Forschungszentrum Karlsruhe
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Benchmark analyses of Ta evaluated data

S.P. Simakov, U. Fischer, I. Schmuck

Institut für Reaktorsicherheit,
Forschungszentrum Karlsruhe,
76021 Karlsruhe, Germany

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Objective and Content

- Objective:
  - validation of the Ta evaluated data 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
- Progress since previous Meeting (*Nov. 2005, EFF-DOC-952: "First Benchmark analyses of Ta evaluated data for fusion neutron transport calculations"):*
  - more information was obtained about Livermore Pulsed Sphere Experiments
  - another Ta shell experiment (with Am-Be) was found in the literature
  - validation of new evaluation for Ta made in FZK: FZK'06

    (see P. Pereslavtsev et al., EFF-DOC-953, Nov. 2005)

Ta isotopes abundances and evaluated cross sections files

	ENDF/B-VI (1972)	JENDL-3.3 (2002)	JEFF-3.1 (2005)	FENDL-2.1 (2004)	FZK'06 (2006)
	adopted ENDF/B-V	updated JENDL-3.2	adopted JENDL-3.3	adopted JENDL-3.3	new
Ta natural abundancies:	< 20 MeV	< 20 MeV	< 20 MeV	< 20 MeV	< 150 MeV
Ta-180^{m} (10^{15}a) - 0.012%	-	-	-	-	-
Ta-181 (stable)	Ta-181	Ta	Ta-181	Ta-181	Ta-181
T_a-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 (was adopted in FENDL-2.1 and JEFF-3.1) and FZK'06 (new evaluation)

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

New Information vs. EFF-DOC-952

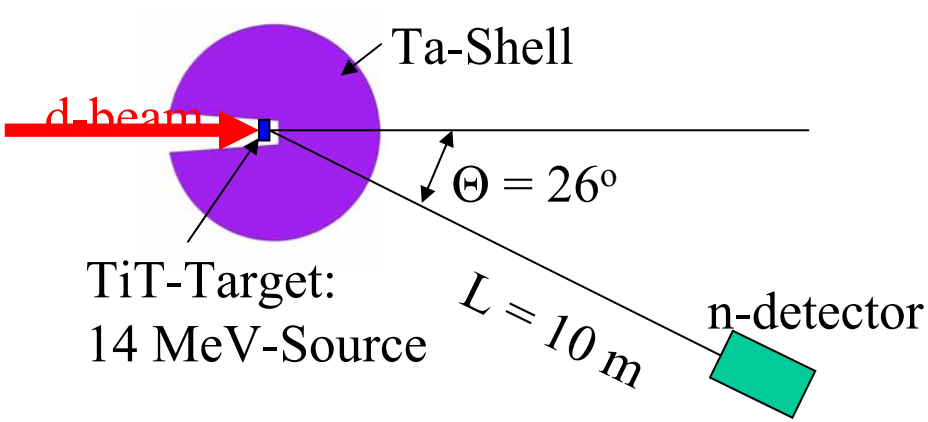
Differential cross sections (n,xn):

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

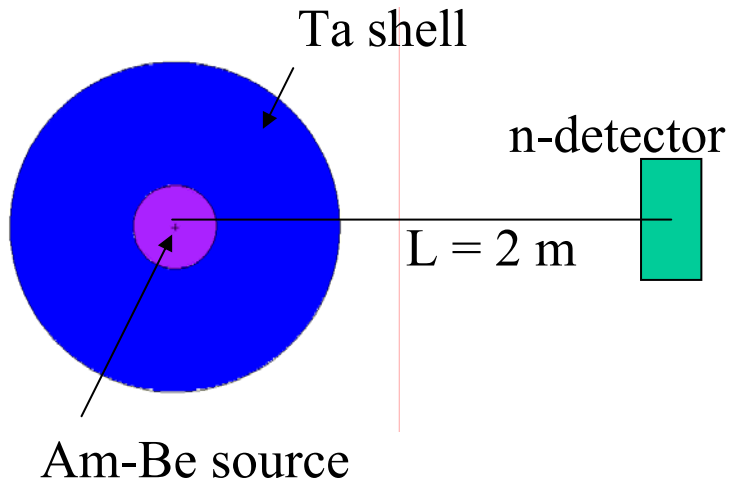
Livermore (1986):

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

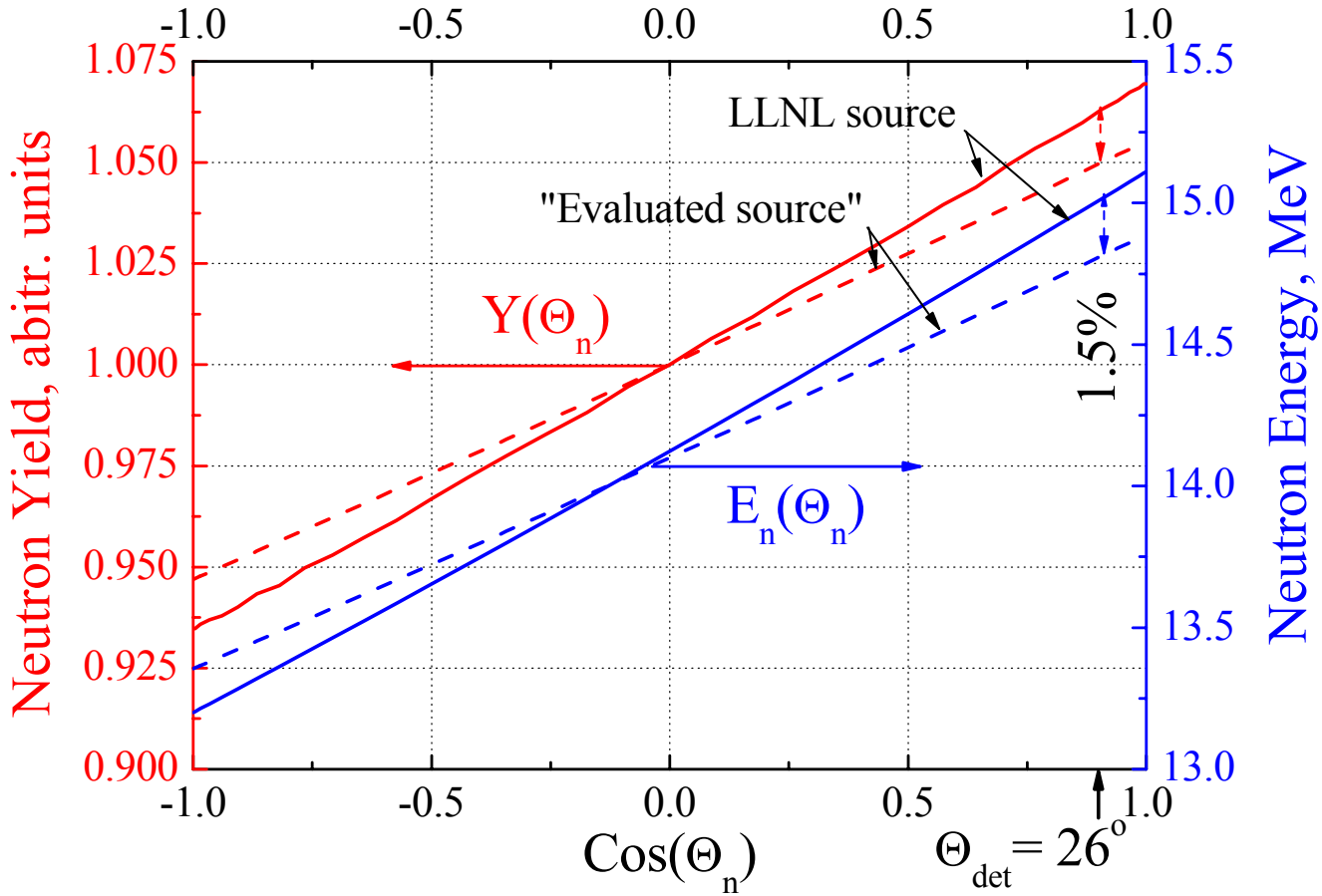


LLNL Ta-Shell Transport Experiment with 14 MeV Neutrons:
T(d,n) Neutron Source Modeling

Thick TiT target
+ d (400 keV):

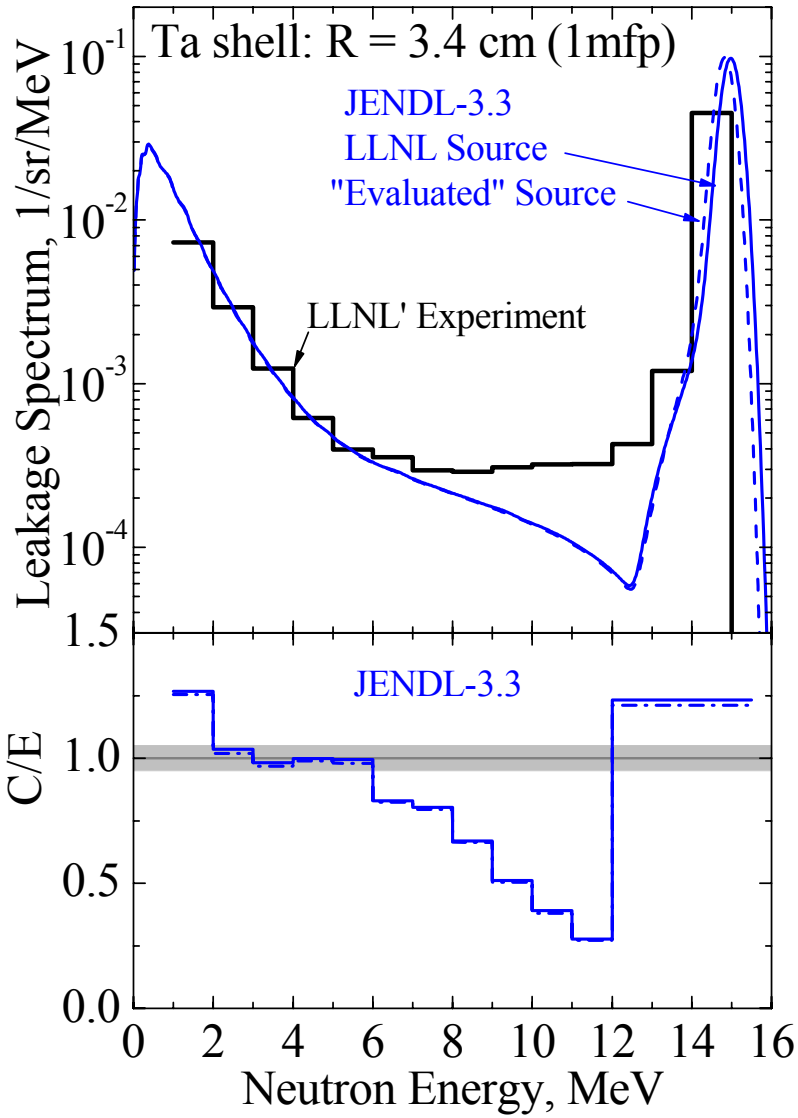
1. LLNL Original Source
   C.Wong et al.
   UCRL-5144

2. Evaluated Source
   J. Chikai et al.
   TECDOC-410



***Findings*: only 1.5% difference between original LLNL and evaluated specifications for T(d,n) neutron yields and energy**

LLNL Ta-Shell Transport Experiment with 14 MeV Neutrons:
Effect of T(d,n) Neutron Source Modeling on neutron leakage spectrum



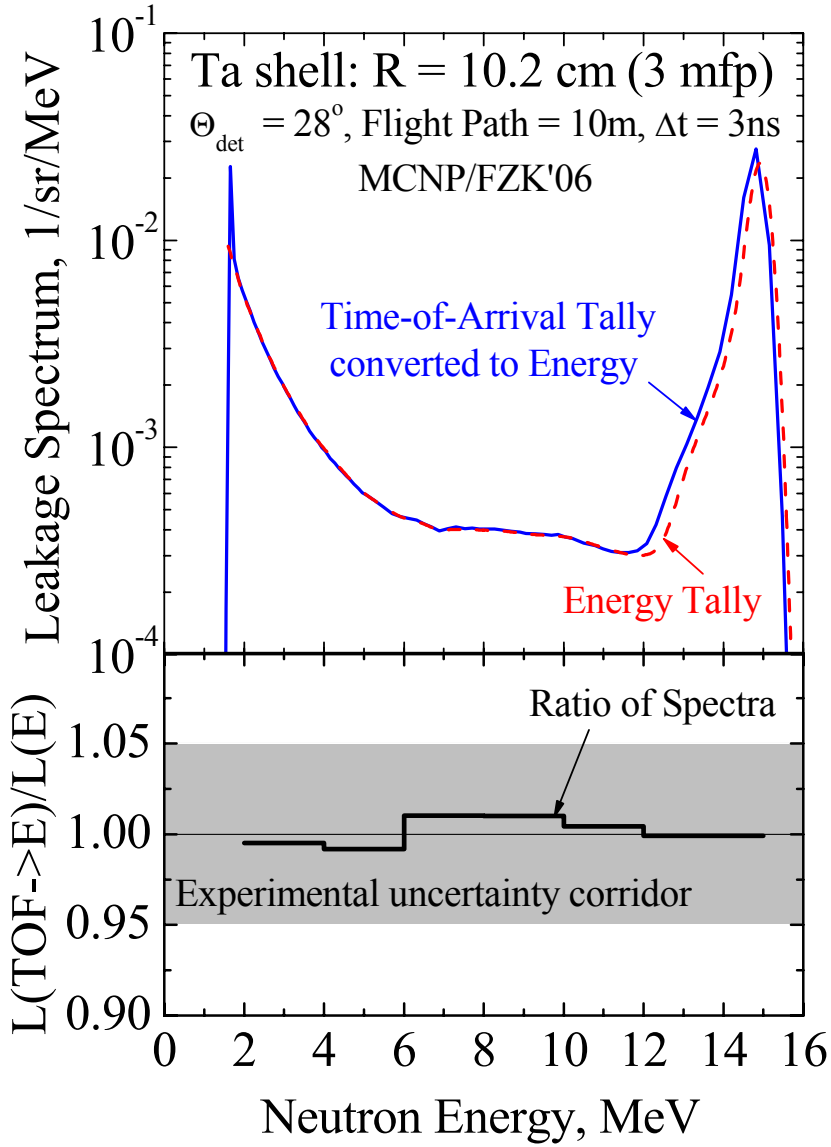
Findings:
around 1.5% difference in 14 MeV group and much less for other energies

LLNL Ta-Shell Transport Experiment with 14 MeV neutrons:
Correction for Time-of-Flight measurement technique

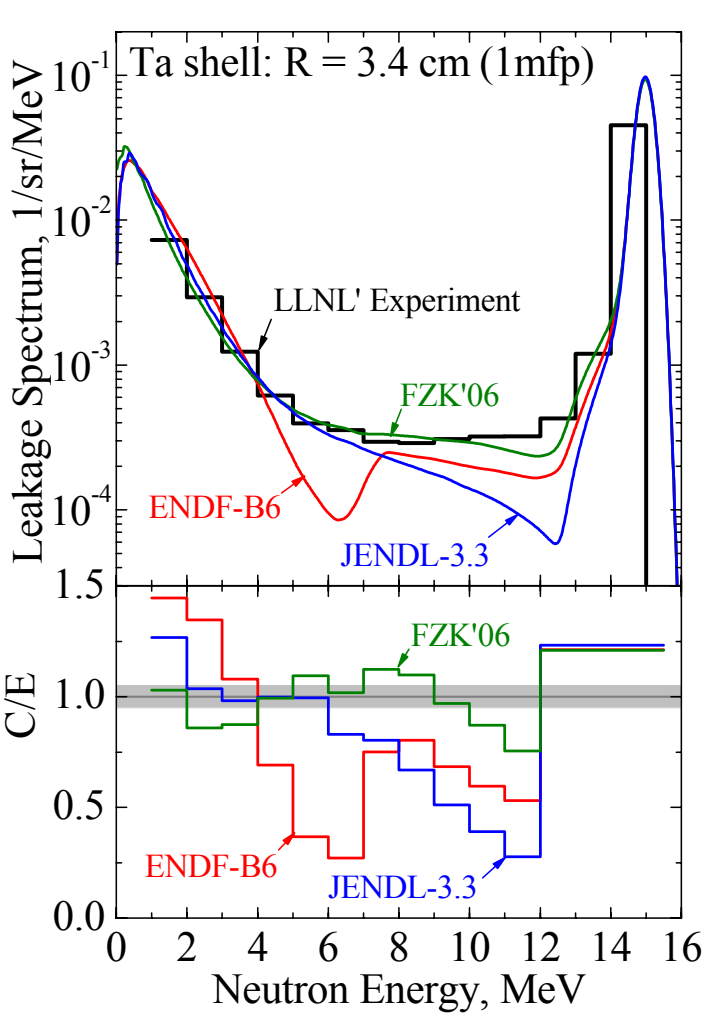
Comparison of two MCNP tallies:

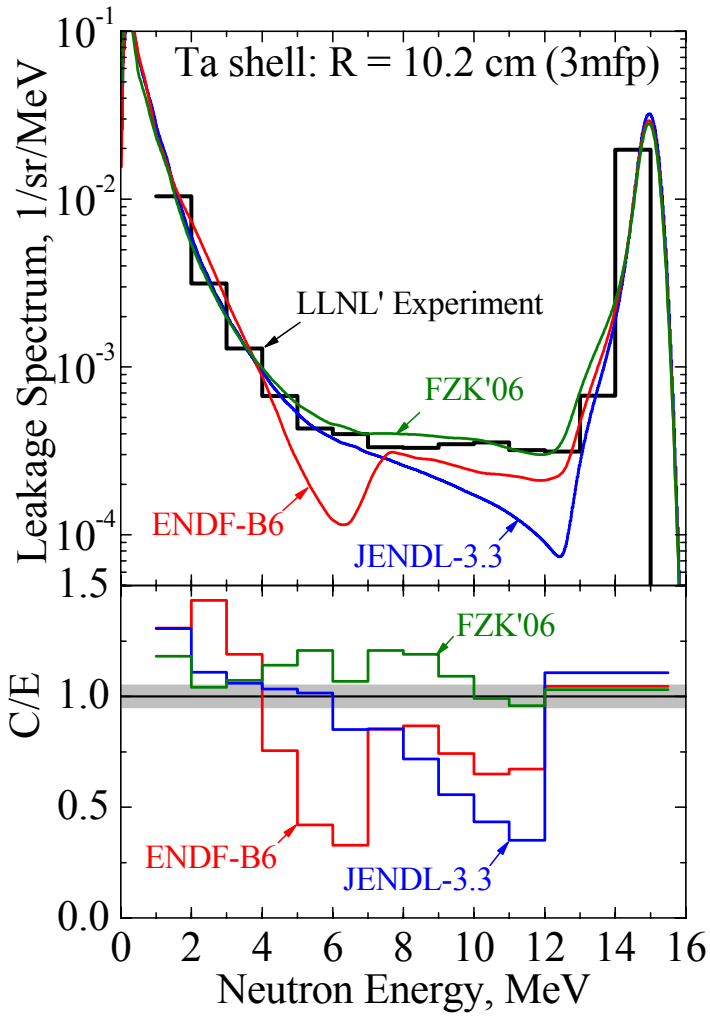
1. Energy tally produces N(E)
2. Time of Arrival tally
   with detector efficiency ε(E)
   produces time spectrum N(t);
   then conversion of N(t) to N(E)
   and division by ε(E)
   gives energy spectrum N(E(t))

Findings: ***correction for TOF technique is negligibly small even for larger Ta shell***



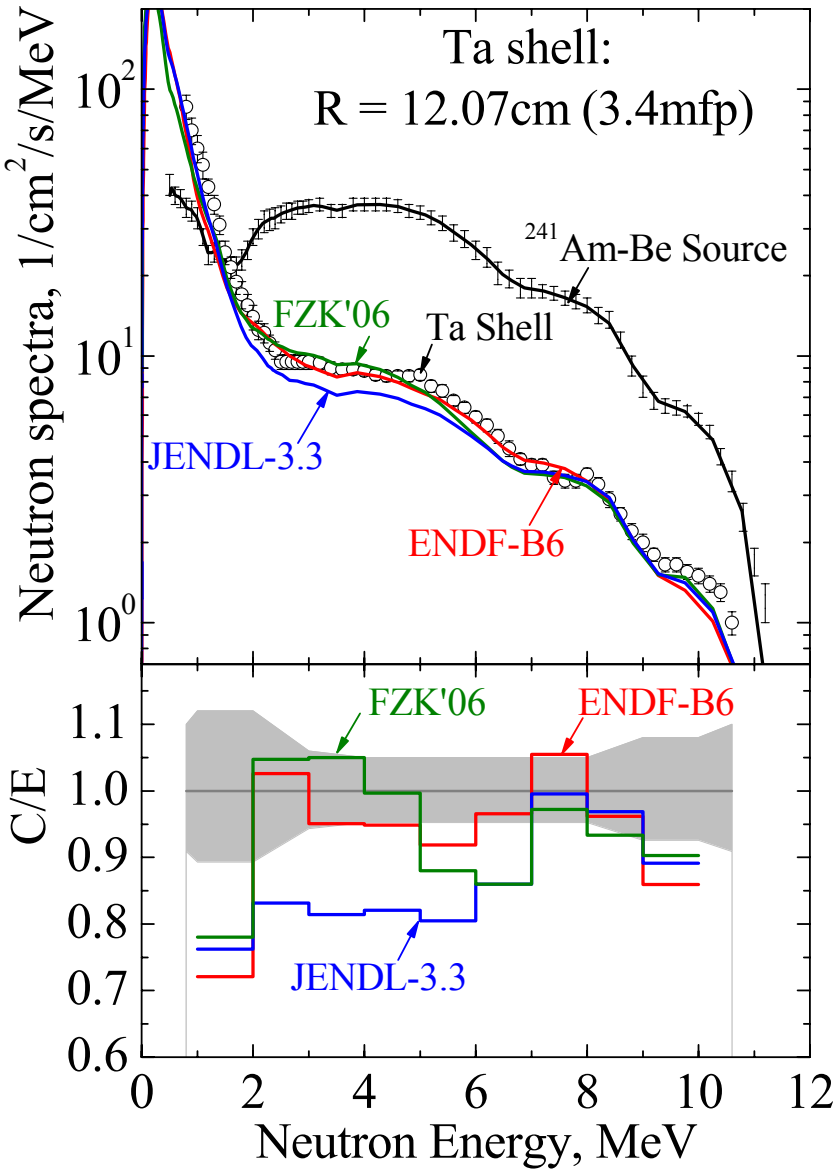
LLNL Ta-Shell Leakage Experiment with 14 MeV Neutrons
evaluated data validation





***Findings*: - ENDF/B-VI & JENDL-3.3: 20 - 70% over- or under-estimation**
- FZK'06: 10 - 20% oscillations around the experimental spectra

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



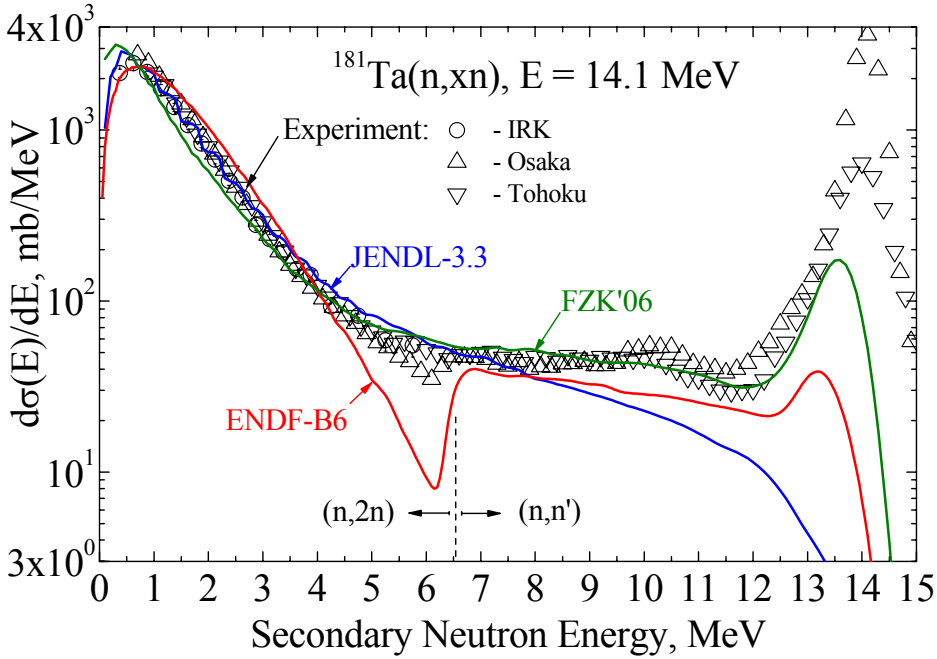
Findings:

- *ENDF/B-VI & FZK'06 predict experiment within 5 – 10 % except energies below 2 MeV (detector threshold effect ?)*

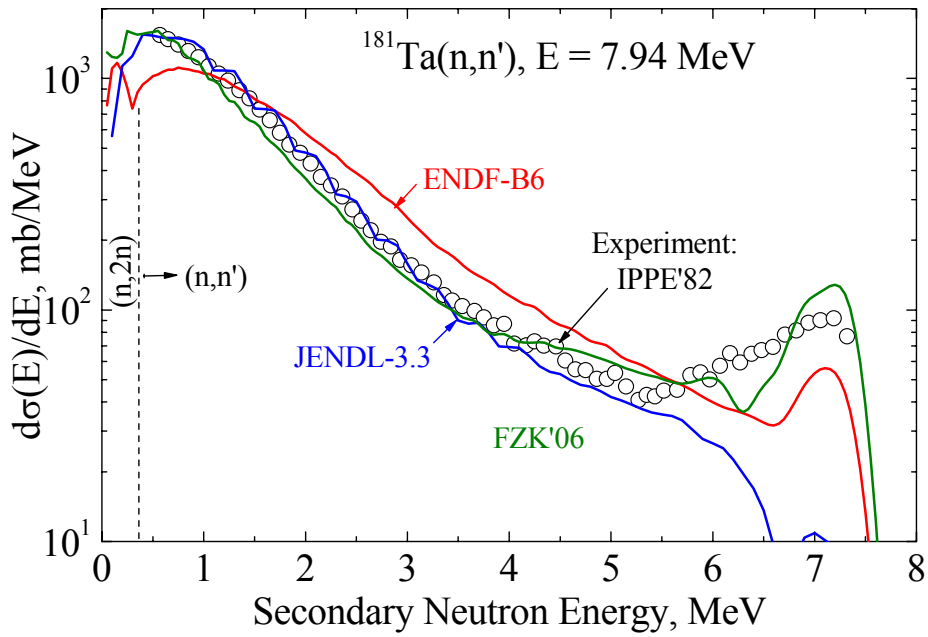
- *JEDL-3.3 underestimates by 20% below 6 MeV*

Validation against Secondary Neutron Energy Spectra from Ta(n,xn) reaction

Neutron emission spectra at 14 MeV



Neutron emission spectra at 8 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 FZK'06***

Conclusions

- Three independent evaluations ENDF/B-VI (rather old 1972), JENDL-3.3 and FZK'06 (new) are presently available for Ta-181, no evaluation does exist for the stable Ta-180m
- Study of LLNL spherical benchmark has indicated:
  - T(d,n) neutron source specification evaluated outside of LLNL is a reasonable approximation
  - TOF spectra transformation to energy one adds no systematic error
- Analyses of the two Ta spherical transport benchmarks (with T(d,n) and Am-Be sources), and series of DDX measurements has indicated satisfactory agreement with FZK'06 evaluation and the need for updating the secondary neutron emission spectra from (n,xn) reactions in ENDF/B-VI and JENDL-3.3 libraries.