F4E-2008-GRT-014 (ES-AC)
NUDATA_Files / Task 6

"EURATOM - MEdC Association Day" Meeting,
Iasi, July 2, 2010

Actual fusion technology needs alpha-particle reaction data analysis

(Improvement of parameters for nuclear model calculations suitable for neutron activation data)

Vlad Avrigeanu, Marilena Avrigeanu, Faustin L. Roman

"Horia Hulubei" National Institute for Physics & Nuclear Engineering, Bucharest, Romania

http://tandem.nipne.ro/~vavrig/, http://fp6.cordis.lu/fp6/partners/RCN 49105

1. Introduction: F4E-2008-GRT-014 (ES-AC) / Task 6

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Grant Proposal Form

Internal Proposal Ref. N°: F4E-2008-GRT-014 (ES-AC)-Action 1

Task 6

Task Title	Improvement of the parameters for nuclear model calculations suitable for neutron activation data in the medium mass region. Generation of cross section data up to 60 MeV for targets in the range from Ti to Ge.
Activity Type	R&D
Principle Applicant Responsible	IFIN HH

DESCRIPTION / SCOPE OF WORK (and role of beneficiary,ies)

1.) How will the scope be achieved

The work to be performed will consist of the following activities:

- Decide on range of targets to be studied, note that as part of previous TTMN-001 studies detailed analysis of some of the nuclides in the target range have already been carried out.
- Identify suitable experimental data to enable nuclear model parameters to be improved.
- Generate calculated cross sections using suitable model codes and compare with experiments, iterate as required.
- Report on new sets on model parameters and ensure that information is fed back to the RIPL database.
- Generate final cross section files in a format suitable for use in a future EAF data file.

History – Project (F4E, ANCS) 1/3

- 14.08.2008: Call F4E-GRT-014 [http://fusionforenergy.europa.eu/Grants.htm]
- 22.08.2008: UKAEA (former EFDA Task TW(0-6)-TTMN-001 coordinator):
  - ask former partners (IFIN-HH) about a common proposal
- 01.09.2008: IFIN-HH: ask Euratom-MEdC opinion (get none)
- 02.10.2008: proposal submitted by UKAEA-led consortium (including IFIN-HH)
- 28.11.2008: F4E talk @ OECD/NEA Data Bank: F4E WP/procedures info
- 02.12.2008: IFIN-HH: ask Euratom-MEdC for IFIN-HH F4E-proposal take-over
  - no action …
- 21.04.2009: Kick-off Meeting (proposal approval: contract until 20.05.2010)
- 31.08.2009: F4E contract signature – note UKAEA – note partners (..IFIN-HH…)
- 03.11.2009: IFIN-HH 2 ANCS: PN-II-CP-M_III project submission
- 25.11.2009: ANCS 2 IFIN-HH: no money, look for 2010 budget approval
- 19.02.2010: Call F4E-GRT-056 [http://fusionforenergy.europa.eu/Grants.htm] – deadline: 12.04.2010
- 27.02.2010: CCFE (UKAEA) ask partners (..IFIN-HH..) about a new proposal
- 05.03.2010: IFIN-HH 2 ANCS: PN-II-CP-M_III proj. resub.; ask re: F4E-GRT-056
- 29.03.2010: IFIN-HH 2 ANCS: PN-II-CP-M_III proj. resub.; ask re: F4E-GRT-056
- 12.04.2010: ANCS 2 IFIN-HH: ask doc from Euratom-MEdC; advice to use PN !
- 12.04.2010: F4E-GRT-056 proposal submitted by CCFE-led consortium
- 16.06.2010: F4E-GRT-014 Closure Meeting (Background/Foreground IPR)

History - F4E, RO(ANCS, Euratom-MEdC) 2/3

http://fusionforenergy.europa.eu/documents/news_events/annual_report/F4E_Annual_Report2008.pdf

- 27.03.2007: Decision 2007/198/Euratom of 27 March 2007: F4E establishment
- 19.04.2007: Decision 2007/198/Euratom of 27 March 2007: entered into force
- 28.06.2007: 1st Governing Board Meeting (..Th. Ionescu-Bujor, Prof. Gh. Popa …)

[2/3 EURATOM-MedC Association Steering Committee]

- 17.07.2007: 2nd Governing Board Meeting: first F4E Director appointment
- 01.10.2007: first F4E Director took up his duties
- 01.11.2007: first F4E staff members appointment
- 2007-2008: 8 Governing Board Meetings

History – F4E, ANCS, EFDA

WORK PROGRAMME 2010

Euratom for Nuclear Research and Training Activities[1]

(European Commission C(2009) 5946 of 30 July 2009)

II.1 Fusion Energy

The content of the Fusion Energy programme has several facets covering the full range of funding schemes. These are:

– ***European Joint Undertaking for ITER and the Development of Fusion Energy ('Fusion for Energy')*** to discharge the responsibilities of the European Union towards the ITER Agreement and the Broader Approach activities;

– ***Contracts of Association*** which are bilateral contracts between research organisations or bodies in all the Member States or Euratom Fully Associated Third States and the Community. Some Contracts of Association will include activities of research institutes in more than one Member State (transnational research Units);

– ***European Fusion Development Agreement*** between all the Associates (signatories of a Contract of Association) to fully exploit the JET Facilities and possibly other fusion devices and coordinate the research activities, including training, carried out under the Contract of Association;

2. Project Results

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FOREGROUND DECLARATION

CONTRACT INFORMATION	
Action title:	Improvement of Nuclear data, development of tools and experiments/validation in support of ITER activities [NUDATA_FILES] – Grant F4E-2008-GRT-014 (ES-AC)
Action type (Brief description of the grant):	Improvement of the parameters for nuclear model calculations suitable for neutron activation data in the medium mass region.
Contact person	Dr. Vlad Avrigeanu, Assoc. Prof. at Bucharest University, IFIN-HH Scientific Director
Contractor (Full name of the company/association)	"Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), P.O.Box MG-6, 76900 Bucharest, Romania
Deliverables (Please include a brief list with the items included in the foreground declaration)	• 2 journal papers (Phys. Rev. C) • 2 ND2010 conference papers (eventually J. Kor. Nucl. Soc. papers) • 1 database
I, declare the information contained in this form is correct to the best of my knowledge.	**IMPORTANT NOTICE:** Foreground refers to any Information and Intellectual Property whether or not protectable generated in the course of the execution of the Contract including subcontracting. The present form is to be used to report on the foreground produced as a result of the contract. A printed copy of this declaration shall be attached by the contractor/beneficiary to the progress reports and to the final report. Further information and guidelines on how to fill in this format are provided in the last section of this annex. If needed, please add further pages to include any relevant Intellectual Property. ***In case that no foreground has been generated**, please include a statement in this respect in the box below and sign the form. In that case only the 1st page needs to be attached to the progress or final report*
Name: Dr. Vlad Avrigeanu, Assoc. Prof. at Bucharest University IFIN-HH Scientific Director	
Signature and date:	

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FOREGROUND DECLARATION

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Short title of the work:	*Additional α-particle optical potential tests below the Coulomb barrier*	
Description: (short abstract of the work)	New results of (alpha,gamma) and (alpha,n) reaction cross section measurements close to the reaction thresholds support the setting up of recent parameters of the alpha-particle optical model potential (OMP) below the Coulomb barrier. Particular features of the alpha-particle optical potential at energies below the Coulomb barrier explain the failure of using the OMP parameters obtained by analysis of only alpha-particle elastic scattering at higher energies.	
Is this work necessary to carry out the contract? (circle the appropriate answer)	**NO** **(YES)**	Explain: The peer review (by RIPL community) is the condition of verification for the milestones 1 and 3 of the task No. 6.
Are there are any related rights involved, such as of producers, publishers, broadcasters, etc? Please provide details		
Publications:	Phys. Rev. C **81**, 038801 (2010)	
Name of creator(s):	M. Avrigeanu and V. Avrigeanu	
Ownership of the work:	"Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), P.O.Box MG-6, 76900 Bucharest, Romania	

Legal Deposit?	No	Name of notary or collecting society :	Date of deposit:	Registration Number:
If yes				

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FOREGROUND DECLARATION

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Short title of the work:		*α-particle nuclear surface absorption below the Coulomb barrier on heavy nuclei*		
Description: (short abstract of the work)		An analysis of all available alpha-particle induced reaction cross sections on nuclei within the mass number range 121≤A≤197, below the Coulomb barrier, is carried out. This analysis leads to an optical potential which describes the alpha-particle elastic scattering at low energies as well, and both elastic-scattering and reaction data for 45≤A≤124. The energy dependence of the surface imaginary potential depth is proved to be essential for the understanding of the alpha-particle interaction behavior below the Coulomb barrier.		
Is this work necessary to carry out the contract? (circle the appropriate answer)		**NO** **(YES)**	Explain: The peer review (by RIPL community) is the condition of verification for the milestones 1 and 3 of the task No. 6. This work represents the Deliverable No. 12.	
Are there are any related rights involved, such as of producers, publishers, broadcasters, etc? Please provide details				
Publications:		Phys. Rev. C, accepted for publication, June 24, 2010 (MS. No. LR12041C)		
Name of creator(s):		M. Avrigeanu and V. Avrigeanu		
Ownership of the work:		"Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), P.O.Box MG-6, 76900 Bucharest, Romania		
Legal Deposit?	No	Name of notary or collecting society :	Date of deposit:	Registration Number:
If yes				

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FOREGROUND DECLARATION

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Short title of the work:	*Key issues for consistent description of neutron-induced reactions on Cr isotopes*			
Description: (short abstract of the work)	The model inconsistency found within a former trial to describe unitary the (n,p) and (n,2n) reaction cross sections for the Cr isotopes, up to 20 MeV, is still actual. On the other hand, only half of the latest results obtained in activation experiments on Cr using a white-spectrum neutron field and quasi-monoenergetic neutrons below 35 MeV has been in agreement with the EAF-2005 library. Thus, both global and local approaches are used within this work for a consistent analysis of all activation data for the Cr isotopes, available up to 40 MeV.			
Is this work necessary to carry out the contract? (circle the appropriate answer)	**NO** **(YES)**	Explain: This work concerns additional analysis of improvement of the parameters for nuclear model calculations suitable for neutron activation data in the medium mass region – the Task 6 objective.		
Are there are any related rights involved, such as of producers, publishers, broadcasters, etc? Please provide details				
Publications:	ND2010#1176, ND2010 proceedings and NET (J. Kor. Nucl. Soc.)			
Name of creator(s):	M. Avrigeanu and V. Avrigeanu			
Ownership of the work:	"Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), P.O.Box MG-6, 76900 Bucharest, Romania			
Legal Deposit?	No	Name of notary or collecting society :	Date of deposit:	Registration Number:
If yes				

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FOREGROUND DECLARATION

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Short title of the work:	*Analysis of deuteron breakup and induced activation on medium nuclei*		
Description: (short abstract of the work)	An extended analysis of the nuclear reaction mechanisms involved within deuterons interaction with ^{59}Co and ^{93}Nb is presented. First, the available elastic-scattering data analysis provided the optical potential for reaction cross sections calculations. An increased effort has been devoted to the breakup mechanism, both the elastic breakup and the breakup fusion contributions to the different activation cross sections being carefully considered. Next, the direct reaction contributions, namely the stripping and pick-up reaction cross sections have been calculated. The overall agreement between the measured and calculated deuteron activation cross sections proves the correctness of nuclear mechanisms account.		
Is this work necessary to carry out the contract? (circle the appropriate answer)	**NO** **(YES)**	Explain: This work makes use of results obtained under this task and aims to provide a sound basis for execution of the Task 5.2 of F4E-GRT-056-1.	
Are there are any related rights involved, such as of producers, publishers, broadcasters, etc? Please provide details			
Publications:	ND2010#1245, ND2010 proceedings and NET (J. Kor. Nucl. Soc.)		
Name of creator(s):	M. Avrigeanu and V. Avrigeanu		
Ownership of the work:	"Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), P.O.Box MG-6, 76900 Bucharest, Romania		
Legal Deposit?	No	Name of notary or collecting society :	Date of deposit: / Registration Number:
If yes			

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FOREGROUND DECLARATION

SOFTWARE/DATABASE

Short title of the work: *The OMP parameter forms and values for 76 target nuclei which were actually involved within the elastic-scattering and reaction data analysis.*
Information for protection
- ROP2010MA.for: source code, with computing and input details as former comments - ROP2010MA.in: input data sample file, for OMP calculations for 76 target nuclei - ROP2010MAza: output file corresponding to the above-mentioned input data file - ROP2010MAza_NDS.dat: the records from the output file, provided to NDS/IAEA
Is this software/database necessary to carry out the contract? ___ X__Yes _____No This work represents the Deliverable No. 6.
What problems of the user/user groups described above does your software/database solve? There are provided the following results within three sections for a given target nucleus, namely (a) particular energy ranges for various OMP parameters energy dependence, for the use within any computer code based on SCAT2 subroutine; (b) the OMP parameters for the given target nucleus, in tabular form and steps of 1 MeV, for the use within TALYS code; (c) the OMP parameters for the given target nucleus, in the RIPL-2 format, for the use within EMPIRE-2 code as well as any RIPL user, provided to NDS/IAEA (http://www-nds.iaea.org/RIPL-3/optical/om-summary/om-parameter-u.dat, 'iref'=9603-9678)
Describe the unique features of the software/database over other software that may be either on the market or is currently being used by others. These OMP describes the alpha-particle elastic scattering at low energies as well as elastic-scattering and reaction data for $45 \leq A \leq 209$.
If known, name and describe the closest known software/database that performs or provides data or information that is similar to what is being disclosed.

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If yes, list all third party sources (including open source and freeware):
Is the software/database a derivative work? _____Yes ___X_No
If yes, name the original software/database.
Has the author of the original work provided written authorization to create derivative works? _____Yes _____No.
If not, explain the steps being taken to obtain authorization.
Disclosures and Background Information for patentable software
For software that may be patentable (i.e. it must be associated with specific hardware in order to produce a technical result), it is important to identify any disclosures of the software that may have been made or will be made in the future. Disclosures may affect patentability.
Please identify any disclosures, of the software that have been made or are ready to be made. Include and attach any overheads or materials used in oral presentations, as well as any journal publications, posters, abstract submissions, and the like. Also, identify all those individuals to whom source code has been distributed (if any).
Are laboratory records pertaining to the software available? If so, give location.
Are there any known related patents? If so, please list.
List the most relevant articles, journals, or abstracts of other authors. See: http://www-nds.iaea.org/RIPL-2/optical/om-data/om-parameter.readme

3. Conclusions

•Achievements

List of Milestones				
No.	**Name**	**Responsible beneficiary (short name)**	**Means of verification**	**Expected date (month)**
1	Improvement of parameters	IFIN HH	Peer review (by RIPL community)	6 [EFFDOC-1081, Nov. 2009] [Submtd. PRC, 7 April 2010]
2	Generation of files	IFIN HH	Testing by UKAEA	10 [To CCFE, 14 April 2010] [To NDS/IAEA]
3	Final report	IFIN HH	Peer review	12 [To CCFE, 14 April 2010]

•F4E-2008-GRT-06 (ES-AC) / Task 5a further work:

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Annex B

DMS #	F4E_D_N10783		
Call #	F4E-2010-GRT-056		
Page	7 / 12	Rev.	00.0

– Task 5.1. Systematic analysis of the optical model potential of incident alpha-particles for target nuclei with the atomic mass number A=40-209 will be used. It will be based on both microscopical and phenomenological real optical potentials, for the suitable involvement within the emission channels. Consistent analysis will be performed and latest measurements of alpha-emission fast-neutron induced reaction cross sections will be taken into account.

4. Annex. Project work: Nuclear Model Calculations

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)

- **Coupled Reaction Channel (CRC)**
  FRESCO-2003 [I.J. Thompson]

*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*

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

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

4.1 Former results basis: α-particle OMP @ E<50 MeV, A<120 (1/3)

Atomic Data and Nuclear Data Tables 95 (2009) 501–532

Contents lists available at ScienceDirect

Atomic Data and Nuclear Data Tables

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

Complementary optical-potential analysis of α-particle elastic scattering and induced reactions at low energies

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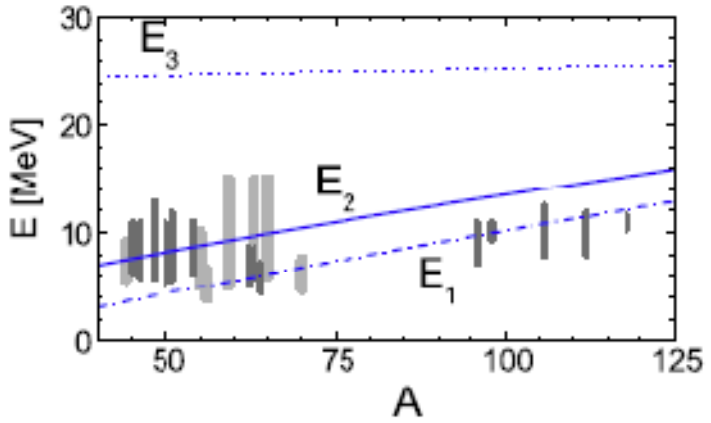
[c] Hahn-Meitner-Institut, Glienicker Strasse 100, 14109 Berlin, Germany

ARTICLE INFO

Article history:
Available online 25 March 2009

ABSTRACT

A previously derived semi
scattering on $A \sim 100$ nuc
and energies from ~13 t
semi-microscopic optical
scopic real potential, and
regional parameter set fo
also obtained for nuclei w
ment of (α,γ), (α,n), and
dent energies below ~12
surface imaginary potenti
description of these data,
well both the low-energy



Graph 16. (Color online) The energies E_1 (dash-dotted curve) below which the imaginary potential depth $W_D = 4$ MeV, E_2 (solid curve) corresponding to $0.9B_C$, and E_3 (dotted curve), at which the present RCP parameters change their energy dependences, versus the target nuclei atomic mass number, and the energy ranges of the (α, x) reaction data formerly analyzed in the present work (thin vertical bars) as well as involved within the additional check of the ROP (thick bars). The mass-dependences corresponding to nuclei with a nuclear asymmetry $(N-Z)/A$ value of 0.1 are shown, while the complete formulae of the energies E_1, E_2, and E_3 are given in Table 3.

Former results basis: α-particle OMP @ E<50 MeV , A<120 (2/3)

α-particle optical potential tests below the Coulomb barrier

M. Avrigeanu and V. Avrigeanu*
"Horia Hulubei" National Institute for Physics and Nuclear Engineering, P. O. Box M
(Received 4 November 2008; revised manuscript received 30 December 2008

The results of two recent papers concerning (α,γ) and (α,n) reaction cross
thresholds are discussed with regard to predictions of a recent α-particle regio
that the new measured cross sections are rather well described especially for t
Particular features of the α-particle optical potential at energies below the Coulon
former regional potential obtained by analysis of α-particle elastic scattering alo
limitations of statistical model calculations for minor reaction channels are also

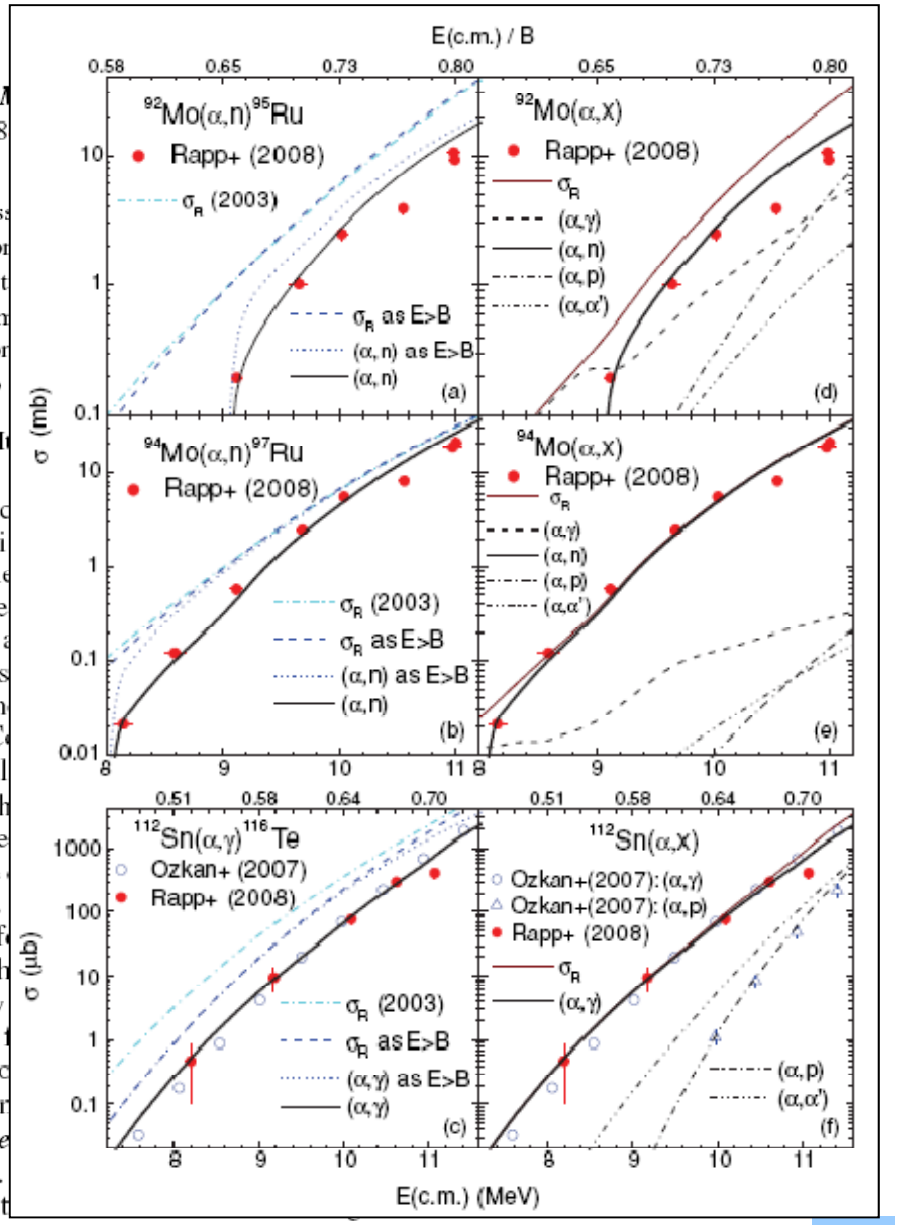
DOI: 10.1103/PhysRevC.79.027601 PACS number(s): 24.10.H

I. Motivation. Two recent studies of (α,n) reactions on ^{92,94}Mo isotopes and α capture on ^{112}Sn [1] and ^{117}Sn [2] were also motivated by the still poor knowledge of the α-particle optical model potential (OMP) below the Coulomb barrier. Thus Rapp *et al.* [1] performed useful comparisons of the new measured data and statistical model calculations with different optical potentials, including a former regional parameter set [3] established by analysis of the α-particle elastic scattering alone. Their results emphasized either a data overestimation by a factor of 2 or an underestimation by a similar factor. On the other hand, additional limitations of the OMP parameters, the more recent being again that of Ref. [3], were found below the Coulomb barrier and considered typical for the available global OM parametrizations [2]. We provide an additional account of the new measured cross sections [1,2] by means of a recent optical potential [4] to check whether it also describes these data.

In the first place, we think it is important to emphasize the particular precondition and aims of our former optical potential [3] that was used in Refs. [1,2]. First, we had focused on two main questions that are still open, namely, the OMP parameter sets obtained from α-particle elastic scattering at high energies (E_α > 80 MeV), which describe

the entrance/exit c
Basically, the regi
tirely on α-particle
$A \sim 50$–120 nucle
Then, an ultimate
(α,p) reaction cross
^{45}Sc to ^{118}Sn and in
out. Because the C
measurements at l
cross sections with
way to validate the
potential. Thus, the
potential as well as
established by the f
be responsible for th
reaction data below
has been modified
obtain an optical po
energy α-particle-in

II. The (α,x) *re*
data of Rapp *et al.*
the results of statist
input parameter set [4,5] except the α-particle optical potential.



Former results basis: α-particle OMP @ E<50 MeV , A<120 (3/3)

PHYSICAL REVIEW C **81**, 038801 (2010)

Additional α-particle optical potential tests below the Coulomb barrier

M. Avrigeanu and V. Avrigeanu*

"Horia Hulubei" National Institute for Physics and Nuclear Enginee

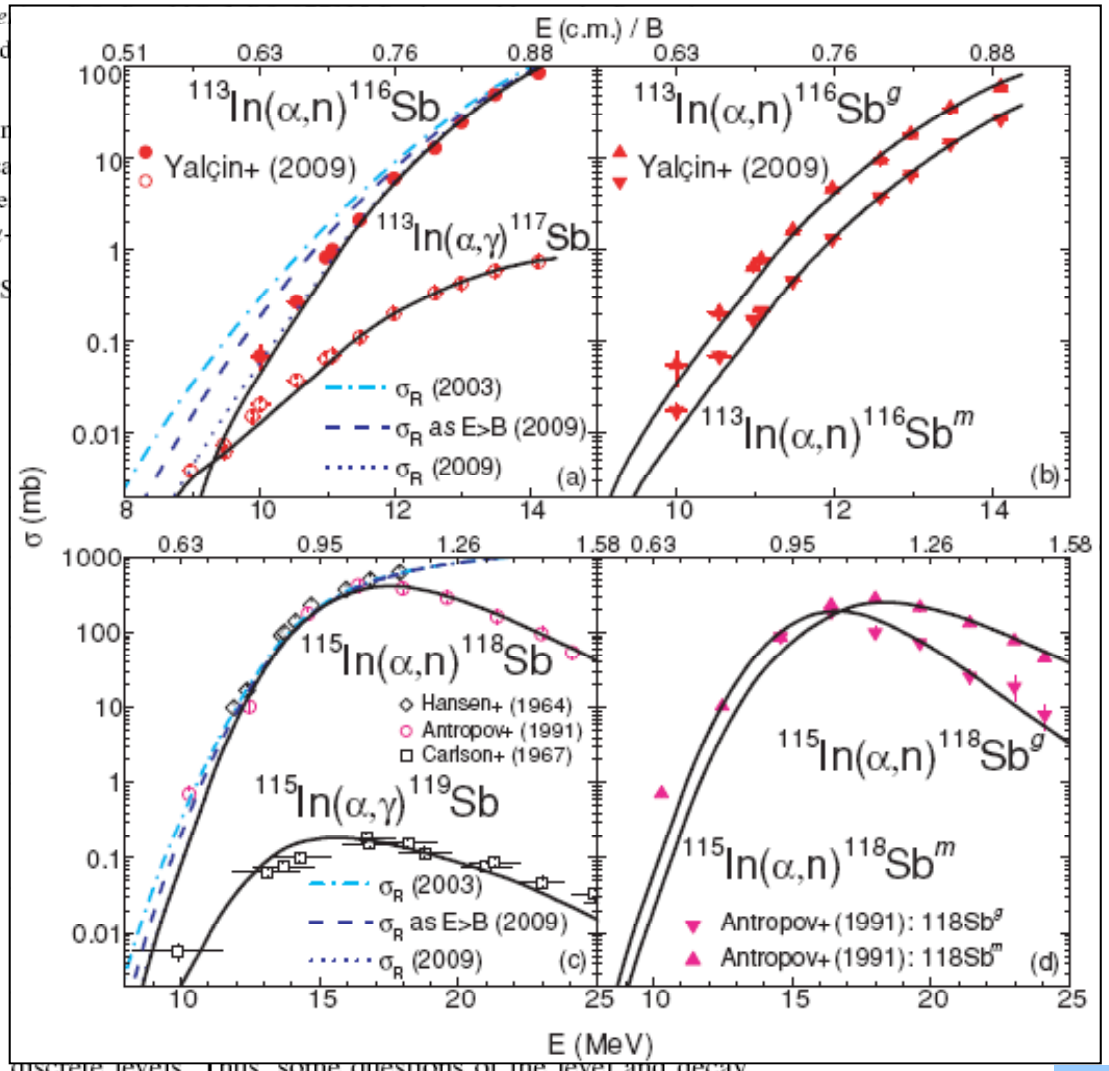
(Received 9 July 2009; revised manuscript received

New results of (α, γ) and (α, n) reaction cross section r
the setting up of recent parameters of the α-particle optica
Particular features of the α-particle optical potential at ene
using the OMP parameters obtained by analysis of only α-

DOI: 10.1103/PhysRevC.81.038801 PACS

Recent studies of (α, *n*) reactions on ^{92,94}Mo isotopes and α capture on ^{112}Sn [1] as well as both reactions on ^{113}In [2] were motivated by the still poor knowledge of the α-particle optical model potential (OMP) below the Coulomb barrier. Thus Rapp *et al.* [1] and Yalçin *et al.* [2] performed useful comparisons of the new measured data and statistical model calculations with different optical potentials, including a former regional parameter set [3] established by analysis of the α-particle elastic scattering, obviously at higher energies. Their results pointed out a large data overestimation especially by the above-mentioned OMP. However, we have already pointed out [4] that the potential of Ref. [3] is not suitable for the data analysis at incident energies $E_\alpha \approx 8$–12 MeV [1], outside the energy range involved for its setting up, while a proper account of these data is provided by its recent extension below the Coulomb barrier [5]. It is shown hereafter that a parallel case is that of the newly measured cross sections of (α, γ) and (α, *n*) reactions on ^{113}In [2] as well as of earlier similar data for the ^{115}In target nucleus.

Actually in Ref. [4] we only highlighted additionally the particular precondition and aims of our former optical potential [3] that was used in Refs. [1,2]. Thus, we started with the



discrete levels. Thus, some questions of the level and decay scheme of the ^{116}Sb nucleus could be related to this lower

4.2 New results: α-particle OMP @ E<50 MeV , A<200

α-particle nuclear surface absorption below the Coulomb barrier on heavy nuclei

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P.O. Box MG-6, 077125 Bucharest-Magurele, Romania
(Received 7 april 2010; accepted: 24 June 2010)

A first analysis of all available α-particle induced reaction cross sections on nuclei with the mass number 121≤A≤197, below the Coulomb barrier, leads to an optical potential which additionally describes the α-particle elastic scattering at low energies as well as similar data for 45≤A≤124. The energy dependence of the surface imaginary potential depth is proved to be essential for the understanding of the α–particle interactions behavior below the Coulomb barrier.

PACS numbers: 24.10.Ht,24.60.Dr,25.55.-e,27.60.+j

I. INTRODUCTION.

While the interactions of α-particles with nuclei have been of special interest from the earliest days of nuclear physics and a unified account of them was expected two decades ago [1], their reaction cross sections predicted below the Coulomb barrier can differ even nowadays by one order of magnitude. This happens because of the one-body complex optical potential describing the combined effect of the Coulomb and nuclear field, which is still uncertain at these energies.

Actually, the widely-used phenomenological optical model potential (OMP) parameters are derived mainly from the analysis of elastic-scattering angular distributions that are, on the other hand, ruled out below the Coulomb barrier B. The extrapolation to very-low energies of global potentials from higher energies has also been proved to be erroneous because of the strong change in the number of open reaction channels close to the Coulomb barrier. This fact leads to a strong energy dependence of the OMP imaginary part [2] which takes into account all non-elastic interactions in a global way and

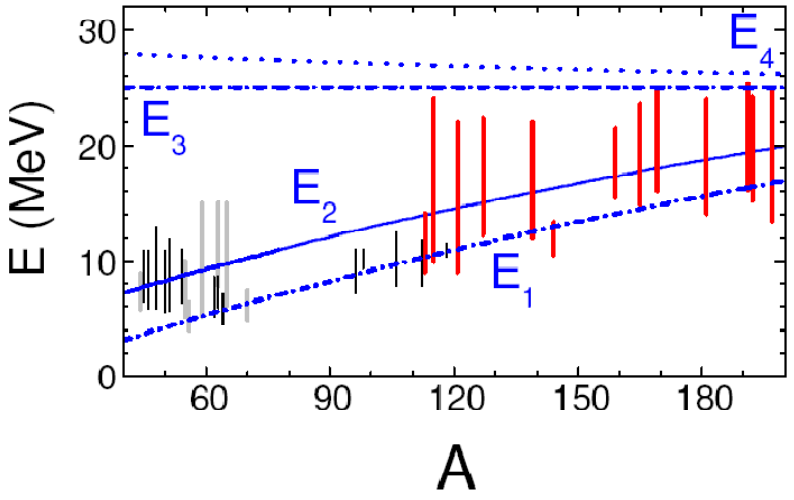
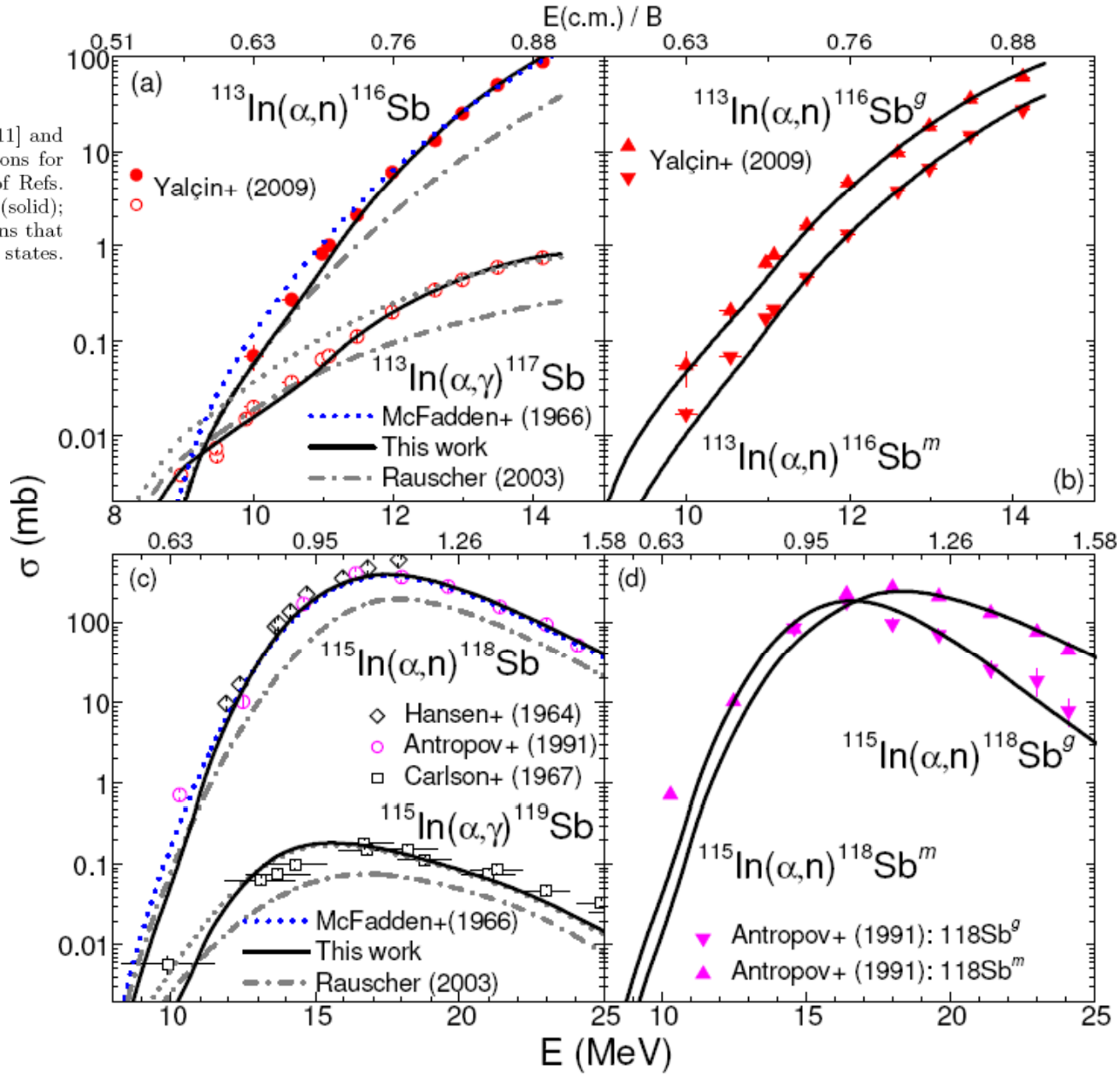


FIG. 1: (Color online) The A-dependence of energies E_1 (dash-dotted) below which the depth W_D is constant, E_2 (solid) corresponding to $0.9B$, E_3 (dashed) and E_4 (dotted) given in Table I, and the energy ranges (thick bars) of the (α, x) reaction data involved in this work for A>113 as well as formerly analyzed (thin bars) and additionally checked in Ref. [2] for A <90.

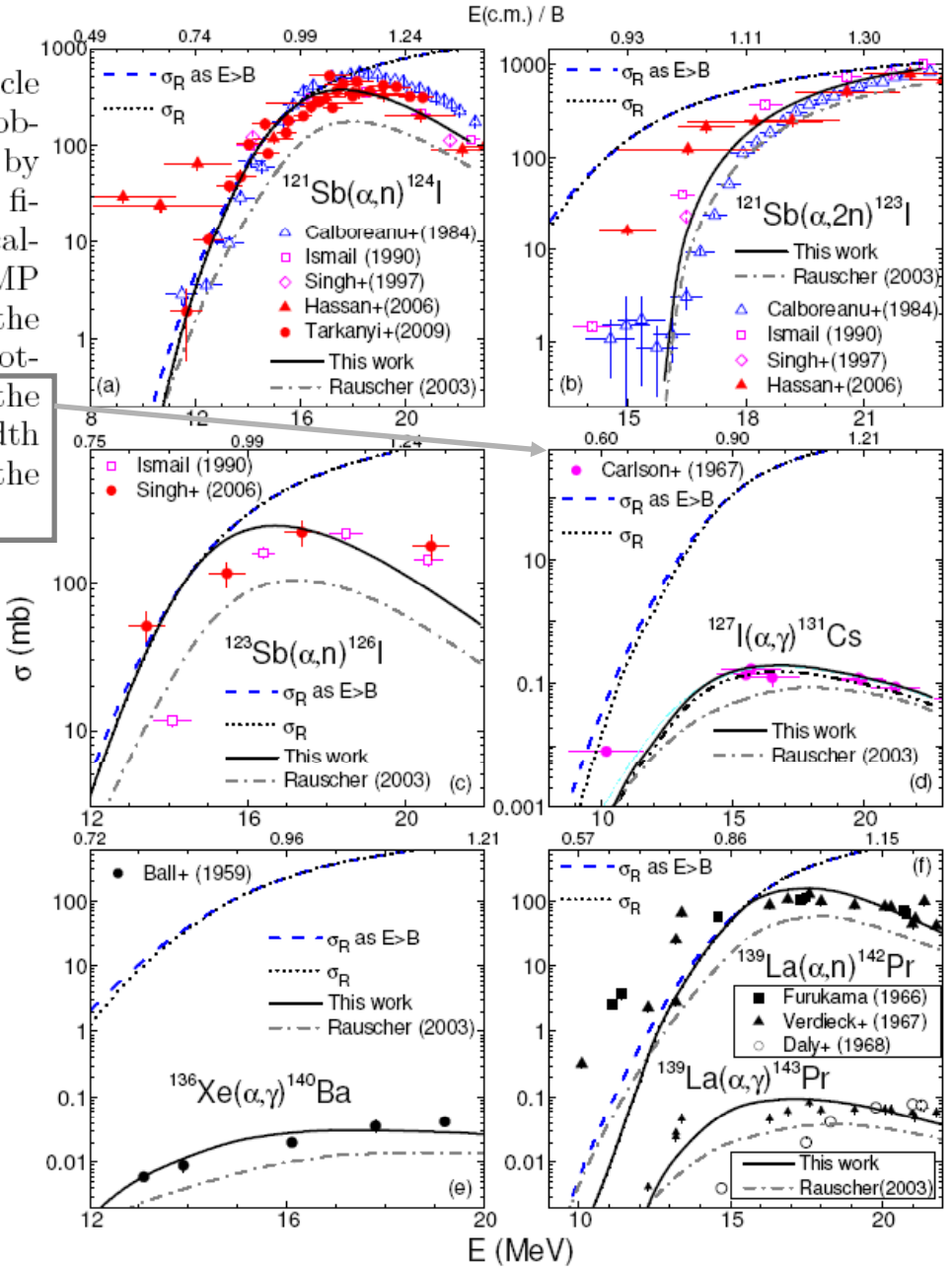
Comparison of α-particle OMPs for heavy nuclei (1/4)

FIG. 2: (Color online) Comparison of measured [7, 11] and (a,c) calculated (α,γ) and (α,n) reaction cross sections for the target nuclei ^{113,115}In nuclei, using the OMPs of Refs. [22] (dotted curves), [23] (dash-dotted), and Table I (solid); (b,d) the latter comparison for ^{113,115}In(α,n) reactions that produce the ground ^{116,118}Sb^{g} and isomeric ^{116,118}Sb^{m} states.



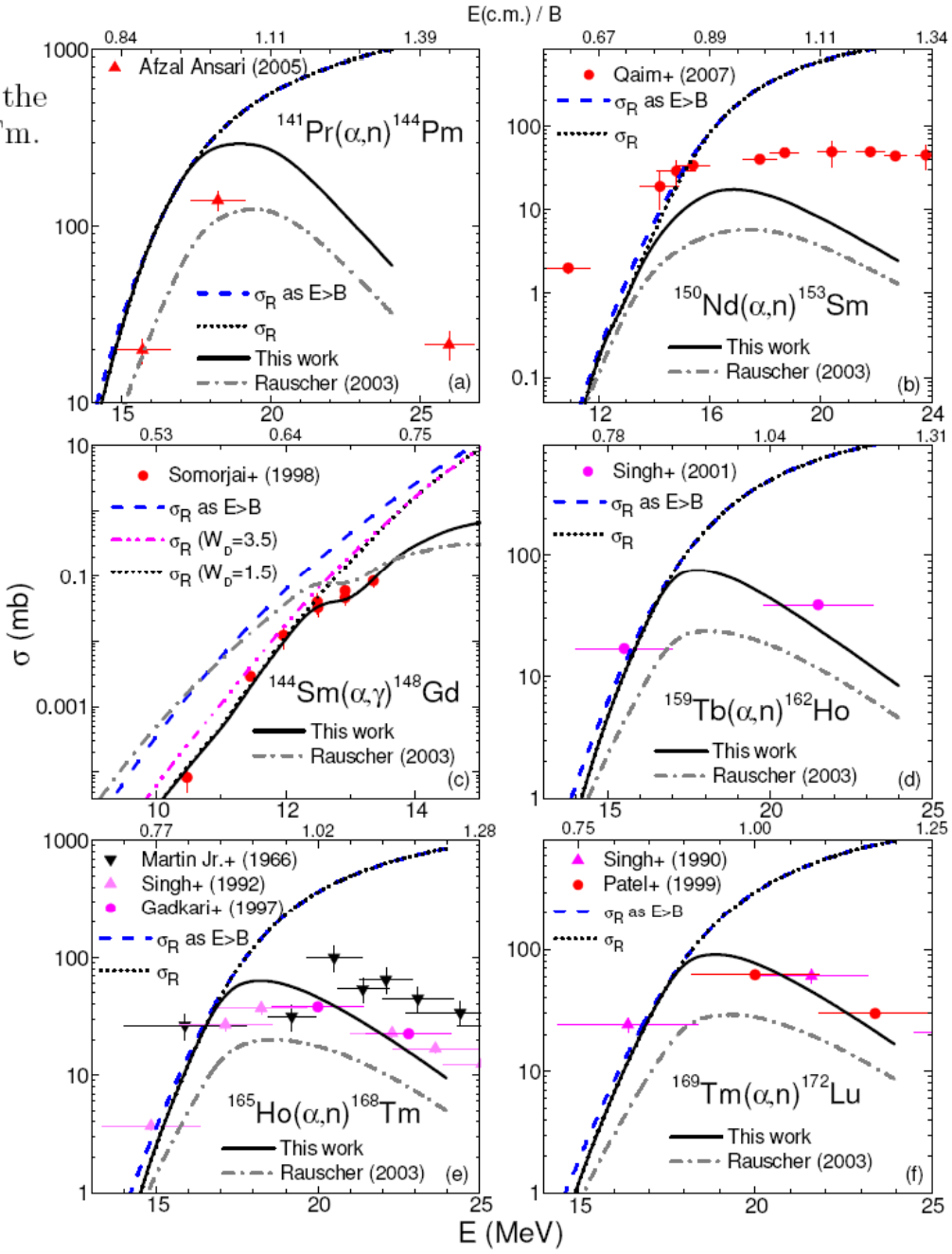
Comparison of α-particle OMPs for heavy nuclei (2/4)

FIG. 3: (Color online) Comparison of calculated α-particle total reaction cross sections using the OMP parameters obtained for energies above the energy limit E_2 (Table I) by elastic-scattering analysis alone (dashed curves), and their final values (dotted), as well as of the measured [11] and calculated cross sections of (α, x) reactions by using the OMP of this work (solid) and Rauscher [23] (dash-dotted) for the target nuclei ^{121,123}Sb, ^{127}I, ^{136}Xe, and ^{139}La. The dash-dot-dotted curve for the target nucleus ^{127}I (d) corresponds to the OMP of this work and a 20% decrease of the radiative width of s-wave neutron resonances used for normalization of the γ-ray strength function (see the text).



Comparison of α-particle OMPs for heavy nuclei (3/4)

FIG. 4: (Color online) The same as in Fig. 3 but for the target nuclei ^{141}Pr, ^{150}Nd, ^{144}Sm, ^{159}Tb, ^{165}Ho, and ^{169}Tm.



Comparison of α-particle OMPs for heavy nuclei (4/4)

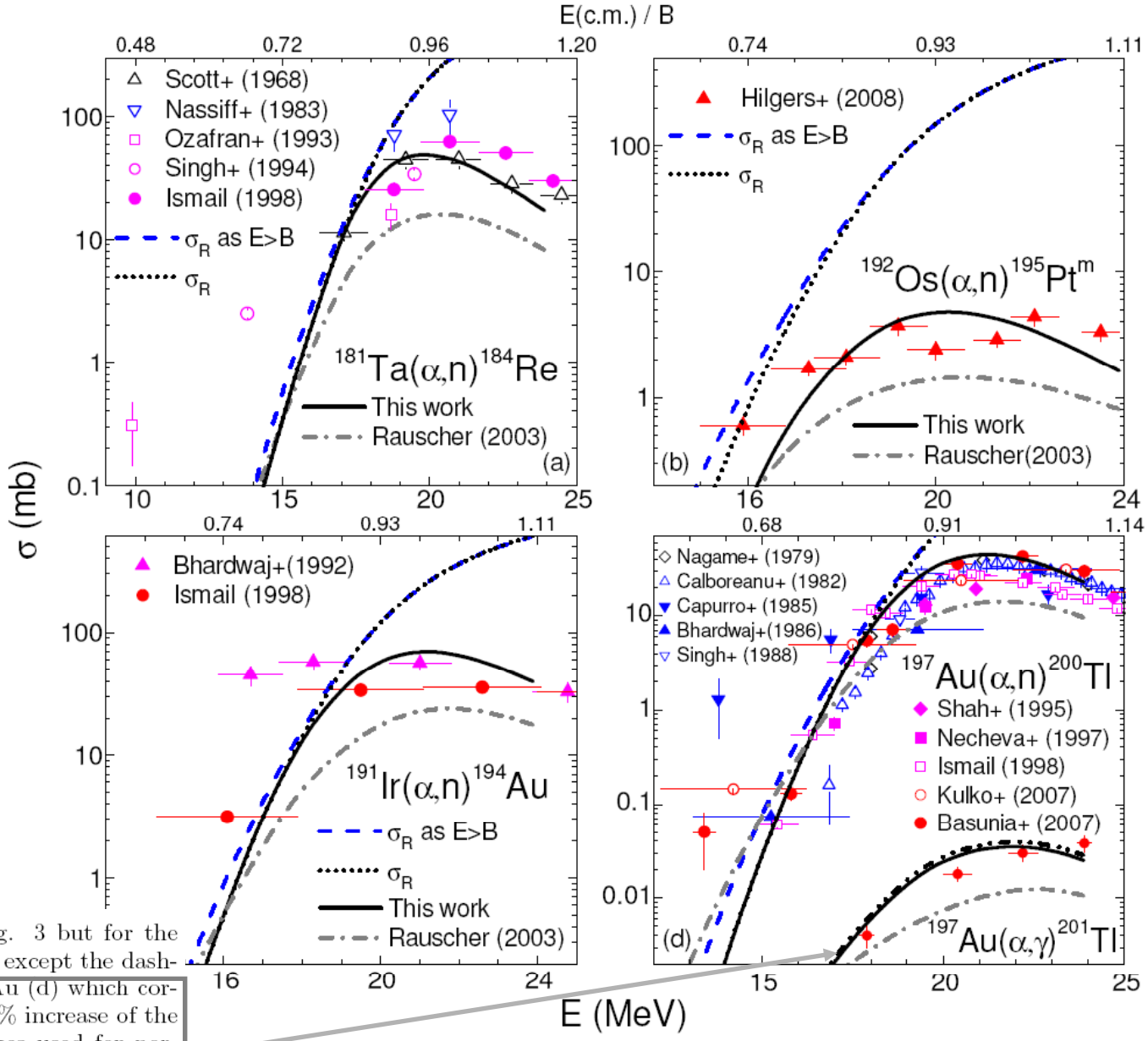


FIG. 5: (Color online) The same as in Fig. 3 but for the target nuclei ^{181}Ta, ^{192}Os, ^{191}Ir, and ^{197}Au, except the dash-dot-dotted curve for the target nucleus ^{197}Au (d) which corresponds to the OMP of this work and a 20% increase of the radiative width of s-wave neutron resonances used for normalization of the γ-ray strength function.

Finally: α-particle OMP @ E<50 MeV , A<200

Changes vs. A=40-120 [ADNDT 95, 501 (2009)]:

TABLE I: Optical potential parameters obtained by fit of the α-particle elastic-scattering and reaction cross sections on nuclei with $45 \leq A \leq 209$, at energies $E<50$ MeV. The energy-range limits[a] are in MeV. A star used as superscript follows the parameters which were changed with respect to the optical potential of Ref. [2].

Potential depth (MeV)		Geometry parameters (fm)	
$V_R^*=165+0.733Z/A^{1/3}-2.64E,$	$E<E_3$	$r_R=1.18+0.012E,$	$E<25$
$=116.5+0.337Z/A^{1/3}-0.453E,$	$E>E_3$	$=1.48,$	$E>25$
		$a_R^*=0.631+0.016Z/A^{1/3}-(0.001Z/A^{1/3})E_2,$	$E<E_2$
		$=0.631+0.016Z/A^{1/3}-(0.001Z/A^{1/3})E,$	$E_2<E<E_4$
		$=0.684-0.016Z/A^{1/3}-(0.0026-0.00026Z/A^{1/3})E,$	$E>E_4$
$W_V=2.73-2.88A^{1/3}+1.11E$		$r_V=1.34$	
		$a_V=0.50$	
$W_D^*=2.5\pm1.0^b$,	$E<E_1$	$r_D=1.52$	
$=22.2+4.57A^{1/3}-7.446E_2+6E,$	$E_1<E<E_2$	$a_D=0.729-0.074A^{1/3}$	
$=22.2+4.57A^{1/3}-1.446E$,	$E>E_2$		

[a] $E_1^*=-3.28-0.762A^{1/3}+1.24E_2$, $E_2=(2.59+10.4/A)Z/(2.66+1.36A^{1/3})$, $E_3^*=22.2+0.181Z/A^{1/3}$, $E_4^*=29.1-0.22Z/A^{1/3}$

[b] $W_D=3.5$ for $A<130$ while $W_D=1.5$ fits better the data for $A>130$.

4.3 RIPL-3 calculated α-particle OMP parameter values (1/3)

Forms f(Z,A):

```
                          Optical Model Potential

iref      =  9999
authors   = M. Avrigeanu and V. Avrigeanu
reference = IFIN-HH, Bucharest, Mar. 2010, Contract No. F4E-2008-GRT-014 (ES-AC)-Action 1
summary:
     Revised parameter set for alpha-particles, from analysis of elastic-scattering
     data for nuclei within 50<A<209 mass and ~13-50 MeV energy ranges, and (alpha,x)
     reaction cross-sections for target nuclei from 45Sc to 197Au, below ~12-20 MeV.
E range   = 1.000 -  60.0000
Z range   =    21 -  83
A range   =    44 - 209

Target: Z = 21  A =  45
        E1= 3.974  E2= 7.907  E3=23.269  E4=27.801

 r_R(fm) =  1.180+0.012*E,     E < 25.0 MeV
         =  1.480,             E > 25.0 MeV

 a_R(fm) =  0.679,                          E <  7.907 MeV
         =  0.725-0.00590*E,  7.907 MeV < E < 27.801 MeV
         =  0.590-0.00106*E,                E > 27.801 MeV

 V_R(MeV)=169.33-2.64*E,    E < 23.269 MeV
         =118.49-0.45*E,    E > 23.269 MeV

 r_WV(fm)=  1.34
 a_WV(fm)=  0.50
 W_V(MeV)= -7.51+1.11*E

 r_WD(fm)=  1.52
 a_WD(fm)=  0.466
 W_D(MeV)=  3.50,                          E <  3.974 MeV
         = -20.42+6.000*E,  3.974 MeV < E <  7.907 MeV
         =  38.46-1.446*E,                 E >  7.907 MeV
```

RIPL-3 calculated o

Parameter values Tables:

----- Calculated Potential Parameters and Total Reaction Cross Sections -----

E(LS) (MeV)	V_R (MeV)	r_R (fm)	a_R (fm)	W_V (MeV)	r_WV (fm)	a_WV (fm)	W_D (MeV)	r_WD (fm)	a_WD (fm)	r_C (fm)	sigma_R (mb)
2.0	164.0	1.204	0.679	0.000	1.340	0.500	3.500	1.520	0.466	1.30	0.4845E-08
3.0	161.4	1.216	0.679	0.000	1.340	0.500	3.500	1.520	0.466	1.30	0.8195E-04
4.0	158.8	1.228	0.679	0.000	1.340	0.500	3.582	1.520	0.466	1.30	0.1789E-01
5.0	156.1	1.240	0.679	0.000	1.340	0.500	9.582	1.520	0.466	1.30	1.022
6.0	153.5	1.252	0.679	0.000	1.340	0.500	15.582	1.520	0.466	1.30	14.13
7.0	150.8	1.264	0.679	0.256	1.340	0.500	21.582	1.520	0.466	1.30	77.68
8.0	148.2	1.276	0.678	1.366	1.340	0.500	26.887	1.520	0.466	1.30	213.0
9.0	145.6	1.288	0.672	2.476	1.340	0.500	25.441	1.520	0.466	1.30	369.9
10.0	142.9	1.300	0.666	3.586	1.340	0.500	23.995	1.520	0.466	1.30	517.1
11.0	140.3	1.312	0.661	4.696	1.340	0.500	22.549	1.520	0.466	1.30	643.8
12.0	137.6	1.324	0.655	5.806	1.340	0.500	21.103	1.520	0.466	1.30	750.5
13.0	135.0	1.336	0.649	6.916	1.340	0.500	19.657	1.520	0.466	1.30	840.0
14.0	132.4	1.348	0.643	8.026	1.340	0.500	18.211	1.520	0.466	1.30	915.5
15.0	129.7	1.360	0.637	9.136	1.340	0.500	16.765	1.520	0.466	1.30	979.6
16.0	127.1	1.372	0.631	10.246	1.340	0.500	15.319	1.520	0.466	1.30	1034.
17.0	124.4	1.384	0.625	11.356	1.340	0.500	13.873	1.520	0.466	1.30	1081.
18.0	121.8	1.396	0.619	12.466	1.340	0.500	12.427	1.520	0.466	1.30	1122.
19.0	119.2	1.408	0.613	13.576	1.340	0.500	10.981	1.520	0.466	1.30	1157.
20.0	116.5	1.420	0.607	14.686	1.340	0.500	9.535	1.520	0.466	1.30	1188.
21.0	113.9	1.432	0.601	15.796	1.340	0.500	8.089	1.520	0.466	1.30	1214.
22.0	111.2	1.444	0.596	16.906	1.340	0.500	6.643	1.520	0.466	1.30	1238.
23.0	108.6	1.456	0.590	18.016	1.340	0.500	5.197	1.520	0.466	1.30	1258.
24.0	107.6	1.468	0.584	19.126	1.340	0.500	3.751	1.520	0.466	1.30	1280.
25.0	107.2	1.480	0.578	20.236	1.340	0.500	2.305	1.520	0.466	1.30	1301.
26.0	106.7	1.480	0.572	21.346	1.340	0.500	0.859	1.520	0.466	1.30	1303.
27.0	106.3	1.480	0.566	22.456	1.340	0.500	0.000	1.520	0.466	1.30	1304.
28.0	105.8	1.480	0.560	23.566	1.340	0.500	0.000	1.520	0.466	1.30	1306.
29.0	105.4	1.480	0.559	24.676	1.340	0.500	0.000	1.520	0.466	1.30	1313.
30.0	104.9	1.480	0.558	25.786	1.340	0.500	0.000	1.520	0.466	1.30	1319.
31.0	104.4	1.480	0.557	26.896	1.340	0.500	0.000	1.520	0.466	1.30	1325.
32.0	104.0	1.480	0.555	28.006	1.340	0.500	0.000	1.520	0.466	1.30	1330.
33.0	103.5	1.480	0.554	29.116	1.340	0.500	0.000	1.520	0.466	1.30	1335.
34.0	103.1	1.480	0.553	30.226	1.340	0.500	0.000	1.520	0.466	1.30	1338.
35.0	102.6	1.480	0.552	31.336	1.340	0.500	0.000	1.520	0.466	1.30	1342.
36.0	102.2	1.480	0.551	32.446	1.340	0.500	0.000	1.520	0.466	1.30	1344.
37.0	101.7	1.480	0.550	33.556	1.340	0.500	0.000	1.520	0.466	1.30	1347.
38.0	101.3	1.480	0.549	34.666	1.340	0.500	0.000	1.520	0.466	1.30	1349.
39.0	100.8	1.480	0.548	35.776	1.340	0.500	0.000	1.520	0.466	1.30	1351.
40.0	100.4	1.480	0.547	36.886	1.340	0.500	0.000	1.520	0.466	1.30	1352.
41.0	99.9	1.480	0.546	37.996	1.340	0.500	0.000	1.520	0.466	1.30	1353.
42.0	99.5	1.480	0.545	39.106	1.340	0.500	0.000	1.520	0.466	1.30	1354.
43.0	99.0	1.480	0.544	40.216	1.340	0.500	0.000	1.520	0.466	1.30	1355.
44.0	98.6	1.480	0.543	41.326	1.340	0.500	0.000	1.520	0.466	1.30	1356.
45.0	98.1	1.480	0.542	42.436	1.340	0.500	0.000	1.520	0.466	1.30	1356.
46.0	97.7	1.480	0.541	43.546	1.340	0.500	0.000	1.520	0.466	1.30	1357.
47.0	97.2	1.480	0.539	44.656	1.340	0.500	0.000	1.520	0.466	1.30	1357.
48.0	96.7	1.480	0.538	45.766	1.340	0.500	0.000	1.520	0.466	1.30	1357.
49.0	96.3	1.480	0.537	46.876	1.340	0.500	0.000	1.520	0.466	1.30	1357.
50.0	95.8	1.480	0.536	47.986	1.340	0.500	0.000	1.520	0.466	1.30	1357.
51.0	95.4	1.480	0.535	49.096	1.340	0.500	0.000	1.520	0.466	1.30	1357.
52.0	94.9	1.480	0.534	50.206	1.340	0.500	0.000	1.520	0.466	1.30	1357.
53.0	94.5	1.480	0.533	51.316	1.340	0.500	0.000	1.520	0.466	1.30	1356.
54.0	94.0	1.480	0.532	52.426	1.340	0.500	0.000	1.520	0.466	1.30	1356.

RIPL-3 calculated α-particle OMP parameter values (3/3)

RIPL Format:

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----- RIPL Library Format -----

 9999
M. Avrigeanu and V. Avrigeanu
IFIN-HH, Bucharest, Mar. 2010, Contract No. F4E-2008-GRT-014 (ES-AC)-Action 1
Revised parameter set for alpha-particles, from analysis of elastic-scattering
data for nuclei within 50<A<209 mass and ~13-50 MeV energy ranges, and (alpha,x)
reaction cross-sections for target nuclei from 45Sc to 197Au, below ~12-20 MeV.
Target: Z = 21   A = 45
   1.000    60.0000
  21   83
  44  209
   0    2    4    0    0
   5
   7.907
   1.18000   1.20000-2  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
   0.67878   0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
 169.32765  -2.64000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
  23.269
   1.18000   1.20000-2  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
   0.72546  -5.90403-3  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
 169.32765  -2.64000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
  25.000
   1.18000   1.20000-2  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
   0.72546  -5.90403-3  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
 118.48965  -4.53000-1  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
  27.801
   1.48000   0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
   0.72546  -5.90403-3  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
 118.48965  -4.53000-1  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
  60.000
   1.48000   0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
   0.58954  -1.06495-3  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
 118.48965  -4.53000-1  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
             0.00000+0  0.00000+0  0.00000+0  0.
```

```
 60.000
   1.48000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
   0.58954 -1.06495-3  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
 118.48965 -4.53000-1  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
 1
 60.000
   1.34000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
   0.50000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
  -7.51385  1.11000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
 0
 3
   3.974
   1.52000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
   0.46579  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
   3.50000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
   7.907
   1.52000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
   0.46579  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
 -20.41816  6.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
 60.000
   1.52000  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
   0.46579  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0
 38.45501  -1.44600+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
            0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0  0.00000+0
 0
 0
 1
 60.000     0.0000     1.3000     0.0000     0.0000     0.0000
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Thank you for your attention !