Application of Nuclear Data Libraries in Fusion Neutronics and Some Comments

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2013.12.9
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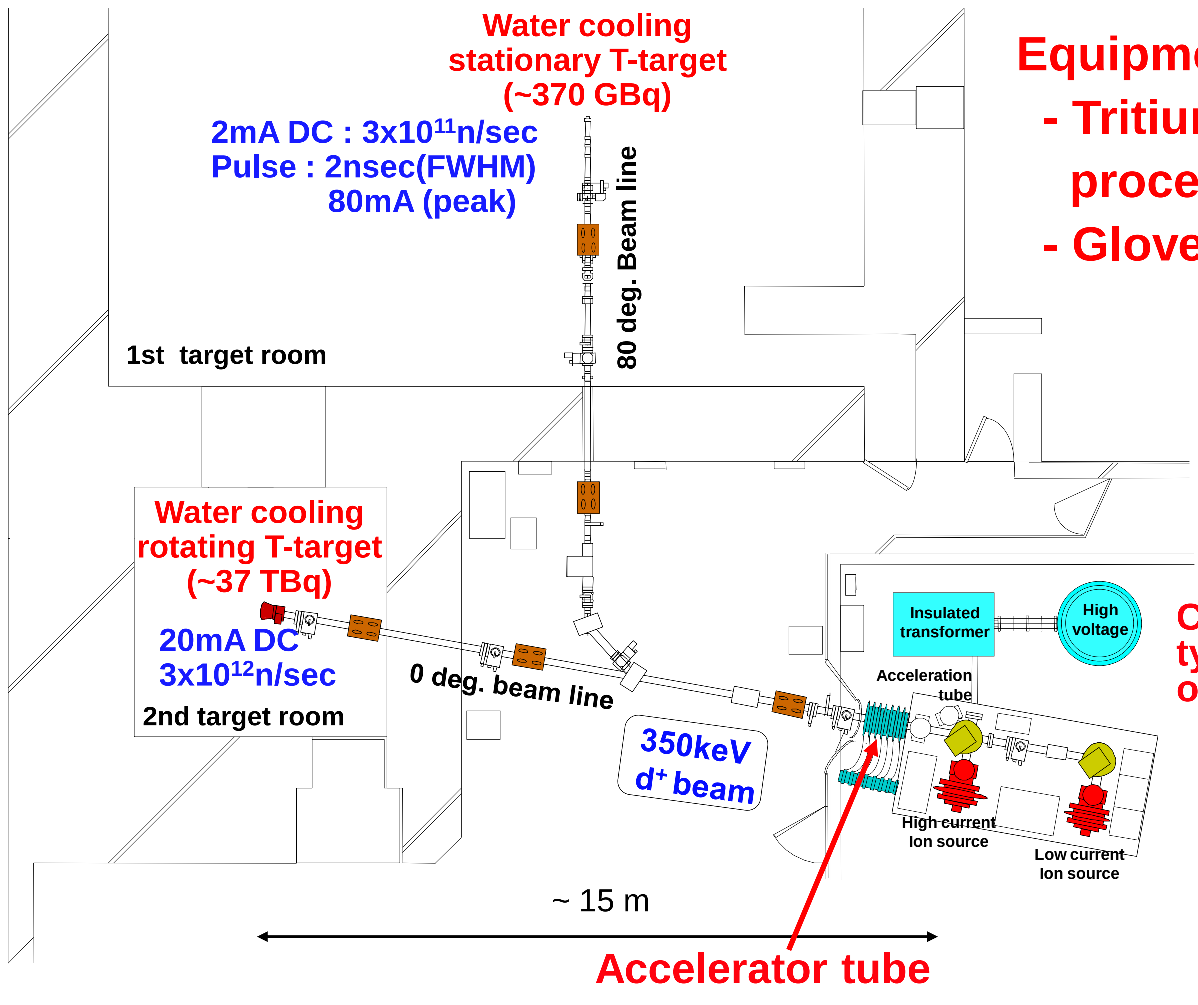
1. **Introduction of our group (Fusion Neutronics Group)**
2. **Our recent studies related to nuclear data**

Fusion Neutronics Source (FNS)

JAEA/FNS **[3]**

- **We have an accelerator-based DT neutron source FNS (Fusion Neutronics Source) at Tokai site in JAEA.**



Equipments for tritium

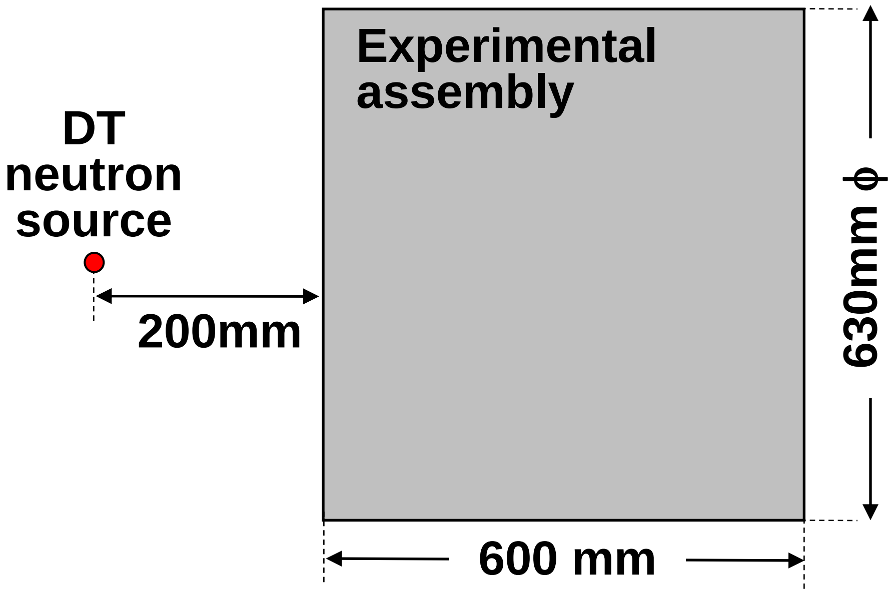
- **Tritium absorption processor (TAP)**
- **Glove box, hood**

Cockcroft Walton type accelerator of 400 kV

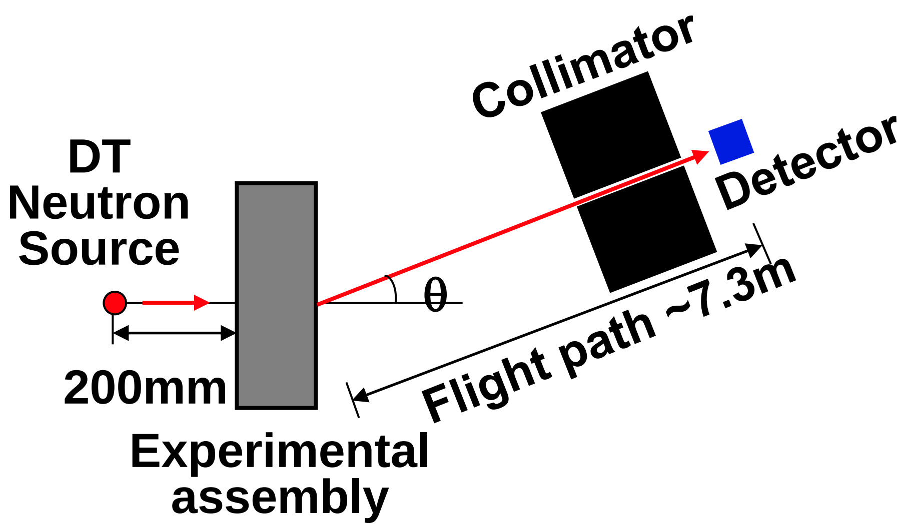
Experimental activities related to nuclear data

JAEA/FNS [4]

- We have performed fusion neutronics experiments for nuclear data benchmarking with FNS since 1981.
  - *In-situ* experiment
  - Time-Of-Flight (TOF) experiment
  - Li_2O, Beryllium, Graphite, SiC, Titanium, Vanadium, Iron, SS316, Copper, Lead, Tungsten, etc.



In-situ experiment



TOF experiment

Calculation activities related to nuclear data

JAEA/FNS [5]

- We analyze these experiments with nuclear data and investigate problems on nuclear data including ACE, MATXS and AMPX files and nuclear analysis codes.
  - Nuclear data library : JENDL, ENDF/B, JEFF, FENDL, etc.
  - Processing code : NJOY, TRANSX, SCAMPI
  - Transport code : MCNP, TRIPOLI, DOORS
  - Sensitivity/uncertainty code : SUSD/FNS
- We also use nuclear data libraries for nuclear designs of fusion reactors such as International Thermonuclear Experimental Reactor (ITER), including activation analyses.

1. Introduction of our group (Fusion Neutronics Group)
2. **Our recent studies related to nuclear data**

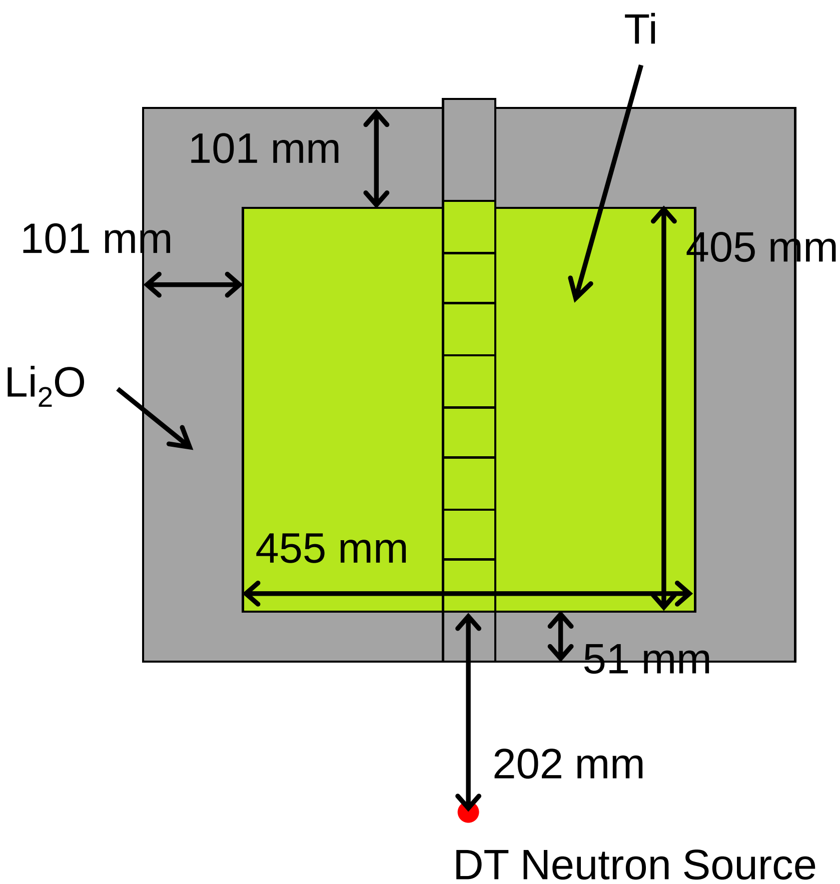
Recent studies related to nuclear data

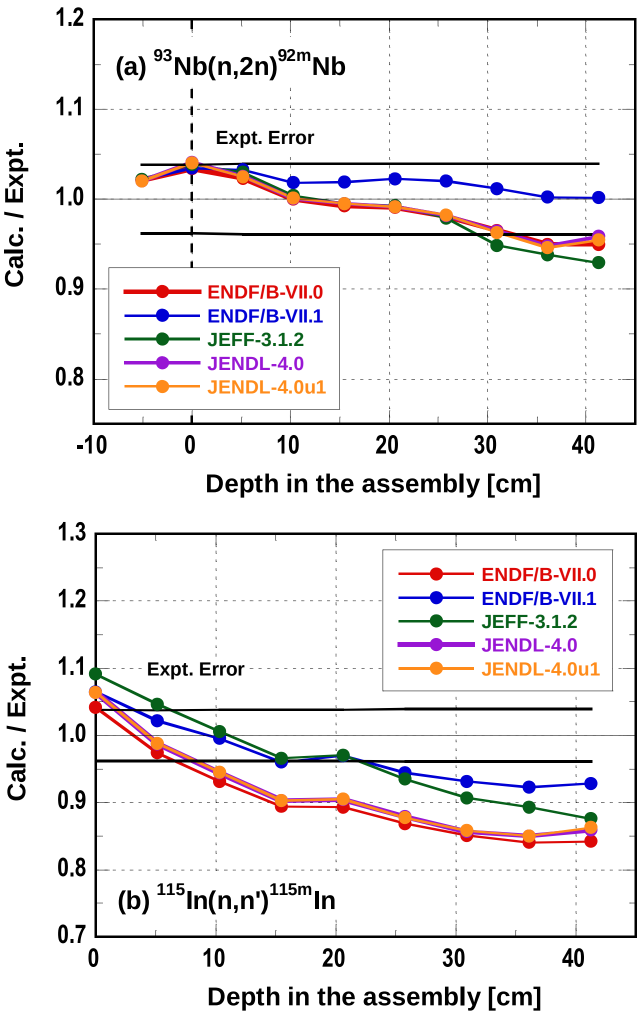
JAEA/FNS [7]

- Now I present our following studies related to nuclear data libraries and processed files in brief.
  - Latest in-situ experiment on titanium
  - Weighting function and background cross section data in multigroup libraries
  - Self-shielding for unresolved resonance data
  - KERMA factors

Titanium Benchmark Expt. –(1)

JAEA/FNS **[8]**



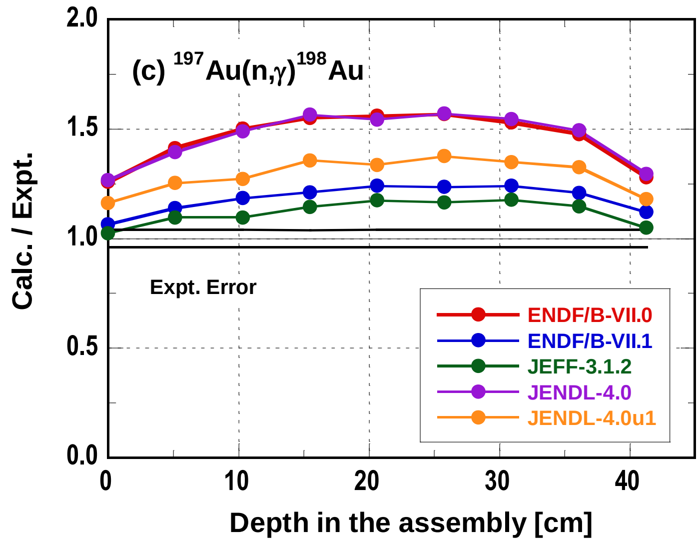


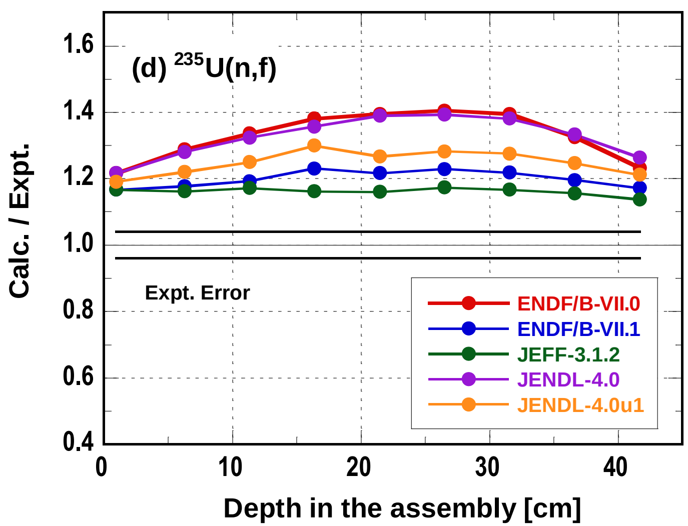
Rectangular assembly

Comparison between calc. and expt. results

Titanium Benchmark Expt. –(1)

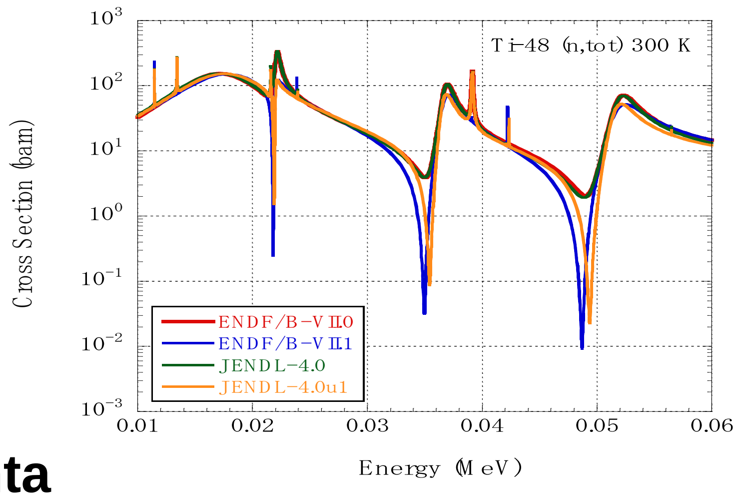
JAEA/FNS **[9]**





Comparison between calc. and expt. results

We found out that titanium data in JENDL-4.0 should be revised for the (n,2n) reaction cross section data and resonance parameters.



Submitted to Fusion Eng. Design by Dr. Ohta

Weighting function and background cross section data in multigroup libraries –(1)

JAEA/FNS [10]

Adequate weighting function for mutigroup libraries

$$W_\ell(E) = \frac{C(E)}{[\sigma_0 + \sigma_t(E)]^{\ell+1}}$$

C(E) : smooth flux
σ_0 : background cross section
σ_t : total cross section

This ℓ is not considered in most cases.

The lowest background cross section is too high in most cases.

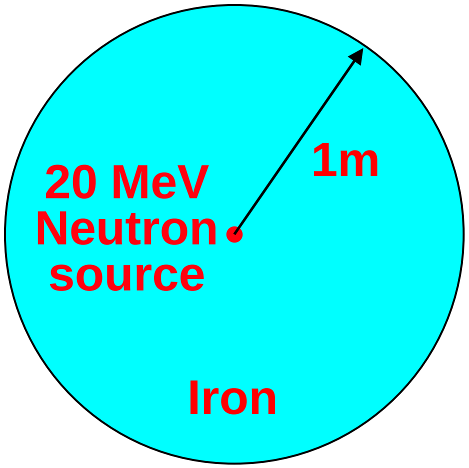
σ_0 of ~ 0.02 barn is required for ^{56}Fe in natural iron, but it is 0.1 or 1.0 in most cases.

Self-shielding correction is not adequate in most cases!

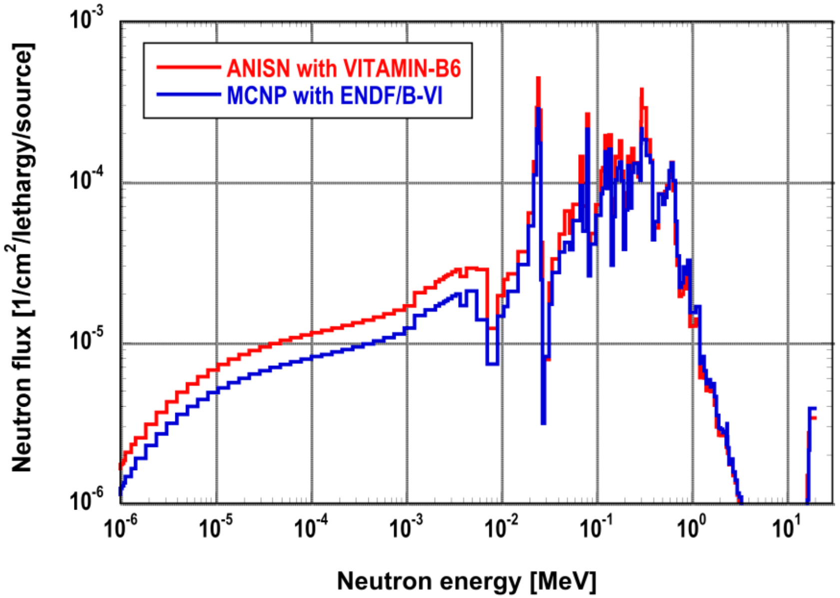
We reviewed the latest multigroup libraries, VITAMIN-B-6, -B7, VITENEA-J, VITJEFF31.BOLIB, MATJEFF31.BOLIB, V7-200N47G in SCALE6, MATXS file in ADS-2.0, HILO2k and MATXSLIB-J33, -J40 through the simple benchmark calculation test.

Weighting function and background cross section data in multigroup libraries –(2)

JAEA/FNS [11]



Calculation model



Neutron spectra at 40cm from center

The self-shielding correction in VITAMIN-B6, -B7, VITENEA-J, VITJEFF31.BOLIB, V7-200N47G in SCALE6, MATJEFF31.BOLIB, MTXS file in ADS-2.0 and HILO2k (except Fe) is not always sufficient, calculations with which can cause unexpected results.

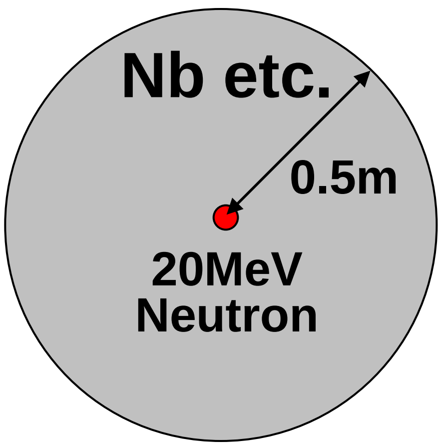
C. Konno et al., Prog. Nucl. Sci. Tech. 1 (2011), 32-35.

C. Konno et al., Prog. Nucl. Sci. Tech. 2 (2011), 341-345.

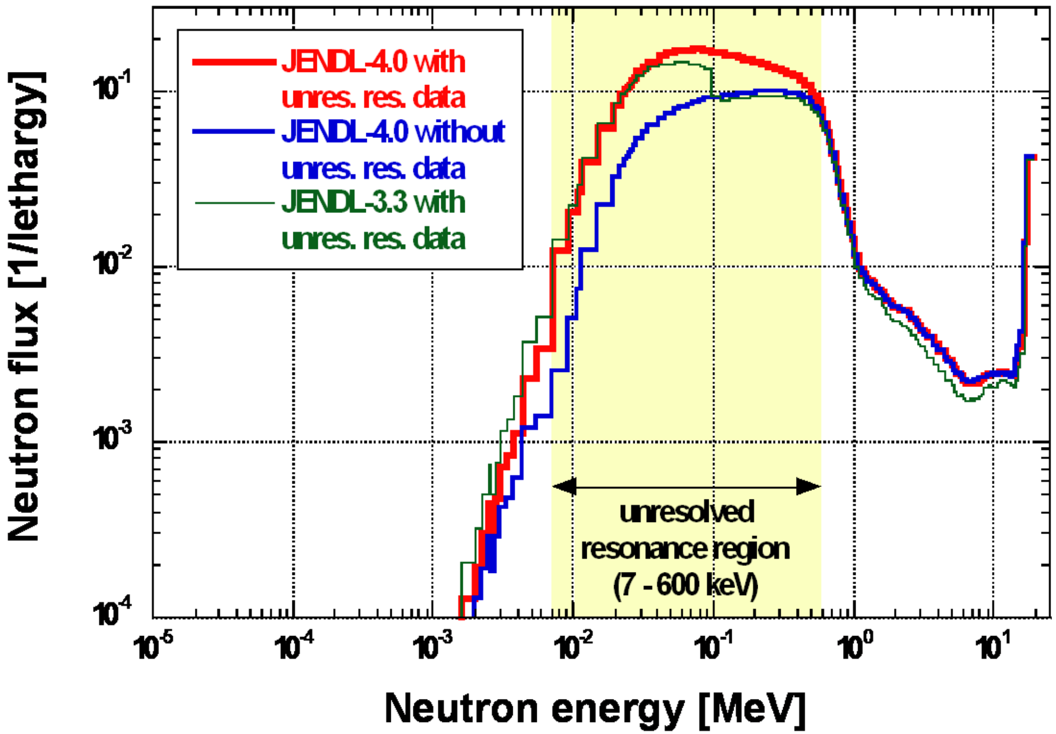
Self-shielding for unresolved resonance data -(1)

JAEA/FNS [12]

- We found out that **the self-shielding was too large around the upper energy of the unresolved resonance region** in JENDL-3.3, ENDF/B-VI.8 and JEFF-3.1.
- JENDL-4.0 tried to solve this problem by increasing the upper energy of the unresolved resonance region.



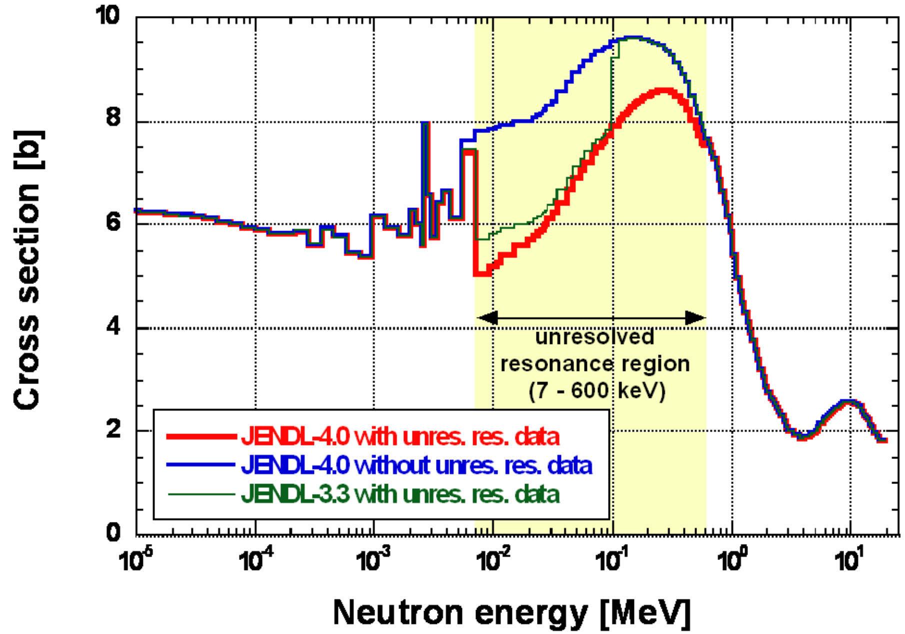
Calculation model



Leakage neutron spectra (MCNP)

Self-shielding for unresolved resonance data -(2)

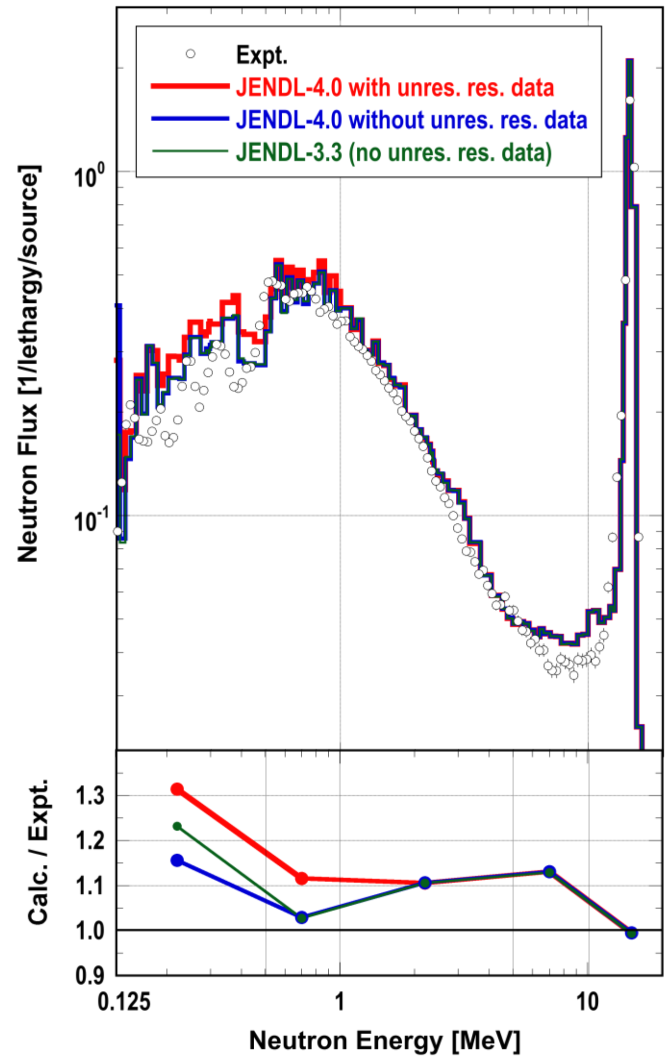
JAEA/FNS [13]



Elastic scattering cross section of ^{93}Nb (deduced from MATXS files with TRANSX)

Are the unresolved resonance data adequate from the view of self-shielding?

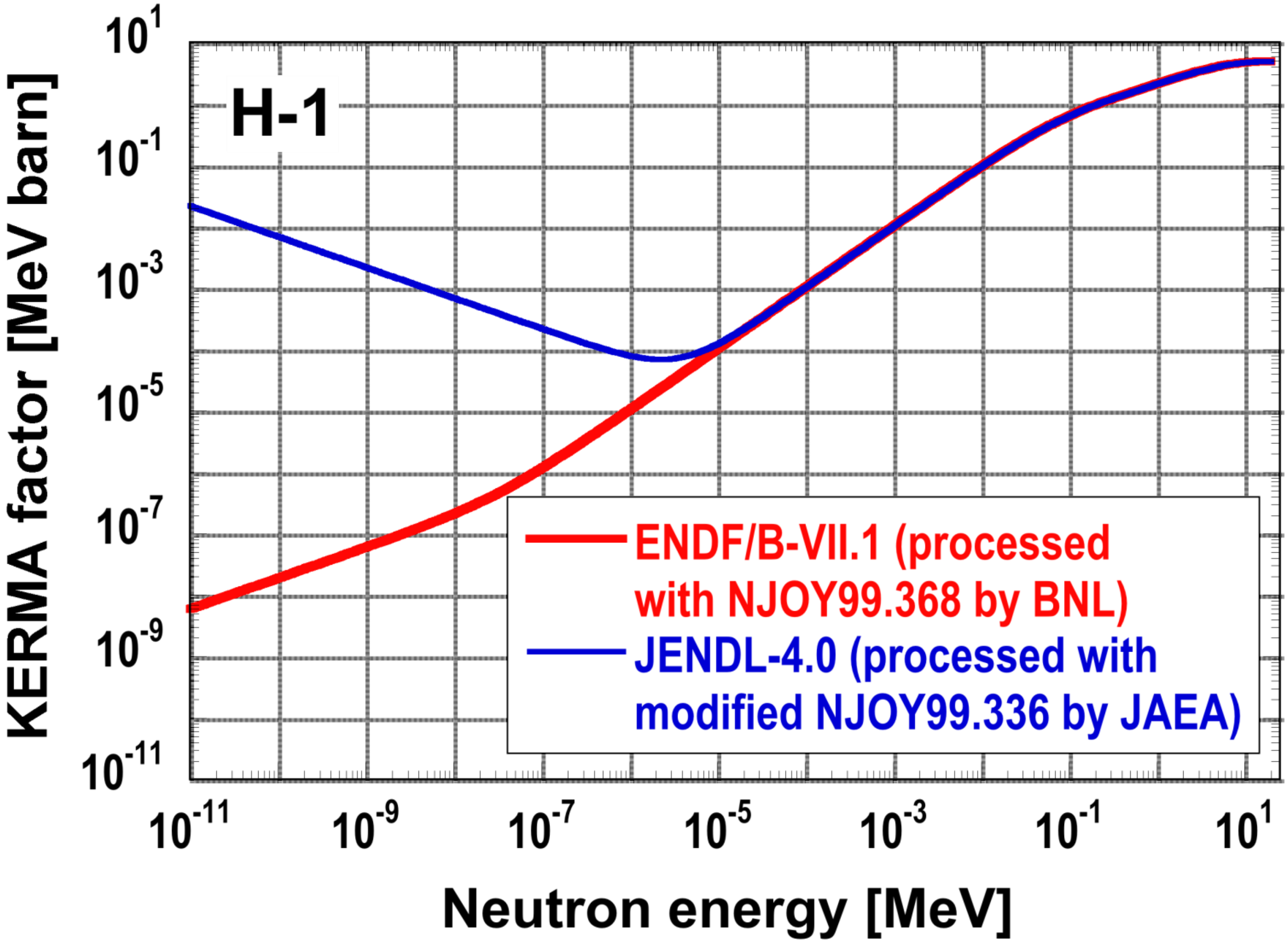
Submitted to Prog. Nucl. Sci. Tech.



Leakage neutron spectra in Mn TOF experiment at OKTAVIAN

KERMA factor -(1)

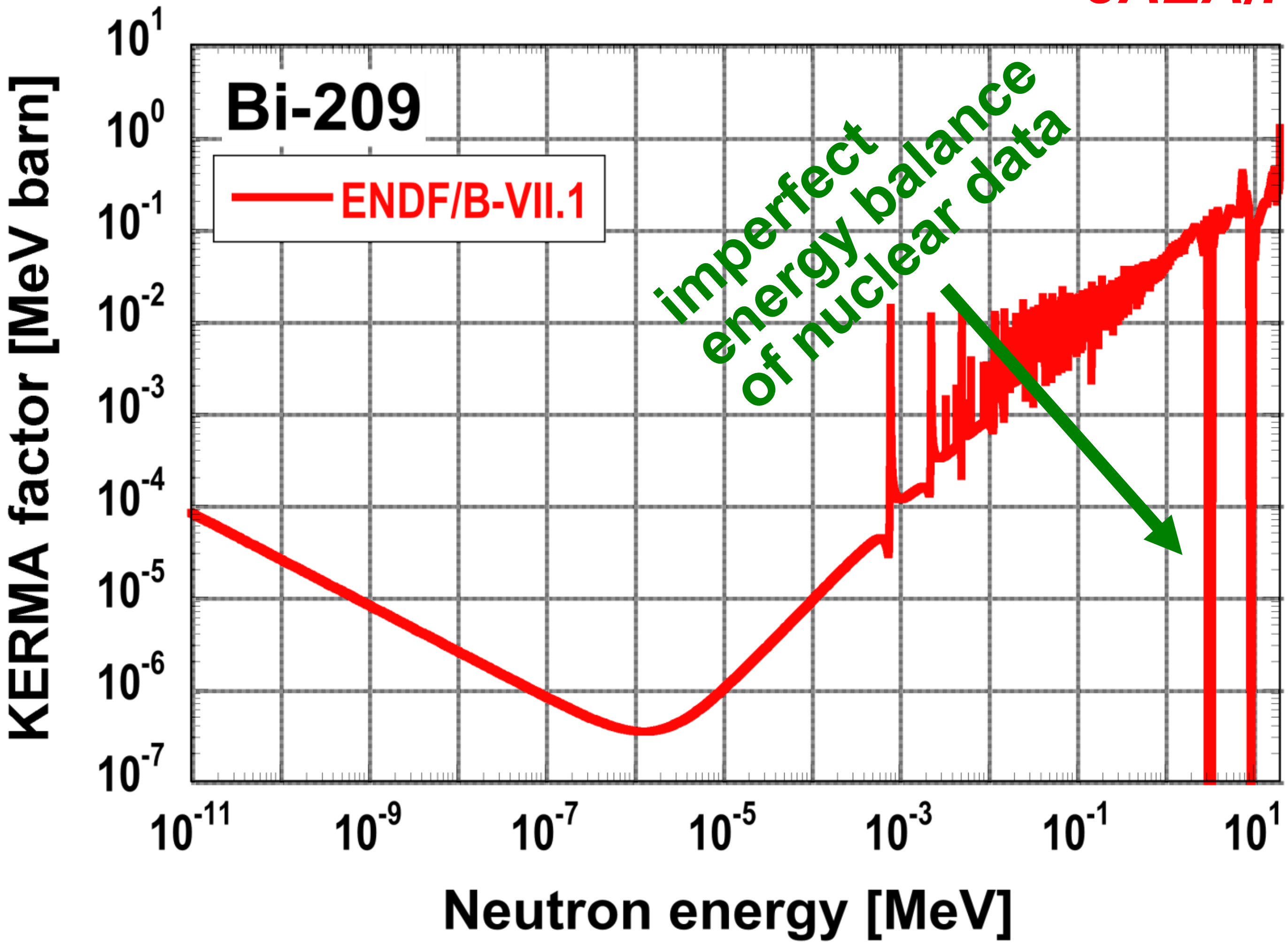
JAEA/FNS [14]



NJOY has a bug in KERMA calculation of ^{1}H.

KERMA factor –(2)

JAEA/FNS [15]



A lot of nuclear data do not keep energy balance.
Neutron KERMA factors in ACE files are not always correct.

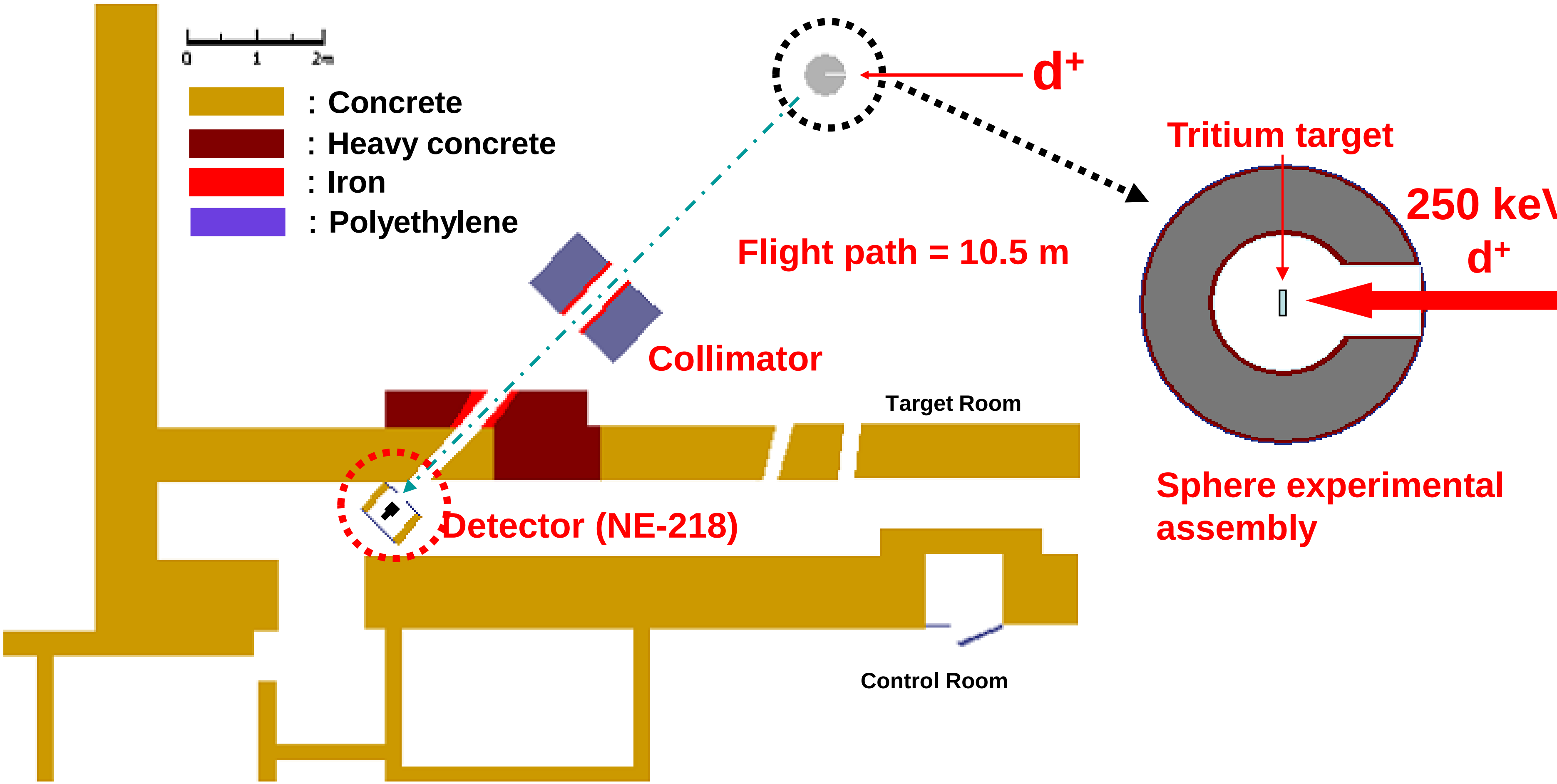
Conclusion and Requests

JAEA/FNS [16]

- We introduced our recent studies related to nuclear data.
  - Latest in-situ experiment on titanium
  - Weighting function and background cross section data in multigroup libraries
  - Self-shielding for unresolved resonance data
  - KERMA factors
- We request the following issues,
  - Adequate codes for nuclear data processing and files processed from nuclear data libraries for nuclear analysis codes
  - Unresolved resonance data adequate from the view of self-shielding
  - Nuclear data libraries with complete energy balance including secondary gamma data

OKTAVIAN Mn Sphere TOF Experiment –(1)

JAEA/FNS [17]



Insufficient self-shielding correction due to weighting function

JAEA/FNS **[18]**

Why does the weighting flux lead the inadequate self-shielding correction?

$$\sigma^{PN}_{\ell t g} = \frac{\int_g \sigma_t(E) W_\ell(E) dE}{\int_g W_\ell(E) dE} \qquad \sigma^{PN}_{\ell g \leftarrow g'} = \frac{\int_{g'} dE' \int_g \sigma_\ell(E' \to E) W_\ell(E') dE}{\int_{g'} W_\ell(E') dE'}$$

$$\sigma^{SN}_{\ell g \leftarrow g'} = \sigma^{PN}_{\ell g \leftarrow g'} \quad \textbf{for } g \neq g'$$

$$\sigma^{SN}_{\ell g \leftarrow g} = \sigma^{PN}_{\ell g \leftarrow g} - (\sigma^{PN}_{\ell t g} - \sigma^{PN}_{0 t g}) - \Delta^N_g$$

$$\sigma^{SN}_g = \sigma^{PN}_{0 t g} - \Delta^N_g$$

Δ^N_g → **0 : Consistent-P Approximation**

$(\sigma^{PN}_{\ell t g} - \sigma^{PN}_{0 t g})$:

= 0 for ℓ≥1 : VITAMIN-B6 $[W_{\ell \geq 1}(E) = W_0(E)]$

≠ 0 for ℓ≥1 : $W_{\ell \geq 1}(E) \neq W_0(E)$ → ***Inadequate cross section*** → ***Insufficient self-shielding correction***

≈ 0 for ℓ≥1 : at no resonance regions (weighting flux : a smooth shape)