Investigation of neutrino properties with the νGEN spectrometer

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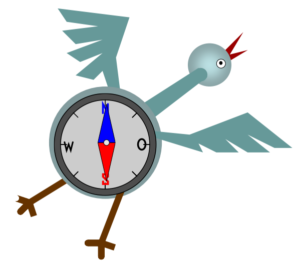
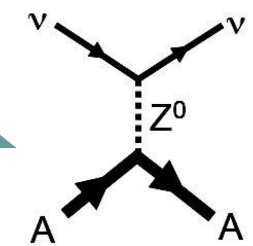
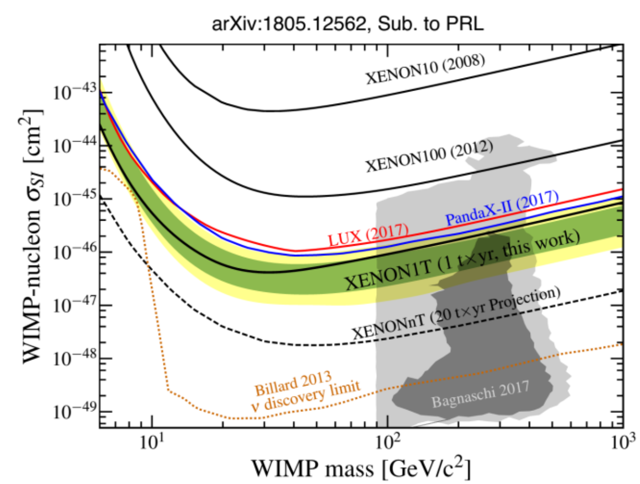
Motivation

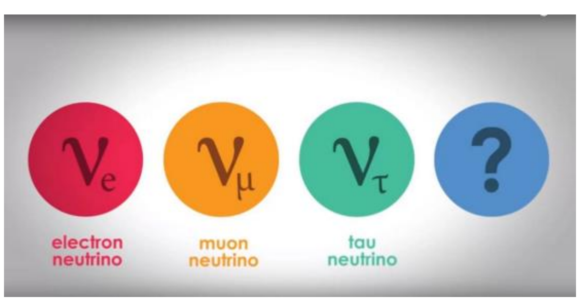
Measurement of the neutrino properties is a very important task for a particle physics, astrophysics and cosmology. Being one of the most abundant particle in the Universe its detection is very challenging due to very weak interaction with matter. Investigations with νGEN:

- Continue search for **Magnetic Moment of Neutrino (MMN)** performed by GEMMA experiment (expected of sensitivity ~ $9{\cdot}10^{-12}\ \mu_B$)
- Investigate **Coherent Elastic Neutrino Nuclear Scattering (CEνNS)**:
  - Sterile neutrino
  - Non-standard neutrino interactions
  - Reactor monitoring
- Investigate background for dark matter experiments, other applications..





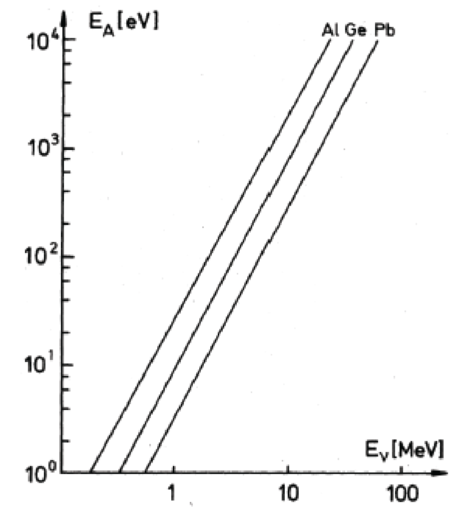




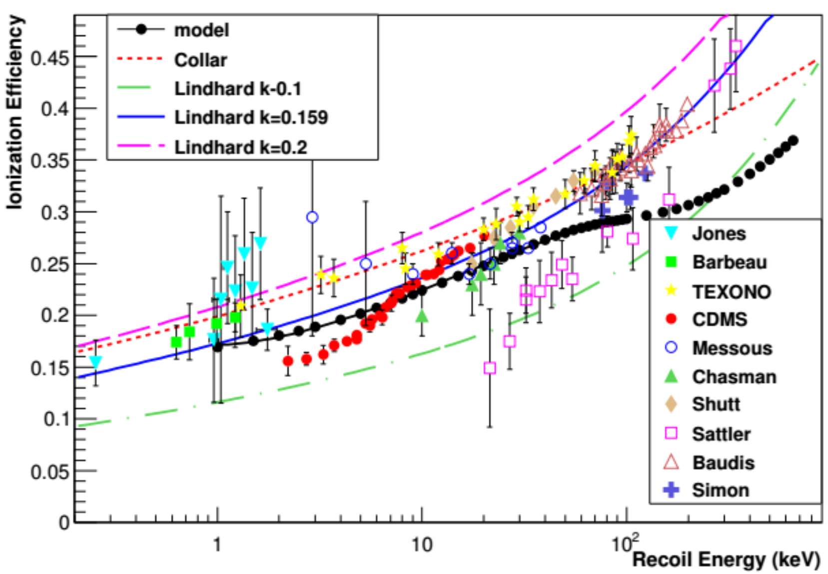
CEvNS detection

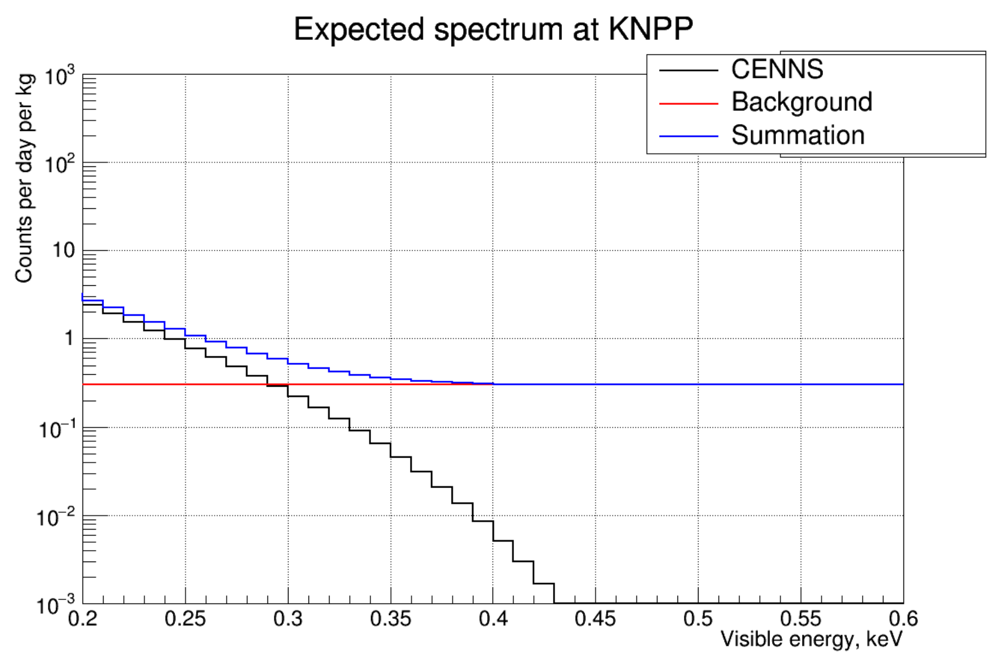
CEvNS cross section is: $$\sigma_{tot} \approx \frac{{G_F}^2}{4\pi^2} \cdot N^2 \cdot {E_\nu}^2$$

- E_ν < 50 MeV (full coherency below ~ 30 MeV)
- Cross section is enhanced by several orders of magnitude
- Proportional to the number of neutrons squared
- Recoil energy is very low – less than few keV



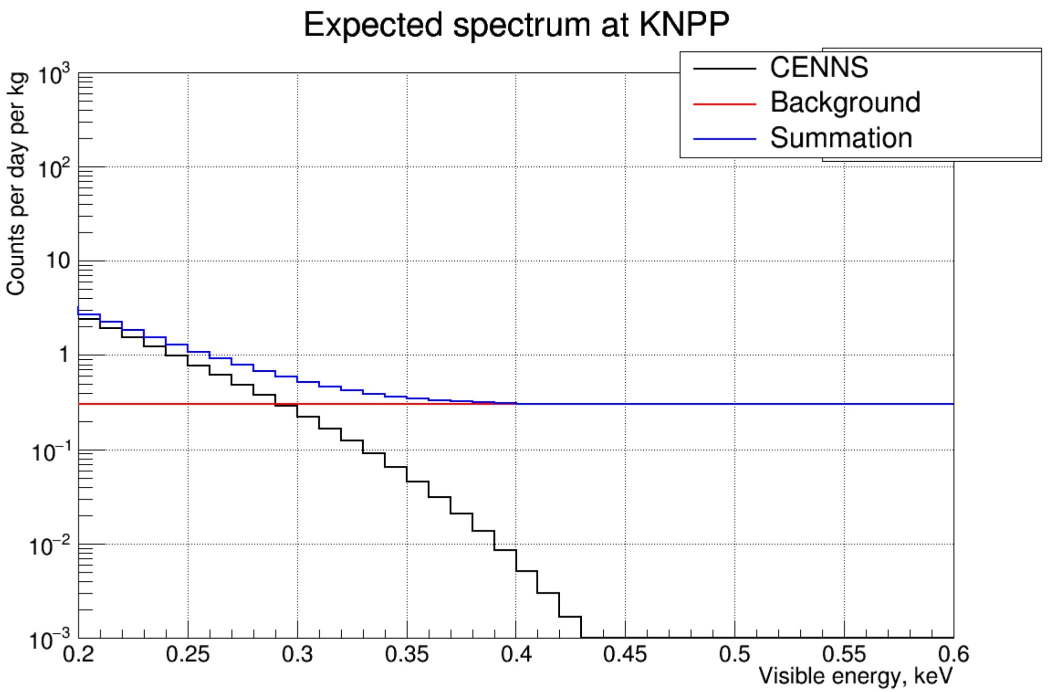
Only a small part of recoil energy can be detected (<25% for HPGe).





Detection of CEvNS

- Signal from CEvNS - continuous spectrum at very low energies.
- Hard to distinguish such type of signal from noise spectrum.
- Detecting CEvNS is a big challenge, however it is became possible with recent development of experimental techniques.



To detect CEvNS we need:

- Powerful source of neutrino
- Detector with very low energy threshold and good resolution
- Low background
- Clear discrimination signal from the noise
- High efficiency and big detector's mass

KNPP

Strong source of neutrinos:
Kalinin Nuclear Power Plant

Neutrino source

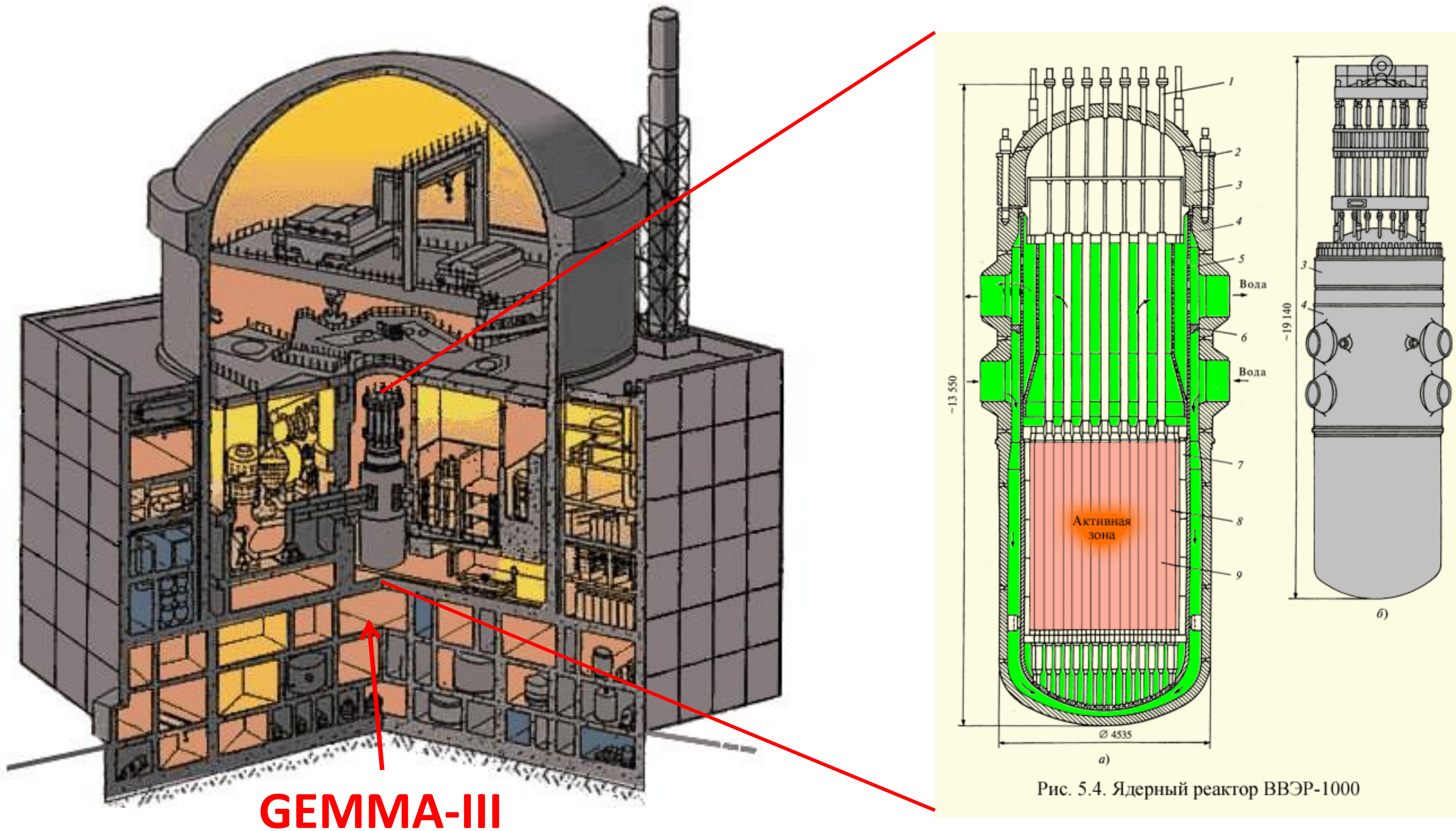
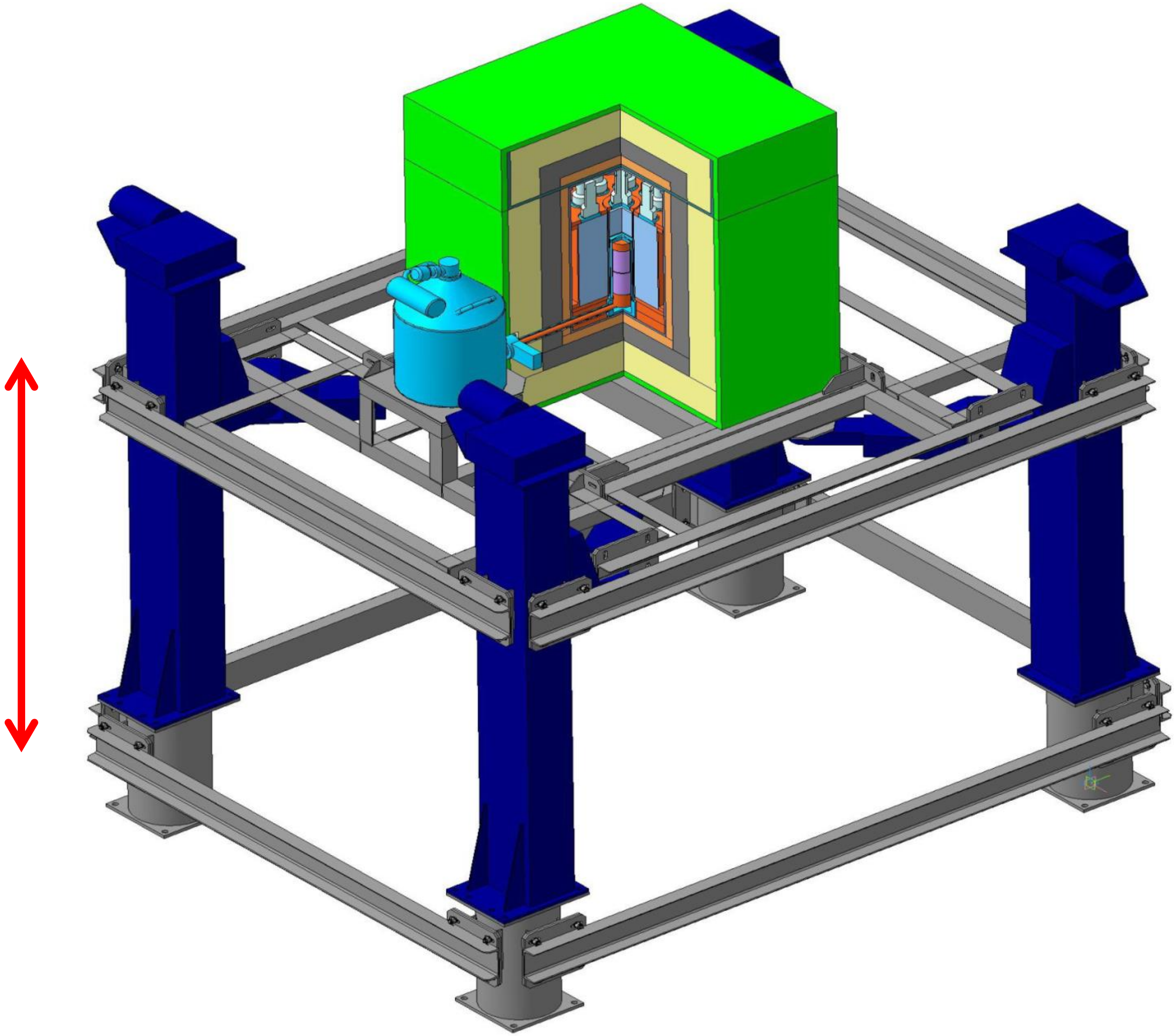


Рис. 5.4. Ядерный реактор ВВЭР-1000

Experimental setup can be located only at **~ 10 m** from **3 GW** reactor's core. The available neutrino flux is **> $5 \cdot 10^{13}$ $\nu/(s \cdot cm^2)$** – the highest in the field. Experimental setup is located under the reactor -> ~50 m w.e. (good shielding against cosmic radiation)

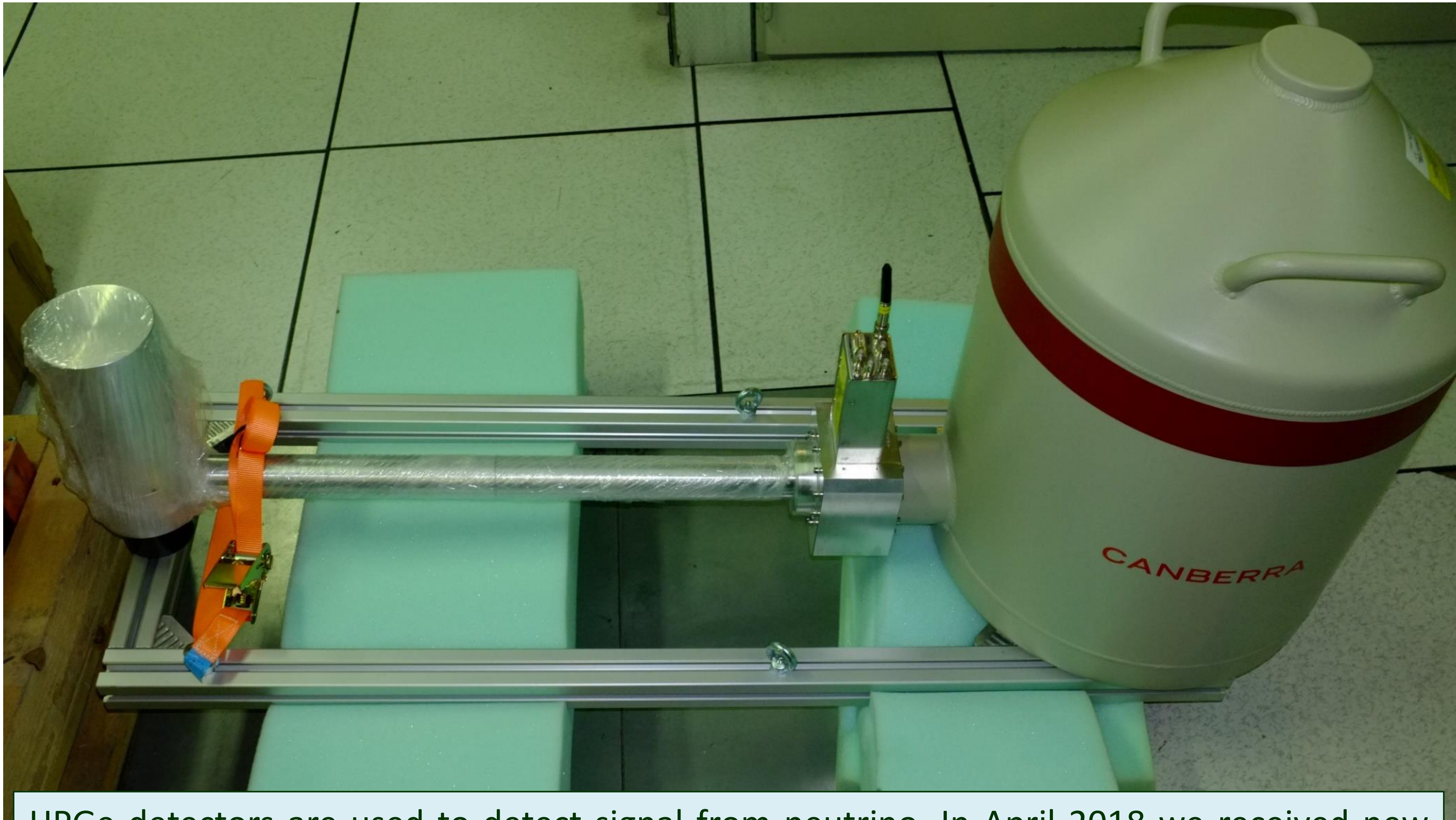
Lifting mechanism



To distinguish of signal from noise spectrum we will use:

- Reactor OFF/ON analysis
- Lifting mechanism which moves experimental setup away and to the core (~10 – 12.5 m).

HPGe detector for νGEN



HPGe detectors are used to detect signal from neutrino. In April 2018 we received new custom made low threshold HPGe detector, produced in a collaboration with CANBERRA (Mirion, Lingosheim). It allows to investigate much lower energy region than we did before.

Measurements at LSM

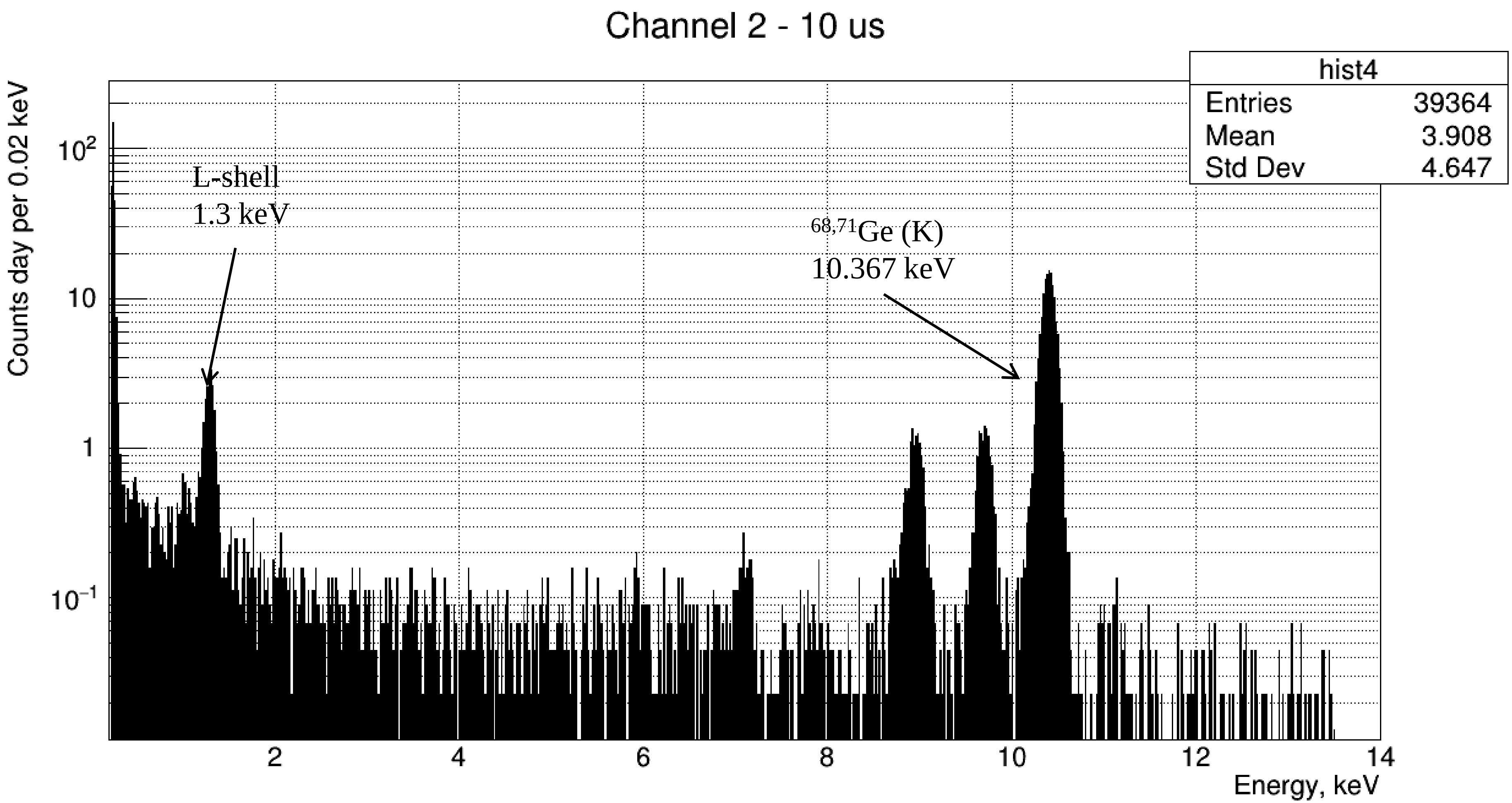
Internal background level of the detector were tested at LSM underground laboratory (Modane, France) from May – July 2018. Overburden equivalent to 4800 m w.e. allows to suppress μ flux in ~ $6 \cdot 10^6$ times, neutrons ~ 10^4 times.

Tests at LSM

Passive shielding from former Edelweiss-I experimental setup was used to suppress background from surrounding.

Low energy spectrum

Only simple ADC acquisition system were available on site for these measurements.

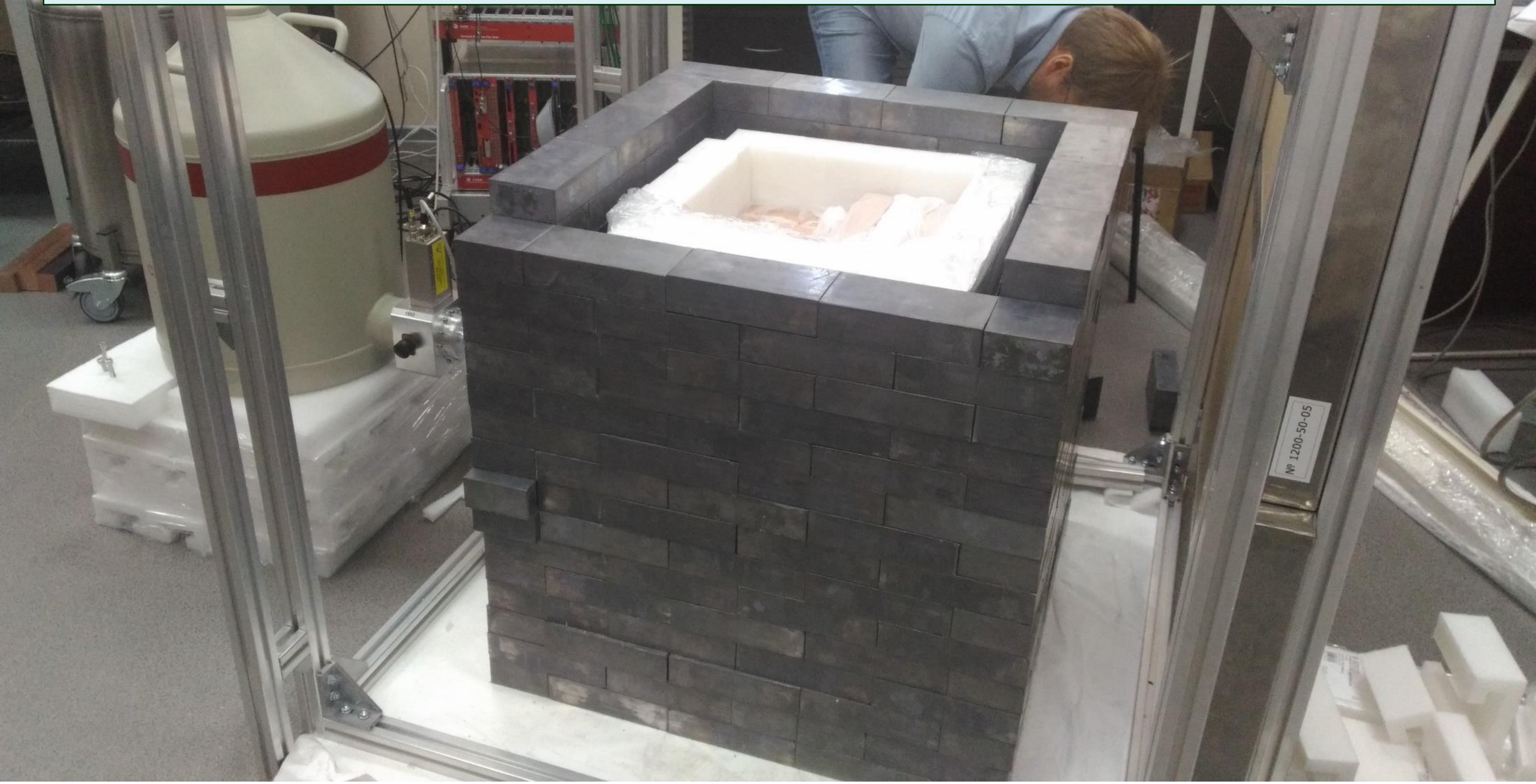


Most of the background at low energies is from cosmogenic activation and decays in time. Background level is better than in some dark matter experiment (for example COGENT).

Tests at JINR

After measurements at LSM detector was deliver to JINR (August 2018).

- Started measurements with new electronics based on real time ADC.
- It allows more efficiently suppress noise events including signal generated by reset of preamplifier.

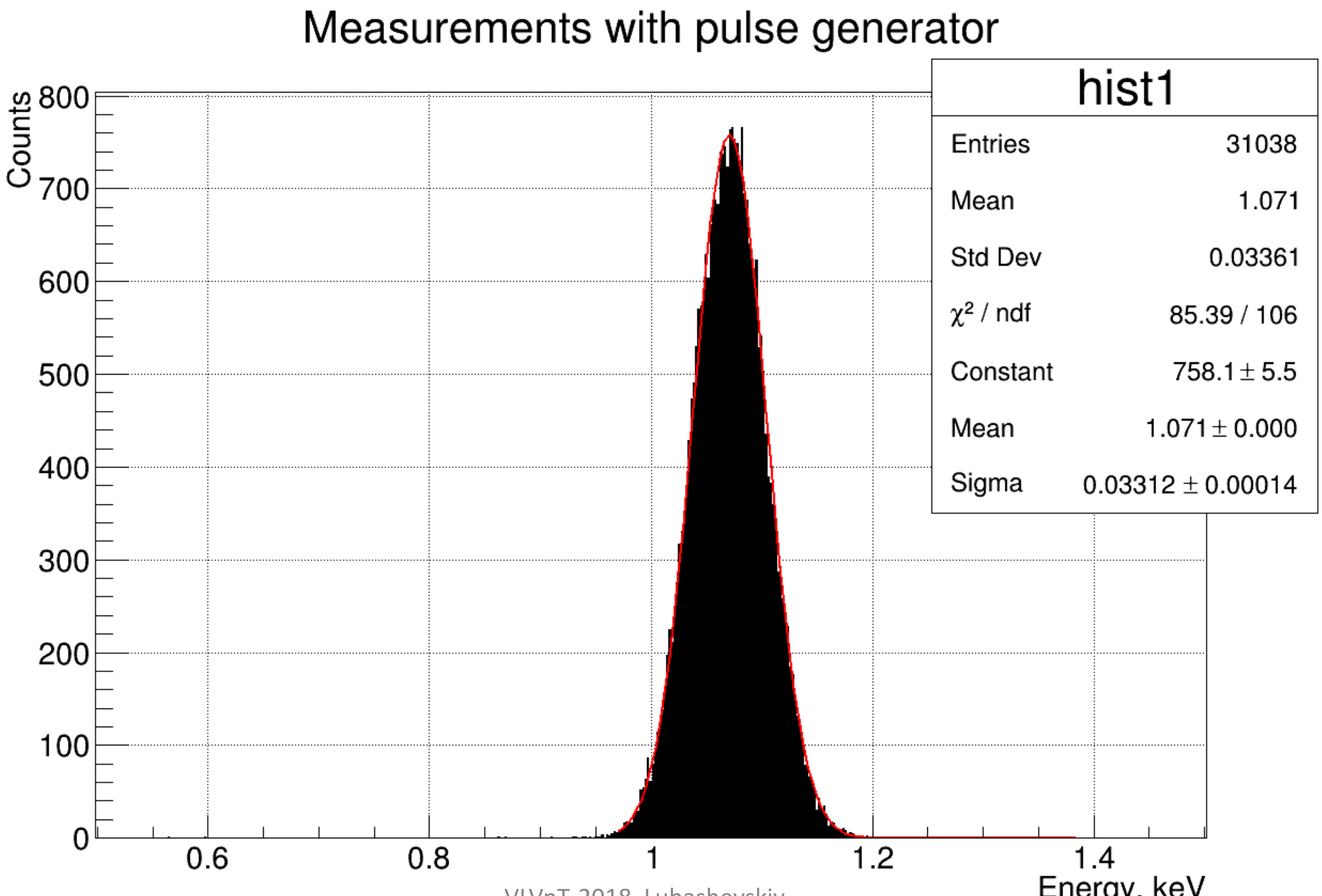


Tests at JINR

- Passive shielding from lead, copper and borated PE is used to suppress background from surrounding.
- μ veto were installed for suppression of cosmogenic background.
- Exactly the same scheme will be at KNPP

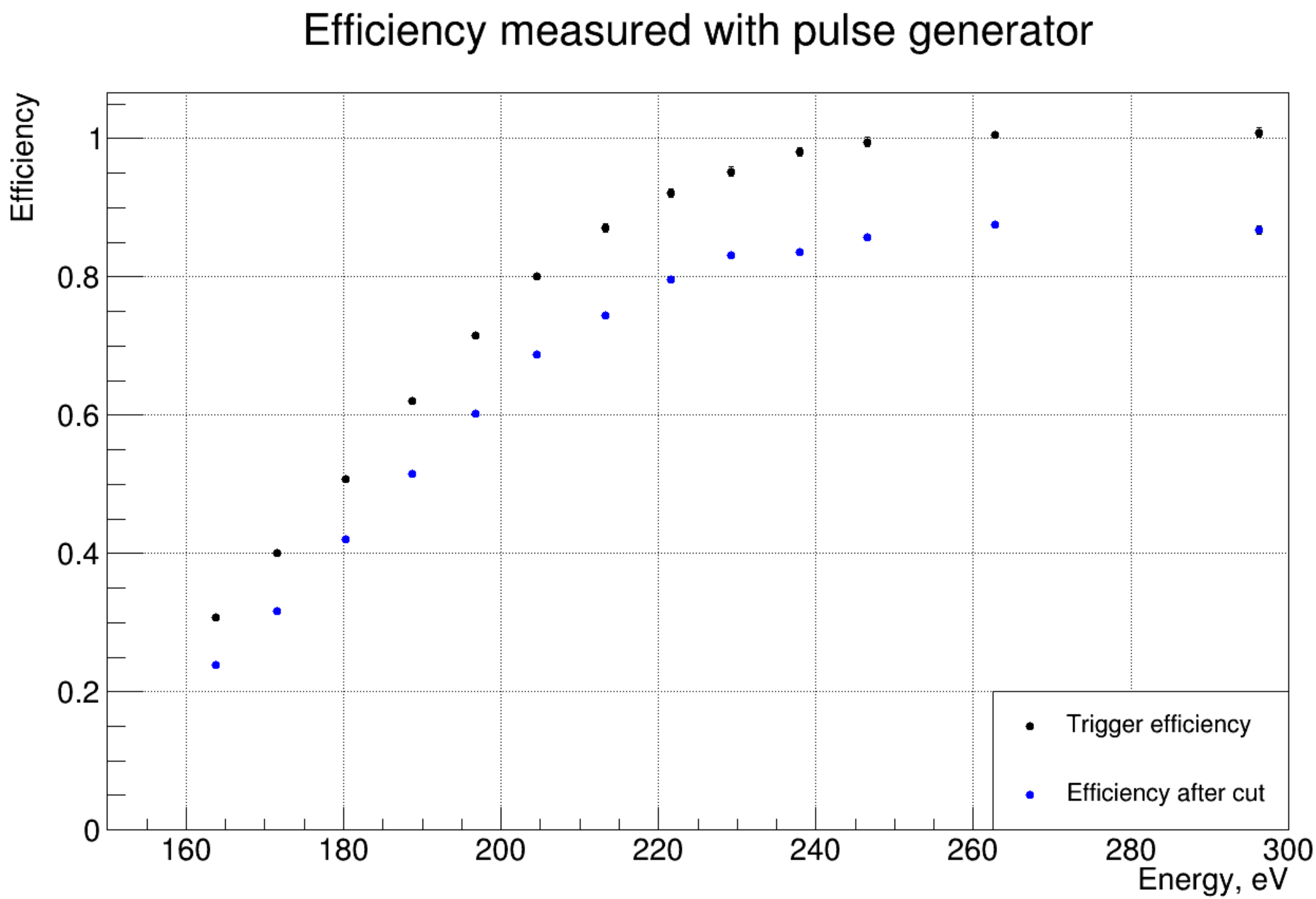
Tests at JINR

Achieved energy resolution is 78.0(3) eV (FWHM) (at LSM it was 85 eV).



Energy threshold

One of the most important parameter of the experimental setup is the energy threshold. Measurements with the pulser demonstrates possibility to acquire signal below 200 eV.



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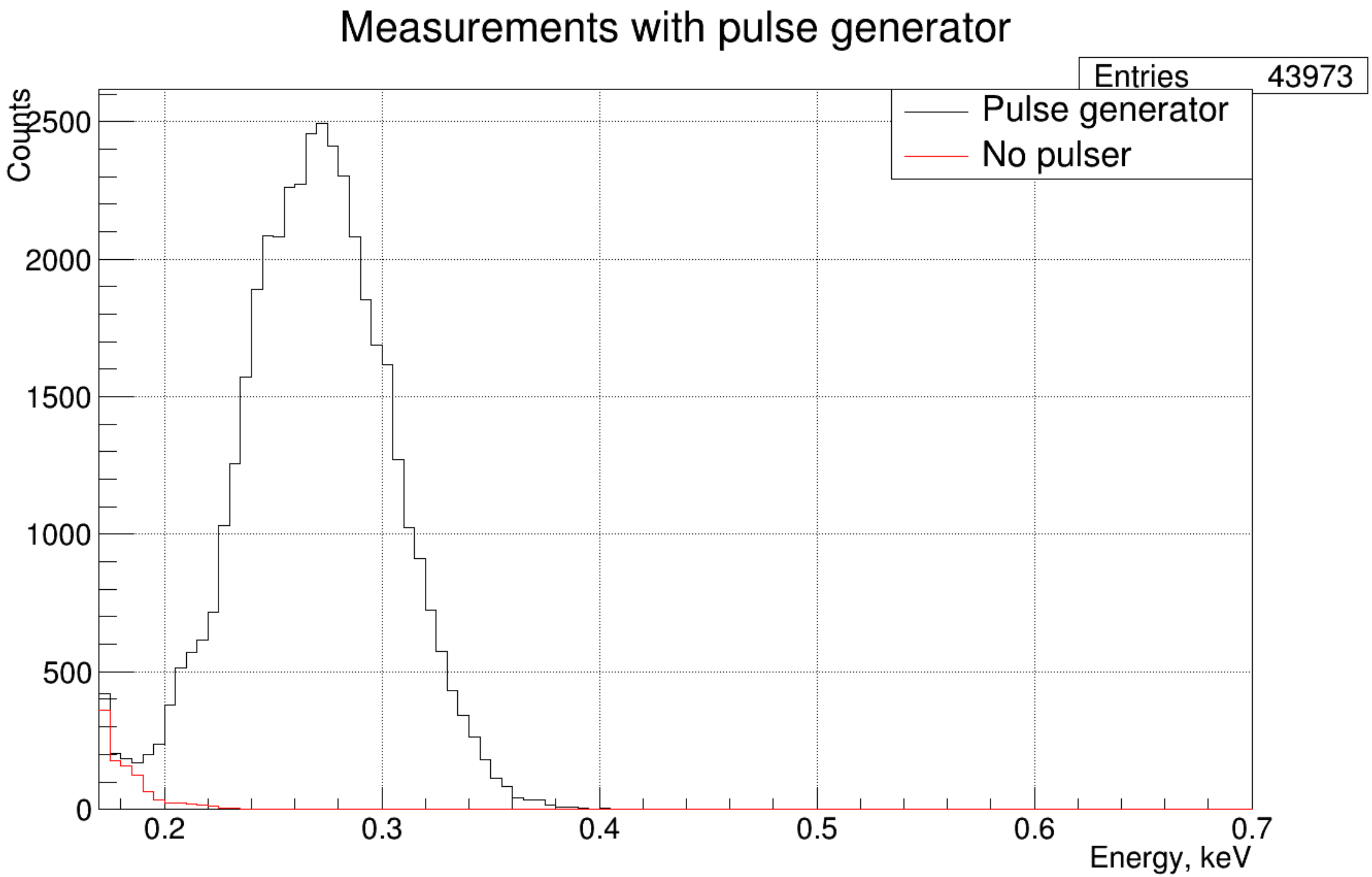

Conclusion

- First low threshold detector for νGEN spectrometer was produced and tested. In total we will have four detectors with a total mass of 5.5 kg.
- Measurements at underground laboratory demonstrate the background level comparable with dark matter experiments.
- Achieved energy resolution is 78 eV (FWHM). Possibility of detection of events below 200 eV was demonstrated.
- Experimental setup is ready to be deliver to KNPP.