TOF measurement of neutron capture cross section of Re-185 in keV region

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Background

Use of Rhenium

- Rhenium has been utilized in various sectors including metallurgy, nuclear medicine and astrophysics.
- Alloy containing Re are one of the attractive candidate of space reactors and fusion reactors.
- Re-185 and Re-186 are utilized as a component of radiopharmacecuticals.
- Re-Os pair is one of the candidates of cosmo-chronometers.

Current situation of capture cross section data of Re-185

- Limited number of experimental data of Re-185 is currently available.
- Most of the experiments were conducted by using activation method.
- There is only one experiment which used Time-of-flight(TOF) method.
- There are large discrepancy in trend of capture cross section, which up to 19% in keV region.
- Precise measurements are required, since an accurate cross section data is needed, especially in the field of astrophysics.

Experimental setup

- The experiment was conducted by using 3 MV Pelletron accelerator at the Tokyo institute of technology.
- A pulsed neutron beam was generated by bombarding a 1.5 nsec pulsed proton beam to the Lithium target.
- The gamma ray was detected by an anti-Compton NaI(Tl) detector, oriented at 125 degree to the proton beam.
- Neutron energy spectrum were obtained by Li glass detector.

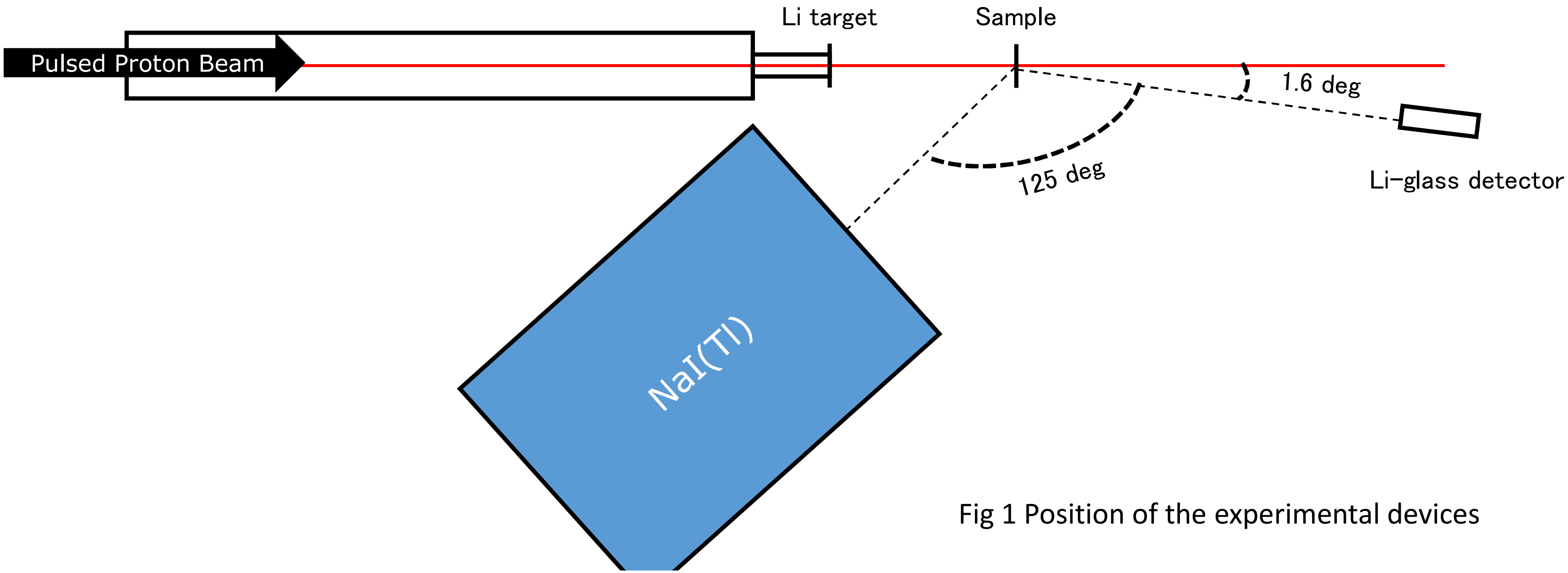

Fig 1 Position of the experimental devices

Analysis method

Time of flight (TOF) method

➢The neutron energy spectrum were obtained by using time of flight method.

$$E_n = \left[\frac{72.3L}{T_n}\right]^2 \qquad T_n = t_{ch}(I_\gamma - I_n) + \frac{L}{c}$$

E_n: Energy of neutron[MeV], T_n: Flight time[ns] , L: Flight length[m],
I_γ: Channel of gamma ray detection[ch], I_n: Channel of neutron detection[ch], t_{ch}: time per channel[ns/ch],
c: speed of light[m/s]

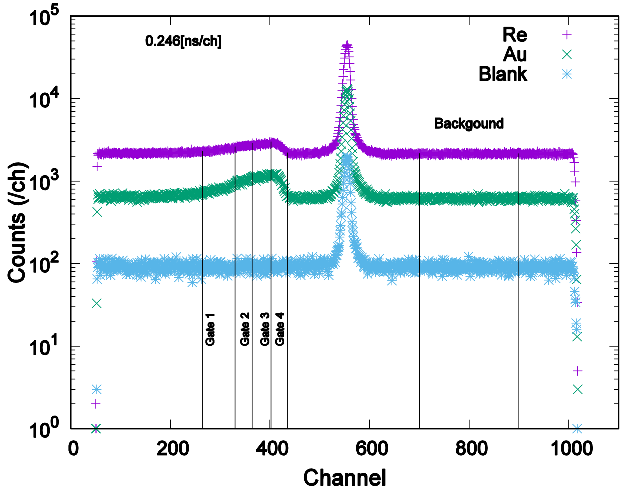

Fig 2 TOF spectrum

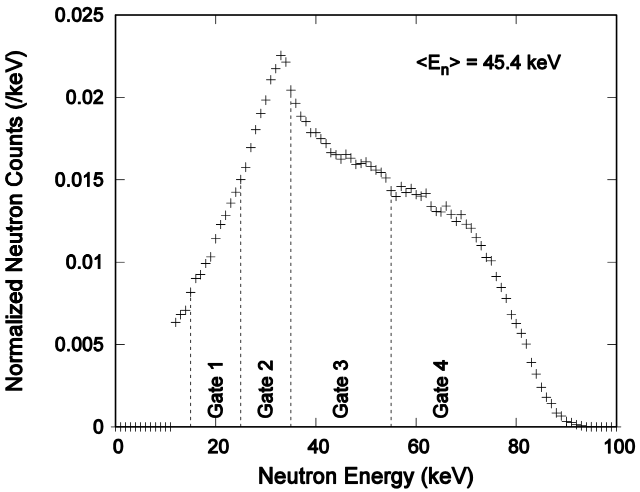

Fig 3 Neutron spectra

Table1 Gate information

Gate No.	Enegy range[keV]	Ave. Enegy [keV]
1	15.0-25.0	20.1
2	25.0-35.0	29.9
3	35.0-55.0	44.0
4	55.0-90.0	66.9
Total	15.0-90.0	45.4

Analysis method

Pulse height weighting method with impurity

- From obtained pulse height spectrum, the capture cross section was obtained. Attributions of impurities of the sample were subtracted by following equation.

$$< \sigma_t >= \frac{\sum_I W(I)S(I)}{(B_{nt} + E_{nt})N_t C_t \phi} - \frac{\sum_i N_i C_i (B_{ni} + E_{ni}) < \sigma_i >}{(B_{nt} + E_{nt})N_t C_t}$$

$W(I)$: Weighting function, $S(I)$: Pulse heigh spectra, B_n: Neutron binding energy[MeV], E_n: Incoming neutron energy[MeV], N:Number of atoms per area[$/cm^2$], C: Correction factor for neutron transportations

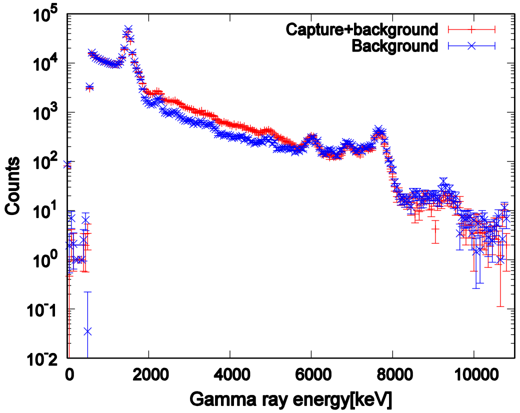

Fig 4-1 Pulse heigh spectrum

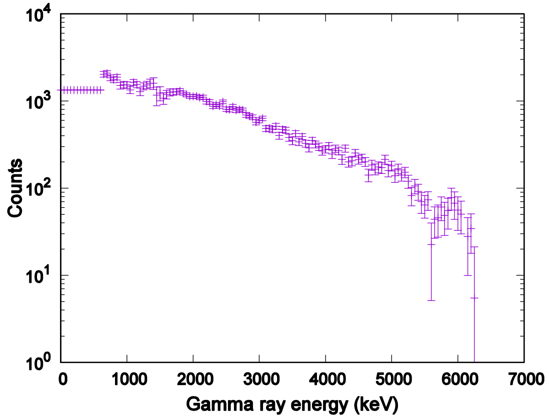

Fig 4-2 Net Pulse heigh spectrum

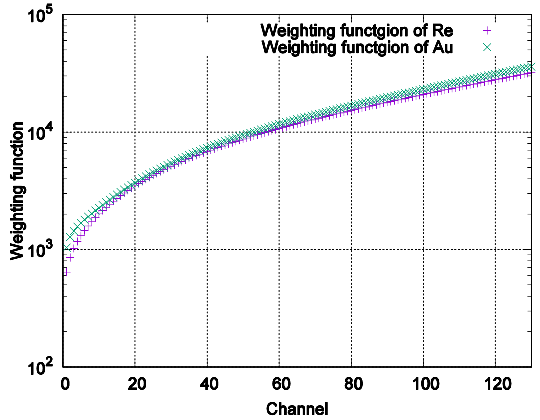

Fig 5 Weighting functions

Results

Comparison with the previous results

➢The present result shows a trend similar to the one by Bergman et.al.
➢The present result provide a data set with the highest energy point which measured by TOF method.
➢The present result has errors smaller than the previous experiments.

Error propagation

➢The largest factor of the uncertainty is the standard cross section which is 3.05%.
➢Statistical errors are the second largest which are from 1.12% to 2.44%.
➢The effect of the uncertainty of cross sections of Re-187 which were used for impurity correction, is as small as 0.35%.

Table2 Cross section values

Gate No.	Cross section [b]	Error [%]
1	1.561	5.38
2	1.229	4.85
3	1.012	4.58
4	0.849	4.71

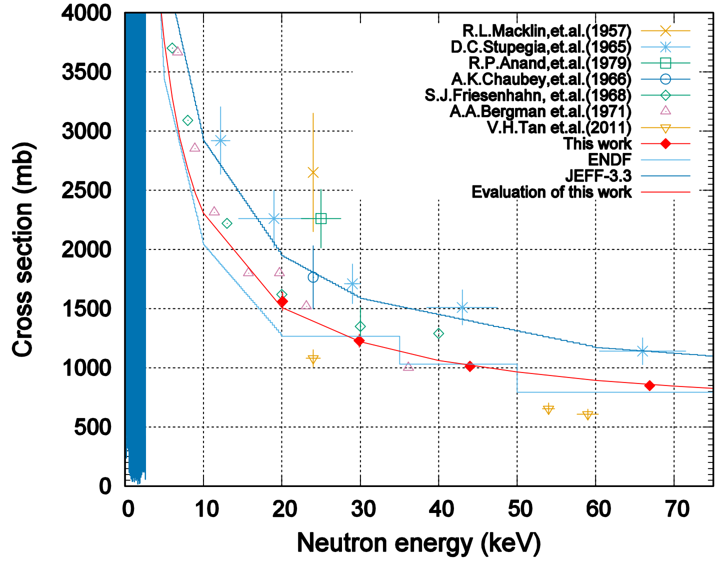

Fig.6 Current results and comparison

Conclusion

Re-evaluation

➢Capture cross section in keV region was re-evaluated by Iwamoto Nobuyuki san, JAEA.
➢The two sets of evaluated nuclear data of Re-185 currently available follow different trends of experimental data as shown in Fig.5 .
➢Using the present results, the neutron capture cross section was re-evaluated.
➢The current evaluation shows a trend similar to the ENDF/B VII.

MACS calculation

➢The Maxwellian-averaged cross sections were calculated by using the current data set.
➢The cross section value at 30 keV was about 10% smaller than the KADoNIS recommendation.
➢MACS at 30 keV by using other evaluated data are also available on KADoNIS.

Table 3 MACS at 30 KeV

KADoNiS 1.0	1.439E+58.0 mb	JEFF-3.1	1.06E+3 mb
ENDF/B-VII.0	1.06E+3 mb	Current	1.30E+3 mb

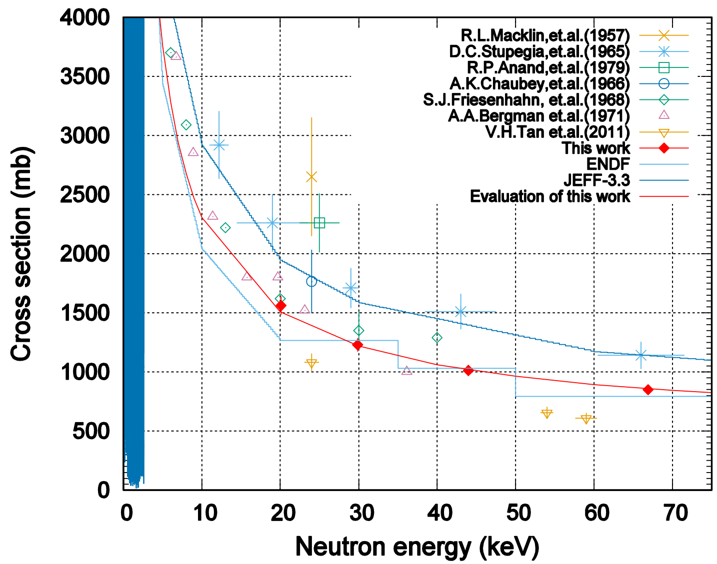

Fig.6 Current results and comparison

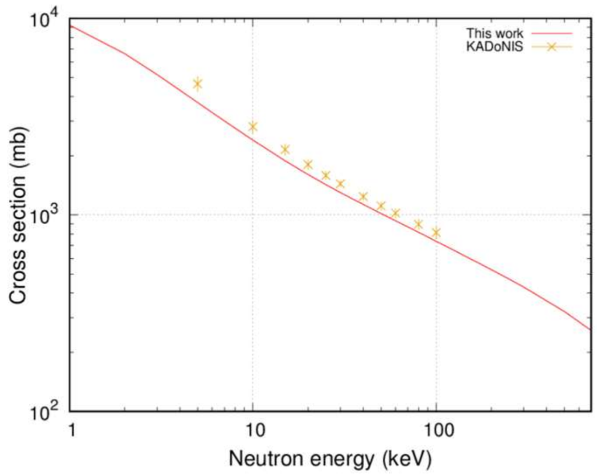

Fig 7 MACS comparison