Mitglied der Helmholtz-Gemeinschaft

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Foundation

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SMART|EDM_lab:

Contribution to the Electric Dipole Moment (EDM) Measurements at COSY

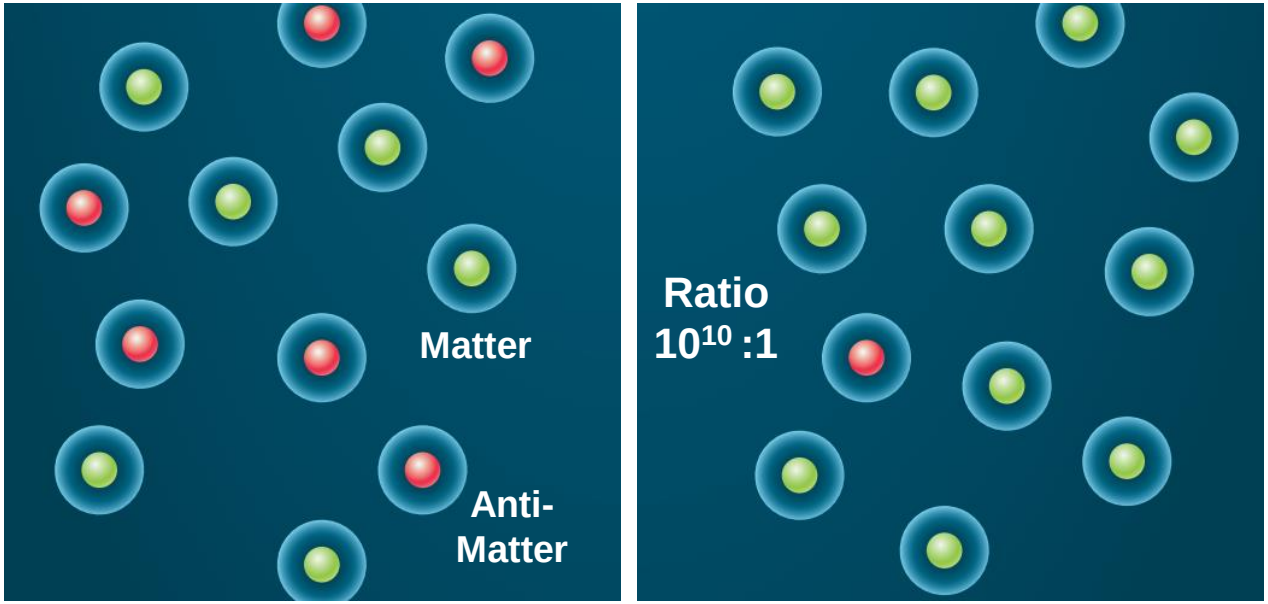
The matter-antimatter asymmetry of the universe:

What we should see:

equal amount of matter and antimatter

What we actually see:

predominantly matter almost no antimatter

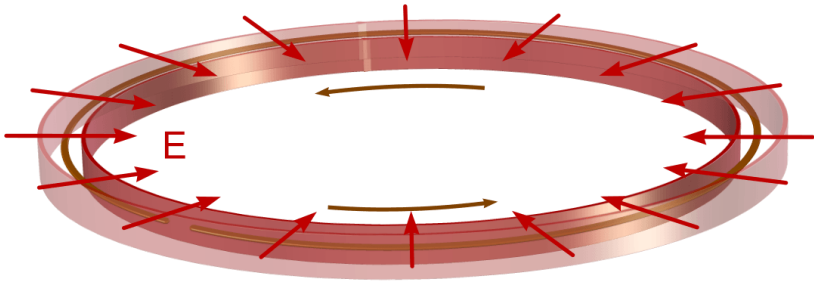


This is one of the big unsolved problems in physics !

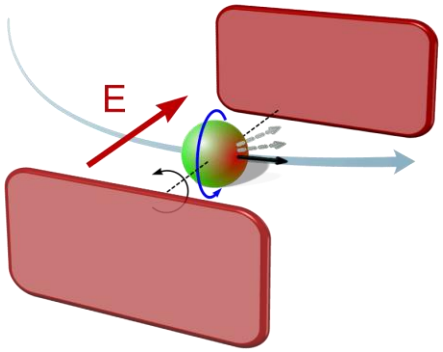
JEDI: Charged-Particle EDM Search

Main principle:

- Inject polarized particles into a storage ring:



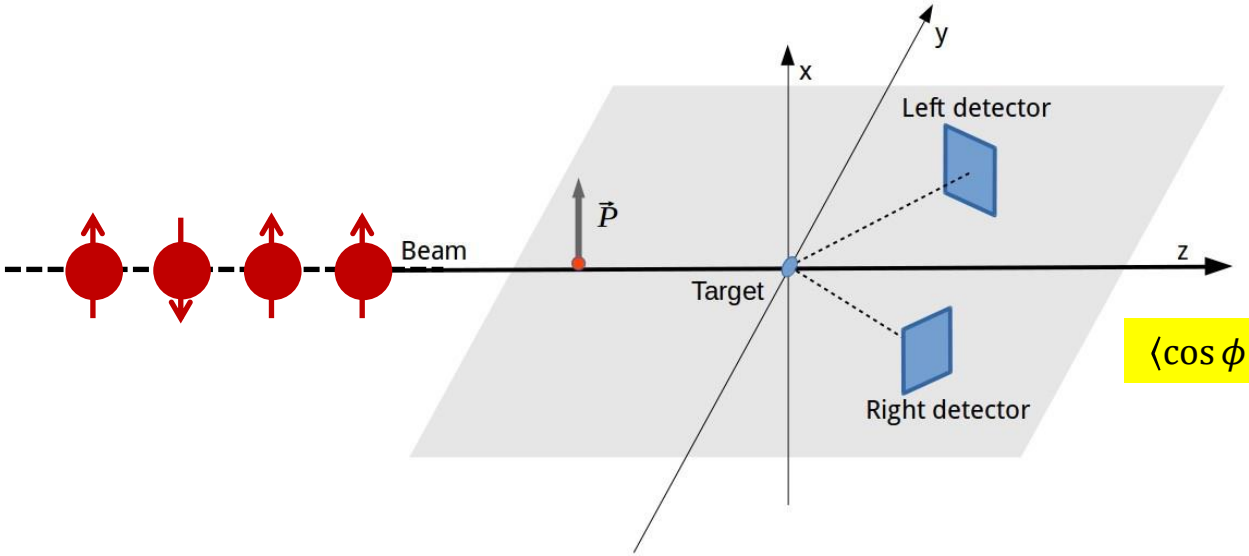
- Apply radial electric field E:

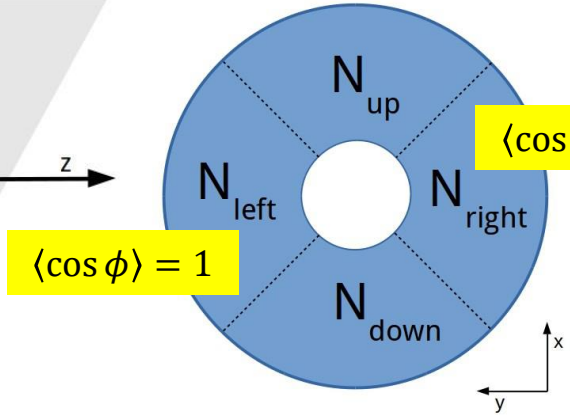


$$\frac{d\vec{s}}{dt} \propto d\vec{E} \times \vec{s}$$

- Non-zero EDM → spin rotation out of the plane
- Track spin rotation → **need precise polarimeter**

How to measure beam polarisation?





$\langle \cos\phi \rangle = -1$

$\langle \cos\phi \rangle = 1$

$$\sigma_{pol}(\theta,\phi) = \sigma_0(\theta)\left[1 + P_y A_y(\theta)\cos\phi\right]$$

Polarisation

Analysing power

$$\varepsilon = \frac{N_L - N_R}{N_L + N_R} = P_y A_y(\theta) \qquad -1 \le P_y \le 1$$

Experimental facility: COSY storage ring

COSY (COoler SYnchrotron) at Jülich (Germany)

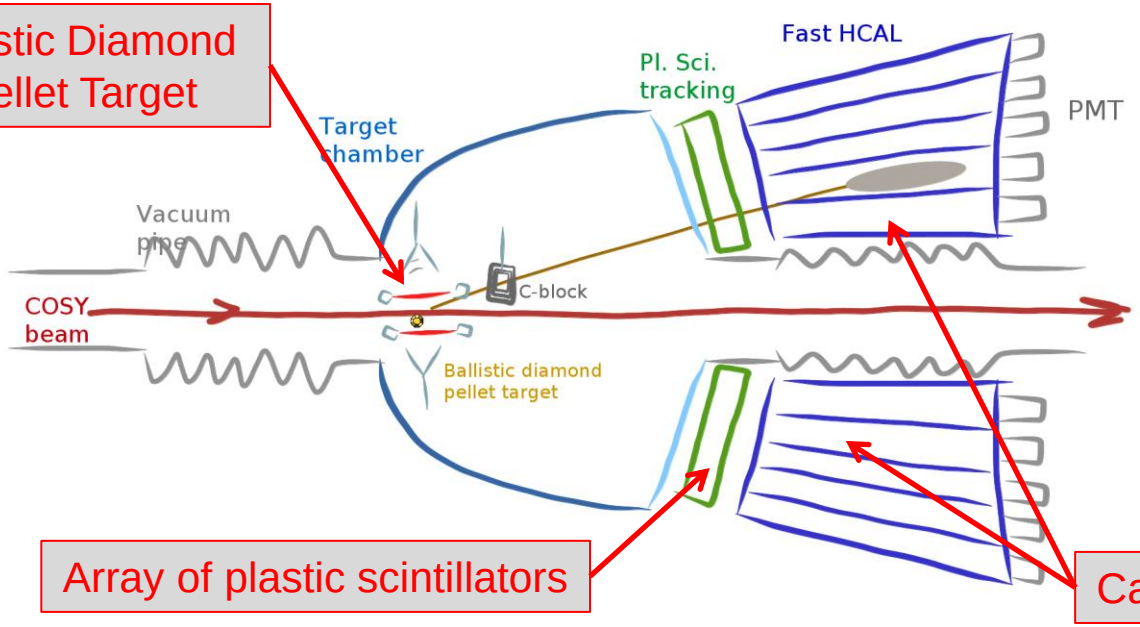
- Energy range:

  0.045 – 2.8 GeV (p)

  0.023 – 2.3 GeV (d)
- Max. momentum ~ 3.7 GeV/c
- Energy variation (ramping mode)
- Electron and Stochastic cooling
- Internal and external beams
- High polarisation (p,d)
- Spin manipulations

JEDI polarimeter (JePo)

Ballistic Diamond Pellet Target



Array of plastic scintillators

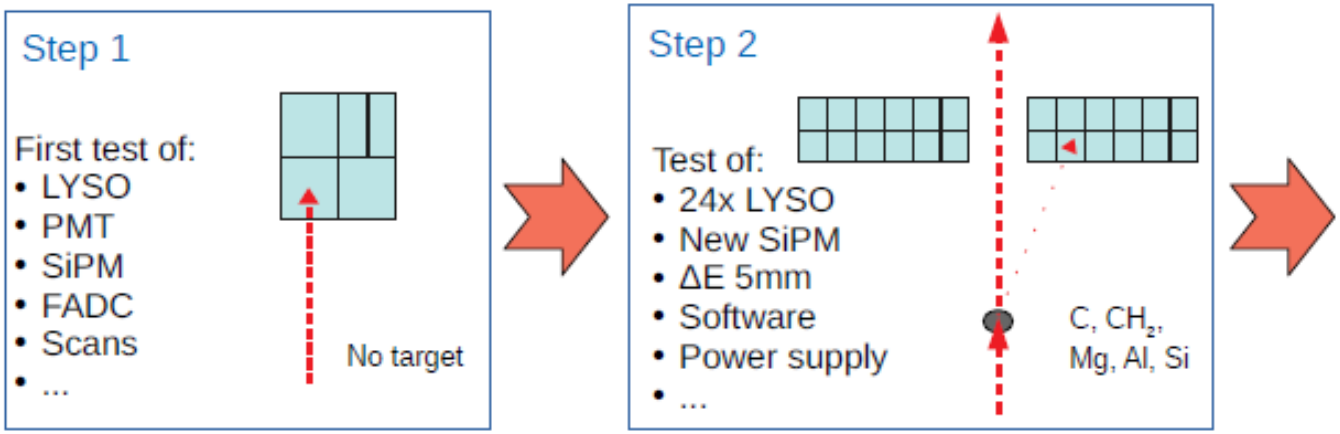
Calorimeter modules

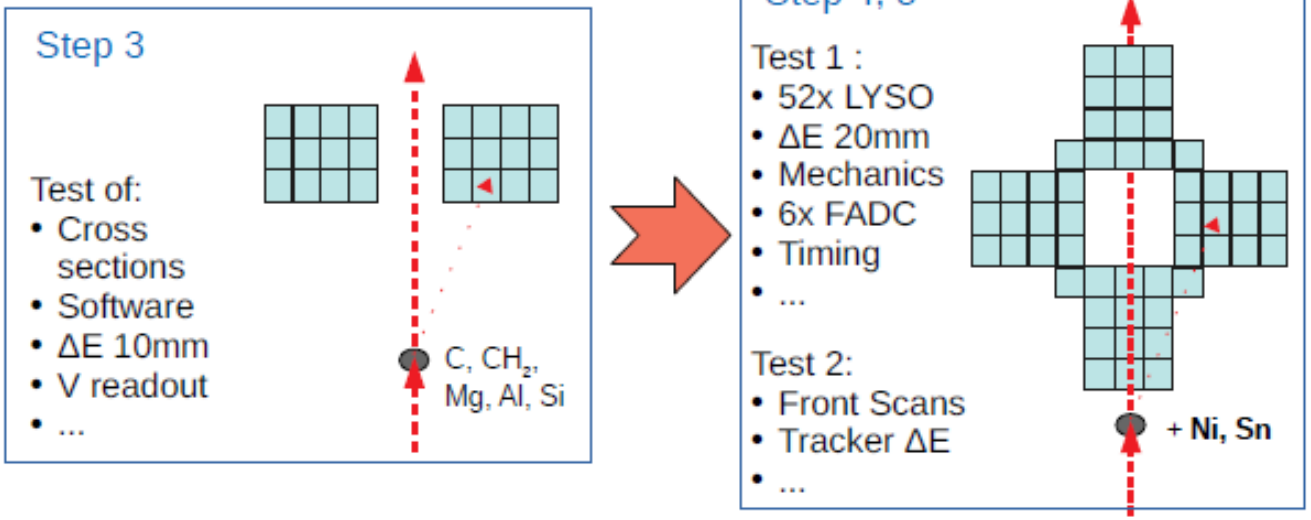
Requirements:

- High precision
- High efficiency
- High stability
- No magnetic / electric field

- LYSO based EM calorimeter for highest energy resolution
- Fast plastic scintillators for particle identification
- FADC based readout for fast data acquisition
- New type of target for unprecedented precision

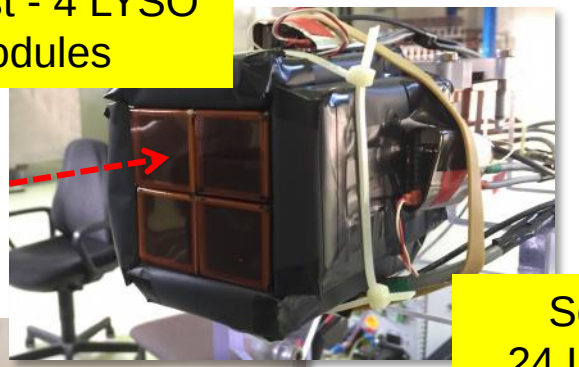
JePo development history

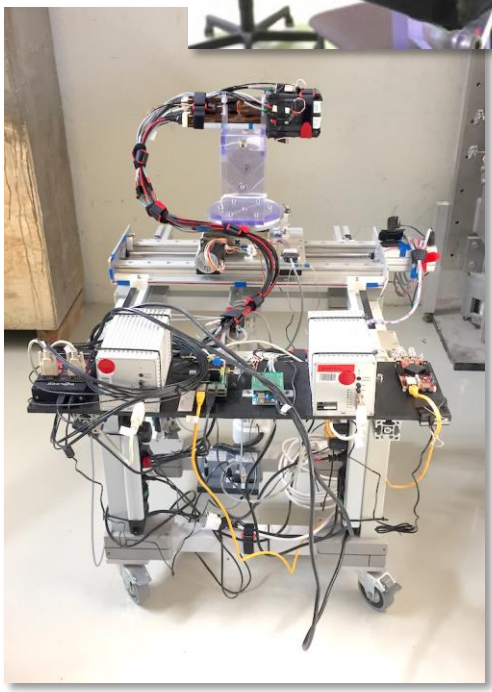




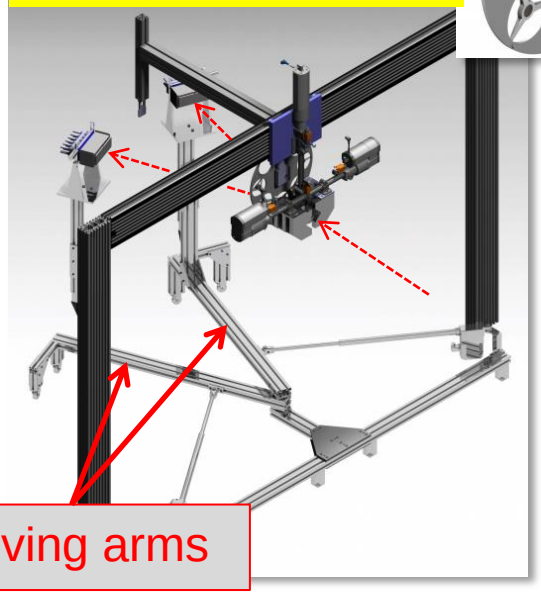
JePo development history

First test - 4 LYSO modules



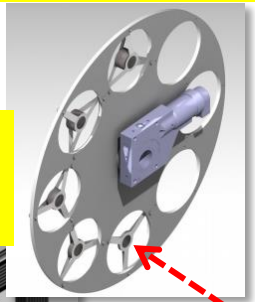


Second test – 24 LYSO modules

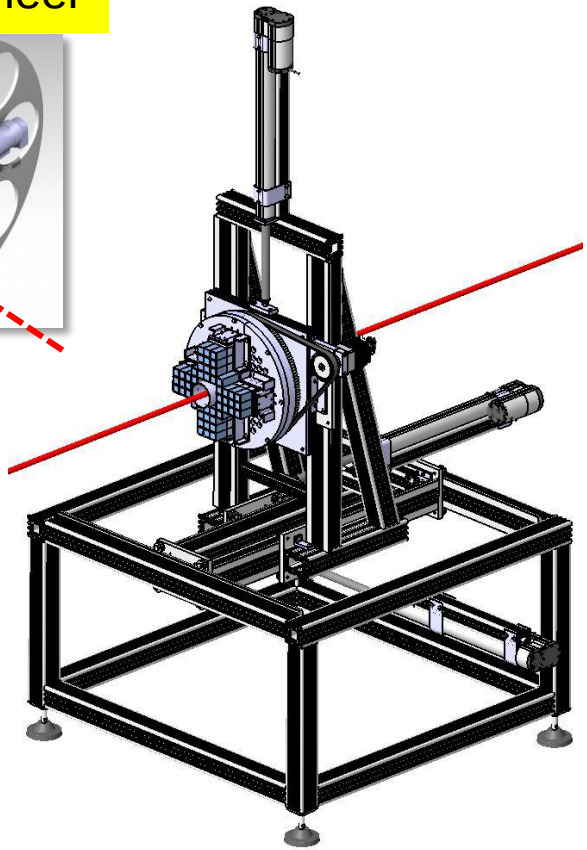


Moving arms

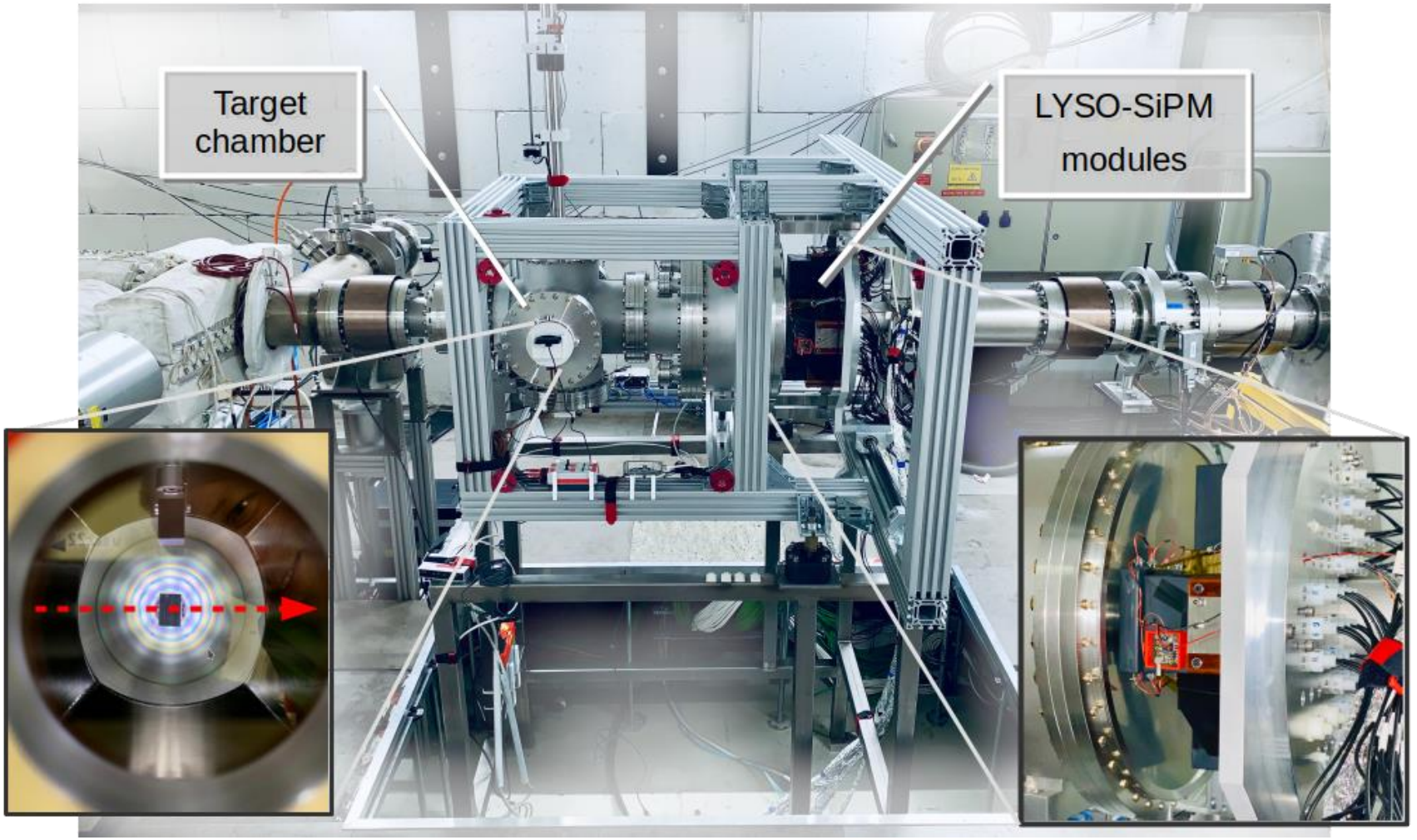
Target wheel



Final – 52 LYSO modules



JePo installed on COSY

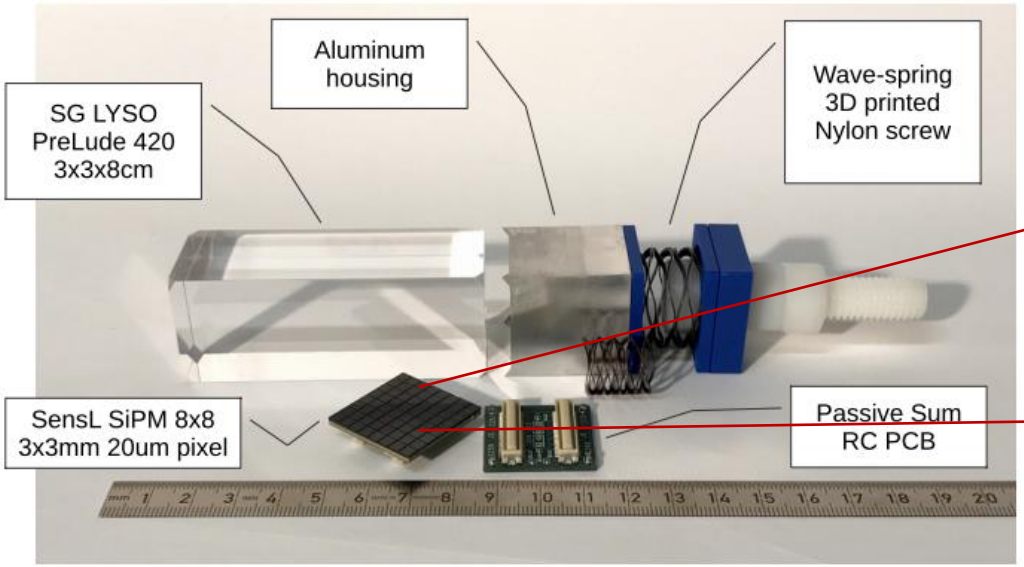


SMART|EDM_lab contribution:

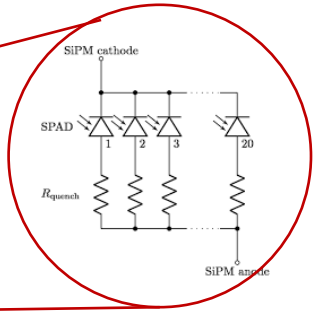
Hardware

Power supply development for SiPMs

SiPM-based LYSO calorimeter module before assembly

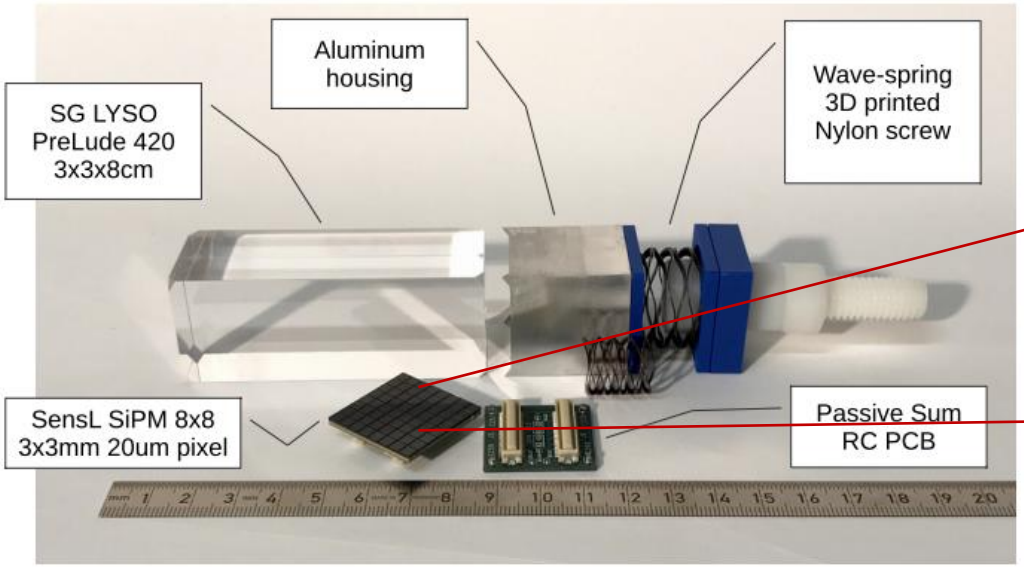


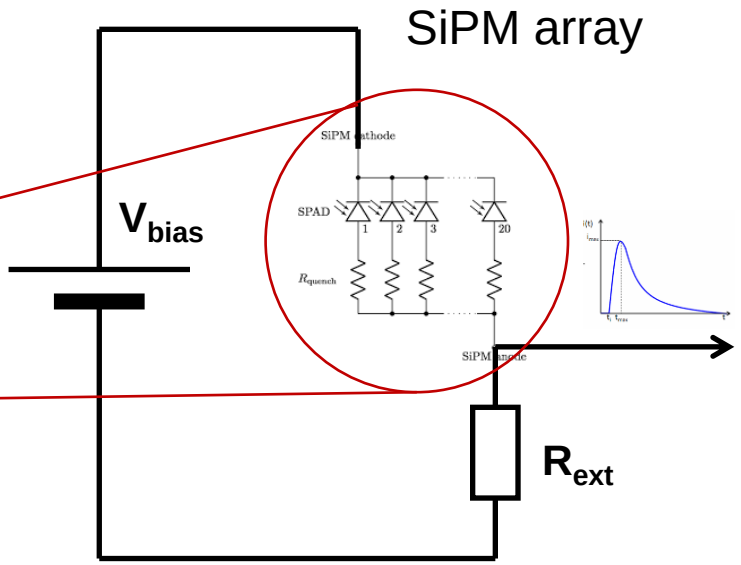
SiPM array



Power supply development for SiPMs

SiPM-based LYSO calorimeter module before assembly



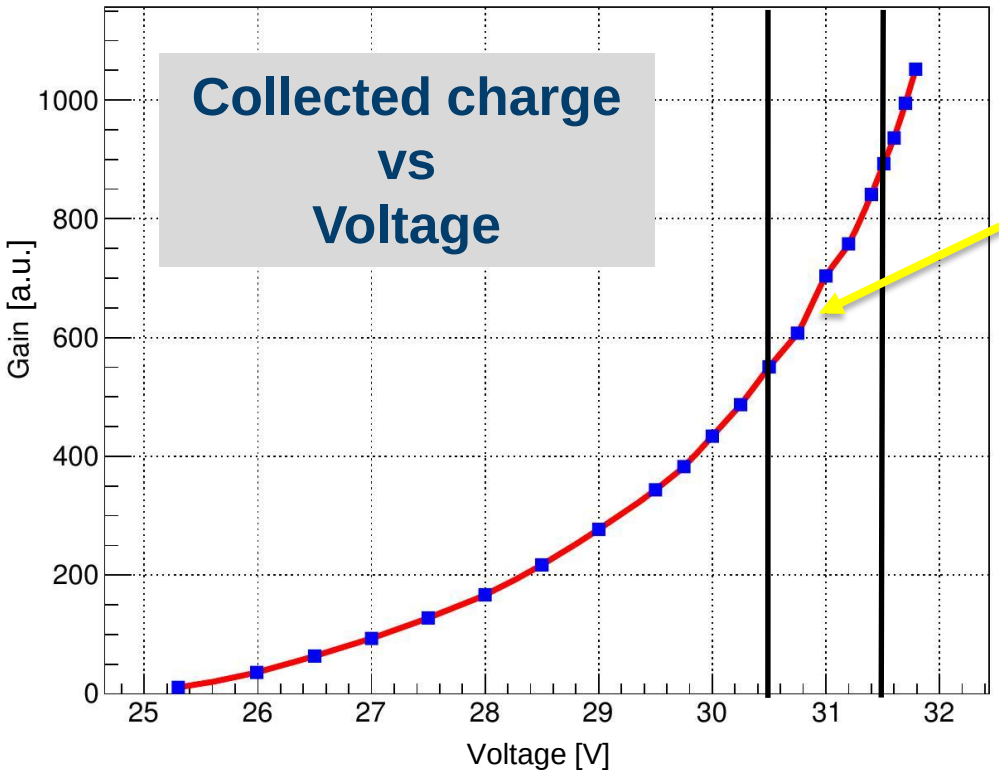


Current demands:

- Internal radiation + dark current: ~10…30 μA (average)
- Single 300 MeV deuteron hit: can reach 100 mA! (peak)

Power supply development for SiPMs

Laboratory test of the SiPM with flasher



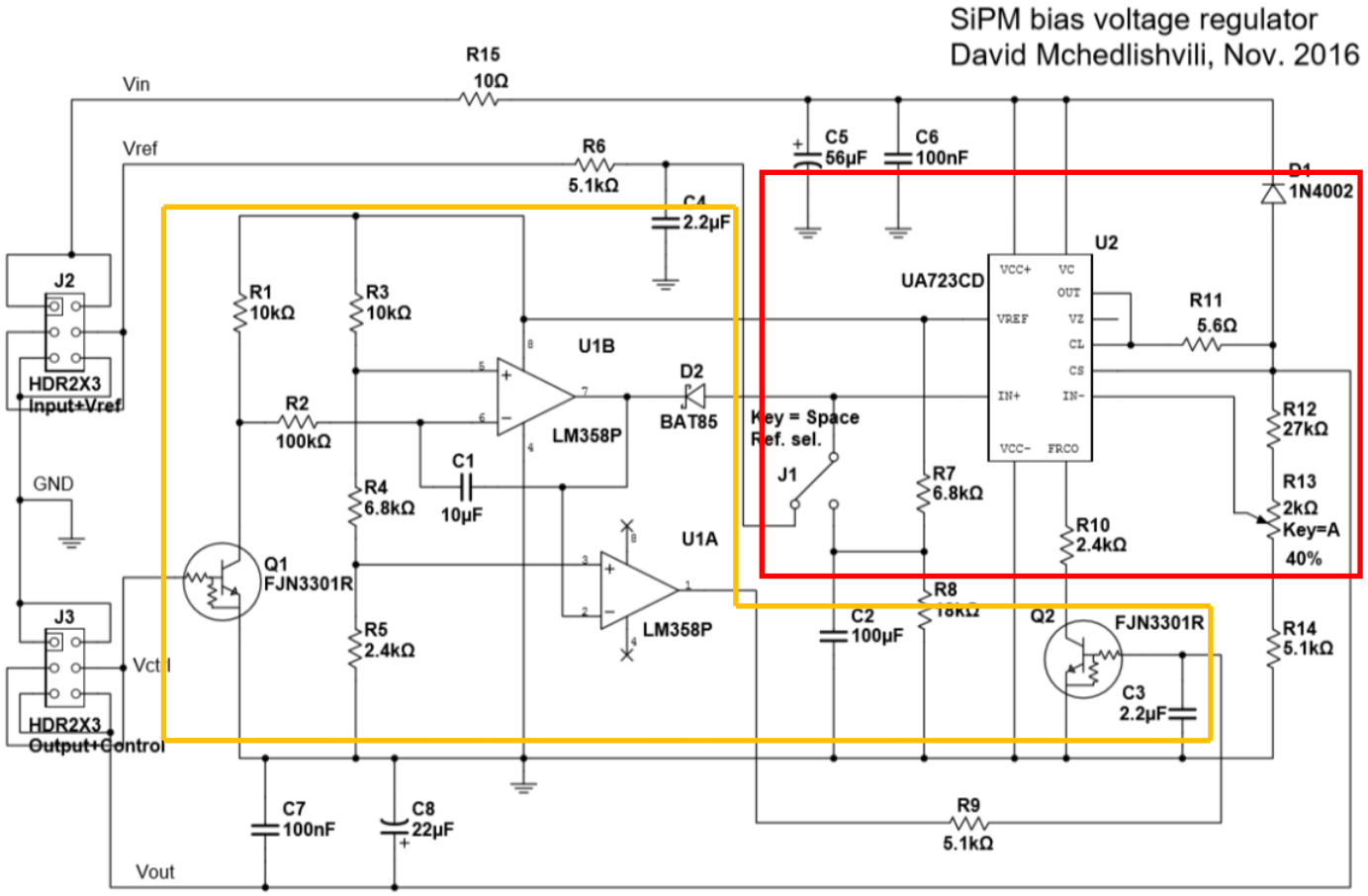
10 mV variation ≈ 0.5%
in charge collection

Main requirements:

- Modular design
- High output stability *(temperature, long/short term, low noise)*
- Remote on/off capability
- Voltage adjustment

Power supply module

- High output stability
- Remote on/off capability with slow ramp up/down

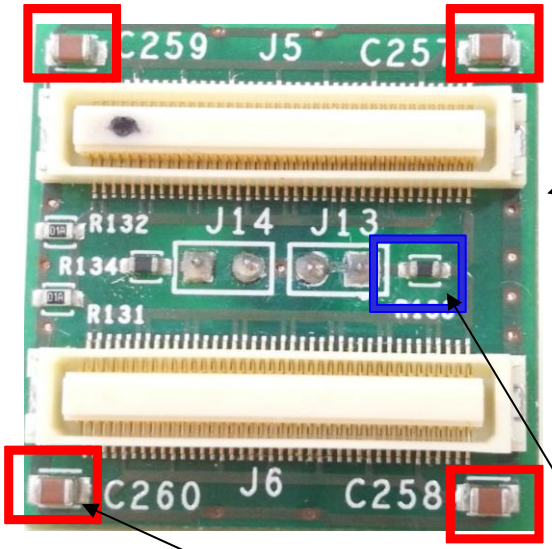


Linear voltage regulator part

Ramp generator and on/off part

Dynamic load test

SiPM board includes 4x2uF capacitors (red) and inductance (blue)



SiPM board designed at Ferrara university, Italy

RedPitaya

Voltage drop measurement

Signal from generator

Power Supply

30 V

Long cable

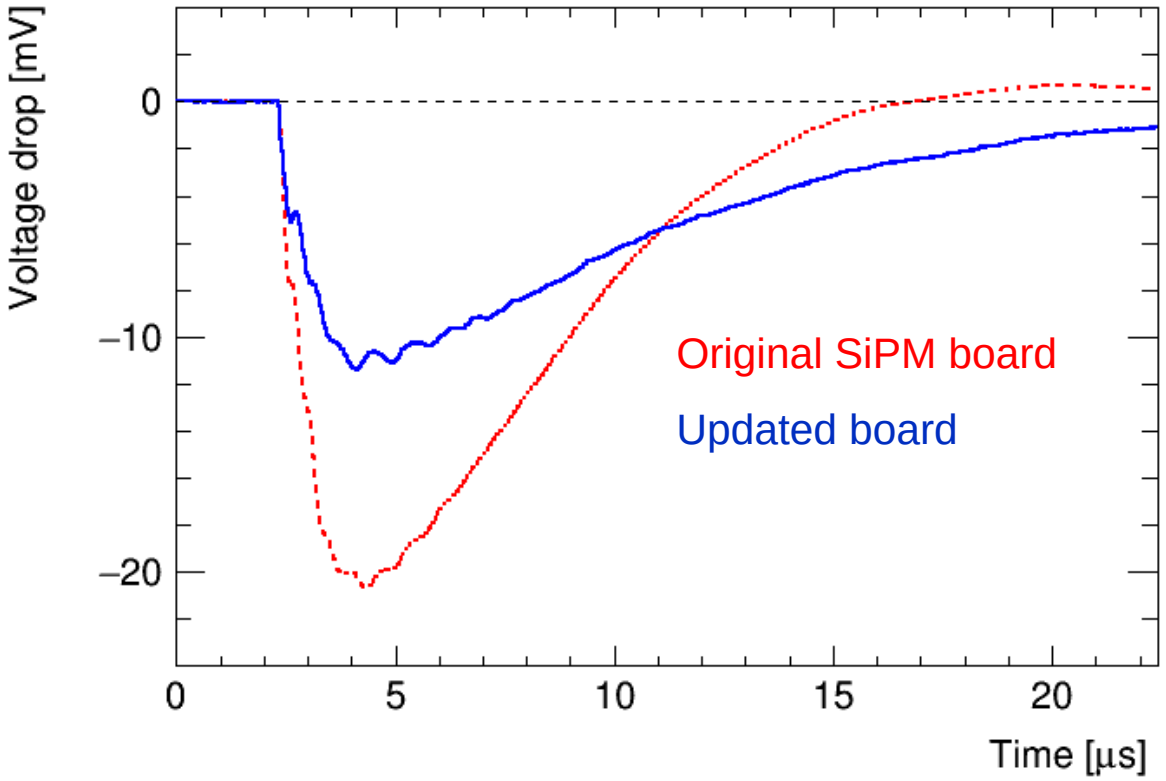
8uF

SiPM board

Fast current sink

Dynamic test load

1. Measurements performed for the original SiPM board
2. Measures taken to reduce the voltage drop
3. New version of the board was developed

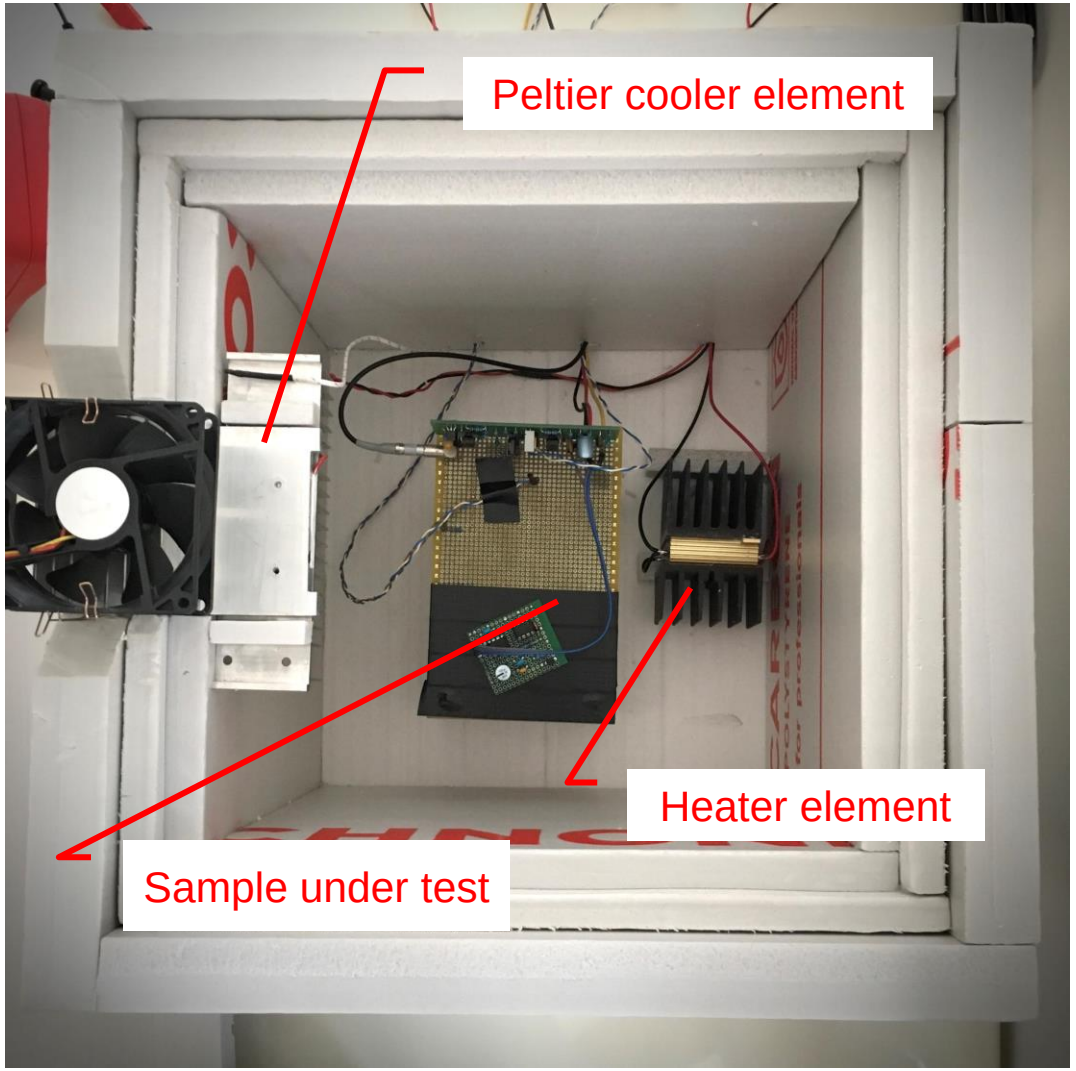


Temperature stability tests

- Thermal chamber built from XPS material
- Peltier and heater elements included
- Online temperature measurement

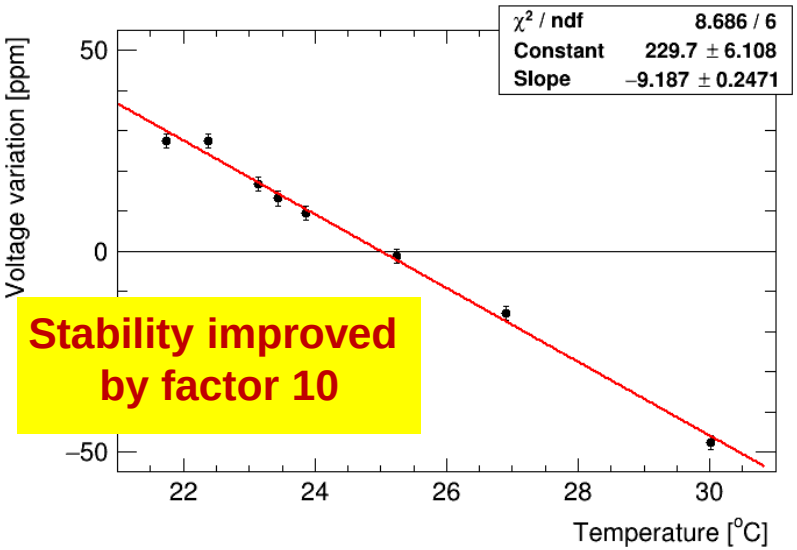
Test procedures:

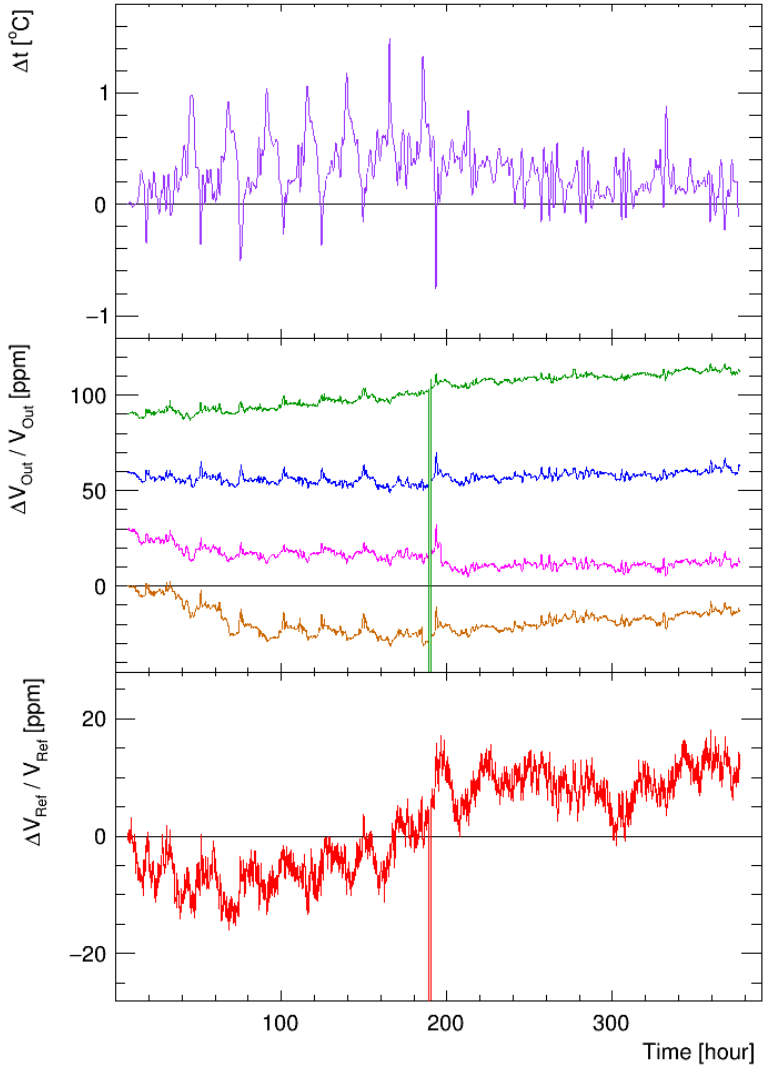
- Different component contributions investigated
- Software modelling
- Improvement possibilities analysed



Temperature stability

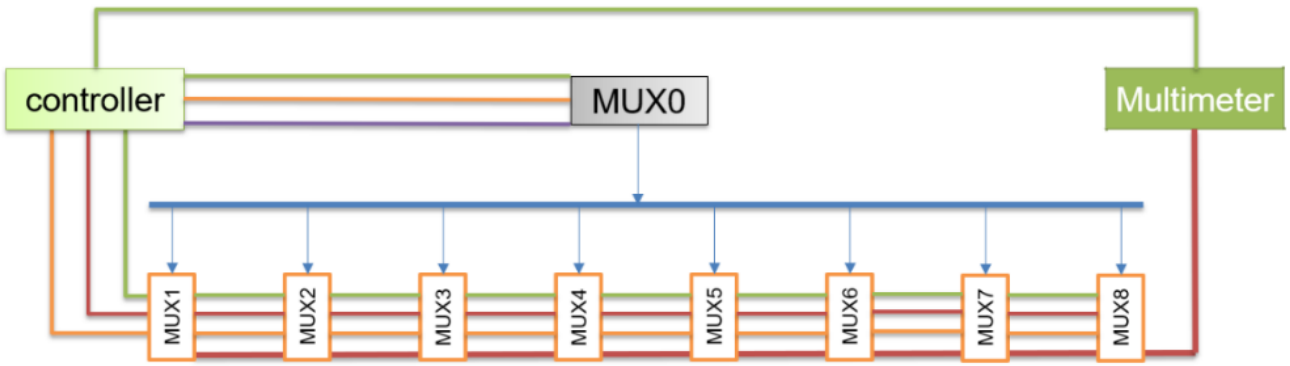
- Most sensitive components identified
- Few components replaced by more temperature-stable versions
- Lab measurements (single module)
- Long-term measurements in real conditions (all modules)

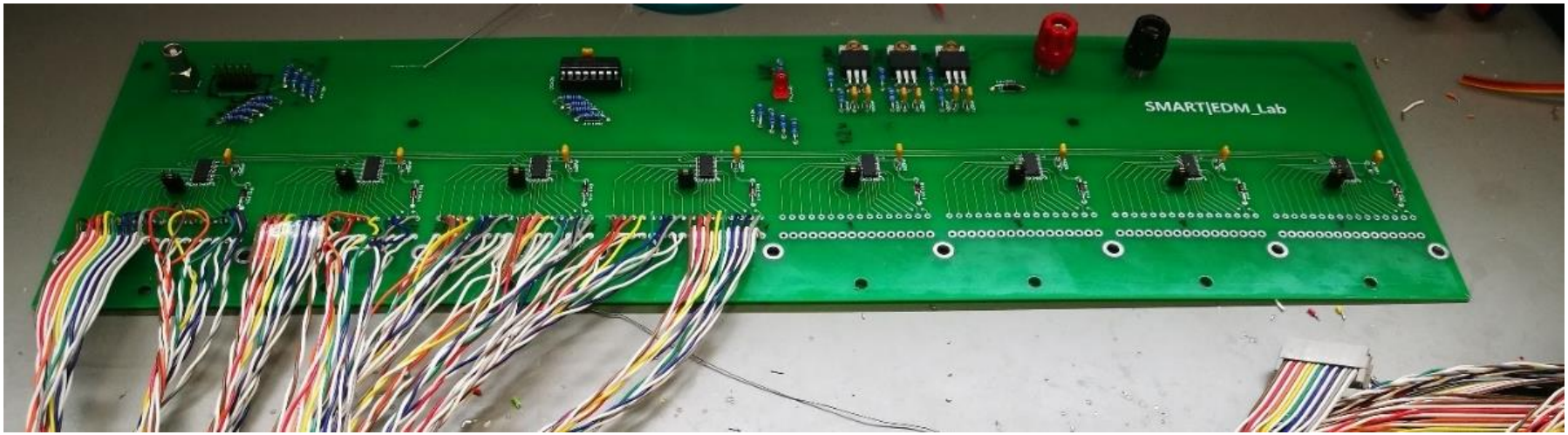


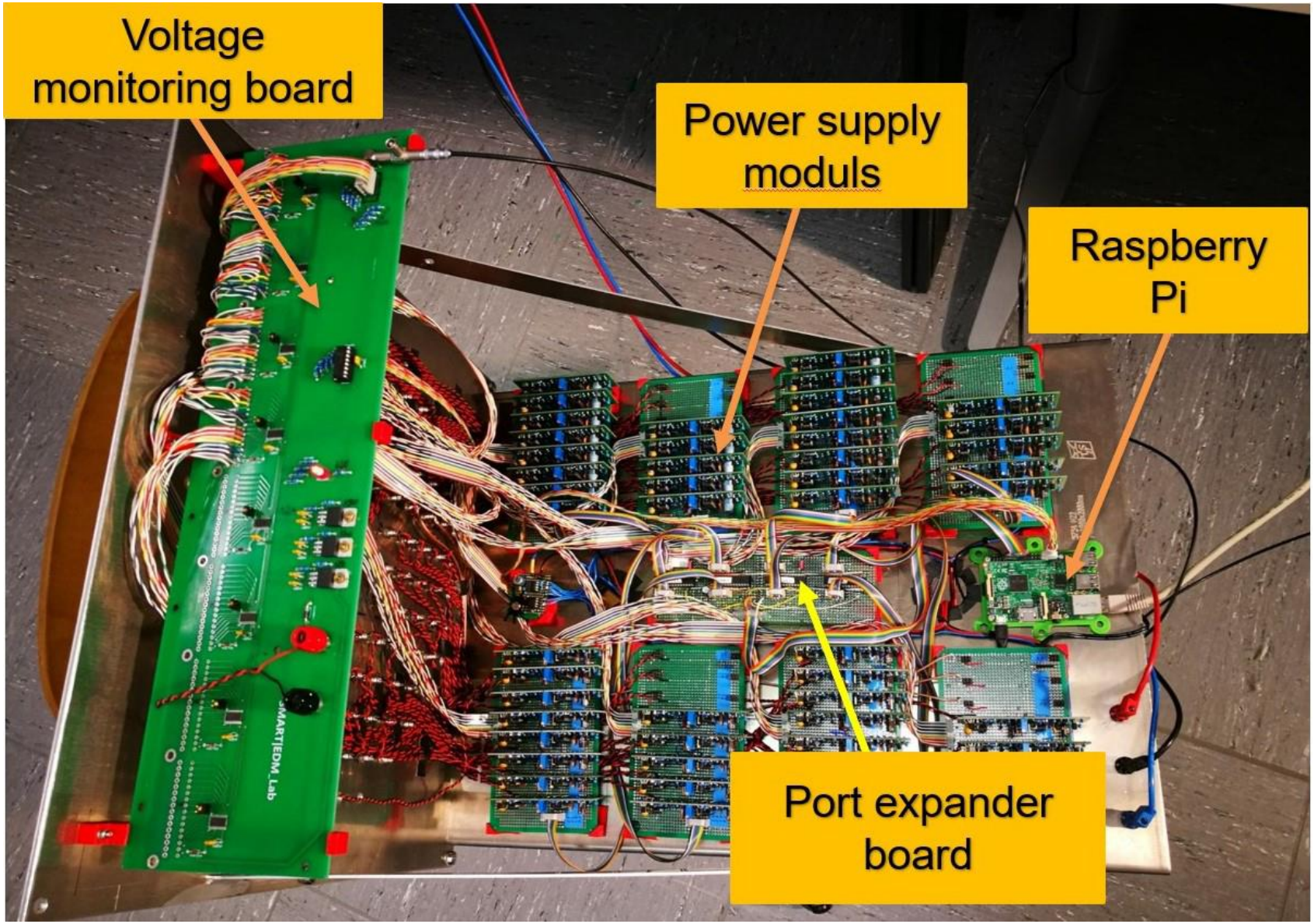


Multi-channel voltage monitoring system

- Based on analog multiplexers
- 128 channel supported
- External voltage readout






Voltage monitoring board
Power supply moduls
Raspberry Pi
Port expander board

SMART|EDM_lab contribution:

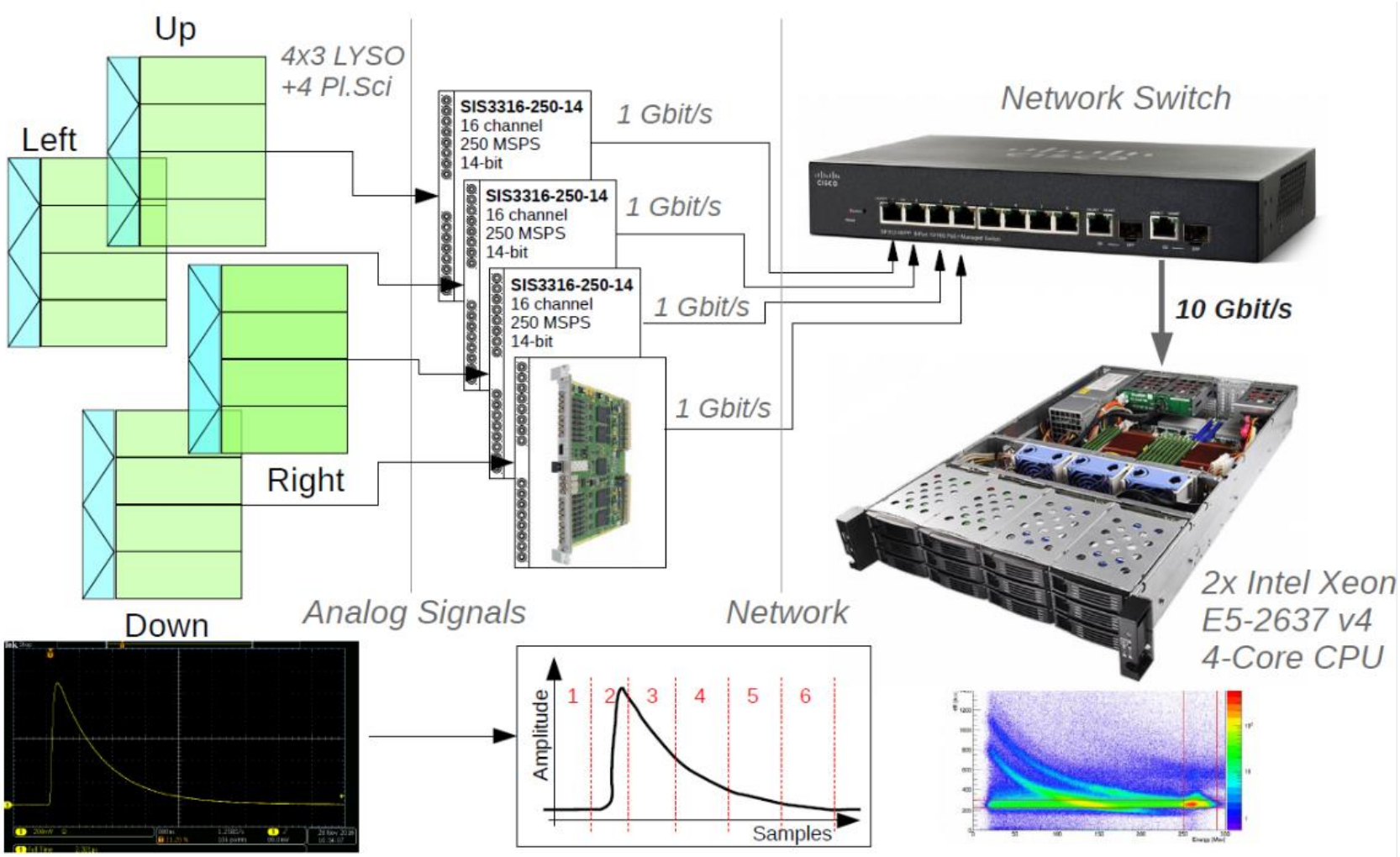
Software

Slow control system for the power supply

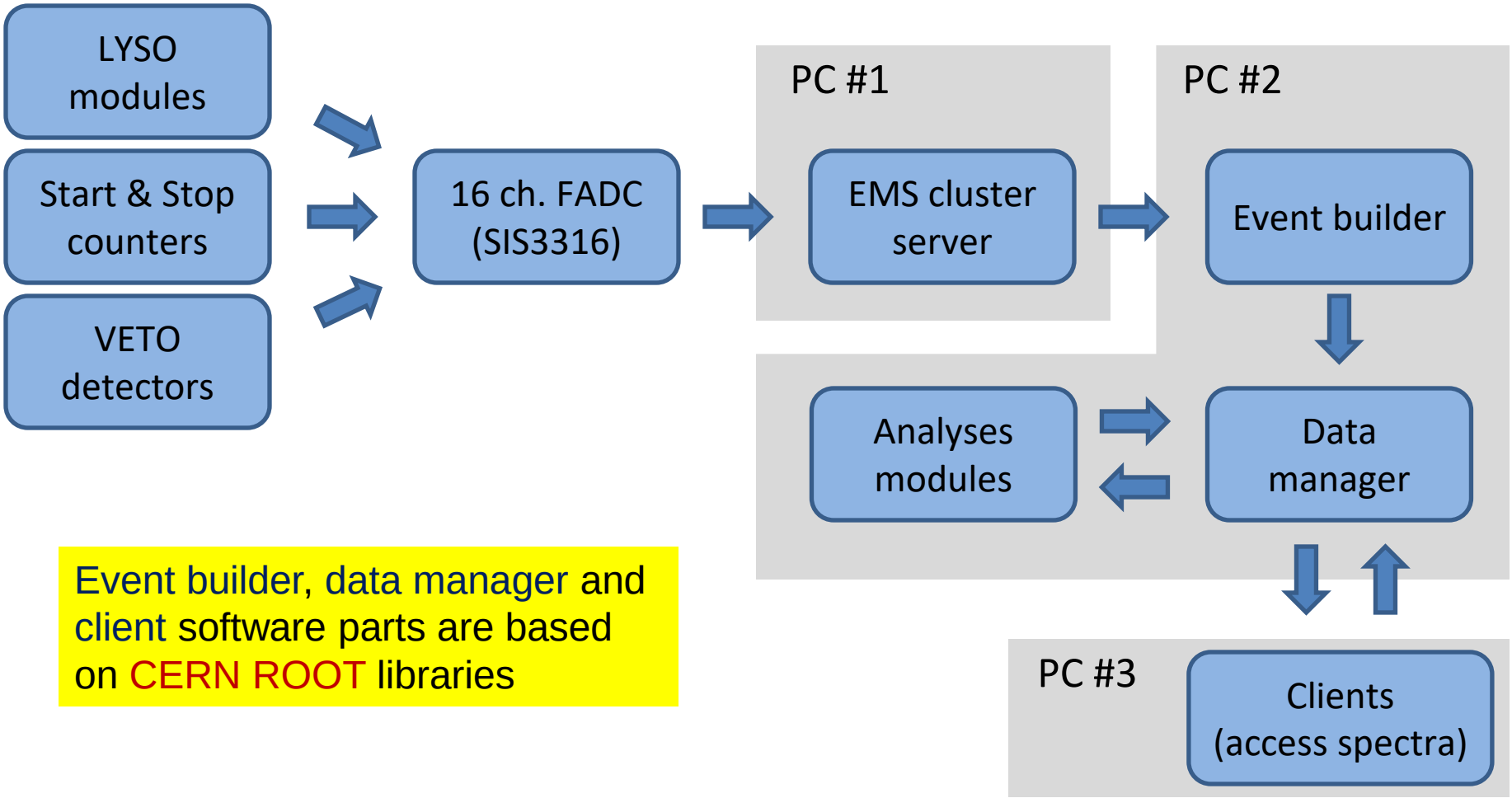
Features:

- Based on Python, Qt
- Module on/off
- Voltage online monitoring
- Voltage history recording
- Voltage distribution histograms

Data acquisition and online analysis software



Data acquisition and online analysis software



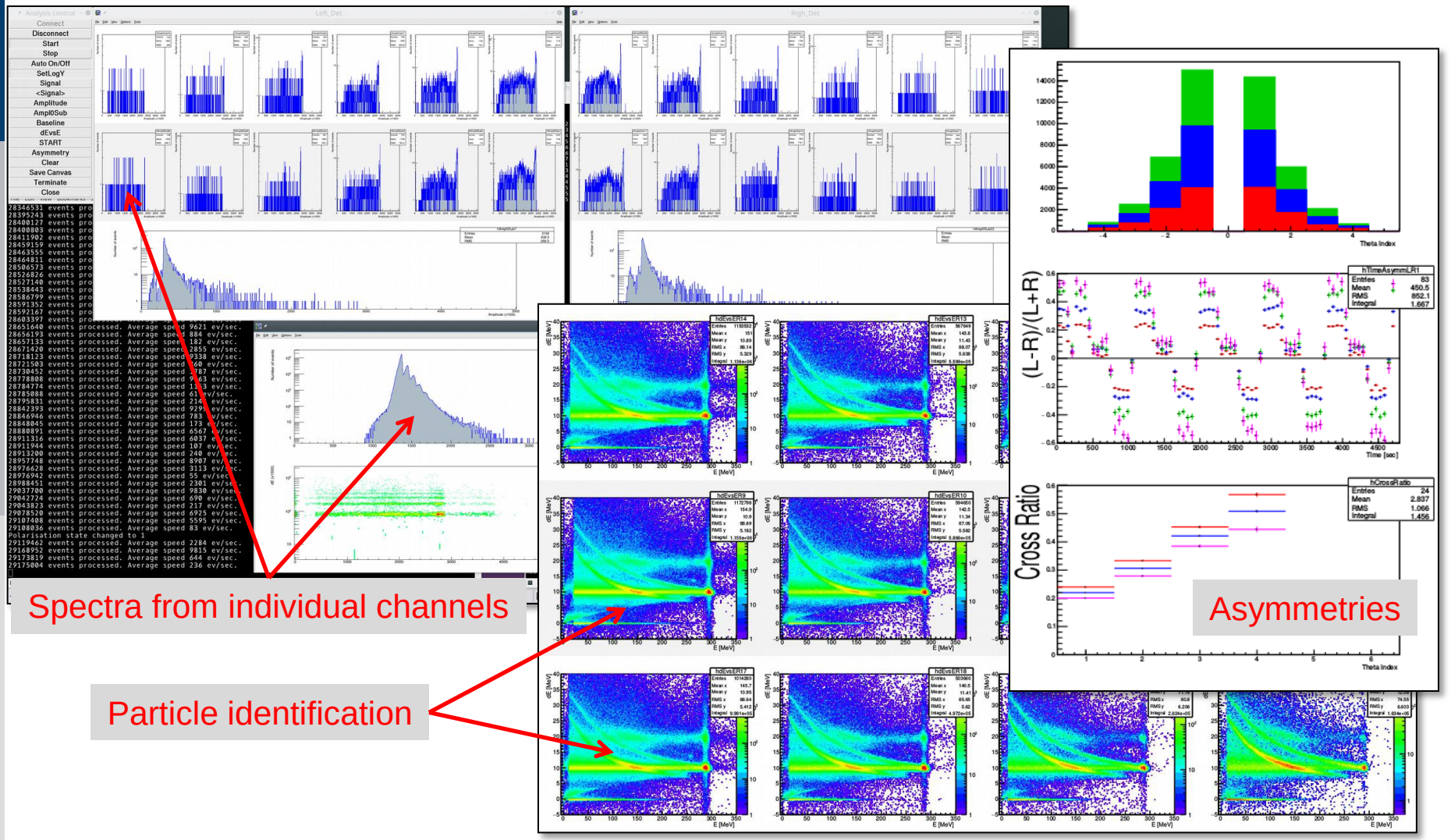
Event builder, data manager and client software parts are based on CERN ROOT libraries

Online data analysis

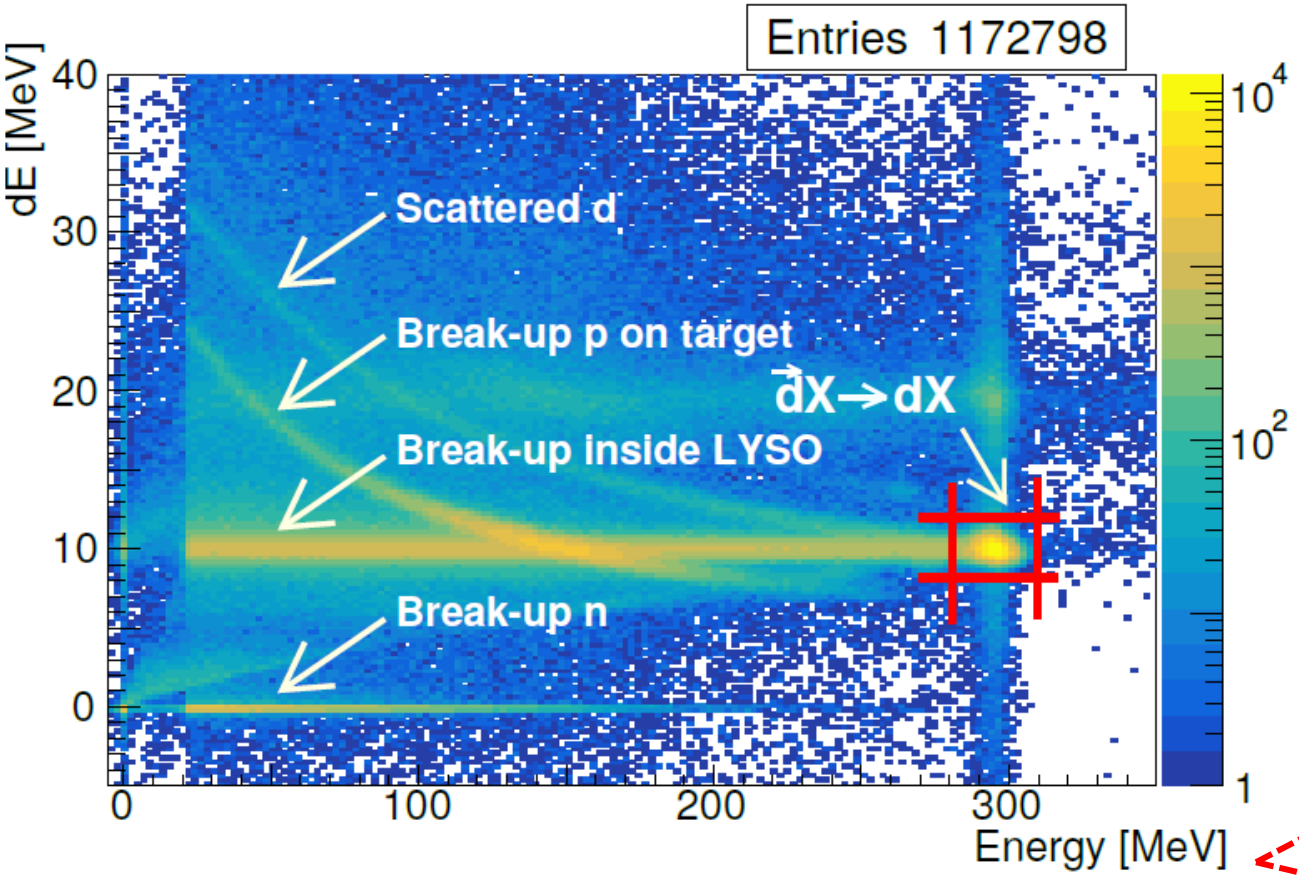
Perform following tasks:

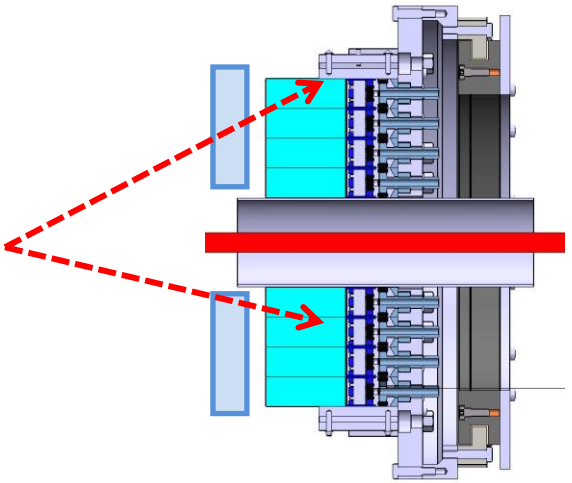
- Build physical events
- Obtain raw amplitude spectra from each calorimeter module + ΔE counters
- Energy calibration
- Sum up the energies (multi hit)
- Build 2D energy spectra (ΔE vs E)
- Identify and select polarimeter reaction events
- Measure vertical polarisation
- Determine spin tune and phase
- Measure horizontal polarisation and SCT

Online data analysis

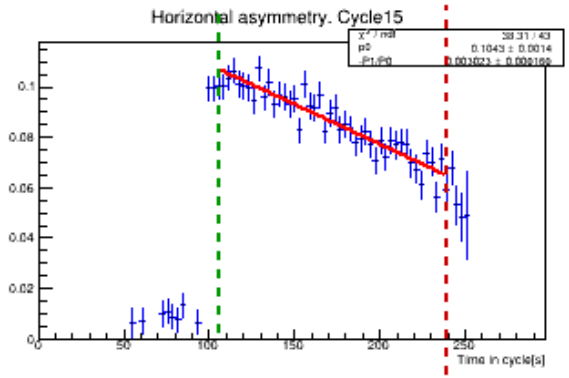


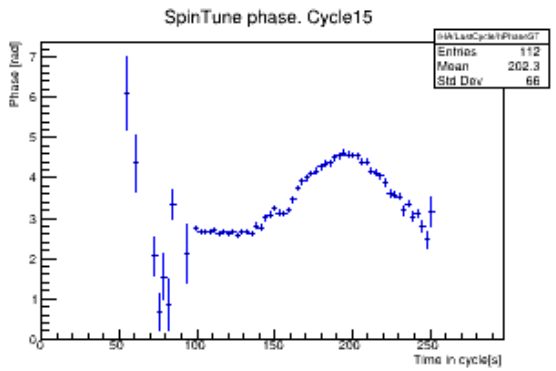
Particle and reaction identification by ΔE vs E

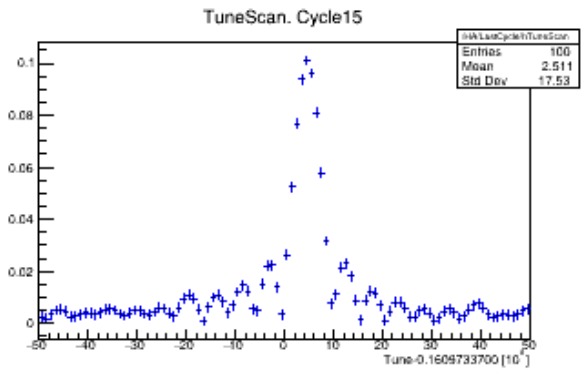


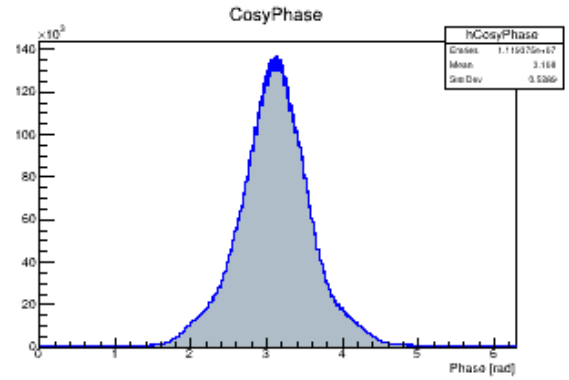


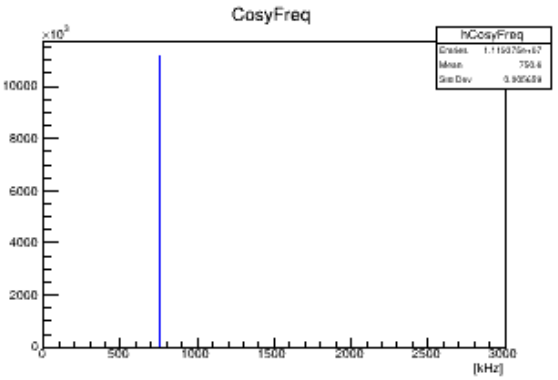
Online measurement of COSY parameters

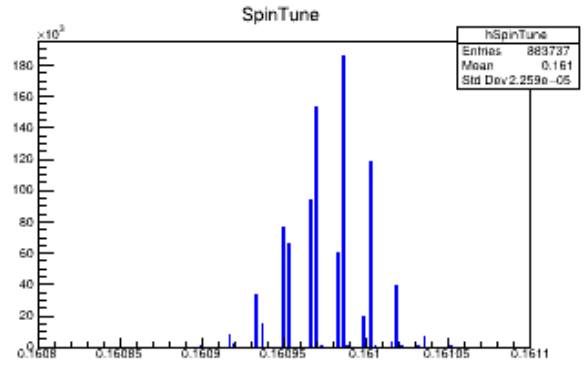








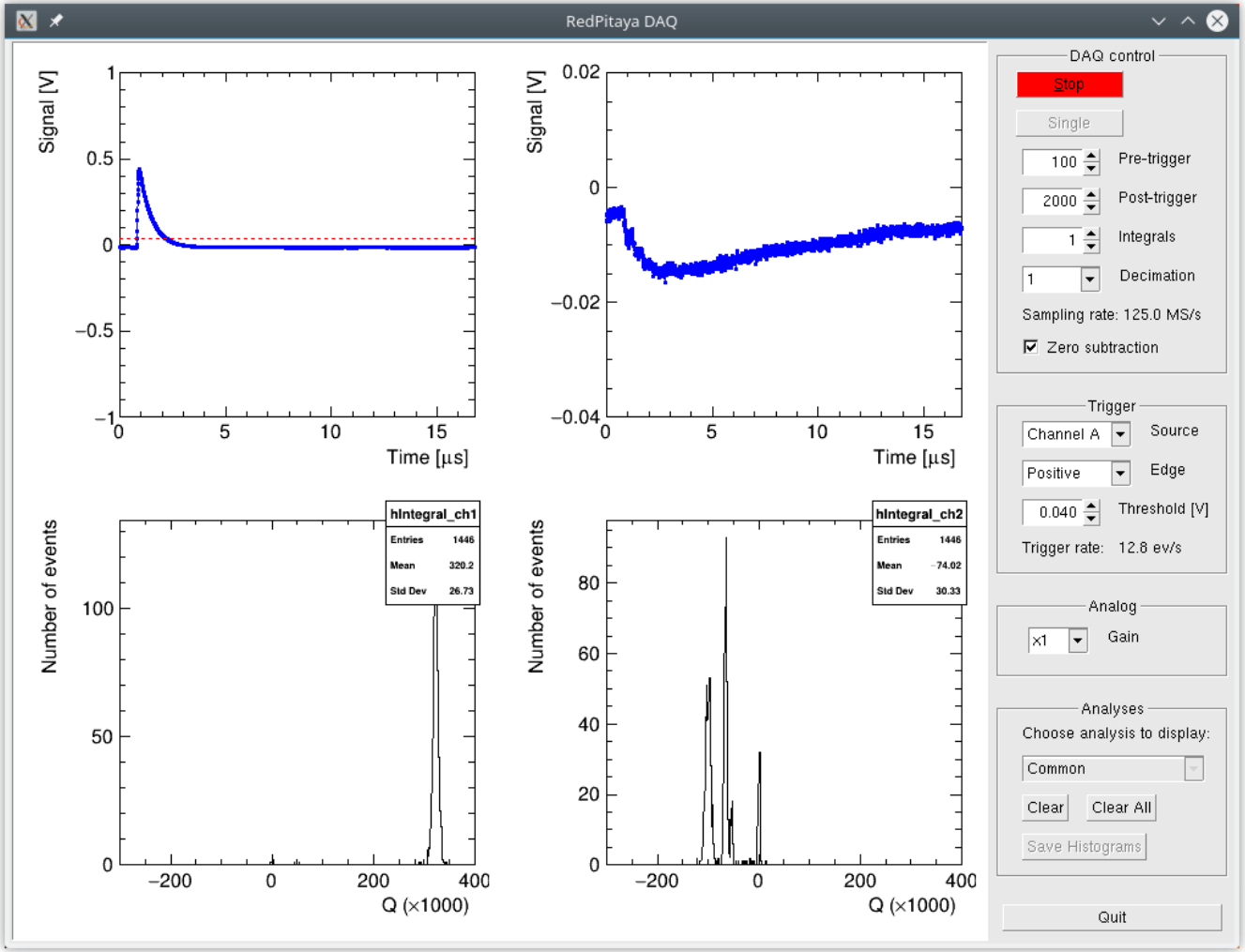




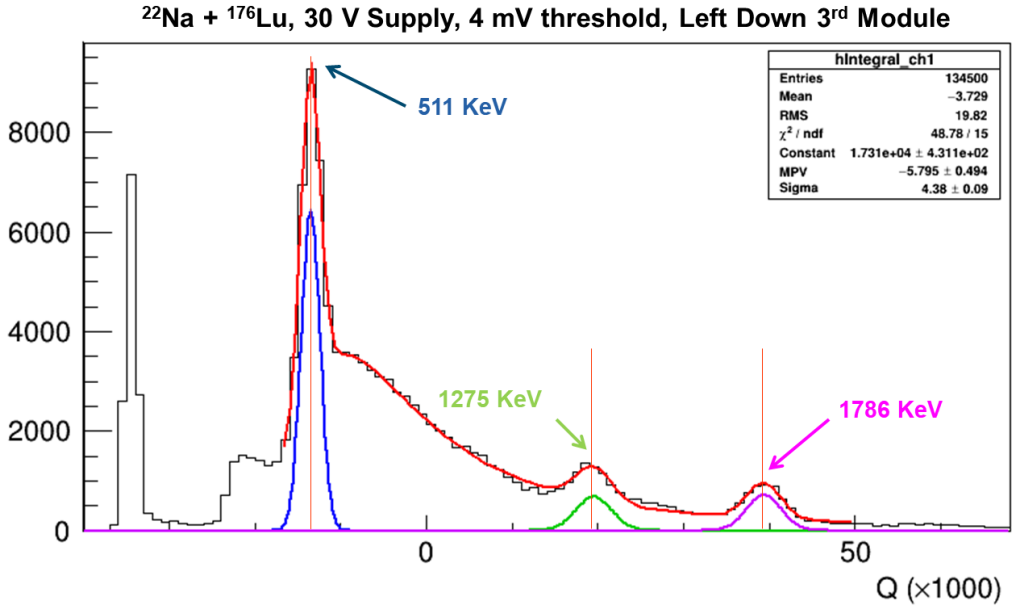
Portable data acquisition system

Redpitaya

- ✓ DAC + ADC
- ✓ 2 ch 125 MS/s
- ✓ Linux on board
- ✓ LAN access

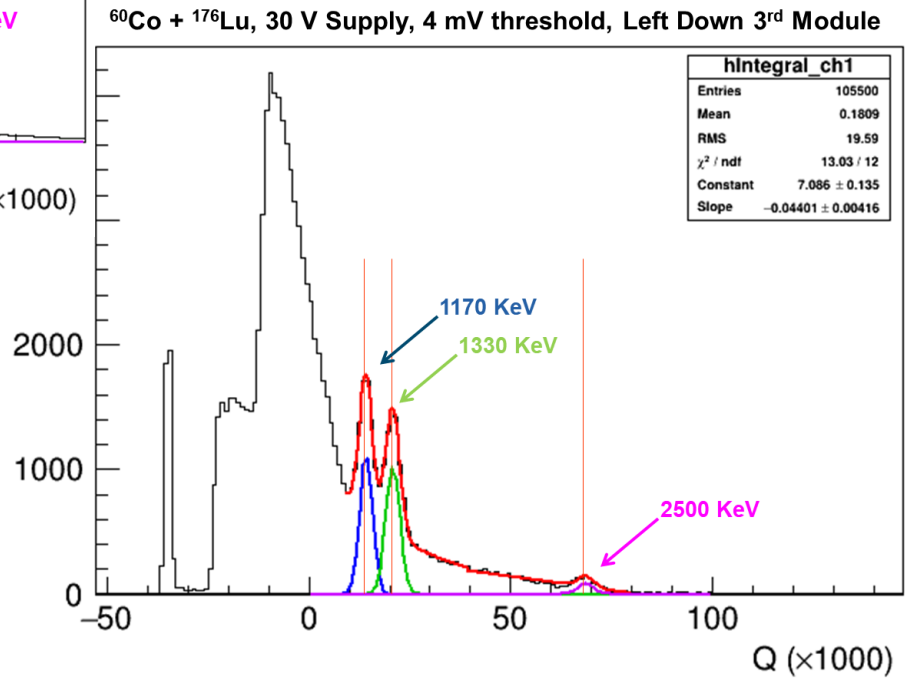


Laboratory tests using Redpitaya DAQ



Tests using radioactive sources

^{22}Na & ^{60}Co + ^{176}Lu + cosmics

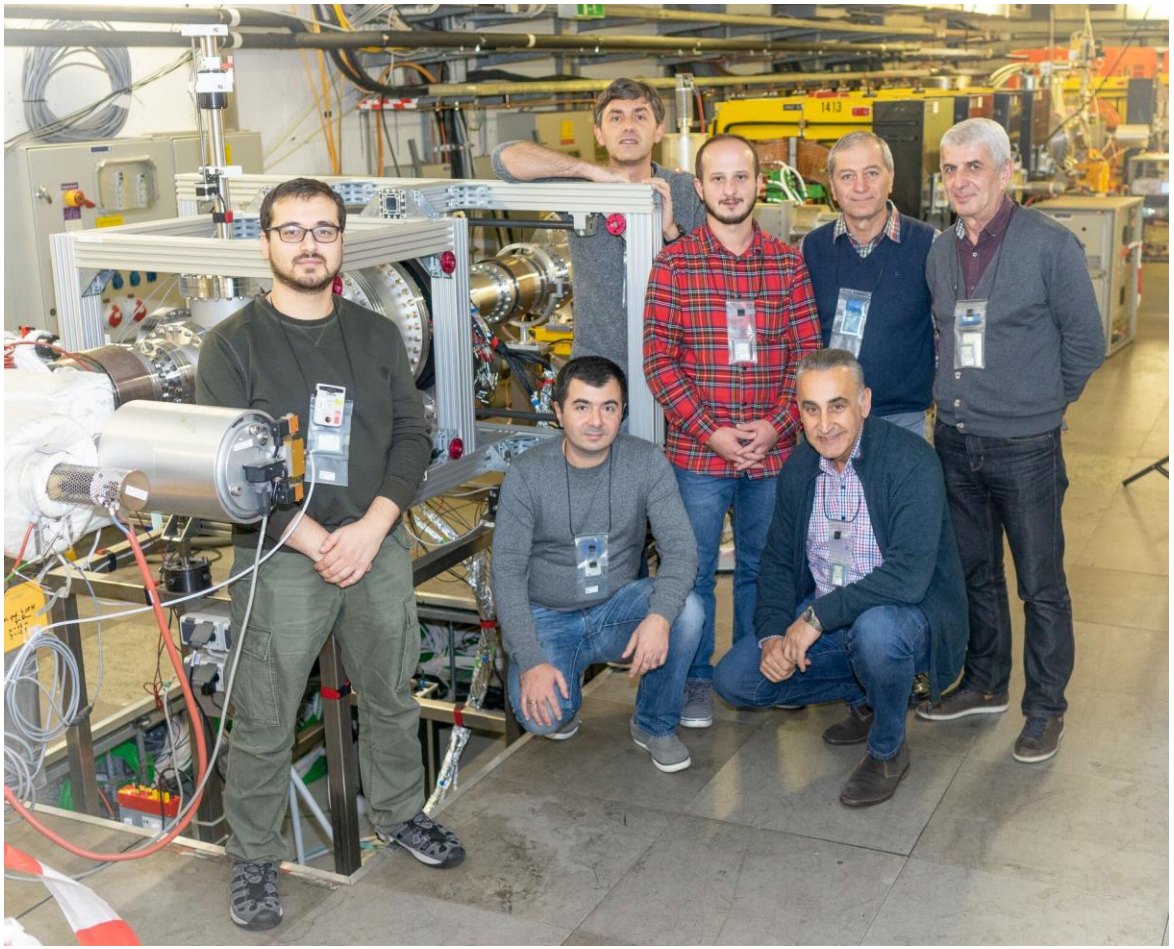


Publications:

- O. Javakhishvili *et al.* - “Development of a multi-channel power supply for silicon photomultipliers reading out inorganic scintillators” - **NIMA 977, 164337 (2020)**
- F. Müller *et al.* – “A new beam polarimeter at COSY to search for electric dipole moments of charged particles”, **JINST 15, P12005 (2020)**
- I.Keshelashvili *et al.* – “A modular calorimeter based on LYSO scintillator crystals with SiPM readout” (*in preparation*)

JEDI-related publications:

http://collaborations.fz-juelich.de/ikp/jedi/documents/colpapers.shtml



Thank you