Evaluation of nuclear yields for tungsten at energies of nucleons up to 3 GeV

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Objective

to get the set of data files suitable for activation, gas production and radiation damage rate calculations reflecting the state of knowledge of reaction cross-sections for tungsten

Sources of the information about reaction cross-sections

Calculations using nuclear models

Various models and systematics of model parameters present in a sense independent information

- CEM03
- INCL4
- CASCADE (HF)

Incorrect: comparison with experiments and simple use of the “best model”, e.g. CEM

Difference in predictions of various models

Correct setting of uncertainties of calculations

Experimental data

Combination of experimental data (σ_{exp} +/- $d\sigma_{exp}$) and results of model calculations (σ_{calc} +/- $d\sigma_{calc}$) taking into account covariance information

- generalized least-squares method
- unified Monte Carlo approach (UMC) (D.Smith)

BEKED code package (KIT)

Evaluated data

the state of our knowledge about considered reactions

Measured yields for p+W reactions

EXFOR: about 1400 (Z_R,A_R,E_0) points

independent (,IND,SIG)

cumulative (,CUM,SIG)

undefined by EXFOR compilers or by authors

Kelley, 2005 (74-W-0(P,X) ELEM/MASS,,SIG). C1225006

Statistical error only

O0768189, (74-W-0(P,X)73-TA-172,IND,SIG)

Disagreement between some measurements E.Porras (2000) and R.Michel (2002) (74-W-0(P,X)73-TA-182,CUM,SIG)

Duplications

R.Michel (2002) O1099053 and M.Miah (2002) O1100011

Incorrect compilation

Bonardi (2011) O1884 „W-0“ is shown instead of W-186

Preliminary calculations

CASCADE (KIT): INC+EQ

Evaluation of uncertainties: MC method of D.Smith

Parameters: *a*, δ, a_0, E_d, σ for *n-n* , *n-*π

$p_0=\{p_{01},\ldots.p_{0M}\}$, $\Delta p_0=\{\Delta p_{01},\ldots\ldots,\Delta\, p_{0M}\}$

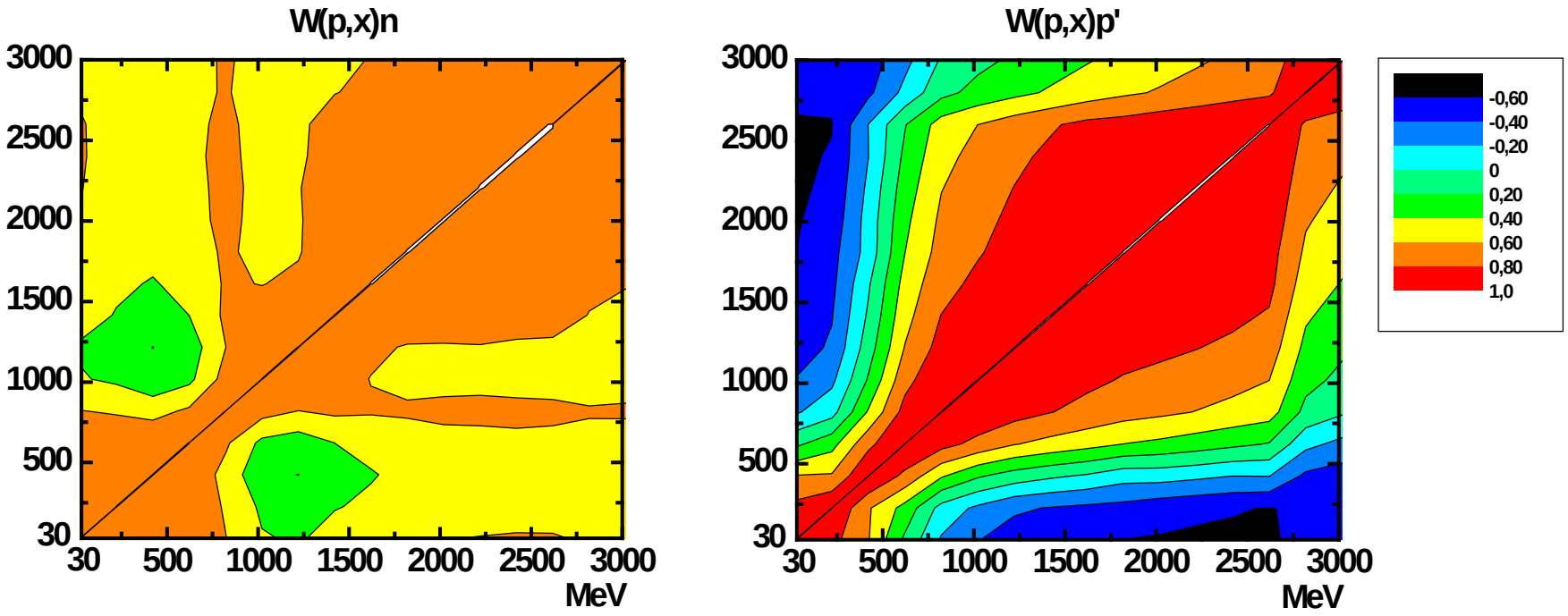
Covariance matrix after K histories

$$V_{i,j} = (1/K)\sum_{k=1,K}^{K}(\sigma_{ki}-\sigma_{0i})(\sigma_{kj}-\sigma_{0j}) \qquad \text{for i,j=1,N (energy)}$$

The time of computation K x N_{MC}

K : 10,000 – 100,000

Correlation matrices for W(p,x)n and W(p,x)p cross-section



High priority evaluations

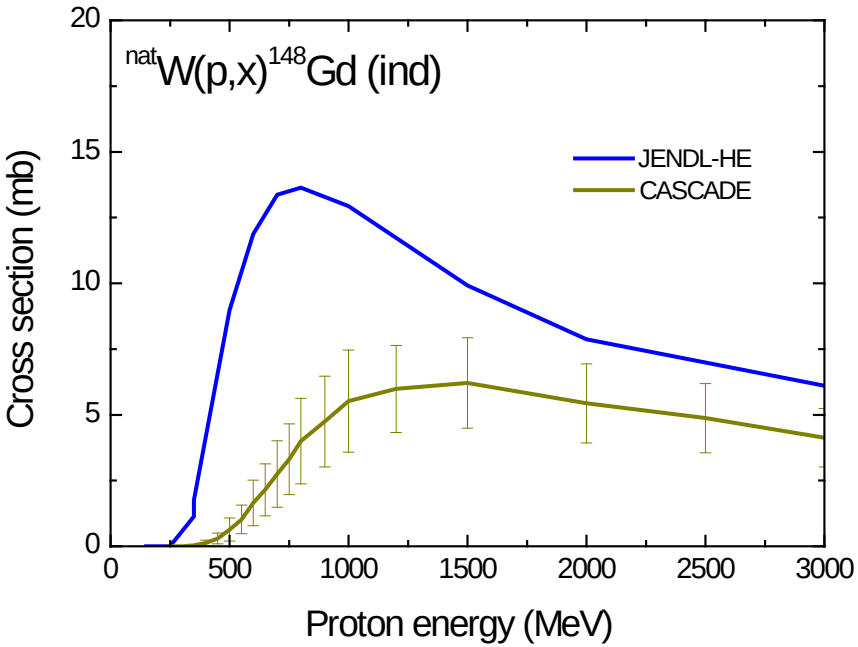
The main contributors to the hazard (D.Ene)

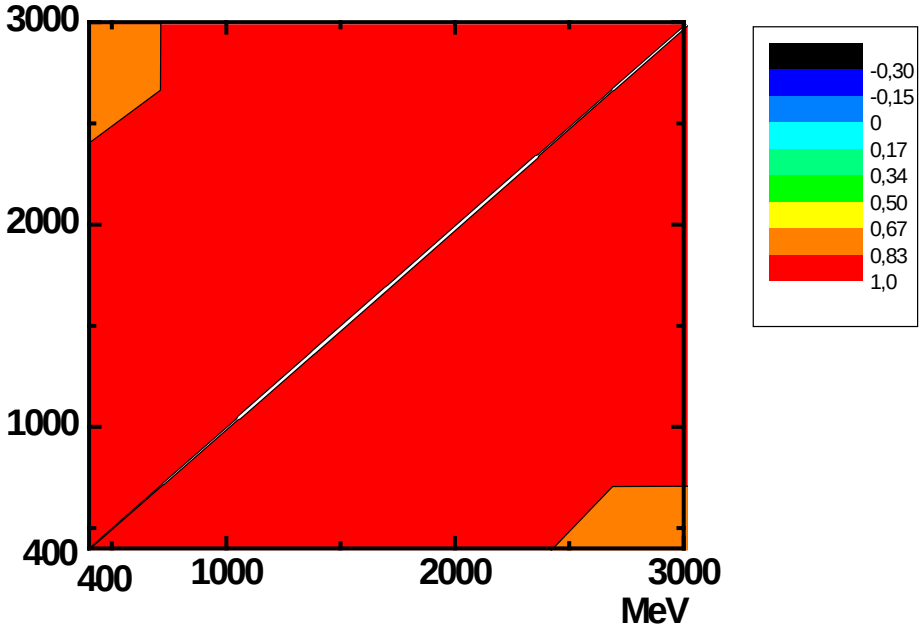
No	nuclide	$T_{1/2}$(s)	H1(%)
1	W187	8.539E+04	17.63
2	Gd148	2.354E+09	14.14
3	Re186g	3.263E+05	12.04
4	Ta182g	9.887E+06	7.85
5	Hf172	5.900E+07	7.79
6	W-185g	6.489E+06	5.97
7	Re188	6.121E+04	5.16
8	Hf178m1	4.000E+00	4.68
9	Hf179m1*	1.867E+01	2.66

W(p,x)^{148}Gd (cumulative)

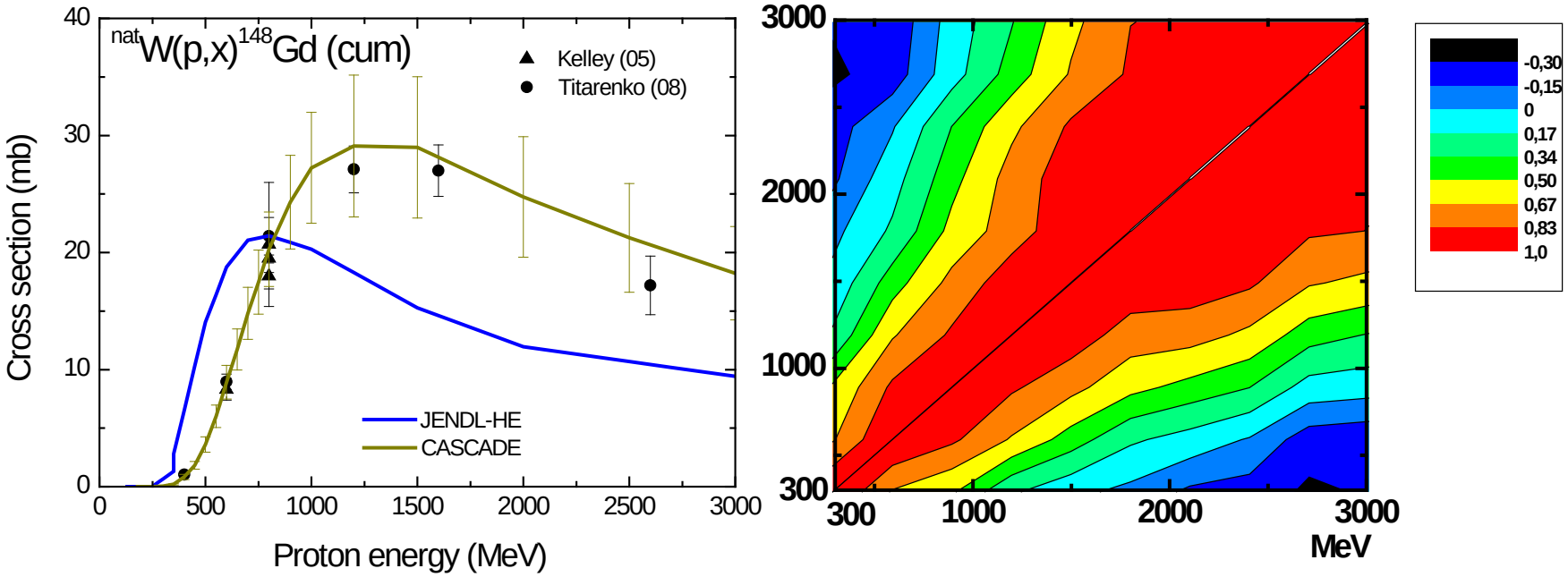
Nuclide	Average contribution to cumulative yield
Gd148	21. %
Tb148	14. %
Tb148m	14. %
Dy148	26. %
Ho148	0.52 %
Ho148m	0.52 %
Ho148m2	0.52 %
Ho152	2.3 %
Ho152m	2.01 %
Er152	16. %
Yb156	1.9 %
Lu160	2.0 %

W(p,x)^{148}Gd


nat W(p,x)148Gd (ind)
JENDL-HE
CASCADE
Cross section (mb)
Proton energy (MeV)
0
5
10
15
20
0
500
1000
1500
2000
2500
3000

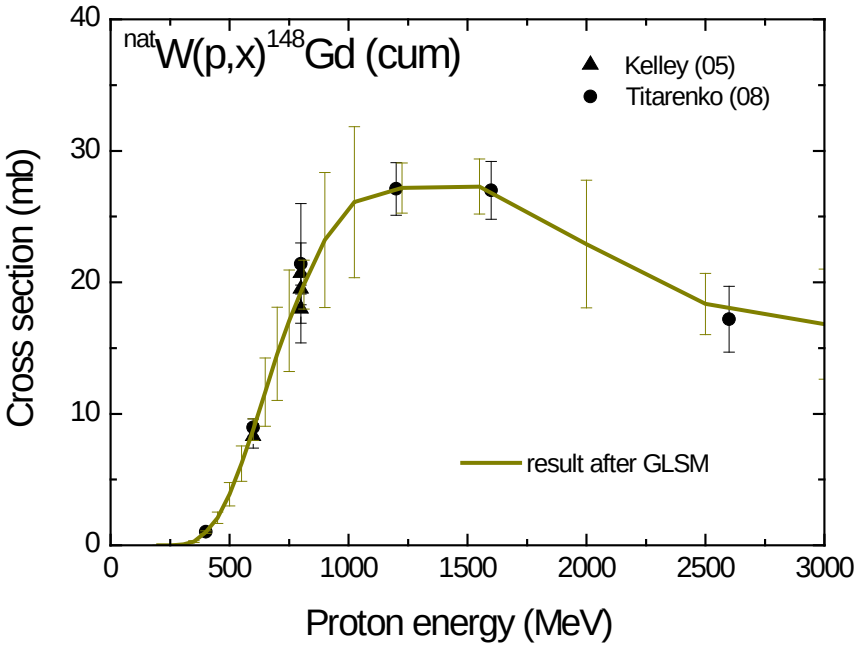

3000
2000
1000
400
400
1000
2000
3000
MeV
-0,30
-0,15
0
0,17
0,34
0,50
0,67
0,83
1,0

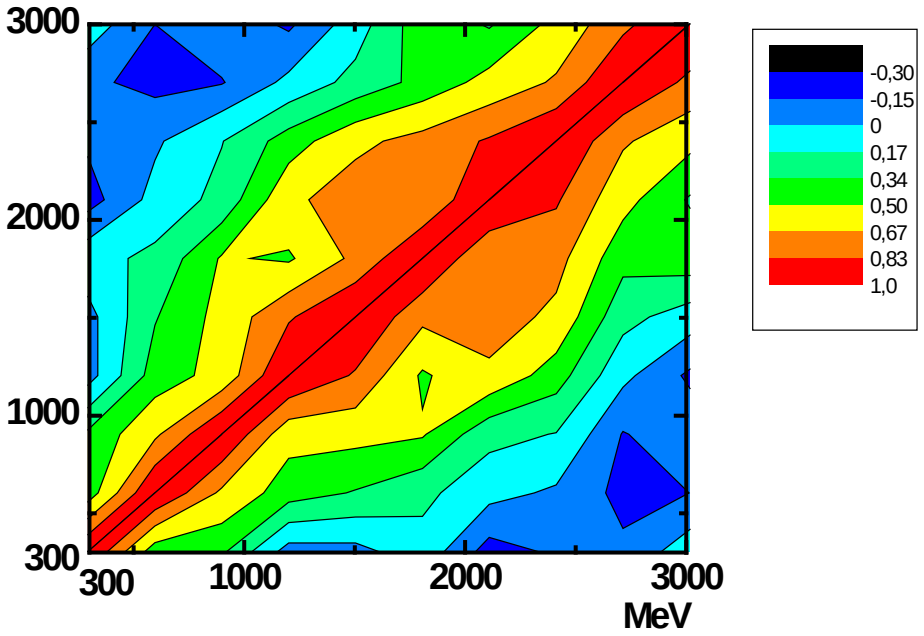
W(p,x)^{148}Gd (cumulative)

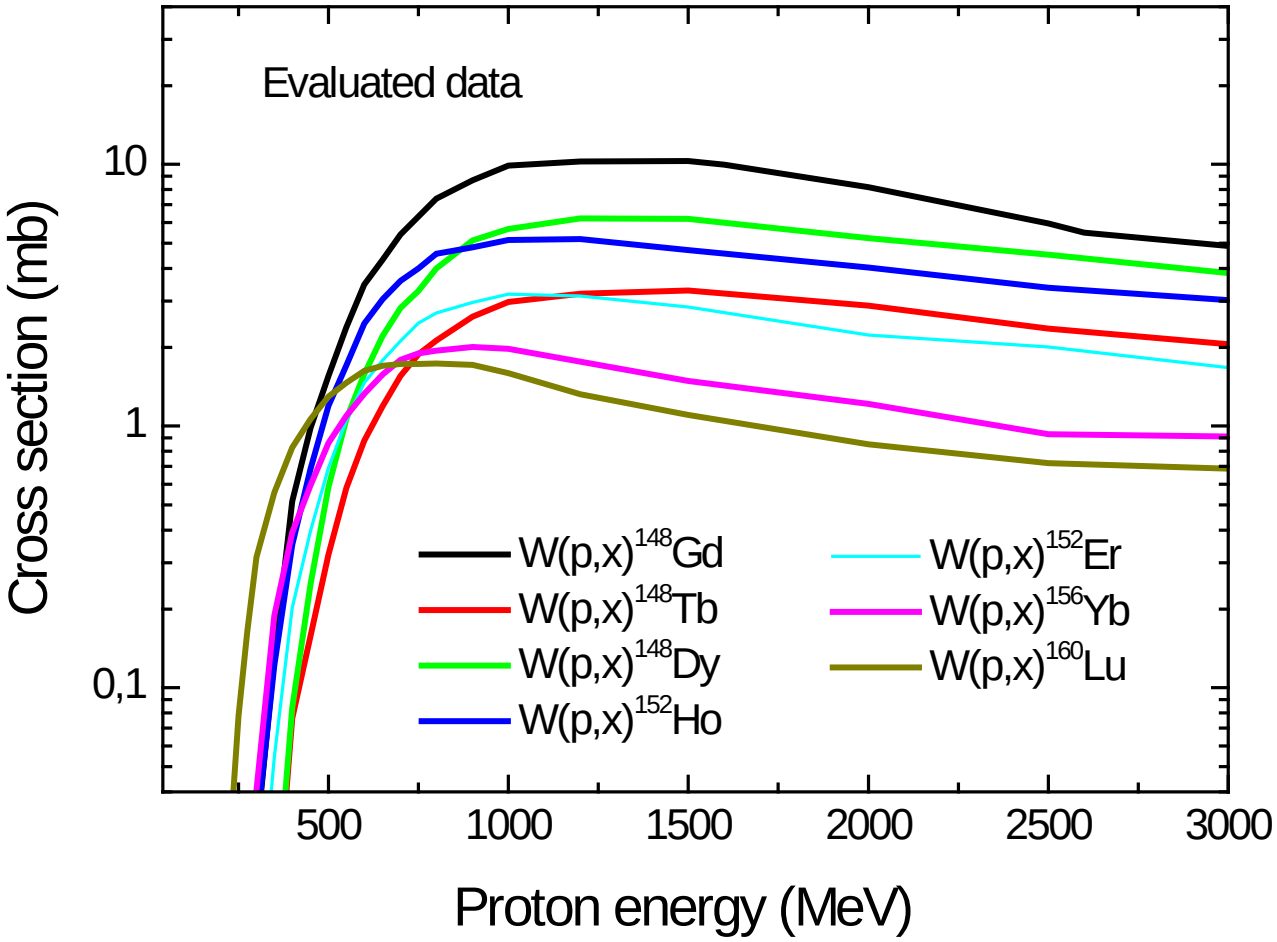


JENDL-HE: Yield of Gd148 is twice underestimated

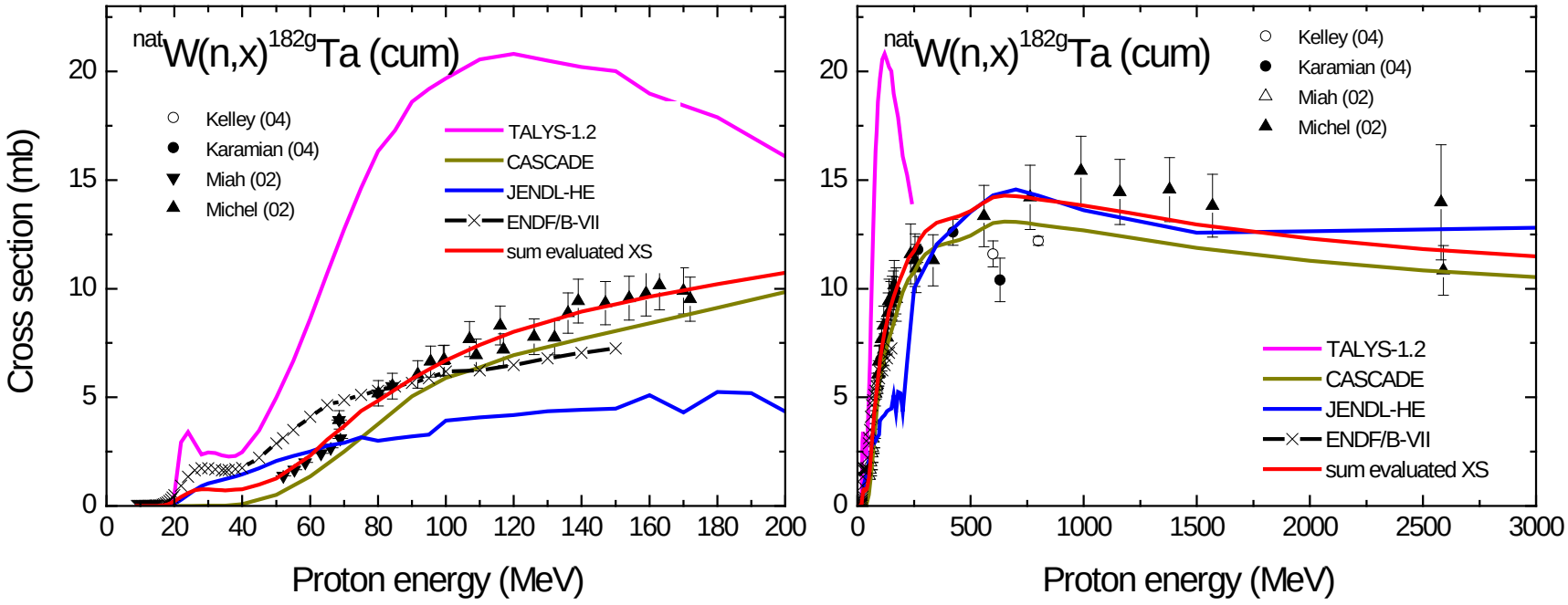
Evaluated cross-section



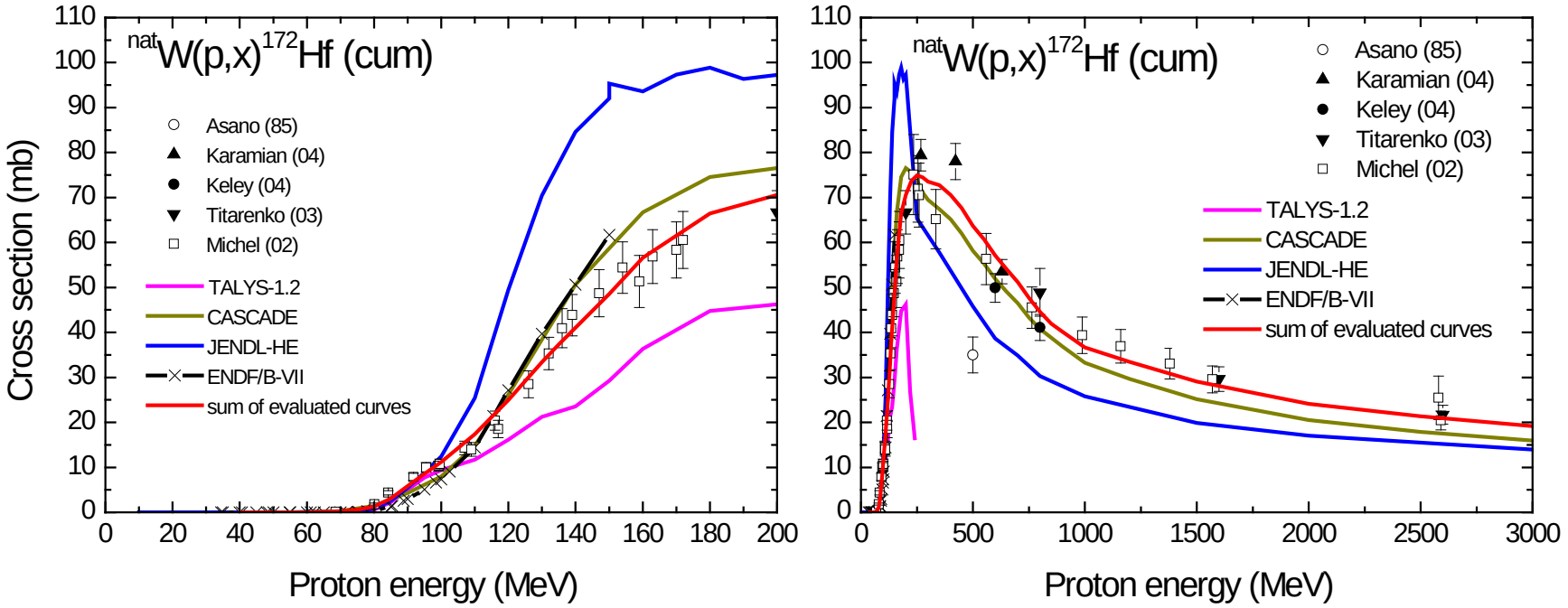



Evaluated data
Cross section (mb)
10
1
0,1
500
1000
1500
2000
2500
3000
Proton energy (MeV)
W(p,x)148Gd
W(p,x)148Tb
W(p,x)148Dy
W(p,x)152Ho
W(p,x)152Er
W(p,x)156Yb
W(p,x)160Lu

W(p,x)^{182}Ta (cumulative)



W(p,x)^{172}Hf (cumulative)



The evaluation is in progress

Expected results:

Evaluated data files for incident protons and neutrons

ENDF/B, ACE, …