Nuclear Reactions for Astrophysics & Nuclear Data

Paraskevi (Vivian) Dimitriou
Institute of Nuclear and Particle Physics
National Center for Scientific Research “Demokritos”
Athens, Greece

Outline

- Nuclear Reactions for Astrophysics
  - Global semi-microscopic alpha-nucleus optical potential
  - Systematics of proton-nucleus optical potential

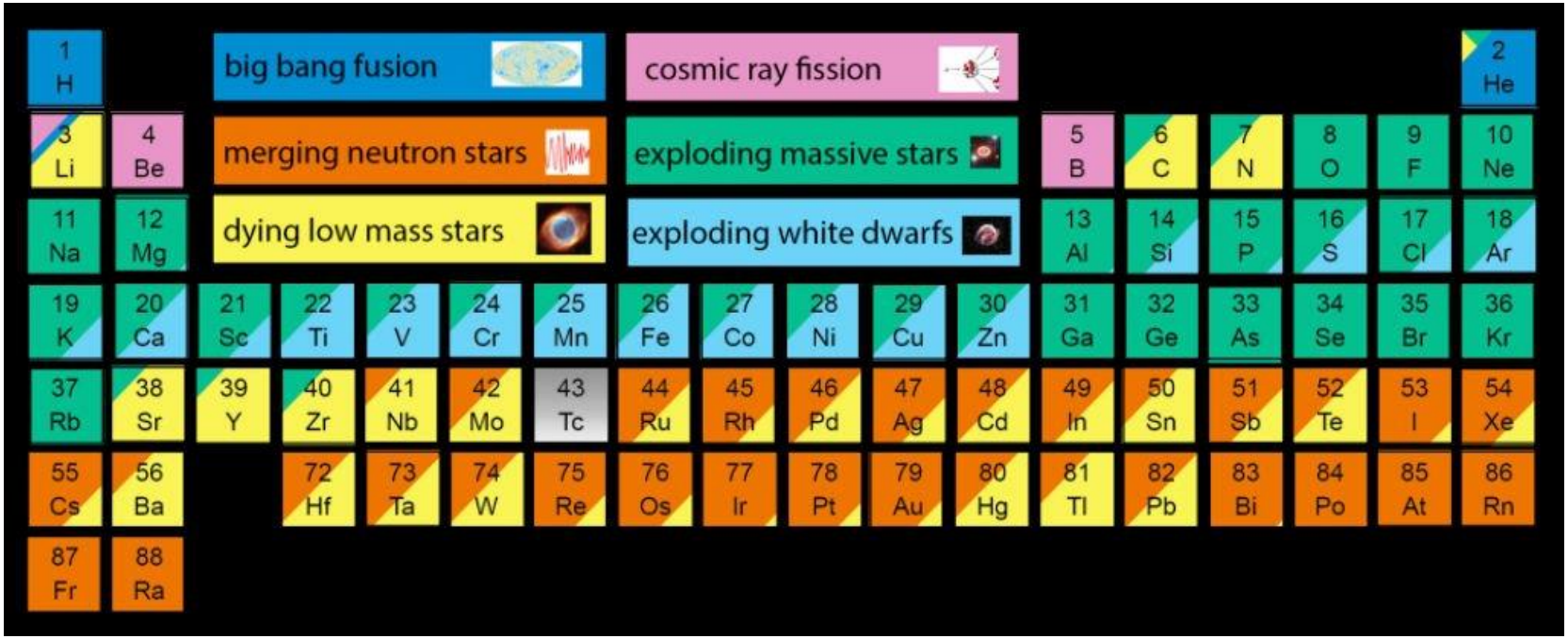
- Nuclear Reaction Data
  - Nuclear reactions in the resolved resonance region
  - Photon strength functions
  - Photonuclear data library
  - Ion Beam Analysis

- Nuclear Structure Data Evaluation
  - Beta-delayed neutron emission data
  - Decay Data for Monitoring Applications

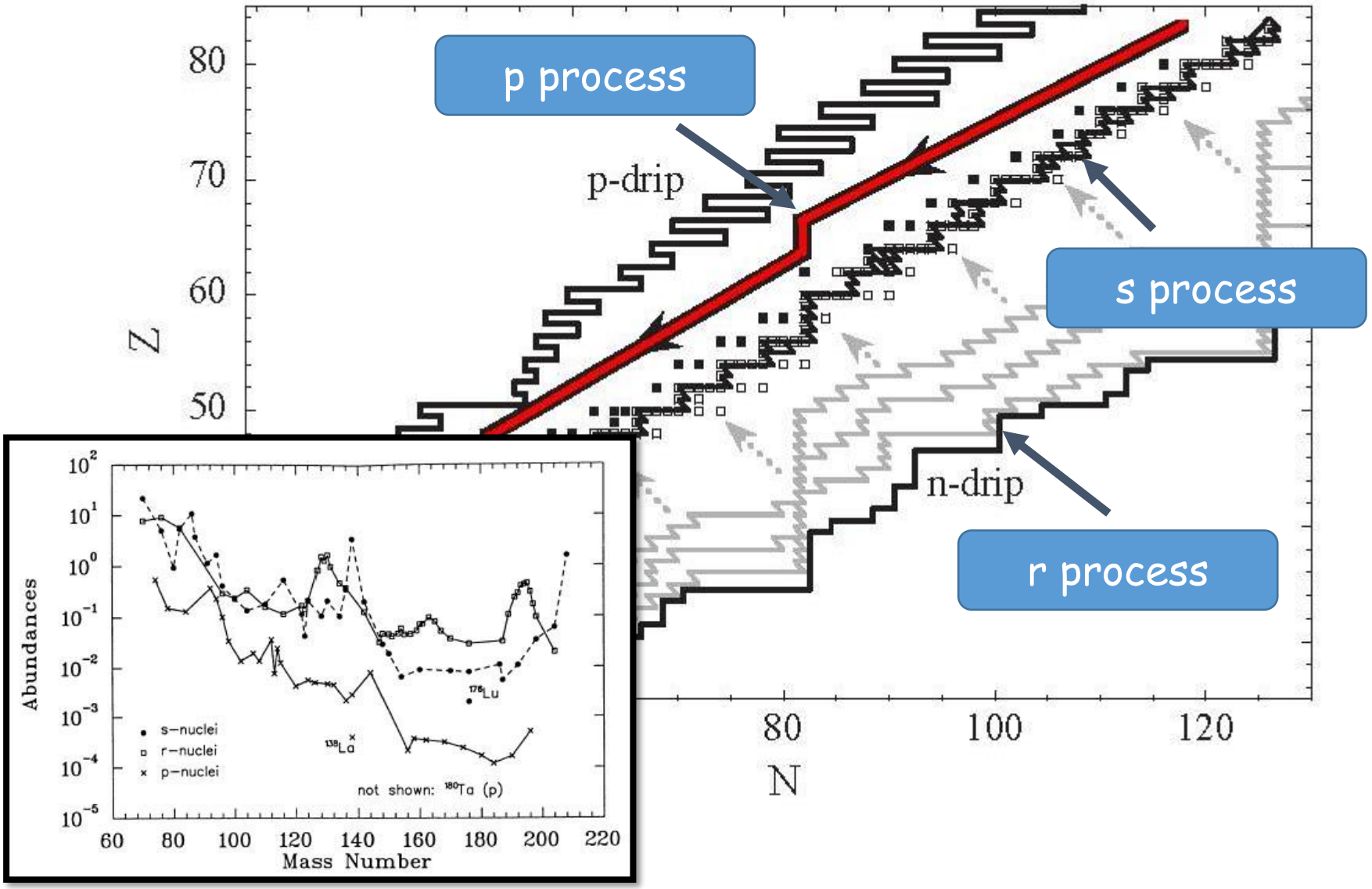
- Other
  - International Network of Nuclear Structure and Decay Data evaluators
  - IAEA-ICTP Workshops
  - 7^{th} International Workshop on Compound-Nuclear Reactions and Related Topics (CNR*20) (CALIBRA WP.1.10)

Nucleosynthesis: the origin of the solar system elements

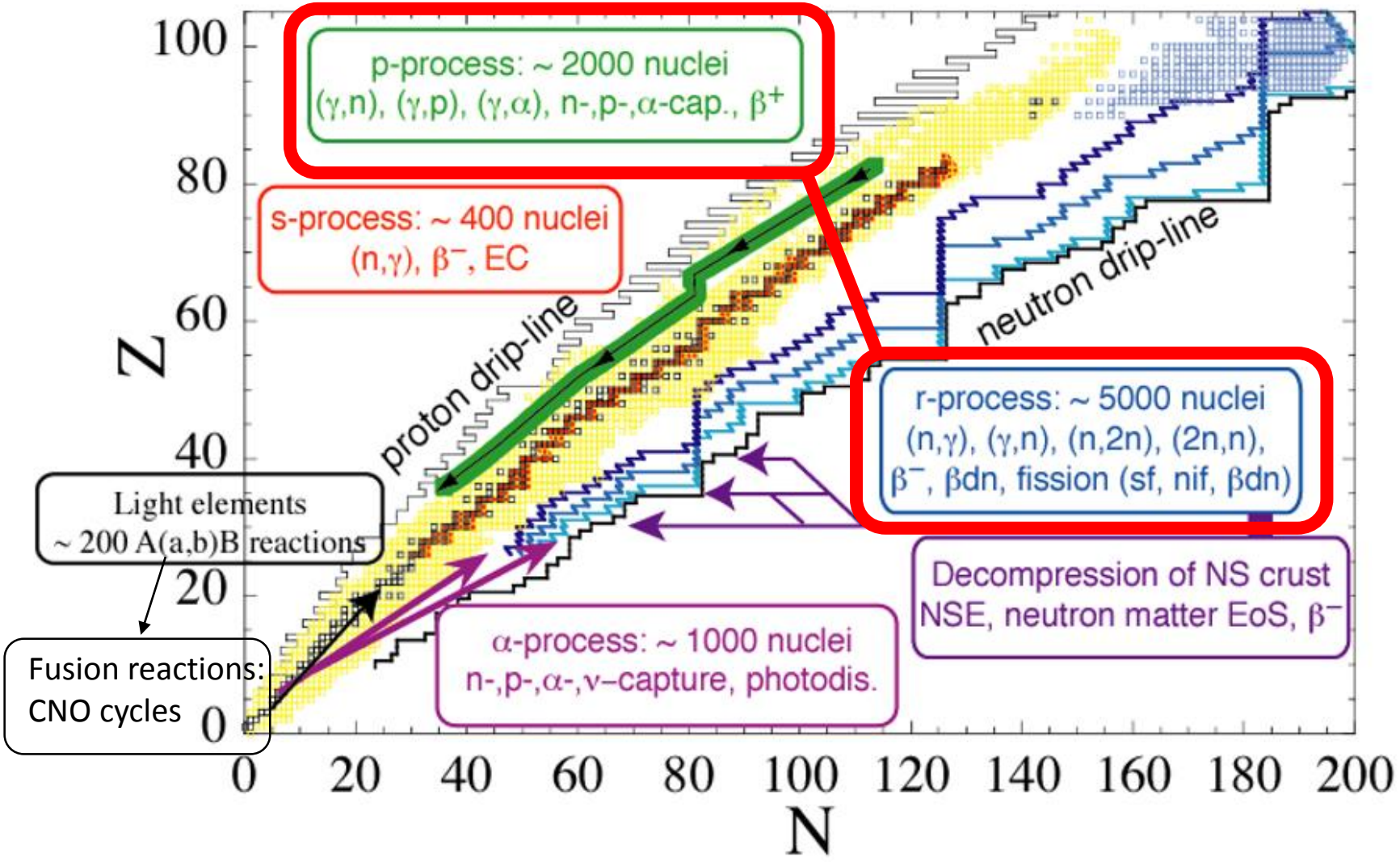
Astro-physics scenarios + Nuclear Physics = Elemental abundances in Universe



Heavy-element Nucleosynthesis



Nuclear Data Needs



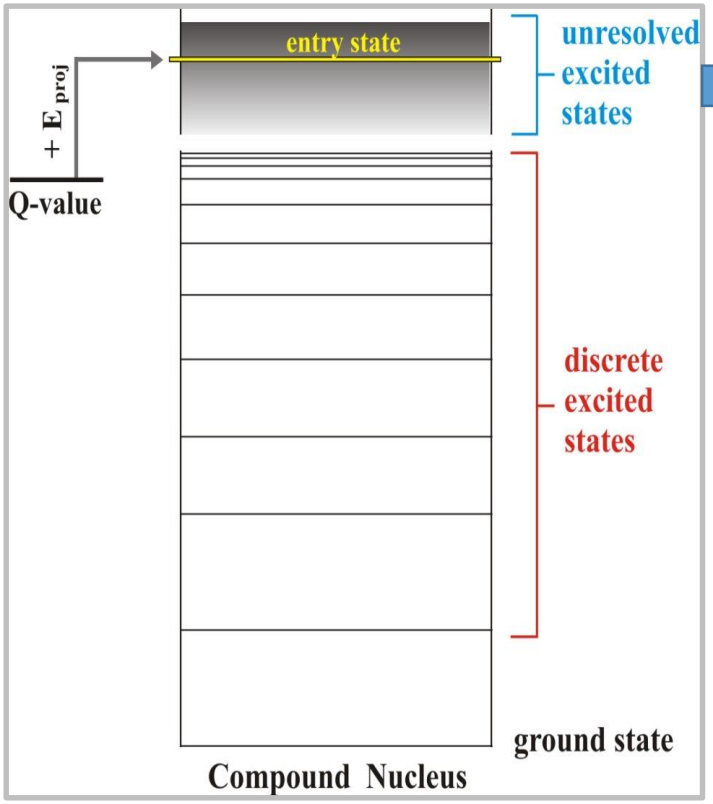
Nuclear reaction theory

- particle-induced
- medium-heavy nuclei
- large particle separation energies

→ compound nucleus reaction mechanism → Hauser-Feshbach theory

$\alpha + A \rightarrow C^* \rightarrow b + B$

$$\sigma_{bB} = \frac{\pi\lambda^2}{(2J_\alpha + 1)(2J_A + 1)} \sum_{J^\pi} (2J_C + 1)\, T_{\alpha A}^{J^\pi} \frac{T_{bB}^{J^\pi}}{\sum_i T_i^{J^\pi}}$$



$$\bar{T}_{\alpha A} = \sum_I \int \rho(E_\alpha, I)\, T_{\alpha A}^I(E_\alpha)\, dE_a$$

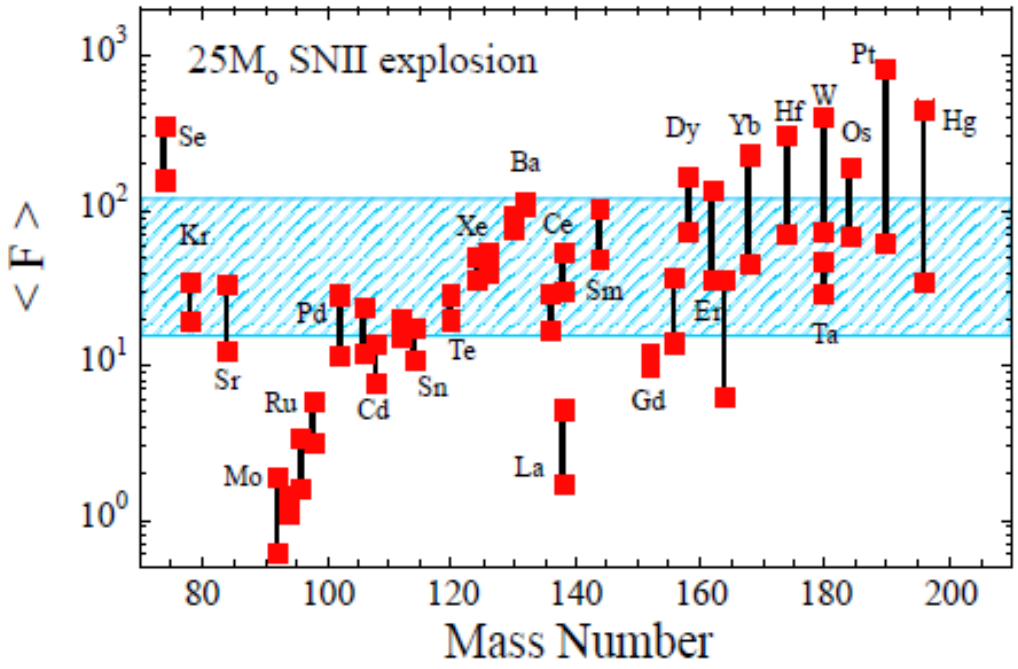
average over level densities

$T_{\alpha A}^{J^\pi}$: Transmission through barrier – particle-nucleus OMP

T_γ^L : E/M response – Dipole strength photon strength function

$\sum_i T_i^{J^\pi}$: sum of transmission probabilities over all exit channels ***i***

Impact of nuclear uncertainties on p-process abundances



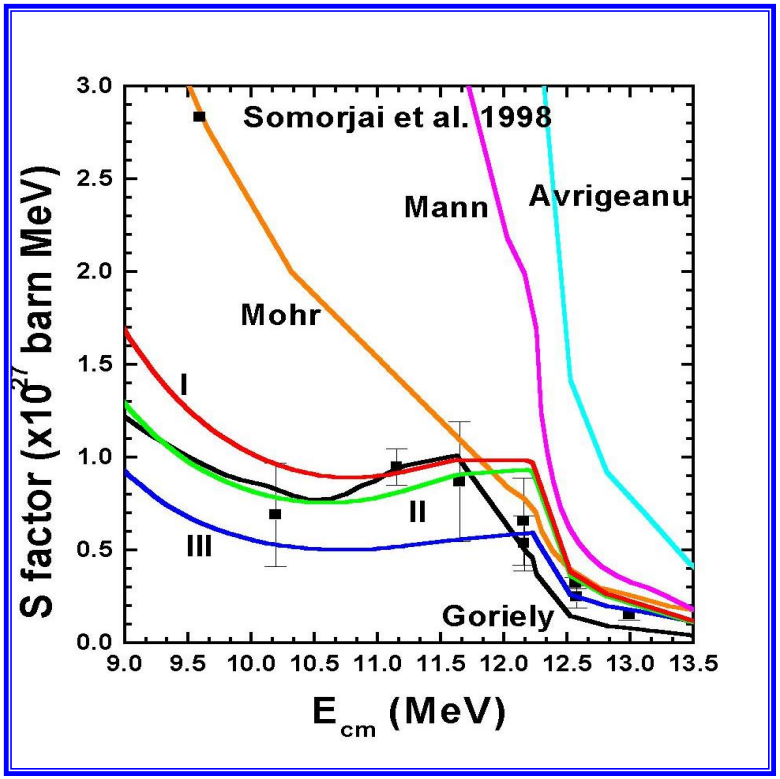
Major nuclear uncertainties in theoretical photo-disintegration rates:

- Global alpha-nucleus optical potential (A>150)
- GLOBAL nucleon-nucleus potential, NLD, γ-strength (light A<90 p-nuclides)

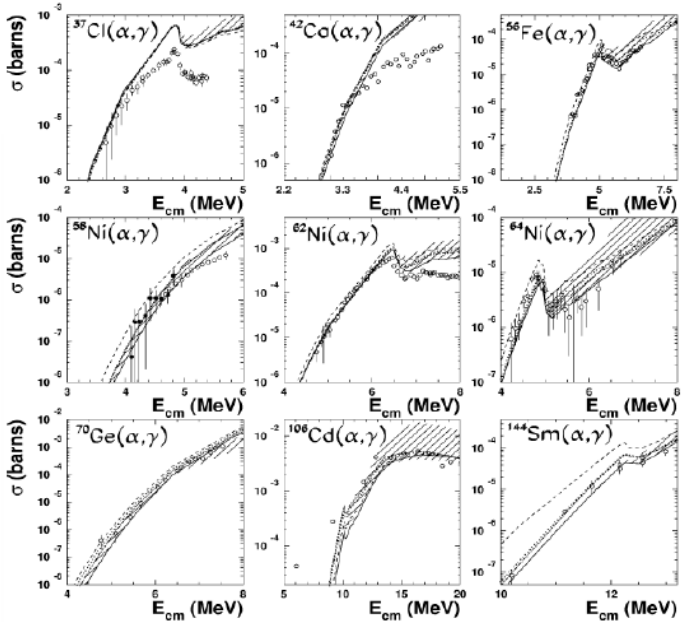
α-nucleus Optical Model Potential

- New global semi-microscopic alpha-nucleus optical potential:
  Demetriou, Grama and Goriely, NPA 707, 253 (2002)
  - Microscopic real V + Woods-Saxon imaginary W
  - W: Fermi-type energy dependence
- Update of alpha-nucleus OMP:
  Demetriou and Axiotis, Proc. Of Tours Symposium, 2007 (Marie Curie ERG FP6)

Demetriou et al, NPA 707, 253 (2002)



Demetriou et al. (2002): Fit to low-energy (α,γ), (α,n), (n,α), (α,p) & scattering cross sections



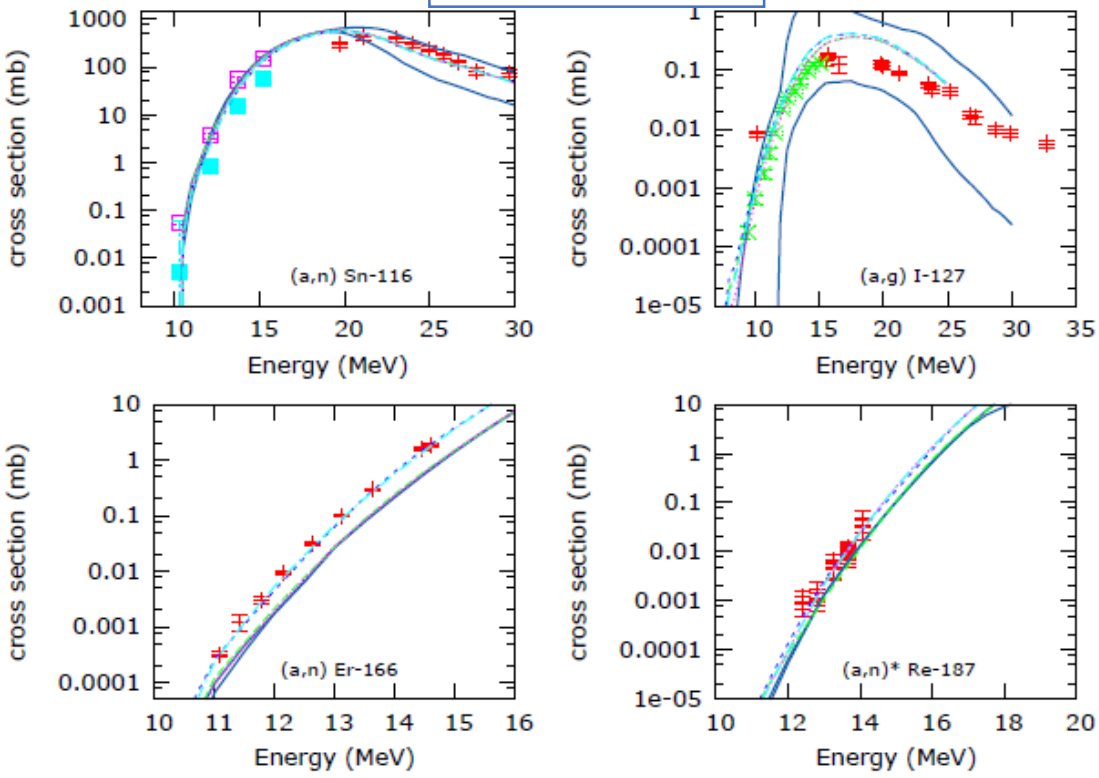
α-OMP implemented in widely used nuclear reaction code TALYS

New: improved global alpha OP for deformed nuclei

- New data since 2007: discrepancies observed for rare-earth nuclei
- Include deformation in real double-folding potential

$$R \rightarrow R \cdot \left(1 + \frac{\beta_2/15}{1 + \exp\left(\frac{E-18}{2}\right)}\right)$$

Average increase 30%



PD, Goriely, in preparation

International collaboration

- Project on Measurements of alpha-elastic cross sections near the Coulomb barrier @ GANIL
- Goal: Assess the two main global alpha-nucleus OMPs: Demetriou III and Avrigeanu (2014)

Alpha-Nucleus Optical Potential Studies for p-process Nuclei

Spokesperson: B. Rebeiro[1]
Co-spokesperson: S. V. Harissopulos[2], B. Bastin[3], C. Ducoin[1]
Experimental facility contact person: N. de Sereville[4]

O. Stézowski[1], J. Dudouet[1], F. Hammache[4], L. Achouri[5], P.Adsley[6,7], V. G. Alcindor[3], M. Axiotis[2], L. Al Ayoubi[8], L. Canete[9], S. Courtin[10], P. Demetriou[2], I. Deloncle[4], T. Faestermann[11], M. Fallot[12], C. Fougerec[3], S. Goriely[13], S. Harrouz[4], J. Kiener[4], A. Kankainen[8], A. Lagoyannis[2], C. Michelagnoli[14], F. de Oliveira[3], A. -M. Sanchez Benitez[15], N. Redon[1], C. Stodel[3], V. Tatischeff[4], J.-C. Thomas[3], and E. Vagena[2]

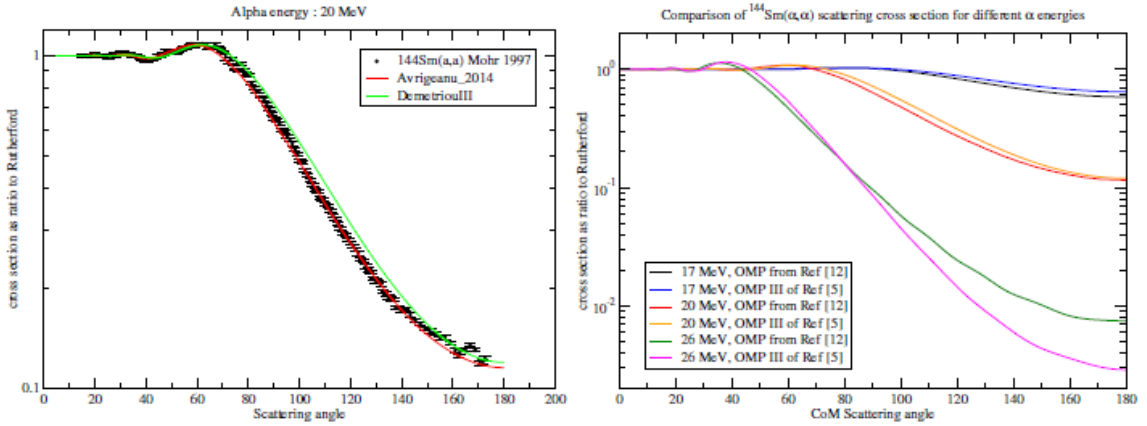


Figure 1: Elastic scattering ratio to Rutherford cross sections for $^{144}Sm(\alpha,\alpha)$ calculated using TALYS for different incident energies using the Avrigeanu [13] and Demetriou III [5] optical potentials. In the left panel TALYS calculated cross sections are compared with existing $^{144}Sm(\alpha,\alpha)$ data from [19].

- Collaboration between GANIL, Universite de Lyon, , NCSR Demokritos , Universite Libre de Bruxelles, Subatech-Nantes, Orsay, ILL-Grenoble, iThemba LABS, Strasbourg, Univ. Surrey, Univ. Huelva, Univ. Jyvaskyla, University of the Witwatersrand
- PAC approved measurements: June/July 2021

Systematics of proton-nucleus JLM/B OMP

JLM/B: Semi-microscopic nucleon-nucleus OMP of Bauge, Girod, Delaroche, PRC 63 (2001) 024607

New measurements by Demokritos groups (yellow boxes):

Spyrou, …,PD, et al., Phys. Rev. C 77, 065801 (2008)

Harissopulos, …,PD, et al., Phys. Rev. C 87, 025806 (2013)

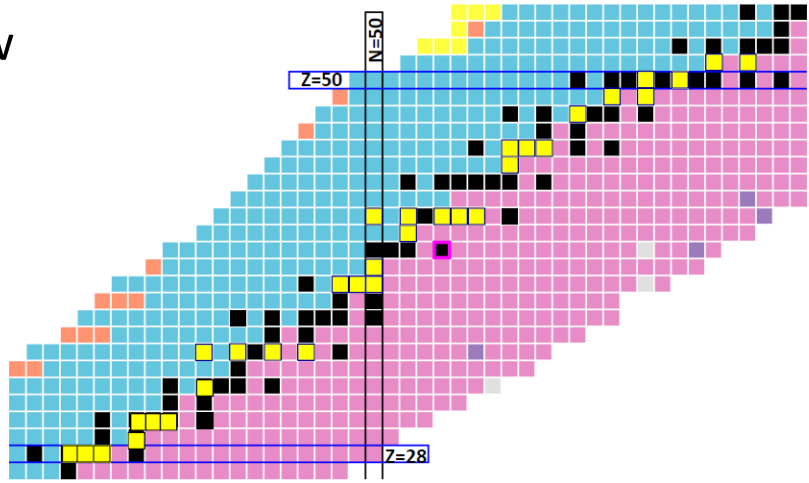
Harissopulos, …,PD, Phys. Rev. C **93**, 025804 (2016)

Foteinou, …., PD, Phys. Rev. C **97**, 035806 (2018)

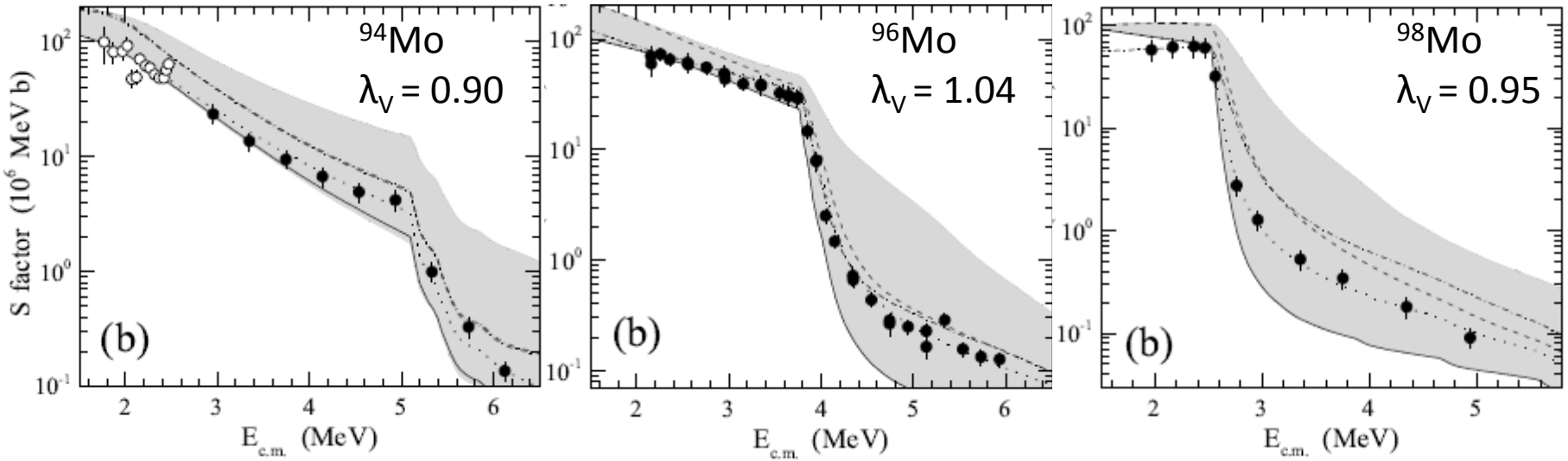
Foteinou,…, PD, et al., Eur. Phys. J. A (2019) **55**: 67

Harissopulos, ..,PD, Phys. Rev. C, accepted for publication

V. Foteinou, PhD Thesis, 2017



Foteinou, et al., Phys. Rev. C **97**, 035806 (2018)



Improved proton JLM/B OMP based on systematics

- All available experimental (p,γ) cross sections at astrophysically relevant energies retrieved
- Criteria for using them in fitting procedure applied
- Experimental uncertainties sorted

39 nuclides; A=50-150

V-51; Cr-50, Cr-54; Fe-54, Fe-56, Fe-58; Co-59; Ni-58, Ni-60, Ni-61, Ni-62, Ni-64; Cu-63, Cu-65; Zn-67, Zn-68; Sr-84, Sr-86, Sr-88, Sr-87; Y-89; Zr-90, Zr-92; Mo-92, Mo-94, Mo-95, Mo-98; Ru-99; Pd-105; In-113; Sn-112, Sn-114, Sn-116; Sb-121; Ba-130; Ce-142; Sm-144, Sn-147; Gd-152

- Verification on all available (p,n) cross sections

50 nuclides; A=50-181

Vagena, Axiotis, PD, submitted to PRC

- New parameterization of global semi-microscopic nucleon optical potential (E and A dependence)

$$V = V_c + \lambda_V \cdot V_R + \imath \cdot \lambda_W \cdot V_W + (\ell \cdot s) \cdot \lambda_{SO} \cdot V_{SO}$$

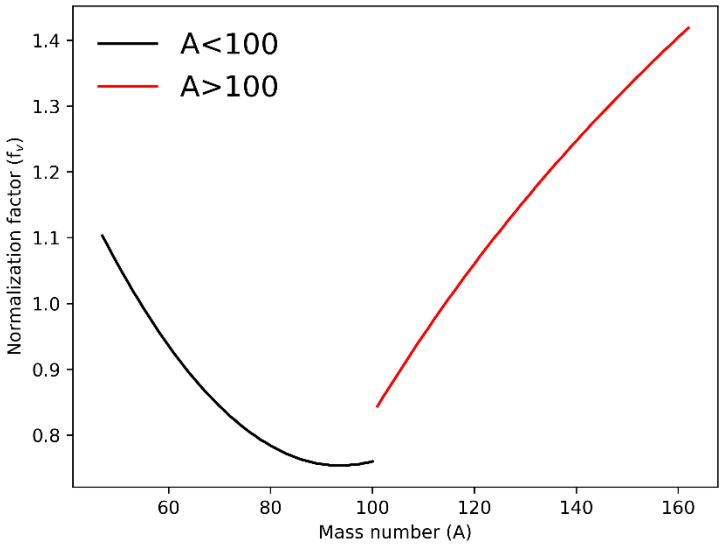
$$\lambda_{V,W} = f(A) \cdot f(E)$$

- New $\lambda_{V,W}$ values adjusted to reproduce experimental data on (p,γ) and (p,n) cross sections

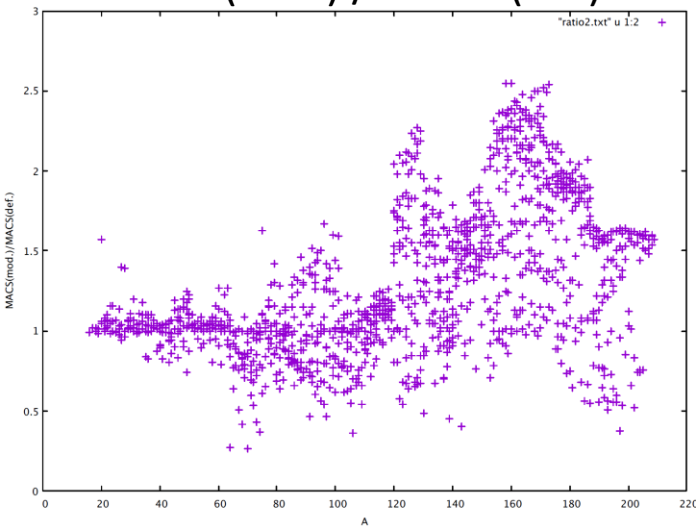
- Large-scale calculations for p-process nucleosynthesis

Systematics

Real V vs A

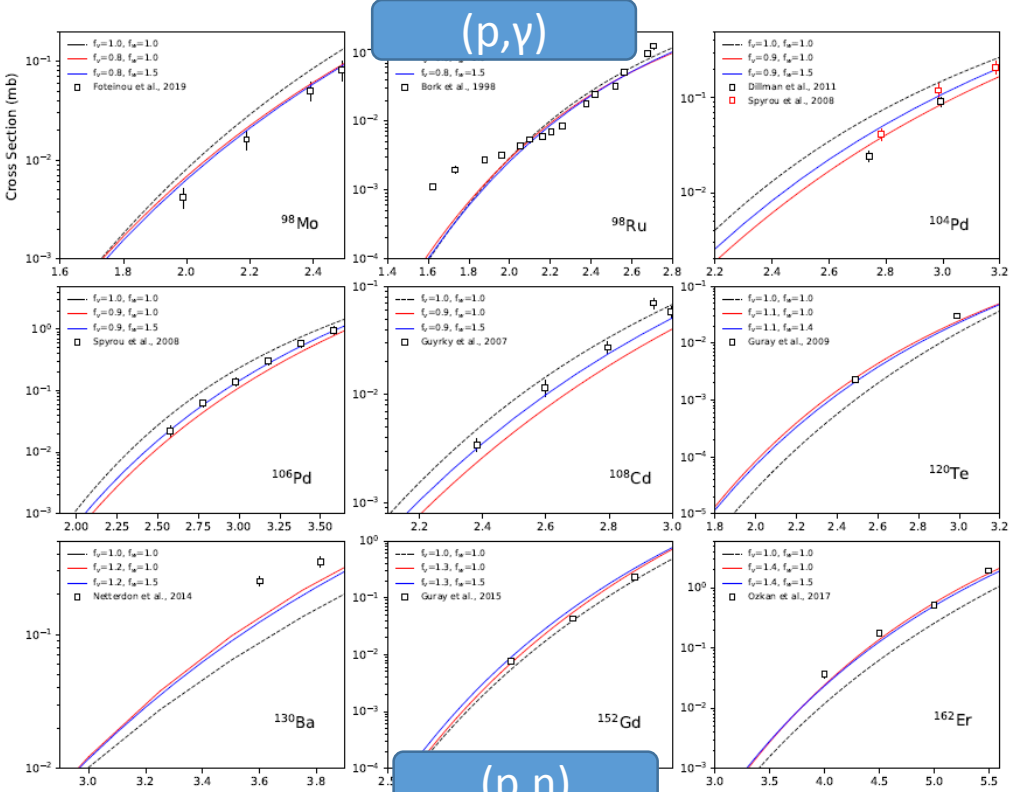


MACS (mod) / MACS (def)

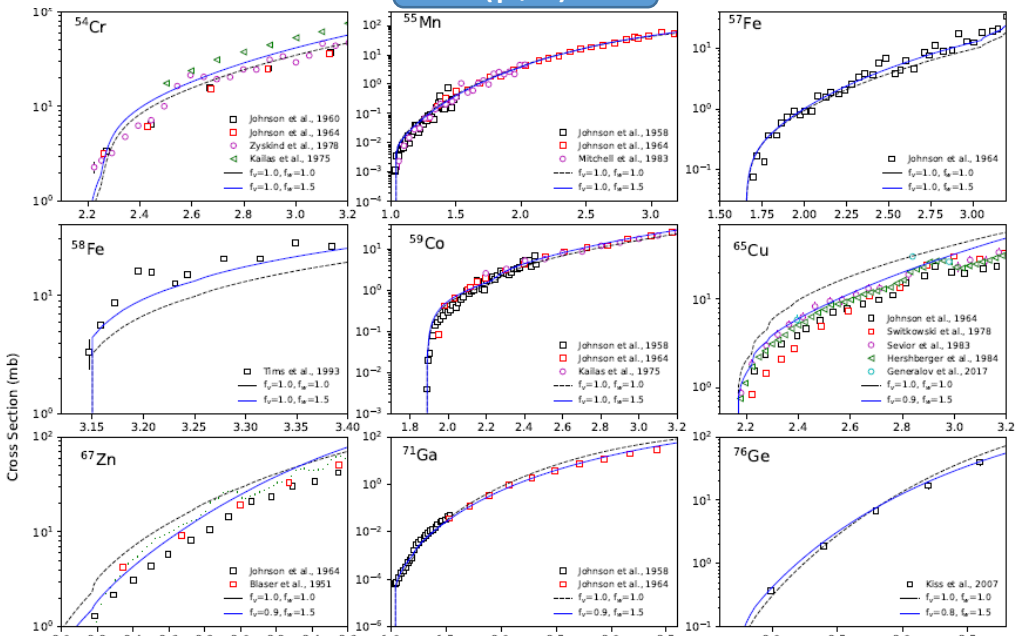


Vagena, Axiotis, PD, submitted to PRC

(p,γ)



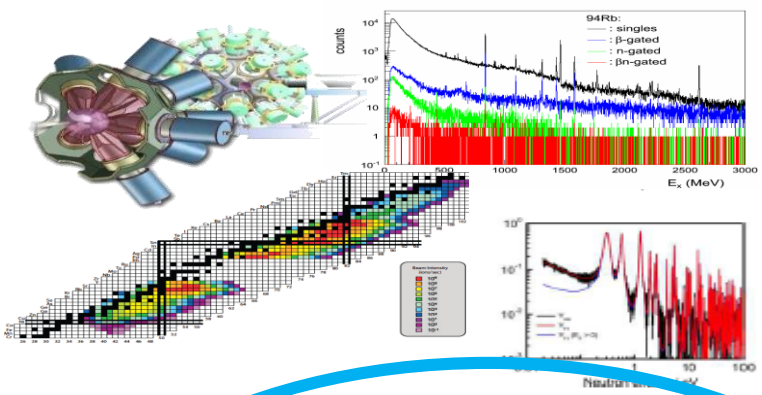
(p,n)



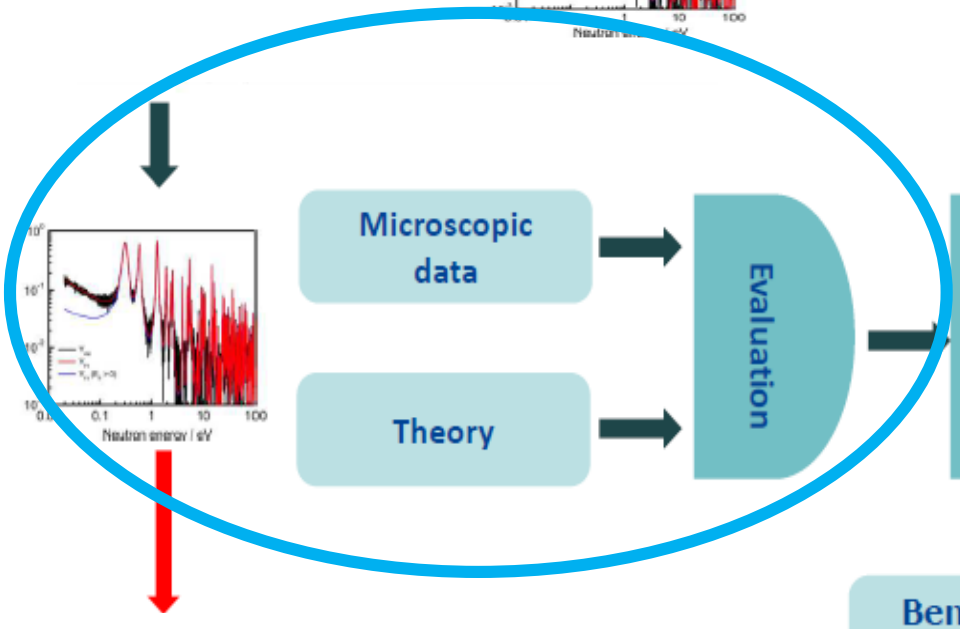
Future plans

- Sensitivity studies of solar abundances with respect to nuclear data using NucNet network calculation code:
  - alpha OMP
  - Proton OMP
  - New photon strength functions
- Verification of photon strength function models
- New photon strength function measurements at Tandem Laboratory; collaboration with iThemba LABS, SA

Nuclear data



Feedback, new data needs



Microscopic data

Theory

Evaluation

Validation & Testing

Benchmark data

Evaluated Data Library

Industry

Regulatory bodies

Research & Development

Evaluation: recommendation of best values based on assessment of Exp. Data and reproduction by theory

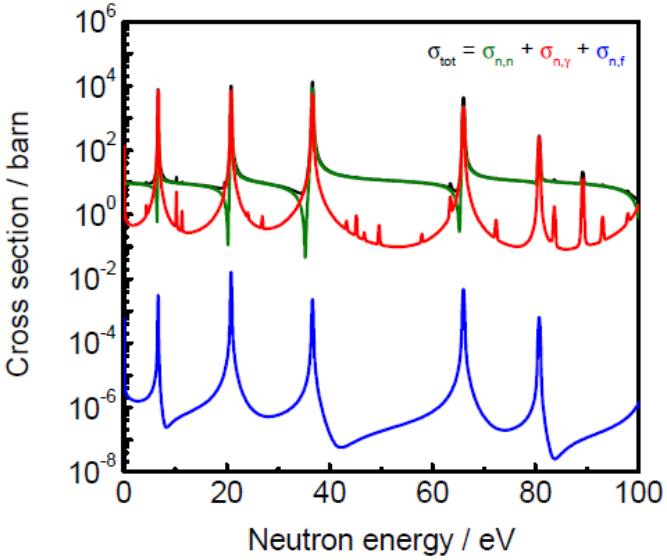
ENDF, JEFF, JENDL
and NDS/IAEA (standards, CIELO)
ENSDF, NuDAT, LiveChart, MIRD

Nuclear Data @ IAEA (2012-2019)

- Coordinated Research Projects (CRP): proposals + budgets evaluated by IAEA research contracts committee
  - CRP on Photonuclear Data Library and Photon Strength Functions (2016-2019), budget: 200K
  - CRP on beta-delayed neutron emission (2013-2018), budget: 150K
  - CRP on Particle Induced Gamma ray Emission Spectroscopy (PIGE) (2011-2015), budget: 150K

- Data Development Projects: proposals+budgets evaluated by Nuclear Data Section; projects ongoing
  - Resolved-Resonance-Region: evaluation of reaction cross sections (2015-)
    - Evaluation of charged-particle reactions in the RRR
    - Ion Beam Analysis Data Library (IBANDL)
  - Decay Data for monitoring applications (2019-)

Compound nucleus – Resonance region



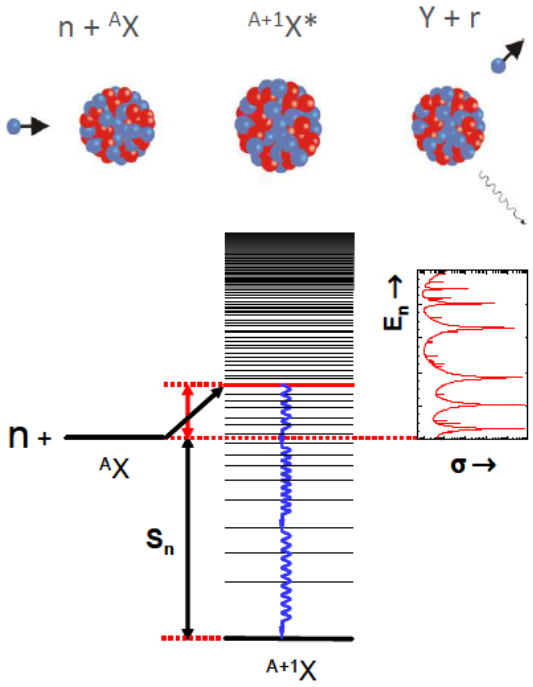
R-matrix theory

Lane and Thomas, Rev. Mod. Phys. 30 (1958) 257

Model parameters

R and $(E_R, J^{\pi}, \Gamma_n, \Gamma_{\gamma}, \ldots)_j$

E_R	resonance energy
Γ_n, Γ_{γ}, Γ_f	partial widths
Γ	total width
	$(\Gamma = \Gamma_n + \Gamma_{\gamma} + \Gamma_f \ldots)$
R	scattering radius



- Resonance parameters cannot be predicted by theory
- Are adjusted to experimental data

→ Experimental data are required

IAEA Project 1: R-matrix codes for charged-particle reactions in the resolved resonance region and evaluation of cross sections

P. Dimitriou, Coordinator

H. Leeb, Technisches Universität Wien

Ian Thompson, Lawrence Livermore National Laboratory

Gerry Hale, Mark Paris, Los Alamos National Laboratory

Marco Pigni, Oak Ridge National Laboratory

James deBoer, Notre Dame University

Zhenpeng Chen, Tsinghua University

Satoshi Kunieda, Japan Atomic Energy Agency

Pierre Tamagno, CEA Cadarache

Budget: 50K +
Duration: 2015 –
Output: publications, data files

- Inter-comparison of R-matrix codes
- Evaluation of compound system Be-7:

Incident channels: p+^{6}Li, ^{4}He+^{3}He → (p,p),
Reactions: (p,alpha), (p, ^{3}He), (p,γ), (^{3}He,p), (^{3}He,n), etc

- Compound systems N-15, N-16:
- Compound system: O-17
- Compoun system: Be-10

Step 1: Verification of R-matrix codes

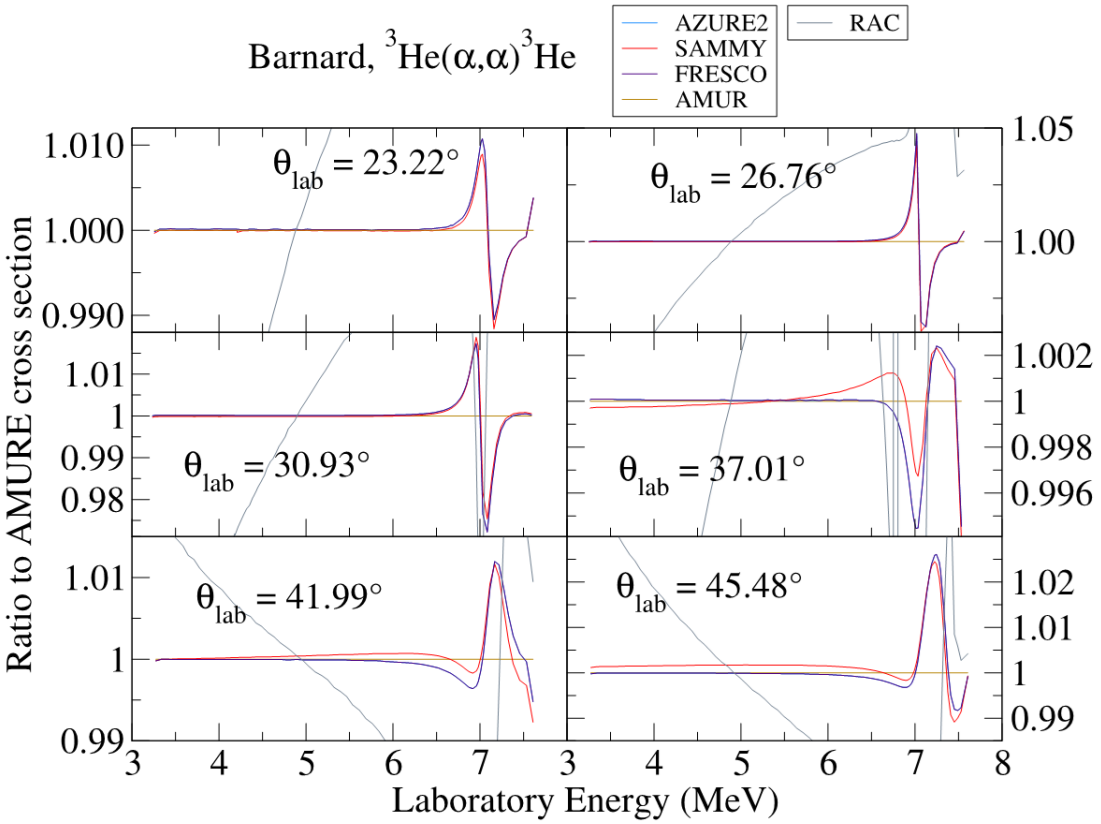
Thompson, deBoer, Dimitriou, Chen et al, Eur. Phys. J. A (2019) 55:92

Most codes agree within 1% to AMUR.

0.1% agreement would be better.

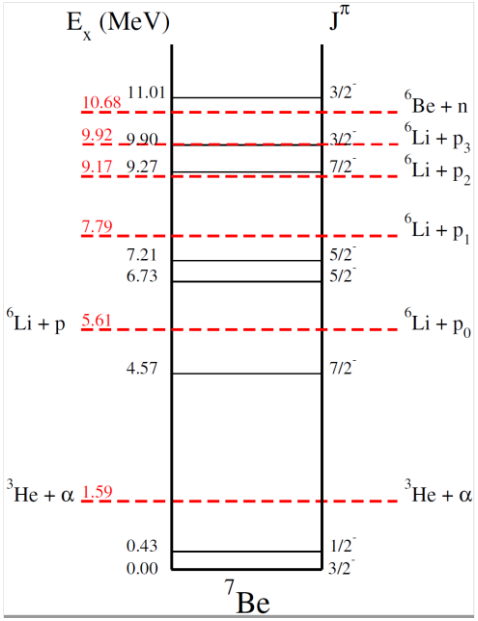
Here only away from the 7 MeV resonance.
(or maybe AMUR code is poor.)

RAC not agreeing.

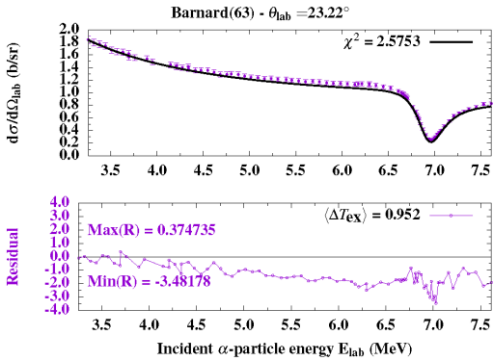


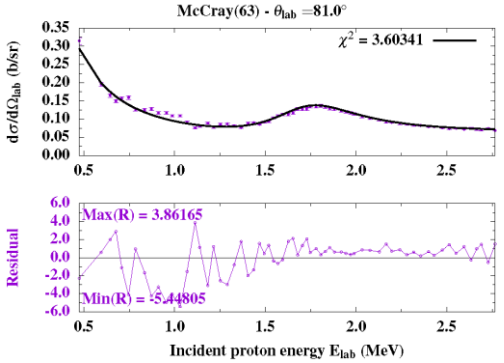
Step 2: Evaluation of Be-7

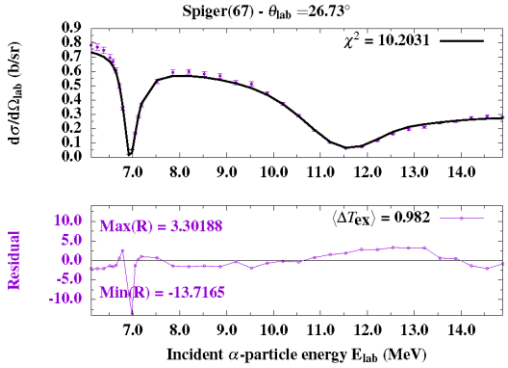
- All channels and exp. data up to 20 MeV [SAMMY R-matix code]

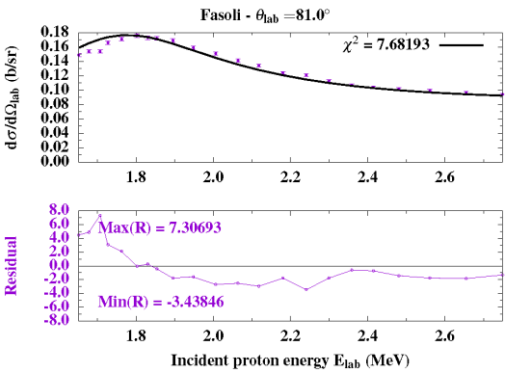


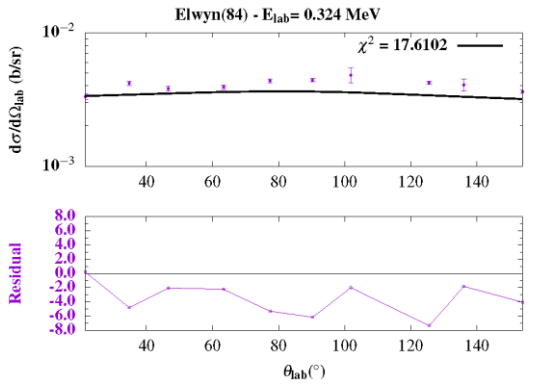
First attempt: up to Ex=8 MeV-no correlation matrix (only statistical uncertainties)- χ^2=6











Work in progress – IAEA collaboration

- Completion of joint evaluation of Be-7 – publication
- Evaluation of other compound systems (N-15,16; O-17)
- Evaluations of other systems relevant to IBA
- Evaluations will include full covariance matrices
- Evaluations will be included in evaluated libraries (ENDF/B) and will also be made available through IBANDL

Electromagnetic response of nucleus: E1

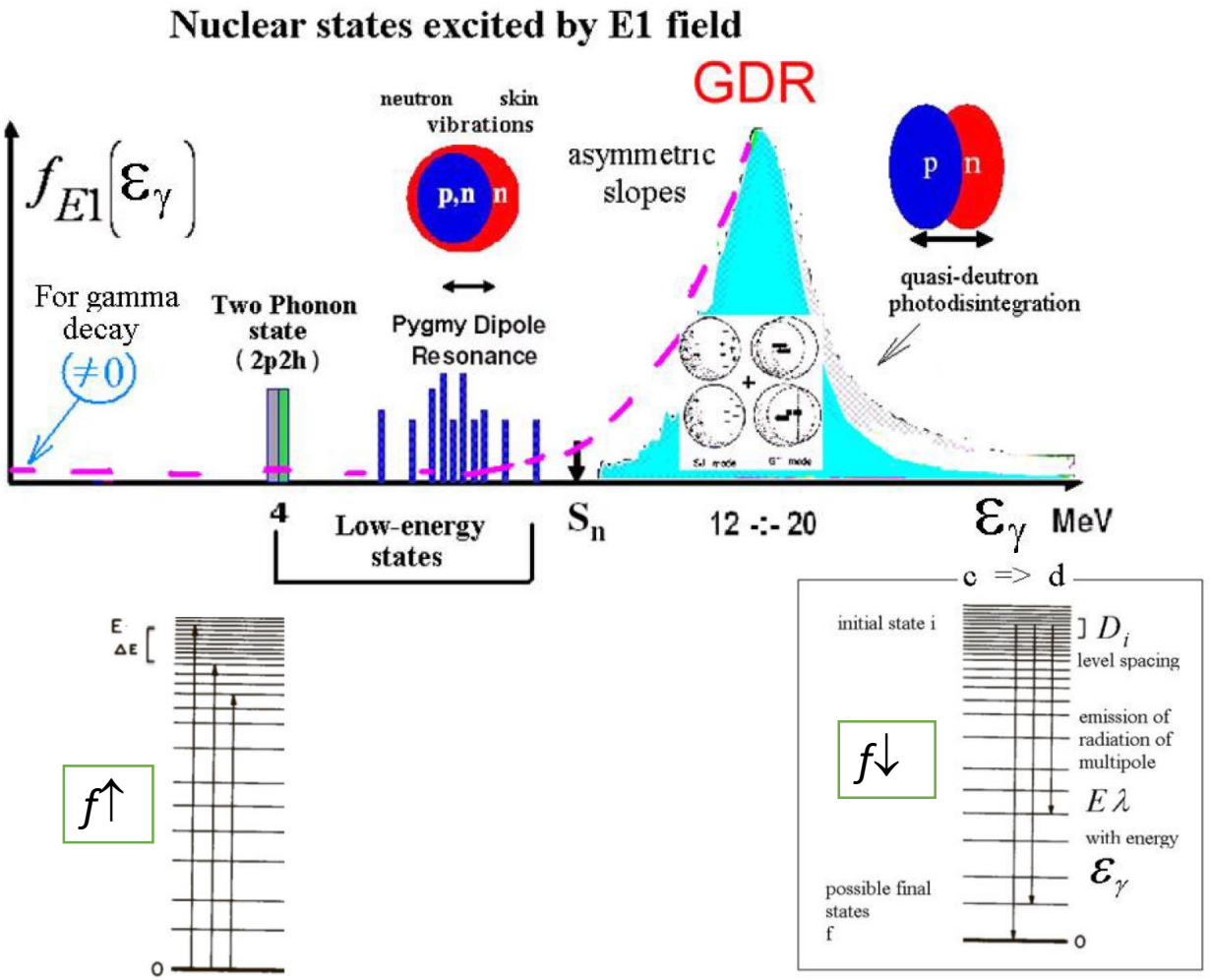


Photo-nuclear: (γ,X)

Photo-deexcitation: (X,γ), (X, γY)

IAEA Project 2: Coordinated Research Project on Photonuclear Data Library and Photon Strength Functions

- Coordinator: P. Dimitriou
- 16 participants/groups from 15 countries:

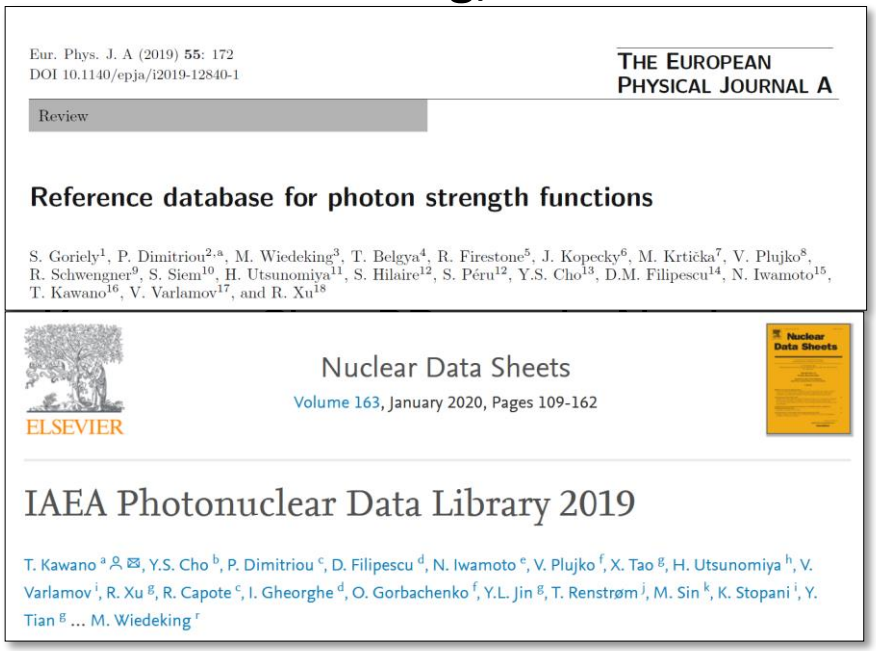
Konan Univ. (Japan),
IFIN-HH (Romania),
Moscow State Univ. (Russia),
CNDC (China),
JAEA (Japan),
KAERI (S. Korea),
Univ. Oslo (Norway),
iTHEMBA LABS (S. Africa),
HZ Dresden-Rosendorf (Germany),
Charles Univ. Prague (Czech Rep.),
Budapest Energy Centre (Hungary),
LBNL/UCB (USA),
Netherlands,
ULB (Belgium),
Kiev University (Ukraine),
LANL (USA)

- Budget: 200K Euros
- Duration: 2016-2019
- Ouput

Online databases:

www-nds.iara.org/PSFdatabase

www-nds.iaea.org/



Eur. Phys. J. A (2019) **55**: 172
DOI 10.1140/epja/i2019-12840-1

THE EUROPEAN PHYSICAL JOURNAL A

Review

Reference database for photon strength functions

S. Goriely[1], P. Dimitriou[2,a], M. Wiedeking[3], T. Belgya[4], R. Firestone[5], J. Kopecky[6], M. Krtička[7], V. Plujko[8], R. Schwengner[9], S. Siem[10], H. Utsunomiya[11], S. Hilaire[12], S. Péru[12], Y.S. Cho[13], D.M. Filipescu[14], N. Iwamoto[15], T. Kawano[16], V. Varlamov[17], and R. Xu[18]

ELSEVIER

Nuclear Data Sheets

Volume 163, January 2020, Pages 109-162

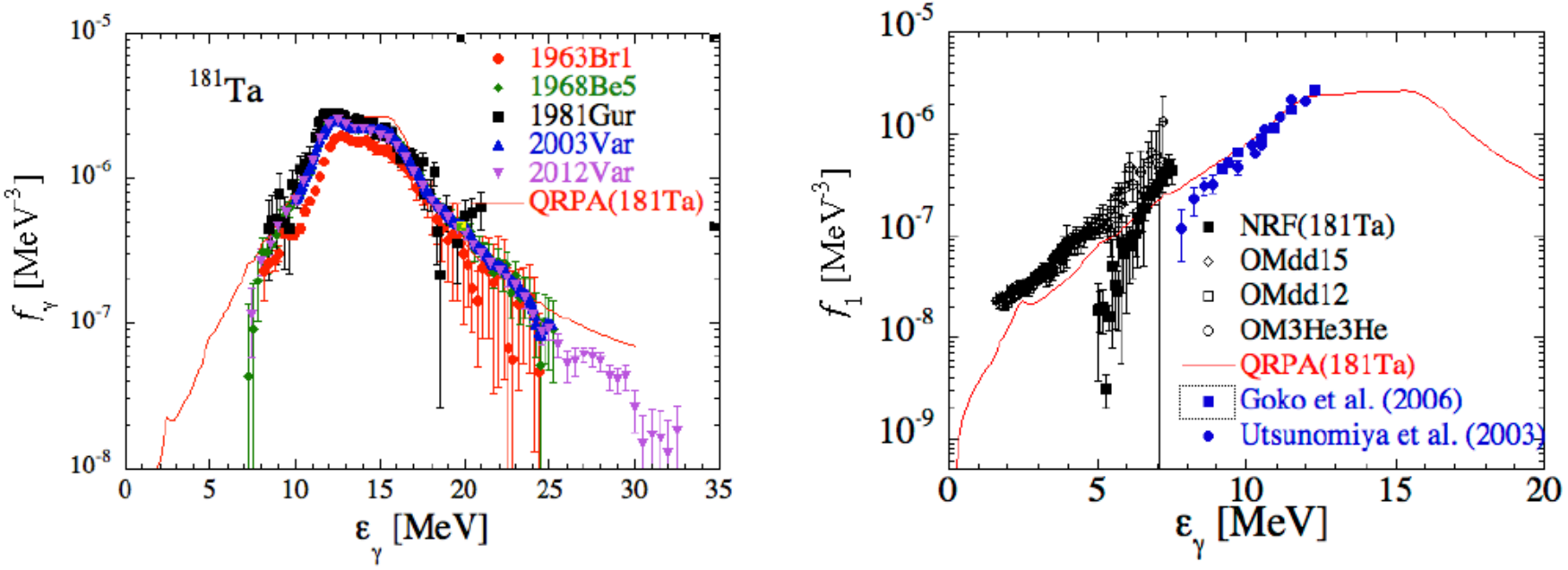
IAEA Photonuclear Data Library 2019

T. Kawano [a] ✉, Y.S. Cho [b], P. Dimitriou [c], D. Filipescu [d], N. Iwamoto [e], V. Plujko [f], X. Tao [g], H. Utsunomiya [h], V. Varlamov [i], R. Xu [g], R. Capote [c], I. Gheorghe [d], O. Gorbachenko [f], Y.L. Jin [g], T. Renstrøm [j], M. Sin [k], K. Stopani [i], Y. Tian [g] ... M. Wiedeking [r]

Scope: Measurements, compilation, evaluation, theory, dissemination I

Comparison for nuclei for which NRF, Oslo & Photodata are available

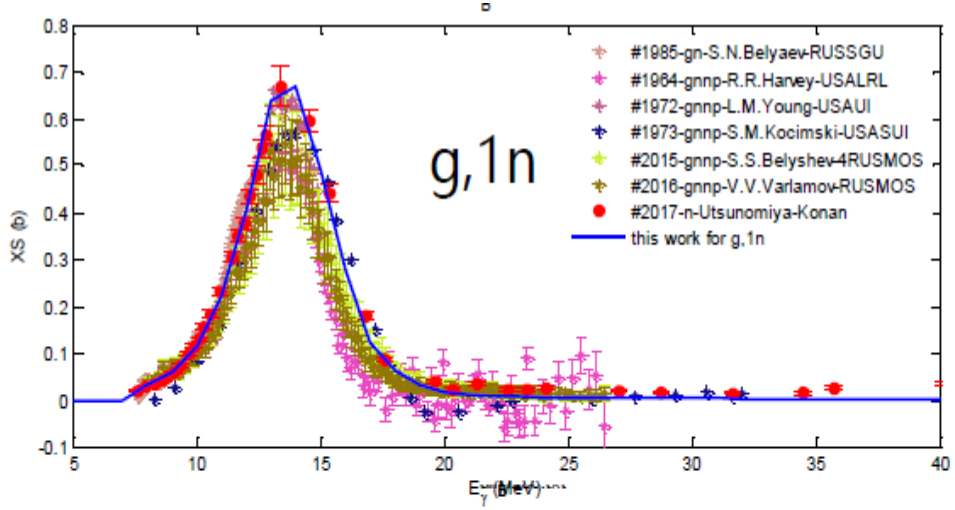
(*E1* + *M1* strength)

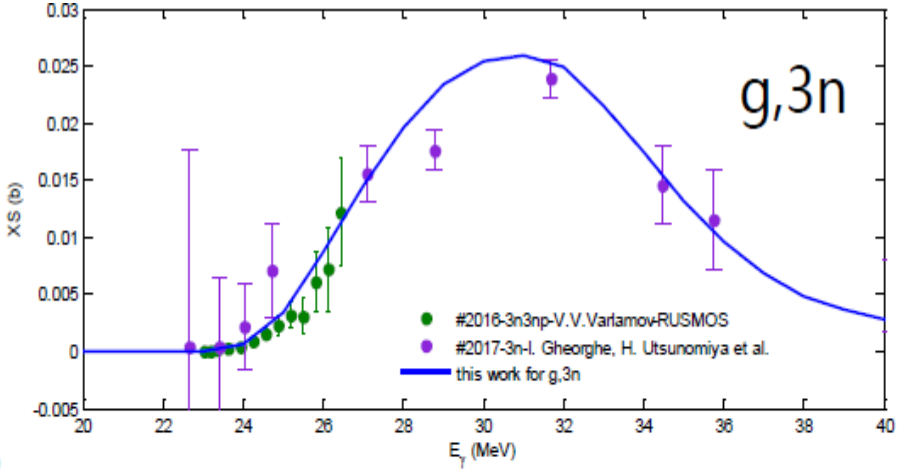


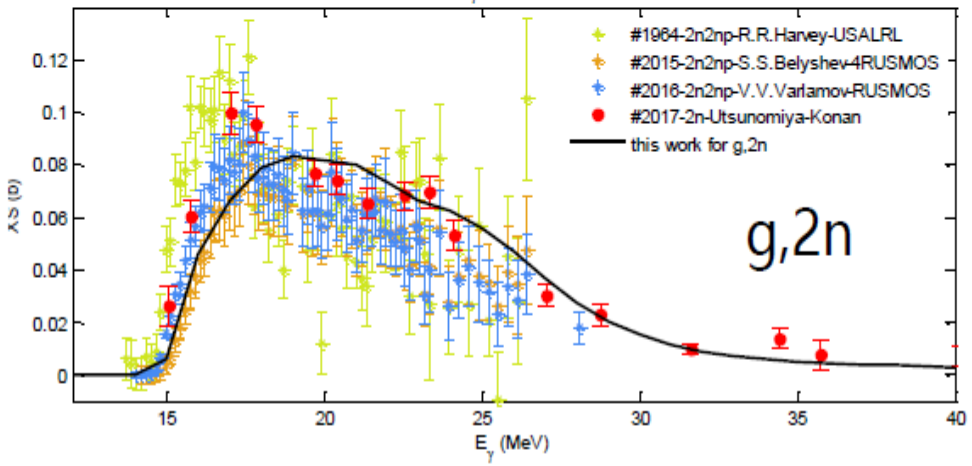
Photon Strength Functions: Connecting GDR and low-energy photon strength

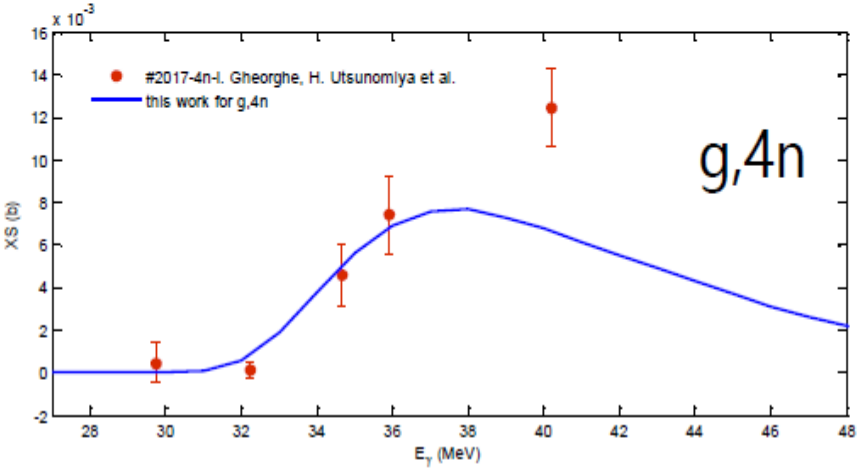
Scope: Measurements, compilation, evaluation, theory, dissemination III

New results for ^{209}Bi(γ,xn): sorting photo-multi-nucleon emission channels









Atlas of Giant Dipole Resonance Parameters: **ground state photoabsorption parameters with uncertainties**

Atom. Data Nucl. Data Tables 123-124 (2018) 1-85
(Plujko, Gorbachenko, Capote, Dimitriou,);
arXiv e-Print – 2018: https://arxiv.org/abs/1804.04445

Atomic Data and Nuclear Data Tables 123–124 (2018) 1–85

Contents lists available at ScienceDirect

Atomic Data and Nuclear Data Tables

journal homepage: www.elsevier.com/locate/adt

Giant dipole resonance parameters of ground-state photoabsorption: Experimental values with uncertainties

V.A. Plujko [a], O.M. Gorbachenko [a], R. Capote [b,*], P. Dimitriou [b]

[a] Nuclear Physics Department, Taras Shevchenko National University, Kyiv, Ukraine
[b] NAPC–Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria

ARTICLE INFO

Article history:
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Received in revised form 26 February 2018
Accepted 5 March 2018
Available online 5 April 2018

ABSTRACT

Updated values and corresponding uncertainties of Isovector Giant Dipole Resonance (GDR) parameters which are obtained by the least-squares fitting of theoretical photoabsorption cross sections to experimental data are presented. The theoretical photoabsorption cross sections are taken as a sum of the components corresponding to the excitation of the GDR and quasideuteron photodisintegration. The current compilation is an extension and improvement of the earlier compilations of Lorentzian

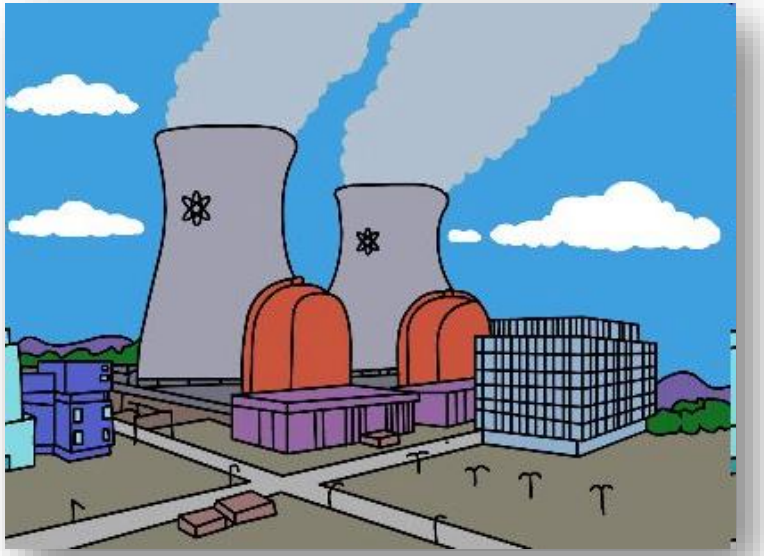
Table 1
Experimental values and uncertainties of GDR parameters within Standard Lorentzian (SLO) approach.

Nucl	Id	$E_{r,1}$ (MeV)	$\Gamma_{r,1}$ (MeV)	s_1	$E_{r,2}$ (MeV)	$\Gamma_{r,2}$ (MeV)	s_2	s	ε_{min}–ε_{max} (MeV)	Ref
^{6}Li	2	23.69 *16*	5.26 *79*	0.341 *31*				0.341 *31*	21.5–27.0	1986Var
	4	12.18 *5*	11.58 *1*	0.334 *150*				0.334 *4*	5.6–24.7	1965Be1
^{7}Li	0	18.59 *21*	16.28 *116*	0.907 *51*				0.907 *51*	13.2–25.6	1985Ahr
	2a	16.39 *11*	16.03 *42*	0.858 *22*				0.858 *22*	13.5–25.0	1986Var
	2b	16.40 *11*	16.03 *42*	0.858 *22*				0.858 *22*	13.5–25.0	1986Var
	4a	16.34 *7*	10.42 *24*	0.236 *4*				0.236 *4*	10.1–24.7	1973Bra
	4b	16.26 *10*	11.17 *41*	0.248 *7*				0.248 *7*	10.1–24.7	1973Bra
^{9}Be	0	23.75 *10*	9.47 *33*	0.577 *17*				0.577 *17*	17.5–26.0	1975Ahr
^{10}B	4a	21.72 *10*	9.08 *16*	0.441 *8*				0.441 *8*	8.5–24.9	1987Ahs
	4b	22.54 *32*	10.81 *63*	0.518 *26*				0.518 *26*	8.5–24.9	1987Ahs

Beta-delayed neutron emission

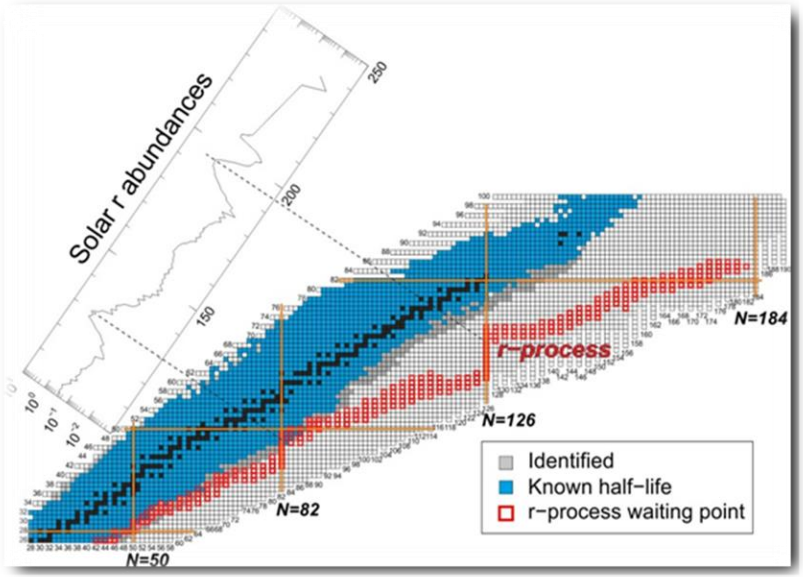
Nuclear Reactors kinetics and safe operation:

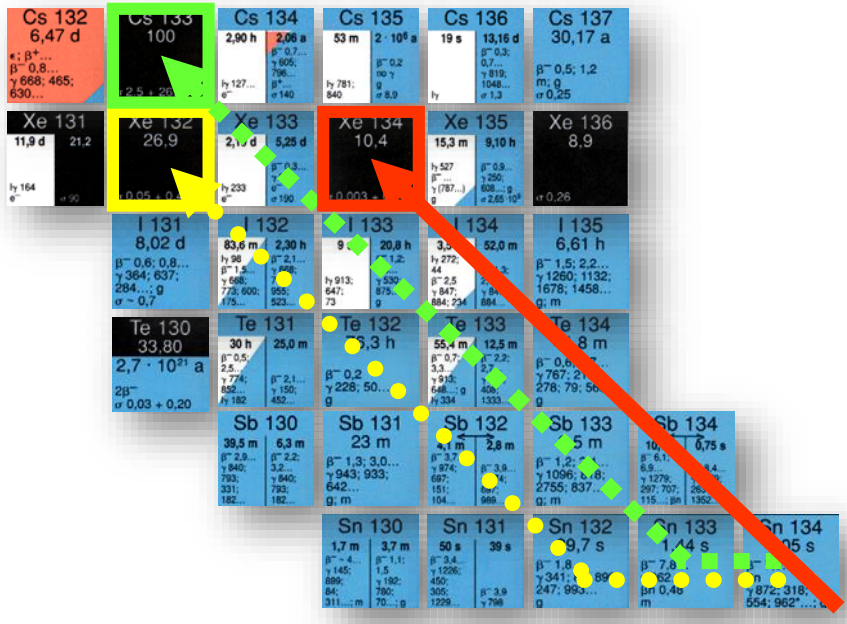
P_n determines the delayed neutron fraction β_{eff} important for reactor kinetics and safety.



Nuclear Astrophysics:

Far from the stability, **β-delayed neutron emission** becomes the dominant decay process and determines abundances after neutron freeze-out in r-process nucleosynthesis.





IAEA Project 3: Coordinated Research Project on beta-delayed neutron emission

- Coordinator: P. Dimitriou
- 17 groups from 14 countries

V. Piksaikin, I. Borzov, IPPE, Kurchatov , Russia
D. Cano, CIEMAT, Spain
S. Chiba, Tokyo Inst. Techn., Japan
M. Fallot, A. Porta, SUBATECH Nantes, France
P. Garrett, I. Dillmann, B. Singh, Univ. Guelph, TRIUMF, McMaster Univ., Canada
G. Mukherjee, P. Banerjee, VECC, India
K. Rykaczewski, R. Grzywacz, ORNL, Univ. Tennesse, USA
J. Tain, A. Algora, CSIC-Univ. Valencia, Spain
X. Huang, CNDC, China
F. Minato, JAEA, Japan
T. Marketin, Univ. of Zagreb, Croatia
R. Mills, NNL, UK
A. Sonzogni, T. Johnson, E. McCutchan, BNL, USA
D. Foligno, P. Leconte, CEA Cadarache, France

- Budget: 150K Euros
- Duration: 2013-2017
- Output:

Database: www-nds.iaea.org/beta-delayed-neutron/database.html

Publication: Nuclear Data Sheets, accepted for publication

Development of a Reference Database for Beta-Delayed Neutron Emission

P. Dimitriou,[1,*] I. Dillmann,[2,3] B. Singh,[4] V. Piksaikin,[5] K.P. Rykaczewski,[6] J.L. Tain,[7] A. Algora,[7] K. Banerjee,[8] I.N. Borzov,[9,10] D. Cano-Ott,[11] S. Chiba,[12] M. Fallot,[13] D. Foligno,[14] R. Grzywacz,[15,6] X. Huang,[16] T. Marketin,[17] F. Minato,[18] G. Mukherjee,[8] B.C. Rasco,[19,6,15,20] A. Sonzogni,[21] M. Verpelli,[1] A. Egorov,[5] M. Estienne,[13] L. Giot,[13] D. Gremyachkin,[5] M. Madurga,[15] E.A. McCutchan,[21] E. Mendoza,[11] K.V. Mitrofanov,[5] M. Narbonne,[13] P. Romojaro,[11] A. Sanchez-Caballero,[11] and N. Scielzo[22]

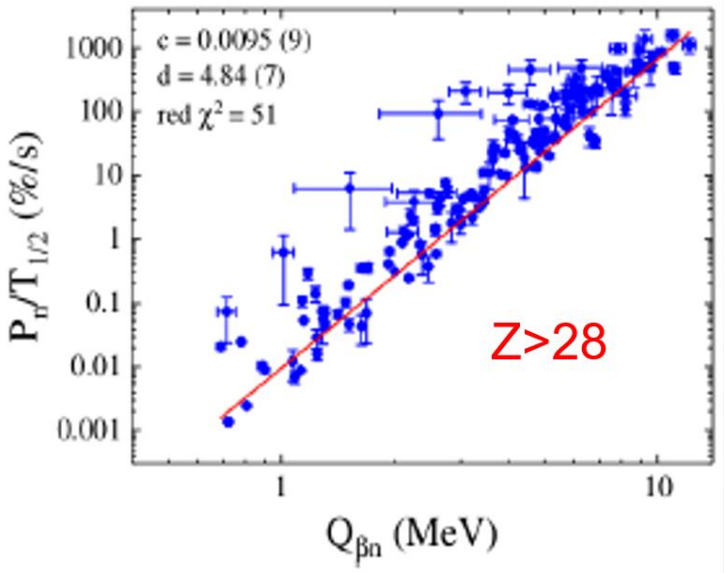
Scope: measurements, compilation, evaluation, theory, validation and dissemination I

Compilation-Evaluation
($T_{1/2}$, P_n) data have been extracted and evaluated for 653 neutron-rich known or potential-delayed neutron emitters from about 600 publications

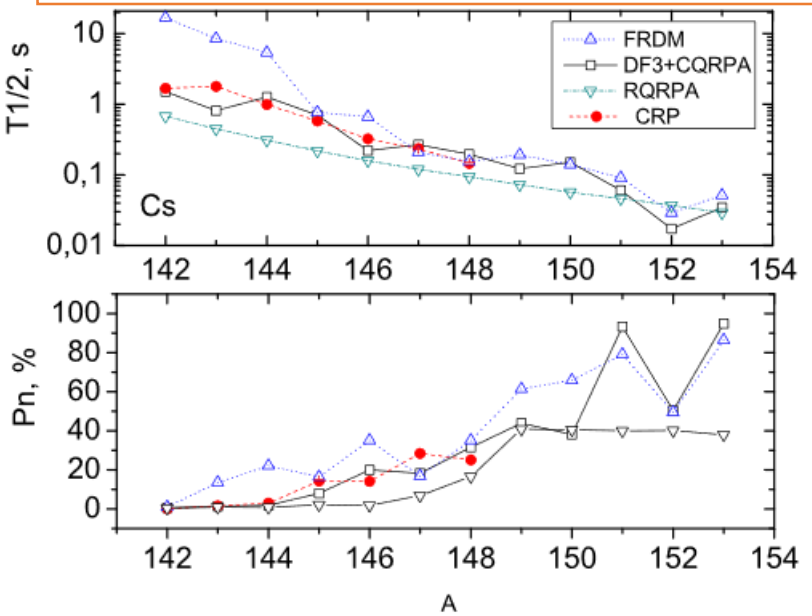
New standards

Nuclide	Half-life (s)	P_{1n} (%)	Ref.
^{9}Li	0.1782(4)	50.5(10)	[31]
^{16}C	0.7546(80)	99.28(12)	[31]
^{17}N	4.171(4)	95.1(7)	[31]
^{49}K	1.263(50)	86(9)	[31]
^{83}Ga	0.310(1)	66(6)	[32]
^{87}Br	55.64(15)	2.54(11)	[32]
^{88}Br	16.29(8)	6.72(27)	[32]
^{94}Rb	2.704(15)	10.3(3)	[32]
^{95}Rb	0.380(4)	8.94(57)	[32]
^{137}I	24.59(10)	7.65(14)	[32]
^{145}Cs	0.581(6)	13.5(6)	[32]
^{146}Cs	0.321(2)	14.3(8)	[32]
^{147}Cs	0.2321(20)	28.5(20)	[32]

New systematics: McCutchan et al 2012



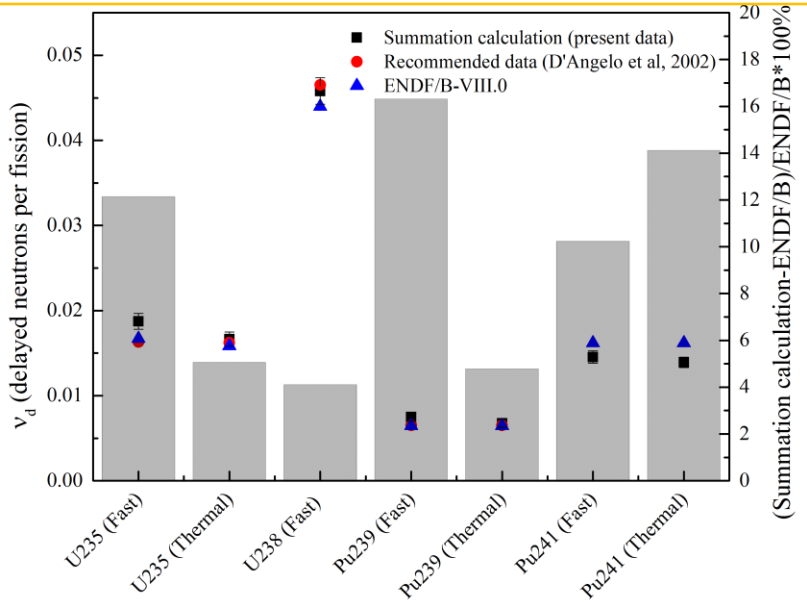
New models: DF3+CQRPA, RHB+QRPA



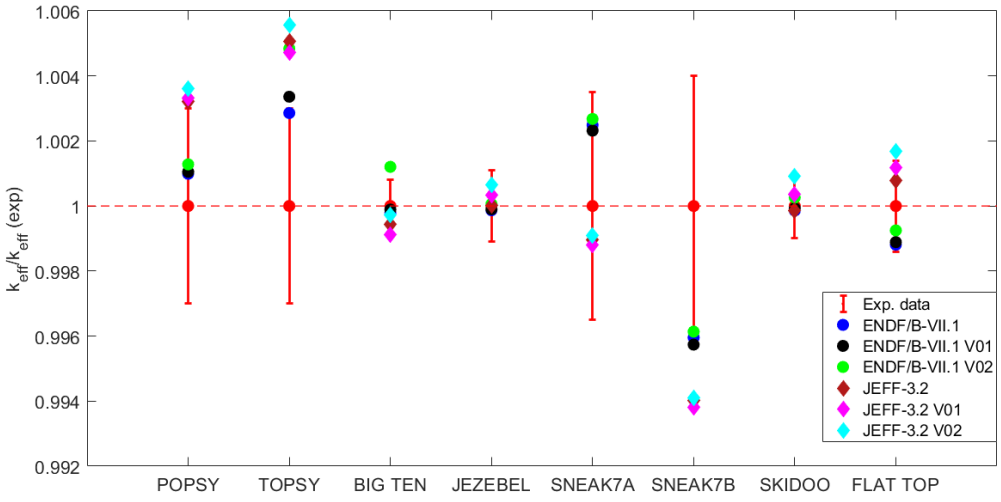
Scope: measurements,compilation, evaluation, theory, validation and dissemination II

- Summation calculations of total delayed neutron yield ν_d
- Time-dependent calculations
- Integral reactor calculations

Comparison with ENDF/B-VIII.0 library and recommended values



Comparisons with keff and βeff benchmarks



IAEA Project 4: Coordinated Research Project on Reference Database for Particle-Induced Gamma-ray Emission spectroscopy (PIGE)

- Coordinator: P. Dimitriou
- 10 participants/groups from 10 countries

Becker, Germany

Bogdanovic-Radovic, Croatia

Chiari, Italy

Raisanen, Finland

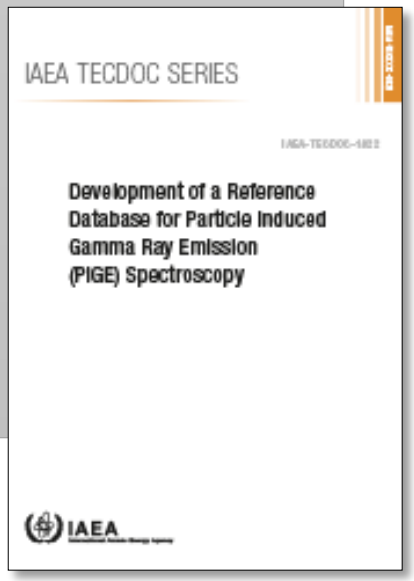
De Jesus, Portugal

Kakuee, Iran

Kiss, Hungary

Lagoyannis, Greece

Zucchatti, Spain



- Budget: 150K Euros
- Duration: 2011-2015
- Output:

Ion Beam Analysis Data Library (IBANDL)

IAEA-TECDOC-1822: Handbook of PIGE analysis

- ✓ Over 600 new data sets in IBANDL
- ✓ 200 new measurements (data sets)
- ✓ Comparisons with measured thick-target yields
- ✓ Assessments - Recommendations

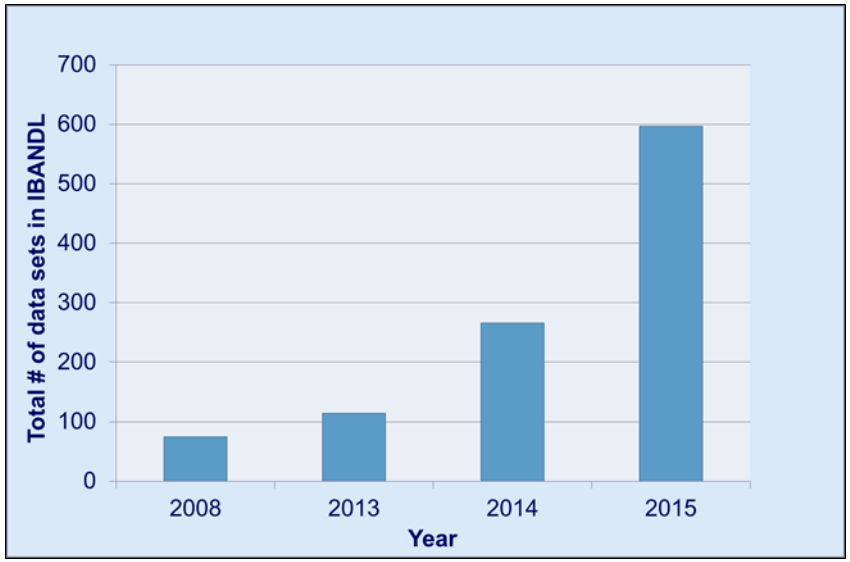
Ion Beam Analysis Nuclear Data Libary (IBANDL)

Nuclear Data Service **IBANDL**

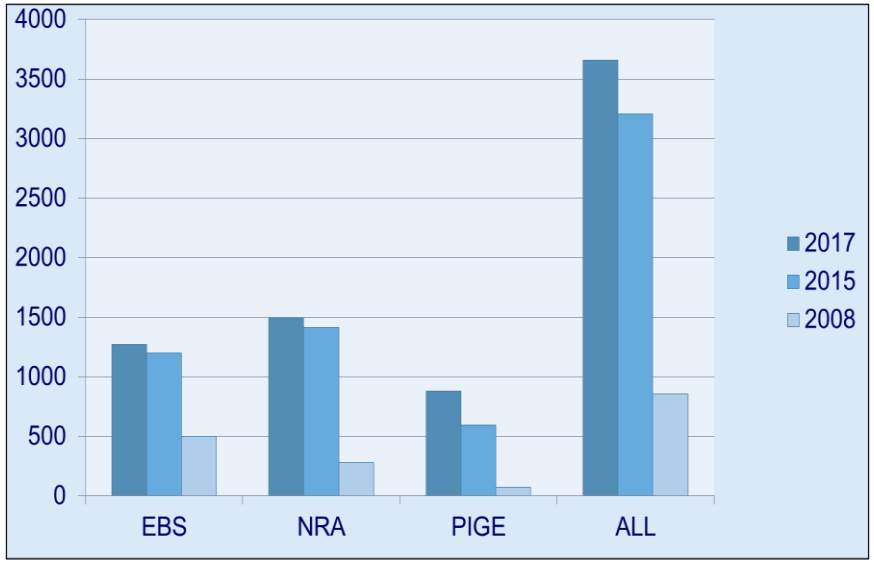
This is the Ion Beam Analysis Nuclear Data Library developed and formerly maintained by A.Gurbich under the IAEA auspices. It contains available **experimental** nuclear cross-sections relevant to Ion Beam Analysis. Differential cross sections are presented both as graphs and data files. The numerical data are in the R33 format. Currently, most of the data are being extracted from EXFOR using an automatic conversion procedure available in EXFOR retrieval system (see details of the algorithm here).

New

- Total cross sections (mb) can be converted to differential cross sections (mb/sr) in cases where the angular distributions are known to be isotropic. Differential cross sections (mb/sr) can be converted to Ratio-to-Rutherford (rr) and vice versa. Press 'Convert units for plotting' button on the data table header.
- Conversion to inverse kinematics is possible. Press 'inverted' button on the data table header.
- User can upload own data files to compare with existing data. See 'Add your dataset in R33 format for plotting' on the bottom of the data table.
- Search data by first author and reference: [Summary] → [+]References → click on » .



Number of PIGE data sets in IBANDL (before and during CRP)



Number of data sets in IBANDL (before and after the CRP)

IAEA Project 5: IAEA Inter-comparison of PIGE Analysis Codes

- Coordinator: P. Dimitriou
- Participants:

Barradas, IAEA

Cruz, Portugal

Lagoyannis, Greece

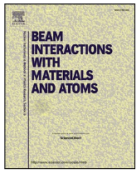
Meyer, Germany

- Budget: 15K Euros
- Recommended PIGE Analysis Codes
- Publication:

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb



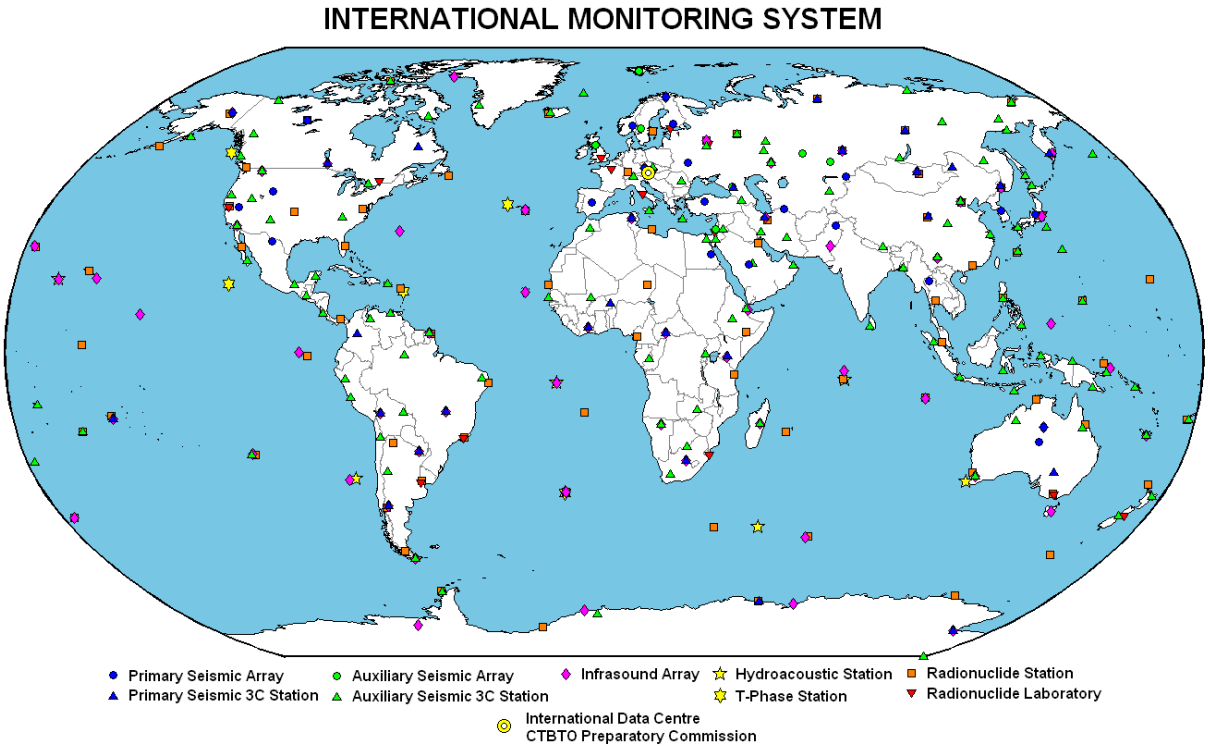
International Atomic Energy Agency inter-comparison of particle induced gamma-ray emission codes for bulk samples

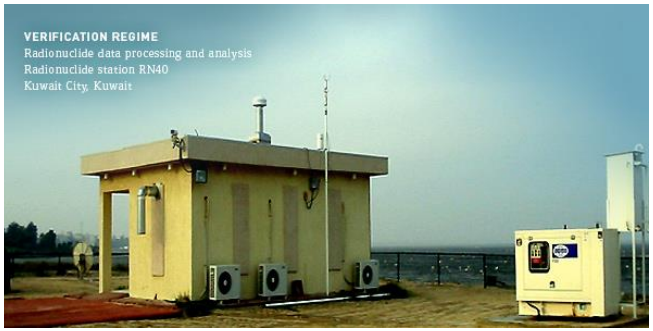
N. Pessoa Barradas[a,*], J. Cruz[b], M. Fonseca[b,c], A.P. de Jesus[b], A. Lagoyannis[d], V. Manteigas[b], M. Mayer[e], K. Preketes-Sigalas[d], P. Dimitriou[a,1]

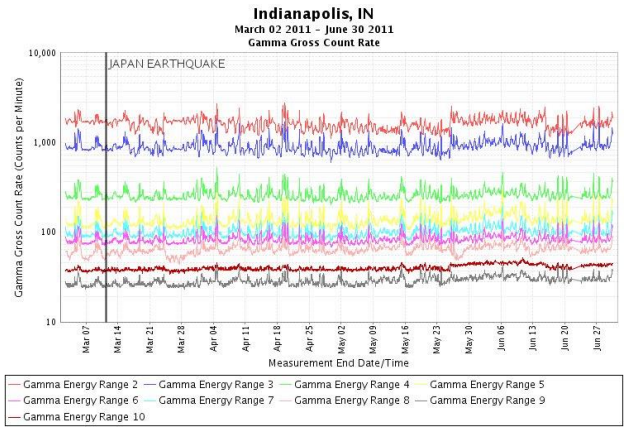
Nuclear Data for Monitoring Applications

An International Atomic Energy Agency Project to create a library of decay data for radionuclides relevant to CTBTO

CTBT Radionuclides:
From nuclear weapons
(fission & activation products)







IAEA Project: Evaluation of decay data for monitoring applications

- Critical assessment of all measurements and uncertainties
- Averaging methods
- Procedures, policies, analysis codes developed and used for the Evaluated Nuclear Structure Data File (ENSDF)

- Budget: 30K Euros per year
- Duration: 2019-2022
- Output:

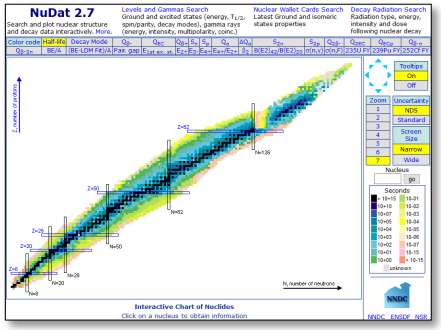
Online data library

Publication

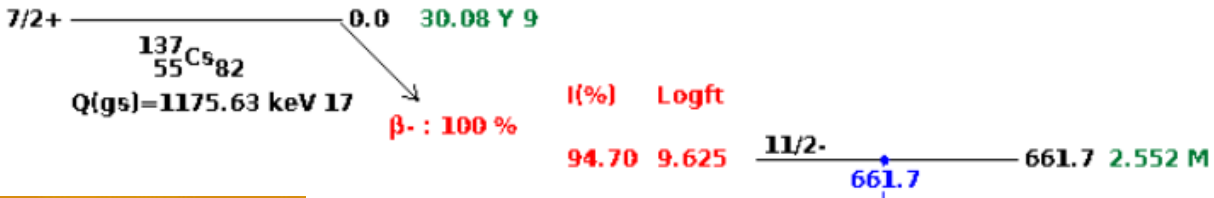
27 top priority fission products for monitoring nuclear explosions by measuring radionuclide concentrations in air samples (CTBTO)

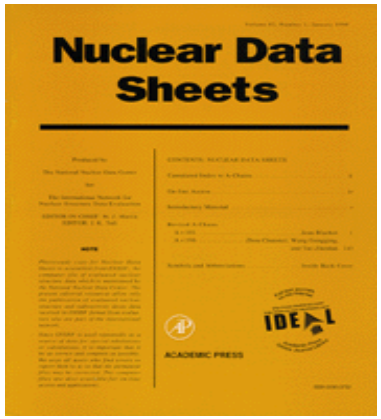
Under the auspices of the International Atomic Energy Agency

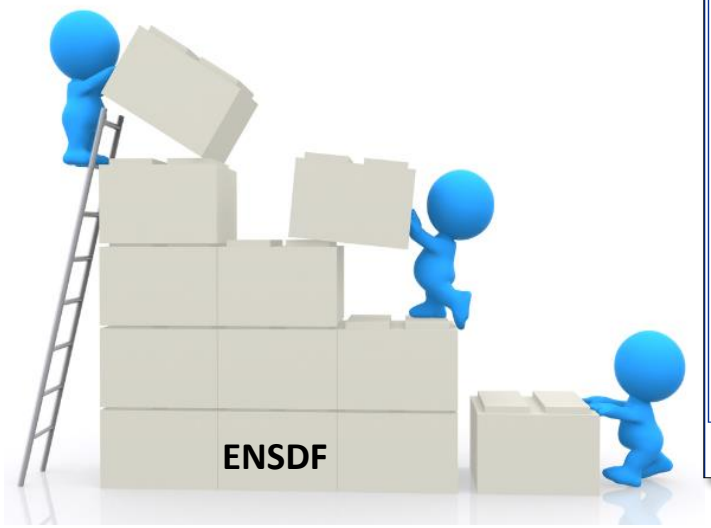
Paraskevi Dimitriou, NCSR "Demokritos"
Balraj Singh, McMaster University
Jagdish Tuli, University of Berkeley
Filip Kondev, Argonne National Laboratory
Tibor Kibedi, Australian National University
Alan Nichols, Surrey University
Jun Chen, NSCL, MSU
Sorin Pascu, IFIN-HH

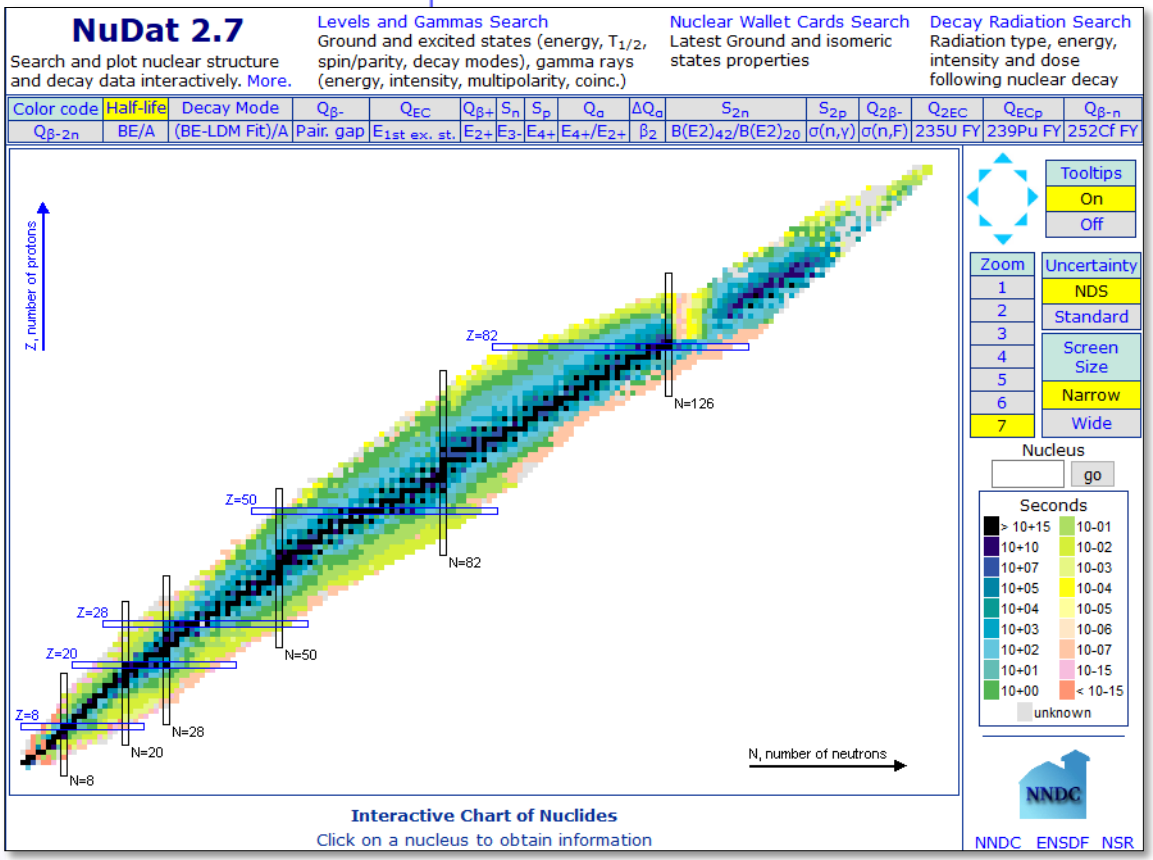


Evaluated Nuclear Structure and Decay Data File: ENSDF









International Network of Nuclear Structure and Decay Data Evaluators

17 Data Centers

AUSTRALIAN NATIONAL UNIVERSITY

JAPAN ATOMIC ENERGY AGENCY

TUNL

BNL

ATOMKI CENTER

ORNL

LBNL

ST KLIMENT UNIVERSITY SOFIA

IFIN-HH

VECC INDIA

MSU

ORNL

McMASTER UNIV

PETESRBURG NUCLEAR PHYSICS INSTITUTE

Texas A&M

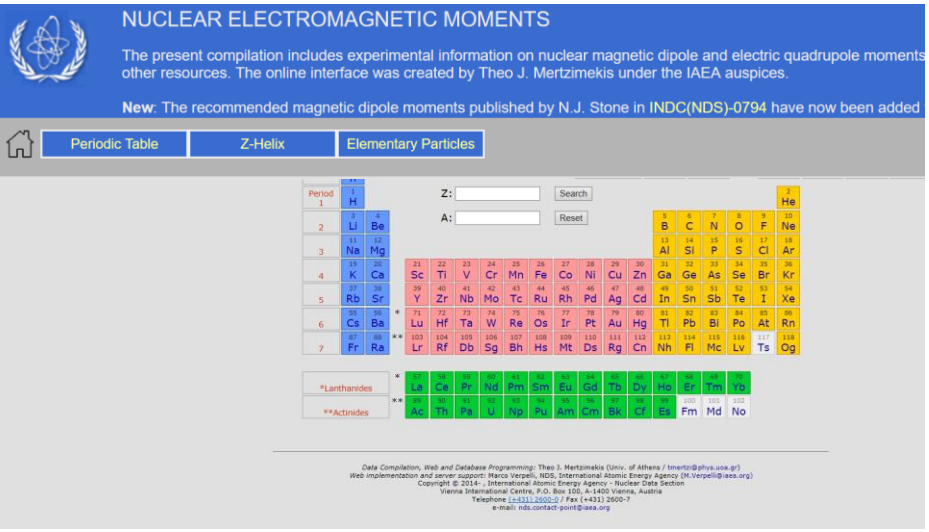
JILIN UNIVERSITY

CHINA INSTITUTE OF ATOMIC ENERGY

Scientific Secretary of the NSDD network 2013-2019

- Coordination: meetings, communication
- Training: IAEA-ICTP workshops, Advanced workshops
- Technical support: evaluation, project on analysis & checking codes, projects on horizontal evaluations (nuclear moments)
- Financial: funding schemes for beginners, horizontal evaluation (nuclear moments, Atlas of Isomers)
- Dissemination: Live Chart, Decay Data Portal

Nuclear Moments database: since 2015 on IAEA web server



- Project on evaluation of Nuclear Moments (2017)
- Participants: Stone, Stuchbery, Jakowski, Persson, Pykko, Kondev, Nuyens, Lloyd, Mertzimekis
- Budget: 30K Euros


IAEA
International Atomic Energy Agency

INDC(NDS)-0704
Distr. G, ND

INDC International Nuclear Data Committee

DEVELOPMENT OF A DEDICATED ONLINE DATABASE FOR NUCLEAR MOMENTS DATA

Theo J. Mertzimekis

Department of Physics, University of Athens,
Zografou Campus, GR-15784,
Athens, Greece


IAEA
International Atomic Energy Agency

INDC(NDS)-079
Distr. EN

INDC International Nuclear Data Committee

TABLE OF RECOMMENDED NUCLEAR MAGNETIC DIPOLE MOMENTS:
PART I, LONG-LIVED STATES

N.J. Stone


IAEA
International Atomic Energy Agency

INDC(NDS)-0816
Distr. EN

INDC International Nuclear Data Committee

TABLE OF RECOMMENDED NUCLEAR MAGNETIC DIPOLE MOMENTS:
PART II, SHORT-LIVED STATES

N.J. Stone

IAEA-ICTP Workshops

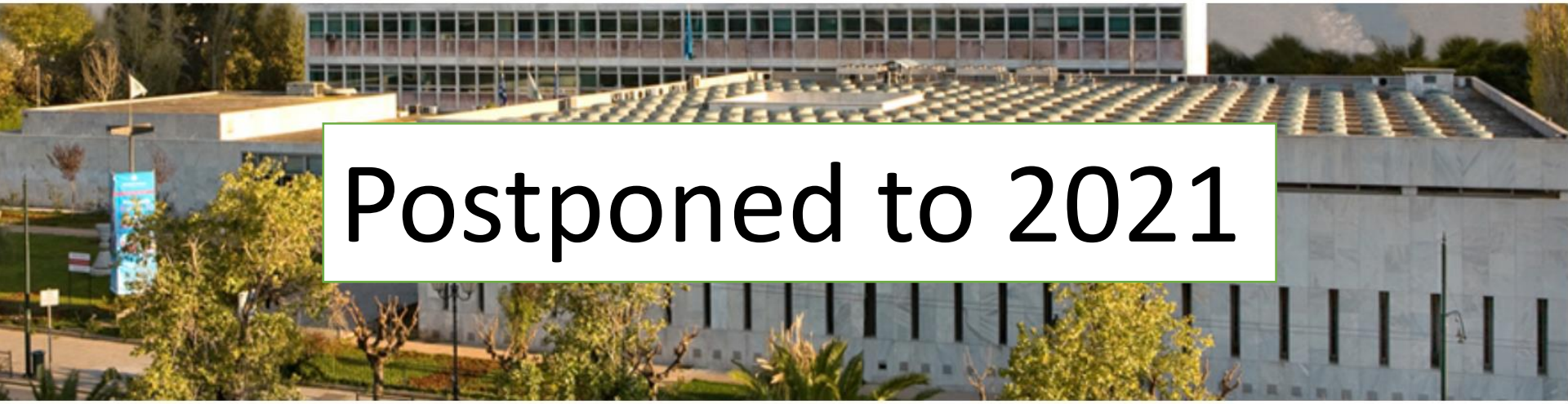
Workshops co-sponsored by ICTP (Trieste) and IAEA
Proposals submitted from IAEA departments are reviewed and selected by ICTP-IAEA committee

- IAEA-ICTP Workshop on Nuclear Data for Analytical Applications, 21-25 October 2013
  - Budget: 15K Euros
  - Trainees: 20
  - Lecturers: 5
- IAEA-ICTP Workshop on Nuclear Structure and Decay Data, 24-28 March 2014
  - Budget: 10K Euros
  - Trainees: 20
  - Lecturers: 5
  - Publication: *Nuclear Data Sheets for A=227, F. Kondev, E. McCutchan, B. Singh, J. Tuli, K. Abusalem, P. Dimitriou, et al., Nuclear Data Sheets 132, 257 (2016)*
- IAEA-ICTP Workshop on Nuclear Structure and Decay Data, 16-30 August 2016
  - Budget: 15K Euros
  - Trainees: 24
  - Lecturers: 10
  - Publication: *Nuclear Data Sheets for A=217, F. Kondev, E. McCutchan, B. Singh, et al., Nuclear Data Sheets 147, 382 (2018)*
- IAEA-ICTP Workshop on Nuclear Structure and Decay Data, 15-26 October 2018
  - Budget: 15K Euros
  - Trainees: 21
  - Lecturers: 8
  - Publication*: Nuclear Data Sheets for A=218, B. Singh, S.M. Basunia, M. Martin, E. McCutchan et al., Nuclear Data Sheets 160, 417 (2019)*

CNR*20

7th International Workshop on Compound-Nuclear Reactions and Related Topics

5-9 October 2020, Athens, Greece



Postponed to 2021

- Series of international conferences: Yosemite National Park (2007), Bordeaux (2009), Prague (2011), Sao Paolo (2013), Tokyo (2015) and Berkeley (2018)
- Venue: National Hellenic Research Foundation
- Organised: by INPP (CALIBRA) in collaboration with Los Alamos National Laboratory
- Proceedings: peer-reviewed in EPJ Web of Conferences; topical issue in EPJ Nuclear Sciences & Technologies
- website: http://www.inp.demokritos.gr/cnr2020
- Local Organizing Committee
  - Paraskevi Dimitriou (NCSR "Demokritos") - Chair
  - Michail Axiotis (NCSR "Demokritos")
  - Anastasia Georgiadou (LANL)
  - Anastasios Lagoyannis (NCSR "Demokritos")
  - Eleni Vagena (NCSR "Demokritos")

Topics:

Nuclear reaction mechanisms (direct, compound, pre-equilibrium, other)
Nuclear fission
Statistical Hauser-Feshbach theory
Surrogate methods
Optical model
Level densities and photon strength functions
R-matrix theory and connecting resolved resonances with statistical regime
Nuclear structure for nuclear reactions
Measurements relevant to compound-nuclear reactions (direct and indirect)
Nuclear data
Applications in nuclear astrophysics, energy, medical physics etc.
Experimental facilities

CALIBRA Cluster of Accelerator Laboratories for Ion-Beam Research and Applications

Los Alamos NATIONAL LABORATORY EST.1943

Future

- Nuclear astrophysics:
  - Nuclear data needs for r-process nucleosynthesis (fission properties)
  - Sensitivity analyses of abundance calculations on nuclear data input
  - R-matrix analyses for nuclear astrophysics

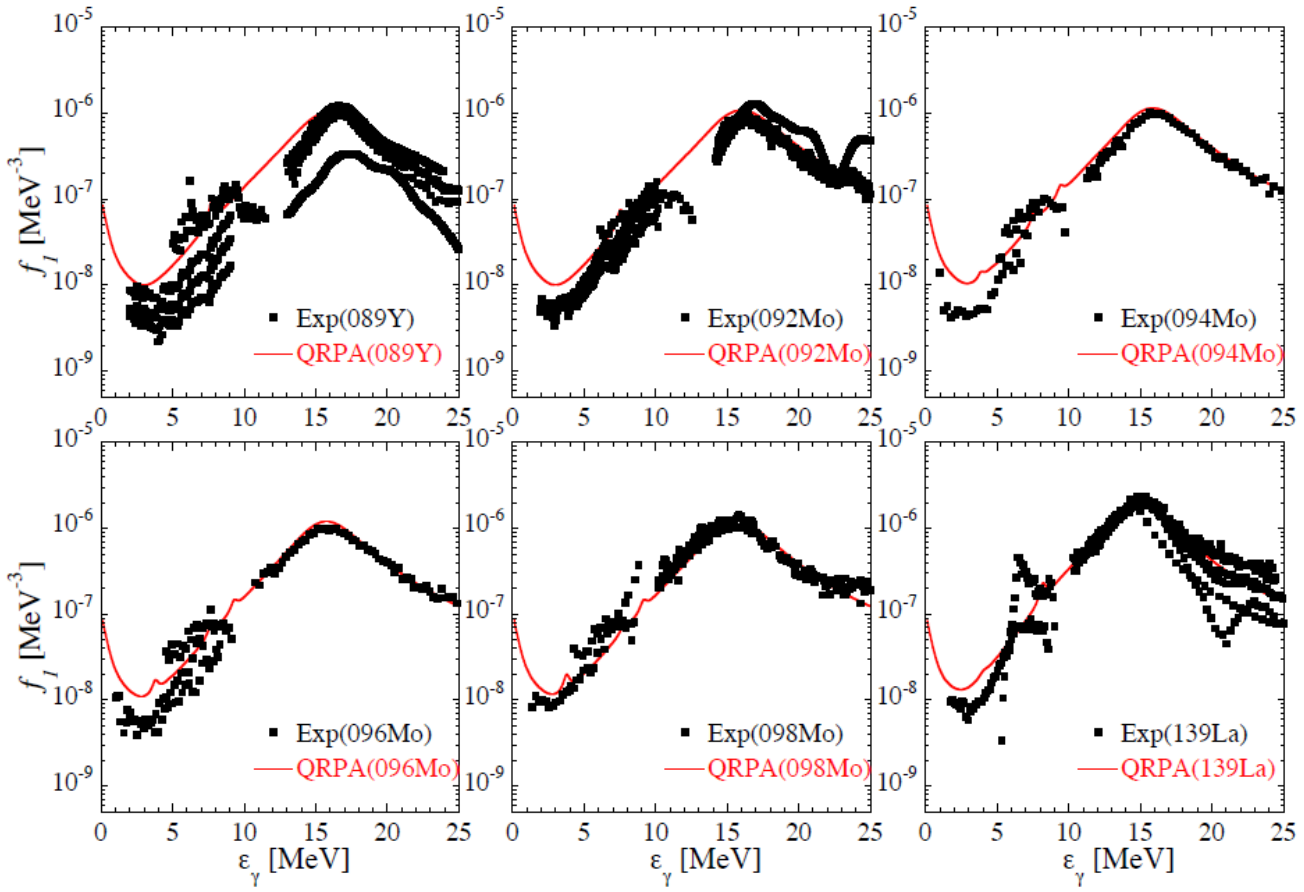
- Nuclear Data – IAEA collaboration
  - Evaluation of reaction data for energy, IBA and astrophysics applications
  - Evaluation of decay data for monitoring applications, decay heat, anti-neutrino spectra

Thank you!

Scope: Measurements, compilation, evaluation, theory, dissemination II

Comparison for nuclei for which NRF, Oslo & Photodata are available

(*E1* + *M1* strength)



Photon Strength Functions: Connecting GDR and low-energy photon strength

IAEA Nuclear Data Section

Reference Database for Beta-Delayed Neutron Emission Data

Search

Nuclide 8he or h

33 ≤ Z ≤ 33 ≤ N ≤ ≤ $T_{1/2}$ [ms] ≤

≤ P(1n)% ≤ ≤ P(2n)% ≤ ≤ P(3n)% ≤

Search Nuclides found:654

Clear

Data plotting

X Axis: A Z N $T_{1/2}$ P1n P2n $Q\beta^-n$

Y Axis: A Z N $T_{1/2}$ P1n P2n $Q\beta^-n$

Numerical data

Evaluation Theory Spectra

Published tables

Range	Evaluation	Compilation
Z ≤ 28		
29 ≤ Z ≤ 87		

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nds.contact-point@iaea.org

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Compilations Comments Qvalues | Systematics Miernik 14 | Theory Moeller et al. 03 Marketin et al. 16 Moeller et al. 19

Recommended values

Nuclide	Isomer	$T_{1/2}$	%P(1n)	%P(2n)	%P(3n)	# of neutrons per decay	Reference	Spectra
$^{8}_{2}He_{6}$		119.4(15) ms	16 (1)	–	–	0.16	2015BI05	1
$^{9}_{3}Li^{*}_{6}$		178.2(4) ms	50.5 (10)[a]			0.505	2015BI05	2
$^{11}_{3}Li_{8}$		8.58(32) ms	86.6 (13)	4.2 (4)	1.9 (2)	1.007	2015BI05	5
$^{11}_{4}Be_{7}$		13740(80) ms	–				2015BI05	–
$^{12}_{4}Be_{8}$		21.47(4) ms	0.50 (3)			0.005	2015BI05	–
$^{14}_{4}Be_{10}$		4.53(27) ms	86 (6)	5 (2)	–	0.96	2015BI05	1
$^{13}_{5}B_{8}$		17.16(18) ms	0.266 (36)			0.00266	2015BI05	–

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- PIGE Concepts and Implementation
  - Bulk analysis
  - Depth profiling
- Minimal PIGE facility
- Examples