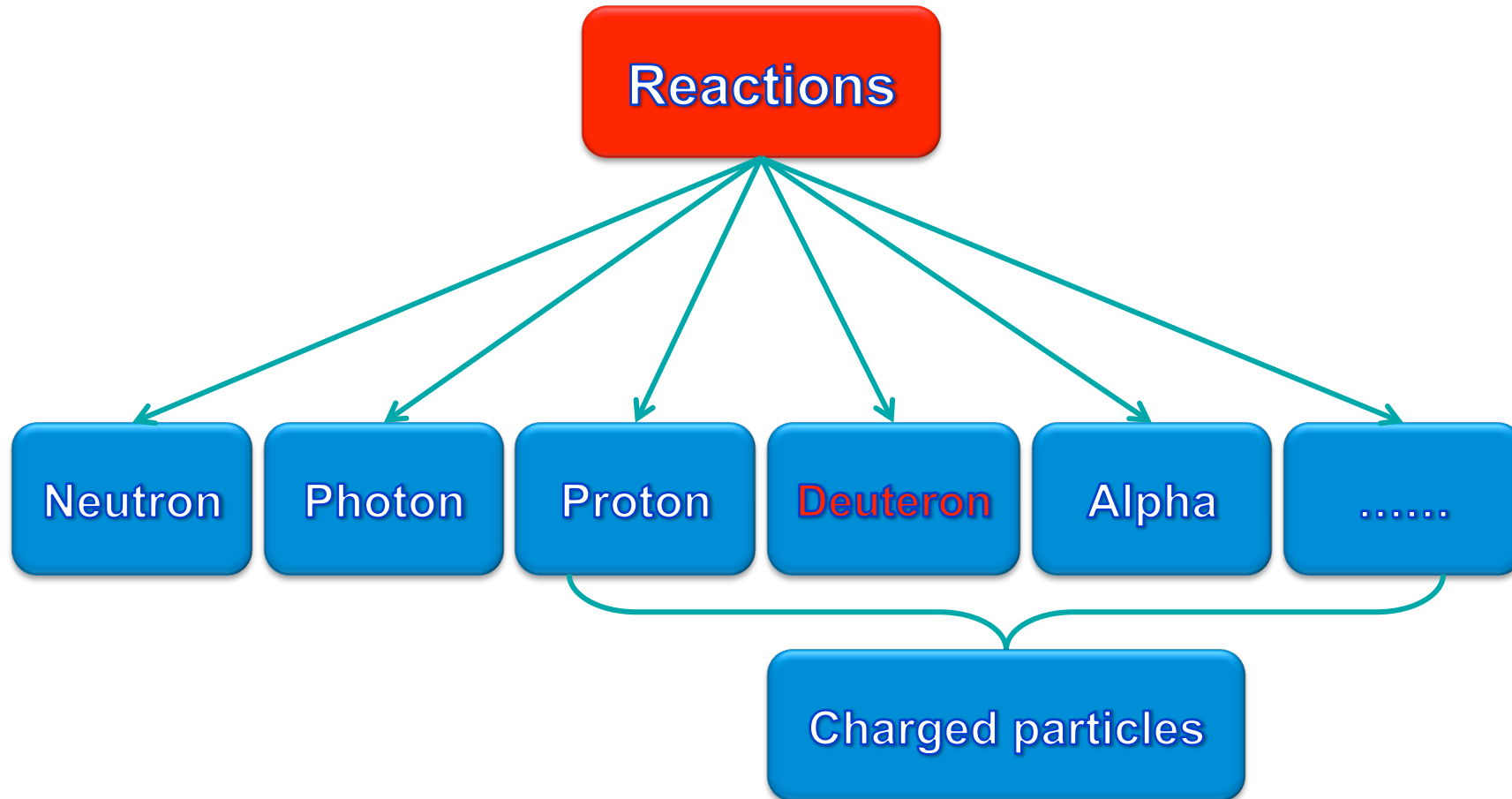


Evaluation of excitation function for $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction

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1. Introduction



1. Introduction(cont.)

■ Medical Application

- ➔ There are about 7,500 people dying for cancer every day.
- ➔ Radioactive therapy is a highly targeted and highly effective way to destroy cancer cells.

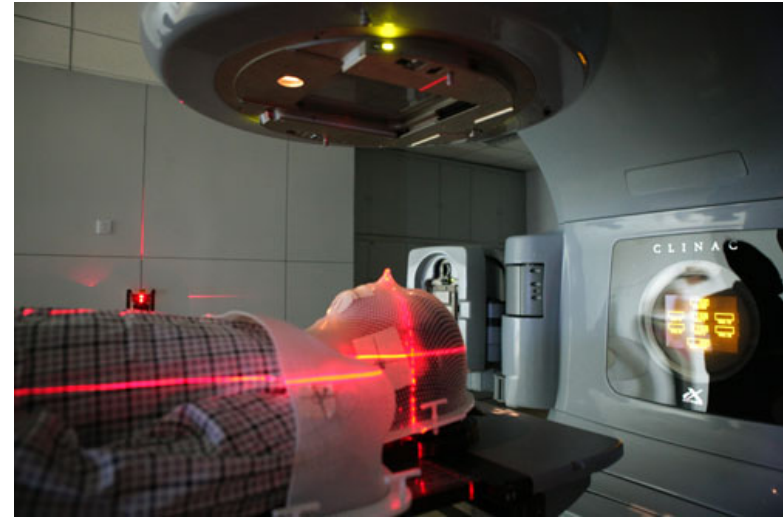


- Much attention has been paid to the radionuclide used in radiotherapy.
- Rhenium-186 is an important medically radionuclide, and regarded very suitable for radiotherapy.

1. Introduction(cont.)

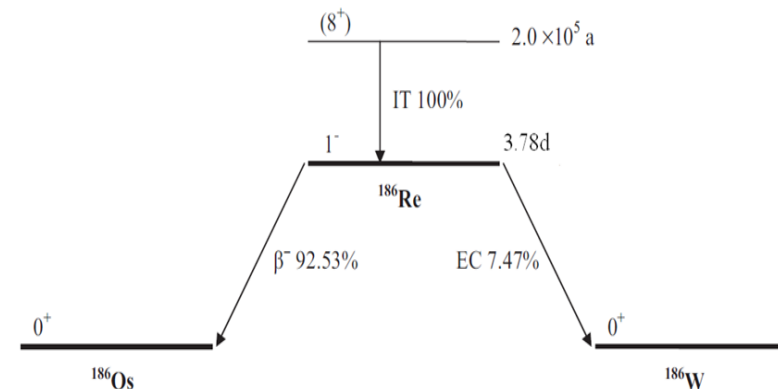
■ Medical Application

- ➔ There are about 7,500 people dying for cancer every day.
- ➔ Radioactive therapy is a highly targeted and highly effective way to destroy cancer cells.



■ Rhenium-186

- ➔ Emission of high-energy β -rays 1.07MeV;
- ➔ Low-abundance (9.42%) γ emission at 137 keV;
- ➔ 90.64 h half-life.



The decay scheme of the ^{186}Re

1. Introduction(cont.)

■ Methods for production of ^{186}Re

➔ By reactors



- Specific activity is medium, not in no-carrier-added form.
- In order to radiolabel antibodies more efficiently, production of no-carrier-added ^{186}Re with high specific activity is required.

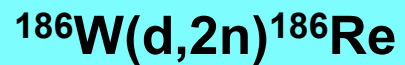
1. Introduction(cont.)

■ Methods for production of ^{186}Re

➔ By reactors



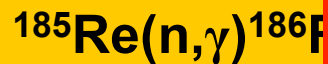
➔ By cyclotron



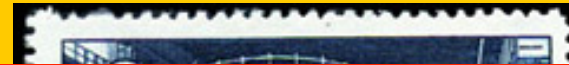
1. Introduction(cont.)

■ Methods for production of ^{186}Re

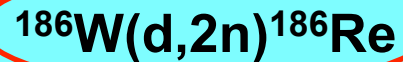
➤ By reactors



The excitation function $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction was evaluated, and the thick target yield (TTY) of ^{186}Re was calculated using the recommended excitation function.



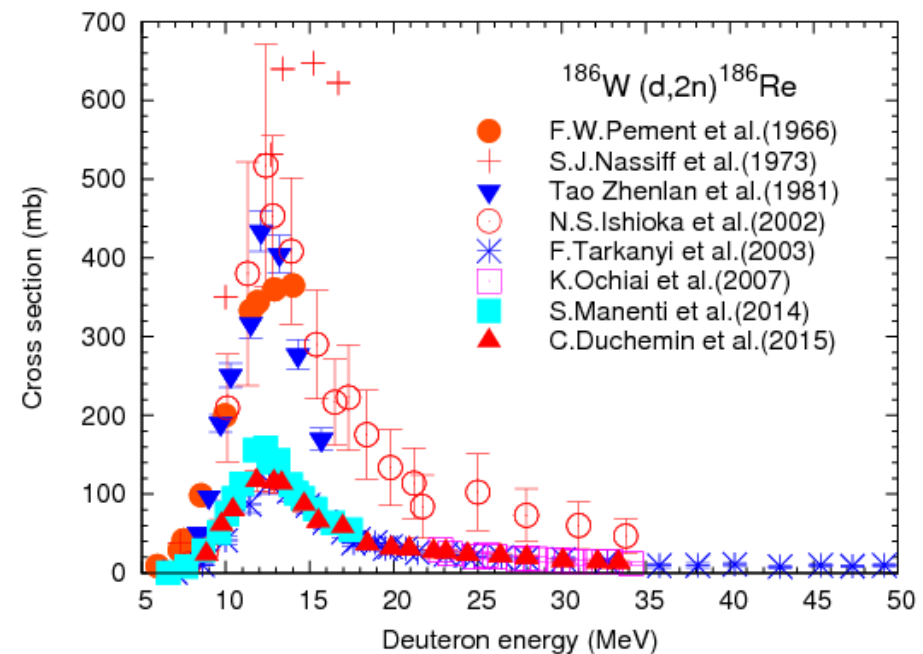
➤ By cyclotron



2. Experimental data

The available experimental data include the latest reports that are not considered in previous works were analyzed and corrected.

Year	Author	Institute	Method	Subentry
1966	F.W.Pement et al.	USAPUP	STTA	P0115 007
1973	S.J.Nassiff et al.	GERKFK	STTA,EXTB, ACTIV,EDEG	A0202 004
1981	Tao Zhenlan et al.	CPRNRS	ACTIV, STTA, BCINT,EXTB	S0014 003
2002	N.S.Ishioka et al.	JPNJAE	ACTIV,STTA, GSPEC	E2083 002
2003	F.Tarkanyi et al.	HUNDEB BLGVUB	ACTIV,EXTB, STTA,GSPEC	D4141 007
2007	K.Ochiai et al.	JPNJAE JPNJPN	ACTIV, STTA	E2121 025
2014	S.Manenti et al.	ITYMIL ZZZISP	ACTIV, STTA, BCINT	O2224 008
2015	C.Duchemin et al.	FRNTE	STTA,BCINT	O2258 002



The experimental data from EXFOR

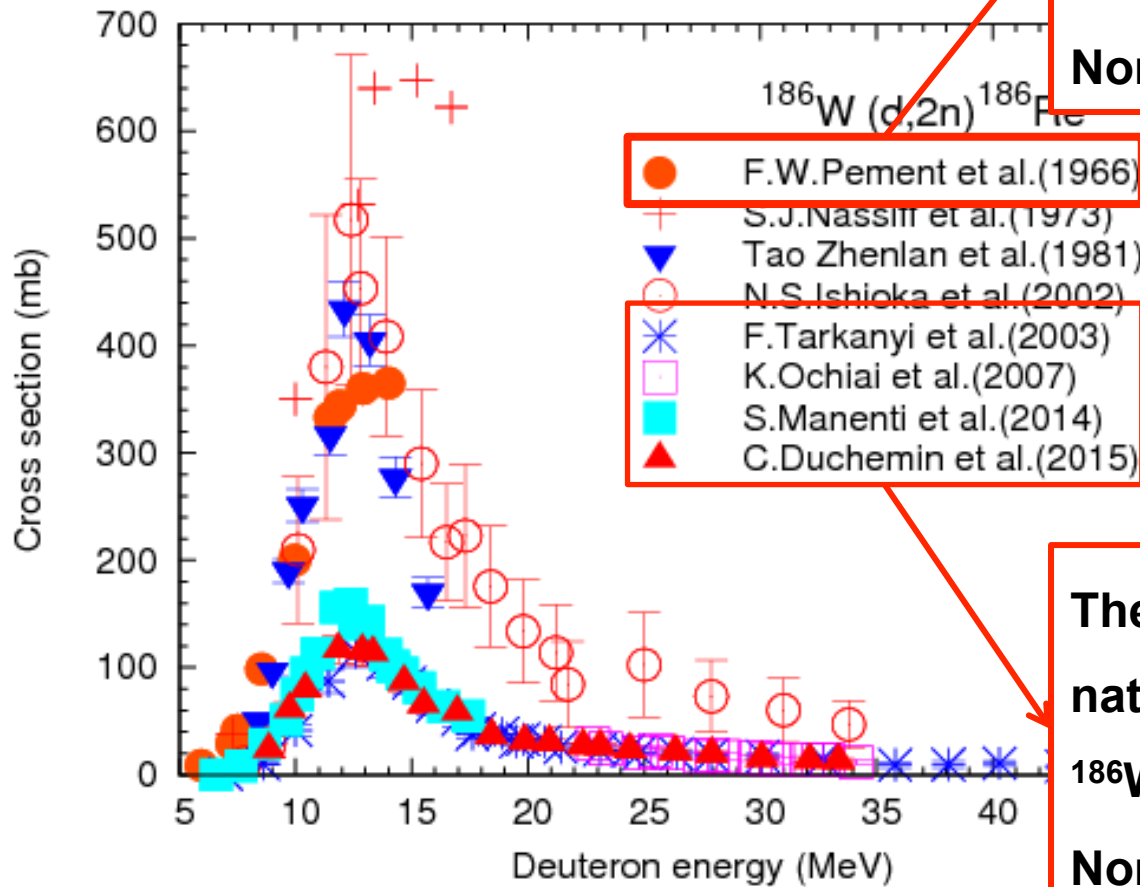
2. Experimental data (cont.)

■ Normalization

- ◆ The data were normalized to 100% enrichment of ^{186}W .
- ◆ The given enrichment of the target in the literature.
- ◆ The isotopic composition of natural W.
 - 74-W-180, NAT=0.0012
 - 74-W-182, NAT=0.2650
 - 74-W-183, NAT=0.1431
 - 74-W-184, NAT=0.3064
 - 74-W-186, NAT=0.2843

2. Experimental data (cont.)

■ Normalization



The sample was WO_3 powder, enriched to 97.2% in ^{186}W for $^{186}\text{W}(d,2n)^{186}\text{Re}$.

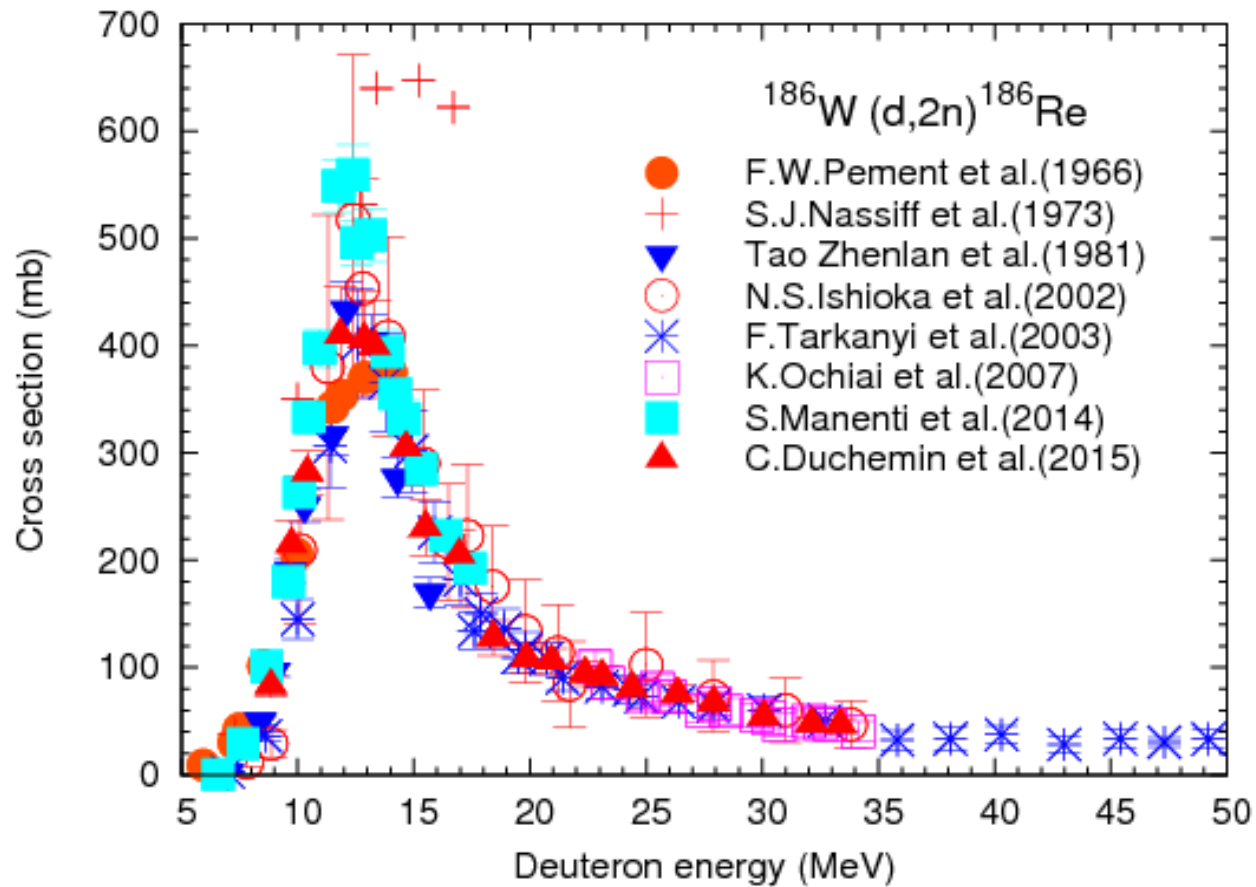
Normalization factor is 1.0288.

The samples were the thick natural W-metal foils for $^{186}\text{W}(d,2n)^{186}\text{Re}$.

Normalization factor is 3.517.

2. Experimental data (cont.)

■ Normalization



2. Experimental data (cont.)

■ Correction

- ◆ The formula for activation method:

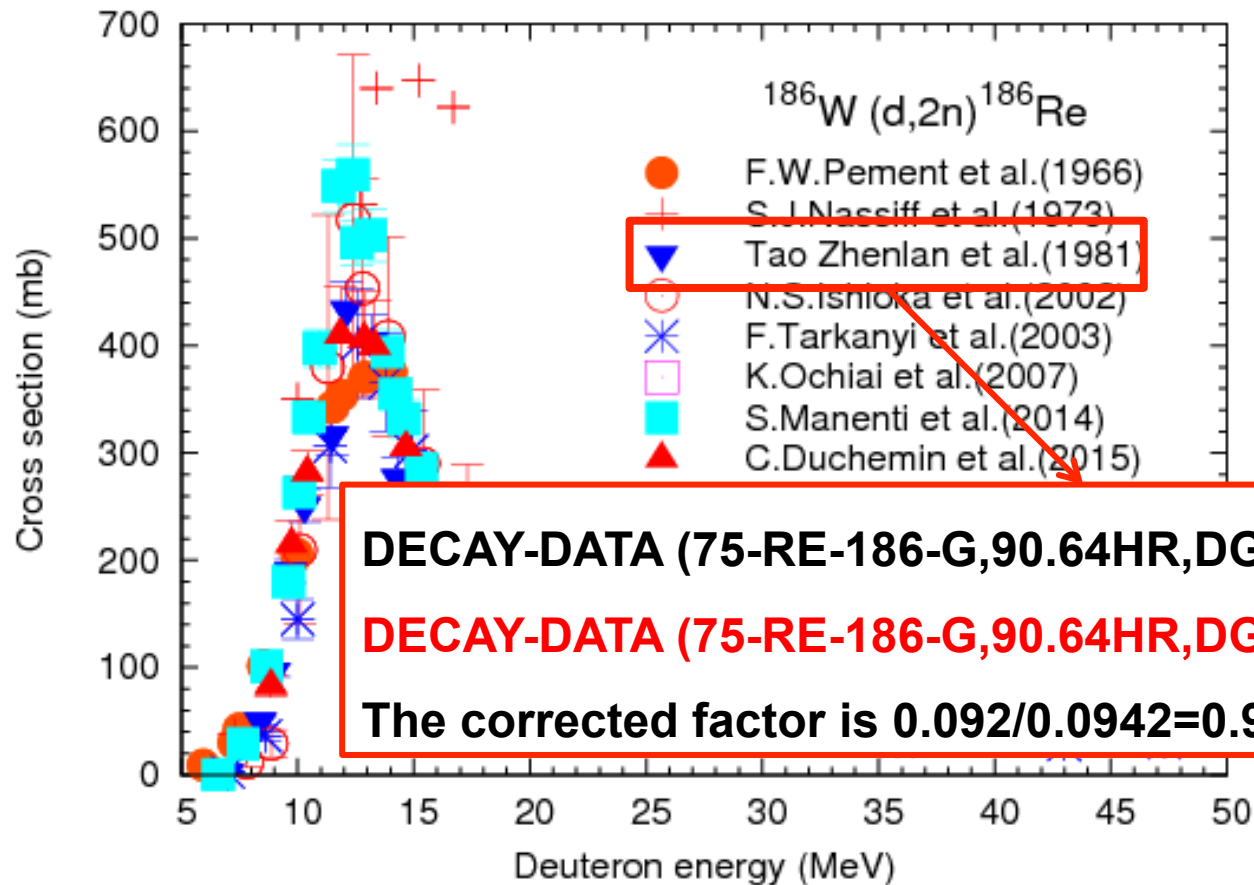
$$\sigma = \frac{M}{n \varepsilon p a N_0} \cdot \frac{c}{t} \cdot \frac{1}{\chi} \cdot \frac{1.6 \times 10^{-19} t_i}{Q} \cdot \frac{e^{\lambda t_d}}{1 - e^{-\lambda t_i}} \cdot 10^{24} \quad (b)$$

- ◆ γ -ray branch ratio, σ [?] $1/p$
- ◆ Radioactive decay constant, σ [?] $e^{\lambda t_d}/(1 - e^{-\lambda t_i})$
- ◆ Standard cross sections, if relative measurement, σ [?]

σ_{standard}

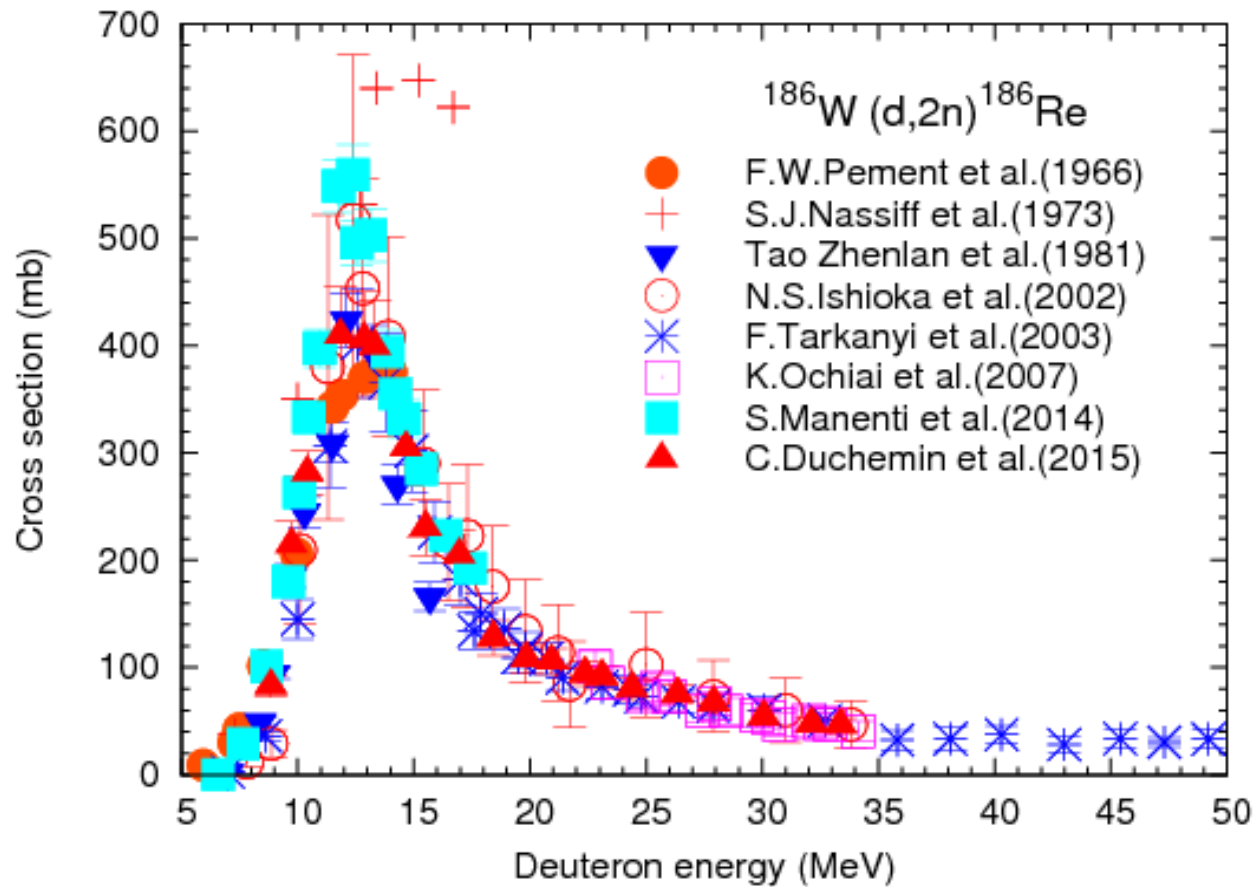
2. Experimental data (cont.)

■ Correction



2. Experimental data (cont.)

■ Correction

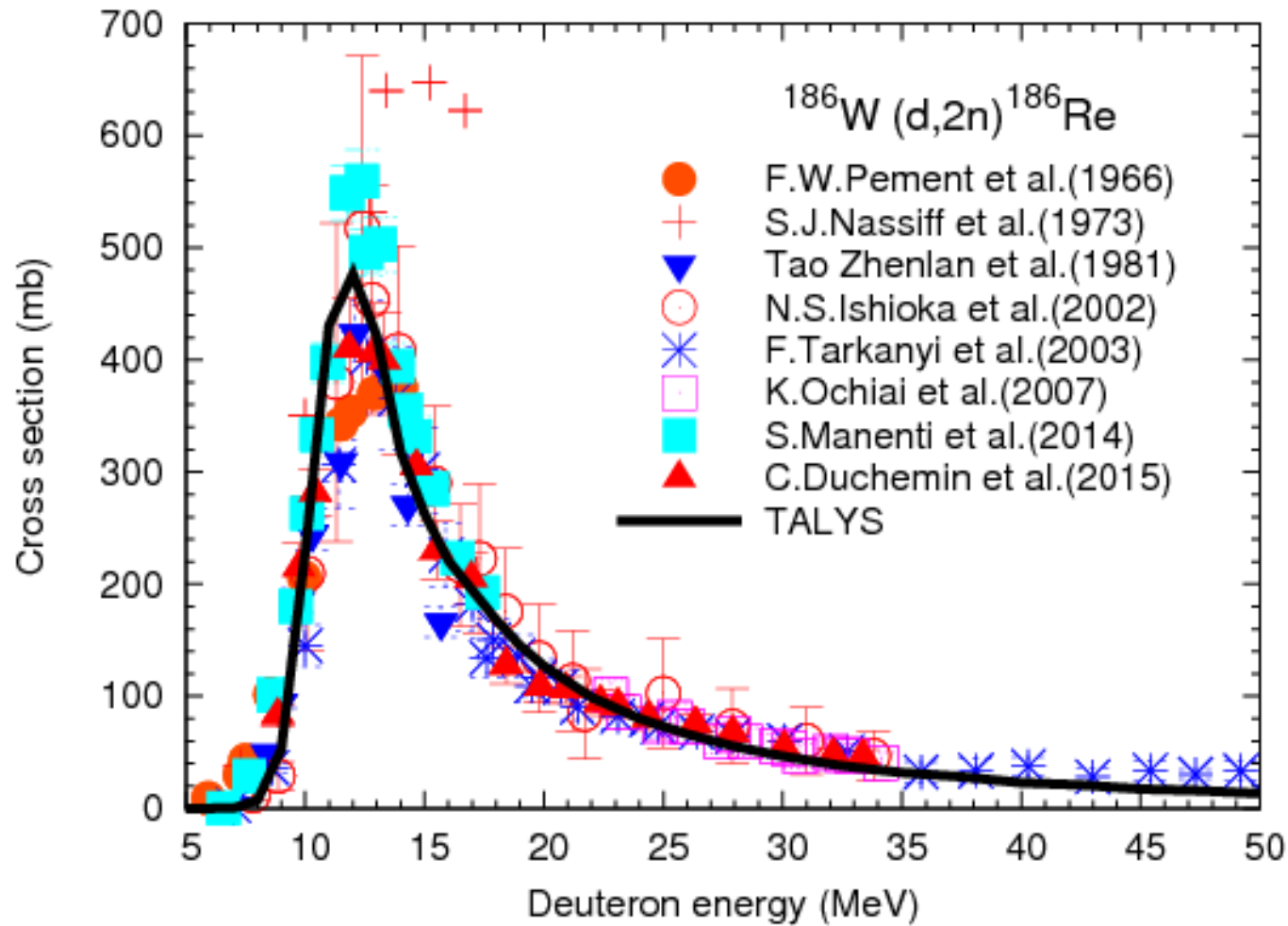


3. Nuclear model calculation

Calculation using TALYS, a nuclear model code, developed by Koning et al.

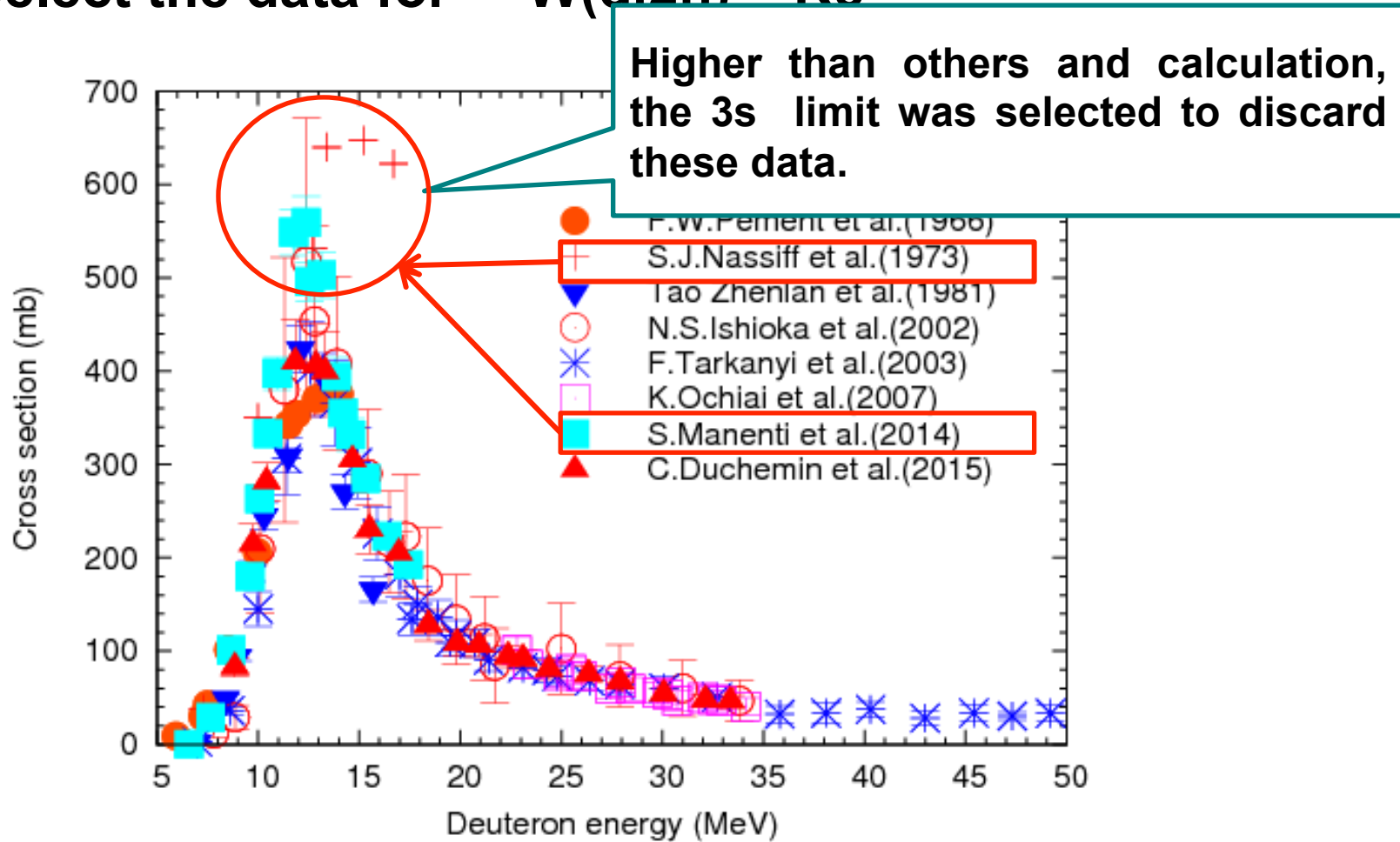
- The nuclei were considered non-spherical in shape;
- The compound nucleus contribution was considered in the frame of Moldaner model;
- The contributions of direct reactions were taken into account by ECIS;
- The back-shifted Fermi gas model (BFM) was used for level densities (ldmodel 2);
- The OM parameters were adjusted, rvsdjust was set to 1.2, the pairing energy of ^{186}Re was set to 0.0.

3. Nuclear model calculation (cont.)



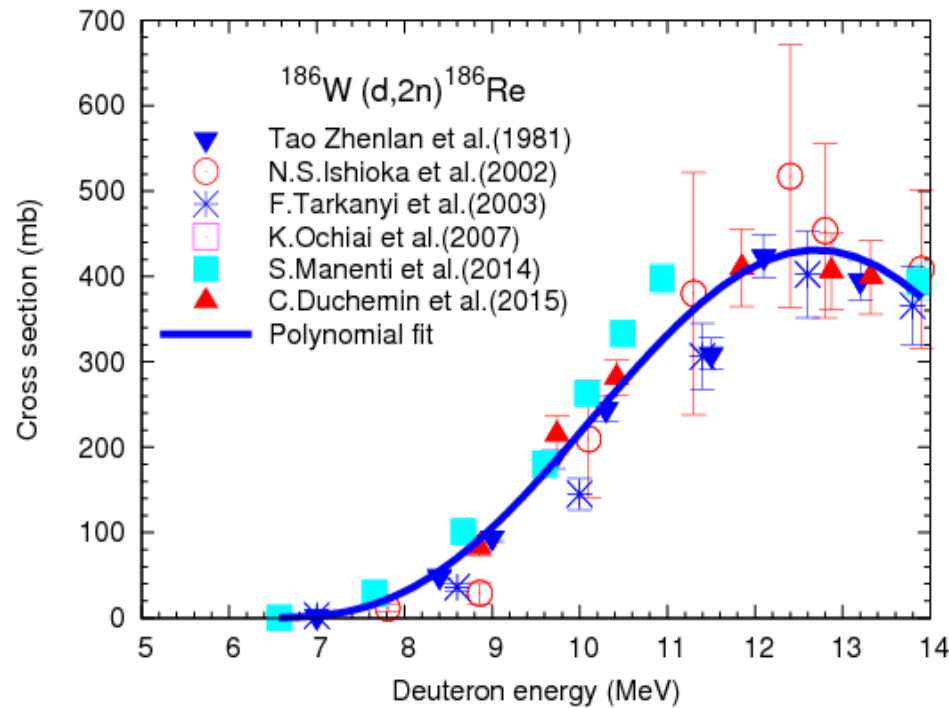
4. Experimental data fitting

■ Select the data for $^{186}\text{W}(d,2n)^{186}\text{Re}$



4. Experimental data fitting(cont.)

■ From threshold to 14 MeV



$$\sigma_{d,2n} = a - bE_d + cE_d^2 - dE_d^3$$

$$a = 4.2176,$$

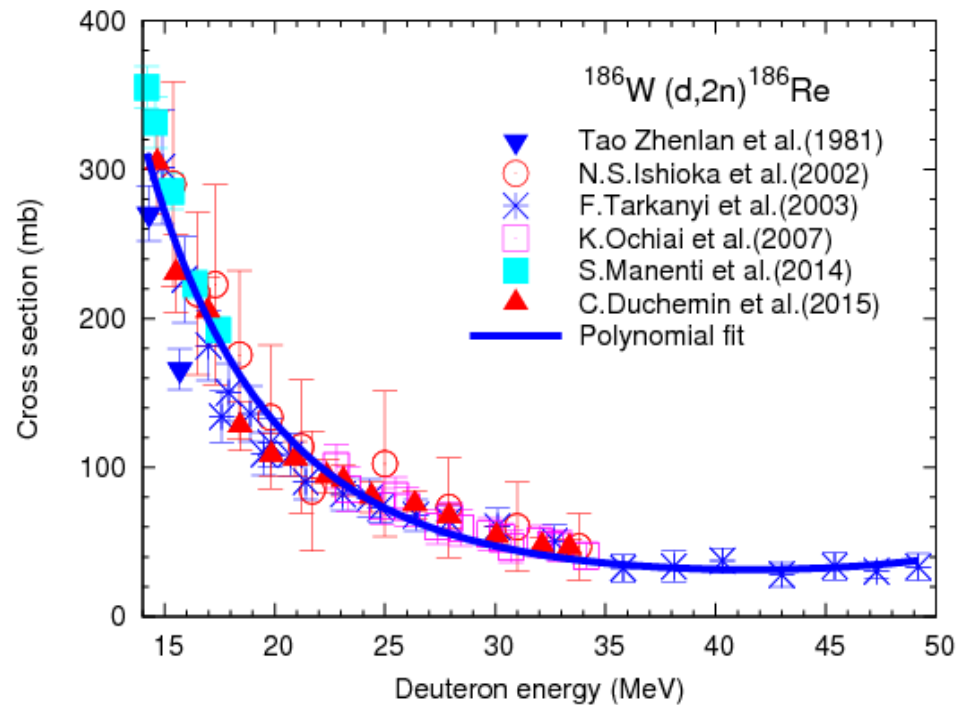
$$b = 1.4378,$$

$$c = 0.1555,$$

$$d = 0.0052$$

4. Experimental data fitting(cont.)

■ From 14MeV to 50 MeV



$$\sigma_{d,2n} = \exp(a - bE_d + cE_d^2)$$

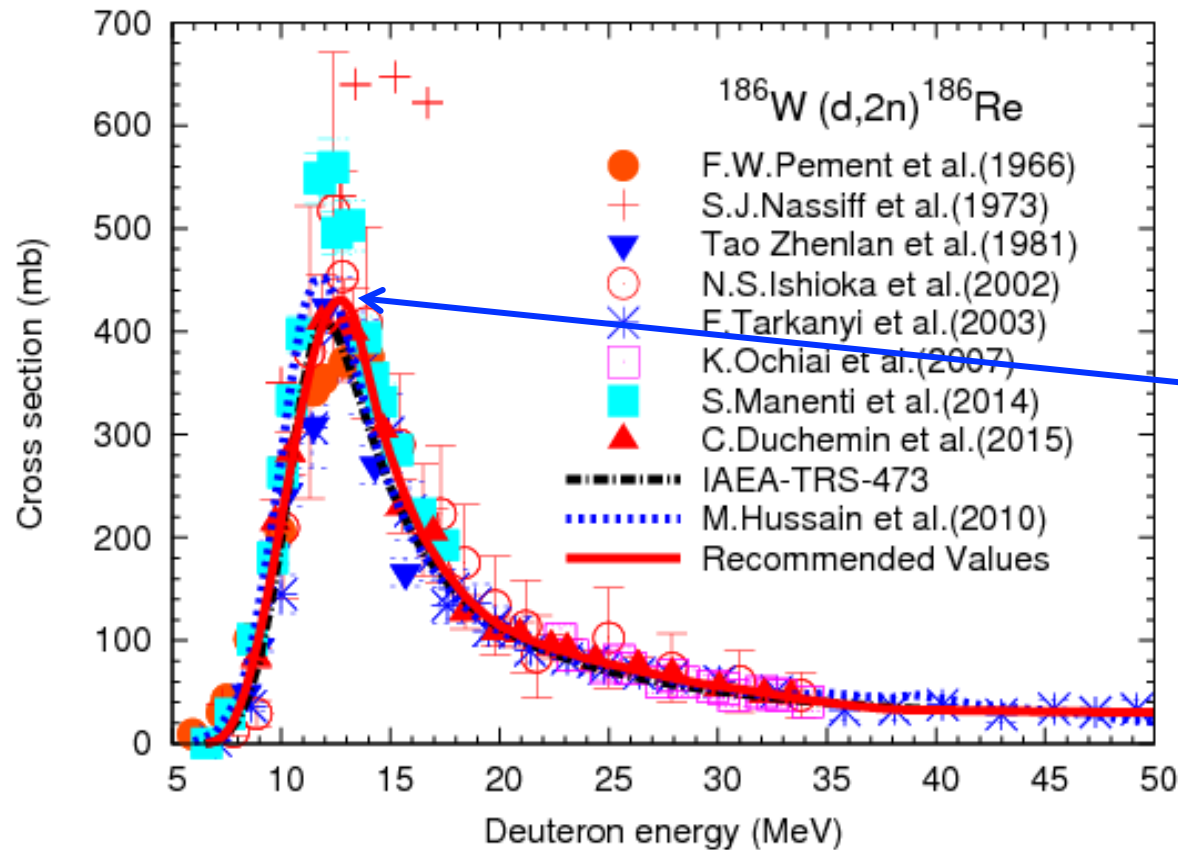
$$a = 1.8248,$$

$$b = 0.2544,$$

$$c = 0.0031$$

5. Evaluation of excitation function

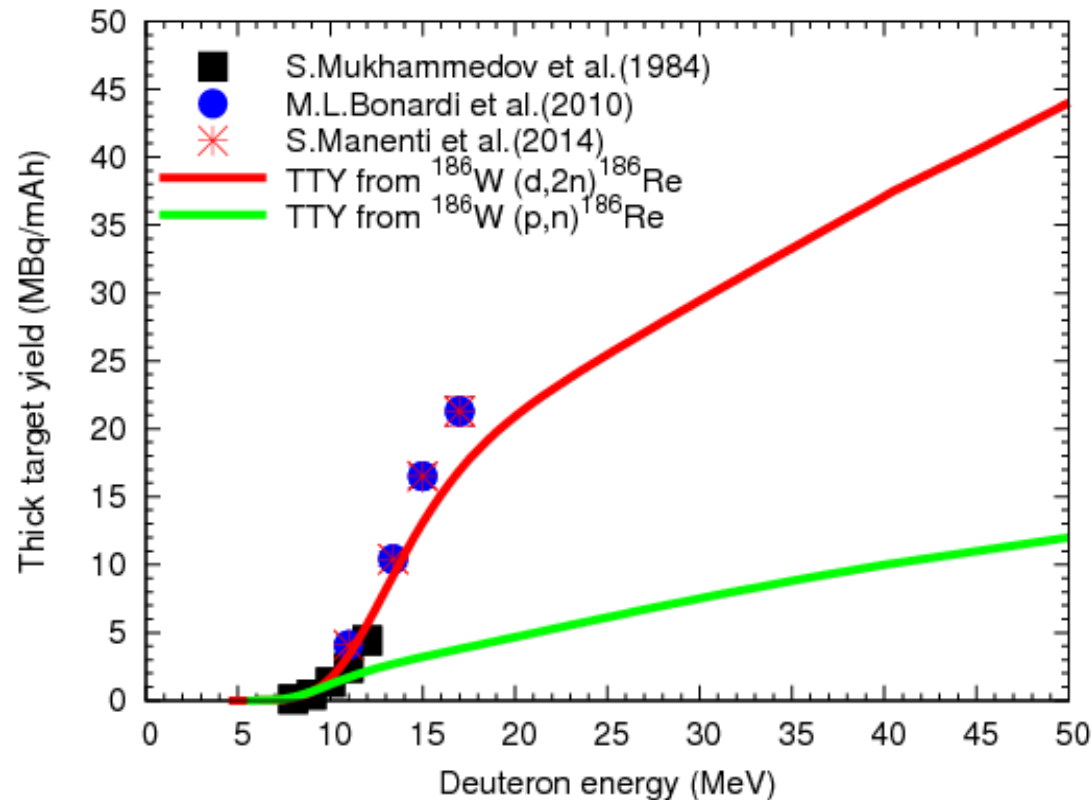
■ After comprehensive evaluation



Agree with the experimental data. The maximum value is 4.8% higher than the value of IAEA TRS 473, and 4.7% lower than the value of M.Hussain et al.

6. Calculation of thick target yields

■ The thick target yield (TTY) of ^{186}Re was calculated



● The TTY of $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction are much higher than the value of $^{186}\text{W}(p,n)^{186}\text{Re}$ reaction.

● The $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction may be more suitable for production of no-carrier-added ^{186}Re for medical application.

The TTY of $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction



7. Conclusion

- The experimental data were collected and analyzed;
- Nuclear model calculation using TALYS;
- Fitting for the evaluated experimental data;
- The excitation function of $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction was recommended below 50 MeV;
- The TTY was calculated using the recommended excitation function of $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction;
- The $^{186}\text{W}(d,2n)^{186}\text{Re}$ reaction is more suitable for production of no-carrier-added ^{186}Re for medical application.

ND Conference 2016

Thank you for your attention !

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■ Formula

$$\sigma = \frac{M}{n\varepsilon p a N_0} \cdot \frac{c}{t} \cdot \frac{1}{\chi} \cdot \frac{1.6 \times 10^{-19} t_i}{Q} \cdot \frac{e^{\lambda t_d}}{1 - e^{-\lambda t_i}} \cdot 10^{24} \quad (b)$$

- ***M***—Target molecular weight
- ***n***—Target nucleus number in a molecule
- **ε** —Detection efficiency of detector at full energy peak
- ***p***— γ -ray branch ratio
- ***a***—Isotope abundance
- **N_0** —Avogadro constant
- **c/t** —Accounting γ -ray number at full energy peak in a unit time
- **χ** —Target weight in a unit area
- **t_i** —Irradiation time
- **Q** —Total integrated beam current (in Coulomb)
- **t_d** —Cooling time (start from stop irradiation)
- **λ** —Radioactive decay constant