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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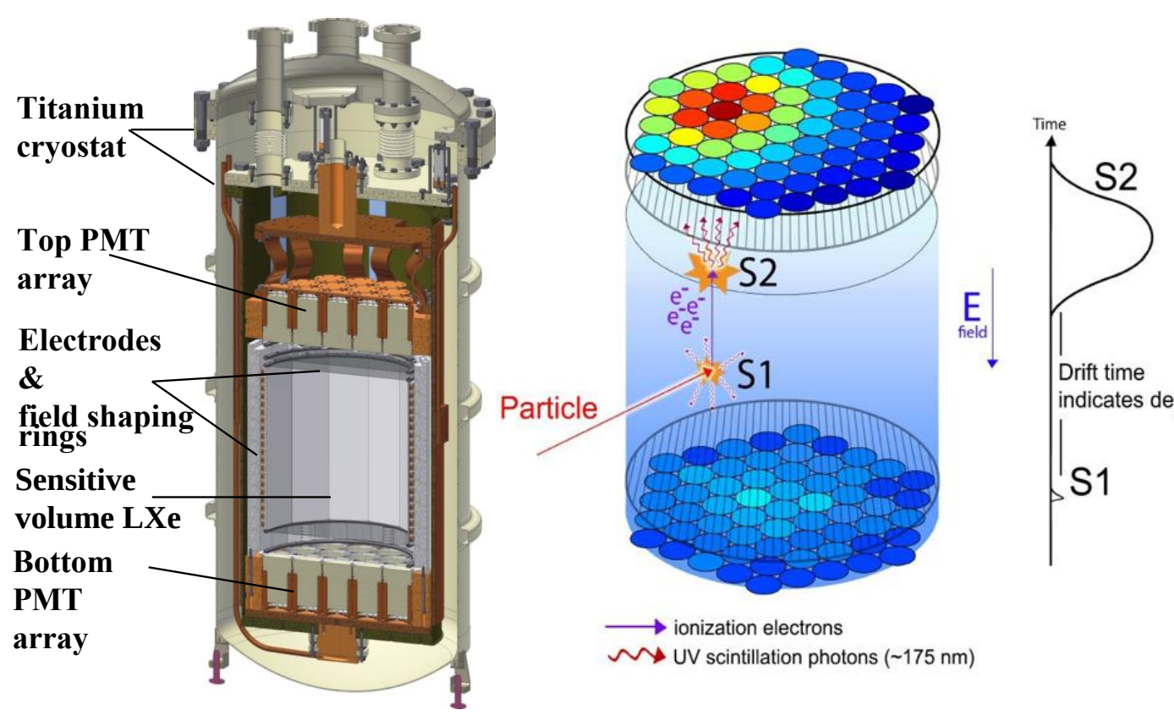
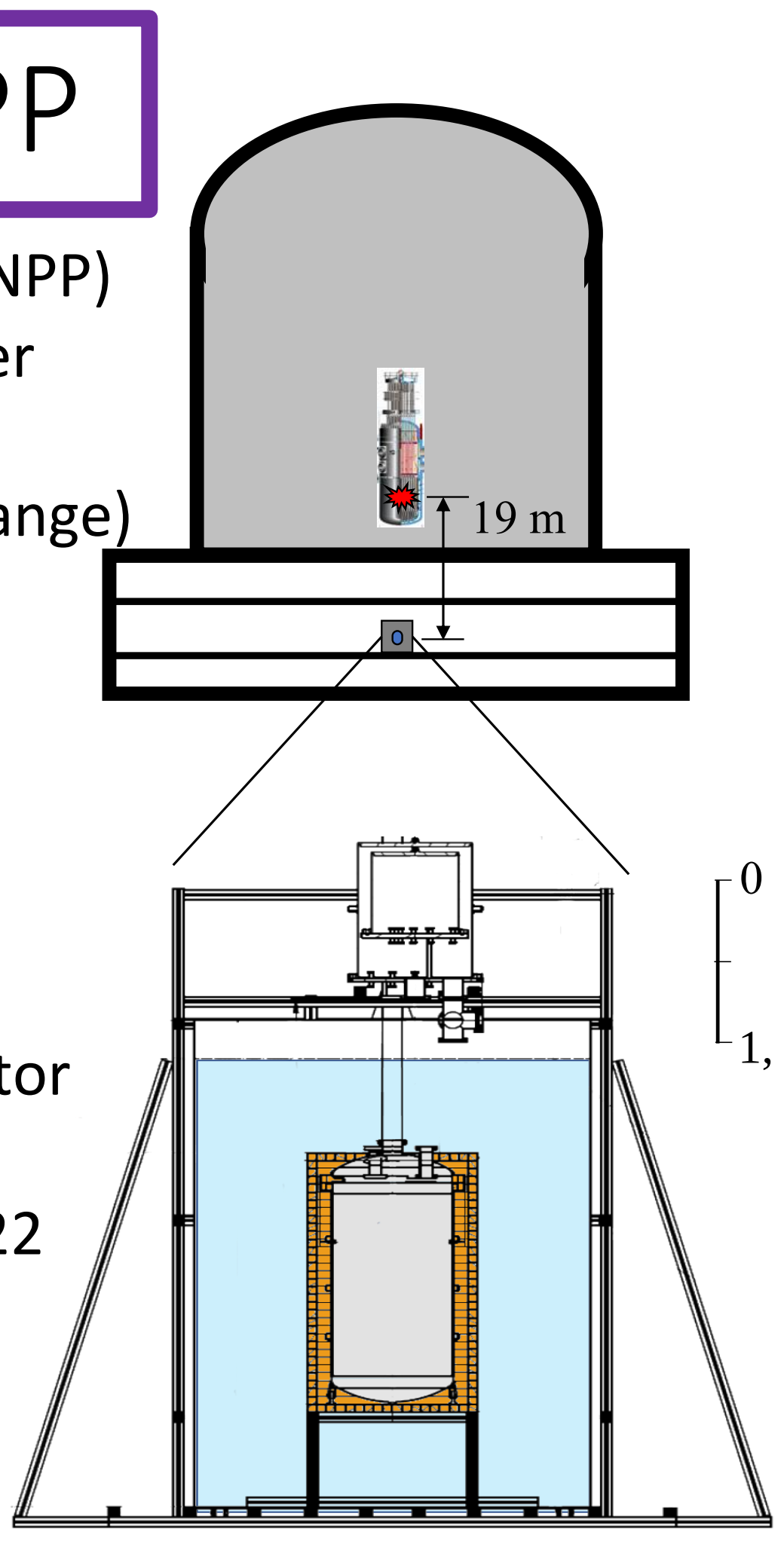


Image by LUX col.

RED-100 at KNPP

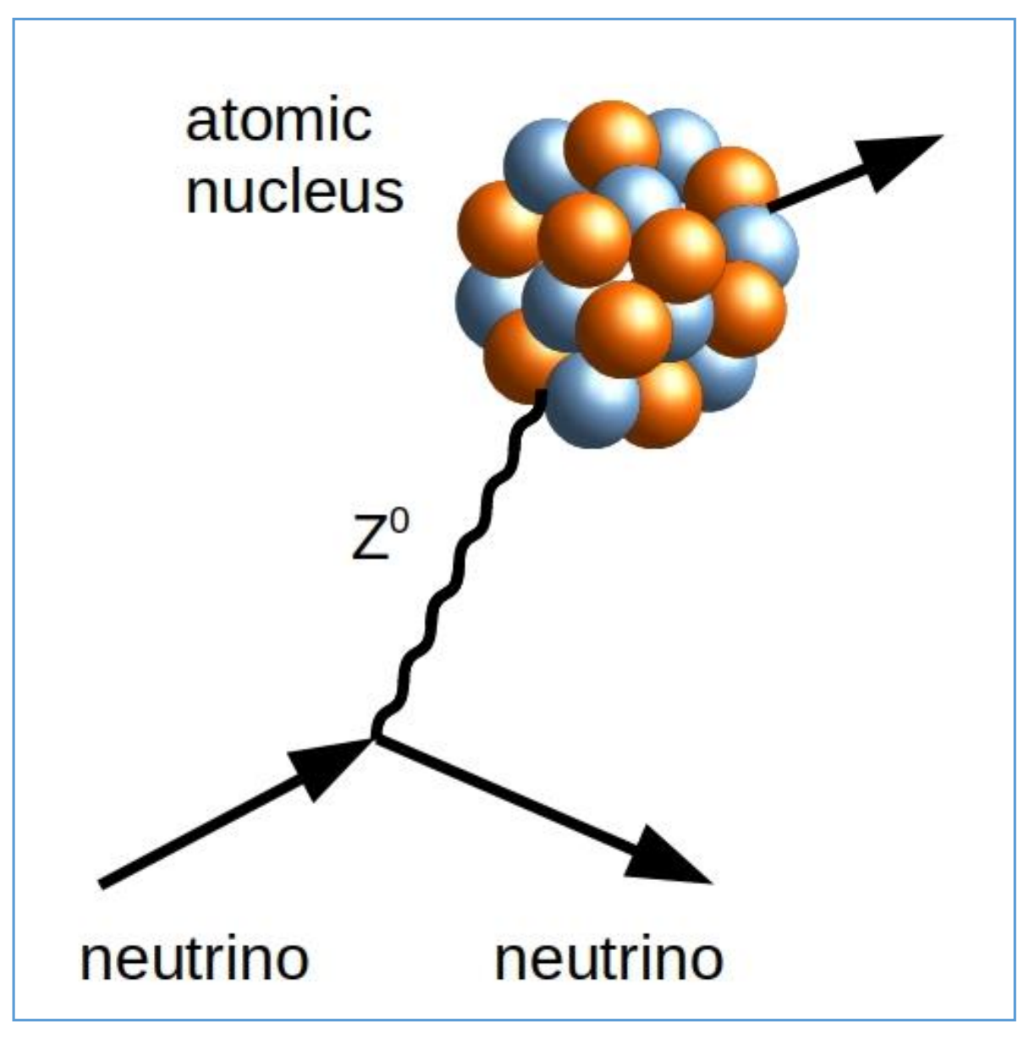
- Kalinin Nuclear Power Plant (KNPP)
- W_{th} ~ 3000 MW thermal power
- L ~ 19 m from the reactor core
- Antineutrino flux (full energy range) ~ $1.35 \cdot 10^{13}$ $cm^{-2}s^{-1}$
- ~50 ÷ 65 m.w.e. in vertical direction
- Passive shielding:
  - ~ 5 cm Cu
  - ~ 60 cm H_2O
- Two-phase LXe emission detector (~ 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 nucleus reacts as bonds, connecting with the neutrino Z^0 boson; in this section, the scattering is several orders of magnitude greater than during the scattering of a neutrino by an electron or a separate nucleon, and does not depend on the type of neutrino. This effect was predicted in 1974 and discovered experimentally in 2017. Using this effect, it is possible to create small portable detectors of neutrino radiation.

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

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

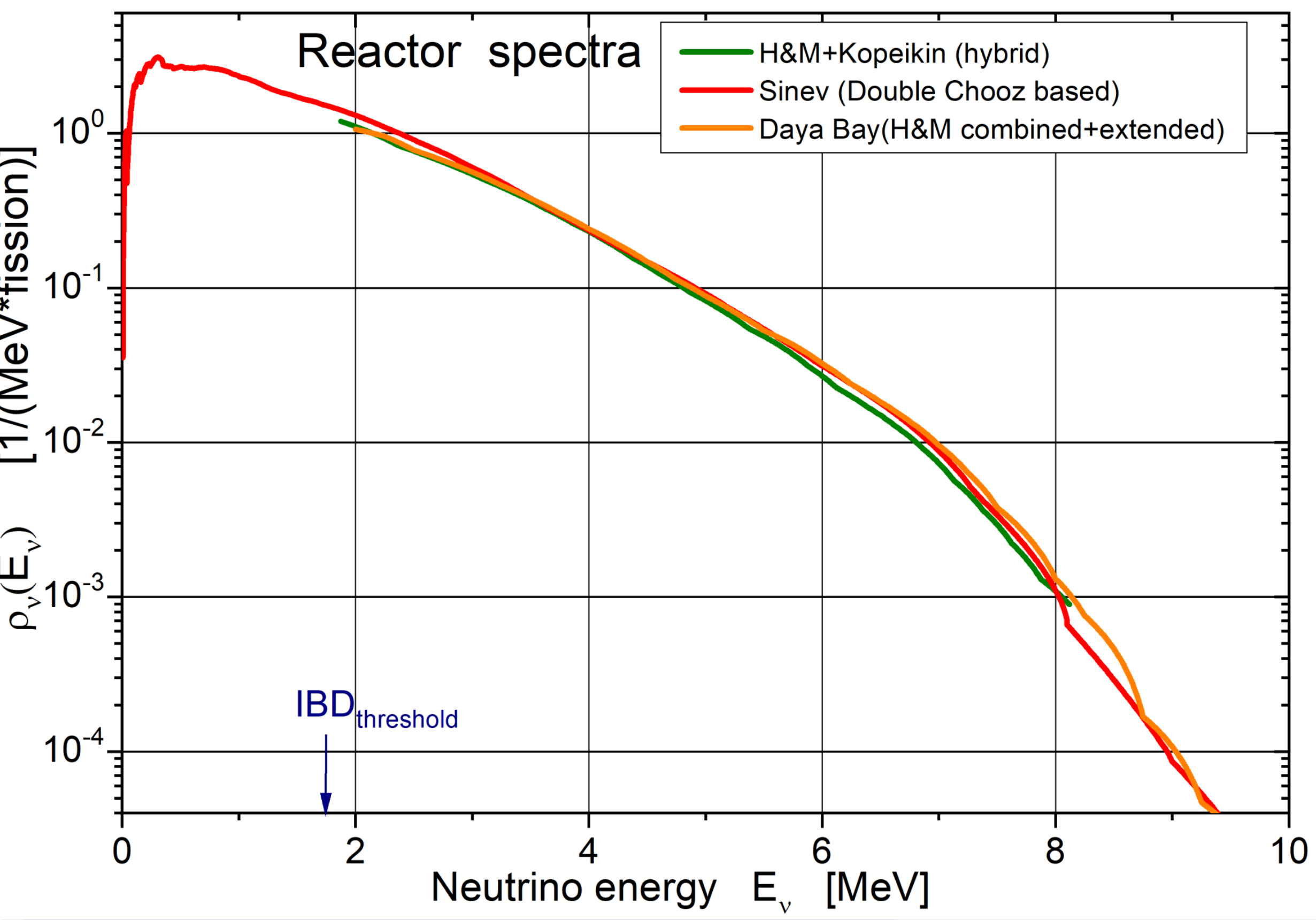


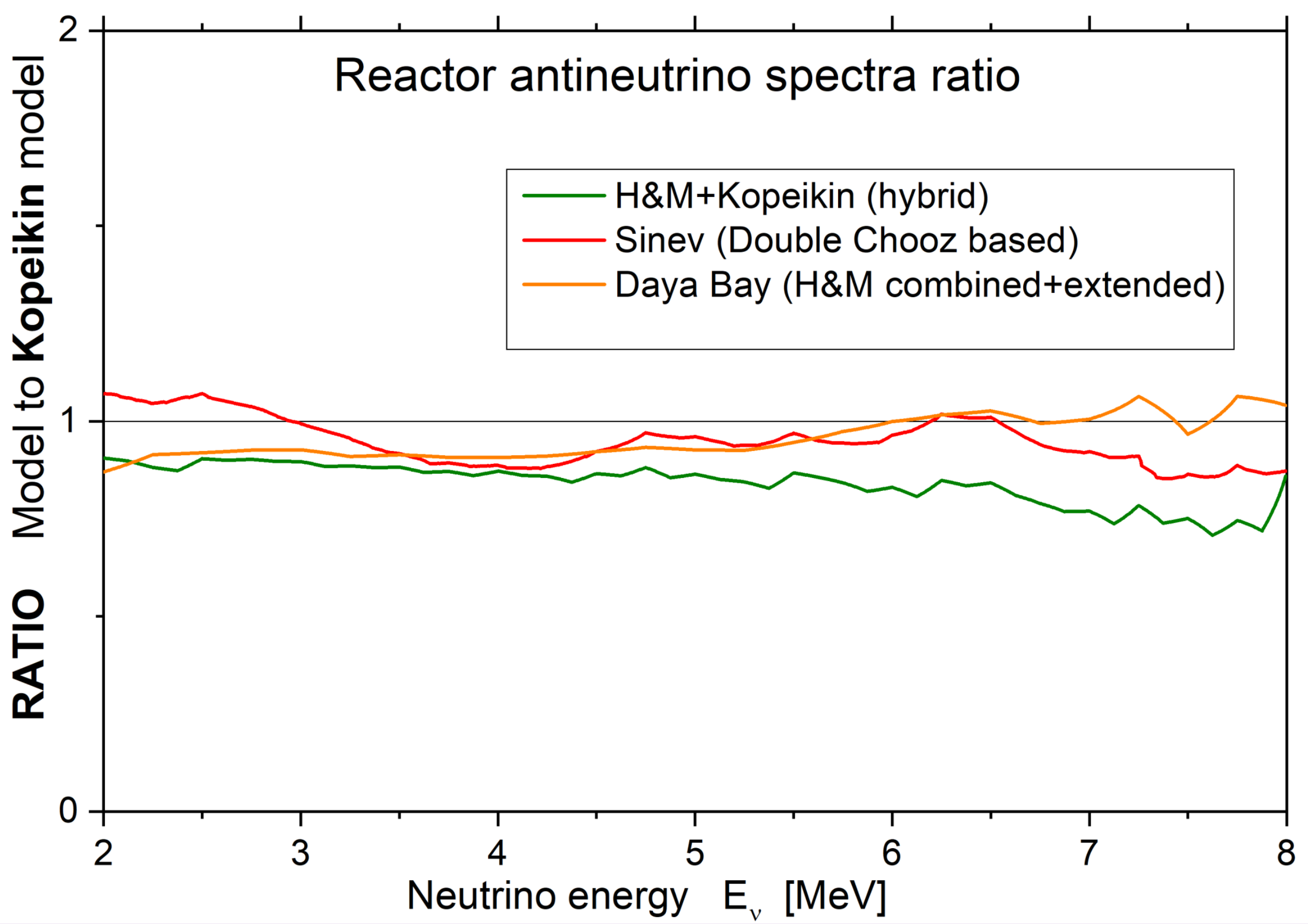
Spectra of reactor antineutrinos and CEvNS

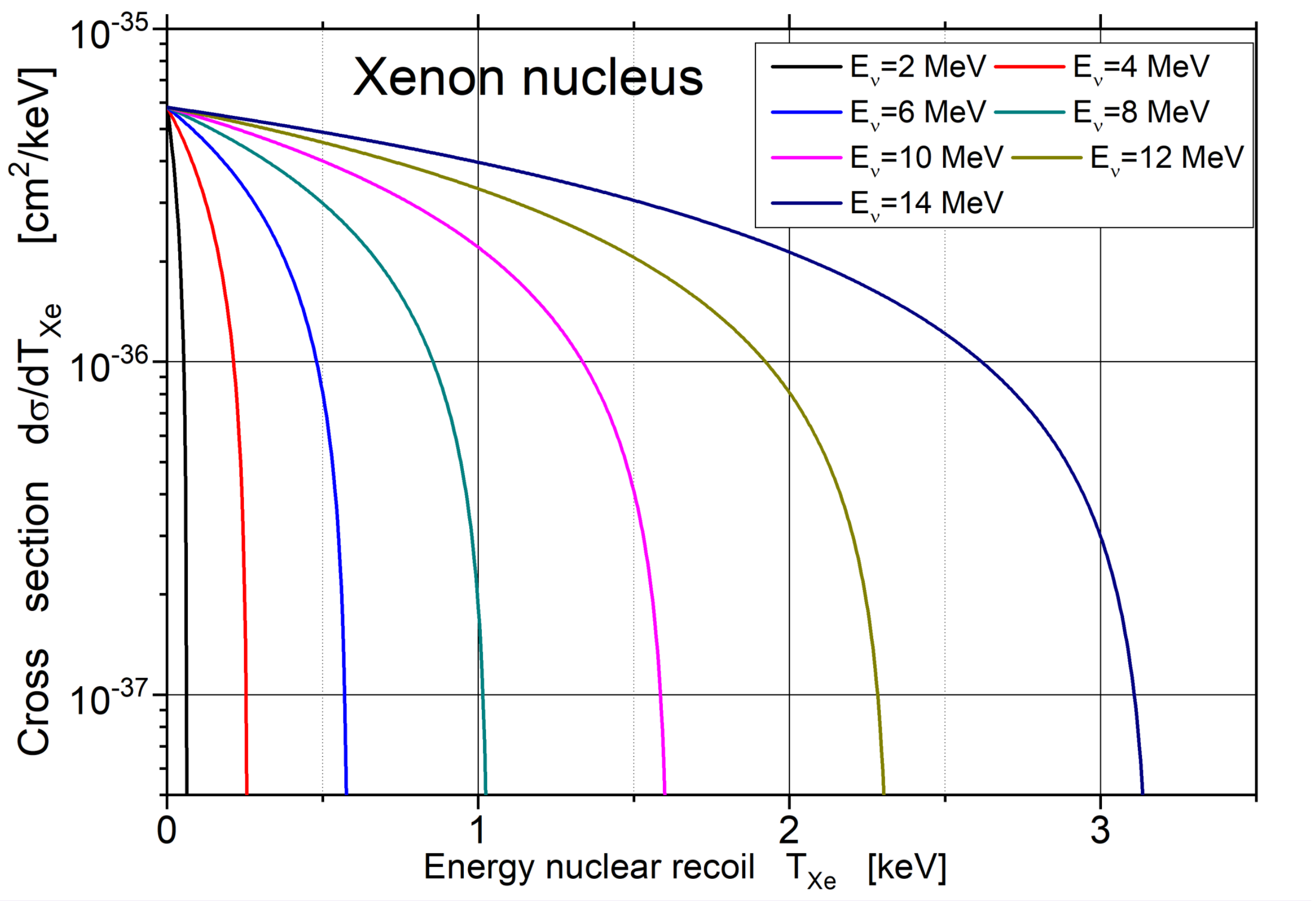
Differential reactor spectra are specified by the authors in different energy ranges.

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 crossection

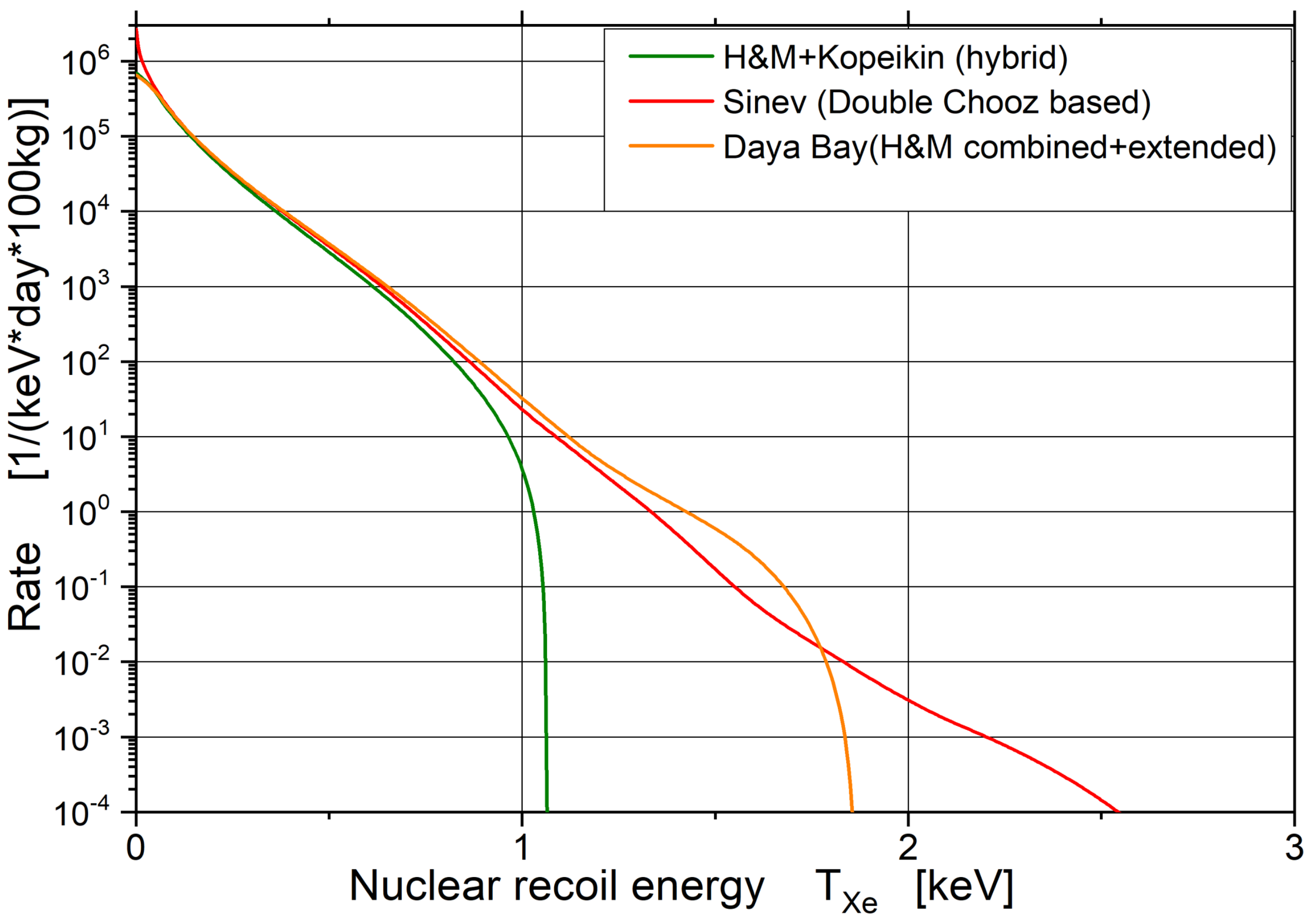
The spectrum of nuclear recoils R(T) can be defined as the integral of the product of two functions in a given range of neutrino energies, like a discrete convolution. Various values of cross sections for the CEvNS process are integrated taking into account the corresponding weighting coefficients, which are specified by the reactor neutrino spectrum. This method is implemented as a summation of partial cross-section functions with weights, with statistics of 10,000 bins, over the entire specified range of the energy spectrum of reactor antineutrinos.

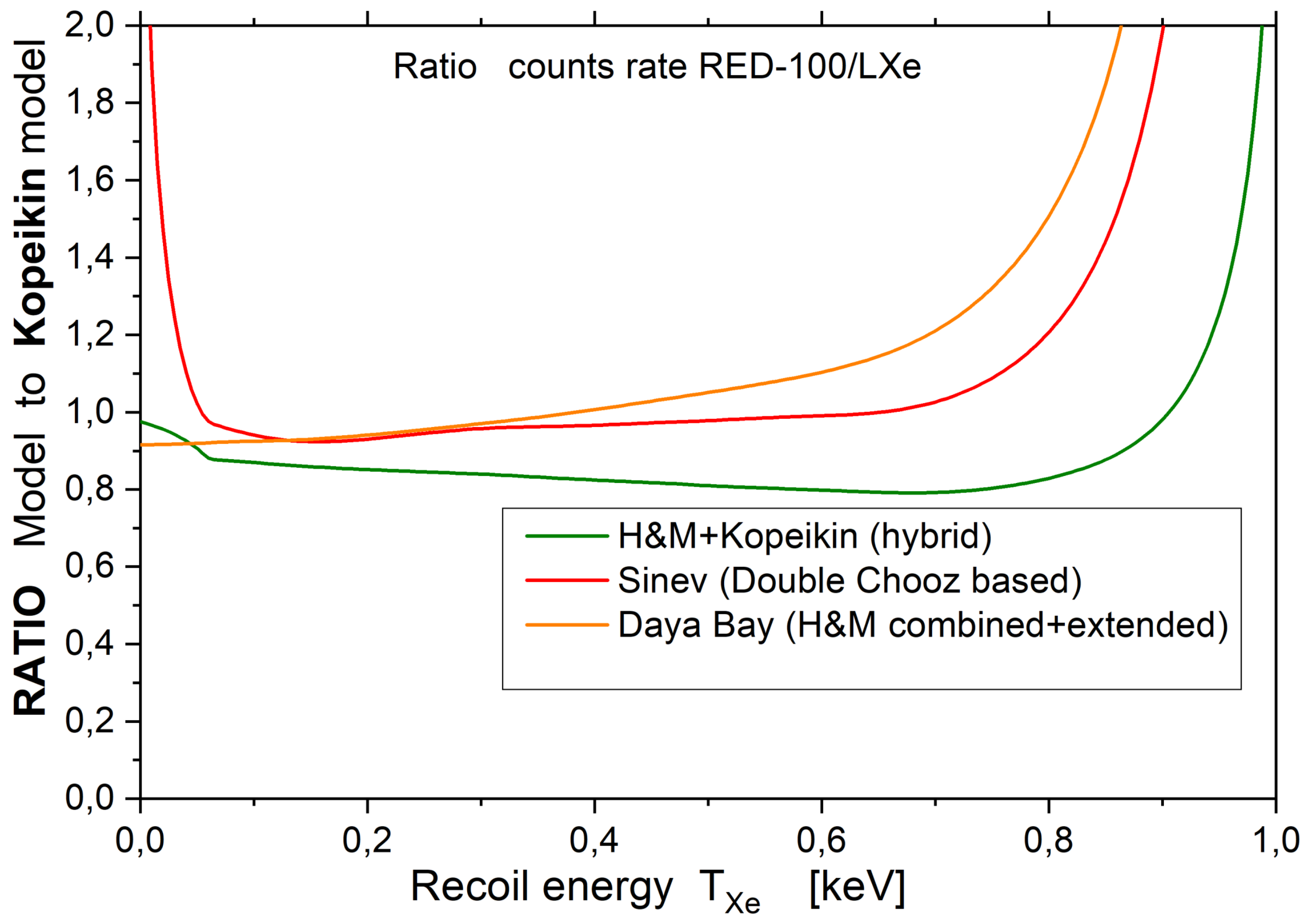
$$R(T_n) = \int_{E_{\nu min}}^{E_{\nu max}} J(E_\nu) \cdot \frac{m}{\mu_n} \cdot N_A \cdot \frac{d\sigma}{dT_n}(E_\nu, T_n) \cdot dE_\nu;$$

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

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

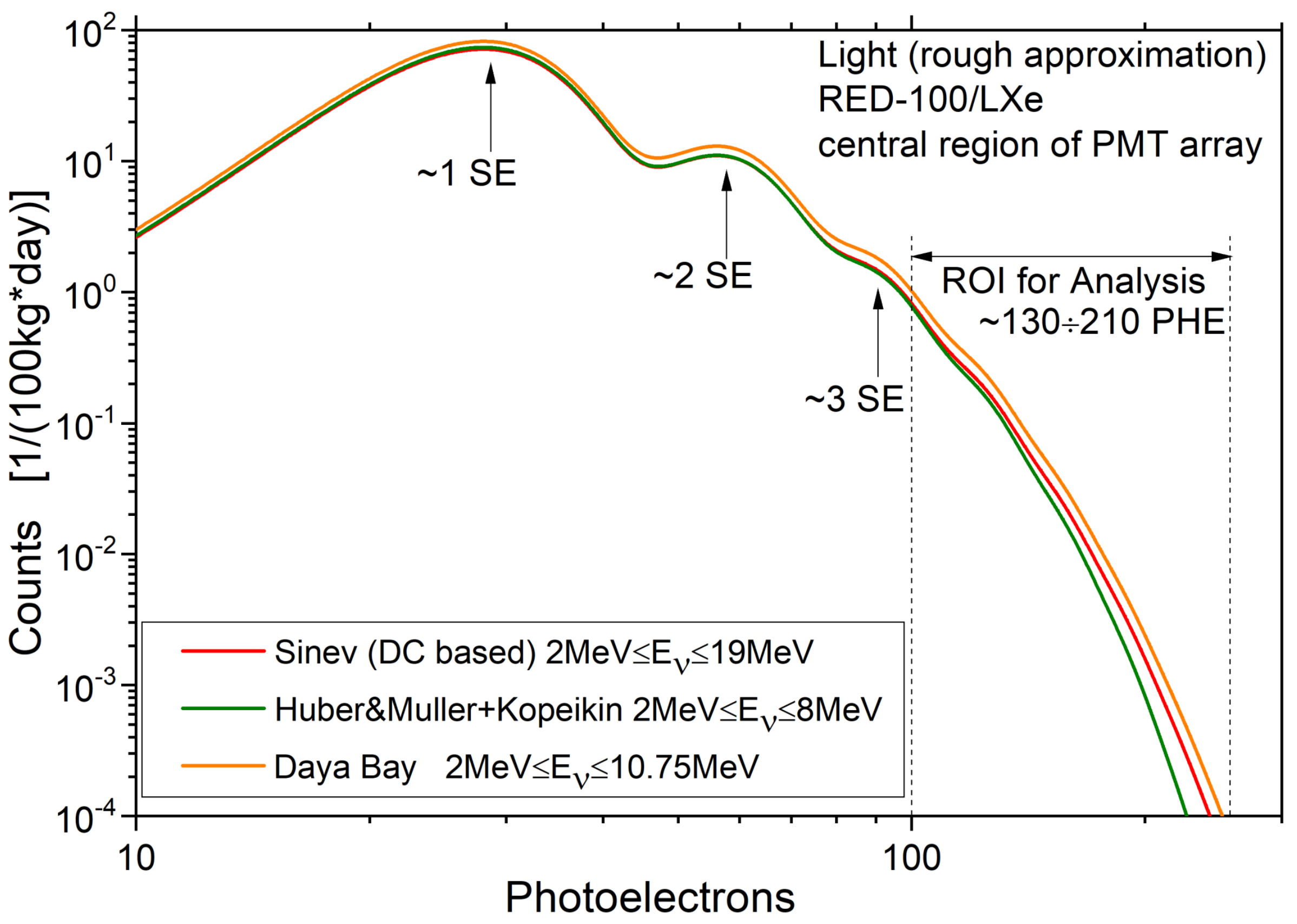
$\langle\varepsilon\rangle = 205.5\ (MeV)$.

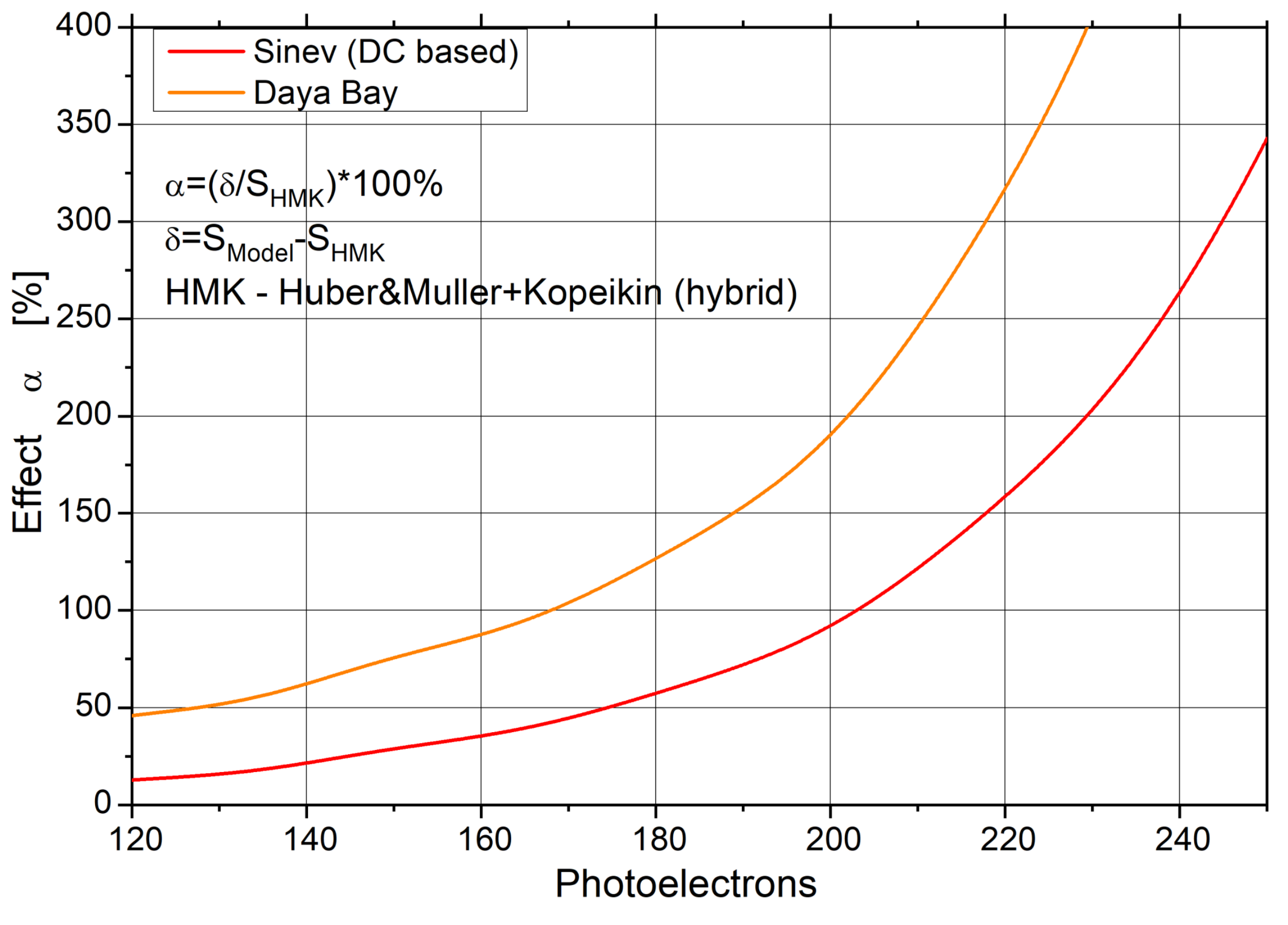




Assessing the impact of the high-energy tail

Preliminary estimates show that, given the threshold in the detector starting from level 5 SE, the new neutrino spectrum gives ~50% more events, compared to the previous calculation (using the old neutrino spectrum), when viewed from the integrated SE spectrum (extracted electrons). Expected amount of light for detector PMT matrices, in the considered working range also increases by more than 20%.





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