Status of investigations of neutrino properties with the νGEN spectrometer at Kalinin Nuclear Power Plant

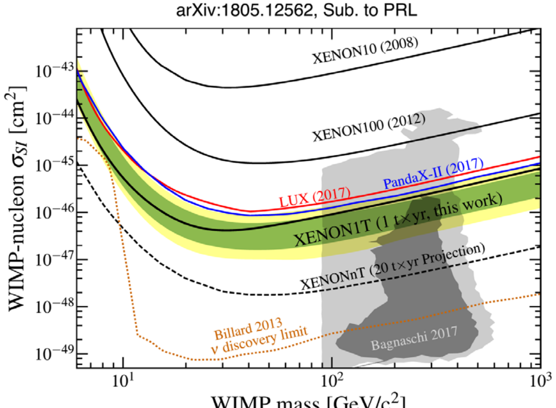
A.V.Lubashevskiy for the νGEN collaboration

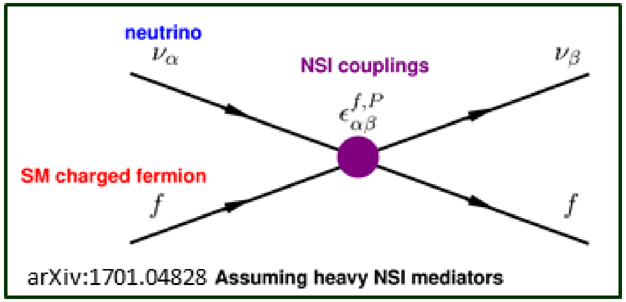
Joint Institute for Nuclear Research, Dubna, Russia

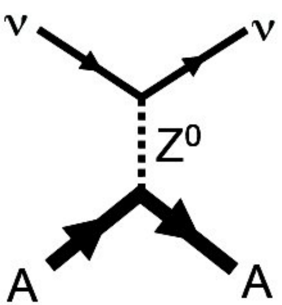
Motivation

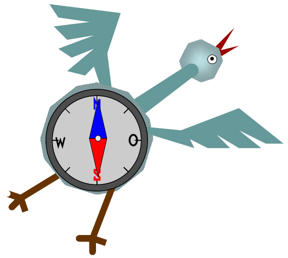
Measurement of the neutrino properties is a very important task for particle physics, astrophysics and cosmology. Being one of the most abundant particle in the Universe its detection is challenging due to very weak interaction with matter. Many task need to be studied:

- Neutrino mass and nature
- Neutrino hierarchy
- **Sterile neutrino(s)**
- **Coherent Elastic Neutrino-Nucleus Scattering (CEvNS)**
- **Magnetic Moment of Neutrino (MMN)**
- **Non-standard neutrino interaction (NSI)**
- **Applied usage, reactor monitoring…**

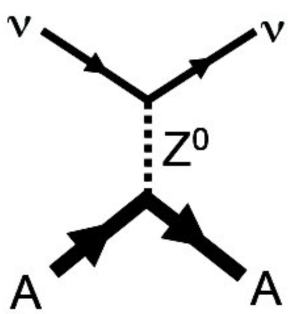








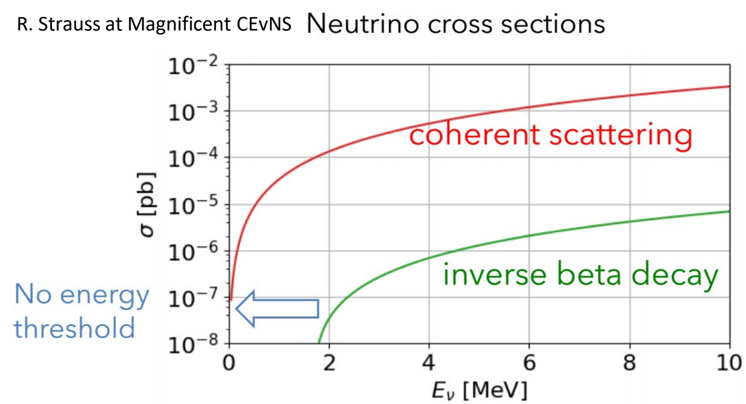
CEνNS

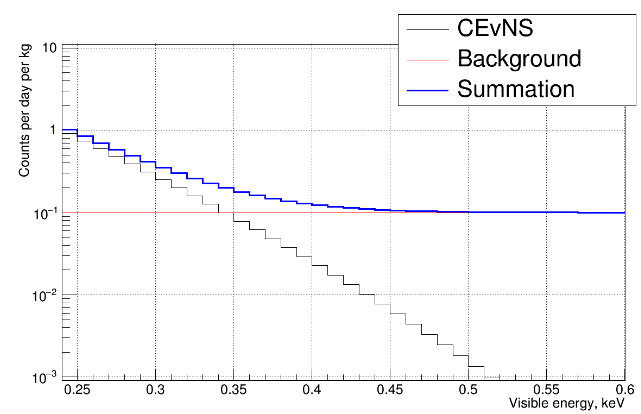


Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) is a process predicted by the Standard Model, but has not been observed yet for the reactor neutrino. The detection of this process would be an important test of the Standard Model. Such observations can also help for the search of non-standard neutrino interactions, sterile neutrinos and other investigations.

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

- Process for low energy neutrino, 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, N^2
- Recoil energy is very low – less than few keV
- Often only a small part of recoil energy can be detected due to quenching (<25% for HPGe).





MMN

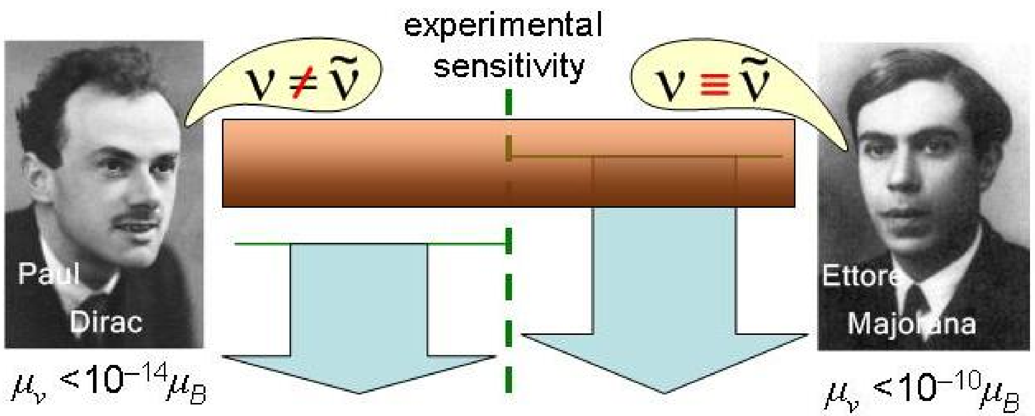
A magnetic moment is the fundamental parameter of the neutrino and its investigation may lead to results beyond the standard concepts of elementary particle physics and astrophysics.

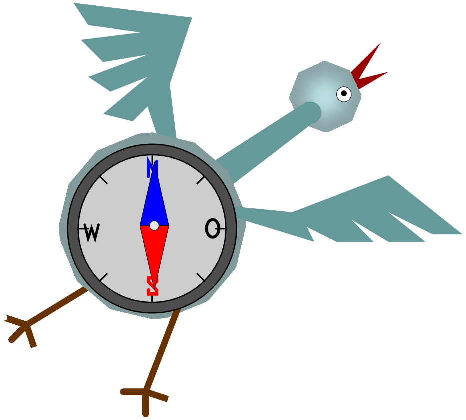
In minimally extended SM: $\mu_\nu \sim 10^{-19}\,\mu_B$

Different extensions of SM gives higher values of MMN:

for Majorana neutrino: $\mu_\nu = (10^{-11} \div 10^{-12})\,\mu_B$

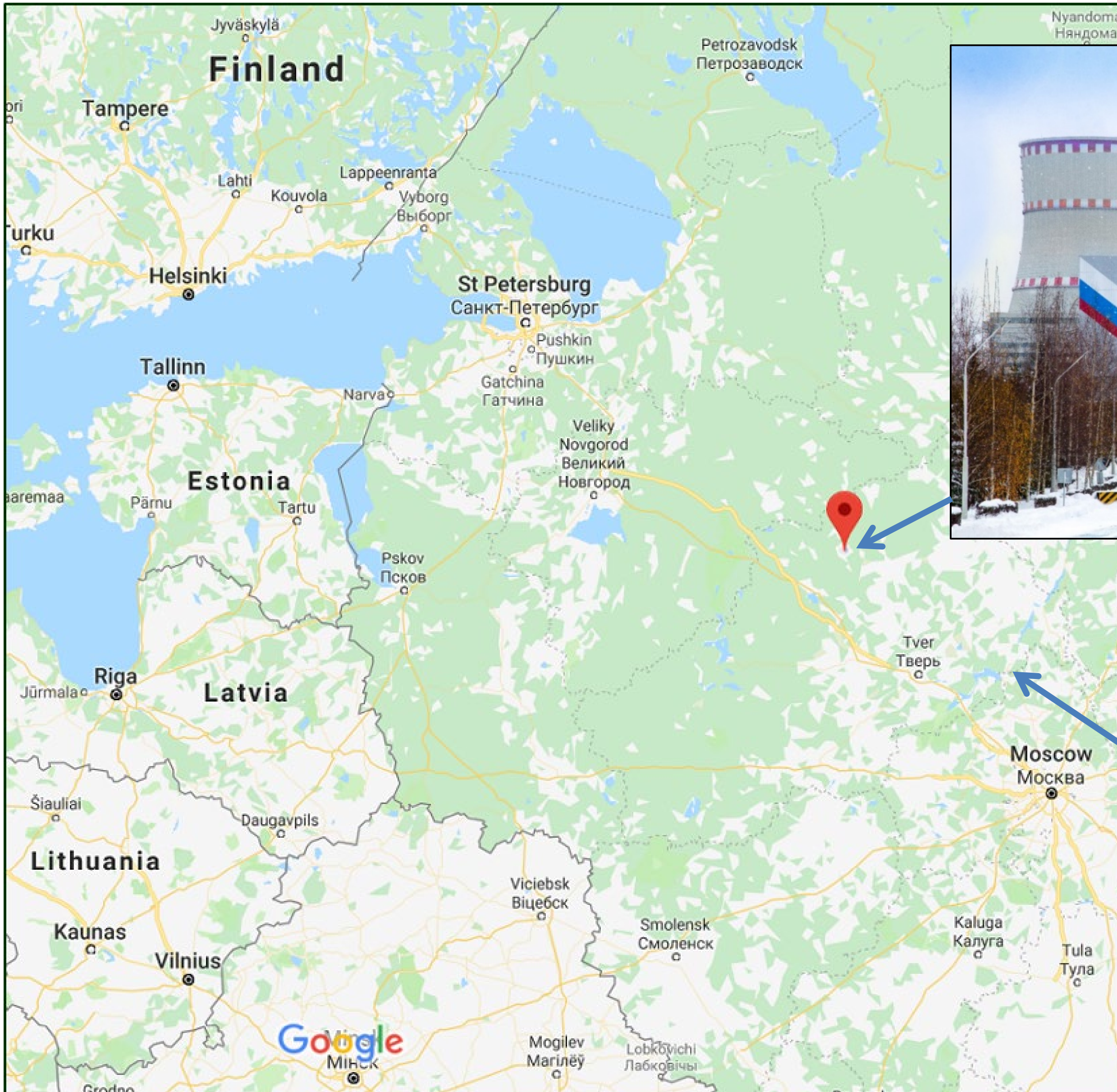
for Dirac neutrino: $\mu_\nu < 10^{-14}\,\mu_B$





The predecessor of νGEN - GEMMA-I experiment set current best laboratory limit of $\mu_\nu < 2.9 \cdot 10^{-11}\,\mu_B$

JINR Reactor’s site at Udomlya

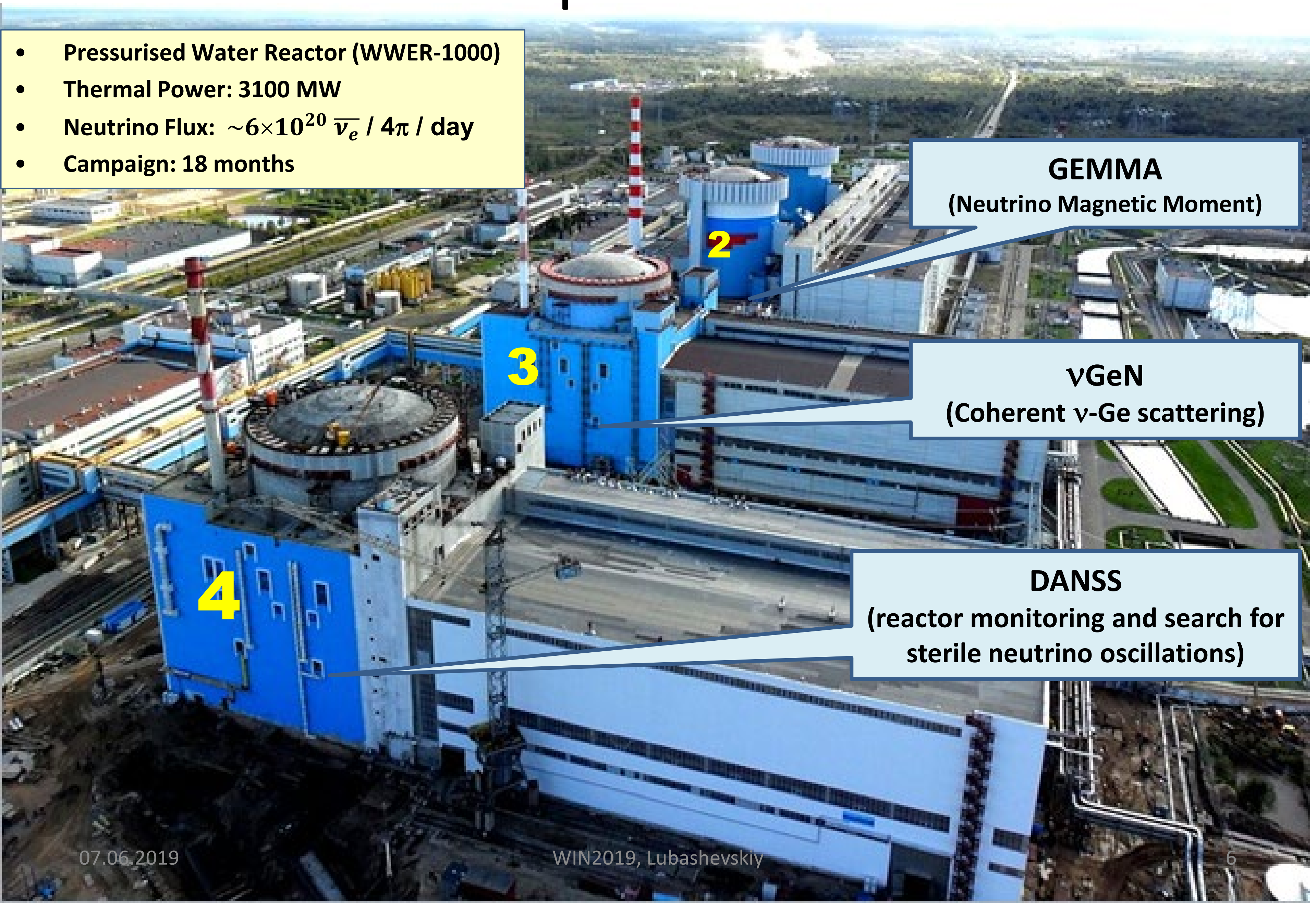


Kalinin Nuclear Power Plant (KNPP)

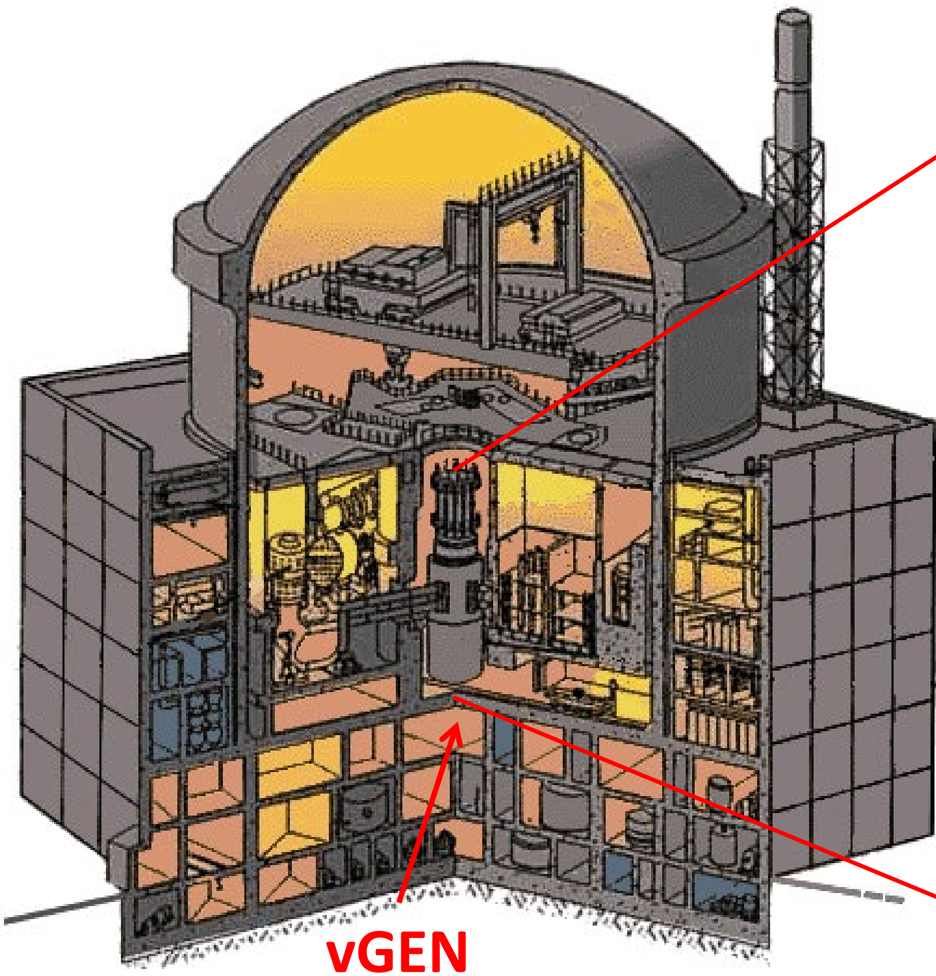
JINR, Dubna, 285 km from KNPP

Neutrino experiments at KNPP

- Pressurised Water Reactor (WWER-1000)
- Thermal Power: 3100 MW
- Neutrino Flux: $\sim 6\times 10^{20}\ \overline{\nu_e}$ / 4π / day
- Campaign: 18 months



Neutrino source



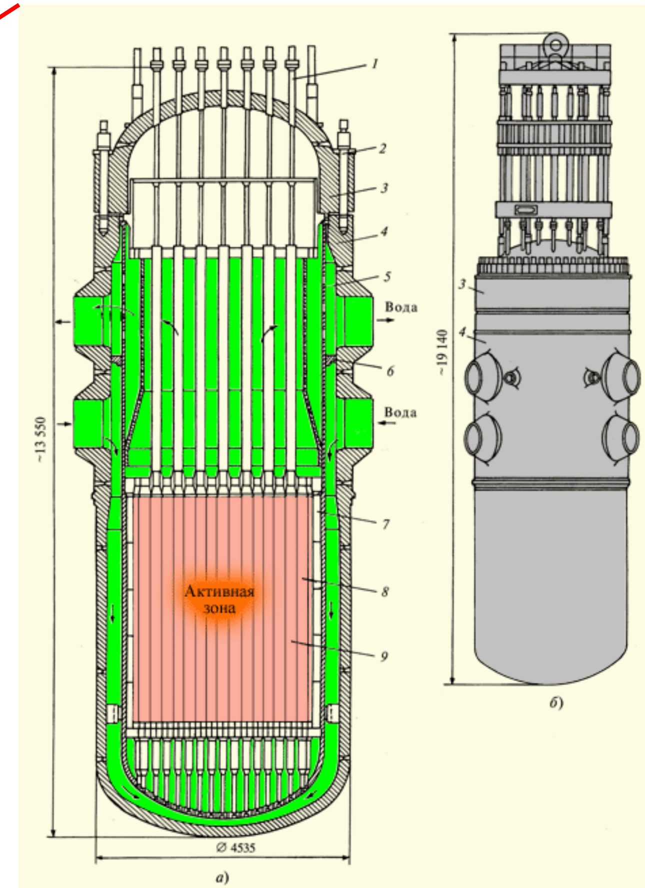
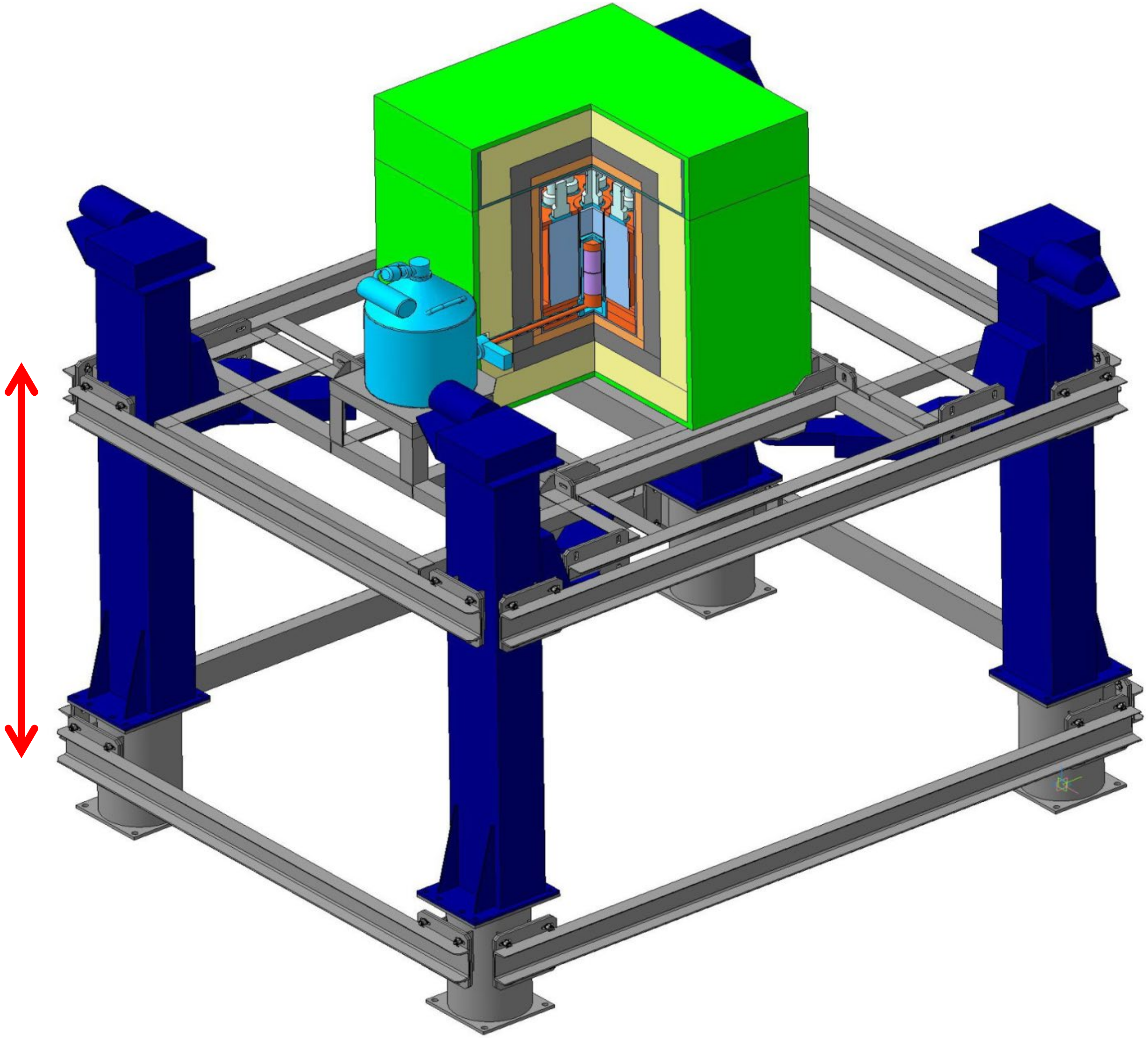


Рис. 5.4. Ядерный реактор ВВЭР-1000

vGEN spectrometer is been constructing at the close vicinity of the reactor core. It is located at **~ 10 m** from powerful 3.1 GW reactor's core under an enormous antineutrino flux of more than **>5·10^{13} ν/(s·cm^2).** Experimental setup is located under the reactor **~ 50 m w.e.** (good shielding against cosmic radiation).

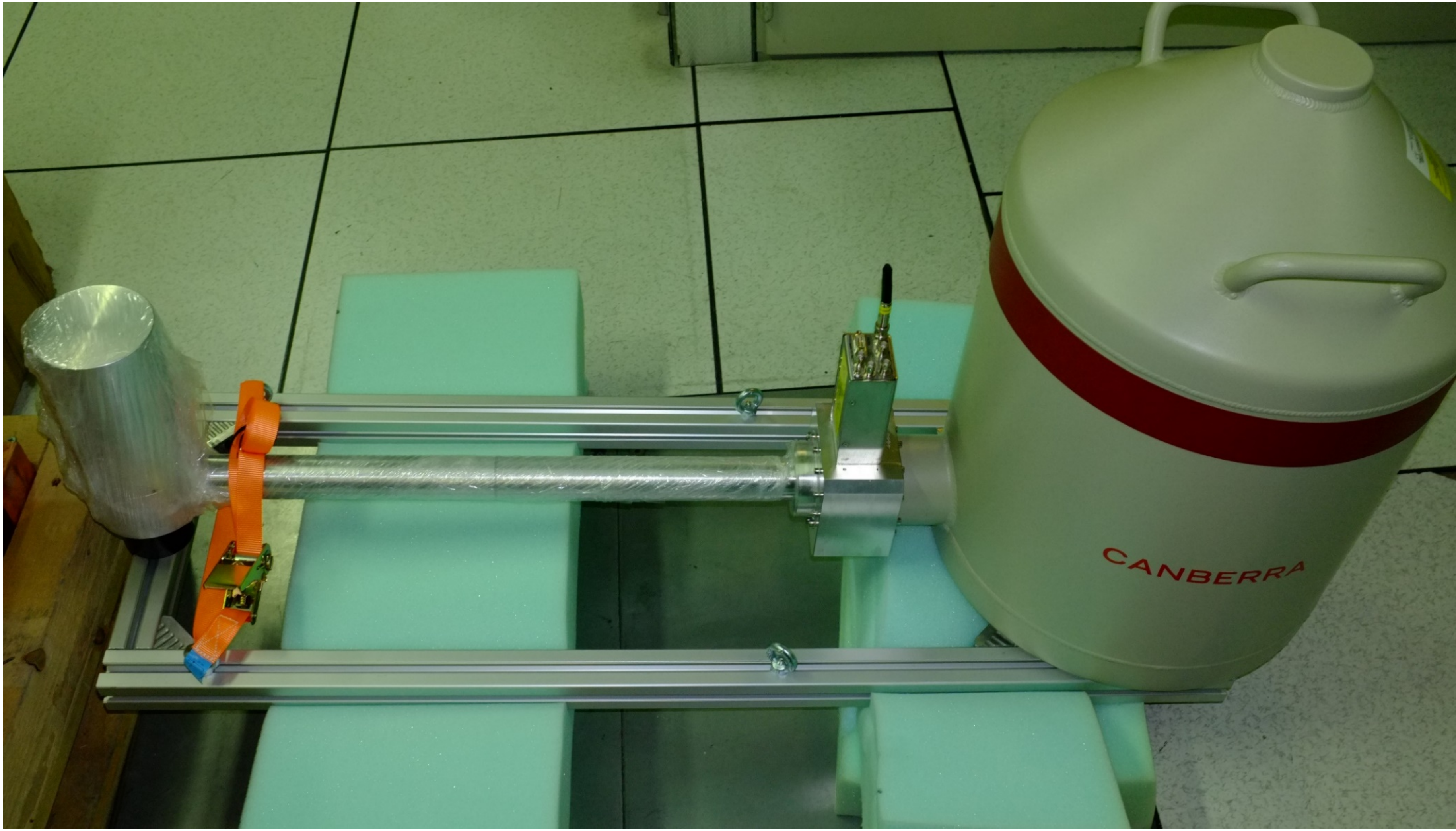
Lifting mechanism



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).
- Changes of the ν flux helps to suppress systematics errors connected with changes of background while reactor ON/OFF

HPGe detector for νGEN

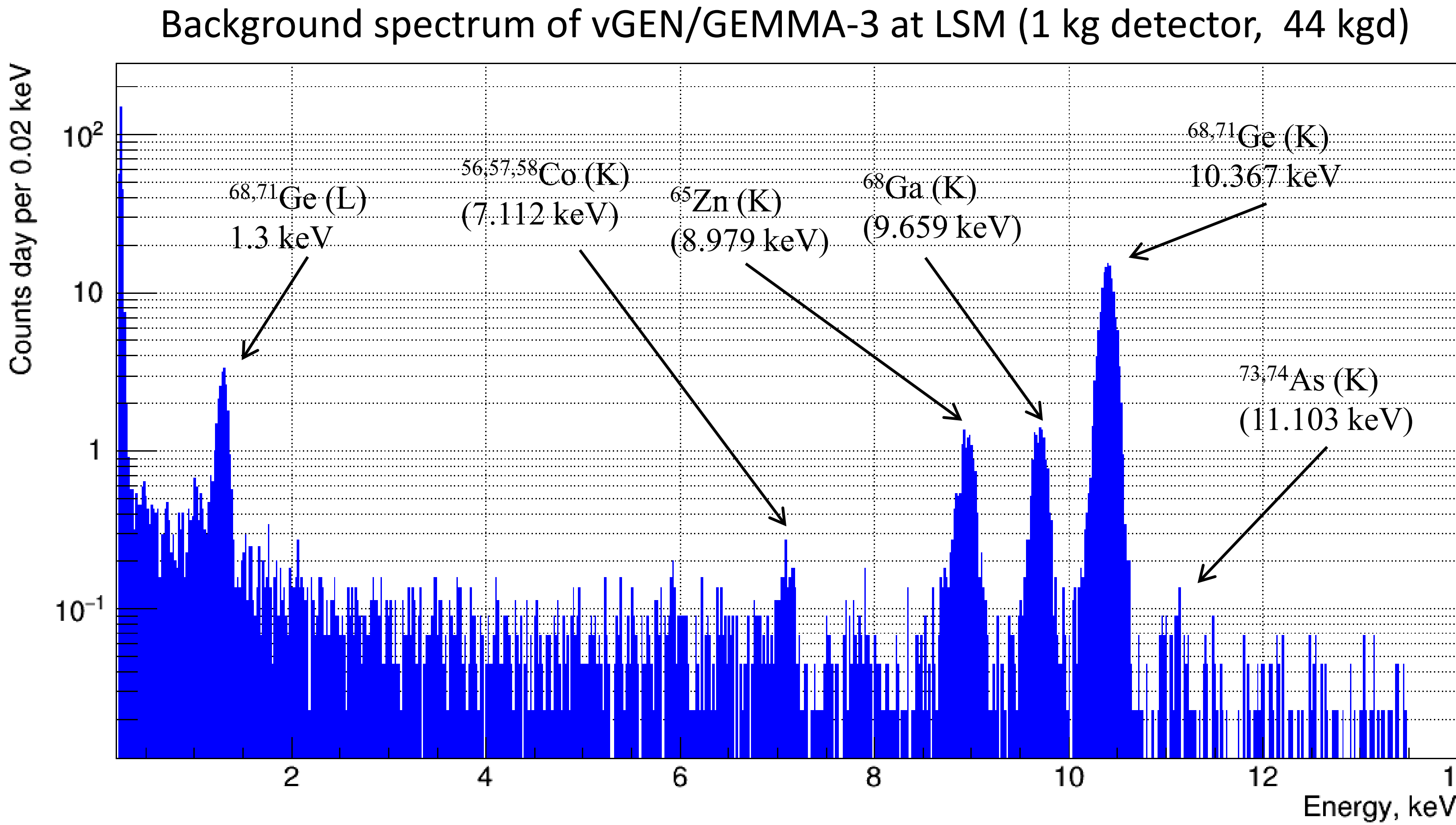


Low threshold HPGe detectors are used to detect signal from neutrino. They are produced by Mirion (CANBERRA, Lingosheim). Detector's mass: 1-1.5 kg.

Measurements at LSM

Internal background level of the detector was tested at LSM underground laboratory (Modane, France). Overburden equivalent to 4800 m w.e. $\rightarrow$ allows to suppress μ flux in ~ $6 \cdot 10^6$ times, neutrons ~ 10^4 times. Passive shielding from former EDELWEISS-I experimental setup was used to suppress background from surrounding.

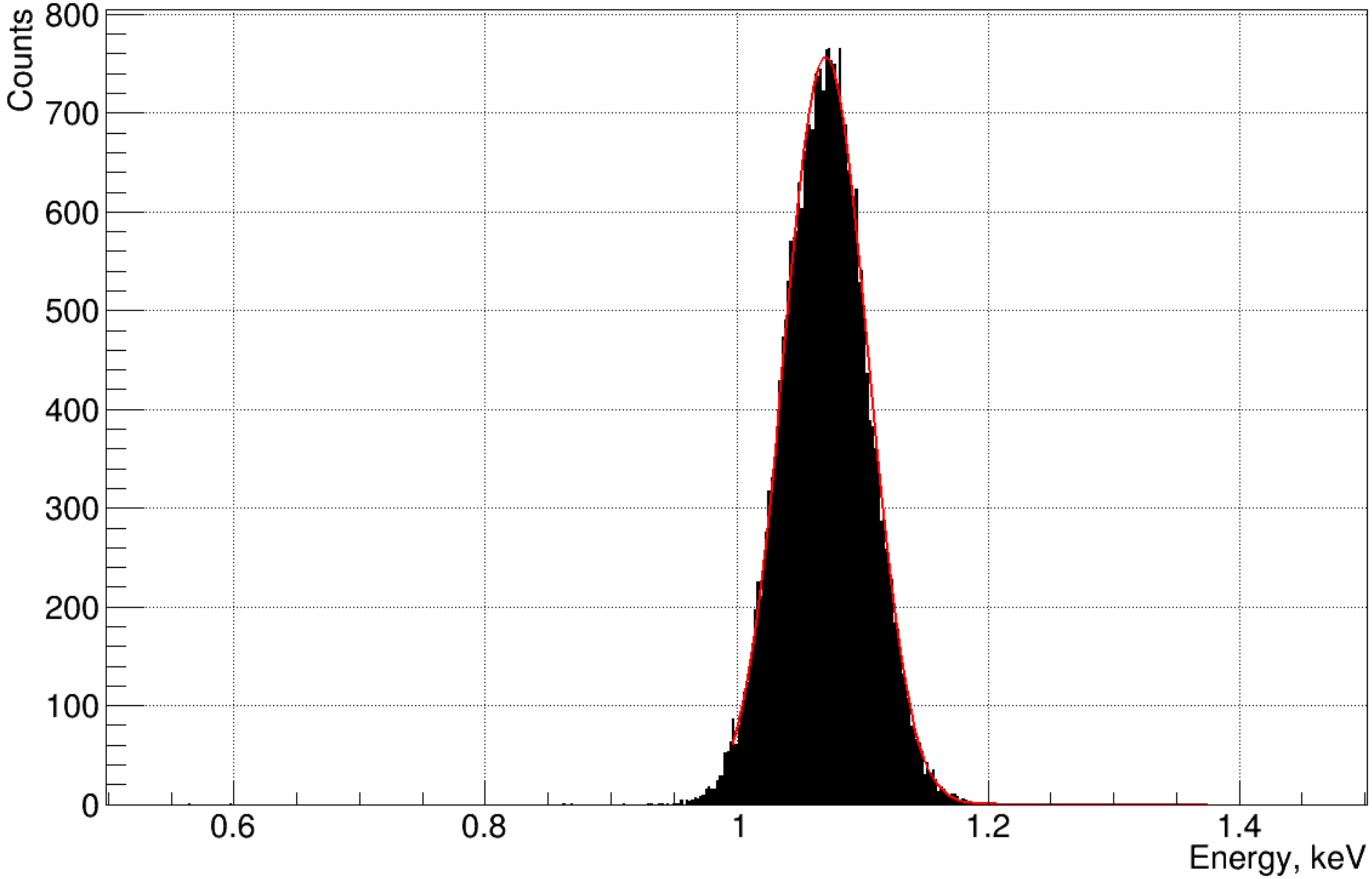
Low energy spectrum



Most of the background (all visible lines) at the low energies is from cosmogenic activation. These isotopes decay in time. Background level is much better than in some dark matter germanium experiments.

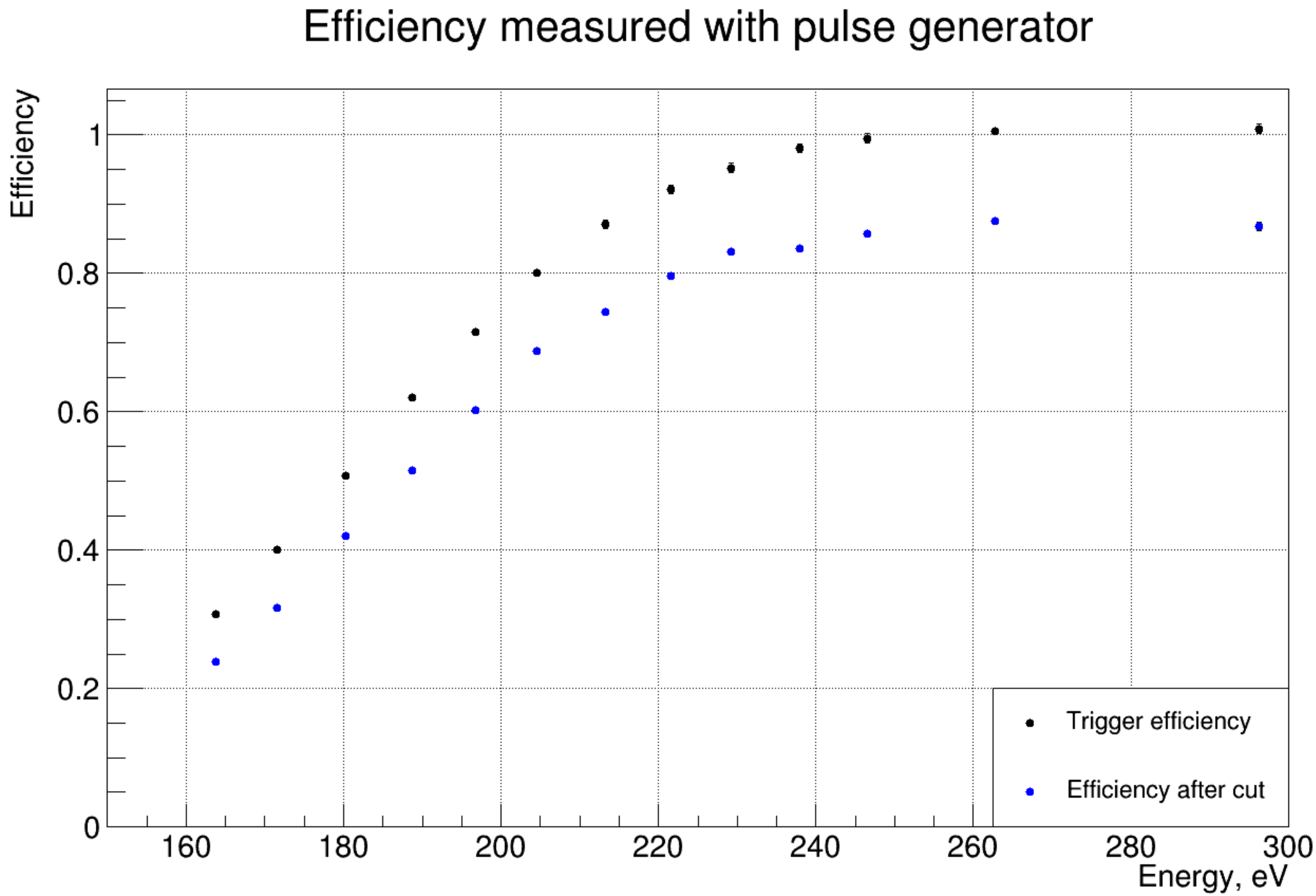
Energy resolution

Subsequent measurements at JINR (Dubna) with a new electronics showed better suppression of the noise events including signal generated by reset of the preamplifier. The achieved energy resolution is **78.0(3) eV** (FWHM)



Energy threshold

It was demonstrated a possibility to acquire signal **below 200 eV** (with trigger efficiency of about 70%).

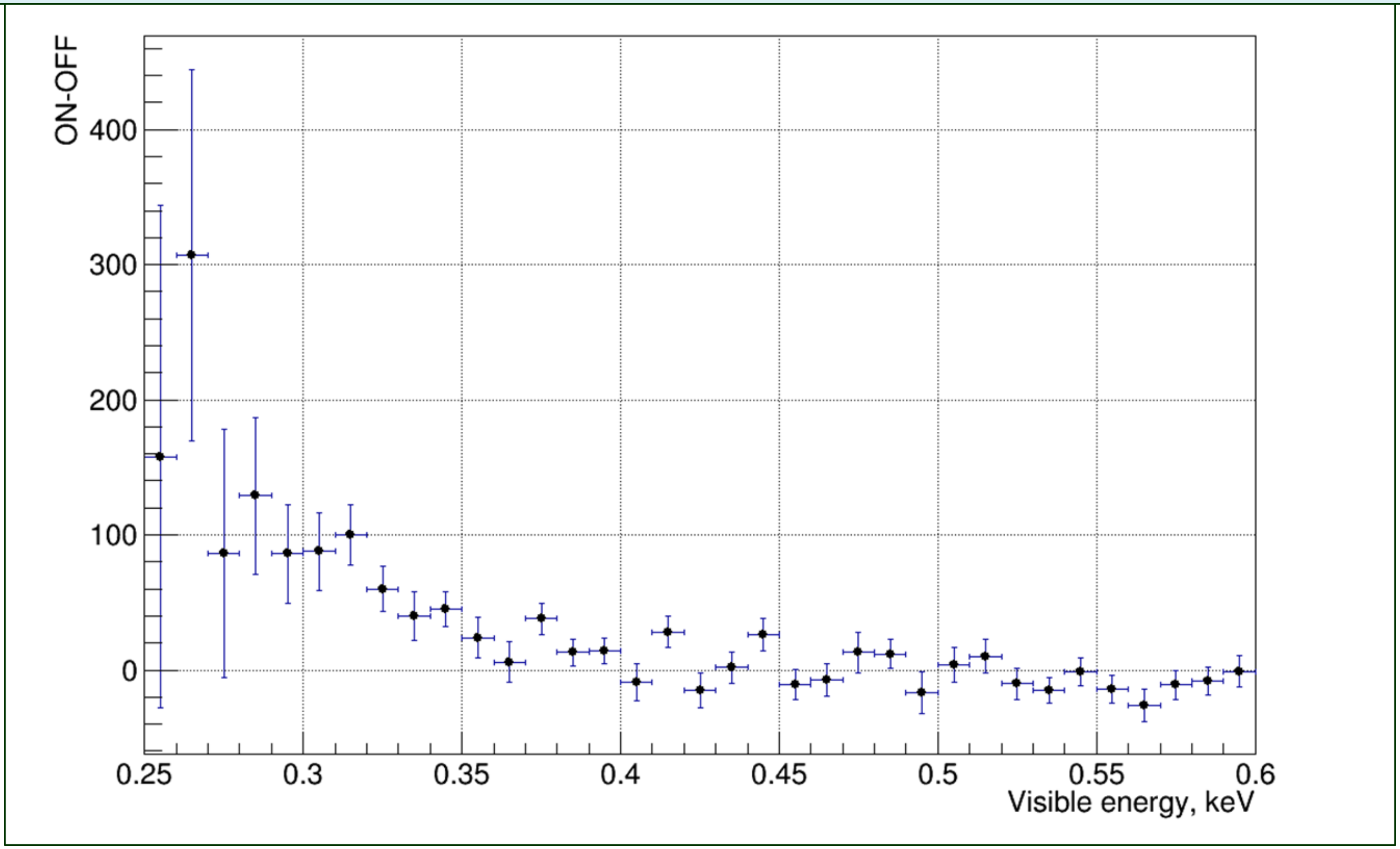


Tests of the setup at JINR

- Passive shielding from lead, copper and PE is used to suppress background from the surrounding.
- Active μ-veto works in the coincidence with germanium detector.
- All parts are ready to move to reactor site.

Expectations

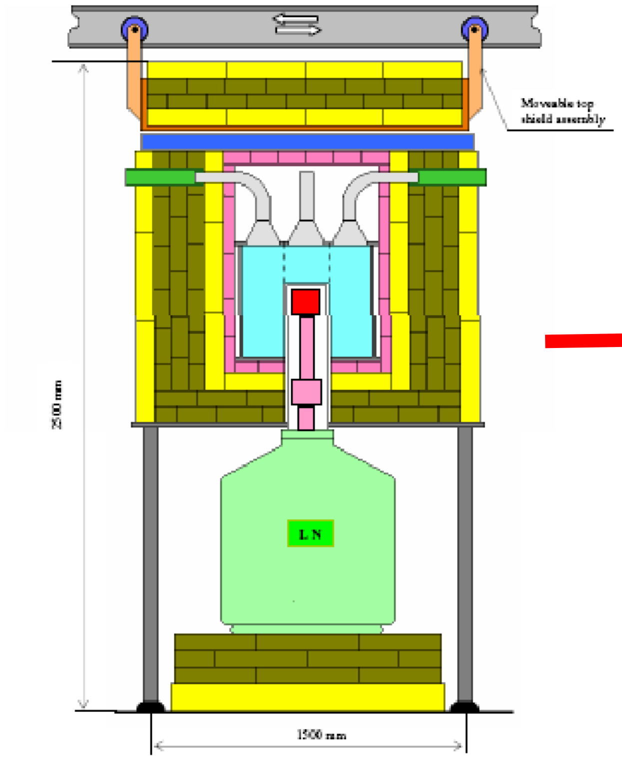
Expected difference from random generated spectrum reactor ON – OFF (30 days measurements each). Parameters for calculation spectrum from CEvNS: detector's resolution – 85 eV (FWHM), parameters of neutrino spectrum from Kopeikin12, Huber11, Haag14, average quenching factor - Scholz16.



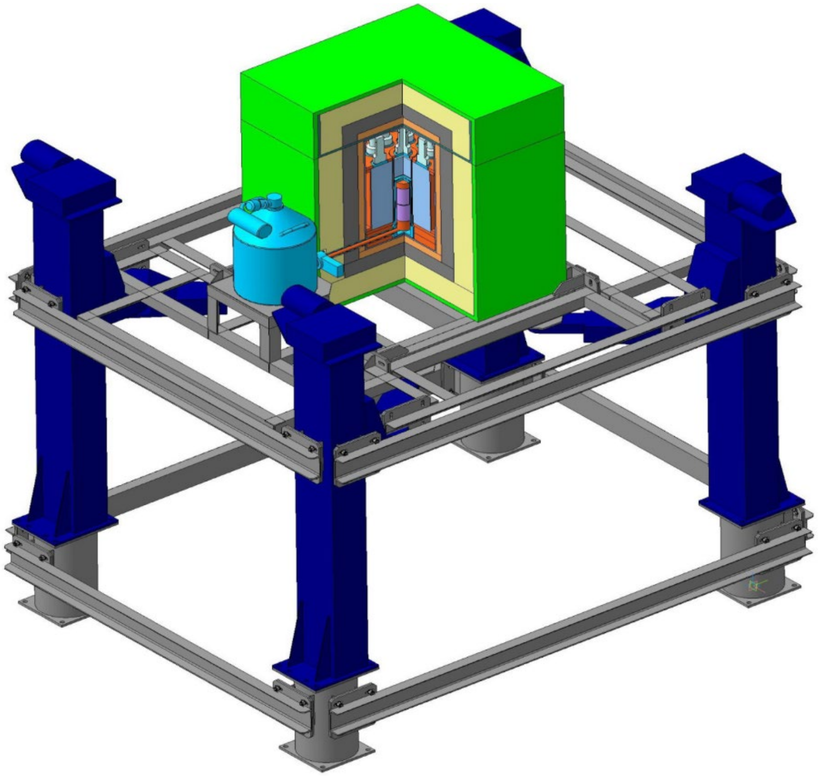
Spectrum of CEvNS at nuclear reactor should be revealed with the available detector soon after start of the measurements!

Expectation about MMN

GEMMA-I



νGEN



Improvement in comparison with GEMMA-I:

- ✓ Energy threshold: 2 keV → **200 eV** (achived)
- ✓ Neutrino flux: $2.6 \cdot 10^{13}\ \nu/(s \cdot cm^2) \rightarrow \mathbf{5 \cdot 10^{13}\ \nu/(s \cdot cm^2)}$ (place is ready)
- ✓ Mass: 1.5 kg → **5.5 kg** (delivery this month)
- ✓ $\mu_\nu < 2.9 \cdot 10^{-11} \mu_B$ (world best limit) → $\mu_\nu < (5\text{-}9) \cdot 10^{-12} \mu_B$ (after few years of data taking)

Start installations at KNPP

Start installations at KNPP

Conclusion

- First low threshold detector for νGEN spectrometer was produced and tested. In total 4 detector with a total mass of 5.5 kg will be used for investigations.
- Measurements at underground laboratory demonstrate the background level sufficient for our studies.
- Achieved energy resolution is 78.0(3) eV (FWHM). Possibility of detection of events below 200 eV has been demonstrated.
- Preparations of the measurements at KNPP are ongoing.

Thank you!