Analysis of shielding experiments calculations with using Russian codes and ND libraries

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Introduction

Shielding experiments (SINBAD) have some specialties, impact on calculation results:

- **Geometry data** – dimension and place of plates, source(s) and detector(s);
- **Material data** – contains of impurities and inaccuracy of compositions;
- **Source data** – a power, energy and spatial distribution of particles;
- **Detector data** – energy distribution both of response function and of reaction rates;
- **Normalization** – a coefficient between of experimental and calculation values.

Fixing of these parameters and varying only cross section data libraries is necessary for nuclear data validation.

Russian codes and ND

Codes for neutron-physics calculations:

- ROZ – one-dimensional, analogue ANISN (ONEDANT);
- KASKAD – two-dimensional, analogue DORT (TWODANT);
- KATRIN – three-dimensional, analogue TORT (THREEDANT).

The MCNP code was used with variance reduction techniques in some cases for shielding calculation.

Nuclear data libraries:

ABBN-93 – a group data library used in many organizations;

ABBN-RF – a new group data library based on the ROSFOND2010 library for reactor core and shielding calculations;

ROSFOND2010 – point-wise neutron data library for MCNP calculations.

Shielding experiments

There were analyzed follow experiments with used Russian tools:

ASPIS: Iron 88, Graphite, Nesdip-2, Nesdip-3, Water-steel arrays, Janus 1 and Janus 8

EURACOS: Sodium and Steel

JASPER: 1A, 5A, 5C and 7B.

OKTAVIAN: Nb and Si

Several of them experiments will discuss below in more details.

An analysis based on general specialties of these experiments will show in presentation on next slides.

Geometry and Material data

1) **Geometrical** dimensions are impact on capability transmission particles through shielding plates. Thus detailed geometry description of benchmark model is important

Benchmarks both of two-dimensional (example, R-Z) and of three-dimensional (example, X-Y-Z, R-θ-Z) geometries are needed.

Detector geometry (size and position) is also important.

2) Detailed **material data** (in concentrations) are allow more precisely of a describe interaction in shielding layers.

Effect of unaccounted nuclide could lead to incorrect nuclear data validation results.

Database of shielding benchmark models for nuclear data validation is needed.

Source and normalization

These are global parameters impact on all calculation results in varies detector positions.

These parameters are connected. Calculation results are normalized on experimental source power.

1) **Source** inputs are entered before start of calculation. If you need clarification of source information you must restart task.

Source power and neutron spectrum have an energy and spatial distribution.

2) **Normalization** coefficient is value for adducting of calculation results to experimental data.

For the nuclear data validation purpose could be normalize on the first detecting point.

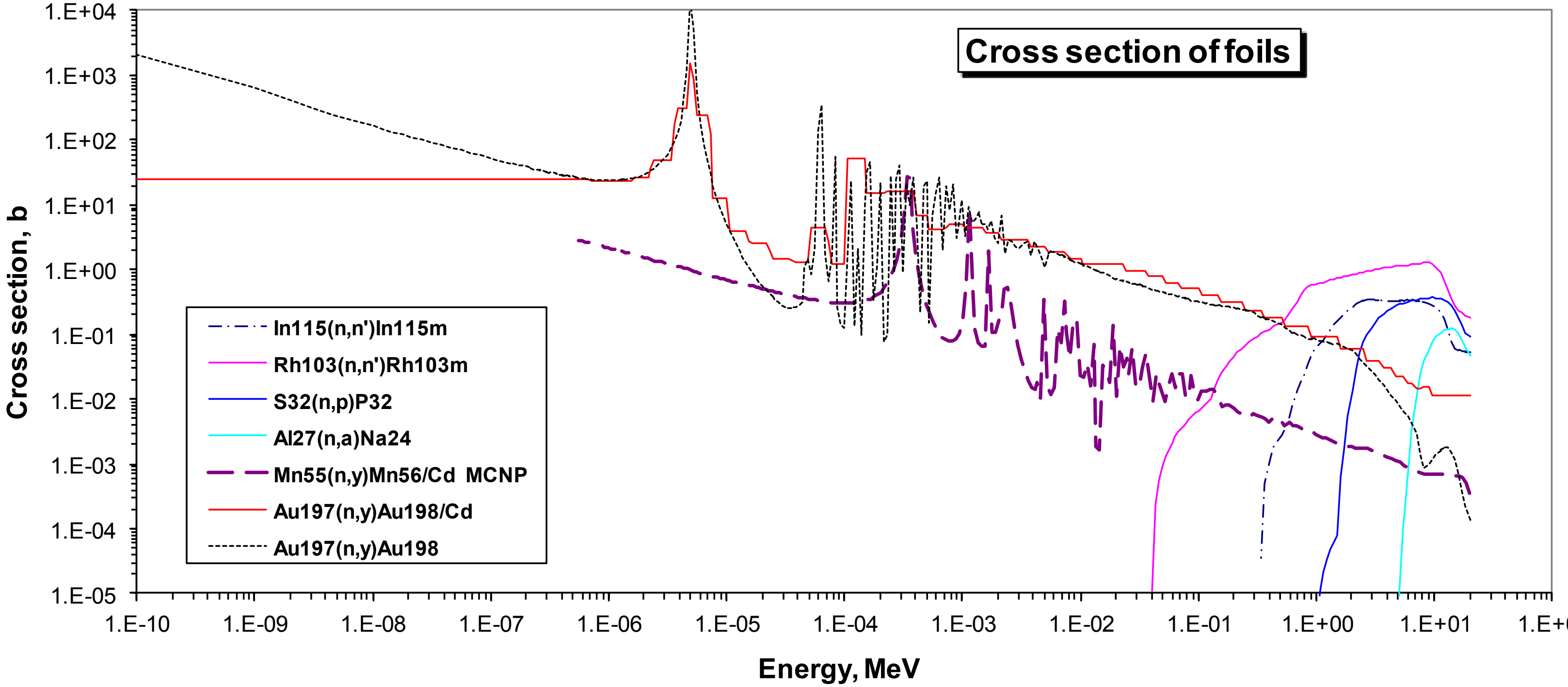
We need to compare of calculation-to-experiment discrepancies shape of graph.

Detector

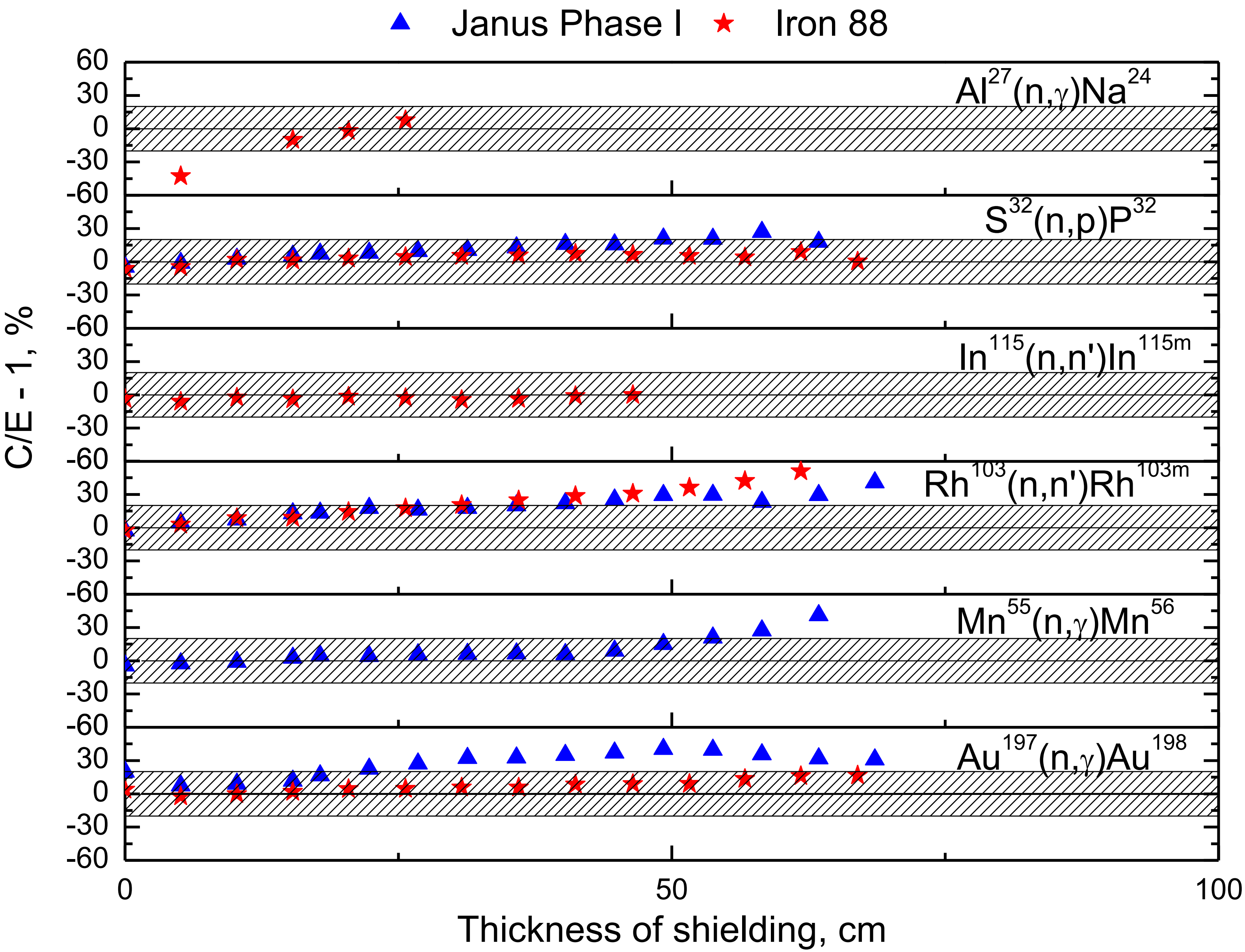
Energy distribution of response functions, Bonner Balls, reaction rates (foils) etc. How to translate these values from experiment to calculation (special for a group calculation)? Need detailed description.

We need use the values for a group calculation from a point-wise calculation.

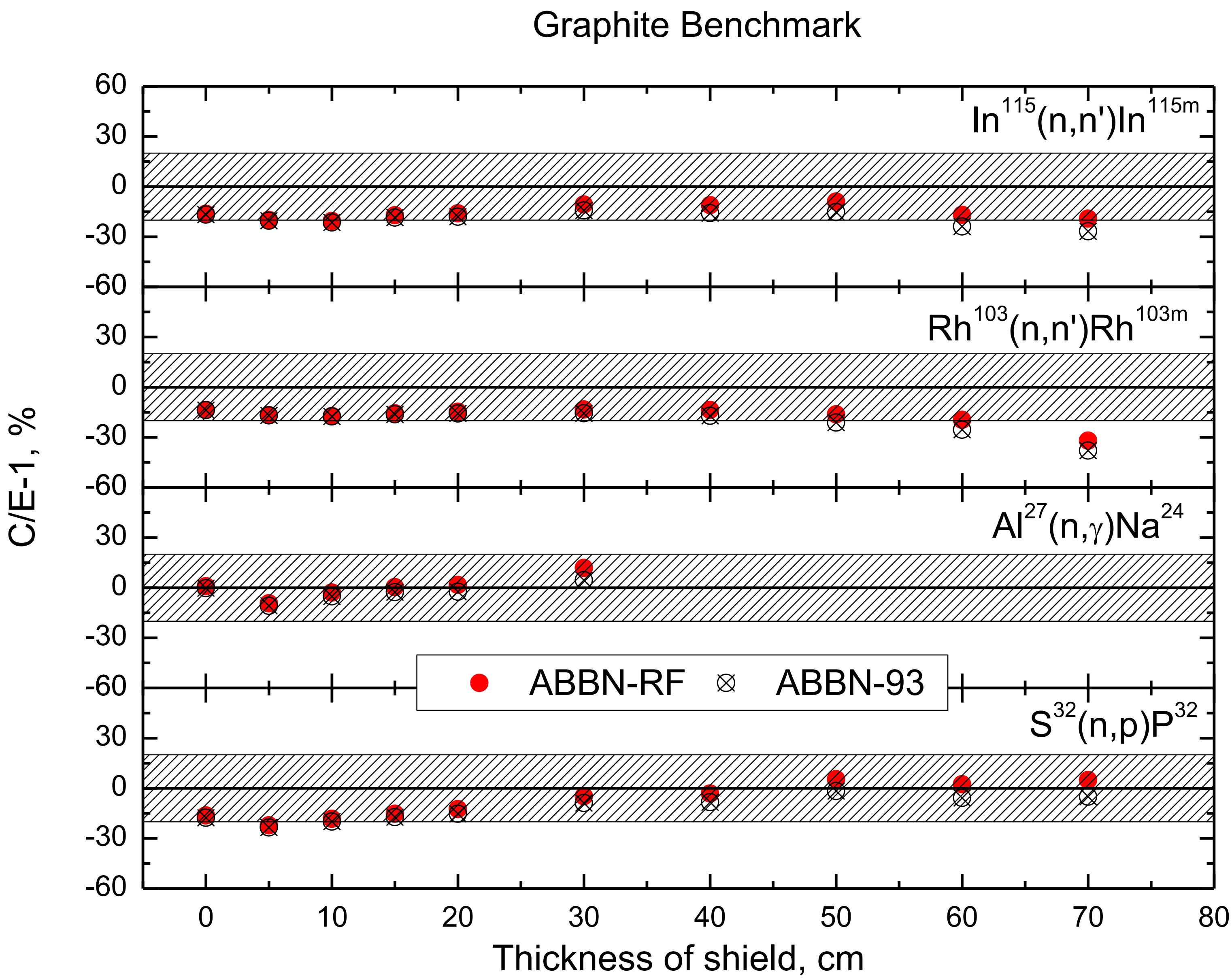
We must explain how a cadmium cover impact on a cross-section of a foil.



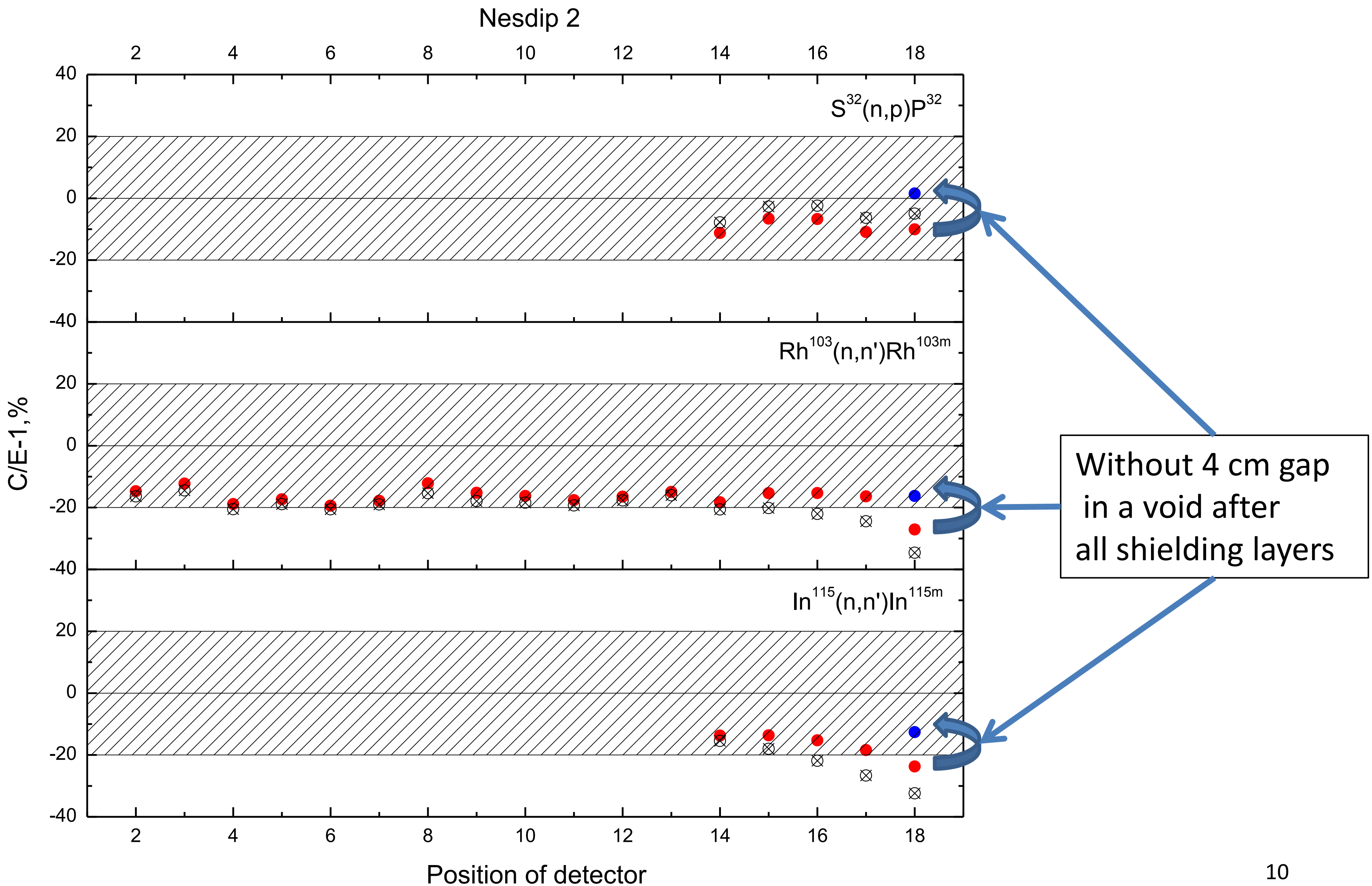
Testing of iron data



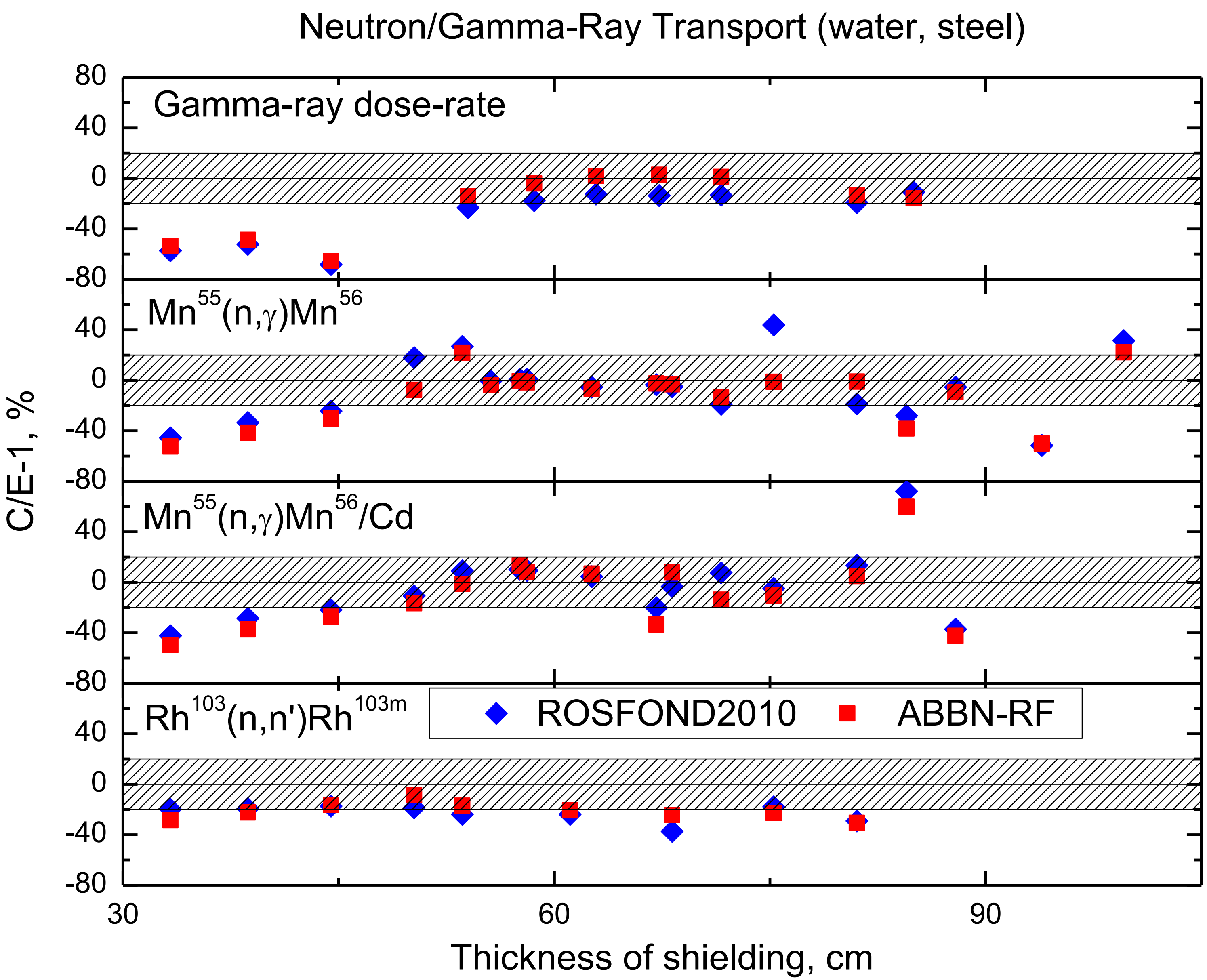
Testing of carbon data



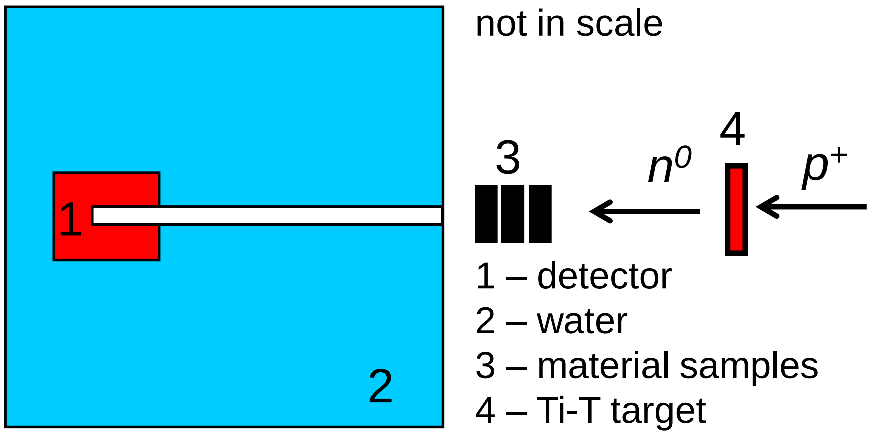
Nesdip 2 benchmark results



Water-steel benchmark



Neutron transmission experiments (1960th)



$$T_t(h) = \int_{E_0-\Delta E/2}^{E_0+\Delta E/2} R(E)\cdot \exp[-\sigma_t(E)\cdot h]\, dE$$

$$\sigma_t(h) = \frac{-\ln(T_t)}{h}$$

Neutron energy was obtained used with kinematic tables from proton energy.

Energy width of neutron transmission depends on a thickness of a titan-tritium target.

Samples of study material were placed between a target and a detector on neutron beam.

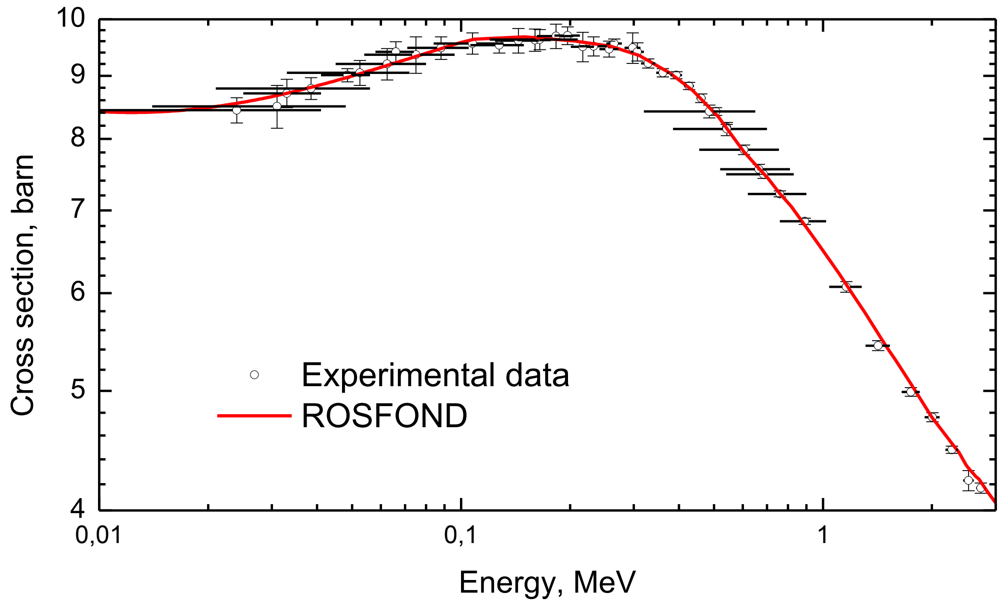
Samples thickness accrues from 0.5 to 50 cm.

Set of neutron transmission experiments for energy region from 1 keV to 3 MeV was conducted by V. Fillipov in 1960th for follows elements:

Fe, Ni, Cr (ICSBEP Handbook), Si, Nb (this work), Be, Cu, Zr, Mo, W, Pb, Bi, Al, Zn, V, Ti, C, Mg, P, S, Ga, Sb, Ba, Ta.

Neutron transmission for Nb 1/2

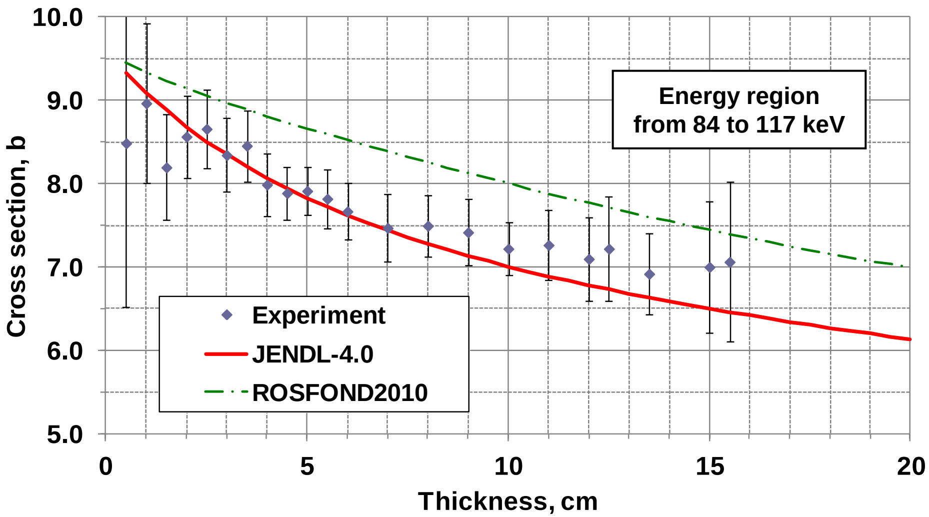
- ✓ Energy region 0.01 – 3.0 MeV.
- ✓ TI-T target thickness from 0.32 to 3.75 mg/cm^2.
- ✓ 44 energy intervals.
- ✓ Max samples thickness – 50,5 cm.

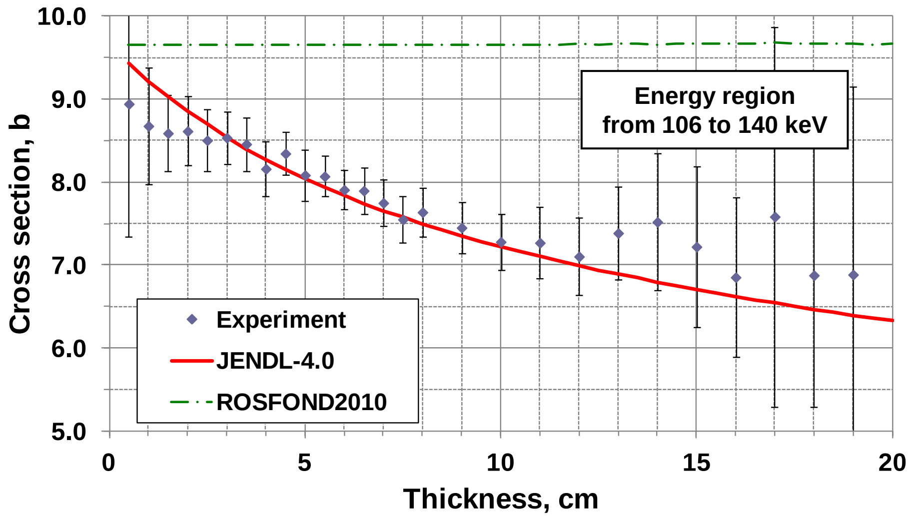


Library	RRR			URR		
	Upper limit, keV	Num. of *l*-values	Num. of resonances	Upper limit, keV	Num. of *l*-values	INT
ENDF/B-VIII	7,0	2	201	600,0	3	5
ENDF/B-VII.7	7,35	2	194	-	-	-
JEFF-3.3	10,08758	2	275	30,4623	2	2
JENDL-4.0	7,0	2	201	600,0	3	5
JENDL-3.3	7,0	2	201	100,0	3	2
РОСФОНД2010	7,0	2	199	100,0	2	2
TENDL-2017	9,476746	3	346	30,4623	3	2

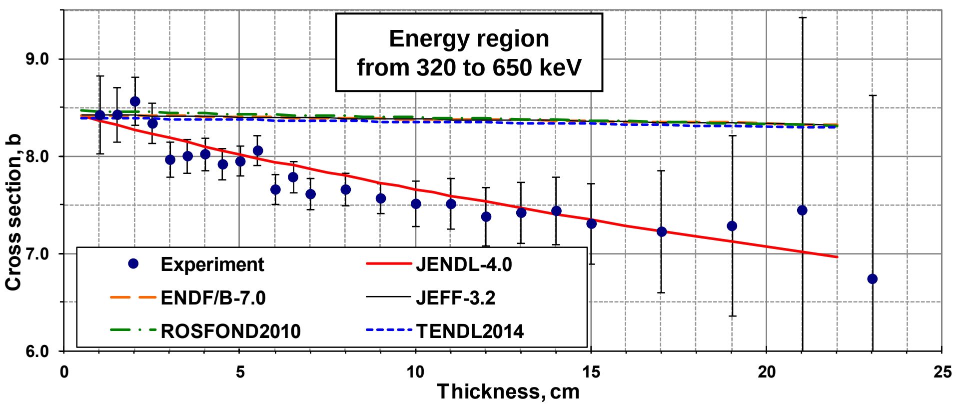
Neutron transmission for Nb 2/2

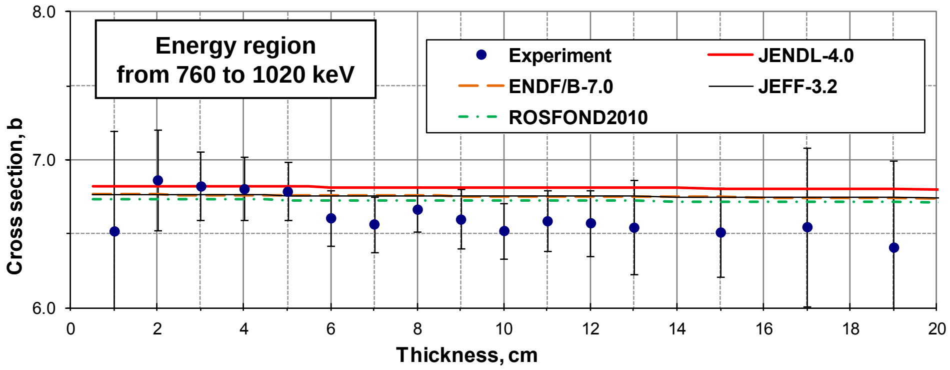
ROSFOND2010 has URR up to 100 keV.





Only JENDL-4.0 ND library well describes neutron transmission experiments (1960th).



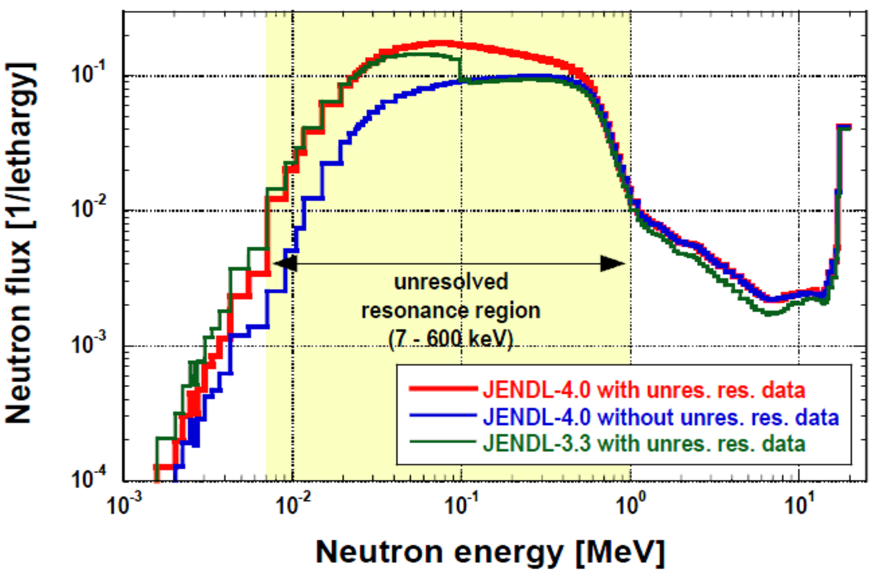


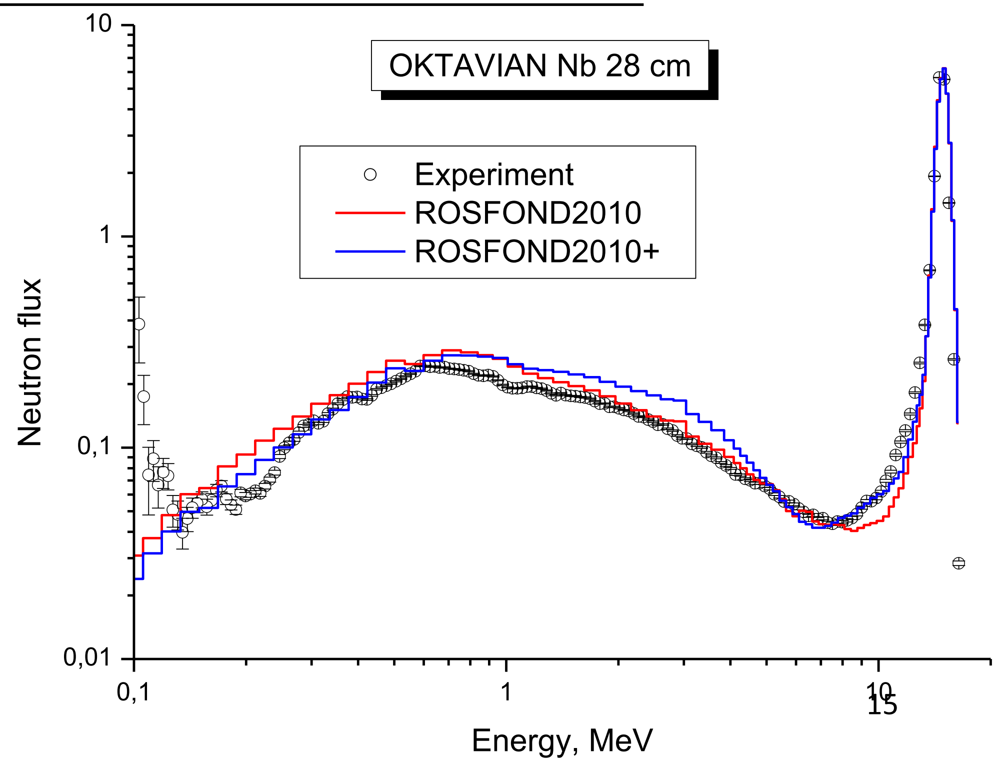
Testing of Nb data

Testing results of a new Nb data based on HEU-MET-FAST-047, OKTAVIAN Nb and a theory model*.

Table– K_{eff} HMF047

Benchmark	ROSFOND	ROSFOND+Nb
1.0007 ± 0.0037	1.00497 ± 0.00025	1.00198 ± 0.00026

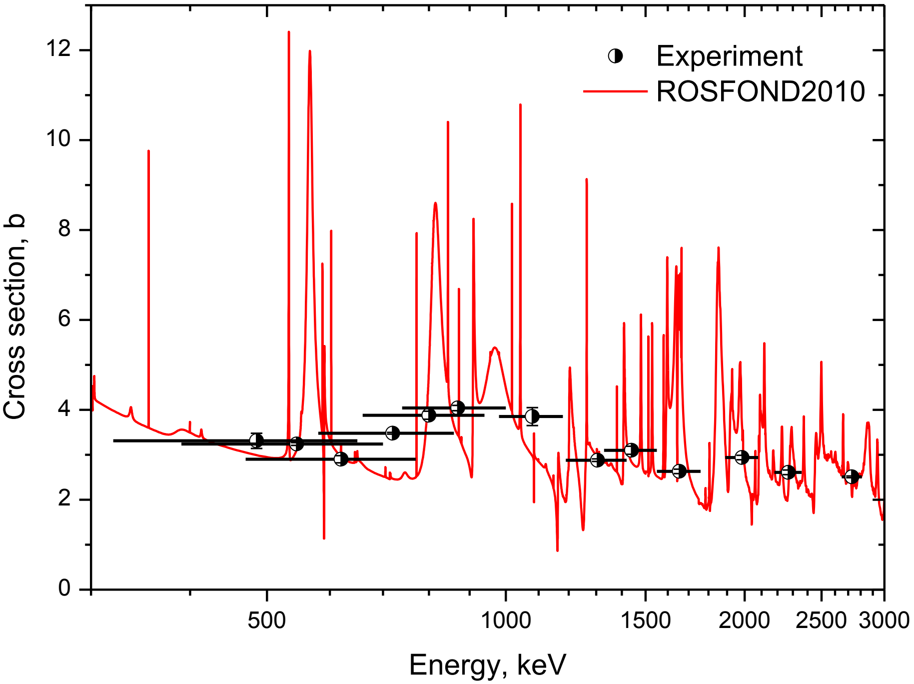




*Ch. Konno, et al. Self-shielding effect of unresolved resonance data in JENDL-4.0 Progress in Nuclear Science and Technology Volume 4 (2014) pp. 606-609.

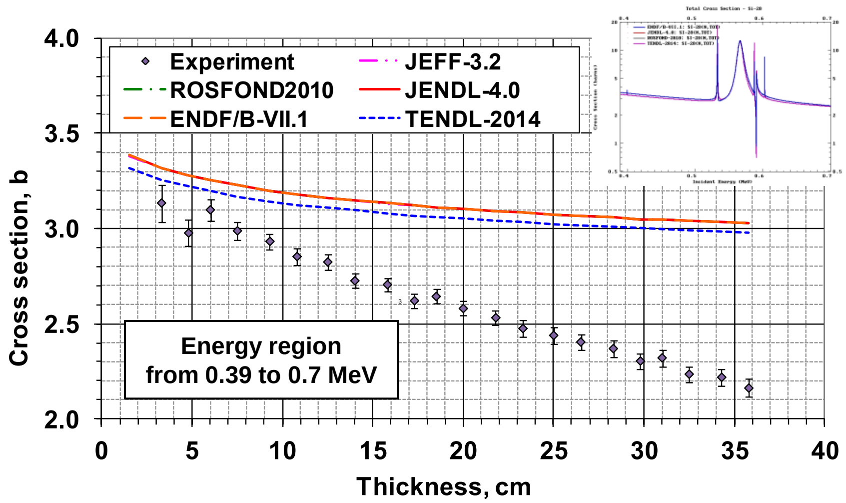
Neutron transmission for Si 1/2

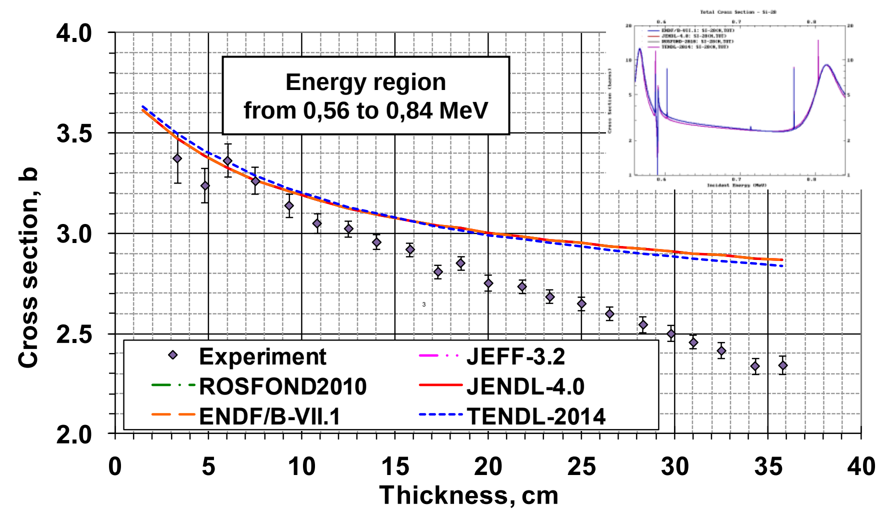
- ✓ Energy region 0.3 – 3.0 MeV.
- ✓ TI-T target thickness 2,6 mg/cm^2.
- ✓ Max samples thickness – 35,8 cm.
- ✓ 14 energy intervals.

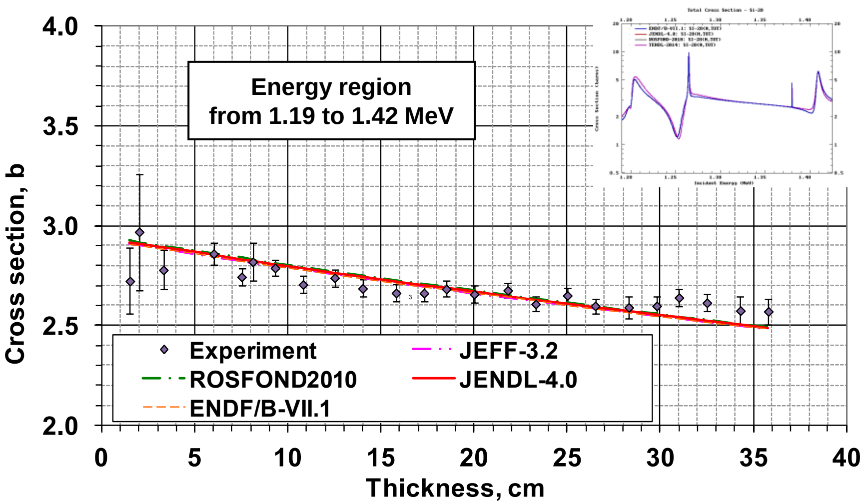


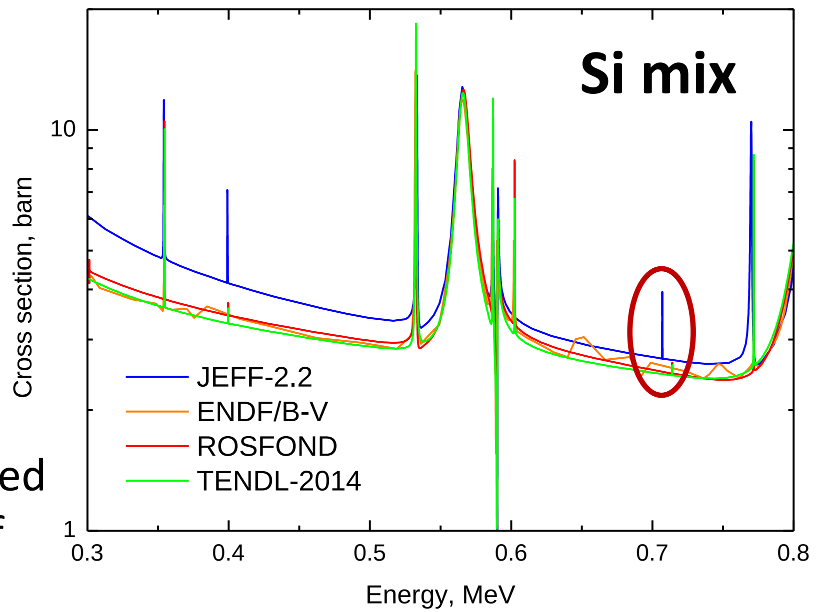
Library	RRR	
	Upper limit, MeV	Num. of *l*-values
ENDF/B-VII.I (VIII)	1.75	RM-3
JEFF-3.2 (3.3)	1.75	RM-3
JENDL-4.0	1.75	RM-3
ROSFOND 2010	1.75	RM-3
TENDL-2017	0.5	MLBW-4
TENDL-2014	1.75	MLBW-4

Neutron transmission for Si 2/2









Resonance parameter selection of ^{28}Si was performed via stochastic optimization technique for describe of neutron transmission.

Resonance at 700 keV is needed for that.

Testing of Si data

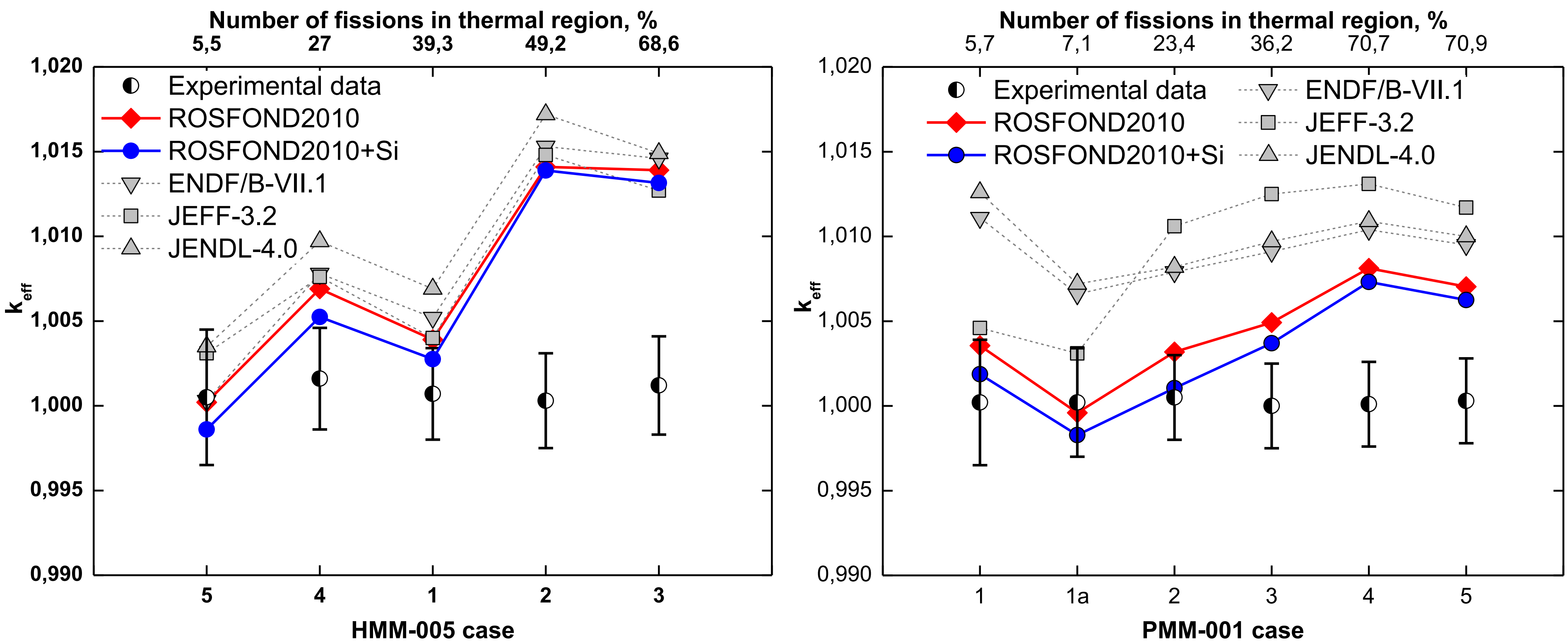


Table – spectral indices of HMM-005-6

Index	Exp.	ND	C/E-1, %
$\sigma_f(^{238}U)/\sigma_f(^{235}U)$	0.015±0.005	RF2010	6.7 ± 3.8
		RF2010+Si	5.3 ± 3.8
$\sigma_c(^{197}Au)/\sigma_f(^{235}U)$	1.15±0.05	RF2010	-21.7 ± 4.9
		RF2010+Si	-2.6 ± 4.7

Adding of missed resonances improves of spectral and of criticality calculation results:

- F238/F235 – on ~1.5%;
- C197/F235 – on ~20%.

Conclusion

1. Analysis of reactor shielding experiments show that Russian tools could be used for nuclear data validation.
2. For nuclear data validation needs benchmark inputs database with precise information about geometry, material, source, detector and normalization data.
3. Normalization by the first experimental point is a possible if we need analyze of a calculation-to-experiment discrepancies shape.
4. Neutron transmission experiments for Nb and Si are propose to include in SINBAD database.
5. An unresolved resonance region for Nb-93 necessary enlarge up to 600 keV.
6. Correctness of adding resonance at 700 keV is need test on more benchmarks.

Thank you for your attention!