ივანე ჯავახიშვილის სახელობის
თბილისის სახელმწიფო უნივერსიტეტი

IVANE JAVAKHISHVILI
TBILISI STATE UNIVERSITY

NODAR AMAGLOBELI HIGH ENERGY PHYSICS INSTITUTE

KUTAISI
INTERNATIONAL
UNIVERSITY

Proton Tomography in HEPI


A
B

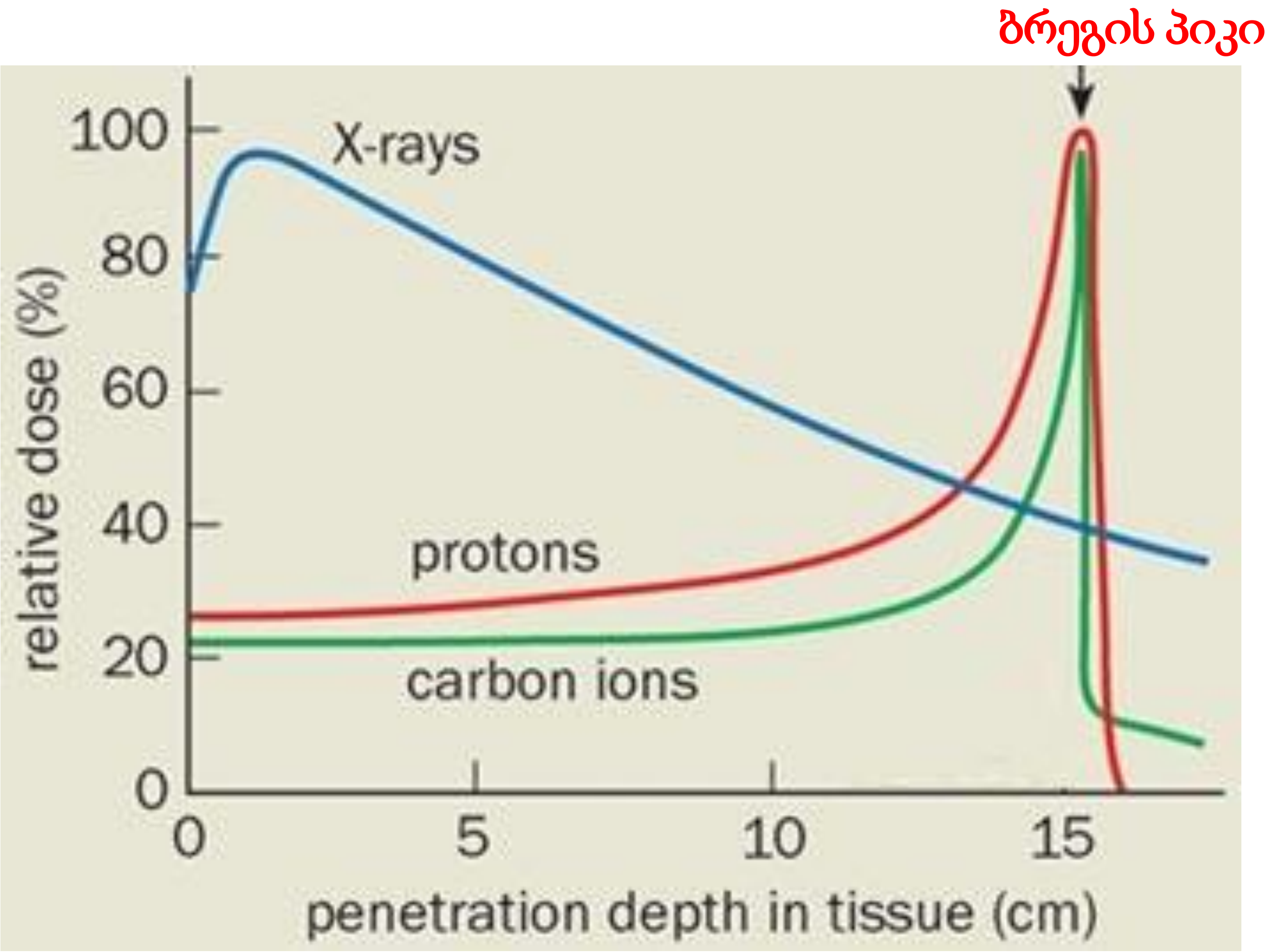
Proton tomography

Proton tomography will be used first to determine the preliminary treatment map. Coordinates of sick cells, energies and doses of protons directed at them will determined.

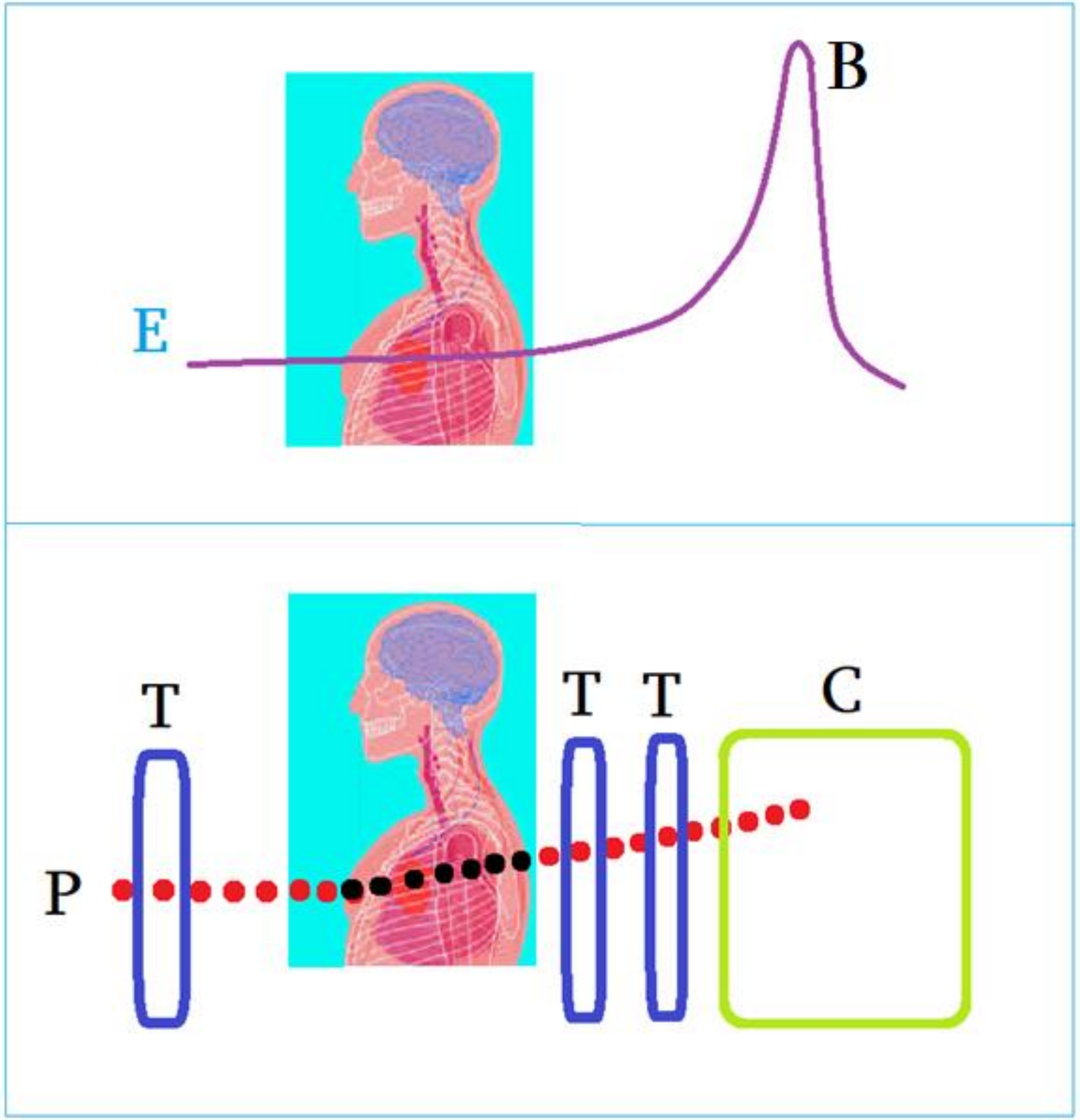
In the process of treatment, the diseased cells are destroyed, during the radiation session it is necessary to adjust this map, energies and doses. In online mode, less than one minute is enough to get updated data.

Thus, a means of optimizing and moniroting of the treatment process is created, with minimal harm to the patient during control radiation.

The existing x-ray control system cannot be used due to the limitations of body irradiation doses.



ენერგიის კარგვები ნაწილაკის სხეულში გავლისას



Protons pass through the body, the initial energy (E) is chosen so that they pass completely through the body.

The protons must to stop after the body. This is why we need only the protons passing through the body completely, losing energy according to density and scattering on dense tissues.

Bragg peak (B) must to stand in calorimeter!

The coordinate tracker (T) determines the scattering of protons (P) - the location of the deviation will calculated.

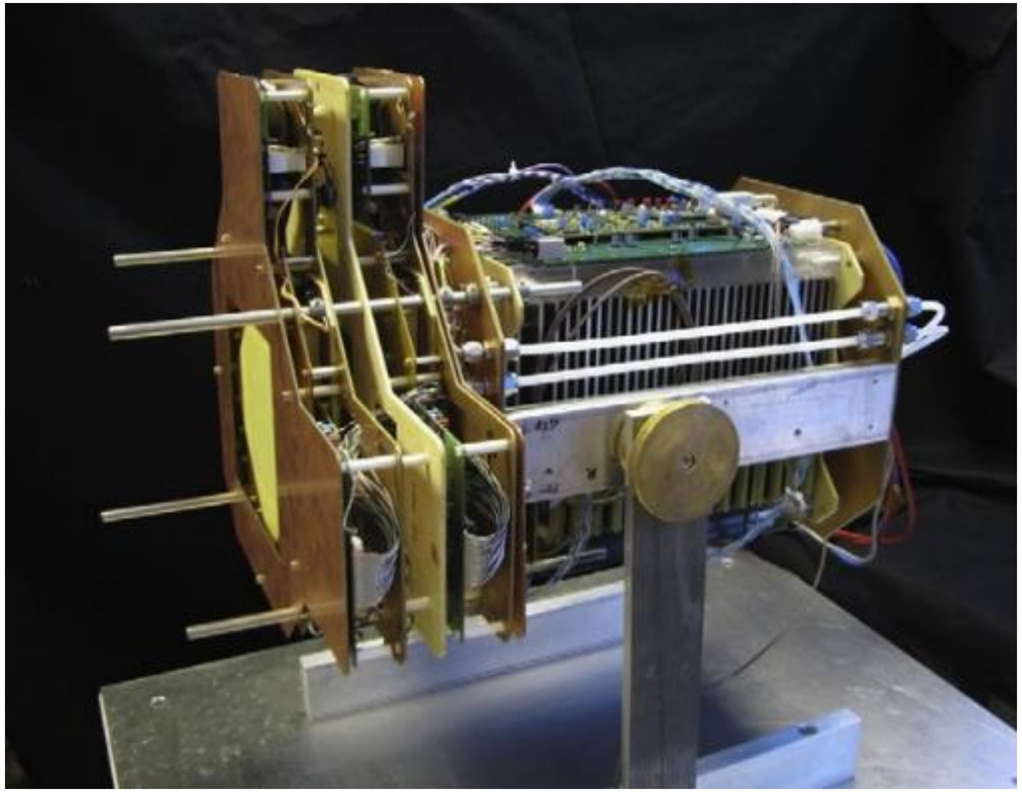
The calorimeter (C) calculates the energy losses - the density of the body tissues on the way will be determined

The coordinates and density 4D image of the body can be realized

Proton beams, which are used in hadronic therapy, can be used in body scans instead of X-rays.

When a protons with energy greater than enough to stop in the body (>200 MeV) is chosen, they pass the body so that the energy lost in the tissues causes little damage to them.

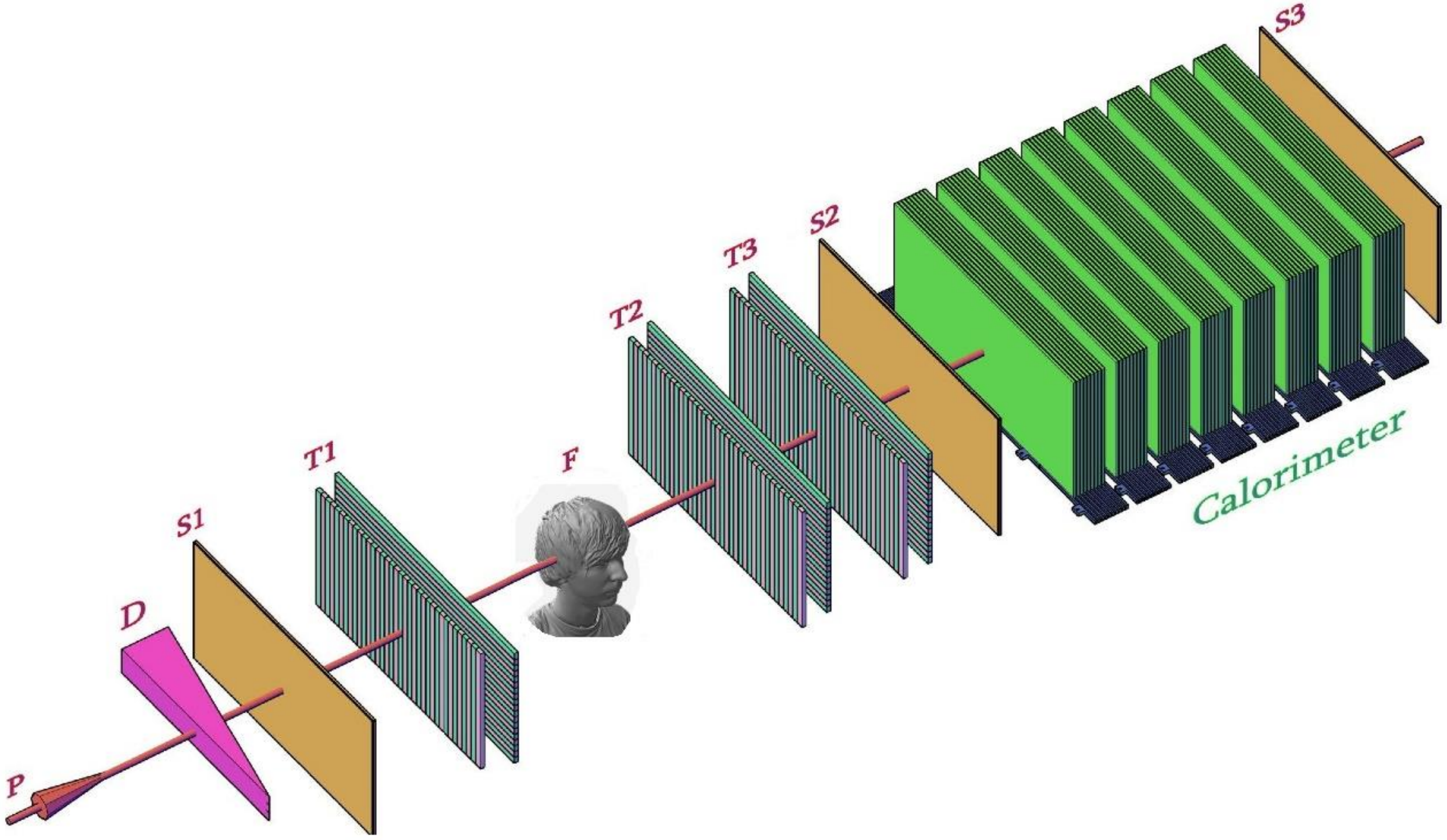
In this case the measurement of energy losses, along with the scattering of protons, will "extract" information about the densities of the tissues along this path.

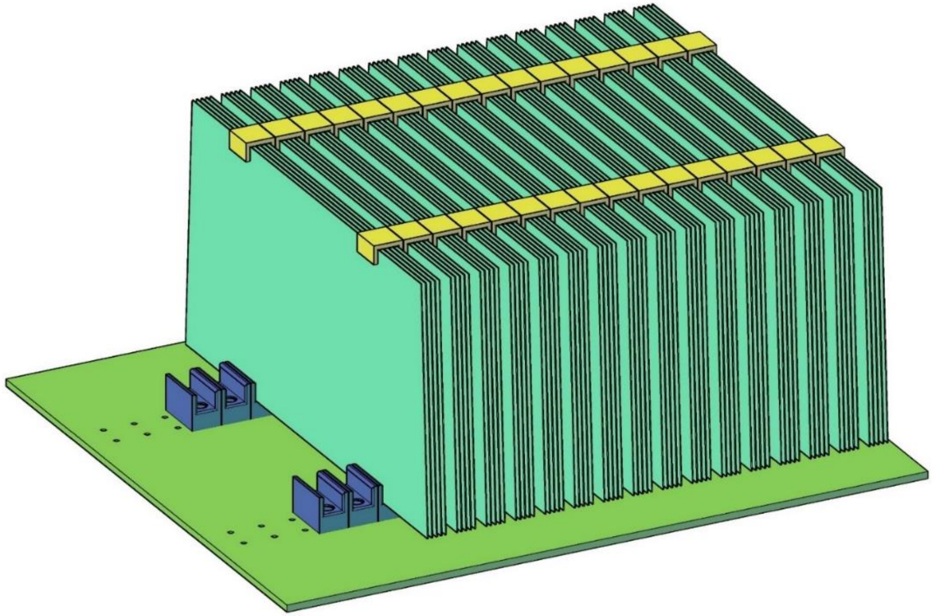


According to preliminary data, compared to X-ray tomography, the coordinate accuracy with proton tomography increases by 2.5 times, and the radiation dose is 50 times less.

- U. Amaldi, et al., Advanced Quality Assurance for CNAO. Nucl. Instr. and Meth. A 617 (2010) 248.
- U. Amaldi, et al., Construction, test and operation of a proton range radiography system. Nucl. Instr. and Meth. A 629 (2011) 337.
- J.Alme et al. A High-Granularity Digital Tracking Calorimeter Optimized for Proton CT. Frontiers in Physics, October 2020, Volume 8, Article 568243

Proton Tomography

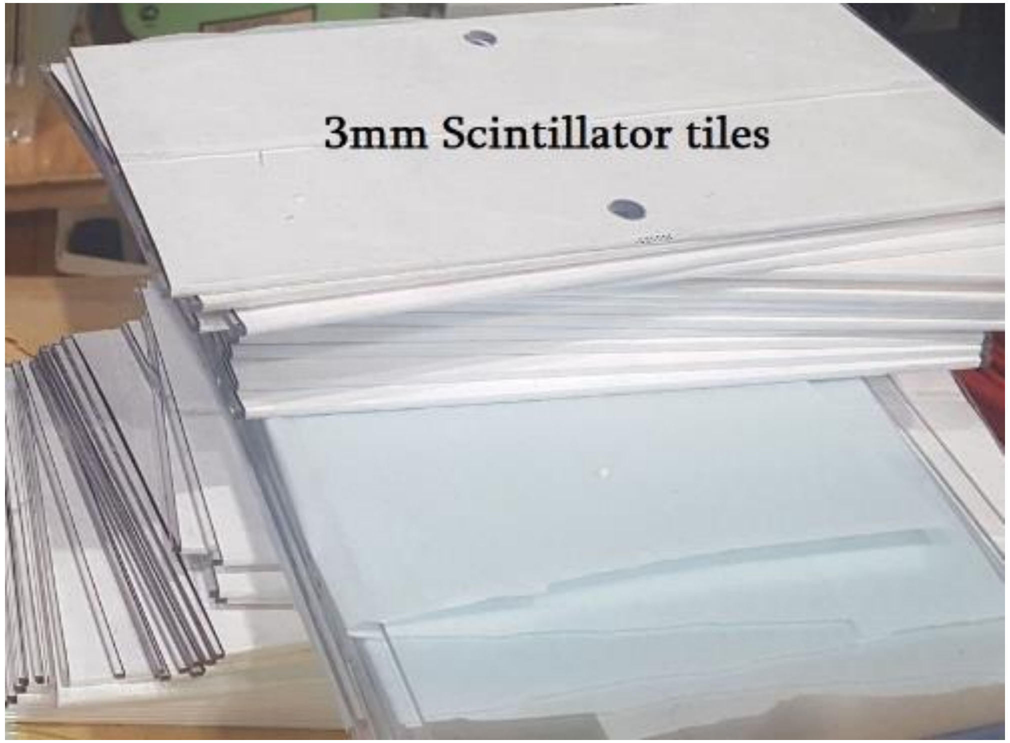




Calorimeter with 310x190 mm scintillators

Donation from CERN-ATLAS:

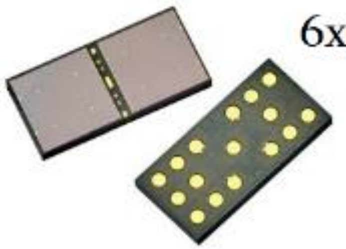
- **3mm thickness Scintillator Tiles (37x19 cm);**

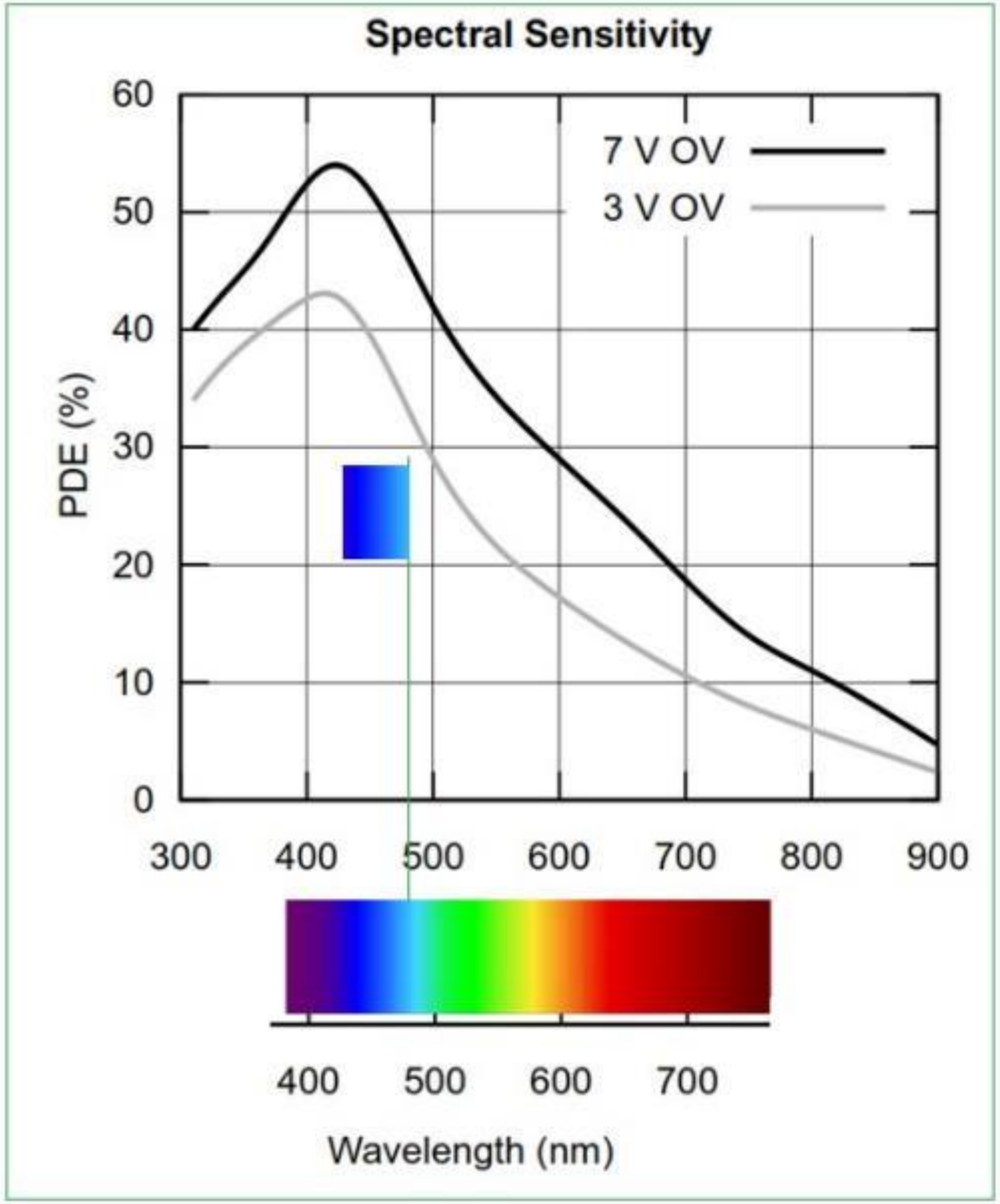


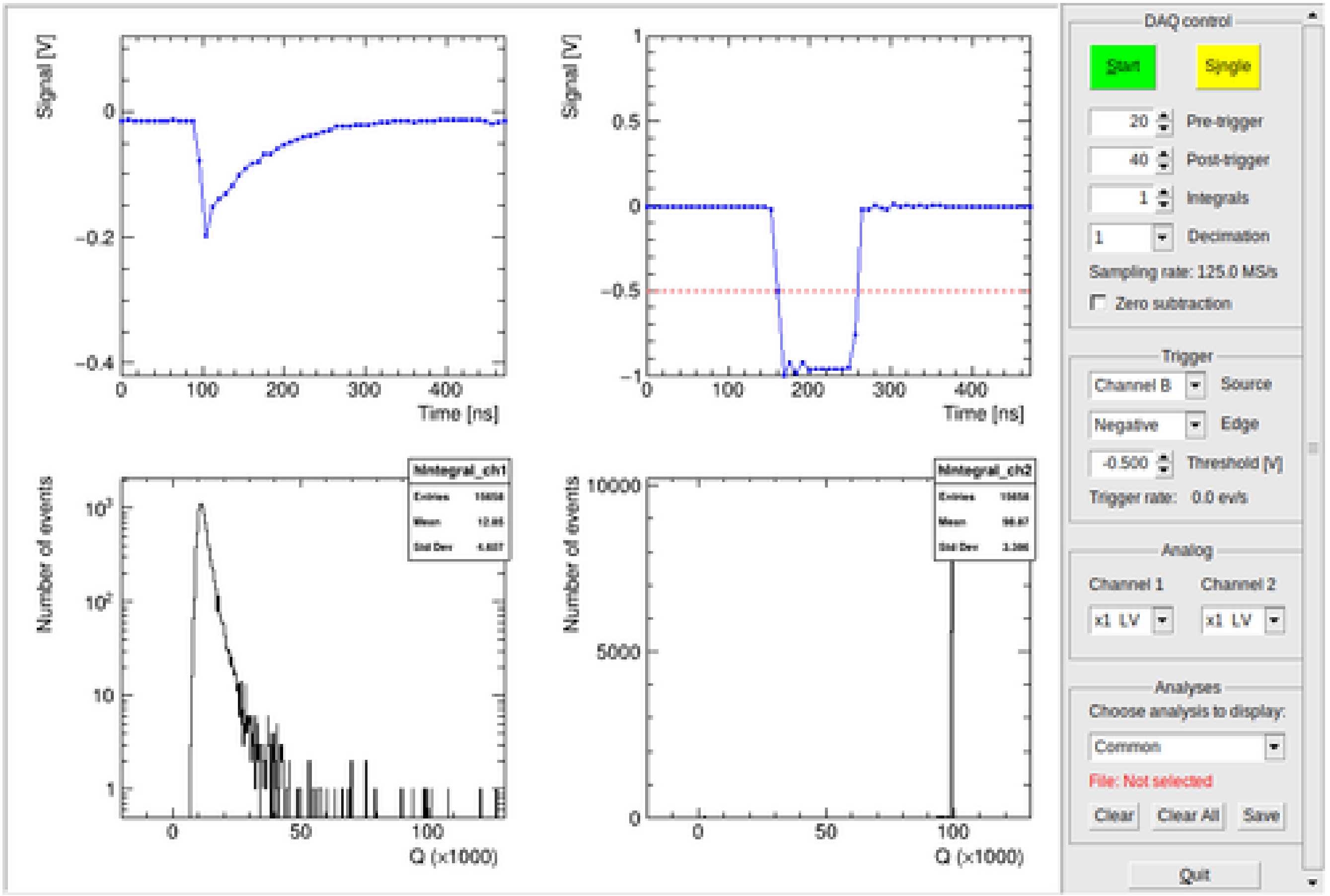
We have SiPMs:

3x3 mm and 6x6 mm active windows

BROADCOM

AFBR-S4N66P024M	AFBR-S4N33C013
2×1 NUV-MT Silicon Photomultiplier	**NUV-HD Single Silicon Photo Multiplier**
 $6x6\ mm^2$	 $3x3\ mm^2$

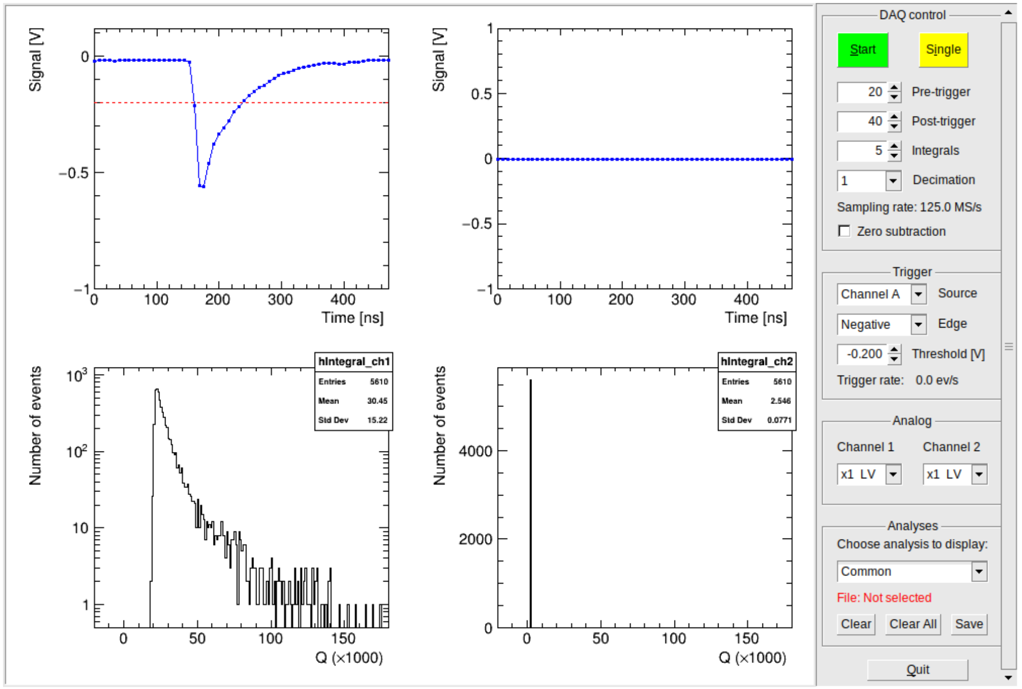




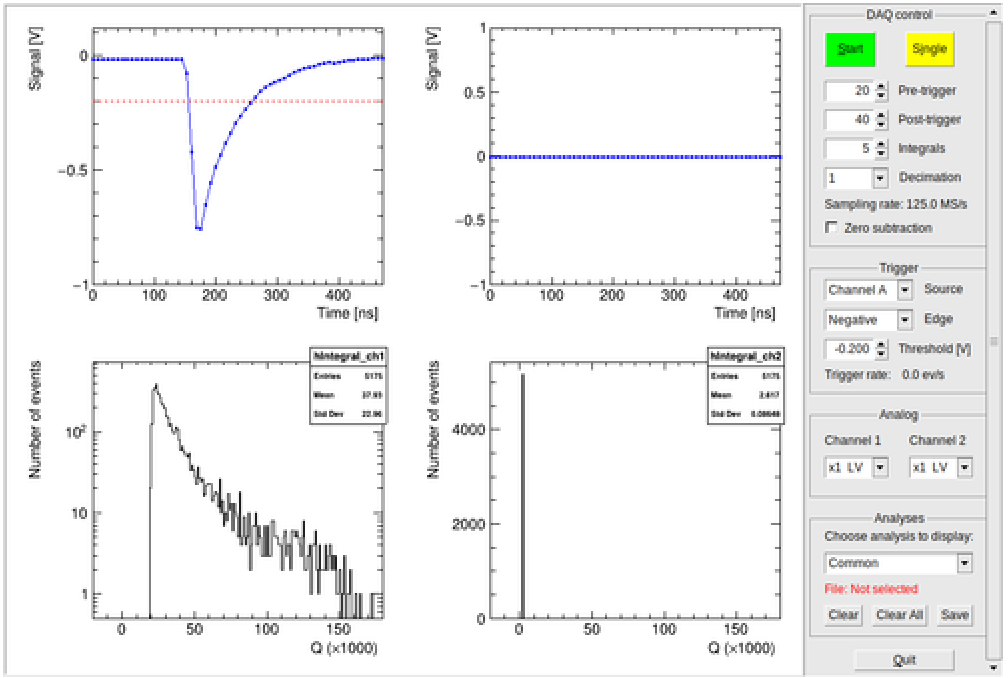
SiPM attached to the side of the scintillator

All SiPM voltage = 30 V (shared power supply!)

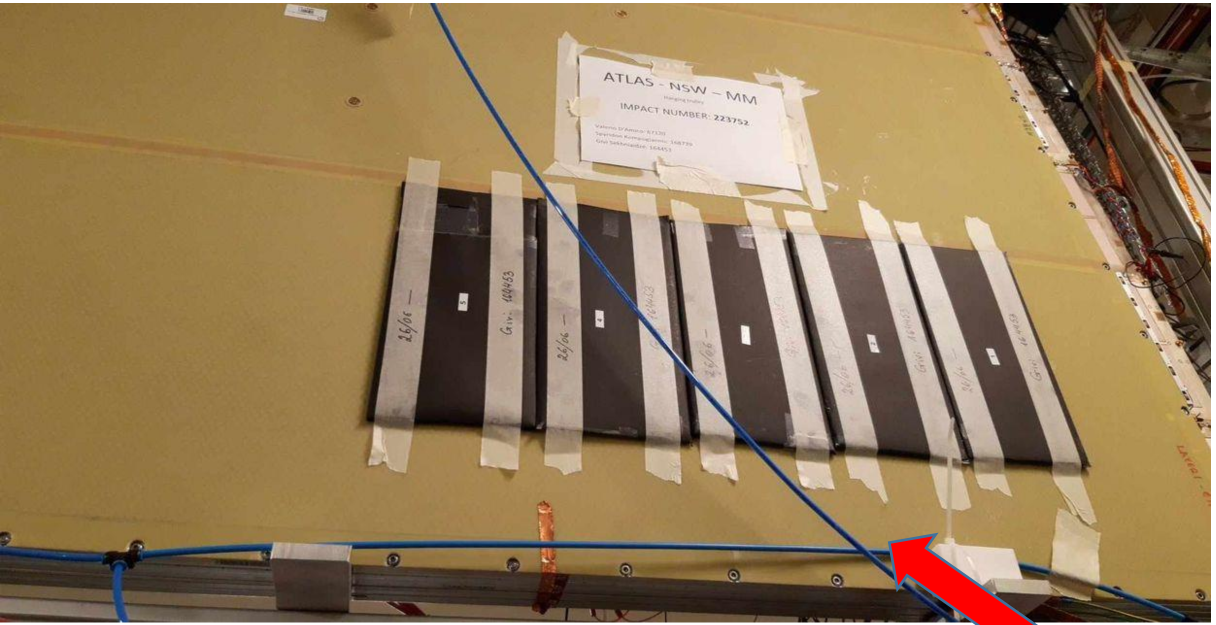
Coinsidence trigger made by JePo scintillators (SiPM)



Module aligned horizontally.
SiPM voltage = 30 V

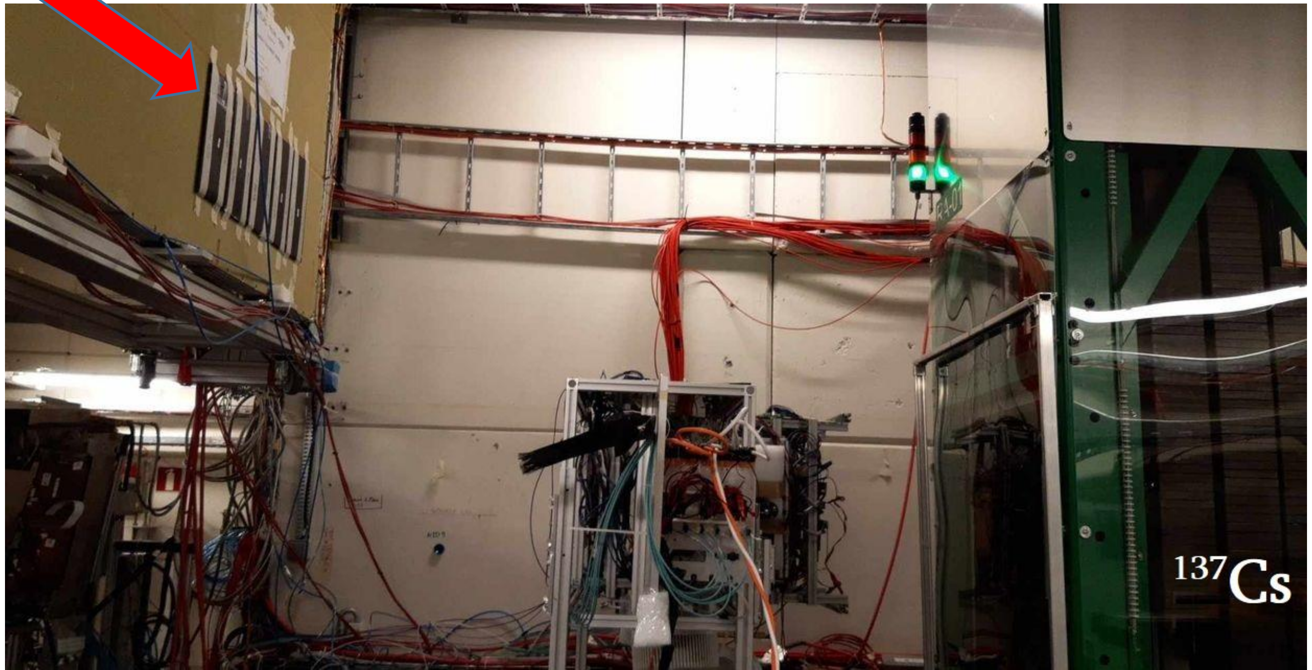


Module aligned vertically.
SiPM voltage = 30 V



Aging test for scintillator tiles

Gamma Irradiation Facility (GIF++) at CERN



Nuclear Inst. and Methods in Physics Research, A 866 (2017) 91–103

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

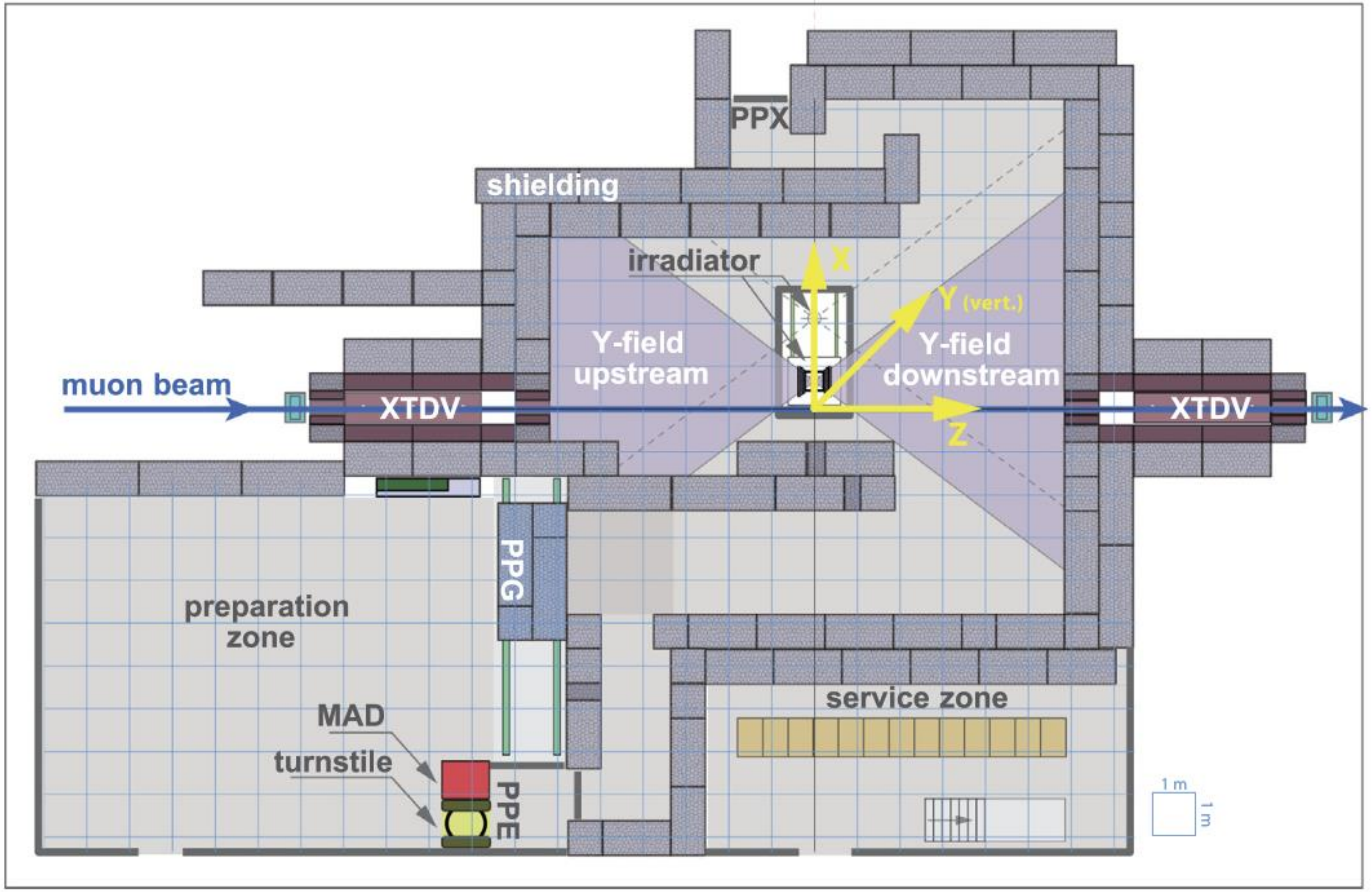
The radiation field in the Gamma Irradiation Facility GIF++ at CERN

Dorothea Pfeiffer[a,b,*], Georgi Gorine[c,a], Hans Reithler[d], Bartolomej Biskup[a,e], Alasdair Day[a], Adrian Fabich[a], Joffrey Germa[a], Roberto Guida[a], Martin Jaekel[a], Federico Ravotti[a]

^{137}Cs source, composed of the primary 662 keV photons and lower energetic scattered photons.

GIF++

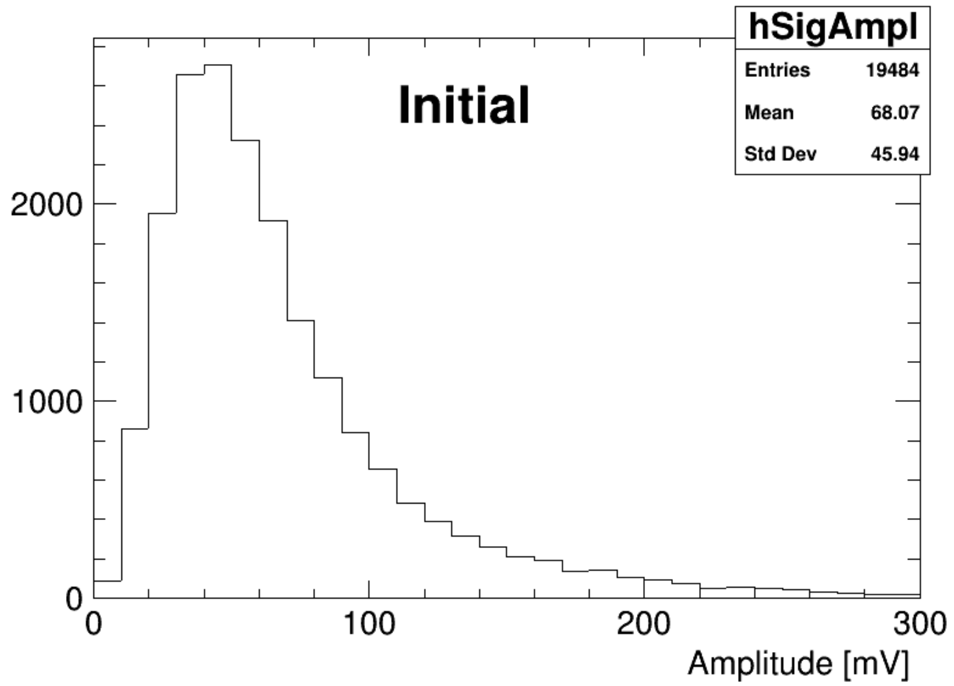
2.2 Gy/h directly in front of the irradiator

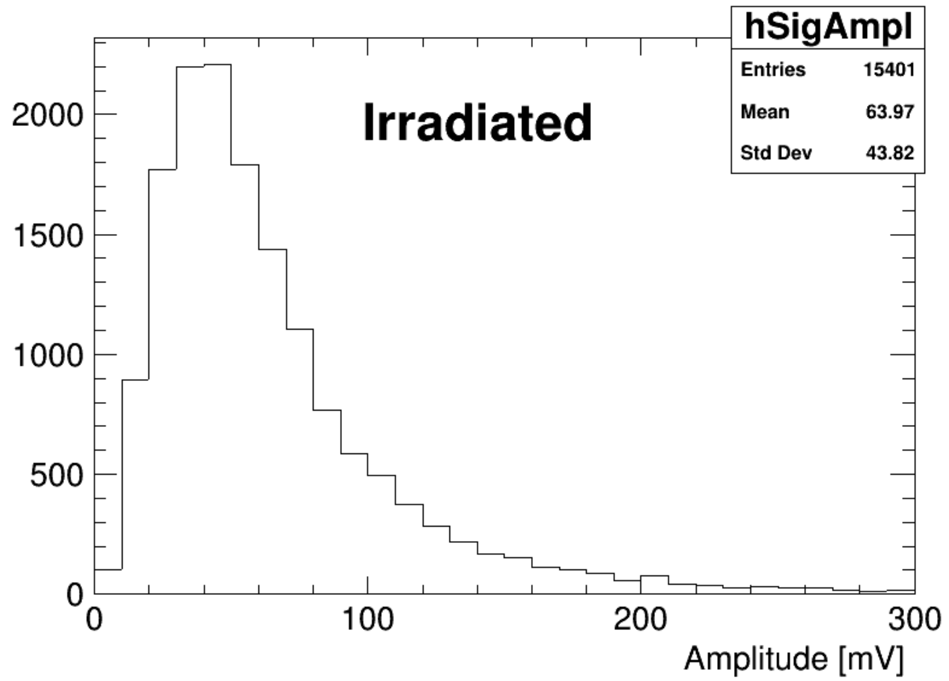


Floor plan of the GIF++ facility with entrance doors MAD (material access door), PPG (personal protection gate), PPE (personal protection entrance), PPX (personal protection exit).

When the facility downstream of the GIF++ takes electron beam, a beam pipe is installed along the beam line (z-axis) between the vertical mobile beam dump (XTDV).

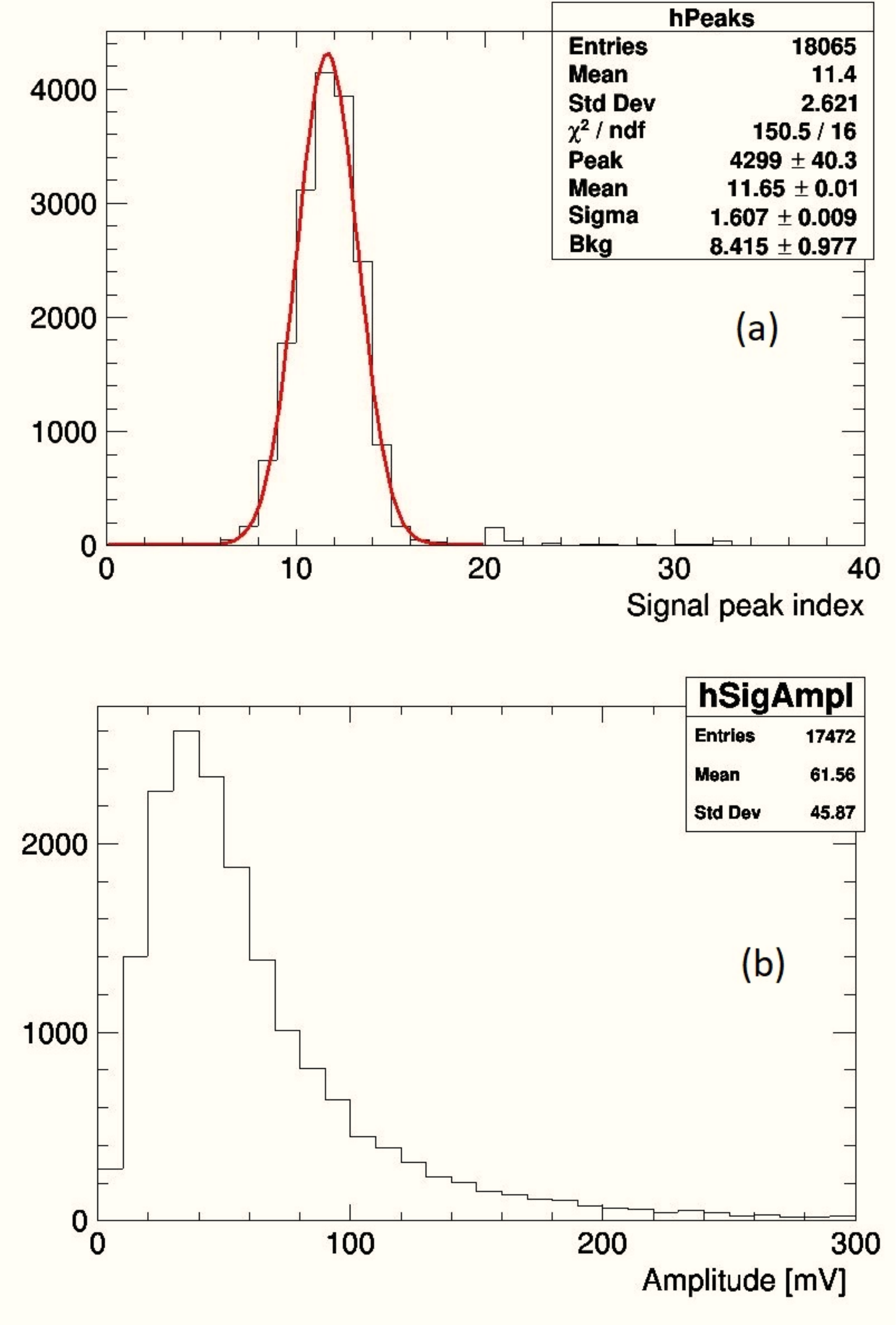
The irradiator can be displaced laterally (its center moves from x = 0.65 m to 2.15 m), to increase the distance to the beam pipe.

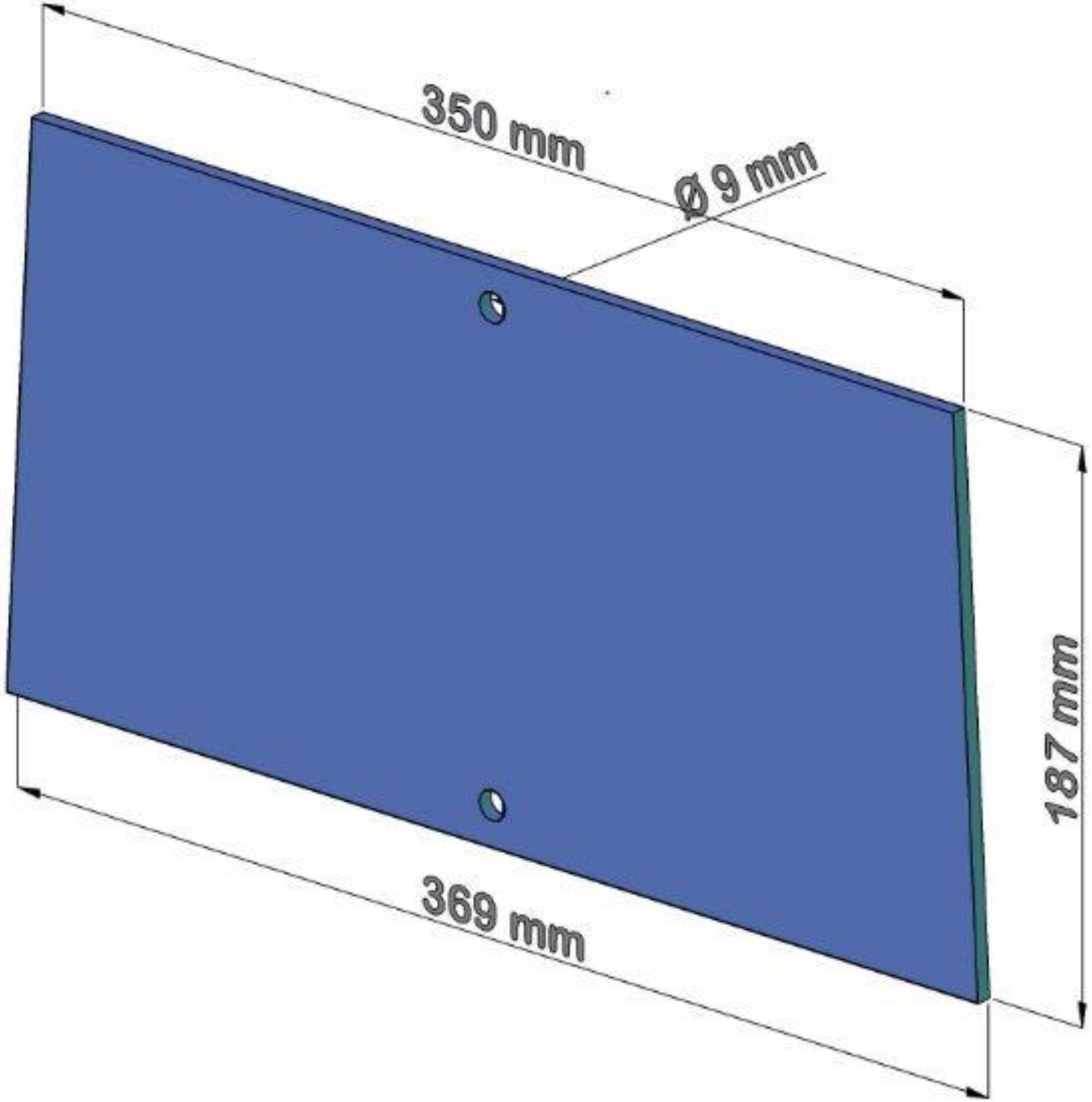




Initial tile measurement:
Efficiency = 0.94 (20 mV trigger threshold)
Av. Rate = 930/h
Ampltudes mean = 68 mV

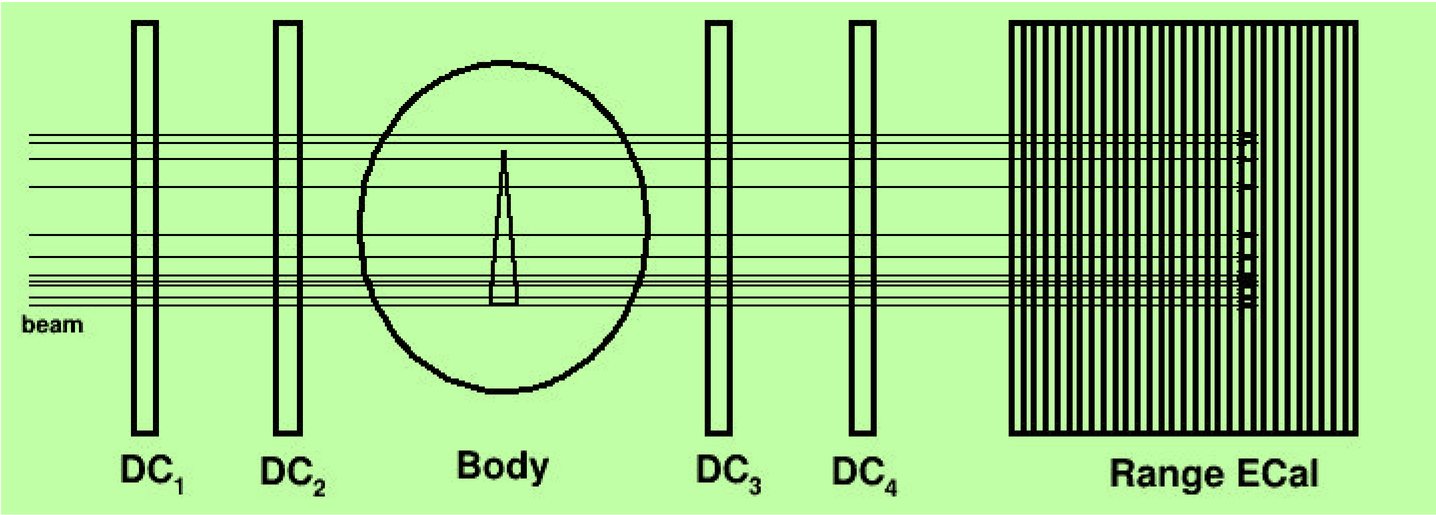
Irradiated tile measurement:
Efficiency = 0.92 (20 mV trigger threshold)
Av. Rate = 834/h
Ampltudes mean = 64 mV

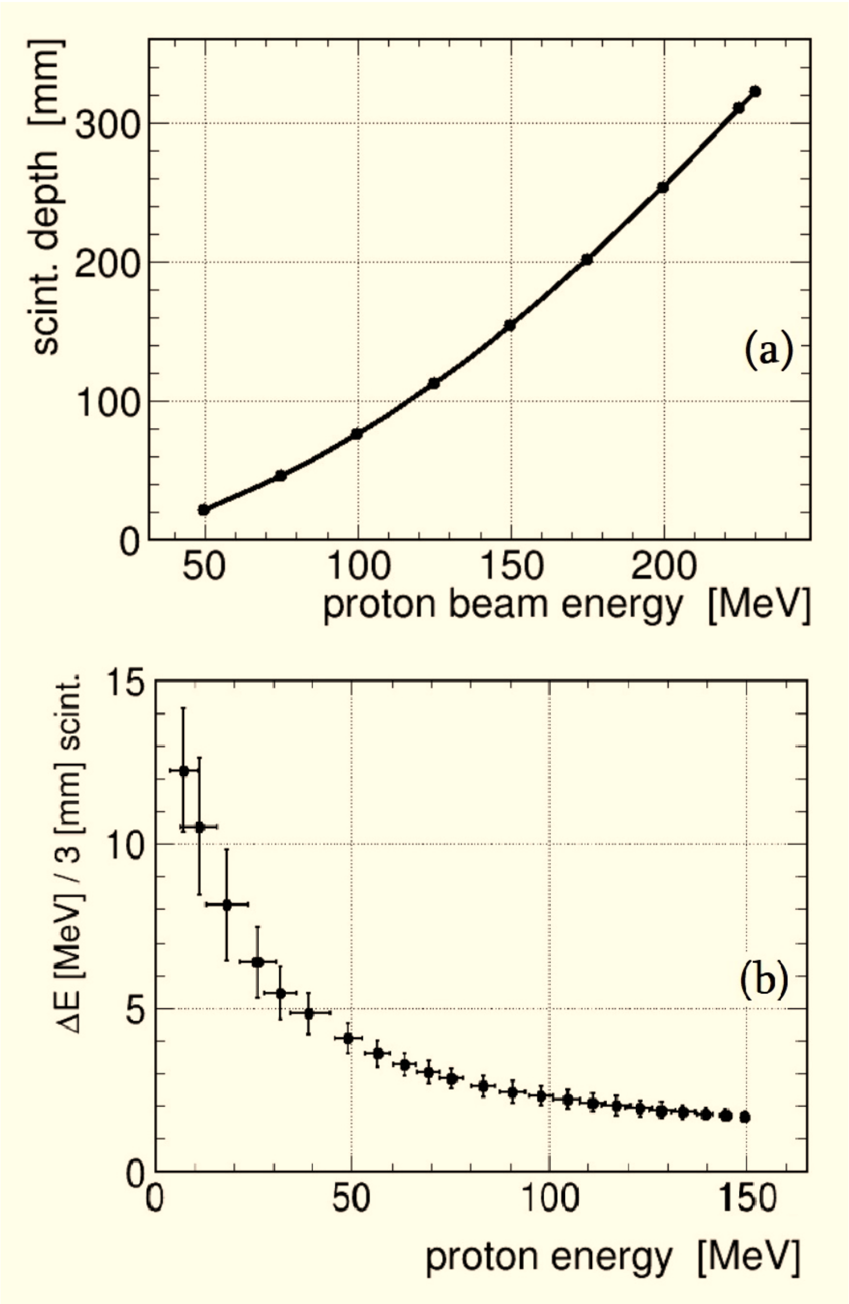

hPeaks
Entries 18065
Mean 11.4
Std Dev 2.621
χ² / ndf 150.5 / 16
Peak 4299 ± 40.3
Mean 11.65 ± 0.01
Sigma 1.607 ± 0.009
Bkg 8.415 ± 0.977
(a)
0
1000
2000
3000
4000
0
10
20
30
40
Signal peak index
hSigAmpl
Entries 17472
Mean 61.56
Std Dev 45.87
(b)
0
1000
2000
0
100
200
300
Amplitude [mV]


350 mm
Ø 9 mm
187 mm
369 mm

Preliminary simulation of proton beam scattering:

- **Determination of the maximum scattering angles for fixing the cross-sectional dimensions of the calorimeter and the tracker system;**
- **Determination of calorimeter length for different starting E_0 energies (70-230 MeV);**
- **Determination of correlations from tracker and trigger detector's materials;**


beam
DC1
DC2
Body
DC3
DC4
Range ECal


scint. depth [mm]
300
200
100
0
50
100
150
200
proton beam energy [MeV]
(a)
ΔE [MeV] / 3 [mm] scint.
15
10
5
0
0
50
100
150
proton energy [MeV]
(b)

საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 18, №2, 2024
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 18, no. 2, 2024

Physics

Development of Low Energy Range Calorimeter for Proton Tomography

Giorgi Macharashvili[*], David Mchedlishvili[*], Edisher Tskhadadze[*,], Levan Kankadze[**], Mirian Tabidze[*], Nodar Lomidze[*]**

[*] *N. Amaglobeli High Energy Physics Institute, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia*
[**] *Kutaisi Hadron Center, Kutaisi, Georgia*

(Presented by Academy Member Anzor Khelashvili)

A low energy range calorimeter for proton tomography, possible future substitution for X-ray tomography is under development. Furthermore, it can also be used for the precise energy monitoring of the proton beam of the cyclotron. Active elements of the calorimeter are based on thin plastic scintillator tiles. Each element is independently read-out by silicon photomultipliers (SiPM). A dedicated SiPM biasing supply and a preamplifier are developed for signal acquisition. The cosmic ray telescope is used to test the calorimeter elements. Tests have not revealed any issue with the light collection and the amplification of the collected charge, thus leading to a reasonably high value for the particle detection efficiency, as expected. Besides, the amplitudes and the lengths of the obtained signals are sufficient to be digitized with relatively simple apparatus. Development of the Monte Carlo simulation software started. The main goal of the simulation is to qualify the limiting factors of the setup, such as multiple scattering and energy losses of the incident protons before and after passing the body. This will also facilitate the estimation of the range determination uncertainty of the calorimeter. The developed simulation code is able to estimate the range dependence on the proton initial energy, as well as the fluctuations of the energy deposit for protons that are stopped in the calorimeter layer. These results together with the laboratory test data of a single calorimeter element will be presented in this paper.

Signals from SiPM

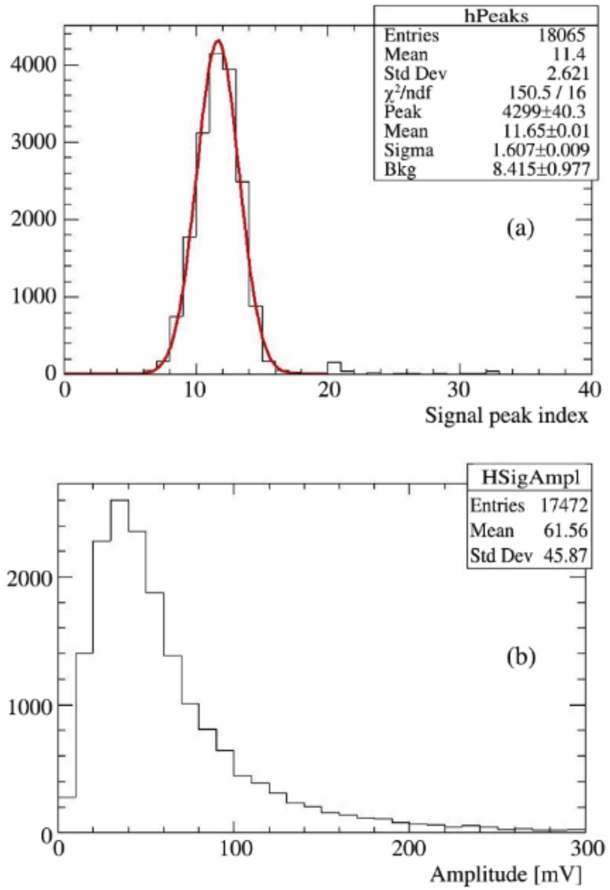


Fig. 2. Distribution of the signal peak positions (a) and the amplitude spectrum of the signals within the fitted Gaussian peak (b).

Simulation

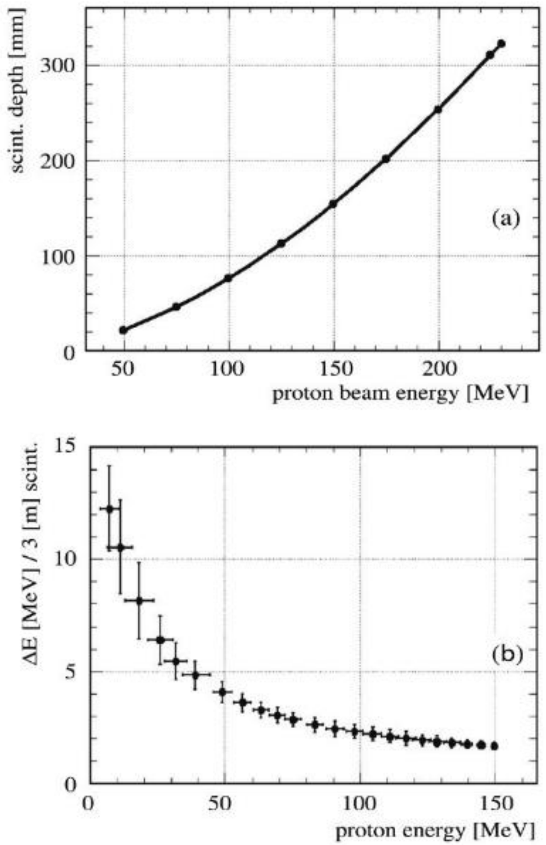
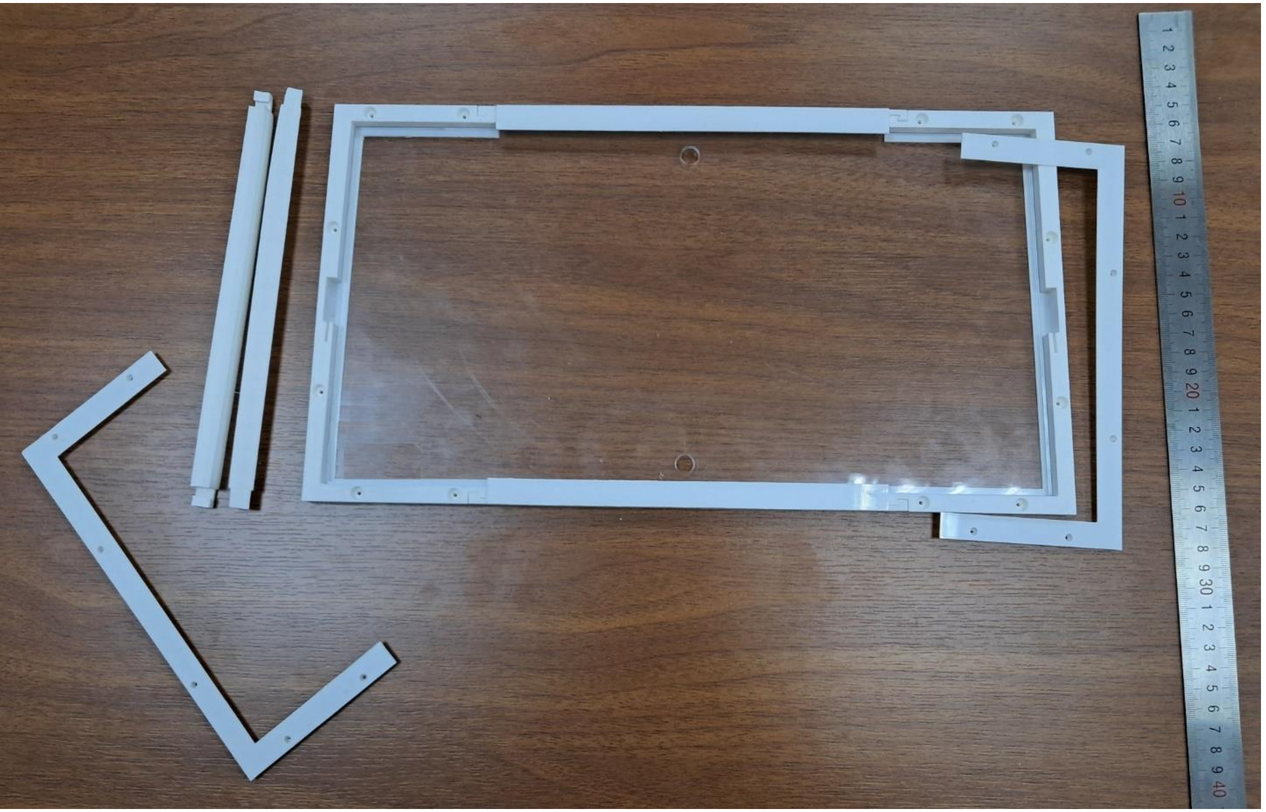
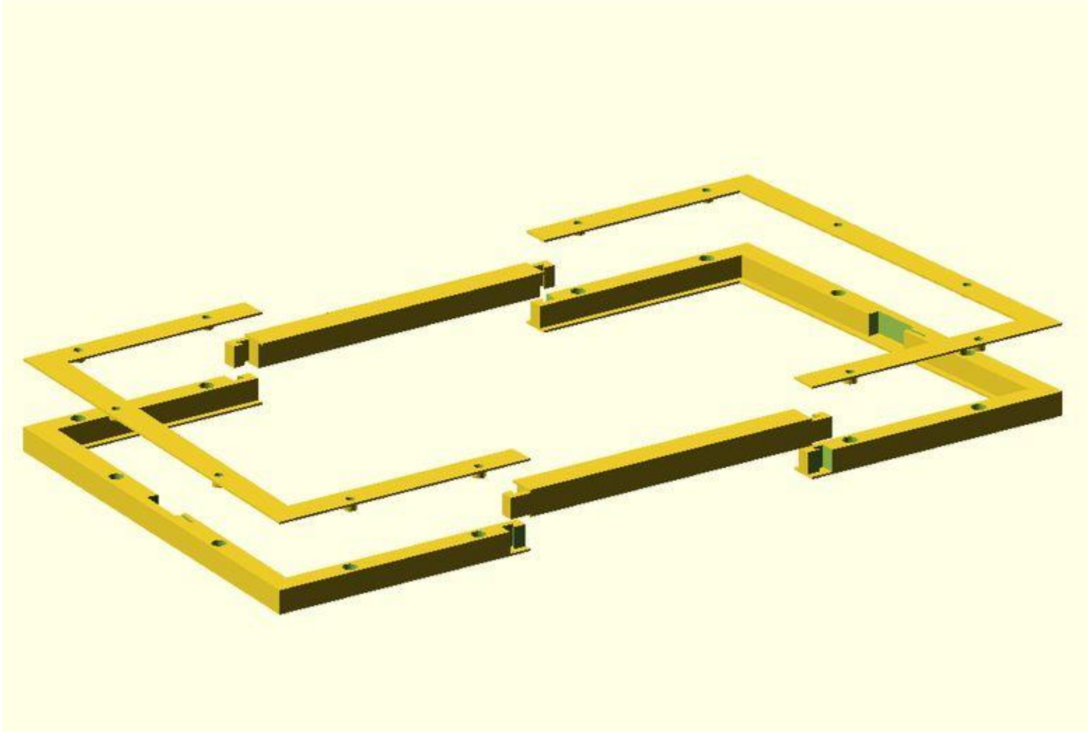
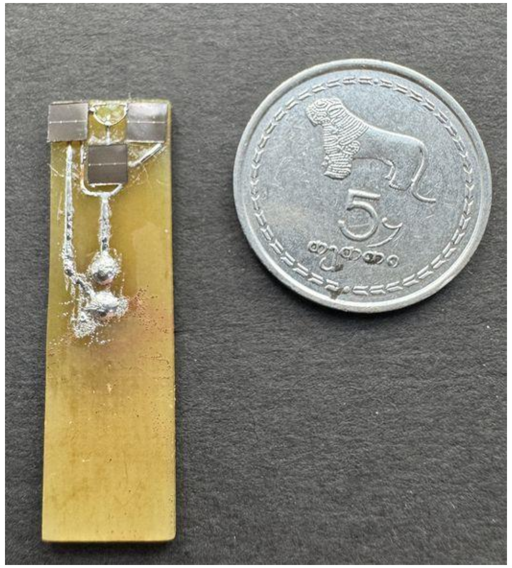


Fig. 4. The Bragg-Koopman dependence (a) and the proton energy deposition in a single layer at different energies (b).

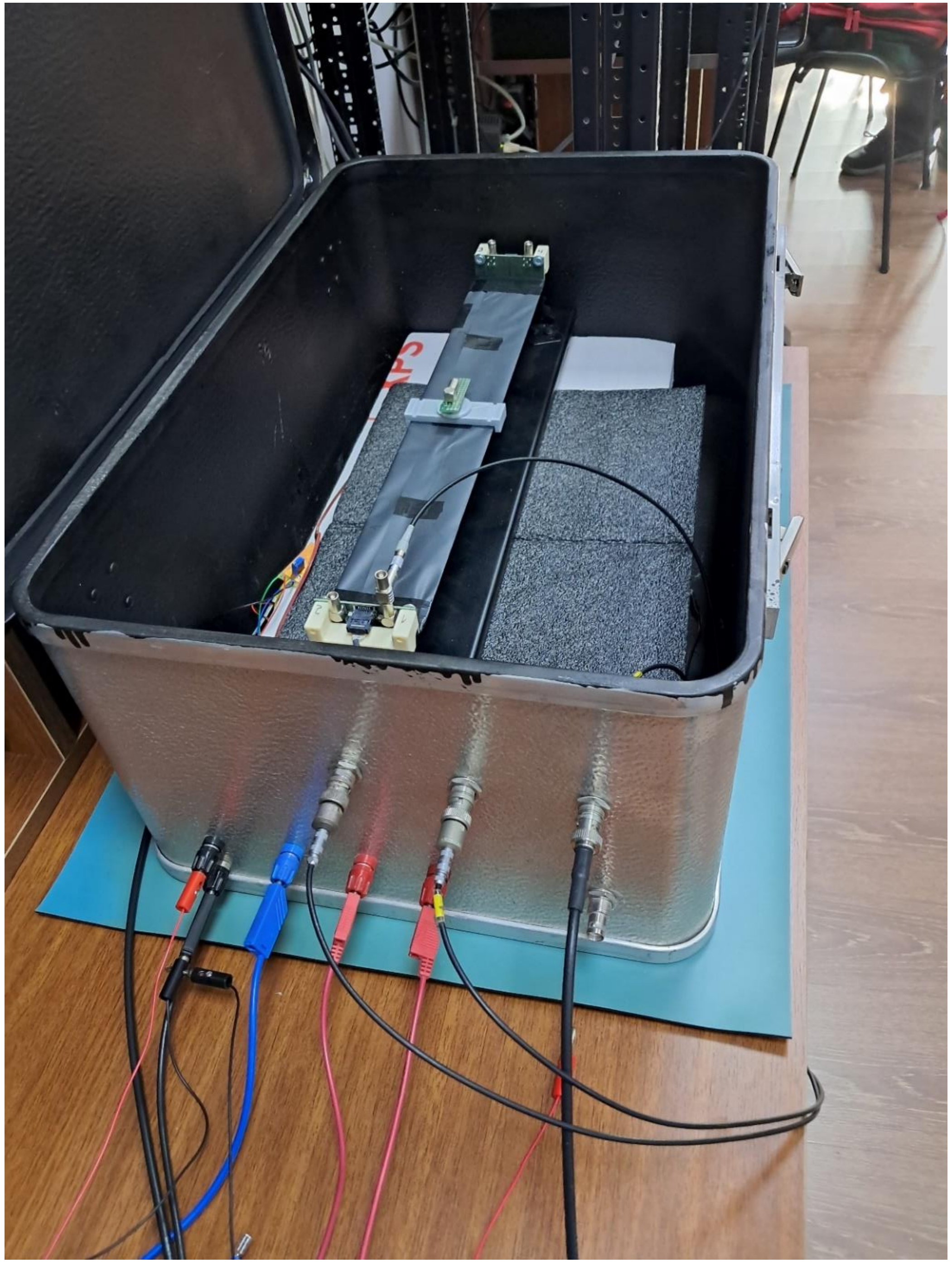
Frame for 3-scintillator block



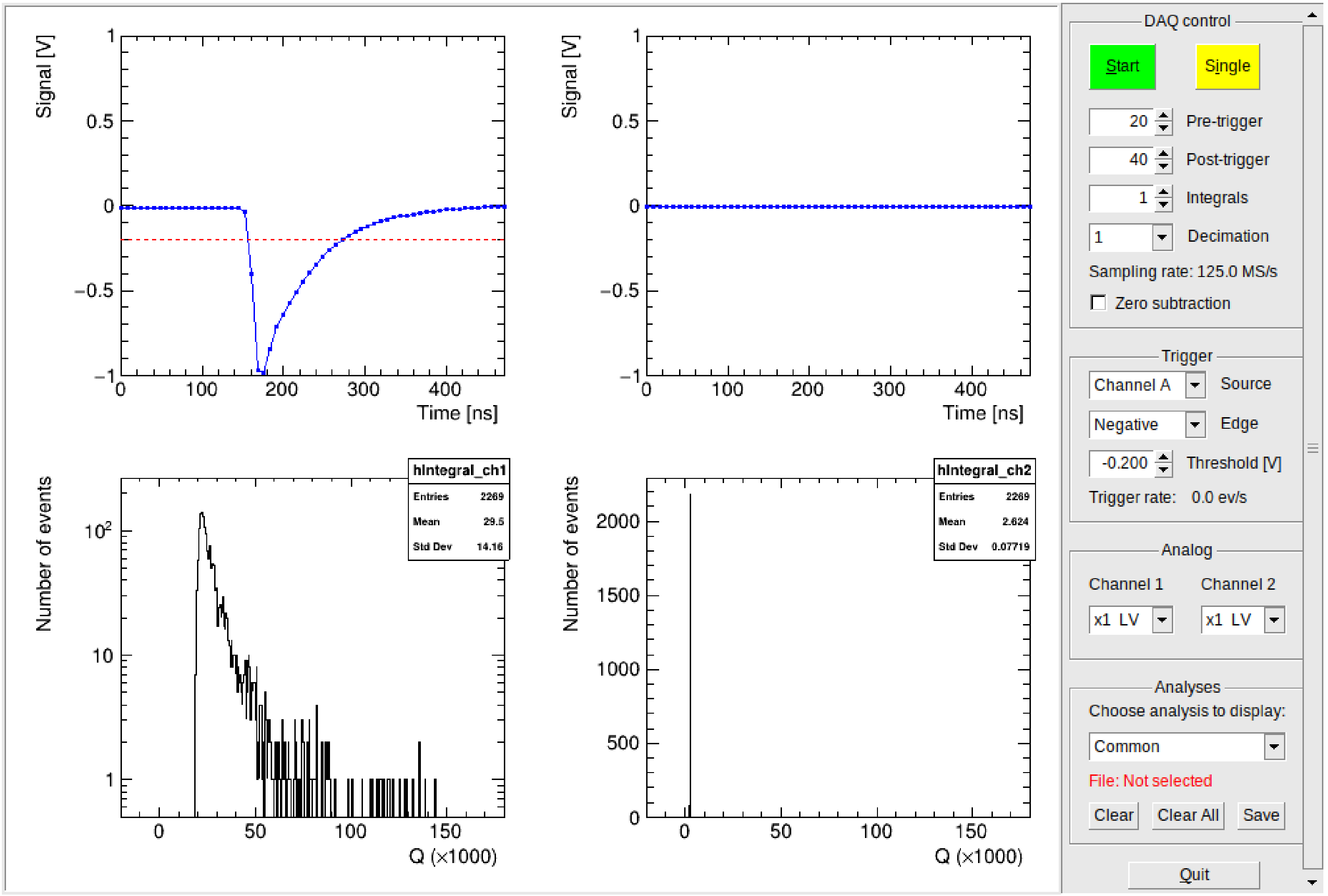




3 SiPMs for the block

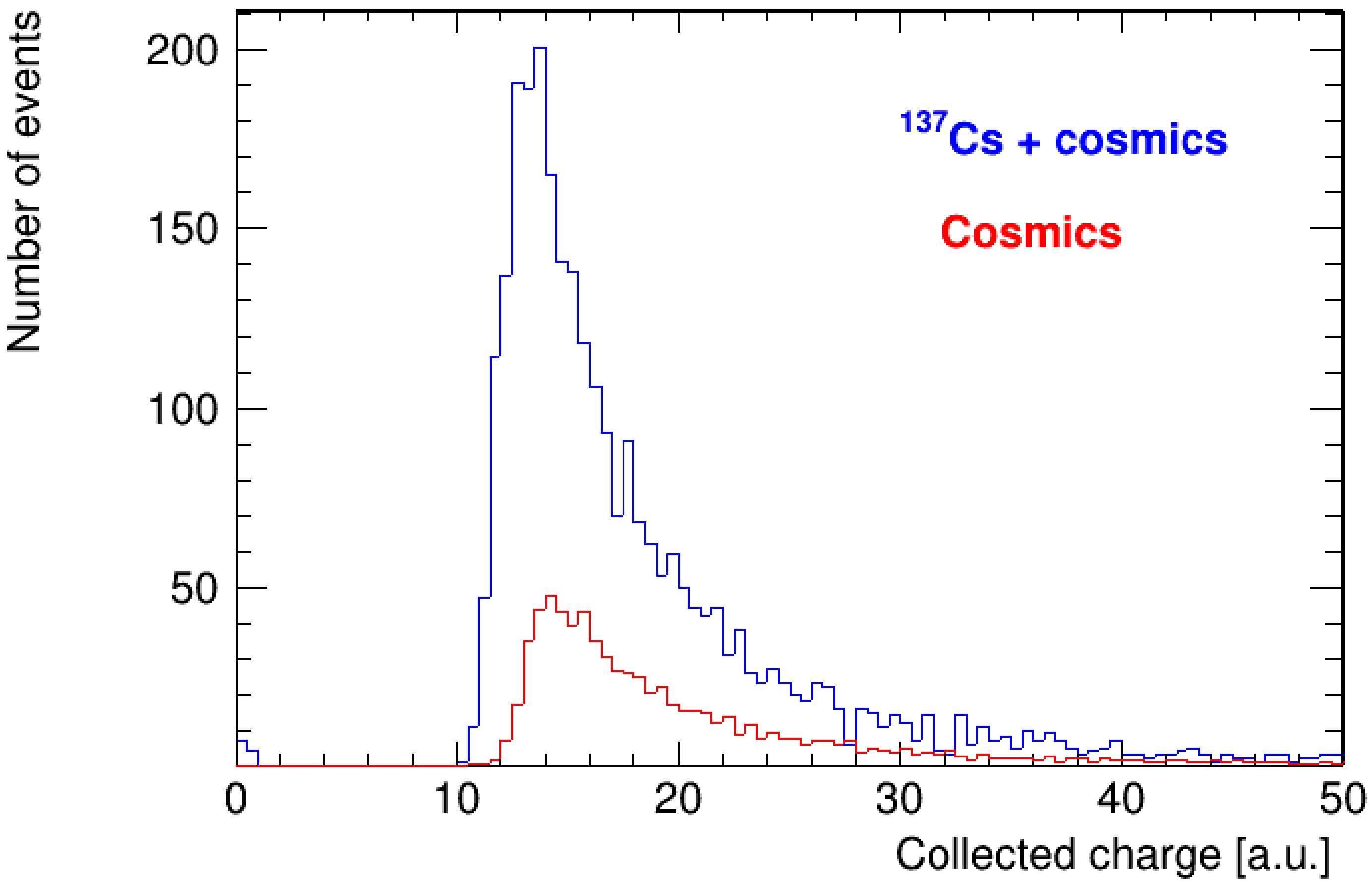


Cosmic Ray stand



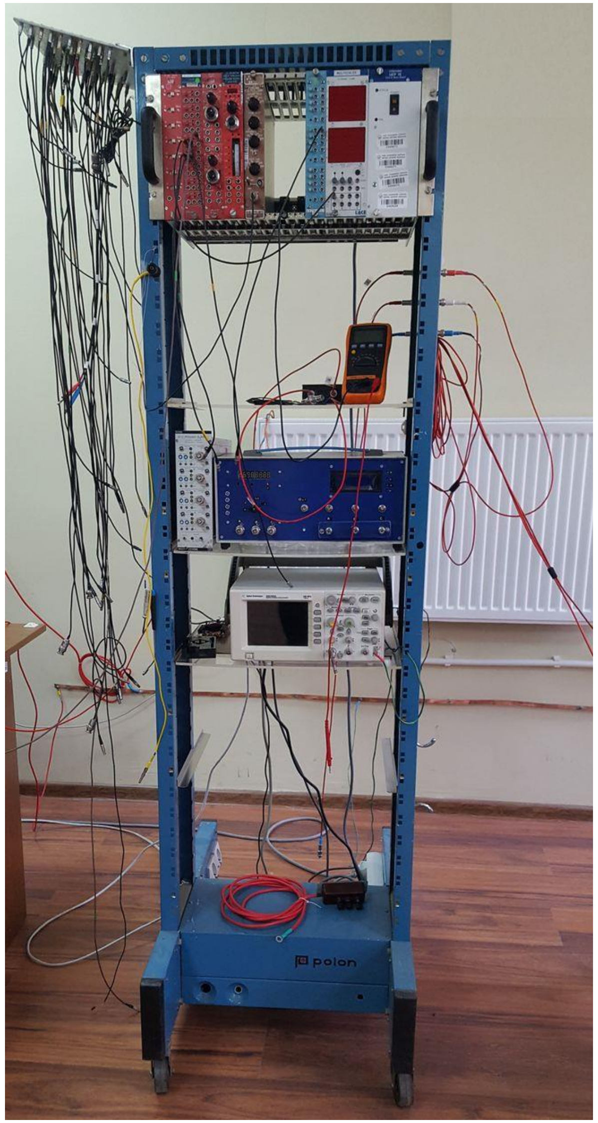
Source put on top of the module (middle)

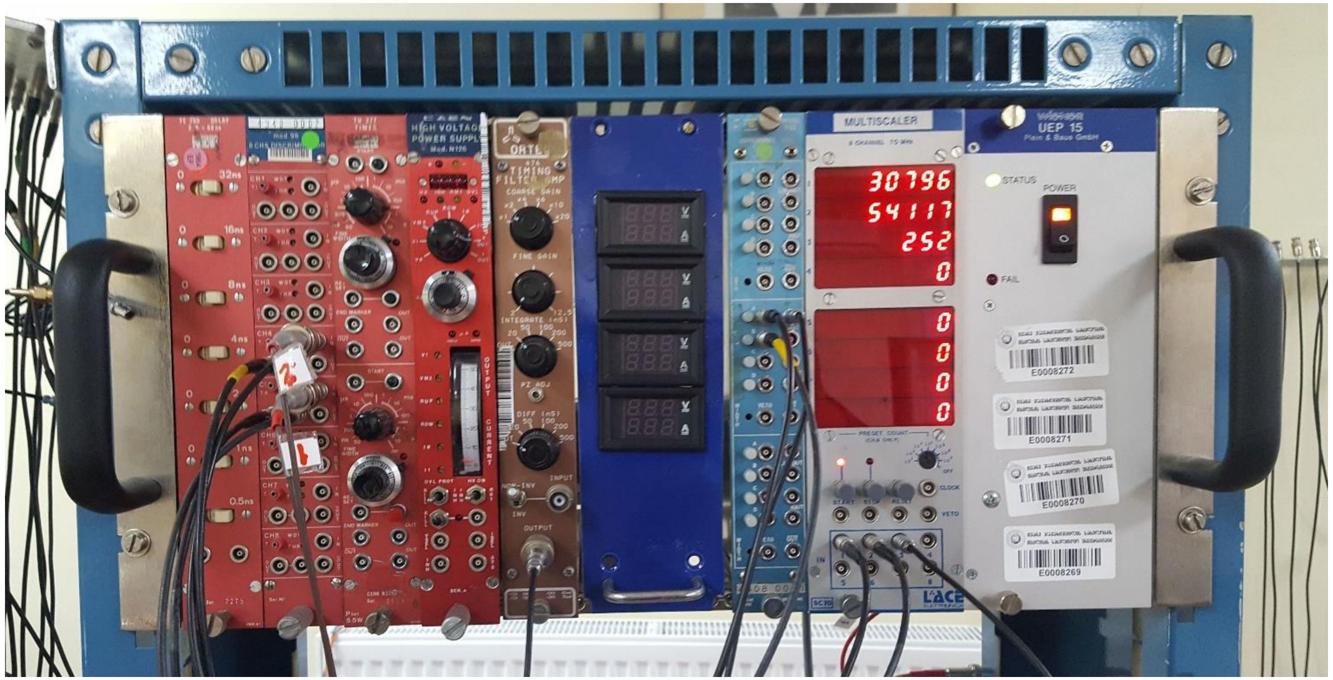
SiPM voltage = 30 V


Number of events
200
150
100
50
0
10
20
30
40
50
Collected charge [a.u.]
137Cs + cosmics
Cosmics


Canon

Signal receiving primary electronics blocks in NIM standard

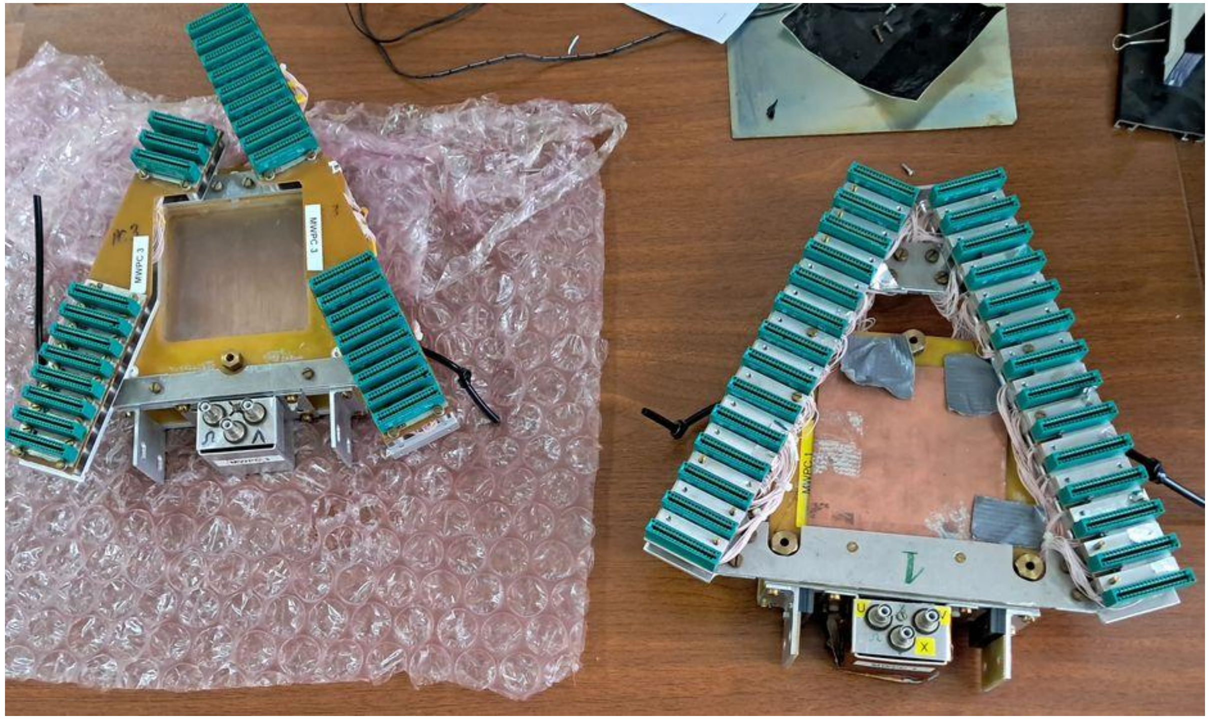




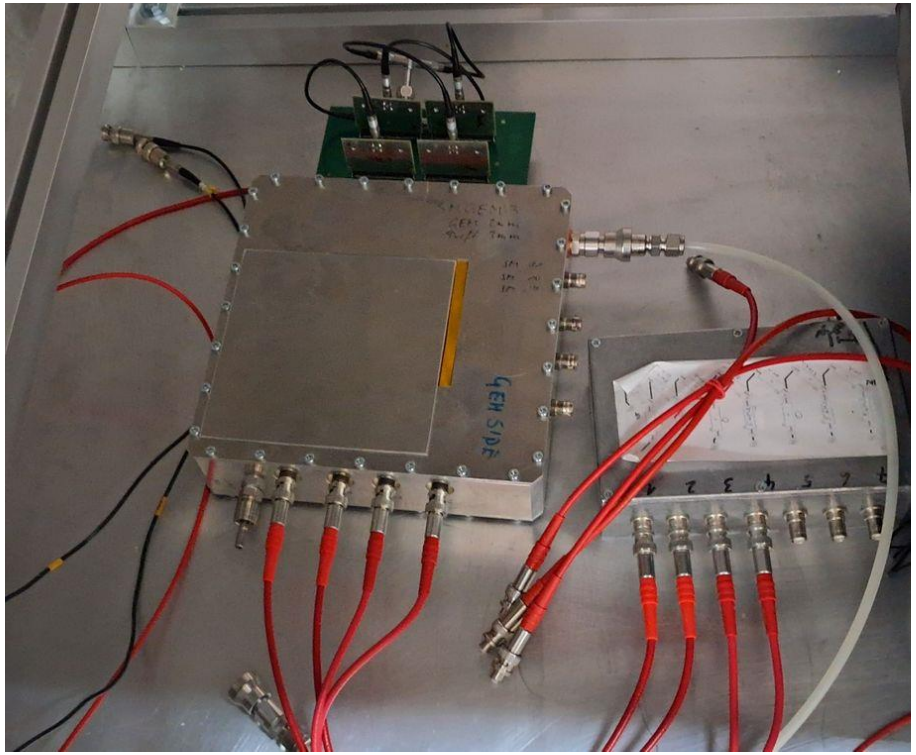
Mini-computer **Red Pitaya**
for SiPM/Scintillator signal
receving-recording-processing

Termo-insulated “Black Box”

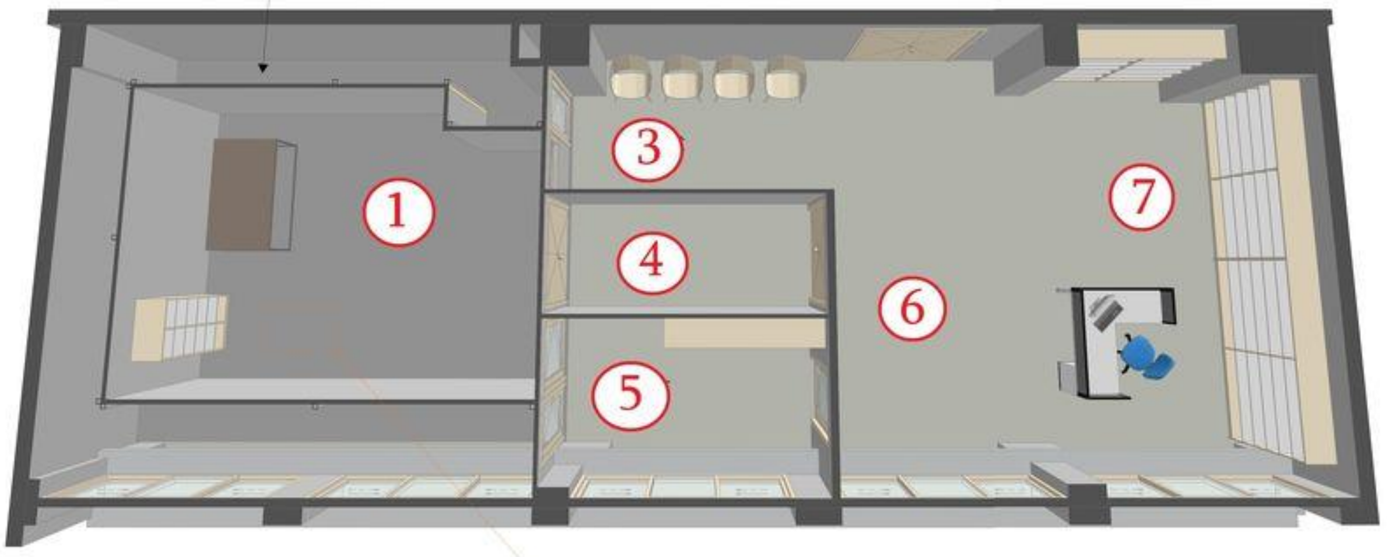
MWPC



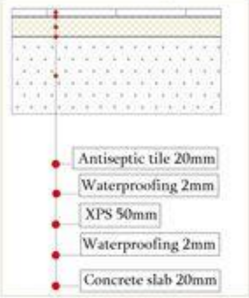
GEM



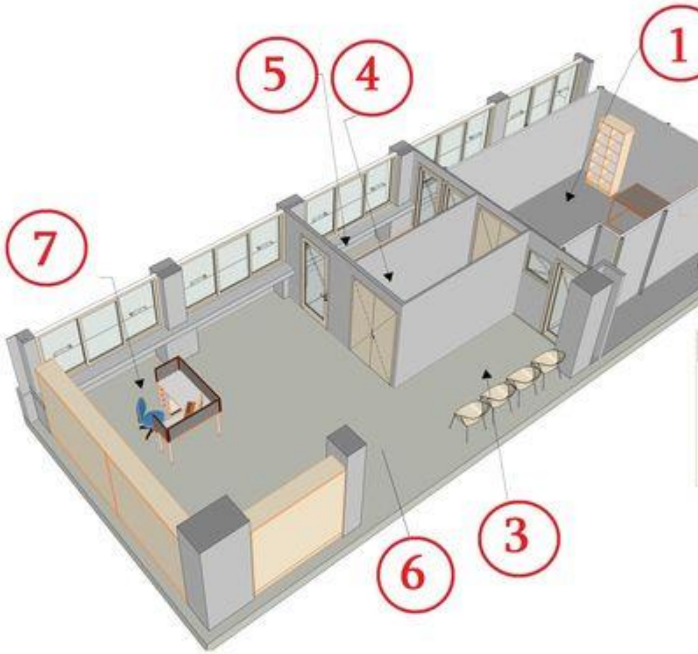
Clean Room; ISO 8



Clean room floor



		m^2
1	Clean room	20.41
2	Technical space	13.54
3	Observation space	7.83
4	Material tambourine	5.53
5	Staff entrance	6.73
6	Central zone	15.98
7	Engineering space	18.80



Wall sandwich panel

პირობითი აღნიშვნა

შენიშვნა: სართულის სიმაღლის ნიშნულები მითითებულია მეტრებში.

შენიშვნა: ზომები მითითებულია სანტიმეტრებში.

დამკვეთი: "ნოდარ ყიფშიძის სახელობის მაღალი ენერგიების ფიზიკის ინსტიტუტი"

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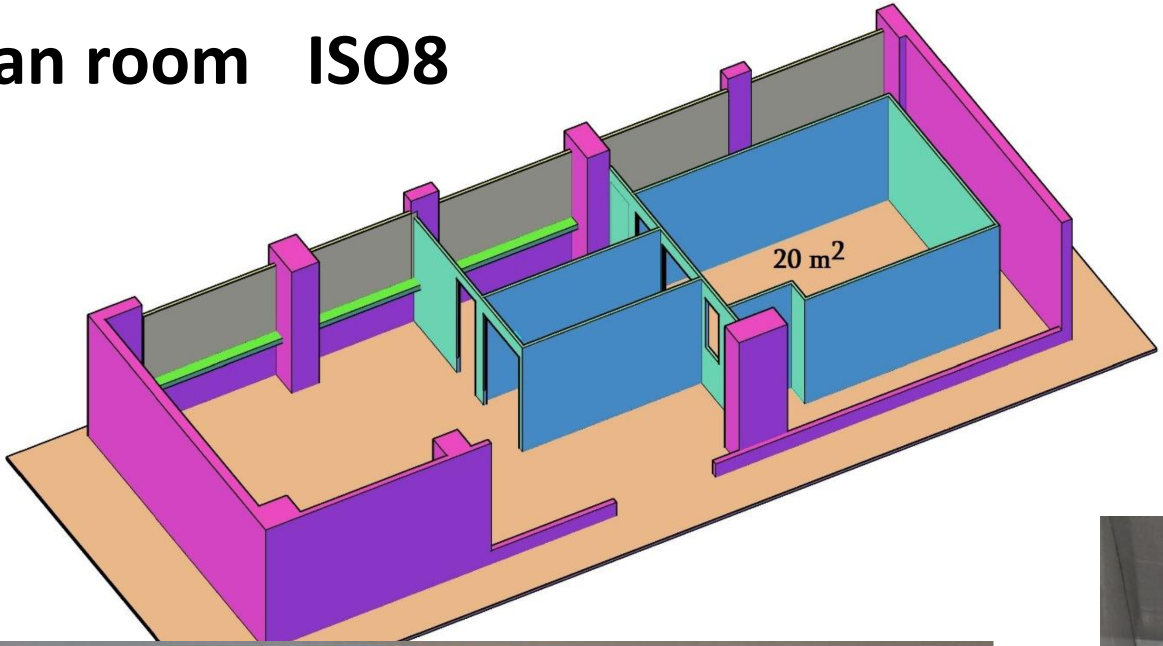
მისამართი: 9 უნივერსიტეტის ქუჩა, თბილისი
ს/კ: 01.14.06.006.040

ნახაზის დასახელება:
3D ვიზუალიზაცია

A3	27	27

2023 წელი

Clean room ISO8



HEPI,
Tbillisi,
GEORGIA

IBA S2C2 cyclotron:

Maximum Energy:	230/250 MeV
Yoke/pole radius:	1.25 m/0.50 m
Weight:	50 tons
Mag. field central/extraction:	5.7 T/5.0 T
Initial cooldown:	12 days
Beam pulse rate/length:	1000 Hz/7 μsec
RF system frequency:	93-63 MHz
Voltage:	10 kV

Average current of 135 nA. (about 1012 p/s)

Support:

Shota Rustaveli National Science Foundation Of Georgia,
STEM - Targeted program – providing long-term support to research projects in engineering, exact and natural sciences
Grant STEM -22-179

Shota Rustaveli National Science Foundation Of Georgia,
RIM - Competition to support the renewal of the material and technical base of independent research units of Higher Education Institutions
Grant RIM-3-22-019

CERN – material and apparatus donations, done during 2021-2023