International Atomic Energy Agency
Nuclear Data Services
Provided by the Nuclear Data Section

Technical Meeting on the International Network of Nuclear Reaction Data Centres (NRDC)

Centre for Photonuclear Experiments Data (CDFE)
Skobeltsyn Institute of Nuclear Physics
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The CDFE Progress Report on the photonuclear data compilation and evaluation activity for 2018/2019

V.V.Varlamov,
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to the Technical Meeting of the International Network of Nuclear Reaction Data Centres at the IAEA Headquarters, Vienna, Austria (9 - 12 April 2019) .

This report contains review of the CDFE main results for the period of time from the Technical Meeting of the International Network of Nuclear Reaction Data Centres (NRDC) at the Global Centre for Nuclear Energy Partnership (GCNEP), Bahadurgarh, Haryana, India from 1 to 4 May 2018.

The CDFE total permanent stuff:
3 professional, 2 general service officers and 2 students (bachelors) of the MSU Physics Faculty.

The main CDFE fields of activity were the following:

- **EXFOR compilation;**
- **EXFOR nuclear data superseding;**
- **NRDC2018 Actions implementation;**
- **photoneutron reaction cross section evaluation;**
- **participation the IAEA CRP;**
- **nuclear database service.**

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CDFE EXFOR Compilation

5 new CDFE EXFOR m095 - m099 TRANSes have been produced and transmitted to the IAEA NDS.
All TRANSes contain both 24 new ENTRYs and 65 old ENTRYs corrected in accordance with the new EXFOR format rules and the NRDC experts, first of all, Naohiko Otsuka, Michael Fleming and Shin Okumuro comments and recommendations.

On the whole new CDFE TRANSes have been produced in the reported period:

TRANS	Old	New	Total
m095	48	45	53
m096	9	3	12
m097	1	2	3
m098	2	11	13
m099	1	3	8
All	65	24	89

CDFE activity on EXFOR nuclear data superseding

In the frame of the IAEA CRP 1996 – 1999 many photoneutron reaction cross sections were evaluated using the special method for putting data obtained at Saclay into consistency with the data obtained at Livermore but without using the objective physical criteria of data reliability.

That method was used for joint evaluation of data obtained for 19 nuclei (^{51}V, ^{75}As, ^{89}Y, ^{90}Zr, ^{115}In, ^{116,117,118,120,124}Sn, ^{127}I, ^{133}Cs, ^{159}Tb, ^{165}Ho, ^{181}Ta, ^{197}Au, ^{208}Pb, ^{232}Th, ^{238}U) investigated at both Saclay and Livermore.

All evaluated cross sections were included into EXFOR ENTRY M0635.

Because of that almost all of those were superseded after obtaining the newly data evaluated using the data reliability criteria and experimental-theoretical method.

The list of the 54 EXFOR area M SUBENTs from ENTRY M0635 superseded by newly evaluated data was submitted to the IAEA NDS.

NRDC2018 Actions implementation

In accordance with the NRDC2018 meeting Action

A 49 Varlamov Check if the volume number is absent for VMU published in 1969 and before

the information table of complete list of VMU (Vestnik Moskovskogo Universiteta - Moscow University Physics Bulletin) volumes and numbers for period 1948 – 2018 was submitted as the Memo-CP/M-36.

It was concluded that the VMU volume number is absent for the issues published in 1948 to 1969 and 1996 to the present.

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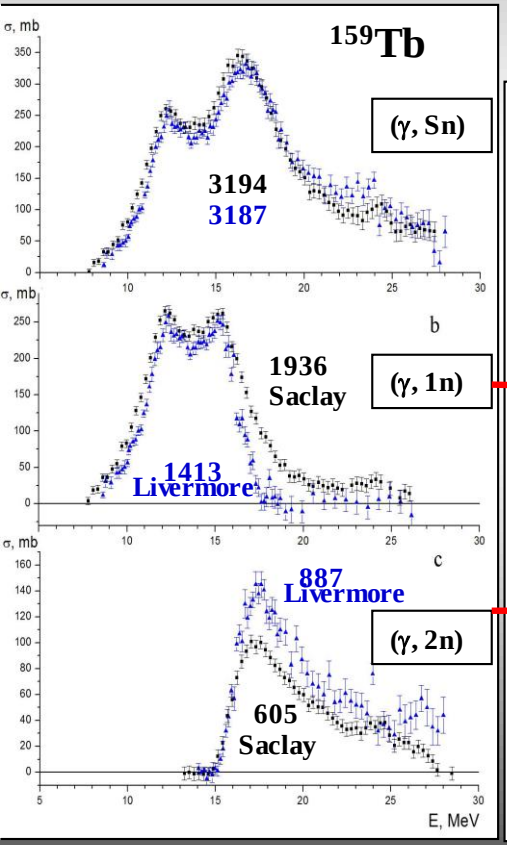
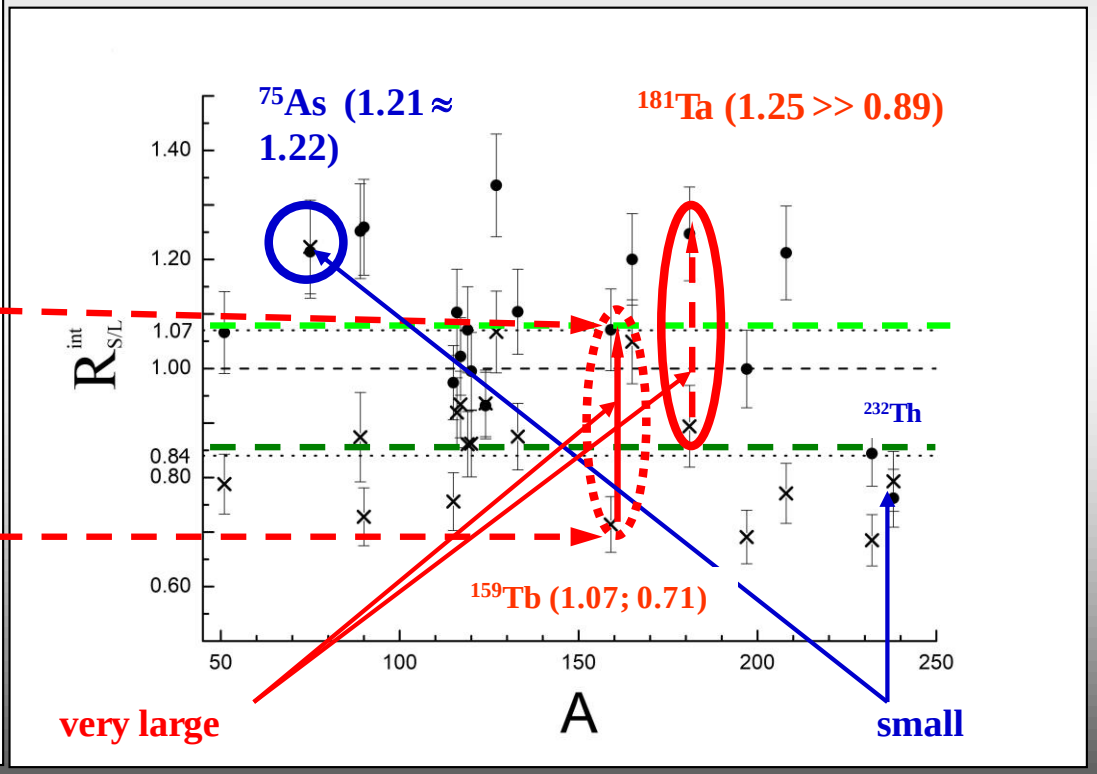
The main CDFE scientific activity is evaluation of photoneutron reaction cross sections obtained in various experiments

Main problem for 19 nuclei investigated in both Labs:
Cross sections for (γ, 1n) are larger at Saclay but for (γ, 2n) - at Livermore.

V.V.Varlamov, N.N.Peskov, D.S.Rudenko, M.E.Stepanov. Consistent Evaluation of Photoneutron Reaction Cross Sections Using Data Obtained in Experiments with Quasimonoenergetic Annihilation Photon Beams at Livermore (USA) and Saclay (France). INDC(CCP)-440, IAEA NDS, Vienna, Austria, 2004, p. 37.



Ratios of integrated cross sections $R^{int}_{S/L} = \sigma^{int}_{S} / \sigma^{int}_{L}$



Circles - ratios for (γ, 1n) reactions – are larger than 1.0:
<R> ~ 1.07.

Crosses - ratios for (γ, 2n) reactions – are smaller than 1.0:
<R> ~ 0.84.

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Very simple and convenient for using objective physical criteria of data reliability not dependent on the methods of their obtaining were proposed.

The most interesting is F_2 – effective tool for investigation of competition between three partial photoneutron reactions under discussion - (γ, 1n), (γ, 2n) and (γ, 3n).

$$F_2 = \frac{\sigma(\gamma, 2n)}{\sigma(\gamma, 1n) + 2\sigma(\gamma, 2n) + 3\sigma(\gamma, 3n) + \ldots}$$

In accordance with definition: $F_1 < 1.00$; $F_2 < 0.50$; $F_3 < 0.33$; $F_4 < 0.25$, $F_5 < 0.20$ …;

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New experimentally-theoretical method of evaluation

using combined model of photonuclear reactions:

- initial data – experimental cross section for the neutron yield reaction

$$(\gamma, Sn) = (\gamma, 1n) + 2(\gamma, 2n) + 3(\gamma, 3n) + \ldots$$

- competition of partial reactions based on theoretical model.

Theoretically calculated in the combined model of photonuclear reactions transitional multiplicity functions

$$F_i^{theor} = \sigma^{theor}(\gamma, in)/\sigma^{theor}(\gamma, Sn)$$

are used for cross section evaluation by following way

$$\sigma^{eval}(\gamma, in) = F_i^{theor}(\gamma, in) \bullet \sigma^{exp}(\gamma, Sn).$$

The evaluation method means that competition of partial reactions is described by the model and their correspondent sum $\sigma^{eval}(\gamma, Sn)$ is equal to the experimental $\sigma^{exp}(\gamma, Sn)$ reaction cross section.

Newly evaluated photoneutron reaction cross sections

In addition to many nuclei investigated before (^{59}Co, ^{63,65}Cu, ^{78,80,82}Se, ^{89}Y, ^{91,94}Zr, ^{115}In, ^{116}Sn, ^{133}Cs, ^{138}Ba, ^{140,142}Ce, ^{141}Pr, ^{159}Tb, ^{181}Ta, ^{186}W, ^{208}Pb, ^{209}Bi and some others)

8 new nuclei were investigated (^{75}As, ^{76}Se, ^{90,92}Zr, ^{98}Mo, ^{103}Rh, ^{153}Eu, ^{165}Ho).

For all 8 nuclei using experimental-theoretical method for evaluation of reliable partial

$(\gamma, 1n)$, $(\gamma, 2n)$, $(\gamma, 3n)$

and total photoneutron reaction

$(\gamma, tot) = (\gamma, 1n) + (\gamma, 2n) + (\gamma, 3n)$

reactions cross sections were obtained.

New reliable evaluated data were included into the EXFOR database.

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Participation the IAEA CRP

The Research Contract N 20501

"Evaluation of Partial and Total Photoneutron Reactions Cross Sections Using New Objective Physical Data Reliability Criteria"

in the frame of the Coordinated Research Project N F41032

"Updating the Photonuclear Data Library and generating a reference database for Photon Strength Functions":

- obtaining new of partial and total photoneutron reactions using physical data reliability criteria and experimental-theoretical method of evaluation (^{63,65}Cu, ^{75}As, ^{76,78,80,82}Se, ^{89}Y, ^{103}Rh, ^{133}Cs, ^{139}La, ^{140,142}Ce, ^{138}Ba, ^{141}Pr, ^{145,148}Nd, ^{160}Gd, ^{165}Ho, ^{186}W, ^{197}Au, ^{209}Bi).

- comparison of new evaluated data with new experimental data obtained using modern facilities, first of all quasi-monochromatic laser Compton-scattering (LCS) γ-ray beams at the NewSUBARU synchrotron radiation facility (Japan) and the novel technique of direct neutron-multiplicity sorting with a flat-efficiency detector;

- comparison of new evaluated data with the results of multi-nucleon reaction yields obtained using bremsstrahlung and activation method at the MSU SINP race-track microtron.

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CDFE Nuclear Database Service

The main CDFE nuclear database service activities are dissemination of modern international nuclear data for providing Lomonosov Moscow State University (Skobeltsyn Institute of Nuclear Physics, primarily) staff and students and also scientific and educational institutes and organizations of Russian Academy of Science with nuclear data for basic research, education and various applications.

EXFOR, ENSDF, and NSR databases are based on the international data sources (USA NNDC and NSDD) but have original Search Engines.

Publications

4 correspondent articles were submitted to the International Conference on Nuclear Data for Science and Technology "ND-2019", Beijing, China, 19-24 May, 2019 and 69th Meeting on Nuclear Spectroscopy and Atomic Nucleus Structure (Nucleus 2019), July 01-05, 2019, Dubna, Russia.

New obtained data were presented as talks at the 68th Meeting on Nuclear Spectroscopy and Atomic Nucleus Structure, «Nucleus 2018», 1 – 6 July 2018, Voronezh, Russia and published in the following journals:
Physical Review C,
Physics of Atomic Nuclei,
Bulletin of the Russian Academy of Sciences,
Moscow University Physics Bulletin,
Memoirs of the Faculty of Physics of Lomonosov Moscow State University.

The number of articles published by the CDFE in 2018/2019 is 10.

2018/2019 Publications

1. V.V.Varlamov, A.I.Davydov, B.S.Ishkhanov, V.N.Orlin. The reliability of photoneutron cross sections for ^{90,91,92,94}Zr. Eur. Phys. J. A 54 (2018) 74.

2. V.V.Varlamov, V.D. Kaidarova. Evaluation of Reliable Cross Sections of Partial and Total Photoneutron Reactions for the ^{139}La Nucleus. Bull. Rus. Acad. Sci. Phys., 82, №6 (2018) 614.

3. V.V.Varlamov, V.D.Kaidarova, M.E.Stepanov. The Reliability of Cross Sections of Partial Photoneutron Reactions for ^{98}Mo. Moscow University Physics Bulletin, 2018, V. 73, N. 1, 68.

4. V.V.Varlamov, V.D.Kaidarova. Reliability of the partial photoneutron reaction cross sections for ^{139}La and ^{145,148}Nd. Memoirs of the Faculty of Physics of the Lomonosov Moscow State University, N4, 2018, 1840201.

5. V.V.Varlamov, A.I. Davydov. New photoneutron reaction cross section data for ^{153}Eu and ^{165}Ho. LXVIII International Conference «Nucleus-2018». Fundamental Problems of Nuclear Physics, Atomic Power Engineering and Nuclear Technologies (LXVIII Meeting on Nuclear Spectroscopy and Nuclear Structure), July 2 – 6, 2018, Voronezh, Russia. Book of Abstracts. Saint Petersburg, Publishing VVM, 2018, p. 97.

6. V.V.Varlamov, V.D. Kaydarova. Evaluation of reliable partial and total photoneutron reaction cross sections for ^{145,148}Nd. LXVIII International Conference «Nucleus-2018». Fundamental Problems of Nuclear Physics, Atomic Power Engineering and Nuclear Technologies (LXVIII Meeting on Nuclear Spectroscopy and Nuclear Structure), July 2 – 6, 2018, Voronezh, Russia. Book of Abstracts. Saint Petersburg, Publishing VVM, 2018, p. 98.

7. V.V. Varlamov, V.D. Kaidarova, V.N. Orlin. New reliable data on the photodisintegration of ^{160}Gd. Memoirs of the Faculty of Physics of the Lomonosov Moscow State University, N1, 2019, 1910202.

8. V.V.Varlamov, A.I.Davydov, B.S.Ishkhanov. New data on photoneutron reaction cross sections for ^{76,78,80,82}Se nuclei. Physics of Atomic Nuclei, 82, N1 (2019) 13.

9. V.Varlamov, A.Davydov, V.Kaidarova. Evaluation of reliable cross sections of photoneutron reactions on ^{103}Rh и ^{165}Ho. Yadernaya Fizika, 82, N3 (2019) 1 (Phys. Atom. Nucl. 2019, submitted).

10. V.Varlamov, A.Davydov, V.Kaidarova, V. Orlin. Photoneutron reaction cross-section data for ^{75}As: experiments and evaluation. Phys. Rev. C 99, N 2 (2019) 024608.

Short-term (2019/2020) CDFE Program

The main items of CDFE (2019/2020) program, main priorities and most important tasks are traditional and the following:

- continuation of new photonuclear data compilation using EXFOR format, new TRANSes (M100, M101, etc.) production;

- correction of old ENTRYs in accordance with new EXFOR coding rule changes and the NRDC Network experts comments and recommendations;

- continuation of analysis and evaluation using objective physical criteria of total and partial photonuclear reaction cross sections obtained in various experiments;

- upgrading of all databases put upon the CDFE Web-site (http://cdfe.sinp.msu.ru).

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THANKS A LOT FOR ATTENTION!