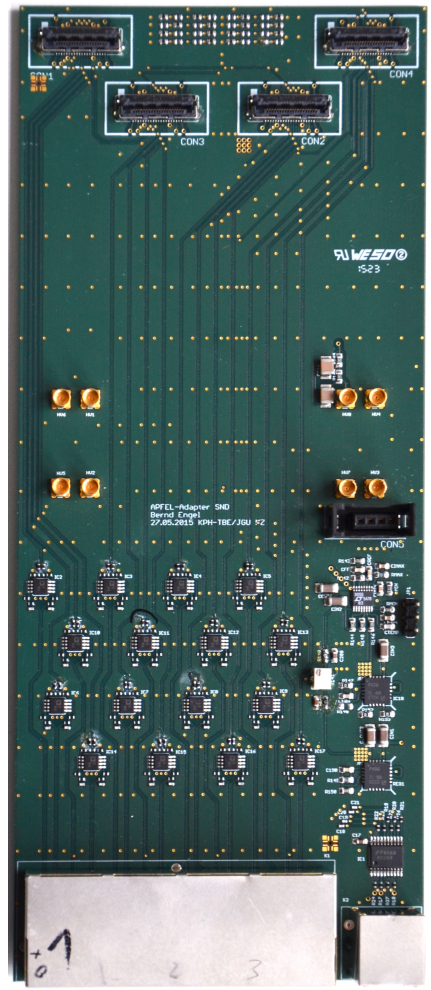






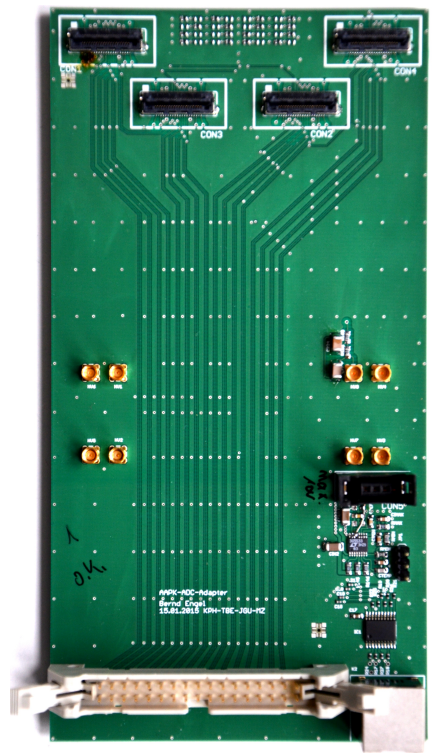
Current activities

- Update distrubution board
  - Finding noise sources
  - Add HV splitter



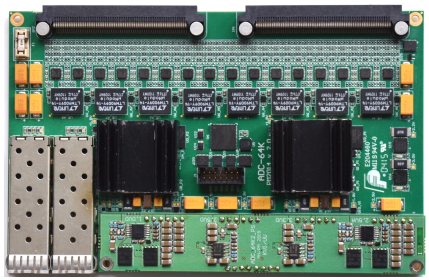
Current activities

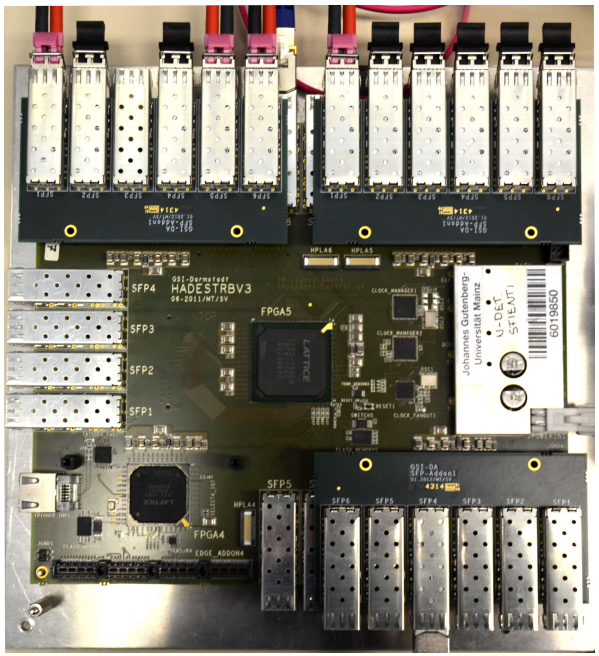
- Update distrubution board
  - Finding noise sources
  - Add HV splitter
- Readout without line drivers



Current activities

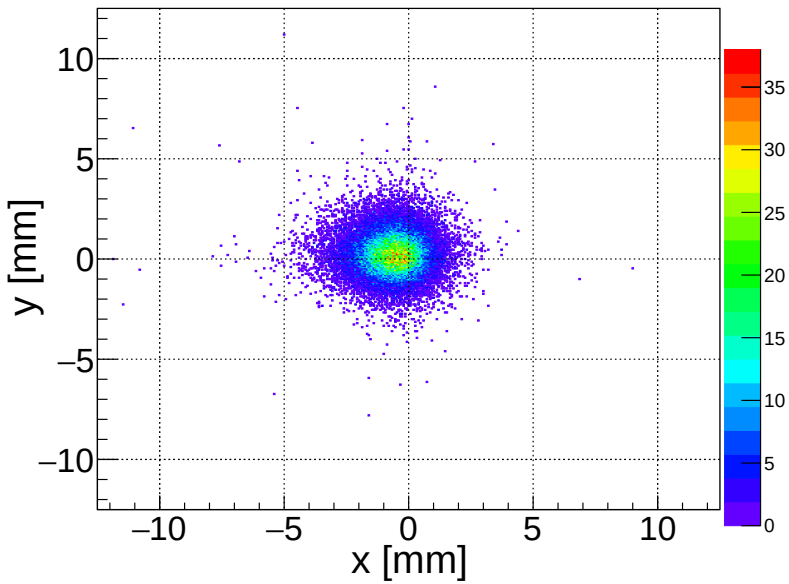
- Update distrubution board
  - Finding noise sources
  - Add HV splitter
- Readout without line drivers
- Uppsala SADC + TRB readout





Current activities

- Update distrubution board
  - Finding noise sources
  - Add HV splitter
- Readout without line drivers
- Uppsala SADC + TRB readout
- Position scans
  - Position dependency of energy res.
  - Position sensitivity (best with electron beam)

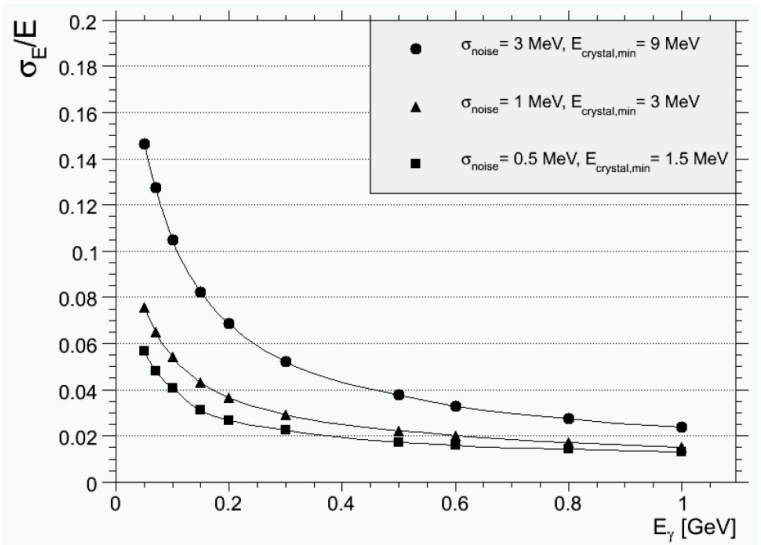


- Beam energy: 855 MeV
- Detector alignment accuracy $\sim$1 mm
- Shower centre of mass (linear weights)

Current activities

- Update distrubution board
  - Finding noise sources
  - Add HV splitter
- Readout without line drivers
- Uppsala SADC + TRB readout
- Position scans
  - Position dependency of energy res.
  - Position sensitivity (best with electron beam)
- Energy resolution as a function of E_{xtl} (high gain data)

From EMC TDR:



Summary

Shown here

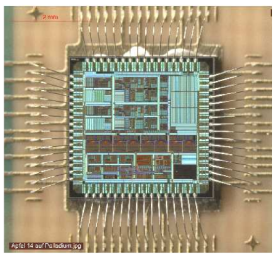
- Readout chain for the backward calorimeter
- Test setup at Mainz
- Data from beam tests
- Design performances achieved
- APFEL ASIC suitable for PANDA

To do

- Finalise the distribution boards/line drivers
- Include the PANDA ADCs and digital readout chain

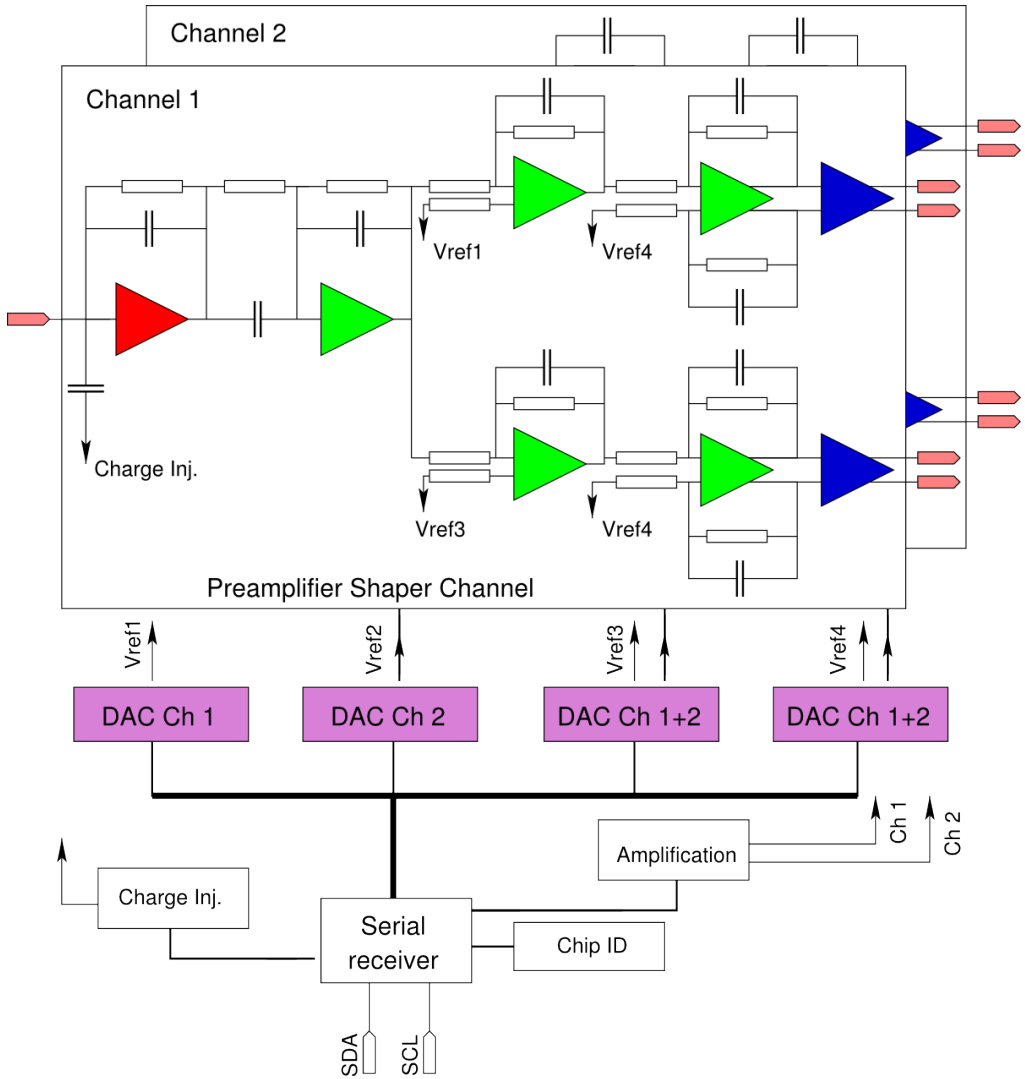
Backup

APFEL ASIC



- reads out 2 APDs
- charge sensitive preamplifier
- shaper (pulse width $\sim \mu$s)
- 2 main amplifiers (2 gains)
- 4 differential output channels

- bonded on a FFC-board
- power and programming lines
- HV lines for the APDs
- output signal lines



P. Wieczorek, H. Flemming, IEEE Nucl.Sci.Symp.Conf.Rec. 2010, 1319-1322

Readout and DAQ

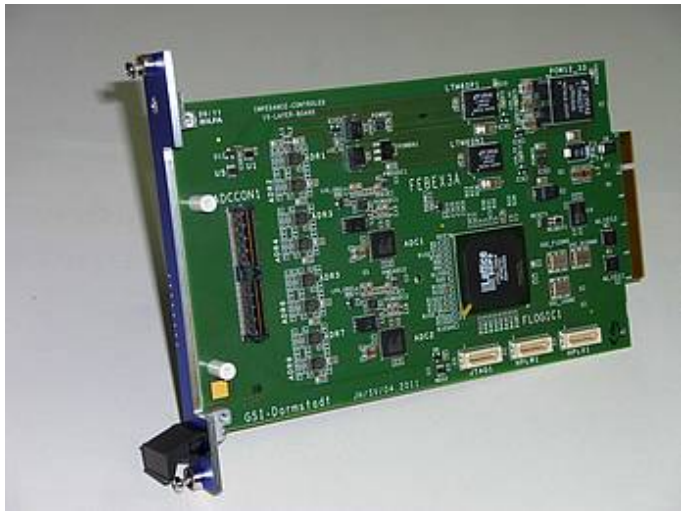
Sampling ADC

- Febex3b module from the GSI
- Sampling rate: 50 MSample/s
- Resolution: 14 bit
- Input range: -1 V ... $+1$ V

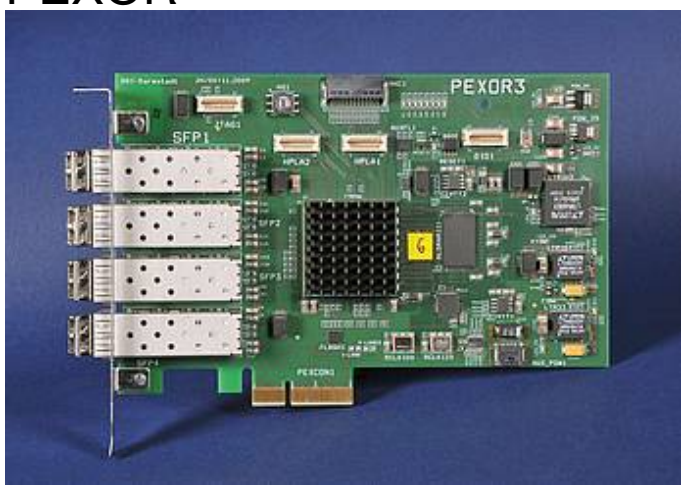
Data acquisition

- MBS system from the GSI
- PCI optical receiver (PEXOR) for ADC interface
- PCI trigger/dead time unit (TRIXOR/EXPLODER)
- Extensible with VME branch

FEBEX



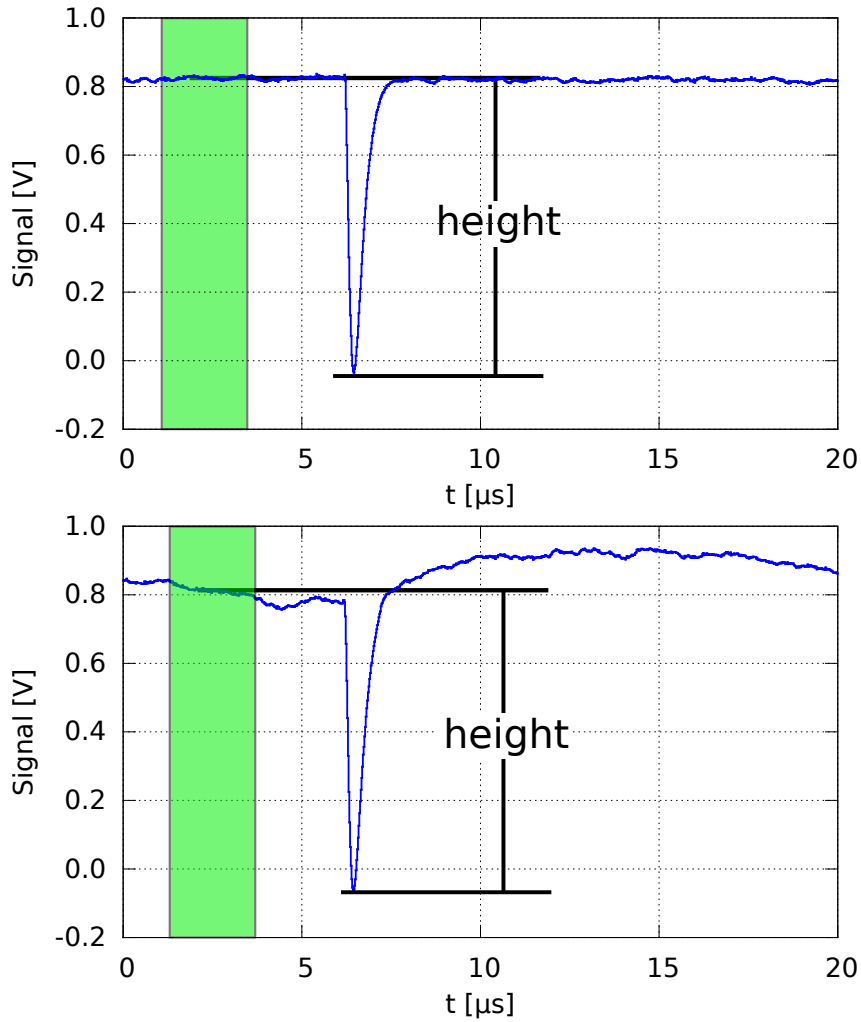
PEXOR



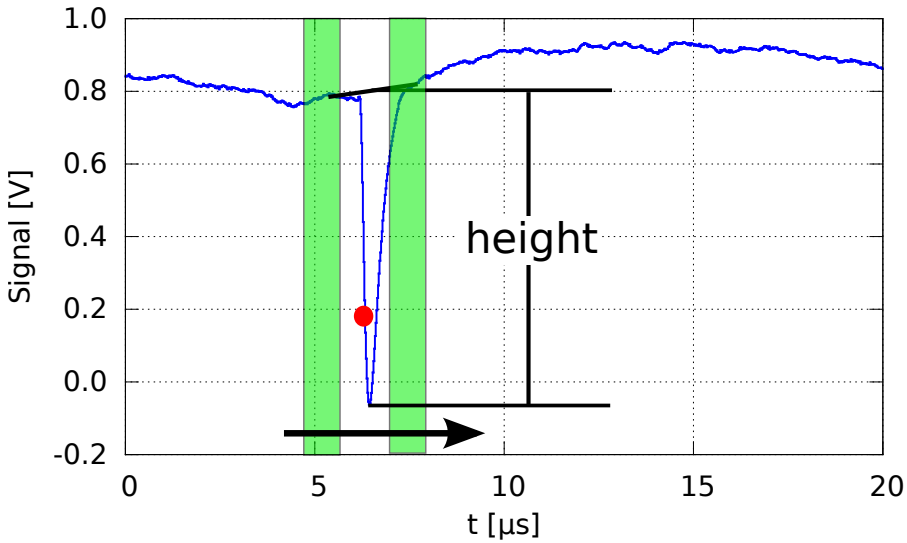
Pulse height determination

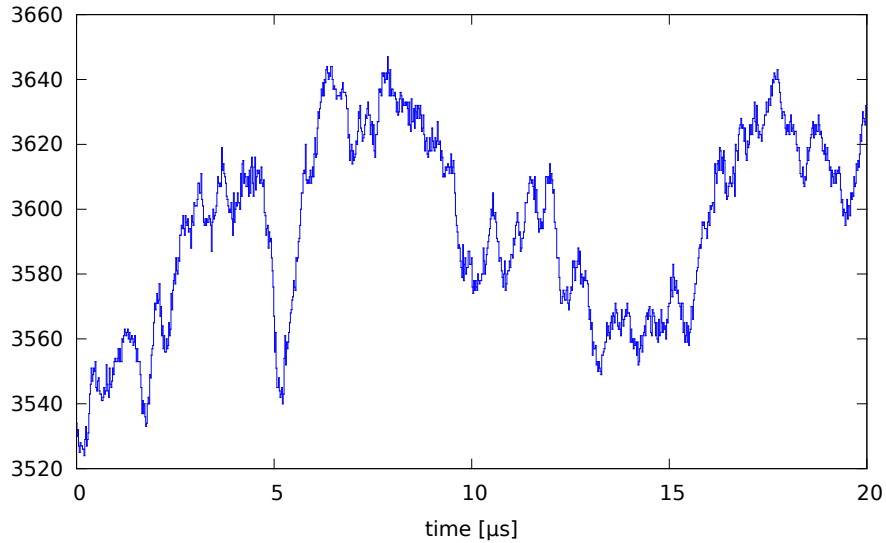
- Easiest approach:
  simple “baseline restoration”
  - calculate baseline on a window
  - find the maximum
  - subtract the baseline

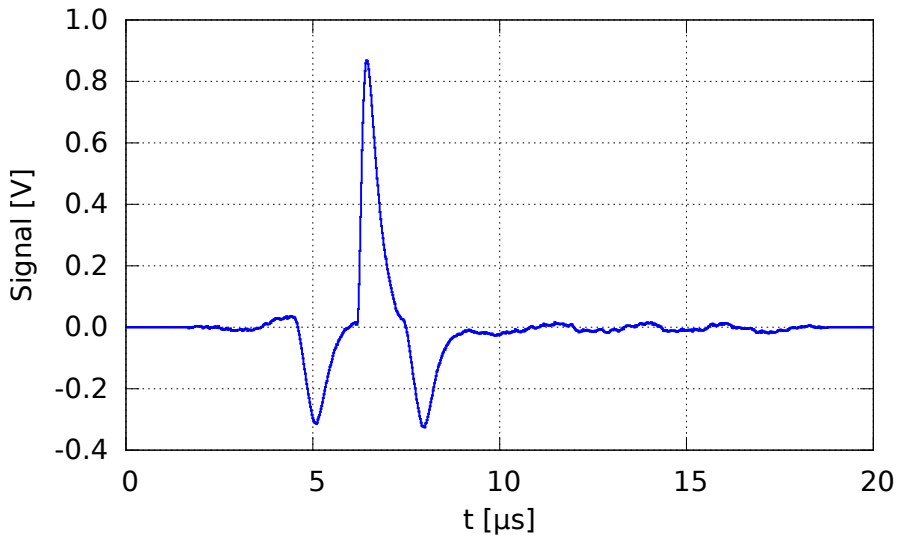
- Not feasible with the hum
  $\Rightarrow$ adds much more noise

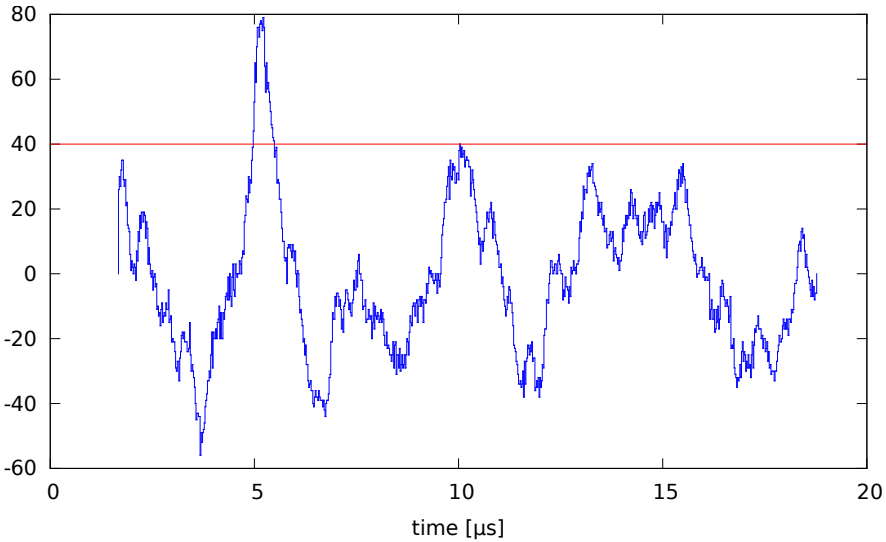


Two-windows filter

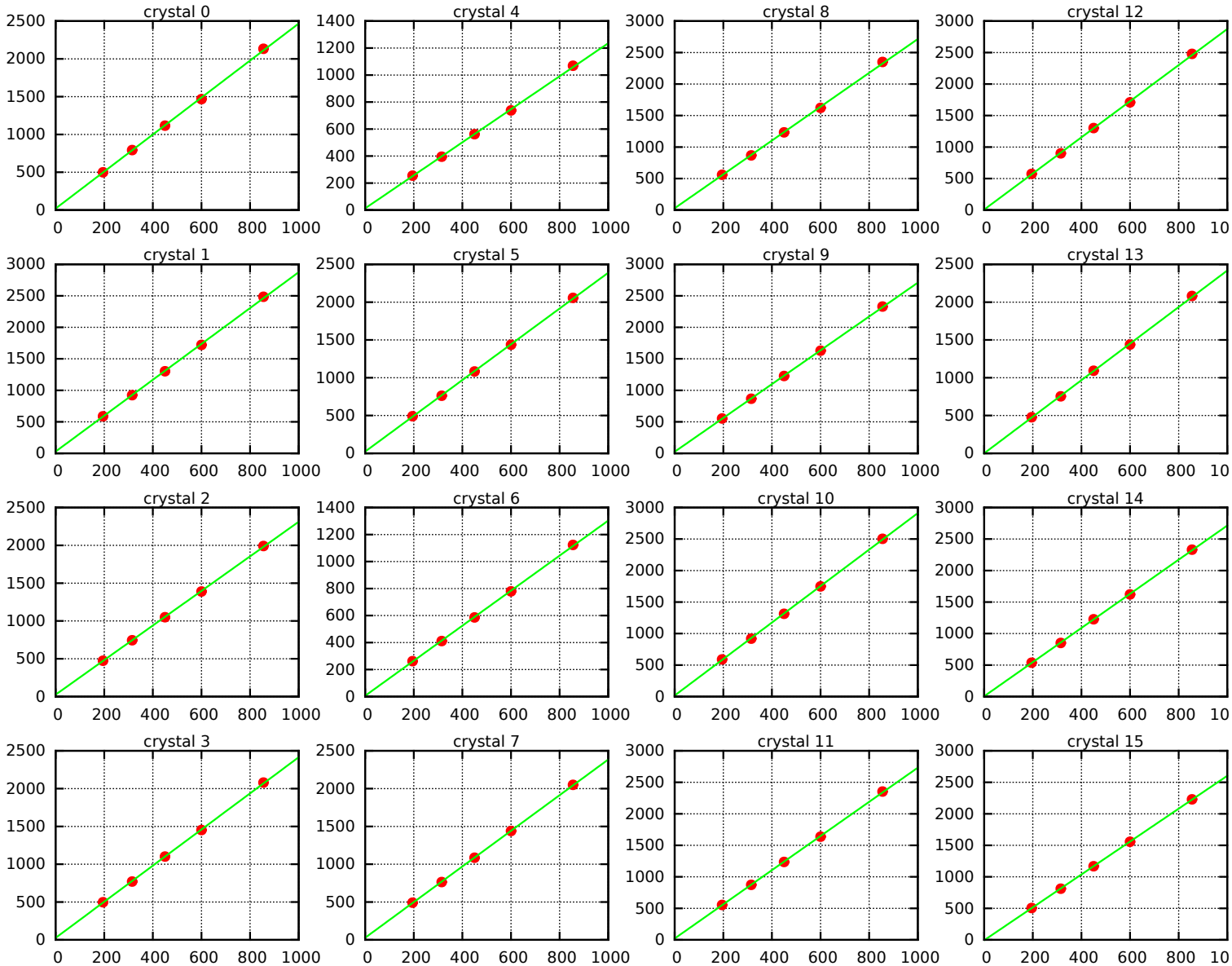




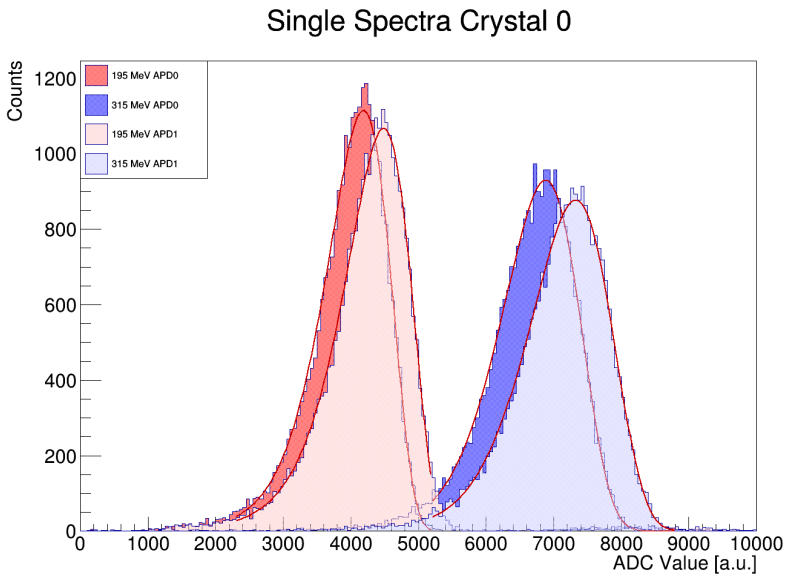




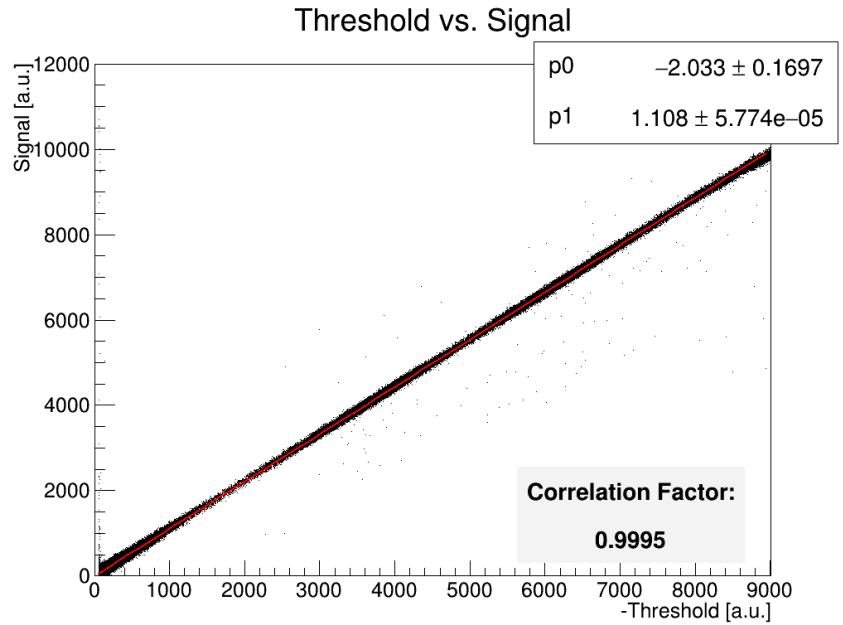
Linearity – all crystals



Threshold determination



- Single crystal energy spectra
- Deposited energy (Geant4): $(85 \pm 5)\%$ of beam Energy



- Conversion factor between pulse height and hit finder
- Very linear dependency

Threshold scans (APD1)