Two years of iDREAM antineutrino data-taking at Kalinin NPP.

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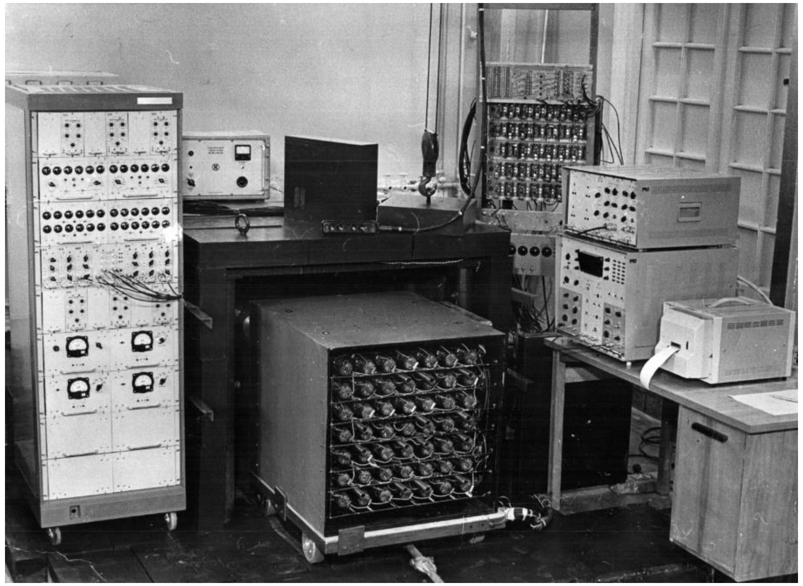
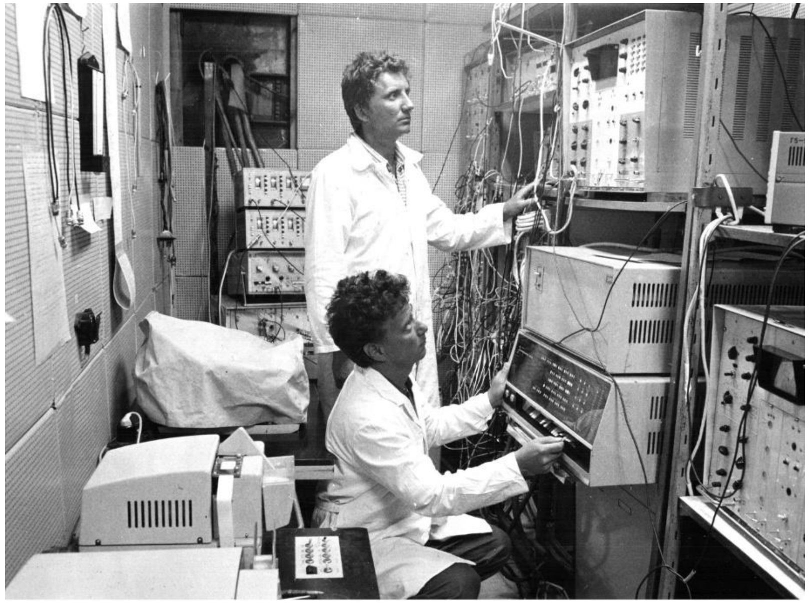
NATIONAL RESEARCH CENTER "KURCHATOV INSTITUTE"

Historic reference

- First observation of the antineutrino has occurred 60 years ago;
- For the first time the antineutrino method for reactor monitoring has been suggested 40 years ago. The fuel isotopic evolution of the active zone leads to:
  - Changes in antineutrino flux;
  - Changes in antineutrino spectrum.
- Many proof-of-principle experiments were carried out. The first one was the ROVNO experiment more than 30 years ago.
- The quantitative studies are necessary within nuclear safeguards framework.



ROVNO antineutrino detector



ROVNO counting room

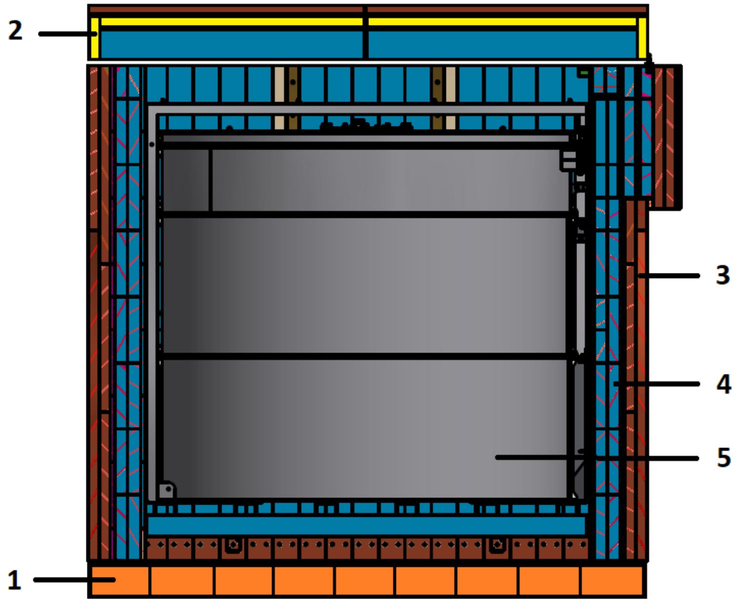
The iDREAMs aims

- Key goal:
  - Build the industrial neutrino detector for the applied researches based on the proven technologies with the simple design for replicating;
  - Implement complementary non-intrusive neutrino-based tool for the monitoring of the reactor state and the estimation of the accumulated fissile materials;

➢ Gain experience, studying new materials and solutions for future industrial neutrino detectors, and provide them to Russian power units, including floating power plants;

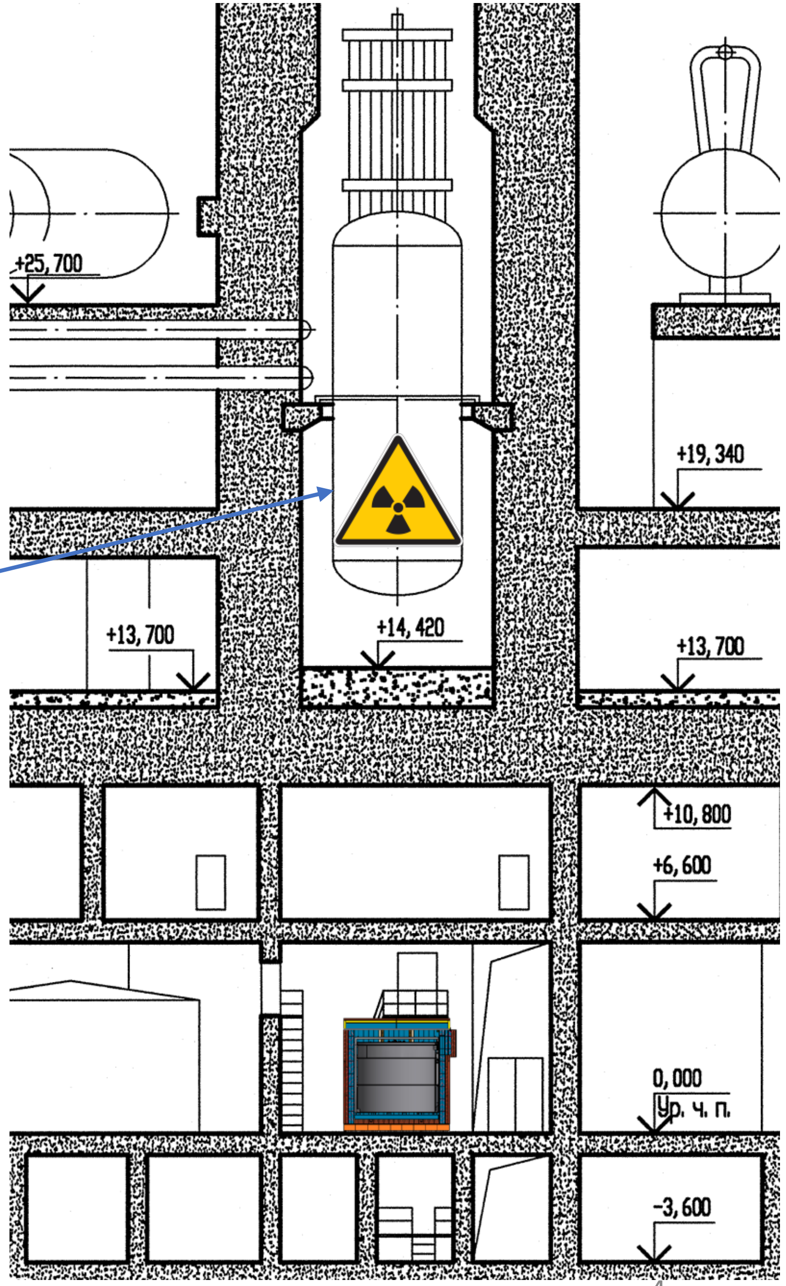
➢ Move towards precision measurements of the nuclear fuel burn-up.

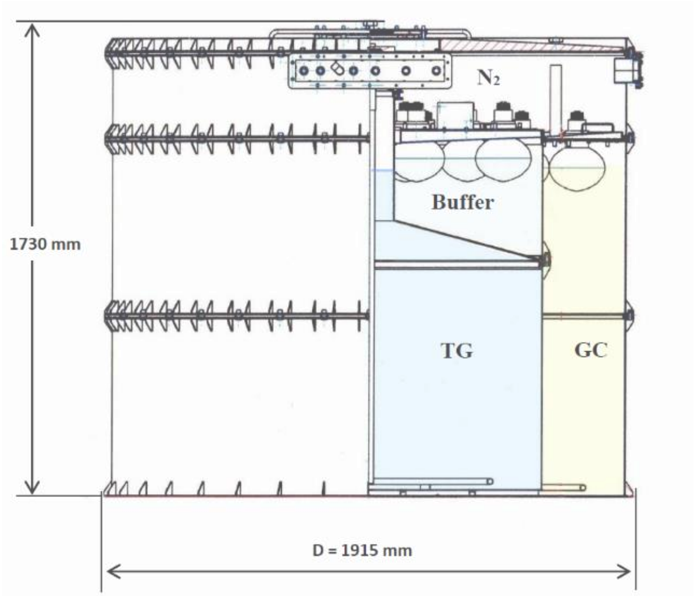
Experimental cite



1 (orange) – cast iron (14 cm)
2 (yellow) – lead (5 cm)
3 (brown) – pure p/e (10 cm)
4 (blue) – borated p/e (16 cm)
5 – detector

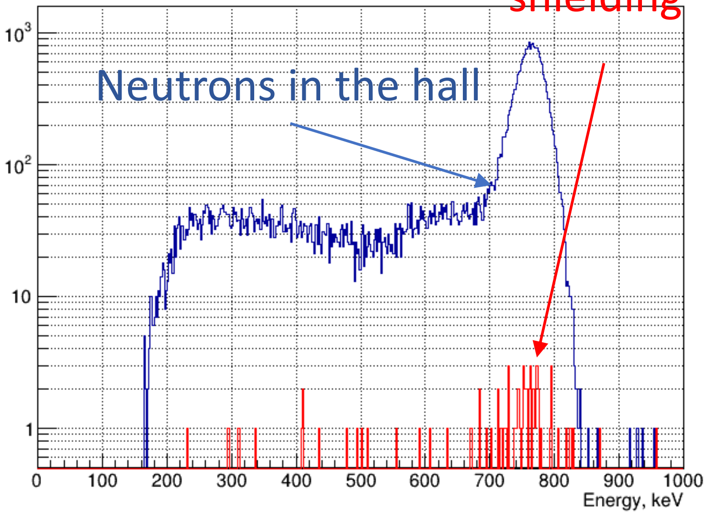
3 GW_{th} VVER type power reactor core (KNPP 3rd unit, Russia)

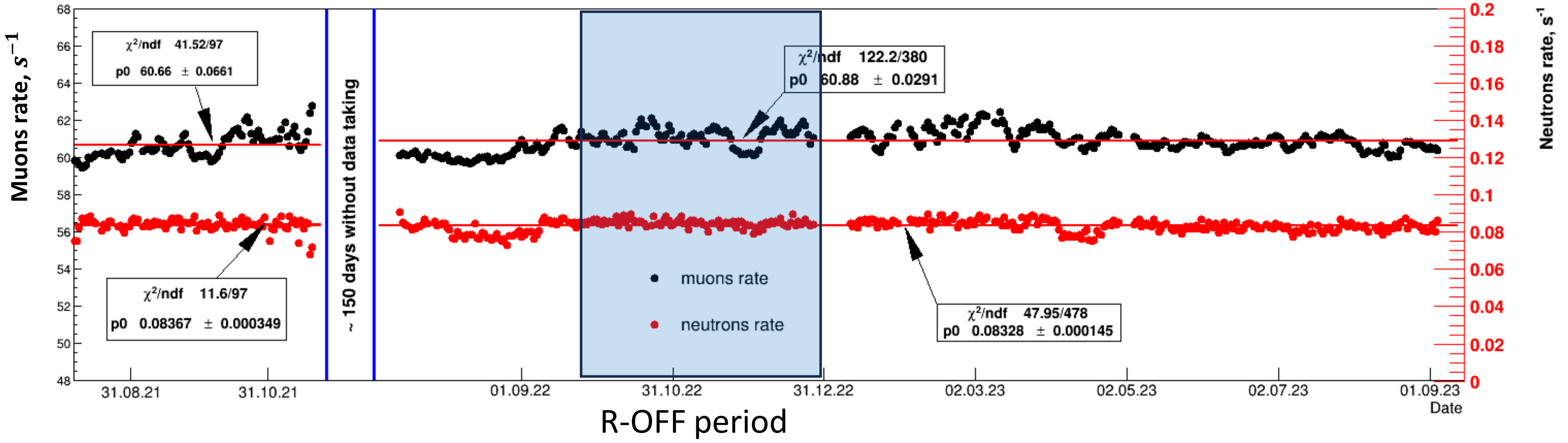




- Target (TG) – Gd-LS (1 g/l) in an inner SS tank, 1 m^3
- G-catcher (GC) – LS w/o Gd in an external SS tank, 1.8 m^3
- Buffer – pure LAB, 0.5 m^3
- 16 R5912 PMTs in the TG, 12 in the GC
- Two muon veto plates on top

Background in the laboratory

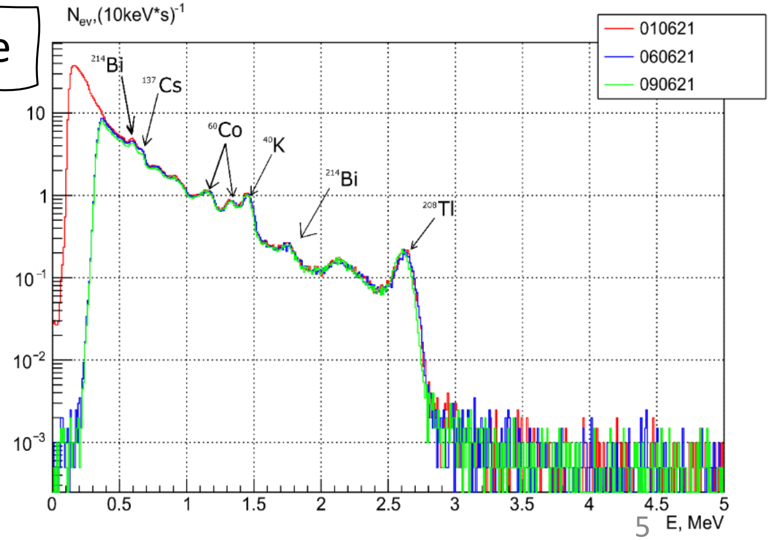




Muons & **cosmogenic neutrons** rate

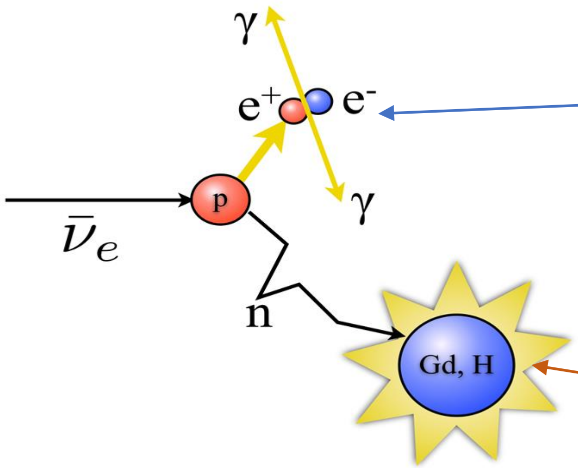
Factor of 100 suppression of neutron flux achieved (measured by ^{3}He counters)

Structure of γ background in the experimental hall <u>understood</u> (measured by NaI)

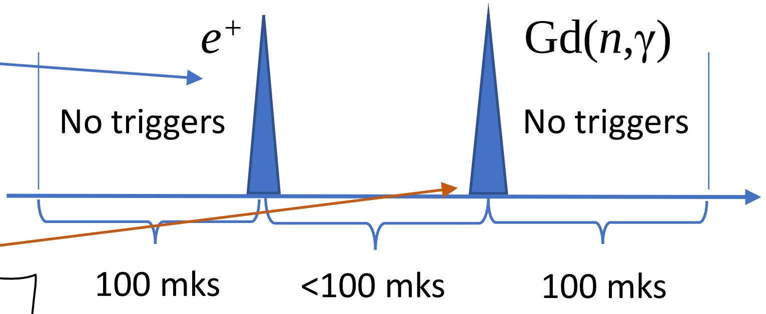


Detection methods and selection cuts

Delayed coincidence technique:



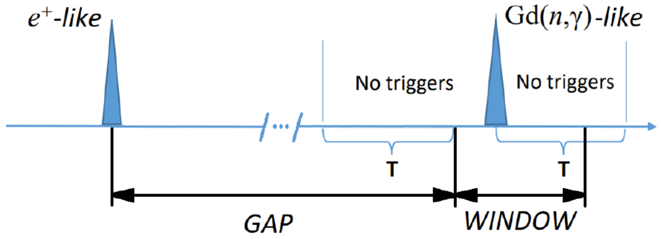
Prompt event - positron



Delayed event - neutron

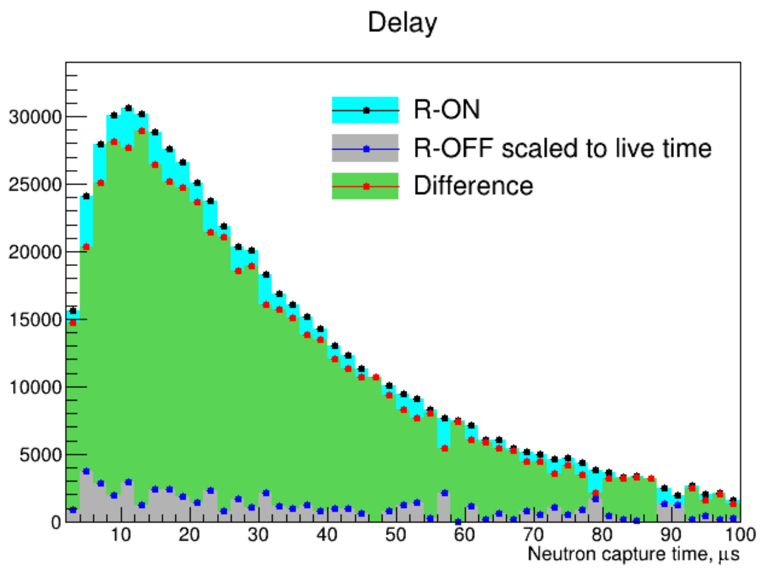
$\overline{\nu}_e + p \rightarrow e^+ + n$ – the inverse beta decay reaction
E_{th} = 1,8 MeV – threshold
$E_{prompt} = E_\nu - 0,78$ MeV – the positron energy dependence of the neutrino energy

Selection cuts:
- $E_{prompt} \in [2; 10]$ MeV
- $E_{delayed} \in [5;10]$ MeV
- $\Delta T < 100\ \mu s$
- absence of any triggers 100 μs before prompt and after delayed events

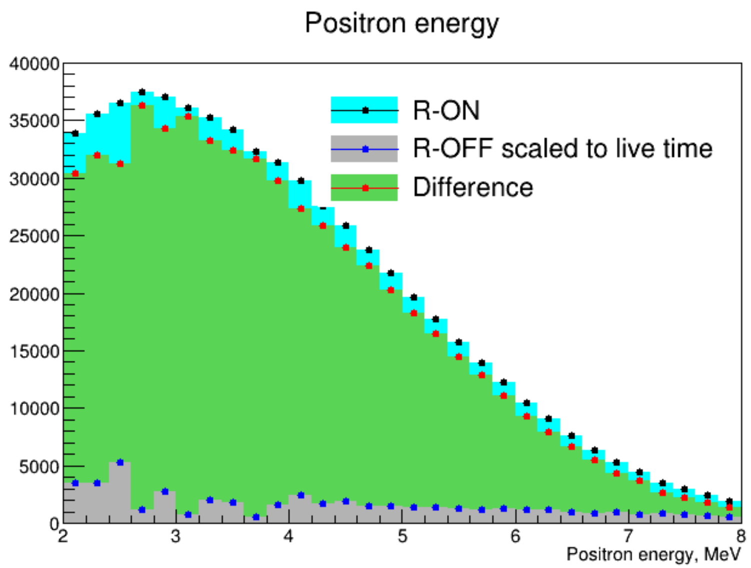


Accidental selection cuts (the “off-time” method:
- GAP = 500 μs;
- WINDOW = 100 μs;
- 100 consecutive windows.

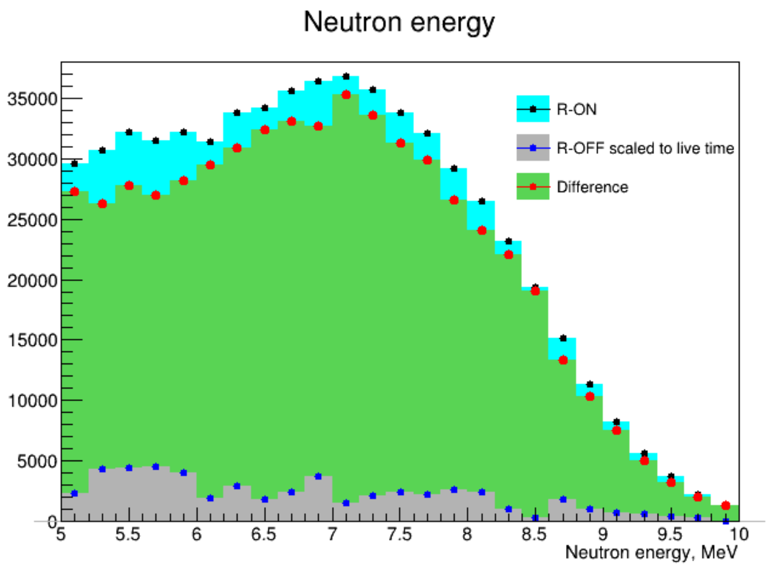
Selected events



The distribution of ΔT- time difference between prompt and delayed events



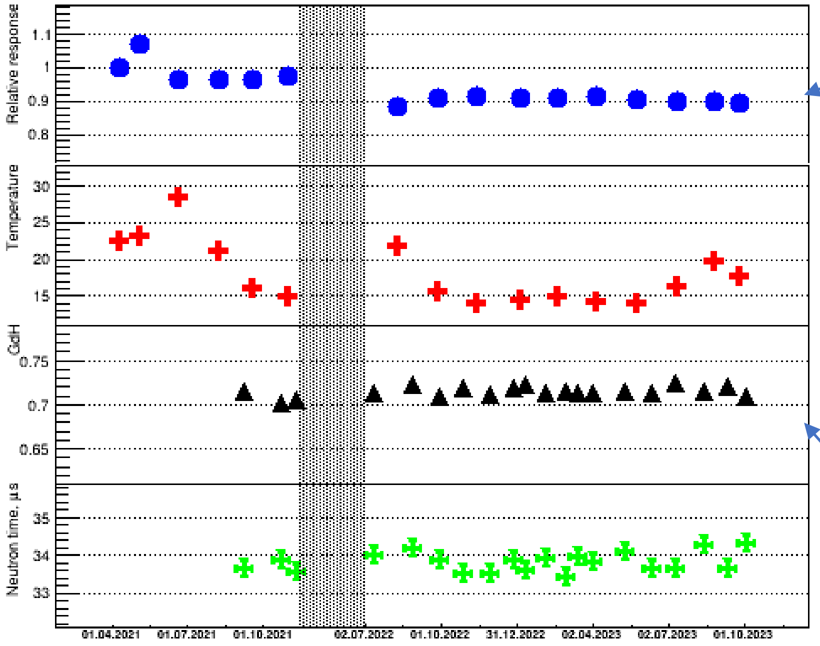
The prompt energy spectrum



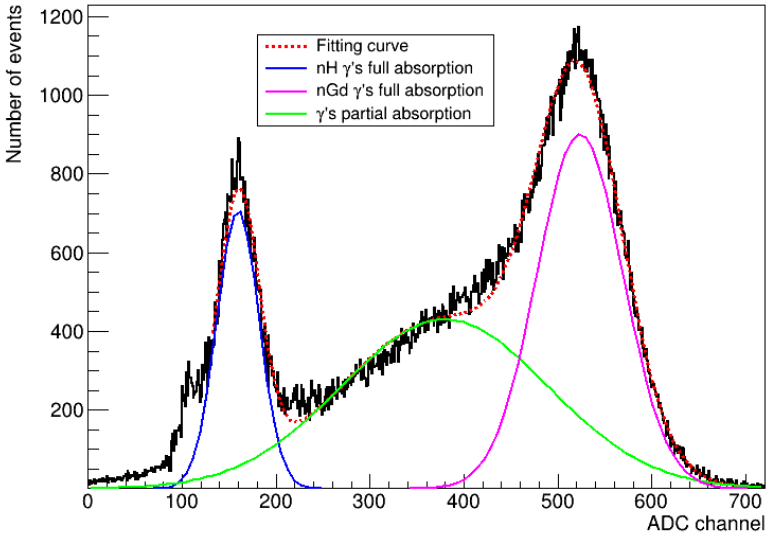
The delayed energy spectrum

The data of more than two months of R-OFF period between reactor campaigns has been obtained.

Response stability

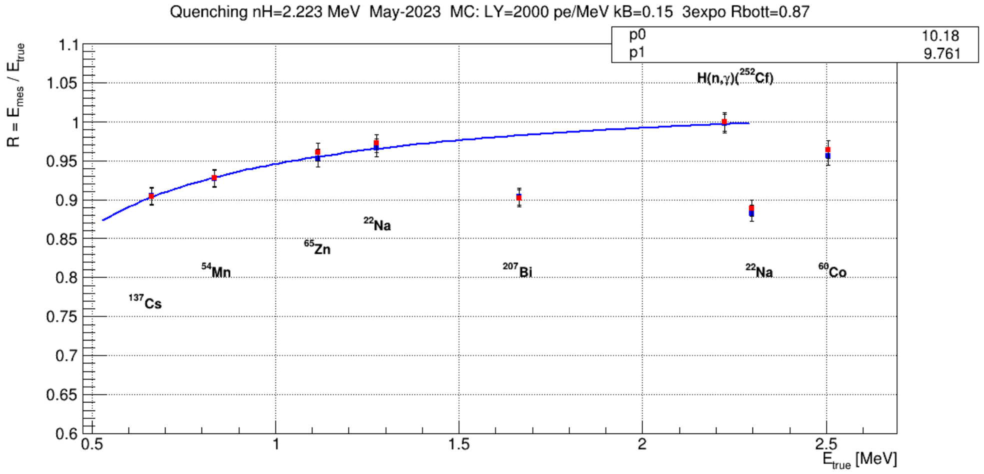


The response stability has been monitored via regular calibration with radioactive sources 60 Co and 252 Cf.



The gadolinium fraction has been calculated following way:

$$R_{Gd-H} = \frac{N_{Gd}}{N_{Gd} + N_H}$$

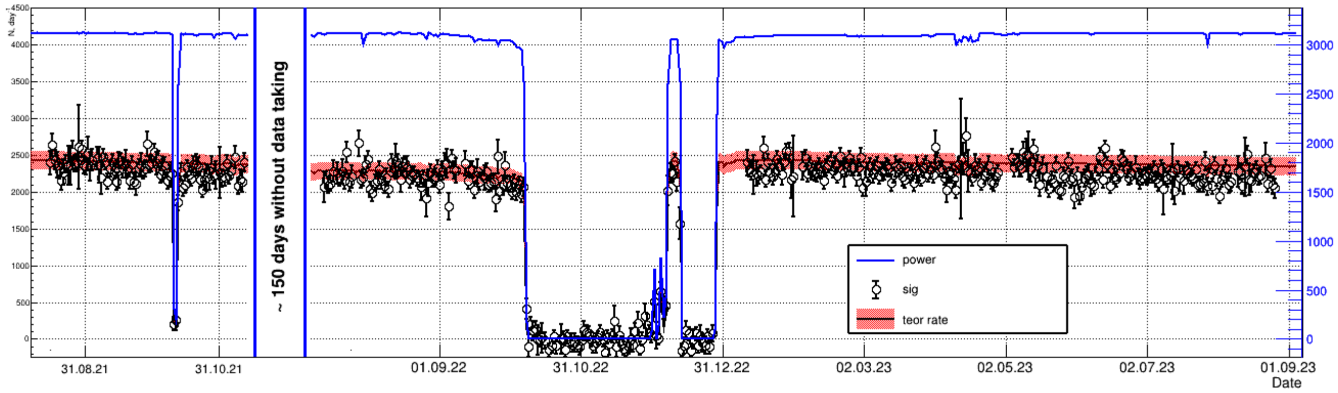


The quenching function has been measured using various sources: 207Bi, 137Cs, 54Mn, 65Zn, 22Na и 60Co.

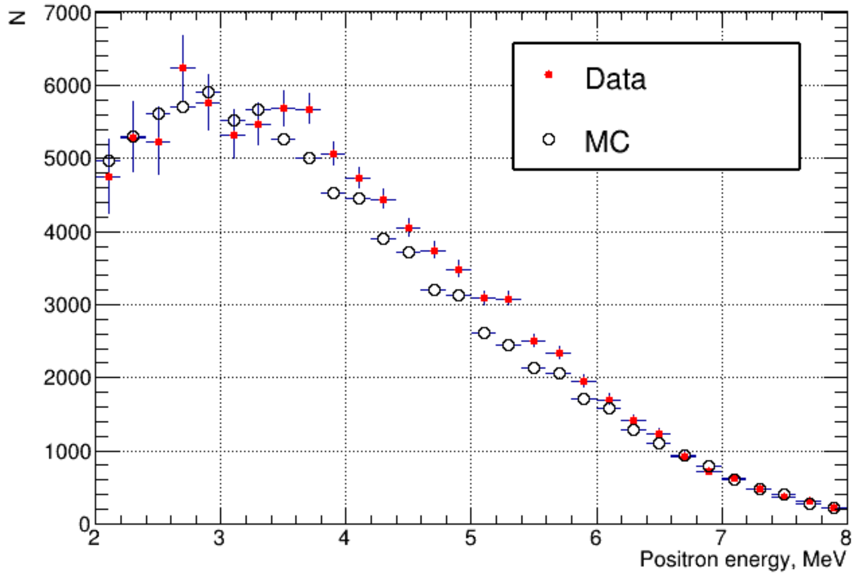
Antineutrino signal

$N_{det} = \frac{\epsilon}{4\pi\, L^2} \cdot N_p \cdot \frac{P_{th}}{E_f} \cdot \langle\sigma\rangle$ - расчетная скорость счета

E_f from V. Kopeikin *et al*, Phys. Atom. Nucl. **67** (2004) 1963
$\langle\sigma\rangle$ from V. Kopeikin *et al*, Phys. Rev. D **104** (2021) L071301



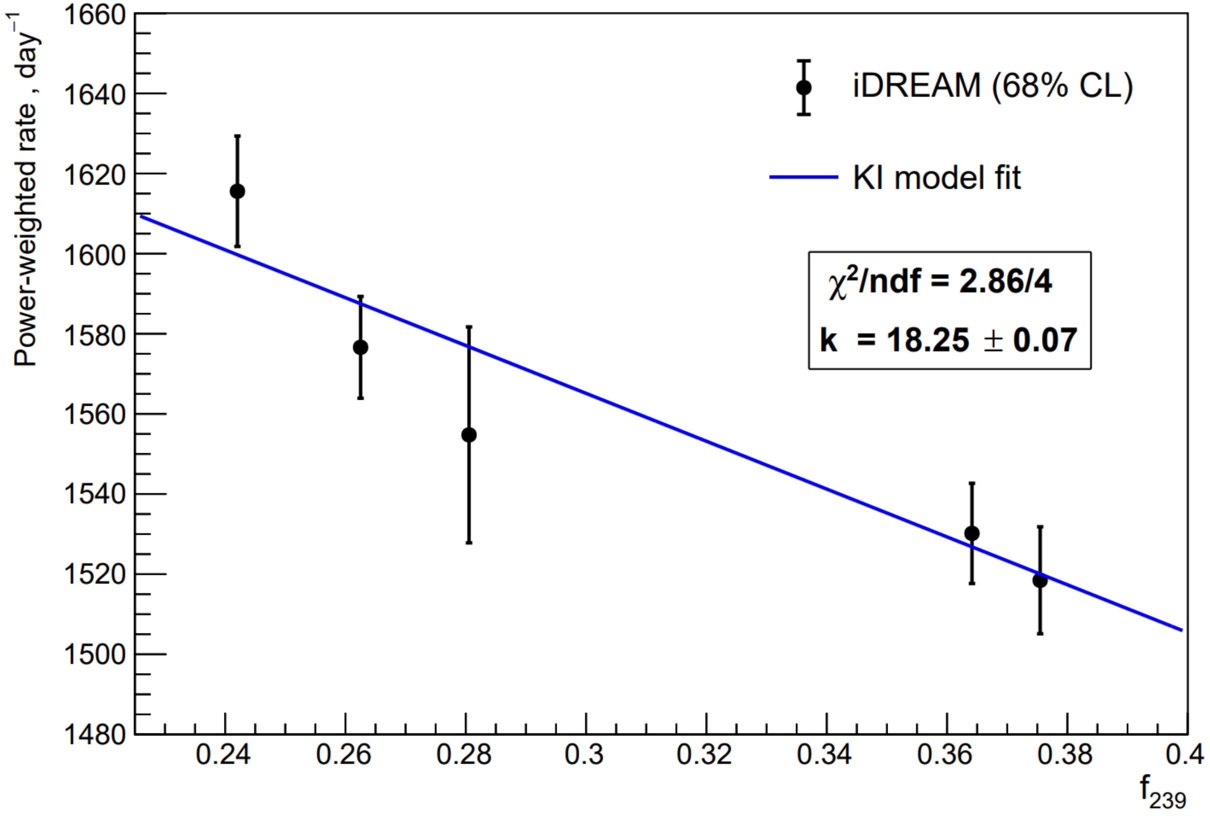
Blue curve – the reported power of the reactor by the NPP services
Empty points – the IBD rate in the iDREAM detector
Black line with the red band – the theoretical rate prediction



The positron spectrum in comparison with a MC prediction based on the reported fissile fractions from KNPP service.

Period	R-ON	R-OFF
Number of live-days	248.6	39.5

The Rate analysis



$$\frac{dN_{det}}{dt} = k \cdot \frac{P_{th}}{\langle E_f \rangle (t)} \cdot \langle \sigma \rangle,$$

where $k = \frac{\epsilon N_p}{4\pi L_r^2}$ - detector-related parameters,

ϵ – detection efficiency,

N_p- number of protons,

L_r- distance between the reactor and the detector

Outline

- R-ON 248.6 live days, R-OFF 39.5 live days data obtained;
- Data acquisition is planned till the next R-OFF period;
- The rate analysis showed the ability to register the fuel burn-up;
- Spectrometric features of the detector are investigating.

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