Dependence of coherent elastic neutrino-nucleus scattering count rate in the RED-100 experiment at Kalinin nuclear power plant on the models of reactor antineutrino energy spectra

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RED
RUSSIAN EMISSION DETECTOR

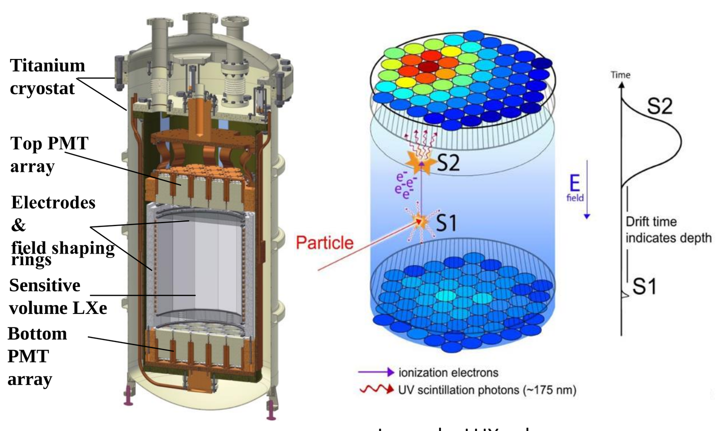
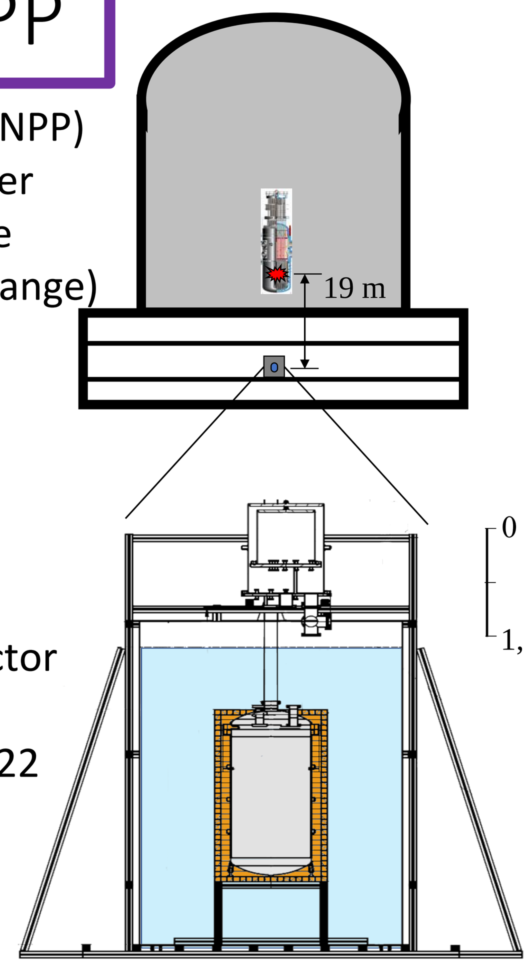


Image by LUX col.

RED-100 at KNPP

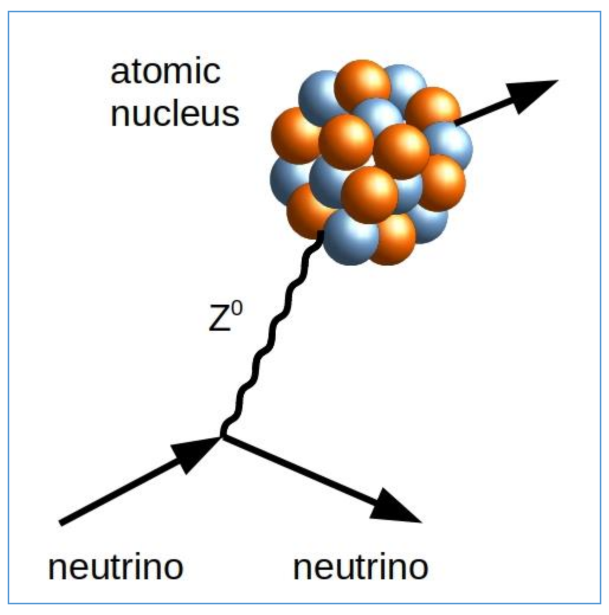
- Kalinin Nuclear Power Plant (KNPP)
- W_{th} ~ 3000 MW thermal power
- L ~ 19 m from the reactor core
- Antineutrino flux (full energy range) ~ $1.35*10^{13}$ $cm^{-2}s^{-1}$
- ~50 ÷ 65 m.w.e. in vertical direction
- Passive shielding:
  - ~ 5 cm Cu
  - ~ 60 cm H_2O
- Two-phase LXe emission detector (~ 130 kg LXe in FV)
- Production run 01.2022-02.2022



Neutrinos at low energies (down to the MeV level) can provide elastic coherent scattering on atomic nuclei (CEvNS), when the nucleons reacts as bound together, exchanging with the neutrino by Z^0 boson; in this case the section of scattering is several orders of magnitude greater than a scattering of a neutrino by an electron or a separate nucleon. Also the value of cross section does not depend on the type of neutrino. This effect was predicted in 1974 and discovered experimentally later in 2017. One can possible to create small portable detectors of neutrino radiation, using this effect.

$$\frac{d\sigma}{dT_n} = \frac{G_F^2}{4\cdot\pi}\cdot Q^2\cdot M\cdot\left(1-\frac{M\cdot T_n}{2\cdot E_\nu^2}\right)\cdot F^2$$

$$T_{max} = \frac{2E_\nu^2}{2E_\nu + M}$$

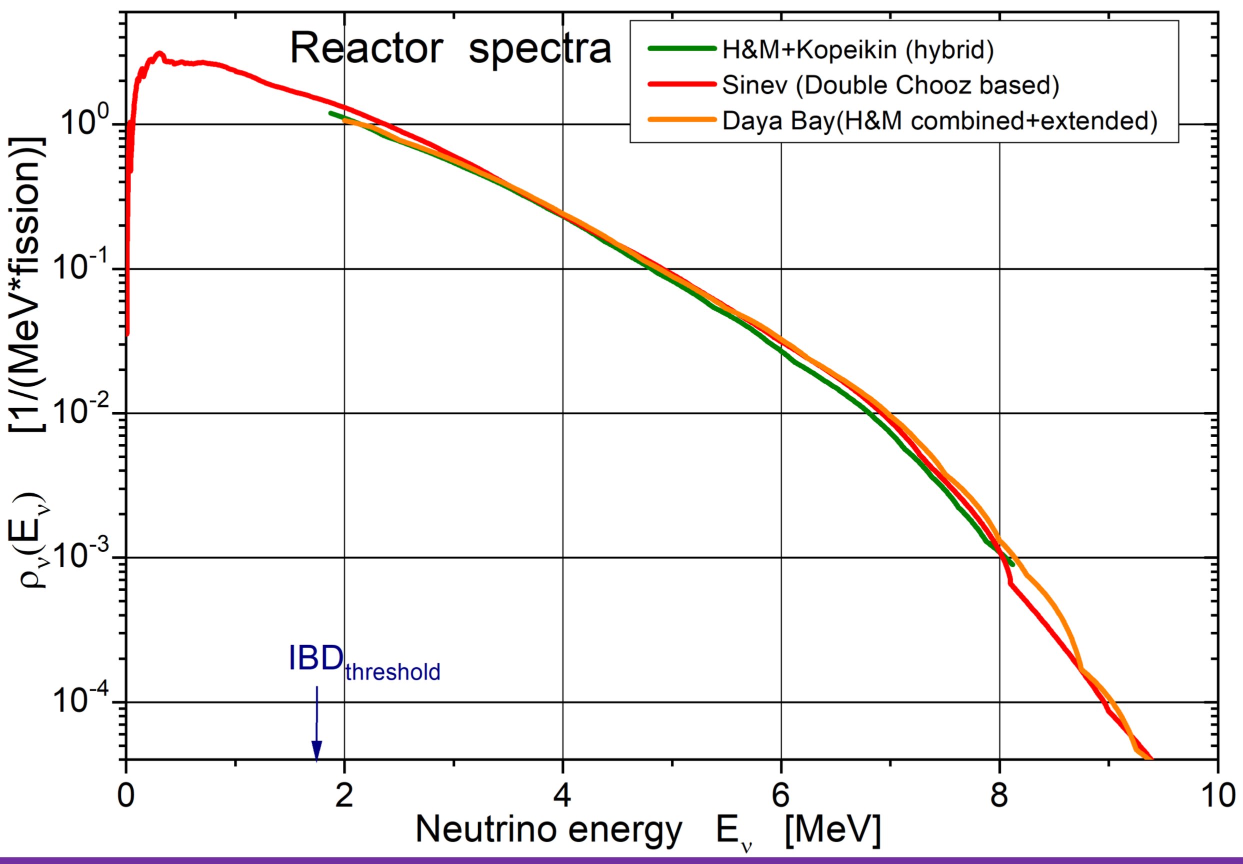


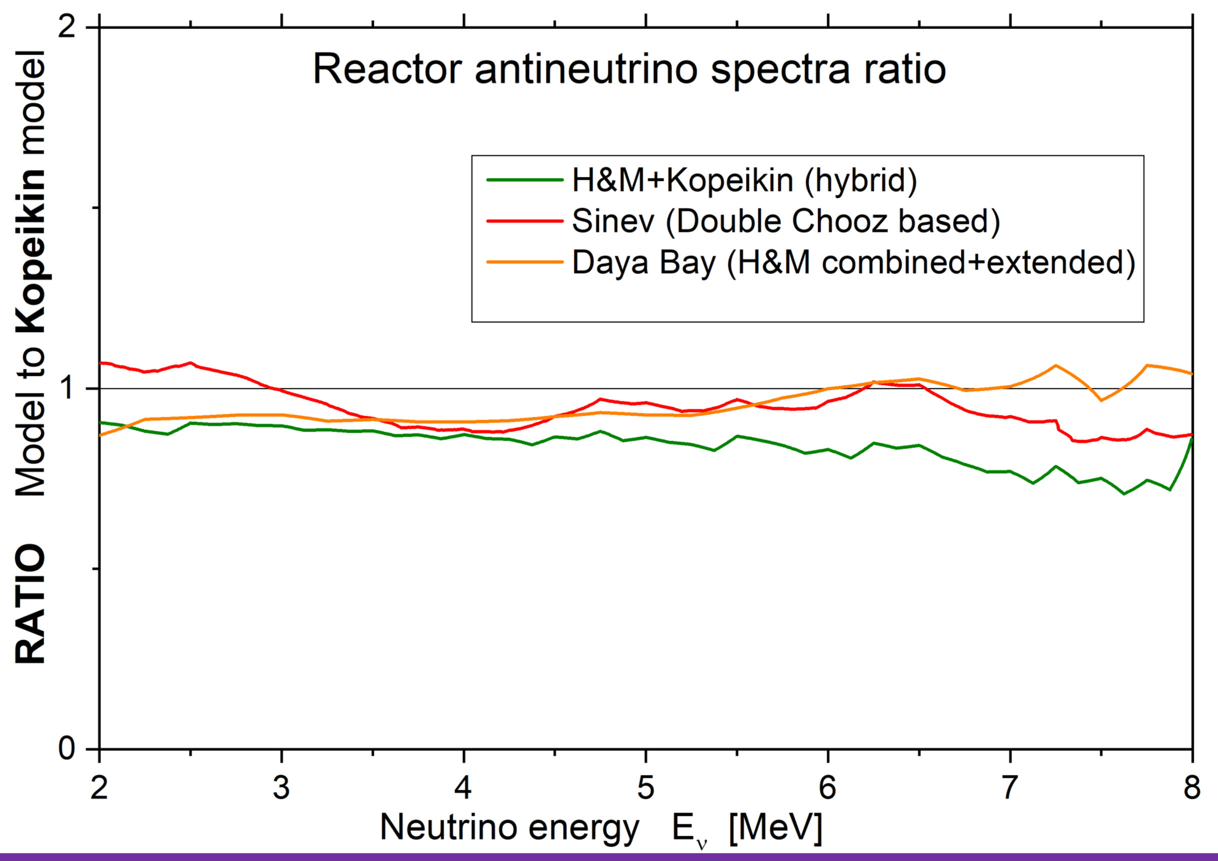
Spectra of reactor antineutrinos and CEvNS

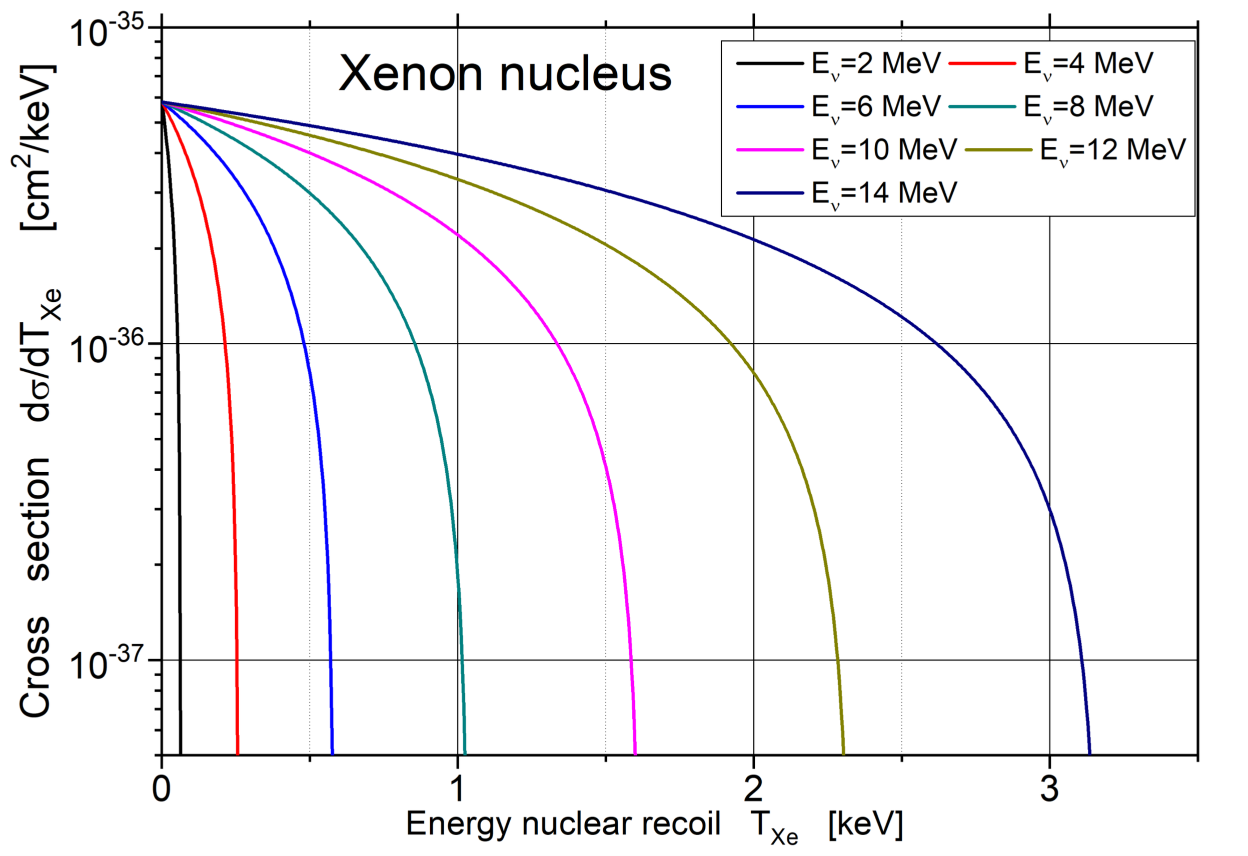
Differential reactor spectra are specified by the authors in different energy ranges.

The reactor antineutrino spectra are formed by a combination of spectra from 4 main (parent) isotopes ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu, taken with partial coefficients on the burn up moment.

To estimate the rate of counting events of the RED-100 detector, it is necessary to take into account the dependences on neutrino energy both the reactor spectrum and the cross section function of the CEvNS process.







Convolution of reactor spectra with cross-section

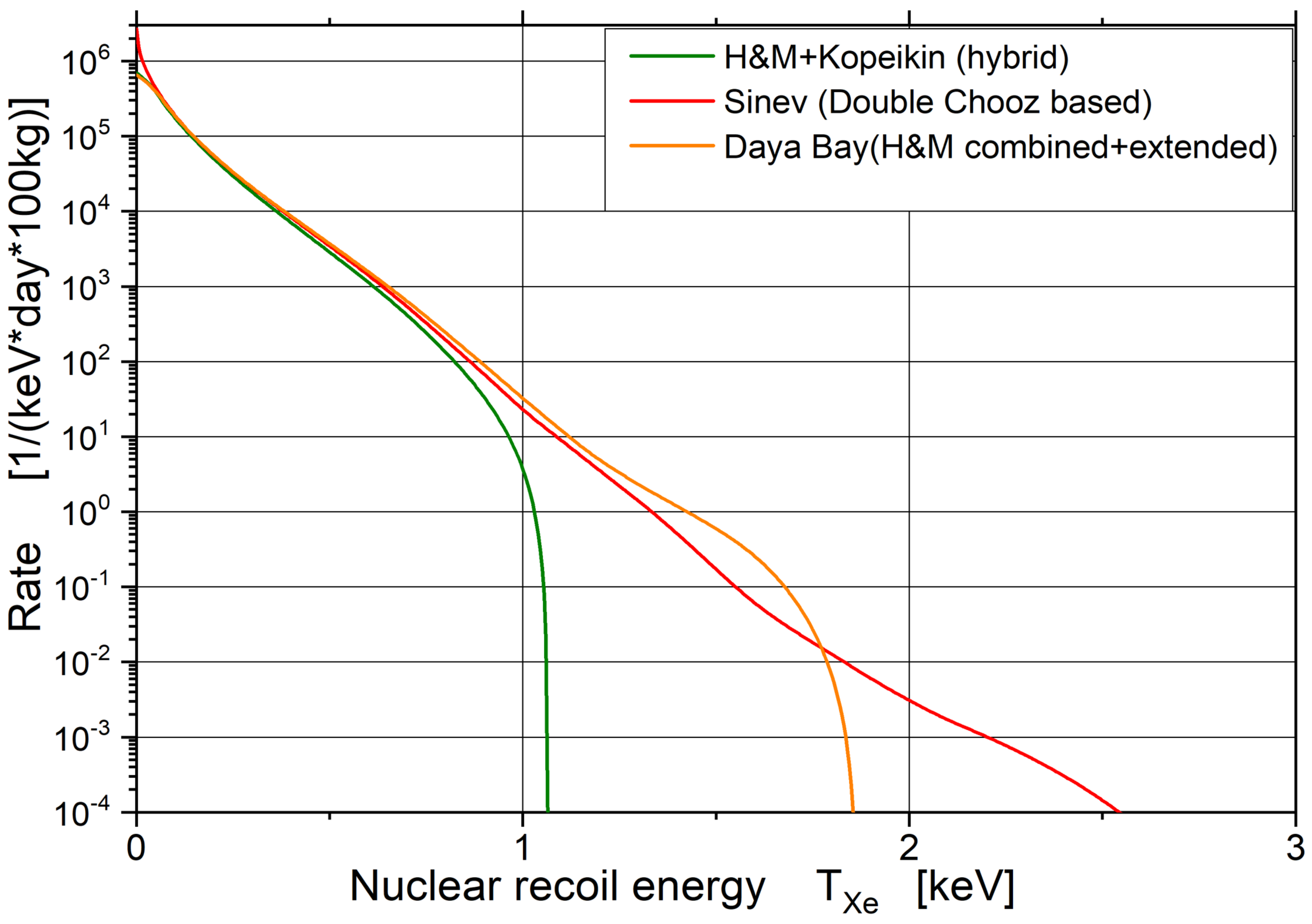
Spectrum of nucleus recoil R(T) can be defined as the integral of the product of two functions by the range of neutrino energies. It was performed as a discret convolution of these two functions $J(E_\nu)$ and $\frac{d\sigma}{dT_n}$ correspondingly. The values of cross sections for the CEvNS process are integrated taking into account the corresponding weighting coefficients. The weighting coefficients are specified by the reactor neutrino spectrum. This method is implemented as a summation of partial cross-section functions with weights over the entire specified range of the antineutrinos energy.

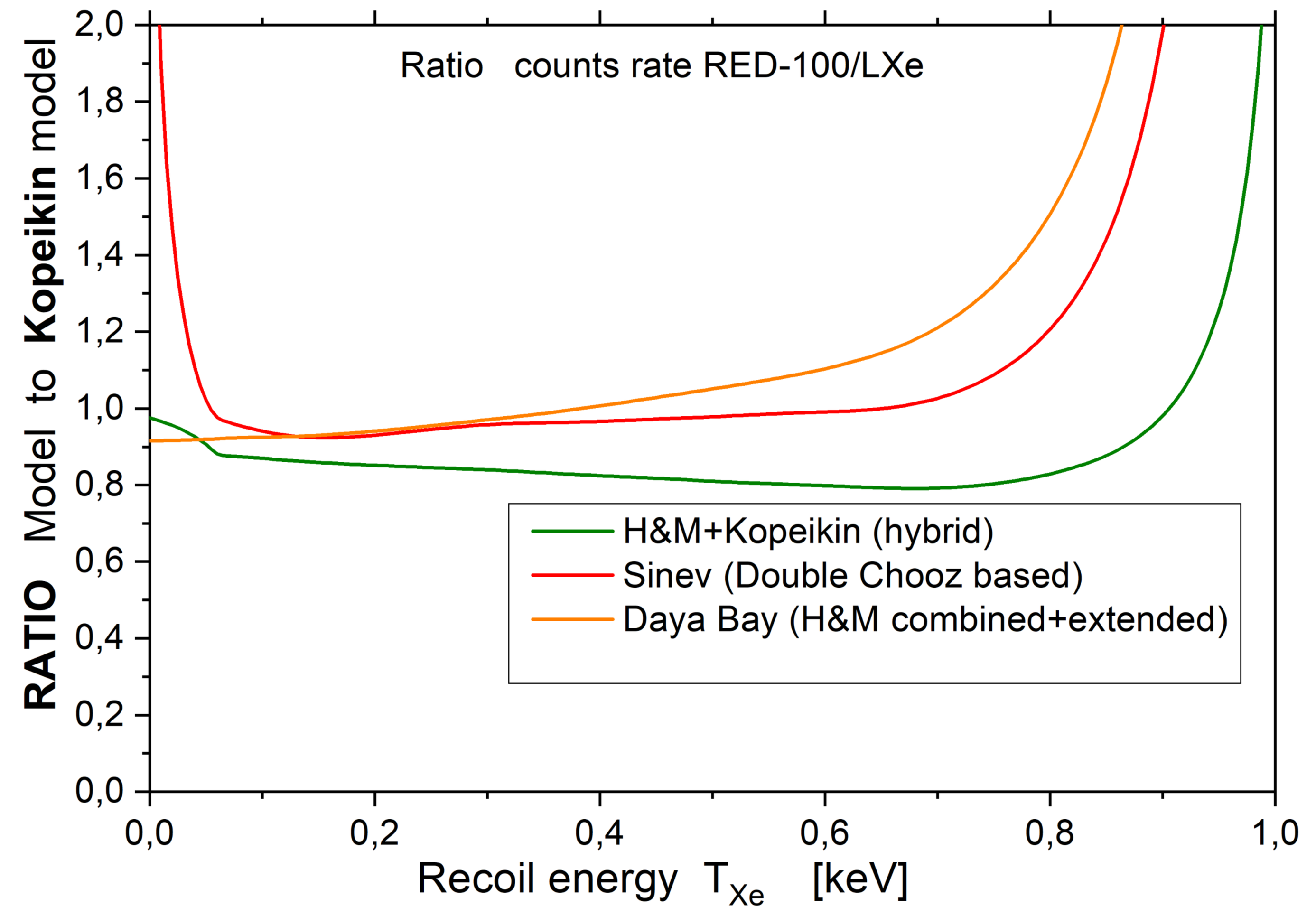
$$R(T_n) = \int_{E_{\nu min}}^{E_{\nu max}} J(E_\nu)\cdot\frac{m}{\mu_n}\cdot N_A\cdot\frac{d\sigma}{dT_n}(E_\nu,T_n)\cdot dE_\nu;$$

$$R(T_n) = \sum_{i=1}^{N}[J_i(E_i)\cdot dE_i]\cdot\frac{d\sigma_i}{dT_n}(E_i,T_n)\cdot\frac{m}{\mu_n}\cdot N_A,$$

When $J(E_\nu) = \frac{W_{th}\cdot\rho(E_\nu)}{\langle\varepsilon\rangle\cdot 4\cdot\pi\cdot L^2}$,

$\langle\varepsilon\rangle = 205.3\ [MeV/fission]$ -average energy per nucleus fission at the beginning of fuel campaign.



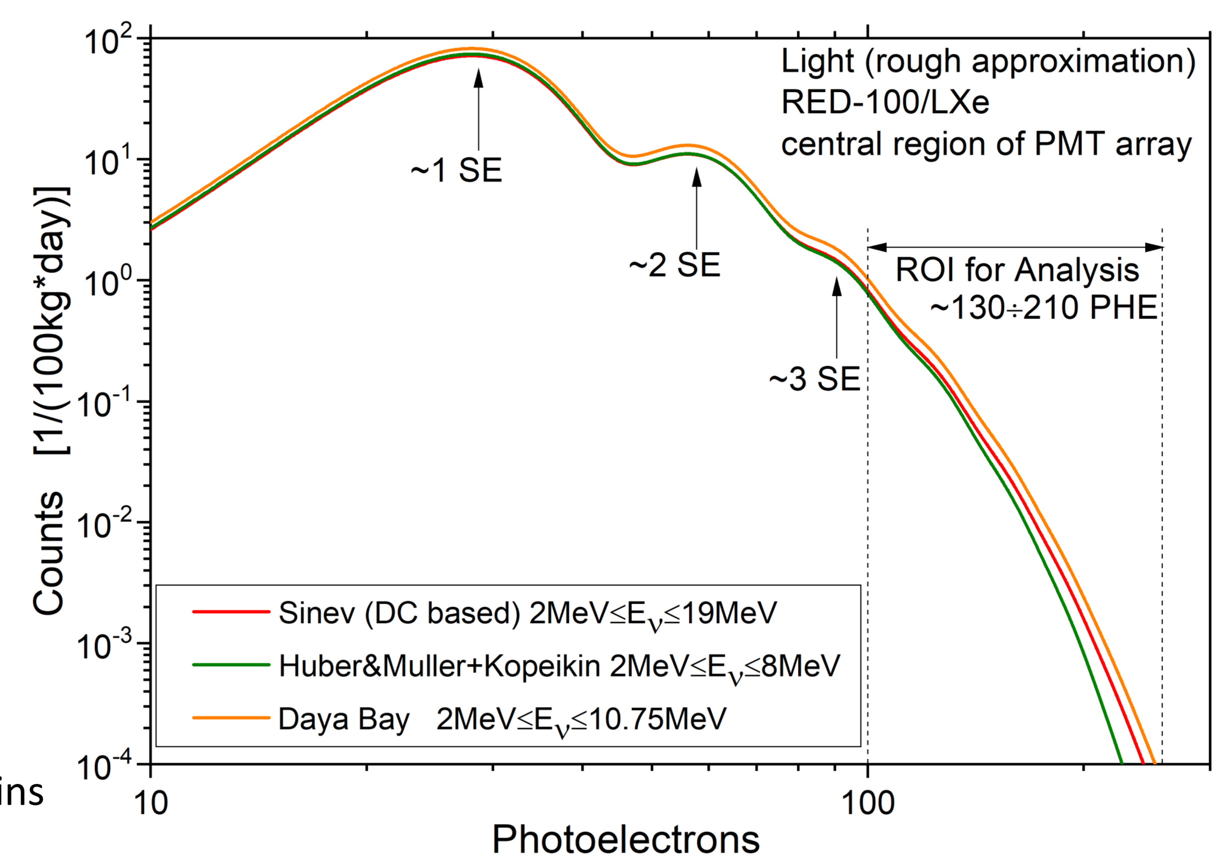


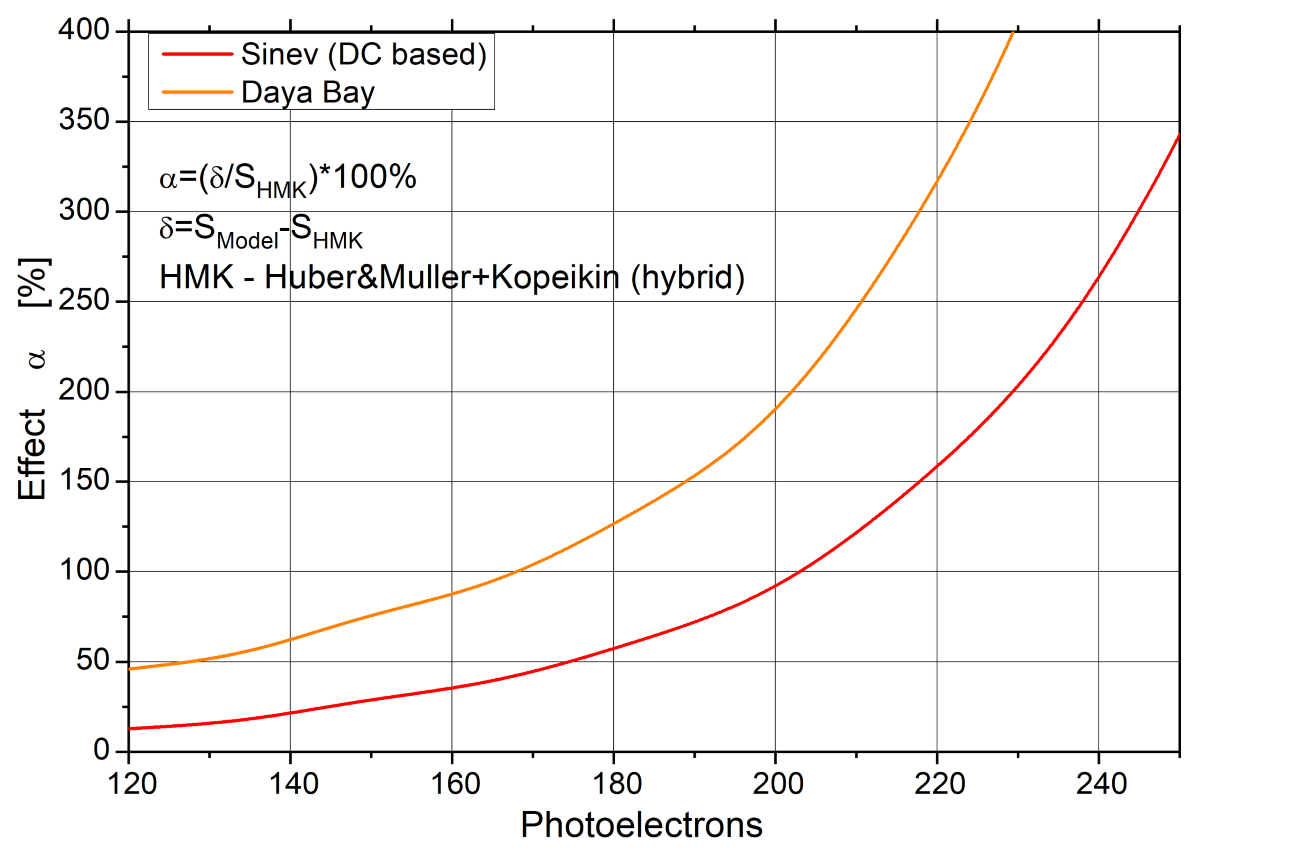
Assessing the impact of the high-energy tail

Spectrum of the extracted electrons was generated via the NEST package. Preliminary estimates show that, given the threshold in the detector starting from level of 5 SE, the new neutrino spectrum gives ~50% more events for the previous calculation. Rough amount of light for the central region of PMT array, in the considered range are also increases by more than 20%.

$$C(N_{PHE}) = \sum_{k=1}^{N}[N_{SE}]_k\cdot\frac{1}{\sqrt{2\pi k\sigma^2}}Exp\left(-\frac{(N_{PHE}-kM)^2}{2k\sigma^2}\right)$$

$M \approx 28$[PHE/e] , $\sigma \approx 14$[PHE/e] , N_{SE} –average counts for k extracted electrons, C – average for expected counts in PHE bins





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MEPhI – National Research Nuclear University Moscow Engeeniring Physics Institute; INR RAS – Institute for Nuclear Research of the Russian Academic of Scinces; RTU-MIREA – Russian Technological University – MIREA, M.V.Lomonosov Institute of FIne Chemical Technologies