Status of IDREAM detector

LXXI International conference
NUCLEUS: 20-25 September 2021.
Nuclear physics and elementary particle
Physics. Nuclear physics
technologies.

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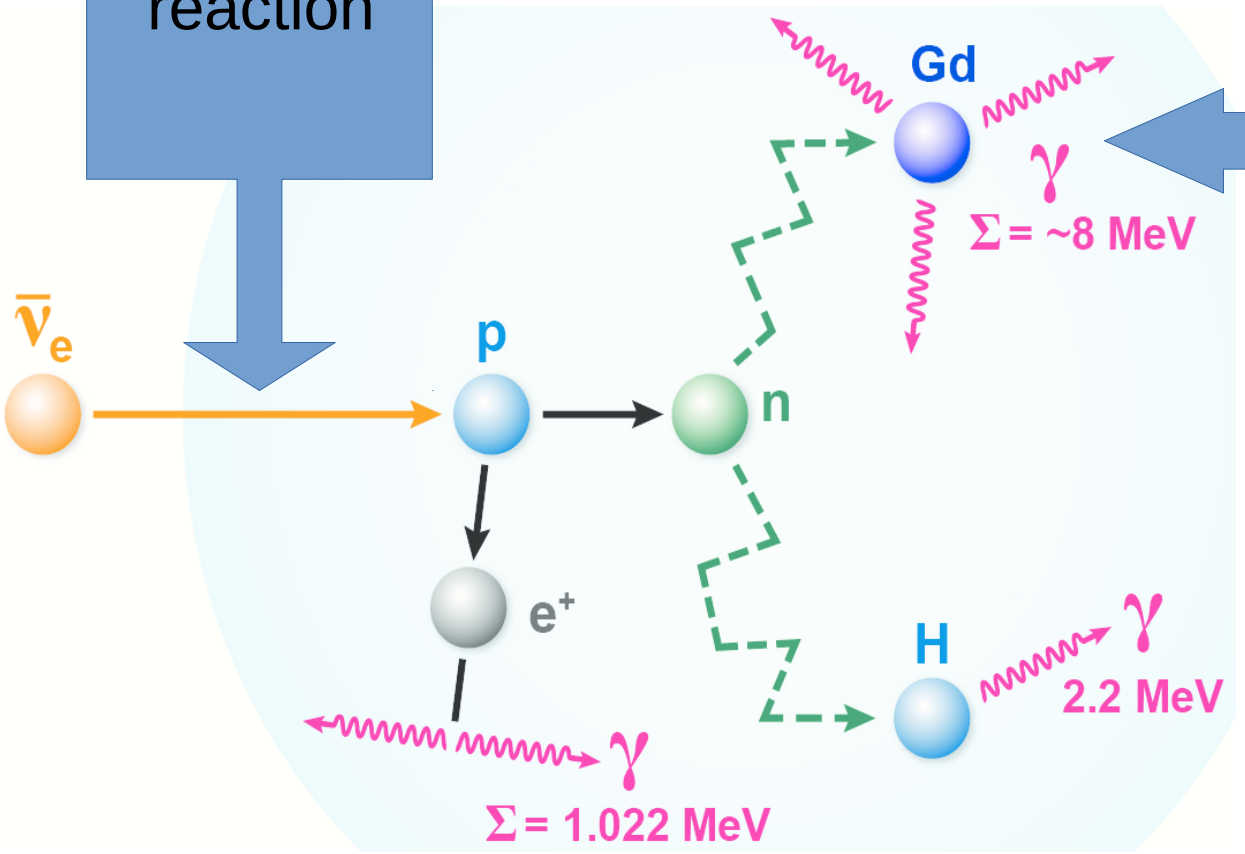
Inverse beta-decay process

Inverse beta-decay reaction

$$\tilde{\nu}_e + p \rightarrow e^+ + n \rightarrow (e^+ + e^- \rightarrow 2\gamma) + n$$



Gd improves the efficiency of neutron detection

$E_{threshold}$ = 1.806 MeV

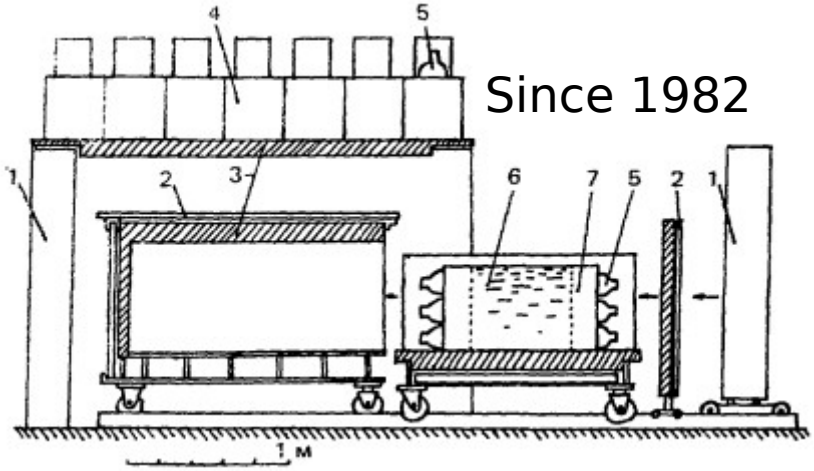
$E_{promt} = E_\nu$ – 0.8 MeV

The initial idea of reactor monitoring

For the first time in the world, idea of the reactor monitoring with IBD process was expressed in the Soviet Union in 1970 years by science team of Kurchatov institute.

Further the first experiments of the antineutrino spectrum measurements were carried out at the Rivne NPP in the 80s.

Since 1982



Scintillation spectrometer: 1 - water tanks; 2 - scintillation plates of active shielding; 3 - boronated polyethylene; 4 - active shielding modules with liquid scintillator; 5 - 24 PMTs - 49B; 6 - spectrometer with liquid scintillator based on paraffin oil(240 litres) dopped Gd-isotop(0.5 g/l); 7 - light conduit.

Neutrino spectral experiments have been carried out since 1980 by the CALTECH-SIN-TUM laboratory at the reactors in Grenoble and Hesse. At the end of 1984, a publication appeared by a French group engaged in similar research at the reactor in Bougie.

1. Vuilleumier J.L., Boehm F., Egger J. et al. New limits on oscillation parameters for electron antineutrino. — Phys. Lett., 1982, vol. 114B,p. 1097.
2. Cavaignac J.F., Houmada A., Koang D.H. etal. Indication for neutrino oscillation from a high statistics experiment at the Bugey reactor. - Phys. Lett., 1984, vol. 148B, p. 387.

1. A. A. Borovoi, L. A. Mikaelyan et al., Possibilities of the practical use of neutrinos, Soviet Atomic Energy, volume 44, pages 589-592(1978).
2. Mikaelyan L.A. Neutrino laboratory in the atomic plant (fundamental and applied reasearch).— Proc. Int. Conf. "Neutrino-77", vol.2.— Moscow: Nauka, 1978, p. 383.

IDREAM design

IDREAM has 3 inner volumes:

- the target(1.1 m^3) contains Gd-loaded

LAB-based liquid scintillator: LAB +

PPO(3 g/l) + bis-MSB(0.02g/l)+Gd(1g/l);

- the gamma-catcher(1.7 m^3): LAB + PPO bis-MSB;

- the buffer volume(0.4 m^3): LAB(linear alkylbenzene).

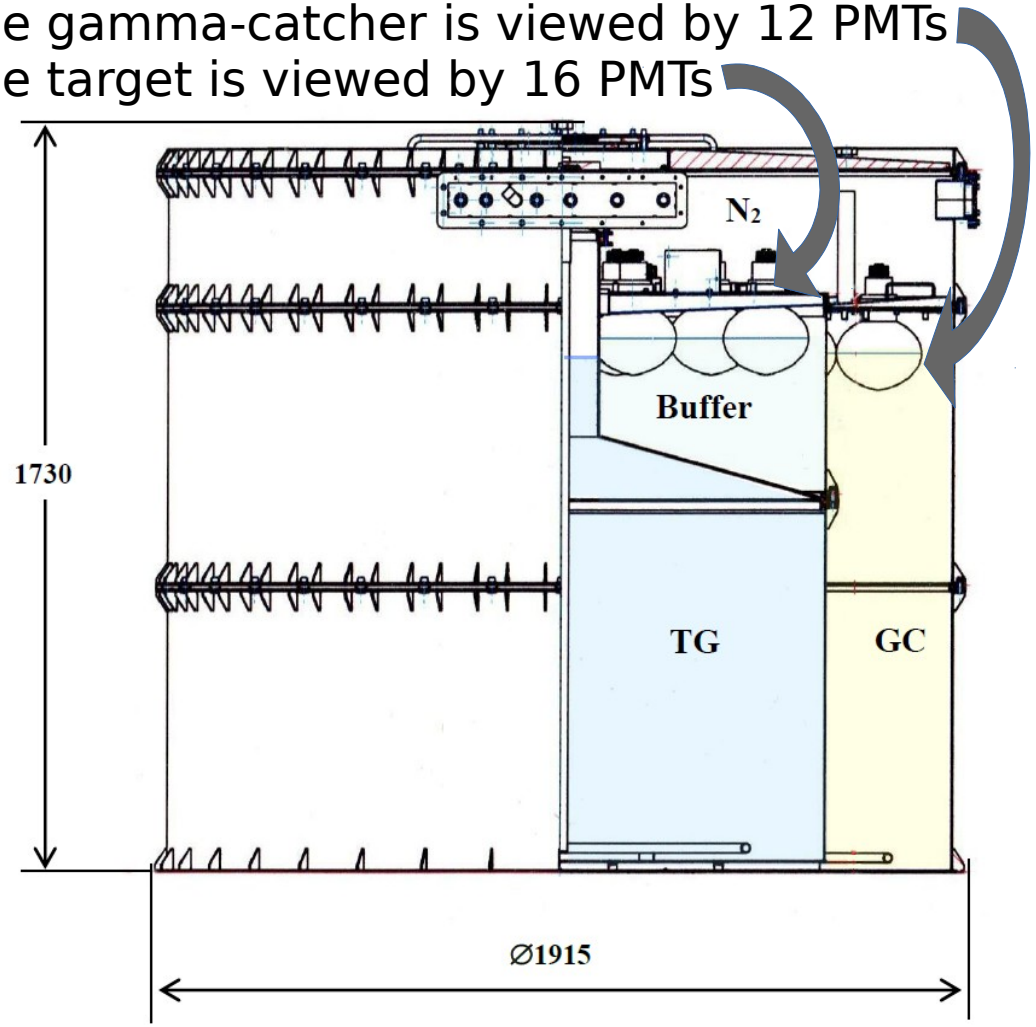
Auxiliary IDREAM systems:

- liquids filling and nitrogen purging systems;

- slow control system;

- DAQ system;

- calibration system and other.



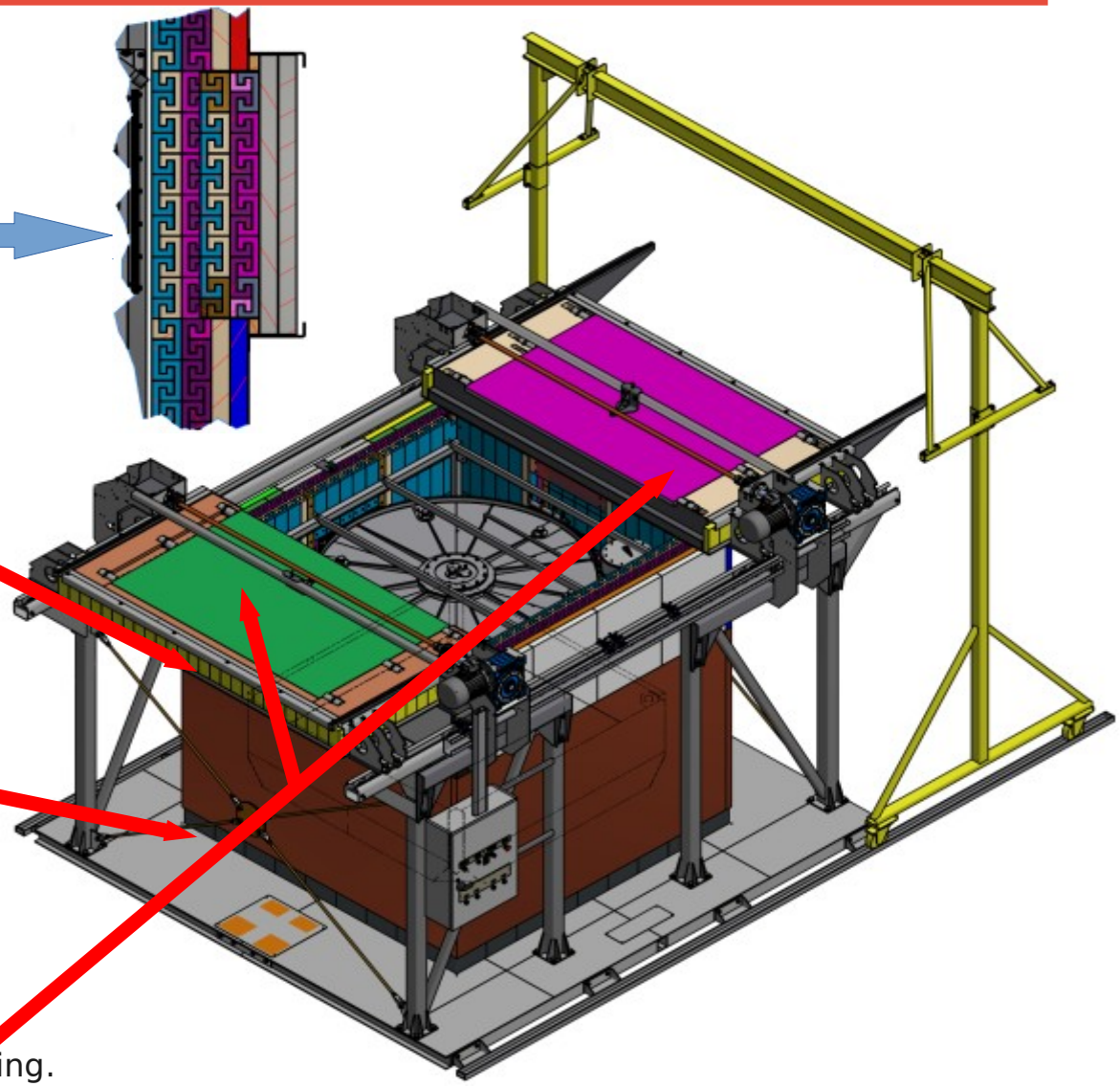
IDREAM shielding

Passive shielding:
- sidewall shield of the detector from left to right: 2 layers of "NEUTRONSTOP" C-type bricks, each 80 mm thick and two layers of pure polyethylene plates, each 50 mm thick, are installed;

- 2 shielding plates on top of the detector: lead (50 mm) + pure p/e (40 mm) + borated p/e (160 mm);

- cast-iron platform under the detector: cast-iron layer (140 mm) + pure p/e (80 mm) + borated p/e (100 mm).

Active shielding from cosmic Muons: detector is equipped with two scintillation polymethyl methacrylate plates. Each plate, 1900x1200x33 mm in size, is placed on the top of each half-door above the shielding.



IDREAM design features

IDREAM is a prototype of industrial detector that
can be placed at NPPs:

- IBD as well-established neutrino detection technology;
- simple design;
- quick-assembly / dismountable construction, high maintainability;
- no need for daily maintenance;
- remote control from other building within NPP site.

IDREAM mounting at Kalinin NPP

Initially, **February 2021** - IDREAM installation started in 3A-121 room(IDREAM place).

IDREAM mounting and commissioning

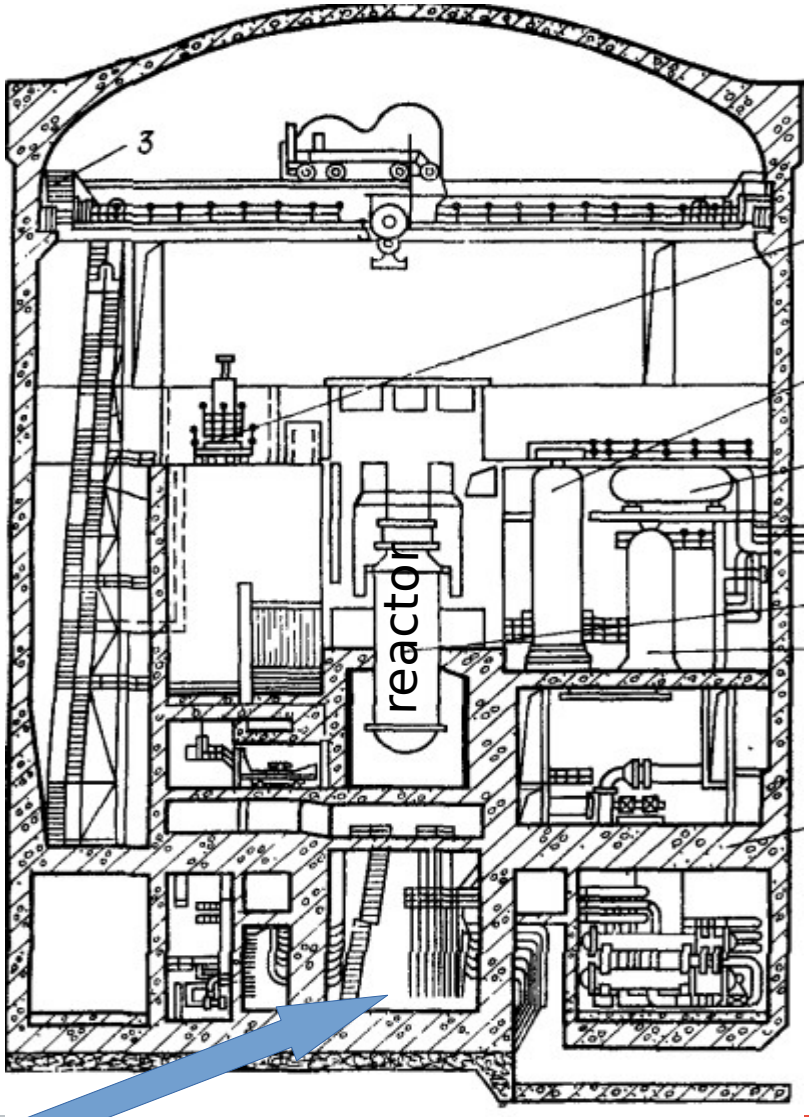
IDREAM mounting at Kalinin NPP

9-12/04/21 - removing part of the scintillator and adding the Gd concentrated solution, nitrogen purging

24/03/21 - Detector filled with the scintillator w/o Gd

IDREAM has been installed at Kalinin NPP (3rd power unit) in the spring 2021

16/04/21 - installation of passive shielding completed.

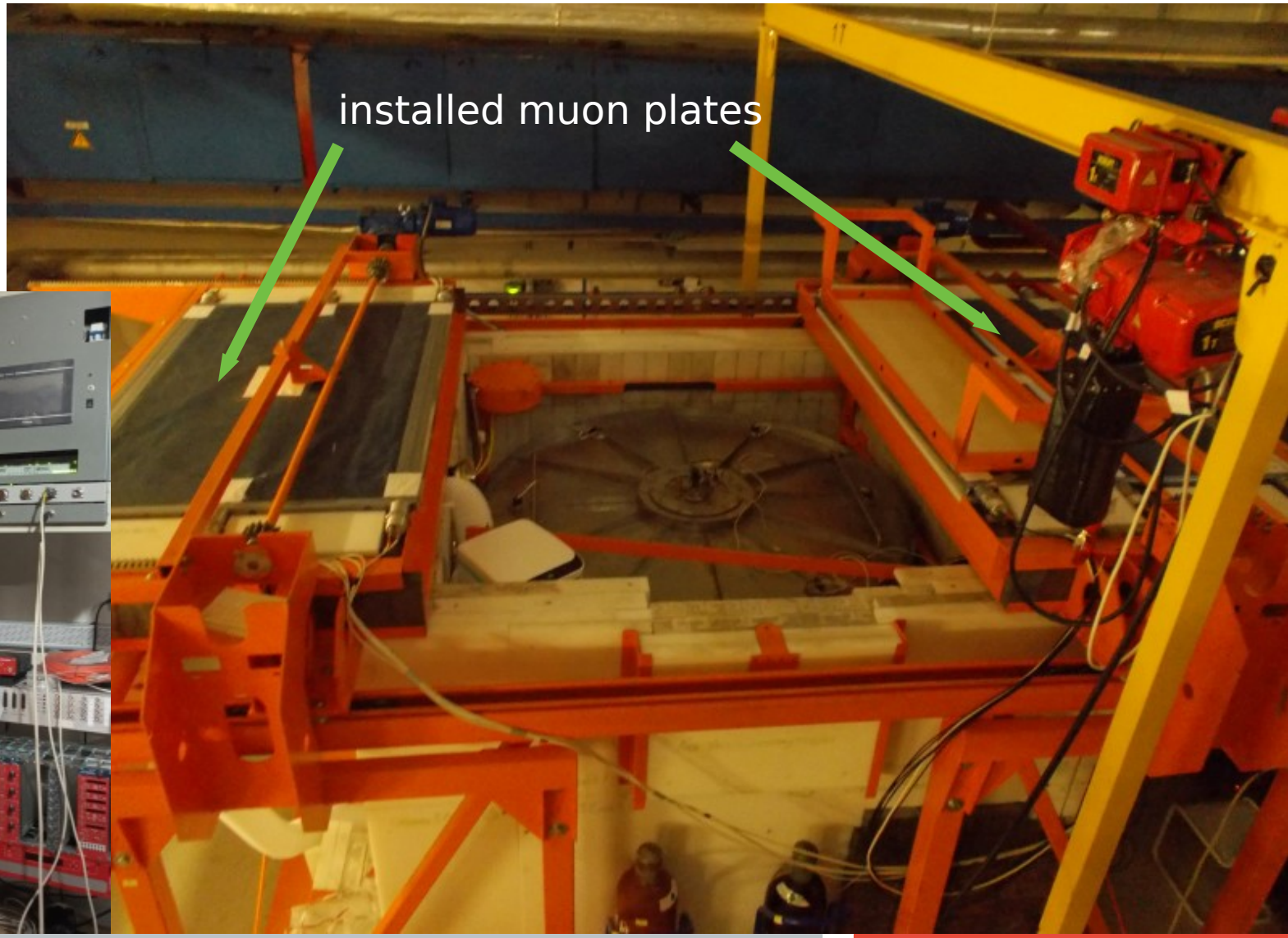


The detector is located in a ground level hall(A-121 room), 19 m from the 3 GW reactor core

VVER-1000 reactor

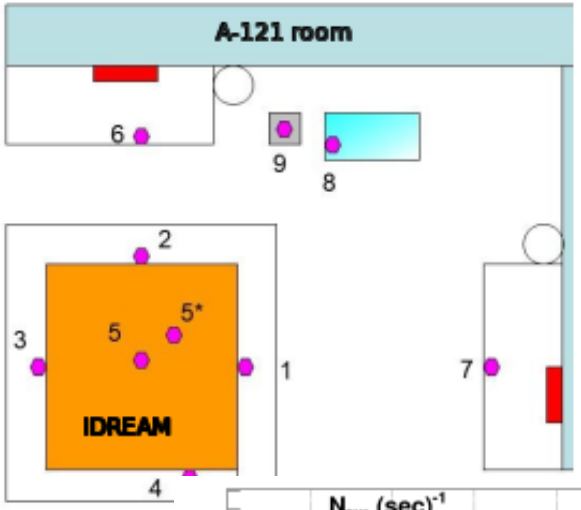
IDREAM setting up at Kalinin NPP

Setting up electronics and DAQ system

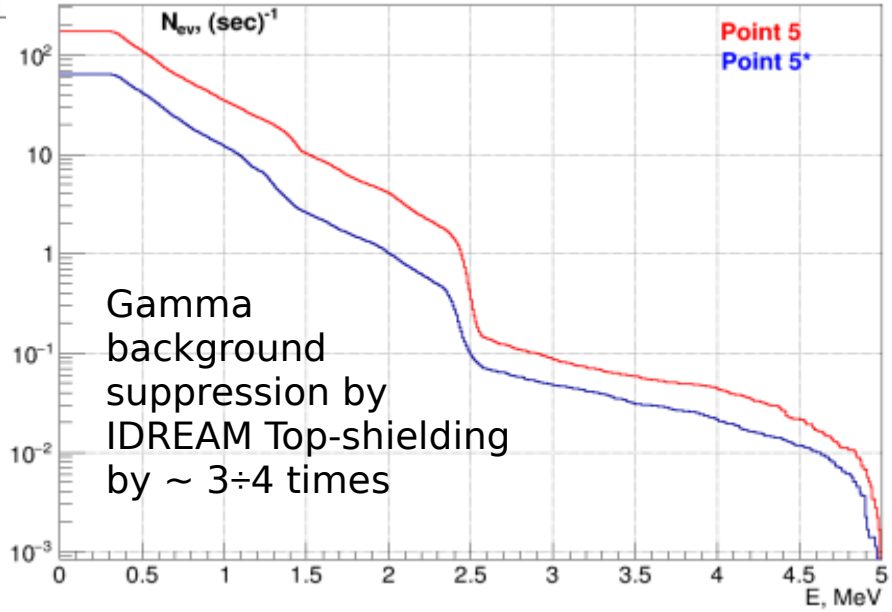


Starting from May - commissioning runs.

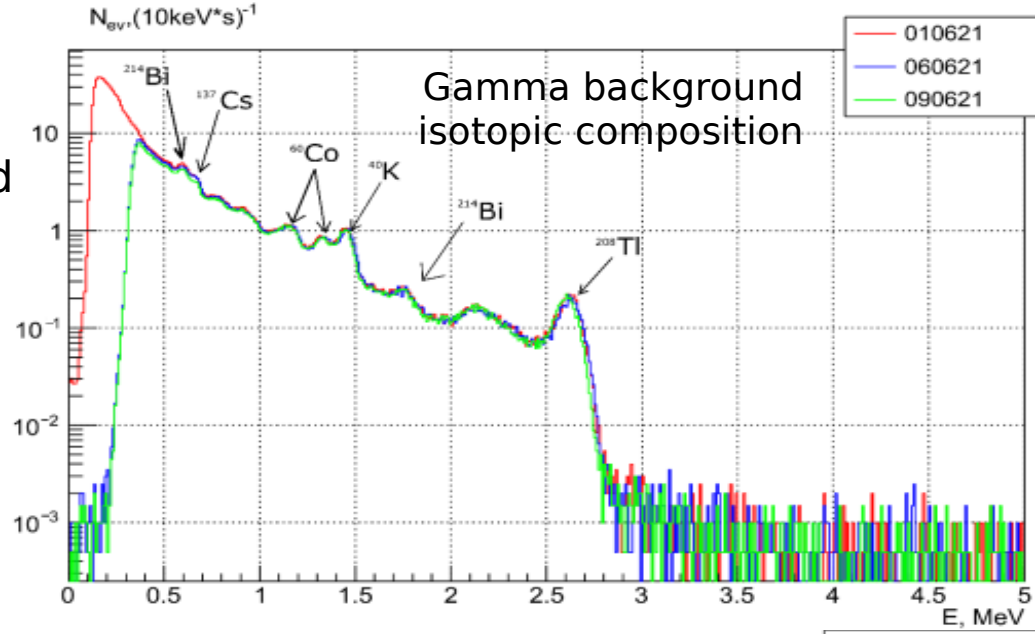
Gamma background



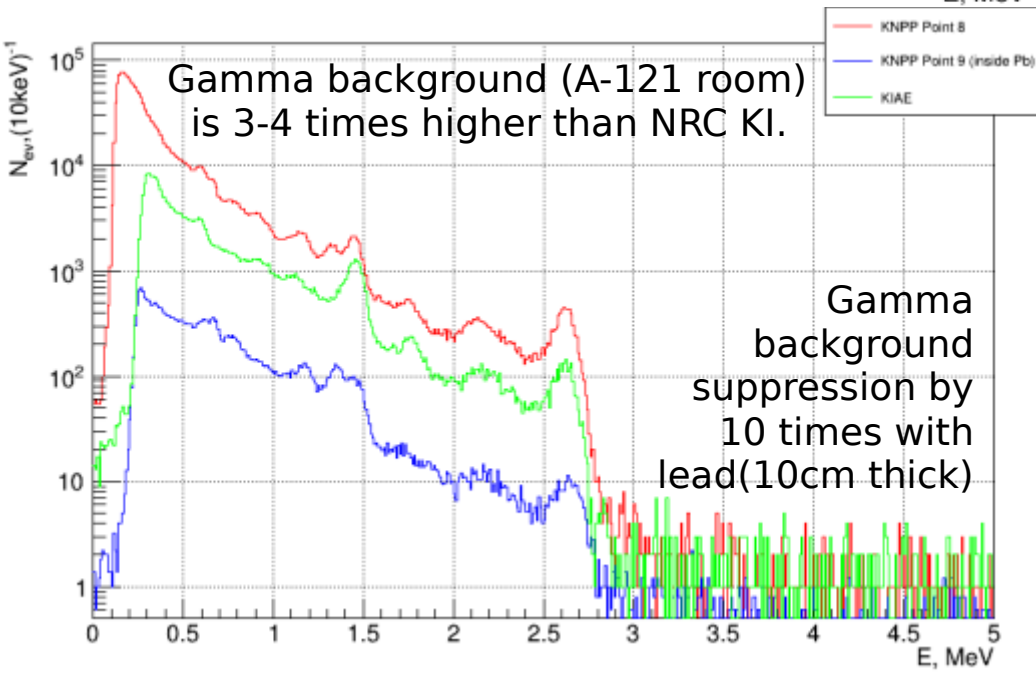
Data collection points of gamma Background using NaI-detector (90x90mm diameter) in A-121 Room (IDREAM place).



Gamma background suppression by IDREAM Top-shielding by ~ 3÷4 times



Gamma background isotopic composition



Gamma background (A-121 room) is 3-4 times higher than NRC KI.

Gamma background suppression by 10 times with lead(10cm thick)

Measurements of the gamma fields in 3A-121(IDREAM place)

Neutron background

Neutron background measurements were carried out using ^{3}He counters:

- the detector made from 12 proportional ^{3}He counters,

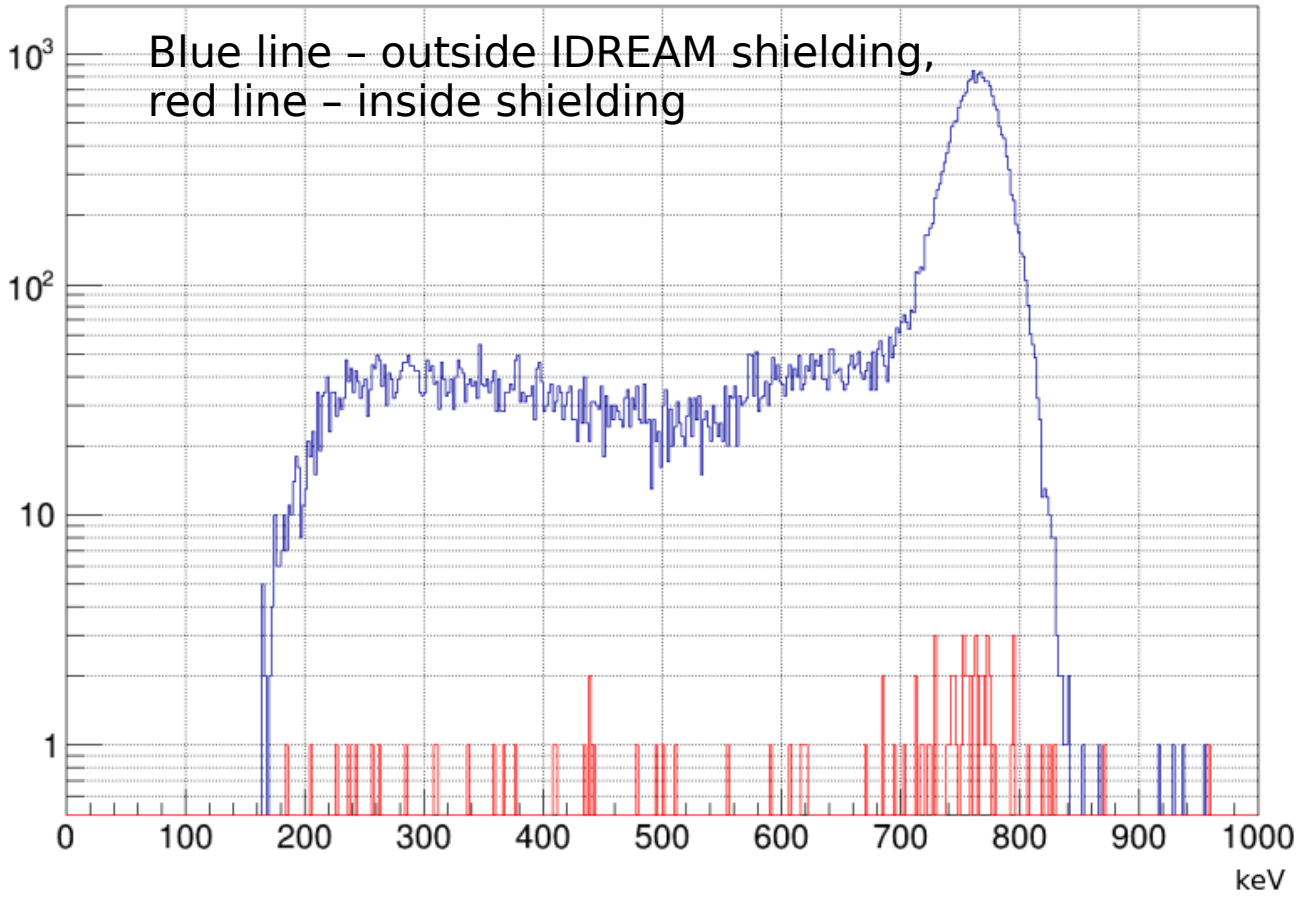
1 m in length;

- the thermal neutrons are detected in the reaction:

$n + {}^3He \rightarrow {}^3H + p + 764$ keV;

- measurements outside

and inside IDREAM shielding.



Count rate outside IDREAM shielding in A-121 room: 5,2±2,3 neutron/s.

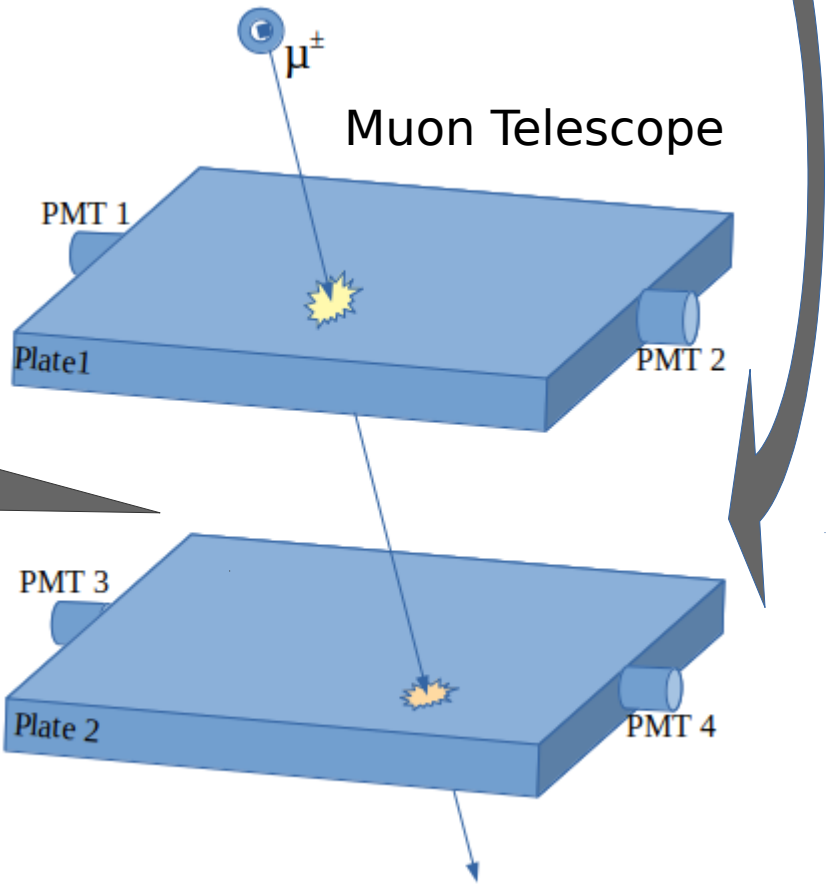
Count rate inside IDREAM shielding ~ 0,03 neutron/s.

So, IDREAM passive shielding suppressed the neutron background by more than 100 times

Muon background

A detector made from 2 parallel plates was used for muon data collection in room A-121 (IDREAM place), each plate is 50x50x5 cm and has two 3” PMTs.

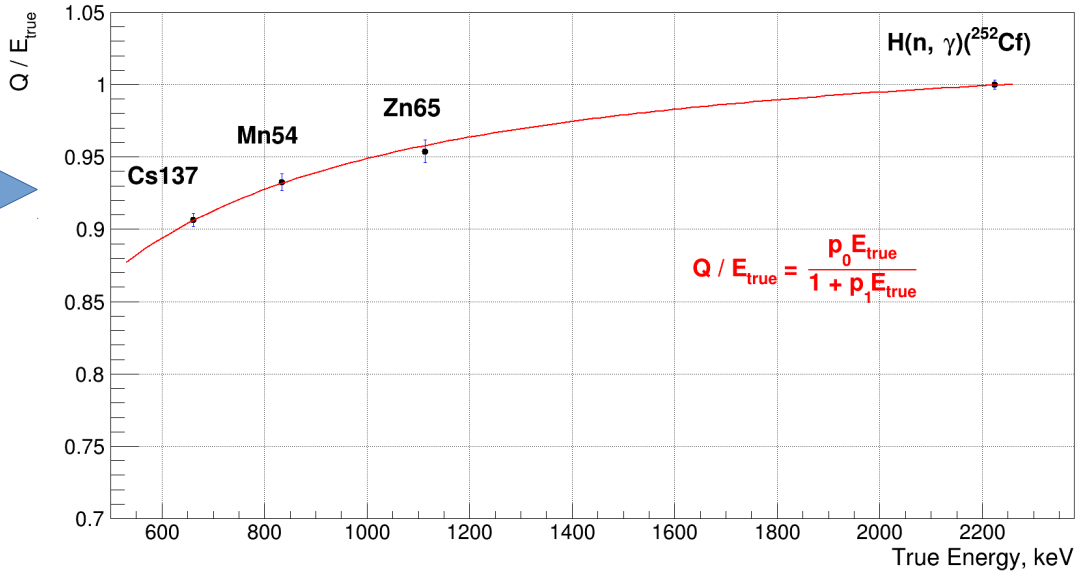
Muon spectra measurements were done for two cases:
0 and 30 cm between the plates.

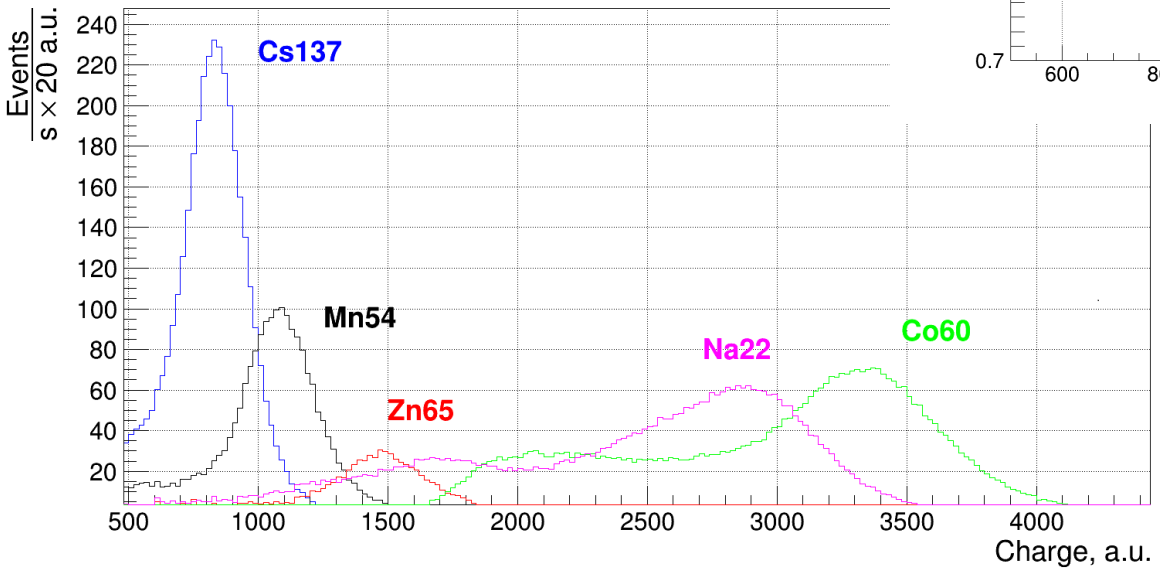


Based on the measurements, the muon flux into A-121 room of Kalinin NPP was suppressed by ~ 8 times compared to the flux in the laboratary hall of Kurchatov institute.

IDREAM calibrations

Study of quenching effect in our scintillator using calibration sources: ^{252}Cf,^{54}Mn,^{65}Zn,^{137}Cs.

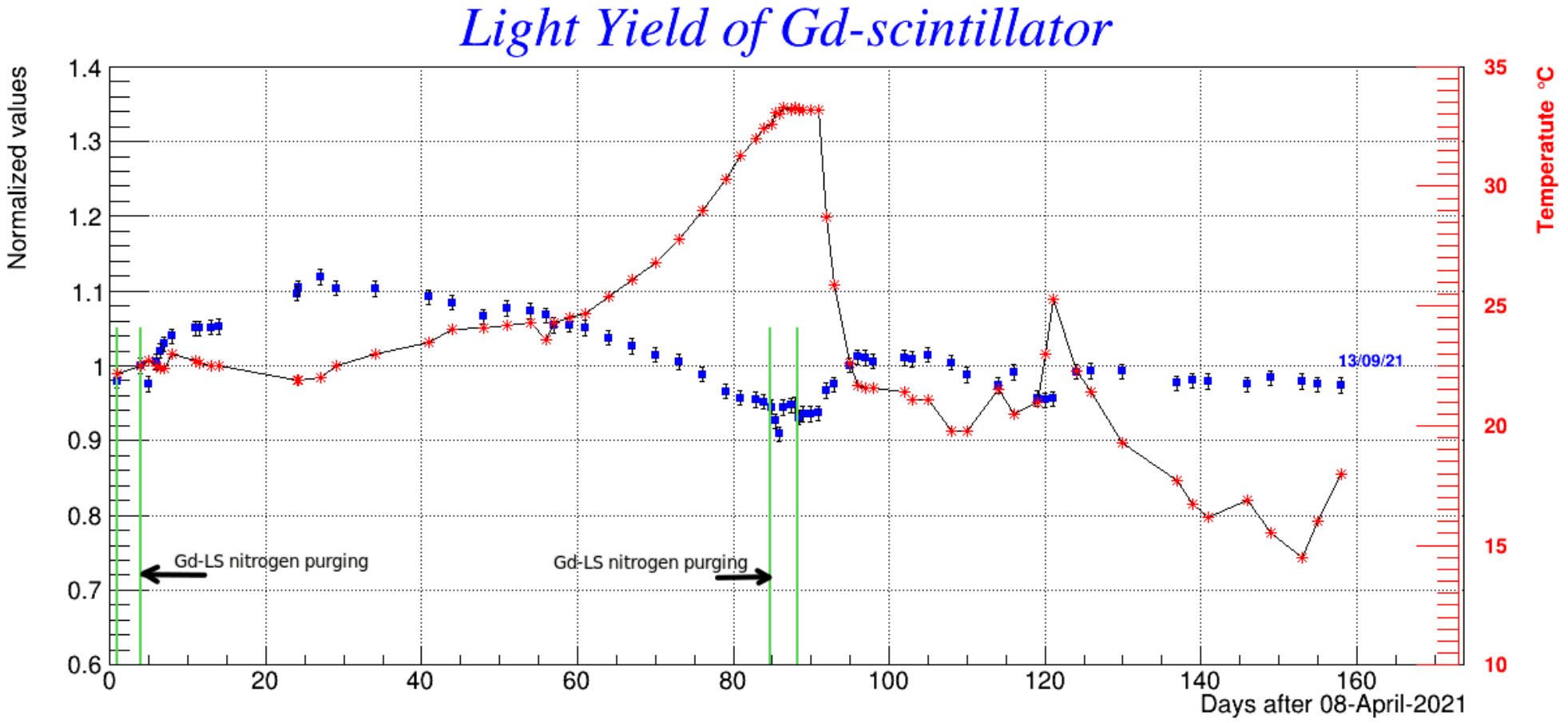




Carrying out calibrations using several sources: ^{22}Na,^{54}Mn,^{60}Co,^{65}Zn,^{137}Cs.

Monitoring the stability of the detector response

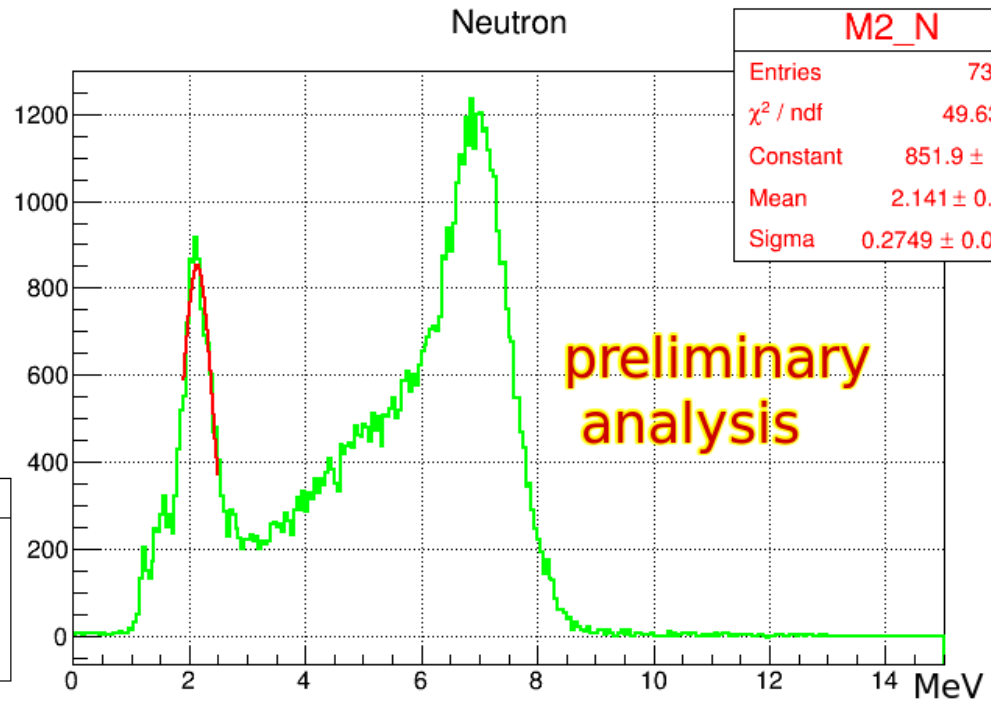
Regular monitoring of the stability of detector response by means of ^{60}Co source.

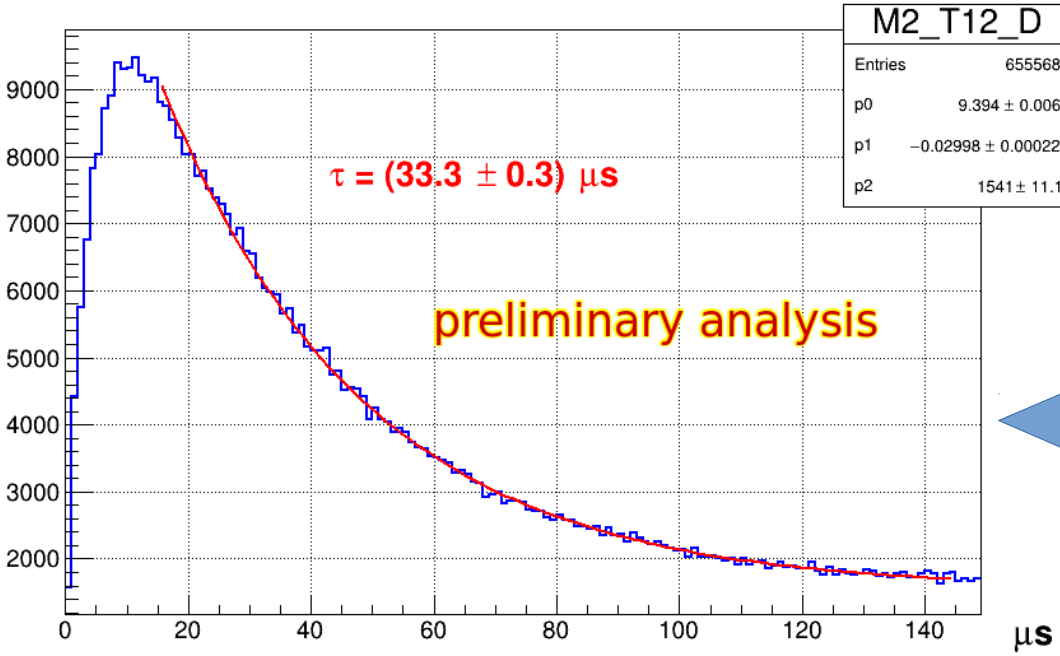


Higher temperature - lower detector response?

Preliminary evaluation of neutron lifetime(^{252}Cf)

Neutron energy spectrum in Gd-LS





Neutrons life-time in Gd-Ls.

Calibration using ^{252}Cf-source

^{252}Cf source

Conclusion

- IDREAM is a compact prototype of industrial detector for reactor monitoring;

- IDREAM detector is mounted on Kalinin NPP and first dataset is coming now;

- cosmic muons, neutron and gamma background measurements were performed at detector's location;

- detector response is regularly monitored since the commissioning;

- studies of the scintillator quenching and neutron's lifetime measurements performed.

Stay tuned and wait for our new results!

The End

www.rosenergoatom.ru/stations_projects/sayt-kalininskoy-aes/fotogalereya/

Kalinin NPP
Udomlya, Russia