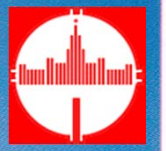
International Atomic Energy Agency
Nuclear Data Services
Provided by the Nuclear Data Section

IAEA Meeting
of the International Network of
Nuclear Reaction Data Centres (NRDC)
16 - 19 April 2012, Paris, France

Centre for
Photonuclear
Experiments
Data



Lomonosov Moscow State University
Skobeltsyn Institute of Nuclear Physics

Vladimir Varlamov

Summary of the CDFE nuclear data activity for 2011 – 2012 period of time

V.V.Varlamov, S.Yu.Komarov, N.N.Peskov, M.E.Stepanov

Progress Report to the IAEA Meeting
of the International Network of Nuclear Reaction Data Centres (NRDC)
16 –19 April 2021, OECD/NEA Headquarters, Issy-les-Moulineaux, France

This report contains the short review of the main fields of nuclear data activity of the Centre for Photonuclear Experiments Data (Centr Dannykh Fotoyadernykh Eksperimentov – CDFE) of Skobeltsyn Institute of Nuclear Physics of Lomonosov Moscow State University and main results obtained. All works were carried out in close co-operation with the Nuclear Science Section in the frame of the IAEA Nuclear Reaction Data Centres Network for the period of time from the IAEA Technical Meeting on the International Network of Nuclear Reaction Data Centers" (23 – 24 May 2011, IAEA, Vienna, Austria) till the spring of 2012.

General

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 modern reliable and authentic 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.

Organization

The CDFE has a status of Nuclear Data Analysis Laboratory within the Skobeltsyn Institute of Nuclear Physics of the Lomonosov Moscow State University. The total permanent stuff includes the Centre head (Vladimir Varlamov), 5 professional (Igor Boboshin, Sergei Komarov, Nikolay Peskov, Mikhail Stepanov, Valery Viazovsky) and 2 general service officers. Because the CDFE exists inside Moscow University there are 3 – 4 students per year participating in nuclear data activity.

Main fields of nuclear data activity

EXFOR Compilations

Photonuclear Data Evaluations

Nuclear Structure Data Evaluations

Nuclear Database Service

EXFOR Compilations

5 new CDFE EXFOR transes **TRANS.M058 - 062** have been produced and transmitted to the IAEA NDS.

All transes contain both new and old corrected entries but the **TRANS.M061** was fully devoted to the correction of area **M** entries in accordance with the NRDC Network experts comments and recommendations (WP21011-16, 26 of previous technical meeting) .

On the whole CDFE trances have been produced in the reported period 2011/2012 contain:

33 new ENTRYs (208 SUBENTs)

and

67 retransmitted ENTRYs (291 SUBENTs).

Photonuclear Data Evaluations

The investigations of reliability and authenticity of data for partial photonuclear reaction cross sections were continued. Using new simple objective and absolute criteria – transitional multiplicity functions Fi = $\sigma(\gamma,in)/\sigma(\gamma,xn)$ which have definite absolute value upper limits 1.0 for i = 1, 0.5 for i = 2, 0.33 for i = 3, etc. that was shown that majority of partial cross section data obtained at Livermore (USA) and Saclay (France) are not reliable and authentic. In the frame of proposed method for partial reaction cross section evaluation new reliable and authentic data were obtained for ^{90}Zr, ^{159}Tb, ^{165}Ho, ^{181}Ta, ^{208}Pb additionally to data obtained before for ^{63}Cu, ^{89}Y, ^{115}In, ^{112,114,116,117,118,119,120,122,124}Sn, ^{197}Au. For all nuclei mentioned above and for reactions (γ,n), $(\gamma,2n)$, $(\gamma,3n)$ and $(\gamma,sn) = (\gamma,n) + (\gamma,2n) + (\gamma,3n)$ (is very important for estimation of (γ,abs) – main reaction for Giant Dipole Resonance - main features were evaluated.

Nuclear Structure Data Evaluations

The CDFE program of nuclear structure data evaluation was continued. Using previously developed method of joint analysis and evaluation of data on nucleon stripping and pick-up nuclear reactions new evaluated data for energies and nucleon occupation numbers were obtained both for proton and neutron subshells of 11 even-even nickel isotopes $^{48-68}$Ni. Data were analyzed in the frame of dispersive optical model. That was shown that systematics obtained helps to one foretell reliable single-particle energies of unstable nuclei inside the isotopic chain.

Nuclear Database Service

Some of the CDFE DB that are available through the CDFE Web-site (http://cdfe.sinp.msu.ru) were based on the international sources and founds of data produced and maintained by Nuclear Reaction Data Centres Network and by USA NNDC and NSDD:

- **"Nuclear Reaction Database (EXFOR)":** many data for reactions induced by photons, neutrons, charge particles and heavy ions;

- **"Complete Nuclear Spectroscopy Database "Relational ENSDF"** contains many nuclear spectroscopy data for all known (~3200) nuclides from the well-known international fund ENSDF (Evaluated Nuclear Structure Data File);

- **"Nuclear Physics Publications ("NSR" Database"** is the really relational DB based on the data fund of NSR (Nuclear Science References).

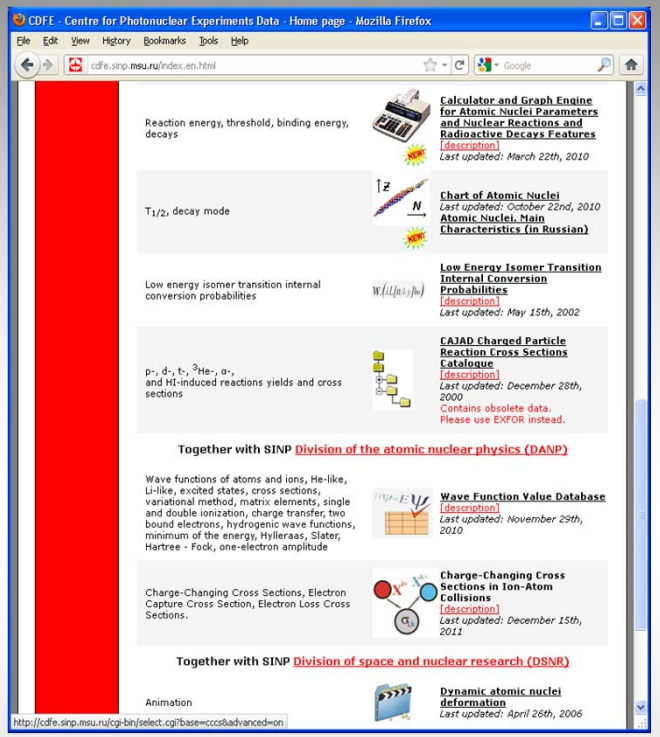
Those databases used international sources of information but CDFE-developed powerful and flexible original Search Engines.

Other databases are CDFE-produced and maintained:

- digital **"Chart of Giant Dipole Resonance Main Parameters"** contains data on main parameters (energy position, amplitude, width, integrated cross section) of GDR for many nuclei;

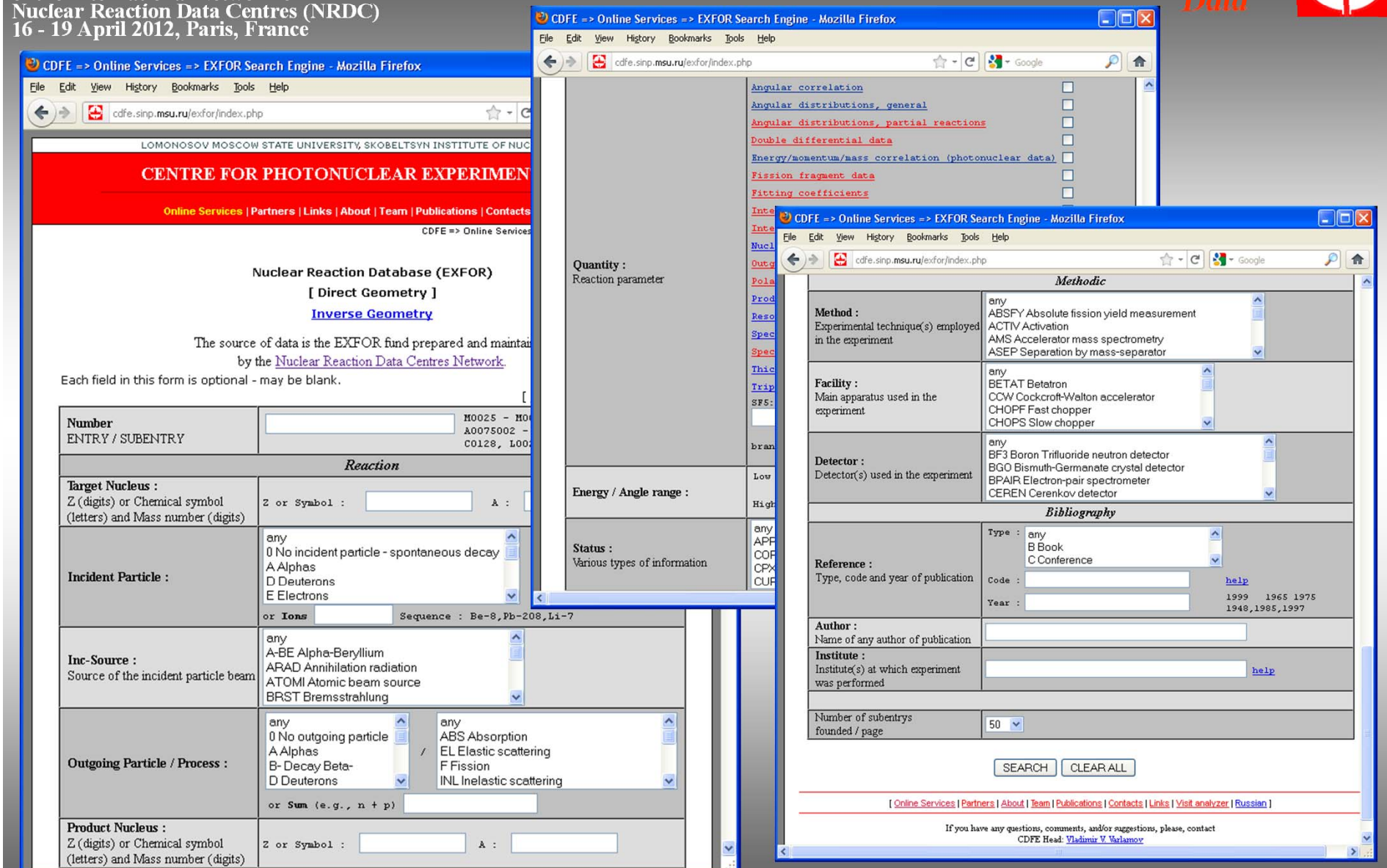
- digital **"Chart of Nucleus Shape and Size Parameters"** contains data on quadrupole moments, parameters of quadrupole deformation and charge radii for many nuclei;

- **"Nucleus Ground and Isomeric State Parameters"** combines many useful information on the nucleus as whole and its ground and isomeric states properties (masses, binding energy, nucleon separation energy, decay mode, energy of various decays, etc).



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.


CDFE => Online Services => EXFOR Search Engine - Mozilla Firefox
File Edit View History Bookmarks Tools Help
cdfe.sinp.msu.ru/exfor/index.php
LOMONOSOV MOSCOW STATE UNIVERSITY, SKOBELTSYN INSTITUTE OF NUC
CENTRE FOR PHOTONUCLEAR EXPERIMEN
Online Services | Partners | Links | About | Team | Publications | Contacts
CDFE => Online Services
Nuclear Reaction Database (EXFOR)
[Direct Geometry]
Inverse Geometry
The source of data is the EXFOR fund prepared and maintai
by the Nuclear Reaction Data Centres Network.
Each field in this form is optional - may be blank.
Number
ENTRY / SUBENTRY
Reaction
Target Nucleus :
Z (digits) or Chemical symbol (letters) and Mass number (digits)
Z or Symbol :
A :
Incident Particle :
any
0 No incident particle - spontaneous decay
A Alphas
D Deuterons
E Electrons
or Ions
Sequence : Be-8,Pb-208,Li-7
Inc-Source :
Source of the incident particle beam
any
A-BE Alpha-Beryllium
ARAD Annihilation radiation
ATOMI Atomic beam source
BRST Bremsstrahlung
Outgoing Particle / Process :
any
0 No outgoing particle
A Alphas
B- Decay Beta-
D Deuterons
any
ABS Absorption
EL Elastic scattering
F Fission
INL Inelastic scattering
or Sum (e.g., n + p)
Product Nucleus :
Z (digits) or Chemical symbol (letters) and Mass number (digits)
Z or Symbol :
A :
CDFE => Online Services => EXFOR Search Engine - Mozilla Firefox
Angular correlation
Angular distributions, general
Angular distributions, partial reactions
Double differential data
Energy/momentum/mass correlation (photonuclear data)
Fission fragment data
Fitting coefficients
Quantity :
Reaction parameter
Energy / Angle range :
Status :
Various types of information
CDFE => Online Services => EXFOR Search Engine - Mozilla Firefox
Methodic
Method :
Experimental technique(s) employed in the experiment
any
ABSFY Absolute fission yield measurement
ACTIV Activation
AMS Accelerator mass spectrometry
ASEP Separation by mass-separator
Facility :
Main apparatus used in the experiment
any
BETAT Betatron
CCW Cockcroft-Walton accelerator
CHOPF Fast chopper
CHOPS Slow chopper
Detector :
Detector(s) used in the experiment
any
BF3 Boron Trifluoride neutron detector
BGO Bismuth-Germanate crystal detector
BPAIR Electron-pair spectrometer
CEREN Cerenkov detector
Bibliography
Reference :
Type, code and year of publication
Type :
any
B Book
C Conference
Code :
Year :
help
1999 1965 1975
1948,1985,1997
Author :
Name of any author of publication
Institute :
Institute(s) at which experiment was performed
help
Number of subentrys founded / page
50
SEARCH
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If you have any questions, comments, and/or suggestions, please, contact
CDFE Head: Vladimir V. Varlamov

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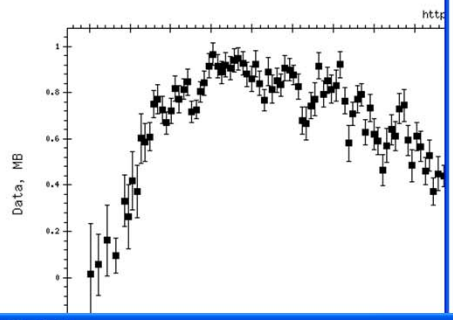
IAEA Meeting of the International Network of Nuclear Reaction Data Centres (NRDC) 16 - 19 April 2012, Paris, France

Centre for Photonuclear Experiments Data

EXFOR L0018002 Data/Graph - Mozilla Firefox

```
SUBENT      L0018002 970129
AUTHOR      (B.L.BERMAN,S.C.FULTZ,P.F.YERGIN)
TITLE       Three-body photodisintegration of He3.
REFERENCE   (J,PR/C,10,2221,7412)
            (J,PRL,24,1494,7006)
INSTITUTE   (1USALRL)
INC-SOURCE  Positron annihilation
FACILITY    (LINAC)
REACTION    (2-HE-3(G,X)0-NN-1,,SIG)
            The sum: (G,N) + (G,NP)
            Threshold of (gamma,n+p) reaction
```



CDFE search engine. - Mozilla Firefox

Save

Look through sel

Subent	First Author	Reference (+NSR)	Target Nucleus
L0152002	YIlieva+	J,EPJ/A,43,261,2010	1-H-2
L0152003	YIlieva+	J,EPJ/A,43,261,2010	1-H-2
L0152004	YIlieva+	J,EPJ/A,43,261,2010	1-H-2
L0152005	YIlieva+	J,EPJ/A,43,261,2010	1-H-2
L0152006	YIlieva+	J,EPJ/A,43,261,2010	1-H-2
L0052002	D.D.Faul+	J,PR/C,24,849,198109	1-H-3
L0052004	D.D.Faul+		
L0052007	D.D.Faul+		
L0052003	D.D.Faul+		
L0052008	D.D.Faul+		
L0157002	R.Nasseripo		
L0157003	R.Nasseripo		
L0018002	B.L.BERMA		
L0149002	M.Karlsson		
M0469002	B.L.BERMA		
M0478002	B.L.BERMA		
L0052005	D.D.Faul+		
L0052006	D.D.Faul+		
M0469003	B.L.BERMA		
L0023002	B.L.BERMA		
M0520002	M.MACCO		
M0546002	M.MACCO		
L0051002	B.L.BERMA		
L0051003	B.L.BERMAN+	J,PR/C,22,2273,8012	2-HE-4 (G,N)* 2-HE-3 ,INT
M0327002	J.D.IRISH+	J,CJP,53,802,75	2-HE-4 (G,N) 2-HE-3 ,DA/D
M0327003	J.D.IRISH+	J,CJP,53,802,75	2-HE-4 (G,N) 2-HE-3 ,DA/D

Mozilla Firefox

```
SUBENT        L0018001     970129                          L0018  1    1C
BIB                8           11                          L0018  1    2
INSTITUTE   (1USALRL)                                      L0018  1    3
REFERENCE   (J,PR/C,10,2221,7412)                          L0018  1    4
            (J,PRL,24,1494,7006)                           L0018  1    5
AUTHOR      (B.L.BERMAN,S.C.FULTZ,P.F.YERGIN)              L0018  1    6
TITLE       Three-body photodisintegration of He3.         L0018  1    7
FACILITY    (LINAC)                                        L0018  1    8
INC-SOURCE  Positron annihilation                          L0018  1    9
DETECTOR    (PROPC) BF3 counters in polyethylene moderator L0018  1   10
HISTORY     (780511T) Converted from Berman compilation    L0018  1   11
            (891201A) BIB Updated                          L0018  1   12
            (950330A) BIB Updated                          L0018  1   13I
ENDBIB             11           0                          L0018  1   14
NOCOMMON            0           0                          L0018  1   15
ENDSUBENT          14           0                          L0018  199999
SUBENT        L0018002     970129                          L0018  2    1C
BIB                1           3                          L0018  2    2C
REACTION    (2-HE-3(G,X)0-NN-1,,SIG)                       L0018  2    3
                                                           L0018  2    4I
                                                           L0018  2    5I
                                                           L0018  2    6
```

) reaction is 7.7 MeV.

Nucleus Ground and Isomeric States Parameters - results - Mozilla Firefox

Return to the CDFE Online Services Main Menu

Nucleus Ground and Isomeric States Parameters - results

$_2$He

The source of data is the current version of Nuclear Wallet Cards database prepared and maintained by the USA NNDC

[See description]

A	JP	$T_{1/2}$, G, *Abundance*	Atomic Mass M, Micro-U	Atomic Mass M, MeV	$D_{A.M.}$, Micro-U	Mass Excess M-A, MeV	Atomic Mass, MeV	$D_{M.E}$ keV
								He -
3	1/2+	**0.000137%**	3.016029	2809.413		14.931	2808.391	

CDFE search engine. - Mozilla Firefox

CDFE ENSDF

Get all data

ENSDF Source	Nucleus	Level energy	Spin-parity	Half-life
11.55	6-C-11	0	3/2-	20.39 M (2)
11.55	6-C-11	2000.0 (5)	1/2-	7.1 FS (5)
11.55	6-C-11	4318.8 (12)	5/2-	< 8.3 FS
11.55	6-C-11	4804.2 (12)	3/2-	< 7.6 FS
11.55	6-C-11	6339.2 (14)	1/2+	< 76.2 FS
11.55	6-C-11	6478.2 (13)	7/2-	< 6 FS
11.55	6-C-11	6904.8 (14)	5/2+	< 48 FS
11.55	6-C-11	7499.7 (15)	3/2+	< 63 FS
11.55	6-C-11	8104.5 (17)	3/2-	0.04 FS (3)
11.55	6-C-11	8420 (2)	5/2-	0.030 FS (8)
11.55	6-C-11	8655 (8)	7/2+	<= 5 KEV

Help

=148197

/C,10,2221,7412

Physics

V, measured |s(E,En),

NSR - 2-HE-3 (G,X) 0-NN-1

4/23/2012

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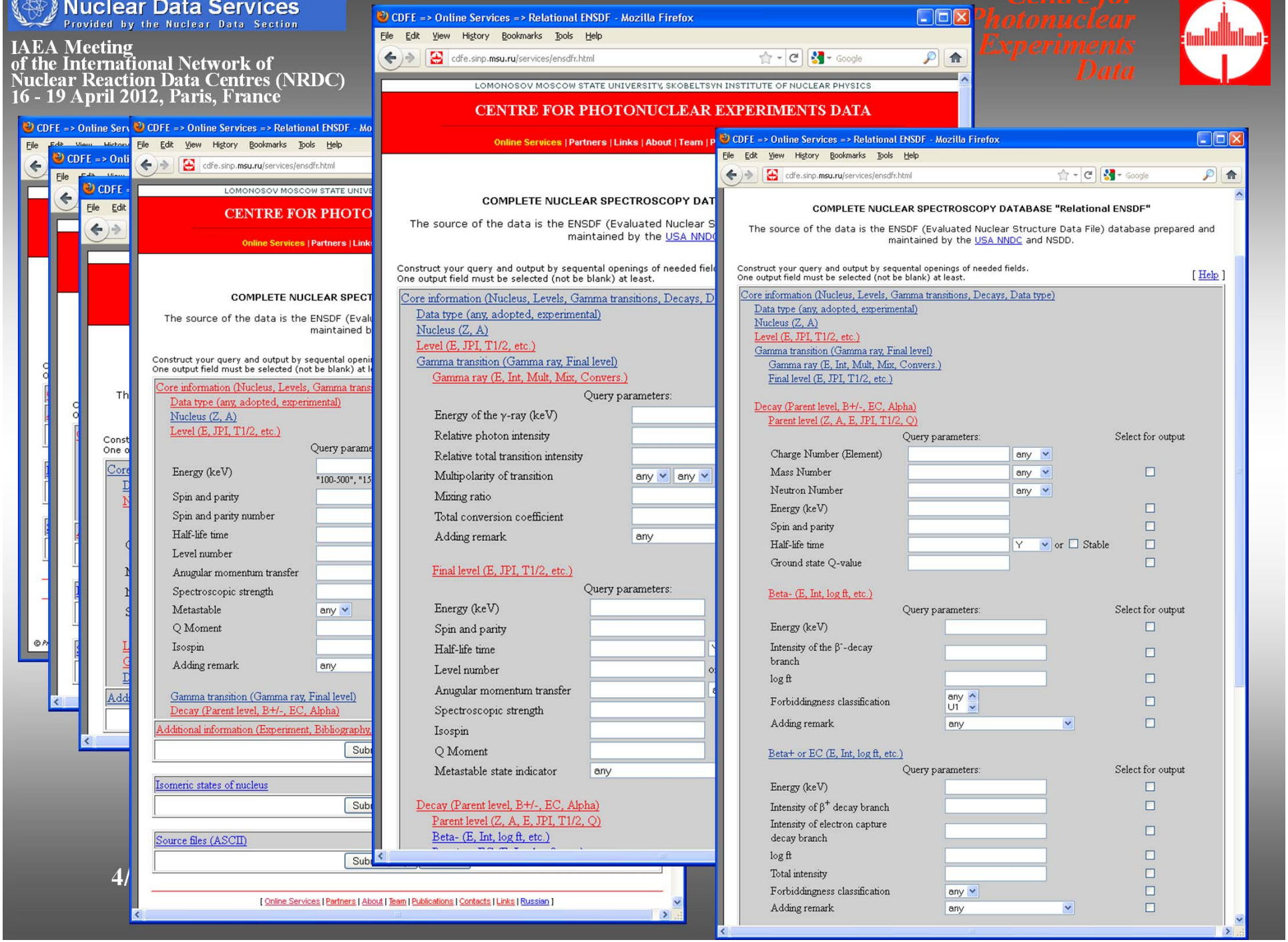
Centre for Photonuclear Experiments Data



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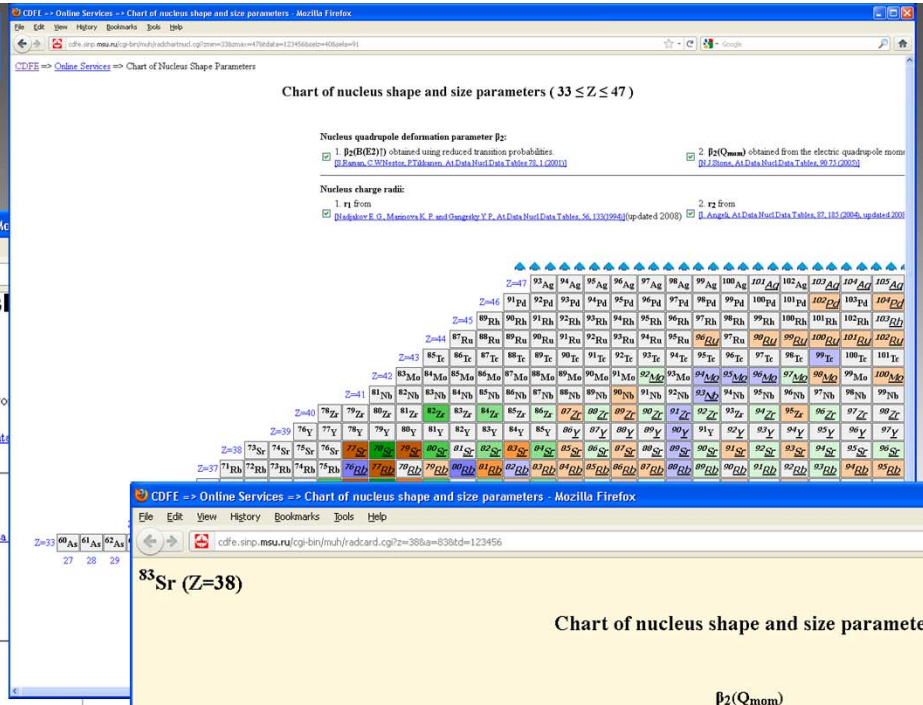
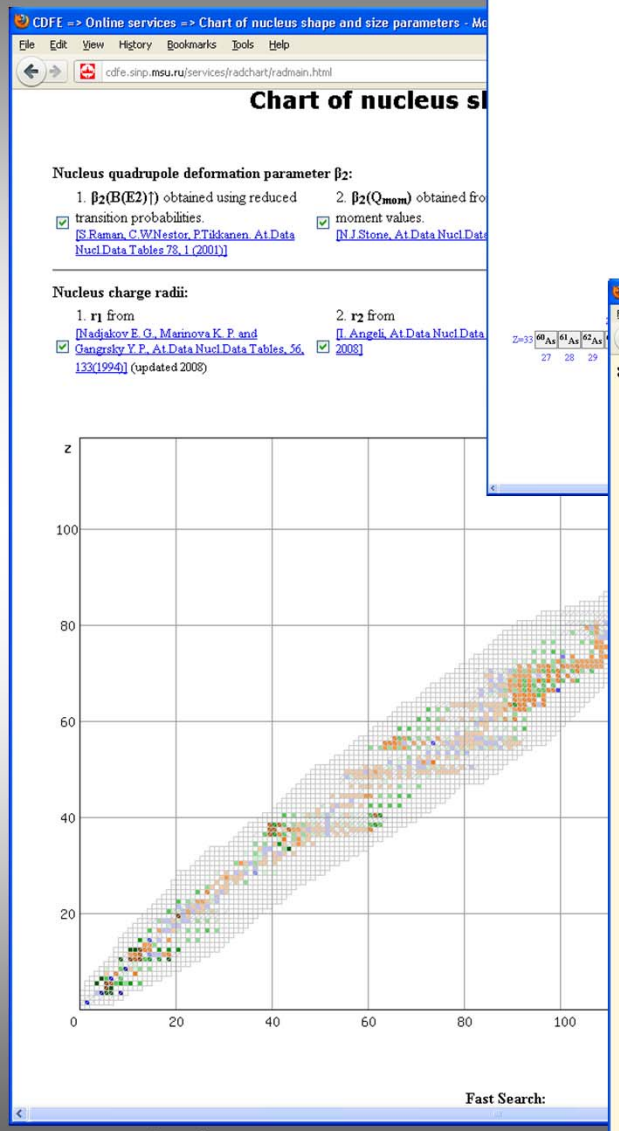
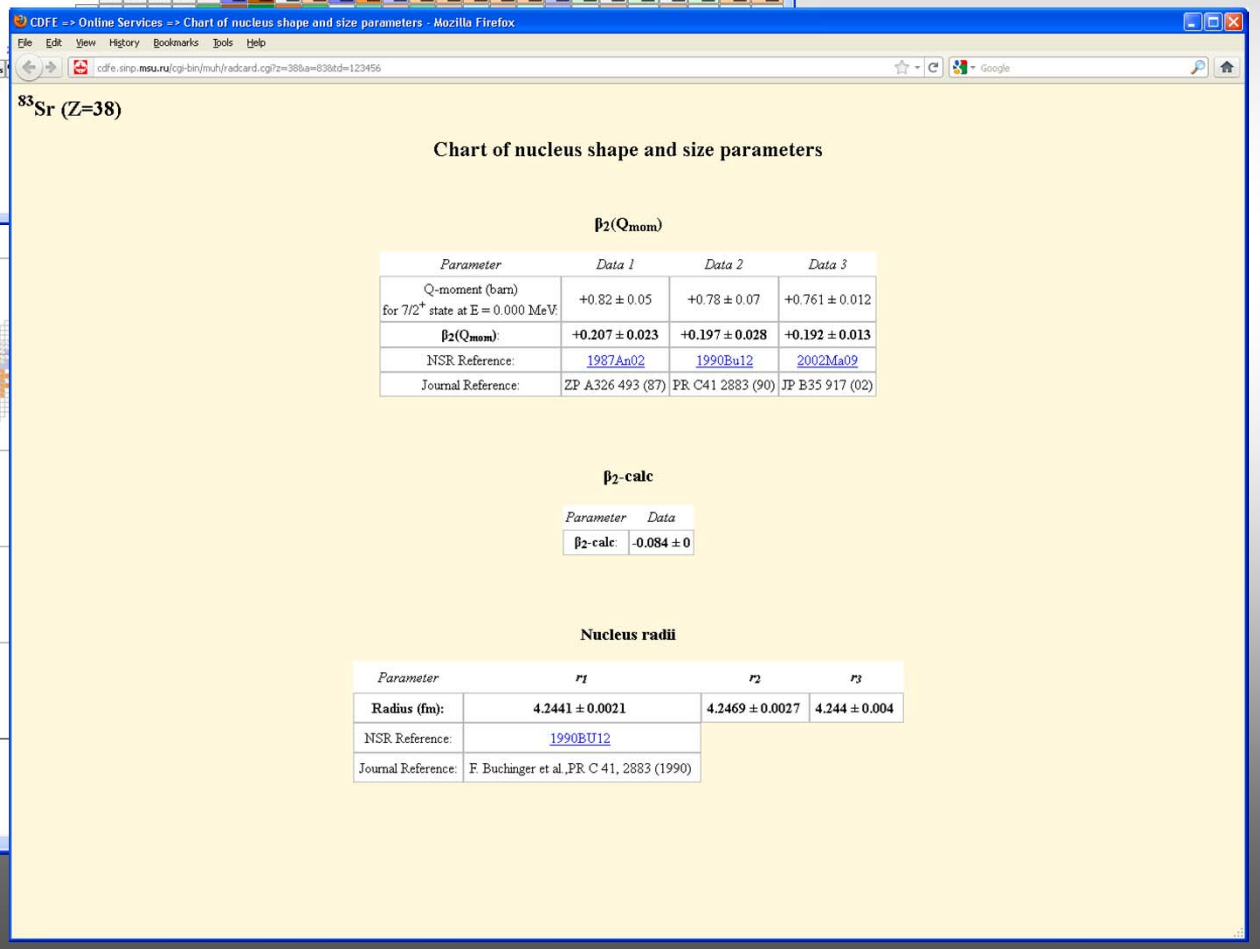
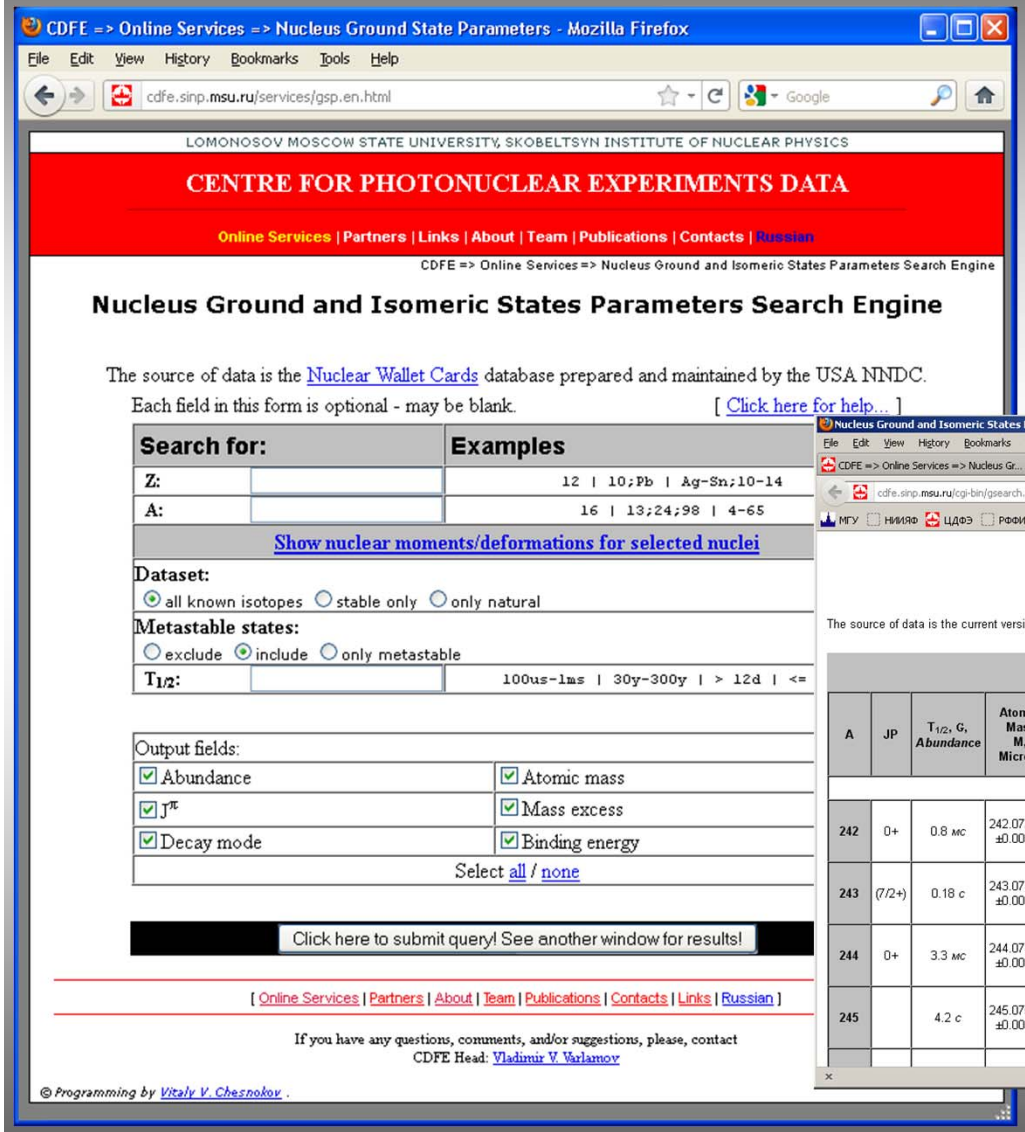






4/23/2012


CDFE => Online Services => Nucleus Ground State Parameters - Mozilla Firefox
File Edit View History Bookmarks Tools Help
cdfe.sinp.msu.ru/services/gsp.en.html
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CENTRE FOR PHOTONUCLEAR EXPERIMENTS DATA
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CDFE => Online Services => Nucleus Ground and Isomeric States Parameters Search Engine
Nucleus Ground and Isomeric States Parameters Search Engine
The source of data is the Nuclear Wallet Cards database prepared and maintained by the USA NNDC.
Each field in this form is optional - may be blank.
[Click here for help...]
Search for:
Examples
Z:
12 | 10;Pb | Ag-Sn;10-14
A:
16 | 13;24;98 | 4-65
Show nuclear moments/deformations for selected nuclei
Dataset:
all known isotopes stable only only natural
Metastable states:
exclude include only metastable
T1/2:
100us-1ms | 30y-300y | > 12d | <=
Output fields:
Abundance
Atomic mass
Jπ
Mass excess
Decay mode
Binding energy
Select all / none
Click here to submit query! See another window for results!
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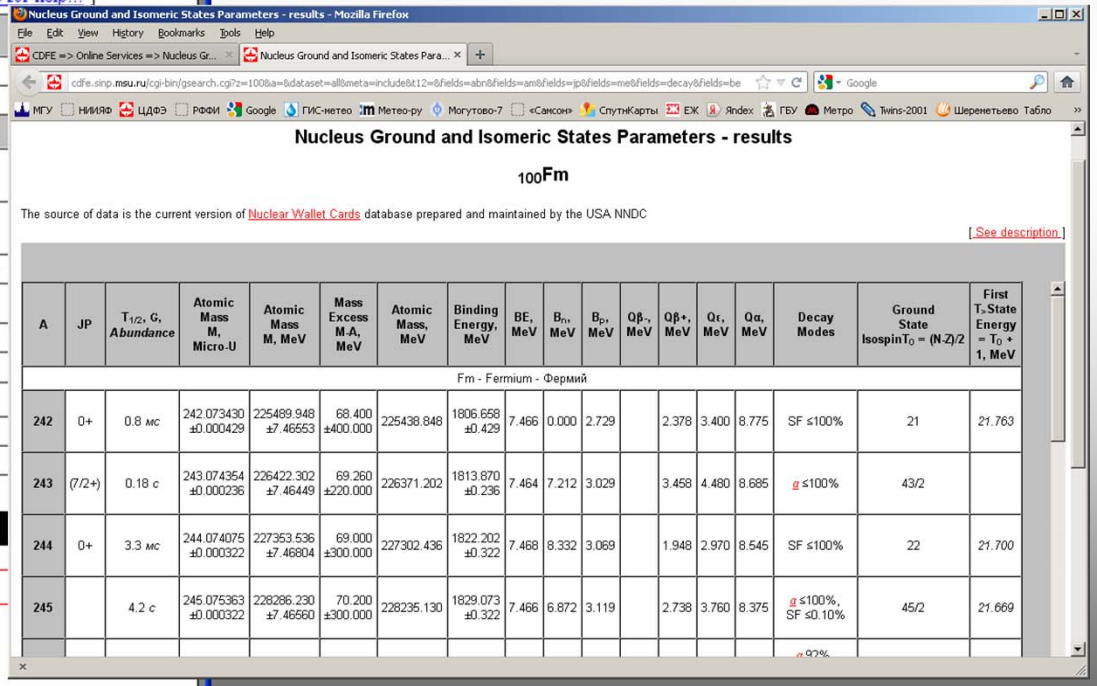
CDFE Head: Vladimir V. Varlamov
© Programming by Vitaly V. Chesnokov .


Nucleus Ground and Isomeric States Parameters - results - Mozilla Firefox
Nucleus Ground and Isomeric States Parameters - results
100Fm
The source of data is the current version of Nuclear Wallet Cards database prepared and maintained by the USA NNDC
[See description]
Fm - Fermium - Фермий
242 0+ 0.8 мс 242.073430 ±0.000429 225489.948 ±7.46553 68.400 ±400.000 225438.848 1806.658 ±0.429 7.466 0.000 2.729 2.378 3.400 8.775 SF ≤100% 21 21.763
243 (7/2+) 0.18 с 243.074354 ±0.000236 226422.302 ±7.46449 69.260 ±220.000 226371.202 1813.870 ±0.236 7.464 7.212 3.029 3.458 4.480 8.685 α ≤100% 43/2
244 0+ 3.3 мс 244.074075 ±0.000322 227353.536 ±7.46804 69.000 ±300.000 227302.436 1822.202 ±0.322 7.468 8.332 3.069 1.948 2.970 8.545 SF ≤100% 22 21.700
245 4.2 с 245.075363 ±0.000322 228286.230 ±7.46560 70.200 ±300.000 228235.130 1829.073 ±0.322 7.466 6.872 3.119 2.738 3.760 8.375 α ≤100%, SF ≤0.10% 45/2 21.669

Photonuclear Data Evaluations

Main direction:

investigations of reliability and authenticity of data for partial photonuclear reaction cross sections

Main results:

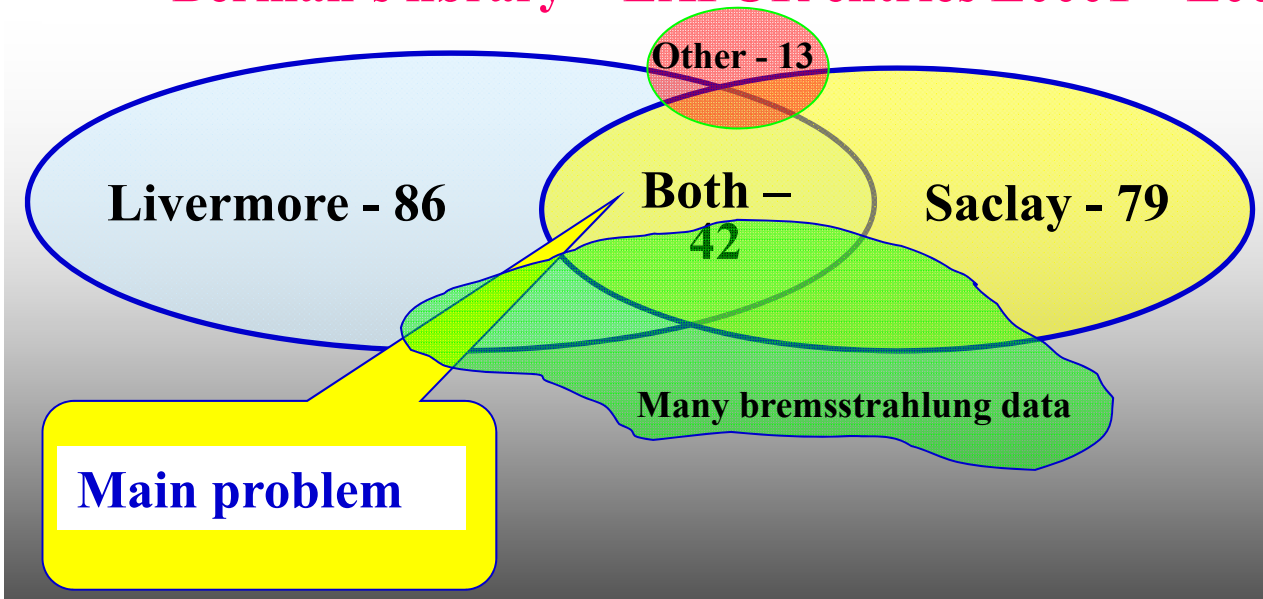
- **many experimental data data for partial photonuclear reaction cross sections from various experiments were analyzed;**
- **new simple objective and absolute criteria were found out for investigation of data reliability and authenticity;**
- **that was shown that majority of experimental data on partial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

Main problem:

- many experimental data data for partial photonuclear reaction cross sections are published (majority was obtained at Livermore and Saclay):

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 (~ 180 nuclei sets)



For each nucleus – cross sections:

(γ,3n)

(γ,2n)

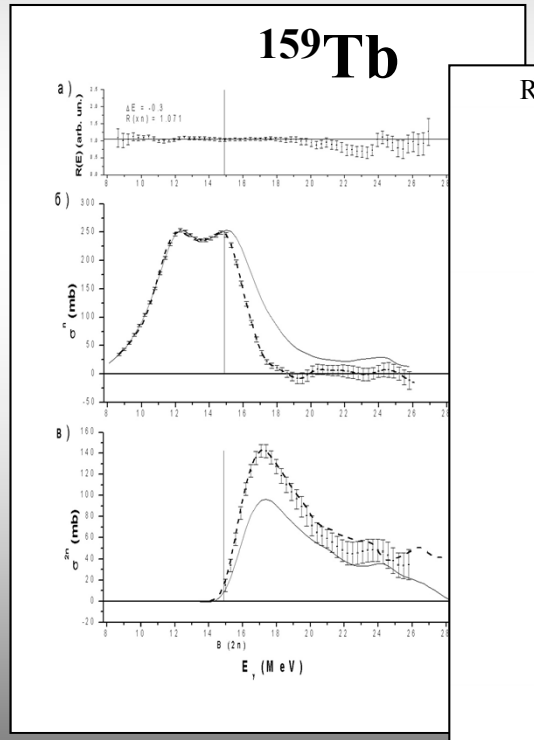
(γ,n)

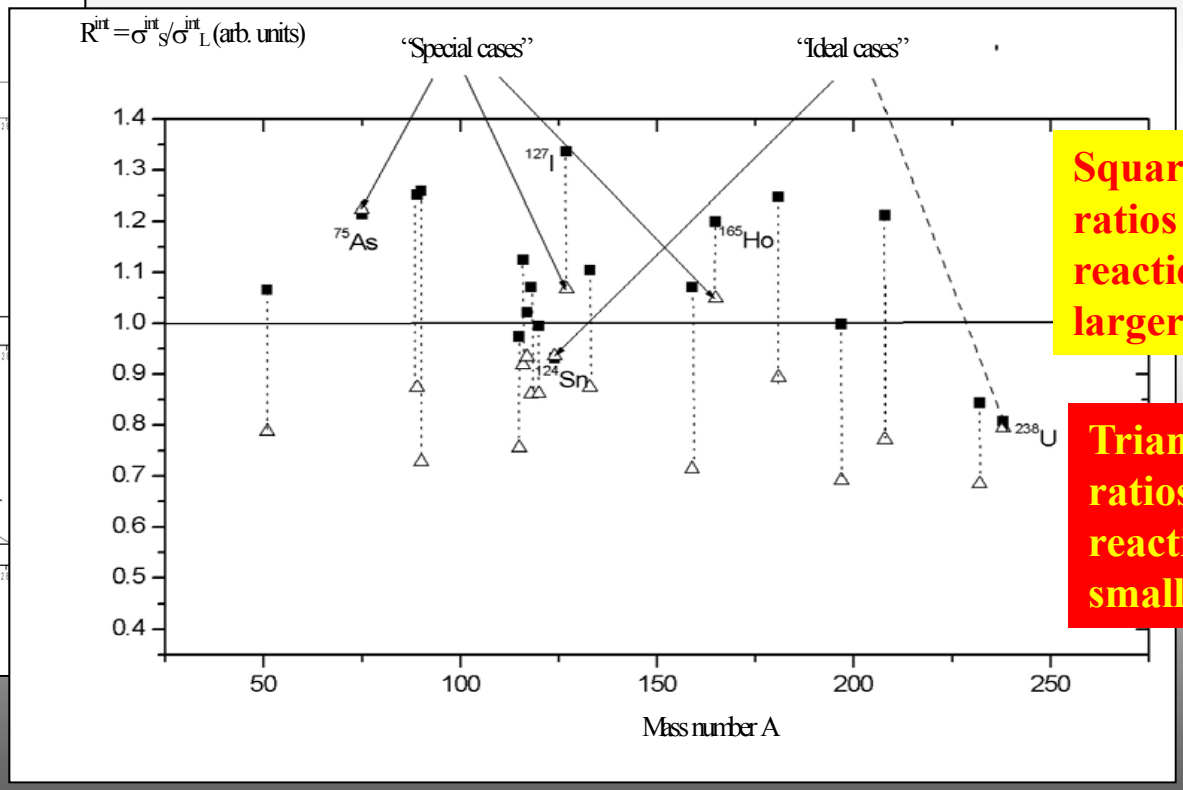
(γ,sn) = + (γ,n) + (γ,2n) + (γ,3n)

(γ,xn) = + (γ,n) + 2(γ,2n) + 3(γ,3n)

Main problem: many significant (till 100 %!) disagreements were found out between data from two laboratories;

(γ,n) – (γ,2n) disagreements between Saclay and Livermore data – ratios of integrated cross sections





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

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

In special investigation (E.Wolinec and M.N. Martin. Revista Brasiera de Fisica, 17 (1987) 56) it was shown that the reason is incorrect procedure for neutron multiplicity sorting used at Saclay – (γ,2n) data are underestimated but (γ,n) vise versa overestimated.

Total photoneutron reaction cross section in GDR energy region

$$(\gamma,xn) = (\gamma,n) + 2(\gamma,2n).$$

Ratio R ("Saclay/Livermore" normalization) for all reactions cross sections

$$R = \sigma^{xn}_S/\sigma^{xn}_L = \sigma^{n}_S/\sigma^{n}_L = \sigma^{2n}_S/\sigma^{2n}_L = (\sigma^{n}_S + 2\sigma^{2n}_S)/(\sigma^{n}_L + 2\sigma^{2n}_L),$$

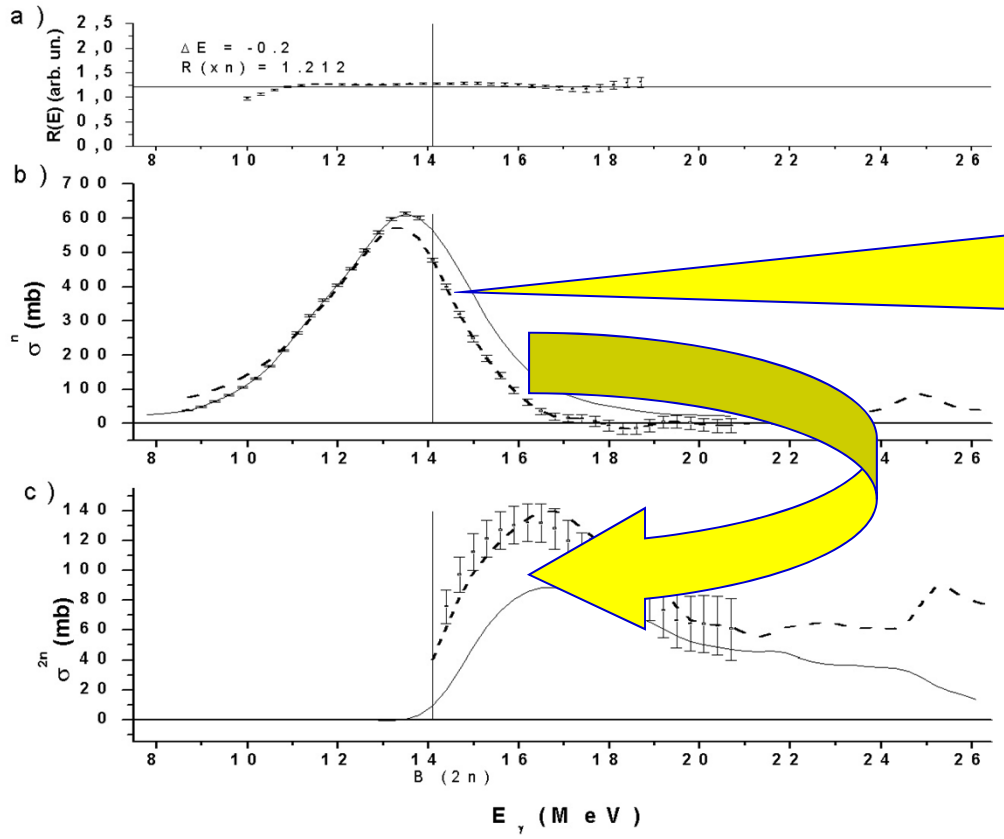
$$\sigma^{xn}_S = (\sigma^{n}_S + 2\sigma^{2n}_S) = R\sigma^{xn}_L = R(\sigma^{n}_L + 2\sigma^{2n}_L) .$$

Saclay corrected $\sigma^{2n}_S{}^*$ must be equal to Livermore corrected: $\sigma^{2n}_L{}^* = R\sigma^{2n}_L$,

therefore: $\sigma^{2n}_L{}^* = \sigma^{2n}_S{}^* = R\sigma^{2n}_L = \sigma^{2n}_S + ½(\sigma^{n}_S - R\sigma^{n}_L)$.

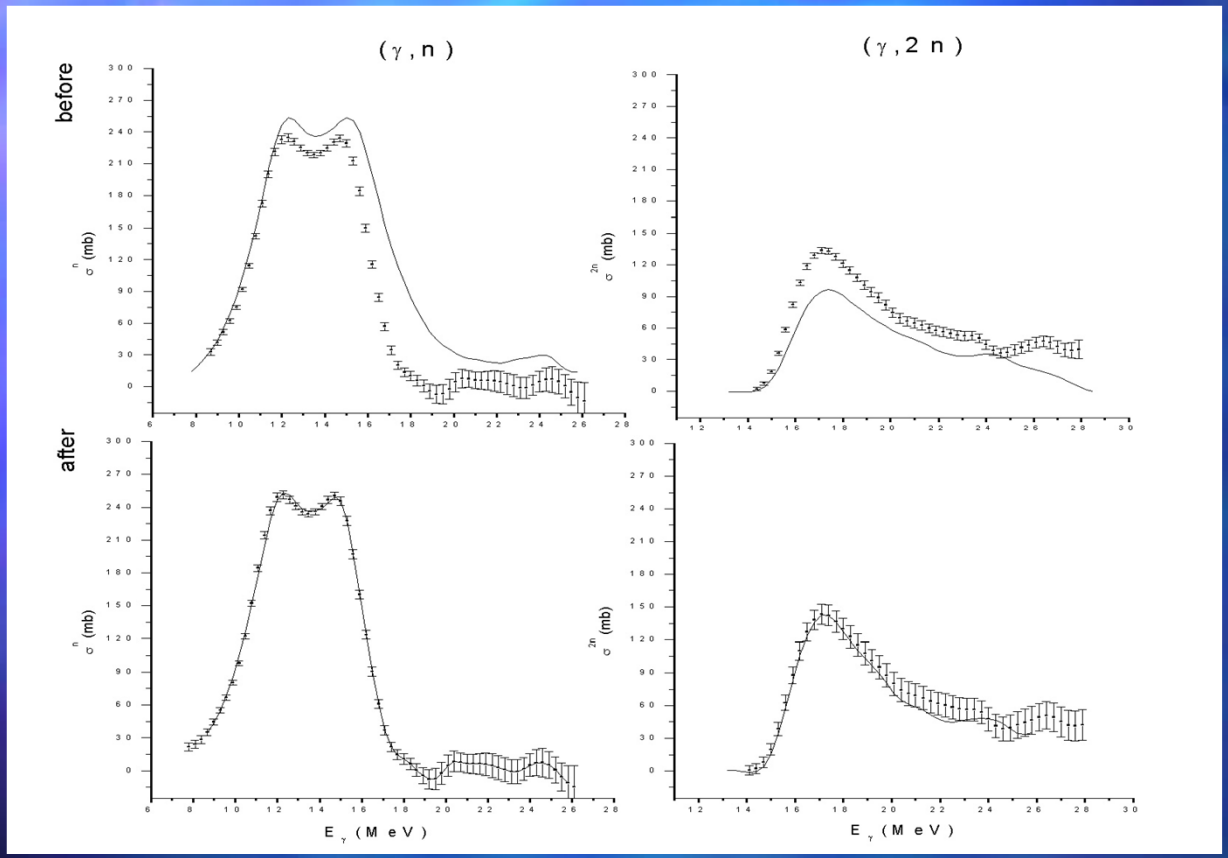
Saclay (γ,n) reaction cross section part $½(\sigma^{n}_S - R\sigma^{n}_L)$ is "transmitted back" to Saclay (γ,2n) reaction cross section σ^{2n}_S.

Joint correction of both (γ,n) and (γ,2n) reaction cross sections of Saclay and Livermore for ^{208}Pb



Part of "incorrect" overestimated Saclay (γ,n) cross section must be transported back into (γ,2n) cross section

^{159}Tb



(γ,n) and (γ,2n) reaction data

← before

and

← after

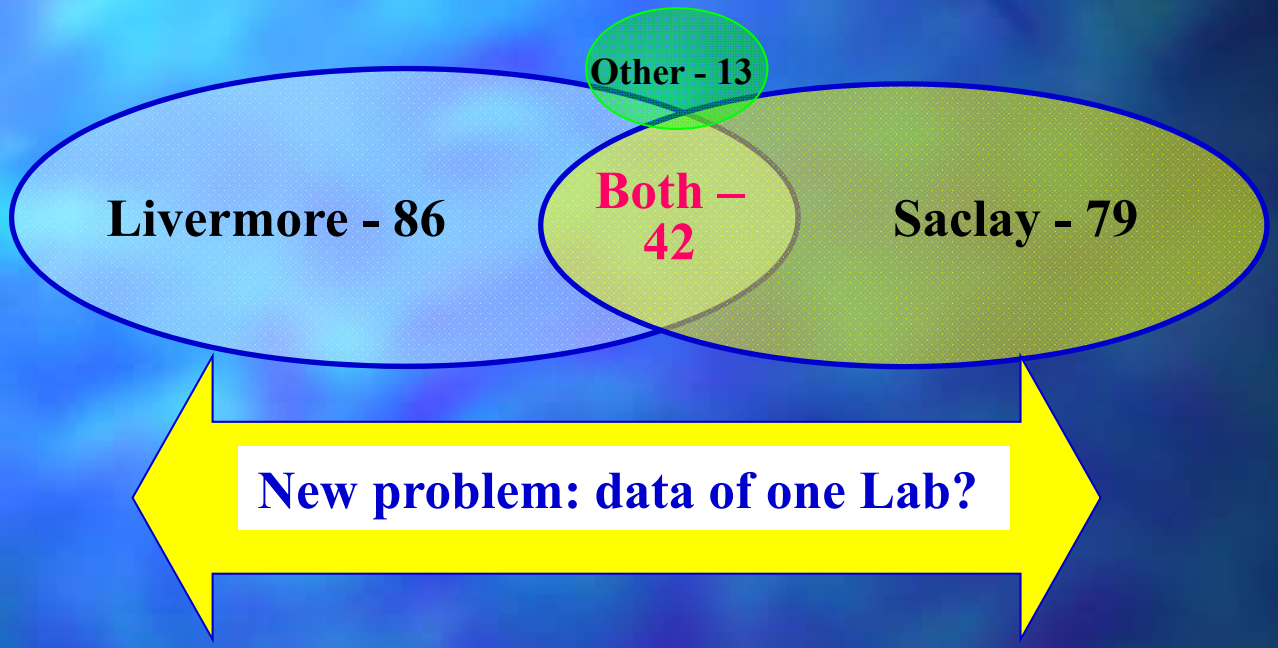
joint correction procedure of recalculation from incorrect Saclay data to correct Livermore ones

Data 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) were corrected (V.V.Varlamov et al. (J,YK,2003,(1-2),48,2003), put into EXFOR library – M0635 and added later by data for 4 actinides (^{232}Th, ^{238}U, ^{237}Np, ^{239}Pu) – M0722.

It was recommended to use "good" Livermore data and do not use "bad" Saclay ones,

but…

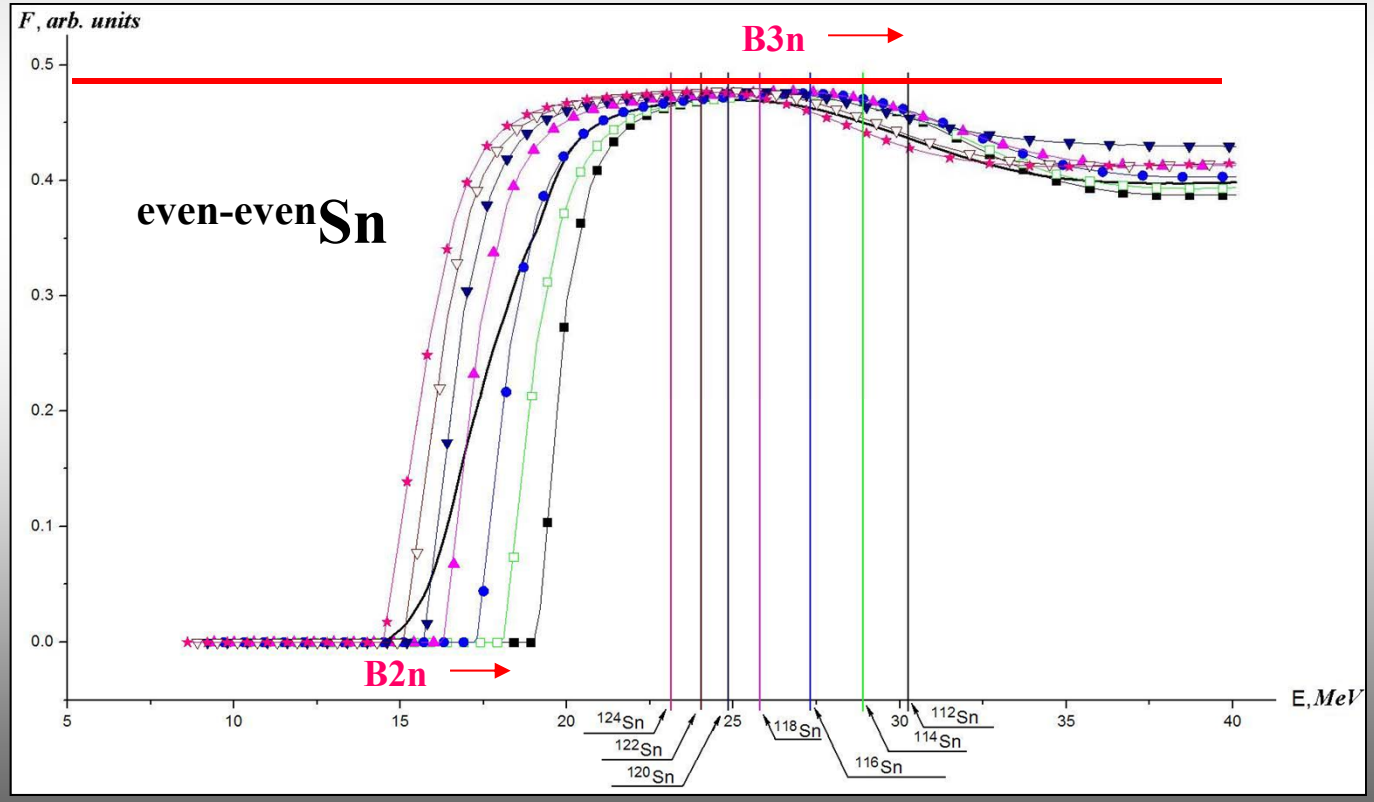
"Before" and "after"



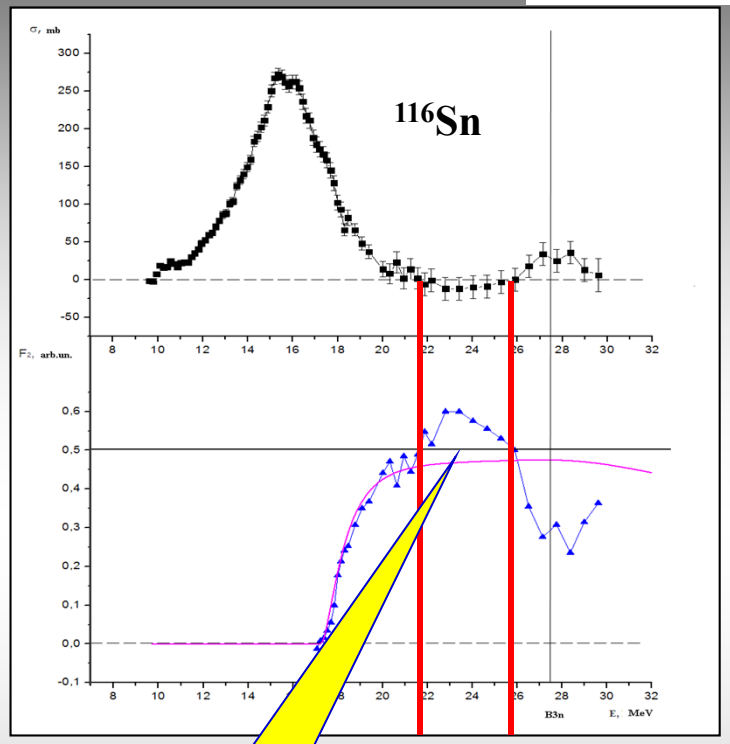
We need the oblective criterium of data reliability

Oblective absolute criterium of "correct" reliable data

$$F_2 = \frac{\sigma(\gamma,2n)}{\sigma(\gamma,n) + 2\sigma(\gamma,2n) + 3\sigma(\gamma,3n) + \ldots} < 0.5\ (!)$$

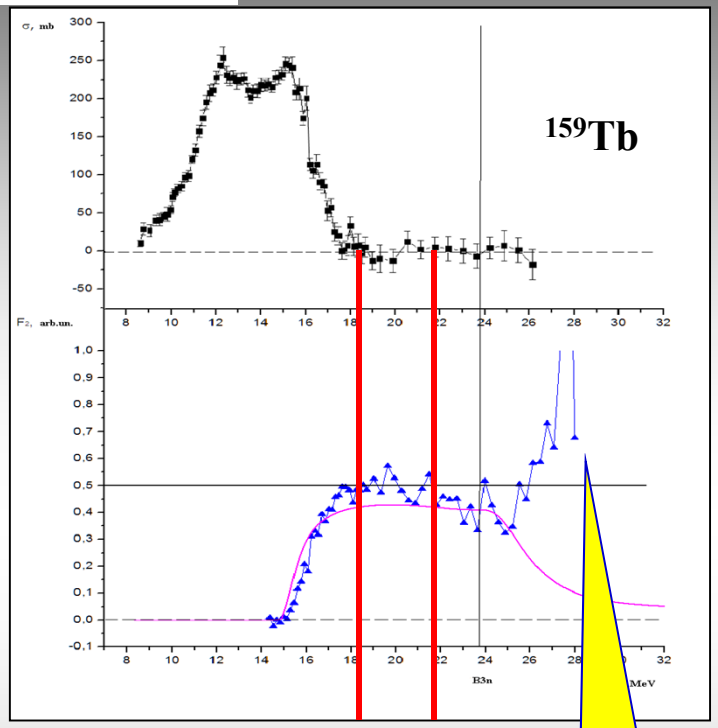


Some examples of "correct" Livermore data



σ(γ,n)

F₂



Dramatic disagreements: $F_2 > 0.5$!

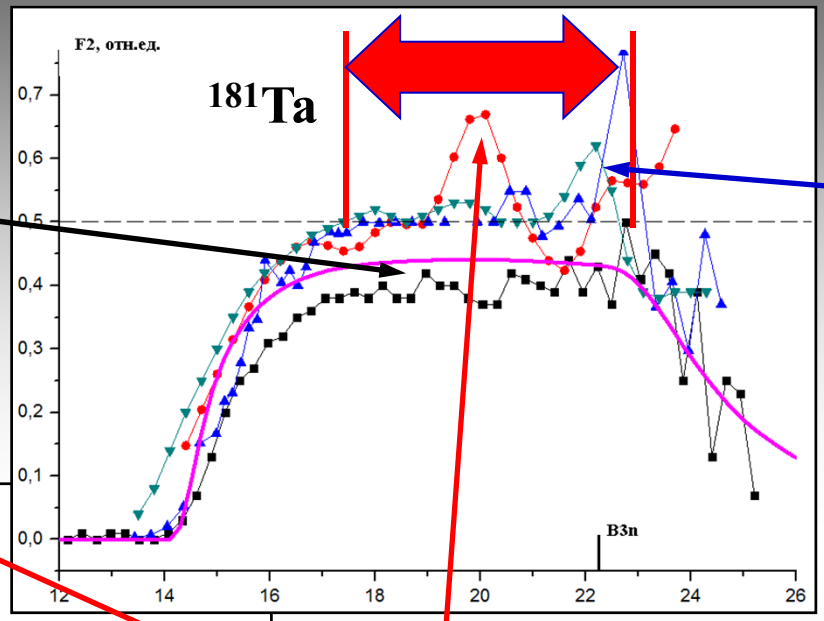
$$F_2 = \frac{\sigma(\gamma,2n)}{\sigma(\gamma,n) + 2\sigma(\gamma,2n) + 3\sigma(\gamma,3n) + \ldots} < 0.5\ (!)$$

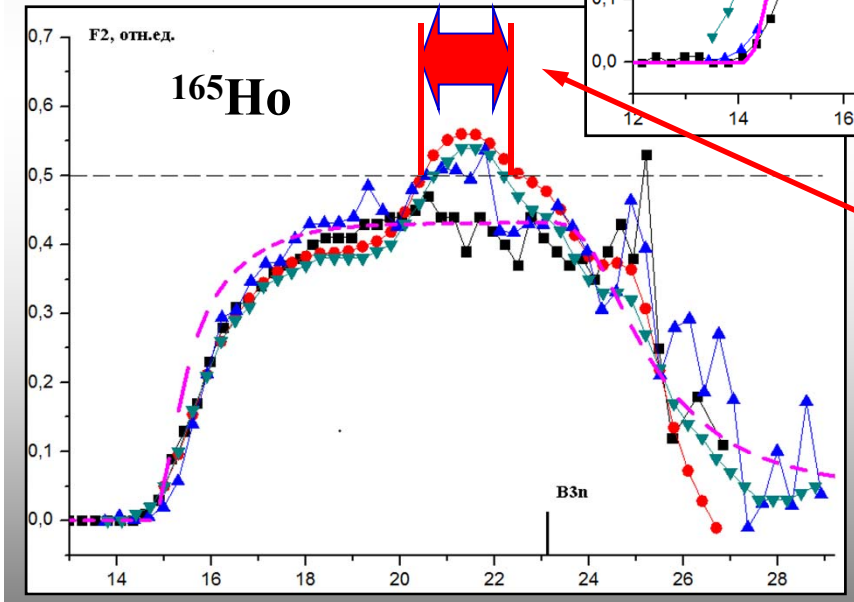
Dramatic disagreements: $F_2 = 1.5 - 2.0$!

But physically not reliable negative cross section values are correlated with physically forbidden values $F_2 > 0.5$

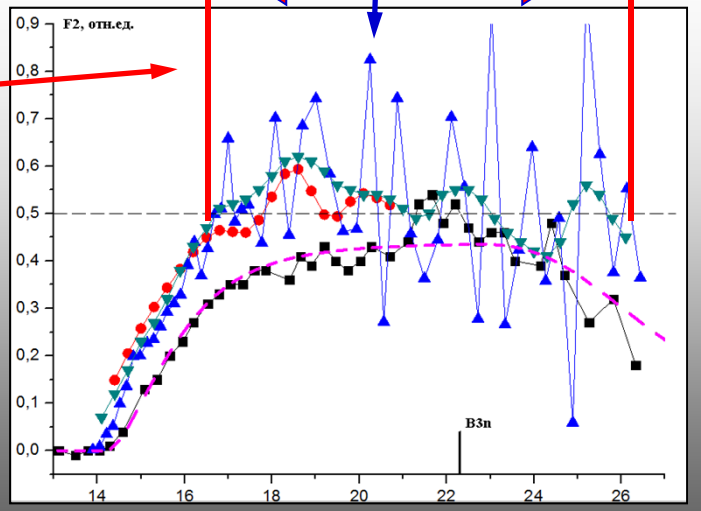
Saclay

Livermore





208Pb



$F_2 > 0.5$

Many data must be reanalyzed and reevaluated!

New experimentally-theoretical method of evaluation

using modern model of photonuclear reactions:

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

- sorting neutrons for multiplicity 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

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

Centre for Photonuclear Experiments Data

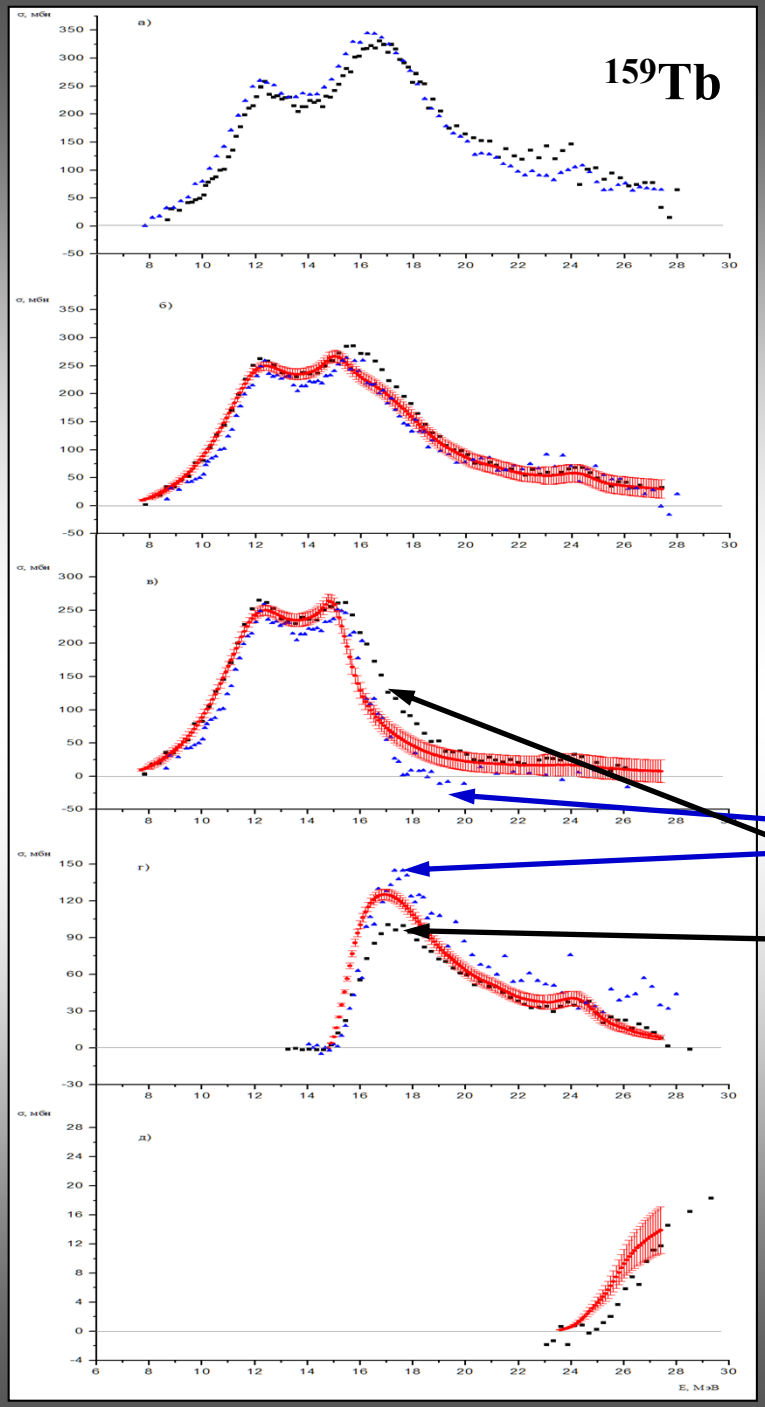
σ(γ,xn)

σ(γ,sn)

σ(γ,n)

σ(γ,2n)

σ(γ,3n)



^{63}Cu, ^{89}Y, ^{90}Zr, ^{115}In,
^{112,114,116,117,118,119,120,122,124}Sn,
^{165}Ho, ^{197}Au, ^{181}Ta, ^{208}Pb

Livermore data are "bad"

Saclay data are "bad"

Centre for Photonuclear Experiments Data

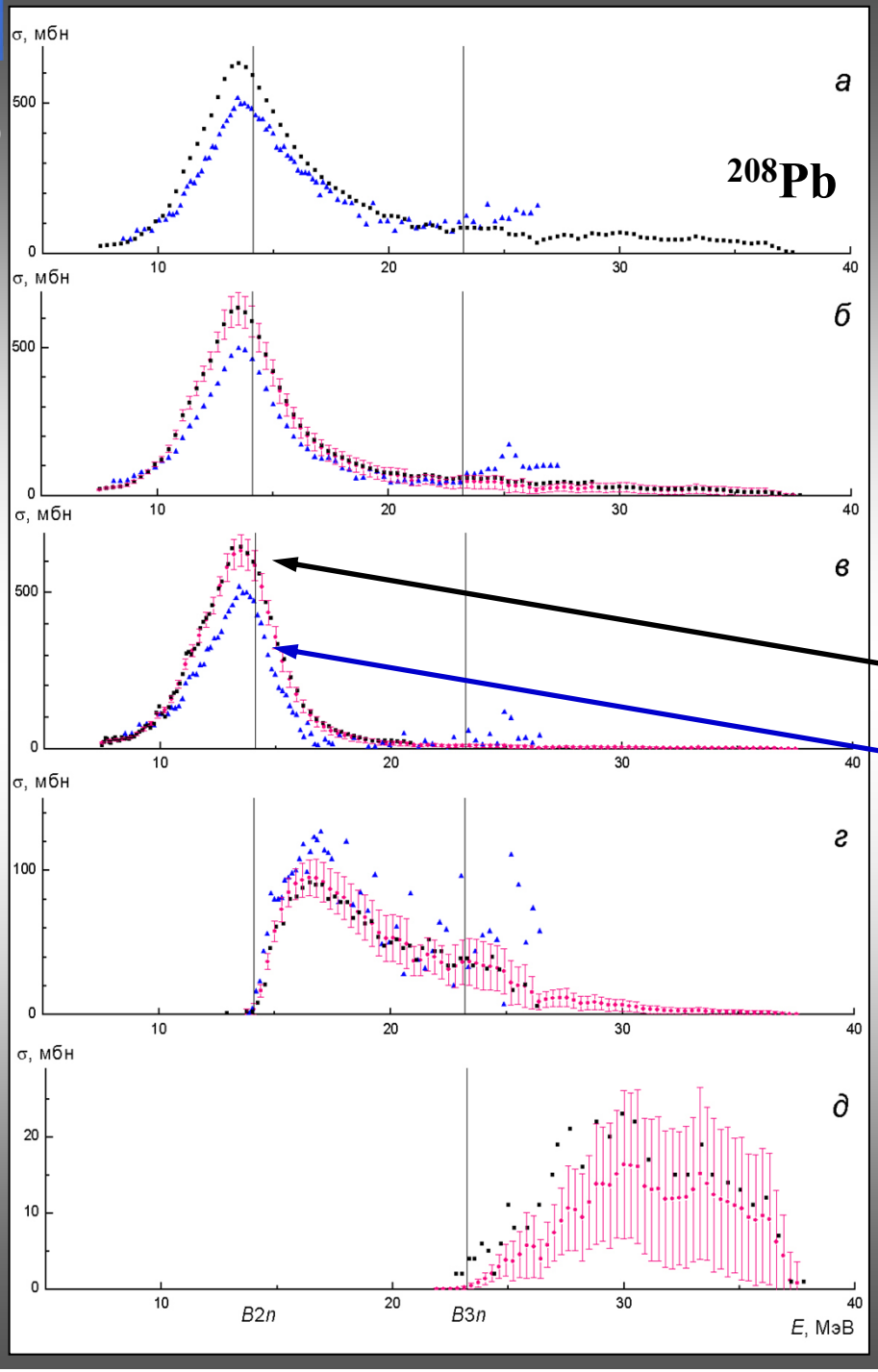
σ(γ,xn)

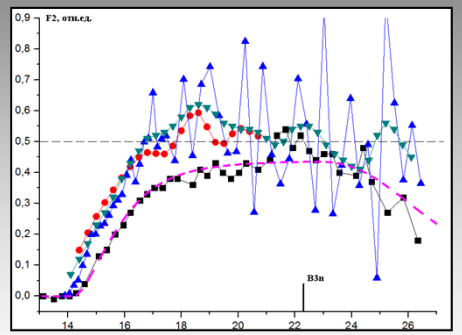
σ(γ,sn)

σ(γ,n)

σ(γ,2n)

σ(γ,3n)





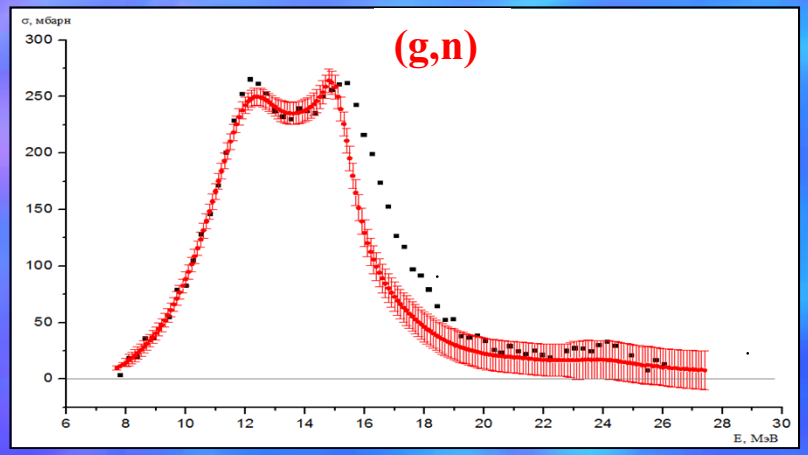
Saclay

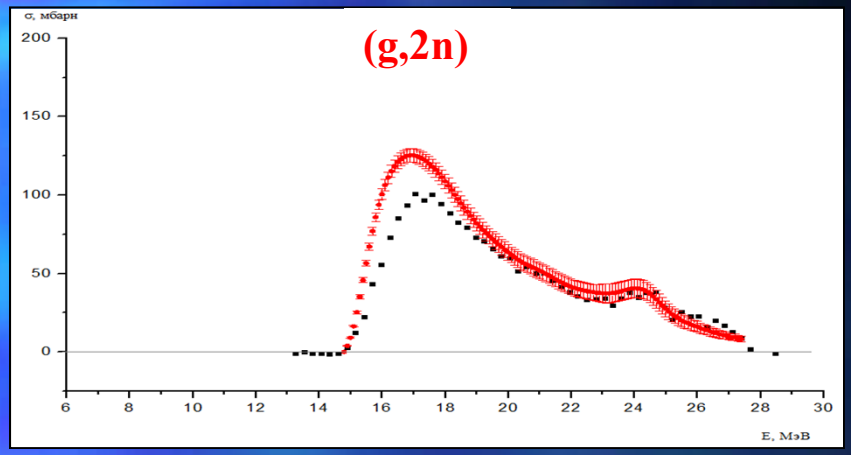
data are "good"

Livermore

data are "bad"

^{159}Tb





Reaction	Center of gravity $E^{c.g.}$, MeV	Integrated cross section σ^{int}, MeV•mb	Integrated cross section σ^{int}, MeV•mb	Center of gravity $E^{c.g.}$, MeV
	New evaluated data		Saclay data	
(γ,xn) *)	16.84	3200	3200	16.84
(γ,sn)	15.78	2383	2557	
(γ,n)	14.04	1642	1950	14.6
(γ,2n)	19.04	714	610	19.9
(γ,3n)	26.29	26	16	26.8

$\sigma^{int}(\gamma,2n)/\sigma^{int}(\gamma,n)$ decreased for 27 %.

Decrease for 9 %!

Decrease for 19 %!

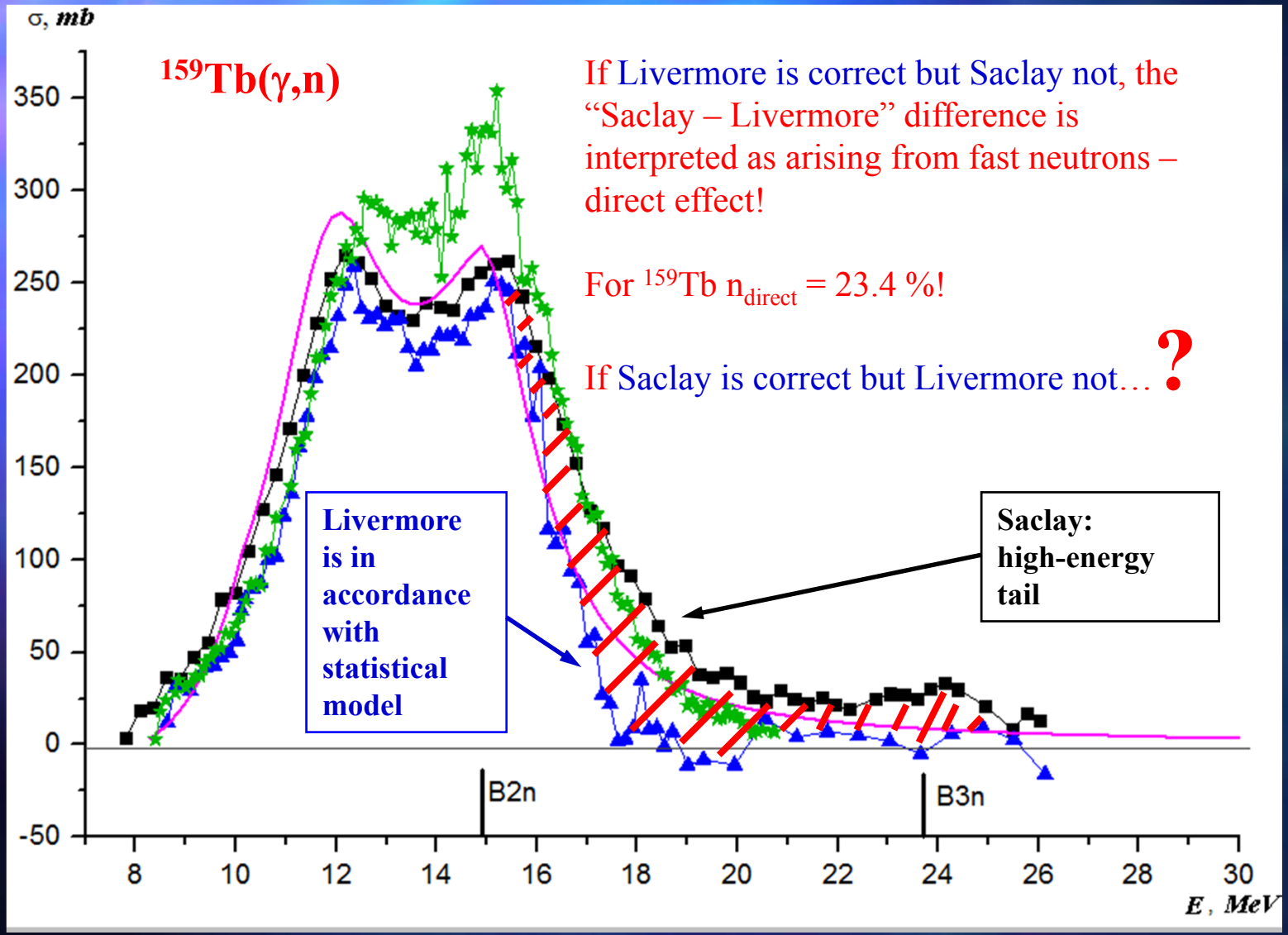
Increase for 15 %!

*) Initial Saclay data

GEANT, TALYS, EMPIRE,…corrections?

^{159}Tb(γ,n)

Ratios	Experiments			Evaluation
	Saclay	Livermore	Activity	$F_{1,2,3}$
of cross sections σ(γ,2n)/σ(γ,n)	0.36 (797.4/2189.5)	0.67 (887.0/1315.7)		0.49 (958.3/1956.3)
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 (137.4/2189.5)			0.055 (107.3/1956.3)
of yields Y(γ,3n)/Y(γ,n)	0.02		0.023 – 0.025**)	0.018*)


σ, mb
159Tb(γ,n)
If Livermore is correct but Saclay not, the "Saclay – Livermore" difference is interpreted as arising from fast neutrons – direct effect!
For 159Tb n direct = 23.4 %!
If Saclay is correct but Livermore not… ?
Livermore is in accordance with statistical model
Saclay: high-energy tail
B2n
B3n
350
300
250
200
150
100
50
0
-50
8
10
12
14
16
18
20
22
24
26
28
30
E, MeV

Short-term (2012/2013) Program

The main items of CDFE (2012/2013) program, main priorities and most important tasks are traditional and the following:

continuation of photonuclear data compilation using EXFOR format, new TRANSes (M062, M063, etc.) production;

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

continuation of joint analysis and evaluation of total and partial photonuclear reaction cross sections obtained using various methods in experiments with quasimonoenergetic annihilation and bremsstrahlung photons;

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

IAEA Meeting
of the International Network of
Nuclear Reaction Data Centres (NRDC)
16 - 19 April 2012, Paris, France

Centre for
Photonuclear
Experiments
Data

Vladimir Varlamov

THANKS A LOT

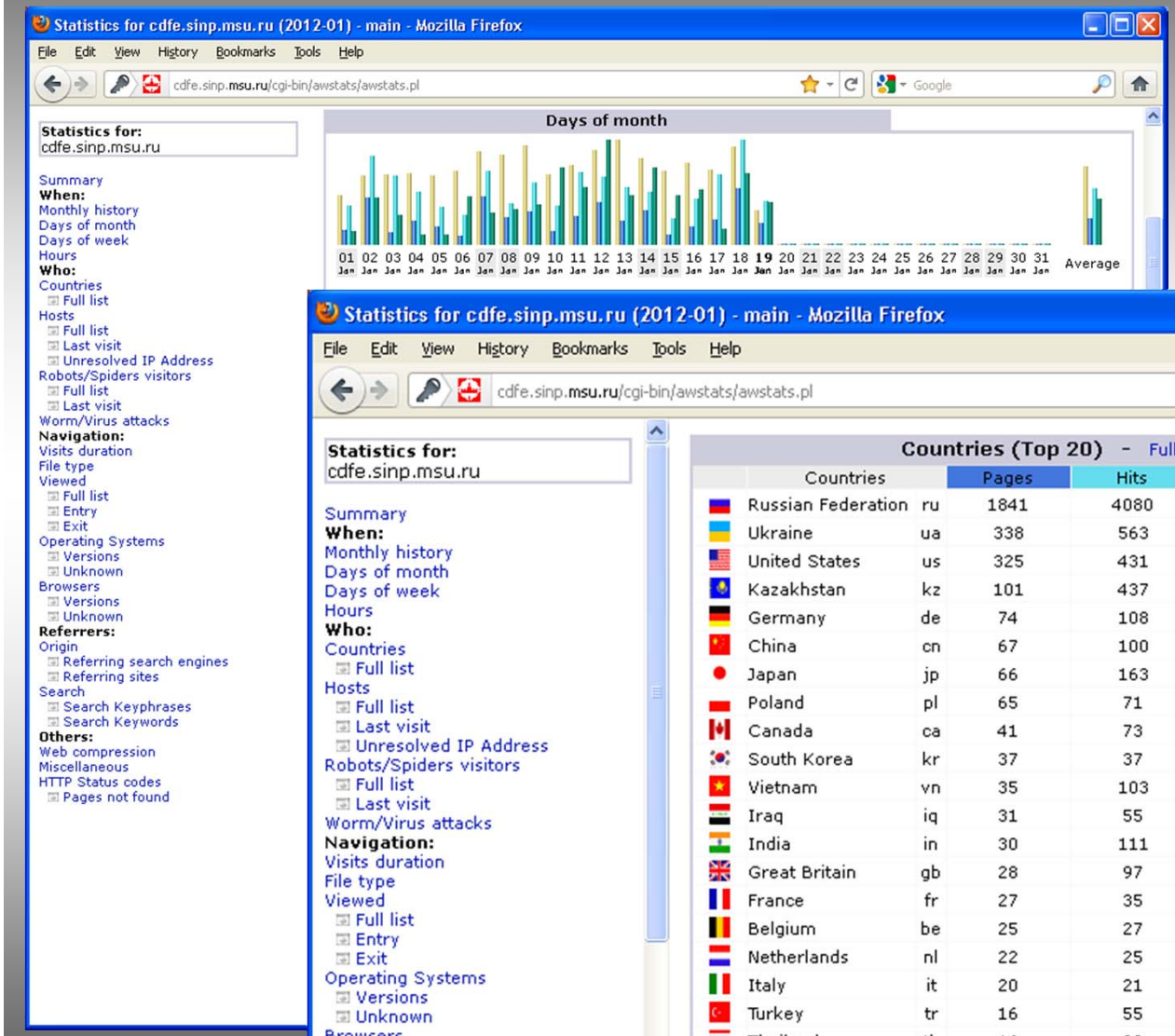
FOR ATTENTION!

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

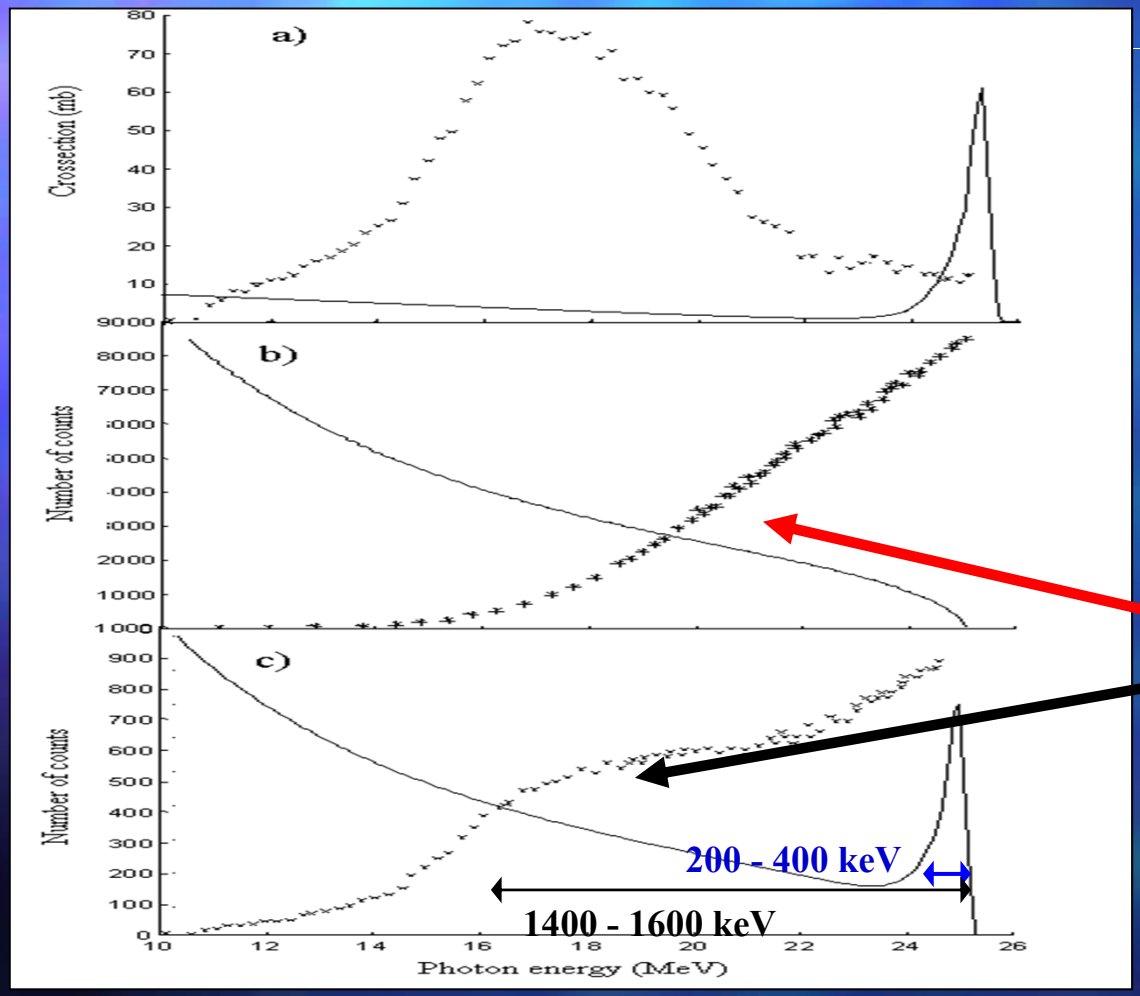
IAEA Meeting
of the International Network of
Nuclear Reaction Data Centres (NRDC)
16 - 19 April 2012, Paris, France

CDFE services statistics: January 2012

Centre for Photonuclear Experiments Data



4/23/2012

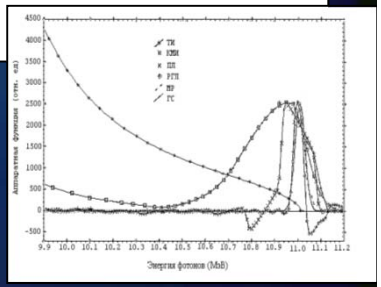


Simple subtraction QMA-procedure gives to one possibility to delete bremsstrahlung tale but does not - to obtain higher energy resolution!

Difference of the yields is not cross section but only yield again:
$\int W_1 \sigma dE - \int W_2 \sigma dE = \int (W_1 - W_2)\, \sigma dE$
only for σ = const!

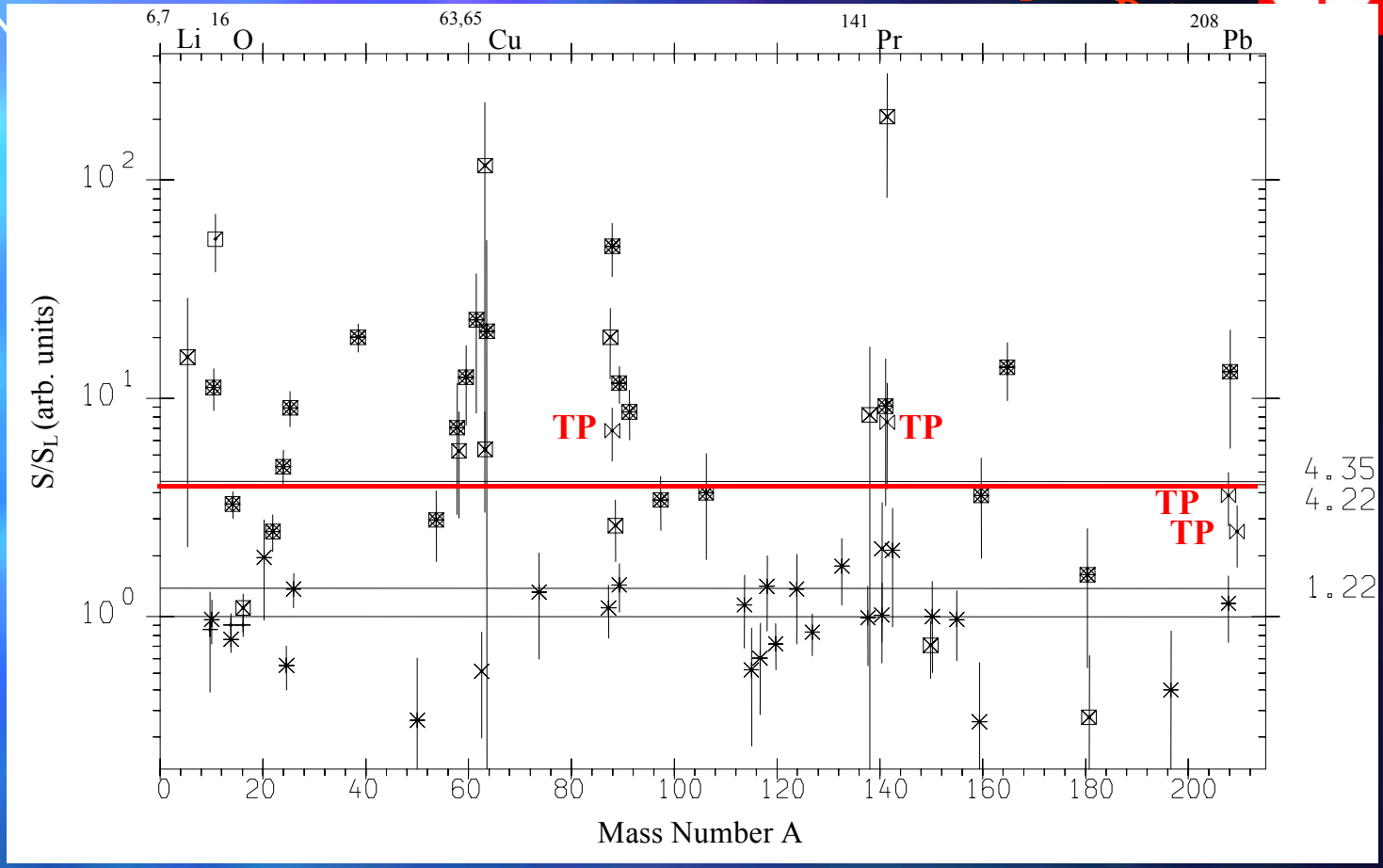
That procedure is subtraction of result obtained with very bad resolution from the result obtained with bad resolution!

Additional processing for real photon spectrum is needed.



$$S = \frac{1}{N}\sum_{i=1}^{N}\frac{(\sigma_i - <\sigma_i>)^2}{<<\sigma>>^2}$$

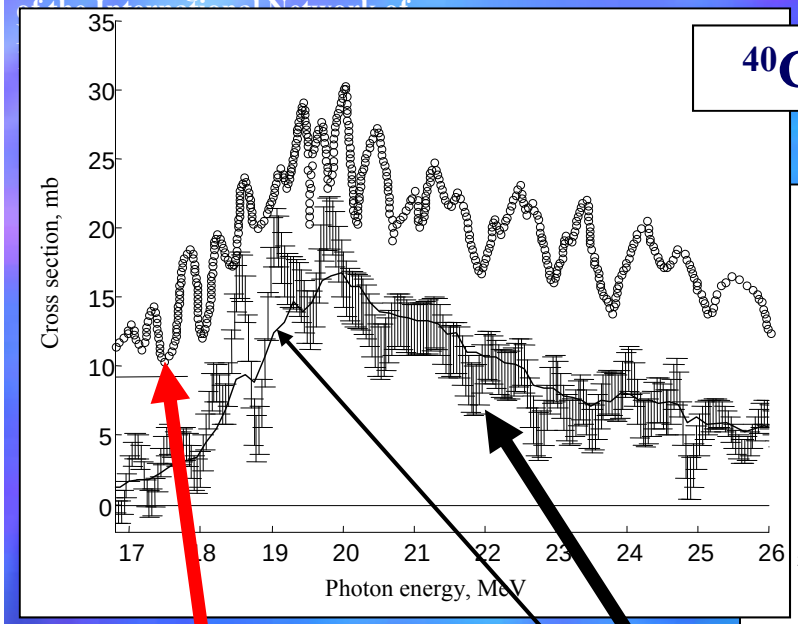
S/S_l are presented, where S were calculated for various laboratories data and S_l - for Livermore QMA-data.



"Structurenes" S/S_l ratios for (γ,xn) reaction cross section data:

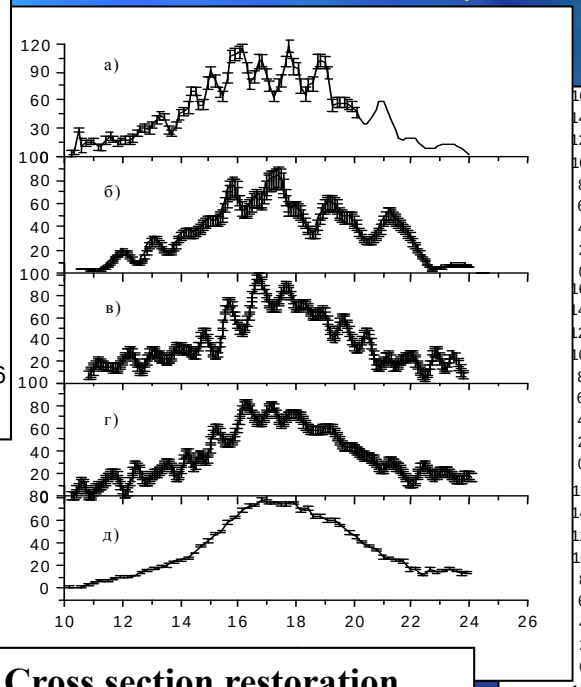
- **squares - BR-data (Moscow, Melbourne (Australia), other) - $< S/S_l > = 4.35$;**
- **crosses - QMA-data (Saclay (France), Giessen (Germany), other) - $< S/S_l > = 1.22$;**
- **bows - Tagged Photons-data (Illinois (USA)) - $< S/S_l > = 4.22$.**

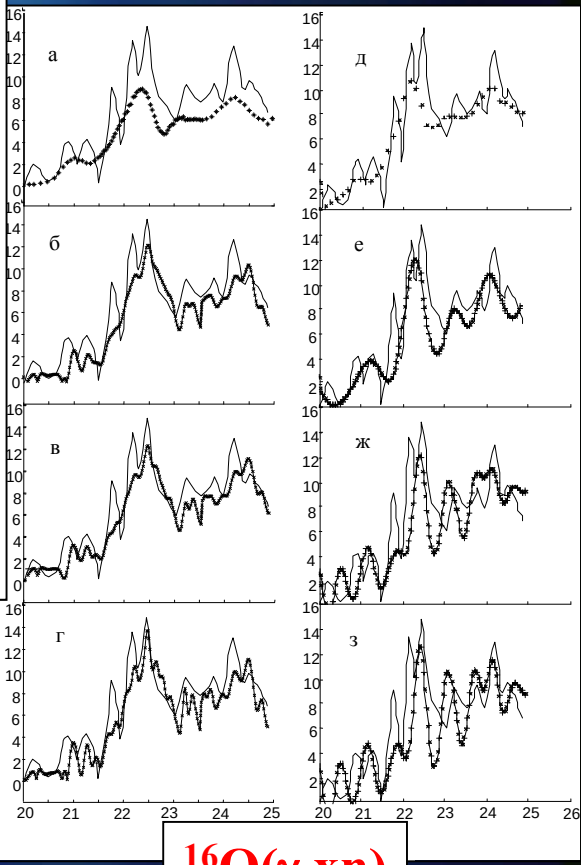
Structure systematic



$^{40}Ca(\gamma,n)^{39}Ca$

$^{63}Cu(\gamma,n)^{62}Cu$





$^{16}O(\gamma,xn)$

Result of bremsstrahlung experiment

Cross section restoration from QMA-experiment result

Real energy resolution of QMA-experiments is 4 - 6 times worse in comparison to its estimation based upon calculated photon spectrum annihilation line width.

Well-known data under discussion:

E.G.Fuller, H.Gerstenberg. Photonuclear Data - Abstracts Sheets 1955 - 1982. NBSIR 83-2742. U.S.A. National Bureau of Standards, 1986.

S.S.Dietrich, B.L.Berman. Atlas of Photoneutron Cross Sections Obtained with Monoenergetic Photons. Atomic Data and Nuclear Data Tables, 38 (1988) 199.

A.V.Varlamov, V.V.Varlamov, D.S.Rudenko, M.E.Stepanov. Atlas of Giant Dipole Resonances. Parameters and Graphs of Photonuclear Reaction Cross Sections. INDC(NDS)-394, IAEA NDS, Vienna, Austria, 1999.

V.V.Varlamov, V.V.Sapunenko, M.E.Stepanov. Photonuclear Data 1976 - 1995. Index. Moscow State University. Moscow, 1996 (bibliographic database URL (http://depni.sinp.msu.ru/cdfe/services/pnisearch.html).

International nuclear (including photonuclear) reaction data relational database (EXFOR):

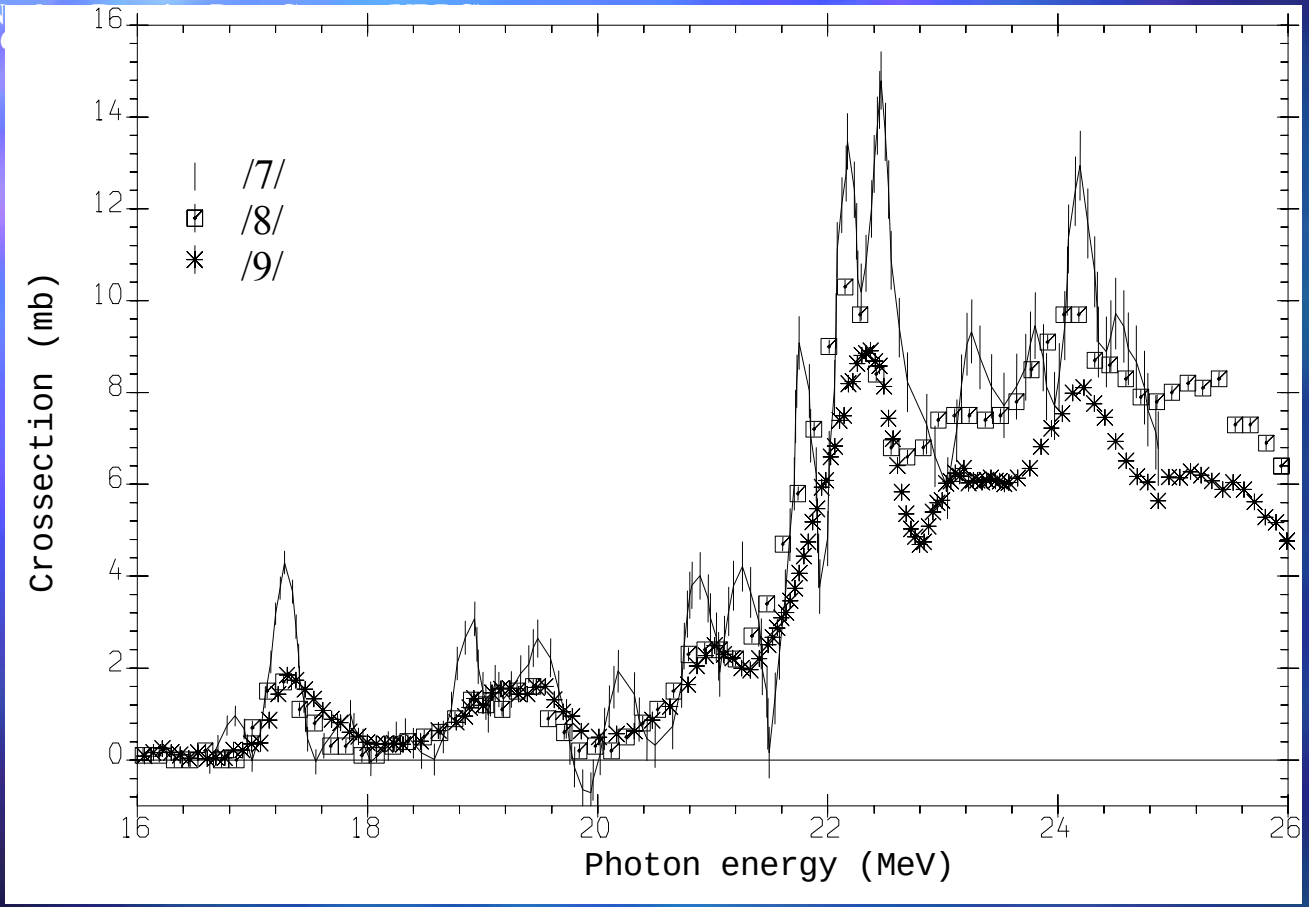
I.N.Boboshin, V.V.Varlamov, E.M.Ivanov, S.V.Ivanov, N.N.Peskov, M.E.Stepanov, V.V.Chesnokov. Relational Nuclear Databases Upon the MSU INP CDFE Web-site and Nuclear Data Centres Network CDFE Activities. Report on the IAEA Consultant's Meeting on the Co-ordination of Nuclear Reaction Data Centres (Technical Aspects), 28 – 30 May 2001, Vienna, Austria. INDC(NDS)-427, IAEA NDS, Vienna, Austria, 2001, p. 49.

All data for quasimonoenergetic photons and many data for bremsstrahlung are included: URL (http://depni.sinp.msu.ru/cdfe/exfor/index.php):

EXFOR database

Centre for Photonuclear Experiments Data

$^{16}O(\gamma,xn)$



In detailes:

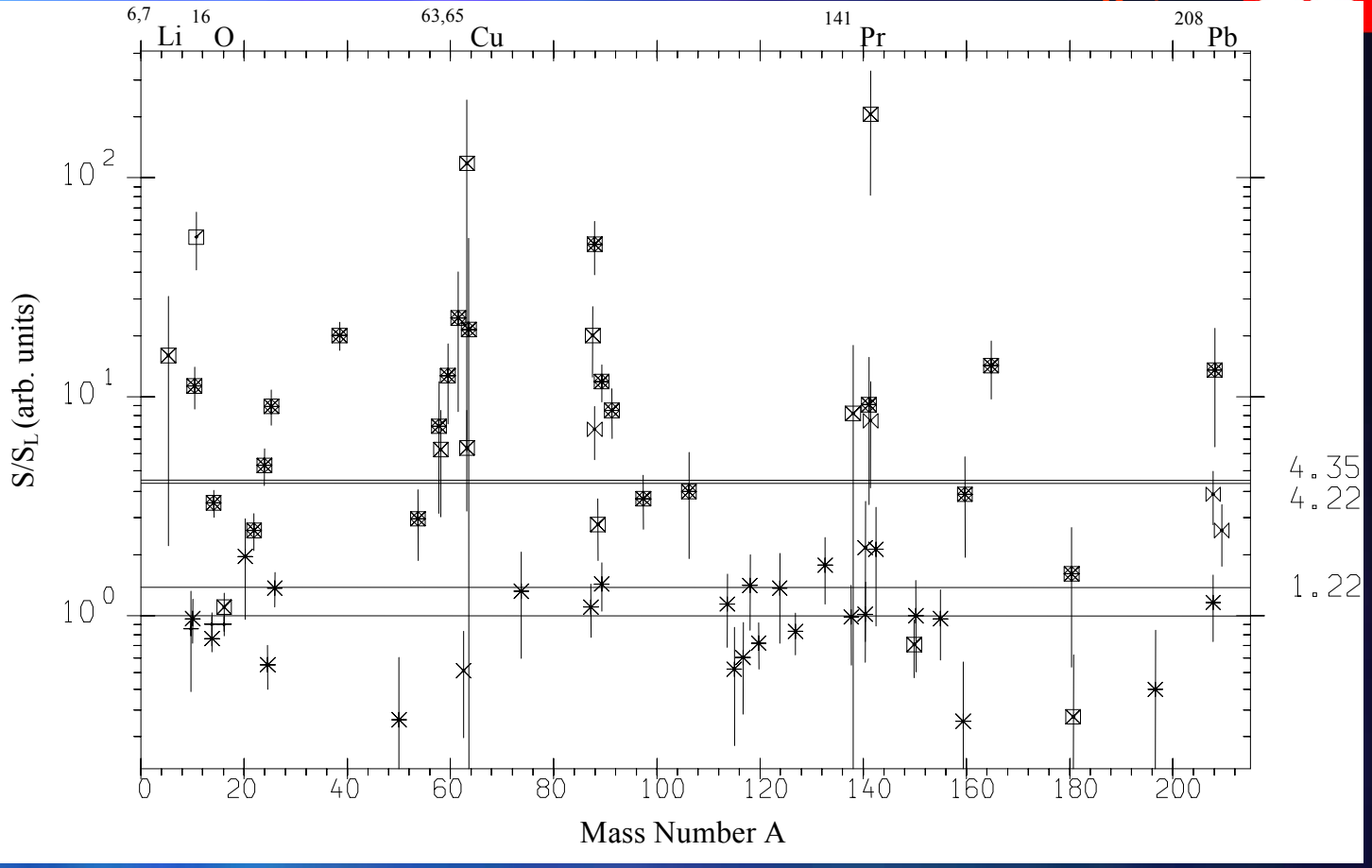
quasimonoenergetic data look like smoothed bremsstrahlung ones.

σ^{int}_{BR}	(MSU - error bars) =	36.9	MeV•mb
σ^{int}_{QMA}	(Saclay - squares) =	34.6	MeV•mb
σ^{int}_{QMA}	(Livermore - crosses) =	32.1 (27.6 • *1.12*)	MeV•mb

BR –QMA

$$S=\frac{1}{N}\sum_{i=1}^{N}\frac{(\sigma_i-<\sigma_i>)^2}{<<\sigma>>^2}$$

S/S_l are presented, where S were calculated for various laboratories data and S_l - for Livermore QMA-data.



"Structurenes" S/S_l ratios for (γ,xn) reaction cross section data:

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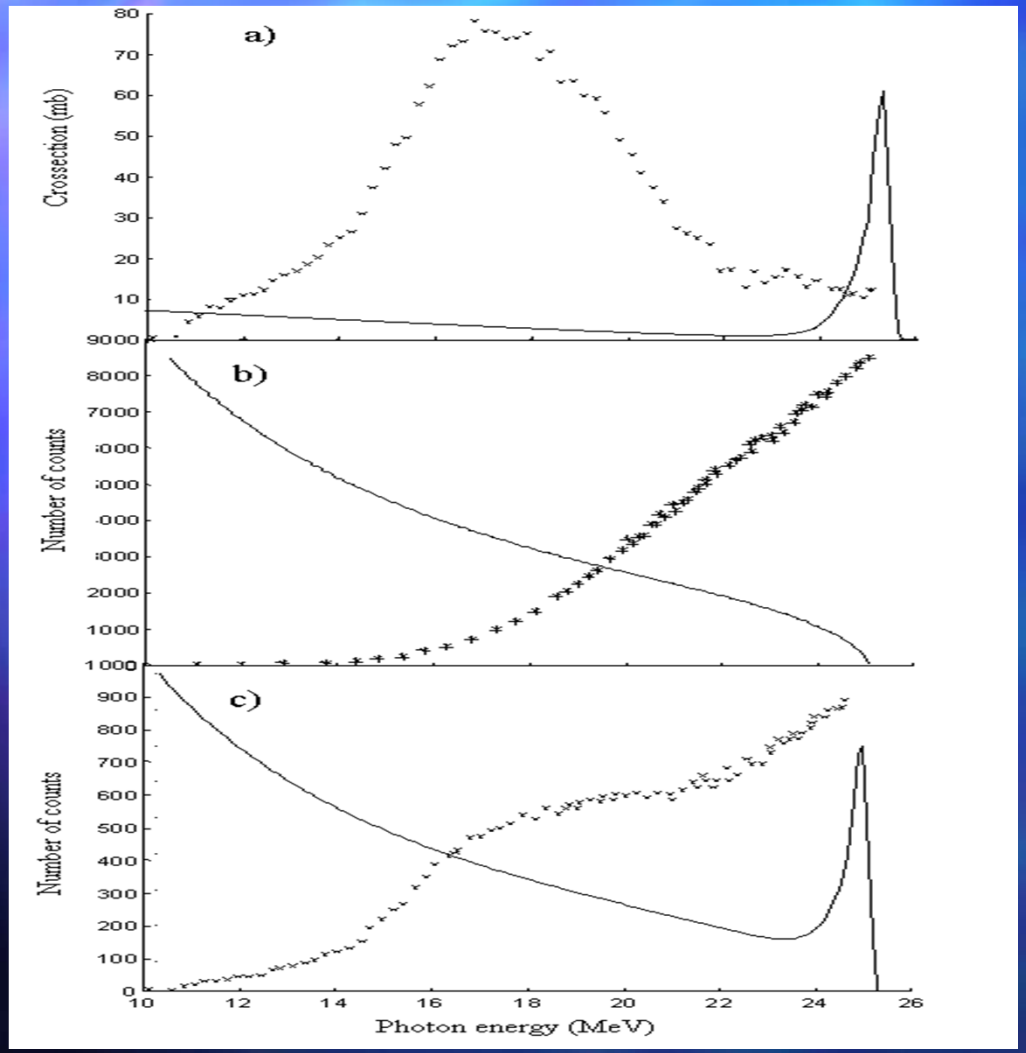
- **bows TP-data (Illinois (USA)) - $< S/S_l > = 4.22$.**

Structure systematic

Once more $^{63}Cu(\gamma,n)^{62}Cu$ reaction cross section in 3 steps QMA-experiment



a) $\sigma(k) \approx Y(E_j) = Y_{e+}(E_j) - Y_{e-}(E_j)$; must be additionally processed taking into account real apparatus function is needed ;

b) $Y_{e-}(E_j)$ measured using electron bremsstrahlung must be processes by one of methods traditional for BR-experiments;

c) $Y_{e+}(E_j)$ measured using photons from sum of positrons annihilation and bremsstrahlung must be processed also using appropriate apparatus function.

$^{63}Cu(\gamma,n)^{62}Cu$

Disagreements (Saclay/Livermore)

of amplitudes – absolute values – integrated cross sections

5 clear cases (from "Atlas…" of S.S.Dietrich and B.L.Berman, Atomic Data and Nuclear Data Tables, 38 (1988) 199) of σ^{int} disagreements for appropriate integration energy limits E_γ^{max} :

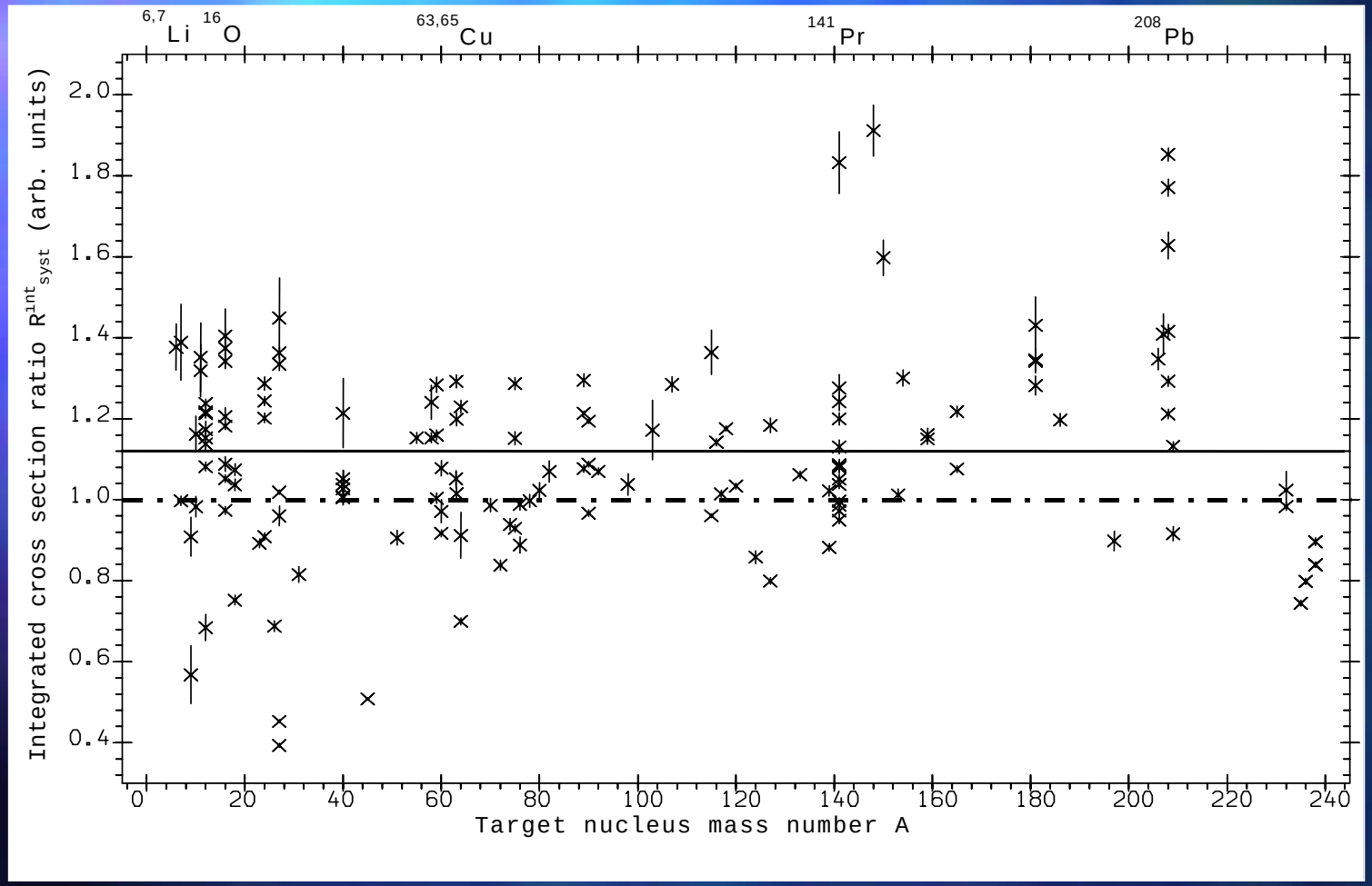
Nucleus	^{51}V	^{75}As	^{90}Zr	^{133}Cs	^{165}Ho
$E_\gamma^{int\text{-}max}$ (MeV)	27.8 27.8	26.2 29.5	25.9 27.6	*24.2* *29.5*	26.8 28.9
σ^{int} s/$\sigma^{int.}$ L	689/654 = 1.06	1306/1130 ≥ 1.16	1309/1158 ≥ 1.13	2484/2505 ≈ *1*	3667/3385 ≥ 1.08

The values obtained at Saclay are higher than that obtained at Livermore for about 6 – 16 %.

Explanation of the reasons (B.L.Berman, et al., Phys.Rev., C36 (1987) 1286): "… an Livermore experiments error either in the photon flux determination or in the neutron detection efficiency or in both".

5 nuclei "S/L"

Systematic of integrated cross section ratios "All other/Livermore" for about 500 total photoneutron reaction (γ,xn) cross sections.



$R^{int}_{syst} = 1.12$

.

Int. cross. sect. ratios

Significant disagreements for partial reaction (γ,n) and (γ,2n) cross section between Saclay and Livermore data (integrated cross section ratios are presented).

	n	*2n*	*xn*			
Nucleus	$\sigma^{int}_{S}(\gamma,n)/\sigma^{int}_{L}(\gamma,n)$, /1, 25/ (= arb. units)	$\sigma^{int}_{S}(\gamma,2n)/\sigma^{int}_{S}(\gamma,2n)$, /1, 25/ (= arb. units)	$R^{int}(\gamma,xn)$ /25/ (arb. units)	$\sigma^{int}_{S}(\gamma,n)/\sigma^{int}_{L}(\gamma,n)$, /26/ (arb. units)	$\sigma^{int}_{S}(\gamma,2n)/\sigma^{int}_{S}(\gamma,2n)$, /26/ (arb. units)	$R^{int}(\gamma,xn)$ /26/ (arb. units)
^{51}V				1.07	0.79	1.07
^{75}As				1.21	1.22	1.21
^{89}Y	1279/960 = 1.33	74/99 = 0.75	1.26	1.25	0.87	1.25
^{90}Zr				1.26	0.73	1.26
^{115}In	1470/1354 = 1.09	278/508 = 0.55	0.94	0.97	0.76	0.97
^{116}Sn				1.10	0.92	1.10
^{117}Sn	1334/1380 = 0.97	220/476 = 0.46	1.01	1.02	0.93	1.02
^{118}Sn	1377/1302 = 1.06	258/531 = 0.59	1.06	1.07	0.86	1.07
^{120}Sn	1371/1389= 0.98	399/673 = 0.75	0.99	1.00	0.86	1.00
^{124}Sn	1056/1285 = 0.82	502/670 = 0.75	0.93	0.93	0.94	0.93
^{127}I				1.34	1.07	1.34
^{133}Cs	1828/1475 = 1.24	328/503 = 0.65	1.11	1.10	0.88	1.10
^{159}Tb	1936/1413 = 1.37	605/887 = 0.68	1.06	1.07	0.71	1.07
^{165}Ho	2090/1735 = 1.20	766/744 = 1.03	1.14	1.20	1.05	1.20
^{181}Ta	2180/1300 = 1.68	790/881 = 0.90	1.22	1.25	0.89	1.25
^{197}Au	2588/2190 = 1.18	479/777 = 0.62	1.00	1.00	0.69	1.00
^{208}Pb	2731/1776 = 1.54	328/860 = 0.38	1.30	1.21	0.77	1.21
^{232}Th				0.84	0.69	0.84
^{238}U				0.76	0.79	0.76

more higher *more lover* *<R> ≈1.12*

While (γ,n) Saclay data are more higher than those from Livermore,

(γ,2n) data are, vise versa, more lower.

"(γ,n) – (γ,2n)" discrepancies

Important results:

- clear data discrepancies force one to use data existed strongly individually;
- quasimonoenergetic photons-data are strongly (3 – 4 times) over-smoothed and must be additionally reprocessed to take into account real shape of apparatus function (effective photon spectrum);
- Livermore total photoneutron reaction (γ,xn) cross sections have in general absolute values smaller then that obtained at various other laboratories; the reason: "… an Livermore experiments error either in the photon flux determination or in the neutron detection efficiency or in both"; therefore Livermore (γ,xn) cross sections data of for 19 nuclei studied specially must be multiplied by appropriate coefficients $R^{int}(\gamma,xn)$ and for others – by $\langle R^{int}_{syst} \rangle = 1.12$ at least;
- Saclay partial photoneutron reactions (γ,n) and (γ,2n) cross sections are not correct and consistent each other because of incorrect neutron multiplicity sorting procedure used and must be recalculated;
- Livermore neutron multiplicity sorting procedure at the same time is correct and therefore Livermore (γ,n) and (γ,2n) cross sections are in consistence with each other and with (γ,xn) cross sections and both can be used but again only multiplied by coefficients $R^{int}(\gamma,xn)$ or $\langle R^{int}_{syst} \rangle$.

3 important physical consequences:

- GDR structure (resonances with width ~ hundreds of keV) exists; BR-data look like preferable for GDR structure detailed study because QMA-data are strongly over-smoothed;
- E1 GDR decays dominantly statistically - Saclay interpretation of high-energy tails of (γ,n) reaction cross sections as contributions of high-energy neutrons from GDR nonstatictical direct decay (those contributions evaluated to be about 17 - 30 %) because of small decreasing of (γ,n) reaction cross sections for energies higher than (γ,2n) reaction threshold B(2n) looks like as very doubtful; Saclay (γ,n) data corrections described decrease those and put them into accordance with Livermore data: direct decay contributions are not more than 10 - 12 %;
- big extra integrated cross section $\sigma^{int}(\gamma,abs) \approx 1.3 - 1.5\ 60NZ/A$ (MeV•mb) became doubtfully being all due to effective mass of nucleon changing because of the effect of exchange forces; Saclay data correction described affects photoabsorption cross section evaluation using cross section data combinations (γ,abs) = (γ,sn) + (γ,p) and (γ,sn) = (γ,xn) - (γ,2n); mistake in (γ,2n) reaction data produces the mistakes in both (γ,sn) and (γ,abs) reaction data; correction described do them noticeably smaller.

Neutron multiplicity sorting procedure test:

Twice measurement of $^{181}Ta(e,2n)^{180}Ta$ cross section $s(e,2n) = \frac{1}{2}(s(e,xn) - s(e,n))$:

1. $\sigma_1(e,n)$ – neutron multiplicity sorting measurement;
2. $\sigma_2(e,n)$ – measurement of induced activity (decay $^{180}Ta \rightarrow {}^{180}Hf$, 93.3 keV, Ge-Li).

Mean-square ratio $\langle \sigma_1(e,n)/\sigma_2(e,n) \rangle = 1.057 \pm 0.023$ means high reliability of multiplicity sorting procedure.

Comparison of (e,n) and (γ,n) data show that Saclay data for (γ,2n) reaction are underestimated and correspondingly that for (γ,n) reaction – vise versa overestimated.

Nucleus	$\sigma^{int}_{S}(\gamma,n)/\sigma^{int}_{L}(\gamma,n)$, both – MeV*mb		$\sigma^{int}_{S}(\gamma,2n)/\sigma^{int}_{L}(\gamma,2n)$, both – MeV*mb	
	Before [6]	After	Before [6]	After
^{89}Y	1279/960 = 1.33	1205.3/1206.1 = 1.00	74/99 = 0.75	112.6/107.3 = 1.05
^{115}In	1470/1354 = 1.09	1298.0/1298.2 = 1.00	278/508 = 0.55	364.6/358.3 = 1.02
^{117}Sn	1334/1380 = 0.97	1261.6/1261.4 = 1.00	220/476 = 0.46	234.1/243.6 = 0.96
^{118}Sn	1377/1302 = 1.06	1281.3/1281.4 = 1.00	258/531 = 0.49	298.9/320.4 = 0.93
^{120}Sn	1371/1389 = 0.99	1282.7/1282.6 = 1.00	399/673 = 0.59	444.5/460.2 = 0.97
^{124}Sn	1056/1285 = 0.82	1042.5/1042.4 = 1.00	502/670 = 0.75	511.5/502.6 = 1.02
^{133}Cs	1828/1475 = 1.24	1619.5/1618.5 = 1.00	328/503 = 0.65	431.8/413.7 = 1.04
^{159}Tb	1936/1413 = 1.37	1485.3/1485.4 = 1.00	605/887 = 0.68	633.9/675.7 = 0.94
^{165}Ho	2090/1735 = 1.20	2040.7/2040.7 = 1.00	766/744 = 1.03	825.6/803.4 = 1.03
^{181}Ta	2180/1300 = 1.68	1616.4/1615.7 = 1.00	790/881 = 0.90	520.1/559.9 = 0.93
^{197}Au	2588/2190 = 1.18	2144.6/2142.4 = 1.00	479/777 = 0.62	367.0/345.0 = 1.06
^{208}Pb	2731/1776 = 1.54	2274.5/2273.8 = 1.00	328/860 = 0.38	611.0/626.0 = 0.98

The effect of joint Saclay and Livermore data correction:
agreement for both (γ,n) and (γ,2n) reaction cross sections is quite well.

Correction (table)

Nucleus	Laboratory	Factor F /23/ (arb. units)	Factor 1/F (arb. units)
^{nat}Rb	S	0.85 ± 0.03	
^{nat}Sr	S	0.85 ± 0.03	1.18
^{89}Y	S	0.82	1.22
^{89}Y	L	1.0	
^{90}Zr	S	0.88	1.14
^{90}Zr	L	1.0	
^{91}Zr	L	1.0	
^{92}Zr	L	1.0	
^{93}Nb	S	0.85 ± 0.03	1.18
^{94}Zr	L	1.0	
^{127}I	S	0.80	1.25
^{197}Au	S	0.93	1.08
^{206}Pb	L	1.22	
^{207}Pb	L	1.22	
^{208}Pb	L	1.22	
^{208}Pb	S	0.93	1.08
^{208}Bi	L	1.22	

Factor “F”