

Deuteron and alpha sub-libraries of JENDL-5



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- ✓ JENDL-5 includes several sub-libraries to contribute to various applications.

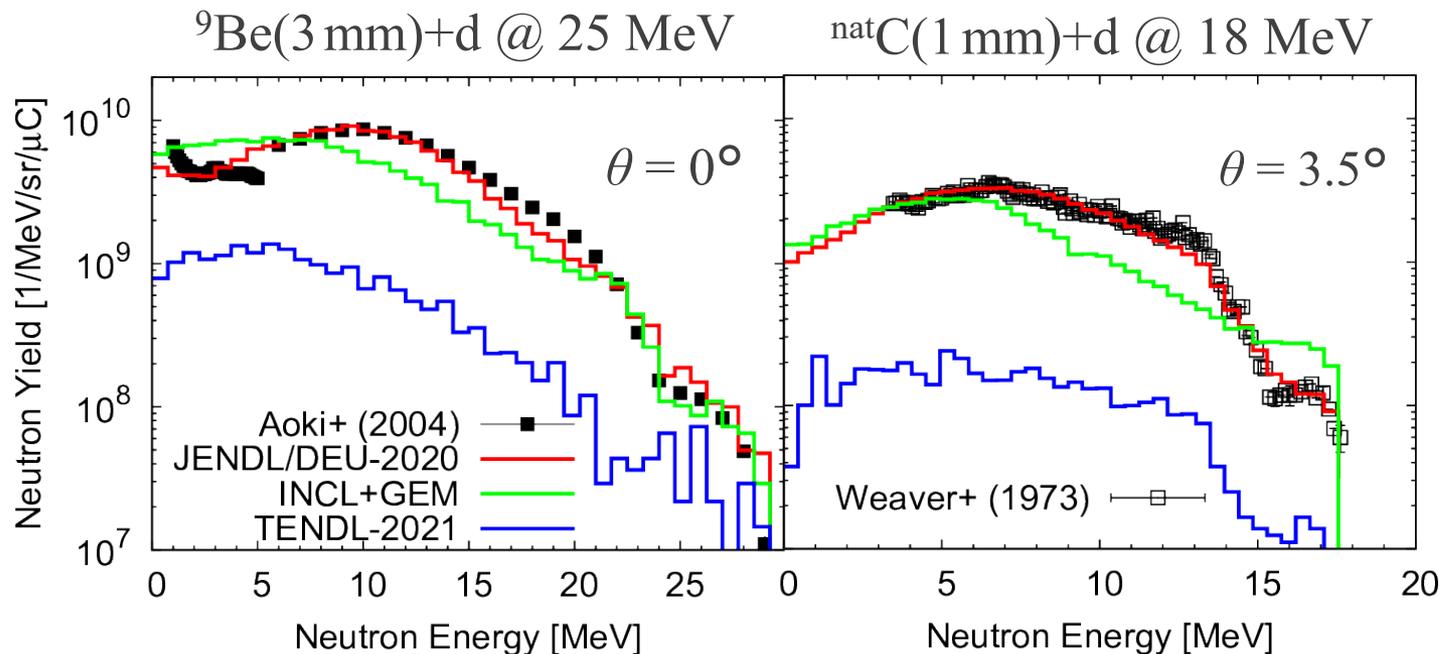
- ✓ The evaluation and validation of the two sub-libraries are outlined.
 1. **deuteron** sub-library
 - design of accelerator-based **neutron sources**

 2. **alpha-particle** sub-library
 - application in **back-end** fields

✓ **JENDL/DEU-2020**^[1], a deuteron nuclear data library for ^{6,7}Li, ⁹Be, and ^{12,13}C up to 200 MeV has recently been developed.

→ Neutron sources using (*d,xn*) reactions are proposed.

Validation results using **PHITS**^[2]



[1] S. Nakayama et al. J. Nucl. Sci. Technol. **58** 805 (2021).

[2] T. Sato et al. J. Nucl. Sci. Technol. **55** 684 (2018).



1. Light nuclides (${}^6,{}^7\text{Li}$, ${}^9\text{Be}$, ${}^{12,13}\text{C}$)

✓ The JENDL/DEU-2020 data were slightly modified and adopted.

→ ${}^6\text{Li}(d,xt)$ cross sections at low incident energies, etc.

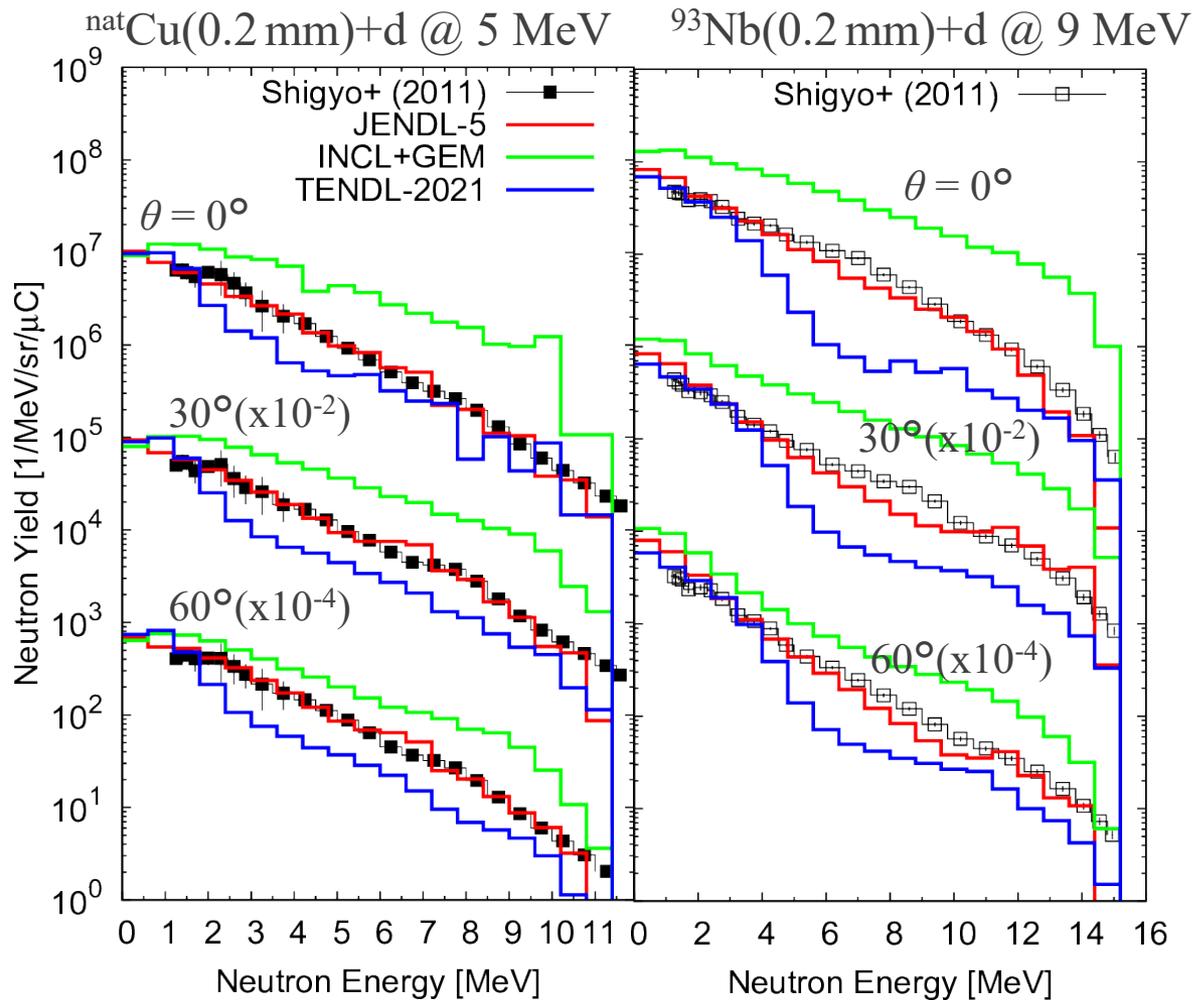
✓ Neutron production data below 50 MeV are not changed.

2. Structural materials (${}^{27}\text{Al}$, ${}^{63,65}\text{Cu}$, ${}^{93}\text{Nb}$)

✓ Important in the shielding design of accelerator facilities.

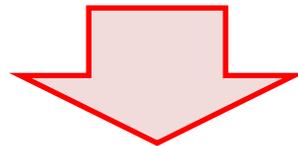
✓ **Newly evaluated** up to 200 MeV with the DEURACS code^[1].

[1] S. Nakayama et al. Phys. Rev. C **94**, 014618 (2016).



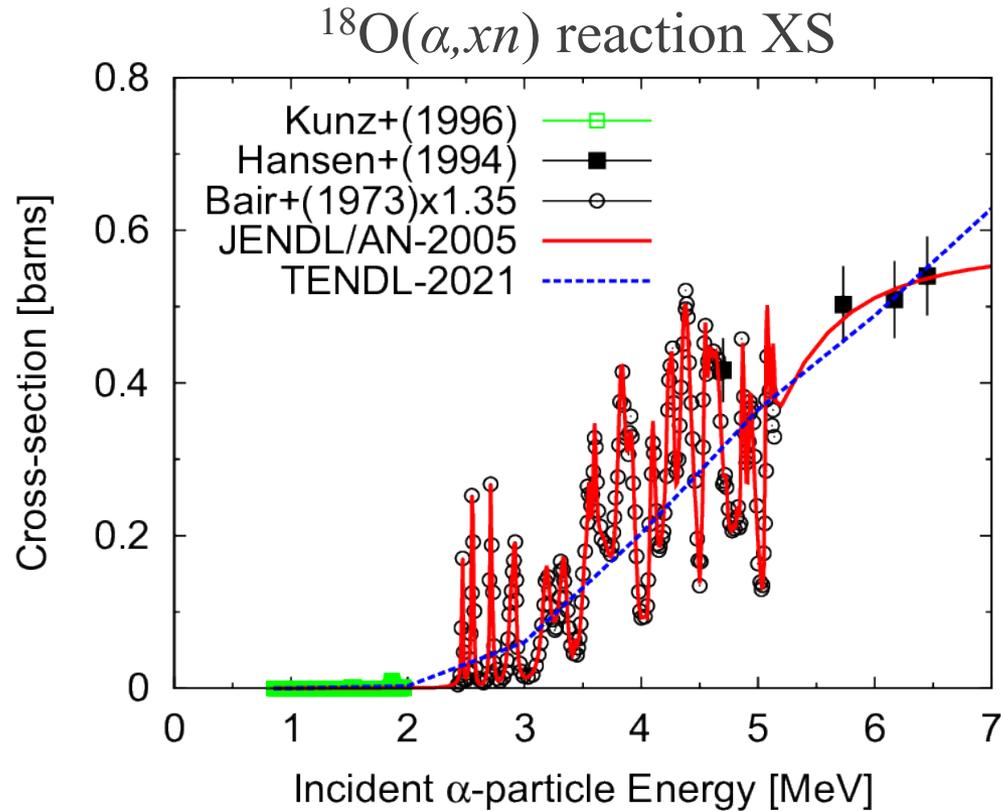
JENDL-5 allows for **more accurate simulations.**

- ✓ Trans-uranium (TRU) and light elements (C, N, O, F, etc.) often coexist in storage and transportation of irradiated fuel.
- ✓ Decay α -rays from TRU can produce neutrons by the reactions with the surrounding light nuclei.
- (α, xn) reaction data on light nuclides are important in the radiation shielding and criticality safety of back-end facilities.

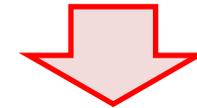


(α, xn) reaction data on 17 light nuclides (from Li to Si) up to 15 MeV were evaluated and released as **JENDL/AN-2005**.

- ✓ There are few evaluated (α, xn) reaction data on light nuclides.



x 1.35 was pointed out by Bair et al. themselves^[1].

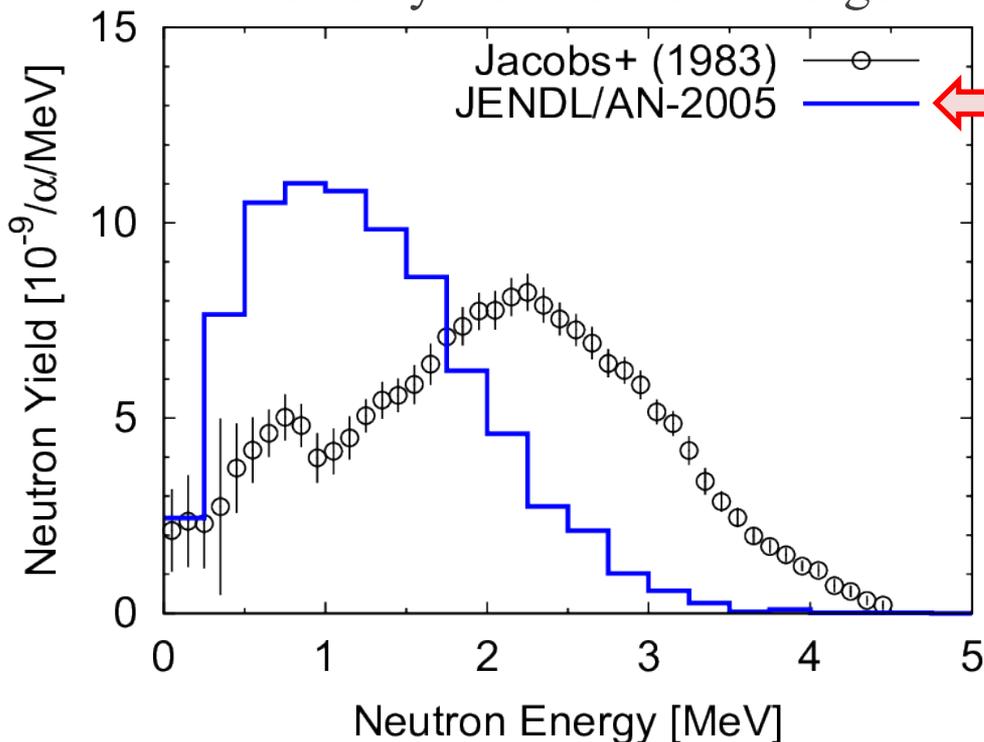


Taken into account in the evaluation of JENDL/AN-2005.

JENDL/AN-2005 is in good agreement with the experimental data including **resonance structures**.

[1] J.K. Bair and J. Gomez del Campo, Nucl. Sci. Eng. **71**, 18 (1979).

UO₂(2 mm)+α @ 5.5 MeV
neutron yields from thick target



← Simulation with the PHITS code

Q-value of (α, n) reaction

0-16 (99.76%) : -12.1 MeV

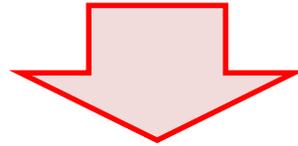
-17 (0.04%) : 0.6 MeV

-18 (0.20%) : -0.7 MeV

Large discrepancies are seen in energy spectra between experiments and simulation results based on JENDL/AN-2005^[1].

[1] D.P. Griesheimer et al., Nucl. Eng. Technol. **49**, 1199 (2017).

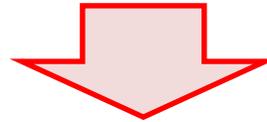
JENDL/AN-2005 contains
only the data related to neutron emission



- ✓ Simulations of γ -ray production cannot be performed.
→ Required for the quantitative analysis of actinides in the **safeguards** area.
- ✓ **ACE format file** cannot be generated.
→ Processing by NJOY^[1] cannot be performed without data of elastic scattering and α -particle spectra from ($\alpha, n\alpha$) reaction.

[1] R.E. MacFarlane, A.C. Kahler, Nucl. Data Sheets **111**, 2739 (2010).

1. Data up to 15 MeV were evaluated based on the calculations with the CCONE code^[1].
2. The cross-sections of neutron emission channels were **replaced** with those of JENDL/AN-2005.

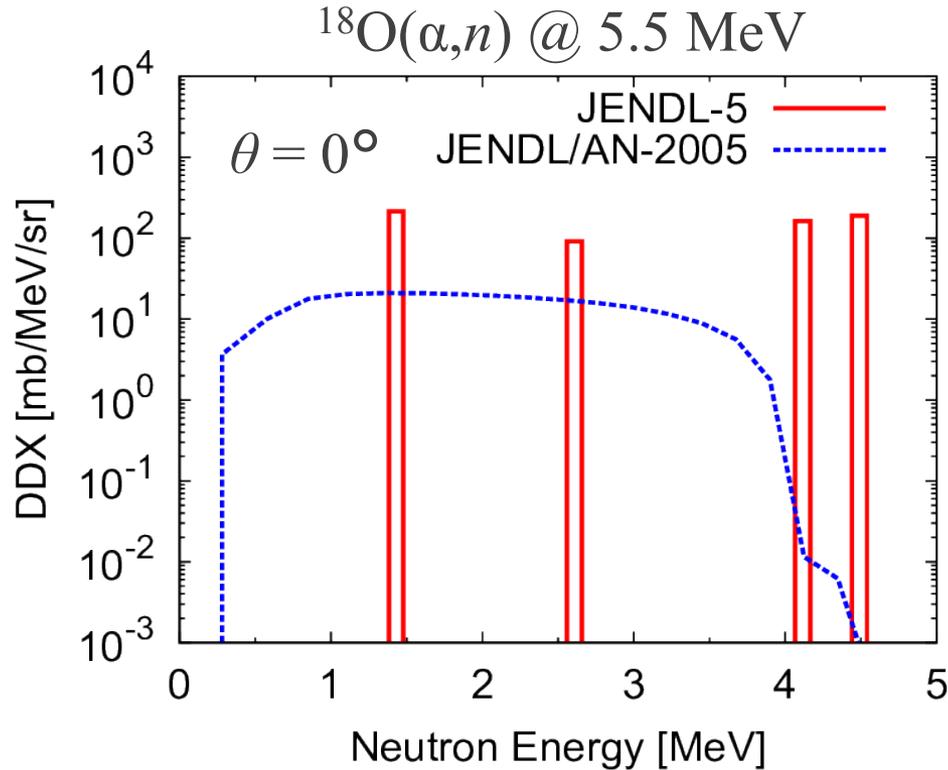


Features

- ✓ **(α, xn) cross sections** of JENDL/AN-2005 are maintained.
- ✓ **Energy and angular distributions** of outgoing neutrons are improved (next page).
- ✓ Production of **γ -rays** from various channels are included.
- ✓ Elastic scattering and outgoing α -particle spectra are included.
- **ACE files** can be generated by the processing with NJOY*.
(*Some modifications are needed to handle MF6/LAW7 data.)

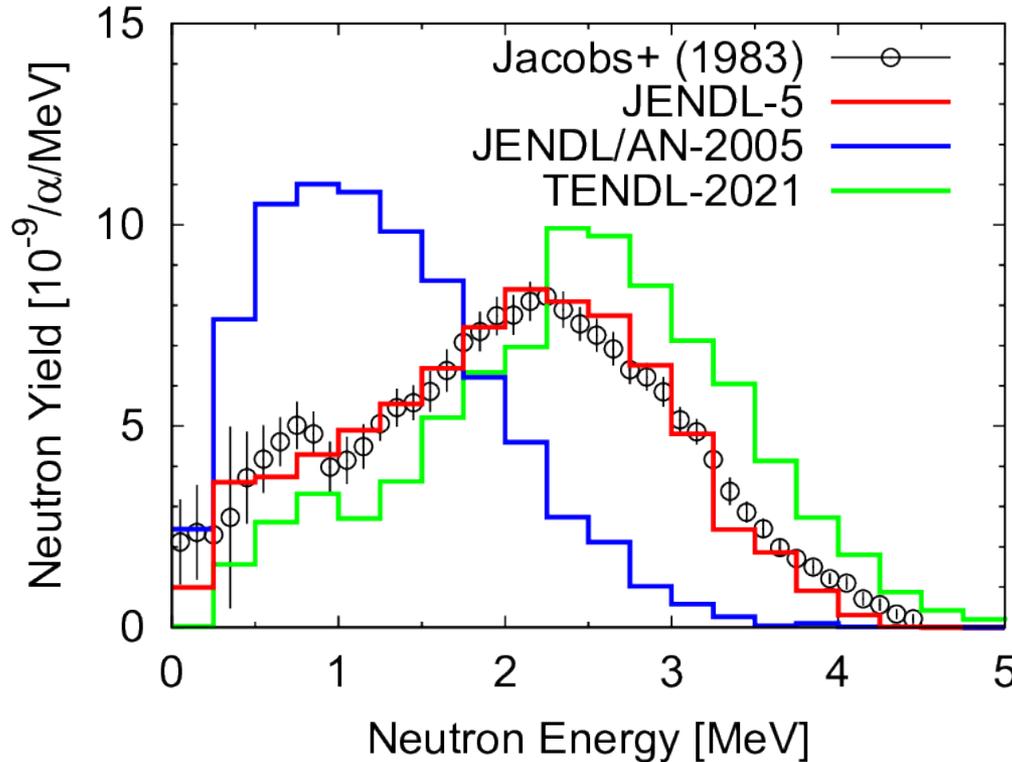
[1] O. Iwamoto et al., Nucl. Data Sheets **131**, 259 (2016).

Improvement of outgoing neutron spectra **11**/₁₃



- ✓ In JENDL/AN-2005, **continuous energy distributions** are given to the (α, n) reaction cross sections.
- In JENDL-5, the peaks corresponding to the discrete states of residual ^{21}Ne are given.

UO₂(2 mm)+α @ 5.5 MeV



*Contribution from $^{18}\text{O}(\alpha, n)$ reaction is dominant.

The PHITS simulation based on the JENDL-5 reproduces the experimental data **better than** those based on the other libraries.

- ✓ **Deuteron sub-library** provides the data on light nuclides (${}^6,{}^7\text{Li}$, ${}^9\text{Be}$, ${}^{12,13}\text{C}$) and structural materials (${}^{27}\text{Al}$, ${}^{63,65}\text{Cu}$, ${}^{93}\text{Nb}$) up to 200 MeV.
- ✓ **Alpha sub-library** provides the data on 18 light nuclides from Li to Si isotopes (${}^6,{}^7\text{Li}$, ${}^9\text{Be}$, ${}^{10,11}\text{B}$, ${}^{12,13}\text{C}$, ${}^{14,15}\text{N}$, ${}^{16,17,18}\text{O}$, ${}^{19}\text{F}$, ${}^{23}\text{Na}$, ${}^{27}\text{Al}$, ${}^{28,29,30}\text{Si}$) up to 15 MeV.
- ✓ For both libraries, **validation by particle transport simulation** with the PHITS code were performed.
- It was confirmed that the simulation based on JENDL-5 showed **good agreement with experimental data**.