Lomonosov Moscow State University
Skobeltsyn Institute of Nuclear Physics

Centre for Photonuclear Experiments Data (CDFE)

Vladimir Varlamov

"Analysis and evaluation of photonuclear data”

Centre for Photonuclear Experiments Data

The CDFE *(Centr Dannykh Fotoyadernykh Eksperimentov)* is specialized Center of the IAEA Nuclear Data Section.

The CDFE provides scientific and educational institutes and for organization of Russian Academy of Science with nuclear reaction and nuclear spectroscopy data for basic research and various applications.

CDFE services include the compilation, verification, and dissemination of reliable nuclear data.

CDFE maintains several relational databases some of which were produced using the international data funds and another – CDFE own sources of information.

All of those databases are available through the CDFE Web-site – http://cdfe.sinp.msu.ru.

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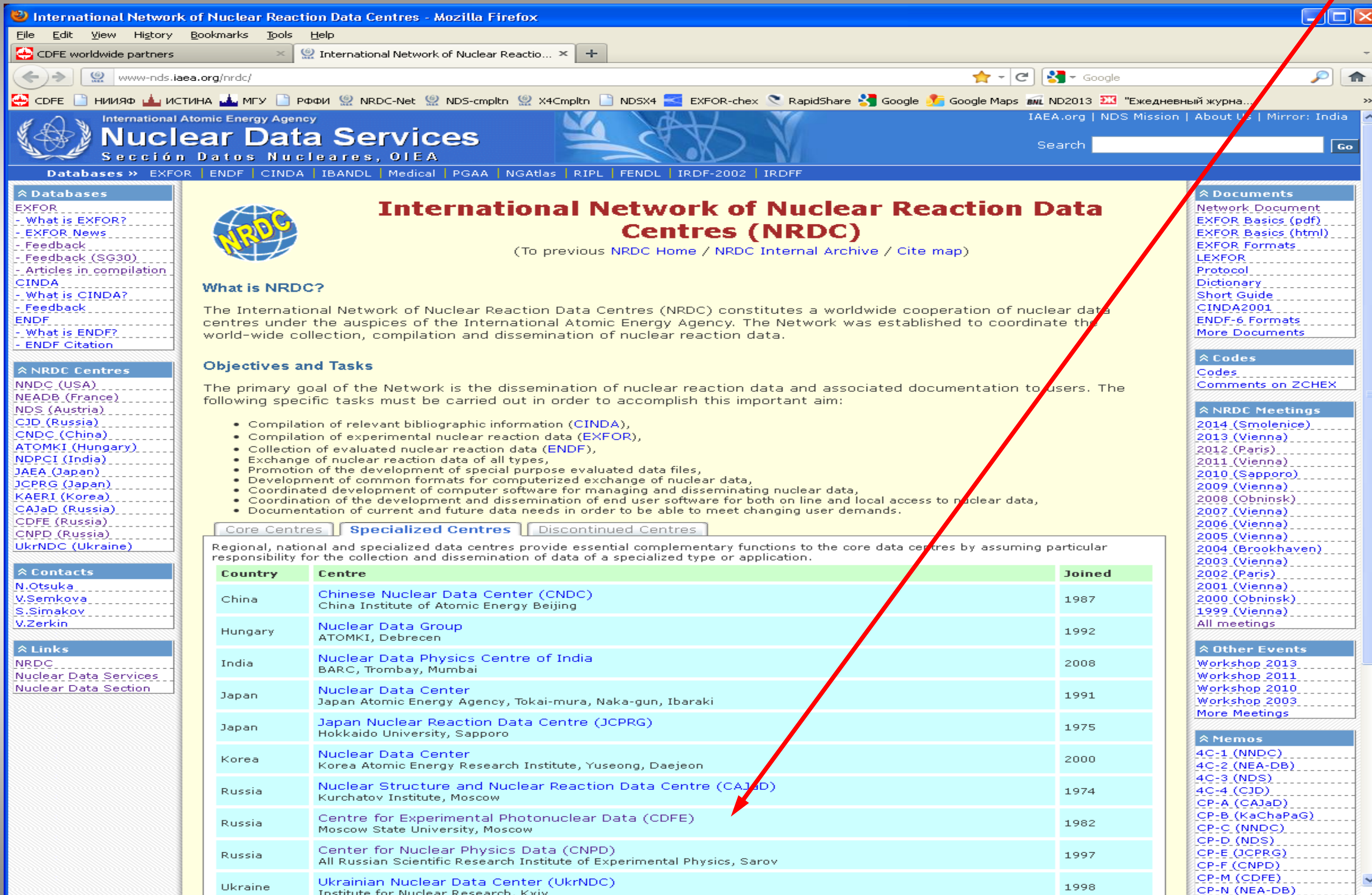

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(To previous NRDC Home / NRDC Internal Archive / Cite map)

What is NRDC?

The International Network of Nuclear Reaction Data Centres (NRDC) constitutes a worldwide cooperation of nuclear data centres under the auspices of the International Atomic Energy Agency. The Network was established to coordinate the world-wide collection, compilation and dissemination of nuclear reaction data.

Objectives and Tasks

The primary goal of the Network is the dissemination of nuclear reaction data and associated documentation to users. The following specific tasks must be carried out in order to accomplish this important aim:

- Compilation of relevant bibliographic information (CINDA),
- Compilation of experimental nuclear reaction data (EXFOR),
- Collection of evaluated nuclear reaction data (ENDF),
- Exchange of nuclear reaction data of all types,
- Promotion of the development of special purpose evaluated data files,
- Development of common formats for computerized exchange of nuclear data,
- Coordinated development of computer software for managing and disseminating nuclear data,
- Coordination of the development and dissemination of end user software for both on line and local access to nuclear data,
- Documentation of current and future data needs in order to be able to meet changing user demands.

Core Centres | Specialized Centres | Discontinued Centres

Regional, national and specialized data centres provide essential complementary functions to the core data centres by assuming particular responsibility for the collection and dissemination of data of a specialized type or application.

Country	Centre	Joined
China	Chinese Nuclear Data Center (CNDC) China Institute of Atomic Energy Beijing	1987
Hungary	Nuclear Data Group ATOMKI, Debrecen	1992
India	Nuclear Data Physics Centre of India BARC, Trombay, Mumbai	2008
Japan	Nuclear Data Center Japan Atomic Energy Agency, Tokai-mura, Naka-gun, Ibaraki	1991
Japan	Japan Nuclear Reaction Data Centre (JCPRG) Hokkaido University, Sapporo	1975
Korea	Nuclear Data Center Korea Atomic Energy Research Institute, Yuseong, Daejeon	2000
Russia	Nuclear Structure and Nuclear Reaction Data Centre (CAJaD) Kurchatov Institute, Moscow	1974
Russia	Centre for Experimental Photonuclear Data (CDFE) Moscow State University, Moscow	1982
Russia	Center for Nuclear Physics Data (CNPD) All Russian Scientific Research Institute of Experimental Physics, Sarov	1997
Ukraine	Ukrainian Nuclear Data Center (UkrNDC) Institute for Nuclear Research, Kyiv	1998

Documents
Network Document
EXFOR Basics (pdf)
EXFOR Basics (html)
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LEXFOR
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Short Guide
CINDA2001
ENDF-6 Formats
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NRDC Meetings
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All meetings

Other Events
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Workshop 2011
Workshop 2010
Workshop 2003
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GANDR
Geant4 Libraries
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INDL/TSL
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EXFOR Experimental nuclear reaction data
LiveChart of Nuclides Interactive Chart of Nuclides
CINDA Nuclear reaction bibliography
ENDF Evaluated nuclear reaction libraries
ENSDF evaluated nuclear structure and decay data (+XUNDL) **
NSR Nuclear Science References *
NuDat 2.6 selected evaluated nuclear structure data **
RIPL reference parameters for nuclear model calculations
IBANDL Ion Beam Analysis Nuclear Data Library
Charged particle reference cross section Beam monitor reactions
PGAA Prompt gamma rays from neutron capture
FENDL 3.0 Fusion Evaluated Nuclear Data Library, Version 3.0
Photonuclear cross sections and spectra up to 140MeV
IRDFF International Reactor Dosimetry and Fusion File
NAA Neutron Activation Analysis Portal
Safeguards Data recommendations, August 2008
Medical Portal Data for Medical Applications
Standards - Neutron cross-sections, 2006 - Decay data, 2005
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IAEA Workshop on modelling and evaluating nuclear data for energy and non-energy applications December 2-6, 2013 IAEA Headquarters Vienna, Austria
Nuclear Physics and Gamma-ray sources for Nuclear Security and Nonproliferation (NPNSNP) January 28-30, 2014 Ricotti, Tokai-mura, Japan
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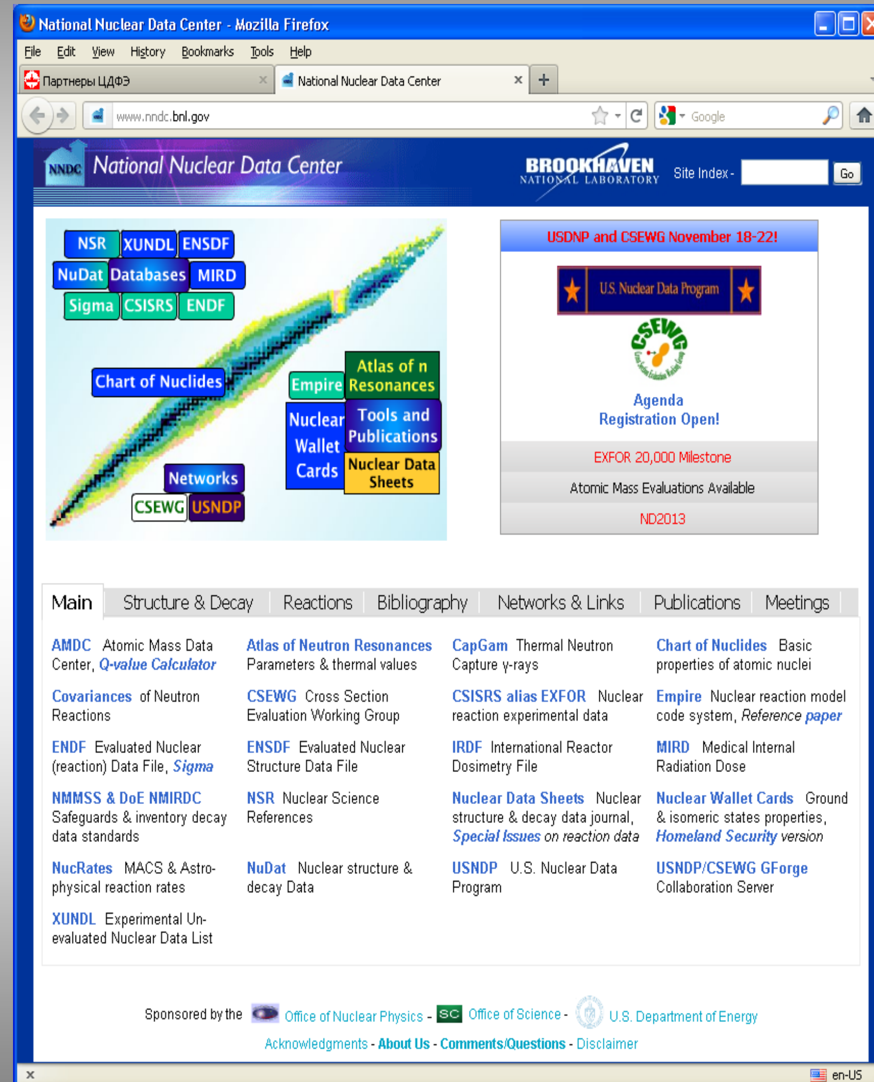
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AMDC Atomic Mass Data Center, Q-value Calculator
Atlas of Neutron Resonances Parameters & thermal values
CapGam Thermal Neutron Capture γ-rays
Chart of Nuclides Basic properties of atomic nuclei
Covariances of Neutron Reactions
CSEWG Cross Section Evaluation Working Group
CSISRS alias EXFOR Nuclear reaction experimental data
Empire Nuclear reaction model code system, Reference paper
ENDF Evaluated Nuclear (reaction) Data File, Sigma
ENSDF Evaluated Nuclear Structure Data File
IRDF International Reactor Dosimetry File
MIRD Medical Internal Radiation Dose
NMMSS & DoE NMIRDC Safeguards & inventory decay data standards
NSR Nuclear Science References
Nuclear Data Sheets Nuclear structure & decay data journal, Special Issues on reaction data
Nuclear Wallet Cards Ground & isomeric states properties, Homeland Security version
NucRates MACS & Astro-physical reaction rates
NuDat Nuclear structure & decay Data
USNDP U.S. Nuclear Data Program
USNDP/CSEWG GForge Collaboration Server
XUNDL Experimental Un-evaluated Nuclear Data List
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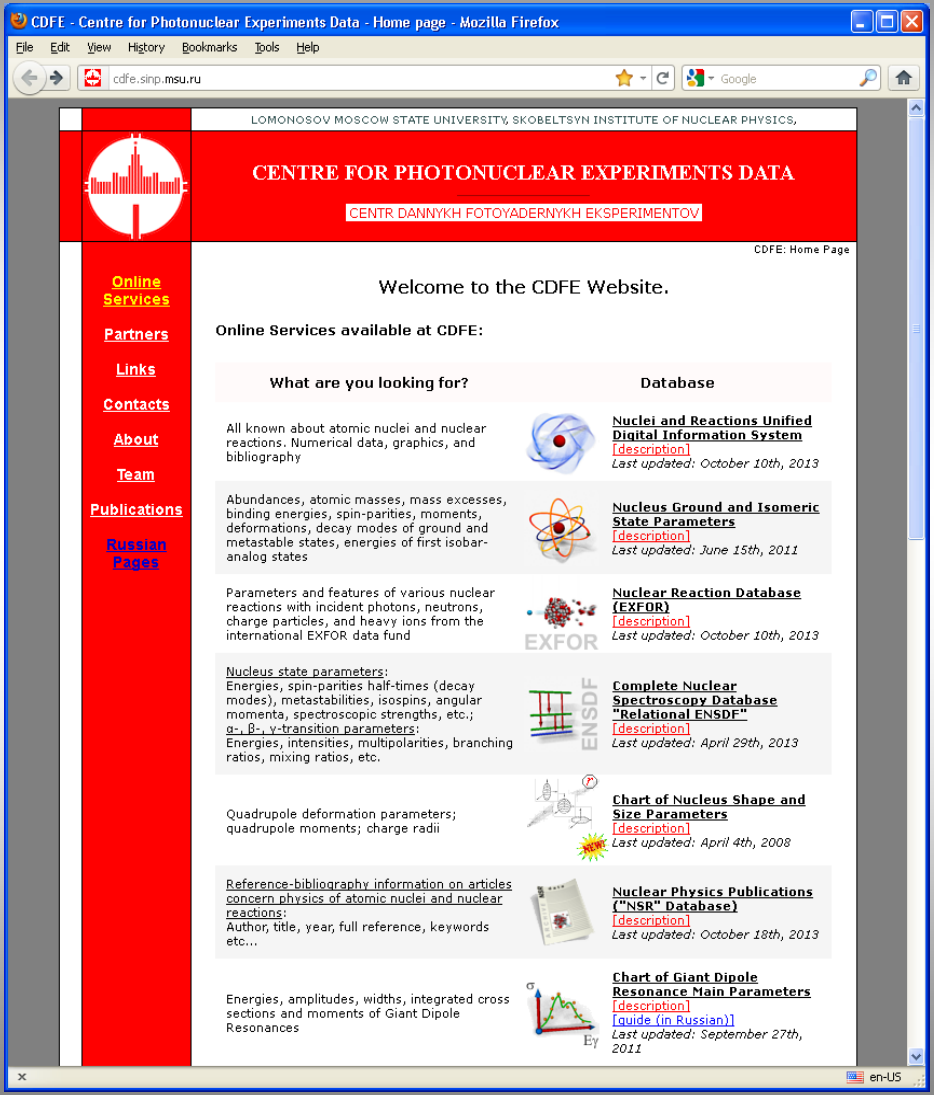
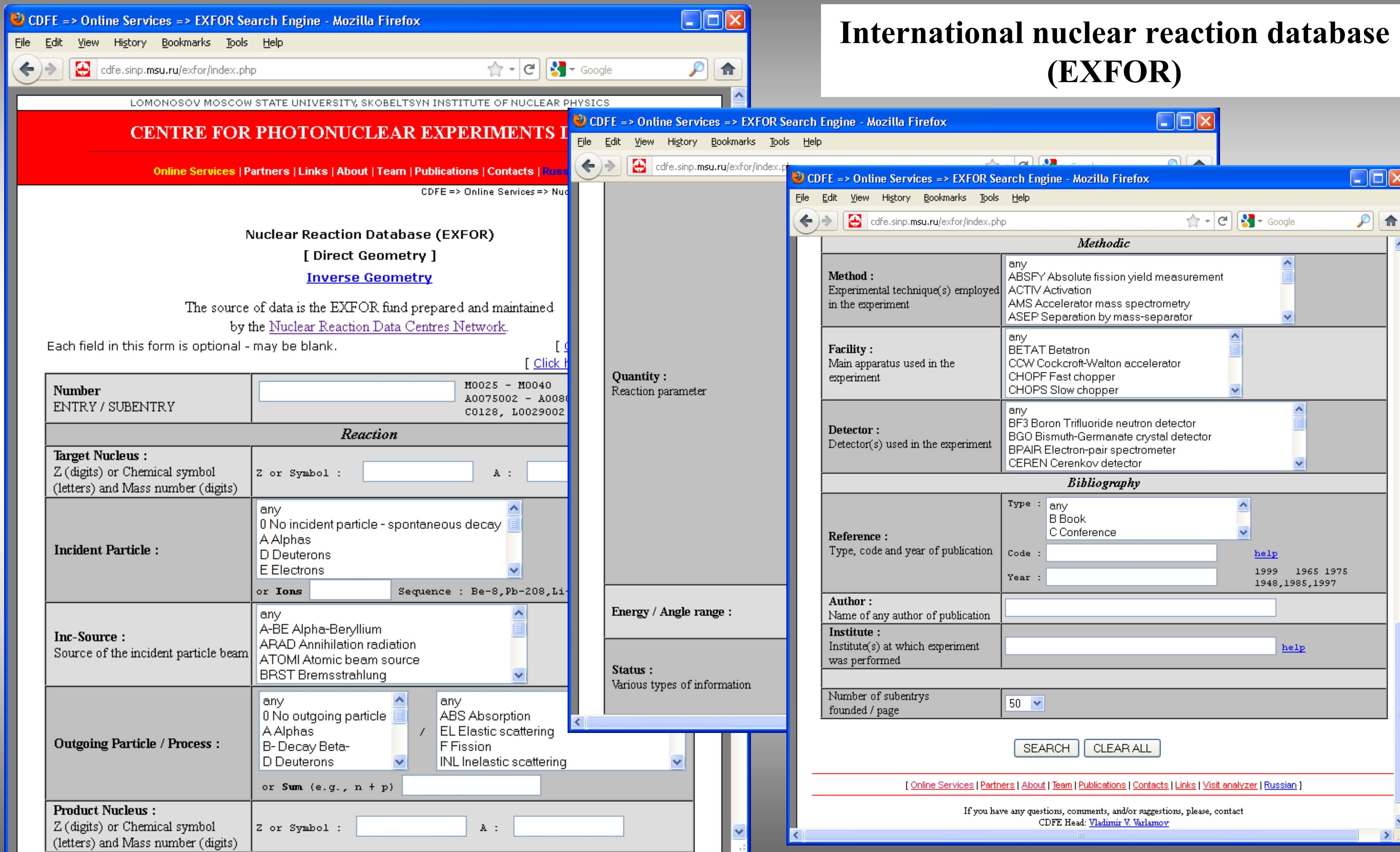


3 CDFE databases (EXFOR, ENSDF, NSR) are based on the international data sources but have original Search Engines.

Other databases are based on the CDFE own data collections.

International nuclear reaction database (EXFOR)



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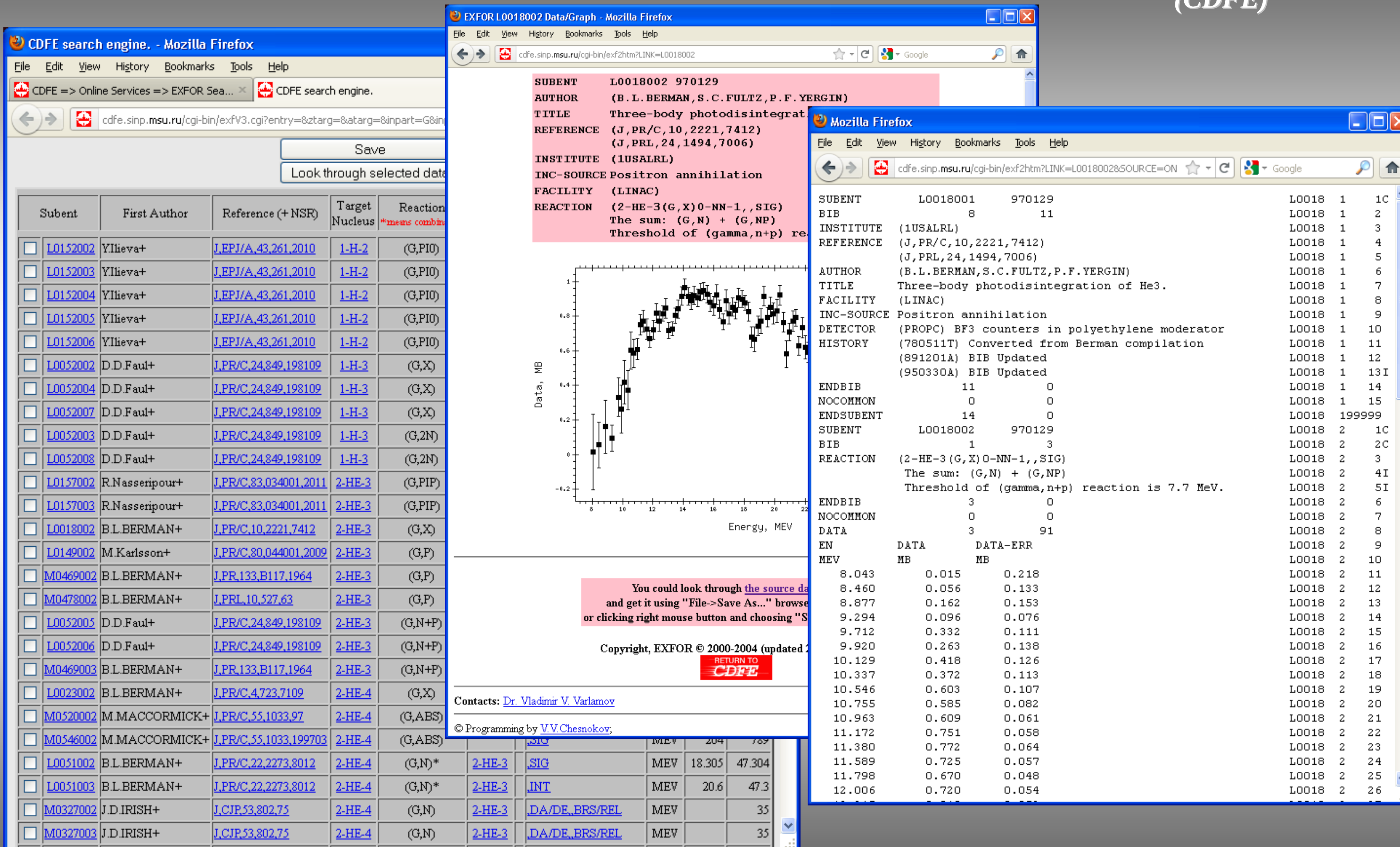


Main field of CDFE nuclear data activity –

photonuclear data evaluations

Main direction:

investigations of data reliability for partial and total photonuclear reaction cross sections.

Main results:

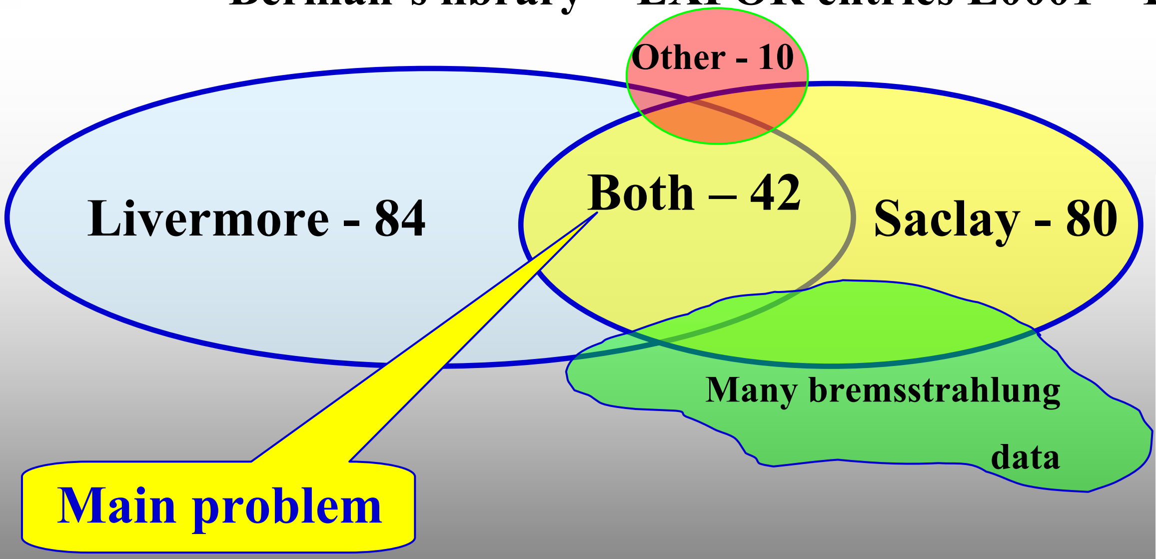
- **many experimental data for partial photonuclear reaction cross sections from various experiments were analyzed;**
- **new simple objective criteria were found out for investigation of data reliability;**
- **that was shown that majority of experimental data on partial photonuclear reaction cross section data are not reliable;**
- **new method for evaluation of reliable data were proposed;**
- **many new data were evaluated.**

Systematics:

many experimental data data for partial photonuclear reaction cross sections obtained in period 1962 - 1986 (the majority was obtained at Livermore (USA) and Saclay (France)), are published in

Atlas of Photoneutron cross sections obtained with monoenergetic photons (S.S.Dietrich, B.L.Berman. Atom. Data and Nucl. Data Tables, 38 (1988) 199)

Berman's library - EXFOR entries L0001 – L0059 (~ 174 nuclei sets)



For each nucleus – cross sections:

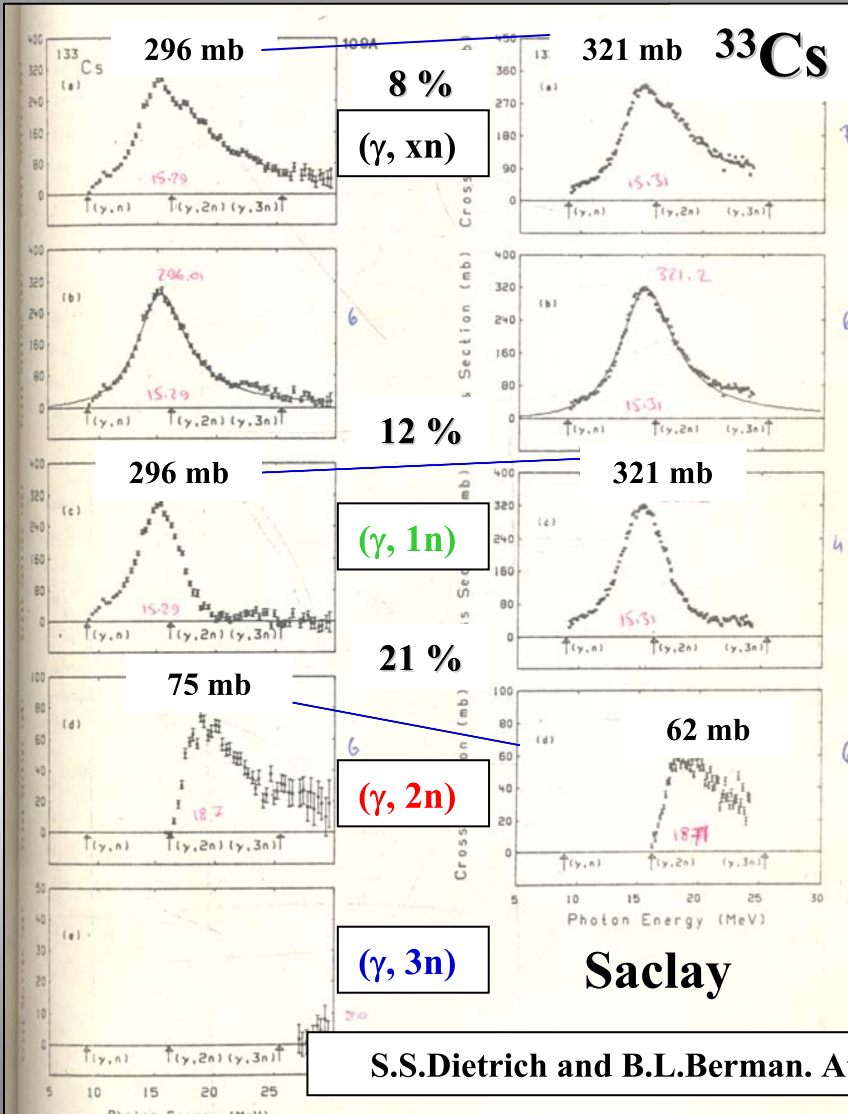
(γ, 3n)

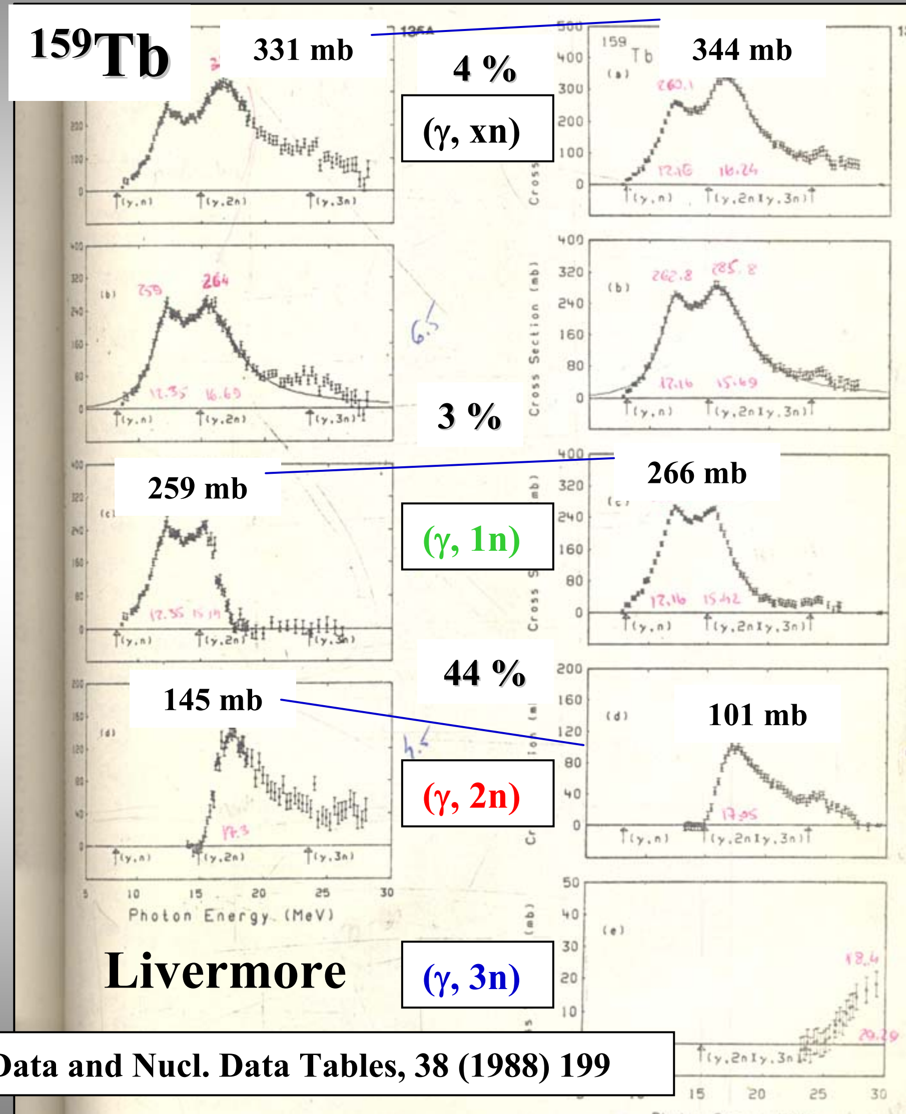
(γ, 2n)

(γ, 1n)

(γ, Sn) = + (γ, 1n) + (γ, 2n) + (γ, 3n) +…

(γ, xn) = + (γ, 1n) + 2(γ, 2n) + 3(γ, 3n) +…



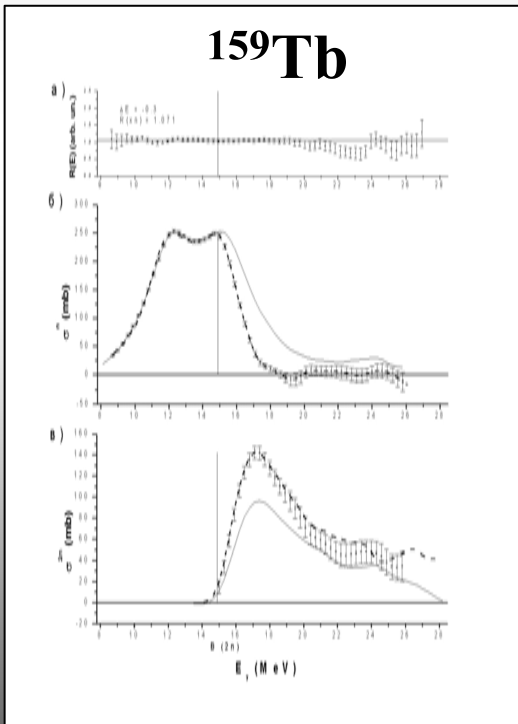


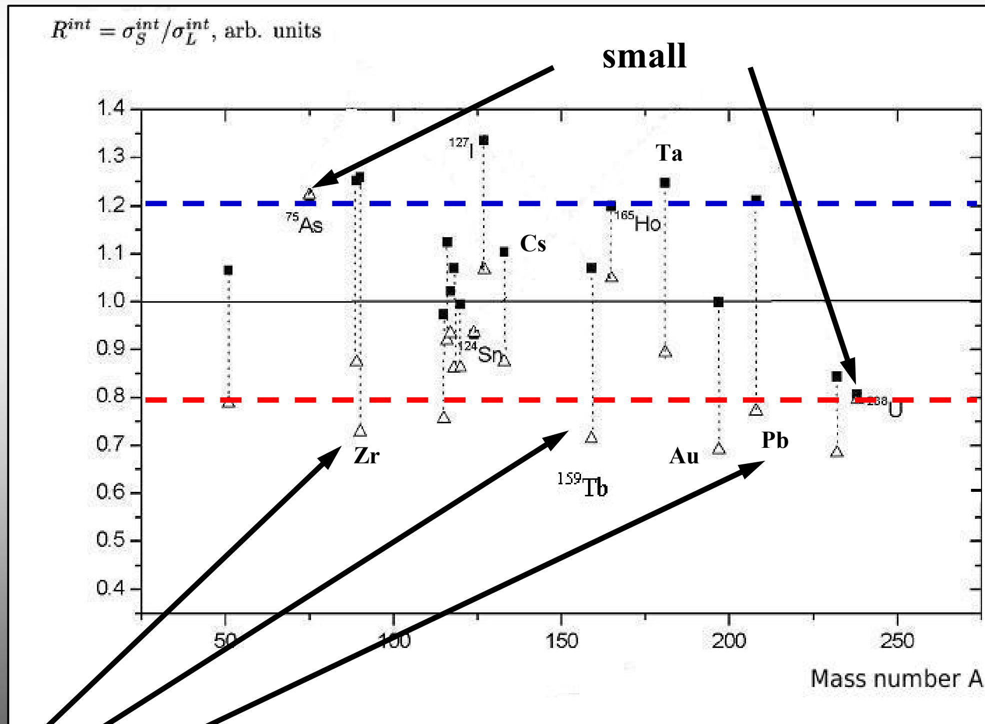
S.S.Dietrich and B.L.Berman. Atom. Data and Nucl. Data Tables, 38 (1988) 199

Main problem:

for 20 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) in Articles Translated from Journal Yadernye Konstanty (Nuclear Constants). INDC(CCP)-440, IAEA NDS, Vienna, Austria, 2004, p. 37.





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

<R> ~ 1.2.

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

<R> ~ 0.8.

Possible reasons for clear systematic disagreements

The same method of neutron multiplicity sorting by neutron kinetic energy measurement was used in both Labs based on supposition that one neutron from (γ, 1n) reaction has energy larger than both neutrons from reaction (γ, 2n) but experimental methods for neutron energy measurements were different:

- at Saclay t ... (“suffered from a high backgrou ... introduced larger uncertainties i ... ctions” – citation from B.L.Bern ...);

We need the objective criteria for data reliability!

- at Livermore so-called “ring-ratio” method was used (concentric rings of counters in paraffin moderator): low-energy neutrons (from reaction (γ, 2n)) should have enough time for moderation in the way to inner ring but high-energy neutrons (from reaction (γ, 1n)) should go to the outer ring passing inner ring (due to multiple scattering high energy-neutron could return to inner ring).

Many efforts:

E. Wolynec et. al., Phys.Rev., 29, 1137 (1984)

E. Wolynec and M.N.Martins, Rev.Bras.Fis., 17, 56 (1987)

B.L. Berman et. al., Phys.Rev., C36, 1286 (1987)

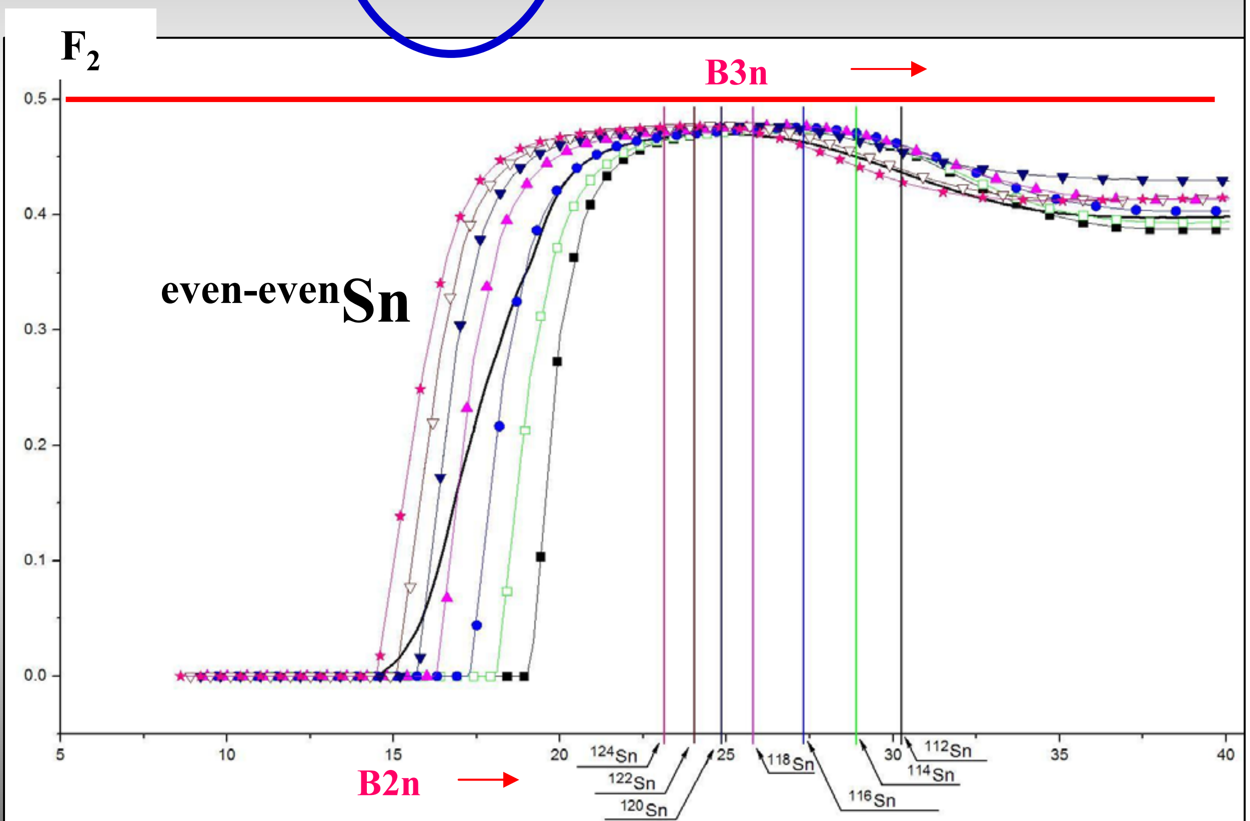
V.V.Varlamov, et. al., INDC(CCP)-440, IAEA NDS, 37 (2004).

Contradictive recommendations: to multiply Livermore data, to divide Saclay data, to recalculate Saclay data for putting them into consistency with Livermore data.

With the aim to find objective criteria we investigated many sums, differences and ratios of various cross sections and at lately found out very simple, clear and physically objective criteria for data reliability – for presence (or absence) of systematic errors.

Main objective criterion for data reliability

$$F_2 = \frac{\sigma(\gamma, 2n)}{\sigma(\gamma, 1n) + 2\sigma(\gamma, 2n) + 3\sigma(\gamma, 3n) + \ldots} < 0.50 \; (!)$$



Theoretically calculated data.

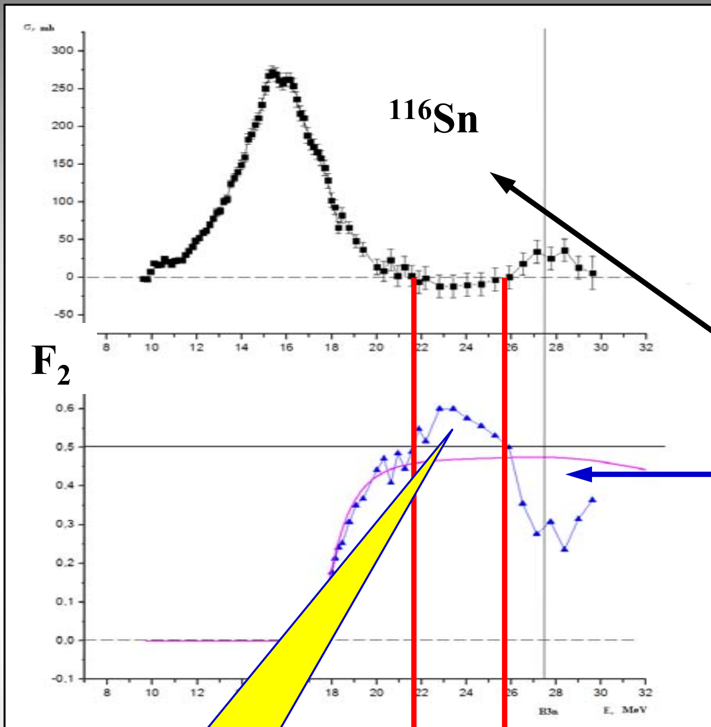
The natural and physically reliable energy dependence of F_2 should be following:

– Below the (γ, 2n) reaction threshold B2n only the (γ, 1n) reaction is possible: $F_2 = 0$;

– Above B2n both (γ, 1n) and (γ, 2n) reactions are possible, F_2 increases due to competition between decreasing $\sigma(\gamma, 1n)$ and increasing $\sigma(\gamma, 2n)$, going to the theoretical limit of 0.50, but never reach it because of a high–energy part in $\sigma(\gamma, 1n)$;

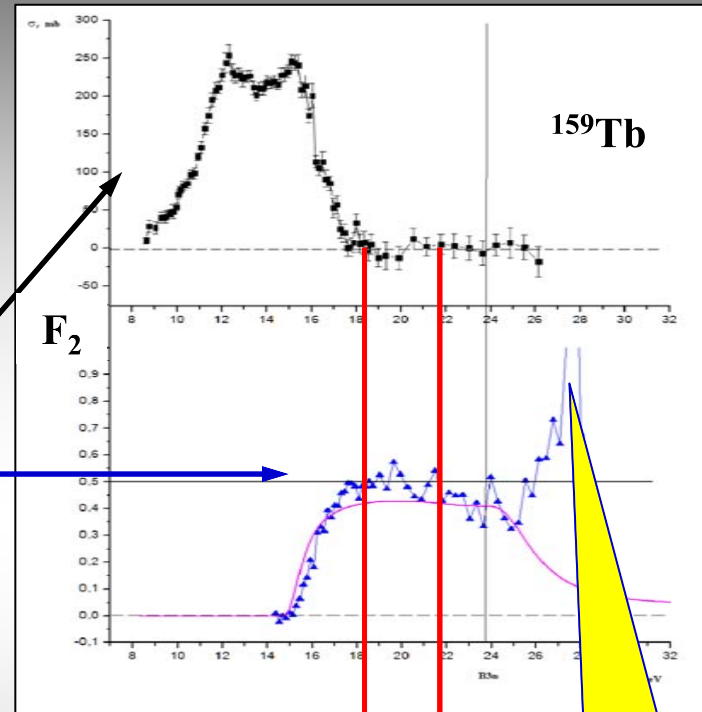
– Above the B3n threshold the (γ, 3n) reaction is also possible, F_2 decreases due to a 3 $\sigma(\gamma, 3n)$.

Livermore data



$\sigma(\gamma, 1n)$

F$_2$

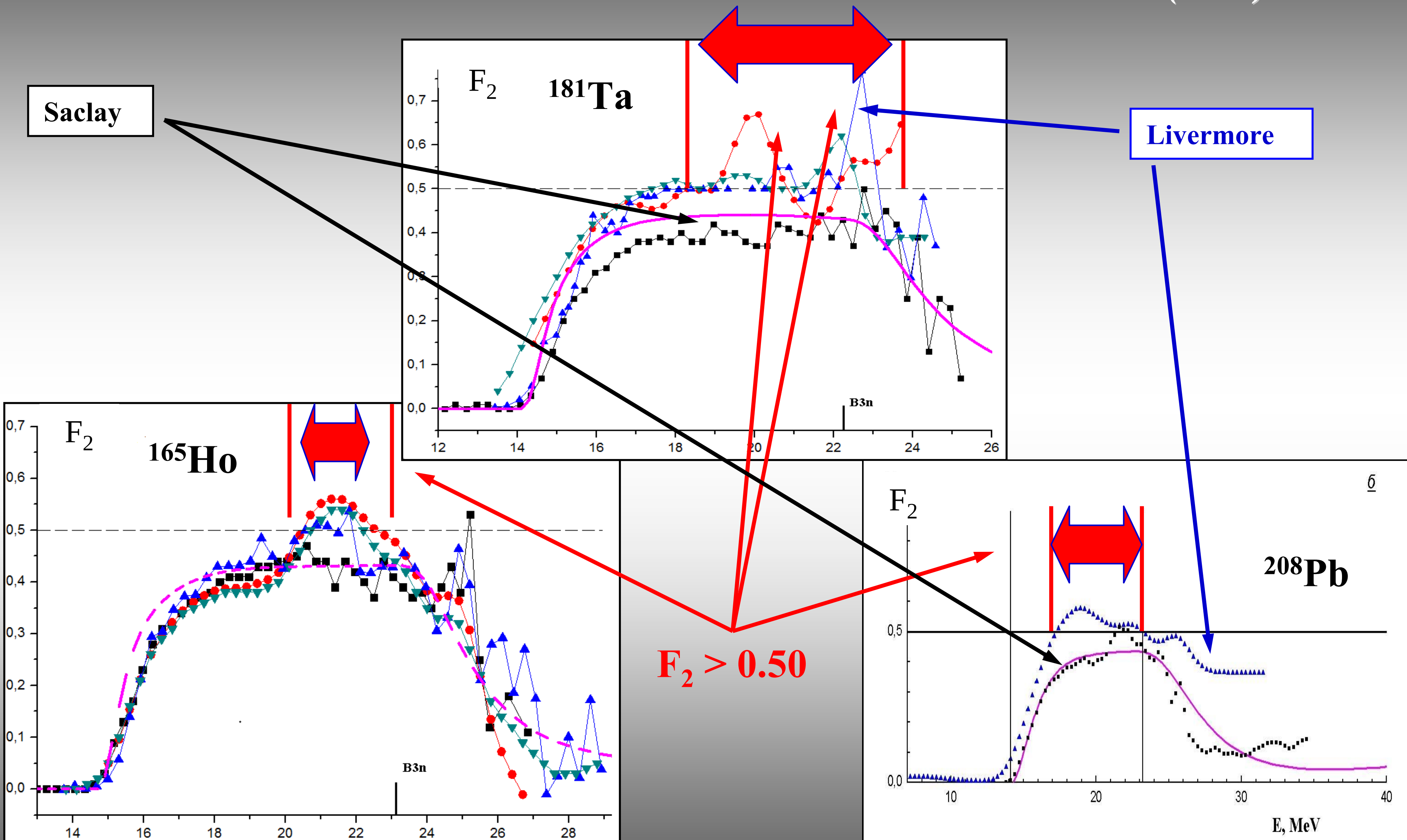


Significant disagreements: $F_2 \sim 0.6$!

$$F_2 = \frac{\sigma(\gamma, 2n)}{\sigma(\gamma, 1n) + 2\sigma(\gamma, 2n) + 3\sigma(\gamma, 3n) + \ldots} < 0.50\ (!)$$

Dramatic disagreements: $F_2 \approx 1.5 - 2.0$!

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


Saclay
Livermore
F_2
^{181}Ta
F_2
^{165}Ho
F_2
^{208}Pb
B3n
B3n
E, MeV
$F_2 > 0.50$

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Physically forbidden negative values

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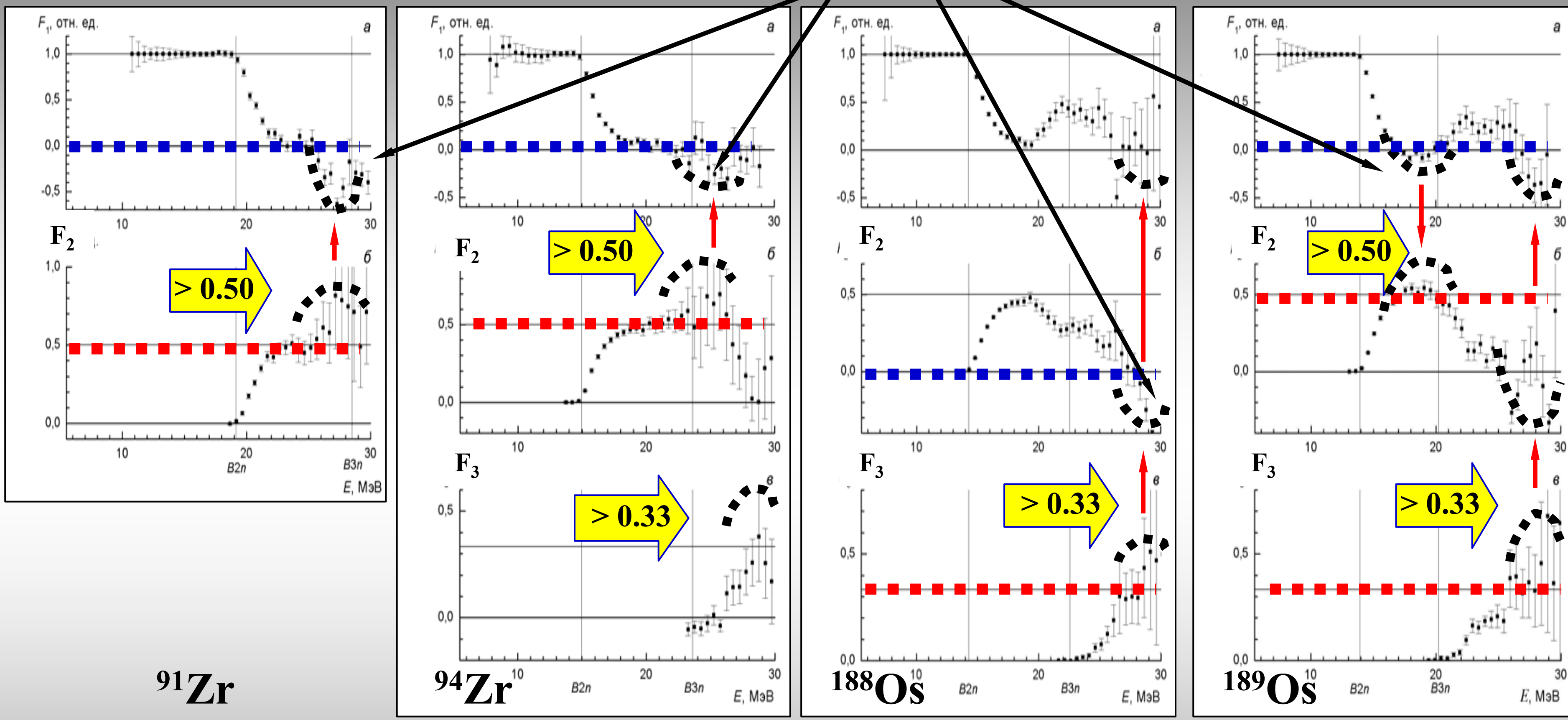


The reliability of many data is doubtful.

Many data should be reanalyzed and reevaluated!

There are additional physically natural criteria:

$F_1 = \sigma(\gamma, 1n) \ / \ \sigma(\gamma, xn) < 1.00$

$F_3 = \sigma(\gamma, 3n) \ / \ \sigma(\gamma, xn) < 0.33$ etc.

New experimentally-theoretical method of evaluation

using combined model of photonuclear reactions:

- initial data – experimental neutron yield reaction (γ, xn) cross section;

- decay channels competition based on theoretical model.

Theoretically calculated transitional multiplicity functions

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

are used for cross section evaluation by following way

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

Our new approach for evaluation of partial traction cross sections

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

means:

i) the competition of partial reactions (γ, 1n), (γ, 2n) and (γ, 3n) is in accordance with equations of model;

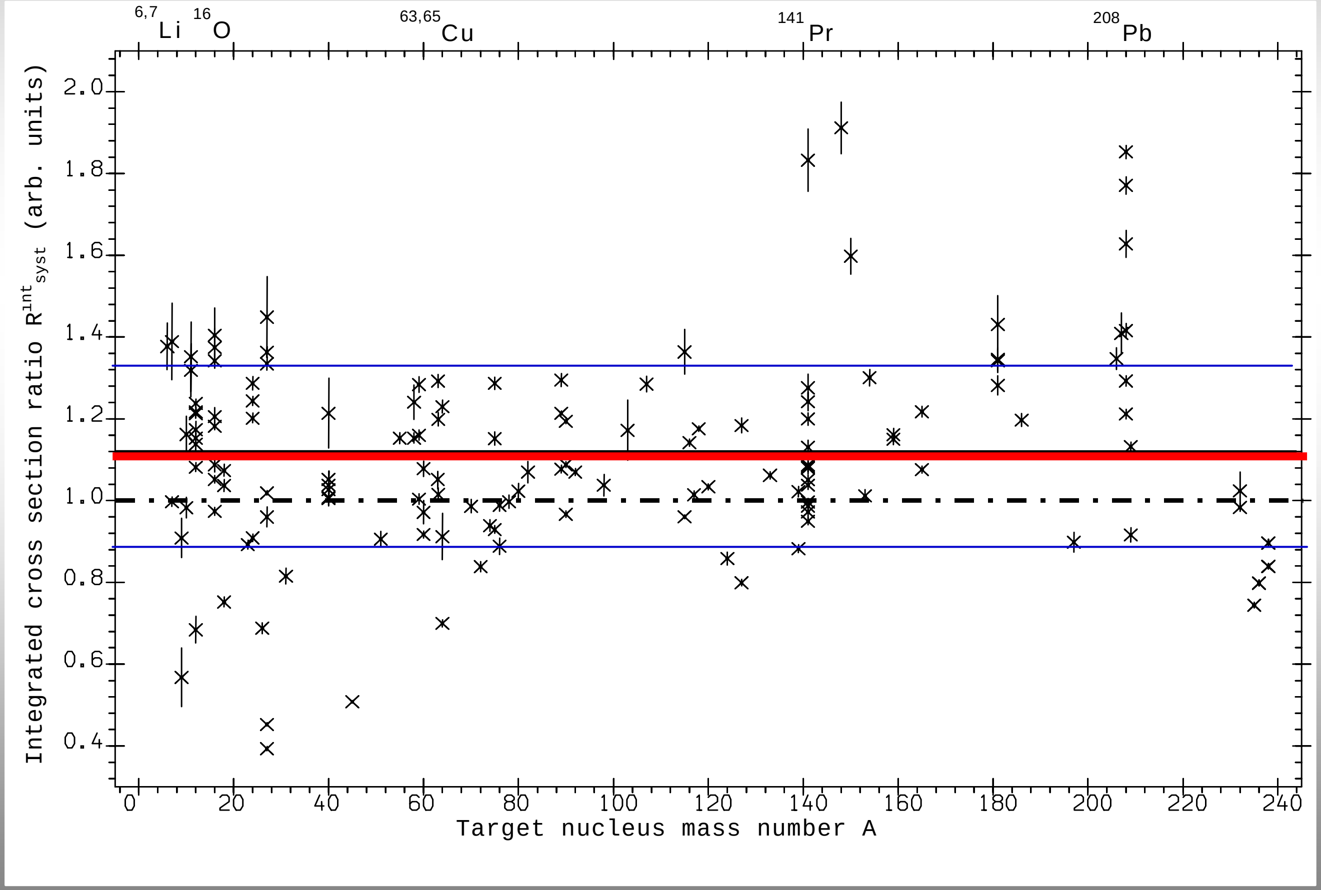
ii) the theoretical sum of evaluated partial reaction cross sections

$$\sigma^{theor}(\gamma, xn) = \sigma^{theor}(\gamma, 1n) + 2\sigma^{theor}(\gamma, 2n) + 3\sigma^{theor}(\gamma, 3n) + \ldots$$

is equal to the experimental $\sigma^{exp}(\gamma, xn)$.

Systematics of (γ,xn) reaction cross section ratios "All/Livermore" for ~ 500 data sets

(V.V.Varlamov, B.S.Ishkhanov. Study of Consistency Between (γ, xn), [(γ, 1n) + (γ, 1n1p)] and (γ, 2n) Reaction Cross Sections Using Data Systematics. Vienna, Austria. INDC(CCP) - 433, 2002)



$<R^{int}_{syst}> = 1.12$:

disagreements are about 12%

Model

B.S.Ishkhanov, V.N.Orlin. Physics of Particles and Nuclei, 38, 232 (2007),
Physics of Atomic Nuclei, 71, 493 (2008):

semiclassical exciton preequilibrium model of photonuclear reaction based on the Fermi gas densities with taking into account effects of nucleus deformation and effects of Giant Dipole Resonance isospin splitting.

Model was well tested on experimental data for neutron yield (γ, xn) reaction.

M.B. Chadwick *et al*., Phys. Rev. C 44, 814 (1991) – analogous model.

Decay channels competition

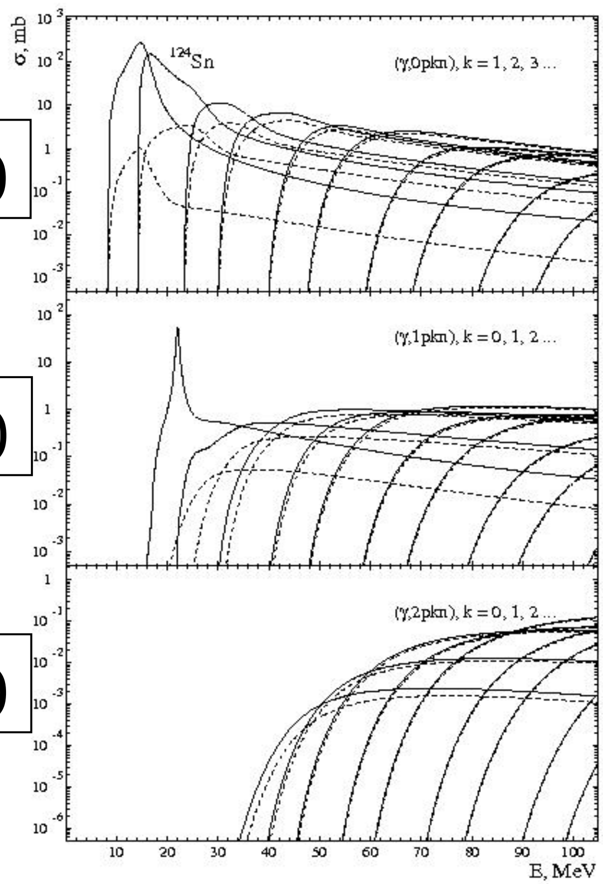
$$\sigma^{eval}(\gamma, in) = F_i^{theor}(\gamma, in) \bullet \sigma^{exp}(\gamma, xn)$$

^{124}Sn

(γ,0pkn)

(γ,1pkn)

(γ,2pkn)



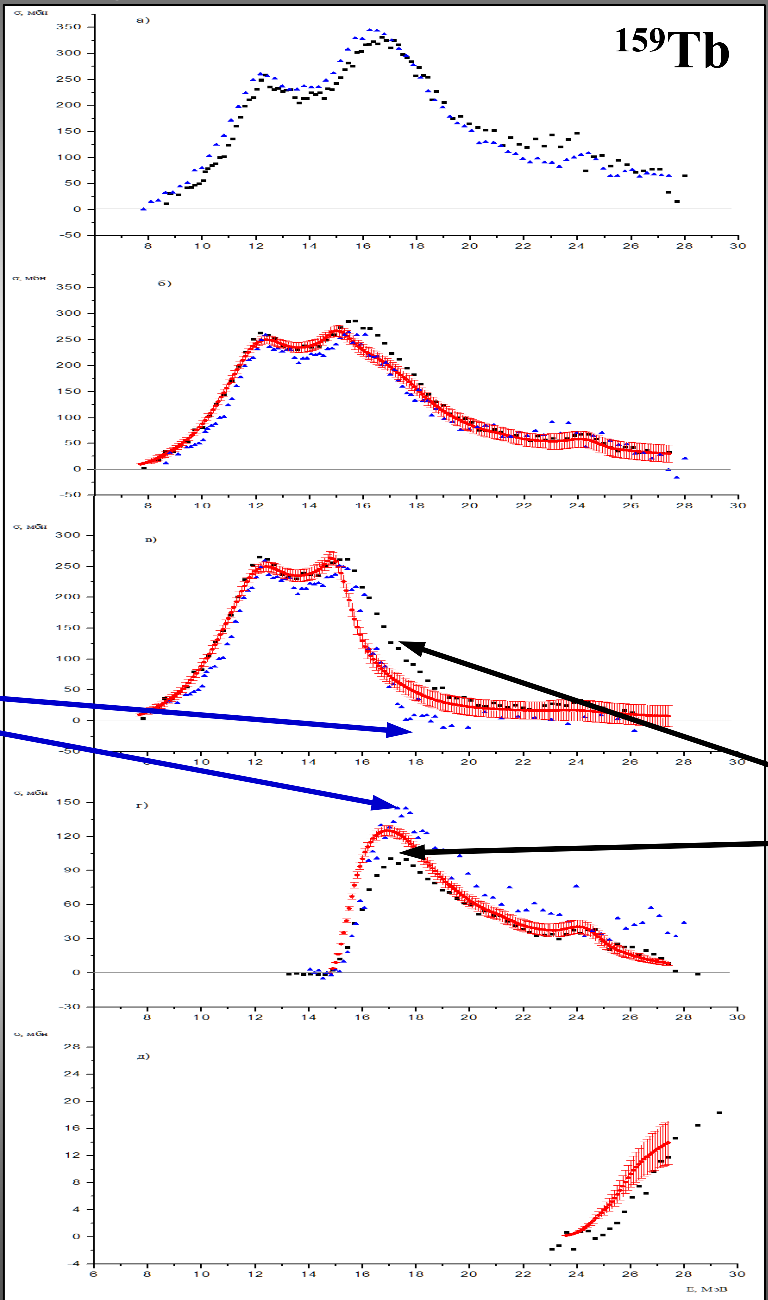
$\sigma(\gamma, xn)$

$\sigma(\gamma, Sn)$

$\sigma(\gamma, 1n)$

$\sigma(\gamma, 2n)$

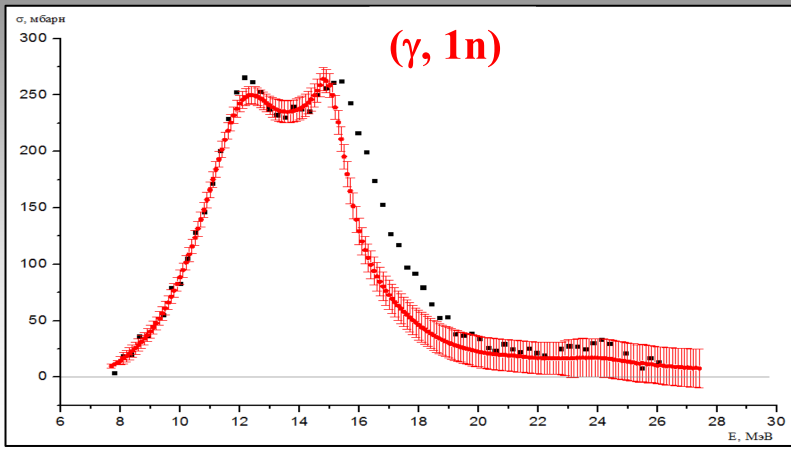
$\sigma(\gamma, 3n)$

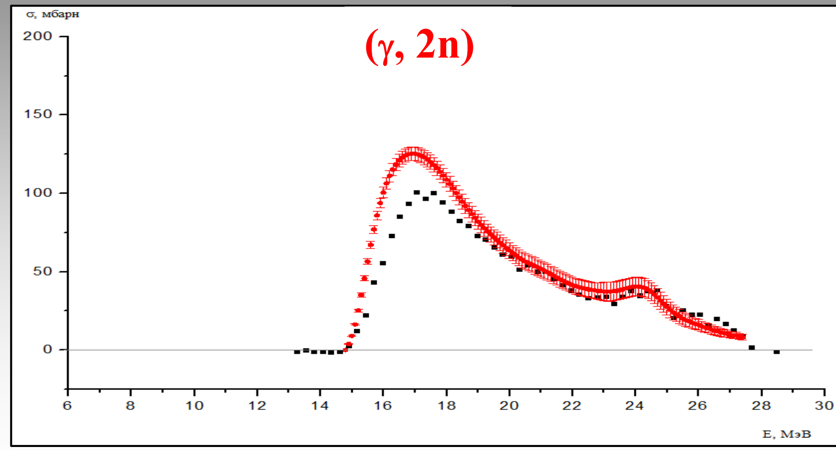


Livermore data

Saclay data

^{90,92,94}Zr, ^{115}In, ^{112,114,116,117,118,119,120,122,124}Sn, ^{159}Tb, ^{186,188,190,192}Os, ^{197}Au, ^{181}Ta, ^{208}Pb





^{159}Tb

Reaction	Integrated cross section σ^{int}, MeV•mb		
	Livermore	Evaluation	Saclay
(γ, xn)	3187	3200	3194
(γ, Sn)	2300	> 2383 <	2557
(γ, 1n)	1413	> 1642 <	1936
(γ, 2n)	887	< 714 >	605
(γ, 3n)	46	< 26 >	16

Noticeable differences between evaluated and experimental data

Up for 4 %!

Up for 16 %!

Down for 24 %!

σ^{int}(γ, 2n)/σ^{int}(γ, 1n) decreased for 31 %.

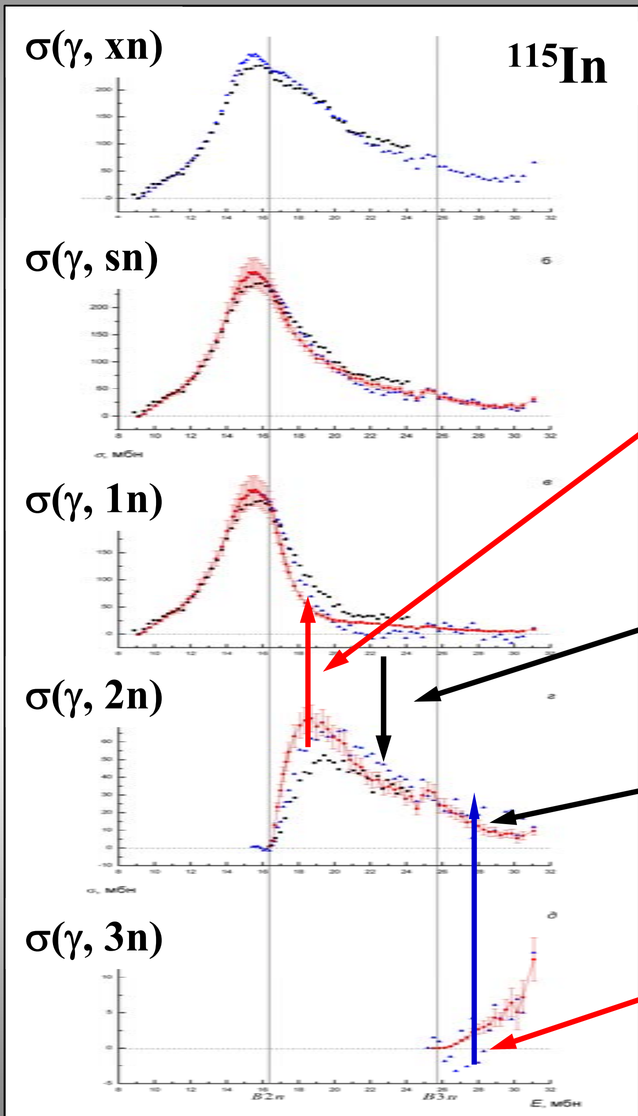
Down for 9 %!

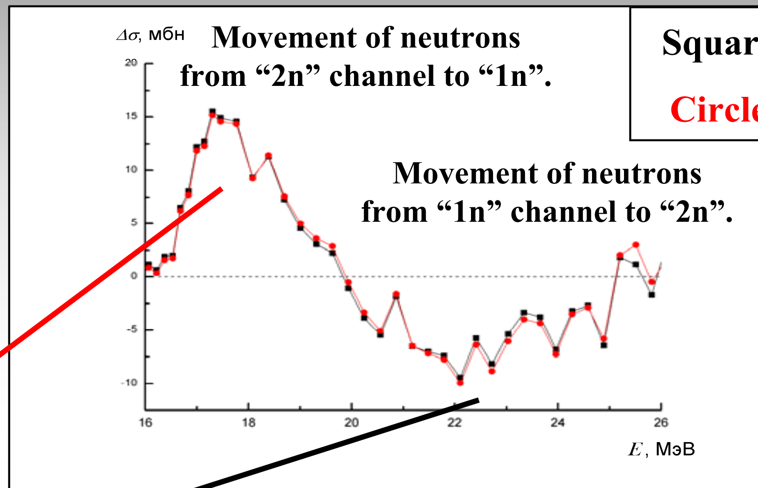
Down for 19 %!

Up for 15 %!

σ^{int}(γ, 2n)/σ^{int}(γ, 1n) increased for 27 %.

Comparison of evaluated and experimental (Saclay, Livermore).



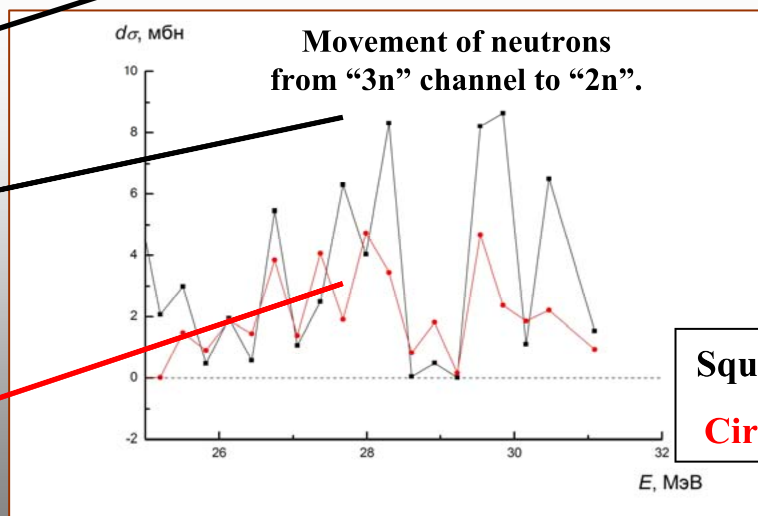


Squares - [σ^{exp}(γ, 1n) - σ^{eval}(γ, 1n)]

Circles - [σ^{eval}(γ, 2n) - σ^{exp}(γ, 2n)]

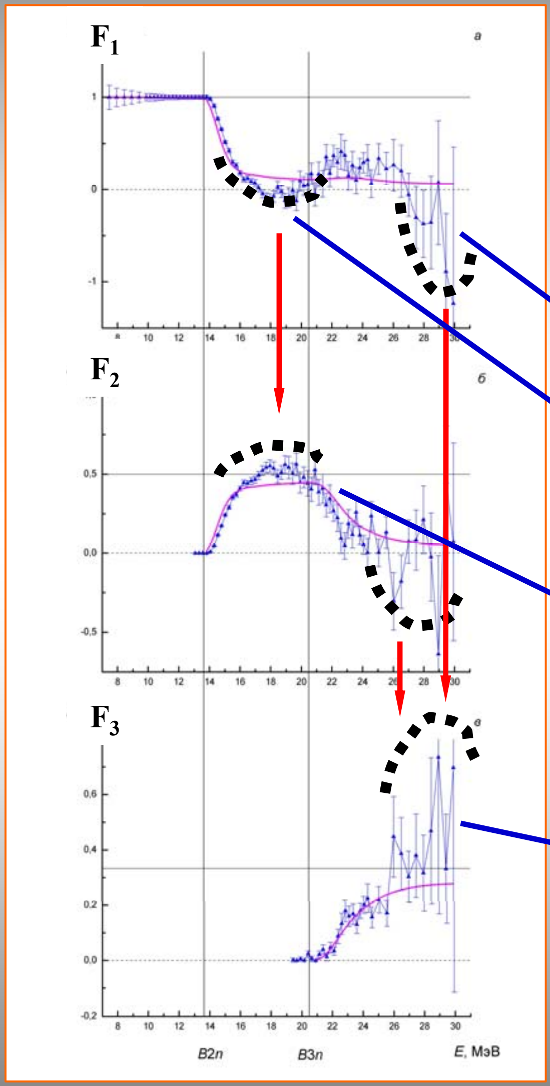
That means that erroneous moving some number of neutrons from “1n” channel to “2n” decrease (γ, 1n) cross section down to physically forbidden negative values and at the same time increase F_2 up to not reliable values “> 0.50”.

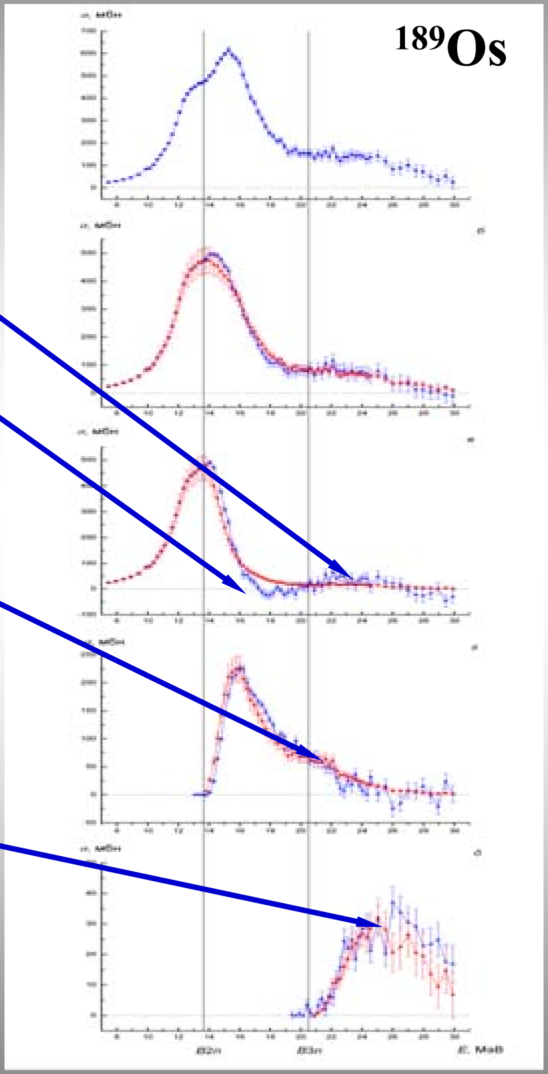
The analogous is the situation for “2n” and “3n” channels.

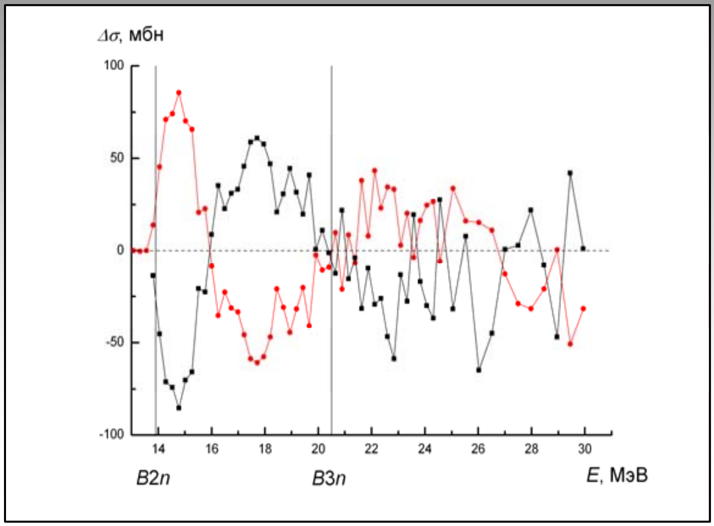


Squares - [σ^{exp}(γ, 2n) - σ^{eval}(γ, 2n)]

Circles - [σ^{eval}(γ, 3n) - σ^{exp}(γ, 3n)]

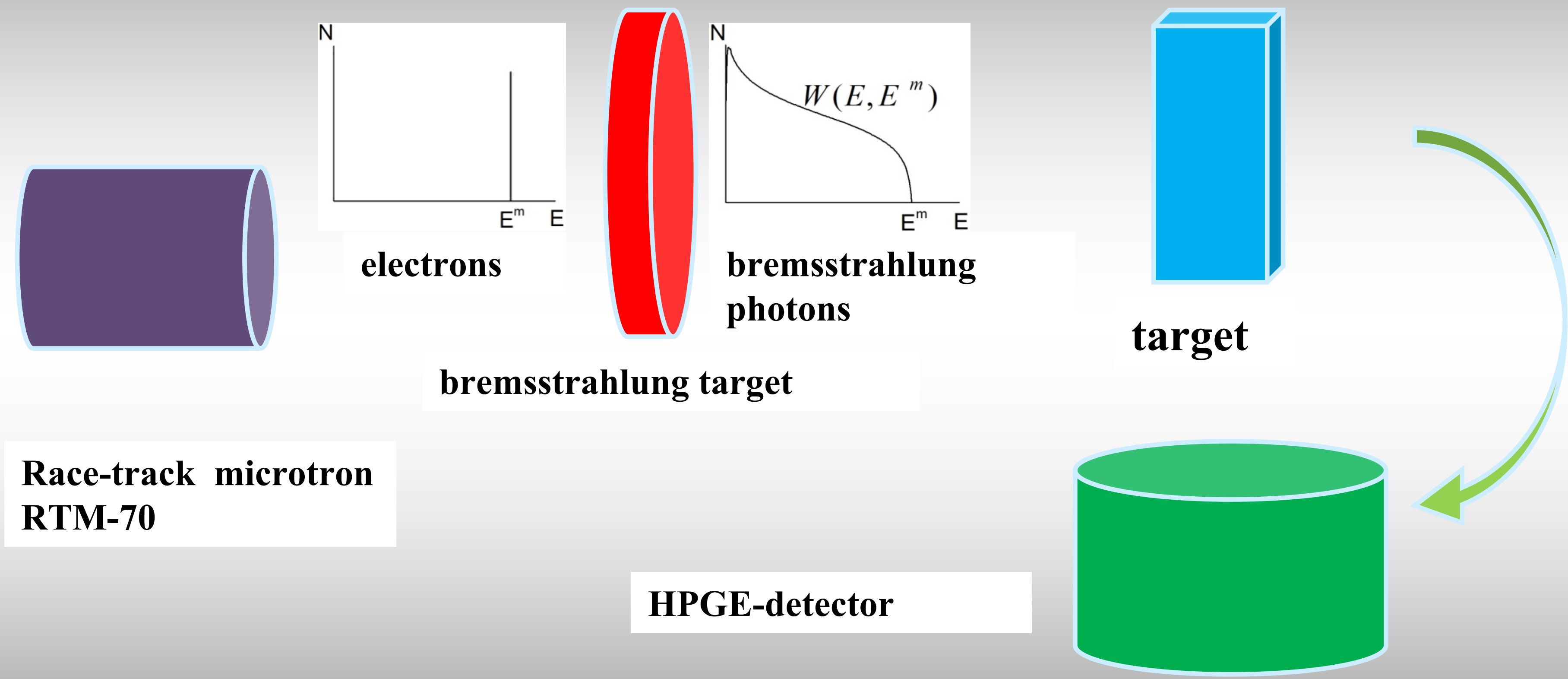






Analogous erroneous moving some number of neutrons from one decay channel to another.

Independent test – activity method: identification of reaction using not outgoing neutrons but final nucleus



^{181}Ta

Decays of ^{181}Ta(γ, 1n) and ^{181}Ta(γ, 2n) reactions final nucleus differ significantly:

^{181}Ta(γ, 1n)^{180}Ta, $T_{1/2}$ = 8.154 hour, E = 93.326 кэВ

E = 103.557 кэВ

^{181}Ta(γ, 2n)^{179}Ta, $T_{1/2}$ = 1.82 year, E = 63.0 кэВ

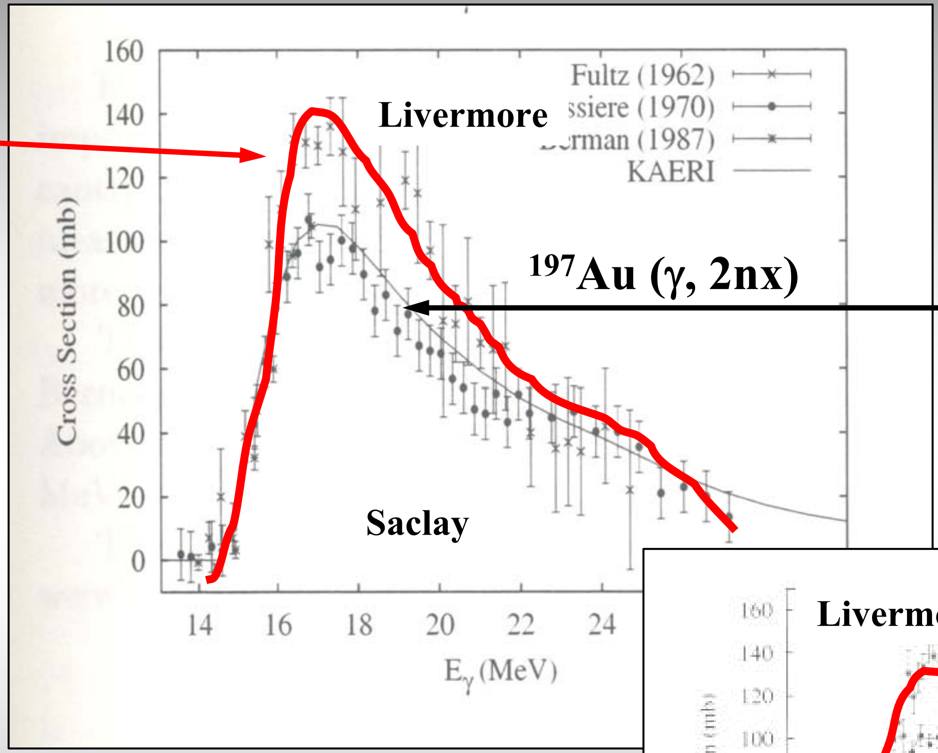
The comparison of ratios of reaction yields Y and integrated cross sections σ^{int} obtained for experimental and evaluated data for ^{181}Ta for E^{int} = 65 MeV.

Ratios	Experiments			Evaluation
	Saclay	Livermore	Activity	$F_{1,2,3}$
of cross sections σ(γ,2n)/σ(γ,n)	0.36 (797/2190)	0.67 (887/1316)		0.49 (958/1956)
of yields Y(γ,2n)/Y(γ,n)	**0.24**	**0.42**	**0.34 ± 0.07**	**0.33**
of cross sections σ(γ,3n)/σ(γ,n)	0.063 (137/2190)			0.055 (107/1956)

Our evaluations based on F-functions:

Livermore data are reliable

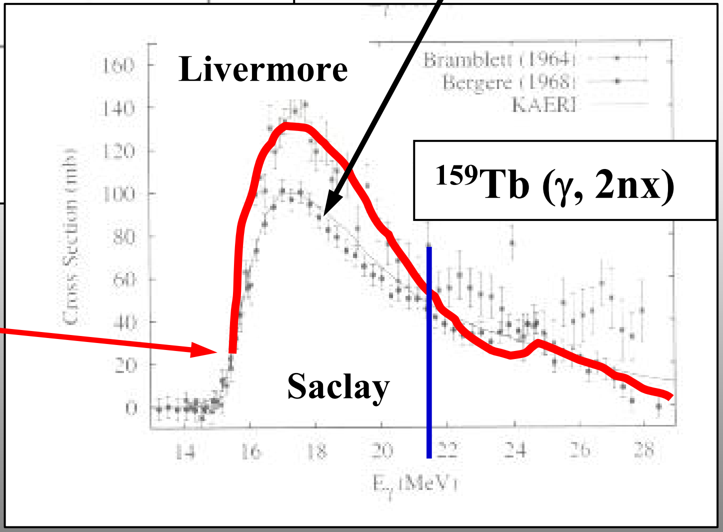
but Saclay not.



IAEA CRP (1996 – 1999) evaluation (IAEA-TECDOC-1178, 2000, IAEA Photonuclear Data Library).

Our evaluations based on F-functions:

both Livermore and Saclay data are not reliable.



^{96}Zr

Disagreements with Utsunomiya data obtained using quasimonochromatic laser Compton-backscattering γ-rays

Utsunomiya

IAEA CRP data were obtained for ^{96}Zr using GUNF code adopting the same model parameters as for ^{90,91,92,94}Zr.

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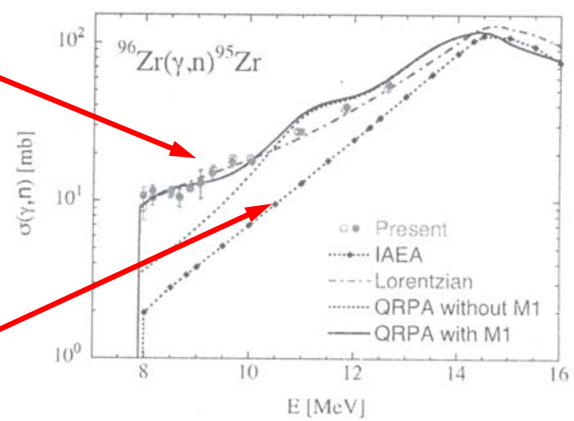
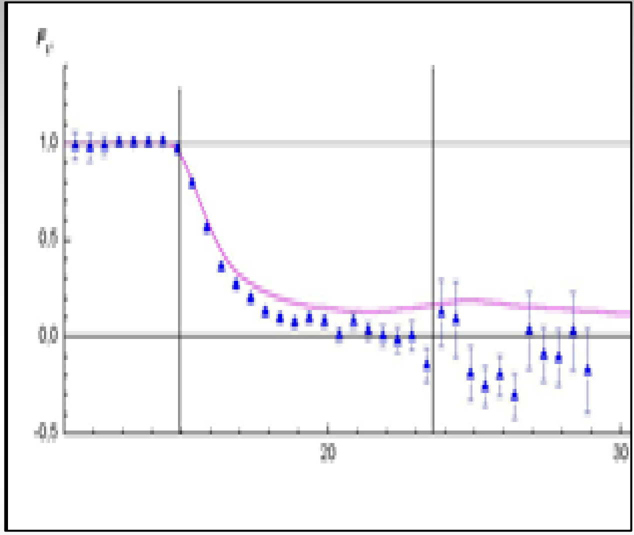


FIG. 2. (Color online) Comparison of experimental and theoretical ^{96}Zr(γ,n)^{95}Zr cross sections. The solid (dotted) line corresponds to the QRPA calculation with (without) the $M1$ component, as discussed in the text. The dash-dot line is obtained with a pure Lorentzian model. The diamonds corresponds to the cross section recommended by the IAEA handbook [14].



Similar disagreements: experimental cross section for ^{91}Zr (triangles) in comparison with our evaluation (line)

No experimental data for ^{96}Zr.

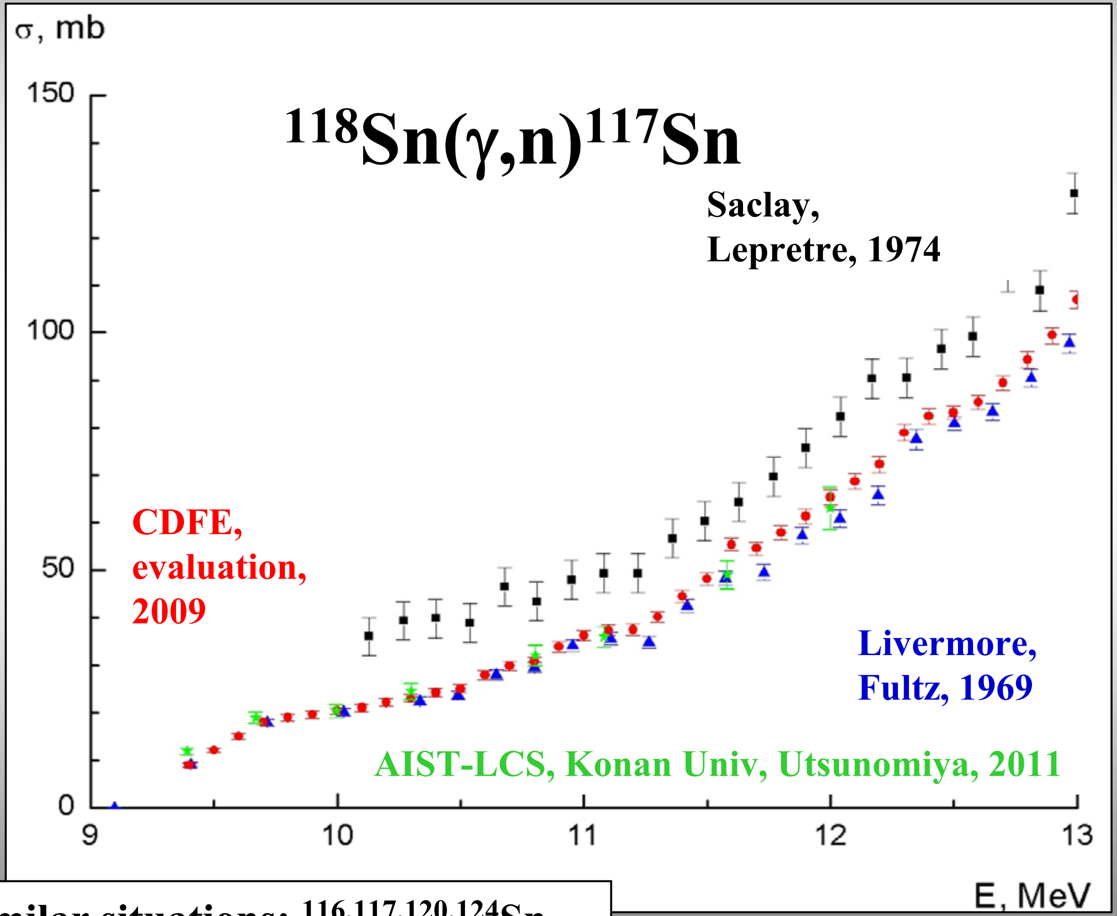
Comparison with data near threshold obtained using quasimonochromatic laser Compton-backscattering γ-rays

A. Lepretre et. al.,
Nucl.Phys., A219, 39 (1974)

V.V. Varlamov et. al.,
MSU SINP Preprint – 3/847, 2009,
Bull.Rus.Acad.Sci, 74, 833 (2010)

S.C. Fultz et. al.,
Phys.Rev., 186, 1255 (1969)

H. Utsunomiya et. al.,
Phys.Rev., C84, 055805 (2011)



Similar situations: $^{116,117,120,124}Sn$.

Current situation with regards to photoneutron reaction data obtained for energies of Giant Dipole Resonance (up to about 50 MeV)

- **there are many experimental data obtained by various methods in various laboratories;**
- **the majority of partial photoneutron reactions (primarily (γ, 1n), (γ, 2n), (γ, 3n)) cross sections has been obtained at Livermore and Saclay using the method of neutron multiplicity sorting;**
- **generally there are enough small (~ 12 %) disagreements between neutron yield reaction (γ, xn) cross sections;**
- **at the same time in many cases there are significant (up to 100 %) disagreements between partial photoneutron reaction cross sections;**
- **those disagreements are clear systematic: as a rule (γ, 1n) reaction cross sections are larger at Saclay but (γ, 2n) reaction cross sections are larger at Livermore.**

Current situation with regards to evaluations

Data for many nuclei do not satisfy to introduced reliability criteria (F – functions):

^{89}Y, ^{90,91,94}Zr, ^{115}In, ^{112,114,116,117,118,119,120,122,124}Sn, ^{127}I, ^{138}Ba, ^{159}Tb, ^{165}Ho, ^{181}Ta, ^{188,189,190,192}Os, ^{197}Au, ^{207,208}Pb

For many nuclei (underlined) new data obtained using new experimentally-theoretical method of evaluation noticeably disagree with both neutron multiplicity sorting experimental data and previous evaluations.

For ^{181}Ta evaluated data disagree with neutron multiplicity sorting but agree with activation data. For ^{118}Sn evaluated data disagree with neutron multiplicity sorting but agree with laser Compton-backscattering data.

Data for many nuclei are very doubtful:

^{65}Cu, ^{80}Se, ^{96,98,100}Mo, ^{92}Zr, ^{124,125}Te, ^{133}Cs, ^{141}Pr, ^{142}Ce, ^{160}Gd, ^{186}W, ^{209}Bi.

Therefore many data should be re-measured without neutron multiplicity sorting or at least evaluated using new criteria.

Important physical consequences

1. ***GDR width problem.*** **Because evaluated (γ ,1n) reaction cross sections are smaller than Saclay's and larger than Livermore's ones the GDR widths should be re-analyzed.**

2. ***GDR decay mechanism.*** **Saclay interpretation of high-energy tails of (γ, 1n) reaction cross sections as contributions of high-energy neutrons from GDR nonstatictical direct decay (those contributions evaluated to be about 17 - 30 %) looks like as very doubtful; Saclay (γ,n) data corrections described decrease those noticeably: direct decay contributions are not more than 10 - 12 %.**

3. ***Sum rule exhaustion.*** **Large Saclay's extra integrated cross section σ^{int}(γ, abs) ≈ 1.3 – 1.5 60NZ/A (MeV•mb) became doubtfully being all due to effective mass of nucleon (effect of exchange forces); Saclay data correction described affects (γ, abs) = (γ, sn) + (γ, 1p) ≈ (γ, sn) = (γ, xn) - (γ, 2n); (γ, 2n) reaction cross section described decrease both (γ, sn) and (γ, abs) data noticeably.**

Main goals
of further photonuclear data activity

- continue analysis and evaluation of photonuclear reaction cross sections using data reliability criteria;
- carrying out new photonuclear data measurement without neutron multiplicity sorting (activity, coincidences);
- production of new reliable photonuclear database;
- preparation of new Atlas of reliable photonuclear data.

Physics involved in photonuclear data:

traditional

- competition of various GDR decay channels;
- competition of direct and statistical processes in decays of highly-excited nuclear states;
- GDR configurational and isospin splitting effects;
- …. many other traditional fields;

specific

- monitoring of the beam luminosity in ultra-relativistic heavy-ion colliders(electromagnetic dissociation of colliding nuclei – neutron emission (primarily (γ, 1n) and (γ, 2n)) rates in mutual electromagnetic dissociation of colliding nuclei);
- nuclear astrophysics - mechanisms of production of heavy chemical elements; p-nuclei production in photonuclear reactions;
- various wide fields applications.

Proposals for future measurements using new monoenergetic γ–quanta source with energies up to ~ 19 MeV.

The new measurements for isotopes for which we found out the most prominent disagreements between experimental and evaluated reaction cross sections are of great interest on the first stage.

The 1-st priority: ^{159}Tb (B2n = 14.9 MeV), ^{181}Ta (B2n = 14.2 MeV), ^{208}Pb (B2n = 14.1 MeV).

The 2-nd priority: ^{94}Zr (B2n = 14.9 MeV), ^{186,188,189,190,192}Os (B2n = 14.9,14.3,13.9,13.7,13.3 MeV).

The 3-d priority (measurements would be possible for narrow energy range (~ 2 - 3 MeV)) ^{115}In (B2n = 16.3 MeV), ^{116}Sn (B2n = 17.1 MeV).

The 4-th priority new data will be evaluated further.

Unfortunately the correspondent final nuclei (^{157,158}Tb, ^{179}Ta, ^{206,207}Pb, ^{92,93}Zr, ^{184}Os, ^{113}In, ^{114,115}Sn) are not suitable candidates for activation measurements.

Therefore the suitable candidates for future measurements using activation method with highest priority are the following nuclei

^{181}Ta(γ, 1n)^{180}Ta, B1n = 7.6 MeV, $T_{1/2}$(^{180}Ta) = 8.54 hour
^{186}Os(γ, 1n)^{185}Os, B1n = 8.3 MeV, $T_{1/2}$(^{185}Os) = 93.6 day
^{115}In(γ, 1n)^{114}In, B1n = 8.3 MeV, $T_{1/2}$(114In) = 71.9 sec

Additionally there are suitable nuclei for which till now we have F-analysis results but have no evaluated data

^{165}Ho(γ, 1n)^{164}Ho, B1n = 8.0 MeV, $T_{1/2}$(^{164}Ho) = 30.0 min
^{165}Ho(γ, 2n)^{163}Ho, B2n = 14.7 MeV, $T_{1/2}$(^{163}Ho) = 1.0 sec

^{141}Pr(γ, 1n)^{140}Pr, B1n = 9.4 MeV, $T_{1/2}$(^{140}Pr) = 3.4 min
^{141}Pr(γ, 2n)^{139}Pr, B2n = 17.3 MeV, $T_{1/2}$(^{139}Ho) = 4.4 hour

^{133}Cs(γ, 1n)^{132}Cs, B1n = 9.0 MeV, $T_{1/2}$(^{140}Pr) = 6.5 day
^{133}Cs(γ, 2n)^{131}Cs, B2n = 16.2 MeV, $T_{1/2}$(^{139}Ho) = 9.7 day

^{127}I(γ, 1n)^{126}I, B1n = 9.1 MeV, $T_{1/2}$(^{126}I) = 12.9 day
^{127}I(γ, 2n)^{125}I, B2n = 16.2 MeV, $T_{1/2}$(^{125}I) = 59.4 day

THANKS A LOT

FOR ATTENTION!