Shota Rustaveli National Science Foundation

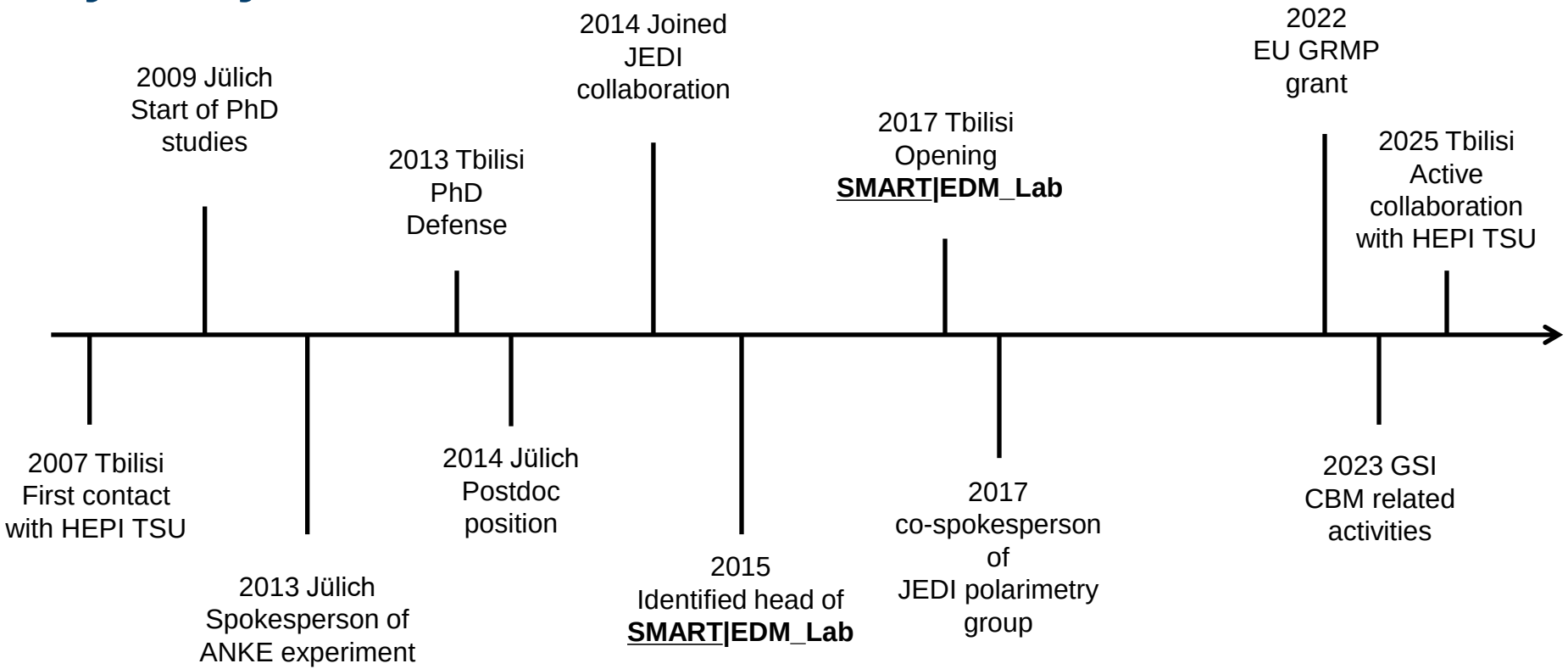
JÜLICH Forschungszentrum

Mitglied der Helmholtz-Gemeinschaft

David Mchedlishvili
(HEPI / SMART|EDM_lab, TSU)

SMART|EDM_lab: New focus on Experimental Development for Medicine

My Story


2009 Jülich
Start of PhD
studies
2013 Tbilisi
PhD
Defense
2014 Joined
JEDI
collaboration
2017 Tbilisi
Opening
SMART|EDM_Lab
2022
EU GRMP
grant
2025 Tbilisi
Active
collaboration
with HEPI TSU
2007 Tbilisi
First contact
with HEPI TSU
2013 Jülich
Spokesperson of
ANKE experiment
2014 Jülich
Postdoc
position
2015
Identified head of
SMART|EDM_Lab
2017
co-spokesperson
of
JEDI polarimetry
group
2023 GSI
CBM related
activities

Overview

Introduction

Past activities

Recent activities

Summary

SMART|EDM_lab opening in 2016

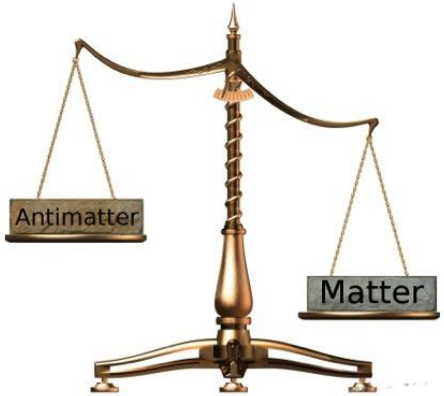
- ✓ Strong cooperation with JEDI international collaboration
- ✓ Well equipped and maintained
- ✓ PhD, Master and bachelor students involved
- ✓ Search for and motivate new students

Support:

- Shota Rustaveli National Science Foundation (*financial*)
- Tbilisi State University (*infrastructure*)
- Research Center Jülich (IKP) (*accelerator facility, equipment donation*)

Science case

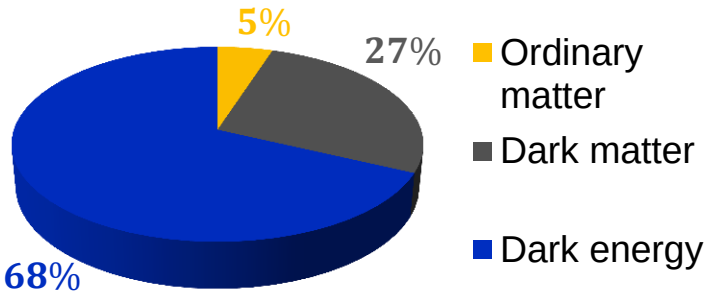
Baryon asymmetry in the Universe



$$\eta = \frac{N_B - N_{\bar{B}}}{N_\gamma} \approx \begin{cases} 10^{-10} & \text{(measured)} \\ 10^{-18} & \text{(SCM prediction)} \end{cases}$$

Answer may be hidden in CP symmetry breaking (Sakharov condition). EDMs?

Dark matter



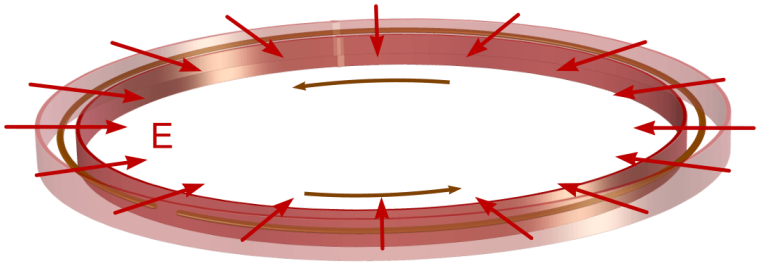
What is dark matter made of?
Axions? ALPs?

Oscillating EDM is related to axion mass!

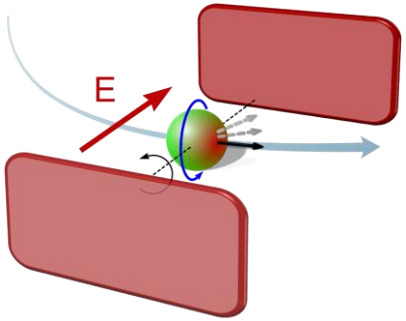
How to measure EDMs

Main principle:

Inject polarized particles into a storage ring:



Apply radial electric field E:

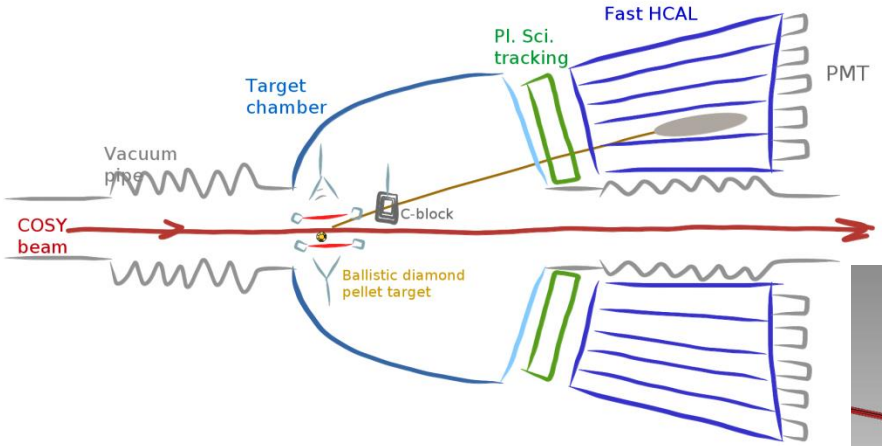


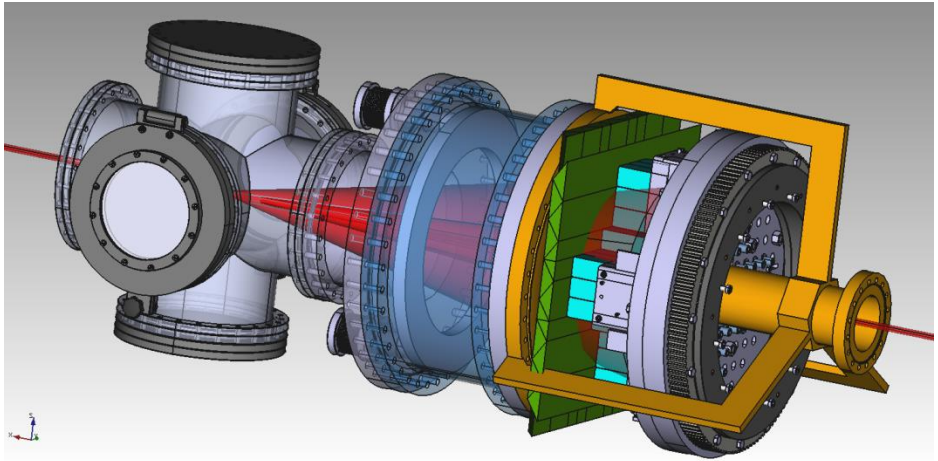
Non-zero EDM → spin rotation out of the plane

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

Track spin rotation → **need precise polarimeter**

JEDI Polarimeter (JePo)



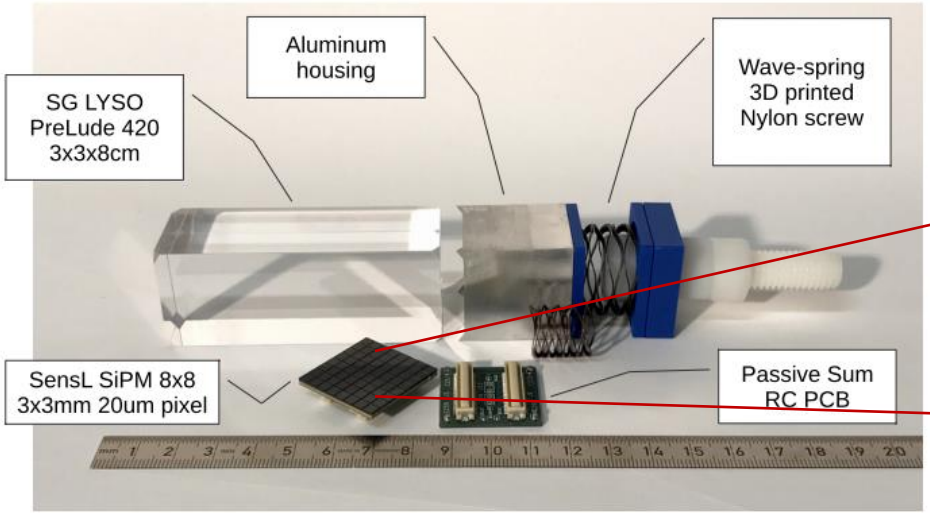


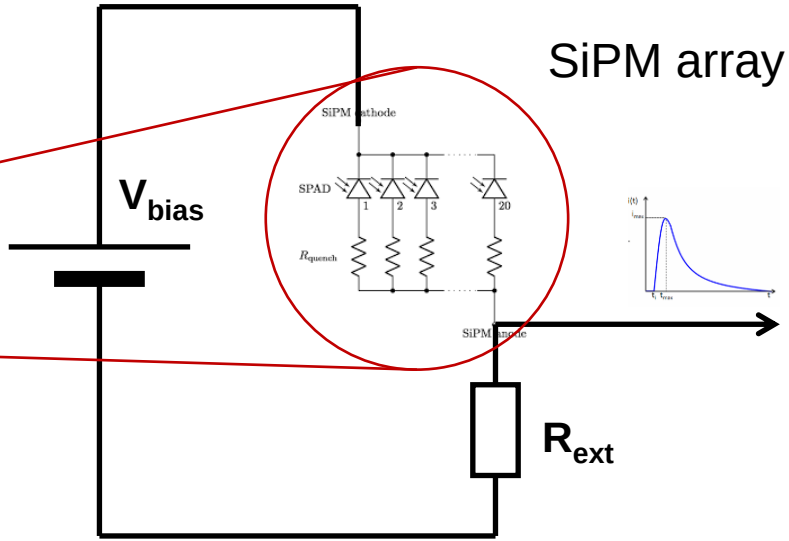
SMART|EDM_lab contribution:

Hardware

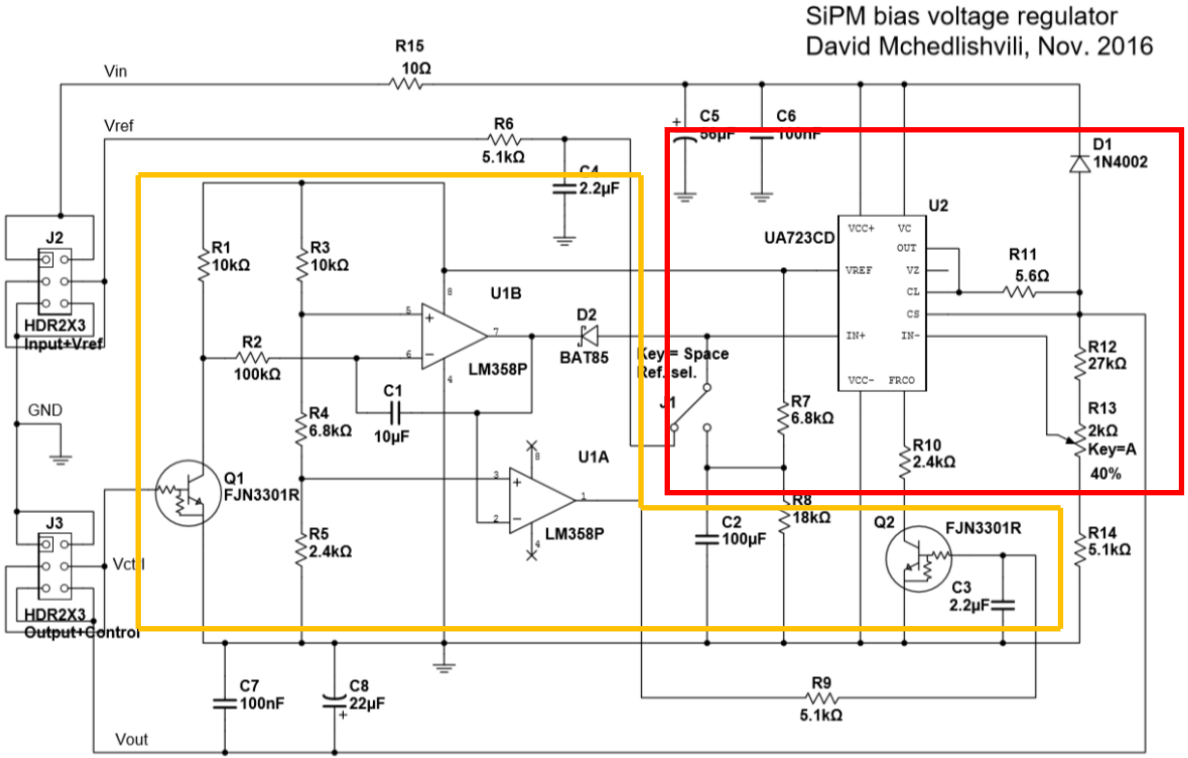
Power supply development for JePo modules

SiPM-based LYSO calorimeter module



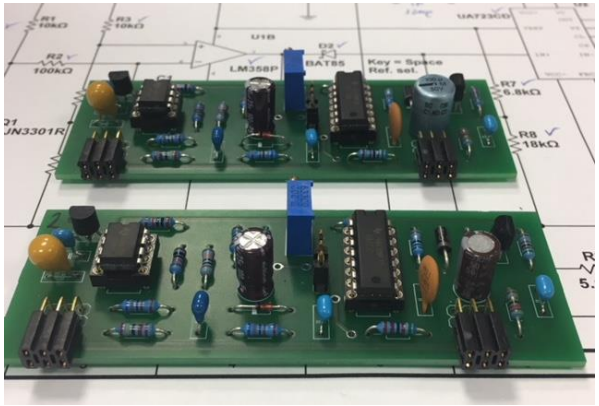


Power supply modules



Linear voltage regulator part

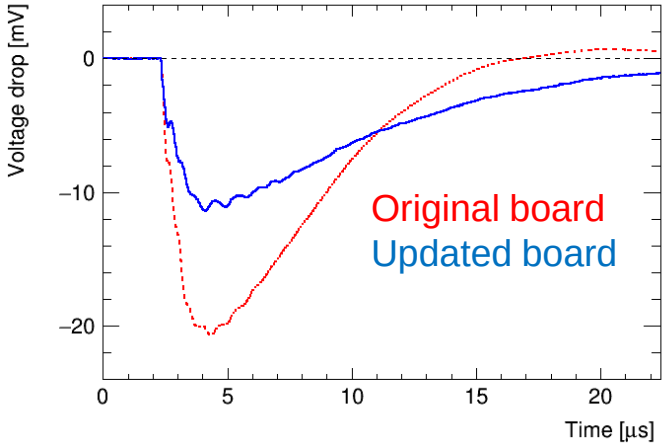
Ramp generator and on/off part



Laboratory tests and improvements

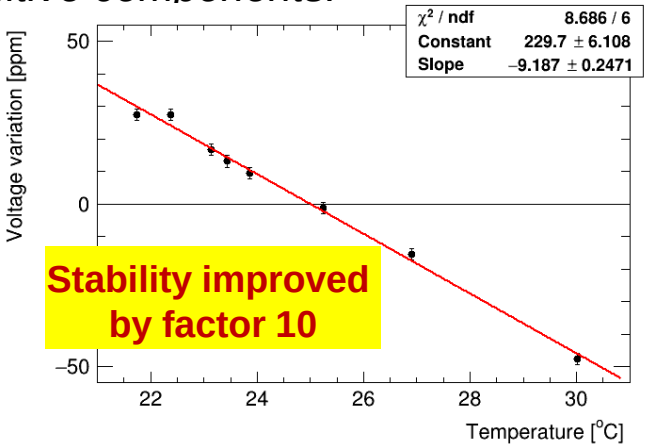
Dynamic loading

- *Simulation of the SiPM breakdown at actual deuteron energies;*
- *Voltage drop measurements on the SiPM support board;*
- ***Result:** Improved SiPM board.*



Temperature stability

- *Module testing in the temperature chamber;*
- *Identifying and improving the most sensitive components.*



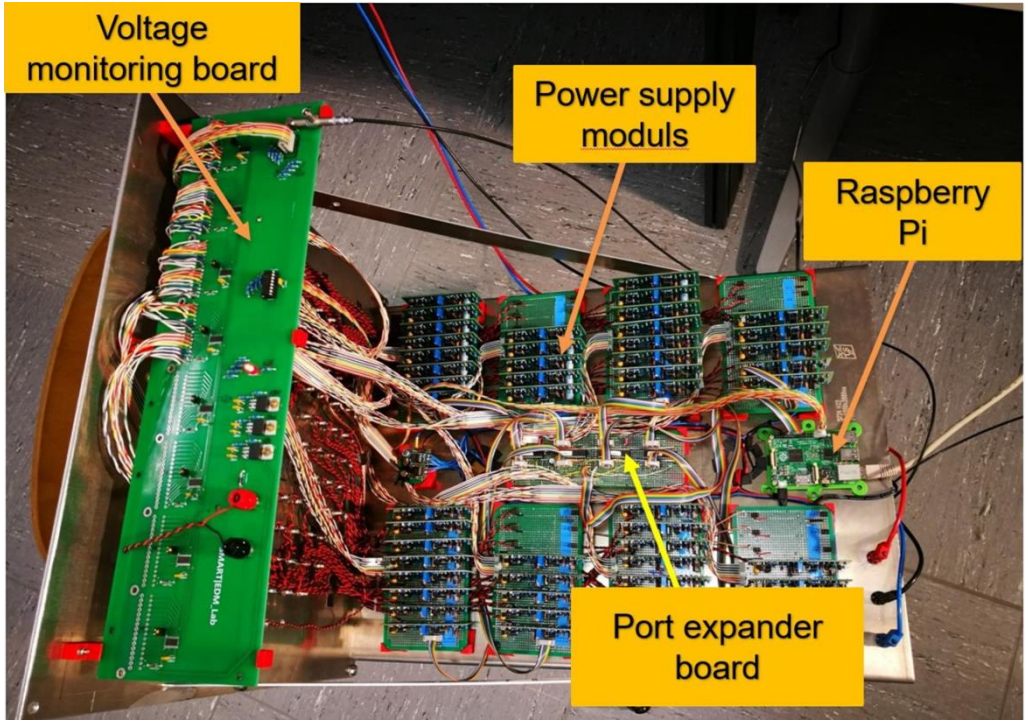
See talk by M. Kalantarovi (student session)

Final assembly of the power supply

- Modular design with 64 independent channels
- High output stability *(temperature, long/short term, low noise)*
- Variable output voltage
- Remote on/off control (via LAN)
- Output slow ramping
- Built-in performance monitoring

Module development and tests in Tbilisi

Assembly and commissioning in Jülich



SMART|EDM_lab contribution:

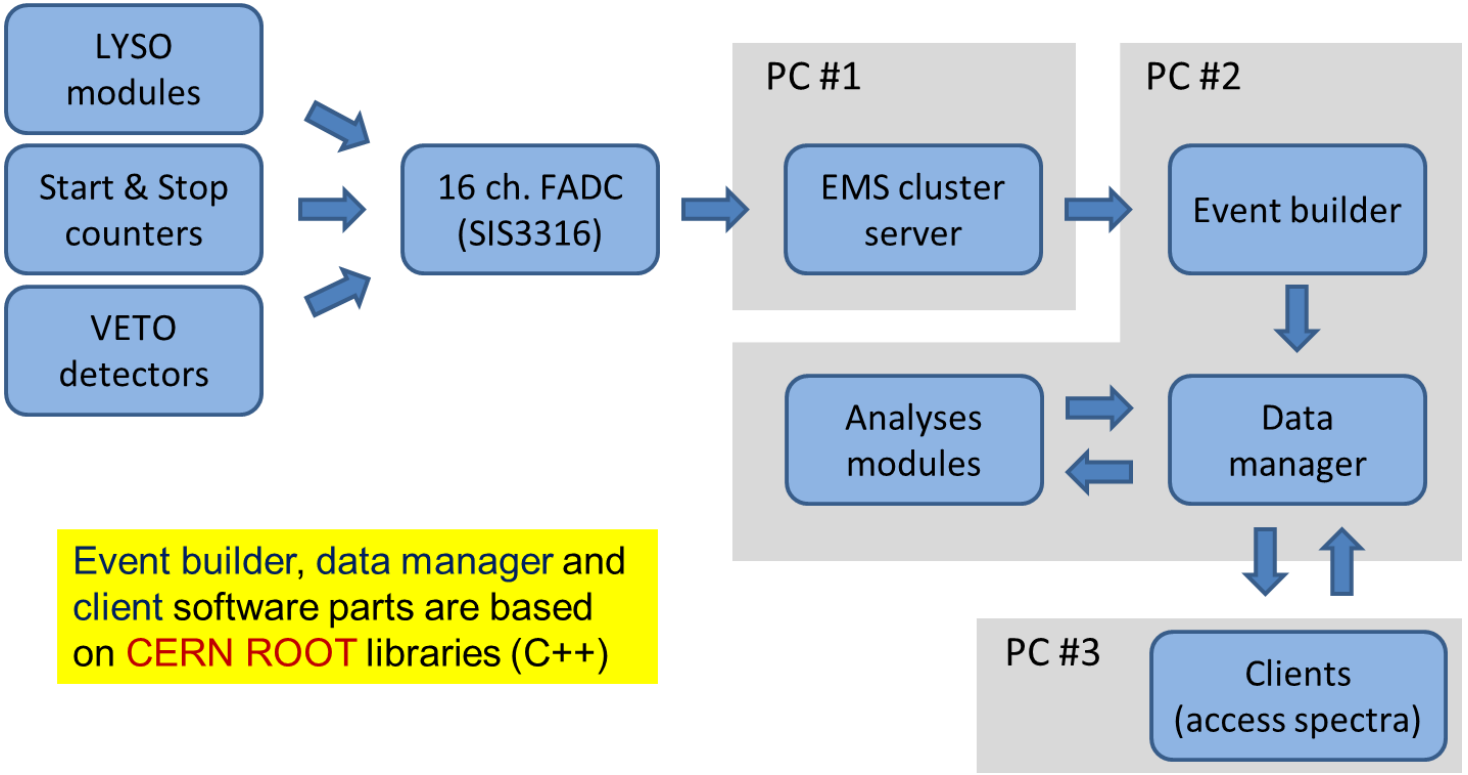
Software

Slow control system for the power supply

Features:

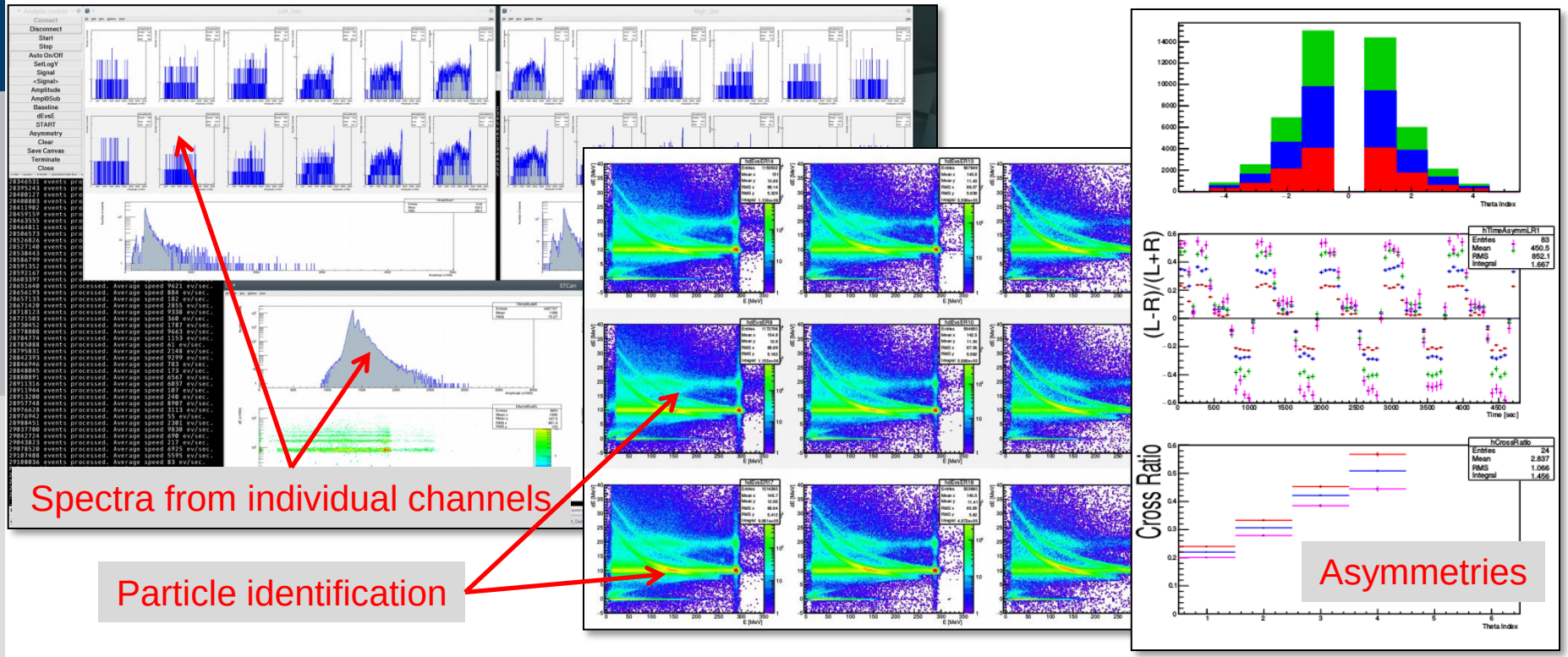
- Based on Python, Qt
- Module on/off
- Voltage online monitoring
- Voltage history recording
- Voltage distribution histograms

Online analysis system for JePo



Event builder, data manager and client software parts are based on CERN ROOT libraries (C++)

Online analysis



New focus:

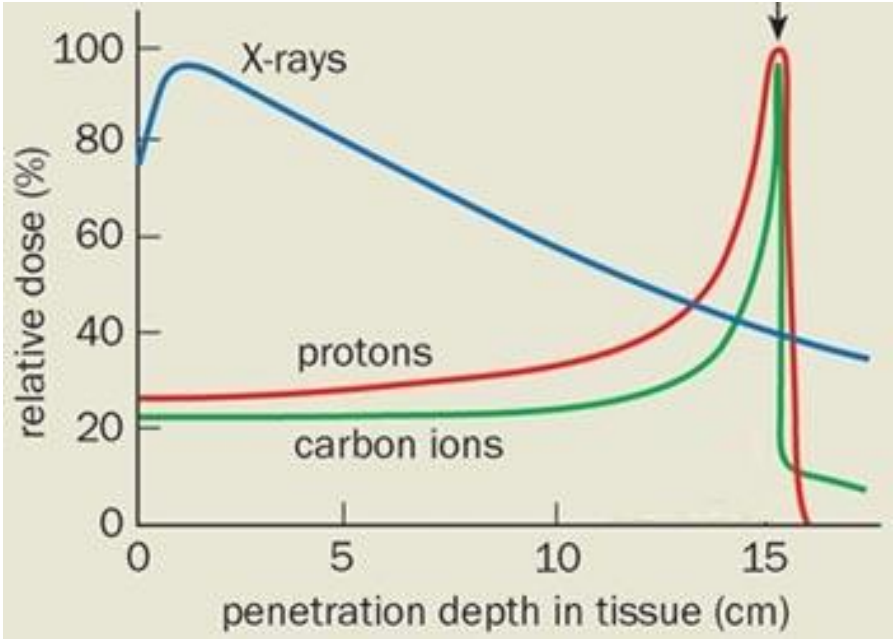
Experimental Development for Medicine

Proton tomography

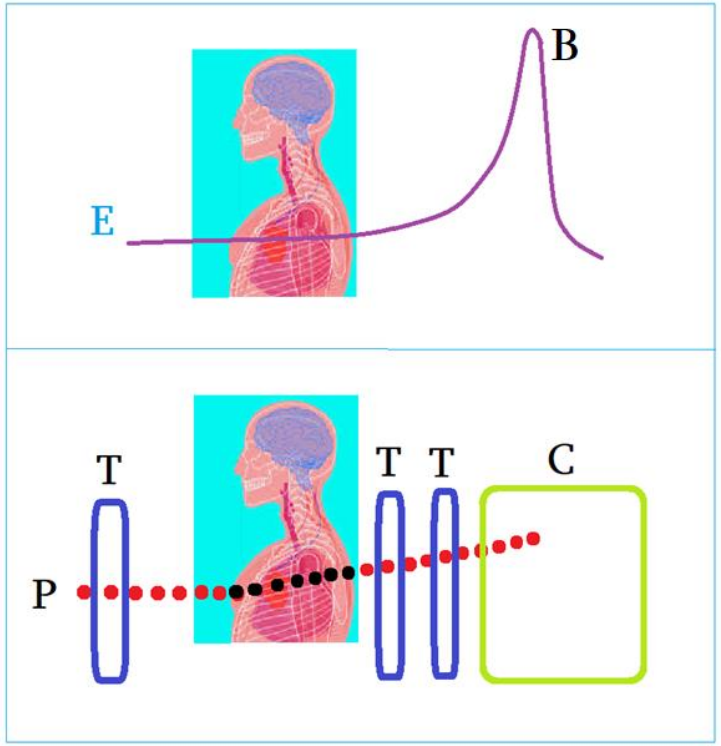
- Can be used to determine treatment maps;
- These maps can be adjusted in online mode, during the treatment irradiation;
- Thus, optimizing and monitoring the treatment process, with minimal harm to the patient.

Use of existing x-ray systems could be restricted due to limitations on the body irradiation doses.

Bragg peak

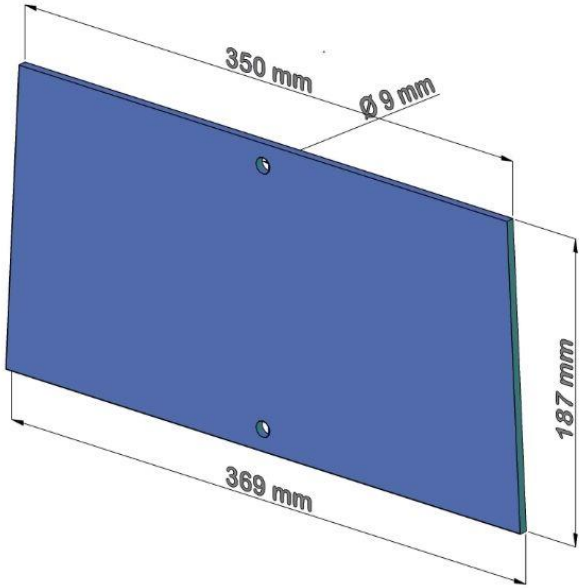


Main principle

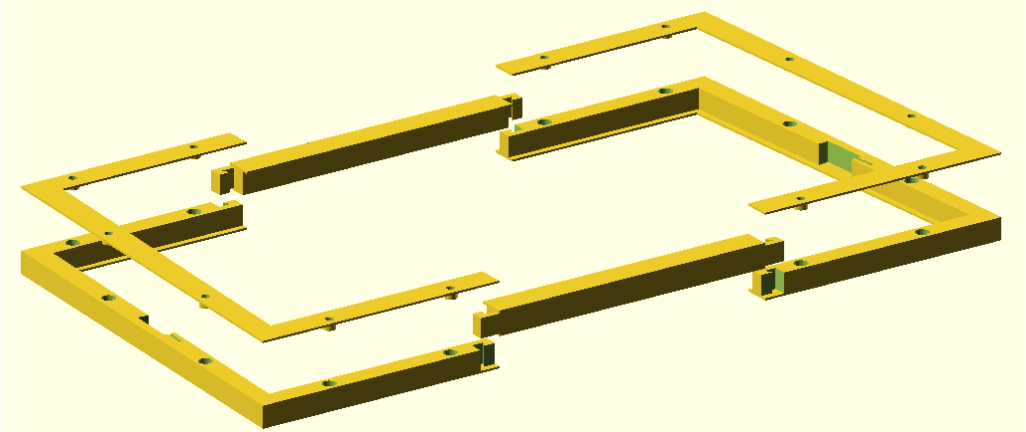


- Initial energy of protons (E) must be such that they pass through the body;
- Protons lose energy while passing through the body and scattering on dense tissues;
- Residual energy of passed protons is measured with the calorimeter (C);
- Bragg peak (B) has to be remained within the calorimeter!
- Good tracking system (T) is needed for precise coordinate/angle determination.

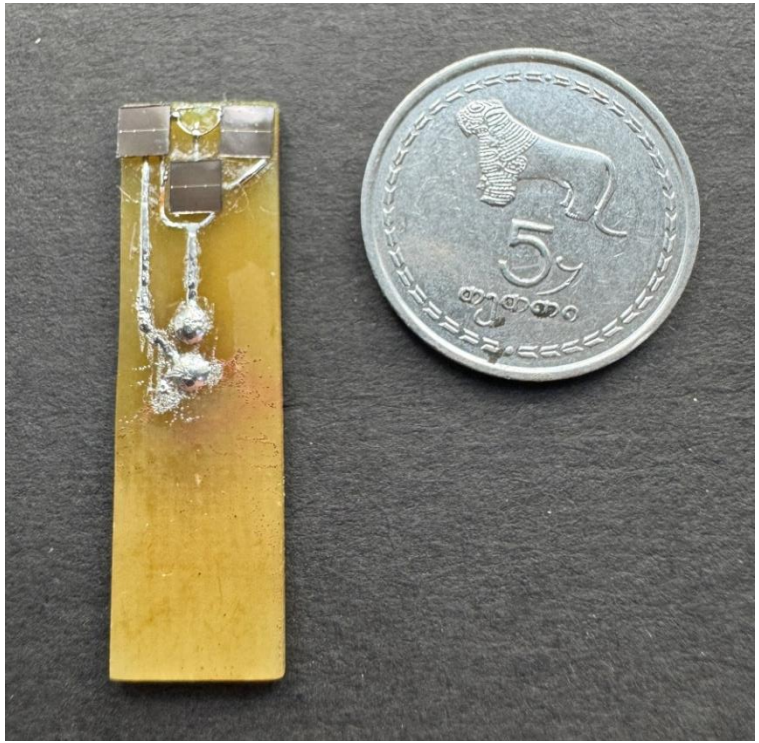
Calorimeter module development



- Based on 3 mm-thick plastic scintillators (donated from CERN);
- 3D-printed supporting enclosure;
- 1-layer and 3-layer modules;

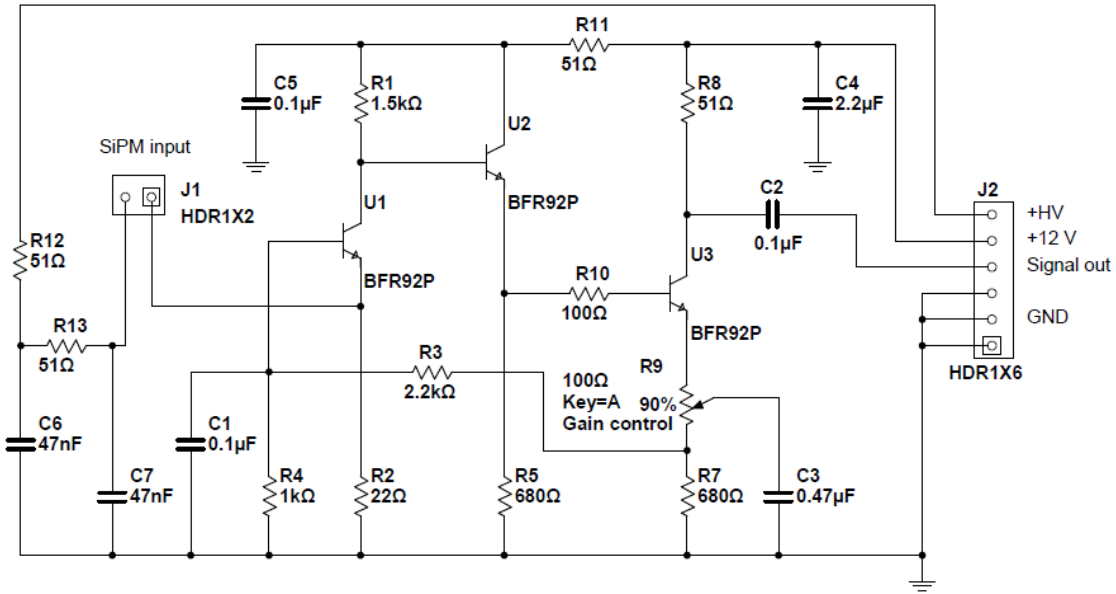


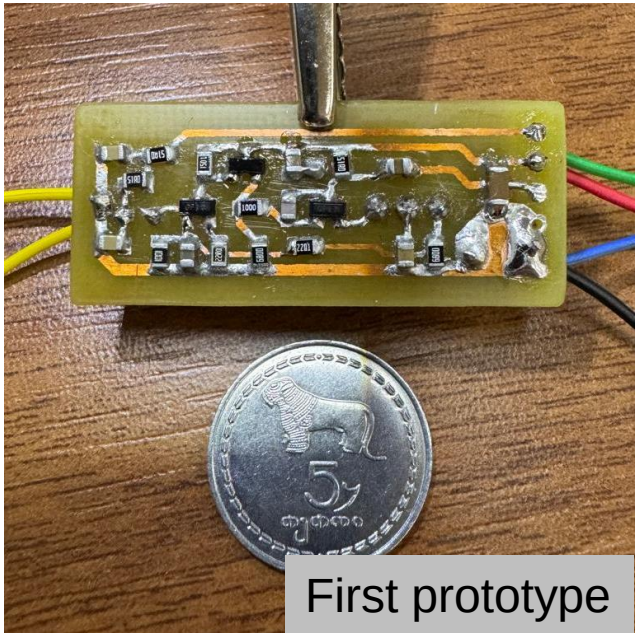
SiPM-based readout (prototypes)



Preamplifier

BJT-based trans impedance amplifier



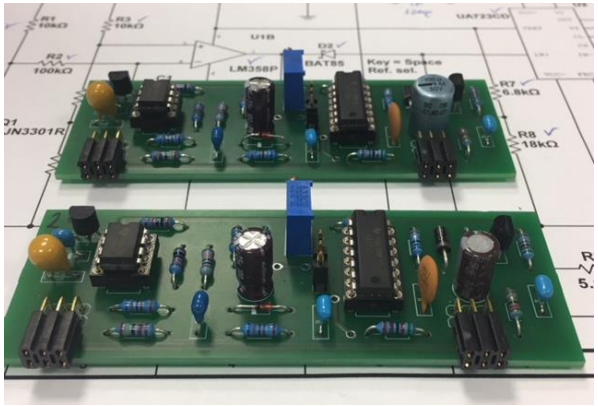


Measured gain: 1.25 V/mA

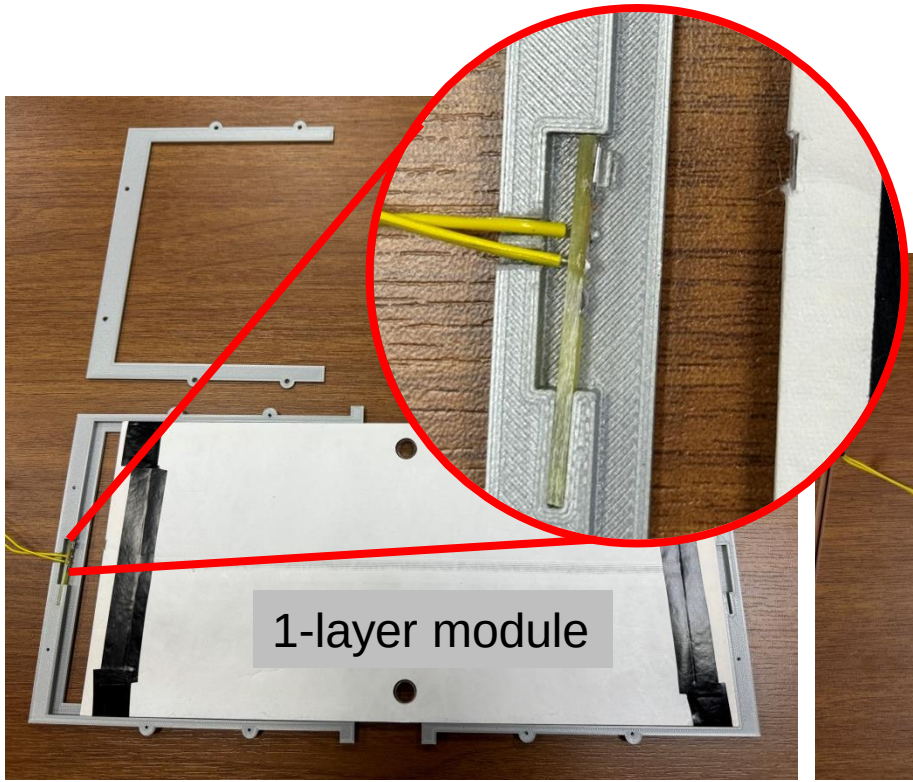
Power supply

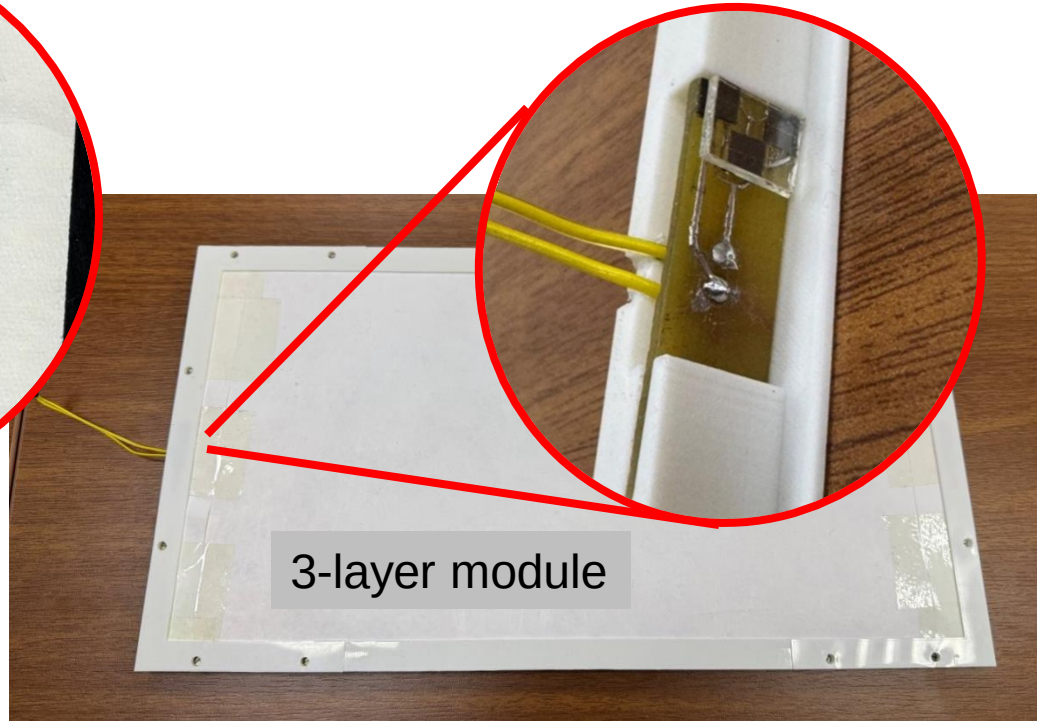
Based on high precision supply modules from JePo

- Linearly regulated (low noise)
- High stability
- Slow ramp up/down
- V_{out} = 24 – 34 V
- I_{out} < 100 mA (active current limiting)



Calorimeter module assembly

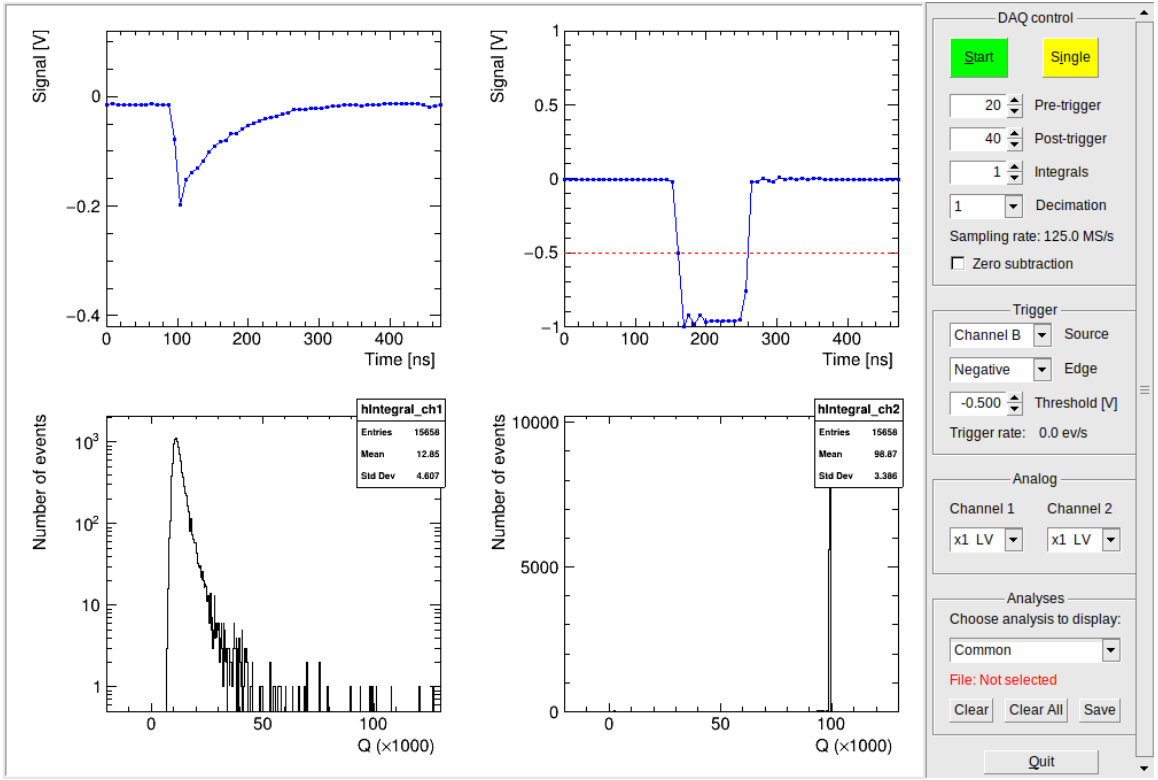




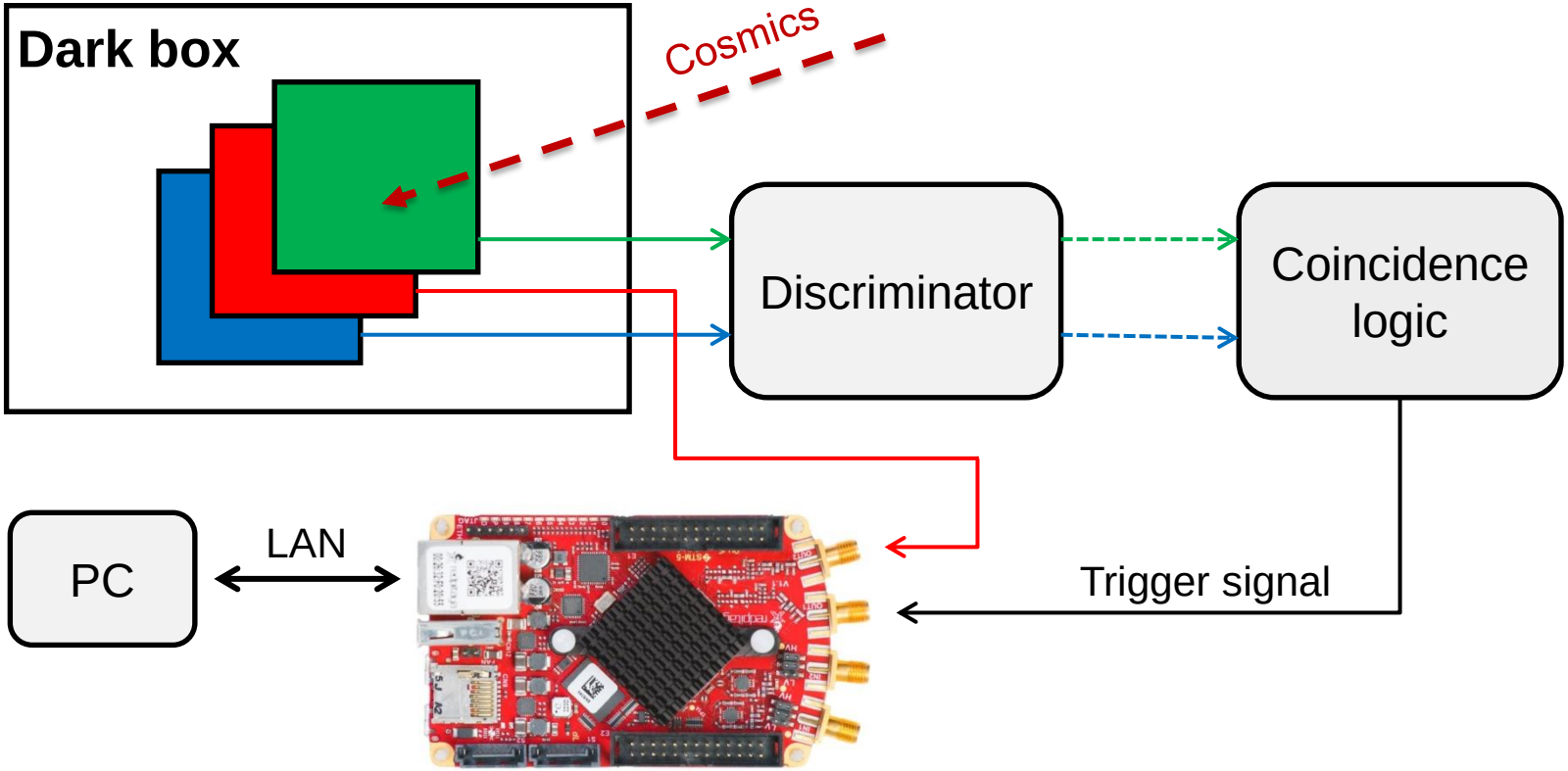
DAQ - Based on Redpitaya + custom-developed software

STEM lab 125-14

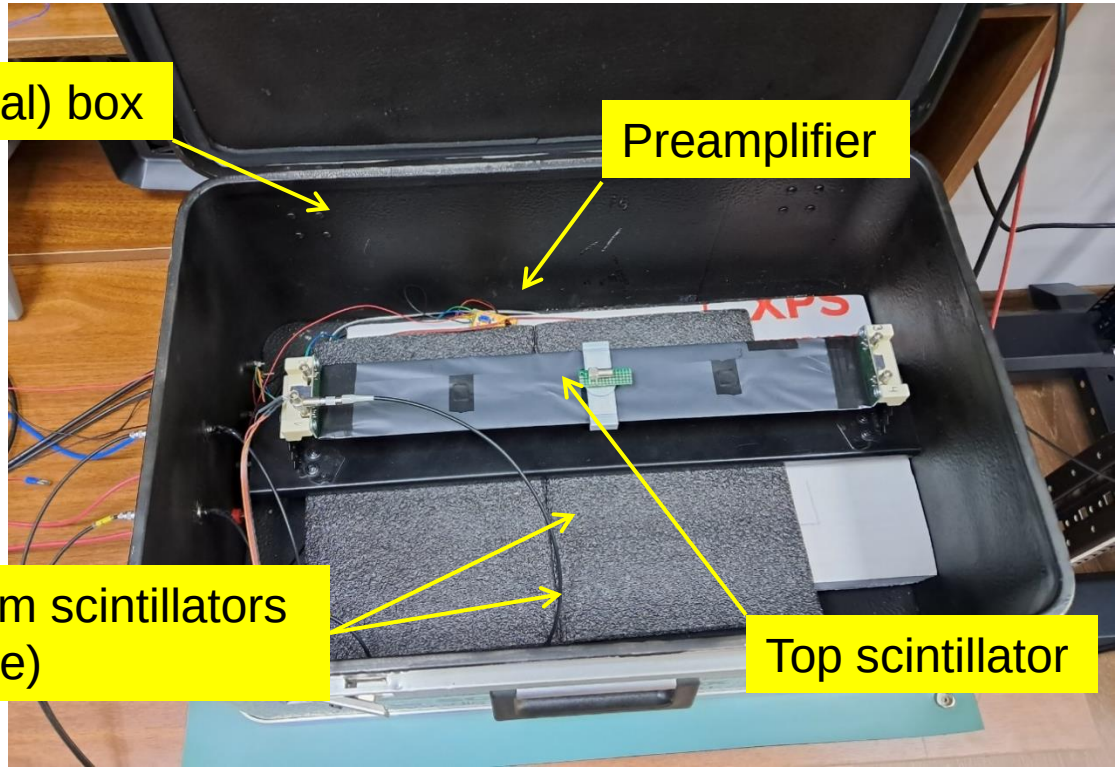
- DAC + ADC
- 125 MS/s – 14 bit
- Linux on board
- Access via LAN



Efficiency tests



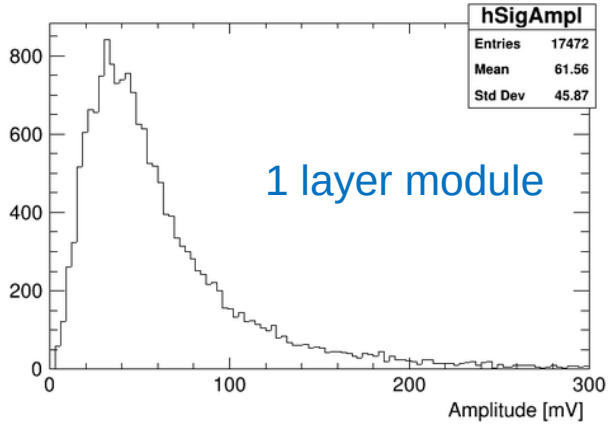
Test setup for efficiency measurement



Efficiency measurements

Signal detection algorithm:

1. Search for the highest peaks within the written signal shapes;
2. Peak position distribution built;
3. Useful signals selected within +/- 3 sigma;
4. Amplitude (mV) distribution built for selected events.

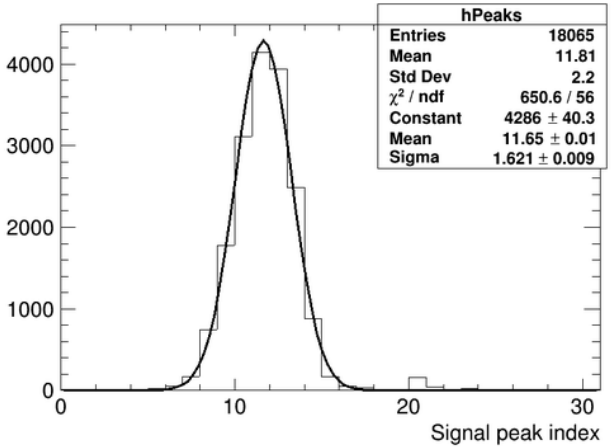


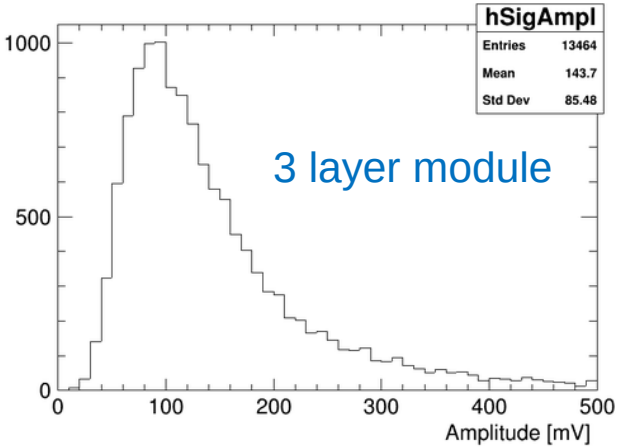
Efficiencies:

(at 20 mV threshold)

1 layer module: **0.95**

3 layer module: **0.99**

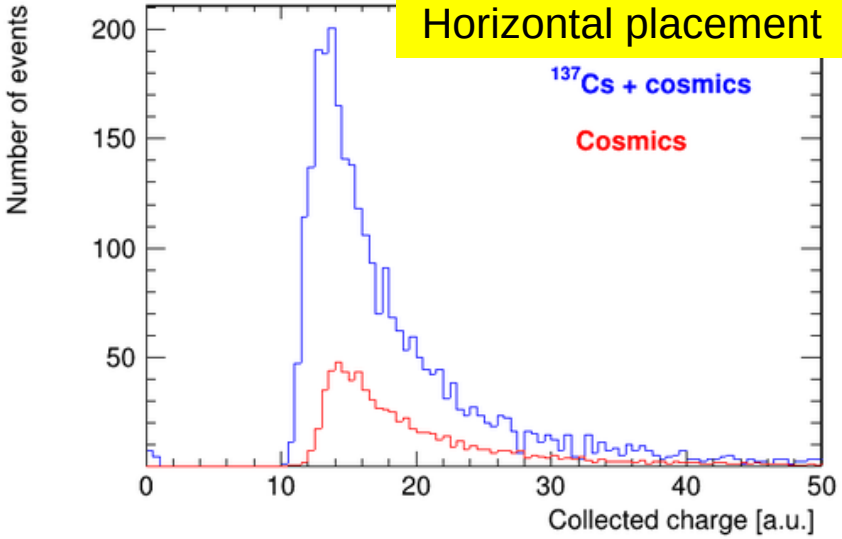




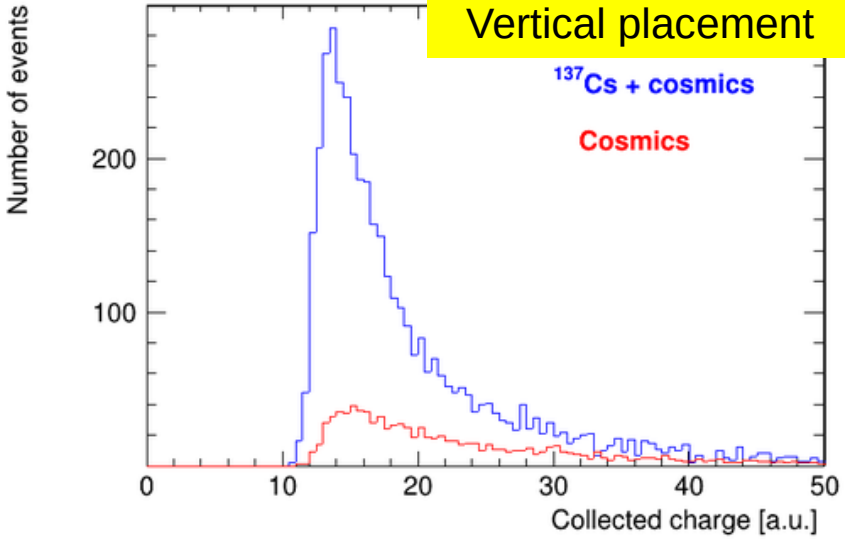
Test with ^{137}Cs source

- Calorimeter module placed in vertical/horizontal positions;
- ^{137}Cs radioactive source attached to the module;
- Cosmic events recorded for the background subtraction (both positions independently);
- Bg weight determined using event rates.

Horizontal placement



Vertical placement



Aging tests

- Scintillator tiles irradiated at Gamma Irradiation Facility (GIF++) at CERN
- Efficiency measurements for the tiles performed before and after irradiation

Tile 1 (≈ 2 months irradiated)

	Initial	Irradiated
Efficiency (at 20 mV threshold)	0.95	0.93
Av. Rate [1/h]	1093	900
Amplitude mean [mV]	81	64

Tile 2 (≈ 5 months irradiated)

	Initial	Irradiated
Efficiency (at 20 mV threshold)	0.94	0.92
Av. Rate [1/h]	930	834
Amplitude mean [mV]	68	64

Three more tiles will be irradiated!

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)**
- G.Macharashvili *et al.* – “Development of Low Energy Range Calorimeter for Proton Tomography”, Bulletin of The Georgian National Academy of Sciences, vol. 18, no. 2, 2024, p.57-62.

JEDI-related publications:

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

Financial support

2016 – 2021	"*A first-ever measurement of the Electric Dipol Moment (EDM) of the deuteron at COSY*" – SRNSFG grant #217854
2017 – 2024	"*Search for Electric Dipole Moments using Storage Rings (srEDM)*" - SRNSFG (*targeted funding for the SMART|EDM_lab*)
2022 – 2024	"*Low-energy calorimeter for hadronic tomography. Creation and mathematical modeling of a test physical detector*" - SRNSFG STEM-22-179 grant

Student involvement

- **PhD:**
  Dito Shergelashvili (TSU)
- **Master**:
  Otar javakhishvili (AUG)
  Giorgi Kvantrishvili (TSU)
  Mikael Gagoshidze (AUG)
  Mariam Abuladze (AUG)
  Irakli Lomidze (AUG)
  Ninea Anasovi (AUG)
  Luka Ghomidze (TSU)

- **Bachelor:**
  David Kordzaia (AUG)
  Rati Chkhetia (AUG)
  Giorgi Chaduneli (AUG)
  Mariam Mukbaniani (TSU)
  Valentina Sarkisova (TSU)
  Lana Rekhviashvili (TSU)
  Dachi Okropiridze (GTU)
  Nino Shukakidze (AUG)
  Mikheil Kalantarovi (AUG)
  Salome Tvauri (AUG)

Students involved in all research activities: Hard- and software development, assembly of detectors and electronics, laboratory and on-site measurements, data taking and offline analysis…

Outlook

- Improving labs infrastructure (*see talk by M. Kalantarovi*);
- Power supply development for HV SiPMs;
- Looking for new financing schemes.

Thank you