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# Benchmark analyses of the final Ta evaluated data for fusion neutron transport calculations

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# Objectives and Content

- Objective:
  - validation of the Ta evaluated data (final version for JEFF-3.2T) relevant for fusion neutron transport calculations
- Content of presentation:
  - available evaluations for Ta isotopes
  - available experimental benchmark and DDX data for Ta
  - comparison of transport calculations and DDX with experiments
  - conclusions

# Ta isotopes abundances and evaluated cross sections files

| Ta natural abundancies: | ENDF/B-VI (1972) | JENDL-3.3 (2002) | JEFF-3.1 (2005) | FENDL-2.1 (2004) | JEFF-3.2T (2007) |
|---|---|---|---|---|---|
| | adopted ENDF/B-V | updated JENDL-3.2 | adopted JENDL-3.3 | adopted JENDL-3.3 | new |
| | < 20 MeV | < 20 MeV | < 20 MeV | < 20 MeV | < 150 MeV |
| $^{180m}$Ta ($10^{15}$a) - 0.012% | - | - | - | - | - |
| Ta-181 (stable) - 99.998% | Ta-181 | Ta-181 | Ta-181 | Ta-181 | Ta-181 |
| Ta-182 (114 d) - 0.0 % | Ta-182 | - | Ta-182 (ENDF/B-IV) | - | - |

***- No evaluation is available for the stable isotope Ta-180m !***

***- Now three independent evaluations do exist: ENDF/B-VI, JENDL-3.3 and JENDL-3.2T = FZK'06 model evaluation (P.Pereslavtsev et al.), subsequent IIK adjustment to the experimental partial cross sections (H.Vonach et al.)***

# Experimental Integral and Differential neutron data relevant for Ta evaluated cross sections validation for fusion application

## Neutron Transport Benchmarks:

**1. Livermore (LLNL) Pulsed Spheres**

- neutron leakage spectra from two Ta spheres with 14 MeV central source

*Information about Experiment is available from:*

- NSE 92 (1986) 382: Ta shell sizes, leakage energy spectra
- UCRL-51144 (1972), LA-12885 (1994): T(d,n) neutron source specification, TOF leakage spectra and MCNP input decks for 28 shperes, except Ta

**2. Lewis Research Center (LRC, Ohio) Sphere**

- neutron leakage spectra from Ta sphere with Am-Be source (mean energy 4 MeV)

*Information about Experiment is available from:*

- NSE 53 (1974) 285: Ta shell sizes, Source and Leakage energy spectra

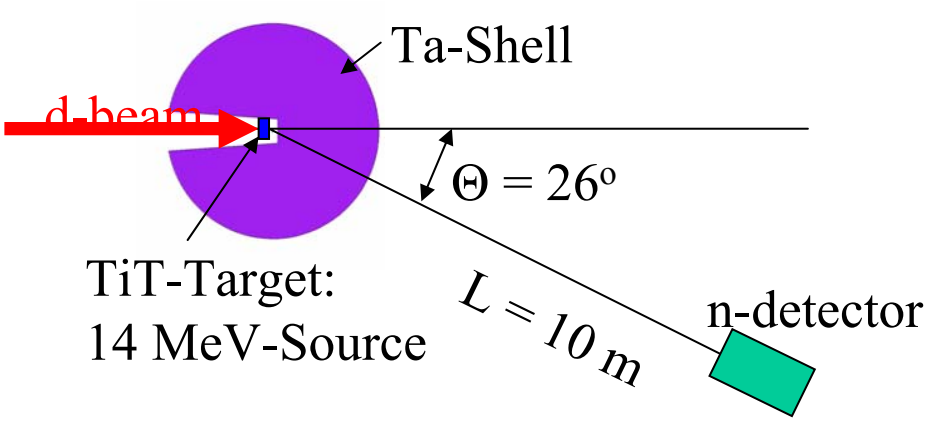
## Differential cross sections (n,xn):

*A few experiments*: IPPE (Obninsk), IRK (Vienna), OSA (Osaka), TOH (Tohoku), TUD (Dresden) … - secondary neutron energy/angular distributions for incident energies 5 to 20 MeV

# Two available Ta-Shell Neutron Transport Experiments

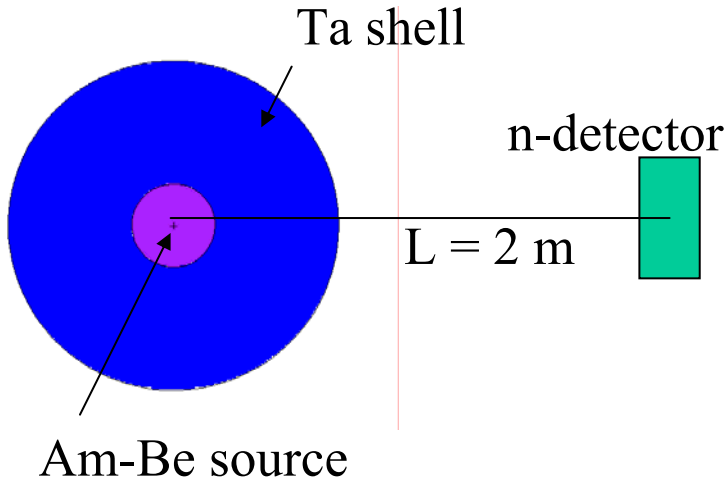
## Livermore (1986):

Shell #1: outer R = 3.4 cm (1 mfp)
Shell #2: outer R = 10.2 cm (3 mfp)
14 MeV-neutron source: TiT +d, $E_d$ = 400 keV
Method: Time-of-Flight, L = 10 m
n-detector: $\Theta = 26^o$, $E_{thresh} > 1$ MeV

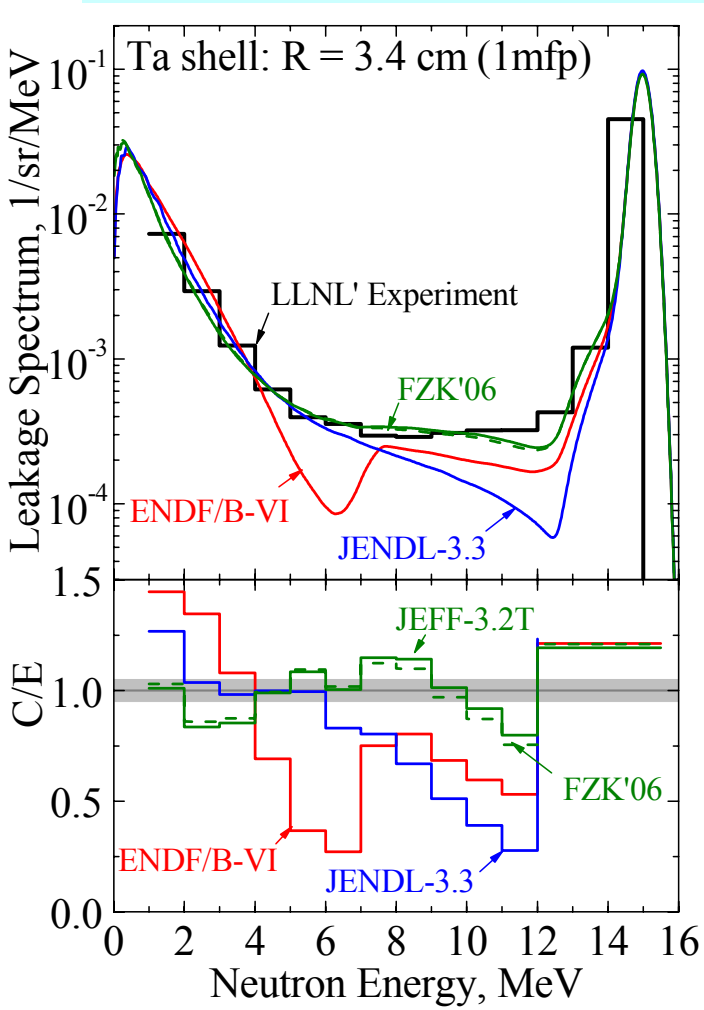


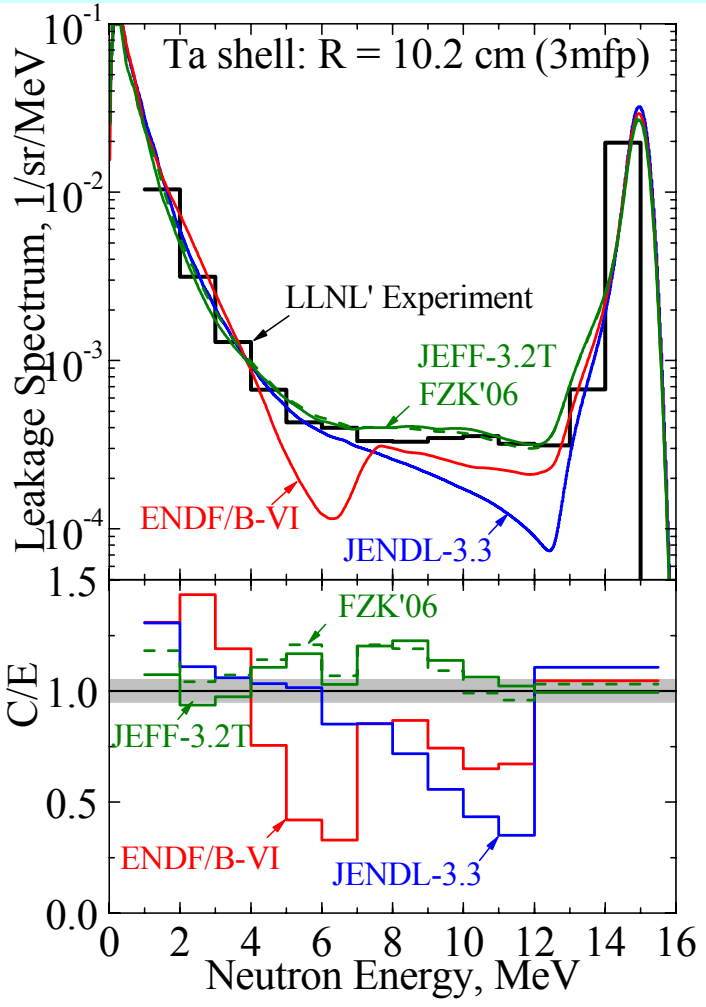

## Lewis Research Center (1974):

Shell: outer R = 12.1 cm
inner r = 3.1 cm (wall 9 cm, 4 mfp)
$^{241}$Am-Be neutron source, <E> = 4 MeV
Method: Proton-recoil scintil. at L = 2 m
n-detector: $\Theta = 26^o$, $E_{thresh} > 1$ MeV



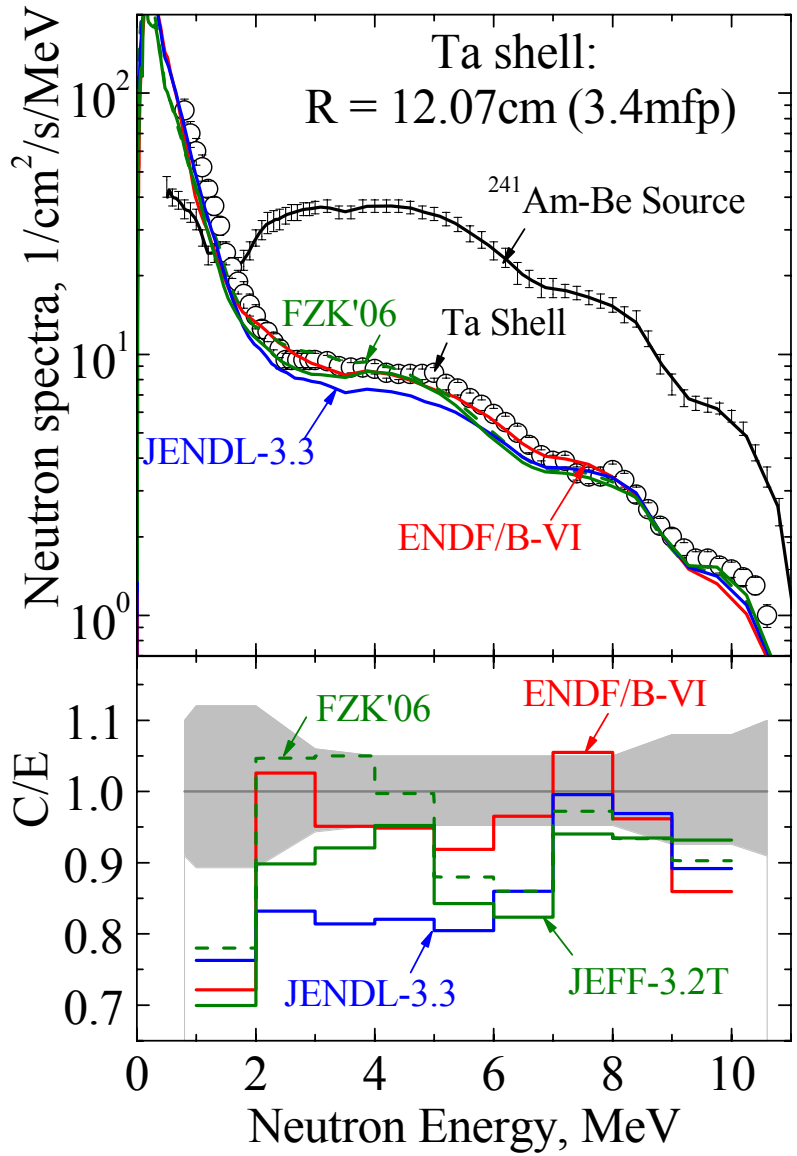
# LLNL Ta-Shell Leakage Experiment with 14 MeV Neutrons
## *evaluated data validation*




***Findings:*** ***- ENDF/B-VI & JENDL-3.3: 20 - 70% over- or under-estimation***
***- FZK'06: 10 - 20% oscillations around the experimental spectra***
***- JEFF-3.2T the same as FZK'06, slight improvements below 7MeV for thicker shell***

# LRC Ta-Shell Neutron Leakage Experiment with Am-Be Neutron Source (mean Energy 4 MeV)



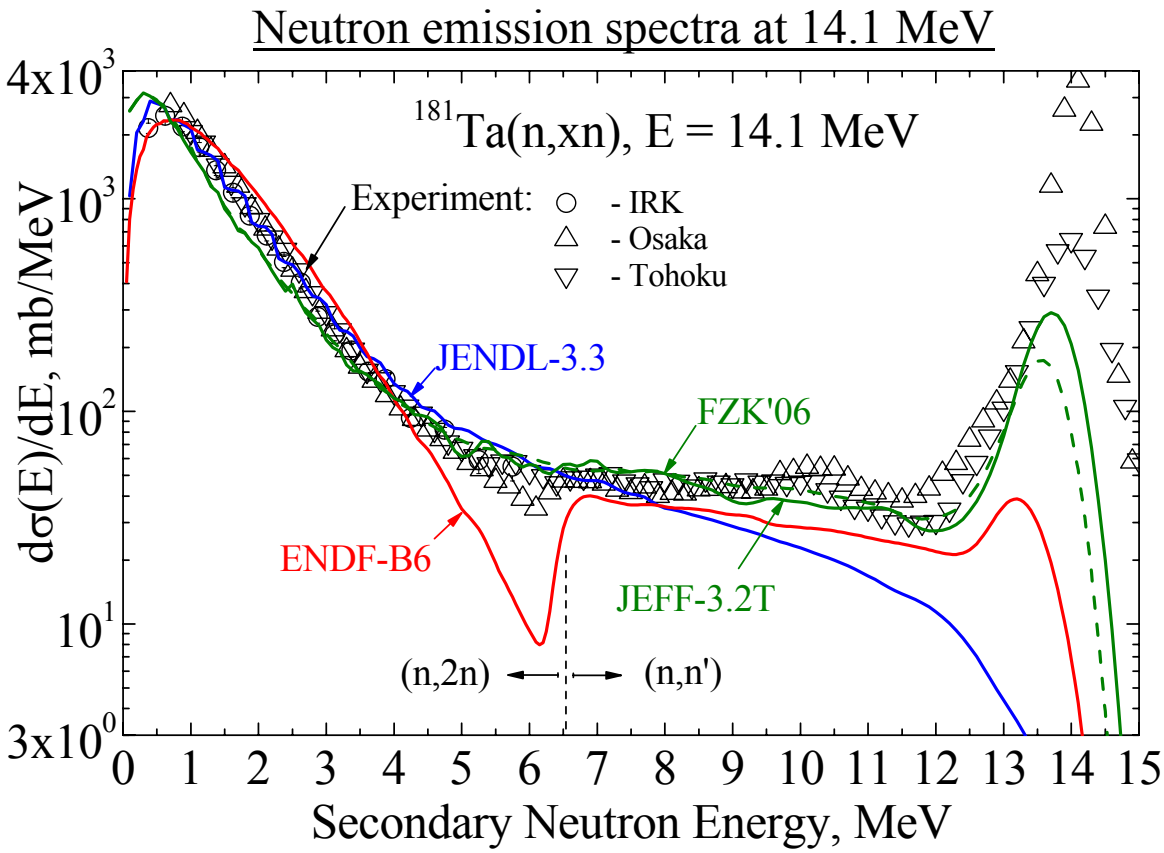

***Findings:***

***- JEDL-3.3 underestimates by 20% below 6 MeV***

***- ENDF/B-VI & FZK'06 predict experiment within 5 – 15% except energies below 2 MeV (detector threshold effect ?)***

***- JEFF-3.2T systematically underestimate by 5 -20%***

# Validation against Differential XS for Ta(n,xn) at 14 MeV

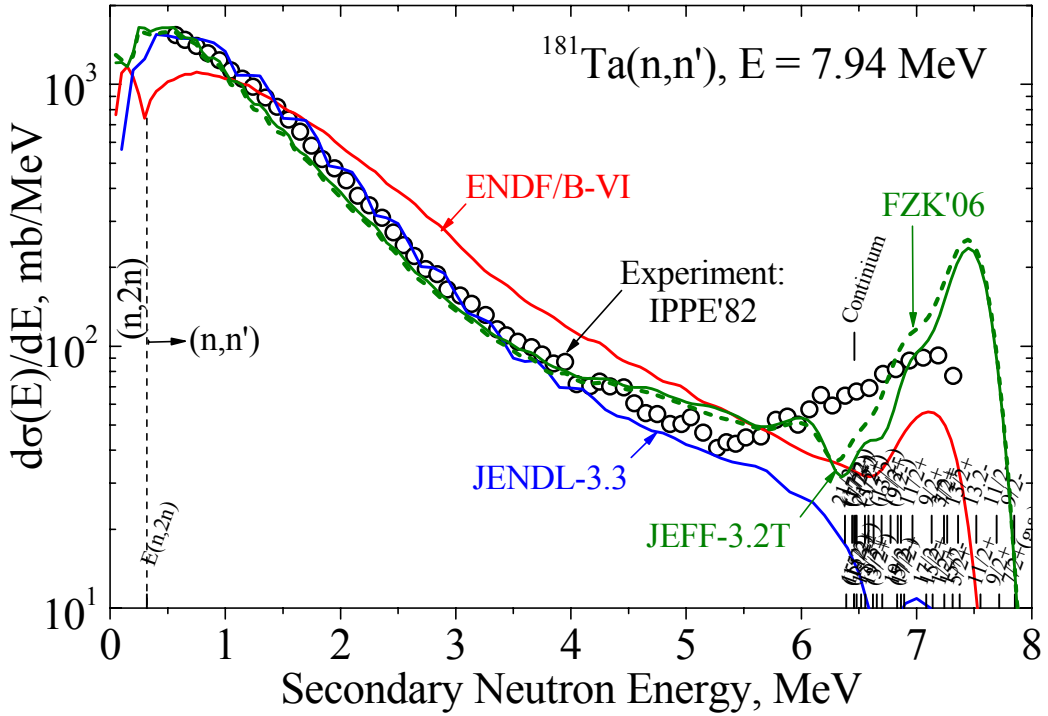



***Findings:***

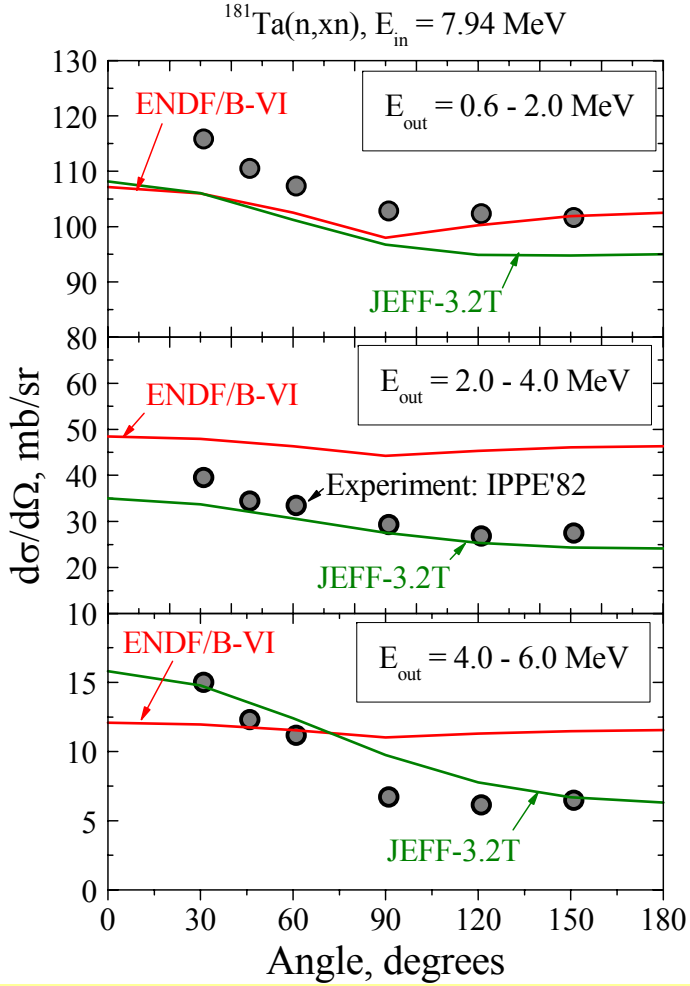
- ***inconsistency of neutron spectra shapes from (n,n') and (n,2n) in ENDF/B-VI***
- ***underestimation of high energy tails (pre-equlibrium/direct processes) from (n,n') reactions in ENDF/B-VI and JENDL-3.3***
- ***satisfactory secondary neutron spectra reproduction by JEFF-3.2T (and FZK'06)***

# Validation against Double Differential XS for Ta(n,xn) at 8 MeV

Neutron emission spectra at 7.94 MeV




Angular distribution at 7.94 MeV

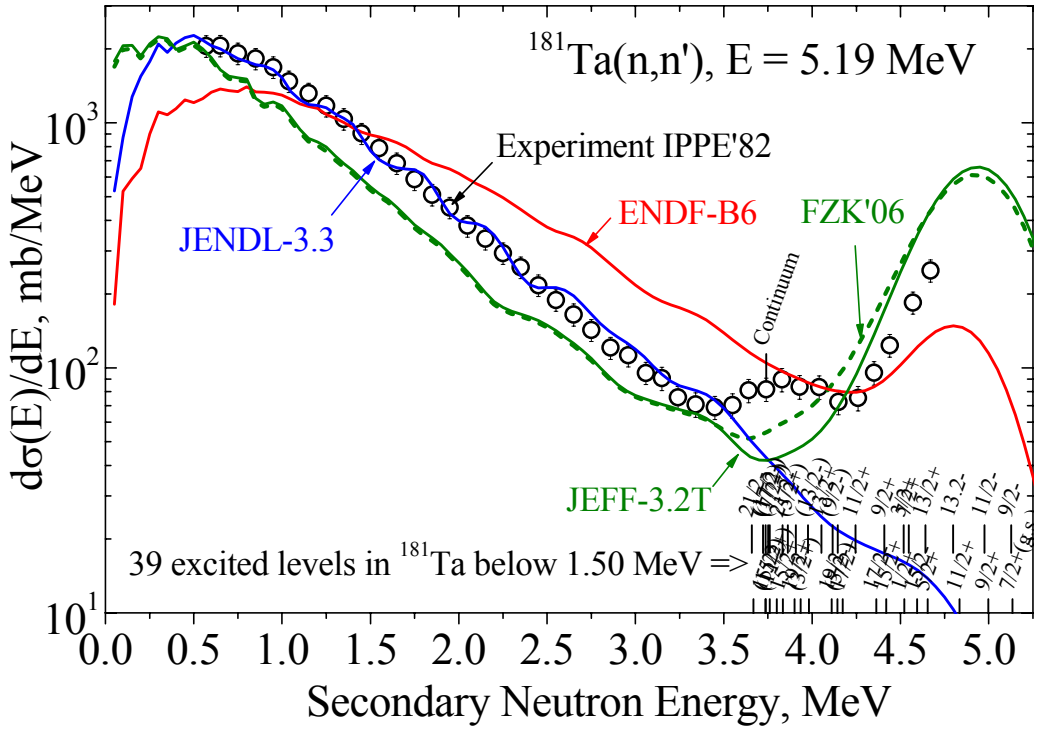



***Findings:***

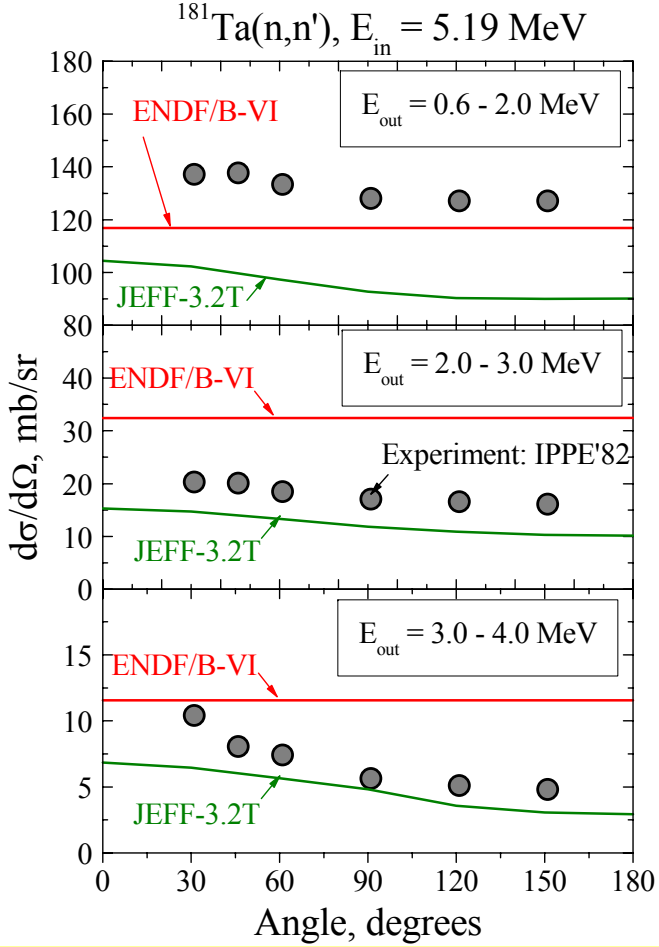
- ***Energy Distribution: JEFF-3.2T (and others) needs updating***
- ***Angular Distribution: JEFF-3.2T looks reasonable, ENDF/B-VI - wrongly isotropic***

# Validation against Double Differential XS for Ta(n,n') at 5.2 MeV

Neutron emission spectra at 5.2 MeV




Angular distribution at 5.2 MeV




***Findings:***

- ***Energy Distribution: JEFF-3.2T (and others) needs updating – will explain unsatisfactory reproduction of spherical benchmark with Am-Be (<E> = 4 MeV )?***
- ***Angular Distribution: JEFF-3.2T looks reasonable, ENDF/B-VI - wrongly isotropic***

# Conclusions

- The new evaluation JEFF-3.2T (FZK/IIK) for Ta-181 reasonably agrees with differential neutron scattering XS at 8 and 14 MeV and predict transport of T-D neutrons through Tantalum up to 3 mfp thickness
- At 5 MeV and probably lower energies the discrepancies have been found both for Ta(n,n') reaction and neutron transport through the sphere driven by Am-Be source