Precision measurements of ^{144}Ce-^{144}Pr beta-spectra with Si(Li)-spectrometers

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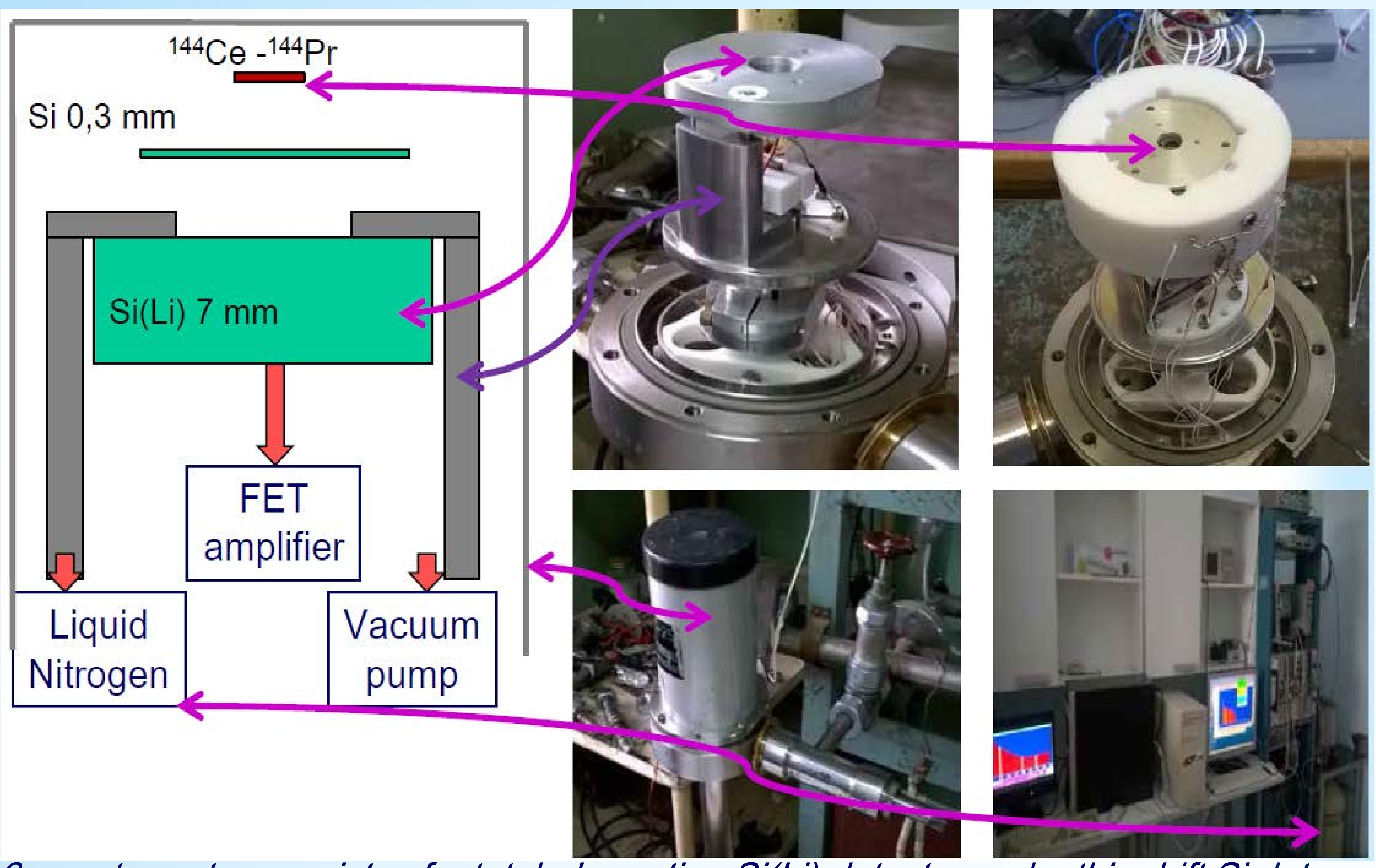
β-spectrometer with Si-detectors



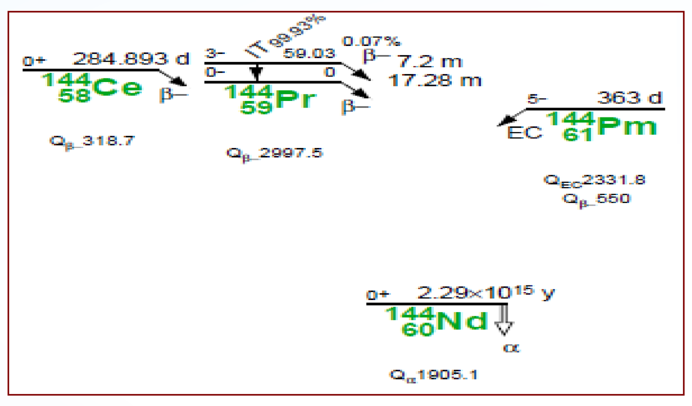
β-spectrometer consists of a total-absorption Si(Li) detector and a thin drift Si detector. The use of coincidences between the signals from the thick and thin detectors makes it possible to efficiently separate β radiation from X- and γ- rays.

4π β-spectrometer with two Si-detectors

Si(Li) detectors produced in PNPI with diameter of sensitive region 16 mm, thick 9 mm, I=10 pA at 1000 V. The energy resolution measured with γ lines of ^{241}Am is FWHM= 1.1 keV. The source was deposited into a small concavity in the center of one of the detectors; the second one was attached to the top of the first one, making up a 4 geometry.

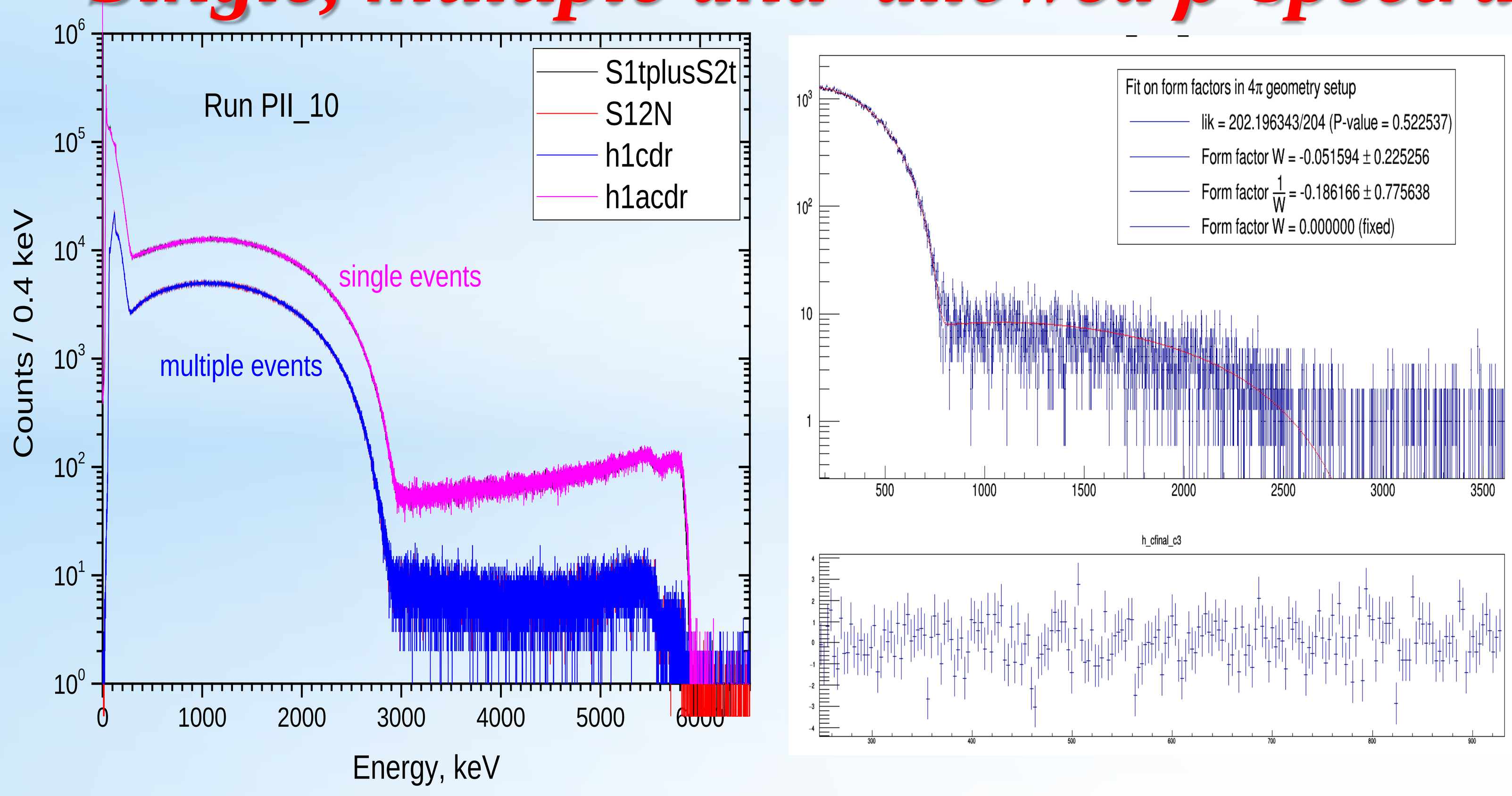
Decay schemes of ^{144}Ce -^{144}Pr

Q_β ^{144}Ce	Q_β ^{144}Pr	γ ^{144}Ce	γ ^{144}Pr
318.7 (76.5%)	2997.5 (97.9%)	133.5 (11.1%)	696.5 (1.3%)
185.2 (19.6%)	2301.0 (1.04%)	80.1 (1.36%)	2185.7 (0.69%)
238.6 (3.9%)	811.8 (1.05%)	41.0 (0.26%)	1489.1 (0.28%)



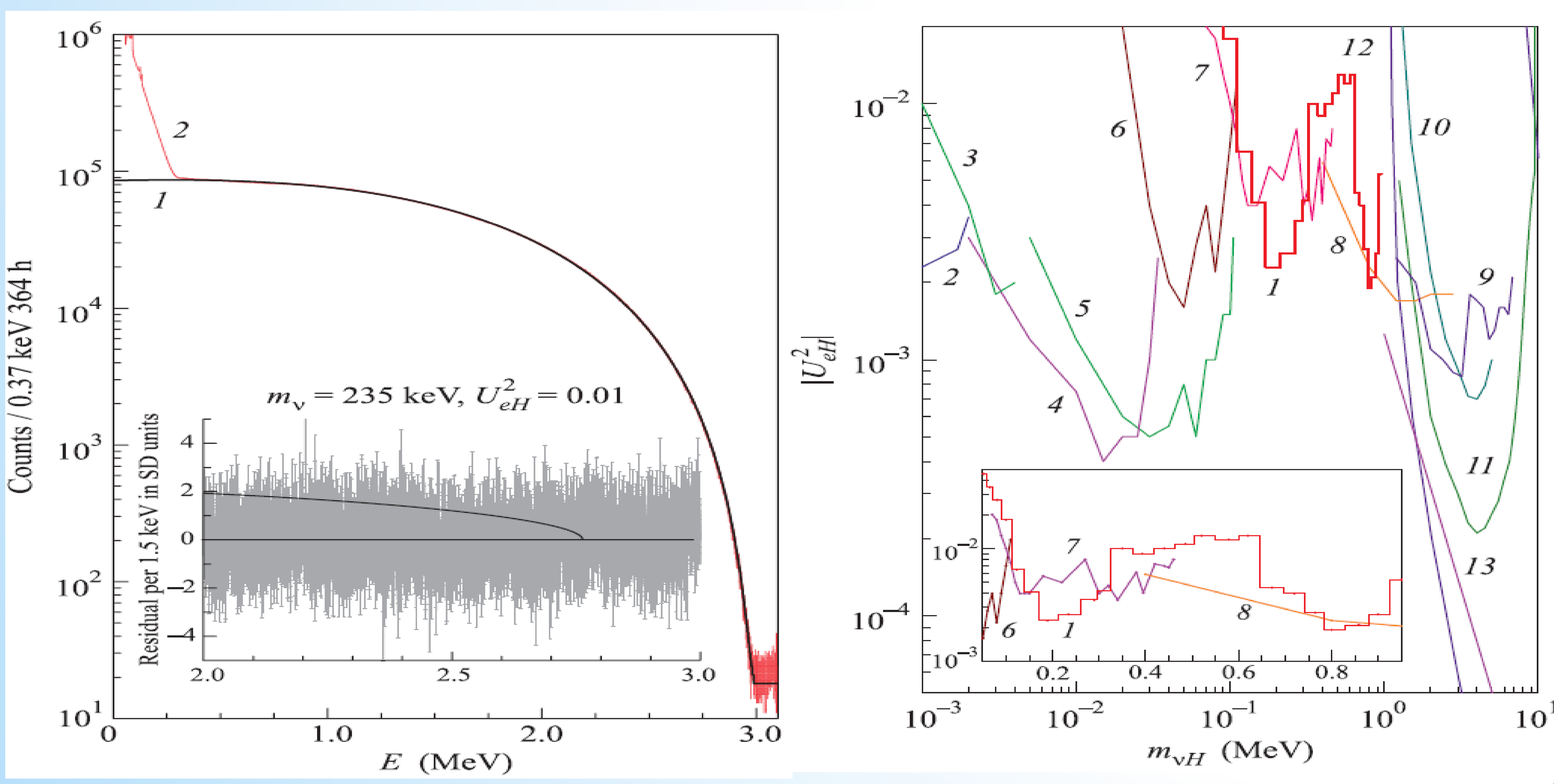
^{144}Ce-^{144}Pr source continues to be the most promising for searches for neutrino oscillations to a sterile state. The shape of 144Pr β-spectrum has a significant effect on the precision of determining of oscillation parameters for sterile neutrino.

Single, multiple and allowed β-spectra



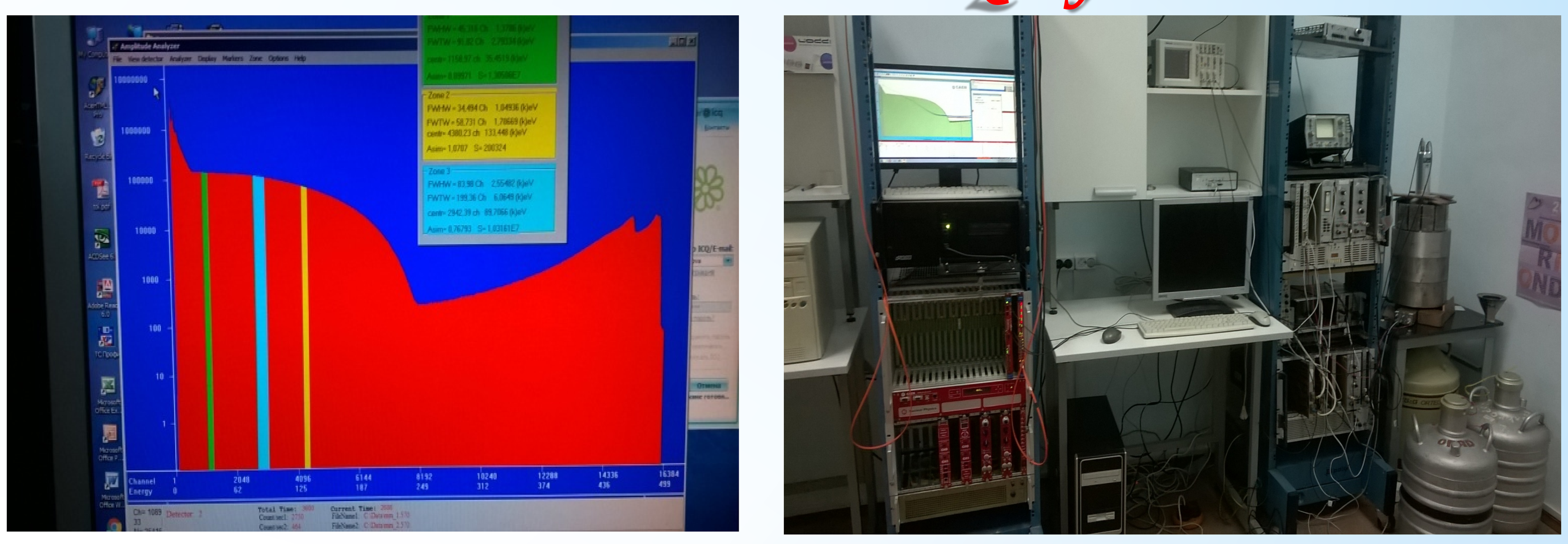
Gaussian response function of 4π-spectrometer allows to directly measure the energy of electrons in β-decay and, accordingly, to determine the spectrum of electron antineutrinos. The measurement of total e-spectrum practically solves the problem if anti-ν spectrum

Search for neutrino with m=0.01-1.0 MeV



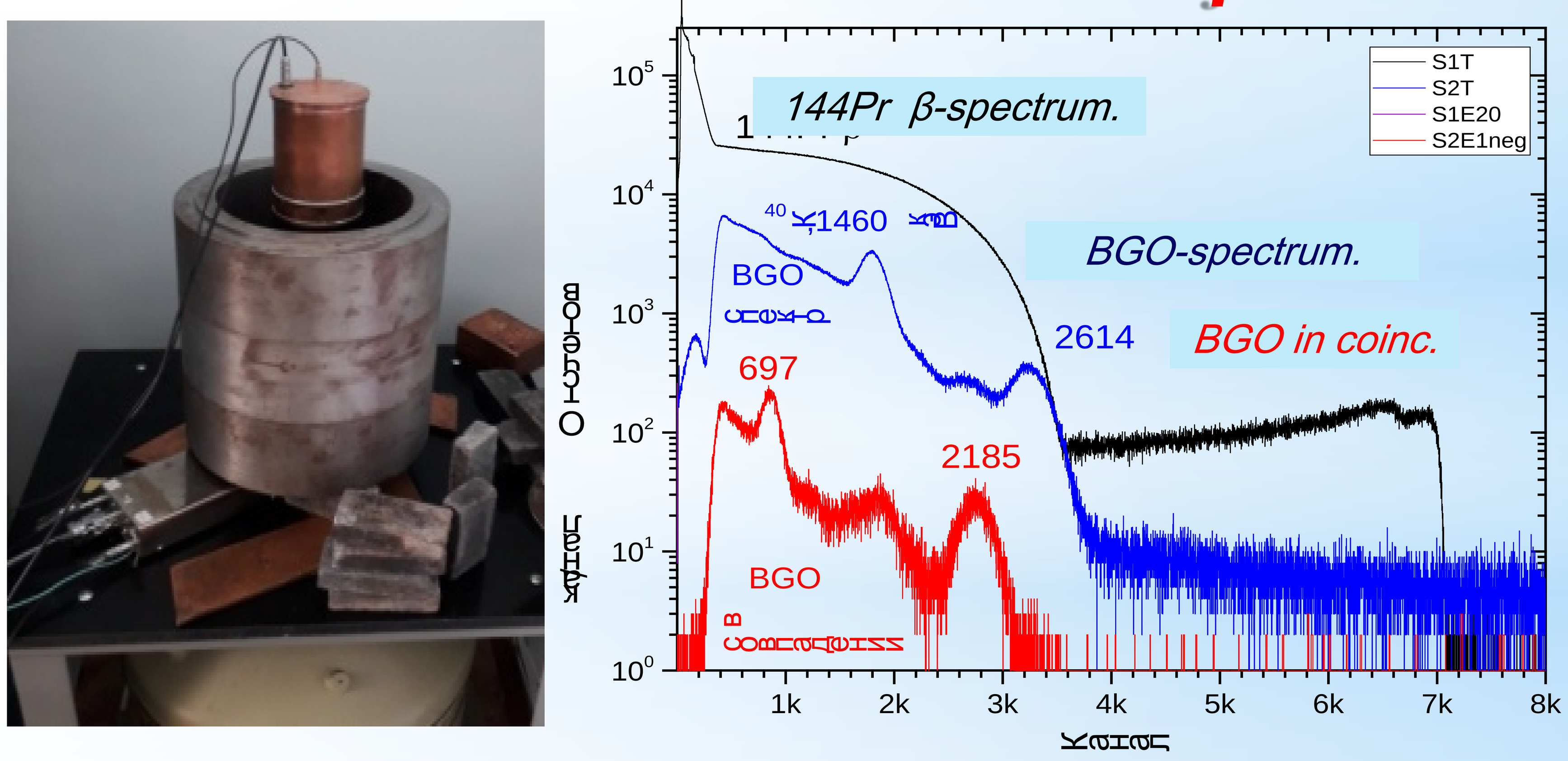
For the neutrino with the mass in the interval of 150–350 keV, new upper limits on mixing parameter $|u_{eH}|^2 \leq (2\text{-}5)\times10^{-3}$ have been obtained. JETP Lett. 108 499 2018

Electronics and DAQ system



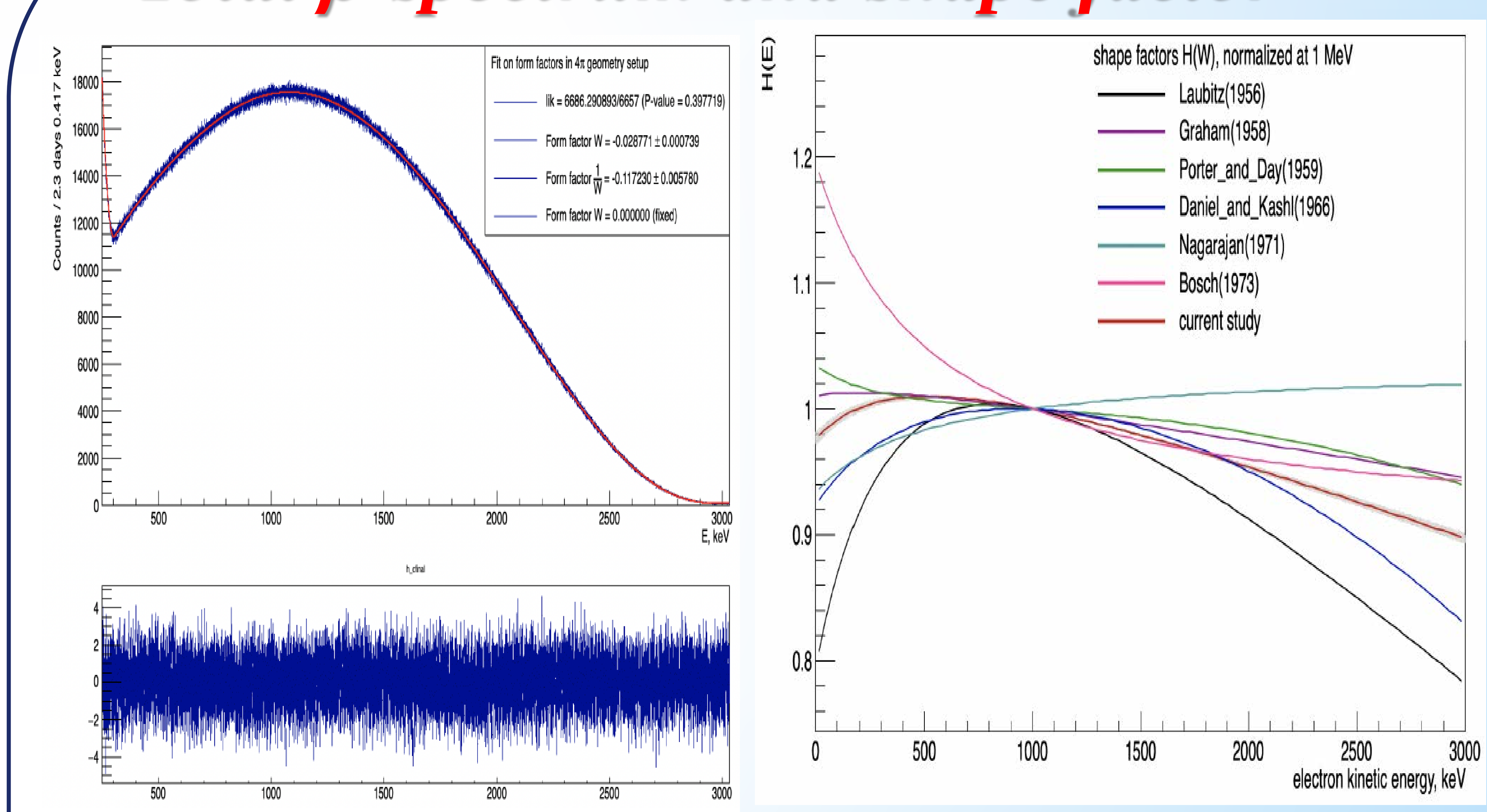
Compound of the Si(Li) detectors was installed into the vacuum cryostat and cooled down to the liquid nitrogen temperature. The electronics included a multichannel 14-bit ADC with 250 MHz and made it possible to select (anti) coincident events from both detectors.

Transitions to the exited states of ^{144}Nd



To study allowed β-transition to the 1^- excited state of 144Nd with excitation energy of 2185 keV the BGO 3" scintillator crystal was located on the top of the setup for the γ - signals detection in coincidence with the signals from the semiconductor detectors.

Total β-spectrum and shape factor



The β-spectra theoretical description: $N(W) = F(W;Z)PW(W - W0)^2C(W)$, where W and P are total energy and momenta of the electron, F(W;Z) - Fermi-function. The form-factor parameters that were obtained are: $C(W) = 1 + (-0.02877 \pm 0.00028)W + (-0.11722 \pm 0.00297)W^{-1}$. Parameters of shape factor are measured with 1% precision that is enough for new neutrino experiments with ^{144}Ce-^{144}Pr source.

S. Bakhlanov et al., 4π semiconductor beta-spectrometer for measurement of ^{144}Ce - ^{144}Pr spectra, Journal of Physics: Conf. Ser. 1390 (2019) 012117
I.E.Alexeev et al., Beta-spectrometer with Si-detectors for the study of ^{144}Ce-^{144}Pr decays, Nuclear Inst. and Methods, A 890, 64-67, (2018)
N. V. Bazlov et al., A Beta Spectrometer Based on Silicon Detectors, Instruments and Experimental Techniques, 2018, Vol. 61, No. 3, pp. 323