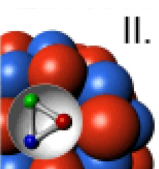
Status of R/O Electronics for Barrel EMC

HG Zaunick

JLU Giessen, Germany

PANDA FEE/DAQ Workshop
GSI, May 28, 2018

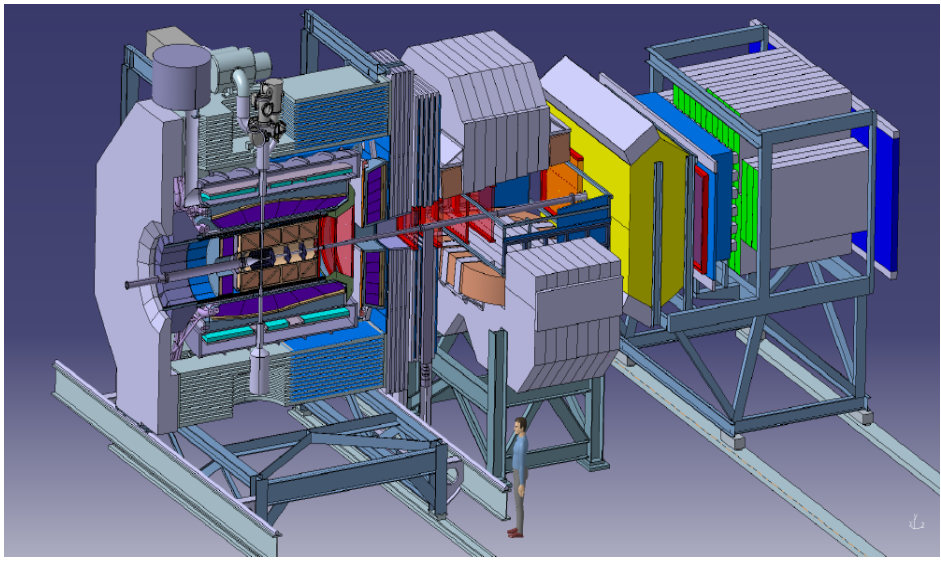


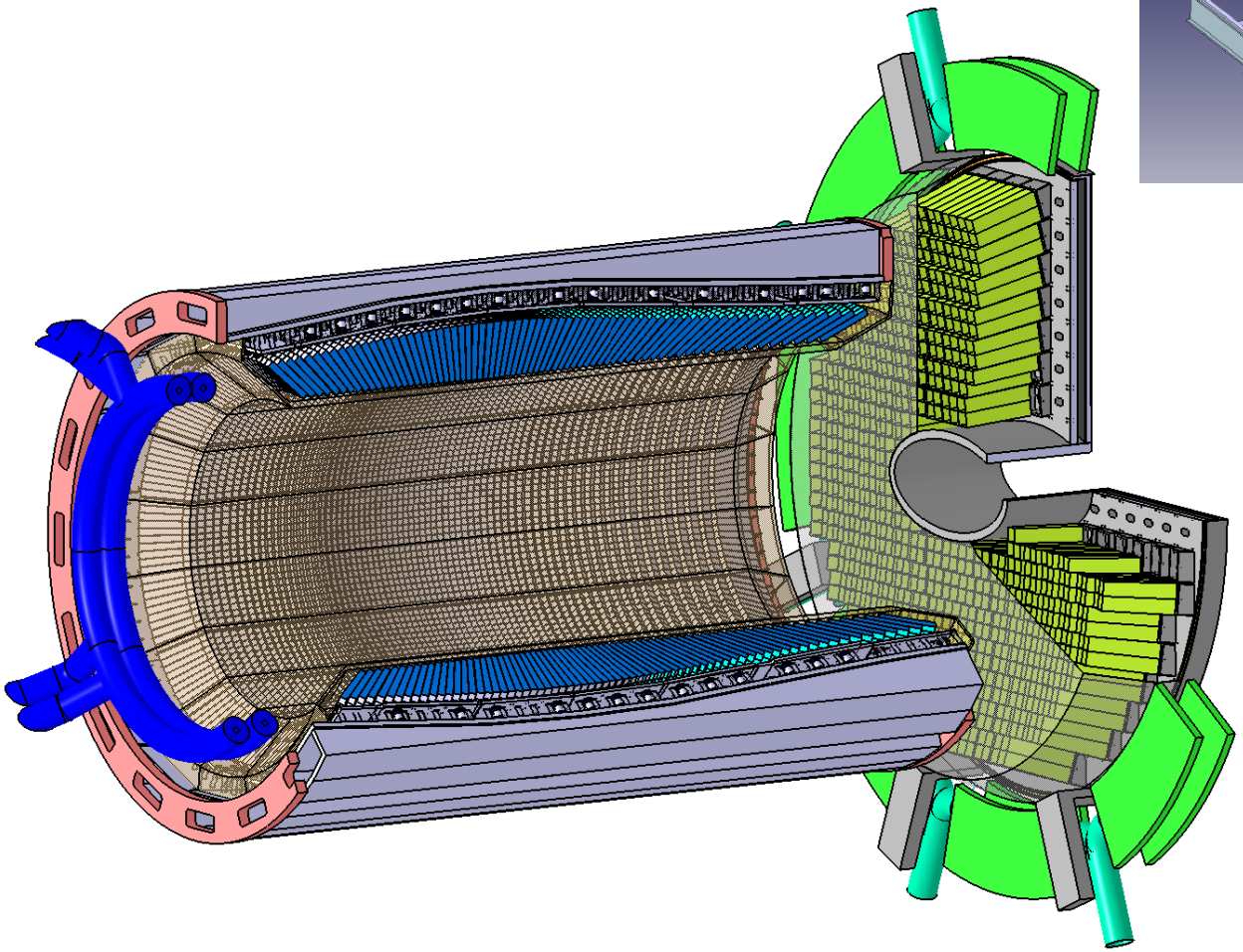
II. Physikalisches Institut

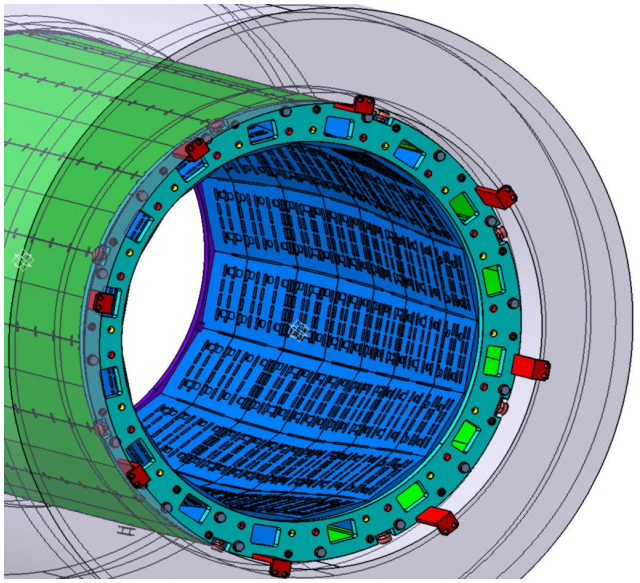
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

PANDA EMC

- ~15,000 PWO-II crystals, 22 X_0
- Operation at -25 °C, 0.1 K stability
- Readout by 2 LA APD photodetectors
- Self-triggered data acquisition

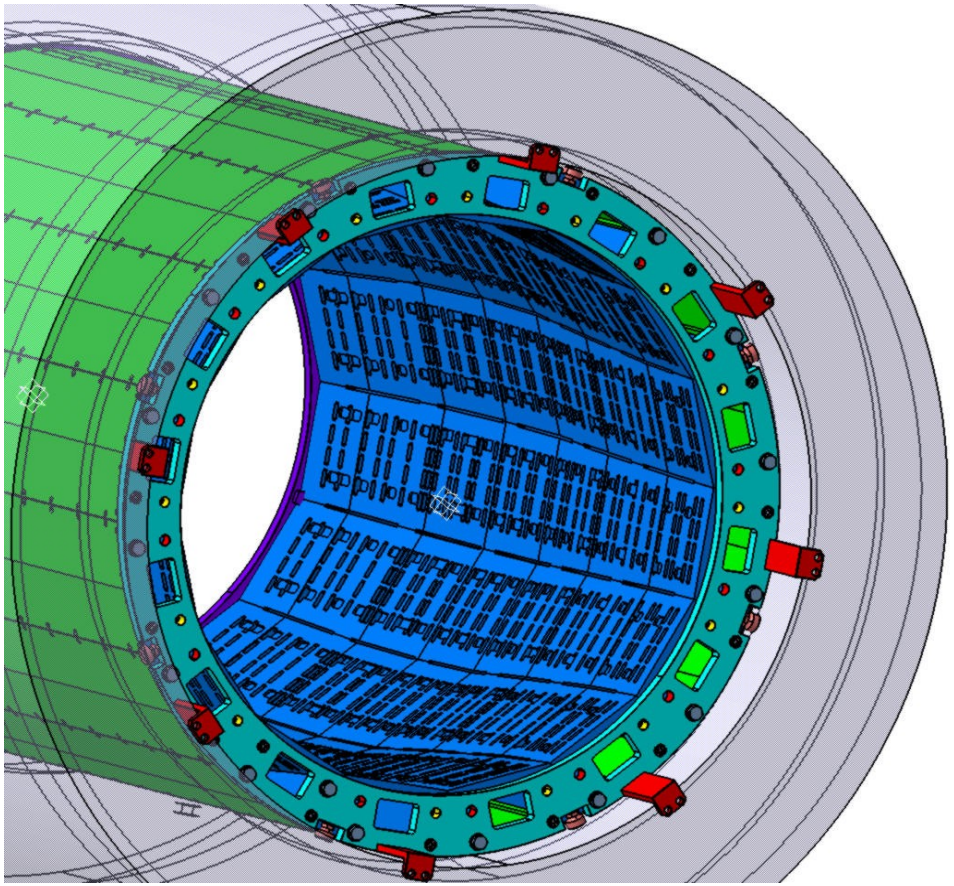




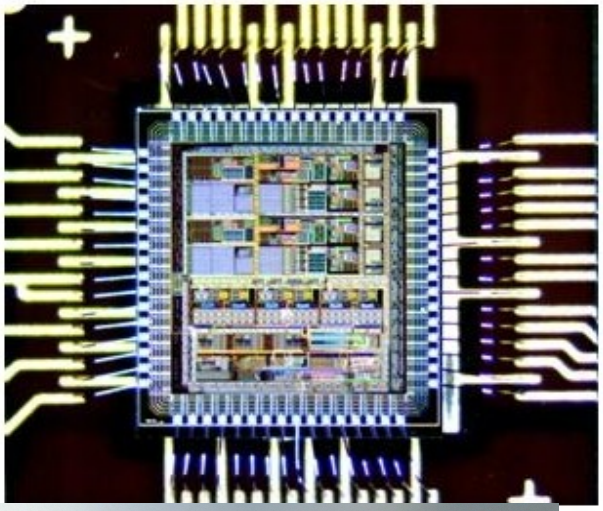


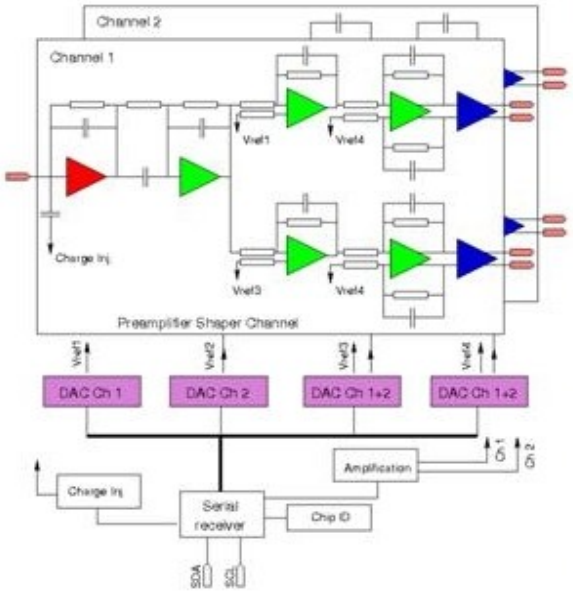
Construction (Barrel)

- Available opening in slice end face for services: 17x9 cm² = 15,300 mm²
- 720 signal cables + 1 slow-control: 3.3 mm diam. + 1 HV cable: 1.7 mm = 1080 cables
- Required cross section for cables ~10,000 mm² (including fill factor)
- Leaves ~5000 mm² for remaining electric services (LV supply)



Front-End ASIC





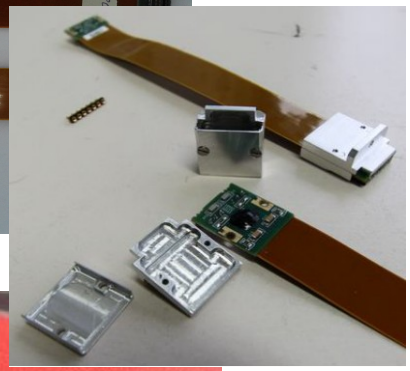
APFEL ASIC 1.5 overview:

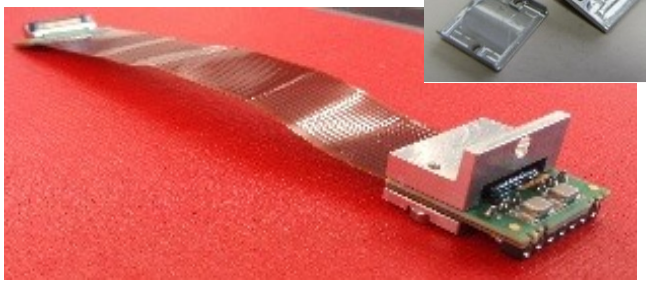
Analog Readout:

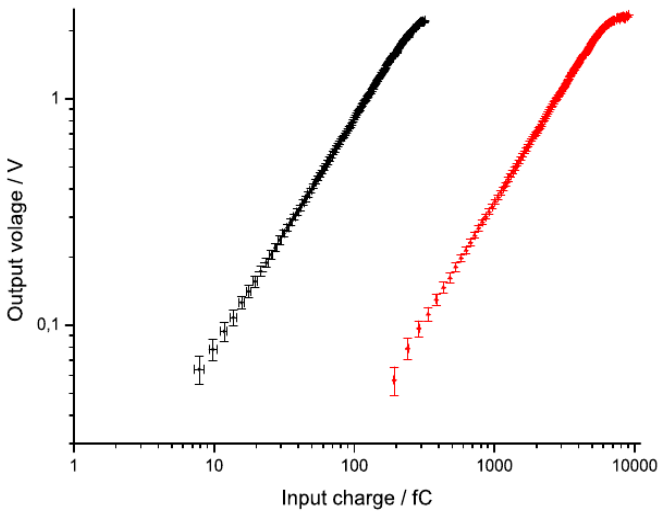
- Each readout channel consist of
  - charge sensitive preamplifier
  - third order shaper stage
  - differential output driver
- Two outputs per channel with different amplification to cover the dynamic range
- Two equivalent channels per chip

Digital Part:

- Serial interface on chip for the autocalibration to detect the right DC voltages for a given temperature to cover the whole dynamic range
- Optional charge injection
- Read and write of the DAC settings
- Chip ID for single chip bus communication



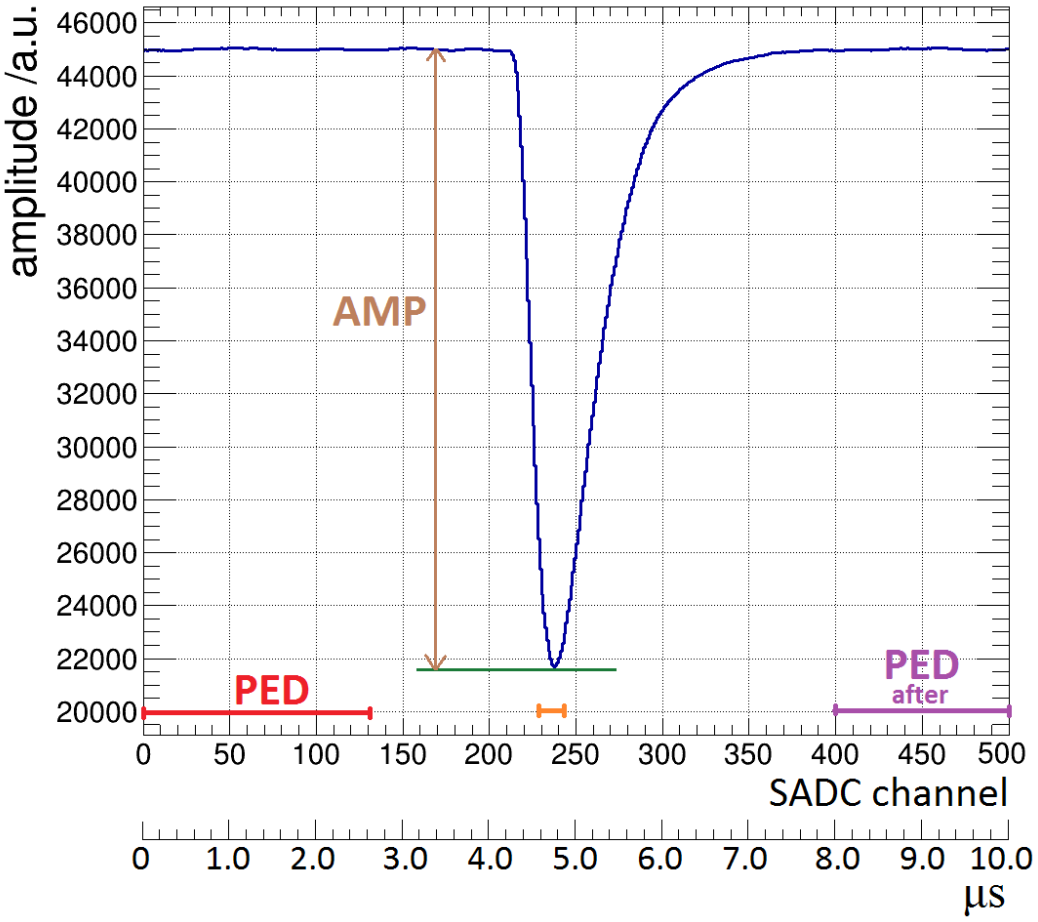


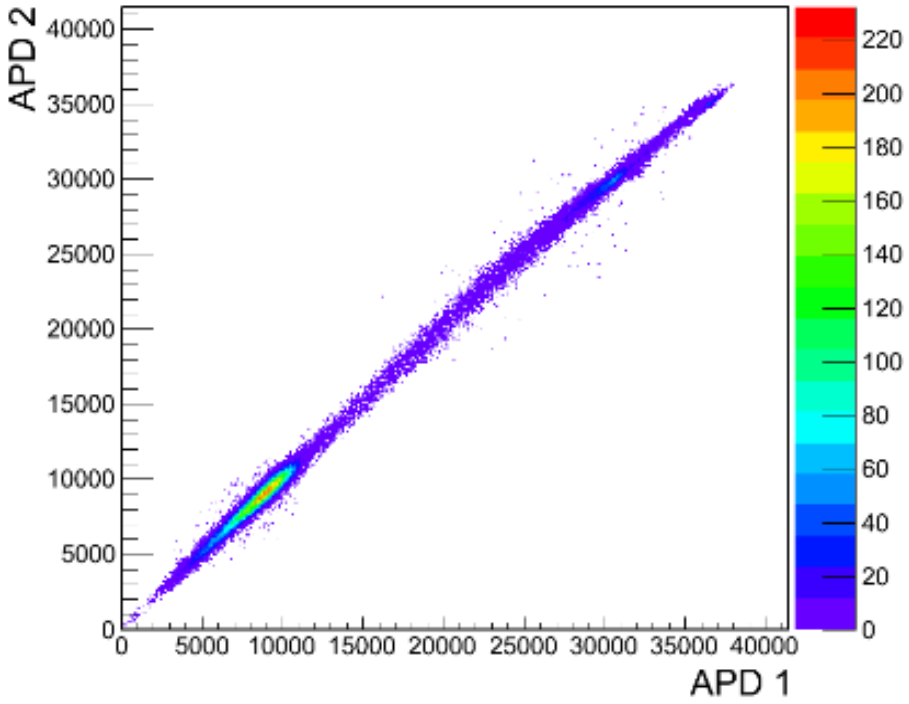


Requirements for the readout electronics

- noise < 2fC
- integration time 250 ns
- detector capacity 280 pF
- event rate per channel up to 350 kHz
- power consumption ≤ 50 mW/channel
- $\approx$ 22 000 channels

Signals

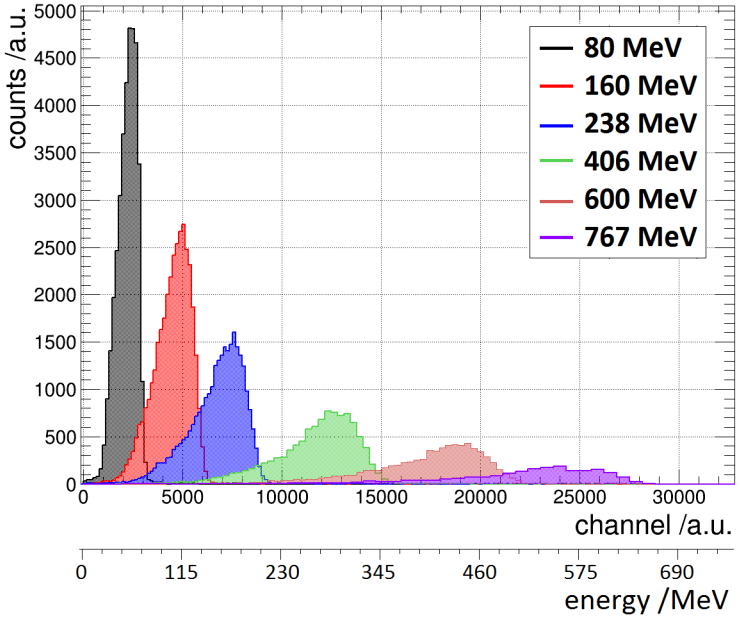




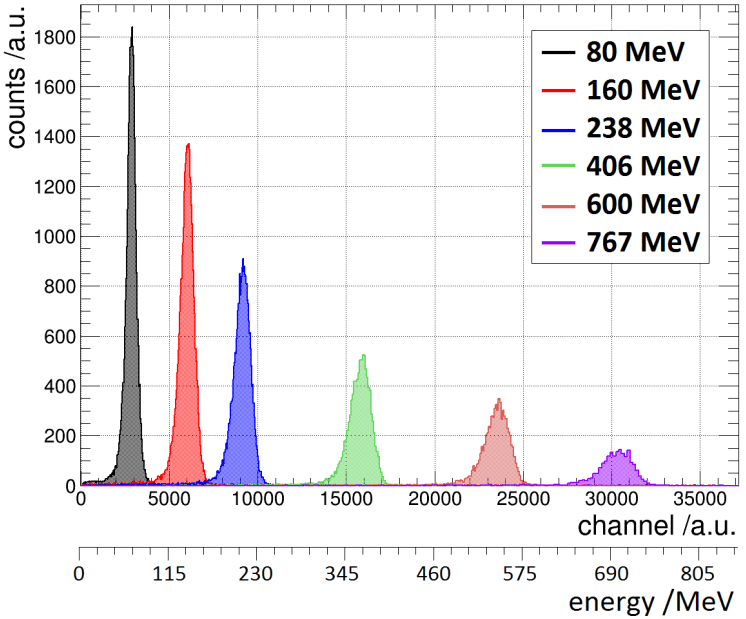
Both APDs show a linear correlated response in the region of the dynamic range

120 Crystal Prototype

Energy peaks for several selected photon energies



Single crystal

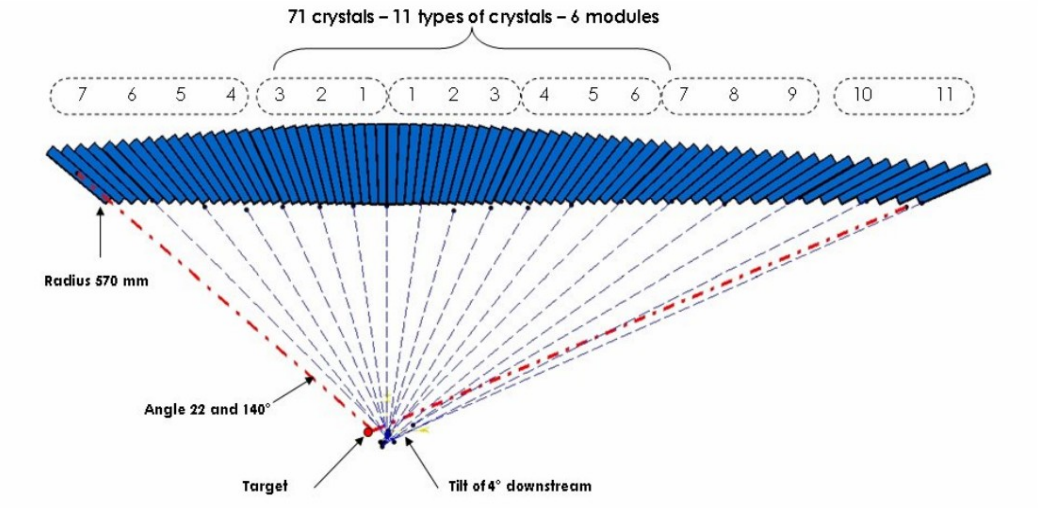


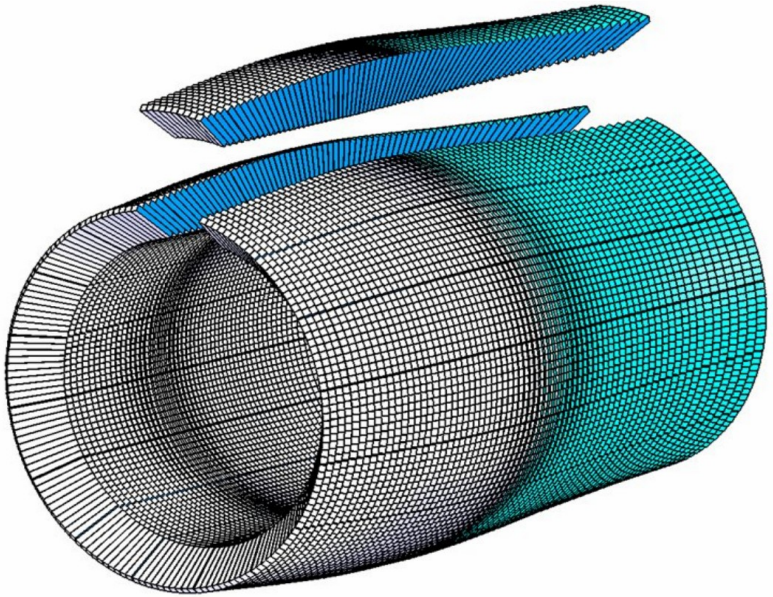
Cluster sum (3x3 matrix)

Current Activity

Assembly of one full Barrel EMC Slice

- 710 crystals in 22 different geometries
- 1420 APDs after 1st screening, irradiation, 2nd screening and matching
- 360 left and 360 right handed APFEL-ASIC flex PCBs
- 3500 m of signal cables

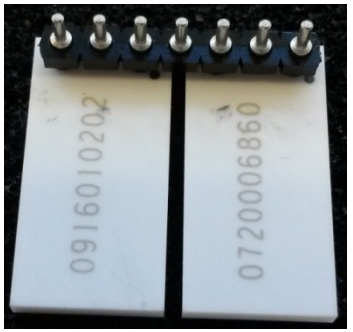


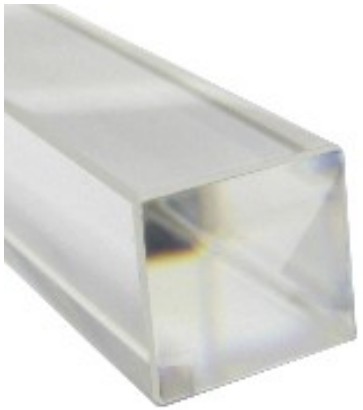


Detector Assembly

Glueing and wrapping of detectors

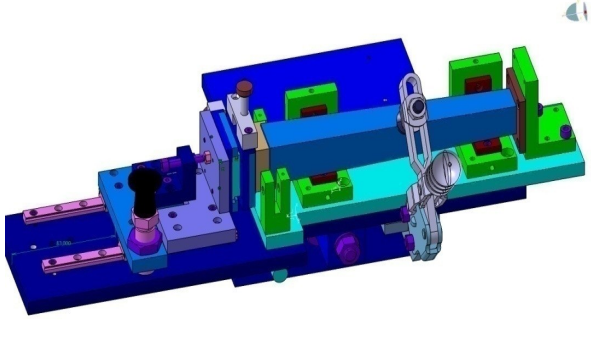
- 8 glueing stations available for parallel processing
- Throughput: 40 crystals (=one module block)/week
- Total processing time 18 weeks/slice
- Reflective foil wrapping: laser-cut foil in all geometries



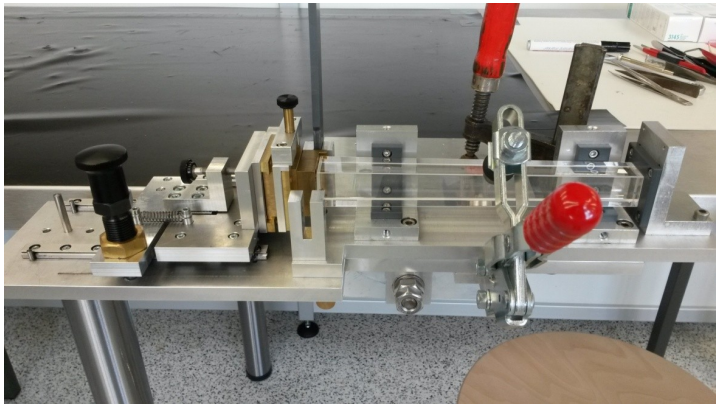


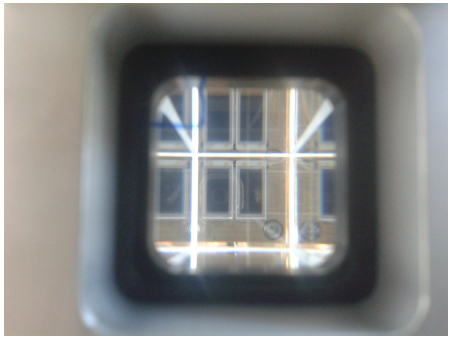
Detector Assembly

Precise mounting of APDs in glueing gauges:
defined glueing force and curing

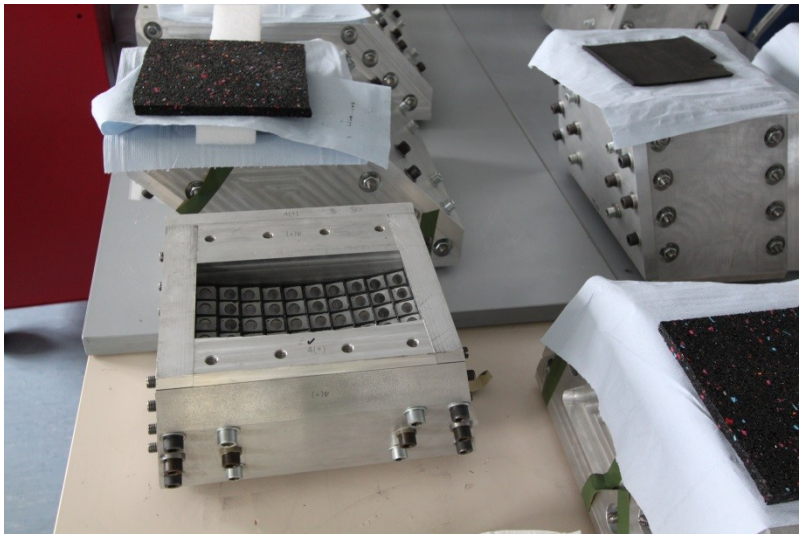


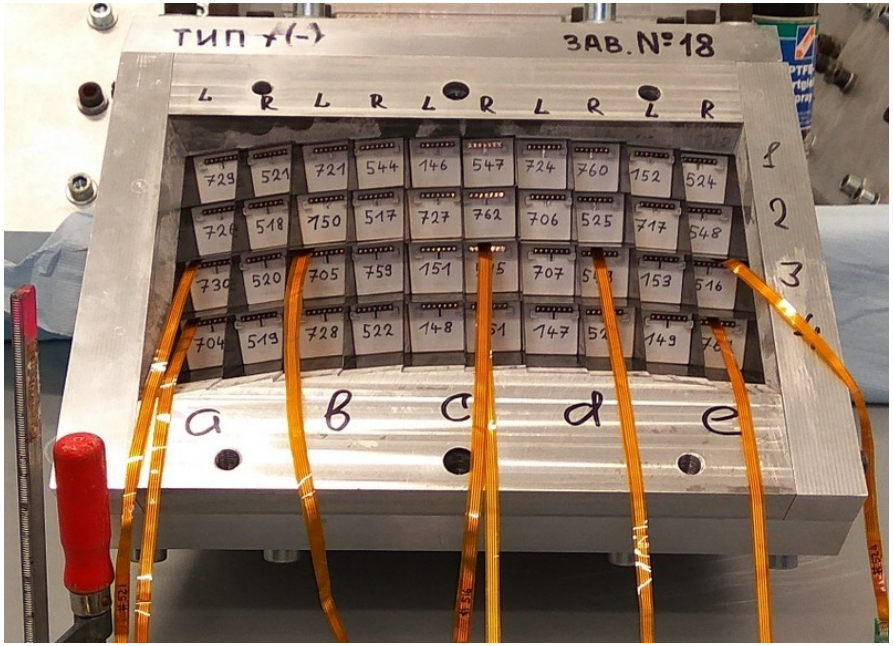
Glueing stations

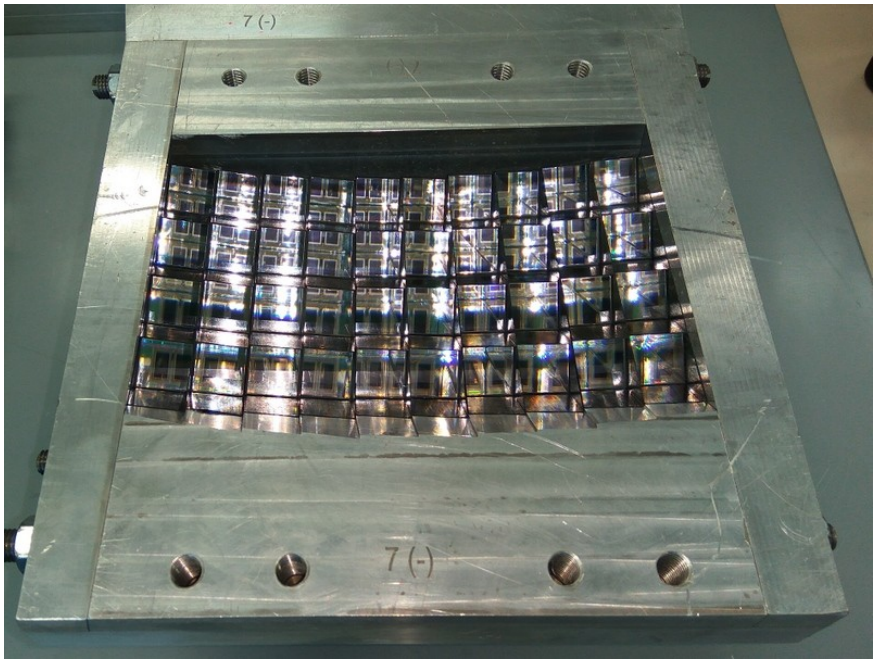




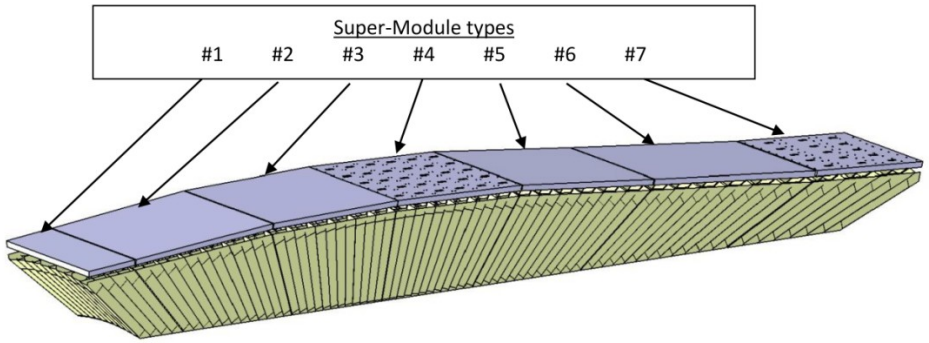
Module Assembly



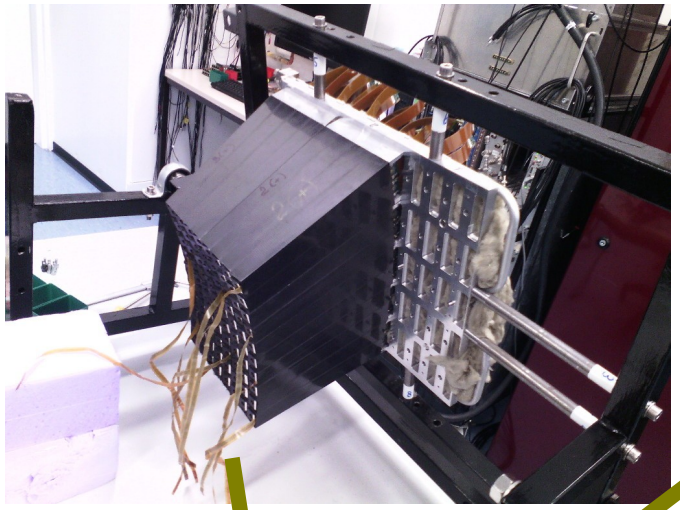


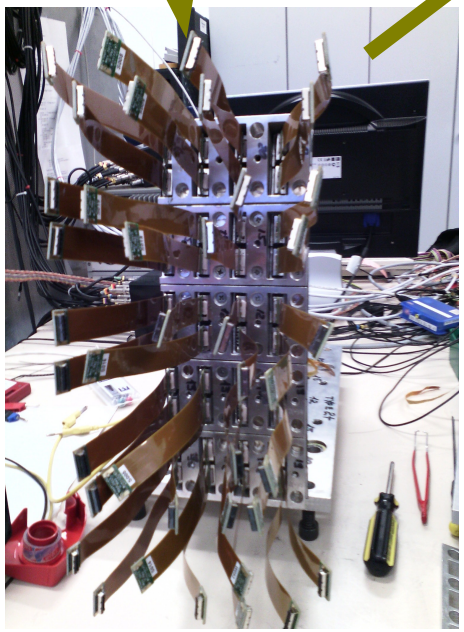


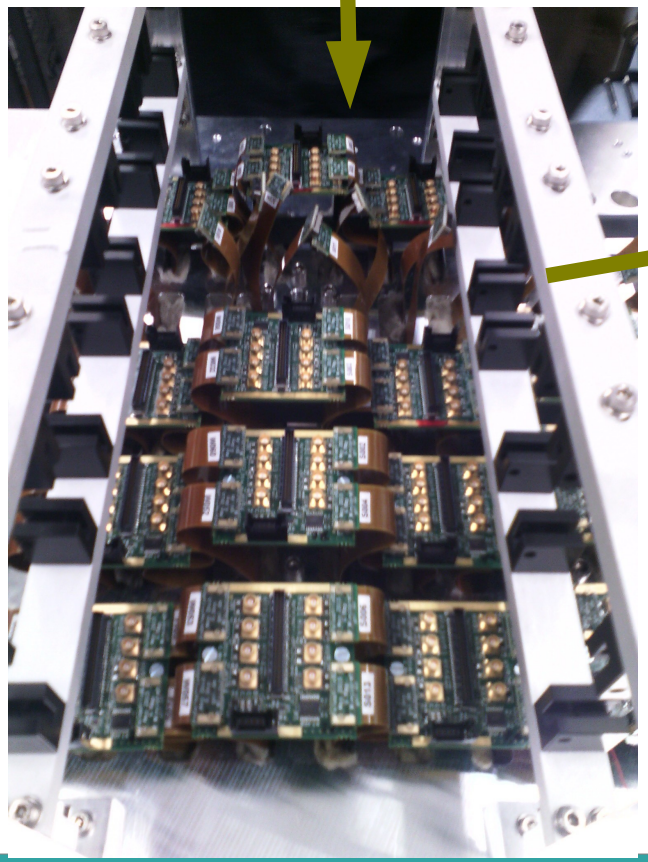
Slice Assembly Hall



Slice Assembly Procedure

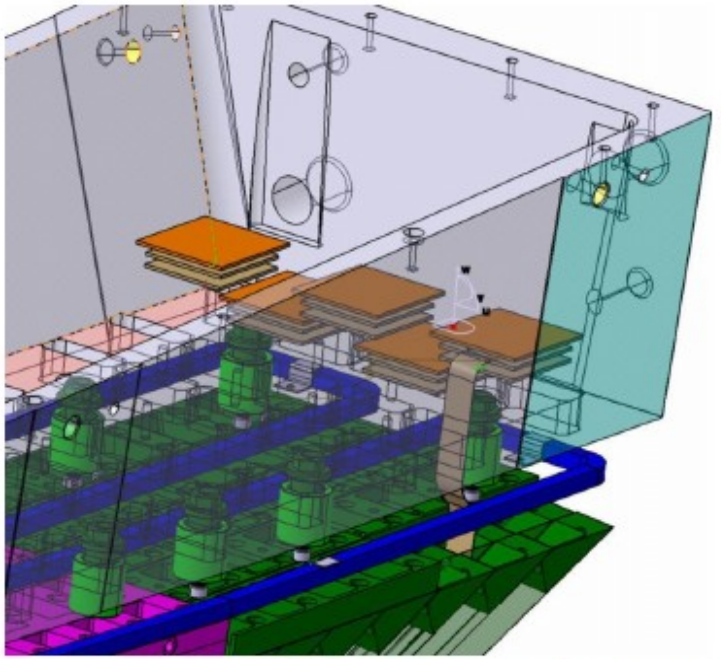


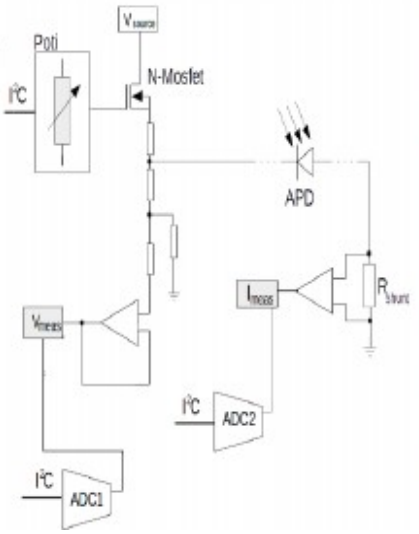




Backplane Electronics

- Present design: 3 Layers
  - HV distribution & regulation
    - Adjust bias voltage of 8 APDs
    - 50V from HV input downwards in < 0,1V steps
    - All channels fed from the same HV source
    - Online measurement of APD voltage and current
  - Connector board for ultrathin custon signal Cables
  - Board for FlexPCBs / ASICS
    - Connectors to FEs
    - 8x2 Diff. Line drivers
    - APFEL I/F buffers
    - Temp/Humidity sensors

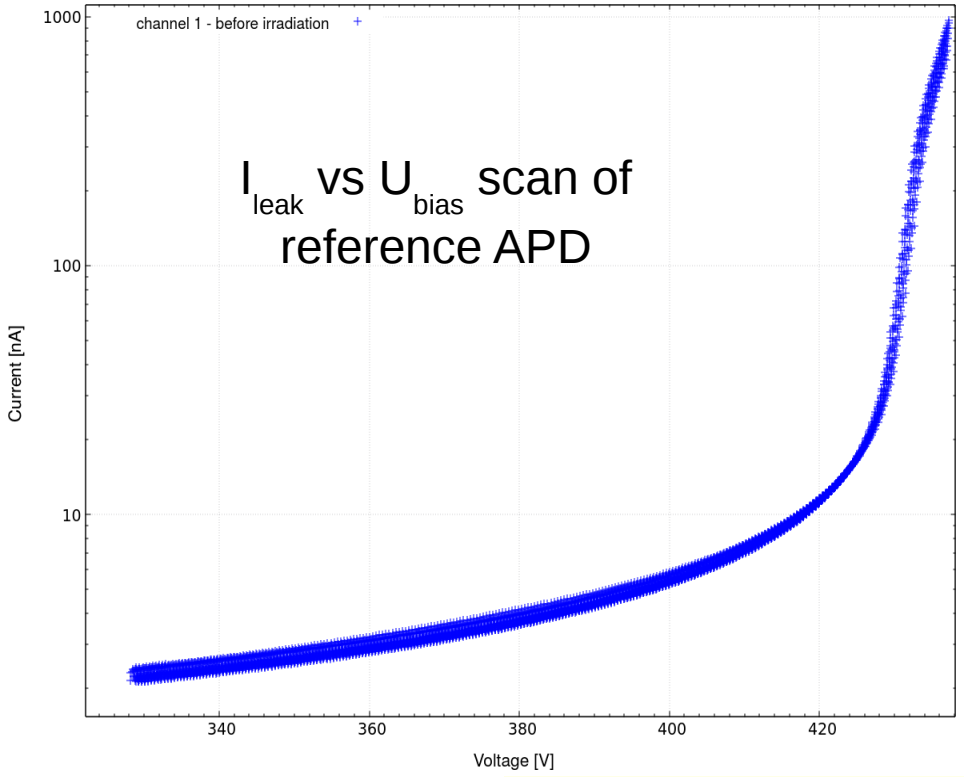




4-ch prototype

HV distribution electronics

- HV adjustment done by potentiometer setting

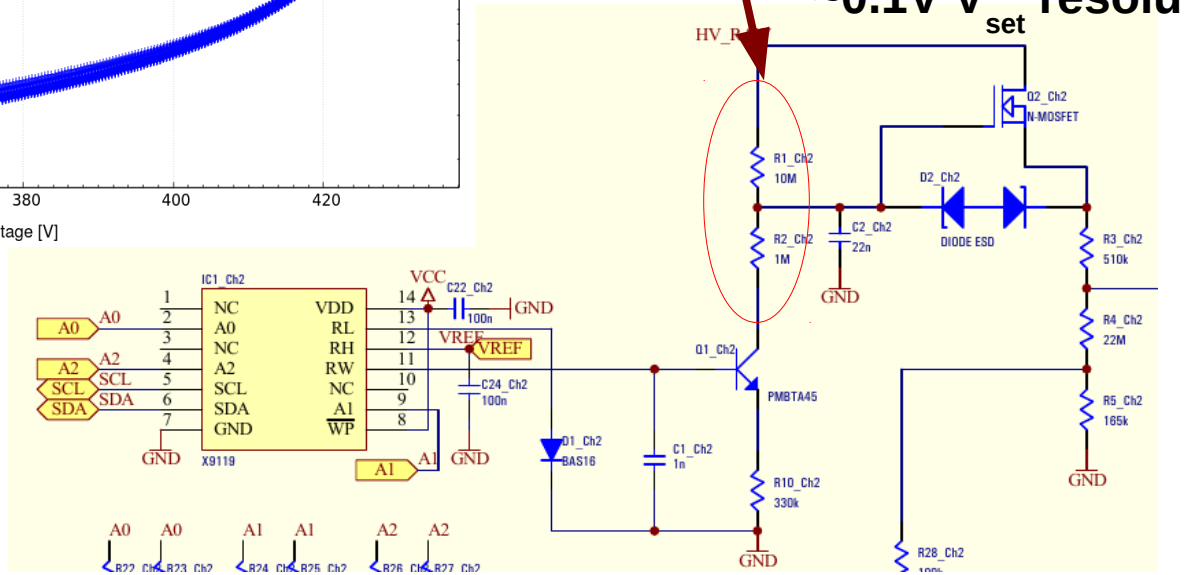


I_{leak} vs U_{bias} scan of reference APD

Regulation voltage range set by voltage divider at gate of HV Mosfet

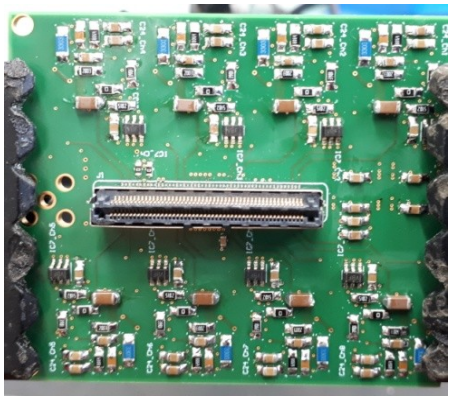
- Current prototype: ~100 V span from HV input downwards
- 10-bit resolution of potentiometer

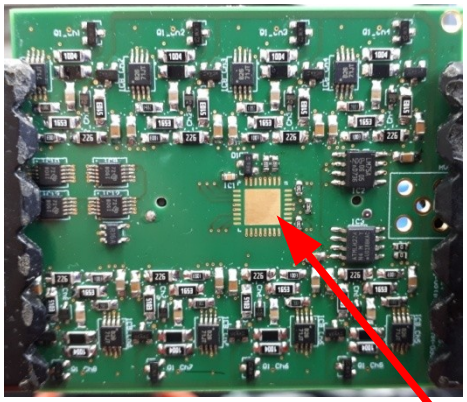
~0.1V V_{set} resolution



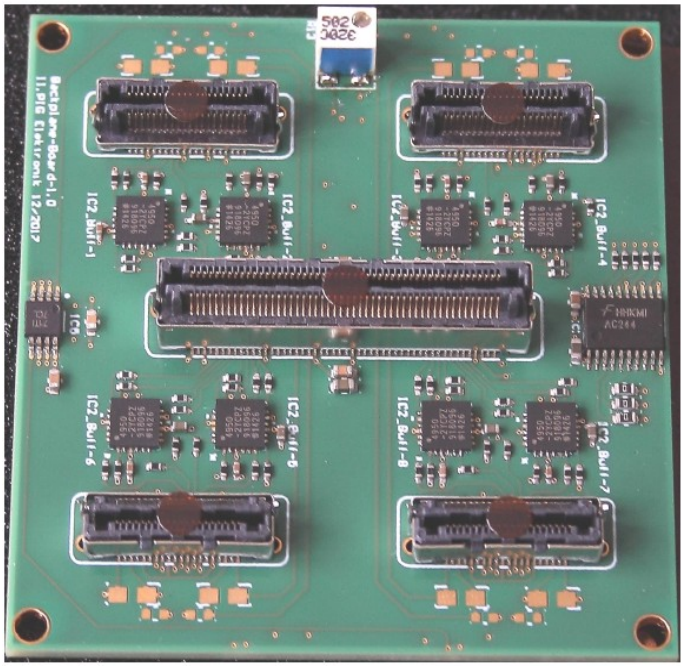
Backplane Electronics

- HVD for control of 4-crystal-unit (8 APDs) in final prototype tests
- Backplane base PCB with line drivers in testing phase
- Test station for test and calibration of the 2-PCB sandwich under development





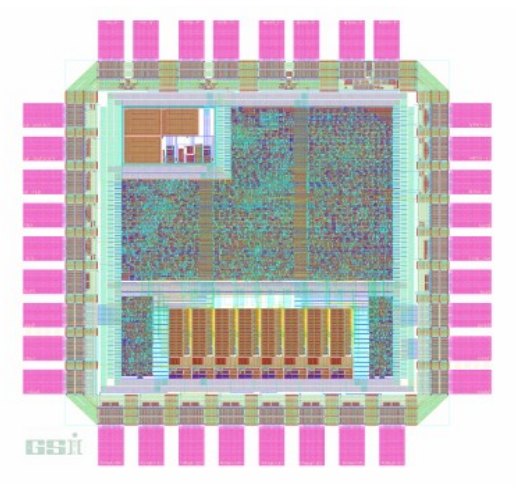
8-ch HVD final prototype
size: 6 x 5.5 cm²



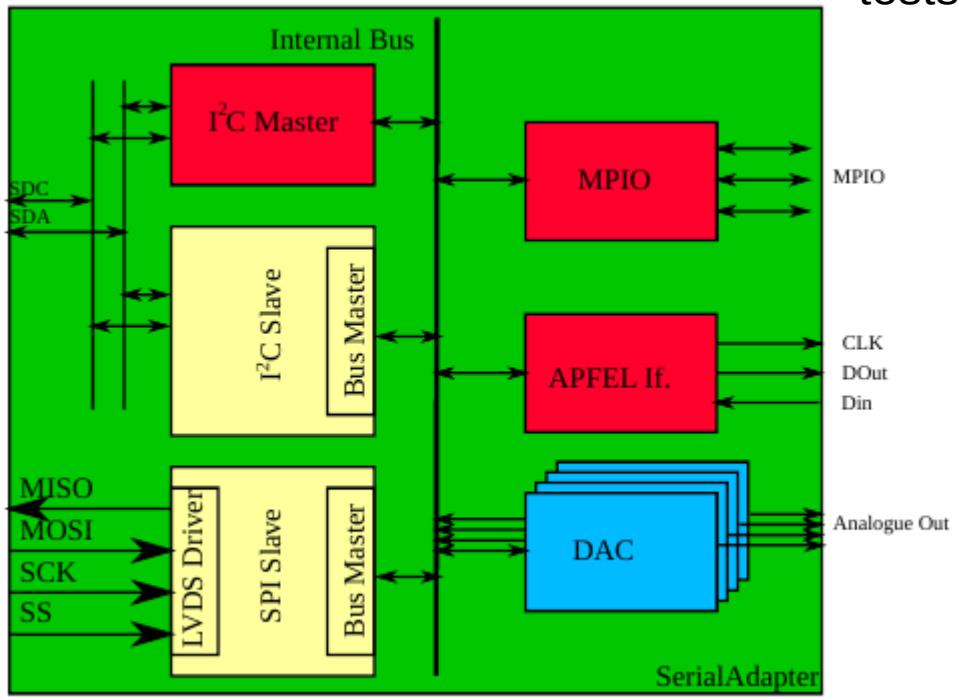
Backplane base PCB
size: 5 x 5.5 cm²

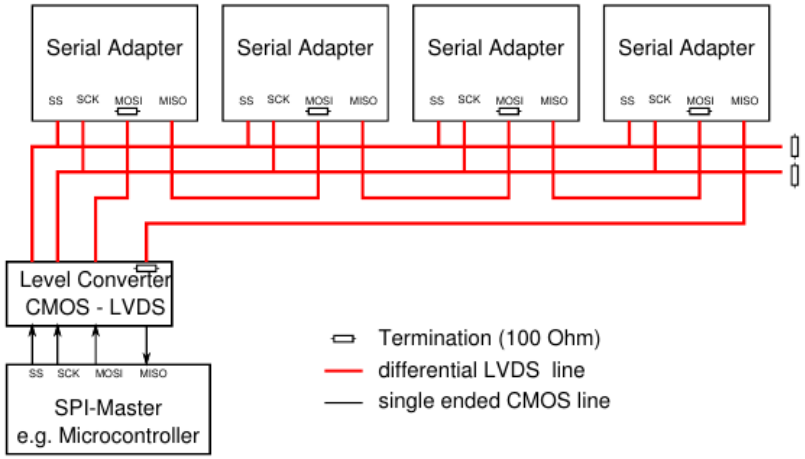
Serial Adapter ASIC
(next slide)

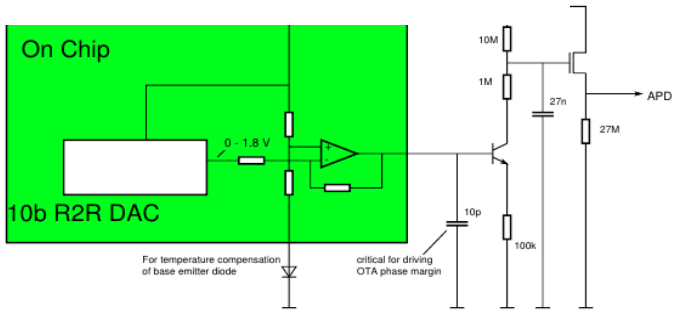
Serial Adapter ASIC (SAA)



- ASIC for bundling several busses and functionalities on backplane electronics
- Still under testing with breakout PCBs and bonded ASICs → encountered some problems with wire bonding reliability
- Some ASICs already packaged in QFN32 and tested, so far everything seems functional, deeper tests pending

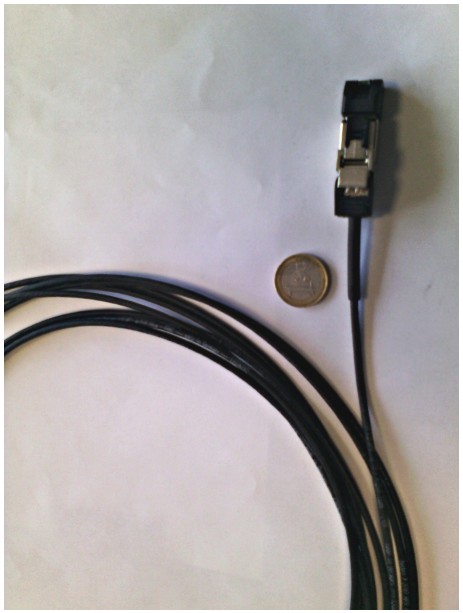


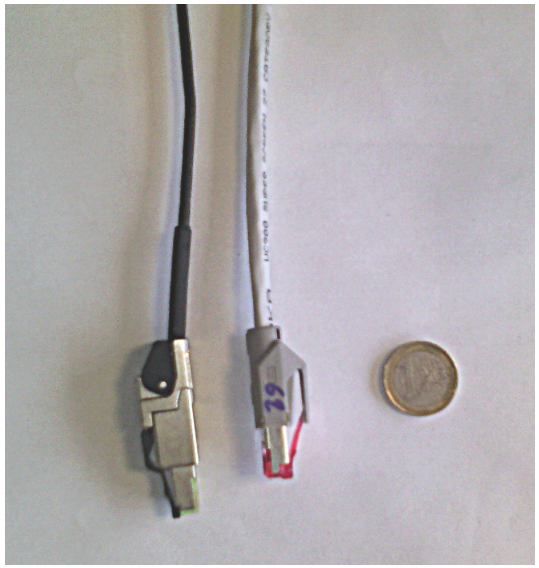


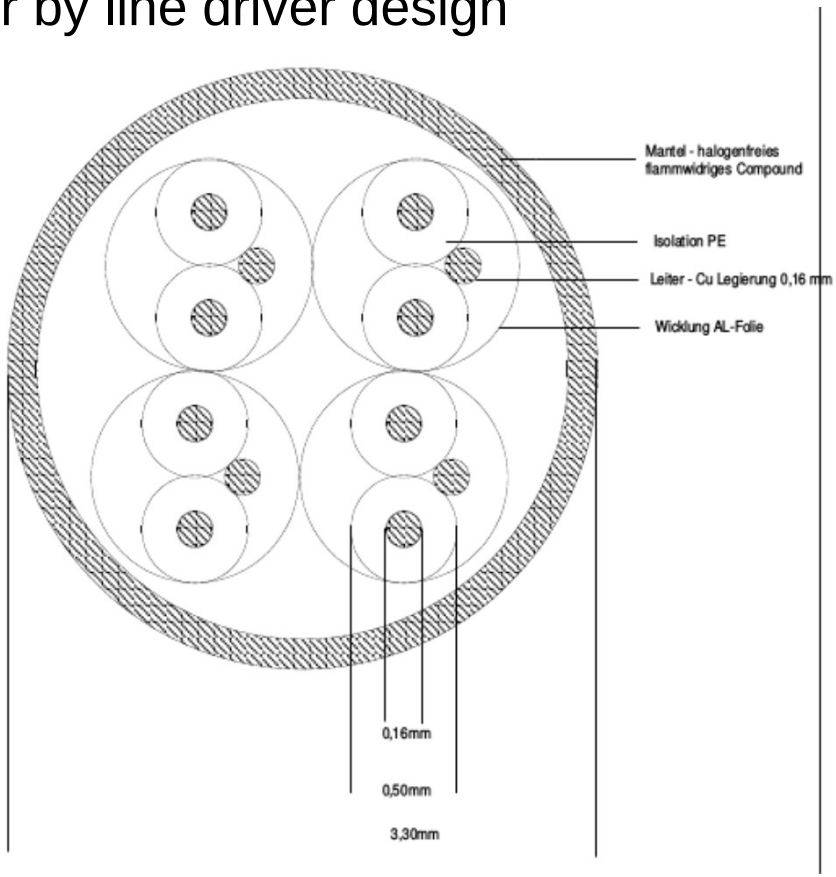


Readout Cabling

- Development of ultra-thin differential cables started with company BEDEA (Asslar/Germany)
- First prototype with stainless steel cores (0.1mm): attenuation too high
- Second prototype produced in May 2015 with copper cores (.16mm) and improved mechanical stability
- Attenuation ca. 2 dB / 5m, compensated for by line driver design

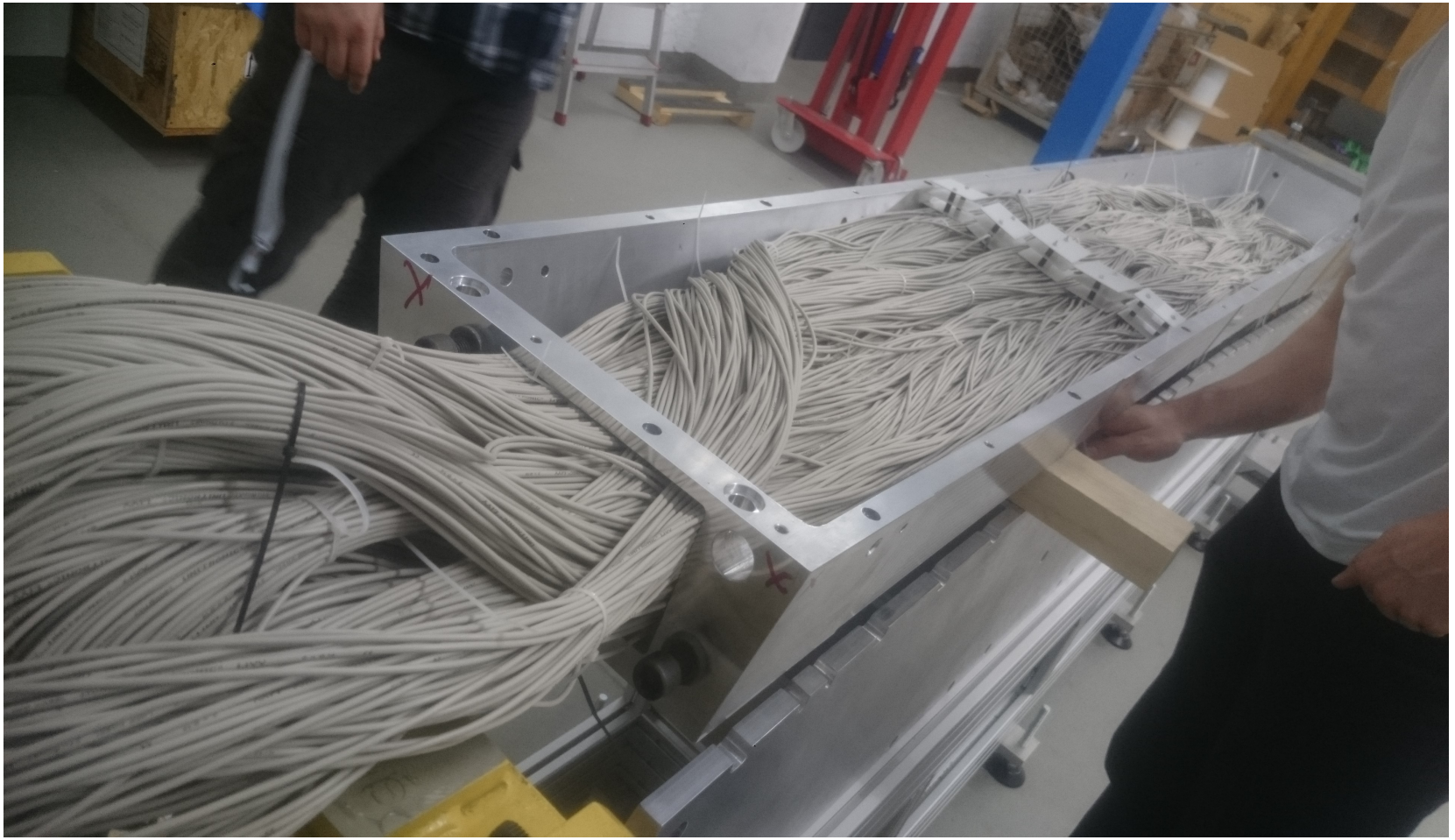






Readout Cabling

Cabling scenario with all readout and slow-control lines (~1000 per slice)

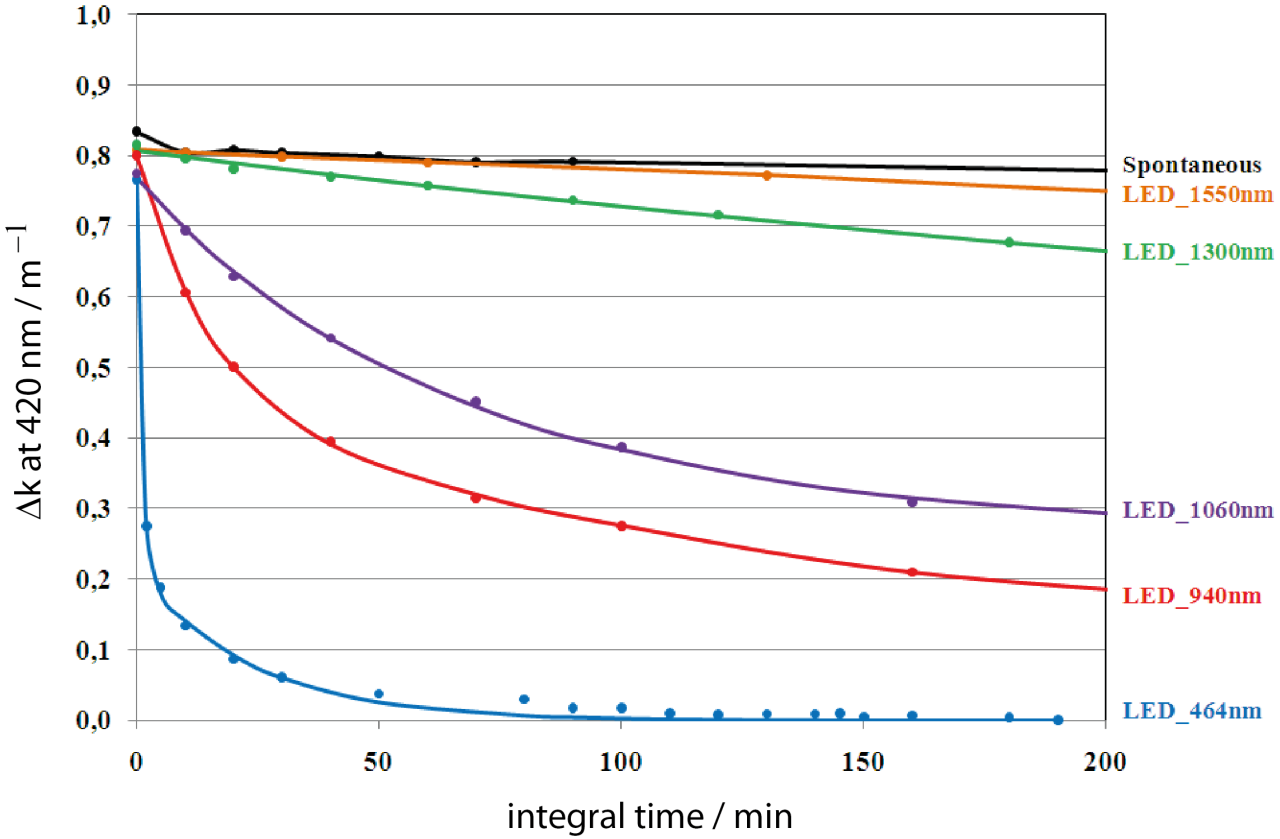


Hit Detection ASIC: reduce number of cables by ¾
→ H. Flemming

Backup

Offline Crystal Recovery

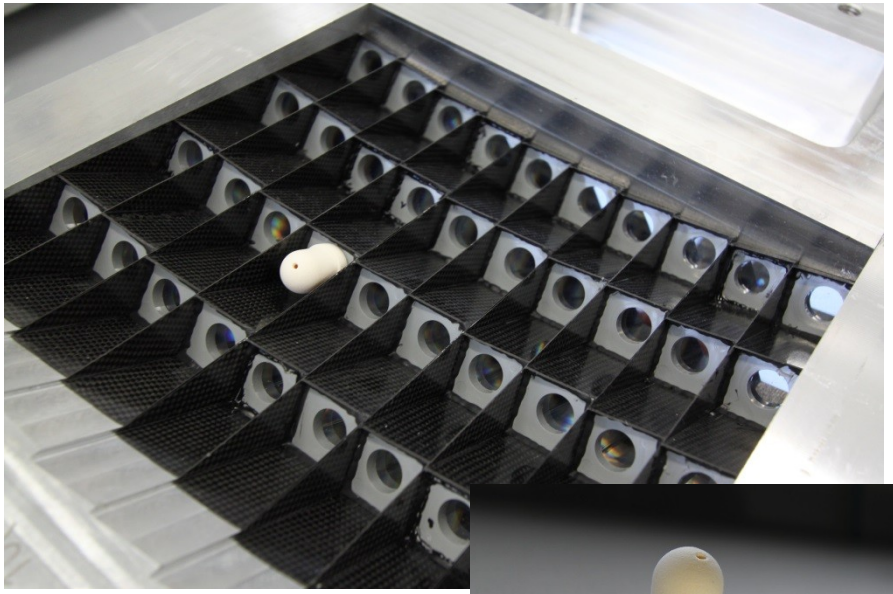
- Annealing of crystals' radiation damage by irradiation with (visible) light from LED

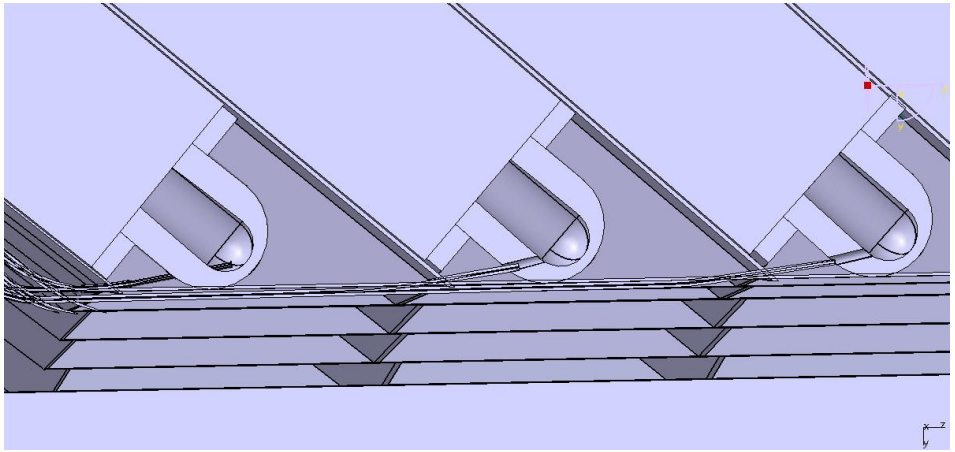


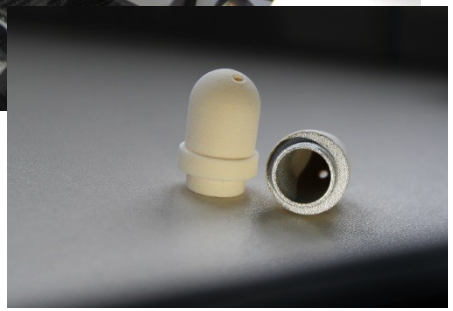
Room temperature

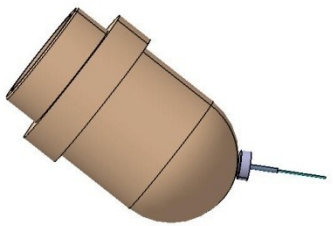
- blue led flux ≈ 10E16 photons/s
  100% recovery after 160 min
- caveat: recovery amplitude includes effect from thermal spontaneous recovery

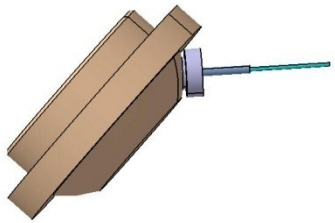
Light Pulser Monitoring System

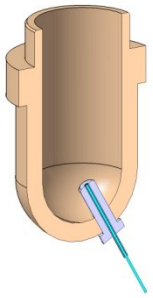


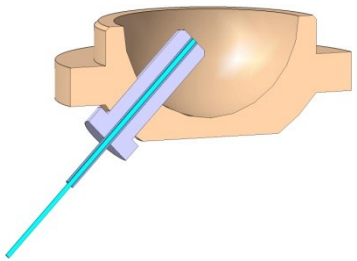








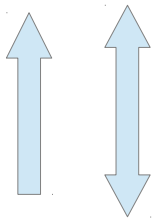




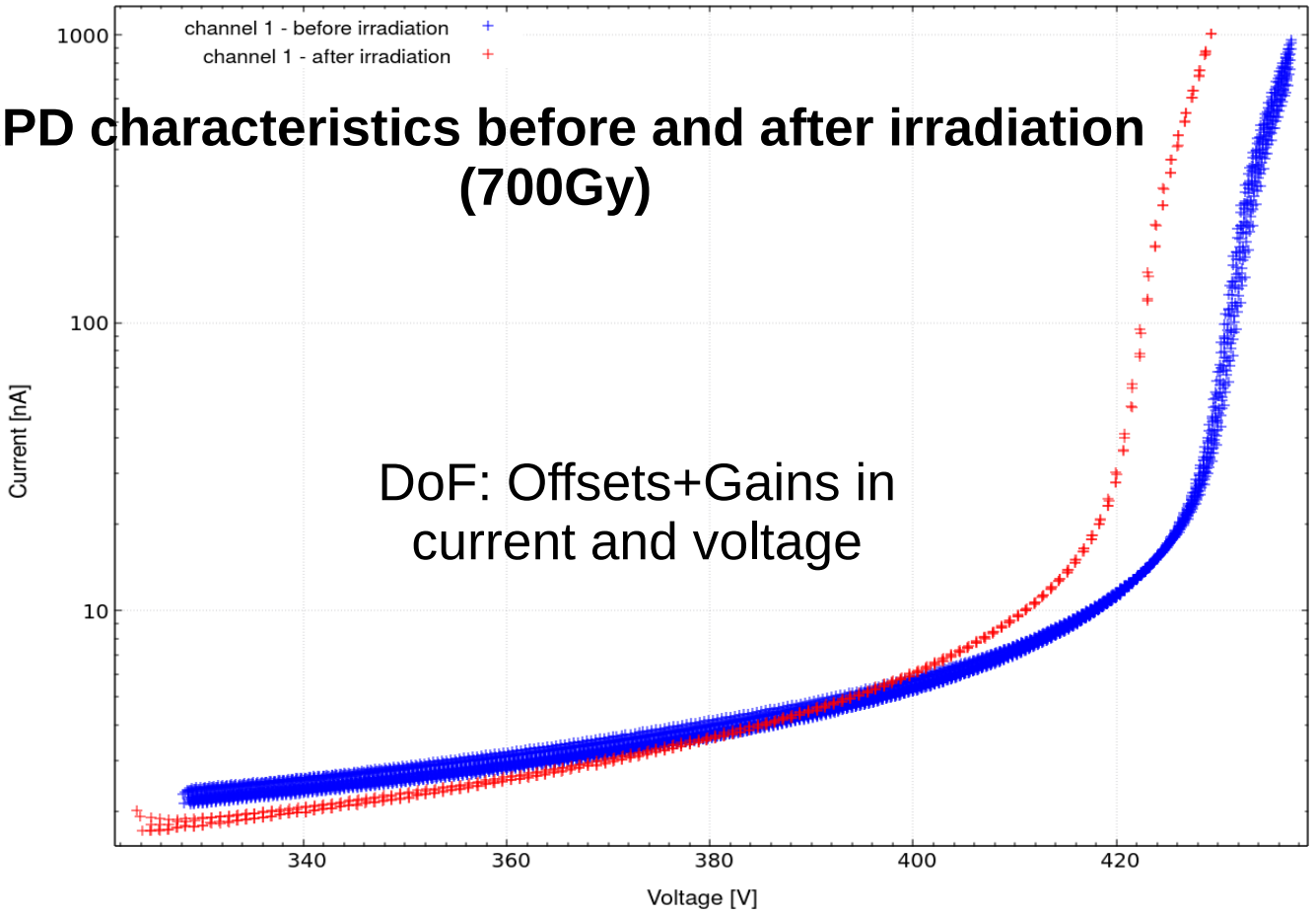
- Fiber couplings into each crystal
- Different lengths for different positions
- Prototypes currently tested

HV distribution electronics

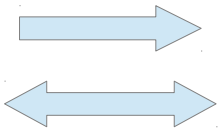
Characterization of HV distributor (DUT), not of the APD itself → use standard reference APDs always at the same channels and under identical conditions



Offset+Gain

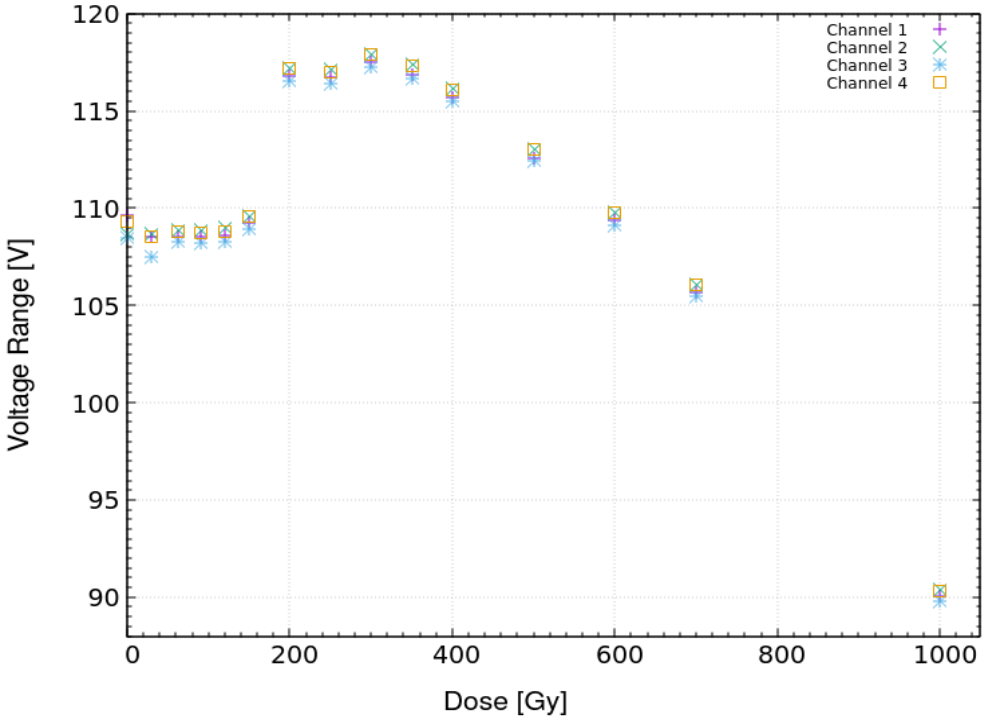


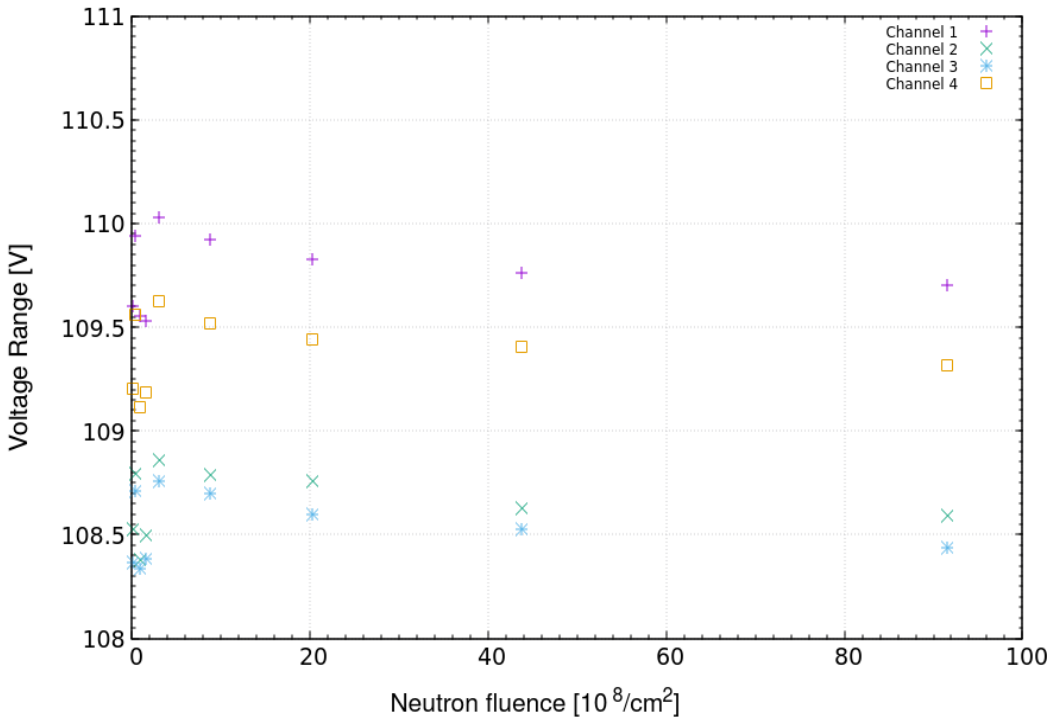
DoF: Offsets+Gains in current and voltage



Offset+Gain

HV distribution electronics





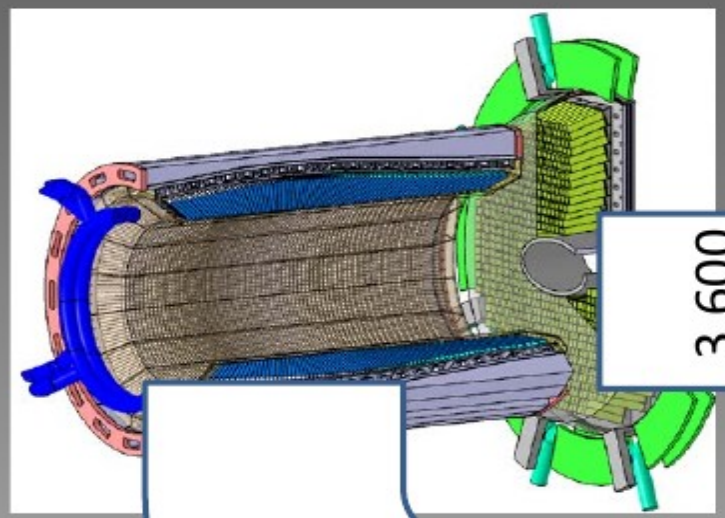
- Usable voltage range reflects radiation induced changes (ADC gain)
- No changes (within measurement precision) for ionizing doses up to ~170 Gy
- Slight shift at low neutron fluence (~10E8 n/cm²), stable up to 10E10 n/cm², max. 0.25 V difference
- Same observation for proton fluence up to 10E10 p/cm² (irrad. At KVI, 180MeV)
- Irradiations at fluences of 10E11 neutrons and protons done. Characterizations pending due to high activation

Data Acquisition

UPPSALA UNIVERSITET

ADC for EMC

- PANDA EMC Readout System



3,600

11,952

Photosensor VPTT

Preamplifier Basel

Photosensor APD

Preamplifier APFEL (GSI)

13,888

46,788

217 ADC 64-ch

366 ADC 64-ch

217

122

22 Data Concentrator, 16-ch

22

Compute Node