The 7th International Conference on Particle Physics and Astrophysics

Development of the NeuCBOT utility for evaluation of neutron yields and spectra from (α, n) reactions

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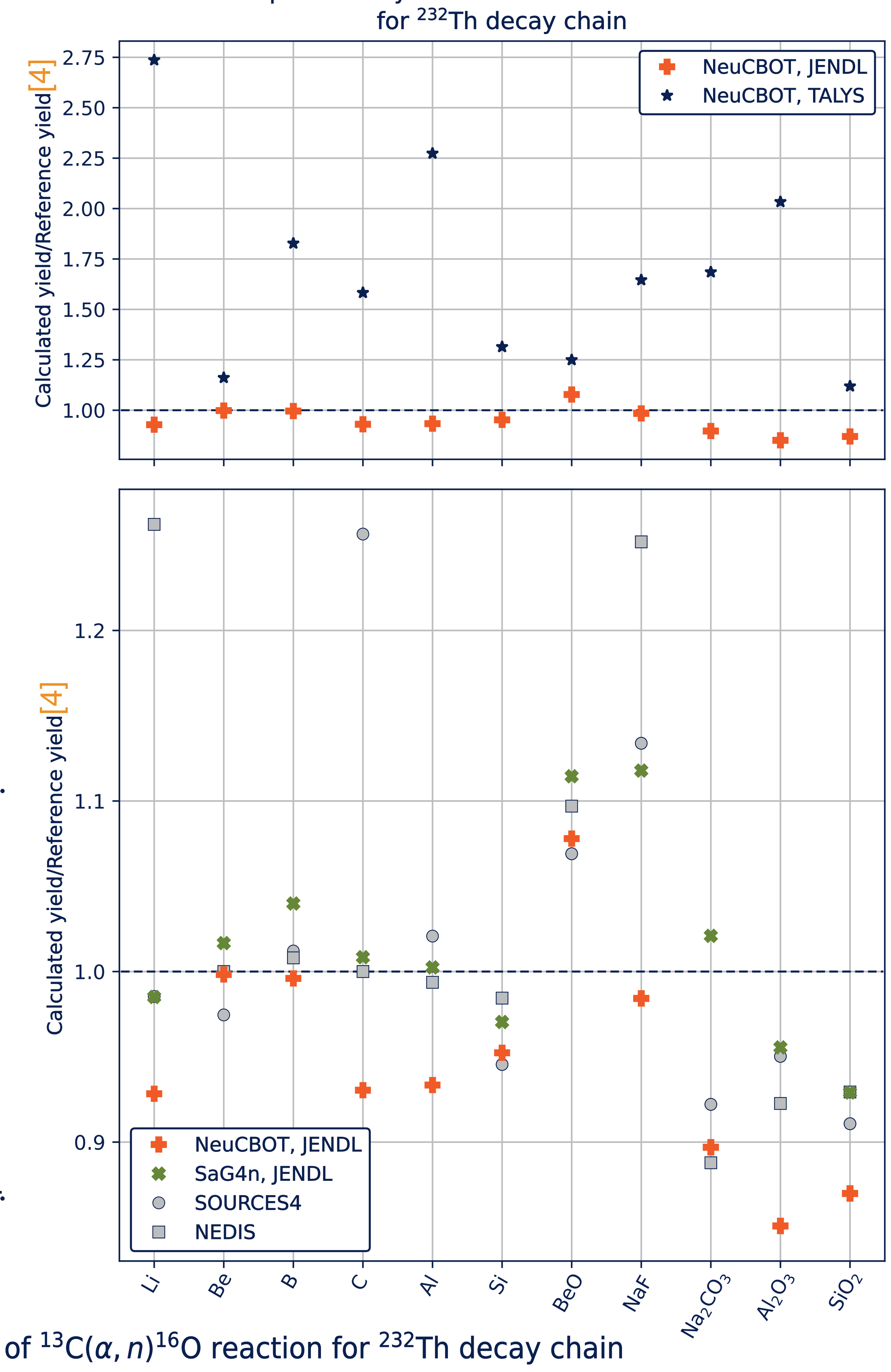
Abstract

Consideration of (α, n) reactions is necessary for conducting precision experiments on detection and study of neutrinos and dark matter particles in modern ultra-low background installations. The NeuCBOT[1] utility, that originally uses the TENDL-2019 (TALYS-1.95) database, has been upgraded[2] by adding an ability to use evaluated experimental data called JENDL[3]. Neutron yields and neutron spectra for (α, n) reactions based on JENDL can be obtained now for the following target nuclei:

$^{6\text{-}7}$Li, ^{9}Be, $^{10\text{-}11}$B, ^{13}C, $^{14\text{-}15}$N, $^{17\text{-}18}$O, ^{19}F, ^{23}Na.

Comparison of yields form different instruments for ^{232}Th decay chain



General information

The NeuCBOT program calculates yields Y_i and neutron spectra $Y_i(E_n)$ using following formula, where P_α – α particle weight, C_m – target nucleus mass fraction, A_m – it's mass number, $\xi\left(E_\alpha\right)$ – stopping power.

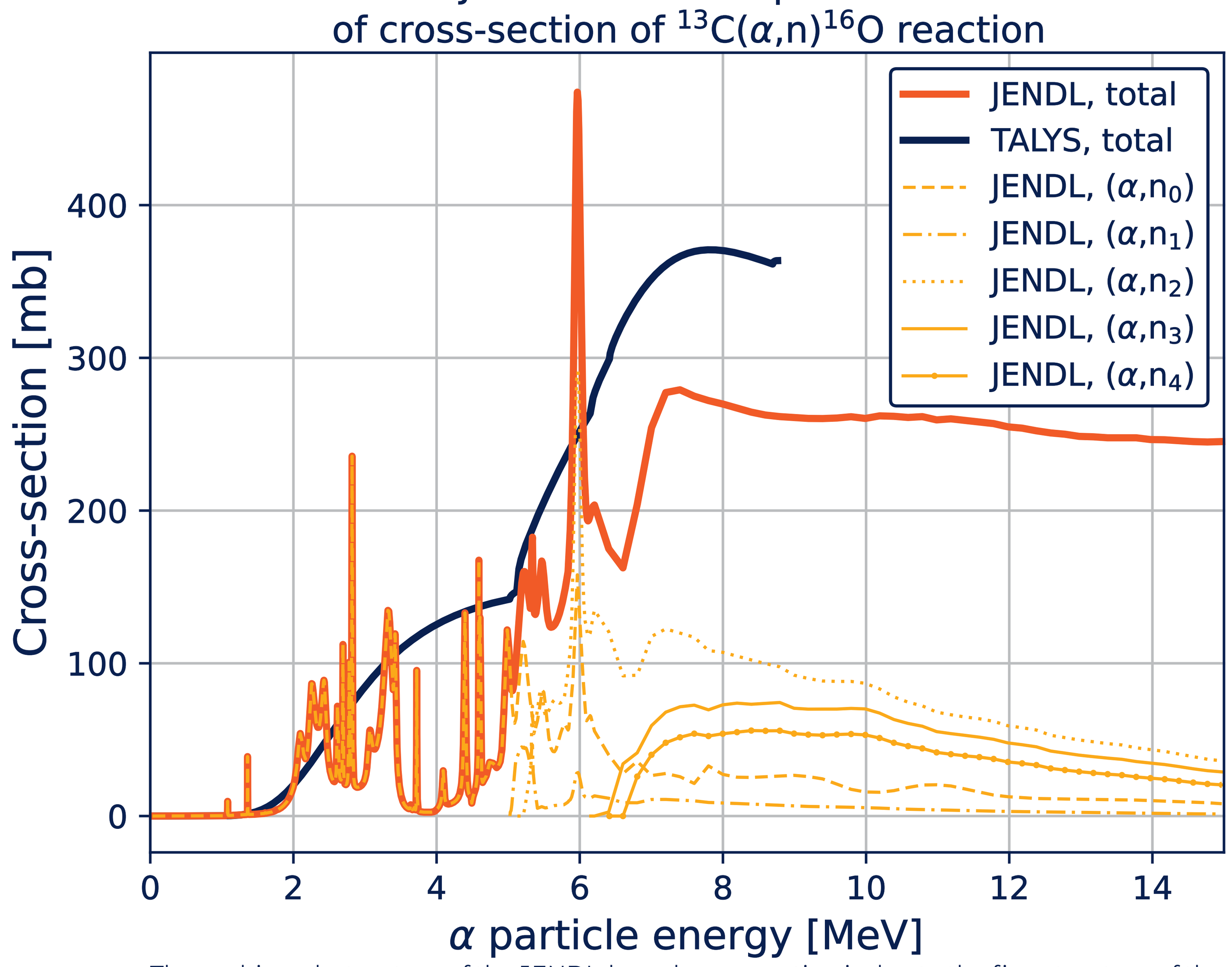
$$Y_i(E_n)=\sum_\alpha P_\alpha \sum_m \frac{N_A C_m}{A_m}\int_0^{E_\alpha}\frac{\sigma_m(\tilde{E}_\alpha,E_n)}{\xi\left(\tilde{E}_\alpha\right)}\,d\tilde{E}_\alpha.$$

JENDL contains normalised angle distributions $p\left(E_\alpha, C_\theta\right)$ and differential x-sections $\sigma_m\left(E_\alpha\right)$ that can be converted to double differential x-sections $\sigma_m\left(E_\alpha,E_n\right)=\frac{\partial C_\theta}{\partial E_n}p\left(E_\alpha,C_\theta\left(E_n\right)\right)\sigma_m\left(E_\alpha\right)$ via kinematics:

$$E_n^{1/2}=\frac{C_\theta\sqrt{m_\alpha E_\alpha m_n}+\sqrt{C_\theta^2\cdot m_\alpha E_\alpha m_n-\left(m_\alpha+m_{In}+E_\alpha\right)\left[\frac{m_{Out}^2-\left(m_\alpha+m_{In}-m_n\right)^2}{2}-E_\alpha\left(m_{In}-m_n\right)\right]}}{m_\alpha+m_{In}+E_\alpha}.$$

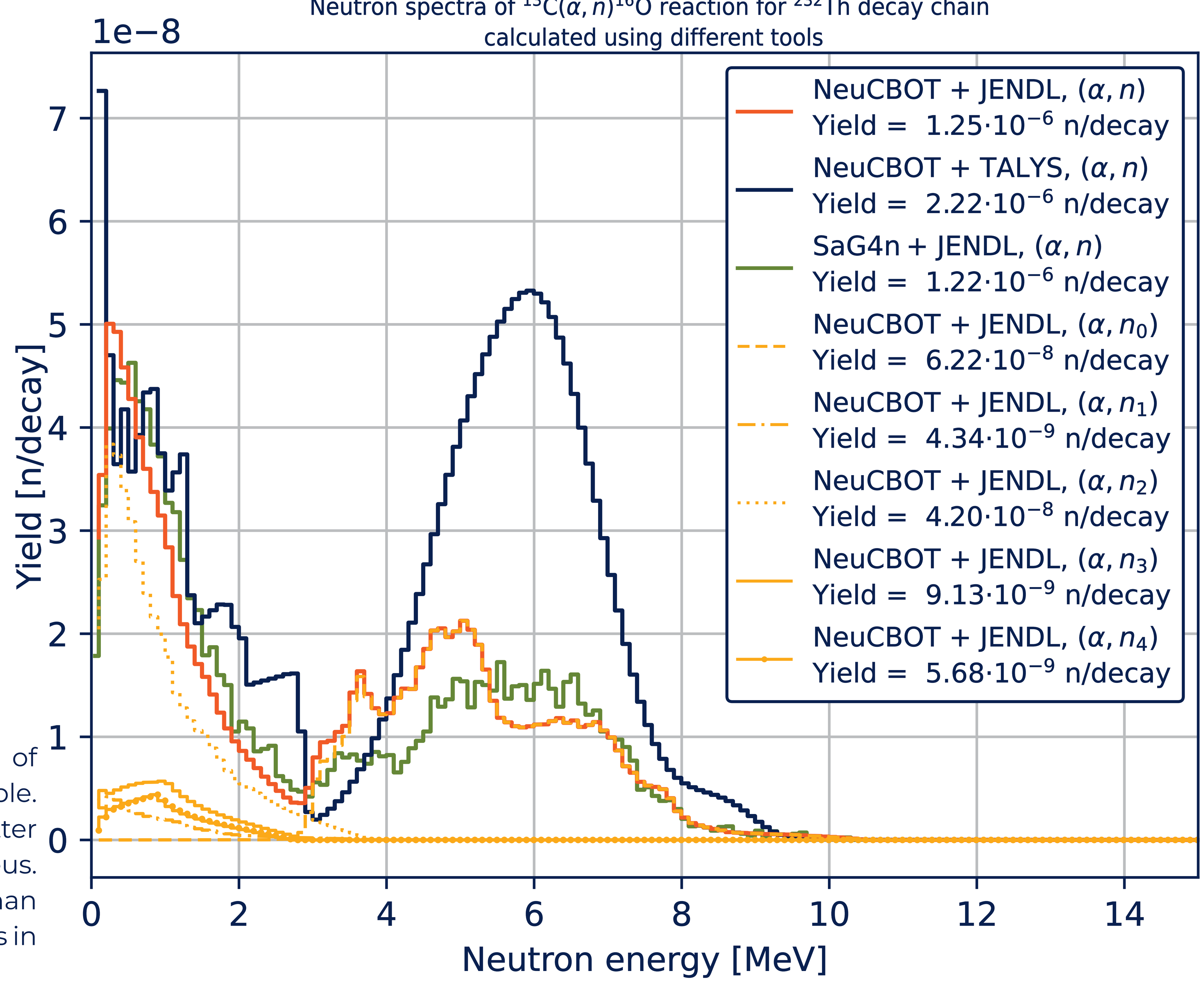
Where C_θ – is cosine of the angle between the emitting neutron momentum and the incident α particle momentum.

JENDL-TALYS comparison of cross-section of ^{13}C(α,n)^{16}O reaction



The multi-peak structure of the JENDL-based cross-section is due to the fine structure of the compound core. Also JENDL provides information about partial cross-sections.

Neutron spectra of ^{13}C(α, n)^{16}O reaction for ^{232}Th decay chain calculated using different tools



The difference of the neutron spectra calculated using SaG4n and NeuCBOT via JENDL and TALYS datasets for ^{238}U decay chain for ^{13}C(α,n)^{16}O reaction.

Results

- Yields and neutron spectra based of different branches of the (α, n) reaction with the help of **JENDL** are now available.
- **JENDL**-based spectra has fractures, which indicates a better accounting of the fine structure of the compound-nucleus.
- The neutron yield calculated based on **JENDL** data is less than that based on **TALYS** and is similar to SaG4n spectra, which is in line with expectations[5].
- Also it is important to note that due to the insufficient number of experiments, the results given in the work are mostly based on data from Gorshkov and Tsvetkov[6] experiment.

NeuCBOT   JENDL5-to-NeuCBOT   Spectra graphs

References

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