

Progress in accounting for the antineutrino spectrum generated by nuclear reactors

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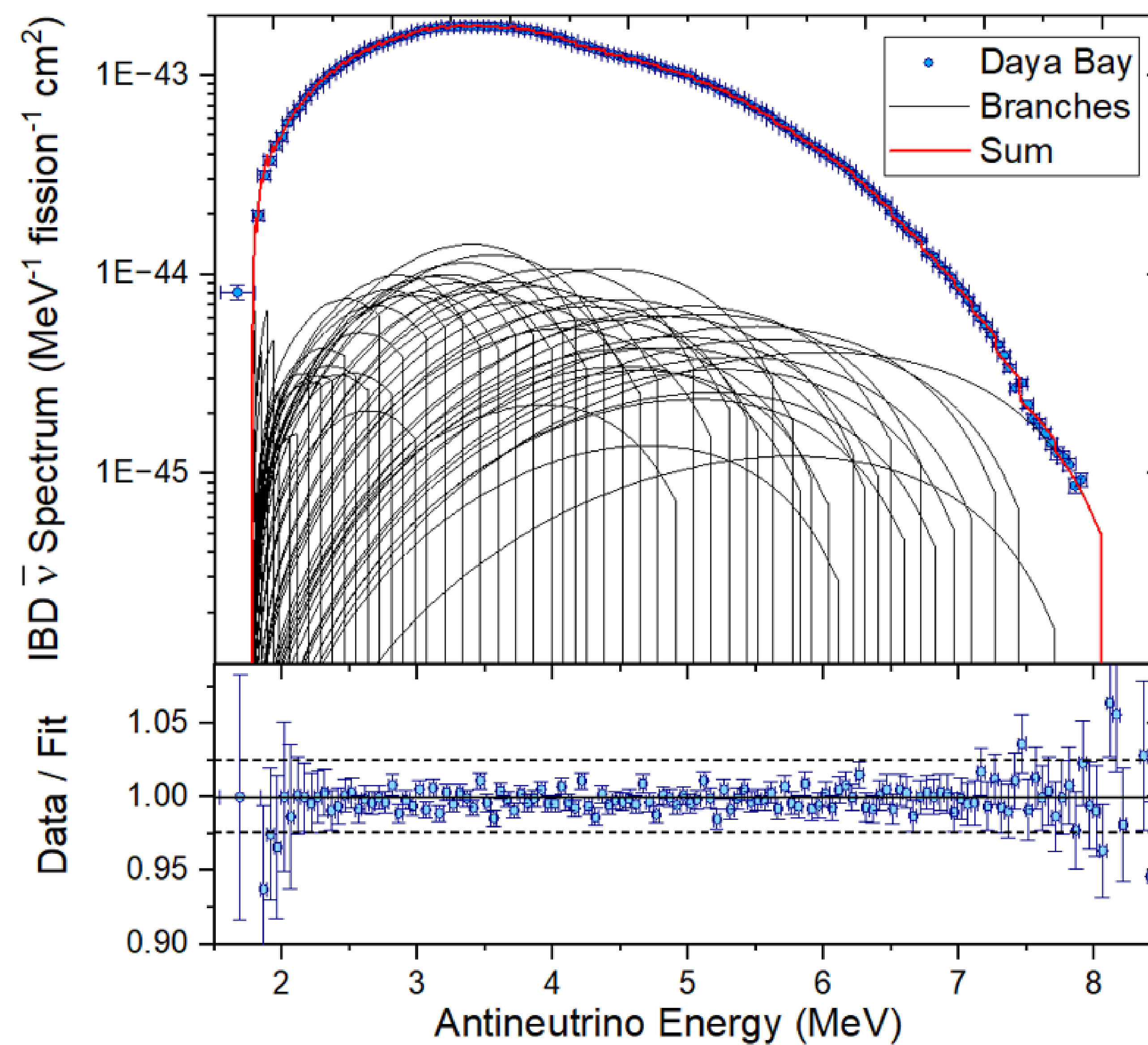
(1) A comprehensive understanding of the antineutrino spectrum generated by nuclear reactors is hindered by (i) normalization issues in the ^{235}U ILL electron spectrum [1] needed in the conversion method, and (ii) incomplete nuclear databases used in the summation method.

For further insights, in this work we will solve an inverse problem, that is, derive electron spectra from a reverse conversion method applied to the Daya Bay 50-keV bin dataset [2], which will then be compared to the ILL and summation values. The starting point is:

$$S_{DB}(E_e) = \sum b_i \sigma_{IBD} S_i(Z_{eff}, Q, E_e),$$

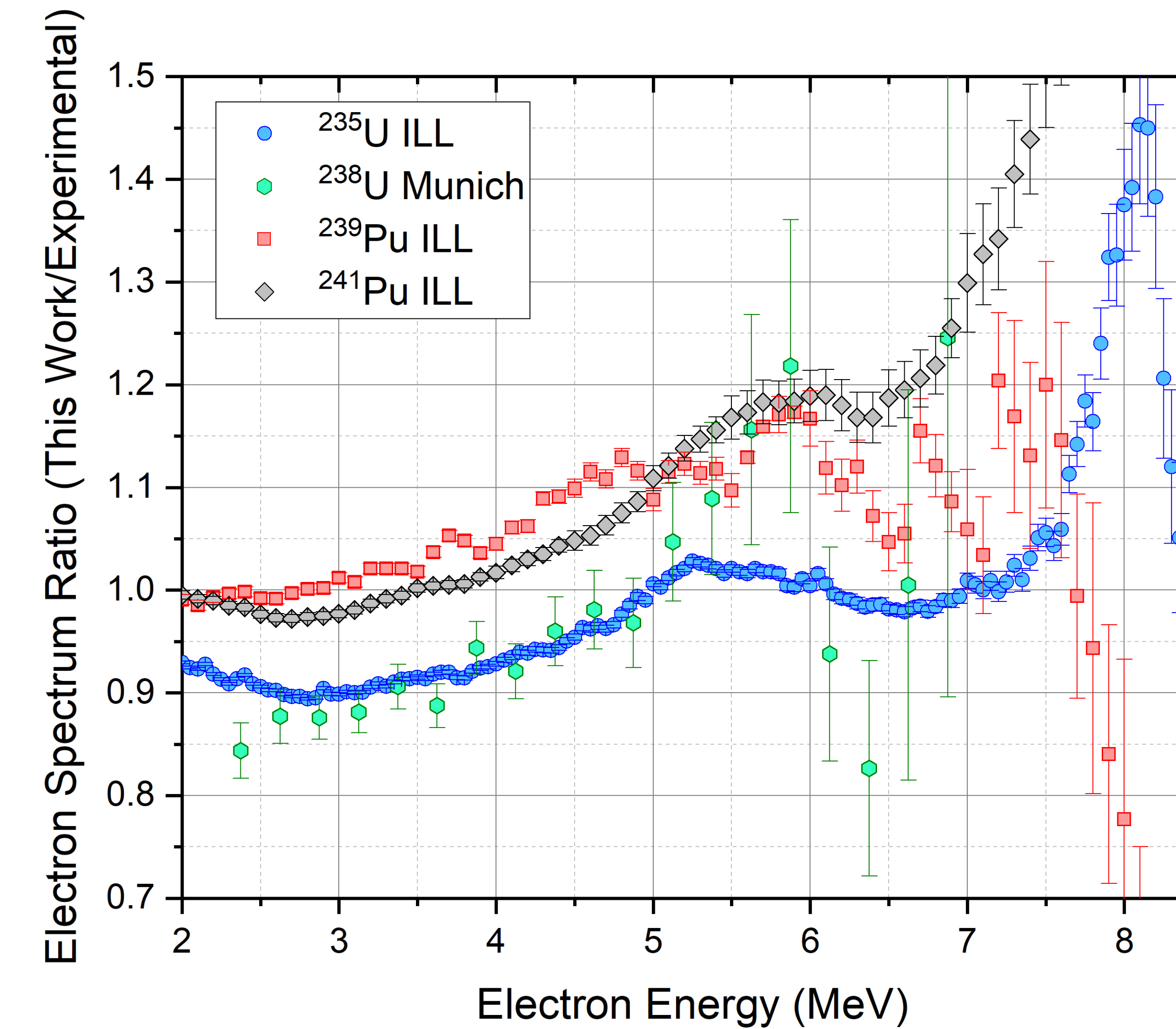
where b_i is the weight of the 57 average branches S_i we were able to fit, and σ_{IBD} is the IBD cross section. A very satisfactory fit is observed, shown on the right, from which we can derive the corresponding electron spectrum, which in turn can be written as:

$$S_{DB}(E_e) = f_5 S_5(E_e) + f_8 S_8(E_e) + f_9 S_9(E_e) + f_1 S_1(E_e)$$

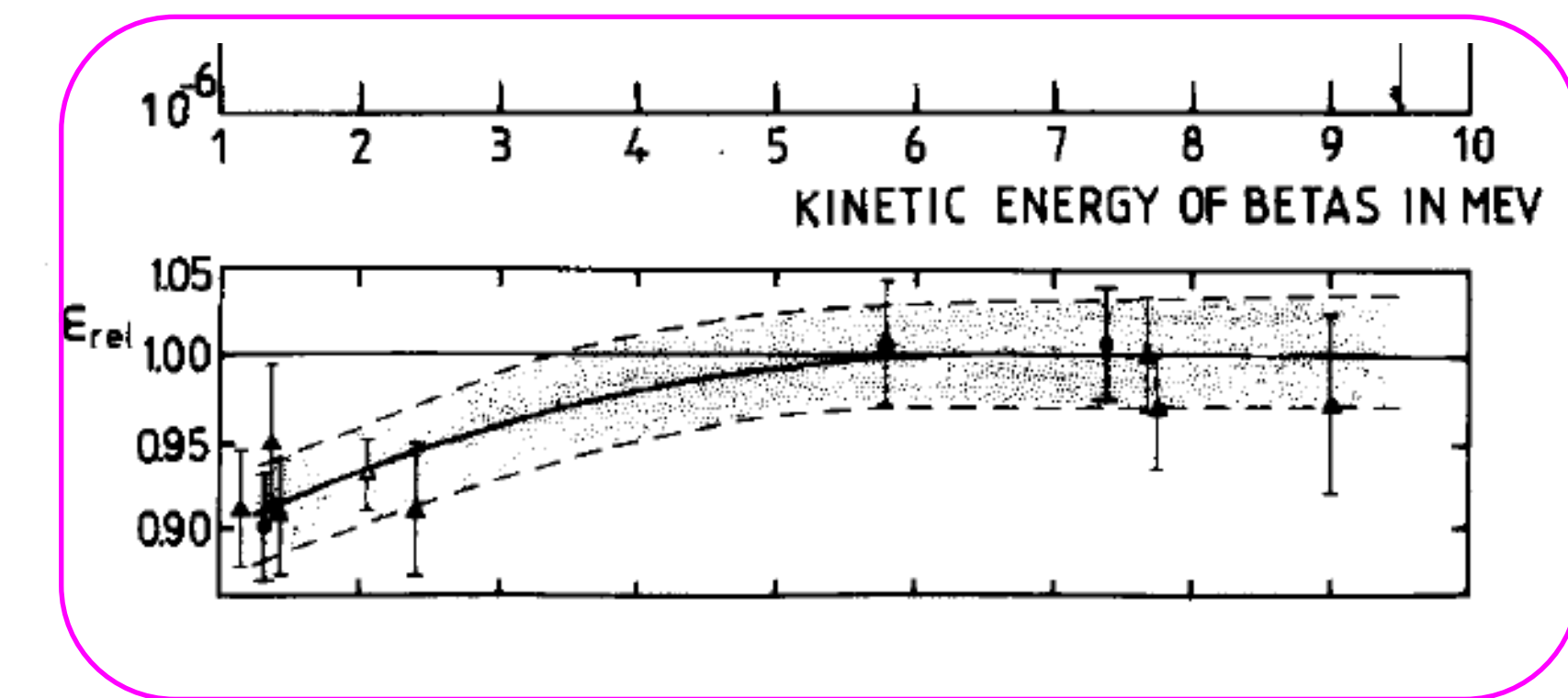


(2) The $^{235,238}\text{U}$ and $^{239,241}\text{Pu}$ electron spectra can be obtained utilizing the ^{235}U to ^{239}Pu electron spectra ratio measured by Kopeikin [3] ($R^{K_{59}}$), and summation values for the sub-dominant $R^{S_{58}}$ and $R^{S_{51}}$ terms.

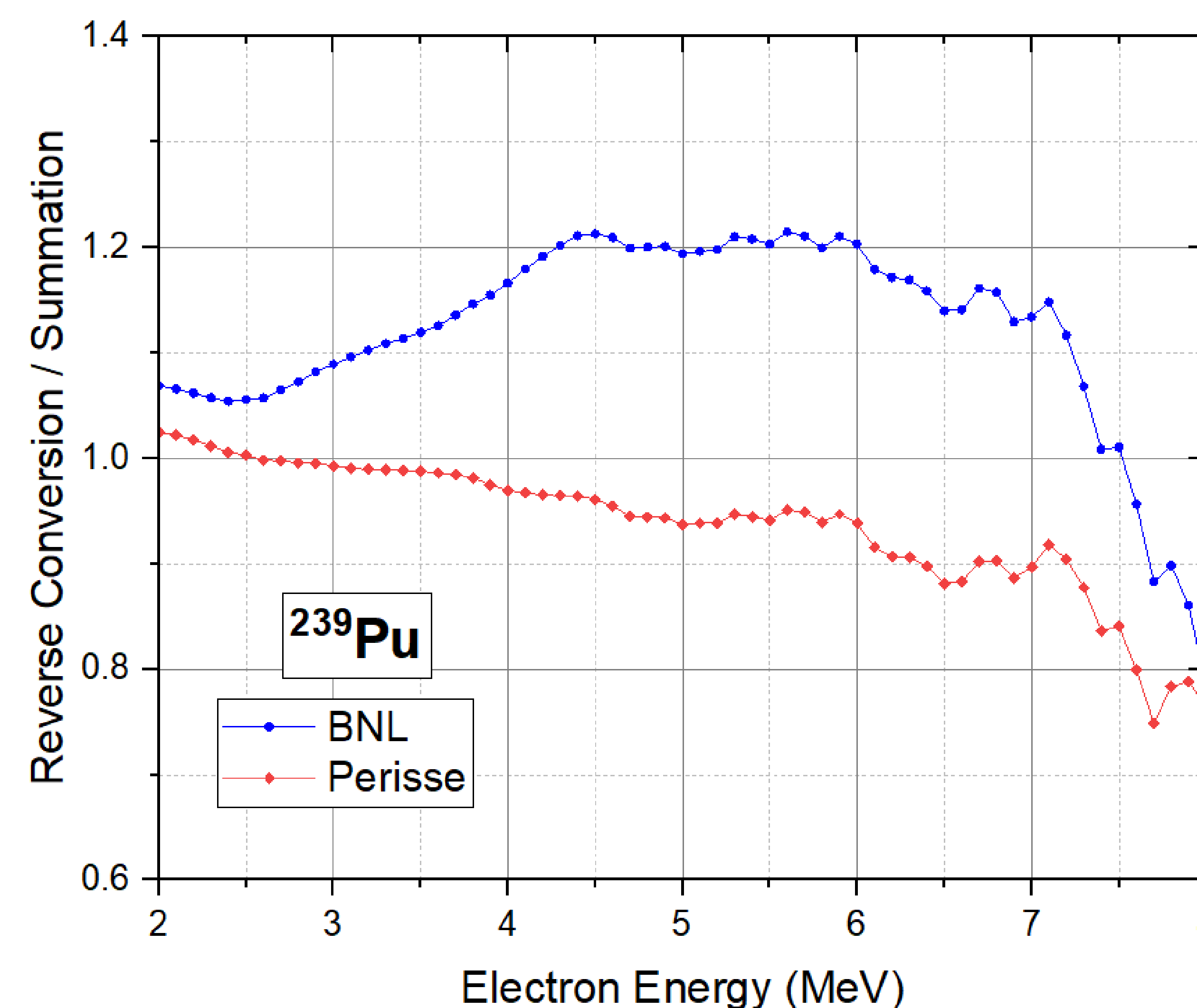
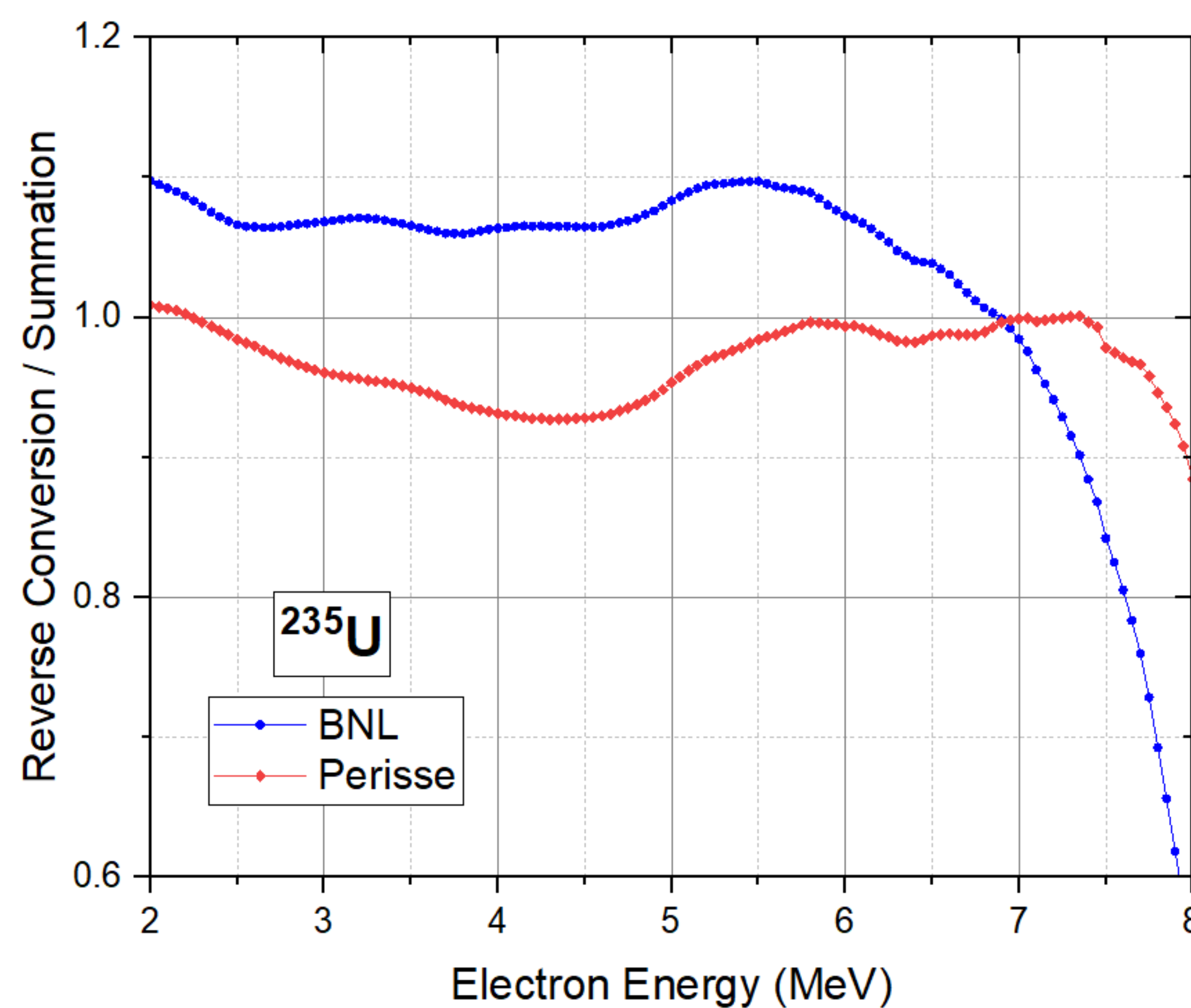
$$S_5(E_e) = S_{DB}(E_e) / (f_5 + f_8/R^{S_{58}}(E_e) + f_9/R^{K_{59}}(E_e) + f_1/R^{S_{51}}(E_e)) \text{ and } S_9(E_e) = S_5(E_e) / R^{K_{59}}(E_e)$$



The ratio to the ILL & Munich electron spectra are shown on the left. The ^{235}U and ^{238}U are affected by the normalization issue in the former, due to the use of a higher $^{207}\text{Pb}(n,\gamma)$ thermal cross section. The lack of linearity could perhaps be due to a lower BILL efficiency, that was not mapped in the 'bump' region of interest [1].



(3) Comparison with our summation calculations and those from Ref. [4] are shown below, reflecting mainly differences for the nuclides with incomplete or unknown decay schemes. We note that our $R^{S_{58}}$ and $R^{S_{51}}$ values agree nevertheless quite well with those from [4].



Conclusions

- ❑ We really need to re-measure the $^{235,238}\text{U}$ and $^{239,241}\text{Pu}$ electron spectra with (i) high-resolution, (ii) high signal to noise ratio, and (iii) very robust normalization and efficiency procedures.
- ❑ Perhaps the 'bump' relative to the Huber-Mueller model is due to a lower BILL efficiency than assumed in the 3-7 MeV range?
- ❑ We need to improve the data behind summation calculations, nearly all the data in nuclear databases has been obtained with other applications in mind.
- ❑ A measurement of the ^{252}Cf electron spectrum could help to prepare for the U and Pu ones, as well as to possibly understand the physical origin of the 'bump'.

References

- [1] K. Schreckenbach *et al.*, Phys. Lett. 160B, 325 (1985).
- [2] F. P. An *et al.*, Chinese Phys. C 45, 073001 (2021).
- [3] V. Kopeikin, M. Skorokhvatov, and O. Titov, Phys. Rev. D 104, L071301 (2021).
- [4] L. Perisse *et al.*, Phys. Rev. C 108, 055501 (2023).

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