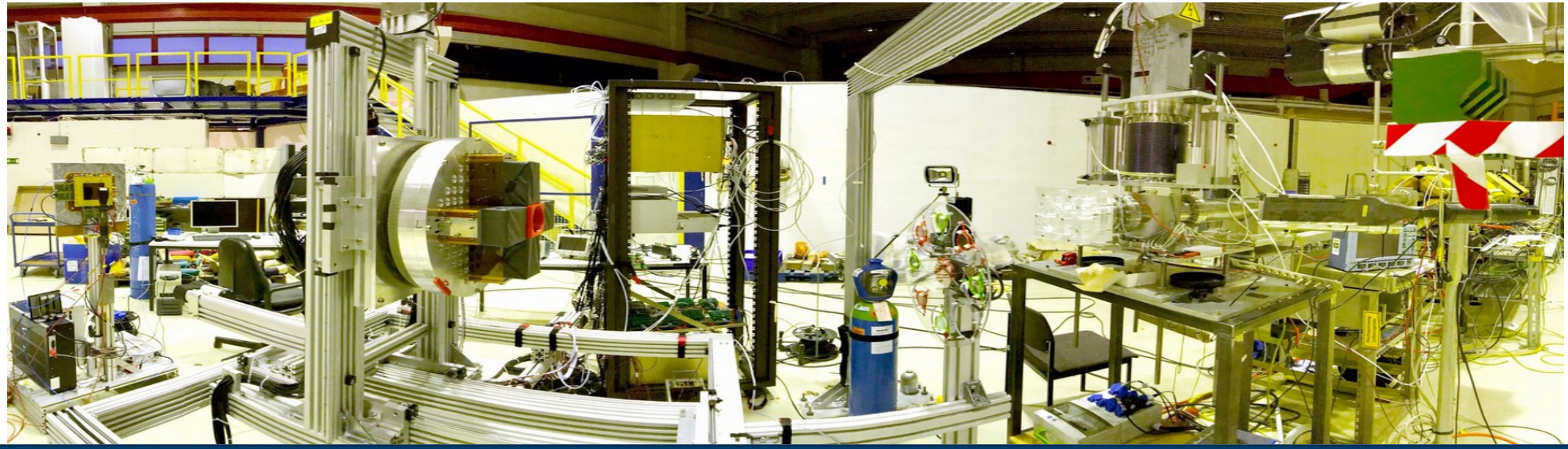


A STORAGE RING EDM POLARIMETER

DeSyT – 2019 International Workshop

12.09.2019 OTARI JAVAKHISHVILI, IRAKLI KESHELASHVILI

Overview

1) EDM
2) JEDI polarimetry
    1) Detector modules
    2) Power supply
    3) Readout system
3) Target development – introduction
    1) Current target Systems
    2) Idea behind new target system
4) Summary

Matter-Antimatter Asymmetry

- Excess of Matter in the Universe:

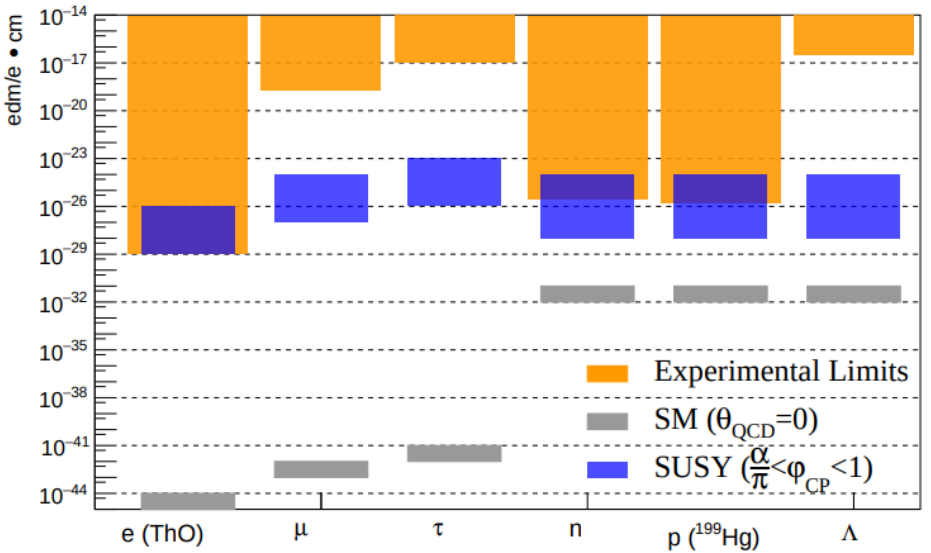
$\eta = \frac{n_B - n_{\bar{B}}}{n_\gamma}$	observed	SM prediction
	6×10^{-10}	10^{-18}

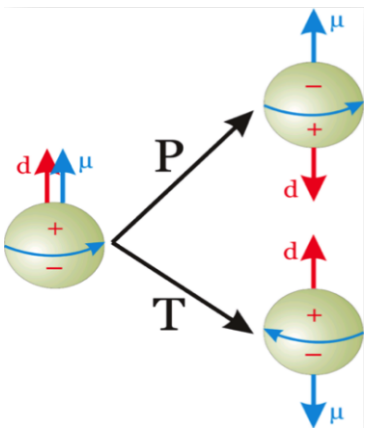
- Sacharov (1967): CP-violation needed for baryogenesis

- New CP-V sources beyond SM needed
- Could show up in EDMs of elementary particles

EDM – Electric Dipole Moment

- fundamental property of particles (like magnetic moment, mass, charge)
- permanent separation of positive and negative charge
- has nothing to do with electric dipole moments observed in some molecules (e.g. water molecule)
- close connection to “matter-antimatter” asymmetry
- existence of EDM only possible via violation of time reversal T ↔ CP assuming CPT conservation





COSY

Internal and **external** beams

High **polarization** (***p, d***)

Spin manipulation !!!

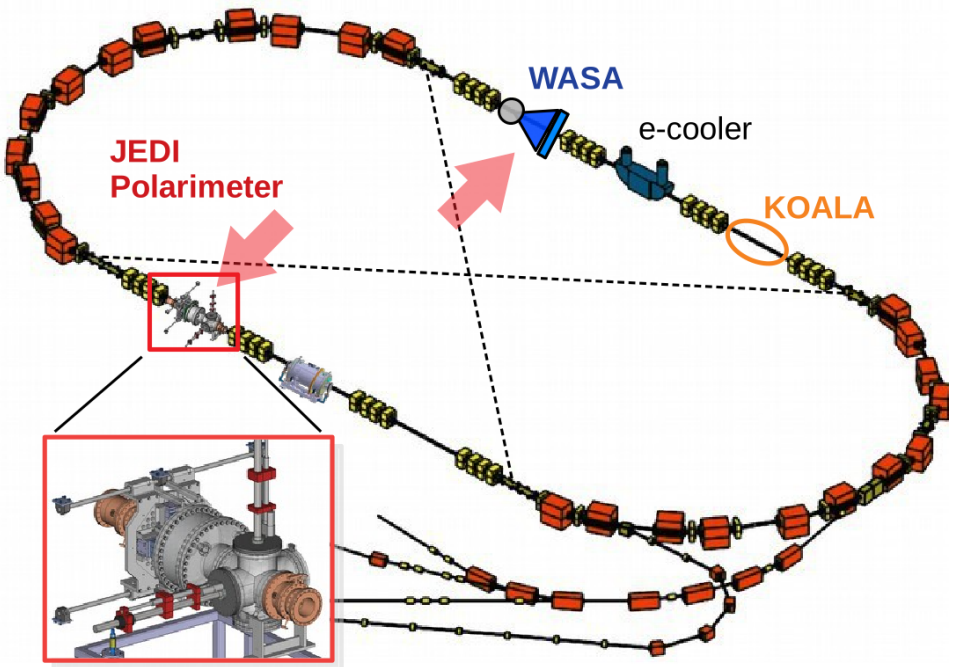
Energy range (min.-- max.):

0.045 – 2.8 GeV (p)

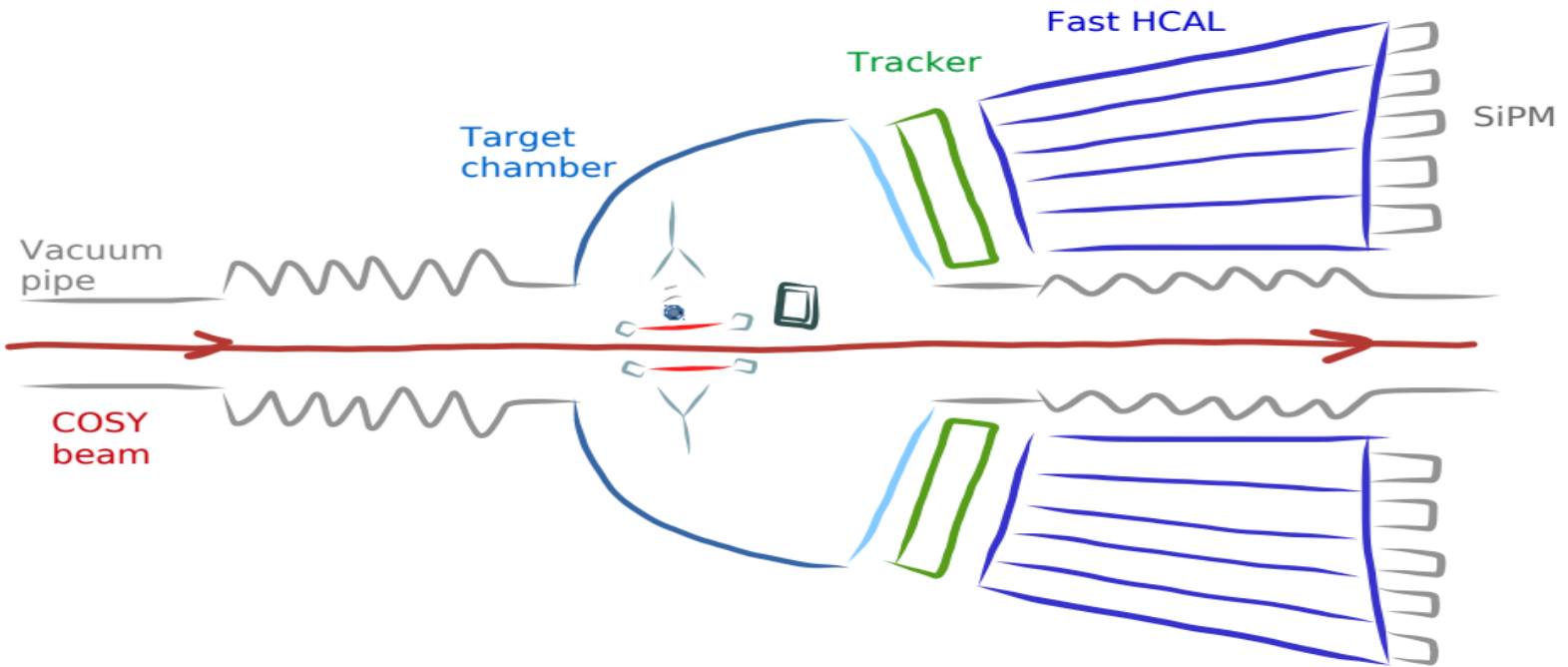
0.023 – 2.3 GeV (d)

Max. momentum ~ **3.7 GeV/c**

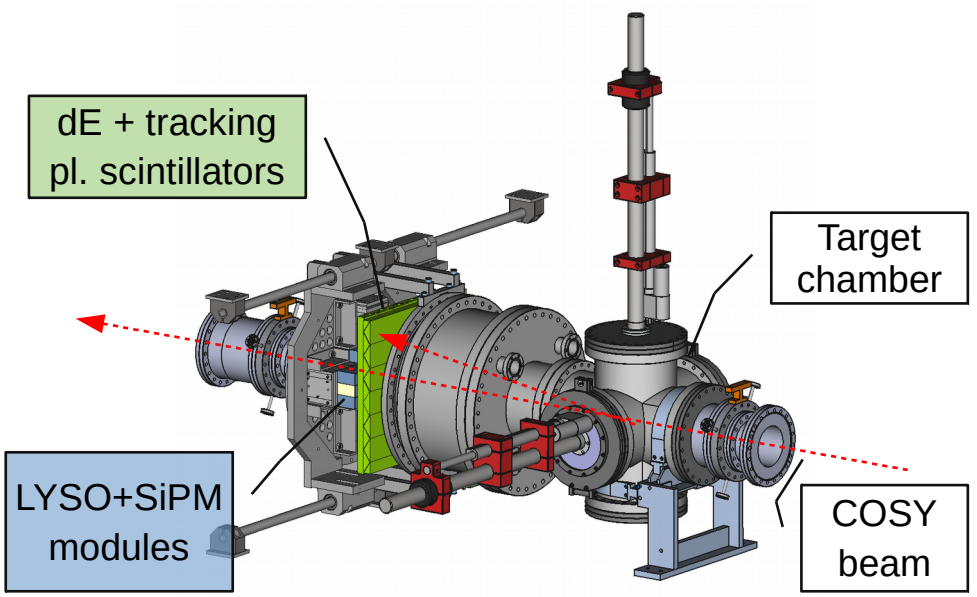
Electron & ***Stochastic*** cooling

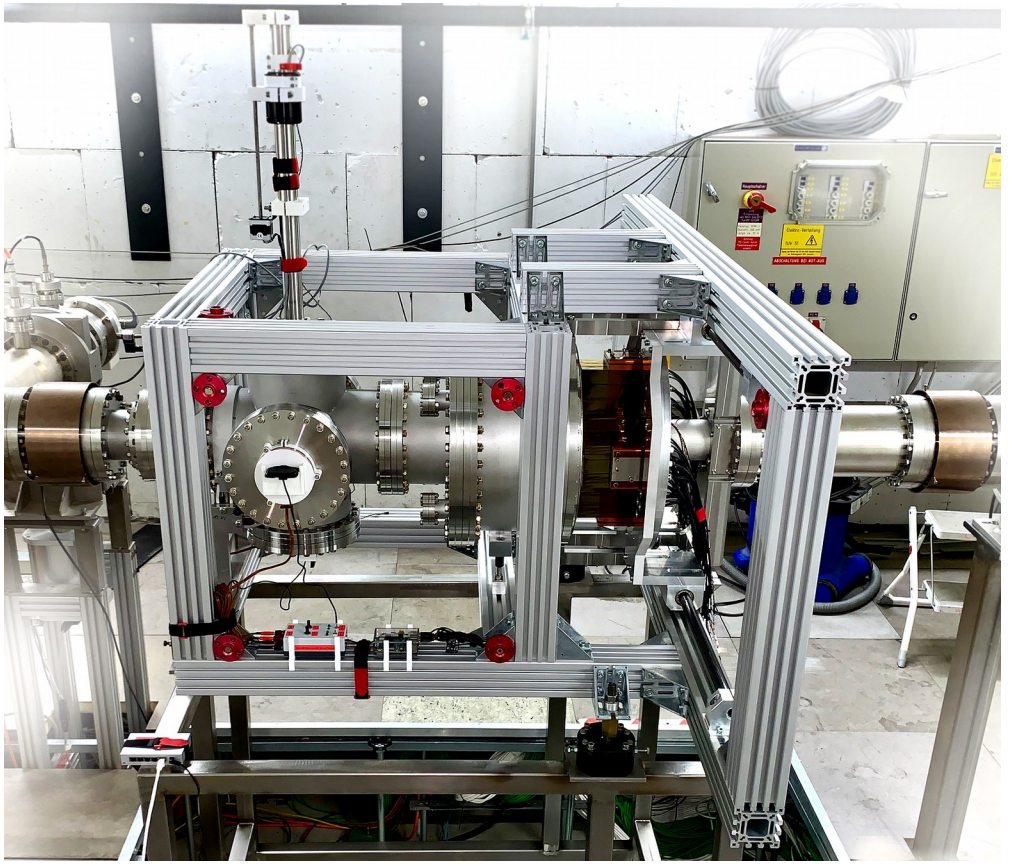


Polarimeter concept



Polarimeter setup in ring

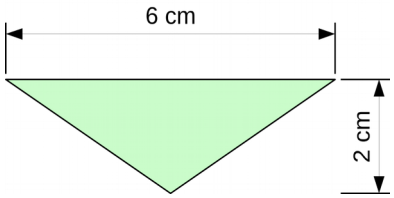


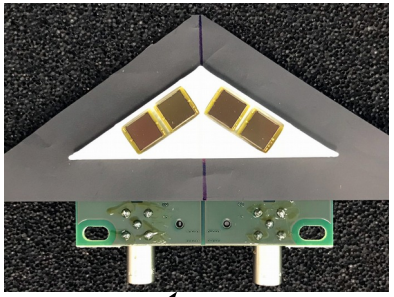


PLASTIC SCINTILLATOR TRACKER

Triangular plastic scintilator bar for tracking system

BC-408 Bicron
Plastic scintillator

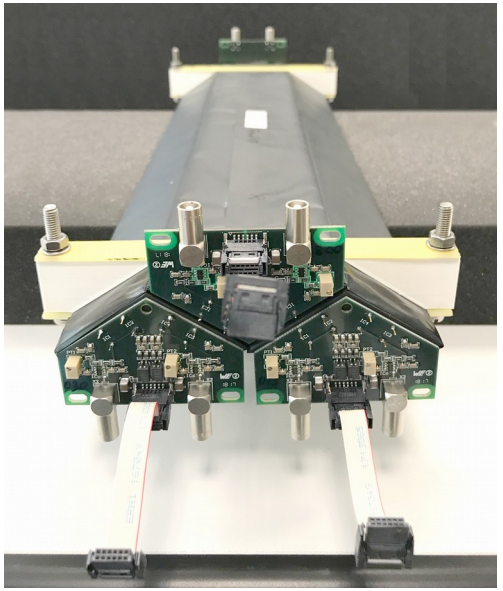




Preamp board with 4 SiPM
split into 2 seperate channels

already attached tracker in front
of LYSO modules

Assembled layer with three scintilator bars. Each bar has 2 preamp board with 4 independent amplifier channels and eight 6X6 mm SiPM, 4 for each end



PLASTIC SCINTILLATOR TRACKER

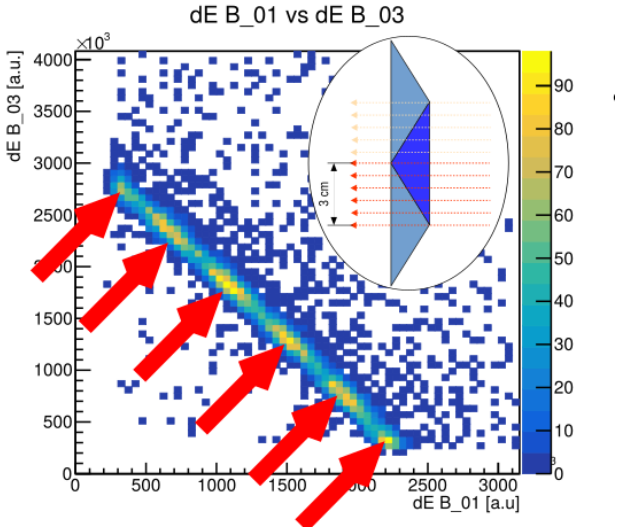
- Each bar is connected to a SiPM

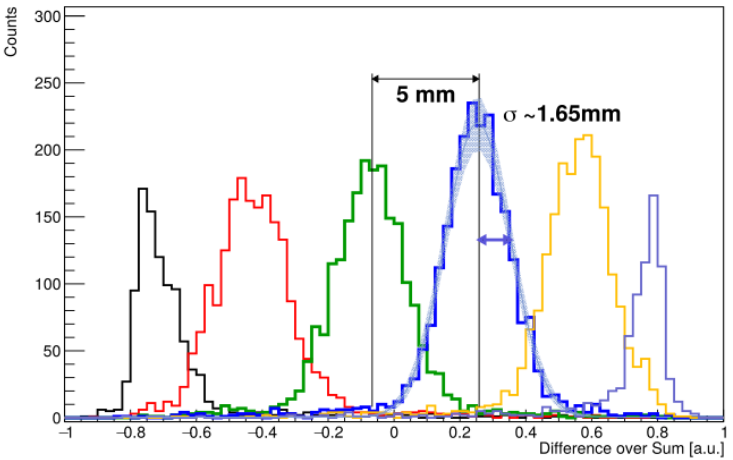
  mounted on a designated pre-amp board
- position information extracted using

  difference over sum: position ~ $\frac{E_{\Delta 1} - E_{\Delta 2}}{E_{\Delta 1} + E_{\Delta 2}}$
- This detector will deliver dE information as well as
  - the position of the particle entering the detector
- First test: resolution of ~ 5mm → big improvement

  compared to the ~ 30mm resolution provided

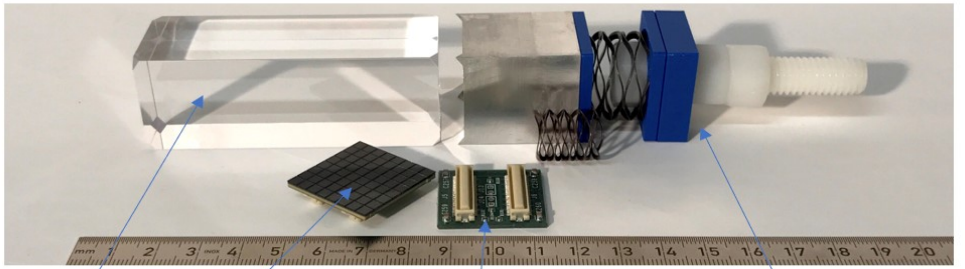
  by the LYSO modules

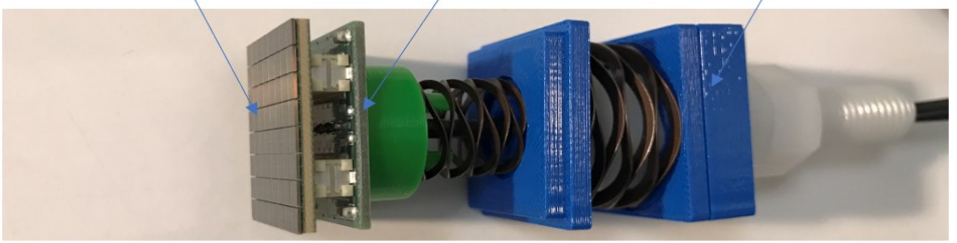


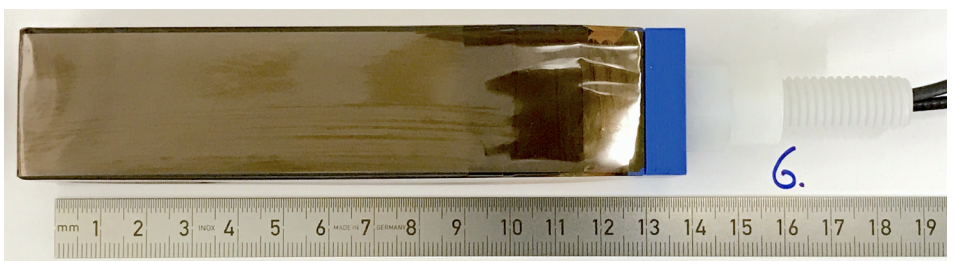


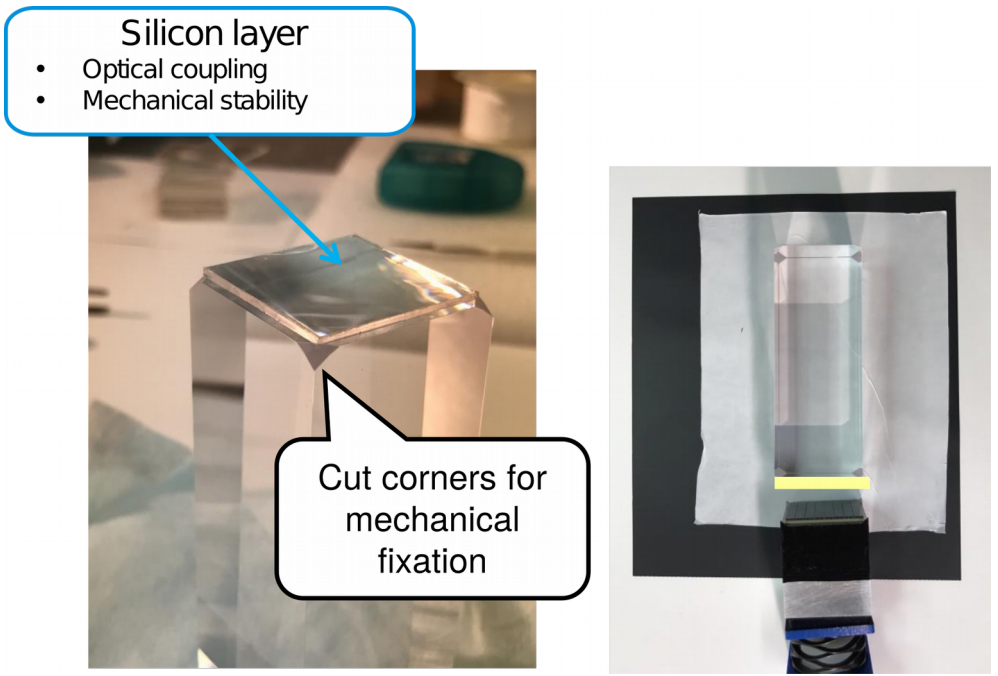
Detector modules

- 52 independent LYSO modules
- Each module is tested and calibrated separately





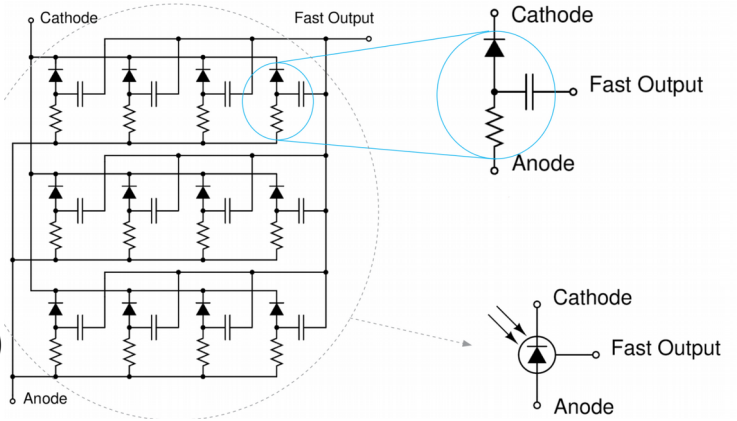


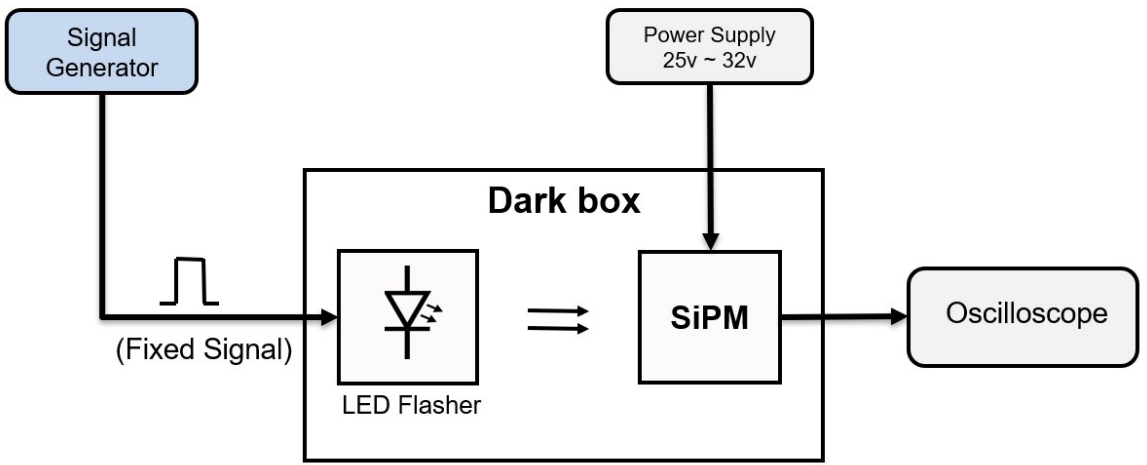


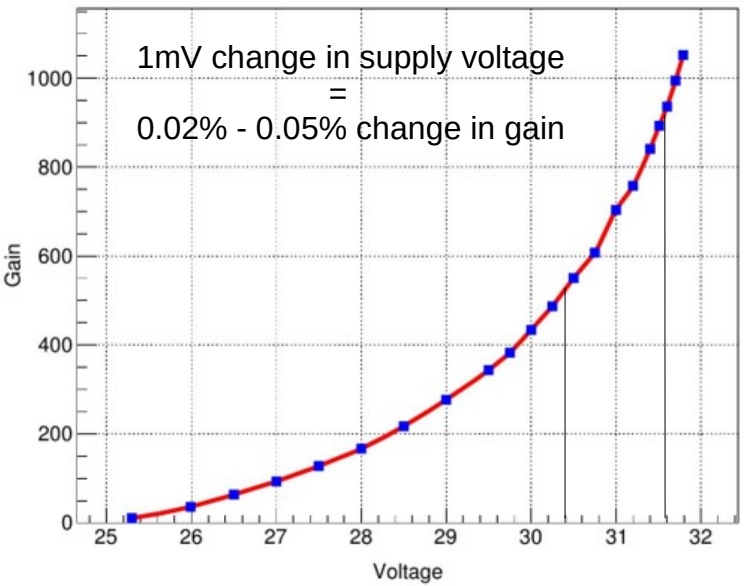
Voltage supply for detector modules

Basic requirements:

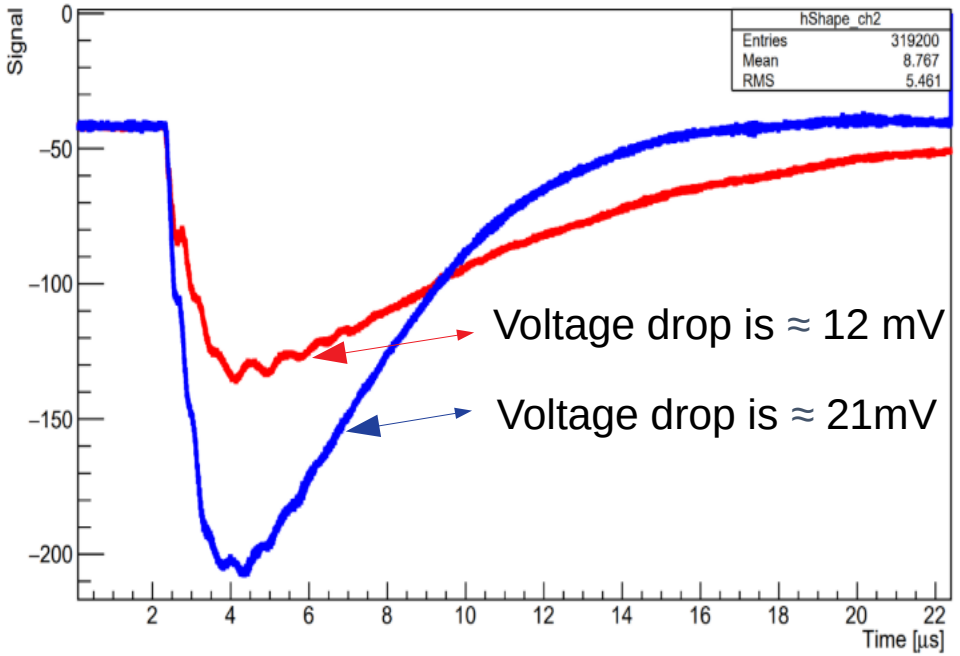
- Modular design
- High output stability (temperature, long/short term, low noise)
- Remote on/off capability (currently organized using Raspberry Pi)
- Voltage adjustment (currently only manual)

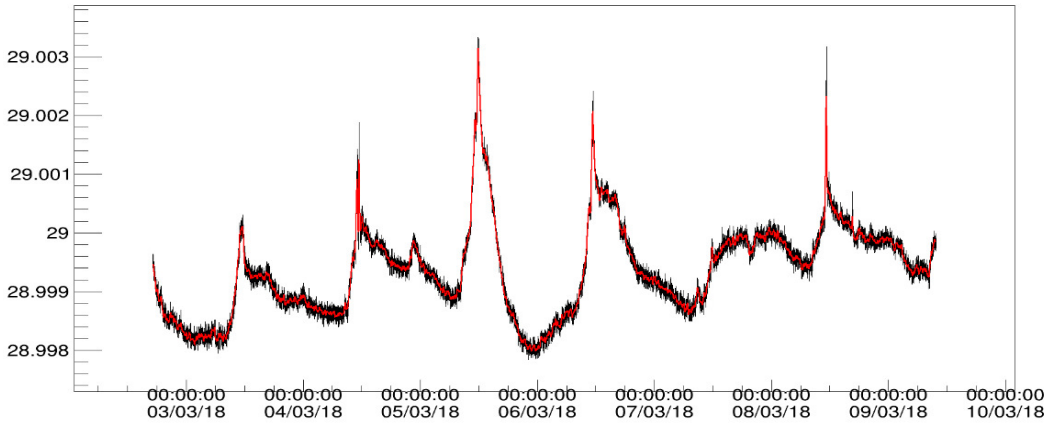


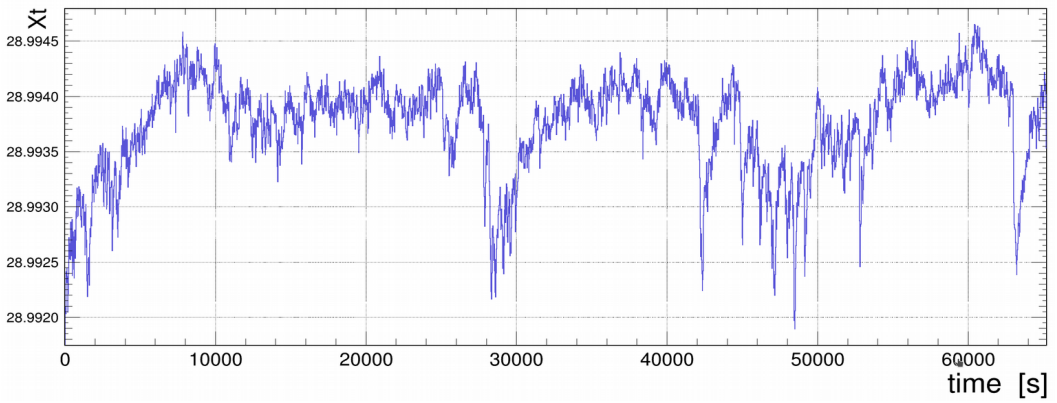




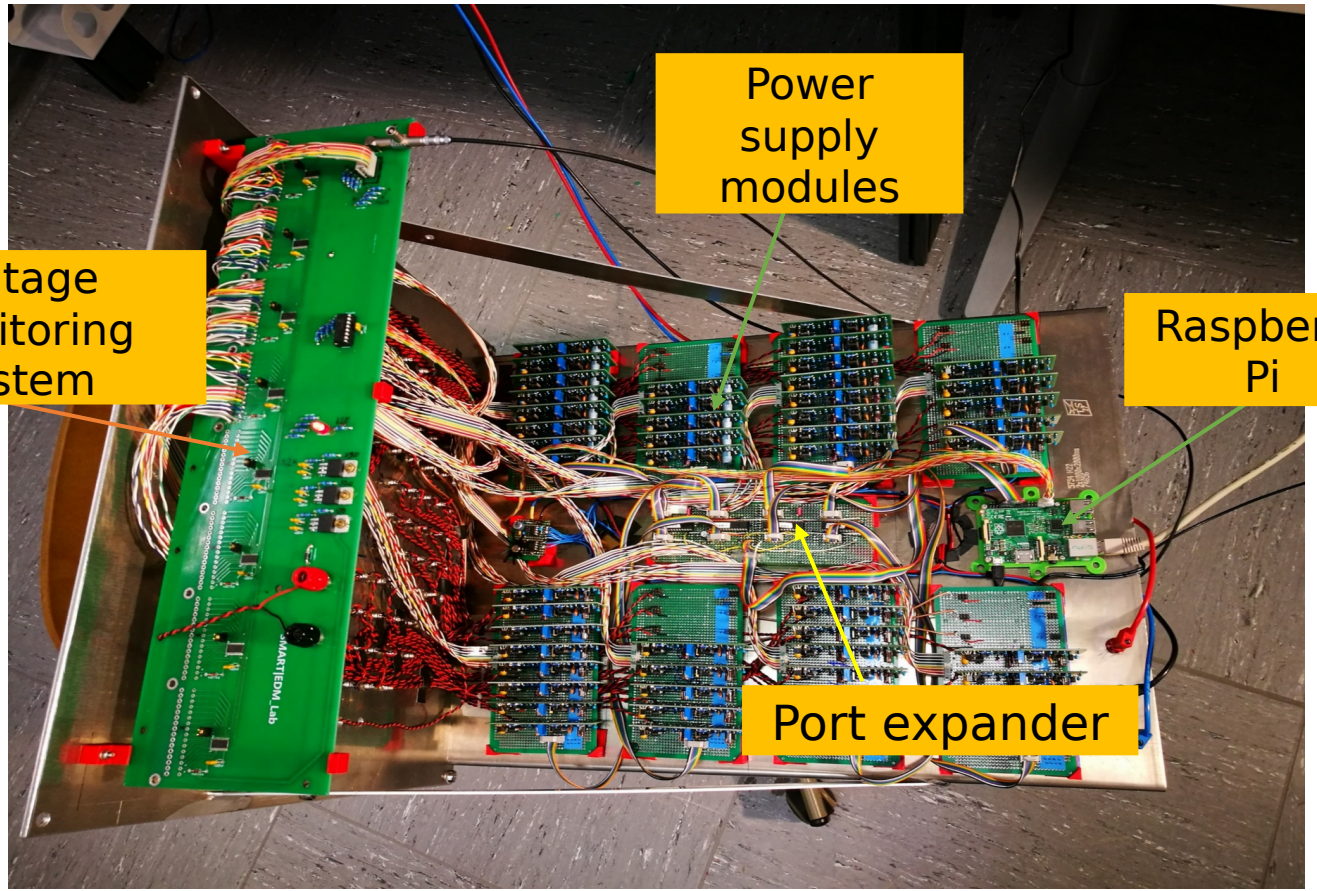
Voltage supply for detector modules



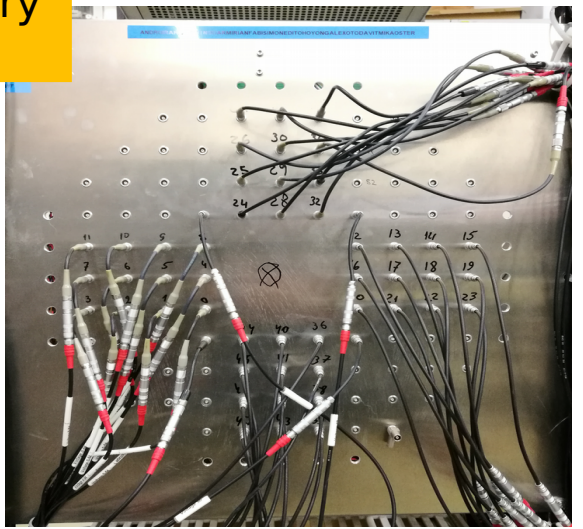




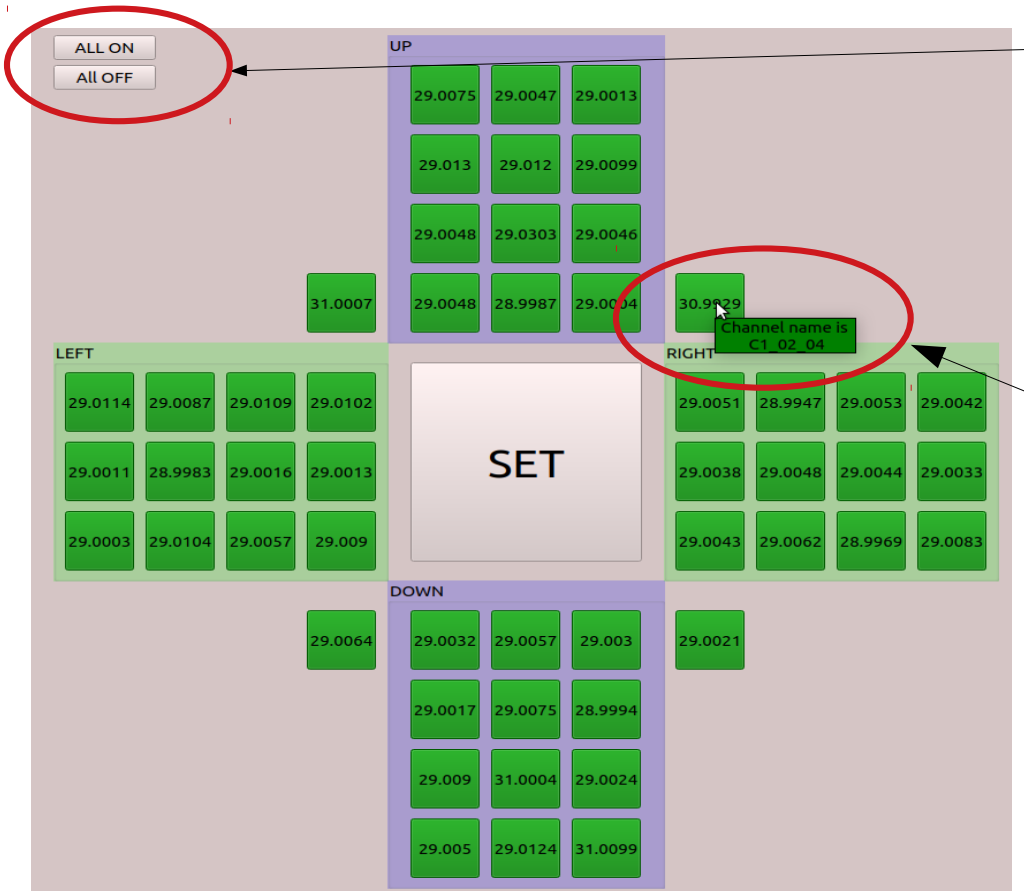
Voltage supply for detector modules



V_{in} = 32 – 40V
V_{out} – Adjustable
V_{reg} < 1mV
T ≈ 3.4mV/C^{o}



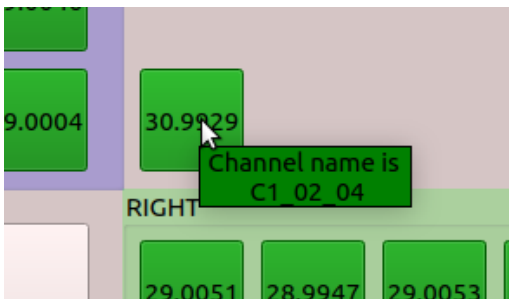
Voltage supply online control and monitoring



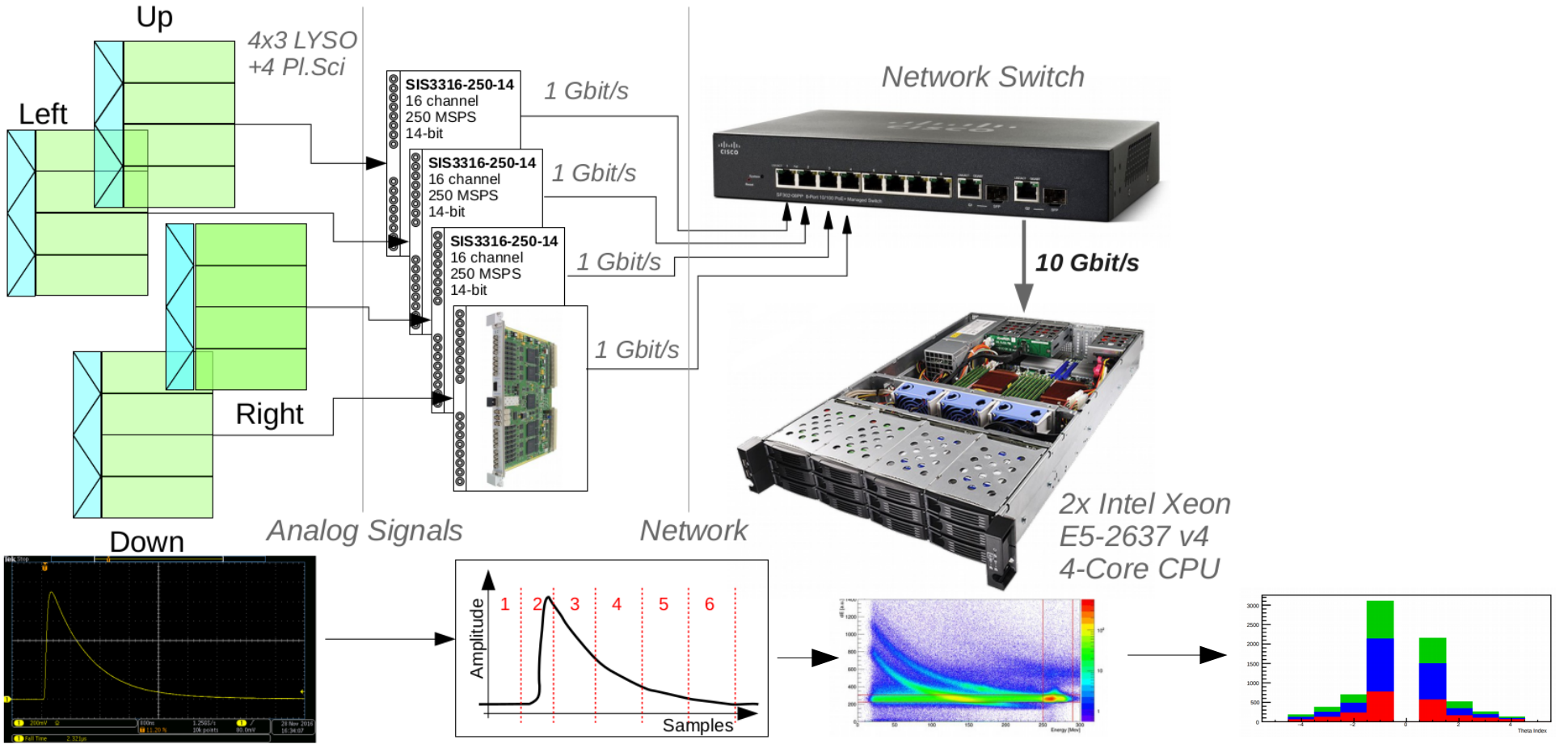
Turn all channels on/off

RED - Turned off channels

GREEN Turned on channels

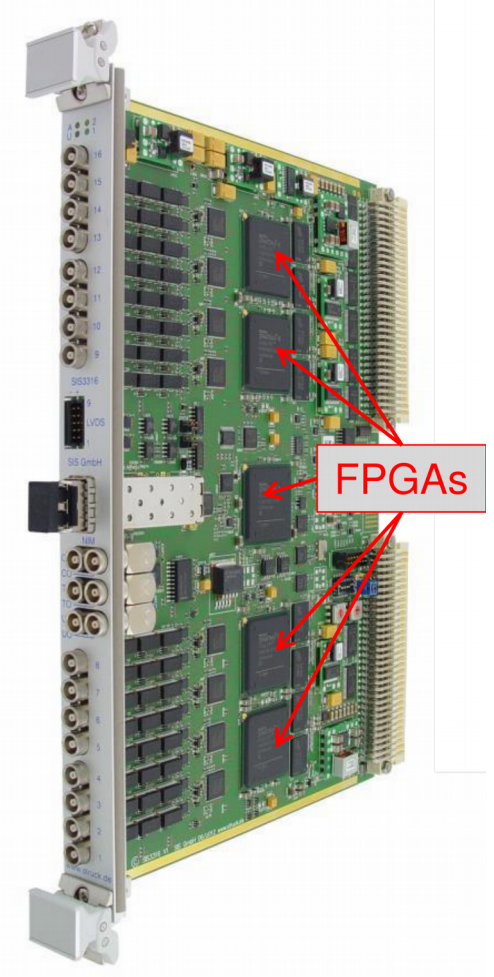


Readout system

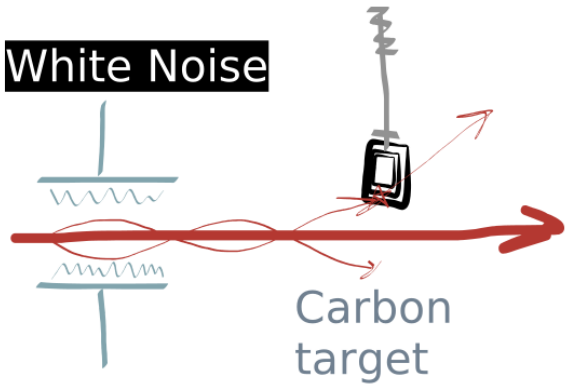


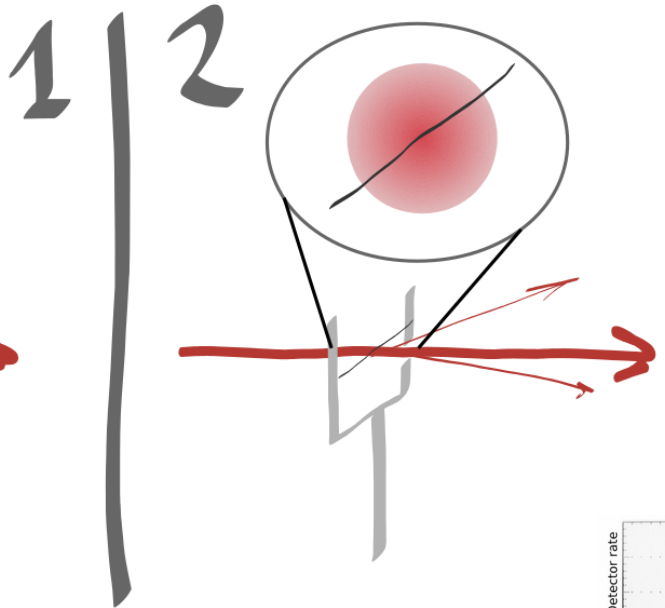
Readout system

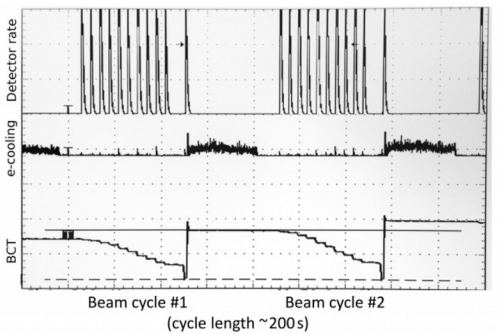
- 16 channels per module
- 250 MS/s per channel
- 125 MHz analog bandwidth
- 14-bit resolution
- Offset DACs
- Internal/External clock
- Readout in parallel to acquisition
- **Capable of working in a chain**
- Built-in hardware features
  (Pile-up detection, averaging and more)
- Self triggering



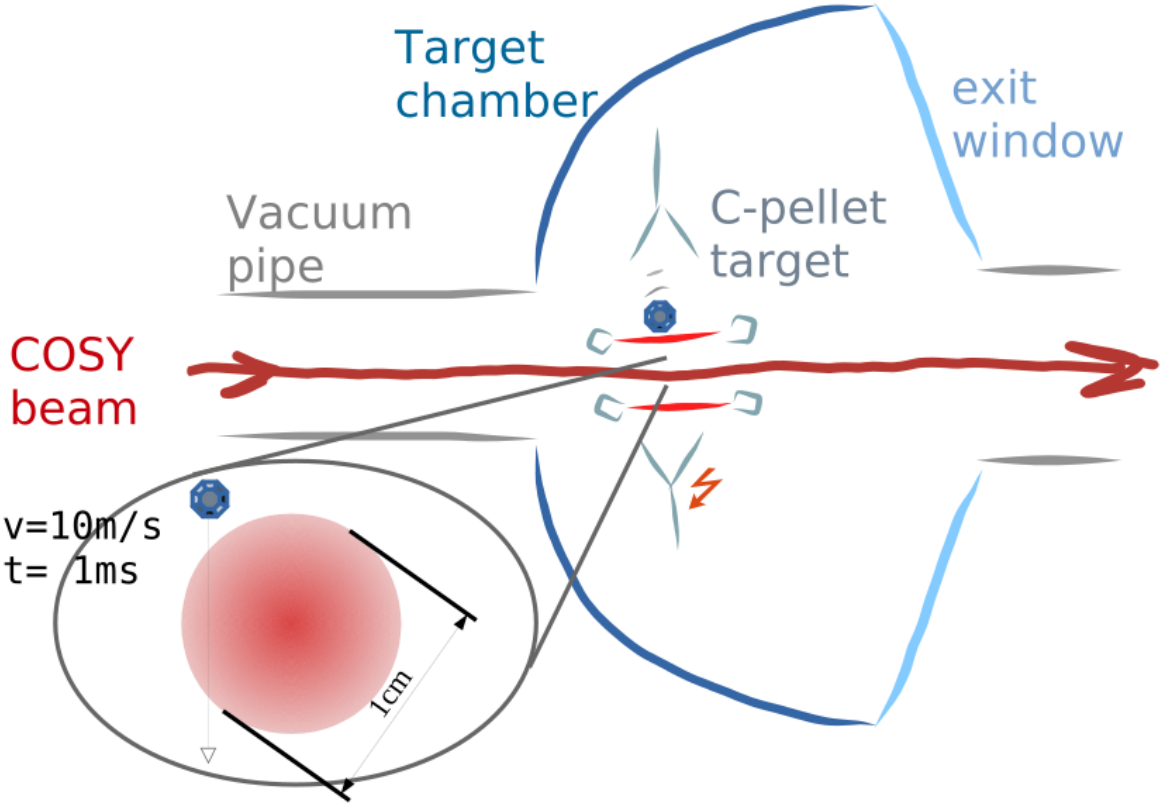
Different target systems

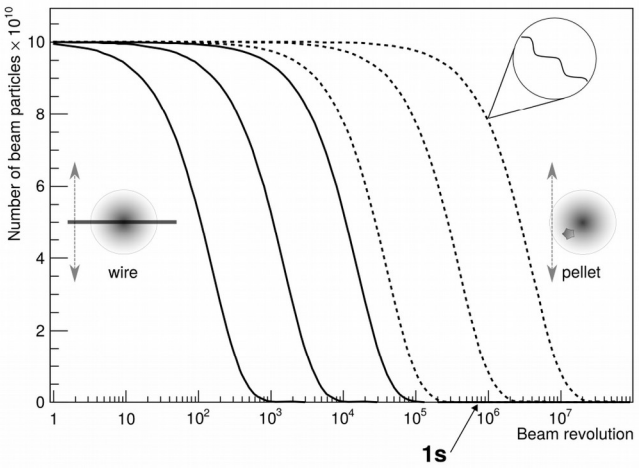




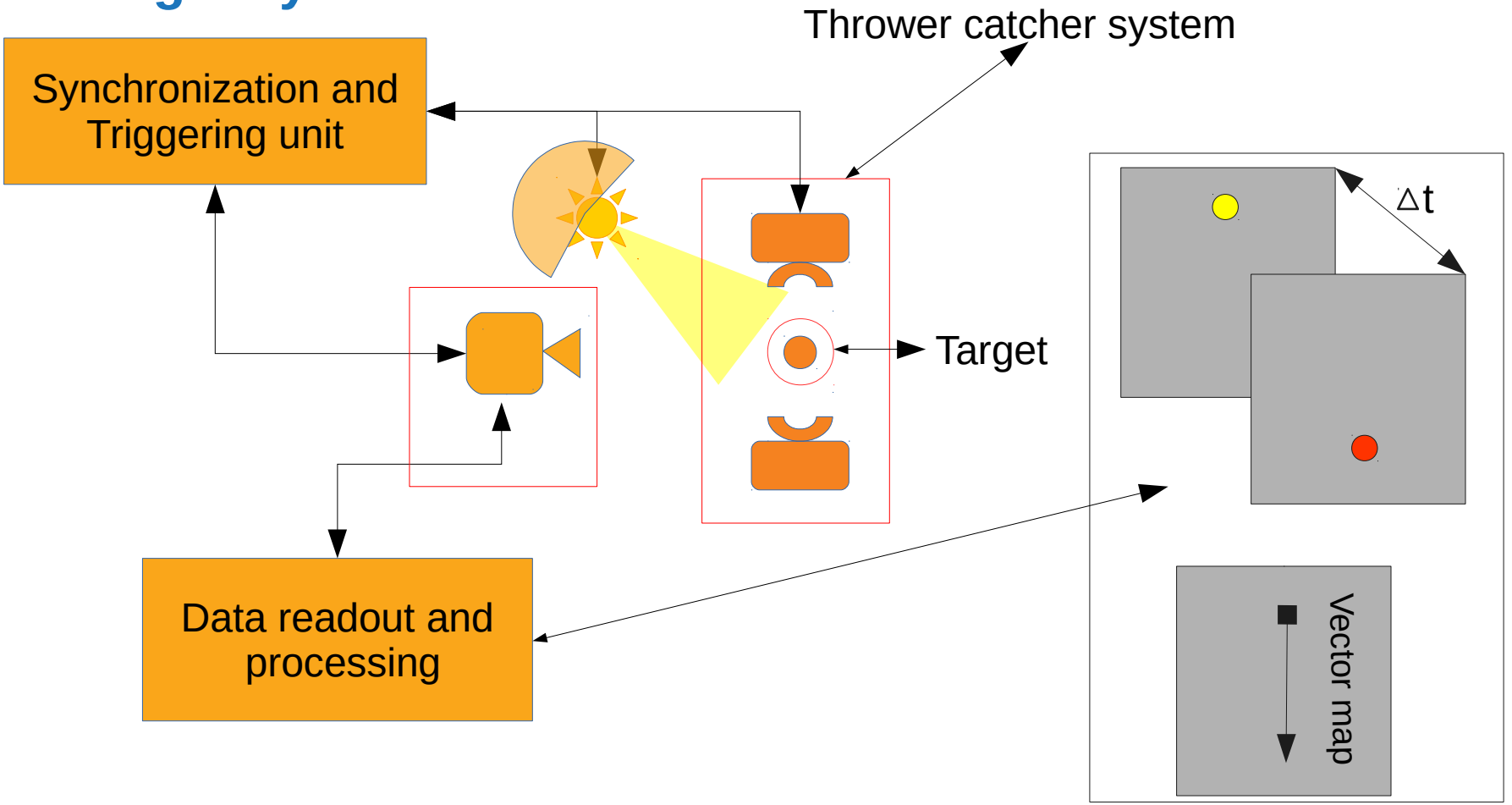


JUDIT
Juelich Ballistic Diamond Pellet Target

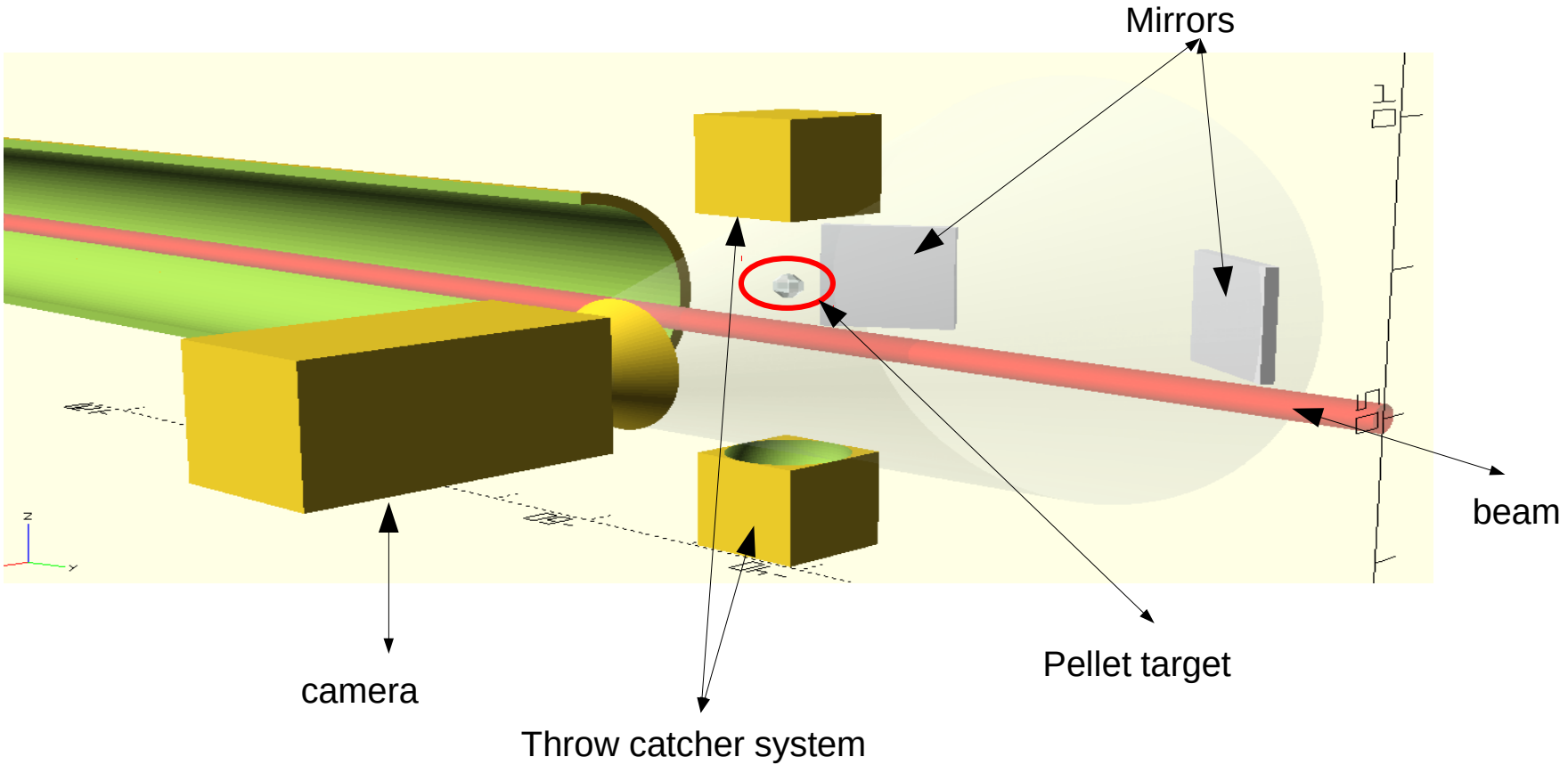




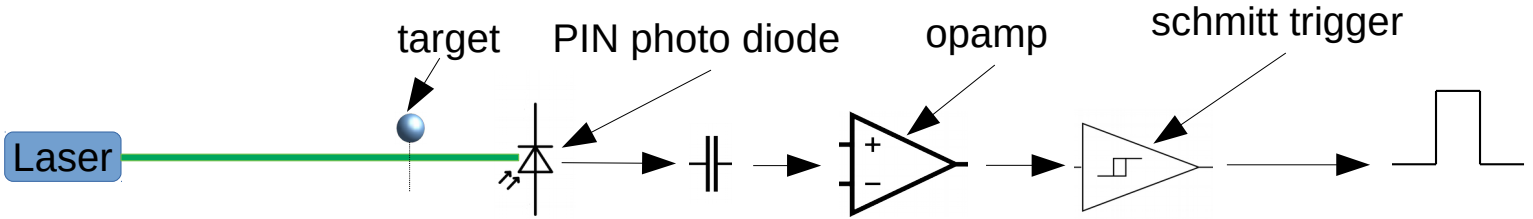
Pellet target system

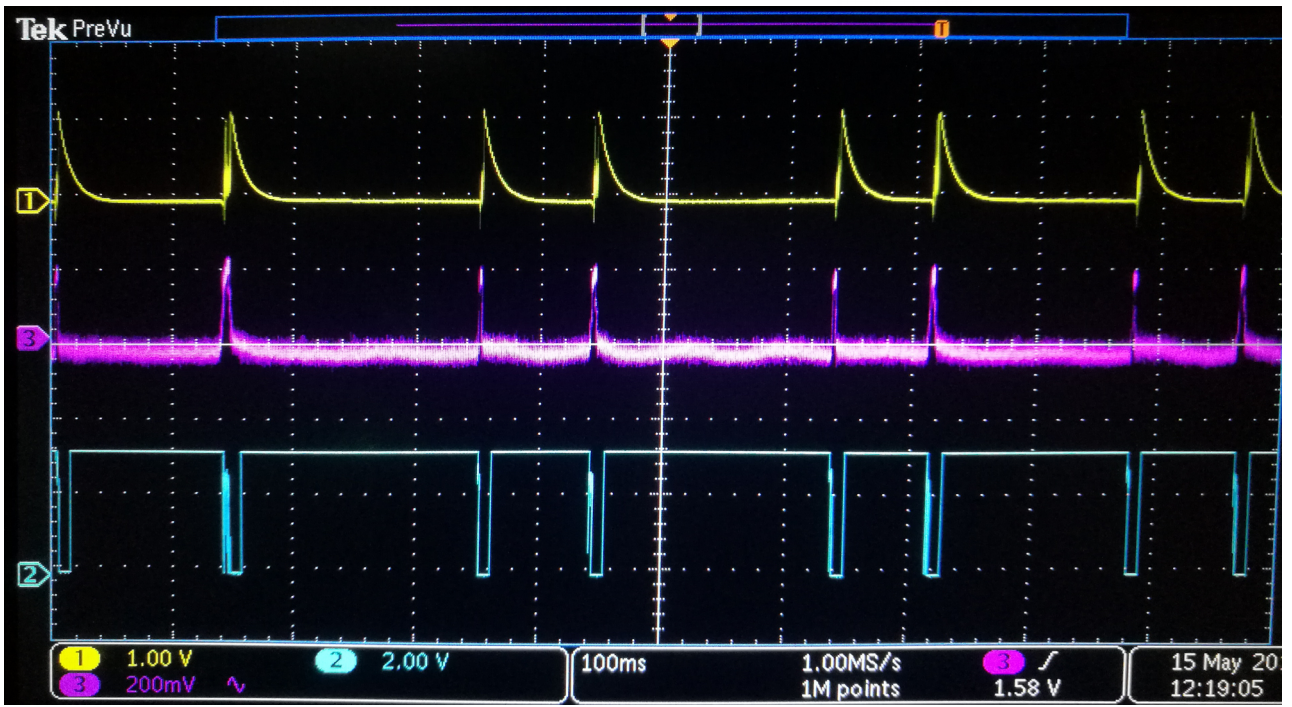


Pellet target system



Pellet TOF measurement





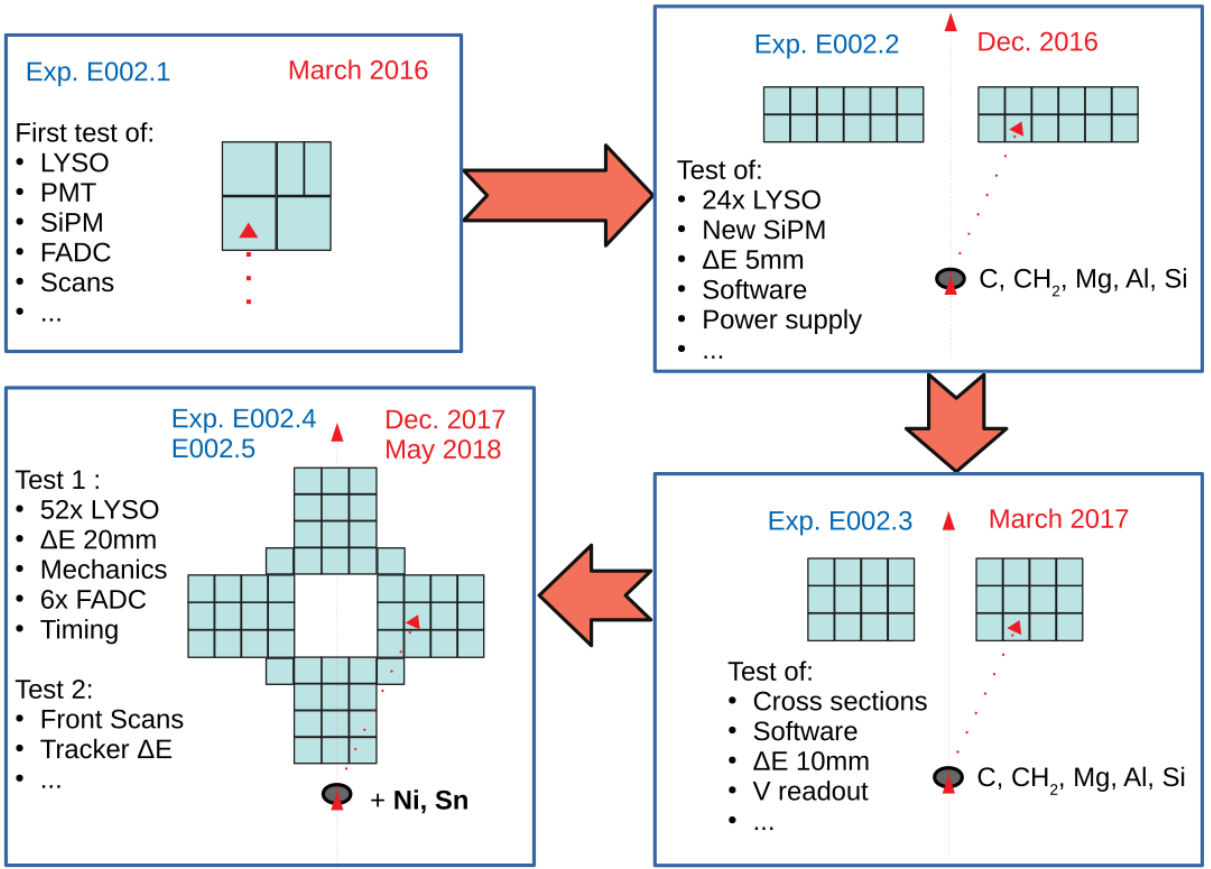
Summary

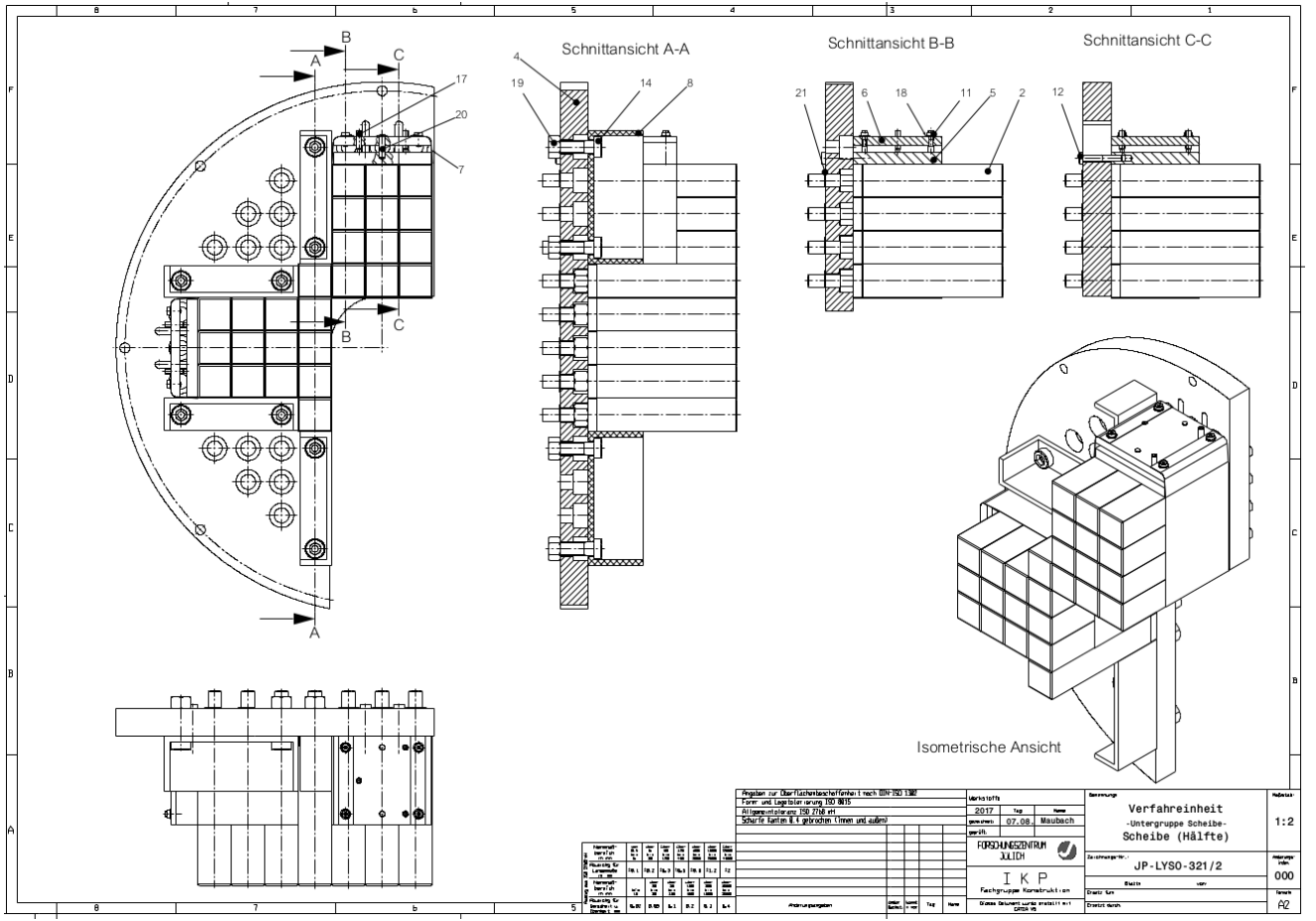
This project has been supported by “Shota Rustaveli National Foundation of Georgia”
"A first-ever measurement of the Electric Dipole Moment (EDM) of the deuteron at COSY"
(SRNSF Grant #217854)

- The detector is fully assembled and installed in COSY.
- The LYSO module production will be continued.
- Triangular plastic scintillating bars for tracking is developed and tested. It will be assembled and installed for next experiment.
- The diamond ballistic pellet target is under development and will be tested until the end of my Ph.D. work.
- We are preparing first beam time after Polarimeter installation at COSY end of October.

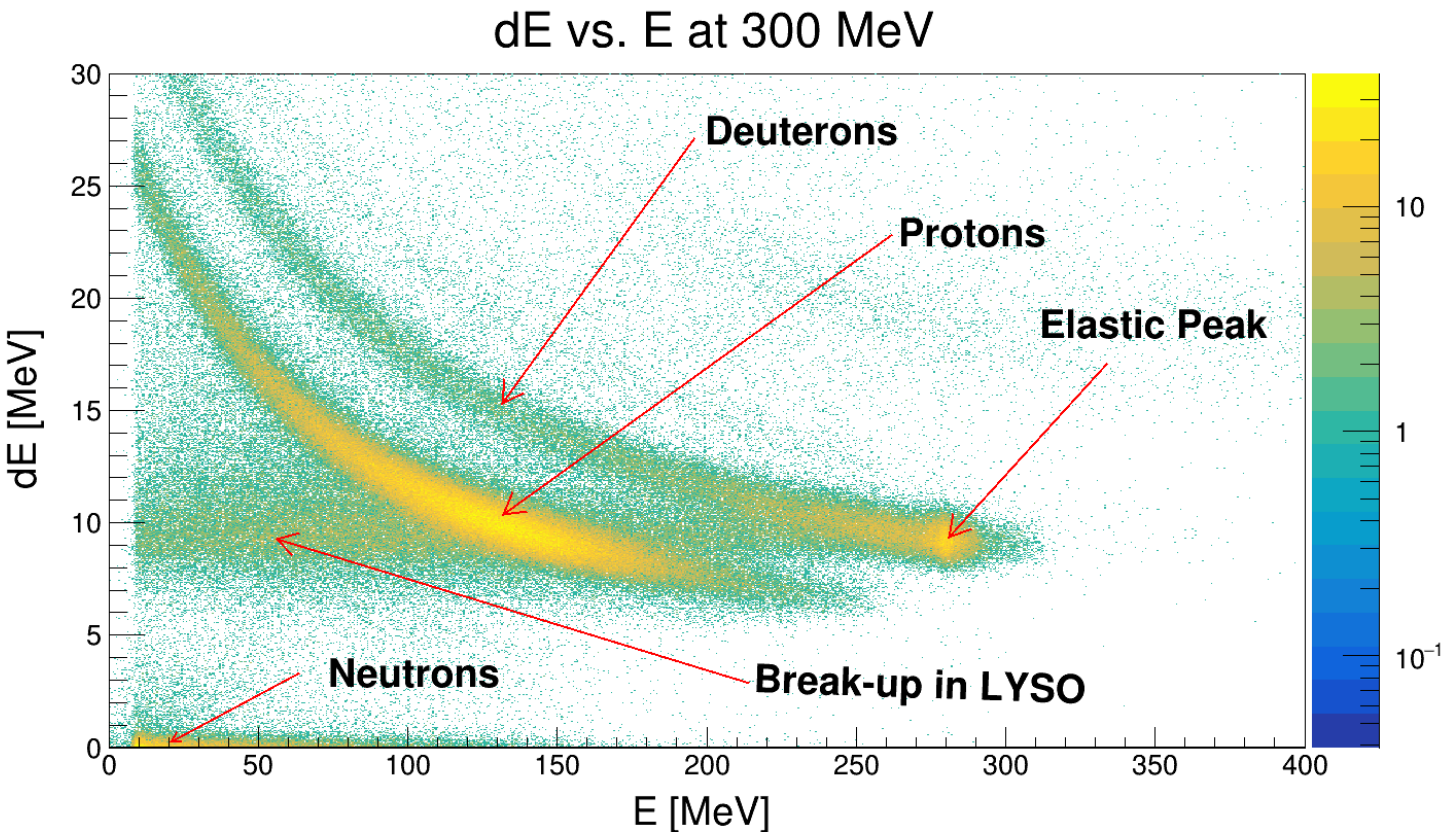
Appendix

History of polarimeter

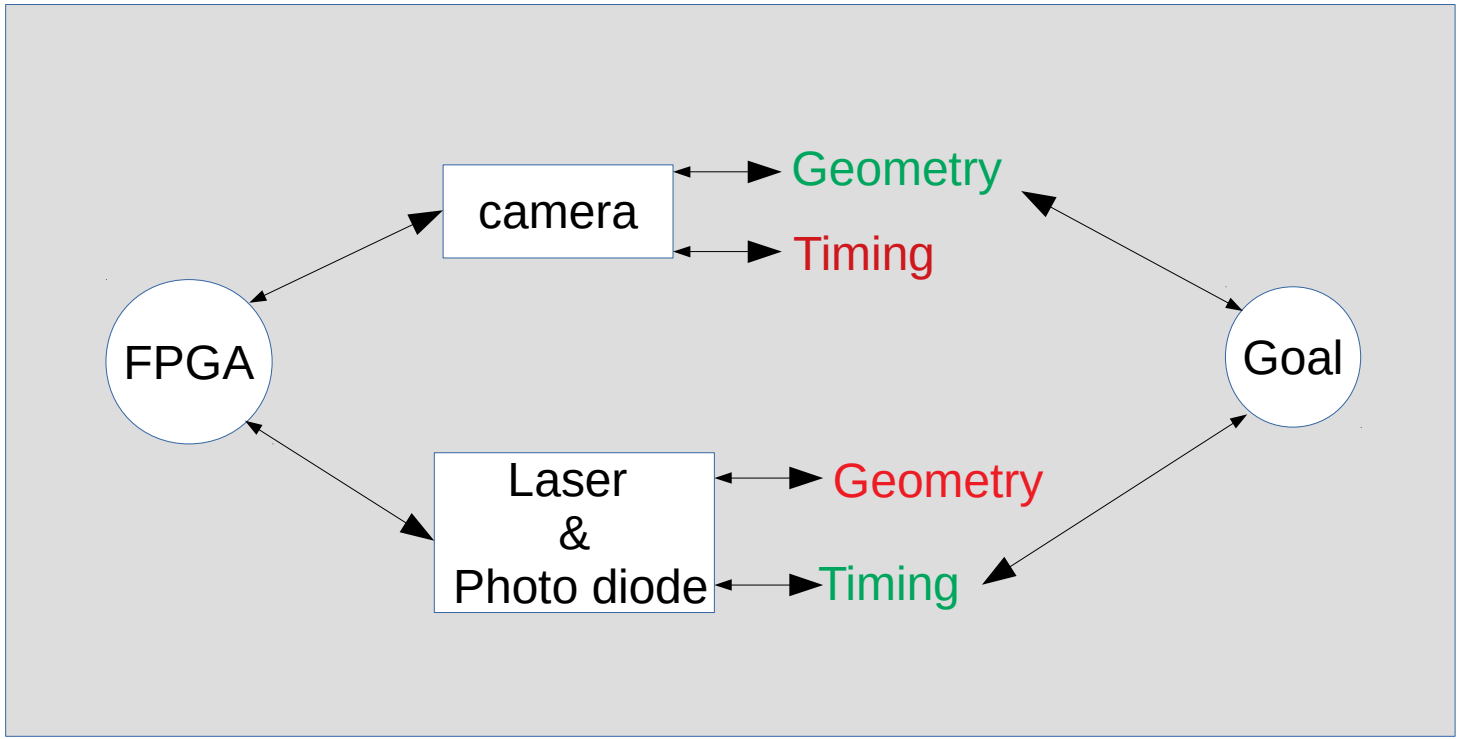



Schnittansicht A-A
Schnittansicht B-B
Schnittansicht C-C
Isometrische Ansicht
Verfahreinheit
-Untergruppe Scheibe-
Scheibe (Hälfte)
JP-LYSO-321/2
1:2
FORSCHUNGSZENTRUM JÜLICH
I K P
Fachgruppe Konstruktion

dE vs E

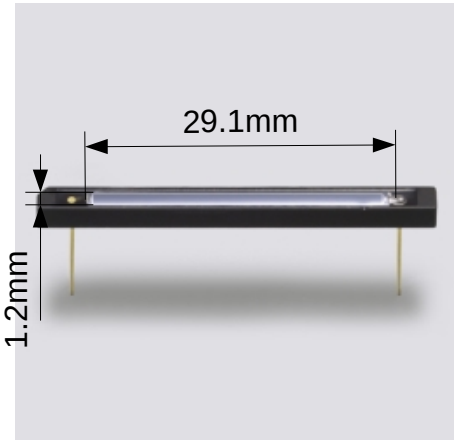

dE vs. E at 300 MeV
Deuterons
Protons
Elastic Peak
Neutrons
Break-up in LYSO
dE [MeV]
E [MeV]
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
10
1
10^{-1}

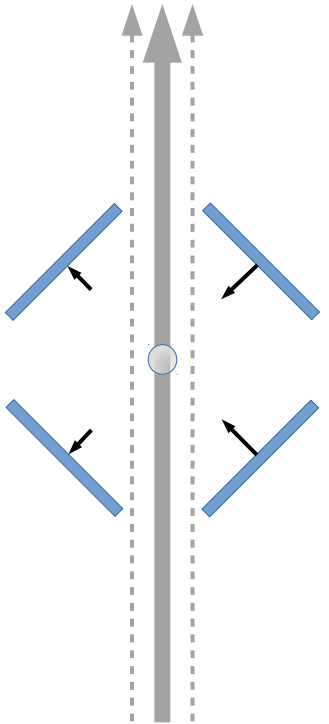
Directions of work



Time measurement

- Triggering
- Position reconstruction





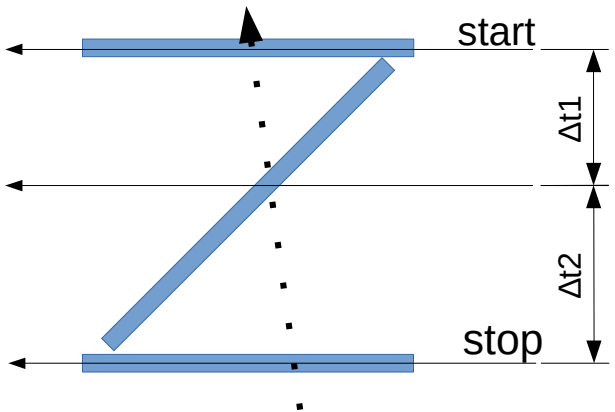
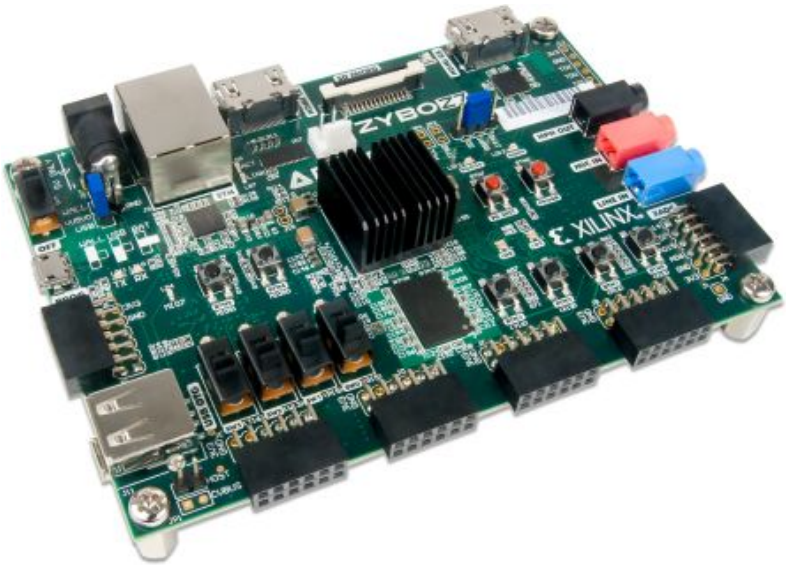


Image processing



667 MHz dual-core Cortex-A9 processor

High-bandwidth peripheral controllers: 1G Ethernet, USB 2.0, SDIO

1 GB DDR3L RAM

FPGA – XC7Z020-1CLG400C

- Look-up Tables (LUTs) 53,200
- Flip-Flops 106,400

5MP color system-on-chip image sensor

Dual lane MIPI CSI-2 image sensor interface

Supports QSXGA@15Hz, 1080p@30Hz, 720p@60Hz, VGA@90Hz and QVGA@120Hz

Output formats include RAW10, RGB565, CCIR656, YUV422/420, YCbCr422, and JPEG compression

Camera requirements

Minimum camera characteristics with window size 1x4 cm and pellet diameter 100µ:

- Minimum 26 fps to get 2 points (free fall)
- Minimum 400 pixels

Pco - pco.dimax HS4
Fps = 2277 @ 4Mpix (2000x2000) or 7039 @ 1MPix (1000x1000)

Interfaces: USB 3.0, GigE/USB 2.0, Camera Link

exposure time range 1.5 µs - 40 ms

Ximea - CB019MG-LX-X8G3

Fps = 2500+ @ 2Mpix (1920x1080)

Interfaces: PCI Express (PCIe) Gen3

exposure time range = 1µs – 1sec