High energy neutron flux density measurements in ADS systems.

Błażej Głowacki - Faculty of Electrical Engineering, PUT (Poznań)

Mateusz Nowak - Faculty of Technical Physics, PUT (Poznań)

Project supervisor: **Dr Marcin Bielewicz** – JINR (Dubna), NCBJ (Świerk)

The aim of the project

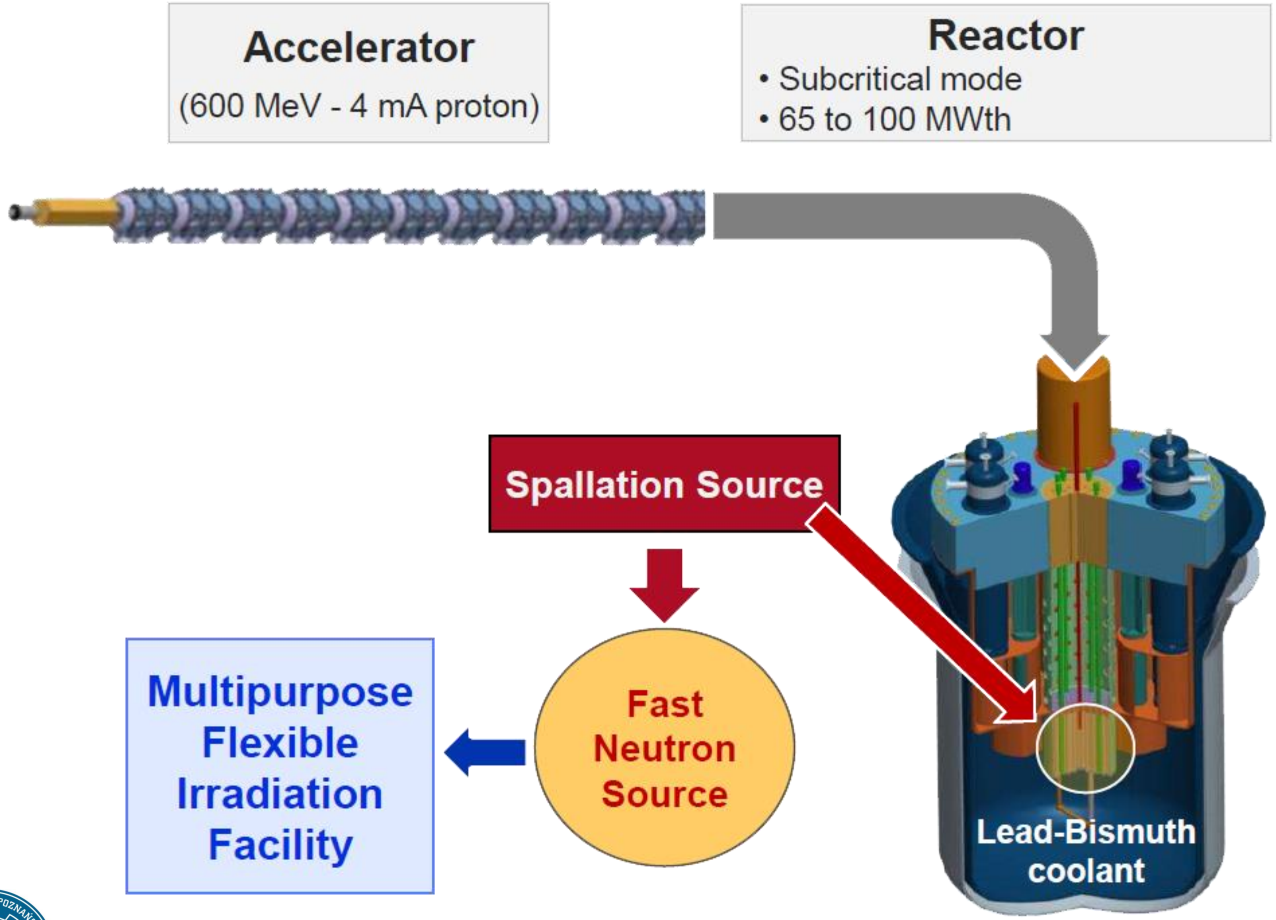
The aim of the project was the research about neutron flux in the experimental assembly based on natural uranium and proton beam from accelerator (’Quinta’ experiment, June 2017).

To gain the knowledge about the neutron flux, a threshold reaction was used. The better knowledge about neutron flux density could be useful to constructing the fourth generation and accelerator-driven subcritical nuclear rectors.

Table of content

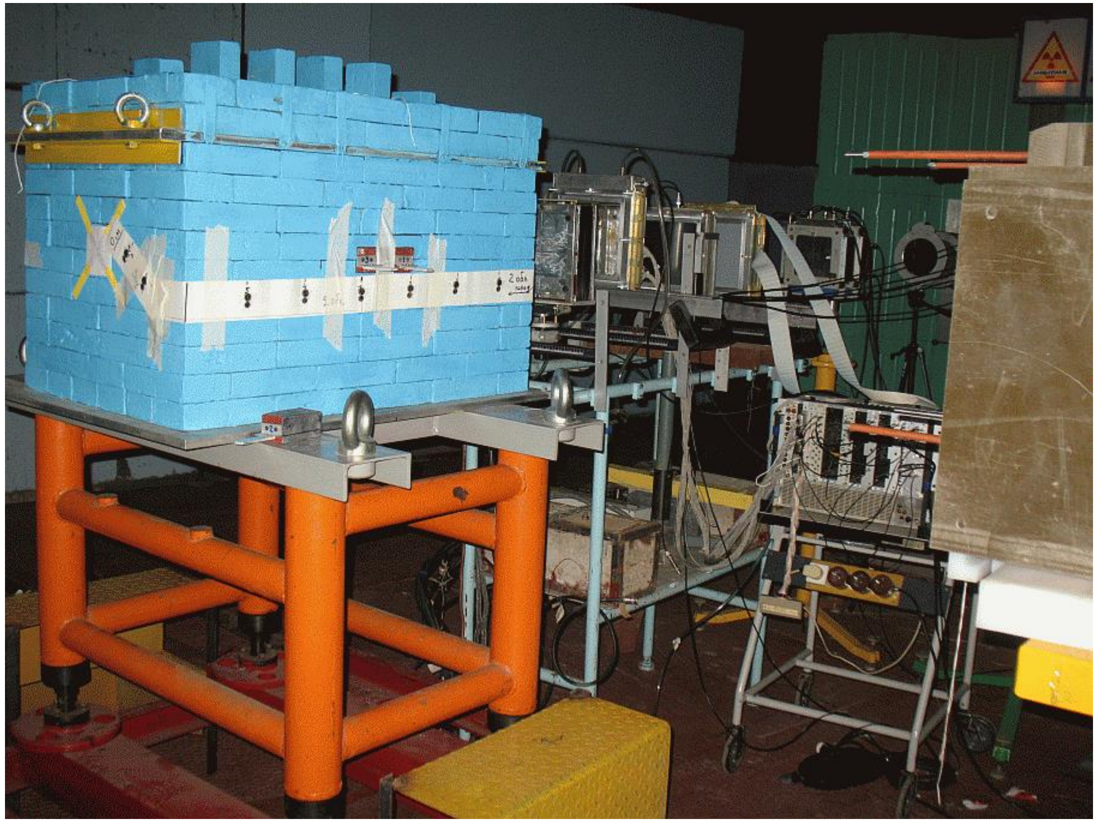
- The idea behind Accelerator-Driven Systems (ADS),
- ’Quinta’ experiment description, construction of an experimental set,
- Measurement of gamma rays by High-purity Germanium Detectors (HPGe) ,
- Energy calibration and spectres analysis using „Deimos” software,
- Calibration formula and results for isotopes production for B parameter,
- Calculations for average neutron flux,
- Conclusions.

Accelerator-Driven System (ADS)



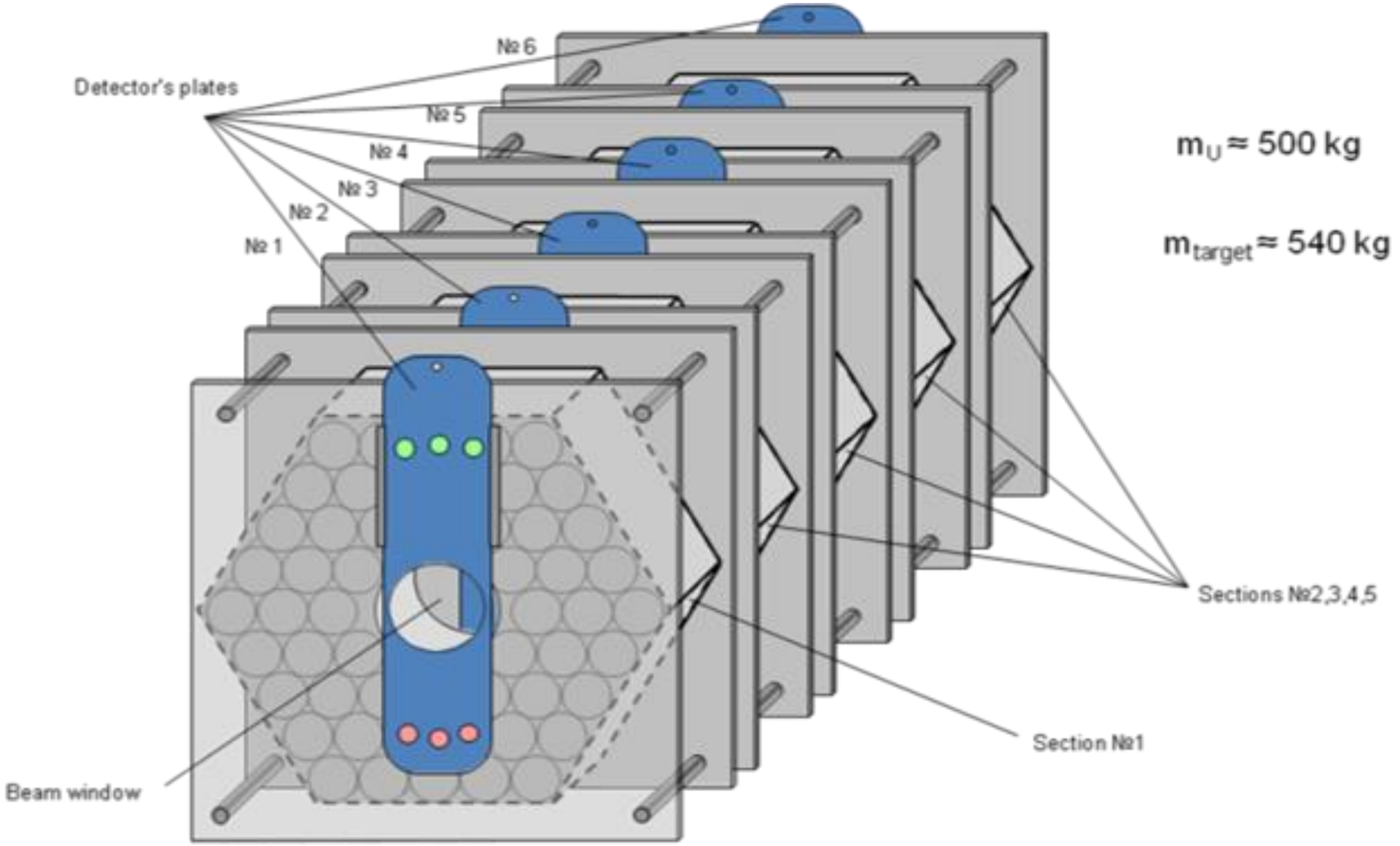
ADS concept.

’Quinta’ Experiment



’Quinta’ experimental set with lead shielding and the ’Quinta’ assembly, with visible separated sections.

'Quinta' Experiment

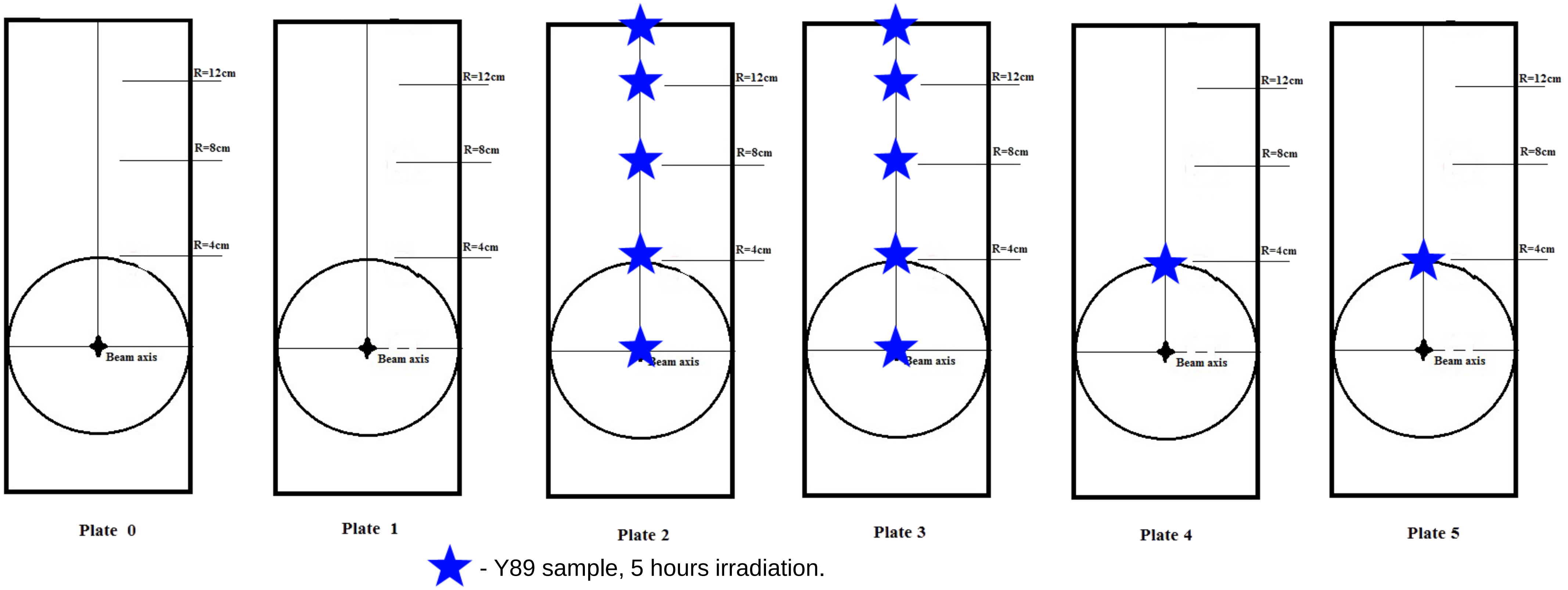


$m_U \approx 500$ kg

$m_{target} \approx 540$ kg

The 'Quinta' assembly, with visible separated sections and marked measurement positions – plates.

’Quinta’ Experiment

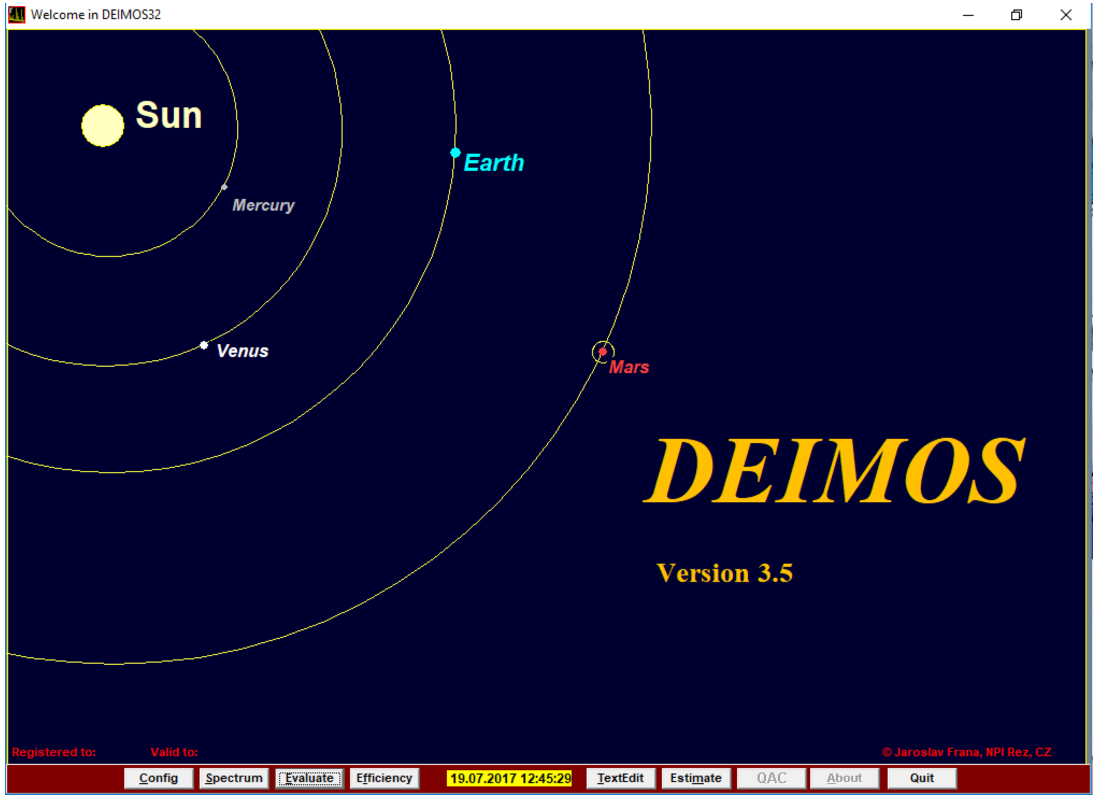


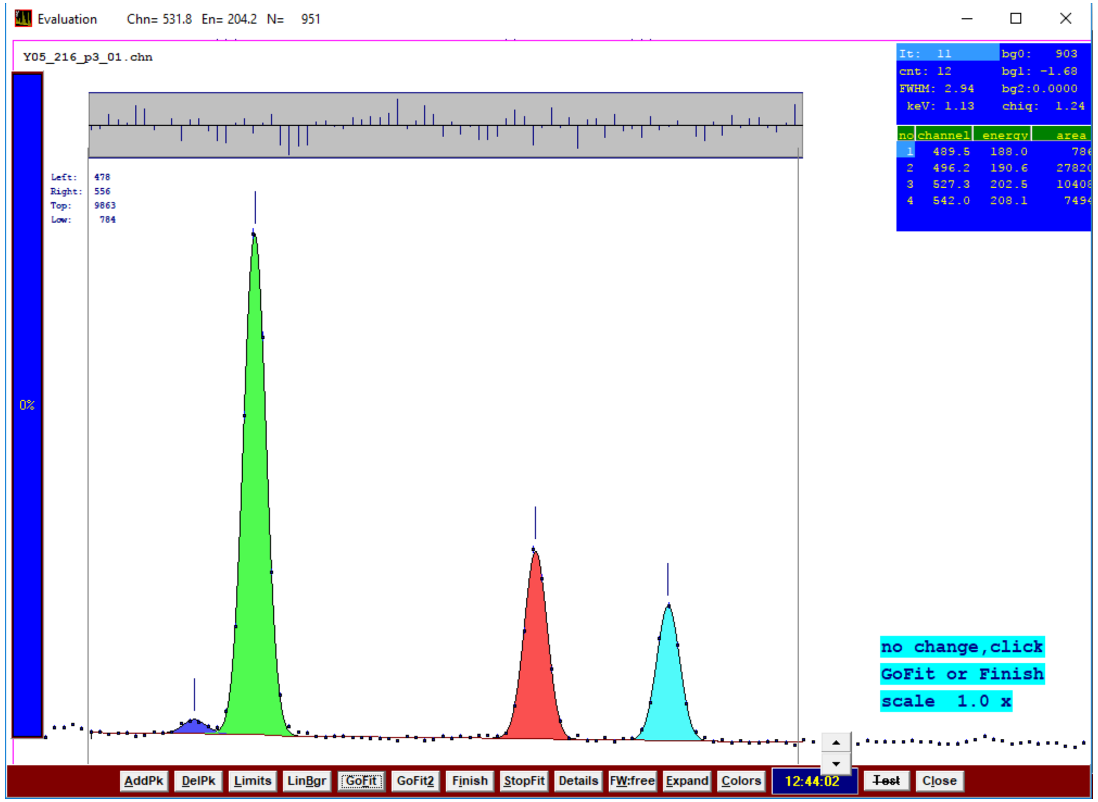
Positions of specified samples inside the ’Quinta’ assembly during the experiment.

Measurement of gamma rays by HPGe detector

HPGe with visible cooling and shielding, samples instaled on measuring possitions inside the detector.

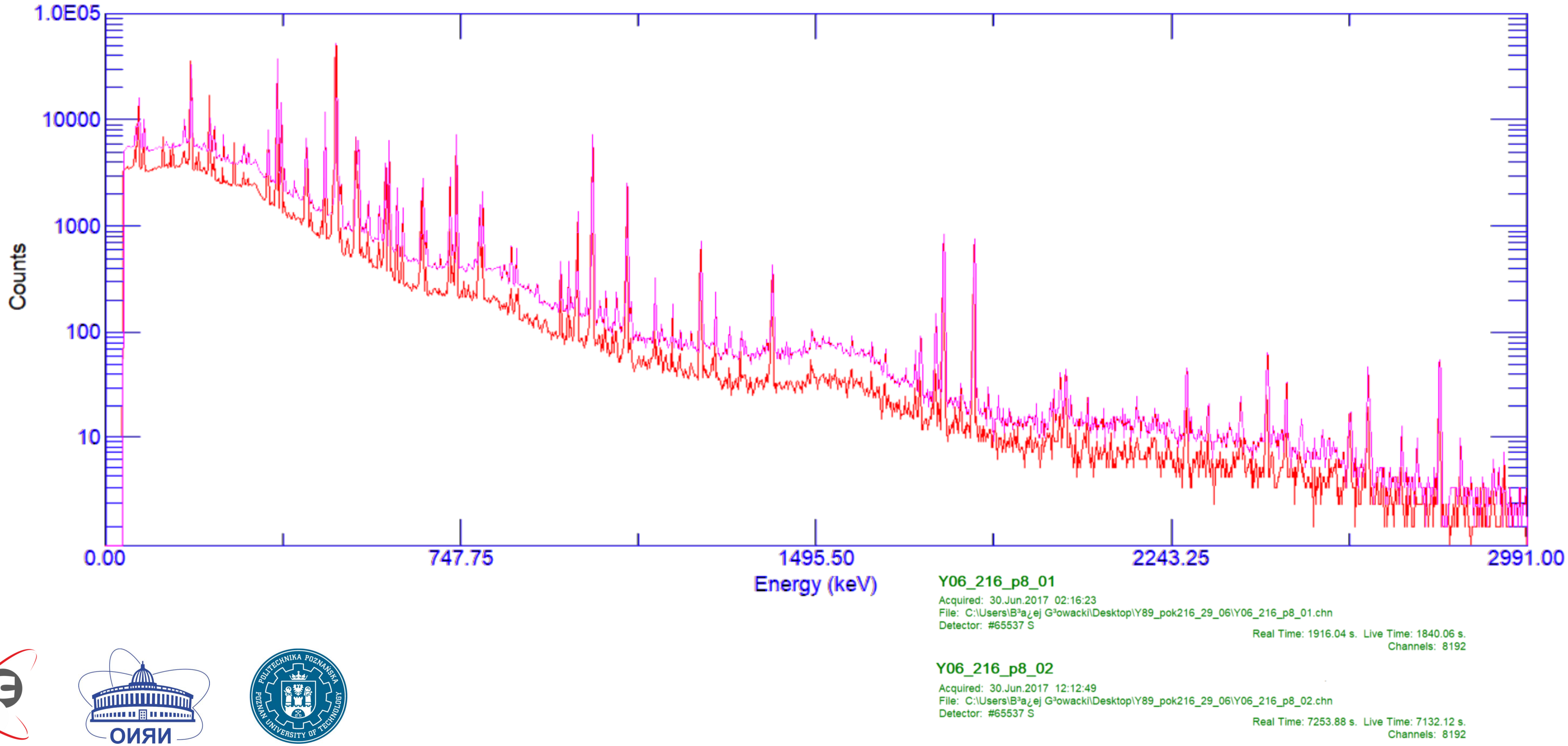
Energy calibration and spectres analysis using „Deimos” software





Screenshots from Deimos software – start screen and a part of analised spectre.

Measurement of gamma rays by HPGe detector



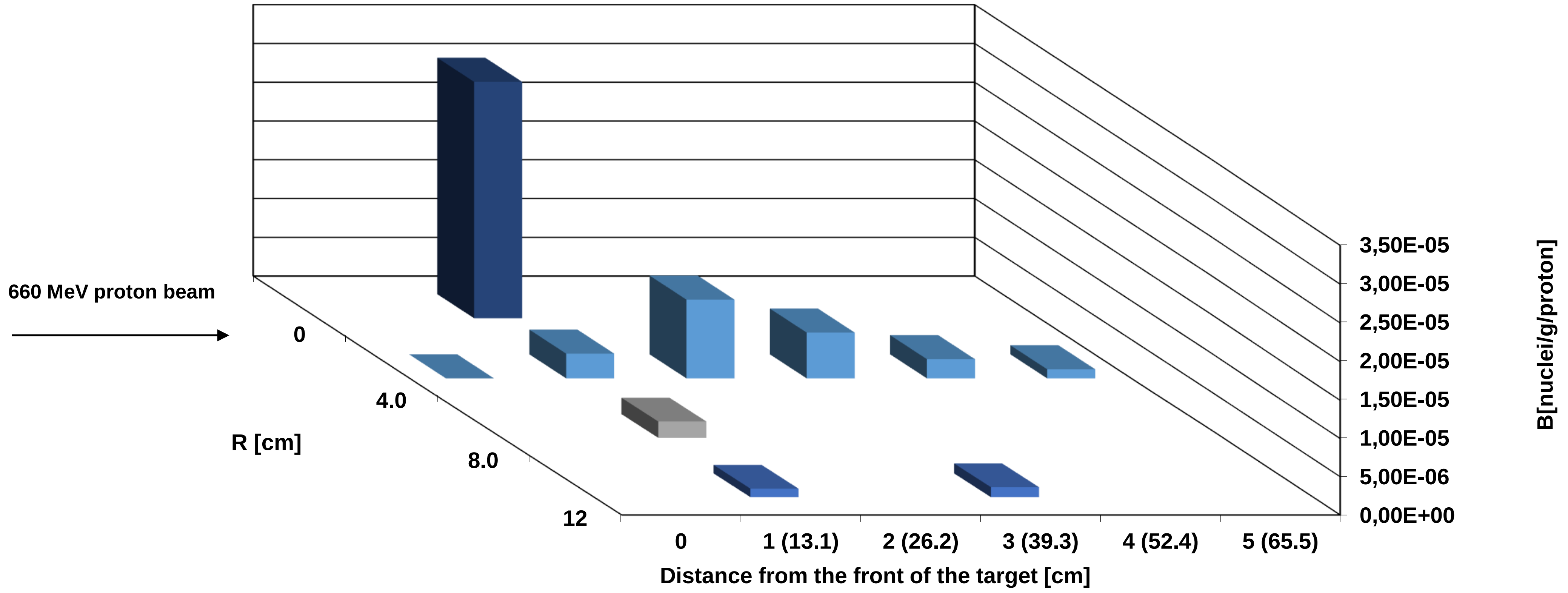
Calibration formula and results for isotopes production - B parameter

$$B = N_1 \cdot \frac{1}{m \cdot I} \cdot \frac{\Delta S(G) \cdot \Delta D(E)}{\frac{N_{abs}}{100} \cdot \varepsilon_p(E) \cdot COI(E,G)} \cdot \frac{(\lambda \cdot t_{ira})}{[1-\exp(-\lambda \cdot t_{ira})]} \cdot \exp(\lambda \cdot t_{+}) \cdot \frac{\frac{t_{real}}{t_{live}}}{[1-\exp(-\lambda \cdot t_{real})]}$$

(a) (b) (c) (d) (e)

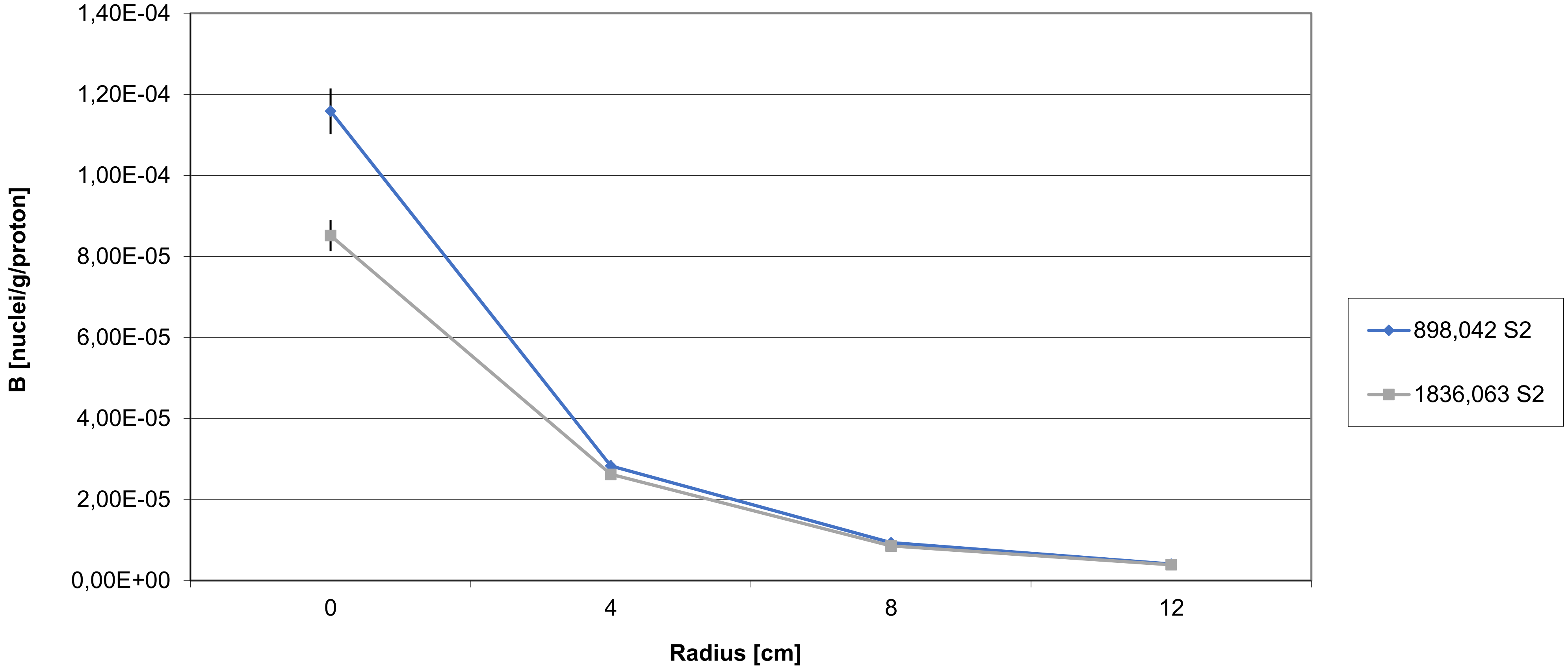
a) B parameter normalization (includes mass of the sample, peak area and total number of particles - protons)
b) all correction except parts with time calibration
c) time of experiment calibration
d) calibration considering time between experiment and measurement gamma rays
e) time of measurement gamma rays calibration

Calibration formula and results for isotopes production - B parameter



Results for isotopes production for B parameter. Spacial distribution for isotope Y-89 Y89(n,3n)Y87

Calibration formula and results for isotopes production - B parameter



Results for isotopes production for B parameter. Spacial distribution for isotope Y-89 Y89(n,3n)Y87

Calculations for average neutron flux

$$\bar{\phi} = \frac{B^{y}\ S\ G}{\bar{\sigma}\ A\ t}\quad [1/\mathrm{cm}^2\cdot\mathrm{s}]$$

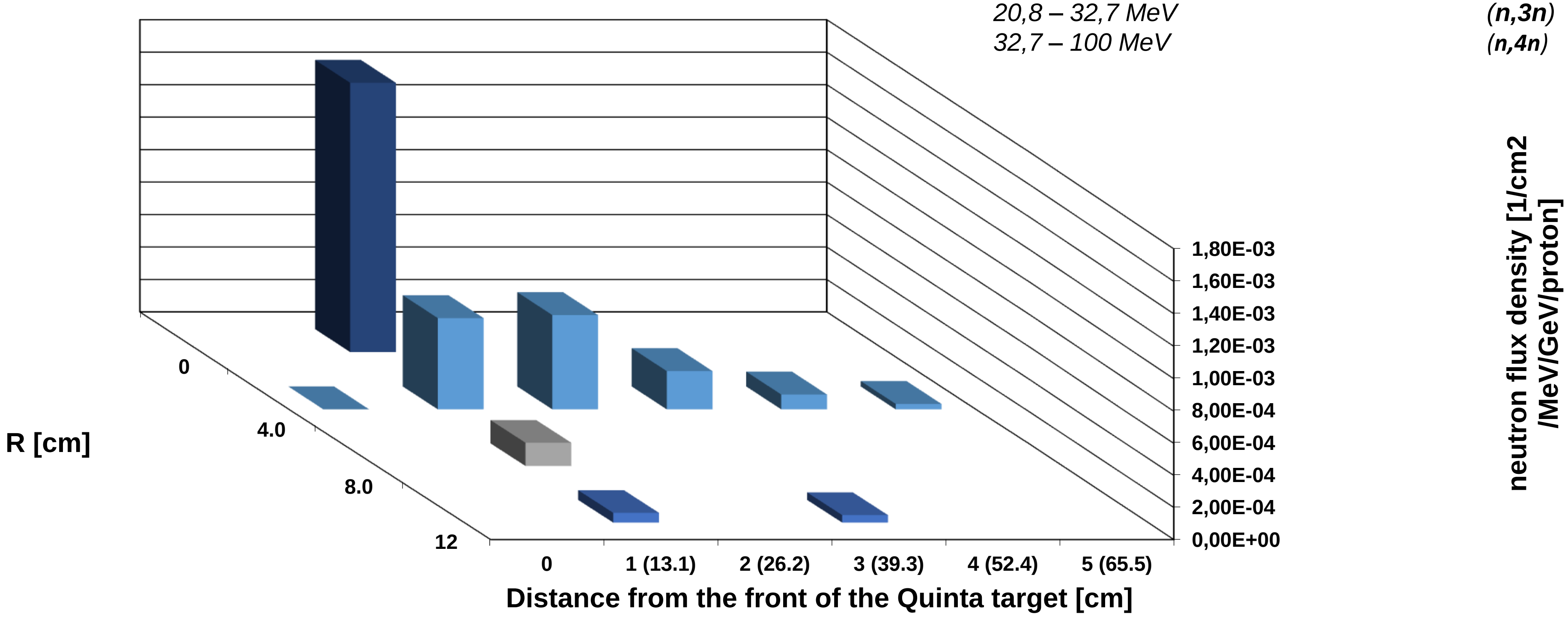
a) B^y - parameter B for the isotope
b) S – total number of protons from accelerator, which incide on the detector during the experiment
c) A - Avogadro constans
d) t – time of irradiation [s]
e) σ – average cross-section for reaction (n,xn) in particular energy range [barn]
f) G – gramoatom for the isotope

Calculations for average neutron flux

We divided energy range into 3 parts because of threshold reactions.

11,5 – 20,8 MeV *(**n,2n**)*
20,8 – 32,7 MeV *(**n,3n**)*
32,7 – 100 MeV *(**n,4n**)*

660 MeV proton beam



Average neutron flux density for the energy range 11,5 to 20,8 MeV

Conclusions

- The aim of the project was the research about neutron flux in the experimental assembly based on natural uranium and proton beam from accelerator ('Quinta' experiment in june 2017).
- The better knowledge about neutron flux density could be useful to constructing the fourth generation and accelerator-driven subcritical nuclear rectors.
- Parameters of experimental assembly were very similar to conditions expected in the ADS reactors,
- The average neutron flux density in experimental assembly was assign after calculations basing on isotopes production during the experiment.

Thank you for your attention