Cross sections of (n,p), (n,α), (n,2n) reactions on isotopes of Dy, Er, Yb at En= 14.6 MeV

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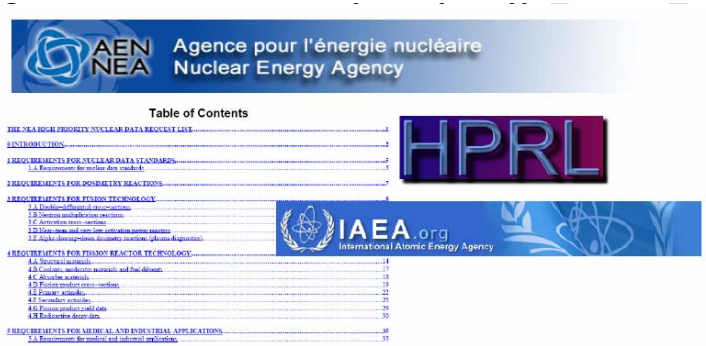
Motivations

Applications of neutron cross sections:

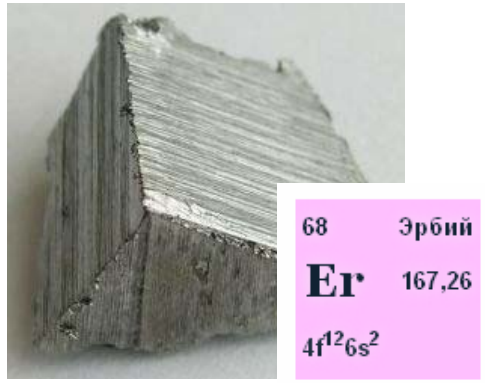
- **Extension and renovation of nuclear data libraries (ENDF, JENDL, JEFF, EXFOR)**
- **Nuclear/thermonuclear power (controlled fusion)**
- **Radiation Physics (application of sources)**
- **Verification of nuclear reactions models and statistical description of excited nuclear states**
- **A performing the nuclear transmutation design and nuclear technologies**
- **Geophysics (microanalysis) and nuclear astrophysics (nucleosynthesis)**

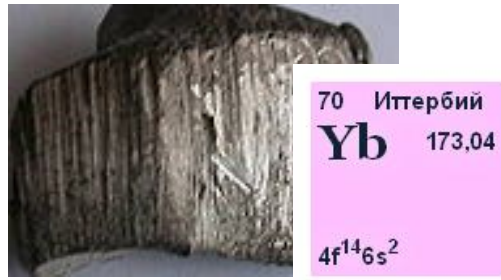
- **Forrest R.A "Data requirements**
  Nuclear data "Data requirement
  II: Decay data EURATOM/UKAI
  Science Center, Abington,Oxo
  Engineering and Design 81 (2006)
- ***High Priority Request List***



Research objectives

- Independent and reliable measurements of (n,x) nuclear reaction cross sections
- Specification of available cross sections in order to remove the uncertainties in the excitation functions
- Theoretical calculations of cross sections targeted to verify the adequacy of theoretical models by means of more accurate experimental data





NO DATA FOUND (EXFOR)

$$^{172,173}Yb(n,x)^{173}Tm$$

$$^{162}Er(n,p)^{162(m+g)}Ho$$

Neutron-activation method and technique

Experimental technique:

- **Source of neutrons is a neutron generator NG-300/15**
- **Spectrometer based on a HPGe detector**

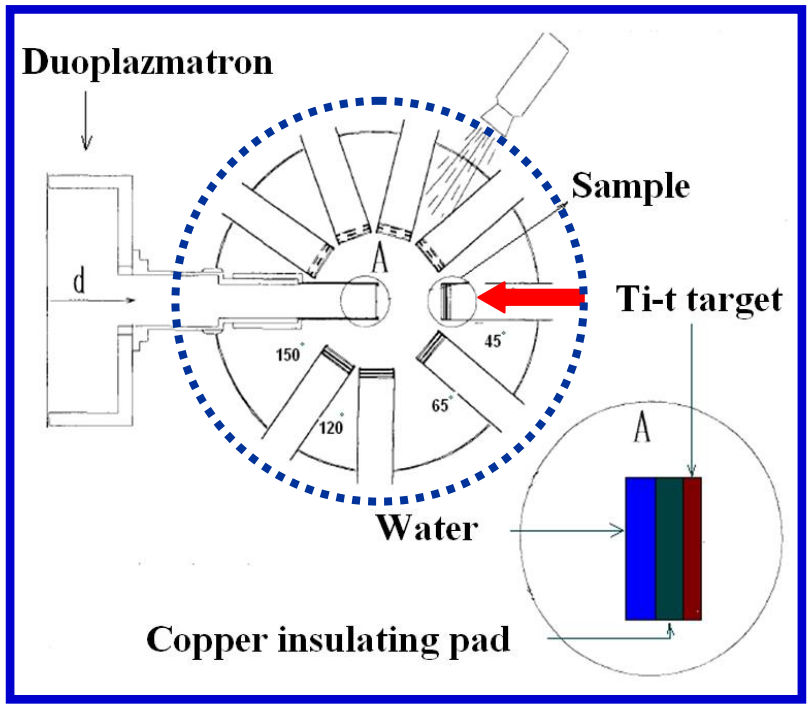
Main characteristics :

- **Neutrons generated by T(d,n)^{4}He reaction with an effective deuteron beam energy of 225 keV**
- **Average incident neutron energy: En = 14,6 MeV**
- **Average neutron flux density: $1 \cdot 10^8$ - $5 \cdot 10^8$ (n/(s · cm^2))**
- **Monitor reaction: ^{27}Al(n,α)^{24}Na**
- **The neutron energy at irradiation position was determined experimentally with the Zr/Nb method and theoretically based on Monte Carlo approach**

Determination of the absolute value of the nuclear reaction cross section:

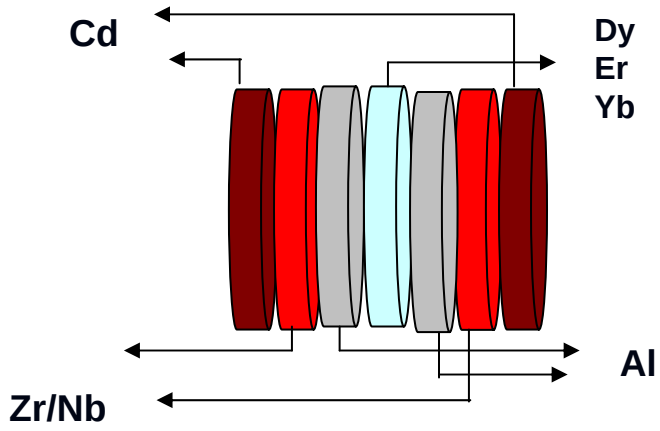
$$\sigma_x = \frac{S_x \cdot \varepsilon_m \cdot \left(1 - e^{-\lambda_m \cdot t_{irrad}}\right) \cdot e^{-\lambda_m \cdot t_{cooling\_m}} \cdot \left(1 - e^{-\lambda_m \cdot t_{mes\_m}}\right) \cdot N_m \cdot n_{\gamma_m} \cdot \lambda_x}{S_m \cdot \varepsilon_x \cdot \left(1 - e^{-\lambda_x \cdot t_{irrad}}\right) \cdot e^{-\lambda_x \cdot t_{cooling\_x}} \cdot \left(1 - e^{-\lambda_x \cdot t_{mes\_x}}\right) \cdot N_x \cdot n_{\gamma_x} \cdot \lambda_m} \cdot \sigma_m$$

Scheme of experiment

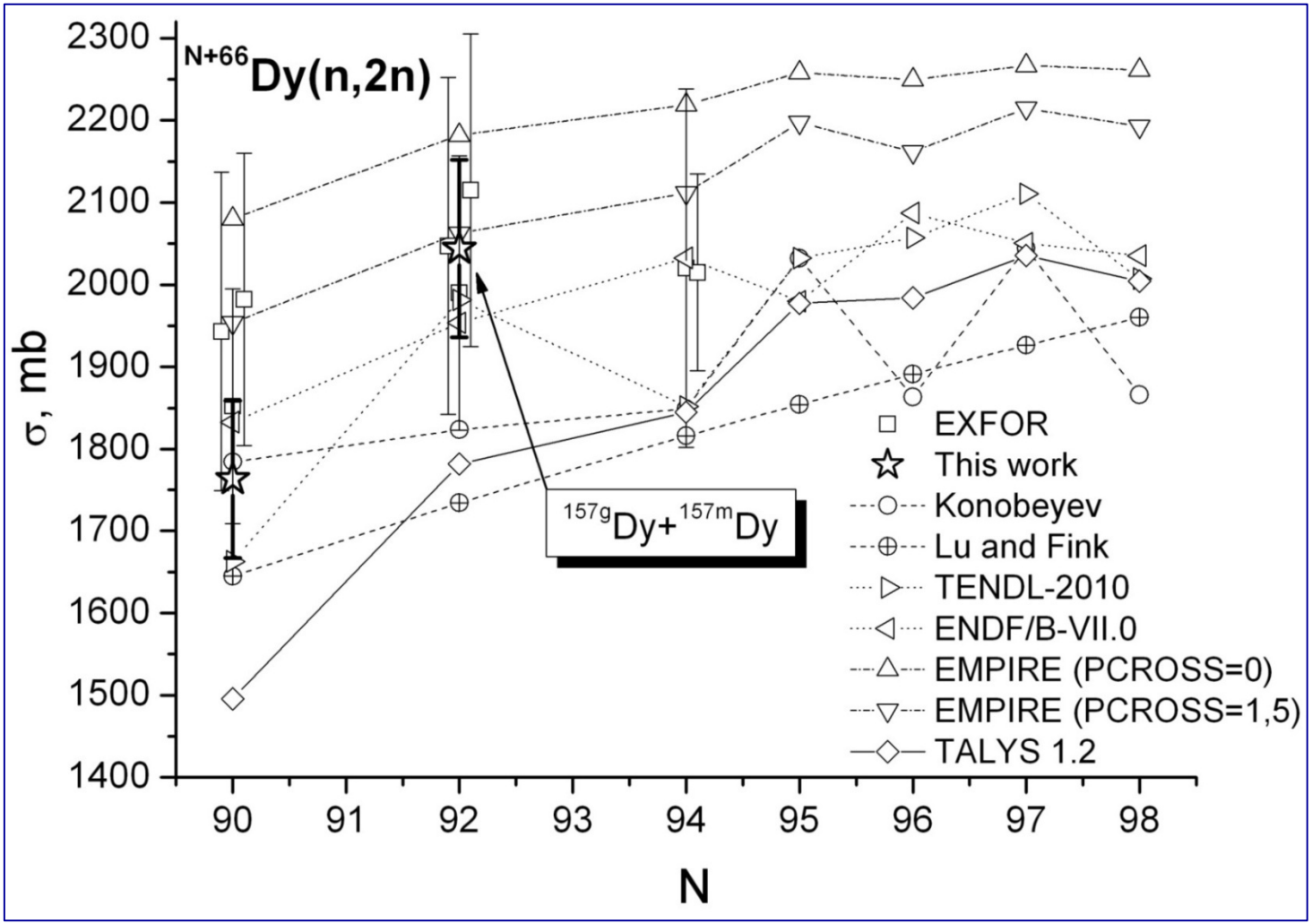


Scheme of experiment

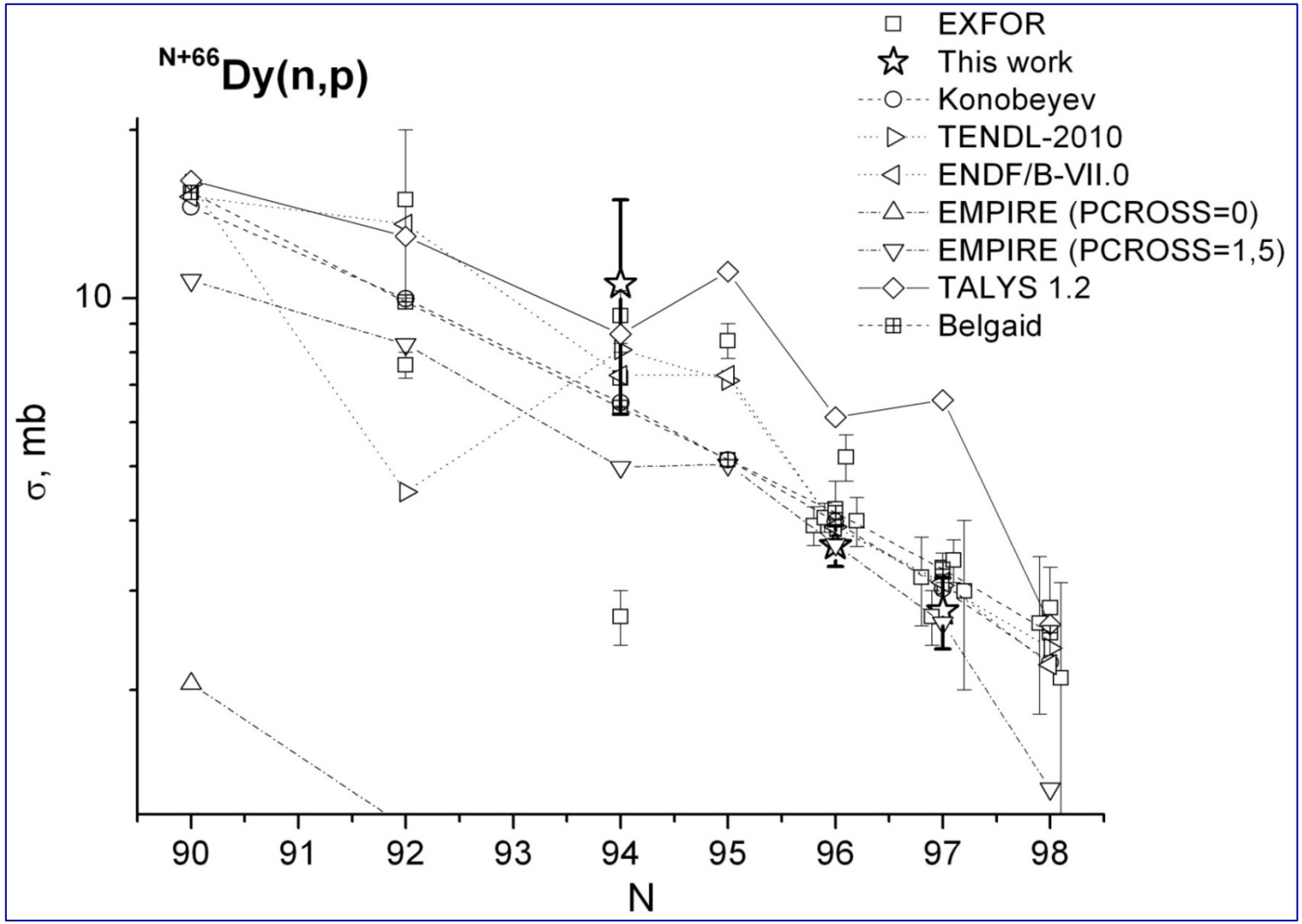
Neutron generator



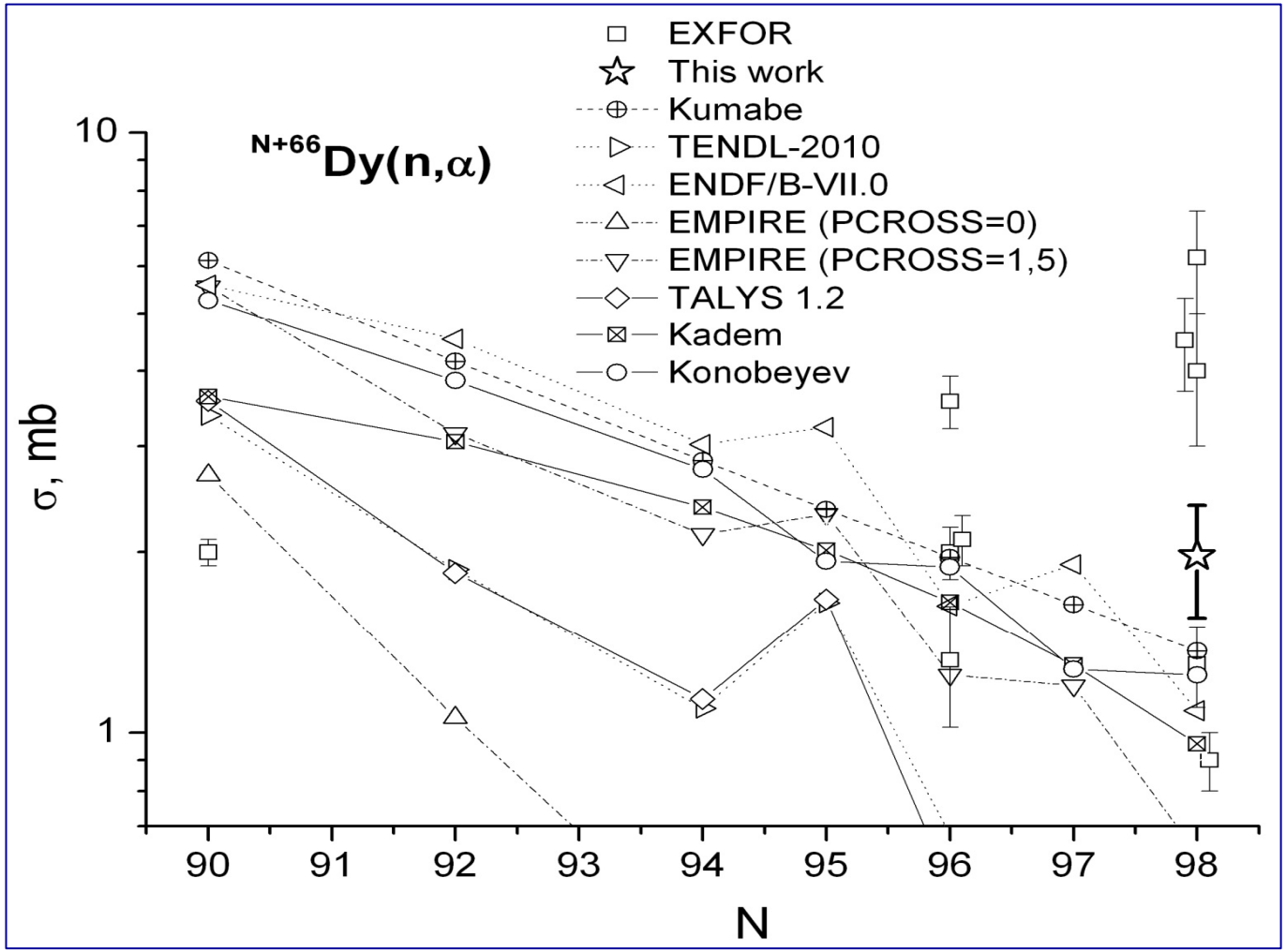
Sketch of irradiated assembly



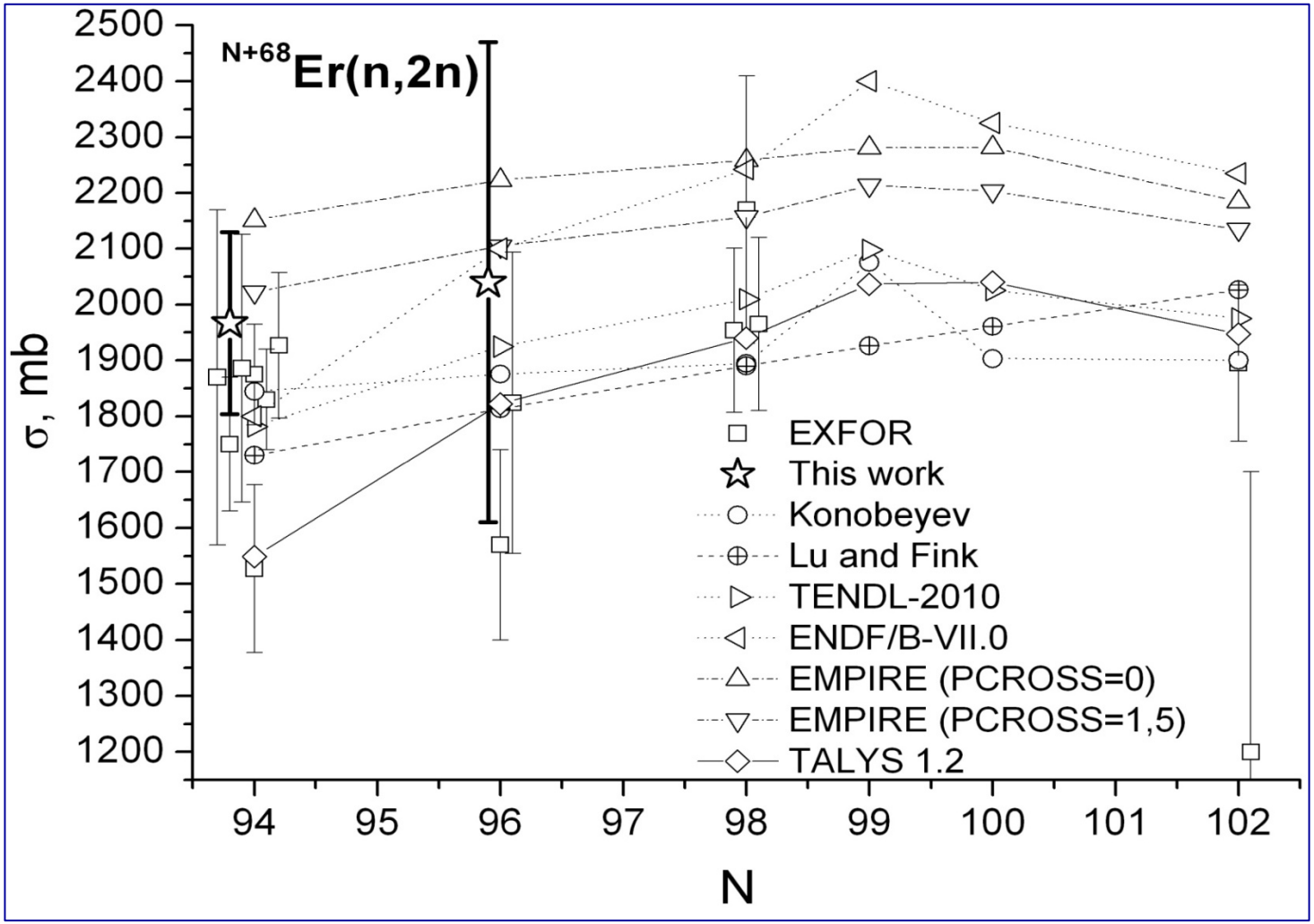
The (n,2n) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Dysprosium calculated by different systematics (Konobeyev, Lu and Fink), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (TENDL-2010, ENDF/B-VII.0)



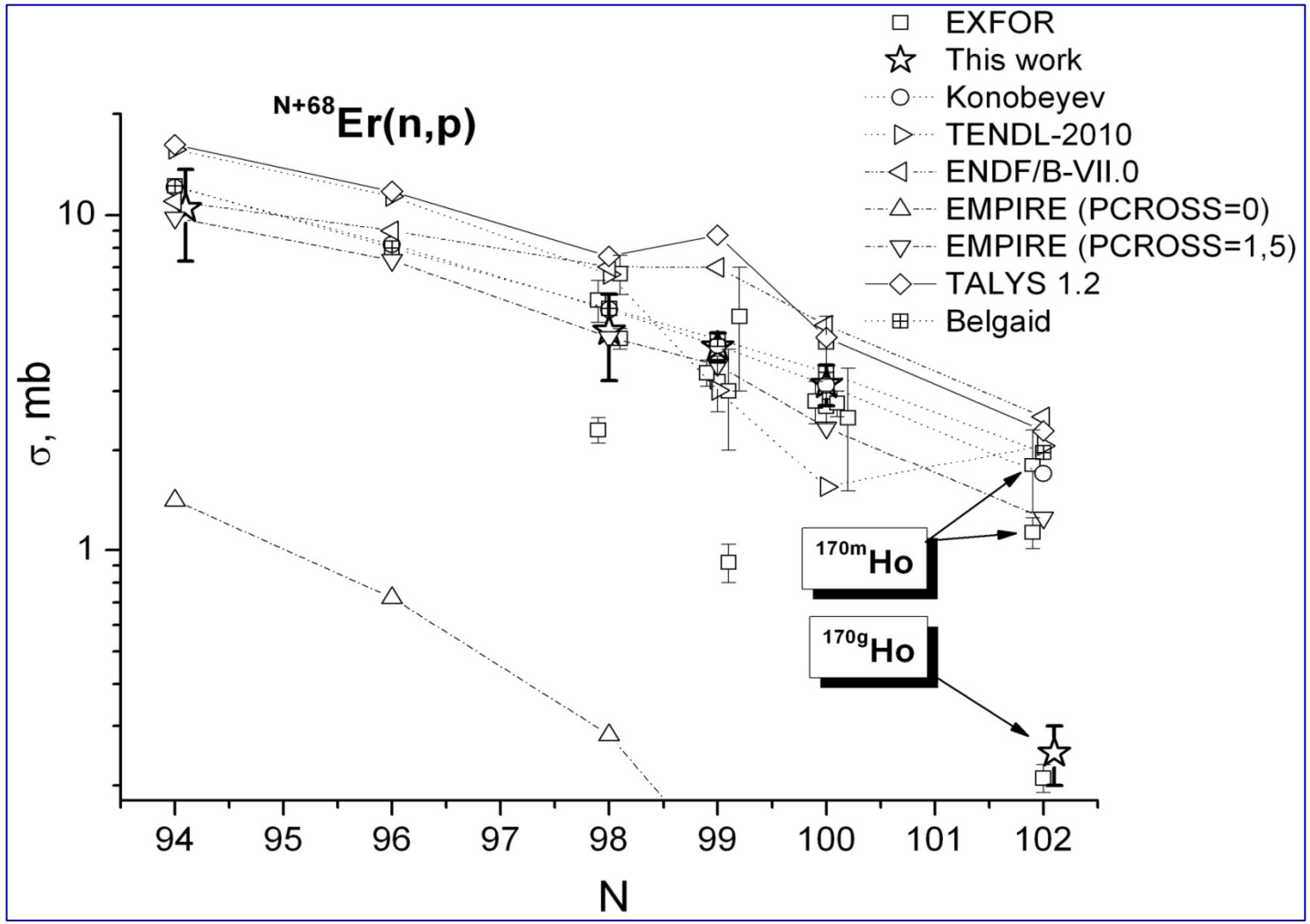
The (n,p) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Dysprosium calculated by different systematics (Konobeyev, Belgaid), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (TENDL-2010, ENDF/B-VII.0)



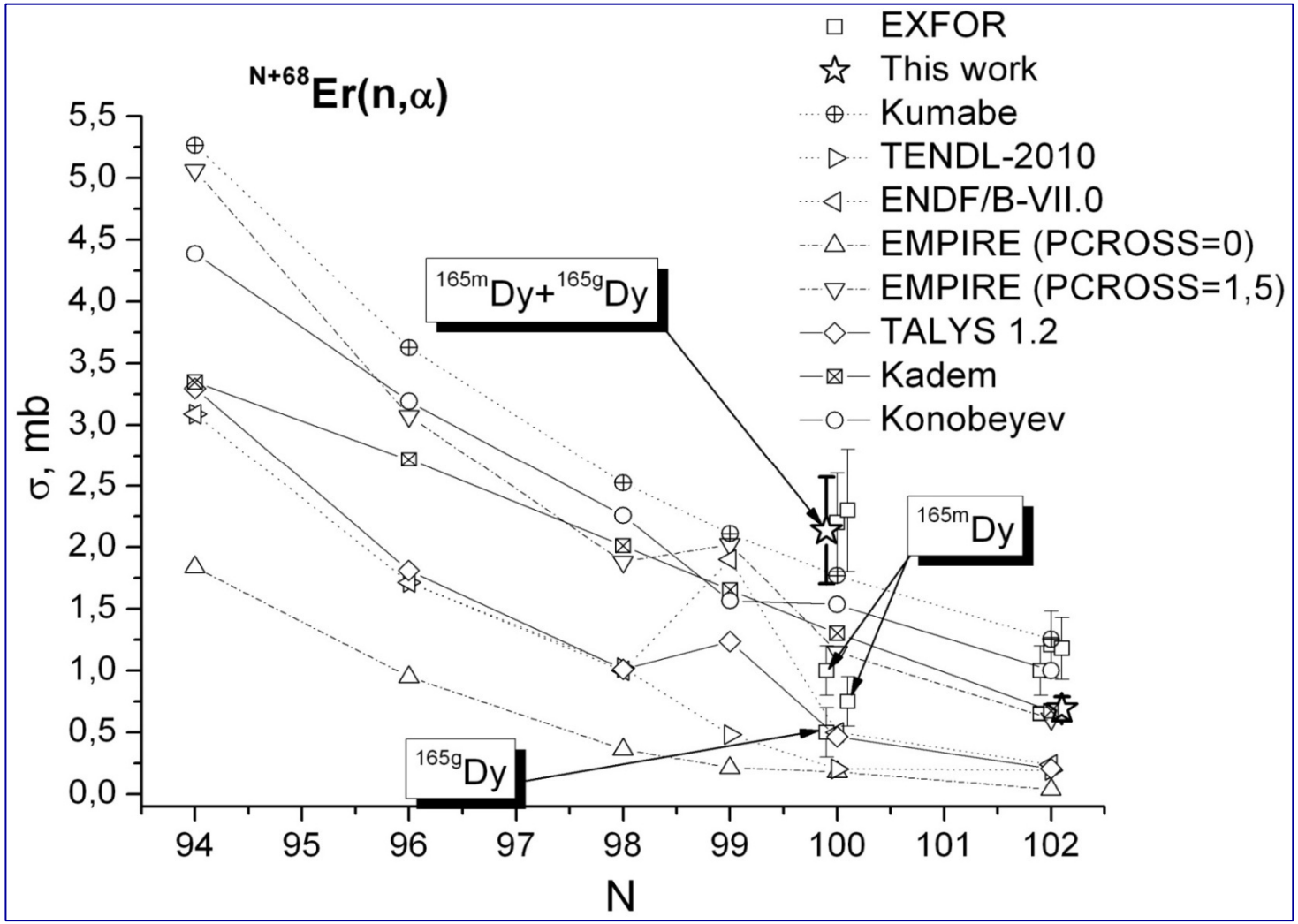
The (n,α) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Dysprosium calculated by different systematics (Konobeyev, Kadem, Kumabe), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (ENDF/B-VII.0)



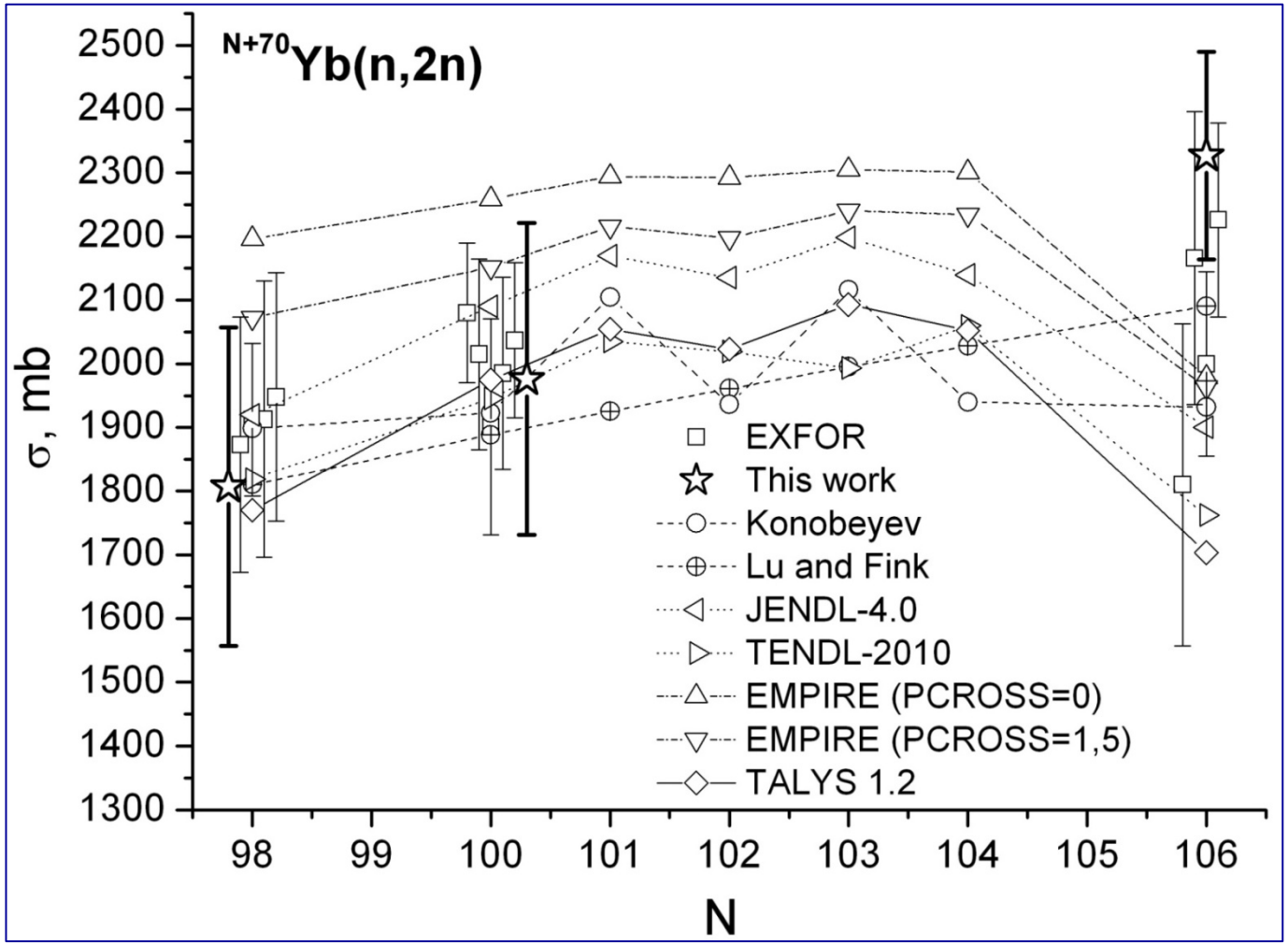
The (n,2n) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Erbium calculated by different systematics (Konobeyev, Lu and Fink), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (TENDL-2010, ENDF/B-VII.0)



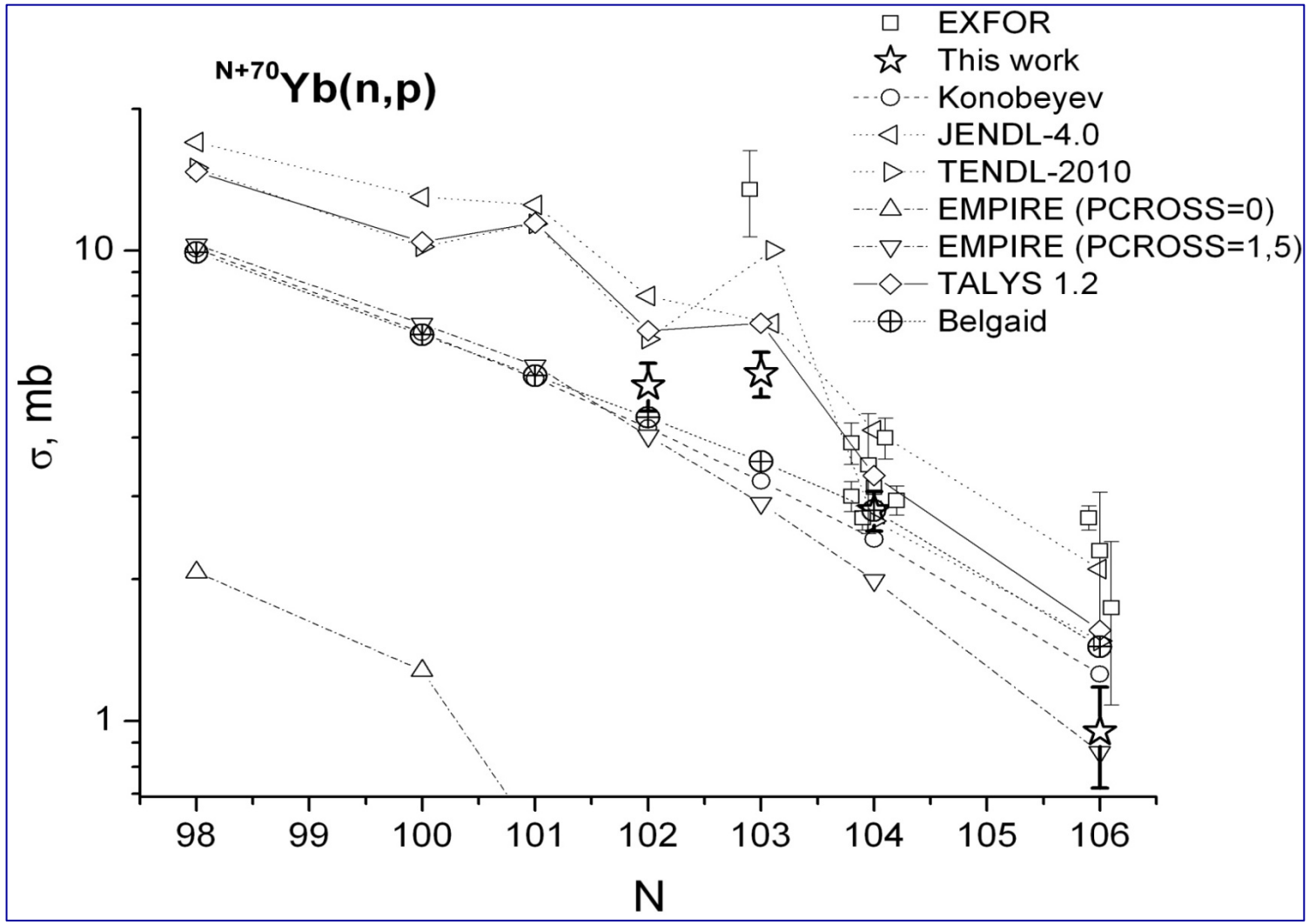
The (n,p) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Erbium calculated by different systematics (Konobeyev, Belgaid), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (TENDL-2010, ENDF/B-VII.0)



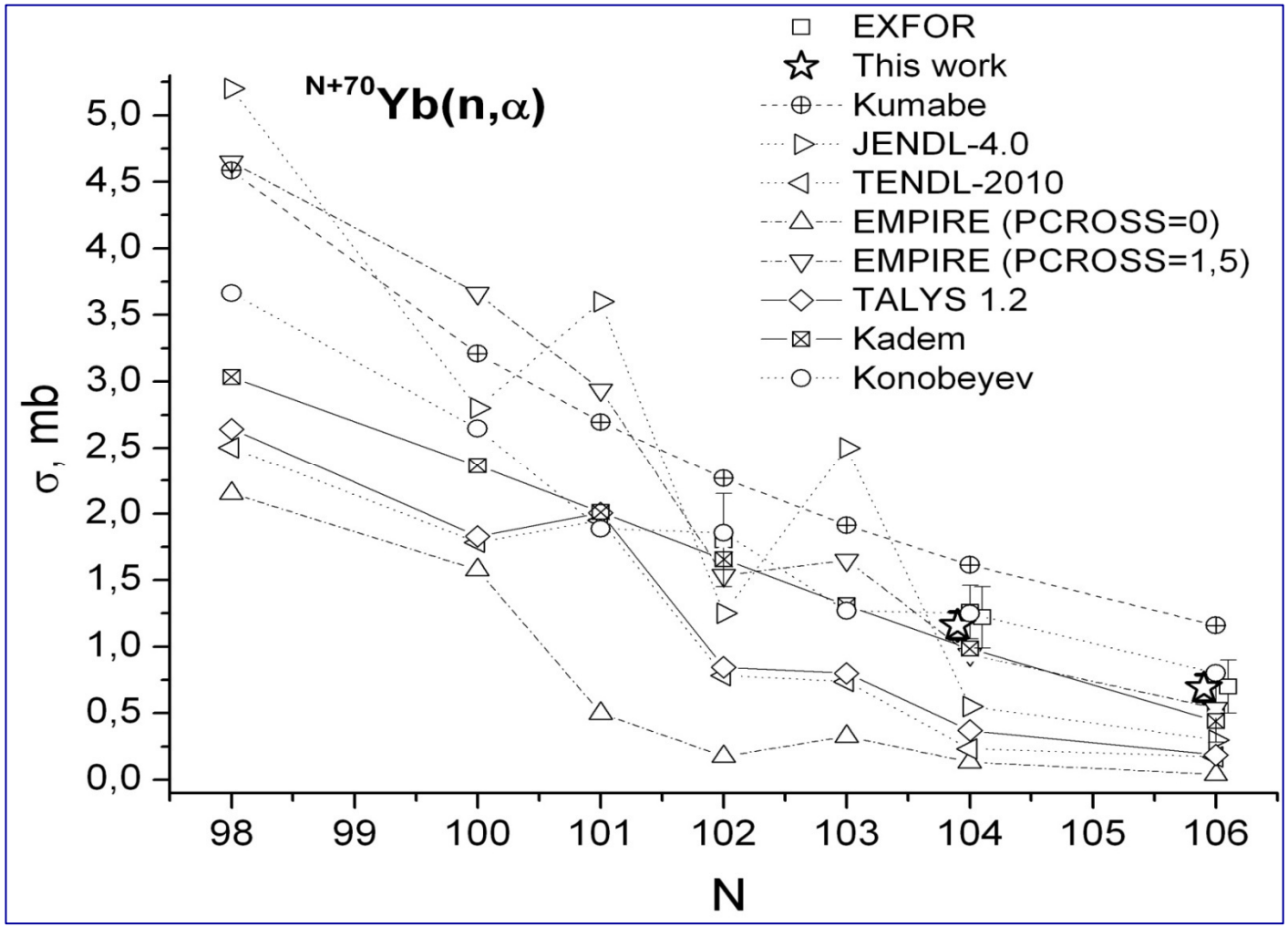
The (n,α) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Erbium calculated by different systematics (Konobeyev, Kadem, Kumabe), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (ENDF/B-VII.0)



The (n,2n) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Ytterbium calculated by different systematics (Konobeyev, Lu and Fink), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (TENDL-2010, ENDF/B-VII.0)



The (n,p) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Ytterbium calculated by different systematics (Konobeyev, Belgaid), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (TENDL-2010, ENDF/B-VII.0)



The (n,α) reaction cross section at the incident neutron energy region of 14.6 MeV for the isotopes of Ytterbium calculated by different systematics (Konobeyev, Kadem, Kumabe), nuclear codes (EMPIRE 3.0, TALYS 1.2) and obtained from the experimental data (EXFOR, This work), evaluated data (ENDF/B-VII.0)

Conclusions

- The cross section of the nuclear reactions (n, p), (n, α), (n, 2n) were measured on isotopes of dysprosium, erbium and ytterbium at the neutron energies (14.6 ± 0.2) MeV.
- Obtained results were compared to available experimental data, evaluated nuclear data, and the results of theoretical calculations. In most cases, the measured in this work data agreed within errors with the available experimental data.
- Calculated values of the reaction cross sections using EMPIRE 3.0 code with considering pre-equilibrium processes better describe experimental data than the calculations using TALYS 1.2 code with parameters in agreement, therefore, for estimation of the nuclear reaction cross section in this mass nuclei region can be recommended EMPIRE 3.0 code calculation.
- Konobeyev and Belgaid systematics are the most agreed with available experimental data and recommended for utilization.
- Presented results can be utilized in the field of nuclear energy applications as well as in a testing of nuclear reaction models.

Acknowledgements

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Thank you for your attention !!!!