Workshop on TALYS/TENDL Developments

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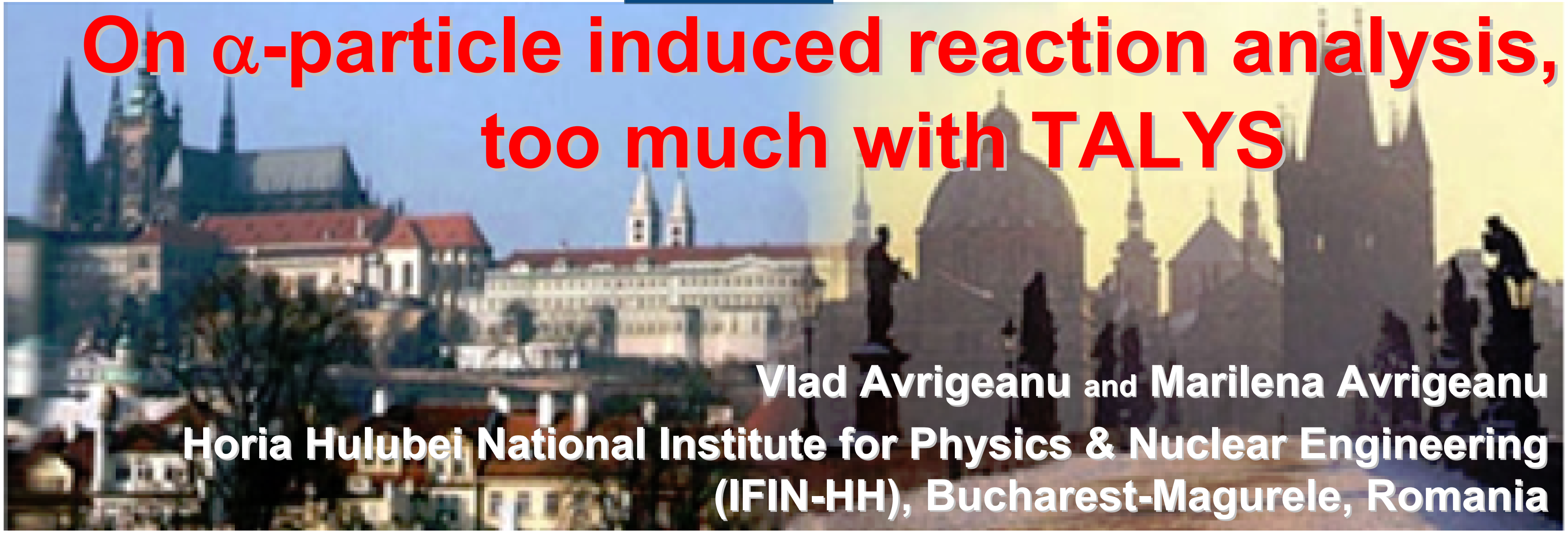
Prague, Czech Republic, 13-15 November 2017



On α-particle induced reaction analysis, too much with TALYS

Vlad Avrigeanu and **Marilena Avrigeanu**
Horia Hulubei National Institute for Physics & Nuclear Engineering (IFIN-HH), Bucharest-Magurele, Romania

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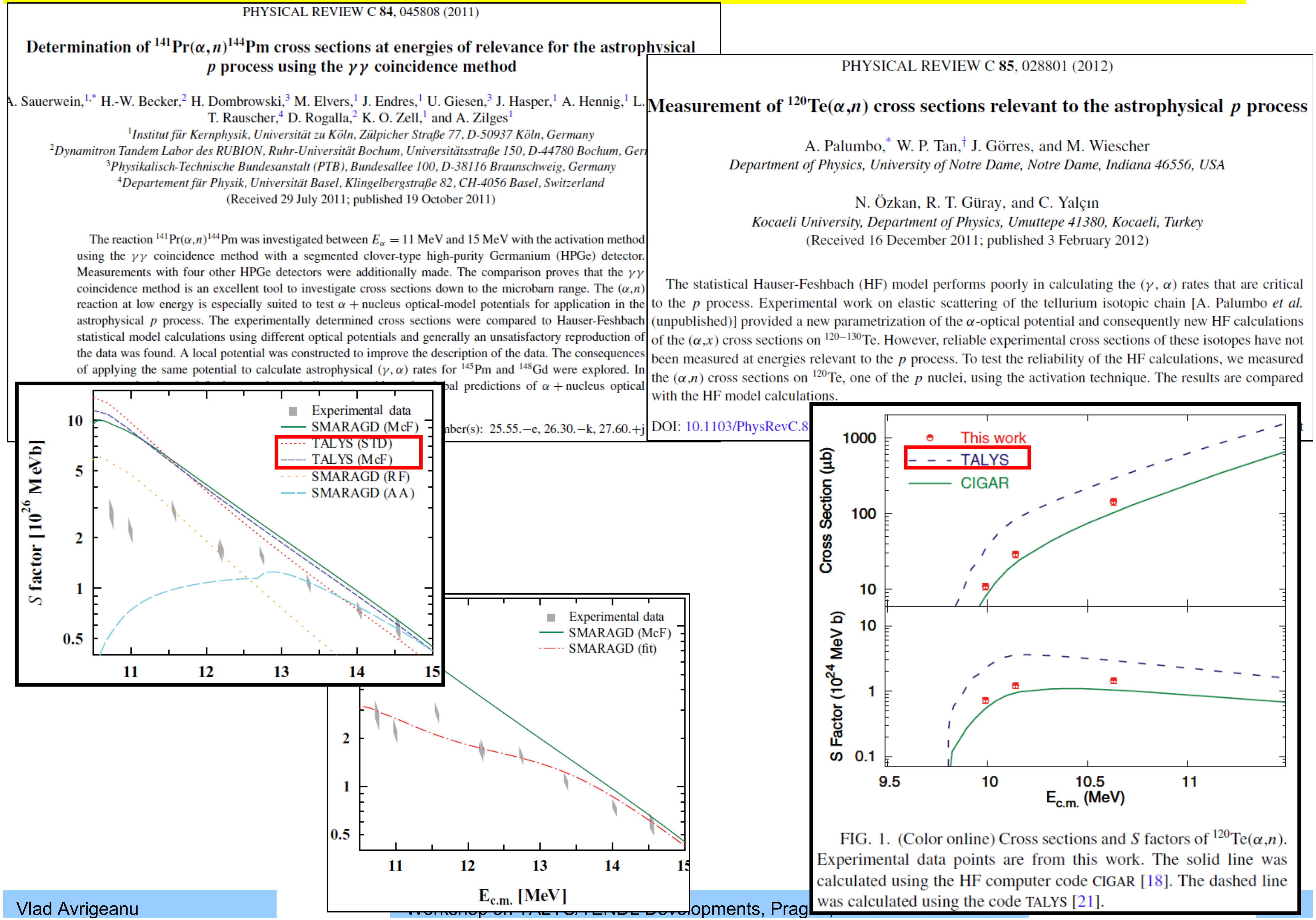
1. Introduction: (α,γ) on ^{141}Pr,^{120}Te,^{130,132}Ba,^{64}Zn,^{187}Re,^{112}Sn,$^{58-64}$Ni,^{70}Ge,$^{90-92}$Zr,^{108}Cd
2. Consistent model calcs. vs χ^2-based predicts.: $^{58-64}$Ni,^{70}Ge,$^{90-92}$Zr,^{112}Sn,^{108}Cd,^{64}Zn
3. Recent (2017) ^{91,92}Zr RSF and ^{93,95}Zr(n,γ) data analysis
4. Consequent minor-addition of a **parameter (keyword) in TALYS**
5. Consequent better presentation of **TALYS Sample Case 26**
6. TALYS within (α,xn) reaction analysis – **proposal for σ^2(E*)**
7. Conclusions

1. TALYS in (α,x) reaction cross-section analysis



PHYSICAL REVIEW C **84**, 045808 (2011)

Determination of ^{141}Pr(α,n)^{144}Pm cross sections at energies of relevance for the astrophysical *p* process using the $\gamma\gamma$ coincidence method

. Sauerwein,[1,*] H.-W. Becker,[2] H. Dombrowski,[3] M. Elvers,[1] J. Endres,[1] U. Giesen,[3] J. Hasper,[1] A. Hennig,[1] L.
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[2]*Dynamitron Tandem Labor des RUBION, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum, Ger*
[3]*Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, D-38116 Braunschweig, Germany*
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(Received 29 July 2011; published 19 October 2011)

The reaction ^{141}Pr(α,n)^{144}Pm was investigated between $E_\alpha = 11$ MeV and 15 MeV with the activation method using the $\gamma\gamma$ coincidence method with a segmented clover-type high-purity Germanium (HPGe) detector. Measurements with four other HPGe detectors were additionally made. The comparison proves that the $\gamma\gamma$ coincidence method is an excellent tool to investigate cross sections down to the microbarn range. The (α,n) reaction at low energy is especially suited to test α + nucleus optical-model potentials for application in the astrophysical *p* process. The experimentally determined cross sections were compared to Hauser-Feshbach statistical model calculations using different optical potentials and generally an unsatisfactory reproduction of the data was found. A local potential was constructed to improve the description of the data. The consequences of applying the same potential to calculate astrophysical (γ,α) rates for ^{145}Pm and ^{148}Gd were explored. In

bal predictions of α + nucleus optical

nber(s): 25.55.−e, 26.30.−k, 27.60.+j

PHYSICAL REVIEW C **85**, 028801 (2012)

Measurement of ^{120}Te(α,n) cross sections relevant to the astrophysical *p* process

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Department of Physics, University of Notre Dame, Notre Dame, Indiana 46556, USA

N. Özkan, R. T. Güray, and C. Yalçın
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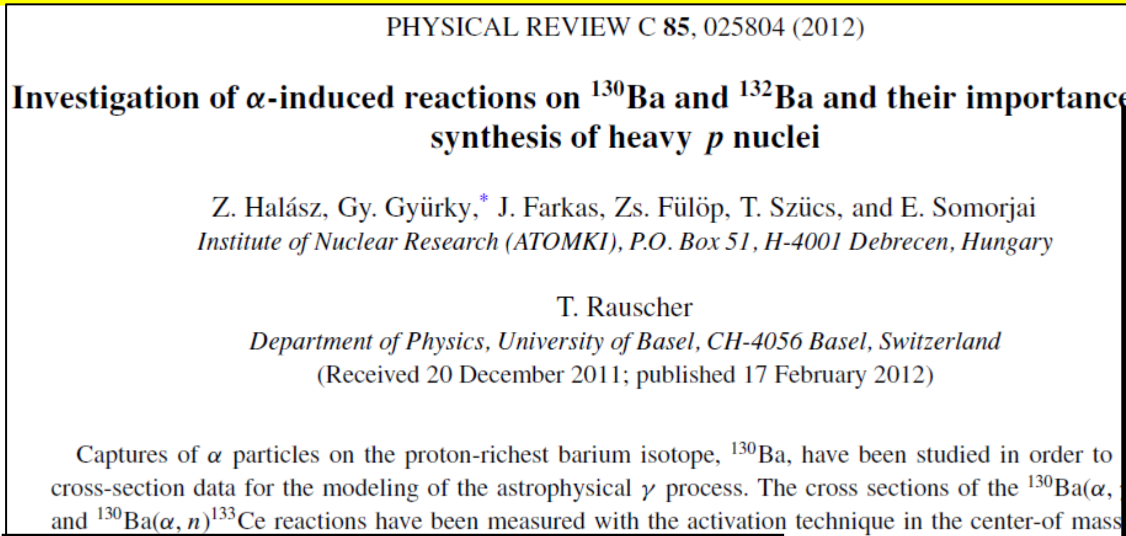
(Received 16 December 2011; published 3 February 2012)

The statistical Hauser-Feshbach (HF) model performs poorly in calculating the (γ, α) rates that are critical to the *p* process. Experimental work on elastic scattering of the tellurium isotopic chain [A. Palumbo *et al.* (unpublished)] provided a new parametrization of the α-optical potential and consequently new HF calculations of the (α,x) cross sections on $^{120-130}$Te. However, reliable experimental cross sections of these isotopes have not been measured at energies relevant to the *p* process. To test the reliability of the HF calculations, we measured the (α,n) cross sections on ^{120}Te, one of the *p* nuclei, using the activation technique. The results are compared with the HF model calculations.

DOI: 10.1103/PhysRevC.8

FIG. 1. (Color online) Cross sections and *S* factors of ^{120}Te(α,n). Experimental data points are from this work. The solid line was calculated using the HF computer code CIGAR [18]. The dashed line was calculated using the code TALYS [21].

1. TALYS in (α,x) reaction cross-section analysis (2/11)



PHYSICAL REVIEW C **85**, 025804 (2012)

Investigation of α-induced reactions on ^{130}Ba and ^{132}Ba and their importance for the synthesis of heavy *p* nuclei

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T. Rauscher
Department of Physics, University of Basel, CH-4056 Basel, Switzerland
(Received 20 December 2011; published 17 February 2012)

Captures of α particles on the proton-richest barium isotope, ^{130}Ba, have been studied in order to
cross-section data for the modeling of the astrophysical γ process. The cross sections of the ^{130}Ba(α,
and ^{130}Ba(α,n)^{133}Ce reactions have been measured with the activation technique in the center-of mass
ant energies. As a side result, th
sults are compared with the predi
+ nucleus optical potentials. It i

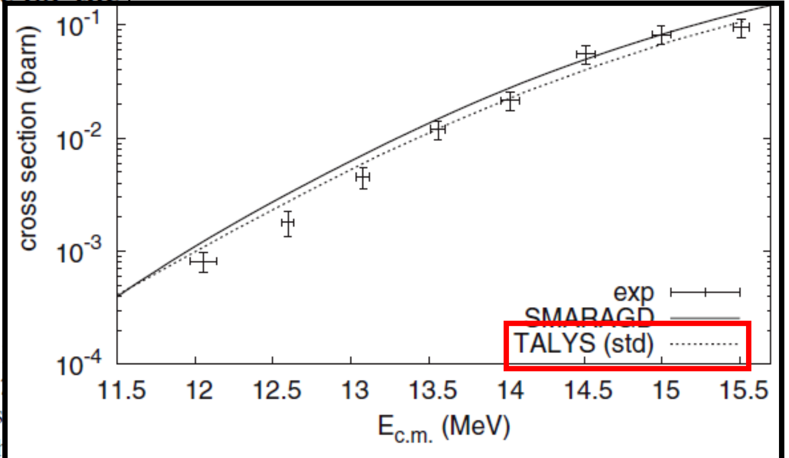

FIG. 9. Comparison of experimental cross sections for ^{132}Ba(α,n)^{135}Ce and theoretical predictions with the codes SMARAGD
efault settings).

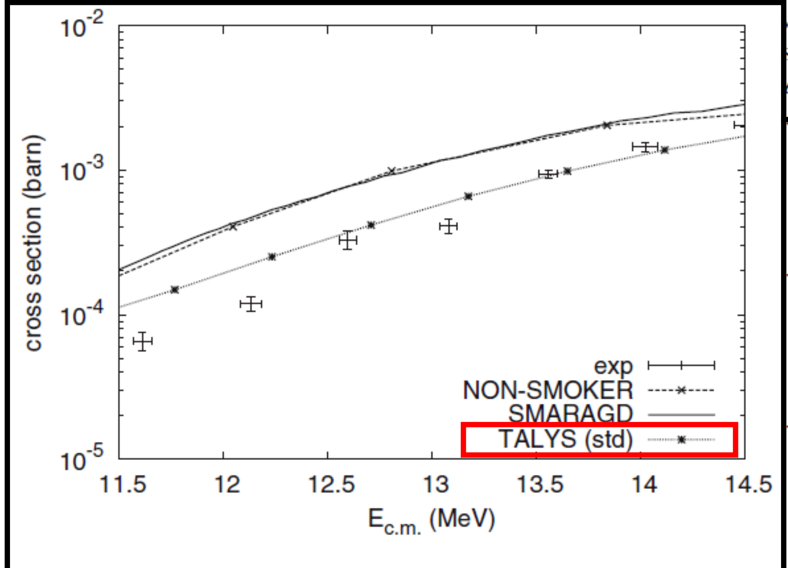

FIG. 5. Comparison of experimental cross sections for ^{130}Ba(α,γ)^{134}Ce and theoretical predictions with the codes NON-SMOKER [26,27], SMARAGD [16,28], and TALYS [29] (using their default settings).

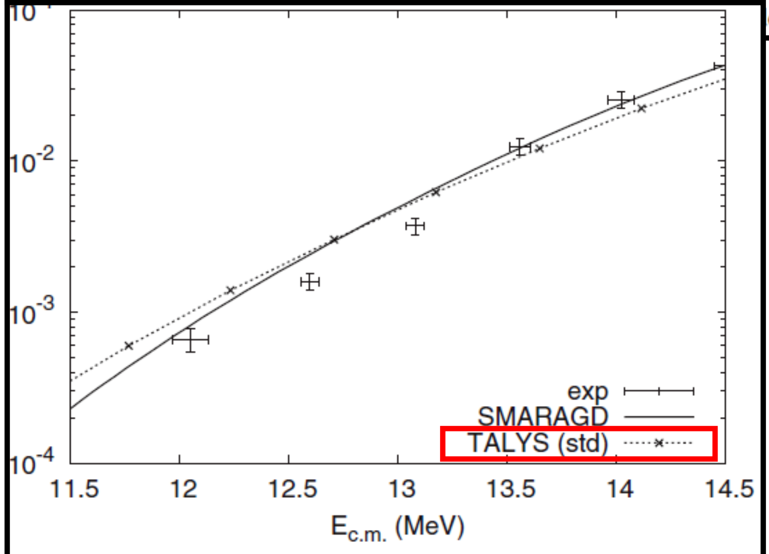

FIG. 7. Comparison of experimental cross sections for ^{130}Ba(α,n)^{133}Ce and theoretical predictions with the codes SMARAGD [16,28] and TALYS [29] (using their default settings).

1. TALYS in (α,x) reaction cross-section analysis

PHYSICAL REVIEW C **86**, 041601(R) (2012)

Relation between total cross sections from elastic scattering and α-induced reactions: The example of ^{64}Zn

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(Received 4 April 2012;

The total reaction cross secti
mechanical relation. We presen
allow for the first time the exper
new experimental reaction data

DOI: 10.1103/PhysRevC.86.04

PHYSICAL REVIEW C **90**, 052801(R) (2014)

Direct study of the α-nucleus optical potential at astrophysical energies using the ^{64}Zn(p,α)^{61}Cu reaction

Gy. Gyürky,* Zs. Fülöp, Z. Halász, G. G. Kiss, and T. Szücs

rates are taken from
the case of reactions
w-energy α-nucleus

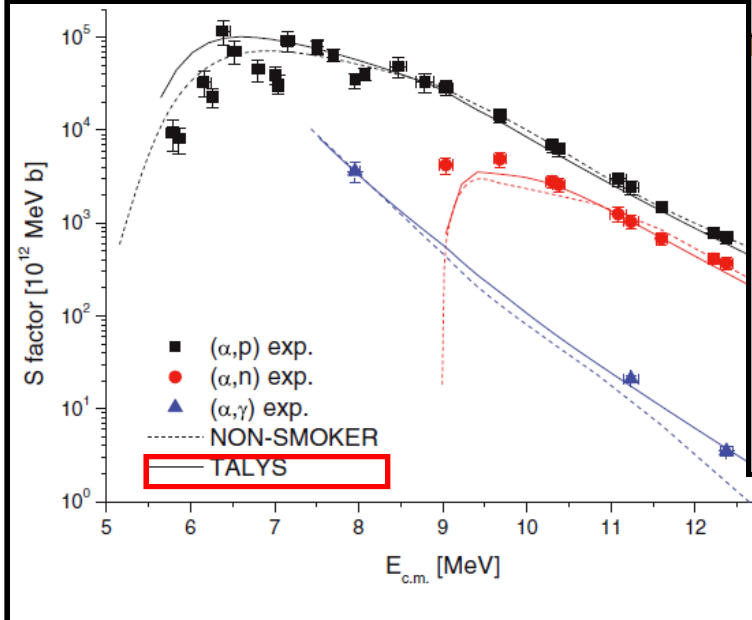
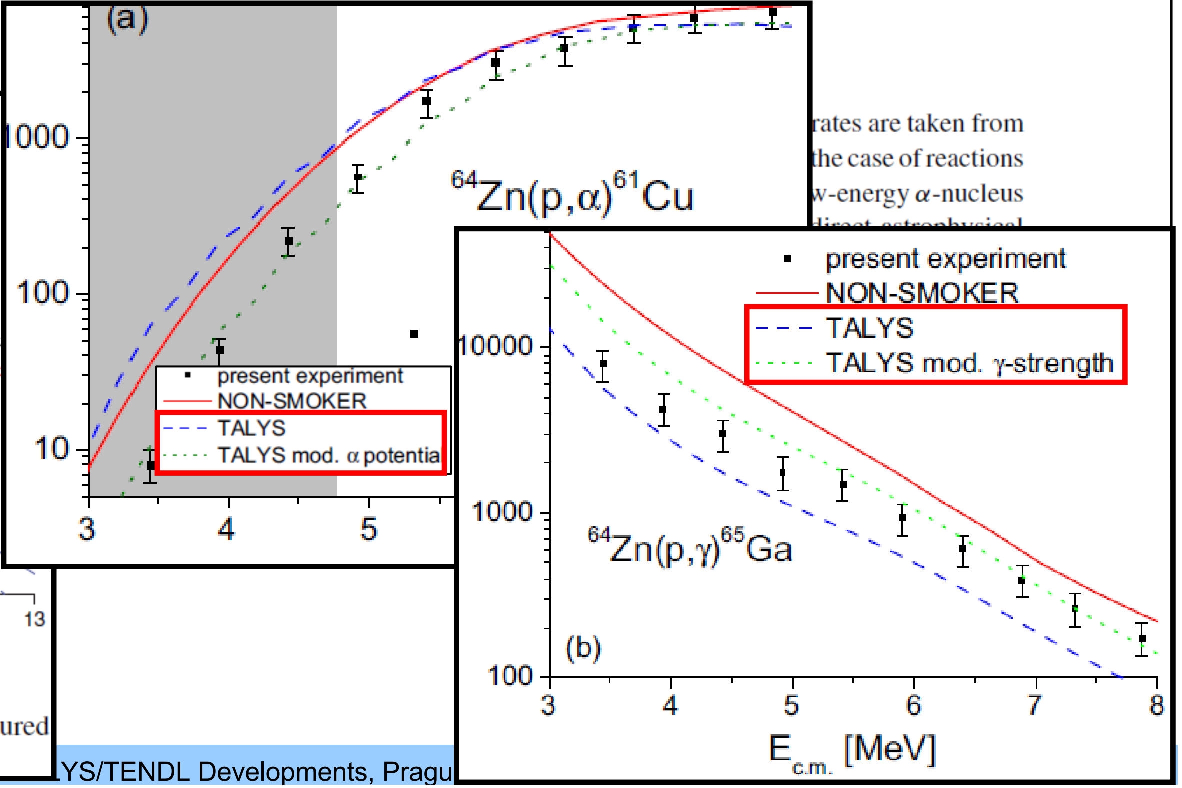


FIG. 2. (Color online) Astrophysical S factor of the measured reactions and the predictions of statistical model calculations.



1. TALYS in (α,x) reaction cross-section analysis

PHYSICAL REVIEW C **90**, 065807 (2014)

Measurement of the ^{187}Re$(\alpha,n)^{190}$Ir reaction cross section at sub-Coulomb energies using the Cologne Clover Counting Setup

P. Scholz,[1,*] A. Endres,[1,†] A. Hennig,[1] L. Netterdon,[1] H. W. Becker,[2] J. Endres,[1] J. Mayer,[1] U. Giesen,[3] D. Rogalla,[2]
K. O. Zell,[1] and A. Zilges[1]
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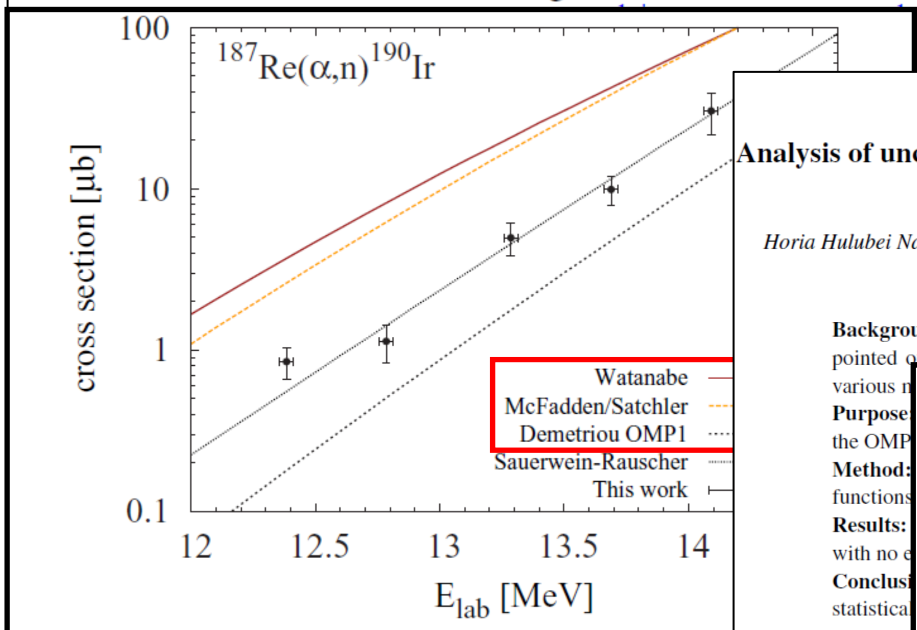

FIG. 8. (Color online) Total cross section as a function of the α-particle energy in comparison to statistical model calculations using the TALYS code [34]. The standard α OMP of TALYS is the one of Watanabe [35] which overestimates the measured values by a factor of four. Also the widely used α OMP of McFadden and Satchler [37] leads to a prediction of cross-section values which are too large. However, as pointed out in Ref. [38], this may be due to the neglect of the Coulomb excitation in the determination of the α optical potential. In contrast to this, the optical-model potentials of Ref. [36] lead to predictions of cross-section values which are too low (OMP1). The

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PHYSICAL REVIEW C **94**, 024621 (2016)

Analysis of uncertainties in α-particle optical-potential assessment below the Coulomb barrier

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(Received 8 April 2016; published 30 August 2016)

Background: Recent high-precision measurements of α-induced reaction data below the Coulomb barrier have pointed out questions about the α-particle optical-model potential (OMP) which are still unanswered within various m

Purpose:
the OMP

Method:
functions

Results:
with no e

Conclusi
statistical

DOI: 10.

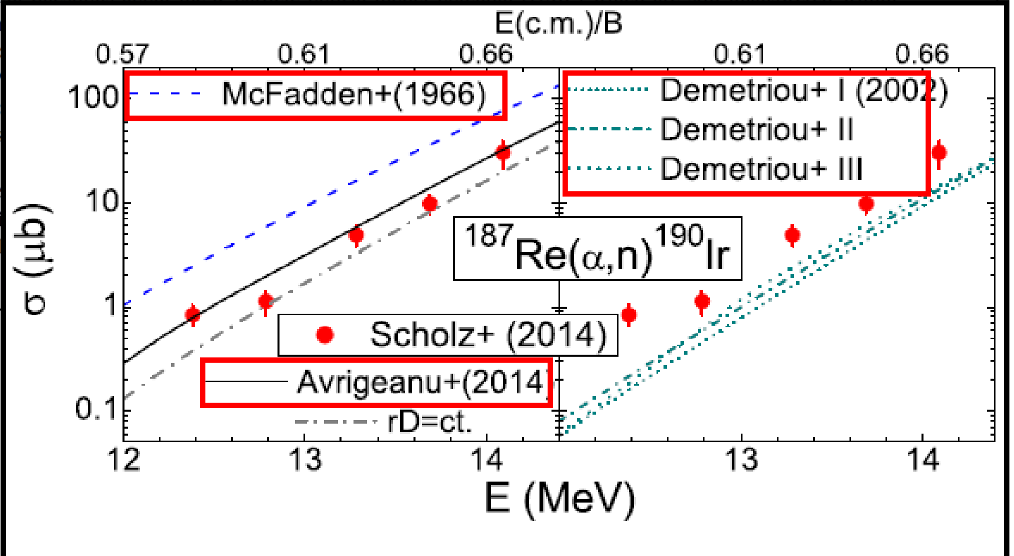
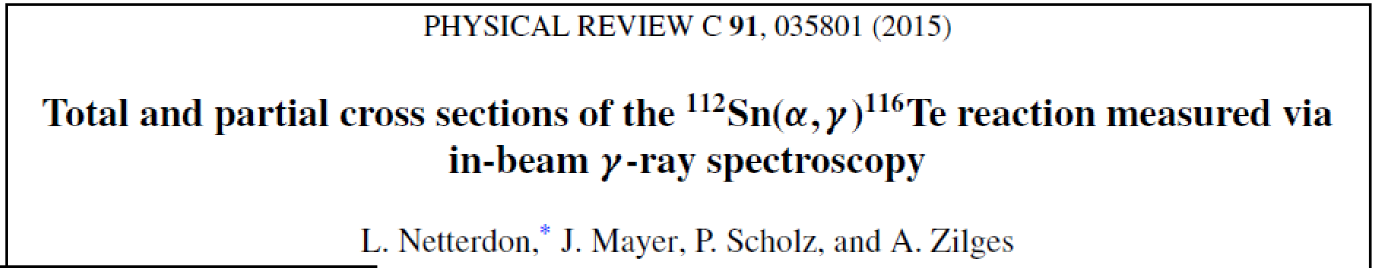


FIG. 9. As Fig. 8 but for ^{187}Re [6] (left), and the OMPs I–III of Ref. [16] (short dotted, short dash-dotted, and short dashed curves, respectively) (right).

1. TALYS in (α,x) reaction cross-section analysis



PHYSICAL REVIEW C **91**, 035801 (2015)

Total and partial cross sections of the ^{112}Sn(α,γ)^{116}Te reaction measured via in-beam γ-ray spectroscopy

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14; revised manuscript received 27 January 2015; published 16 March 2015)

thesis of the neutron-deficient p nuclei remains an open question in nuclear
nties on the astrophysical side, the nuclear-physics input parameters entering
for the nucleosynthesis of the p nuclei must be put on a firm basis.
se of experimental data is needed to address uncertainties of the nuclear-physics
Feshbach calculations. Especially α + nucleus optical model potentials at low
The in-beam technique with an array of high-purity germanium (HPGe) detectors
e measurement of absolute cross sections of an (α,γ) reaction on a heavy nucleus

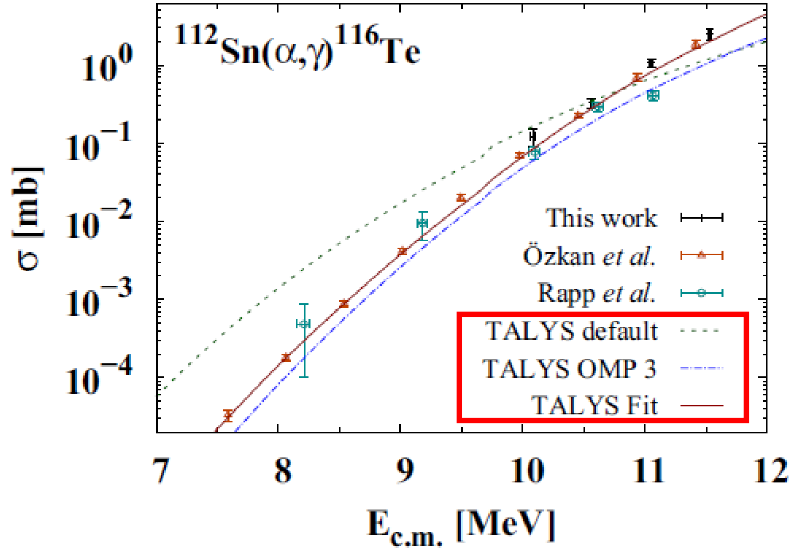
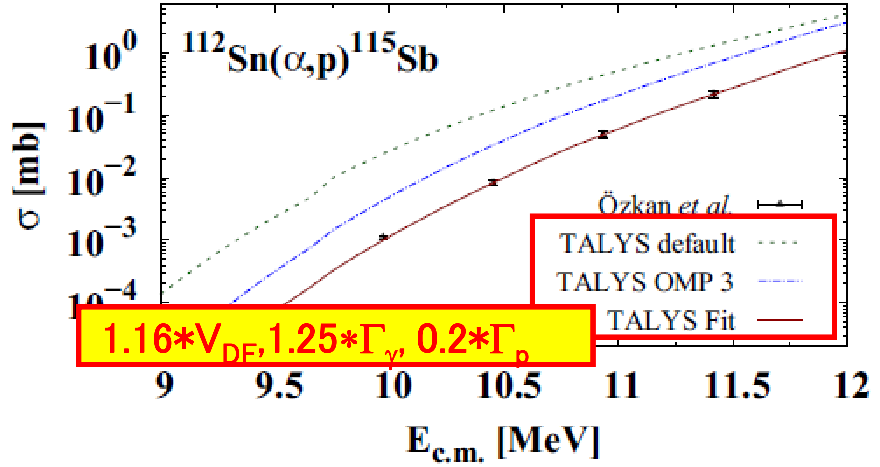


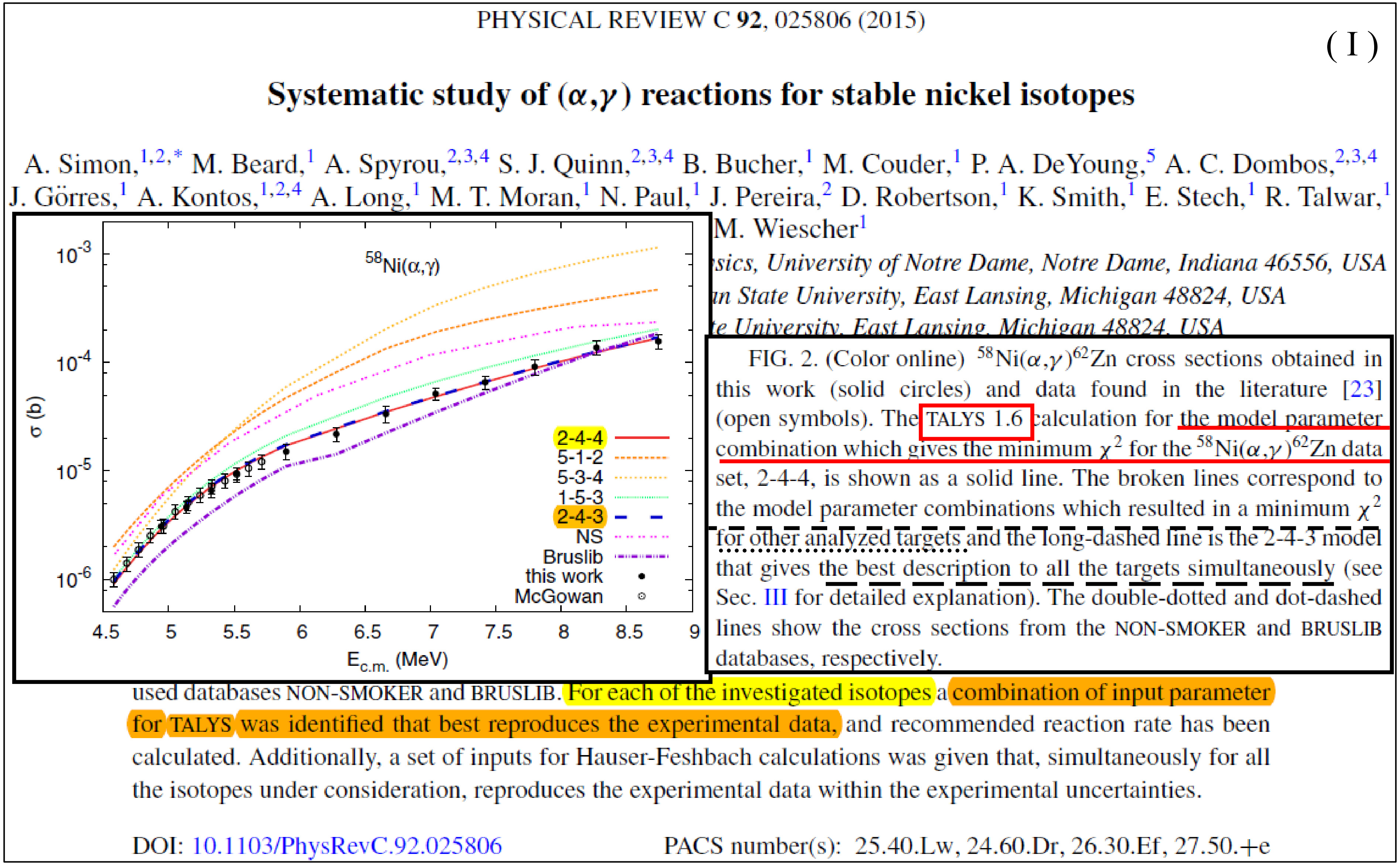
FIG. 5. (Color online) Experimental total cross section of the ^{112}Sn(α,γ)^{116}Te reaction as a function of center-of-mass energy. Results were obtained from this work as well as from activation measurements of Ref. [32] (Özkan *et al.*, triangles) and Ref. [33] (Rapp *et al.*, circles). The total cross-section values are compared to statistical model calculations using the TALYS code. Using the default settings ("TALYS default"), neither the energy dependence nor the absolute values are predicted well. Using the semimicroscopic OMP 3 of Ref. [37], the agreement is significantly improved ("TALYS OMP 3"). An adjustment of the α-OMP as well as the proton- and γ widths leads to an excellent accordance ("TALYS Fit"). Details about the input parameters can be found in the text.



$1.16*V_{DF}, 1.25*\Gamma_{\gamma}, 0.2*\Gamma_{p}$

FIG. 6. (Color online) Experimental total cross section of the ^{112}Sn(α,p)^{115}Sb reaction. The experimental data were taken from Ref. [32]. Regarding the theoretical calculations, a pattern similar to the ^{112}Sn(α,γ) case arises; see text for details.

1. TALYS in (α,x) reaction cross-section analysis (6/11)



PHYSICAL REVIEW C **92**, 025806 (2015)

(I)

Systematic study of (α,γ) reactions for stable nickel isotopes

A. Simon,[1,2,*] M. Beard,[1] A. Spyrou,[2,3,4] S. J. Quinn,[2,3,4] B. Bucher,[1] M. Couder,[1] P. A. DeYoung,[5] A. C. Dombos,[2,3,4] J. Görres,[1] A. Kontos,[1,2,4] A. Long,[1] M. T. Moran,[1] N. Paul,[1] J. Pereira,[2] D. Robertson,[1] K. Smith,[1] E. Stech,[1] R. Talwar,[1] M. Wiescher[1]

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in State University, East Lansing, Michigan 48824, USA

te University, East Lansing, Michigan 48824, USA

FIG. 2. (Color online) ^{58}Ni$(\alpha,\gamma)^{62}$Zn cross sections obtained in this work (solid circles) and data found in the literature [23] (open symbols). The TALYS 1.6 calculation for the model parameter combination which gives the minimum χ^2 for the ^{58}Ni$(\alpha,\gamma)^{62}$Zn data set, 2-4-4, is shown as a solid line. The broken lines correspond to the model parameter combinations which resulted in a minimum χ^2 for other analyzed targets and the long-dashed line is the 2-4-3 model that gives the best description to all the targets simultaneously (see Sec. III for detailed explanation). The double-dotted and dot-dashed lines show the cross sections from the NON-SMOKER and BRUSLIB databases, respectively.

used databases NON-SMOKER and BRUSLIB. For each of the investigated isotopes a combination of input parameter for TALYS was identified that best reproduces the experimental data, and recommended reaction rate has been calculated. Additionally, a set of inputs for Hauser-Feshbach calculations was given that, simultaneously for all the isotopes under consideration, reproduces the experimental data within the experimental uncertainties.

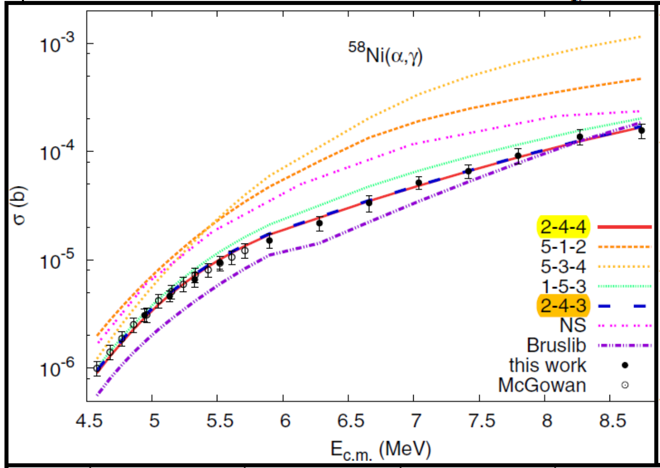
DOI: 10.1103/PhysRevC.92.025806 PACS number(s): 25.40.Lw, 24.60.Dr, 26.30.Ef, 27.50.+e

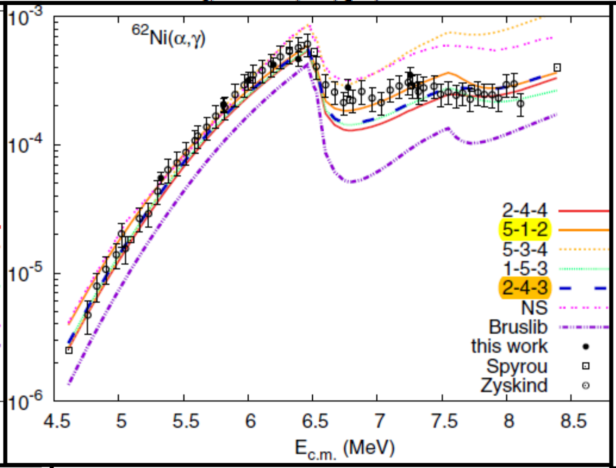
1. TALYS in (α,x) reaction cross-section analysis (7/11)

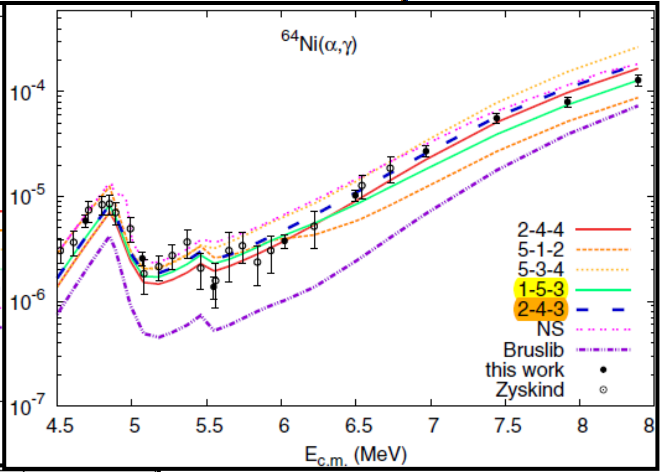
PHYSICAL REVIEW C **92**, 025806 (2015)

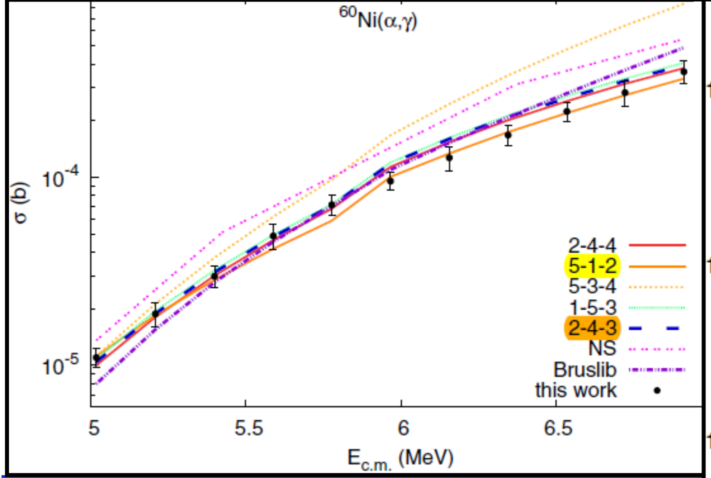
Systematic study of (α,γ) reactions for stable nickel isotopes

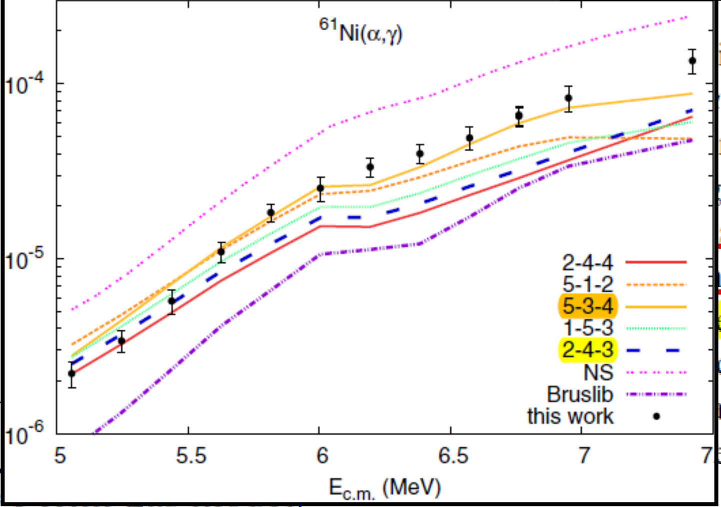
(II)











isotopes has been performed using
-capture cross sections have been
ment is in excellent agreement with
e of the measured cross sections up
s of Hauser-Feshbach calculations.
the TALYS .6 code and commonly
es a combination of input parameter
commended reaction rate has been
s given that, simultaneously for all
e experimental uncertainties.

0.Lw, 24.60.Dr, 26.30.Ef, 27.50.+e

(1) Constant temperature matched to the
(CT+BSFG) [27]
(2) Back-shifted Fermi gas model (
(3) Generalized super fluid model [
(4) Hartree Fock using Skyrme forc
(5) Hartree-Fock-Bogoliubov (Sky
torial method [32]
(6) Microscopic model, Gogny force [33].

(1) Kopecky-Uhl generalized Lorentzian (KU) [36]
(2) Brink-Axel Lorentzian (BA) [37,38]
(3) Hartree-Fock BCS (HF-BCS) [26]
(4) Hartree-Fock-Bogolyubov (HFB) [26
(5) Modified Lorentzian (Gor-ML) [2]

(1) Koning-Delaroche [39]
(2) McFadden-Satchler [40]
(3) Demetriou *et al.* given in Table 1 of Ref.
(4) Demetriou *et al.* given in Table 2 of Ref.
(5) Demetriou *et al.* [41], dispersive model.

1. TALYS in (α,x) reaction cross-section analysis

PHYSICAL REVIEW C **92**, 045805 (2015)

(α,γ) cross section measurements in the region of light *p* nuclei

S. J. Quinn,[1,2,3] A. Spyrou,[1,2,3,*] A. Simon,[1,3,4] A. Battaglia,[4] M. Bowers,[4] B. Bucher,[4] C. Casarella,[4] M. Couder,[4]
P. A. DeYoung,[5] A. C. Dombos,[1,2,3] J. Görres,[4] A. Kontos,[4] Q. Li,[4] A. Long,[4] M. Moran,[4] N. Paul,[4] J. Pereira,[1] D. Robertson,[4]
K. Smith,[4] M. K. Smith,[4] E. Stech,[4] R. Talwar,[4] W. P. Tan,[4] and M. Wiescher[4]
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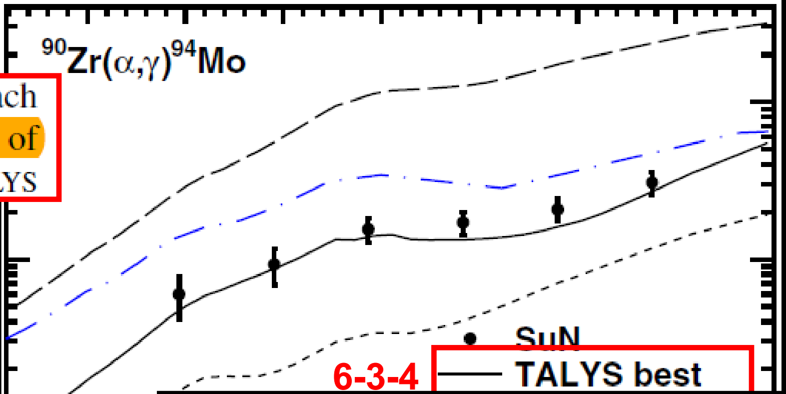
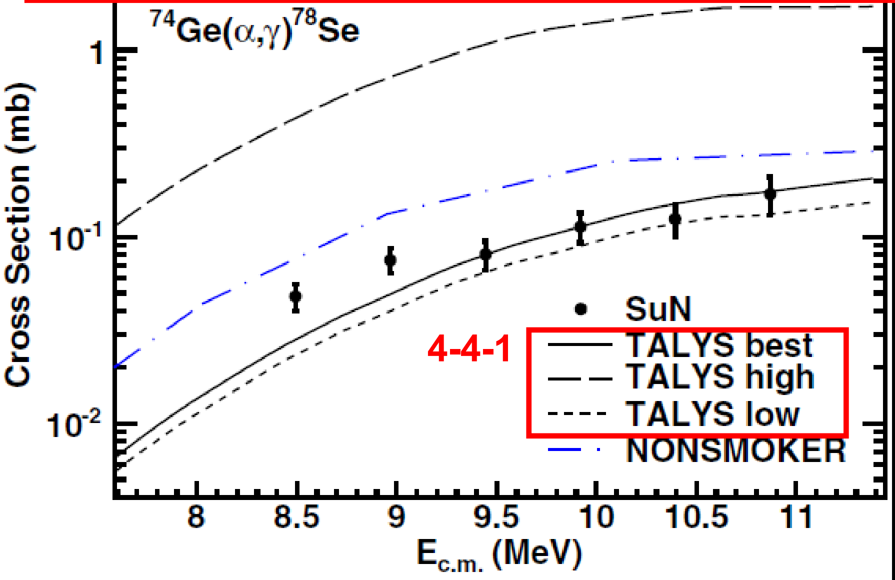
[2] *Department of Physics & Astronomy, Mi*
[3] *Joint Institute for Nuclear Astrophysics, M*
46556, USA

In total, 300 TALYS calculations were performed for each reaction in an attempt to determine which combination of parameters best describes the data. In addition to the TALYS

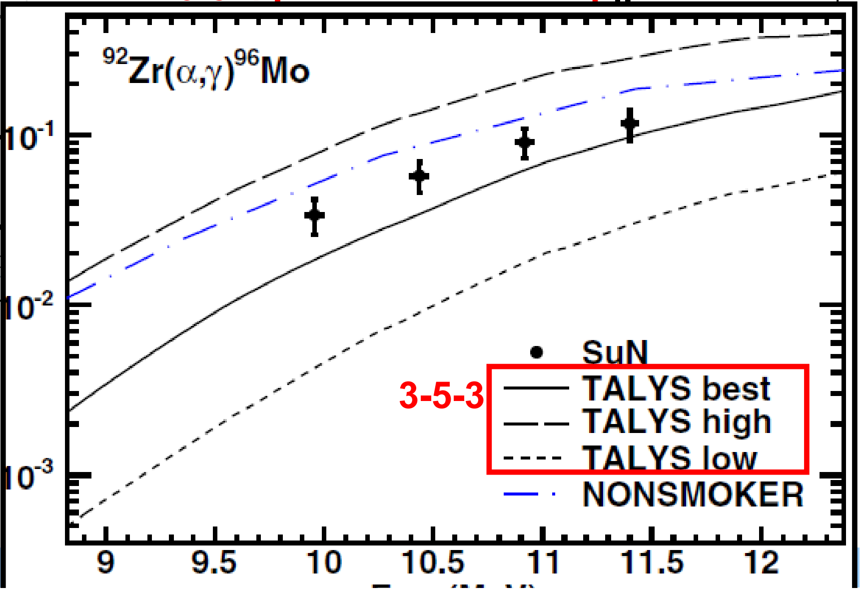


6-3-4



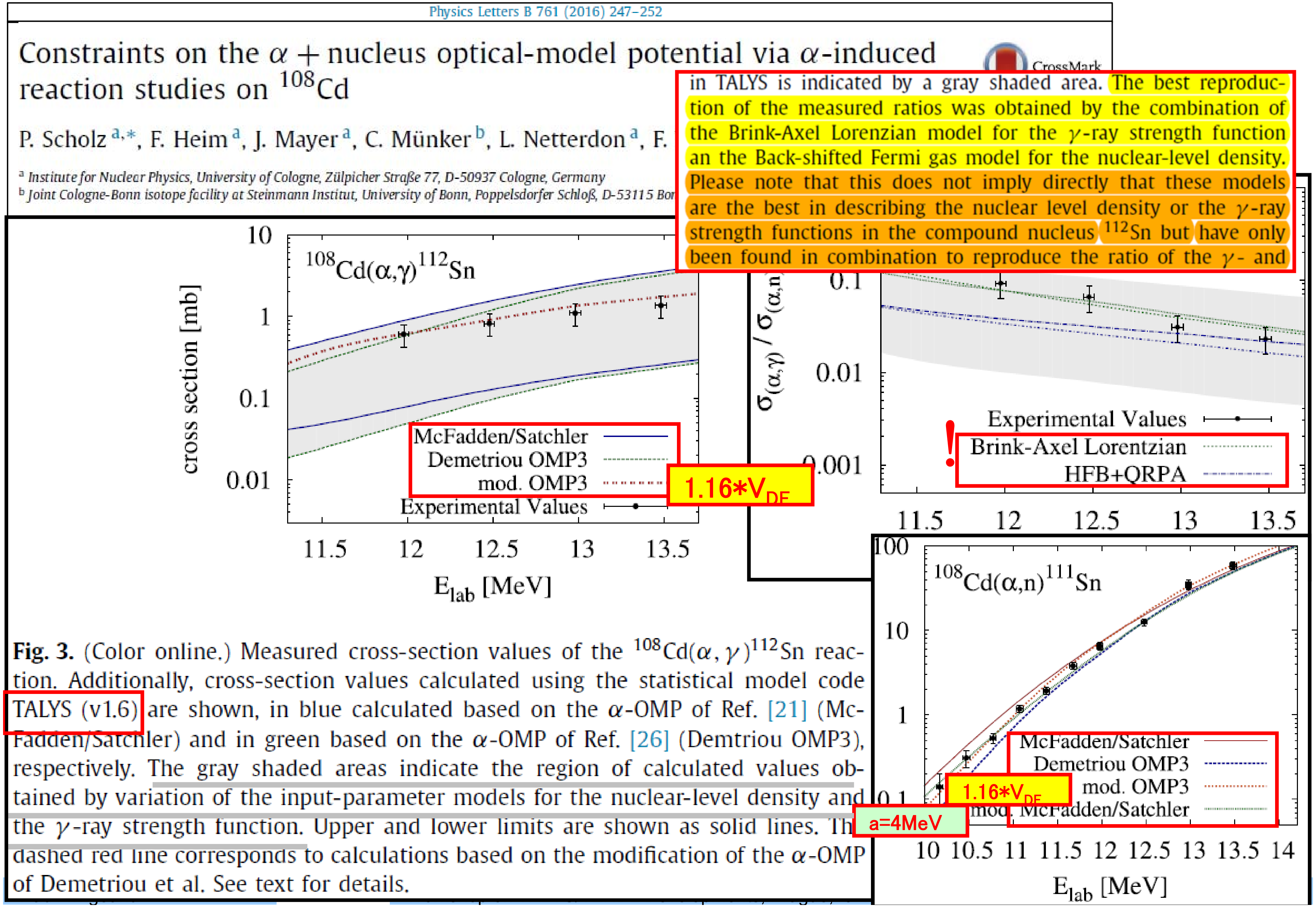
4-4-1

FIG. 7. (Color online) Experimental cross sections for the ^{74}Ge(α,γ)^{78}Se reaction compared to TALYS and NON-SMOKER calculations. The three TALYS curves correspond to the upper limit, lower limit, and best-fit calculations (see text for details).



3-5-3

1. TALYS in (α,x) reaction cross-section analysis



Physics Letters B 761 (2016) 247–252

Constraints on the α + nucleus optical-model potential via α-induced reaction studies on ^{108}Cd

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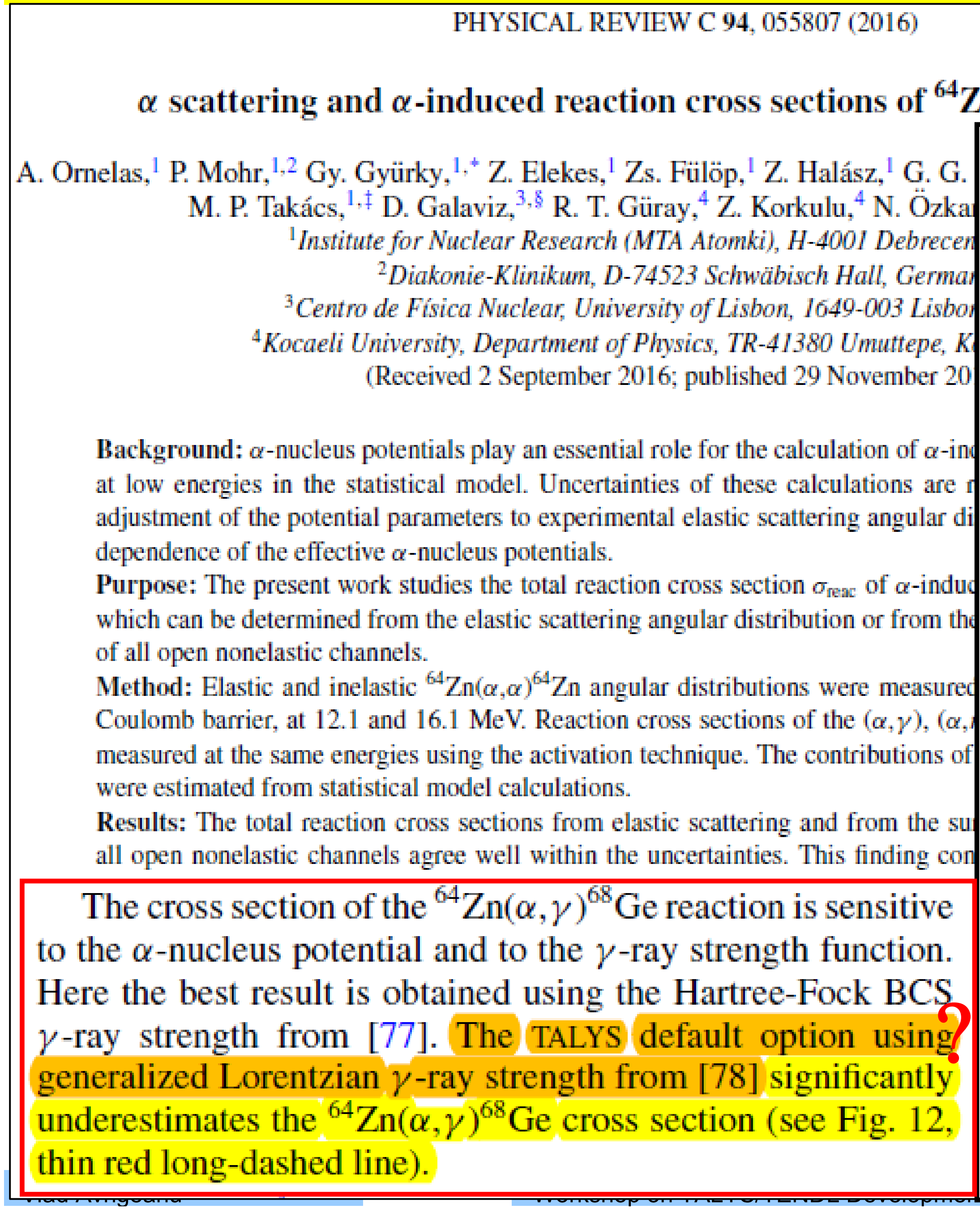
[b] Joint Cologne-Bonn isotope facility at Steinmann Institut, University of Bonn, Poppelsdorfer Schloß, D-53115 Bor

in TALYS is indicated by a gray shaded area. The best reproduction of the measured ratios was obtained by the combination of the Brink-Axel Lorenzian model for the γ-ray strength function an the Back-shifted Fermi gas model for the nuclear-level density. Please note that this does not imply directly that these models are the best in describing the nuclear level density or the γ-ray strength functions in the compound nucleus ^{112}Sn but have only been found in combination to reproduce the ratio of the γ- and

Fig. 3. (Color online.) Measured cross-section values of the ^{108}Cd(α,γ)^{112}Sn reaction. Additionally, cross-section values calculated using the statistical model code TALYS (v1.6) are shown, in blue calculated based on the α-OMP of Ref. [21] (McFadden/Satchler) and in green based on the α-OMP of Ref. [26] (Demtriou OMP3), respectively. The gray shaded areas indicate the region of calculated values obtained by variation of the input-parameter models for the nuclear-level density and the γ-ray strength function. Upper and lower limits are shown as solid lines. Th dashed red line corresponds to calculations based on the modification of the α-OMP of Demetriou et al. See text for details.

1. TALYS in (α,x) reaction cross-section analysis



PHYSICAL REVIEW C **94**, 055807 (2016)

α scattering and α-induced reaction cross sections of ^{64}Zn at low energies

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[2]*Diakonie-Klinikum, D-74523 Schwäbisch Hall, Germa*
[3]*Centro de Física Nuclear, University of Lisbon, 1649-003 Lisbo*
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(Received 2 September 2016; published 29 November 20

Background: α-nucleus potentials play an essential role for the calculation of α-in
at low energies in the statistical model. Uncertainties of these calculations are
adjustment of the potential parameters to experimental elastic scattering angular di
dependence of the effective α-nucleus potentials.
Purpose: The present work studies the total reaction cross section σ_{reac} of α-induc
which can be determined from the elastic scattering angular distribution or from th
of all open nonelastic channels.
Method: Elastic and inelastic ^{64}Zn$(\alpha,\alpha)^{64}$Zn angular distributions were measured
Coulomb barrier, at 12.1 and 16.1 MeV. Reaction cross sections of the (α,γ), $(\alpha,$
measured at the same energies using the activation technique. The contributions of
were estimated from statistical model calculations.
Results: The total reaction cross sections from elastic scattering and from the su
all open nonelastic channels agree well within the uncertainties. This finding con

The cross section of the ^{64}Zn$(\alpha,\gamma)^{68}$Ge reaction is sensitive to the α-nucleus potential and to the γ-ray strength function. Here the best result is obtained using the Hartree-Fock BCS γ-ray strength from [77]. The TALYS default option using? generalized Lorentzian γ-ray strength from [78] significantly underestimates the ^{64}Zn$(\alpha,\gamma)^{68}$Ge cross section (see Fig. 12, thin red long-dashed line).

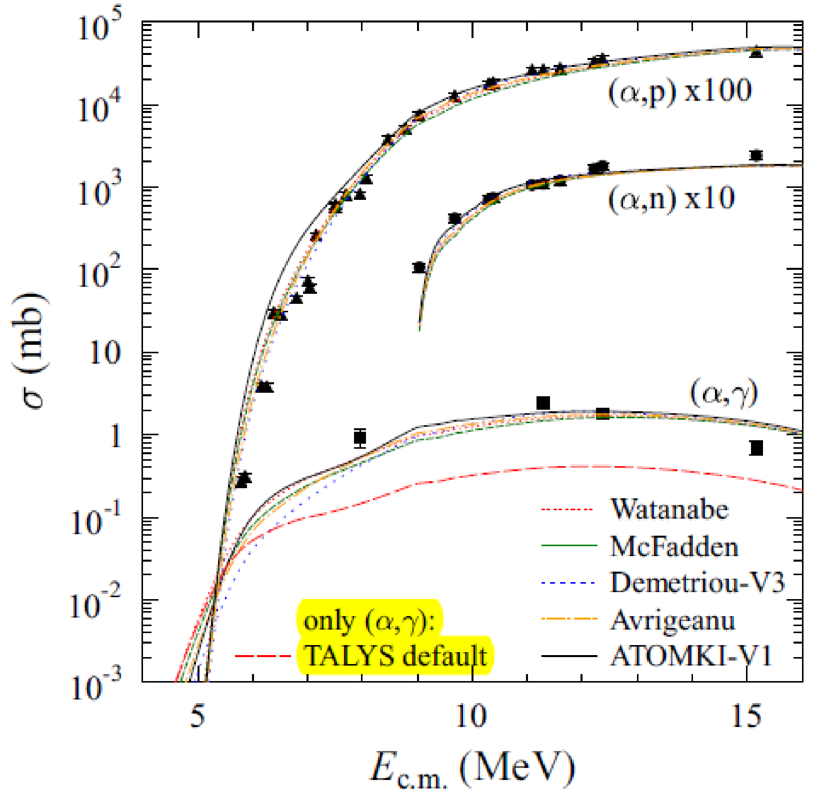

FIG. 12. Cross sections of the ^{64}Zn$(\alpha,\gamma)^{68}$Ge, ^{64}Zn$(\alpha,n)^{67}$Ge, and ^{64}Zn$(\alpha,p)^{67}$Ga reactions. The experimental data are taken from our previous work [37] except the new results at the highest energy $E_\alpha = 16.1$. The calculations are based on different global α-nucleus optical potentials [9,11,29,31,75]. For better readability, two versions of [31] have been omitted. The differences between the predictions from various α-nucleus potentials are relatively small. TALYS default parameters have been used in general except for the γ-ray strength function; the default γ-ray strength underestimates the (α,γ) cross section (thin red long-dashed line). For further discussion see text.

1. TALYS in (α,x) reaction cross-section anal

PHYSICAL REVIEW

Statistical model analysis of α-induced rea

P. Mohr,[1,2,*] Gy.
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[2]Diakonie-Klinikum, D-7

(Received 16 December 2

potentials play an essential
atistical model. Uncertaint
l parameters to experiment
y dependence of the effect
ork studies cross sections
input parameters of the sta
nents allow for a χ^2-based

red data for the (α,γ), $(\alpha,n$
survey of the parameter s
ined χ^2 landscape are discu
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or of 2.
experimental data for ^{64}Zn
ysical reaction rate within
emands further improveme

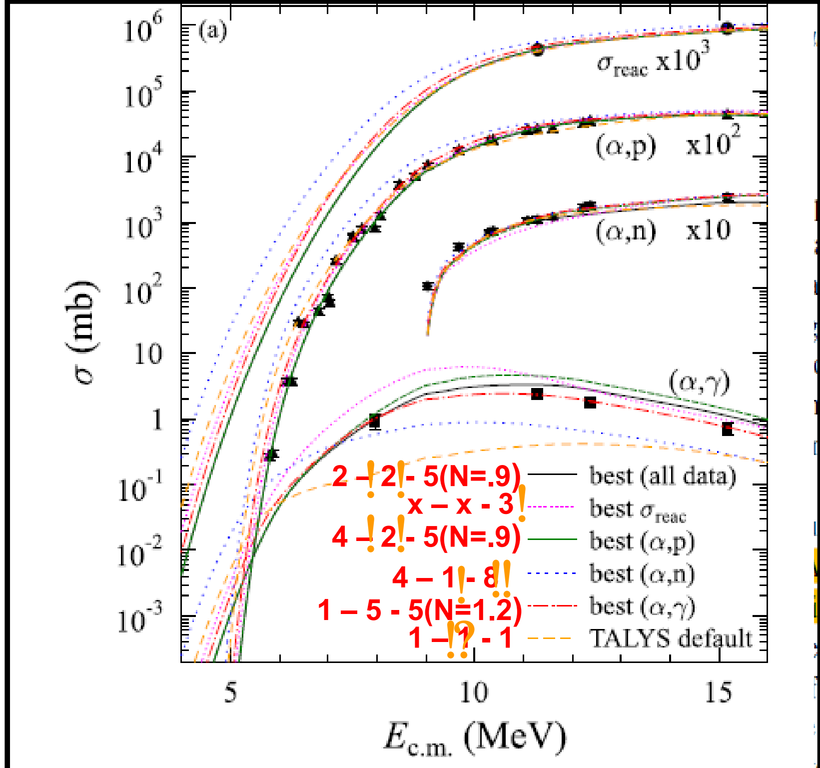


FIG. 2. Cross sections of α-induced reactions on ^{64}Zn; for better readability, the total reaction cross sections σ_{reac} have been multiplied by a factor of 1000, the $(\alpha$,p) data by a factor of 100, and the $(\alpha$,n) data by a factor of 10. The best fit of all 6720 combinations of the TALYS parameters is shown by the solid black line. Best fits to the σ_{reac} data are represented by the narrow-dotted magenta line; to the individual $(\alpha$,p) reaction, by the dashed green line; to the individual $(\alpha$,n) reaction, by the dotted blue line; and to the individual (α,γ) reaction, by the dash-dotted red line. The TALYS default calculation is shown by the short-dashed orange line. (a) Calculated excitation functions in

TALYS default calcu
which results from
cross sections at lov
the (α,γ) cross secti

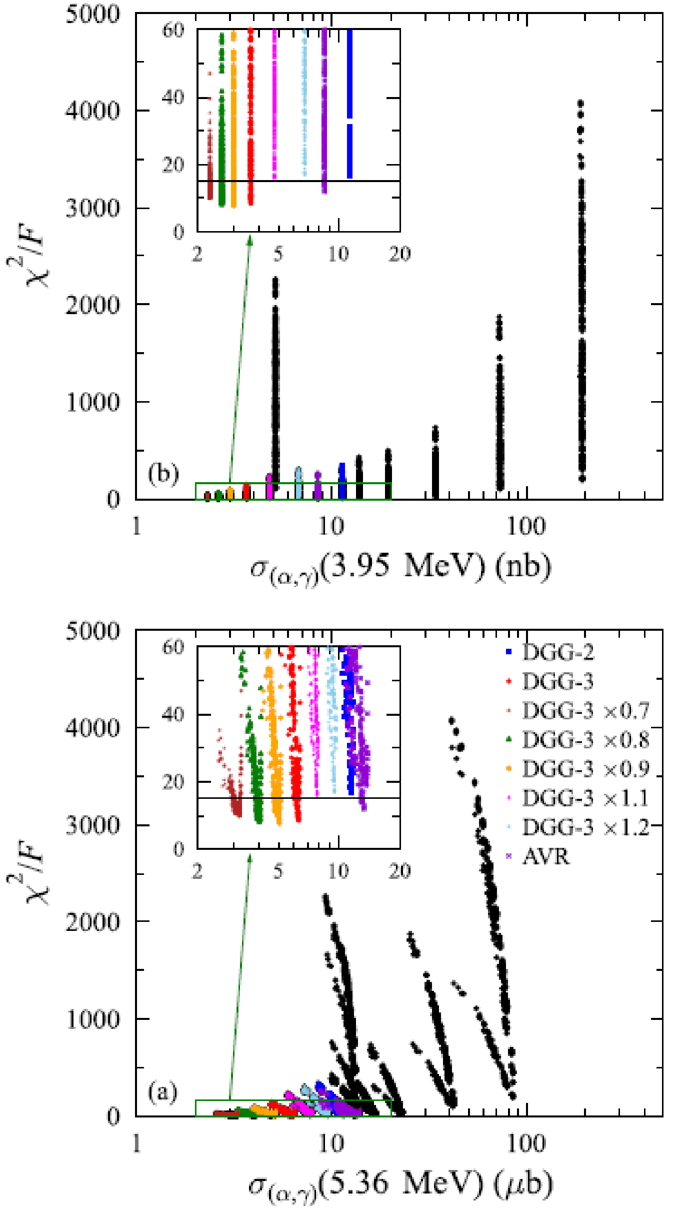


FIG. 3. χ^2/F as a function of the (α,γ) cross section (a) at 5.36 MeV (corresponding to the effective energy at $T_9 = 2.5$) and (b) at 3.95 MeV. Huge variations, between about 8 and 5000, are found for χ^2/F. Insets: All calculations with small $\chi^2/F < 60$. The chosen criterion $\chi^2/F \leqslant 15$ is indicated by the horizontal dashed

2. *Consistent* model calc. [Method, tools, IP] vs χ^2-based predictions (1/11)

[E.D. Arthur – P.G. Young, LANL, ’80]

[e.g., Nucl. Sci. Eng. **76**, 137 (1980)]

[IAEA/NDS RCs (12), Bucharest, 1982-2011]

YES **i.** **unitary use of *common* Input Parameters for different mechanisms**

ii. **use of *consistent sets* of Input Parameters - determined by *analyses of various independent* experimental data**

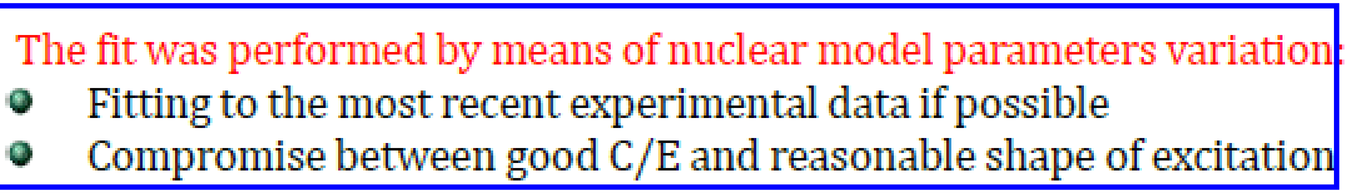
iii. **unitary account of *whole body* of related experimental data for *isotope chains* and *neighboring elements***

[activation & particle-emission spectra]

[enlarged incident-energy range]

NO **re-normalization or free parameters, widely-used within ND libraries, *e.g.:***

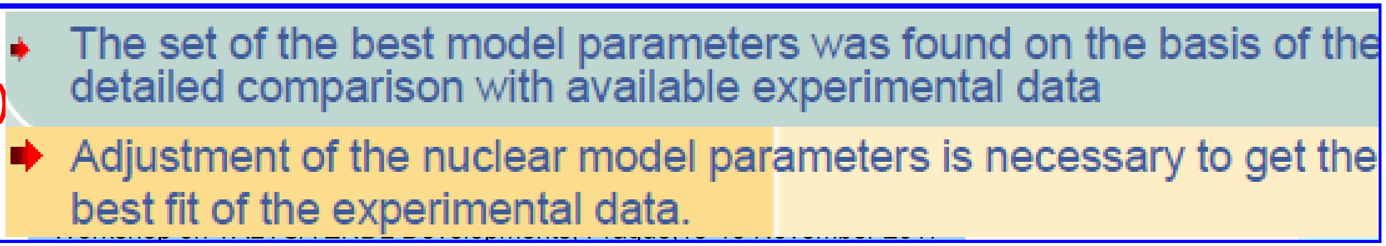
EFFDOC-1288:
(NRG-Petten)



The fit was performed by means of nuclear model parameters variation:

- Fitting to the most recent experimental data if possible
- Compromise between good C/E and reasonable shape of excitation

EFFDOC-1289:
(KIT-Karlsruhe)



- The set of the best model parameters was found on the basis of the detailed comparison with available experimental data
- Adjustment of the nuclear model parameters is necessary to get the best fit of the experimental data.

2. *Consistent* model calc. [Method, tools, IP] vs χ^2-based predictions (2/11)

OPTICAL MODEL : prime tool for all cross section calculations

- **Phenomenological OMP (global parameter sets): still extensively used**
- **Microscopic OPs: reduced uncertainties (e.g., OM ambiguities)**

- **Pure elastic scattering OP analysis**

  SCAT2 [O. Bersillon]

  - phenomenological OP
    + semi-microscopic (DF) OP →
    (local version)

*Phys. Rev. C**62** (2000) 017001*
*Nucl. Phys. **A693** (2001) 616*
*Eur. Phys. J. **A12** (2001) 399*
Int. J. of Mod. Phys. E, 11 (2002) 249
*Nucl. Phys. **A**723 (2003) 104*
*Nucl. Phys. **A** 759 (2005) 327*
*Nucl. Phys. **A** 764 (2006) 246*

- **Coupled Reaction Channel (CRC)**

  FRESCO-2003 [I.J. Thompson]

- **Composite system equilibration**
  - **Geometry Dependent Hybrid** (GDH) preequilibrium-emission model
  - **Hauser-Feshbach** (HF) statistical model

  STAPRE-H95 [V. Avrigeanu, M. Avrigeanu]
  (updated)

2. *Consistent* model calc. [Method, tools, IP] vs χ^2-based predictions (3/11)

LOCAL APPROACH:

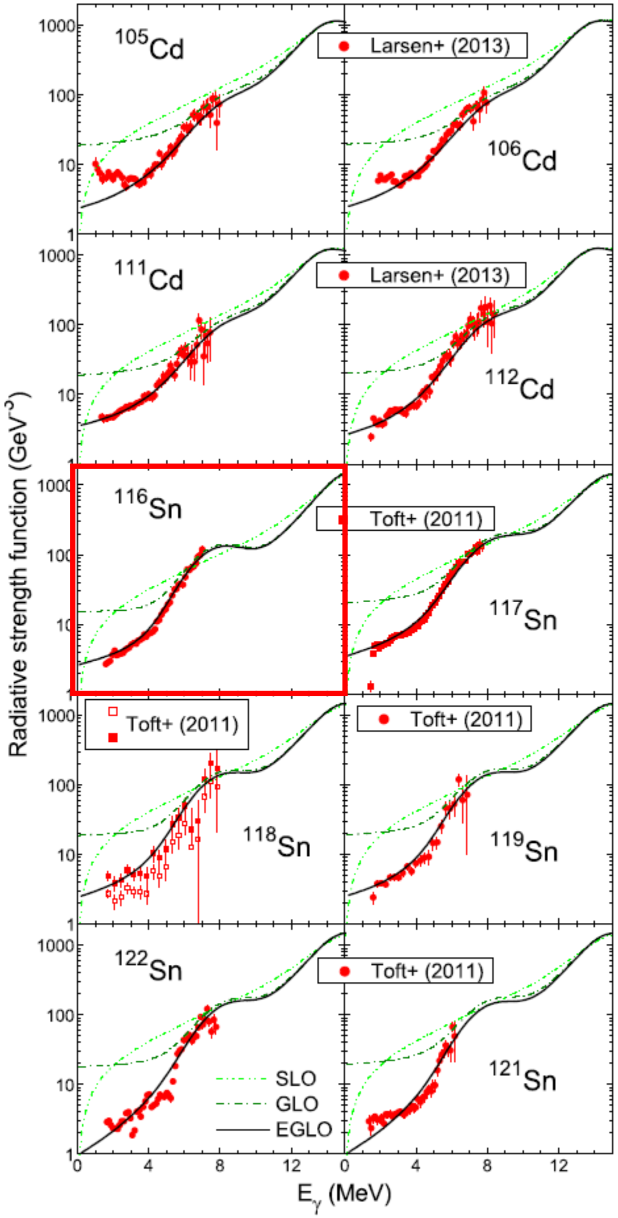
STAPRE-H95 (updated-2014) [OM/PE/SM: SCAT2, GDH, HF]

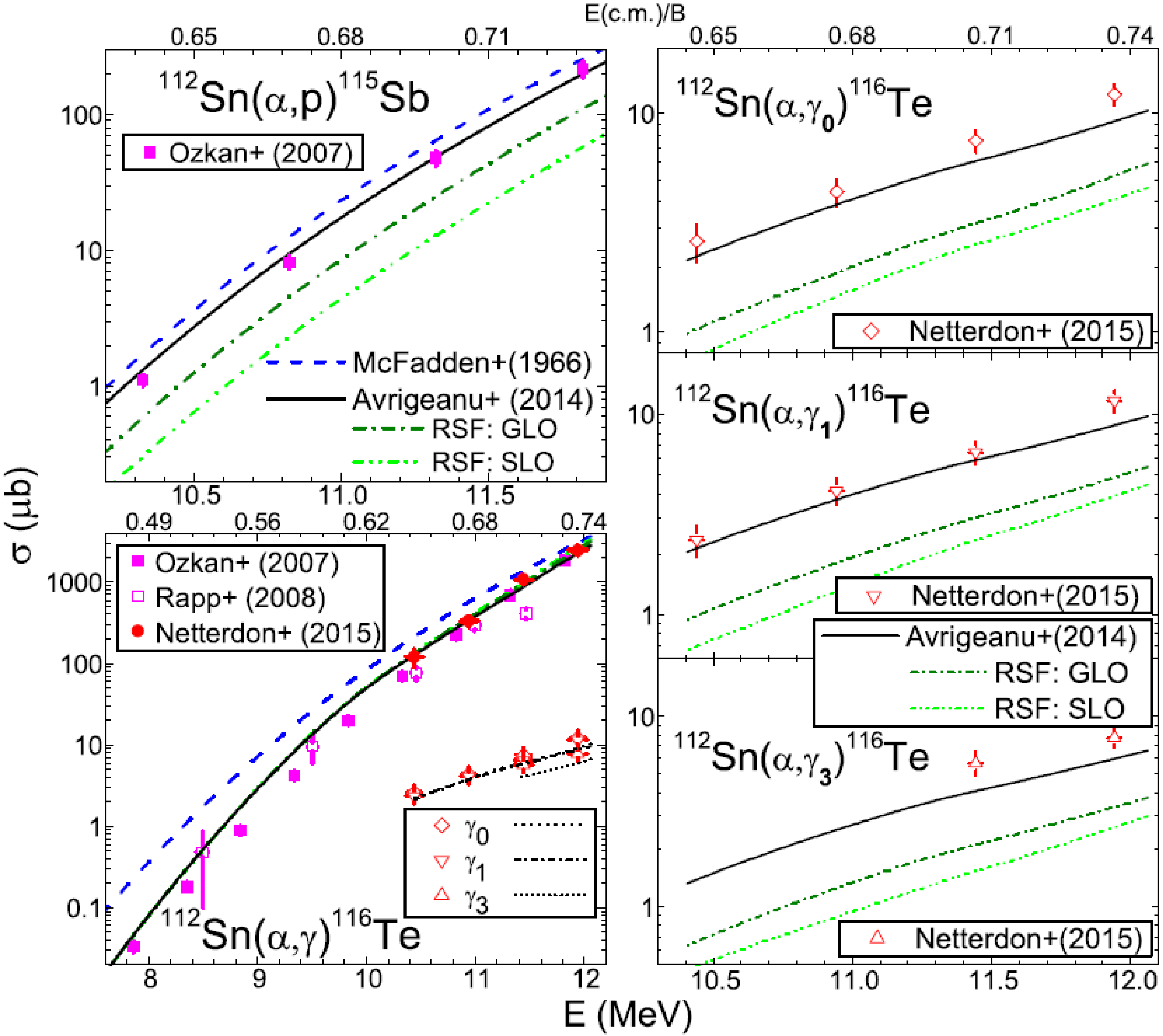
- **neutron- spherical OMP** [Koning-Delaroche, Nucl.Phys. **A713**, 231 (2003)]
- **p-, α- spherical OMP:** [**Johnson+ (1968)**, V. Avrigeanu+, PRC **49**, 2125 (1994),
  V. Avrigeanu+, PRC **90**, 044612 (2014)]
- **γ-ray strength functions:** E1[EGLO/OCL:PRC **93**,045810(2016**),** *ibid.* **94**,025804(2016)]
  M1(SLO, 1990 [RIPL-1])
- **PE: Geometry Dependent Hybrid model** [M. Blann+, PRC **28**, 1493 (1984)]
  - **+ α-particle emission** [Z.Phys. A **329**,177(1988)]
  - **+ J^{π}-conservation** [Z.Phys. A **329**,177(1988)]
  - **+ $g_{FGM}(e)$, $A_K(p,h)$, $f_K(p,h,E,F_1(I,E_i)$** [Phys. Rev. C **58**, 295 (1998)]

- **Nuclear-level density** ($E>E_d$ [**ENSDF**]): **BSFG:**
  - **+ $E^*<B_n$: (a,Δ) from fit of [D_0 (RIPL-3), N_d (ENSDF,RIPL3)]**
  - **+ $E^*>B_n$: $a(E^*)$** [A.R. Junghans+, NP**A629**, 635 (1998);
    A.J. Koning, M.B. Chadwick, PRC **56**, 970 (1997)]
  - **+ I/I_r: 0.5(g.s.)-0.75(B_n)-1(15 MeV)** [V.Avrigeanu+, JNST **S2**,746 (2002)

2. Consistent model calculations vs χ^2-based predictions (A ~ 110) (4/11)

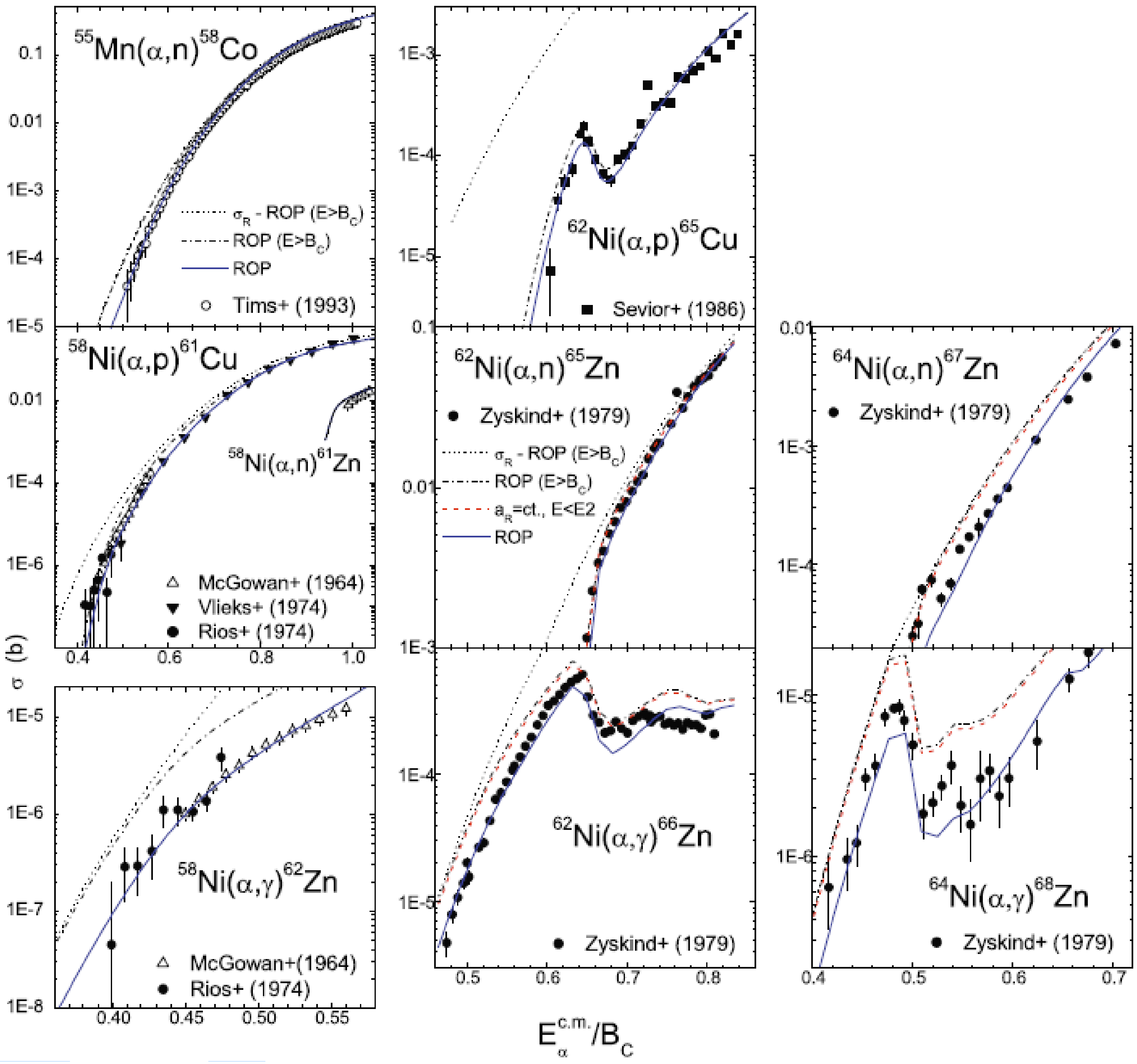
V. AVRIGEANU AND M. AVRIGEANU PHYSICAL REVIEW C **94**, 024621 (2016)





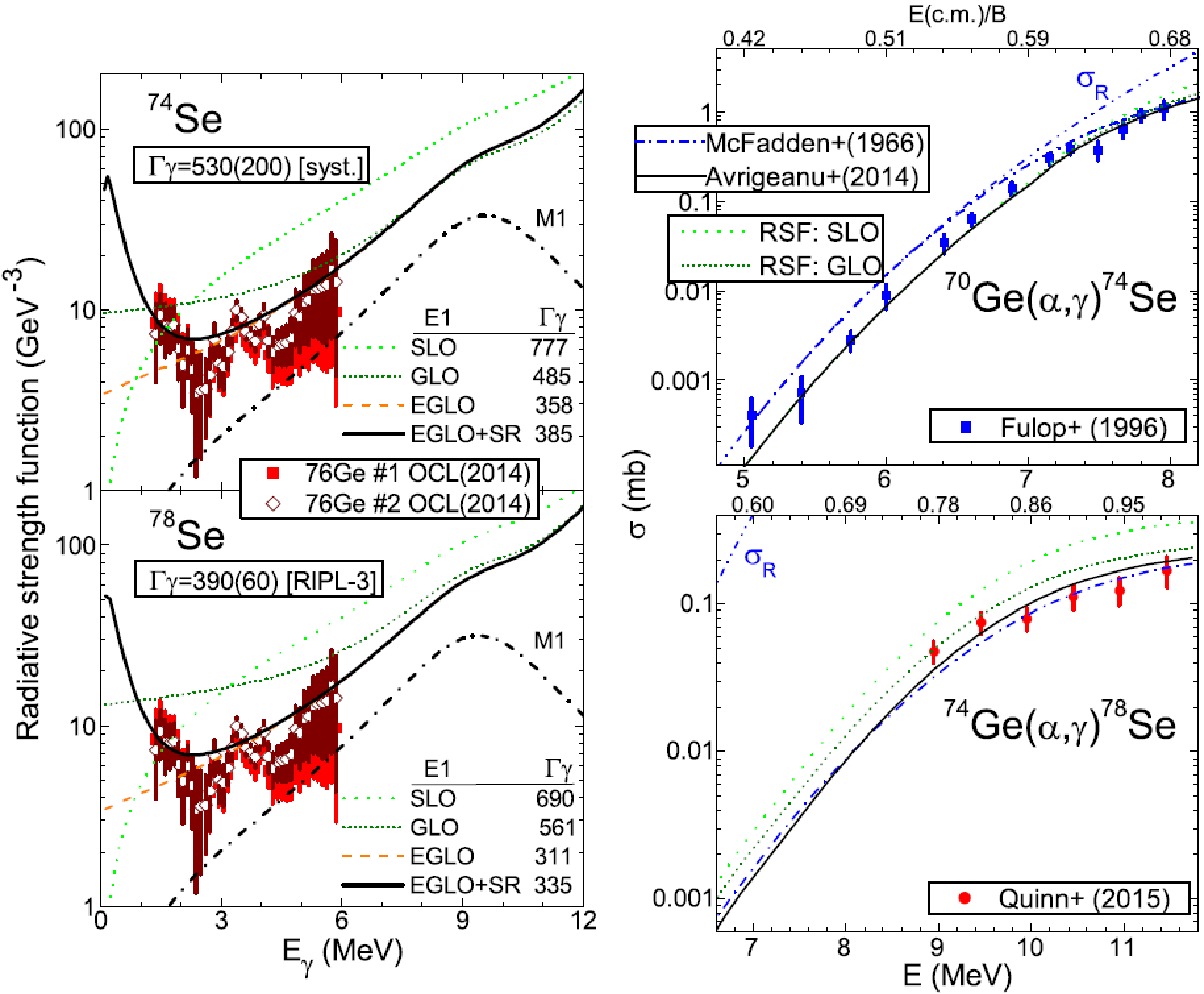
2. Consistent model calculations vs χ^2-based predictions (A ~ 60)

M. Avrigeanu et al. / Atomic Data and Nuclear Data Tables 95 (2009) 501–532



2. Consistent model calculations vs χ^2-based predictions (A ~ 70) (6/11)

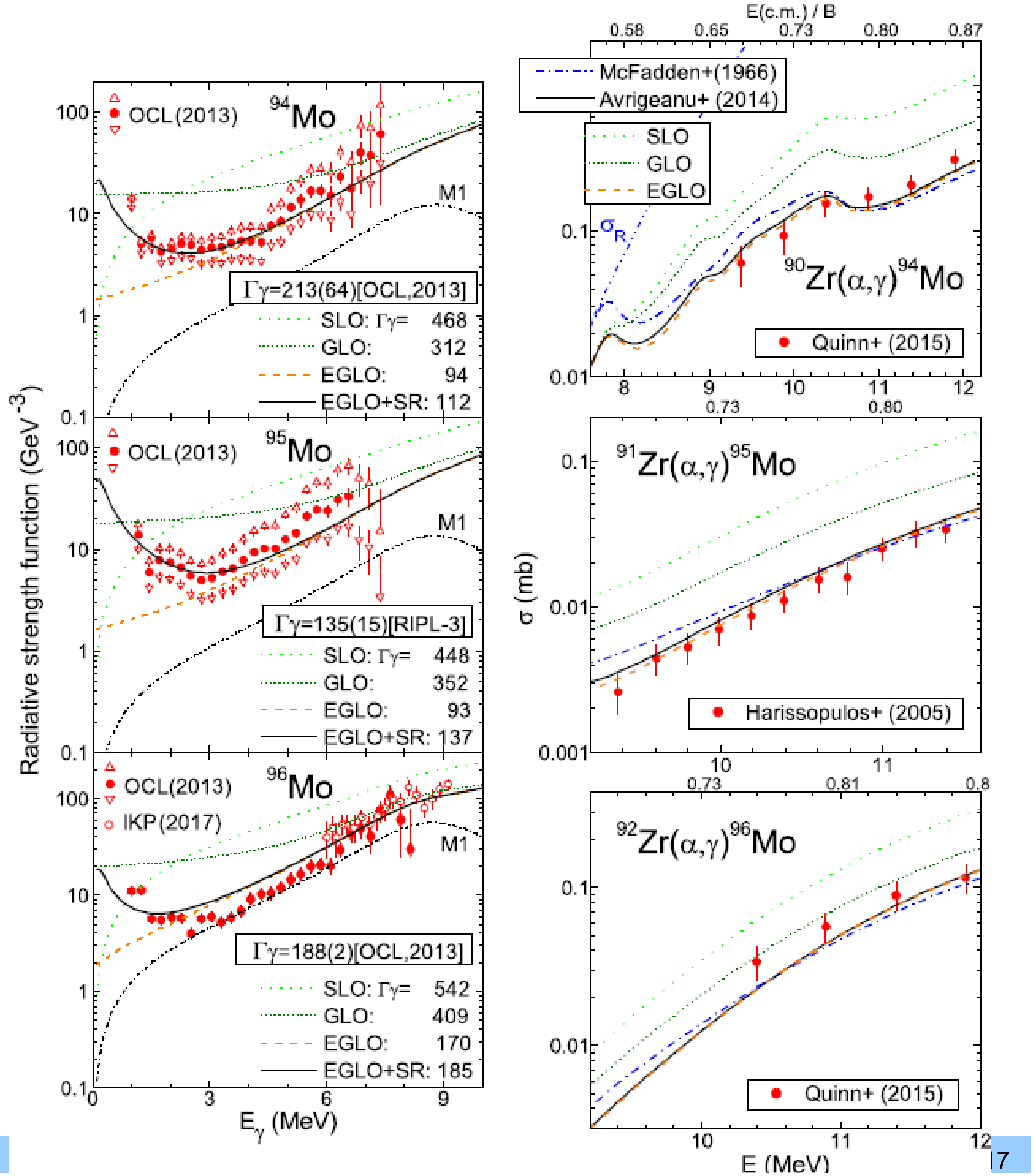
V. AVRIGEANU AND M. AVRIGEANU PHYSICAL REVIEW C **96**, 044610 (2017)



2. Consistent model calculations vs χ^2-based predictions (A ~ 90) (7/11)

V. AVRIGEANU AND M. AVRIGEANU

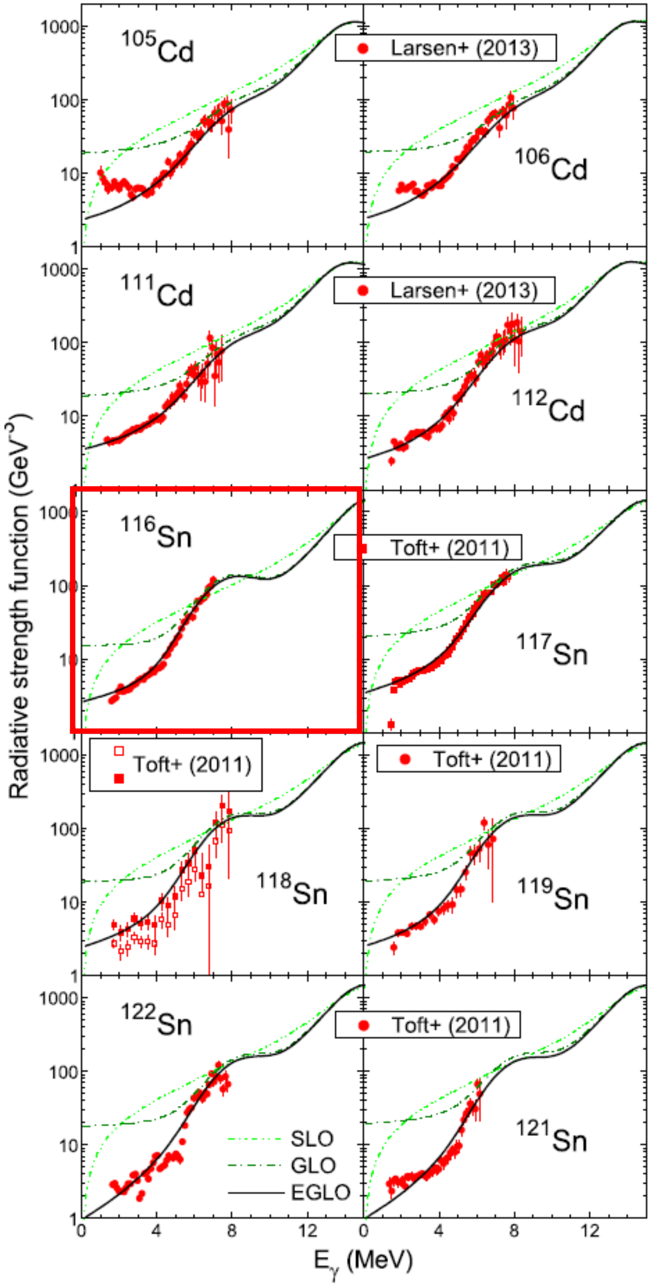
PHYSICAL REVIEW C **96**, 044610 (2017)

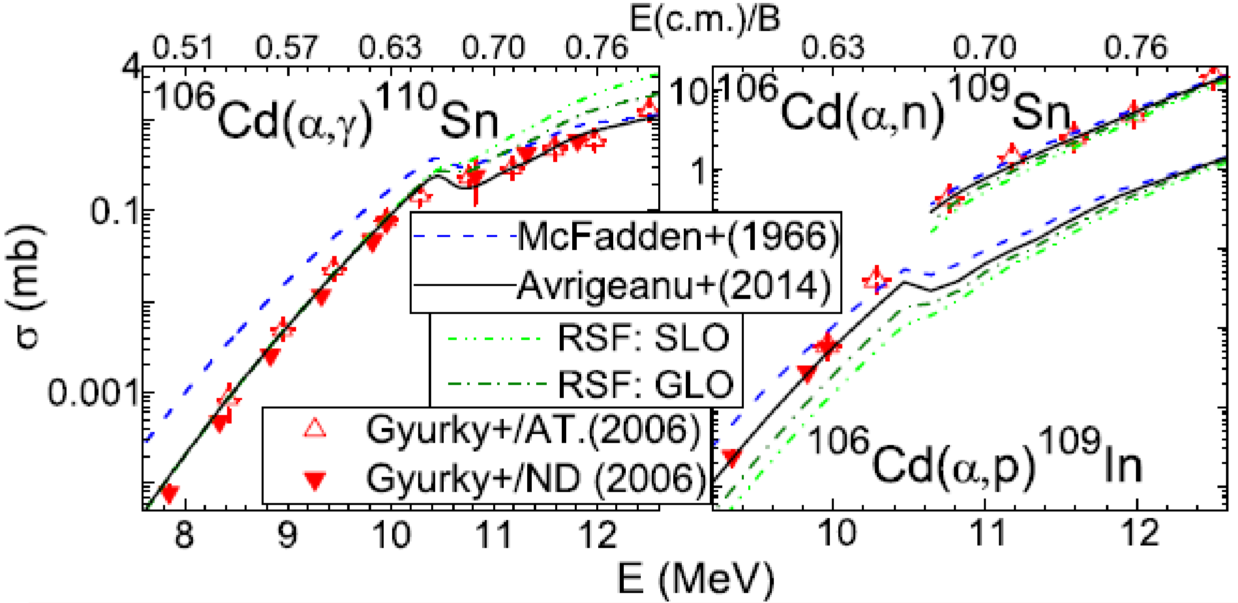


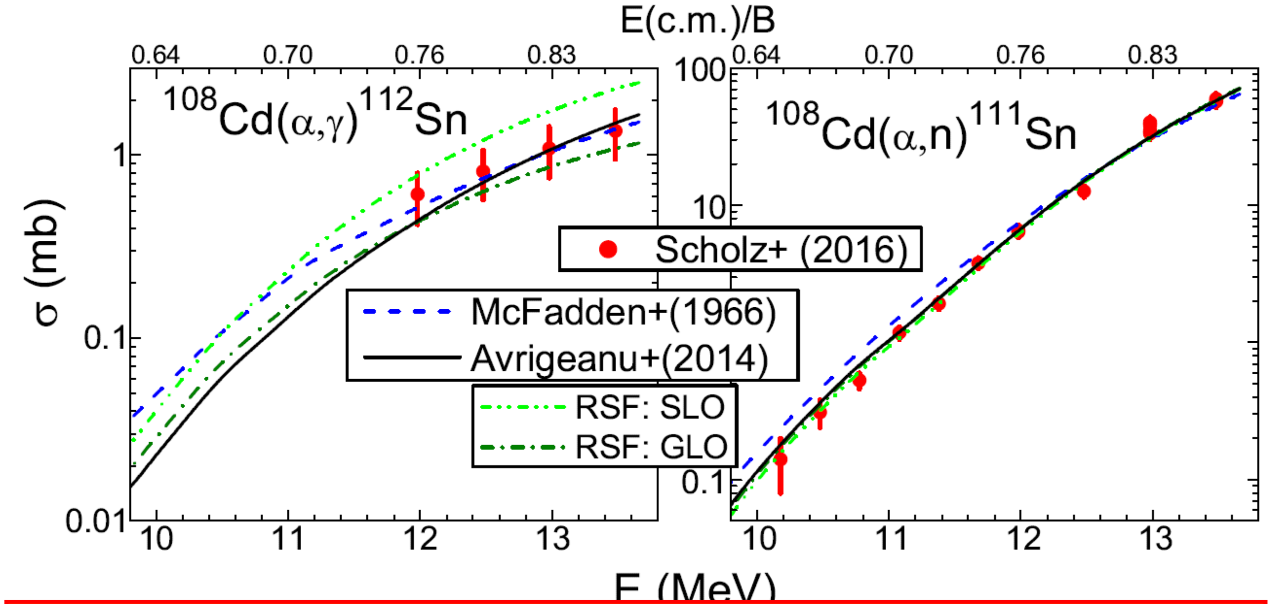
2. Consistent model calculations vs χ^2-based predictions (A ~ 110)

V. AVRIGEANU AND M. AVRIGEANU

PHYSICAL REVIEW C 94, 024621 (2016)

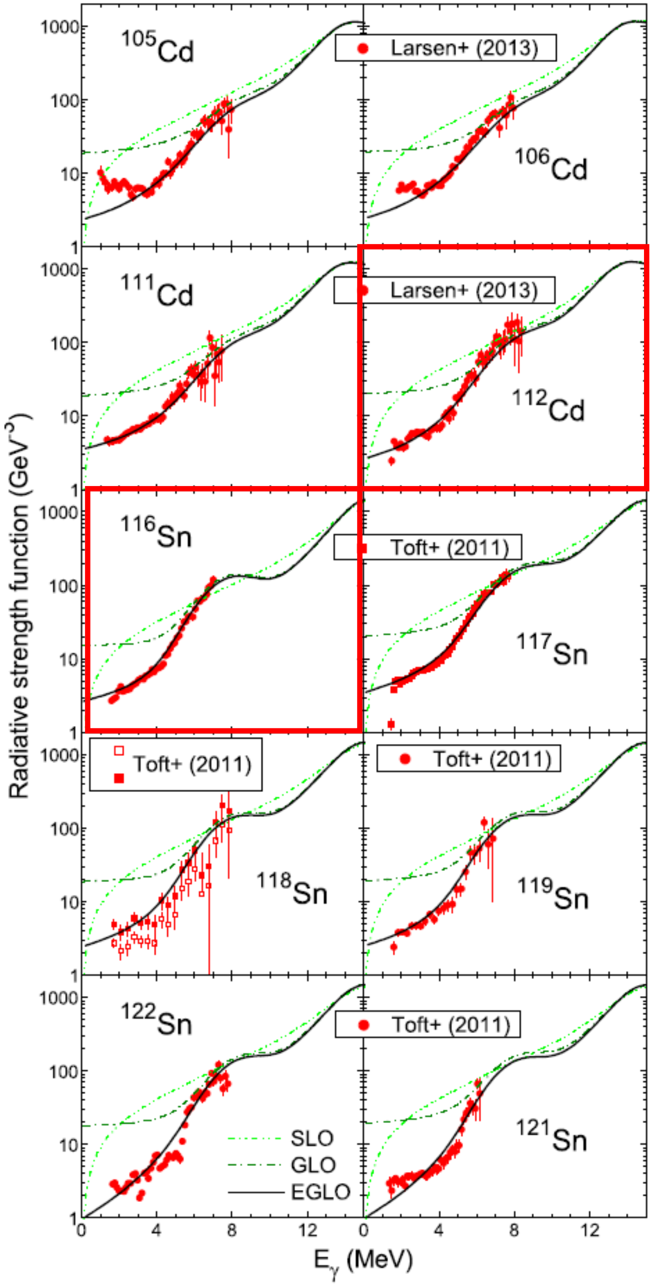


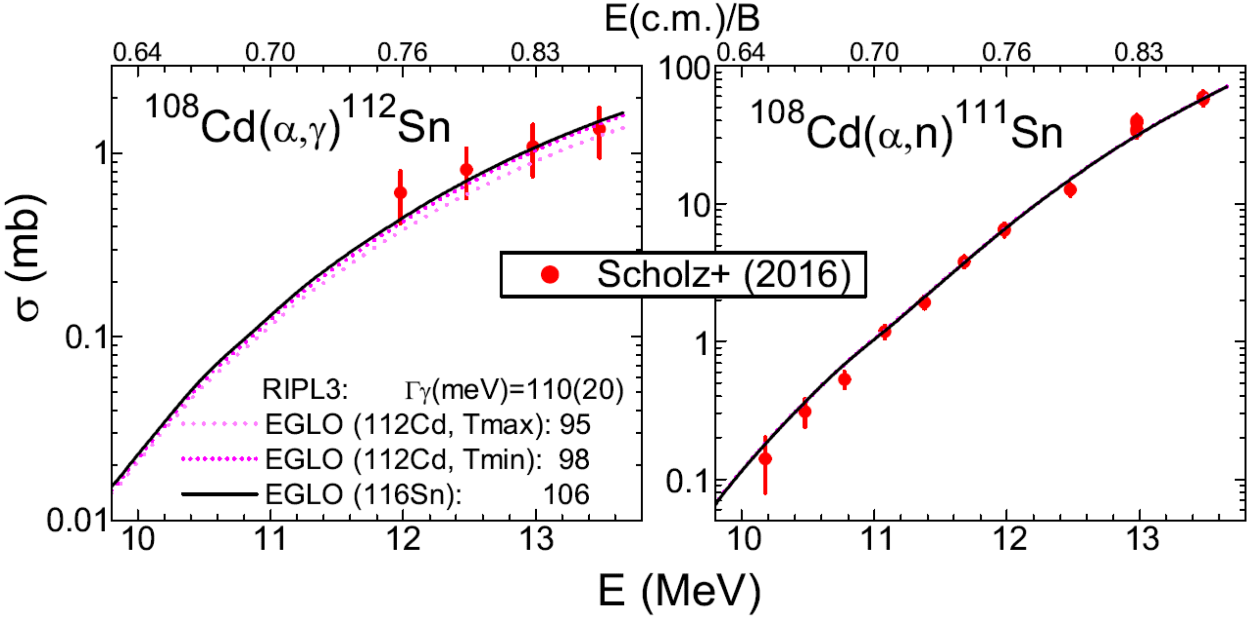




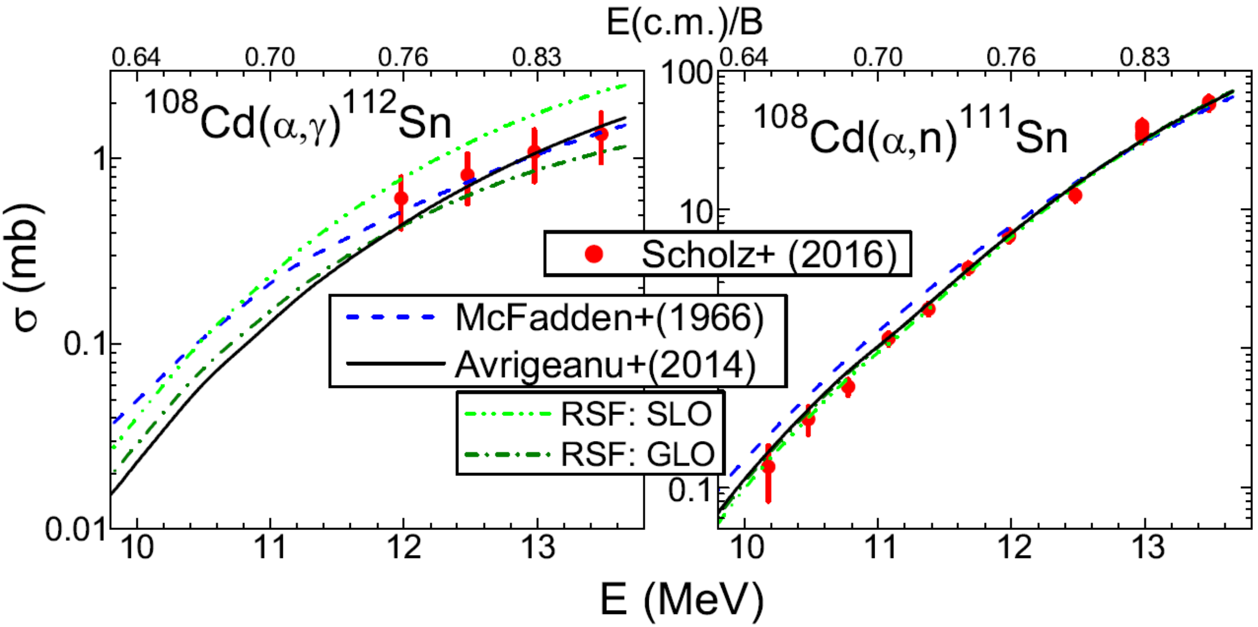
http://tid.uio.no/workshop2017/talks/OsloWS17_VAvrigeanu.pdf

2. Consistent model calculations vs χ^2-based predictions (A ~ 110)





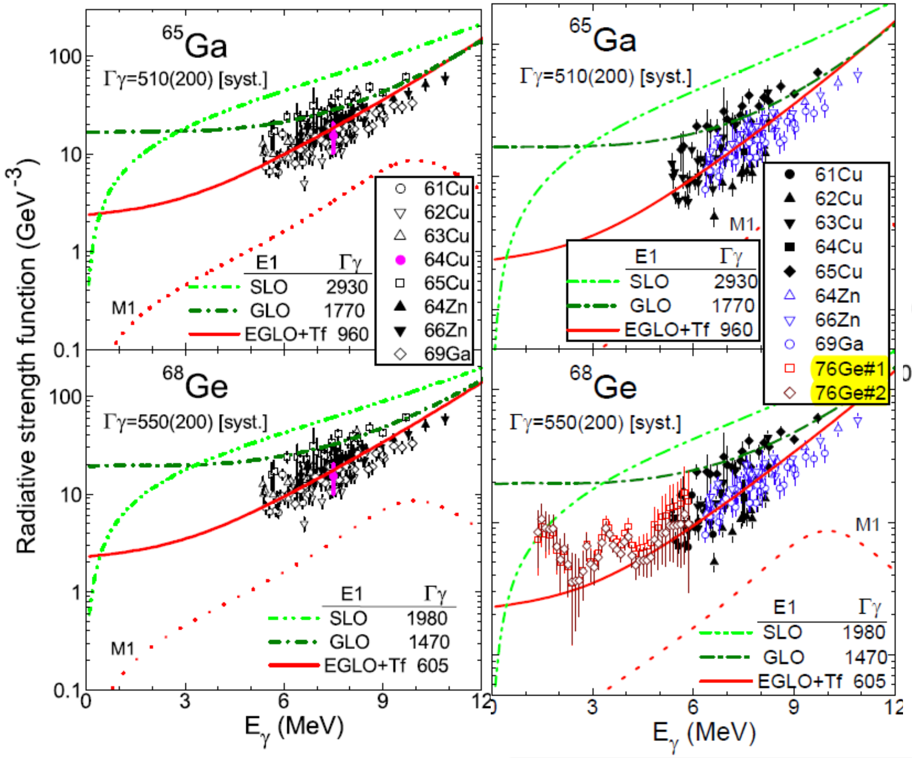
112Cd: A. C. LARSEN *et al.* PHYSICAL REVIEW C **87**, 014319 (2013)
116Sn: H. K. TOFT *et al.* PHYSICAL REVIEW C **83**, 044320 (2011)

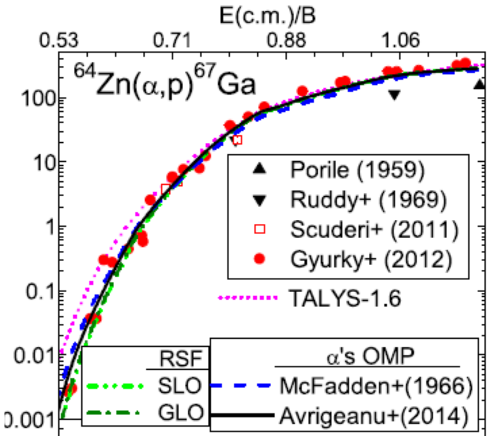


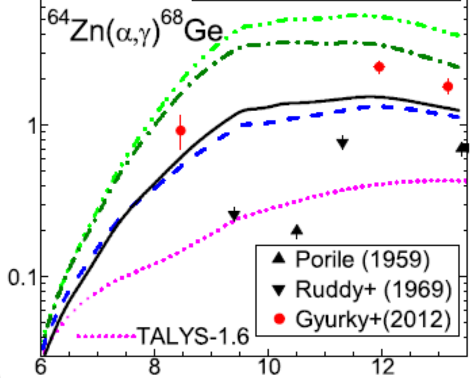
2. Consistent model calculations vs χ^2-based predictions (A=64)

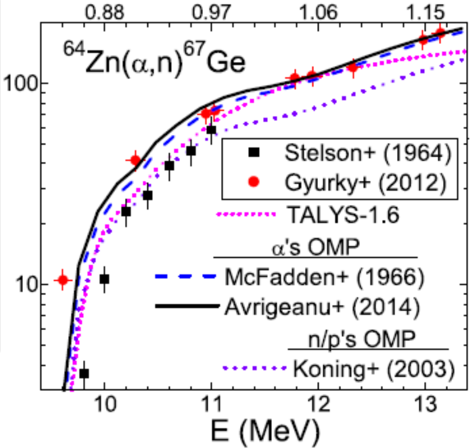
V. AVRIGEANU AND M. AVRIGEANU
PHYSICAL REVIEW C **91**, 064611 (2015)

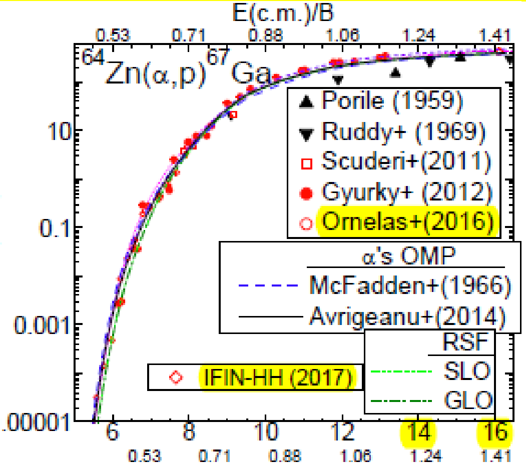
2017

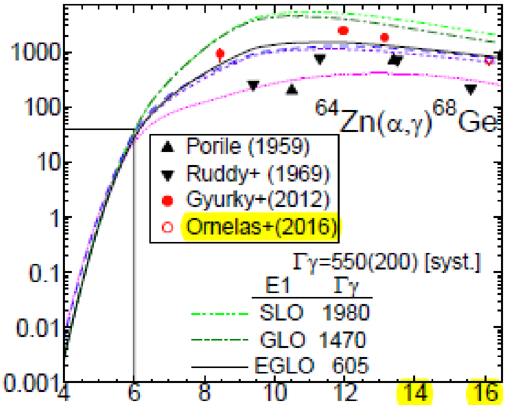


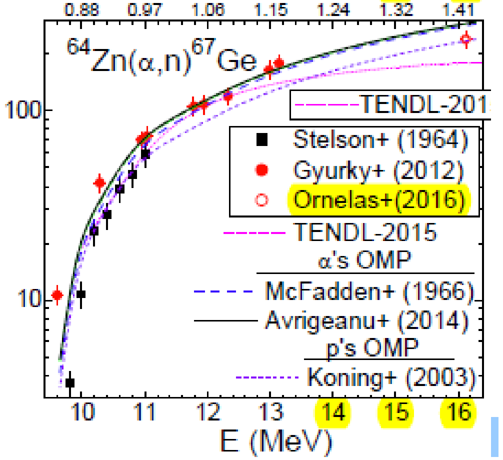


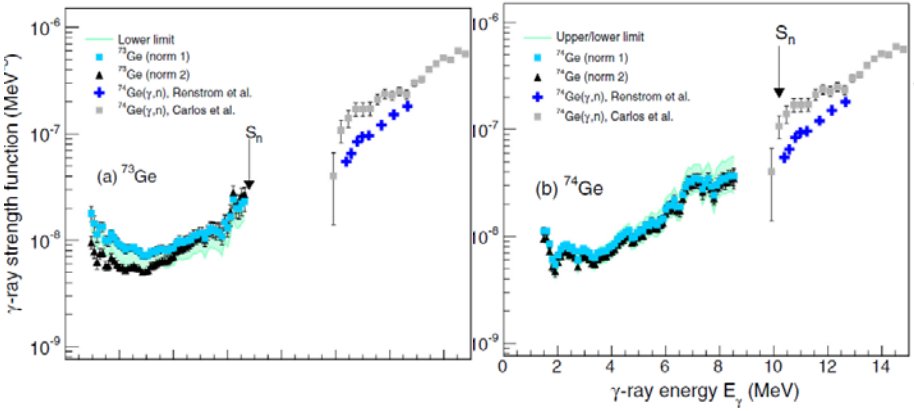








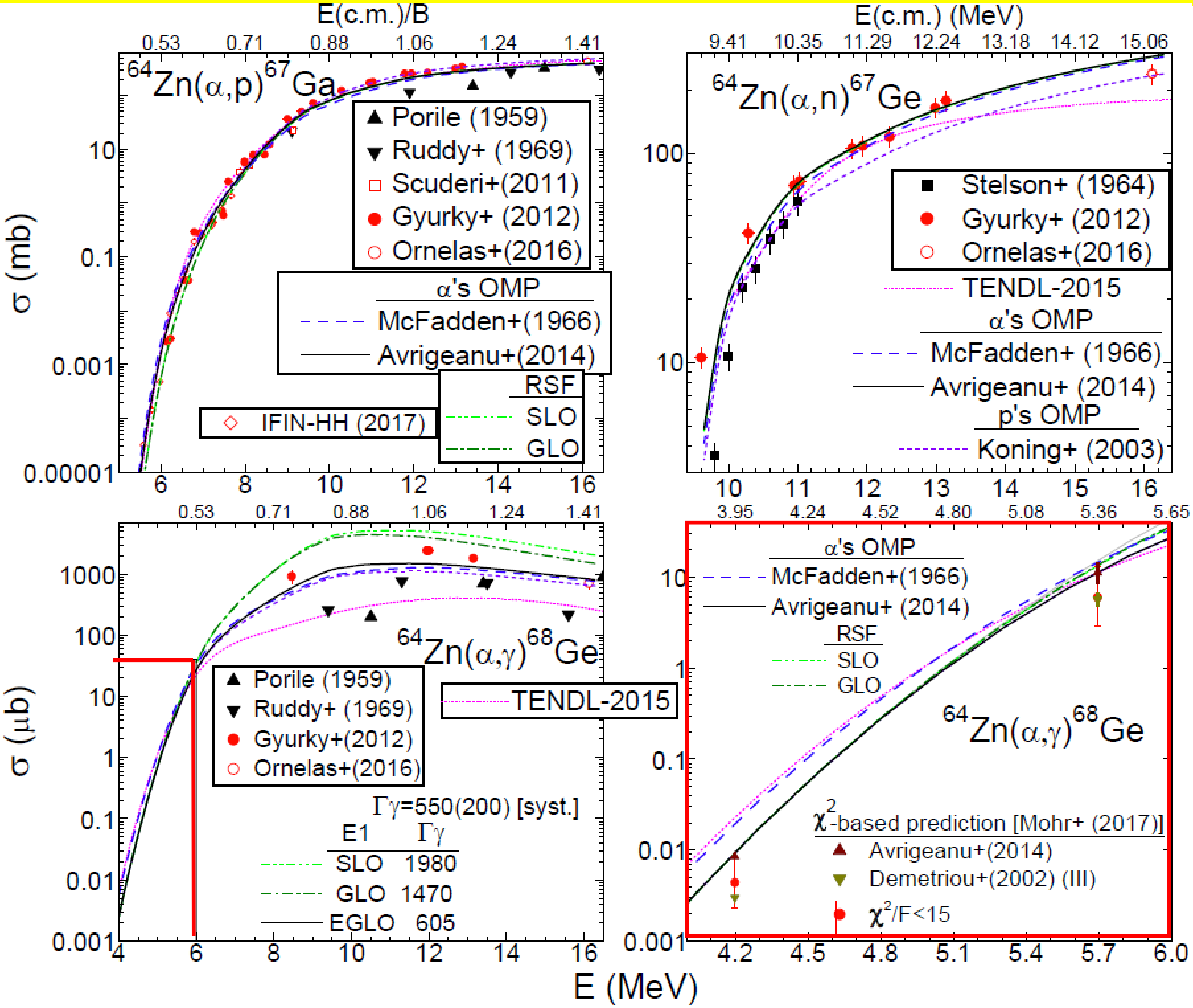




T. RENSTRØM *et al.* PHYSICAL REVIEW C **93**, 064302 (2016)

2. Consistent model calculations vs χ^2-based predictions (A=64) (11/11)

2017



3. Recent (2017) ^{91,92}Zr RSF and ^{93,95}Zr (n,γ) data analysis (1/4)

PHYSICAL REVIEW C **96**, 024313 (2017)

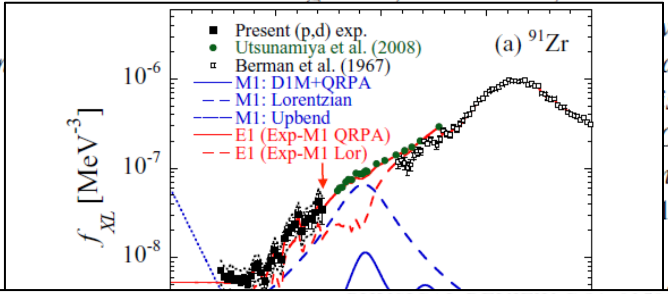
Quasicontinuum γ decay of ^{91,92}Zr: Benchmarking indirect (n, γ) cross section measurements for the s process

M. Guttormsen,[1,*] S. Goriely,[2] A. C. Larsen,[1] A. Görgen,[1] T. W. Hagen,[1] T. Renstrøm,[1] S. Siem,[1] N. U. H. Syed,[1]
G. Tagliente,[3] H. K. Toft,[1] H. Utsunomiya,[4] A. V. Voinov,[5] and K. Wikan[1]

ersity of Oslo, N-0316 Oslo, Norway
[2] In
de Bruxelles, Campus de la Plaine, CP-2
sica Nucleare, 70126 Bari, Italy
Okamoto 8-9-1, Higashinada, Kobe 658-
ty, Ohio University, Athens, Ohio 45701,

17; published 21 August 2017)

oth functions (γSFs) have been extract



PHYSICAL REVIEW C **81**, 035801 (2010)

Photoneutron cross sections for ^{96}Zr: A systematic experimental study of photoneutron and radiative neutron capture cross sections for zirconium isotopes

H. Utsunomiya,[1] S. Goriely,[2] H. Akimune,[1] H. Harada,[3] F. Kitatani,[3] S. Goko,[3] H. Toyokawa,[4] K. Yamada,[4] T. Kondo,[1]
V. Lui,[5] S. Hilaire,[6] and A. J. Koning[7]
to 8-9-1, Higashinada, Kobe 658-8501, Japan
elles, Campus de la Plaine, CP-226, B-1050 Brussels, Belgium
ura, Naka, Ibaraki 319-1195, Japan
e and Technology, Tsukuba 305-8568, Japan
ty, College Station, Texas 77843, USA
ysique Nucléaire, B.P. 12 F-91680 Bruyères-le-Châtel, France
Box 25, NL-1755 ZG Petten, The Netherlands

published 15 March 2010)

ar neutron threshold with quasimonochromatic laser-
f photoneutron and radiative neutron capture data for
leads to a unified picture of low-energy γ-ray strengths
PA model of E1 strength supplemented with an extra
f the systematic analysis including radiative neutron
are presented.

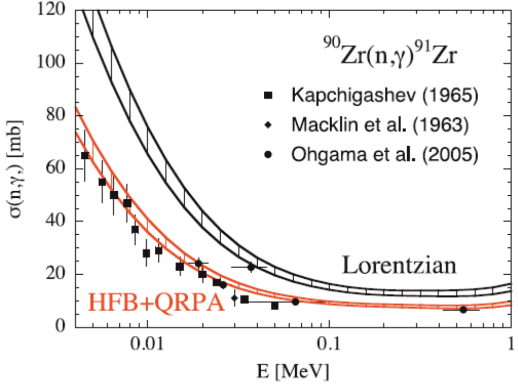


FIG. 3. (Color online) Comparison of experimental and theoretical ^{90}Zr$(n,\gamma)^{91}$Zr cross sections. The theoretical curves were obtained with the $E1$ HFB + QRPA strength [16] supplemented with a strong $M1$ resonance as well as with the standard Lorentzian for both the $E1$ and $M1$ strengths, as recommended in Ref. [17]. The error bars on the theoretical estimate are obtained using different nuclear level-density prescriptions. The experimental data are from Refs. [18–20].

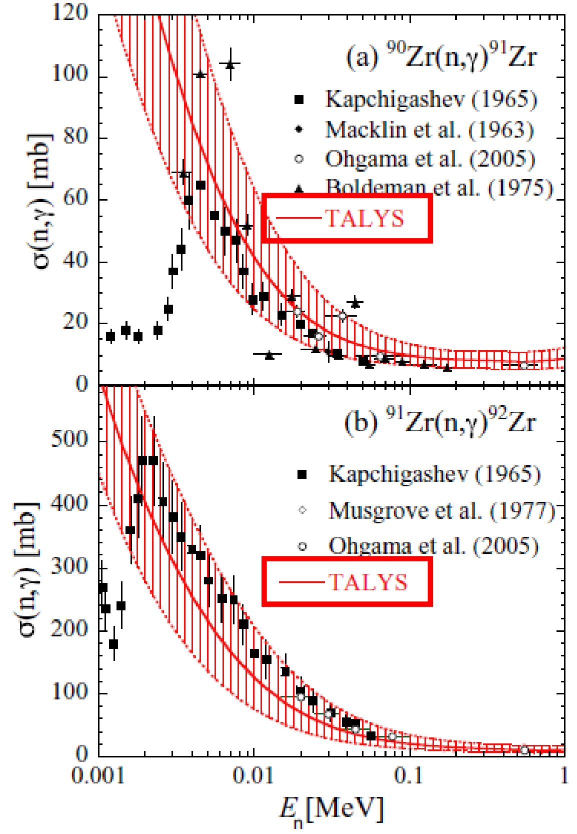


FIG. 9. (a) Comparison between the experimental ^{90}Zr$(n,\gamma)^{91}$Zr cross section [50–52] and the one obtained with the TALYS code on the basis of the NLD and γSF derived experimentally in the present work. The hashed area depicts all the experimental and model-dependent uncertainties taken into account in the present analysis. (b) Same

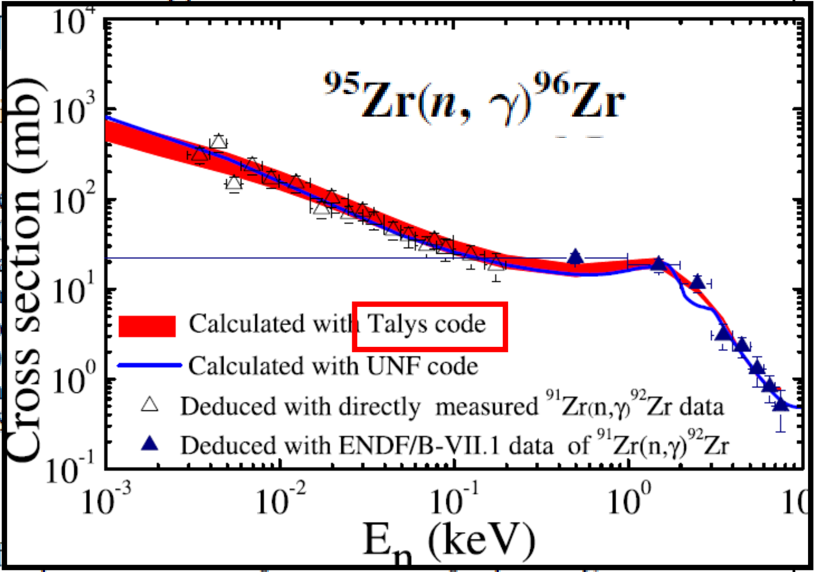
3. Recent (2017) ^{91,92}Zr RSF and ^{93,95}Zr (n,γ) data analysis (2/4)

The Astrophysical Journal, 848:98 (8pp), 2017 October 20
https://doi.org/10.3847/1538-4357/aa8c74
arXiv:1709.04635

The ^{95}Zr(n, γ)^{96}Zr Cross Section from the Surrogate Ratio Method and Its Effect on s-process N

S. Q. Yan (颜胜权)[1], Z. H. Li (李志宏)[1], Y. B. Wang (王友宝)[1], K. N
P. Mohr[5,6], J. Su (俊苏)[1], Y. J. Li (李云居)[1], I. Nishinaka[2], K. Hirose[2], Y.
B. Guo (冰郭)[1], S. Zeng (晟曾)[1], G. Lian (钢连)[1], Y. S. Che
[1] China Institute of Atomic Energy, P.O. Box 275(10), Beijing 1

calculations were later extended using the code TALYS for an estimate of the uncertainties. For this purpose the complete parameter space of TALYS was investigated and includes variations of the gamma-ray strength function, the level density, and the nucleon optical model potential. Because of



Abstract

The ^{95}Zr(n, γ)^{96}Zr reaction cross section is crucial in the modeling of
branch stars because it controls the operation of the branching point at the unstable ^{95}Zr and the subsequent production of ^{96}Zr. We have carried out the measurement of the ^{94}Zr(^{18}O, ^{16}O) and ^{90}Zr(^{18}O, ^{16}O) reactions and obtained the γ-decay probability ratio of ^{96}Zr* and ^{92}Zr* to determine the ^{95}Zr(n, γ)^{96}Zr reaction cross sections with
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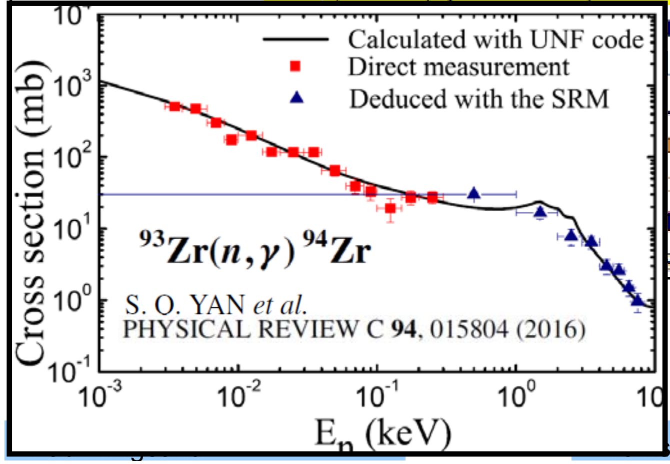


the (n, γ) data $\chi^2/F \approx 1.3$ and a similar average deviation of about 1.3 is found; because of the larger uncertainty of the

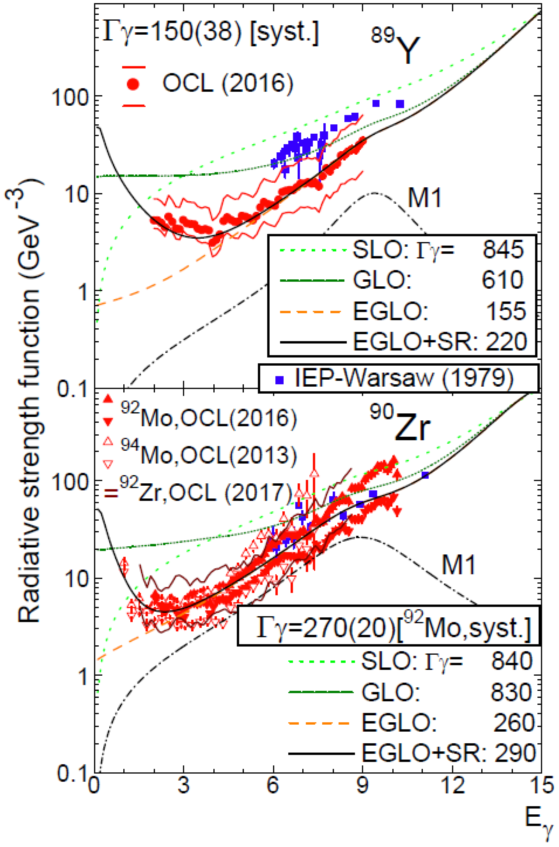
$\chi^2/F \leqslant (\chi^2/F)_{\rm min} + 1$; for a discussion of this choice, see Mohr et al. (2017). It is found that this choice essentially selects the gamma-ray strength function, whereas the sensitivity of the calculated cross sections to the chosen level density and the chosen nucleon optical model potential remain minor. All reasonable χ^2/F are obtained from the simple Brink-Axel Lorentzian gamma-ray strength function (Brink 1957; Axel 1962;

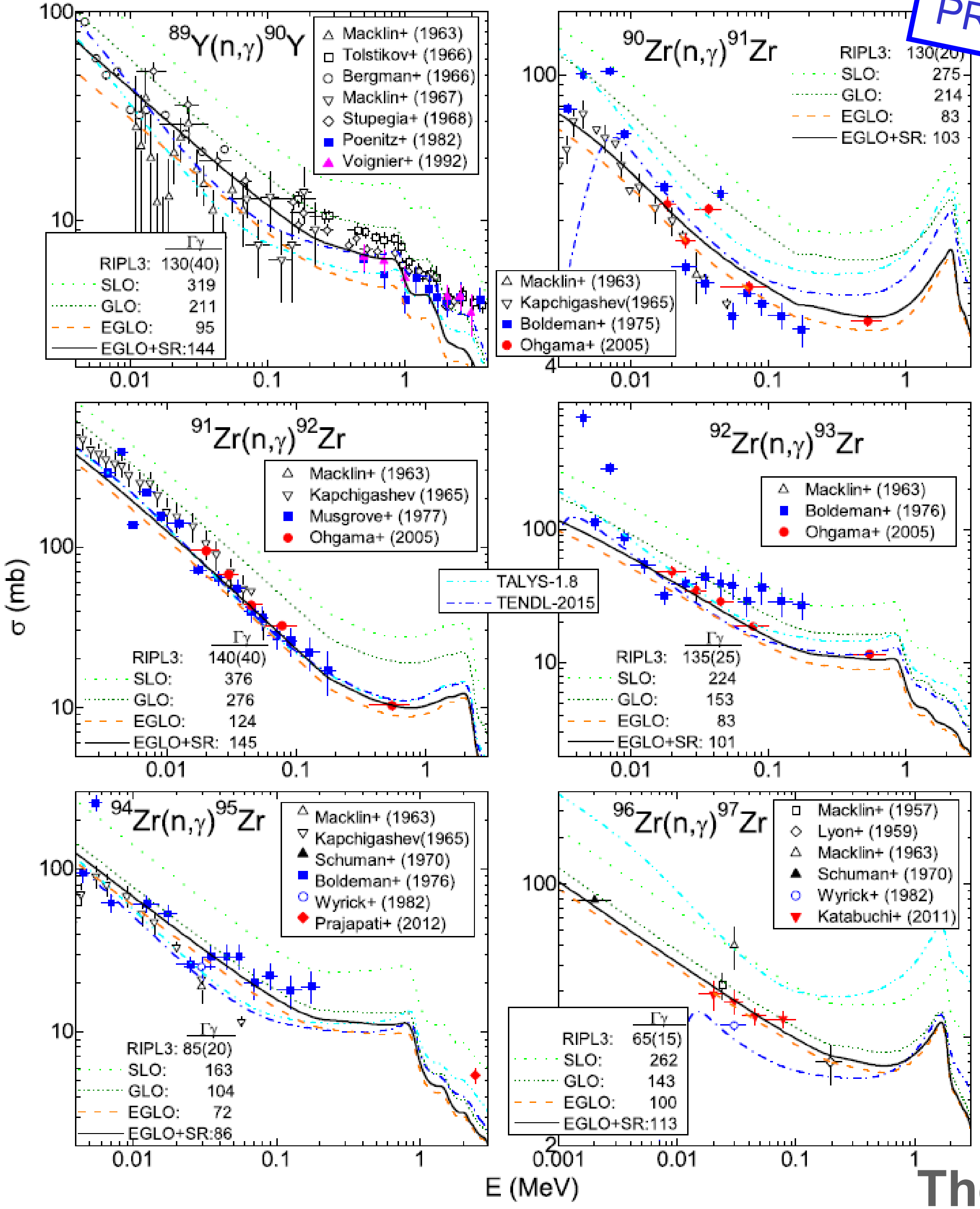
!

3. Recent (2017) ^{91,92}Zr RSF and ^{93,95}Zr (n,γ) data analysis (3/4)

EFFDOC-1299

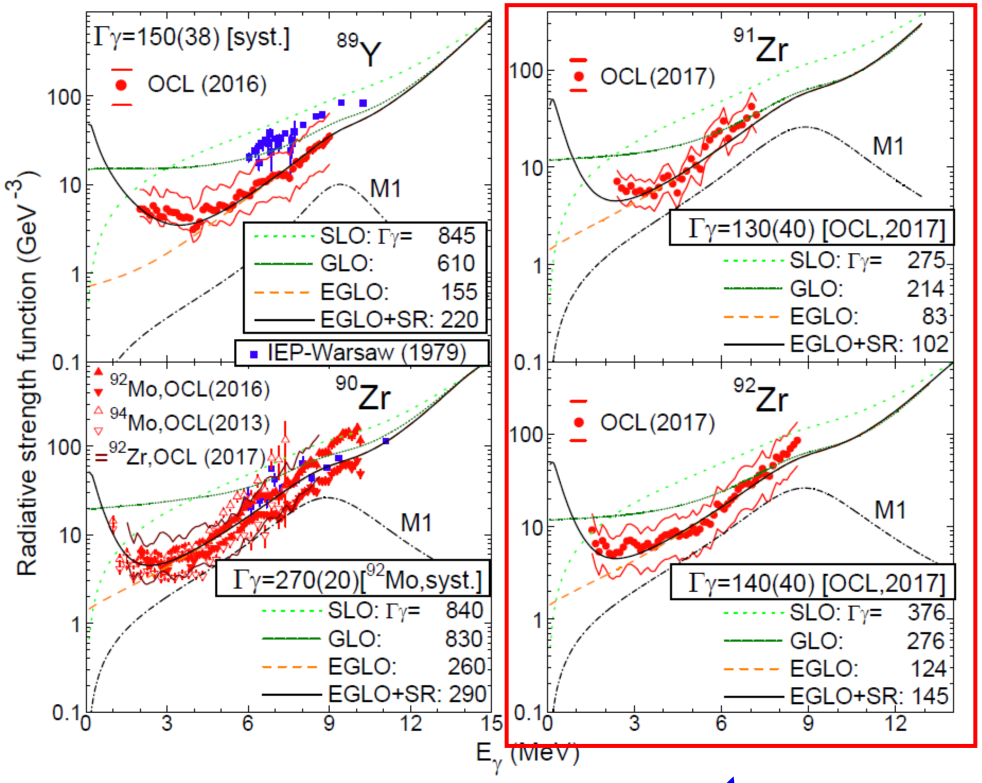
PRC **96**,044610

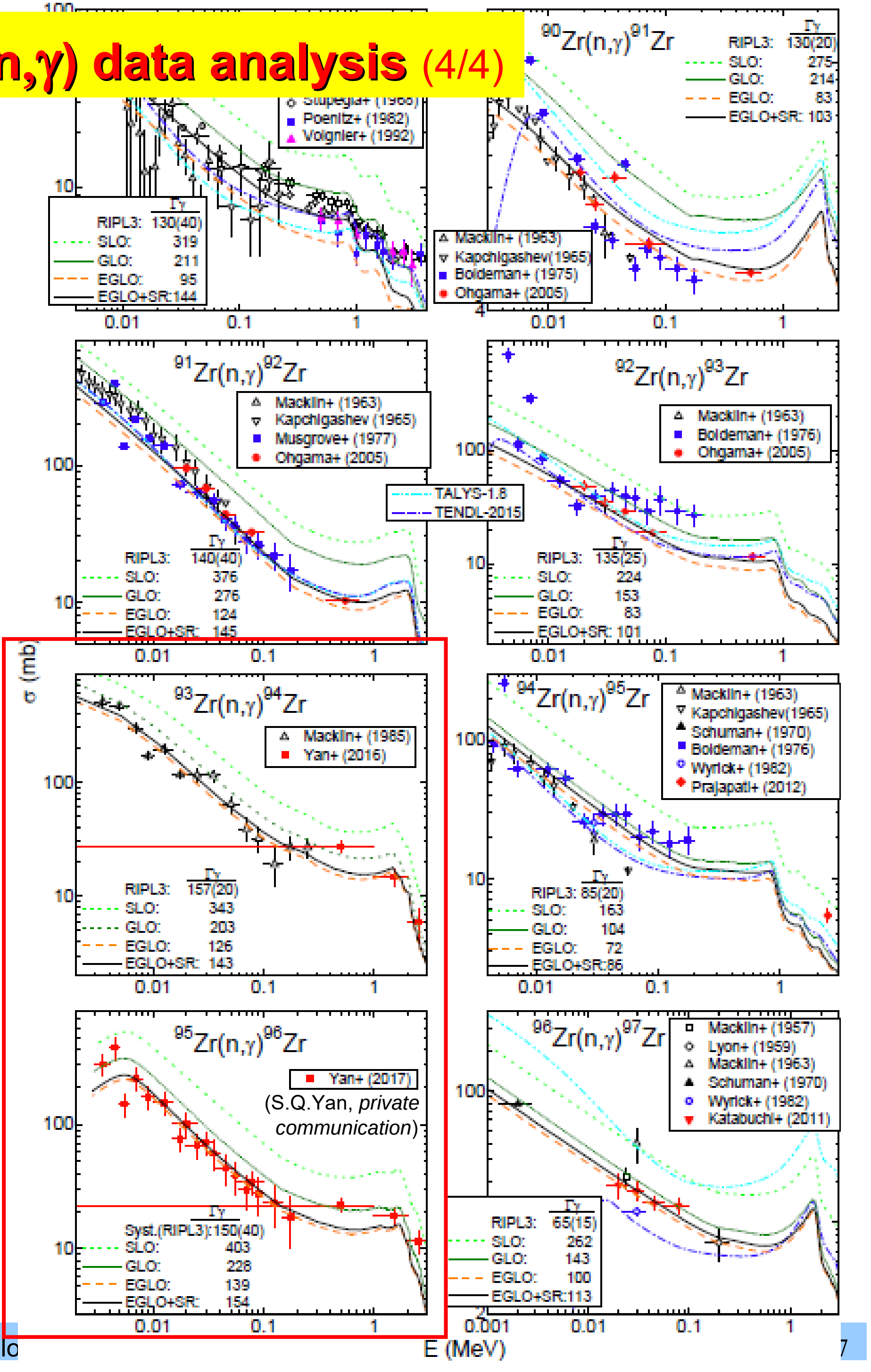




The same IP

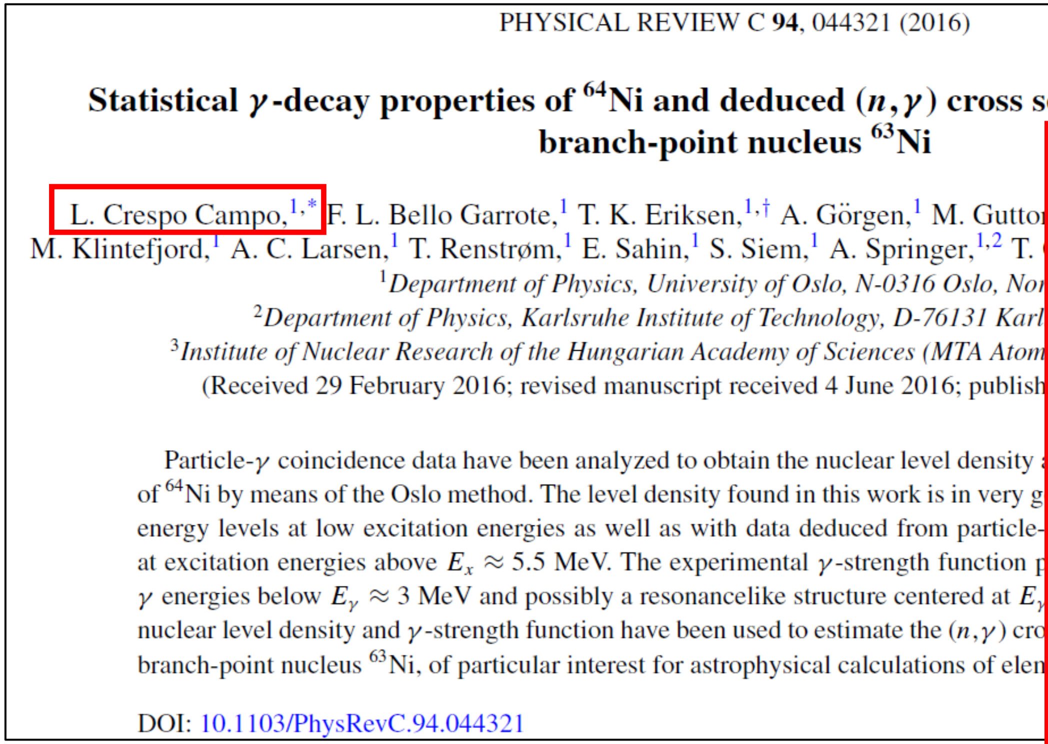
3. Recent (2017) ^{91,92}Zr RSF and ^{93,95}Zr (n,γ) data analysis (4/4)





***a posteriori* validation of the adopted RSF**

4. Consequent minor-addition of a parameter (keyword) in TALYS



PHYSICAL REVIEW C **94**, 044321 (2016)

Statistical γ-decay properties of ^{64}Ni and deduced (n,γ) cross section of the *s*-process branch-point nucleus ^{63}Ni

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Particle-γ coincidence data have been analyzed to obtain the nuclear level density
of ^{64}Ni by means of the Oslo method. The level density found in this work is in very g
energy levels at low excitation energies as well as with data deduced from particle-
at excitation energies above $E_x \approx 5.5$ MeV. The experimental γ-strength function p
γ energies below $E_\gamma \approx 3$ MeV and possibly a resonancelike structure centered at E_γ
nuclear level density and γ-strength function have been used to estimate the (n,γ) cro
branch-point nucleus ^{63}Ni, of particular interest for astrophysical calculations of elen

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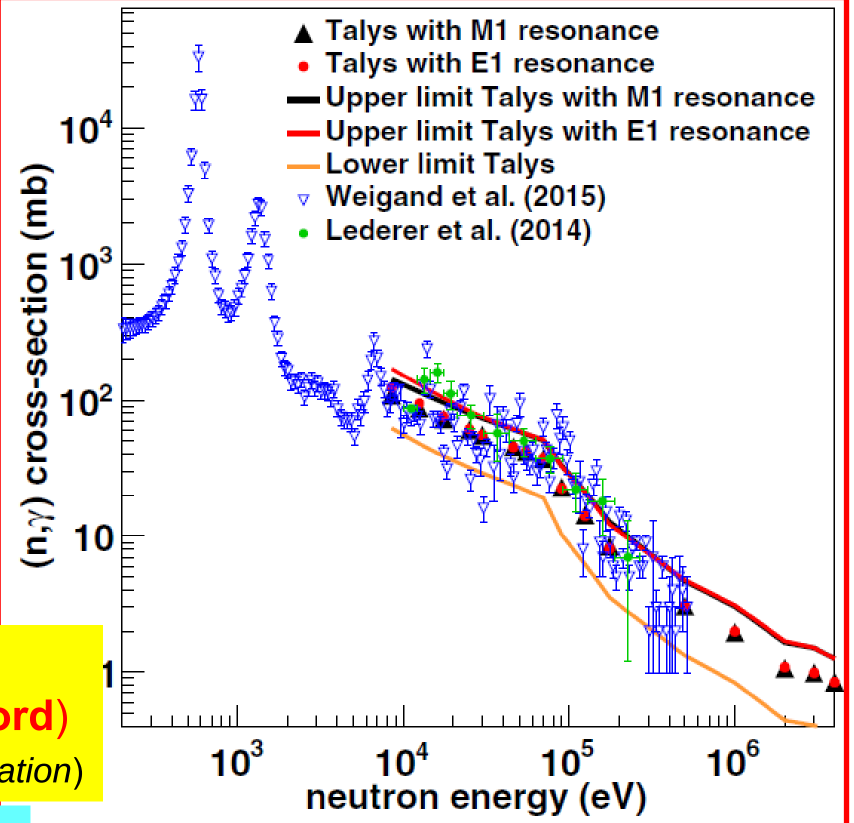


FIG. 6. The ^{63}Ni$(n,\gamma)^{64}$Ni cross section from Refs. [29] and [28]
e level density and
er and upper limits
systematic errors
he ^{64}Ni γ strength
V, the calculations
rely $M1$ character

Proposal in fstrength.f : Tnuc: *either* Eq. (4.71)
or input ct. value (**keyword**)
(L.C.Campo, *private communication*)

Proposal: *Default:* **strength 1** (for **any** incident particle)

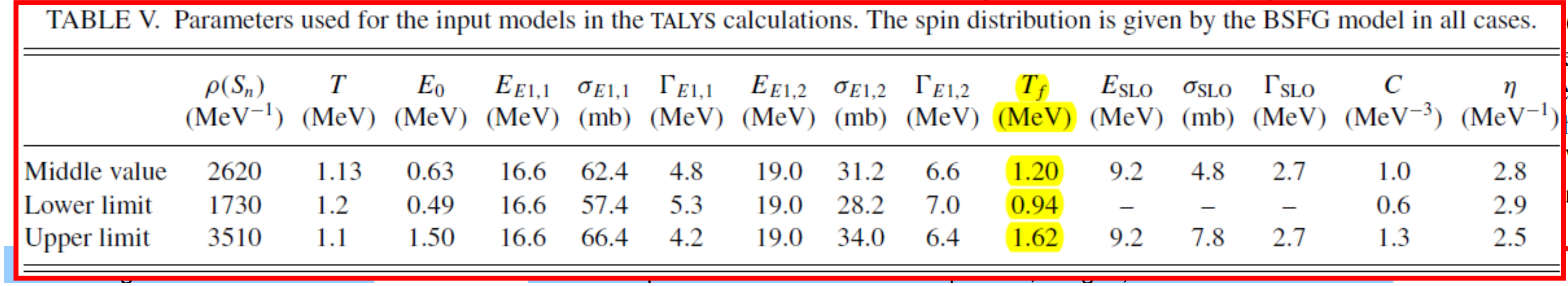
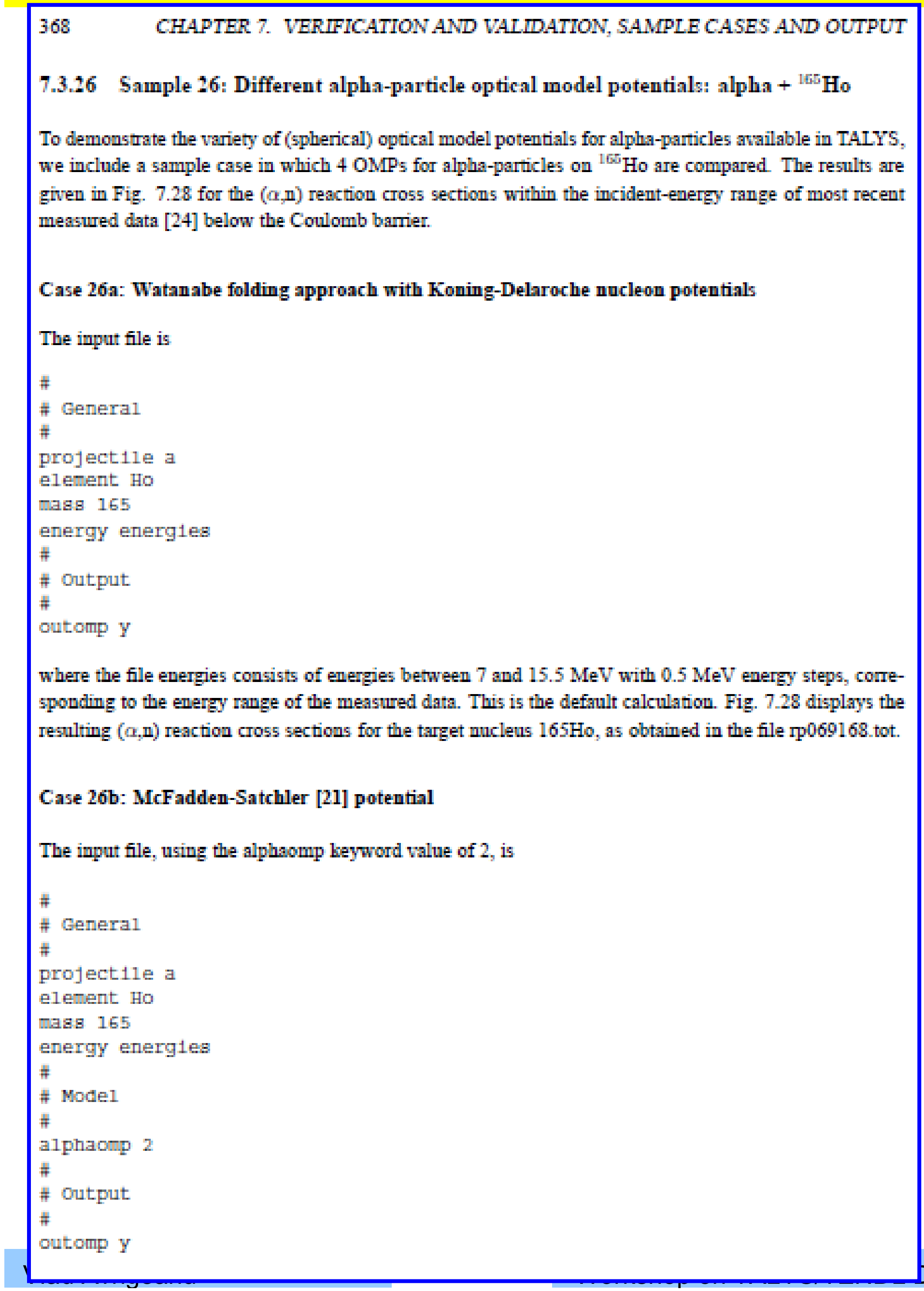


TABLE V. Parameters used for the input models in the TALYS calculations. The spin distribution is given by the BSFG model in all cases.

	$\rho(S_n)$ (MeV^{-1})	T (MeV)	E_0 (MeV)	$E_{E1,1}$ (MeV)	$\sigma_{E1,1}$ (mb)	$\Gamma_{E1,1}$ (MeV)	$E_{E1,2}$ (MeV)	$\sigma_{E1,2}$ (mb)	$\Gamma_{E1,2}$ (MeV)	T_f (MeV)	$E_{\rm SLO}$ (MeV)	$\sigma_{\rm SLO}$ (mb)	$\Gamma_{\rm SLO}$ (MeV)	C (MeV^{-3})	η (MeV^{-1})
Middle value	2620	1.13	0.63	16.6	62.4	4.8	19.0	31.2	6.6	1.20	9.2	4.8	2.7	1.0	2.8
Lower limit	1730	1.2	0.49	16.6	57.4	5.3	19.0	28.2	7.0	0.94	–	–	–	0.6	2.9
Upper limit	3510	1.1	1.50	16.6	66.4	4.2	19.0	34.0	6.4	1.62	9.2	7.8	2.7	1.3	2.5

5. Consequent better presentation of TALYS Sample Case 26 (1/2)



7.3.26 Sample 26: Different alpha-particle optical model potentials: alpha + ^{165}Ho

To demonstrate the variety of (spherical) optical model potentials for alpha-particles available in TALYS, we include a sample case in which 4 OMPs for alpha-particles on ^{165}Ho are compared. The results are given in Fig. 7.28 for the (α,n) reaction cross sections within the incident-energy range of most recent measured data [24] below the Coulomb barrier.

Case 26a: Watanabe folding approach with Koning-Delaroche nucleon potentials

The input file is

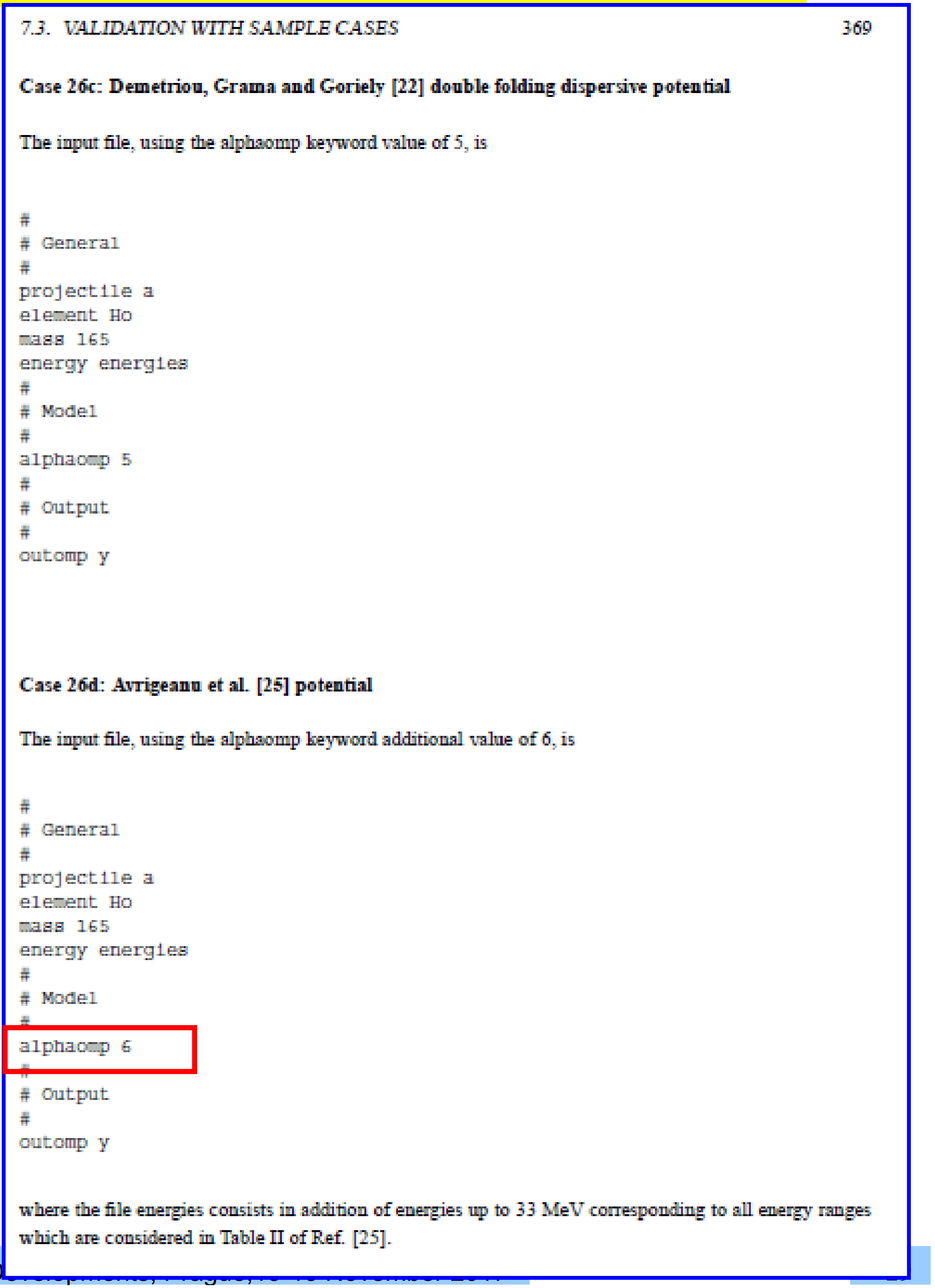
```
#
# General
#
projectile a
element Ho
mass 165
energy energies
#
# Output
#
outomp y
```

where the file energies consists of energies between 7 and 15.5 MeV with 0.5 MeV energy steps, corresponding to the energy range of the measured data. This is the default calculation. Fig. 7.28 displays the resulting (α,n) reaction cross sections for the target nucleus 165Ho, as obtained in the file rp069168.tot.

Case 26b: McFadden-Satchler [21] potential

The input file, using the alphaomp keyword value of 2, is

```
#
# General
#
projectile a
element Ho
mass 165
energy energies
#
# Model
#
alphaomp 2
#
# Output
#
outomp y
```



Case 26c: Demetriou, Grama and Goriely [22] double folding dispersive potential

The input file, using the alphaomp keyword value of 5, is

```
#
# General
#
projectile a
element Ho
mass 165
energy energies
#
# Model
#
alphaomp 5
#
# Output
#
outomp y
```

Case 26d: Avrigeanu et al. [25] potential

The input file, using the alphaomp keyword additional value of 6, is

```
#
# General
#
projectile a
element Ho
mass 165
energy energies
#
# Model
#
alphaomp 6
#
# Output
#
outomp y
```

where the file energies consists in addition of energies up to 33 MeV corresponding to all energy ranges which are considered in Table II of Ref. [25].

5. Consequent better presentation of TALYS Sample Case 26 (2/2)

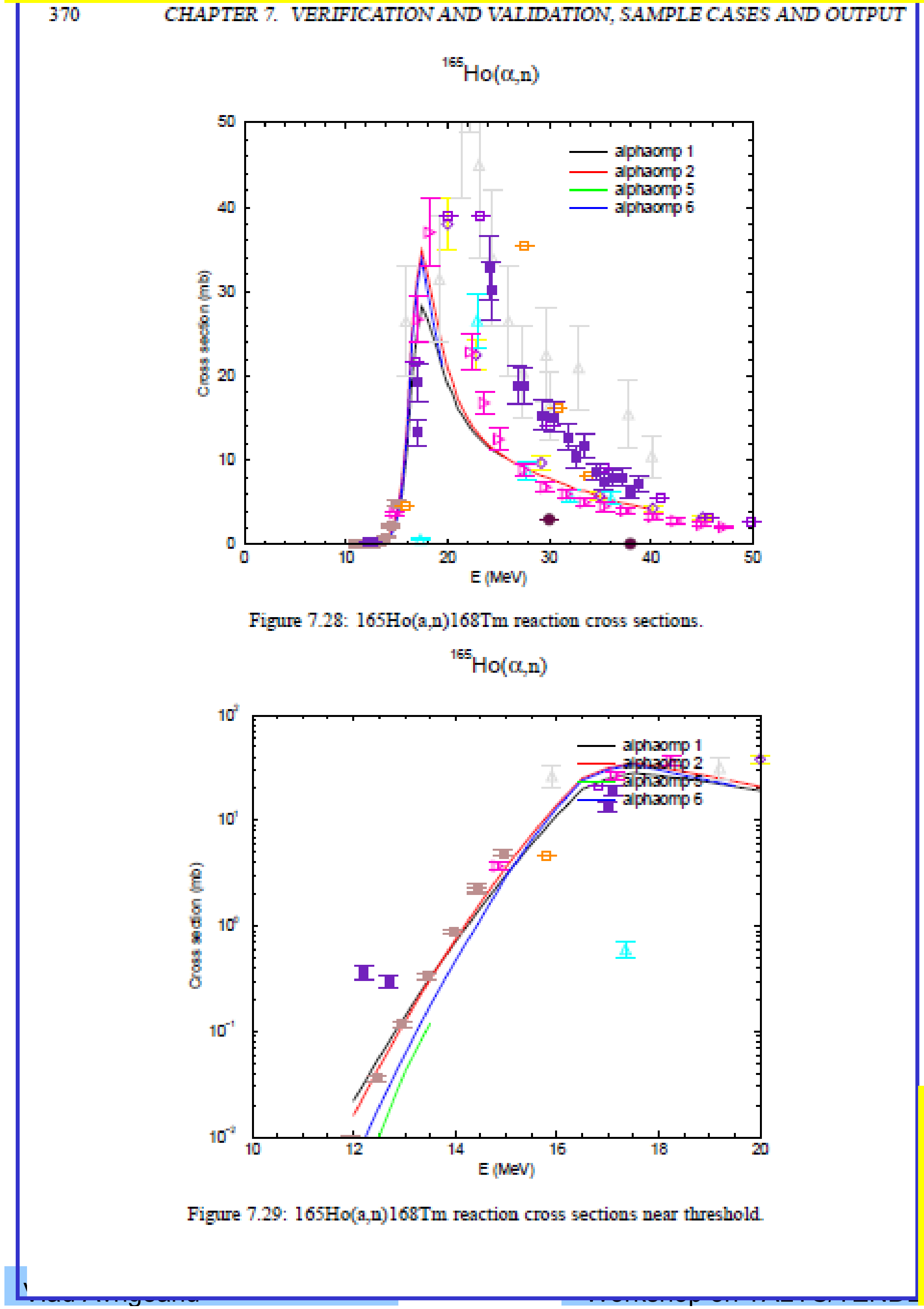

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Figure 7.28: 165Ho(a,n)168Tm reaction cross sections.

Figure 7.29: 165Ho(a,n)168Tm reaction cross sections near threshold.

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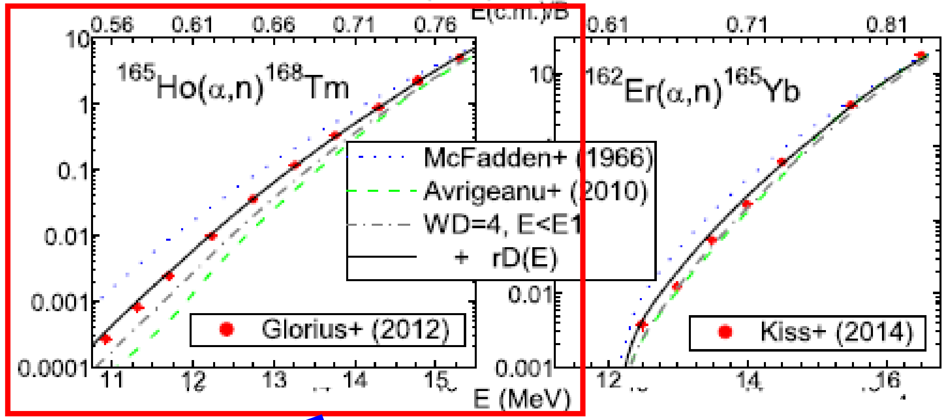

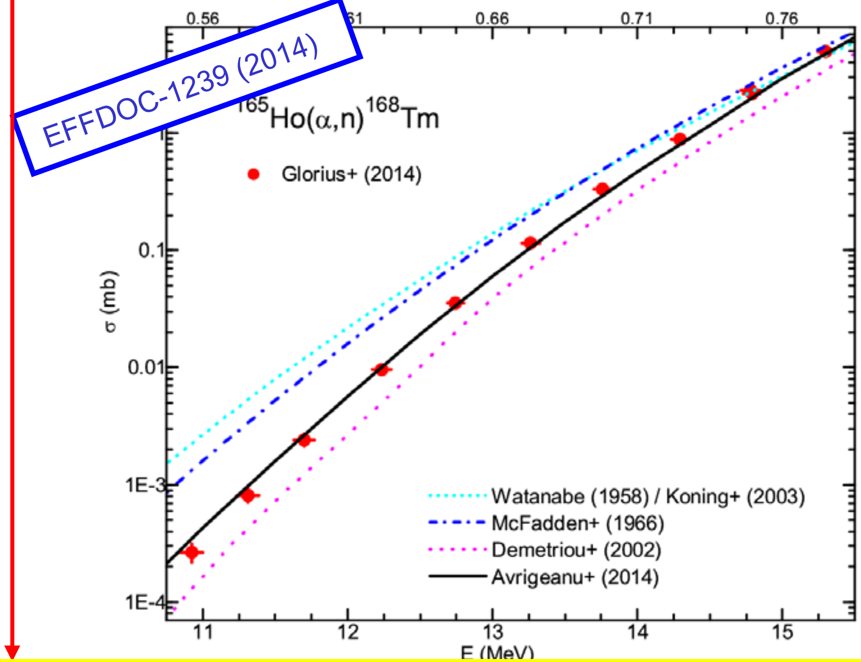
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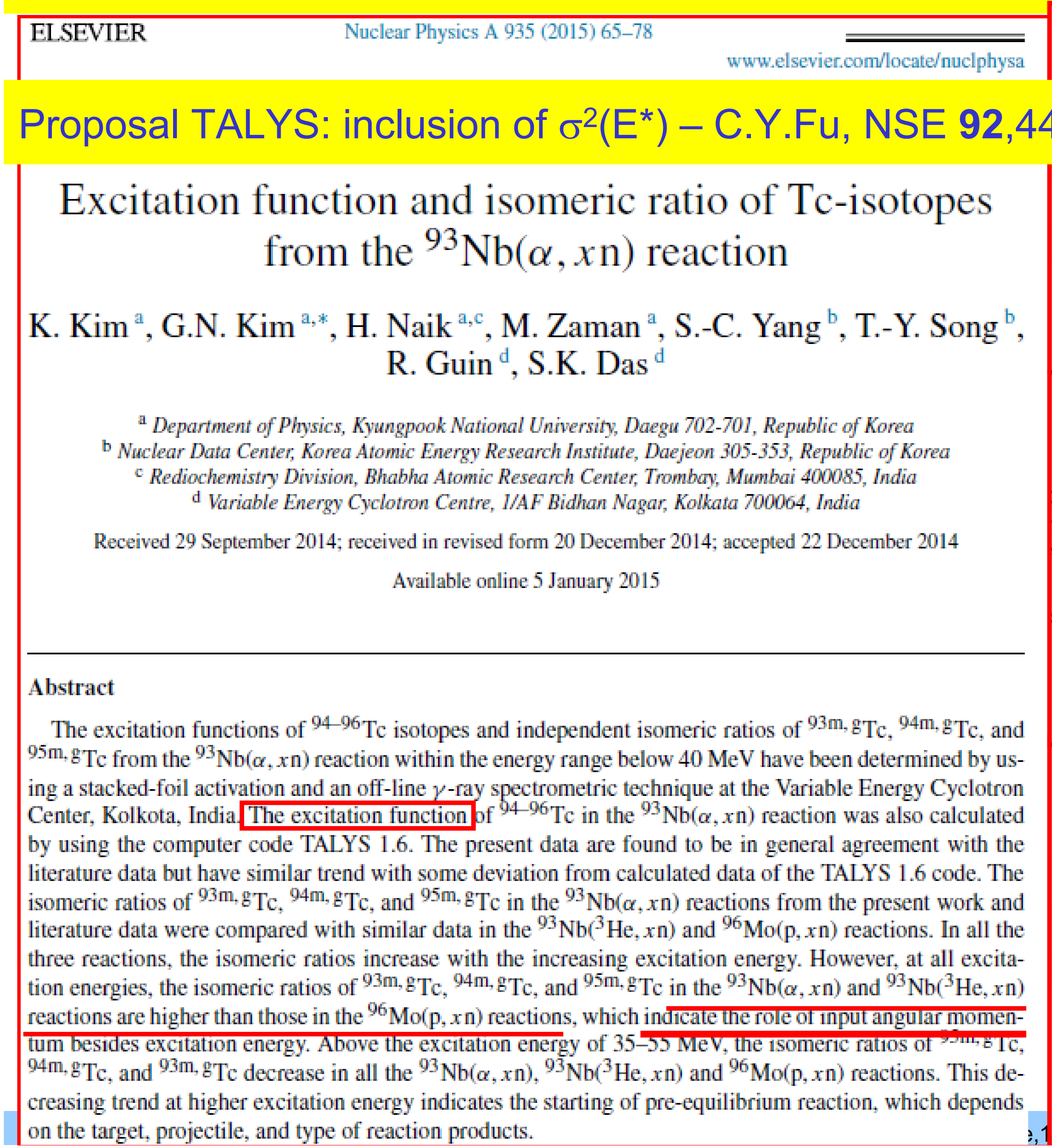
- E<B matter for α-particle OMP discusion
- 8 -> 11 data points [Glorius+ (2014)]
- ΔE matters as much as Δσ
- **strength 2** (*default*) turned out the case

6. TALYS within (α,xn) reaction analysis – proposal for $\sigma^2(E^*)$

Proposal TALYS: inclusion of $\sigma^2(E^*)$ – C.Y.Fu, NSE **92**,440(1986)



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Excitation function and isomeric ratio of Tc-isotopes from the ^{93}Nb(α, xn) reaction

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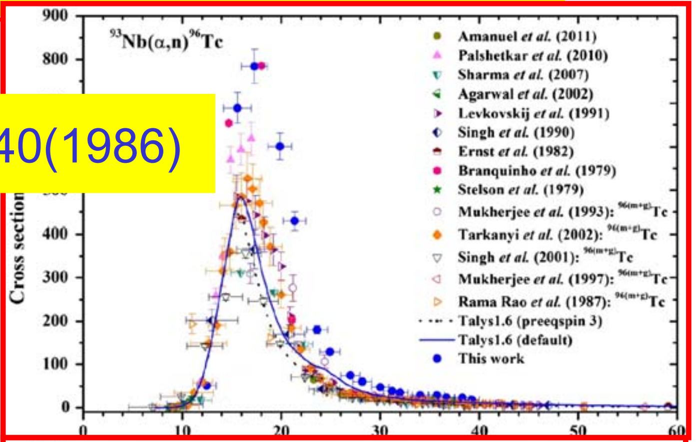
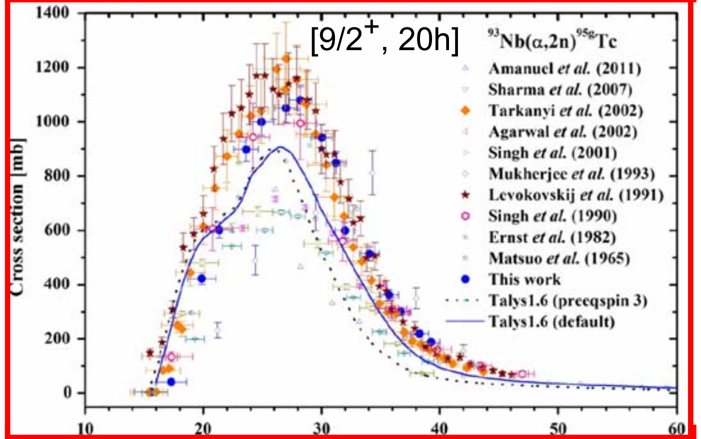
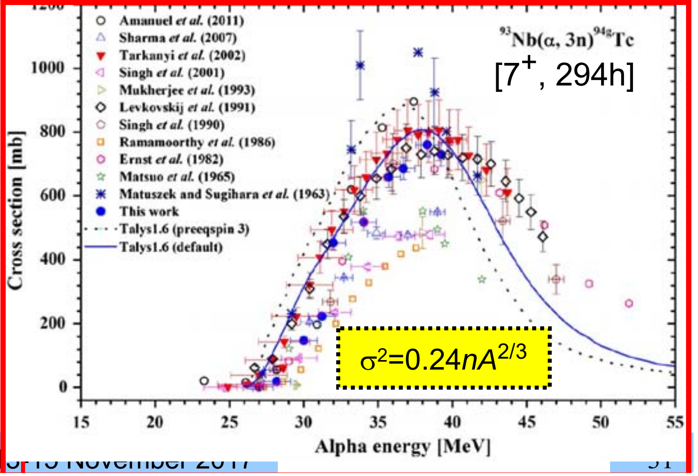
Abstract

The excitation functions of $^{94-96}$Tc isotopes and independent isomeric ratios of ^{93m,g}Tc, ^{94m,g}Tc, and ^{95m,g}Tc from the ^{93}Nb(α, xn) reaction within the energy range below 40 MeV have been determined by using a stacked-foil activation and an off-line γ-ray spectrometric technique at the Variable Energy Cyclotron Center, Kolkota, India. The excitation function of $^{94-96}$Tc in the ^{93}Nb(α, xn) reaction was also calculated by using the computer code TALYS 1.6. The present data are found to be in general agreement with the literature data but have similar trend with some deviation from calculated data of the TALYS 1.6 code. The isomeric ratios of ^{93m,g}Tc, ^{94m,g}Tc, and ^{95m,g}Tc in the ^{93}Nb(α, xn) reactions from the present work and literature data were compared with similar data in the ^{93}Nb(^{3}He, xn) and ^{96}Mo(p, xn) reactions. In all the three reactions, the isomeric ratios increase with the increasing excitation energy. However, at all excitation energies, the isomeric ratios of ^{93m,g}Tc, ^{94m,g}Tc, and ^{95m,g}Tc in the ^{93}Nb(α, xn) and ^{93}Nb(^{3}He, xn) reactions are higher than those in the ^{96}Mo(p, xn) reactions, which indicate the role of input angular momentum besides excitation energy. Above the excitation energy of 35–55 MeV, the isomeric ratios of ^{93m,g}Tc, ^{94m,g}Tc, and ^{93m,g}Tc decrease in all the ^{93}Nb(α, xn), ^{93}Nb(^{3}He, xn) and ^{96}Mo(p, xn) reactions. This decreasing trend at higher excitation energy indicates the starting of pre-equilibrium reaction, which depends on the target, projectile, and type of reaction products.





[9/2$^+$, 20h]

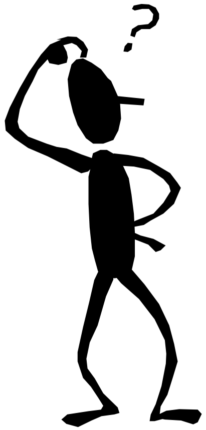


[7$^+$, 294h]

$\sigma^2 = 0.24nA^{2/3}$

7. Conclusions

- **TALYS replaced NON-SMOKER / MOST in (n,γ), (p,γ), (α,γ), (α,x) analysis**
- **Consistent results validate consistent analysis** vs **χ^2-based predictions**
  [NO fit / parameter change]
- **Proposed further inclusions** in **TALYS: EGLO+Tf=ct. , σ^2(E)**



Thank you for your attention !