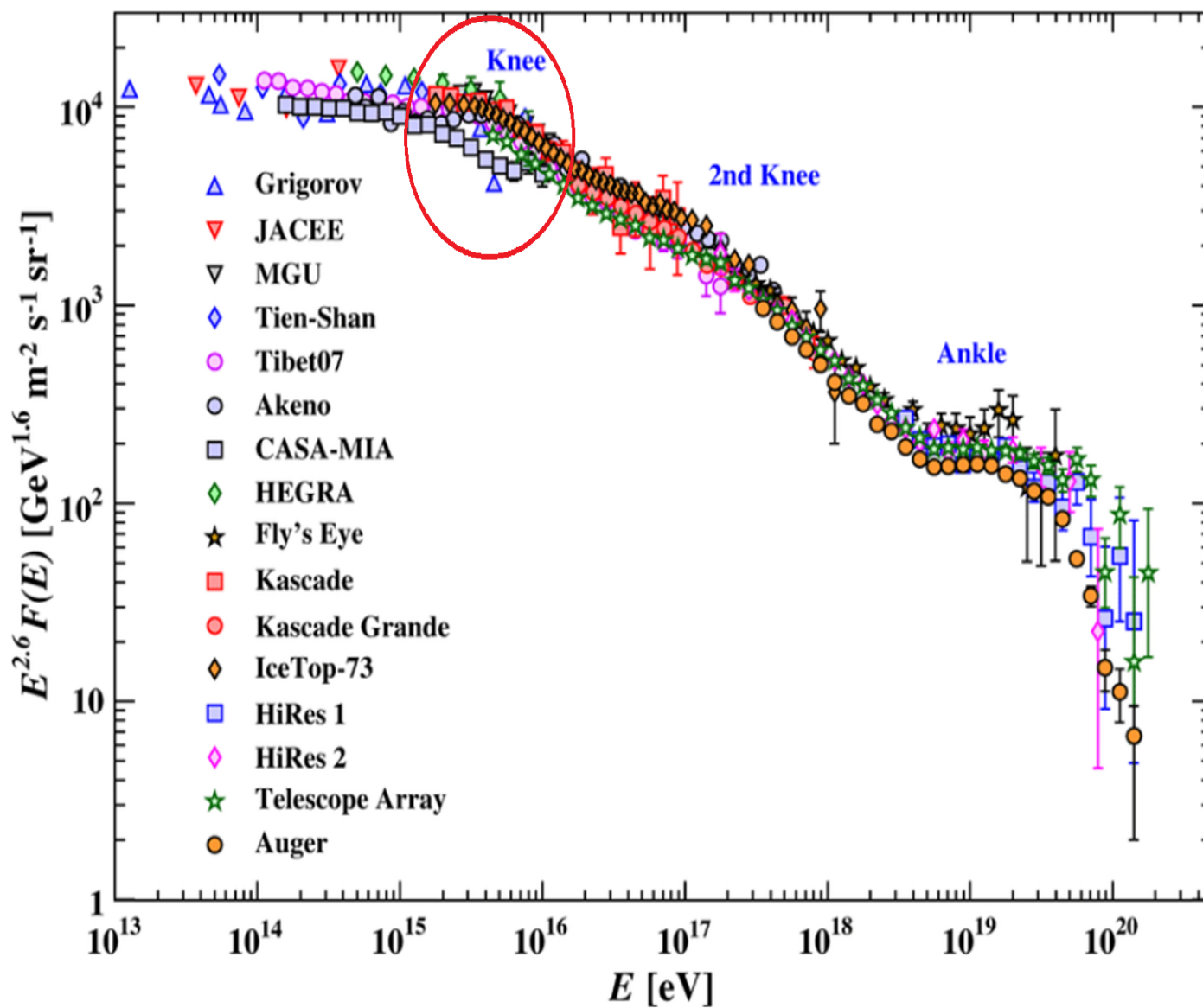




COSPAR 2024
45th Scientific Assembly
July 13-21, 2024
BEXCO, Busan, Korea

The High-Energy Ray Observatory prototype beam tests at SPS CERN

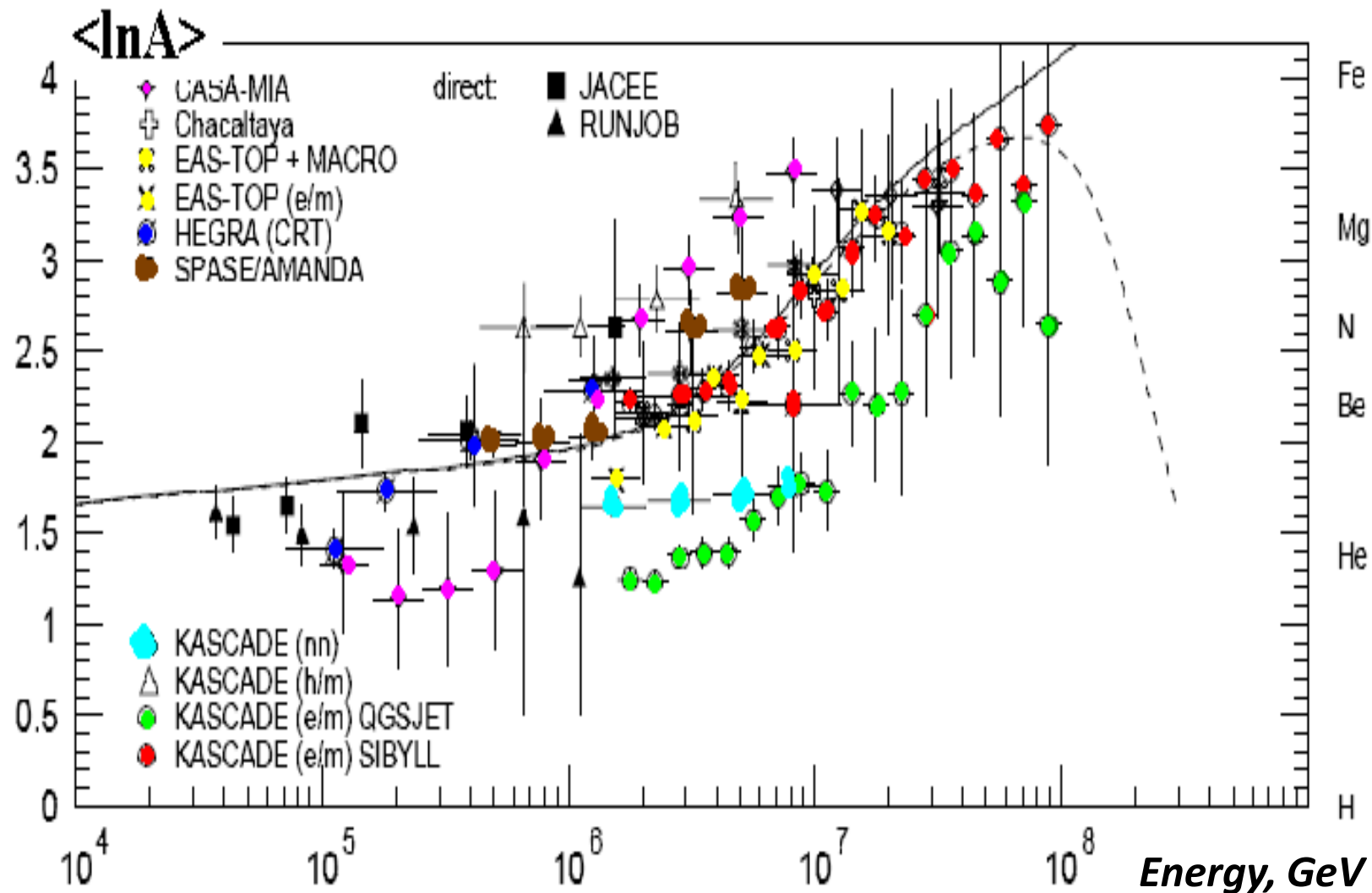
Khussein Karatash
Presenting author: Ksenia Belocopitova
Dubna, Joint Institute for Nuclear Research (JINR)



“Knee” region $\sim 10^{14} - 10^{16}$ eV
 Precision measurement of the Cosmic Rays spectrum at energies below the “knee”

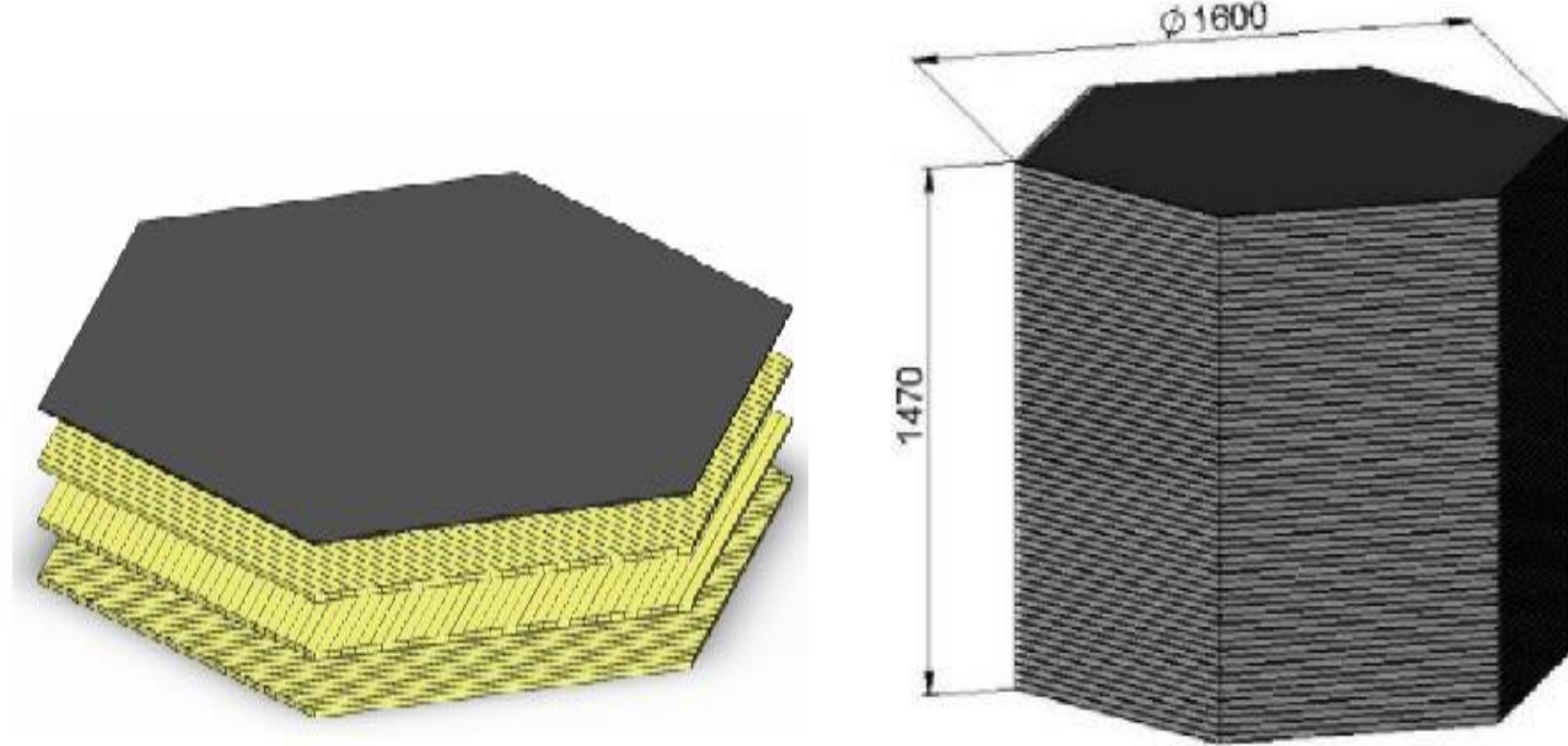
Measurement of spectra with element-by-element charge identification in the region of the 3 PeV

The energy spectrum of all particles of primary cosmic ray(PCS)



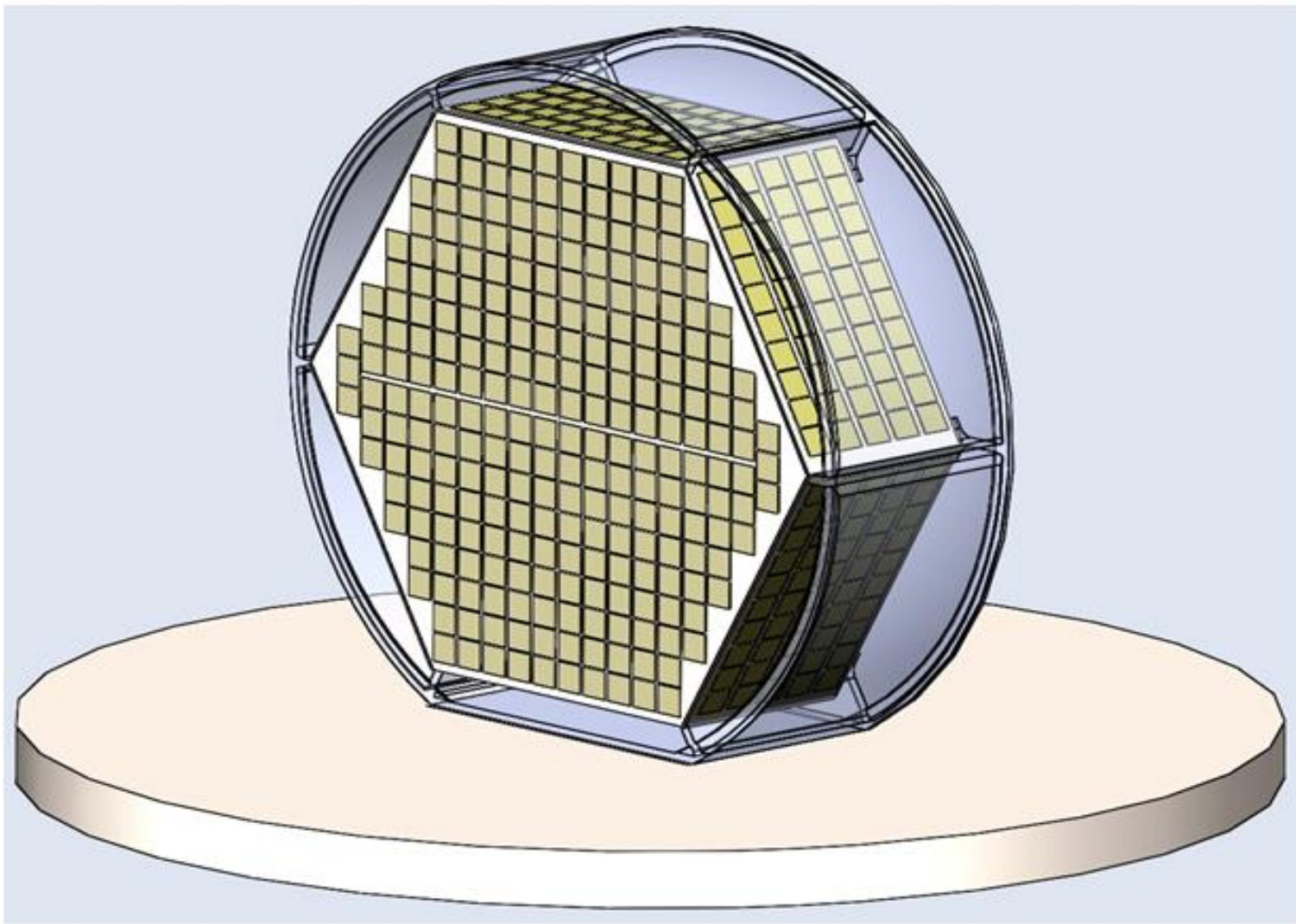
Average value $\ln A$ (logarithm of the atomic mass number) in the spectrum of cosmic ray versus energy

The High Energy Ray Observatory (HERO) is a space experiment based on a high-granularity tungsten scintillation calorimeter for studying cosmic rays (CRs) in the energy range 10^{12} - 10^{16} eV



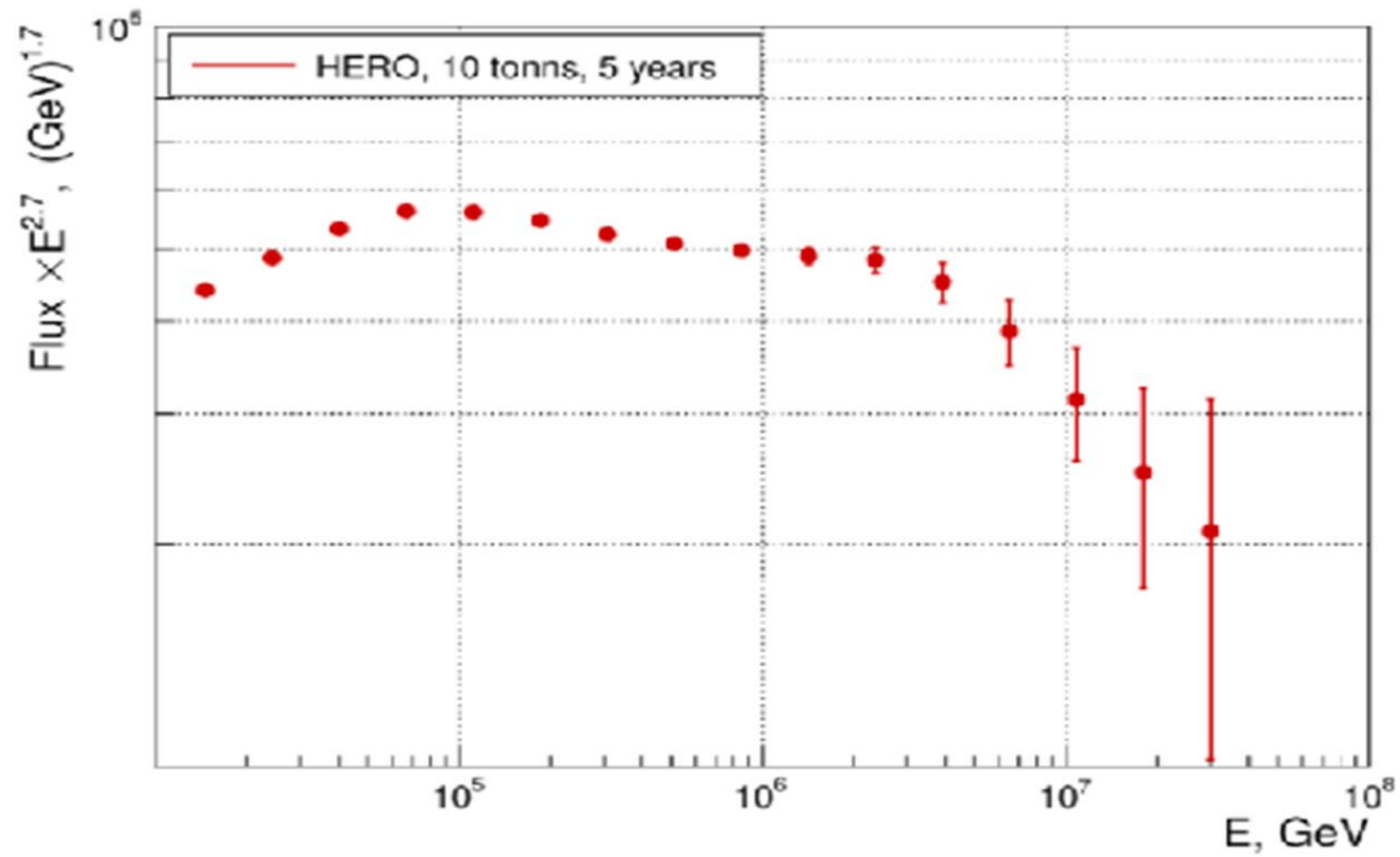
The calorimeter contains
62 hexagonal detectors :
Tungsten layer ~ 2 mm
3 scintillator layers ~ 8 mm
Mass ~ 16 tons

At the left is one calorimeter layer for a cluster of three scintillator detectors rotated 60° relative to each other.. On the right is a general view and dimensions of the calorimeter.

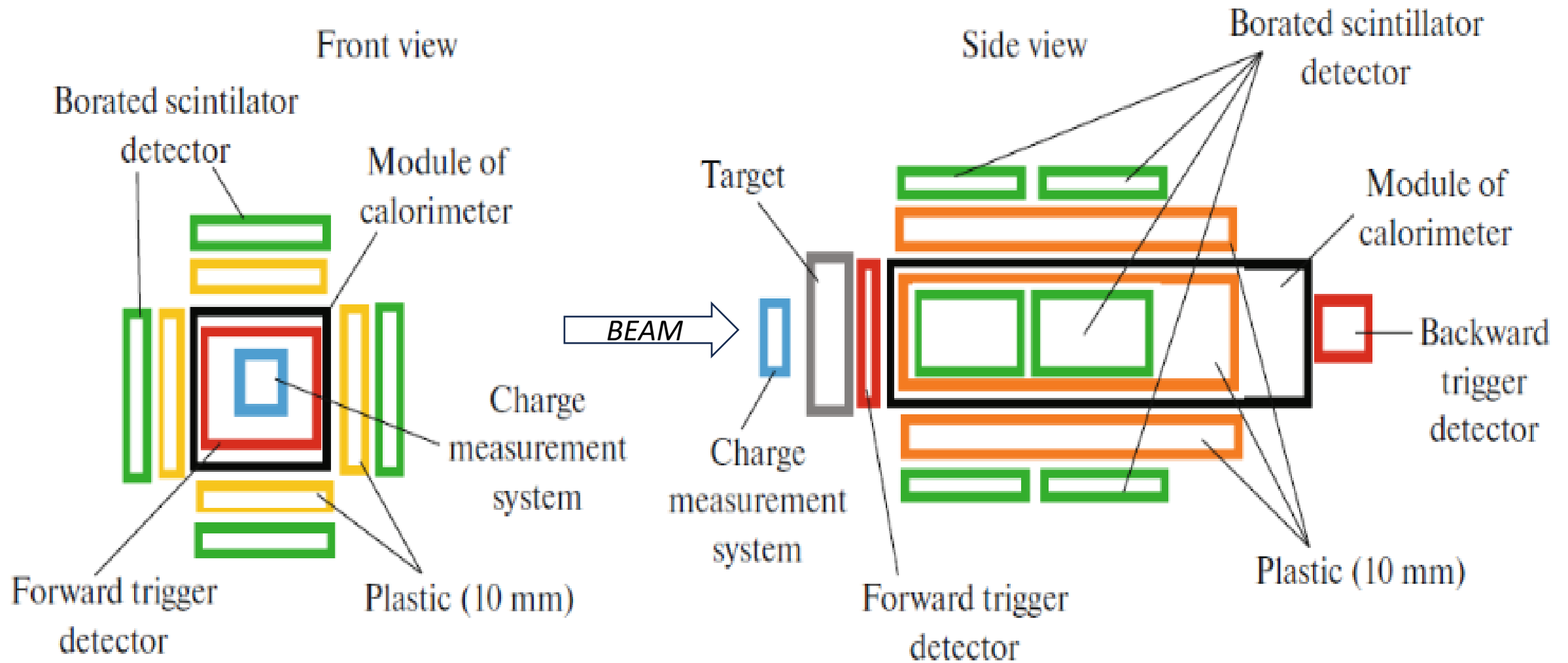


Four-layer silicon
matrix
cell size 1 cm^2
Charge
resolution $\sim 0.2e$

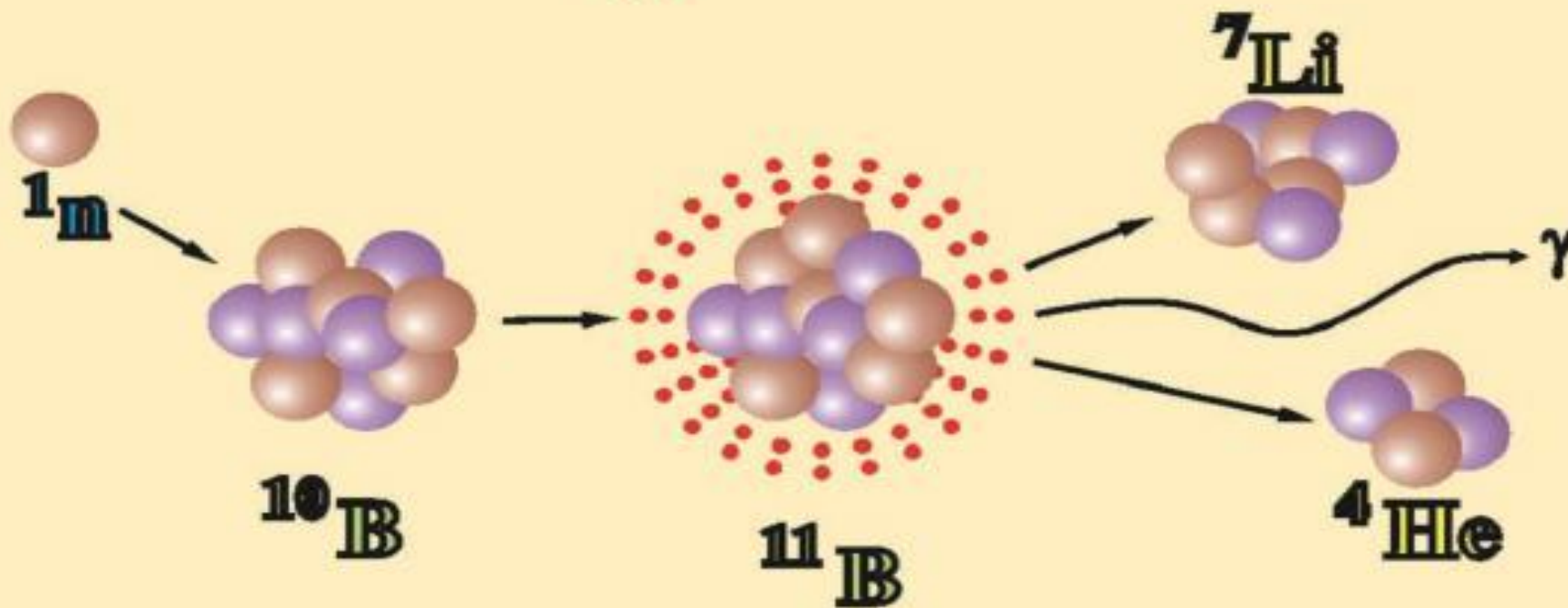
Layout of the charge measurement system (CMS)



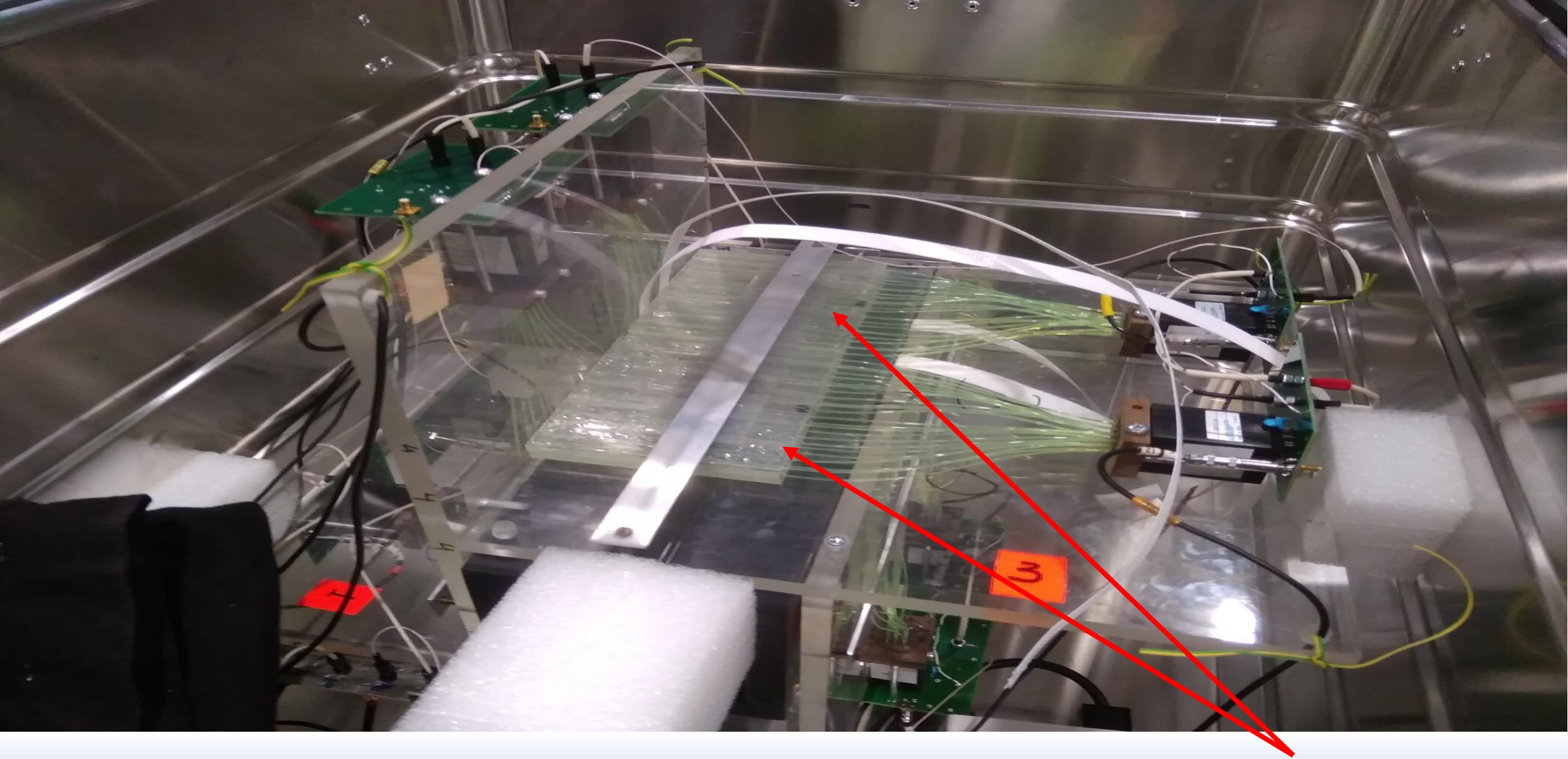
Expected CR spectrum for 5 years of data set



Schematic view of the HERO prototype

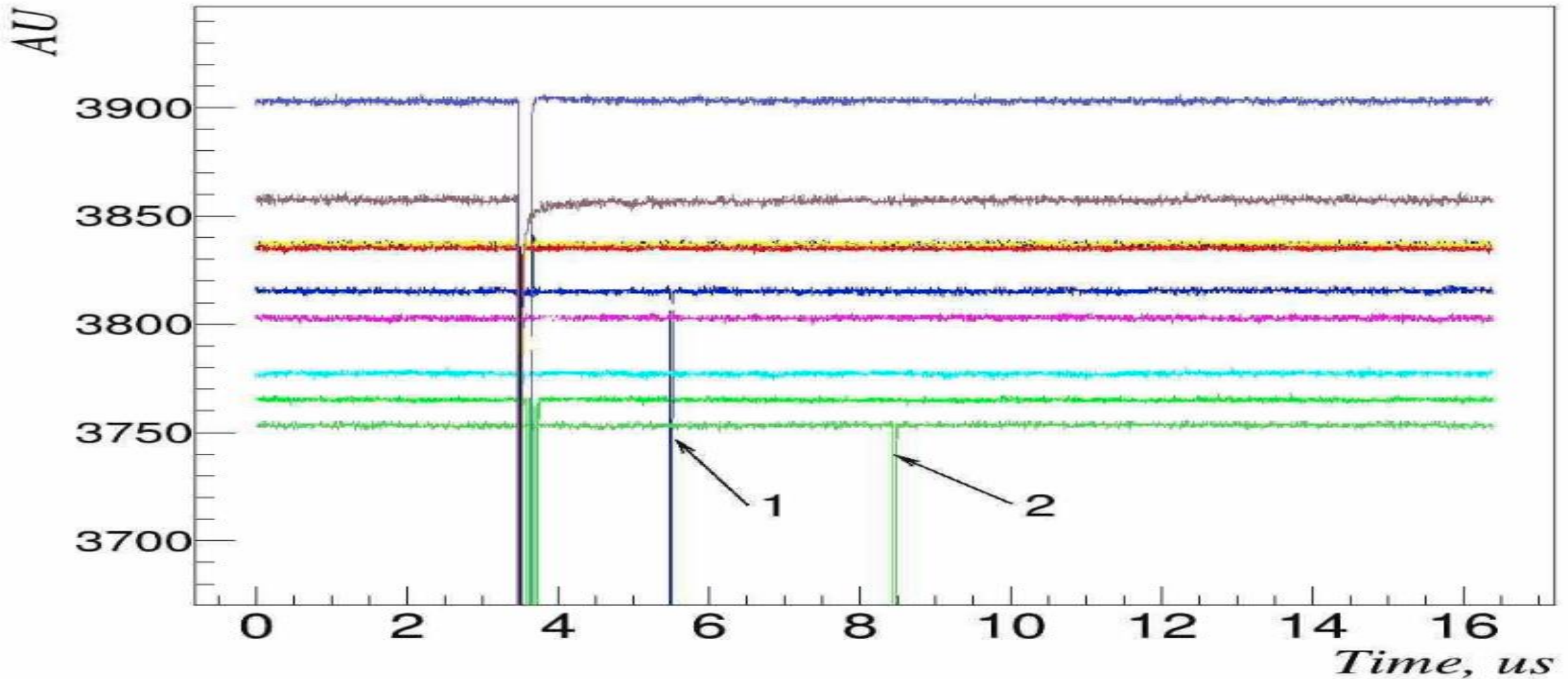


Thermal neutron capture reaction by boron
(for neutron's with energy $E \sim 0.025$ eV, cross section = 755 barn)

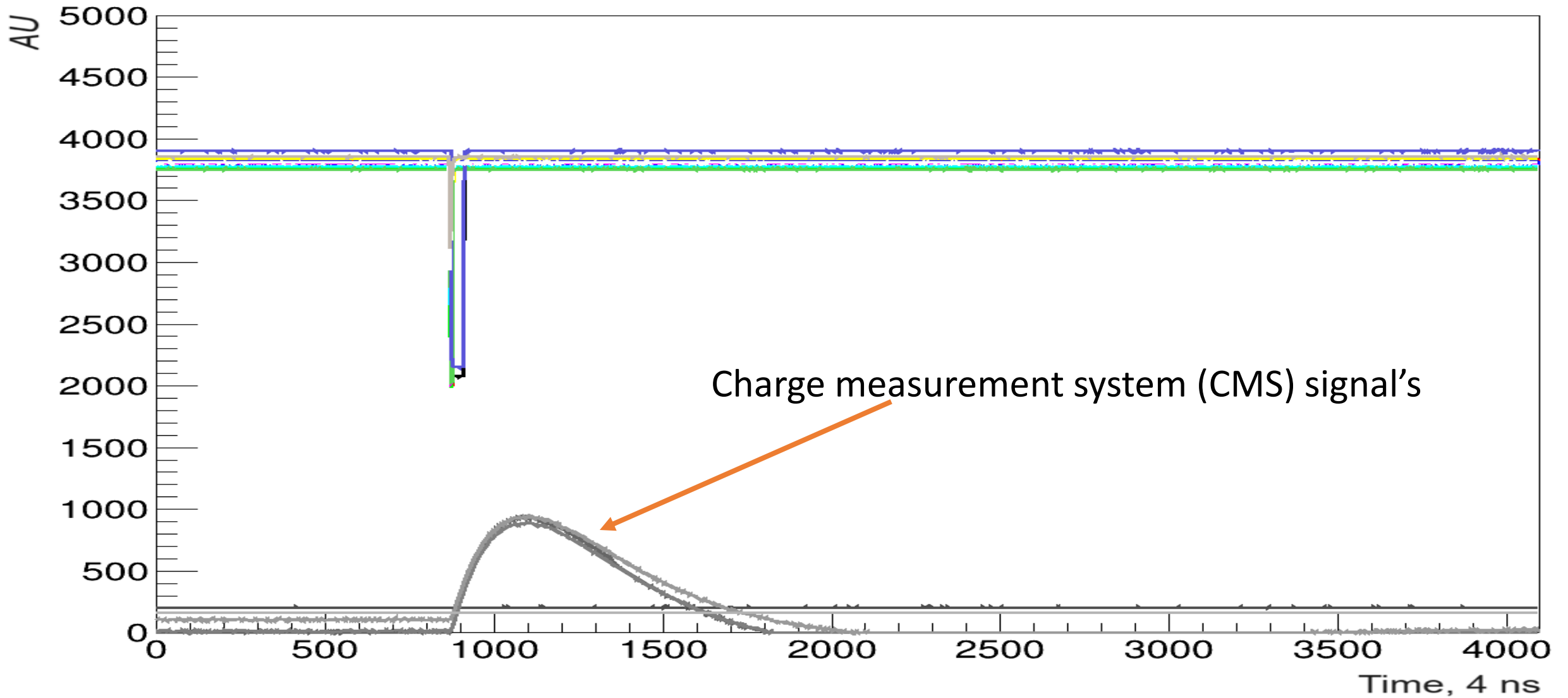


View of the HERO prototype

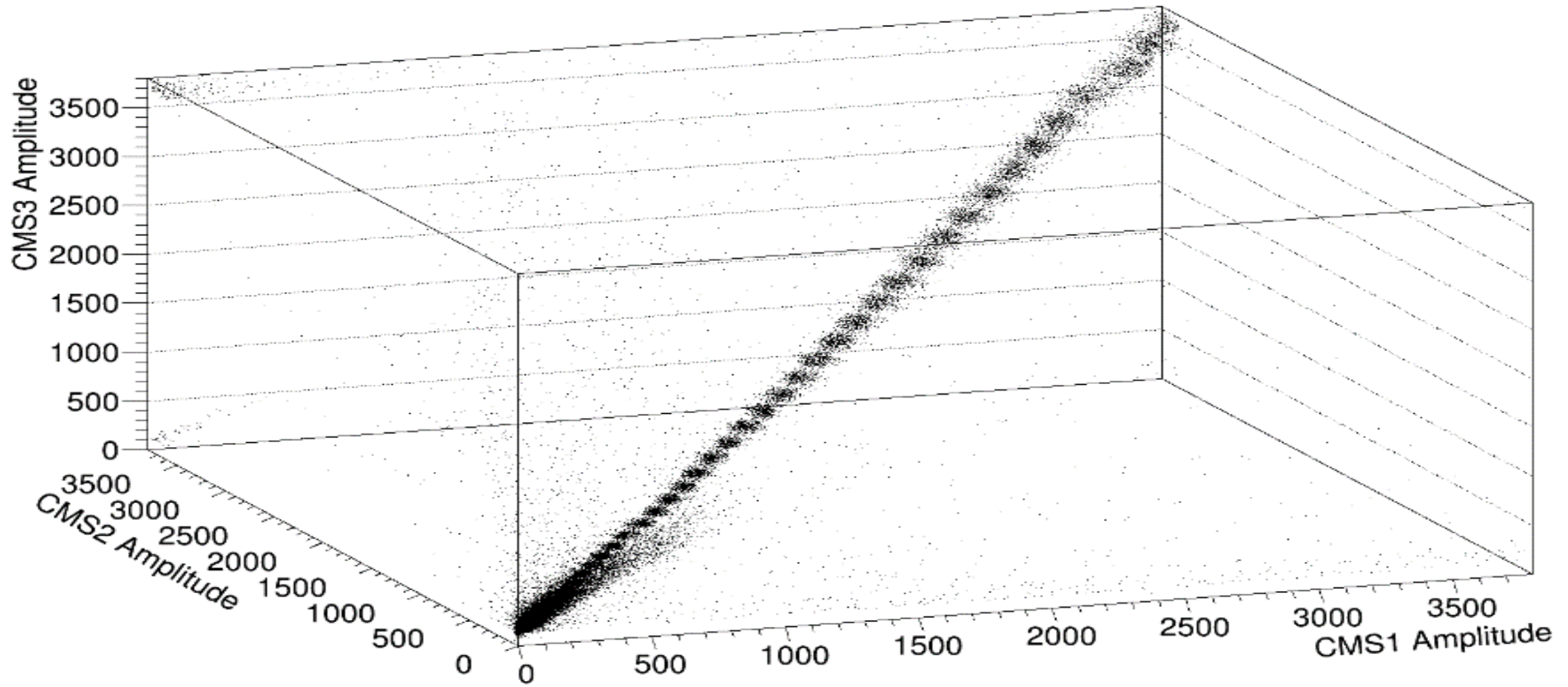
Scintillator detector's with boron



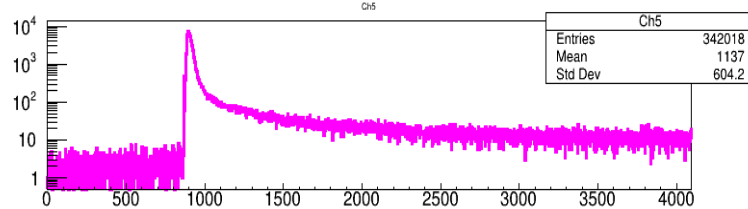
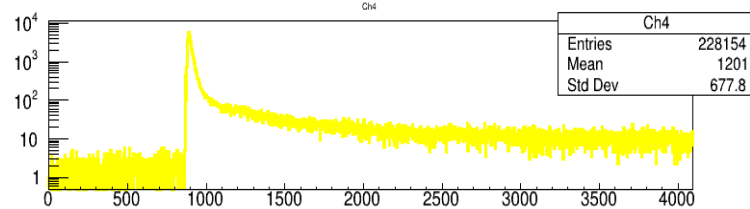
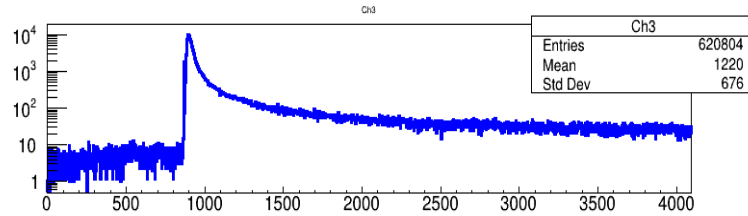
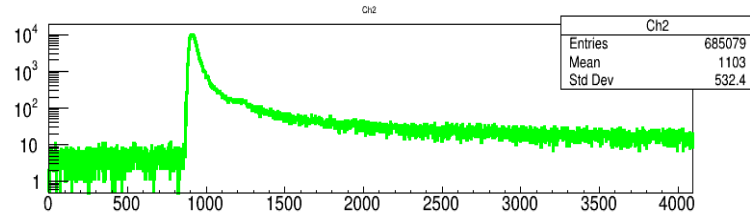
Oscillogram of one event - time dependences of amplitudes with a step of 4 nanoseconds with 4096 clock cycles, recorded in a window of 16 μs . An example of the operation of borated detector channels



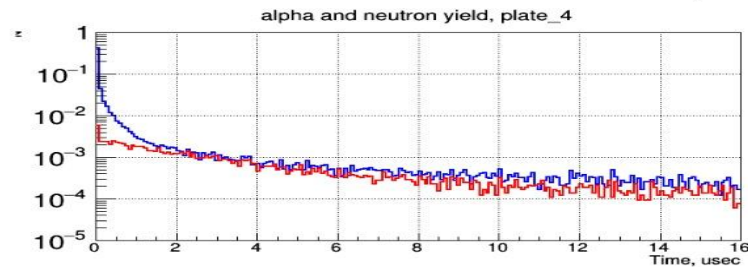
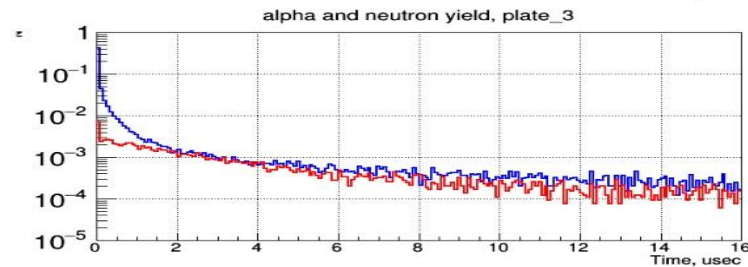
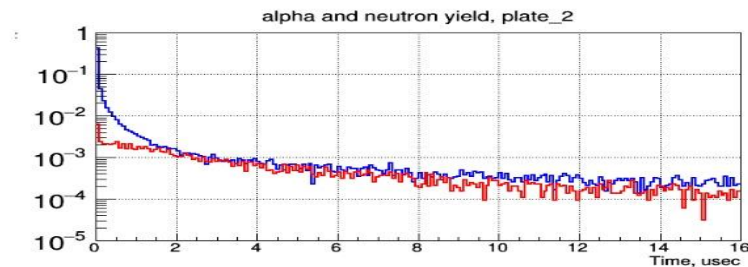
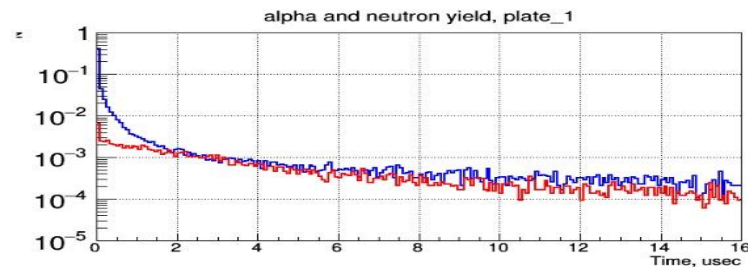
Oscillogram of one event - time dependences of amplitudes with a step of 4 nanoseconds with 4096 clock cycles, recorded in a window of $16\ \mu\text{s}$. An example of the operation of borated detector signal's with signal's of a charge measurement system



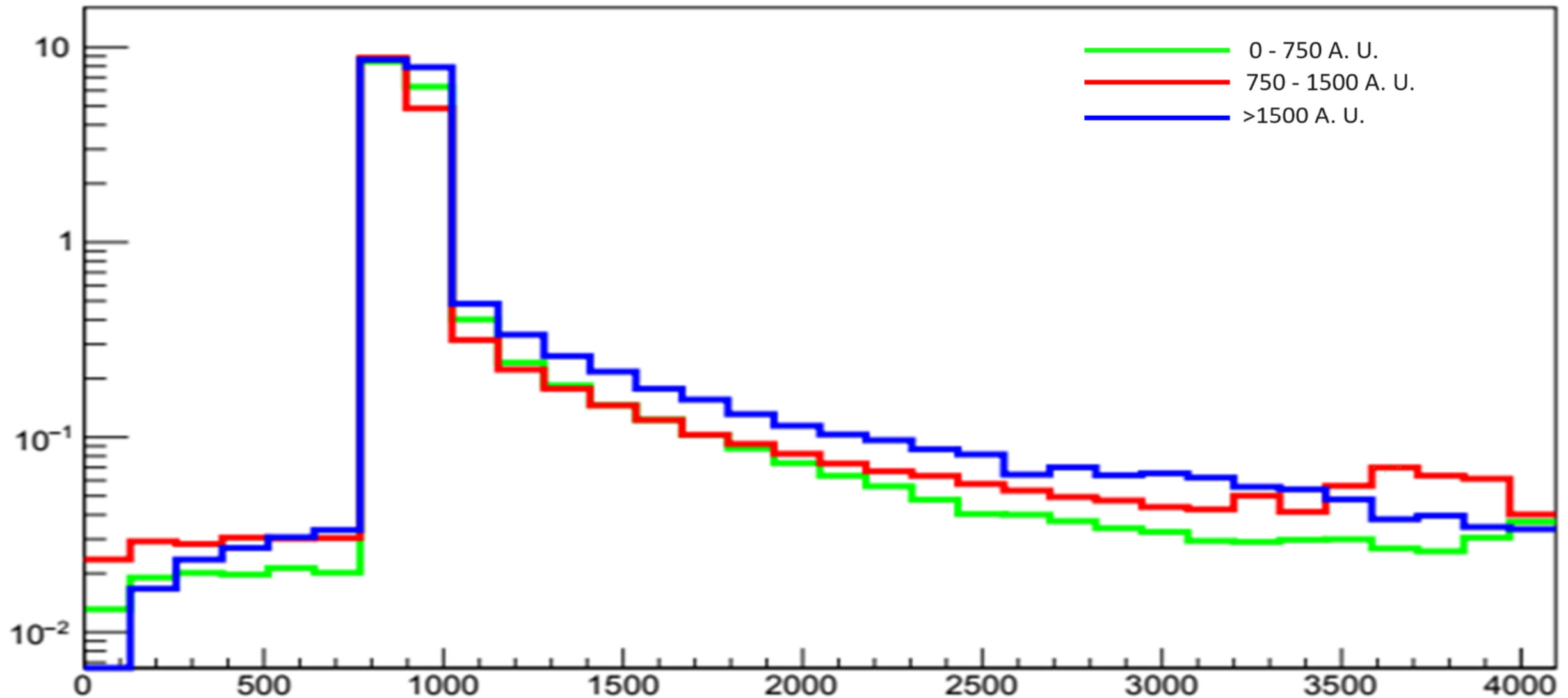
Graph of measuring signal amplitudes of 3 CMS channels



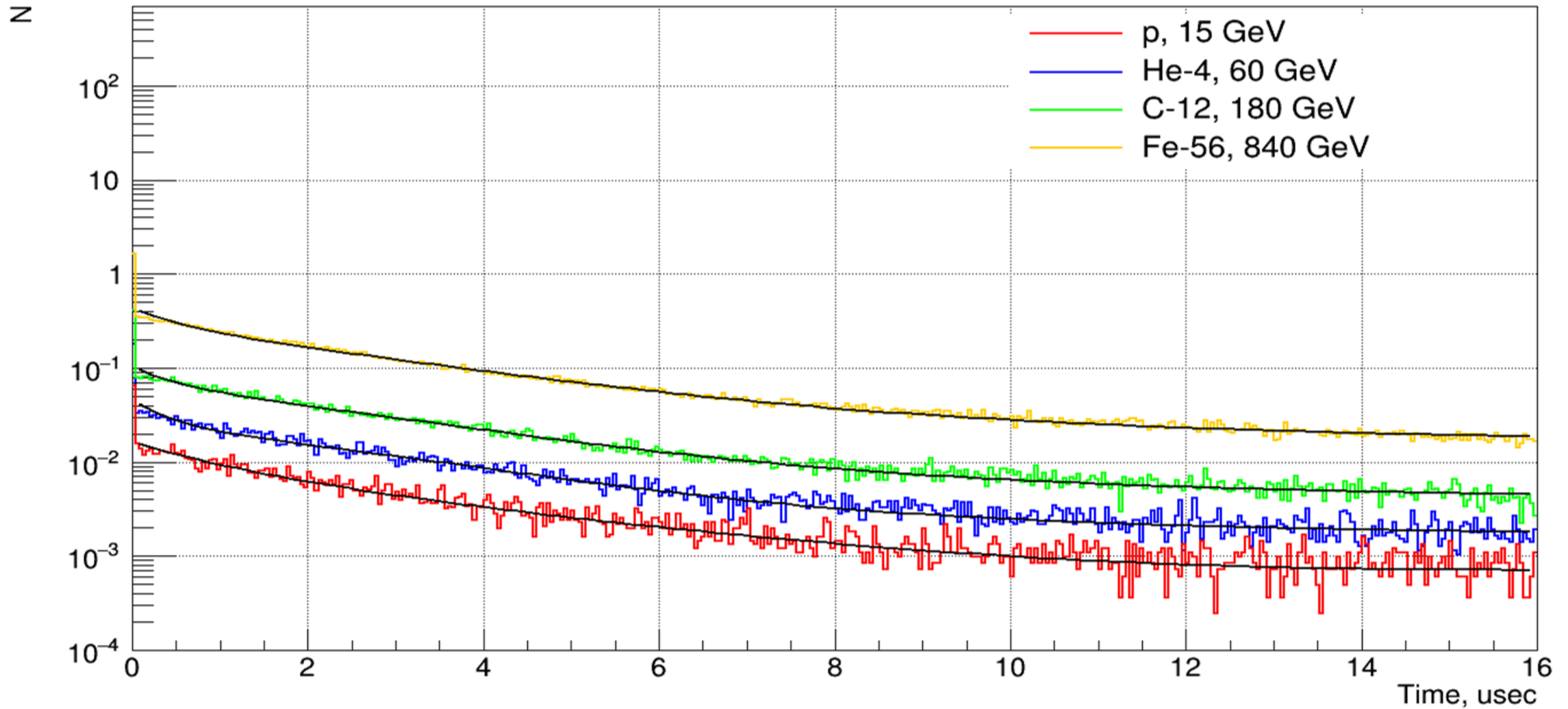
Histograms of plate signals (channels 1-4) - time distributions of alpha particle output in different plates with a step of 4 nanoseconds with a clock cycle of 4096



Histograms of thermal neutrons (blue) and alpha particles (red) hitting borated scintillator plates (1-4) in a Monte Carlo simulation

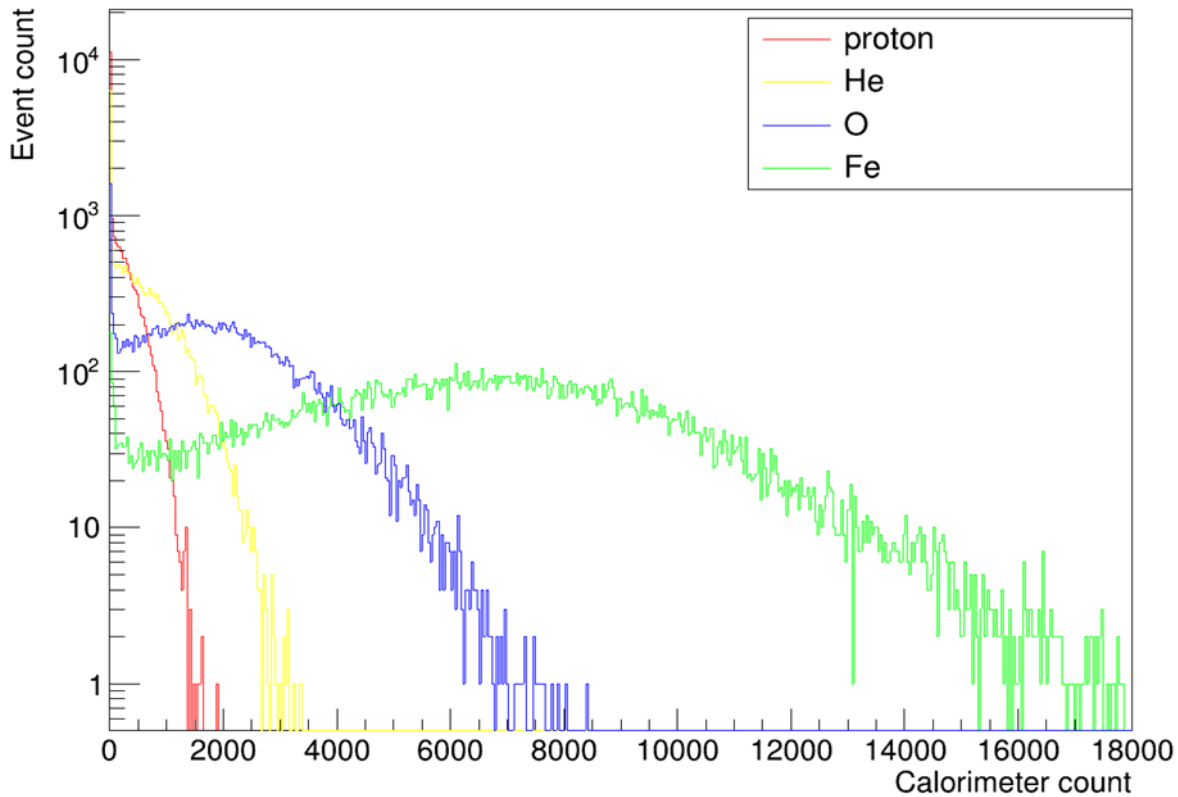


Time dependence of alpha particle yields in borated scintillation detectors. Histograms of different colors: green, red and blue for small, medium and heavy nuclei, respectively. (A. U. $\sim Z^2$)



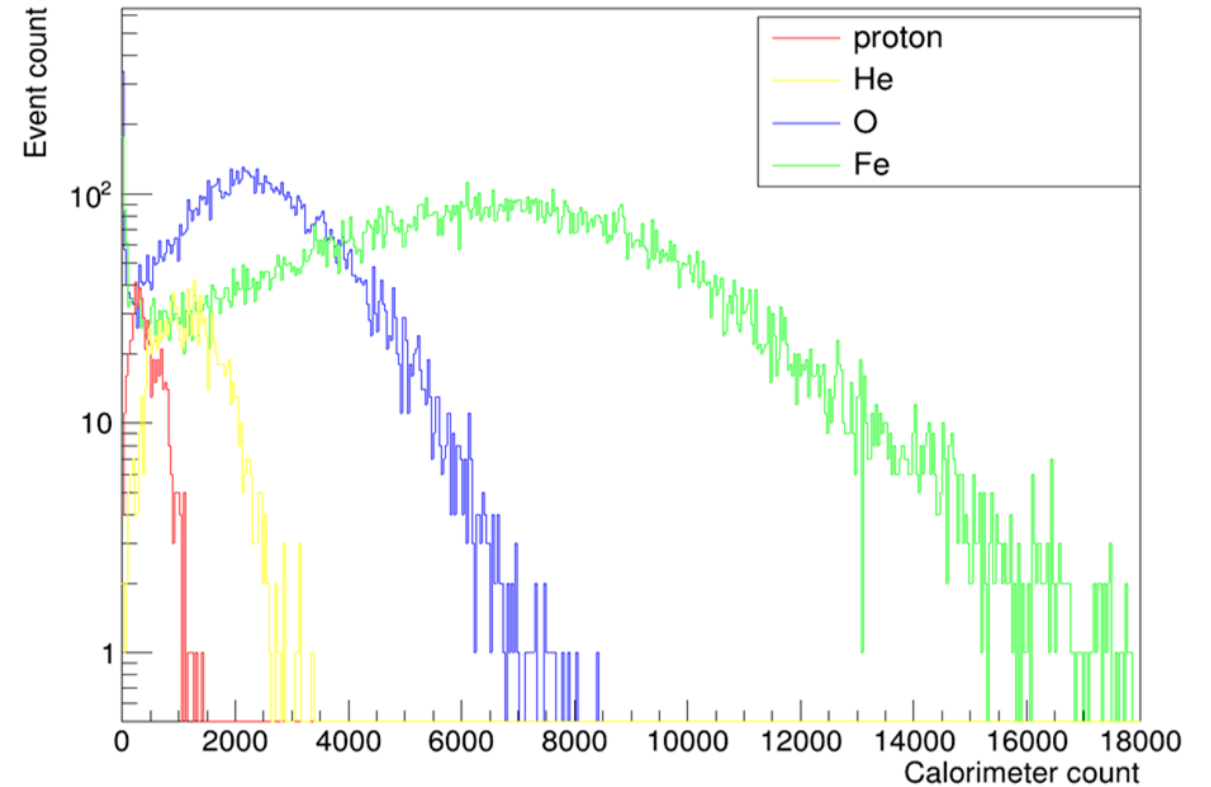
Monte Carlo distribution of alpha particle yield for proton and helium, carbon, iron nuclei

triggercount => 0

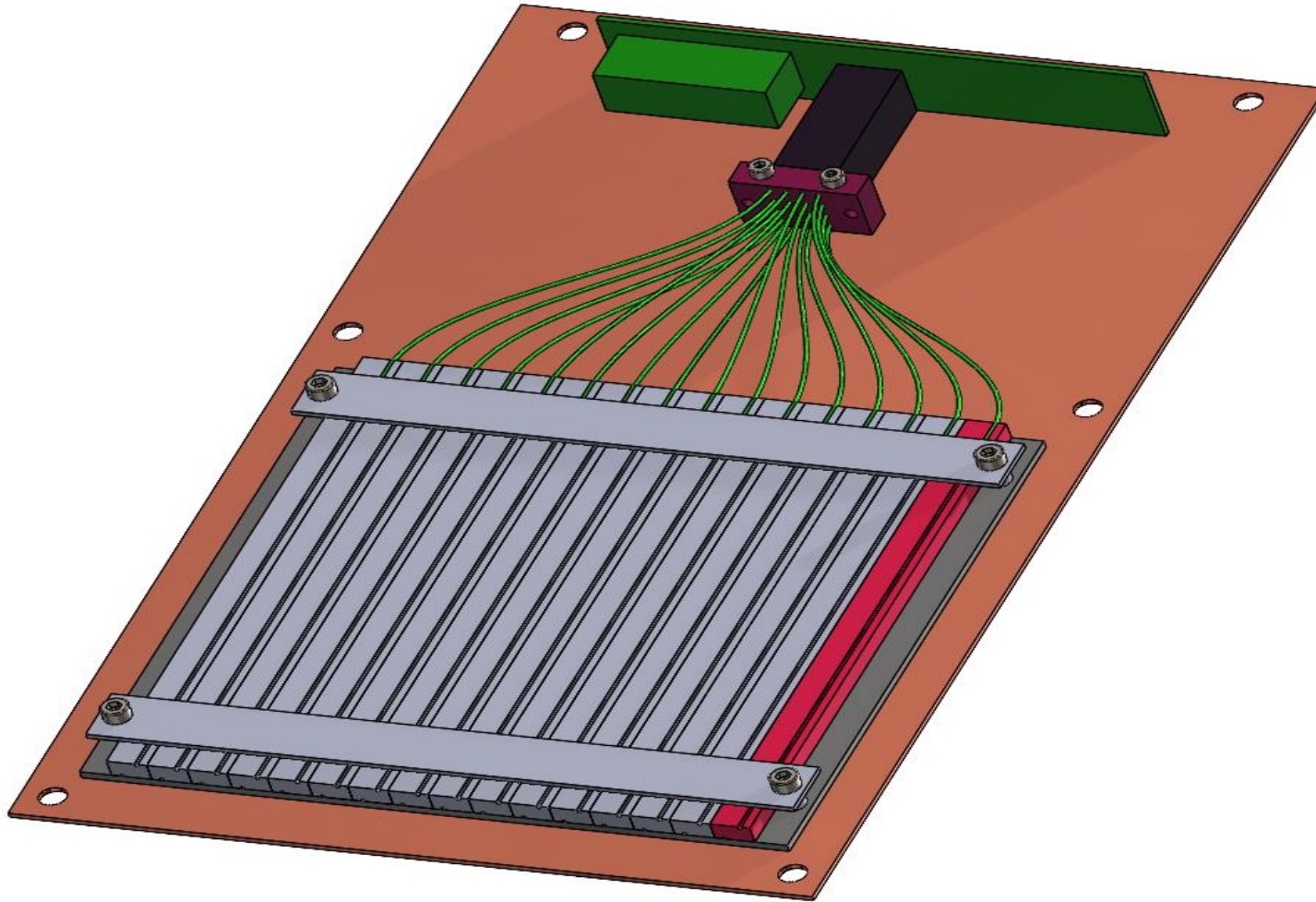


MC simulation of the dependence of the multiplicity of secondary particles in a calorimeter with an increase in the charge of the incident nucleus-fragment during interaction at the primary vertex without the multiplicity condition and energies $E = 15$ GeV/nucleon

triggercount => 20



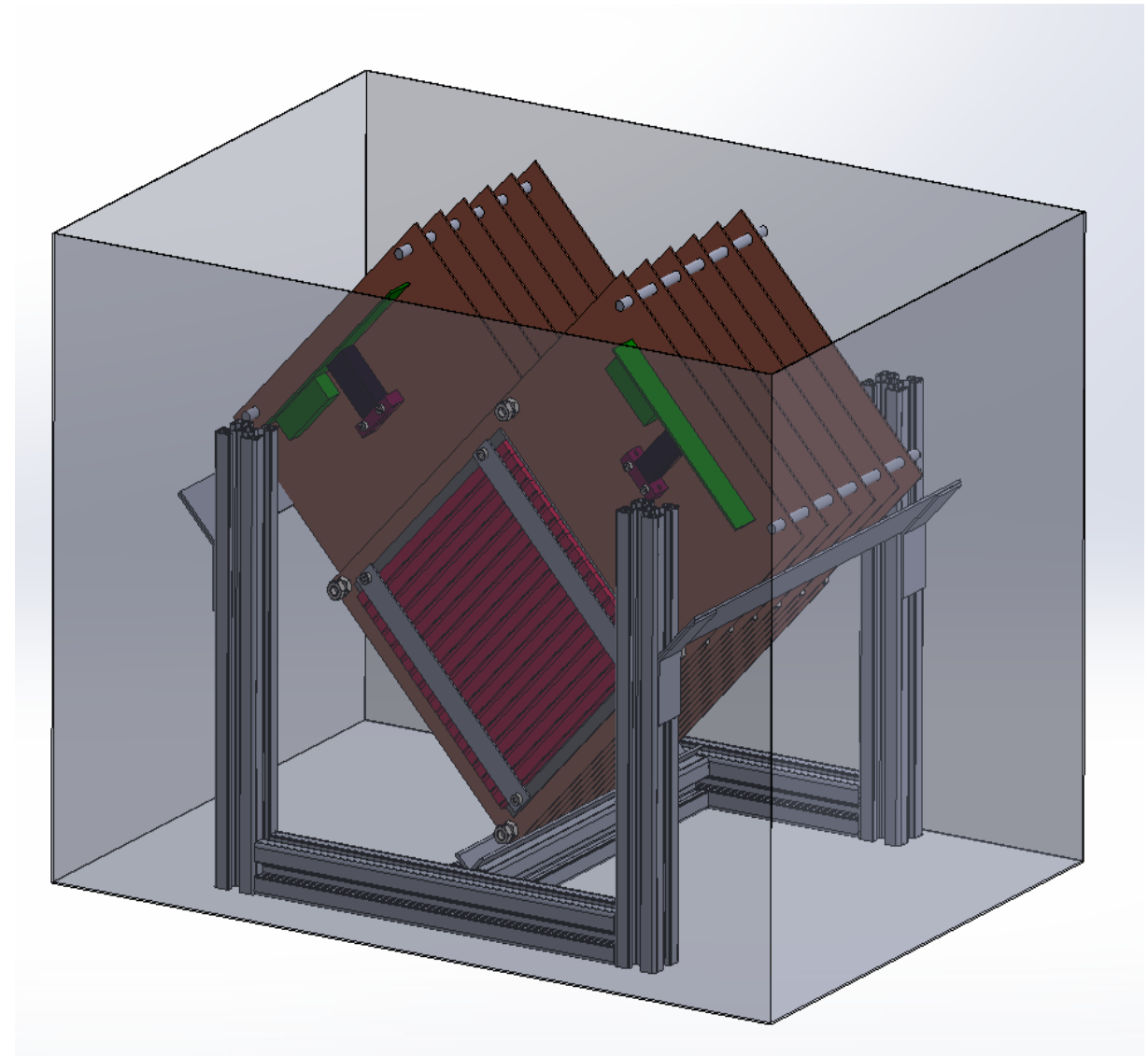
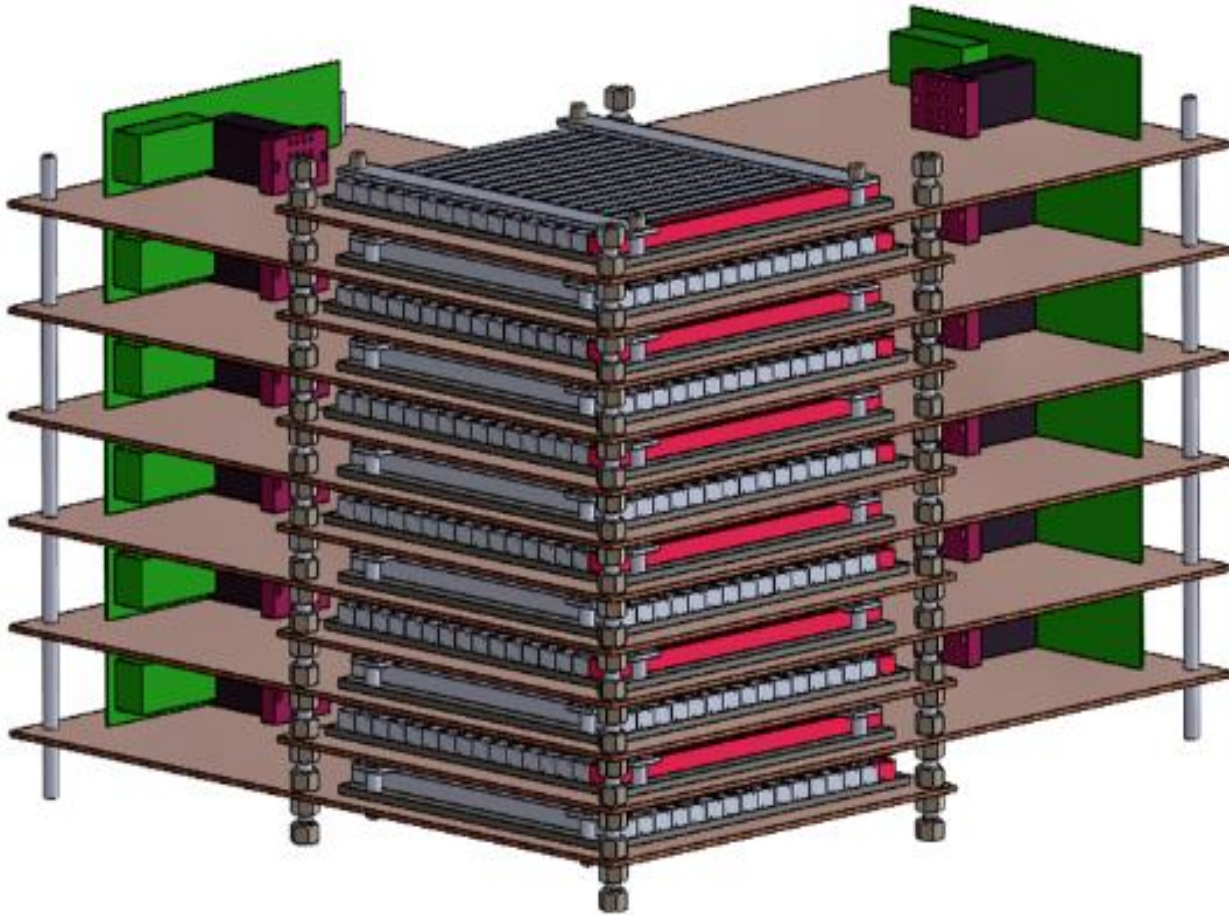
MC simulation of the dependence of the multiplicity of secondary particles in a calorimeter with an increase in the charge of the incident nucleus-fragment at a multiplicity at the primary vertex of at least 20 and energy $E = 15$ GeV/nucleon



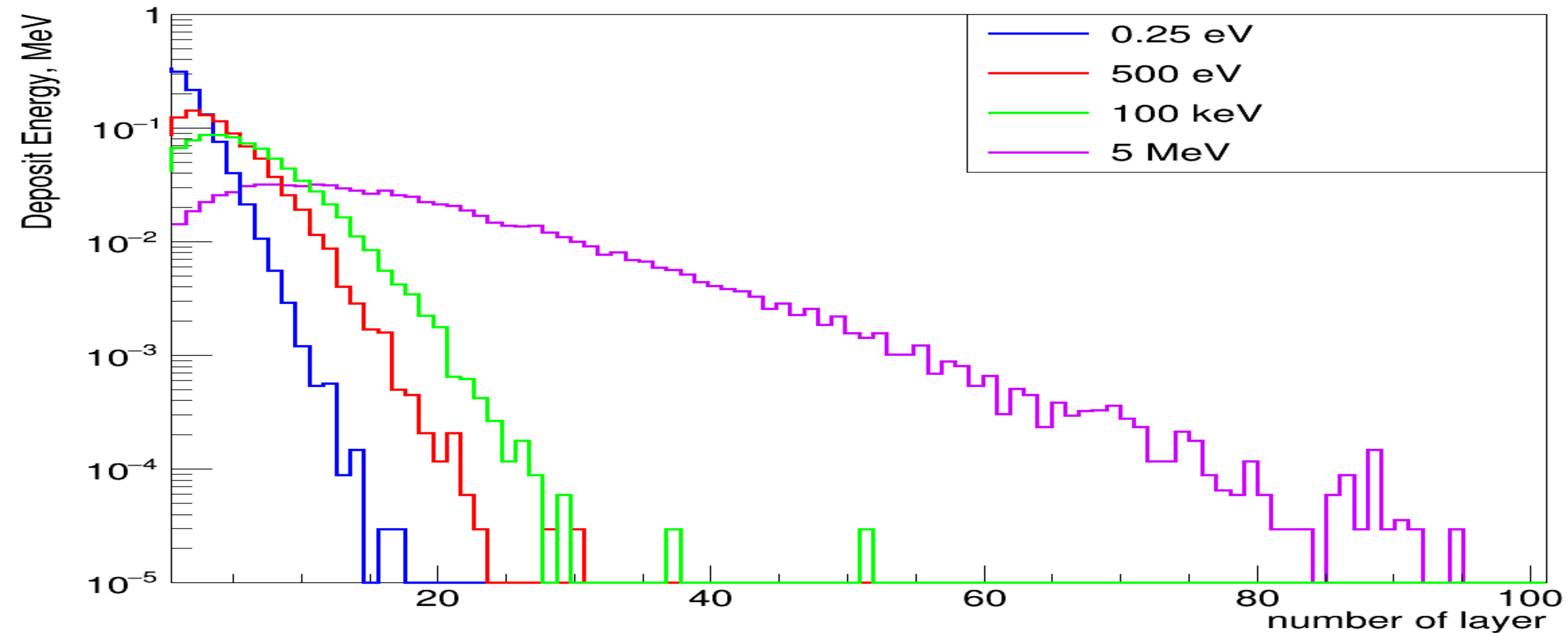
16 strips on plane
Length = 200 mm
Width = 12.5 mm
Thickness = 7 mm
4% boron by weight

Copper thickness = 2 mm
Lead thickness = 3 mm

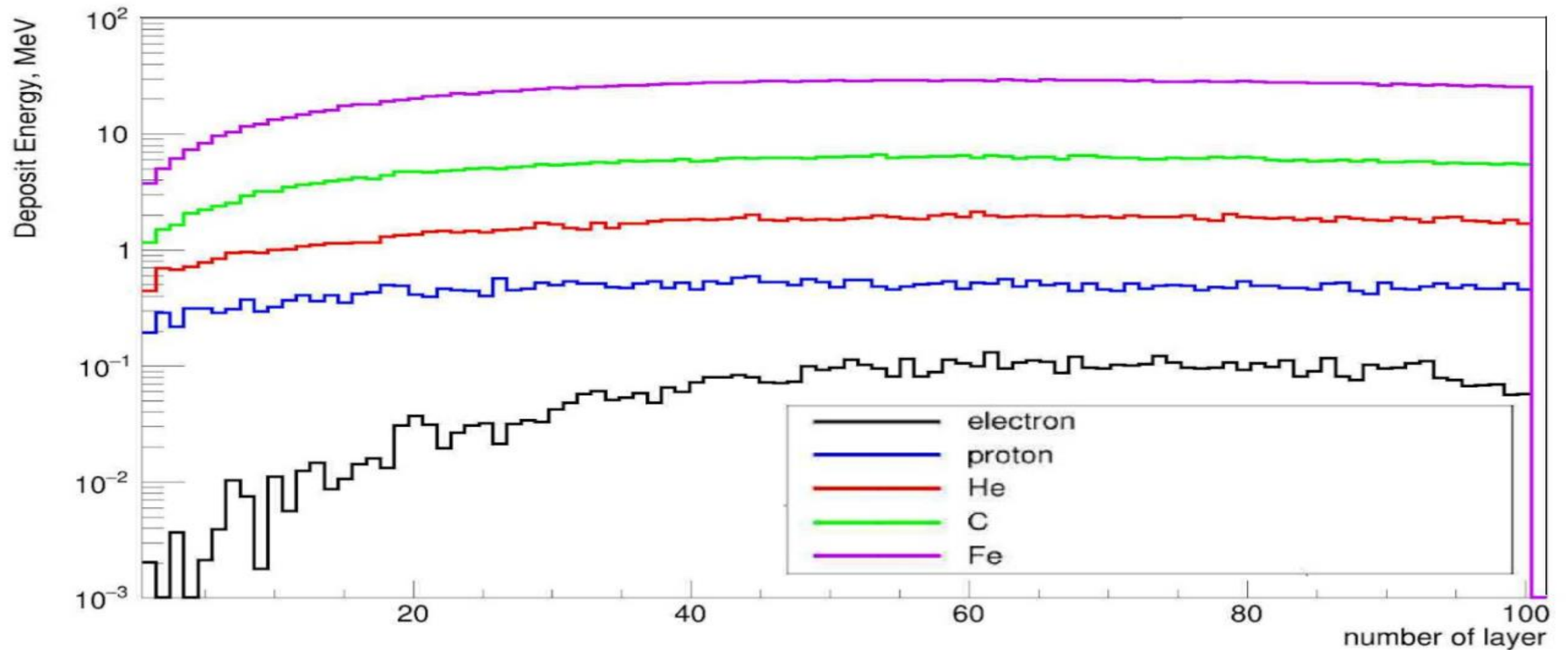
View of one detector of the new prototype of the HERO detector



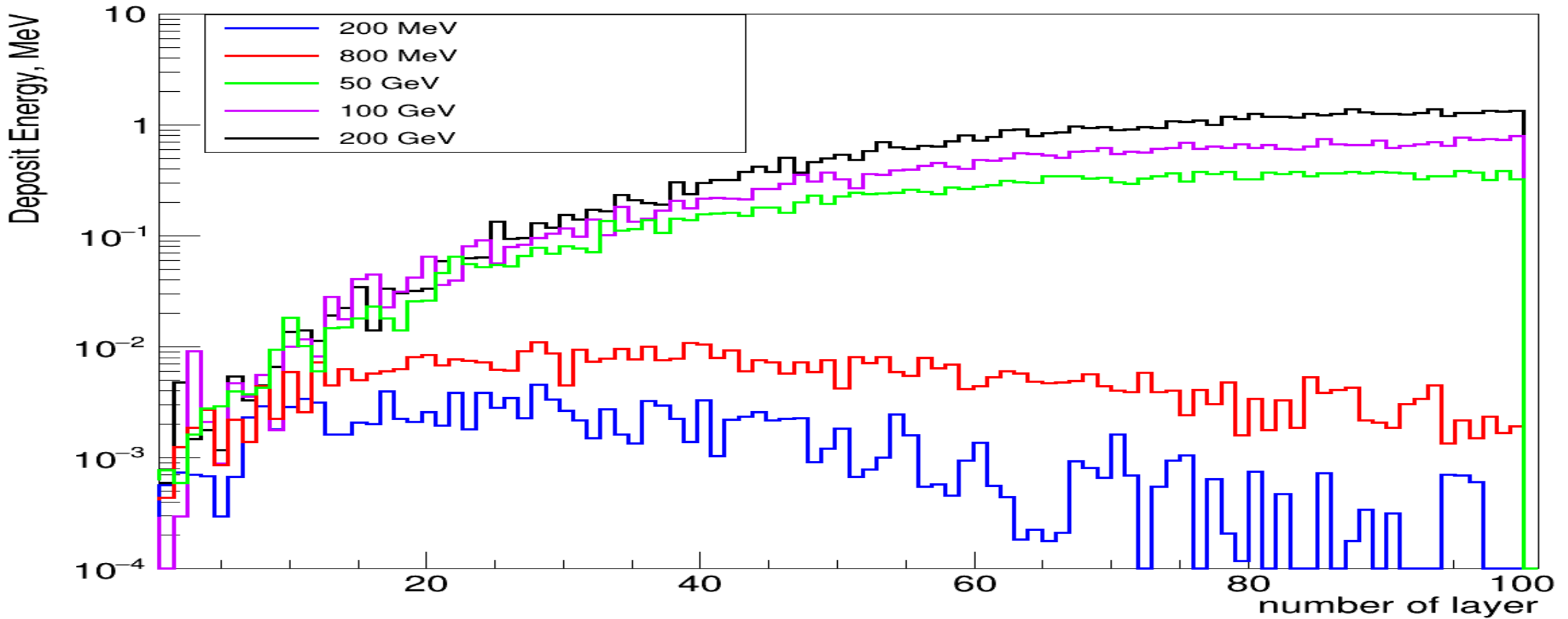
Assembly view of the new prototype of the HERO detector



Histogram comparing energy losses from alpha particles in the layer for neutrons with initial energies of 0.25 eV (blue), 500 eV (red), 100 keV (green) and 5 MeV (magenta). Histograms are normalized to the number of events



Histogram comparing energy losses from alpha particles in the layer for electrons (black), protons (blue), helium nuclei (red), carbon (green) and iron (magenta) with initial energies of 13 GeV/nucleon. Histograms are normalized to the number of events



Histogram comparing energy losses from alpha particles in the layer for electrons with initial energies of 200 MeV (purple), 800 MeV (green), 50 GeV (red), 100 GeV (blue) and 200 GeV (pink). Histograms are normalized to the number of events

Conclusion

- Monte Carlo simulation and test of the prototype HERO detector made it possible to study the effect of boron on the detector's ability to reject between hadronic and electromagnetic events.
- The HERO detector prototype will allow detailed studies of the influence of the signal from alpha particles to discriminate the nuclear and electromagnetic components of radiation both at accelerator beams at JINR and at CERN.
- The space experiment HERO in its characteristics is a “breakthrough” experiment, which for the coming decades will determine the directions of research in the astrophysics of high-energy particles.

Thank you for your attention!

If you have any questions, please contact
karatash@jinr.ru