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

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

Centre for Photonuclear Experiments Data (CDFE)
Skobeltsyn Institute of Nuclear Physics
Lomonosov Moscow State University

The CDFE 2017/2018 Progress Report on the results of photonuclear data compilation and evaluation.

V.V.Varlamov, A.I.Davydov,V.D.Kaydarova, M.E.Stepanov

1 - 4 May 2018, Bahadurgarh, Haryana, India

The CDFE 2017/2018 Progress Report on the results of photonuclear data compilation and evaluation

***V.V.Varlamov*, A.I.Davydov, V.D.Kaydarova, M.E.Stepanov**

Progress report
to the Technical Meeting of the International Network of Nuclear Reaction Data Centres
at the Global Centre for Nuclear Energy Partnership (GCNEP), Bahadurgarh, Haryana, India (1 - 4 May 2018) .

This report contains review of the Russia Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics Centre for Photonuclear Experiments Data (CDFE - Centr Dannykh Fotoyadernykh Eksperimentov) main results for the period of time from the Technical Meeting of the International Network of Nuclear Reaction Data Centres (NRDC) at the IAEA Headquarters in Vienna, Austria (23 - 26 May 2017) concern new photonuclear data compilations and old data corrections, analysis and evaluation of photonuclear data obtained in various experiments and nuclear data service in the whole.

The main CDFE responsibility in the NRDC Network is compilation and processing of photonuclear data. The main CDFE scientific activity is evaluation of photonuclear reaction cross sections using data obtained in various experiments.

The CDFE total permanent stuff includes now three professional, three general service officers and two students of the MSU Physics Faculty.

The CDFE maintains several nuclear databases available through the CDFE Web-site – http://cdfe.sinp.msu.ru for solving the main task - dissemination of international nuclear data for providing Lomonosov Moscow State University (Skobeltsyn Institute of Nuclear Physics, primarily) and scientific and educational institutes and organizations of Russian Academy of Science for basic research, education and various applications.

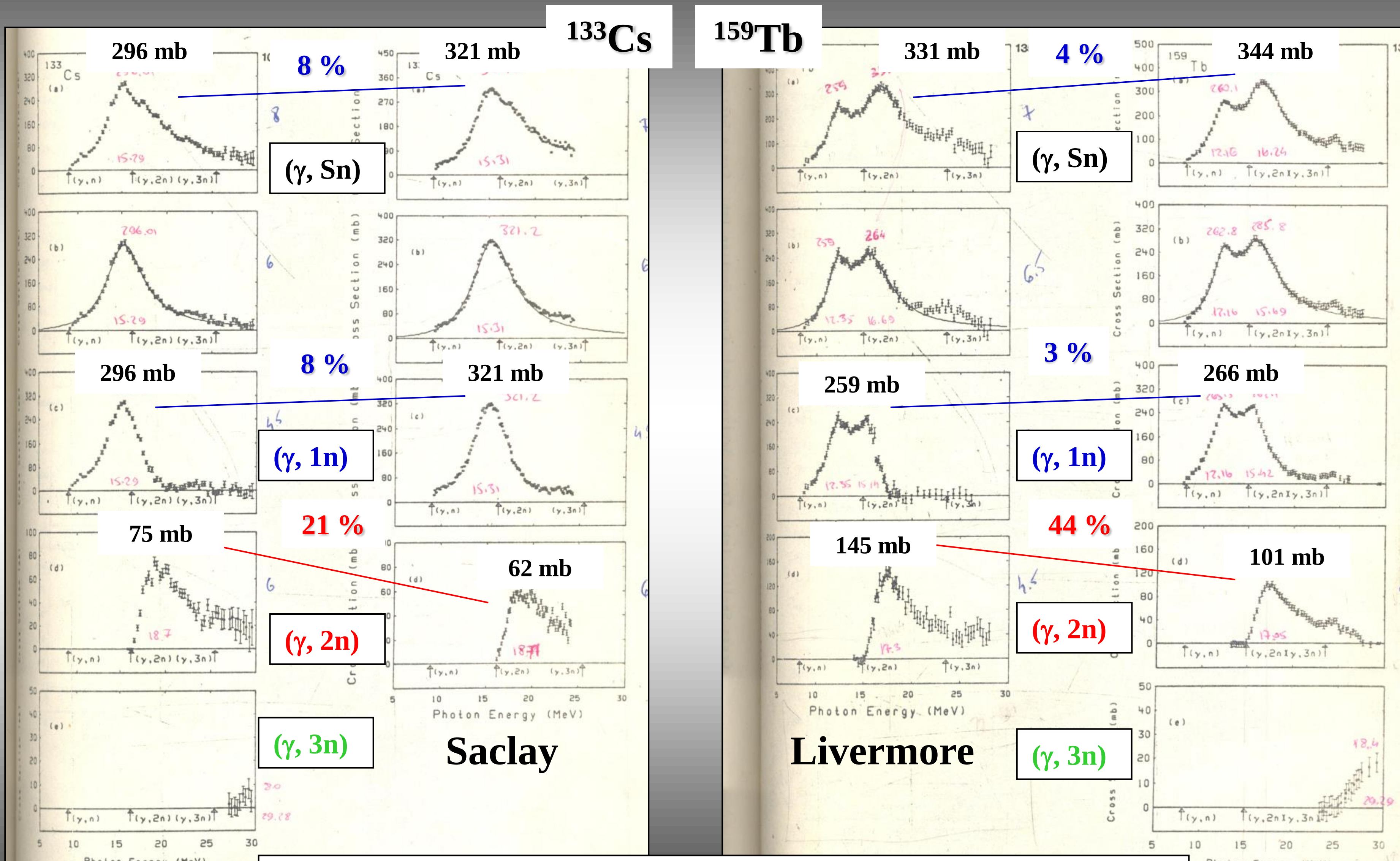
CDFE EXFOR Compilation

7 new CDFE EXFOR **trans.m088 - 094** transes and *1* ***prelim.m095*** have been produced and transmitted to the IAEA NDS.
All TRANSes contain both **32** (37) new ENTRYs and **55 (107)** old ENTRYs corrected in accordance with the new EXFOR format rules and the NRDC experts,
first of all Naohiko Otsuka and Manuel Bossant comments and recommendations and with the great help of Svetlana Dunaeva.

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

TRANS	Old	New	Total
m088	**18**	**4**	**22**
m089	**2**	**4**	**6**
m090	**2**	**1**	**3**
m091	**3**	**2**	**5**
m092	**1**	**14**	**15**
m093	**1**	**7**	**8**
m094	**28**	**0**	**28**
prelim.m095	**52**	**5**	**50**
All	**55 (*107*)**	**32 (*37*)**	**79 (*129*)**

CDFE Photonuclear Data Evaluation



S.S.Dietrich and B.L.Berman. Atom. Data and Nucl. Data Tables, 38 (1988) 199

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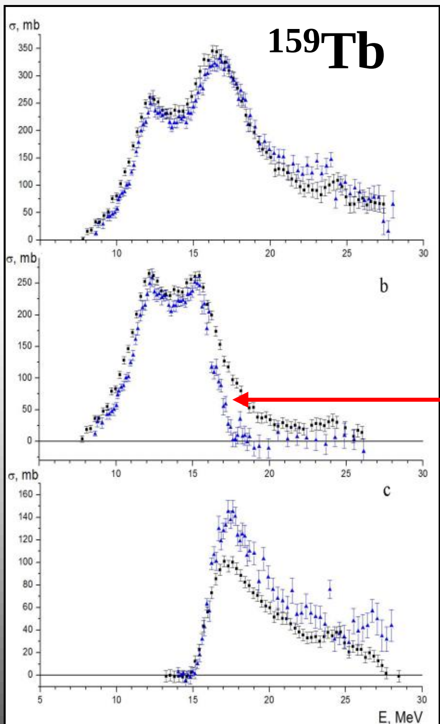
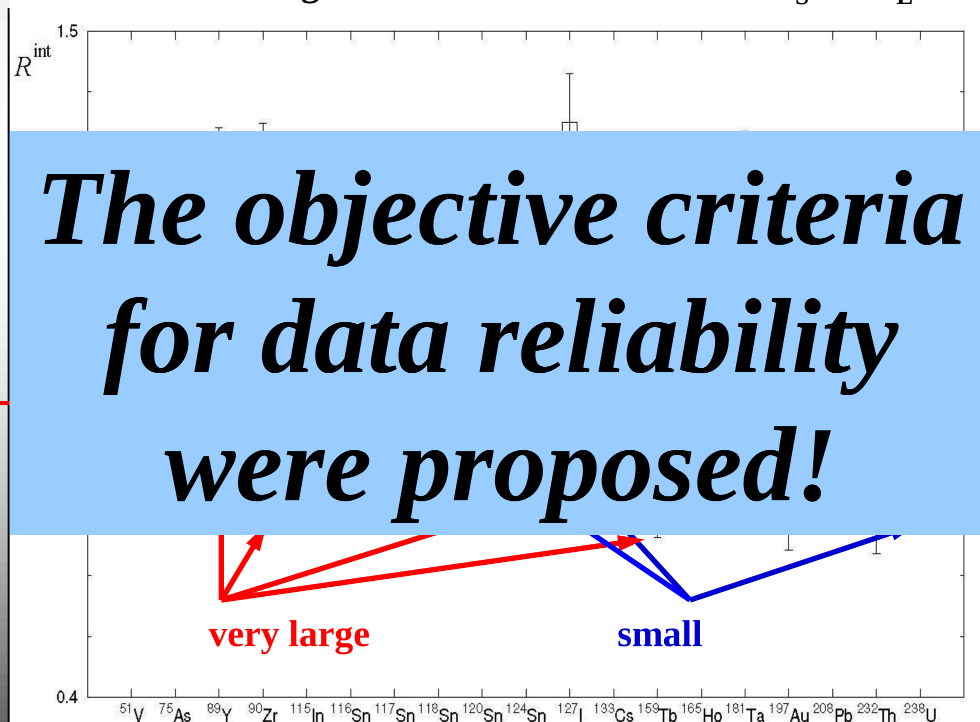
Main problem for 19 nuclei investigated in both Labs:

(γ, 1n) cross sections are larger at Saclay but those 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 $R^{int} = \sigma^{int}_S / \sigma^{int}_L$



The objective criteria for data reliability were proposed!

Squares - ■ - ratios for (γ, 1n) reactions – are larger than 1.0:

<R> ~ 1.07.

Triangles - △ - ratios for (γ, 2n) reactions – are smaller than 1.0:

<R> ~ 0.84.

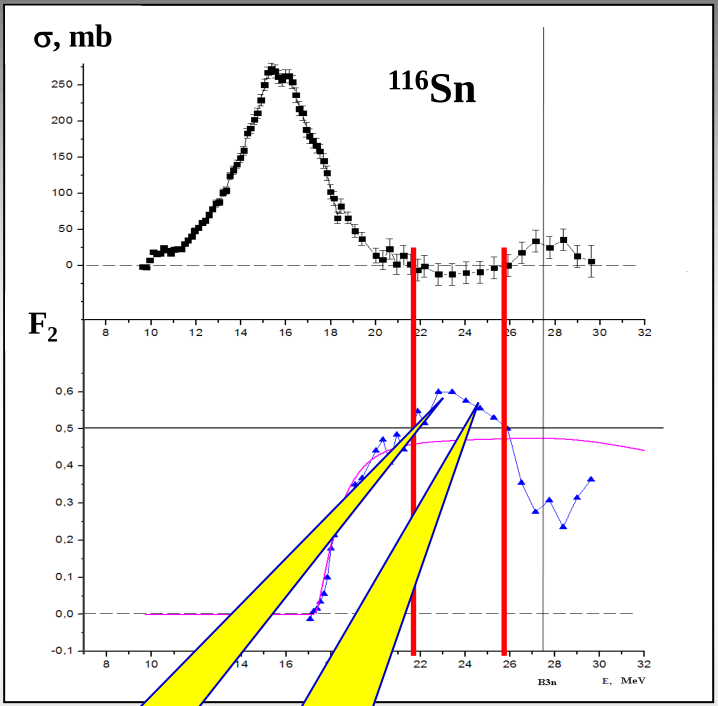
Very simple and convenient for using
objective physical criteria of data reliability
not dependent on the methods of their obtaining were proposed.

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

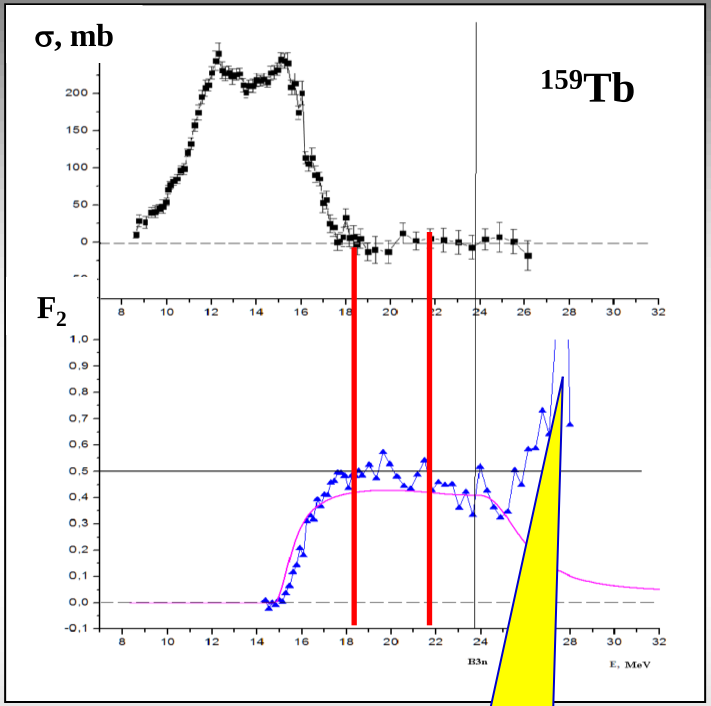
Some examples of Livermore data



$\sigma(\gamma, 1n)$

negative values

$F_2 > 0.50$

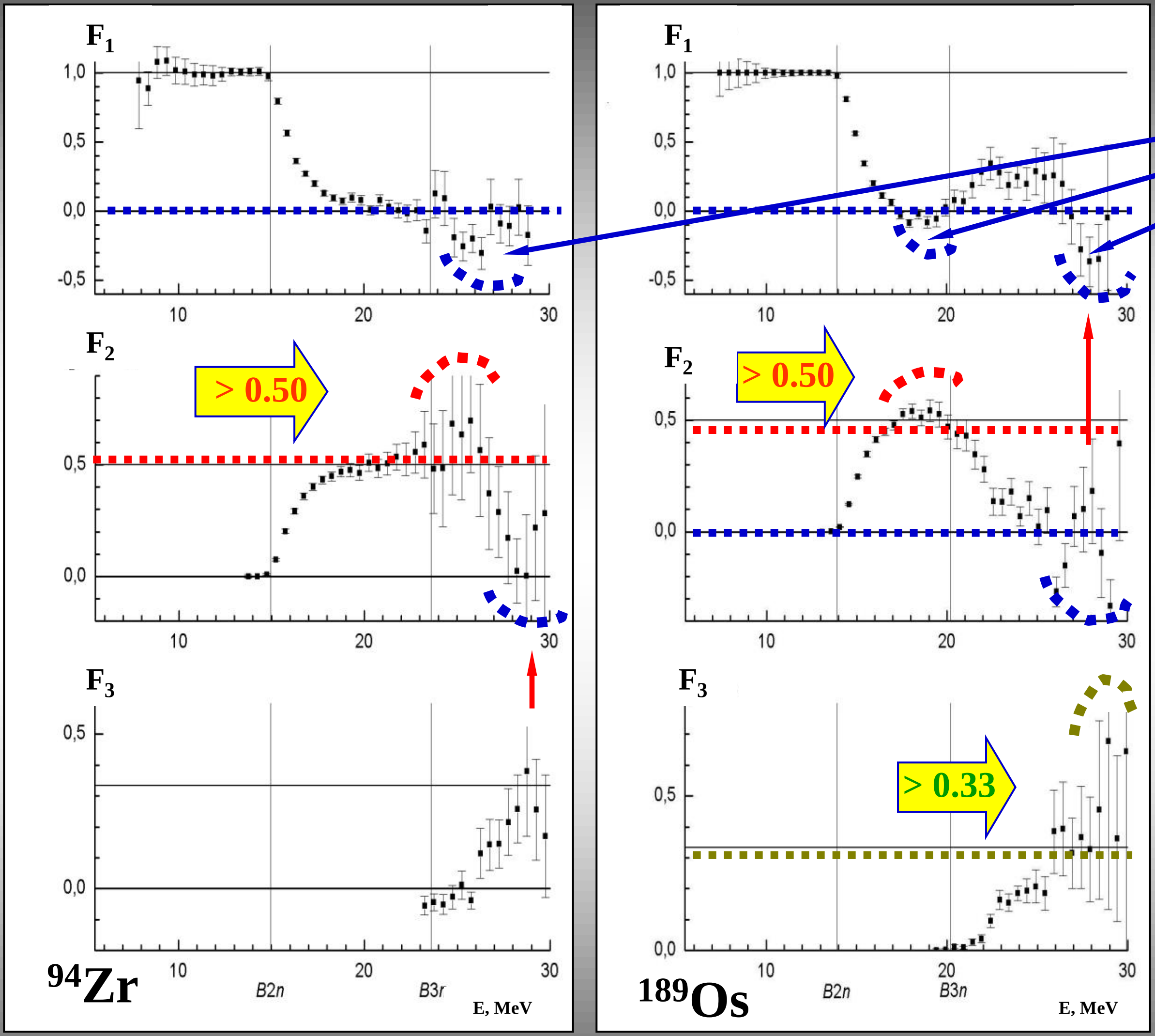


$F_2 > 0.50$!

Decrease before B3n

$F_2 \approx$ 2.00?!

Physically not reliable negative cross section values are correlated with physically forbidden values $F_2 > 0.50$



Physically forbidden negative values

Physically unreliable values: $F_2 > 0.50$

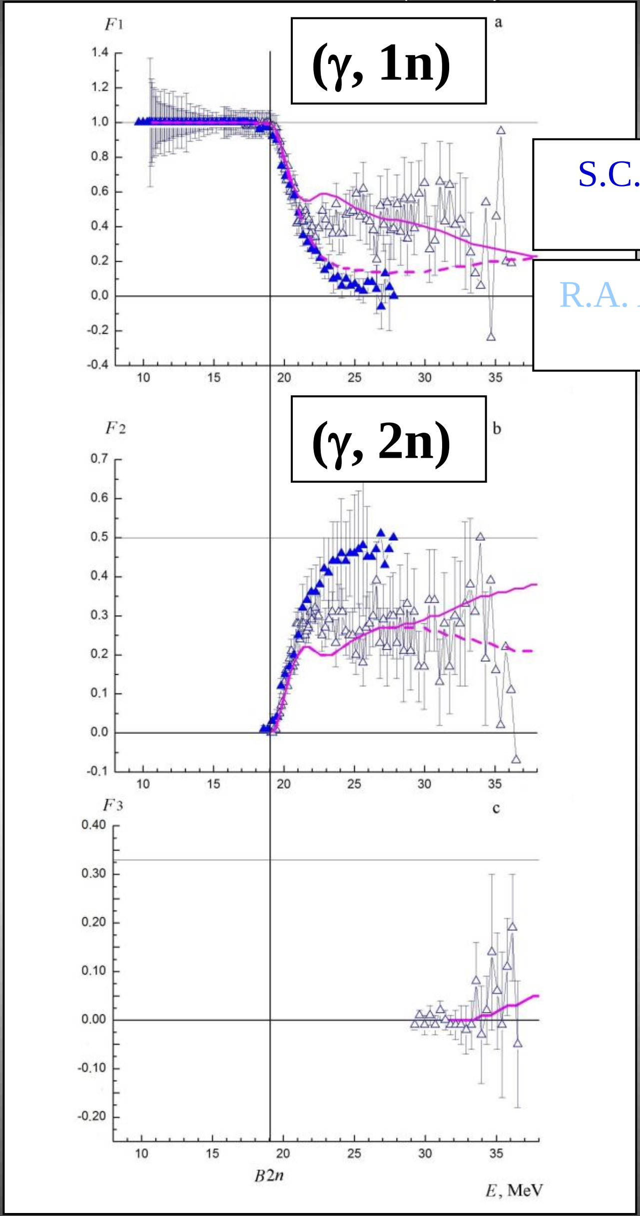
Physically forbidden negative values

Physically unreliable values: $F_3 > 0.33$

The reliability of many data is doubtful.

Many data should be reanalyzed and reevaluated!

Livermore data for ^{59}Co



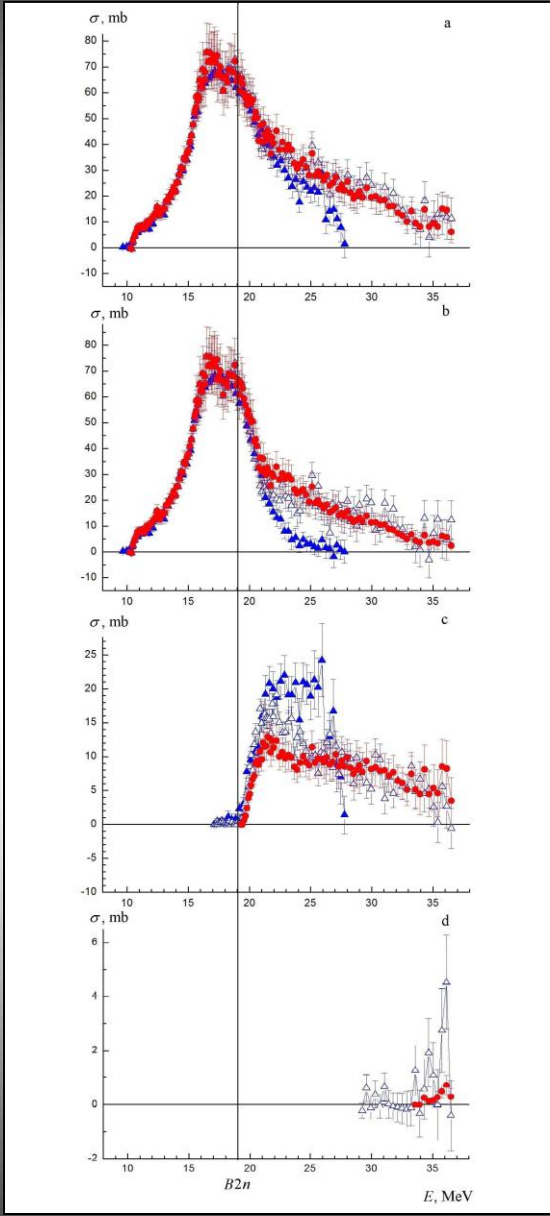
S.C. Fultz et.al., 1962. Phys. Rev. 128. 2345 - filled triangles

R.A. Alvarez et al., 1979. Phys. Rev. C 20. 128 - open triangles

Significant differences between two experiments data.

Significant differences between experimental and theoretical data.

Evaluated data:
V.V.Varlamov et. al., Eur. Phys. J. A, 53 (2017) 180.



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.

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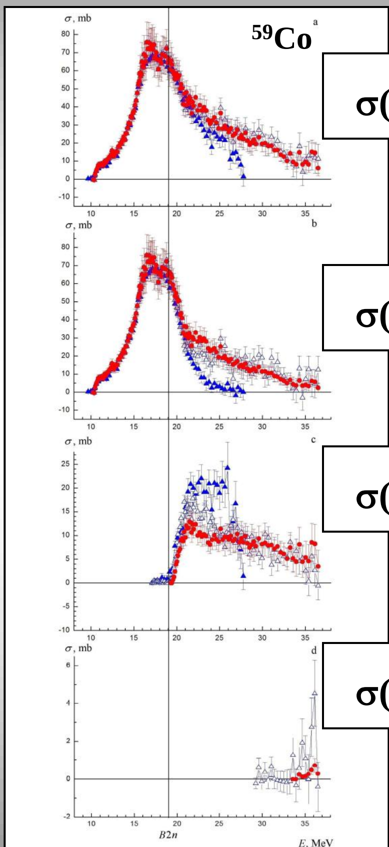
(γ, tot) = (γ,1n) + (γ,2n) + (γ,3n)

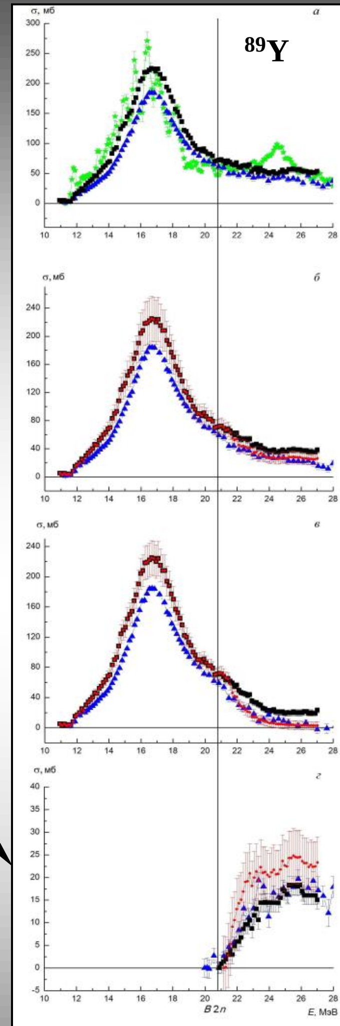


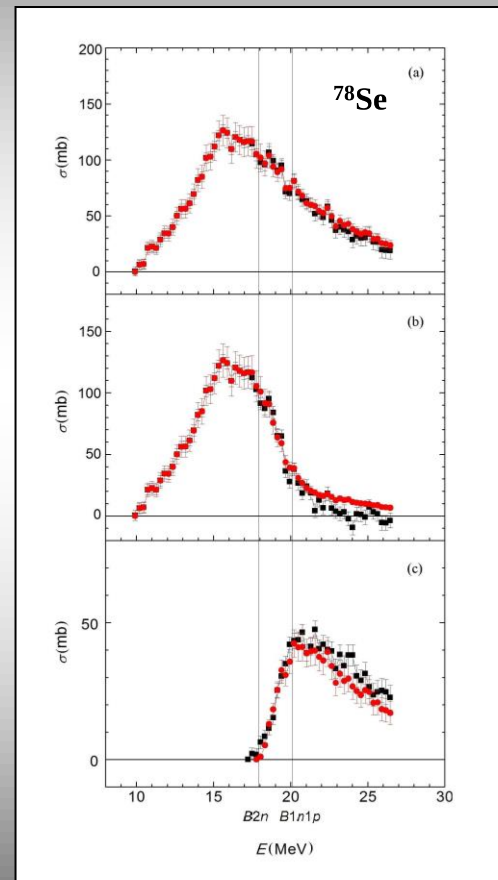
σ(γ, tot)

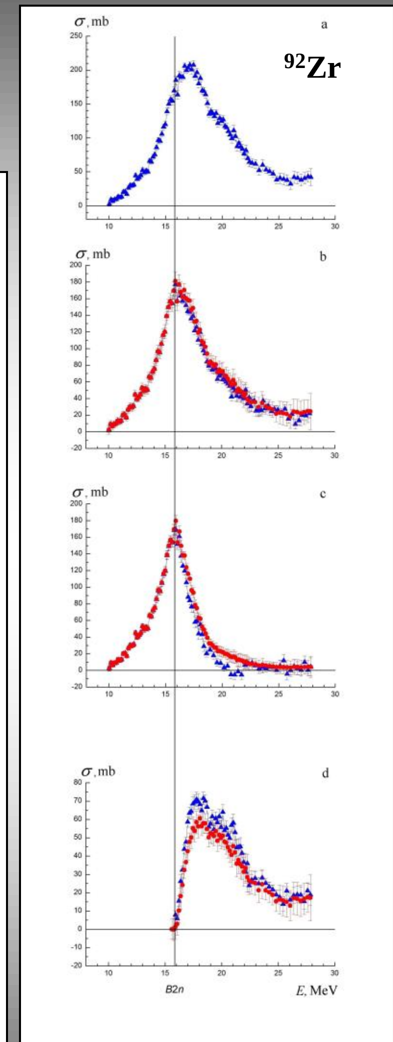
σ(γ, 1n)

σ(γ, 2n)

σ(γ, 3n)

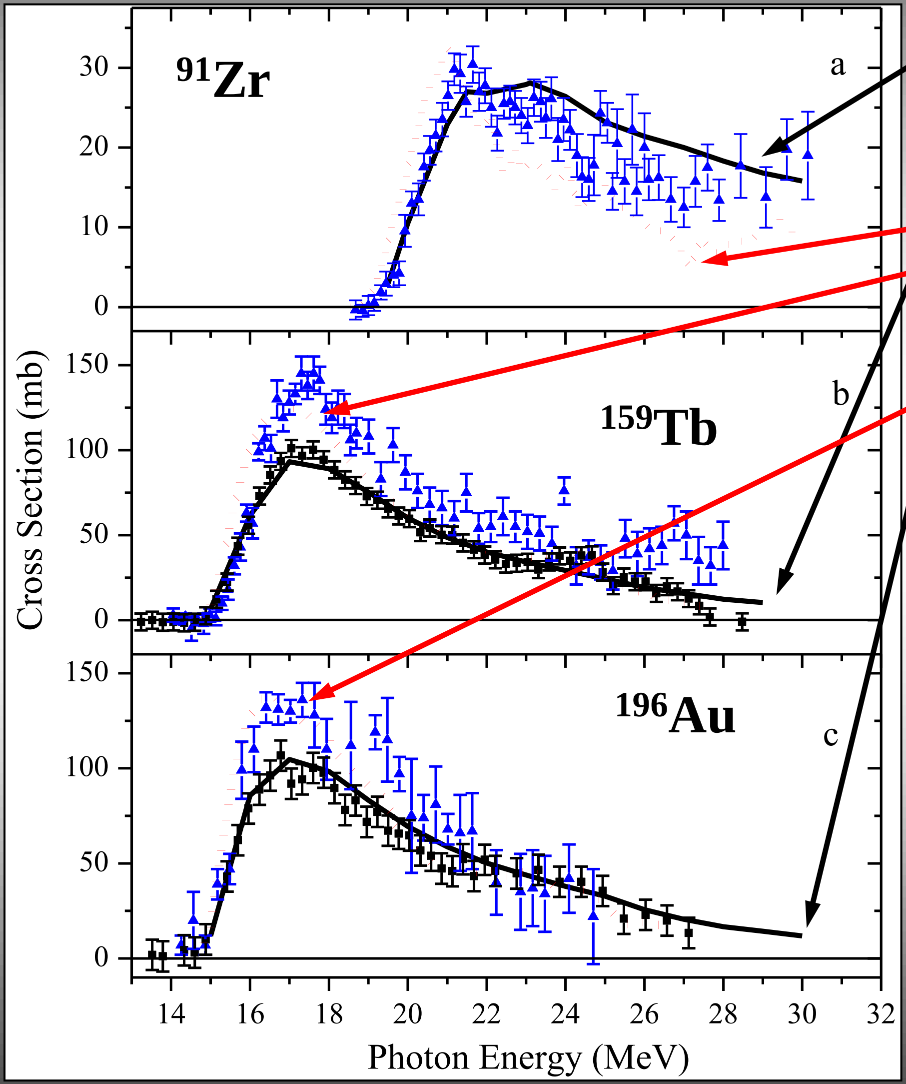






The evaluated cross sections noticeably differ from the experimental once.

σ(γ, 2n)



IAEA CRP (1996 – 1999) evaluations (GUNF and GNASH codes)

are quite different from our evaluations based on F-functions

Previous CRP evaluation has been done to model accurately Saclay (γ, tot) data.

The possible reason for new and old evaluations disagreements:

Because at energies below B3n
σ(γ, tot) ≈ σ(γ, Sn) - σ(γ, 2n)
large systematic errors in σ(γ, 2n) can lead to systematic errors in σ(γ, tot)
and correspondingly
to those in data for partial reaction cross sections evaluated on the base of using σ(γ, tot).

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”.

In addition to activity in photonuclear data compilation and the CDFE continued the program of investigation of reliability partial photoneutron reaction cross sections obtained in various experiments using specially proposed objective physical criteria of data reliability. In addition to many nuclei investigated before (for example ^{63,65}Cu, ^{80}Se, ^{89}Y, ^{94}Zr, ^{115}In, ^{116}Sn, ^{133}Cs, ^{138}Ba, ^{141}Pr, ^{159}Tb, ^{165}Ho, ^{181}Ta, ^{186}W, ^{208}Pb, ^{209}Bi) 12 new nuclei were investigated (^{59}Co, ^{76,78,82}Se, ^{90,91,92}Zr, ^{98}Mo, ^{140,142}Ce, ^{141}Pr, ^{153}Eu).

For all 12 nuclei using experimental-theoretical method for evaluation of reliable partial (γ, 1n), (γ, 2n), (γ, 3n) and total photoneutron reaction (γ, tot) = (γ, 1n) + (γ, 2n) + (γ, 3n) reactions cross sections were obtained.

New reliable evaluated data were prepared for including into the EXFOR database, maintained both in the Web-sites of the:

IAEA NDS (https://www-nds.iaea.org/exfor/esfor.htm),

USA NNDC (http://www.nndc.bnl.gov/exfor.htm),

CDFE (http://cdfe.sinp.msu.ru/exfor/index.php).

The correspondent talks were presented at the 67th Meeting on Nuclear Spectroscopy and Atomic Nucleus Structure, «Nucleus 2017», 12 – 15 September 2017, Almaty, Kazakhstan.

Correspondent articles were submitted to the 68th Meeting on Nuclear Spectroscopy and Atomic Nucleus Structure), July 01-06, 2018, Voronezh, Russia and to the journals Physical Review C, European Physical Journal A, EPJ Web of Conference, Physics of Atomic Nuclei and Bulletin of the Russian Academy of Sciences, Journal of Faculty of Physics of Lomonosov Moscow State University, Memoirs of the Faculty of Physics of Lomonosov Moscow State University.

Articles published by the CDFE on all area in 2017 – 2018 are 16 .

Main (from 16) Publications

1. V. Varlamov, B. Ishkhanov, V. Orlin. Reliability of (γ,1n), (γ,2n), and (γ,3n) cross-section data on ^{159}Tb. Phys. Rev. C, 95, N5 (2017) 054607.

2. V.Varlamov, B.Ishkhanov, V.Orlin. Experimental and evaluated photoneutron cross sections for ^{197}Au. Phys Rev. C 96, N4 (2017) 044606.

3. V.V.Varlamov, A.I.Davydov, B.S.Ishkhanov. Photoneutron cross sections for ^{59}Co: Systematic uncertainties of data from various experiments. Eur. Phys. J. A, 53 (2017) 180.

4. Vladimir Varlamov, Boris Ishkhanov, Vadim Orlin, Nikolai Peskov, Mikhail Stepanov. Photoneutron reaction cross sections from various experiments – analysis and evaluation using physical criteria of data reliability. EPJ Web of Conferences, 146 (2017) 05005.

5. B.S.Ishkhanov, V.N.Orlin, N.N.Peskov, V.V.Varlamov. Photoneutron reactions in the range of Giant Dipole Resonance. Physics of Particles and Nuclei, 48, N1 (2017) 76 – 83.

6. V.V.Varlamov, B.S.Ishkhanov. Modern status of photonuclear data. Physics of Atomic Nuclei, 80, N5 (2017) 957 - 967.

7. V.V.Varlamov, B.S.Ishkhanov, V.N.Orlin. Evaluated cross sections for photoneutron reactions on the isotope ^{116}Sn and spectra of neutrons originating from these reactions. Physics of Atomic Nuclei, 80, N6 (2017) 1106 – 1118.

8. V.V.Varlamov, A.I.Davydov, V.N.Orlin, N.N.Peskov. Physical criteria of the reliability of data on the photodisintegration of the ^{89}Y nucleus. Bull. Rus. Acad. Sci. Phys., 81, №6 (2017) 664 - 669.

9. V.V.Varlamov, V.N.Orlin, and N. N. Peskov. Cross sections of the photoneutron reaction for ^{141}Pr and ^{186}W nuclei, estimated from physical criteria of data reliability. Bull. Rus. Acad. Sci. Phys., 81, №6 (2017) 670 - 678.

10. V. V. Varlamov, B. S. Ishkhanov, A. A. Kuznetsov, V. N. Orlin, A. A. Prosnyakov. Influence of models of the atomic nuclei on the evaluated cross sections of photonuclear reactions on ^{116}Sn. Memoirs of the Faculty of Physics of Lomonosov Moscow State University, N3, 2017, 17302.

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.

Nuclear Database Service

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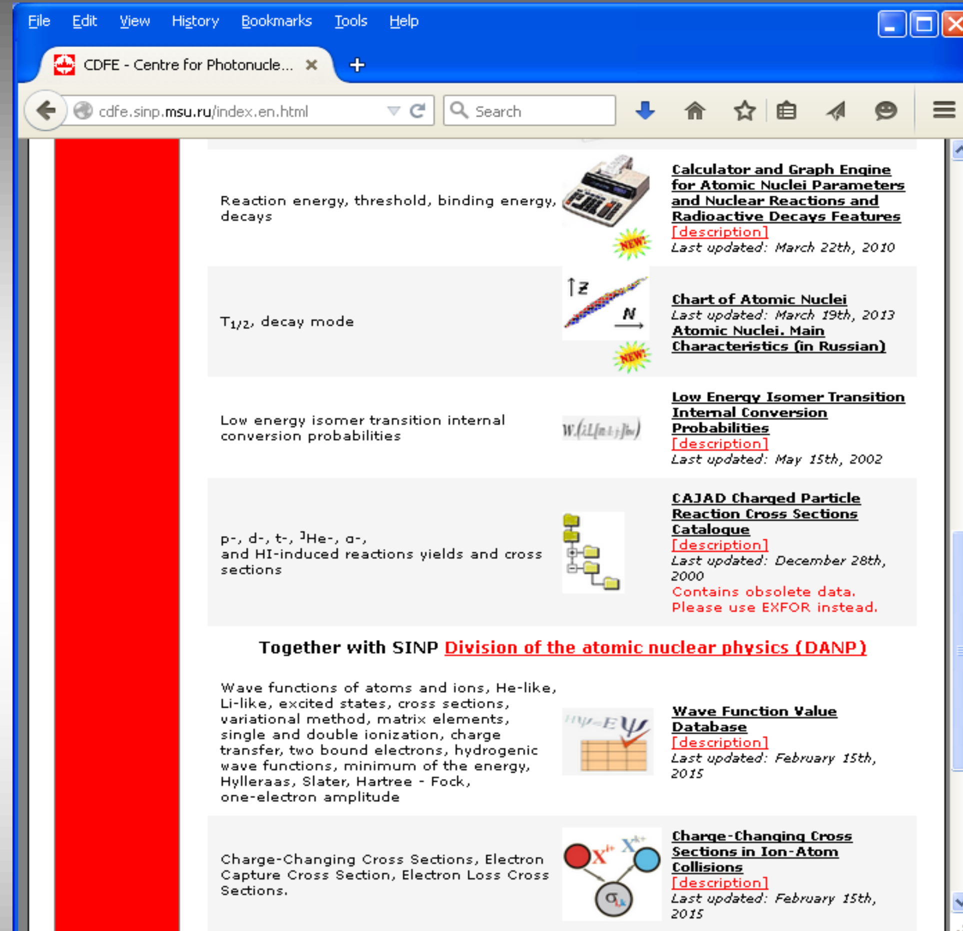

EXFOR, ENSDF, and NSR databases are based on the international data sources (USA NNDC and NSDD) but have original Search Engines.

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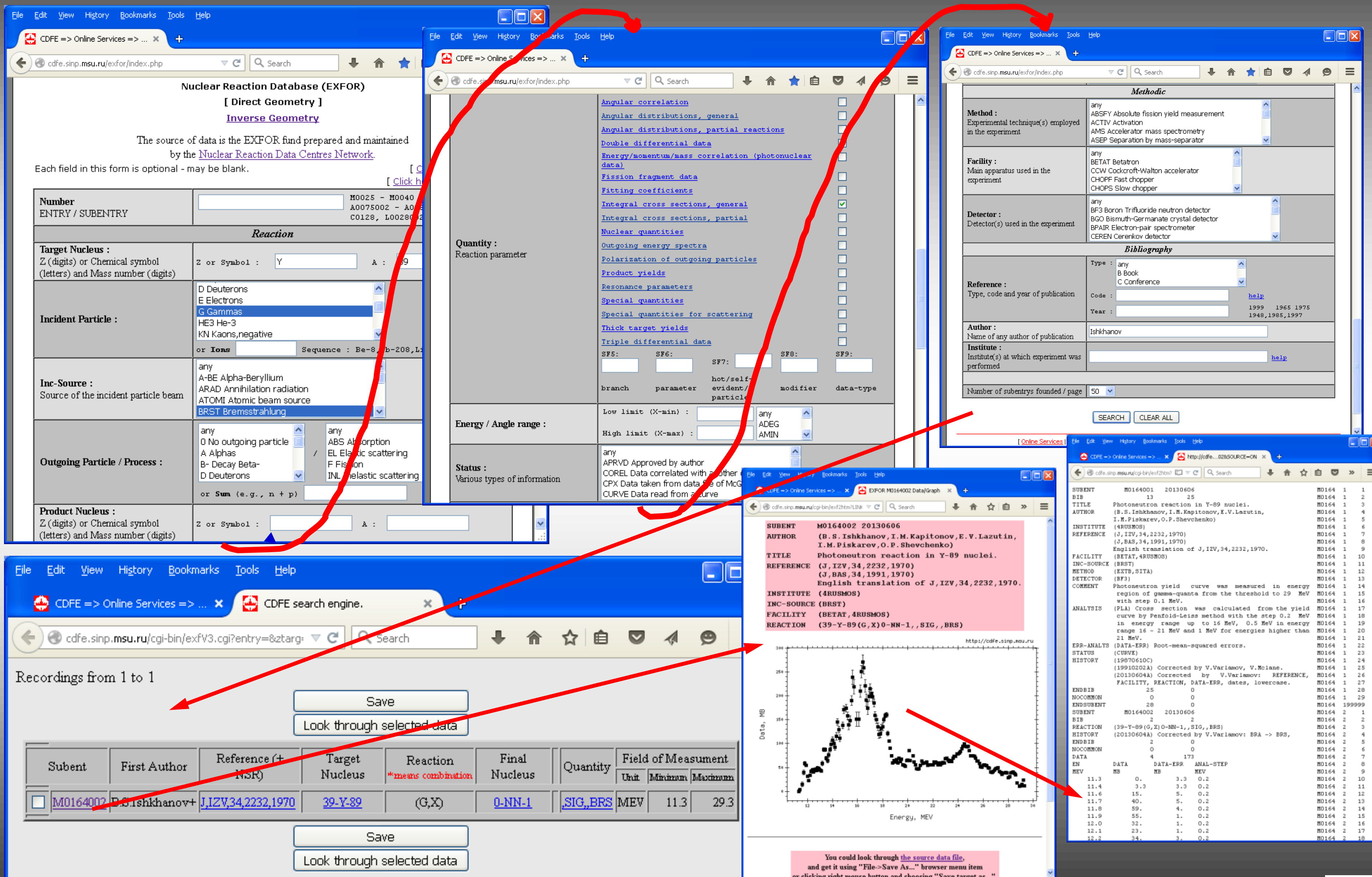
The main database: EXFOR



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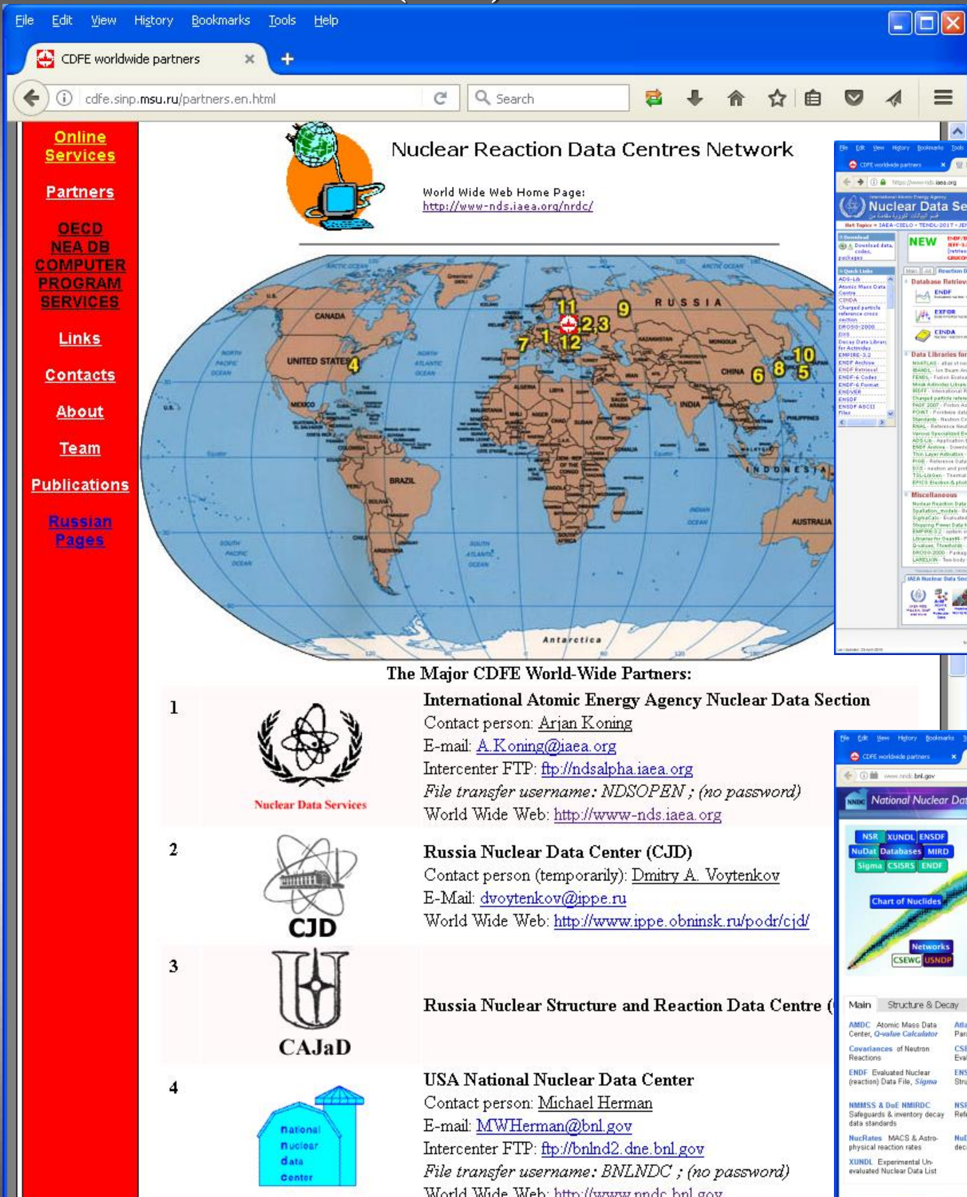

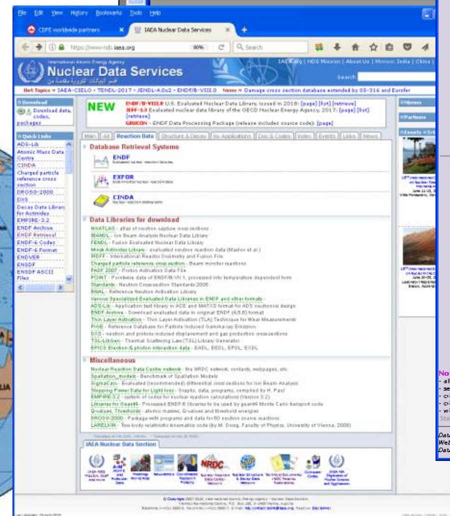

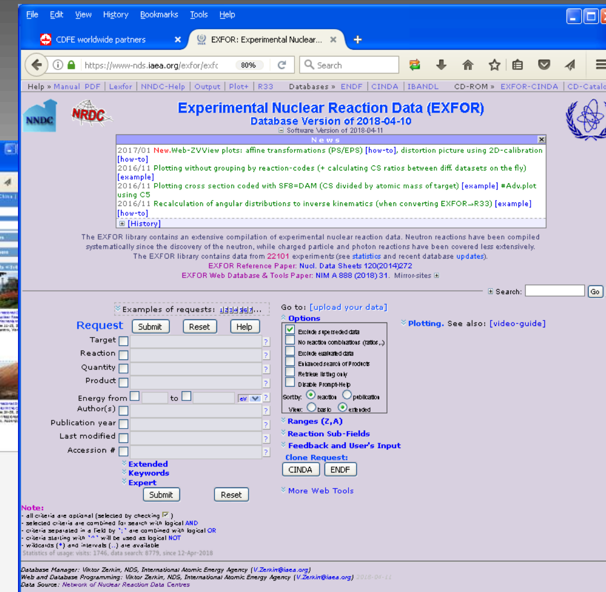

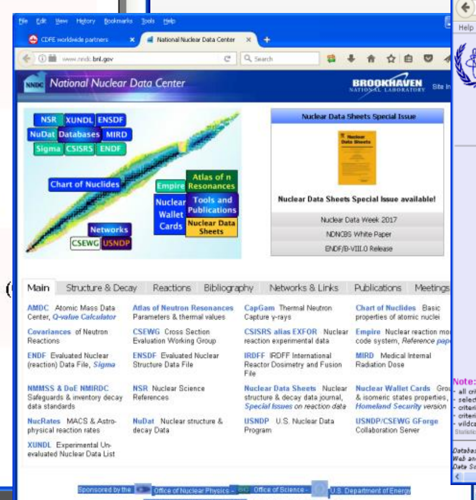

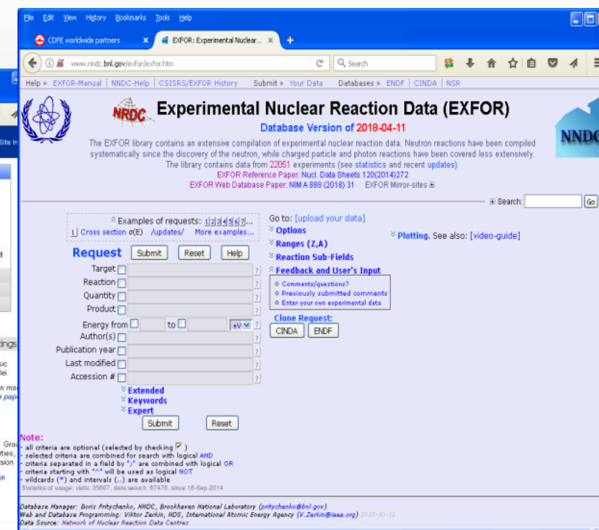

Short-term (2018/2019) CDFE Program

The main items of CDFE (2018/2019) program, main priorities and most important tasks are traditional and the following:

- continuation of new photonuclear data compilation using EXFOR format, new TRANSes (M096, M097, 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!