

Raport stiintific

privind implementarea proiectului in perioada 16 decembrie 2014 – 31 decembrie 2015

Denumirea proiectului: Reactii nucleare induse de deuteroni la energii joase si medii:

Analiza consistenta a mecanismelor de reactii directe si statistice

[http://tandem.nipne.ro/~dante/projects/PN2P3_0450/index.html]

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Etapa unica 2015: Analiza consistenta a interactiunii deuteronilor cu nucleele ^{58,60,62}Ni la energii joase

1.1. Analiza componentelor sectiunii eficace ale procesului de 'breakup' pentru interactiunea deuteronilor cu nucleele ^{58,60}Ni

Rezultatele obtinute in cadrul prezentei activitati a proiectului de fata, proiect ce are ca obiectiv analiza consistenta a interactiilor deuteronilor cu nuclee de masa medie la energii joase, cu luarea in considerare a interactiilor directe, au contribuit in principal la realizarea unei lucrari¹ asupra importantei procesului de rupere ('breakup' - BU) a deuteronilor in comparatie cu procesele statistice. Aceasta lucrare a fost elaborata pentru cazul interactiunilor deuteronilor cu nuclee din imediata vecinatate a izotopilor elementului Ni, pentru care nu exista date experimentale similare astfel incat a fost necesara o analiza pentru nuclee apropiate, cu urmatorul rezumat:

„Abstract. Background: Recent studies of deuteron-induced reactions around the Coulomb barrier B pointed out that numerical calculations for deuteron-induced reactions are beyond current capabilities. The statistical model of nuclear reactions was used in this respect since the compound-nucleus (CN) mechanism was considered to be responsible for most of the total-reaction cross section σ_R in this energy range. However, specific noncompound processes such as the breakup (BU) and direct reactions (DR) should be also considered for the deuteron-induced reactions, making them different from reactions with other incident particles. **Purpose:** The unitary and consistent BU and DR consideration in deuteron-induced reactions is proved to yield results at variance with the assumption of negligible noncompound components. **Method:** The CN fractions of σ_R obtained by analysis of measured neutron angular distributions in deuteron-induced reactions on ²⁷Al, ⁵⁶Fe, ^{63,65}Cu, and ⁸⁹Y target nuclei, around B , are compared with the results of an unitary analysis of every reaction mechanism. The latter values have been supported by the previously established agreement with all available deuteron data for ²⁷Al, ^{54,56-58,nat}Fe, ^{63,65,nat}Cu, and ⁹³Nb. **Results:** There is a significant difference between the larger CN contributions obtained from measured neutron angular distributions and calculated results of an unitary analysis of every deuteron-interaction mechanism. The decrease of the latter values is mainly due to the BU component. **Conclusions:** The above-mentioned differences underline the key role of the breakup and direct reactions that should be considered explicitly in the case of deuteron-induced reactions.”

¹ M. Avrigeanu and V. Avrigeanu, *Role of breakup and direct processes in deuteron-induced reactions at low energies*, Phys. Rev. C **92**, 021601 (R) (2015). DOI: [10.1103/PhysRevC.92.021601](https://doi.org/10.1103/PhysRevC.92.021601) .

1.2. Analiza sectiunilor eficiente de activare ale deuteroniilor cu nucleele ^{58,60}Ni

Odata validata descrierea procesului de 'breakup' pentru nuclee din zona de masa atomica a izotopilor elementului Ni, ponderea principala a etapei de fata a reprezentat-o realizarea unei lucrari invitate prezentate oral², asupra sectiunilor eficiente de reactie ale deuteroniilor la energii joase cu nucleele ^{58,60}Ni, cu urmatorul rezumat:

„Abstract. The consequences which the suitable consideration of direct interaction, namely the breakup, stripping and pick-up processes, may have for the analysis of the deuteron surrogate reactions as well as for studies of nuclear-level density models on the basis of nucleon spectra analysis in deuteron-induced reactions are discussed. An increased attention is paid to the deuteron breakup which is the dominant mechanism for the interaction processes at low incident energies around Coulomb barrier, particularly on actinides.”

Aspecte complementare ale mecanismelor de reactie specifice interactiei deuteroniilor cu nuclee din acelasi domeniu de mase atomice, aplicabile in egala masura izotopilor elementul Ni, au fost discutate intr-o lucrare prezentata oral³ la principala conferinta din domeniul mecanismelor de reactii nucleare, aflata la a 14-a editie de-a lungul ultimilor 39 ani, cu urmatorul rezumat:

„Abstract. An extended analysis of the key role of direct interactions, i.e., breakup, stripping and pick-up processes, for the deuteron-induced surrogate reactions is presented. Particular comments concern the deuteron breakup which is dominant in the case of the (d, pγ) surrogate reactions on actinides target nuclei, around the Coulomb barrier”

1.3. Analiza componentelor sectiunii eficiente ale procesului de 'breakup' pentru interactiunea deuteroniilor cu nucleul ⁶²Ni

Aspecte caracteristice ale procesului de 'breakup' pentru interactiunea deuteroniilor cu nucleul ⁶²Ni au fost analizate de asemenea in lucrarea realizata in cadrul primei activitati a acestui proiect, descrisa mai sus. In acelasi timp aceste aspecte au fost discutate si intr-o lucrare invitata prezentata oral⁴, avand urmatorul rezumat:

„Abstract. Nuclear level densities of residual nuclei in various reactions are commonly obtained from statistical neutron evaporation spectra. The statistical Hauser-Feshbach model is used in this respect, being considered that the compound-nucleus (CN) mechanism is responsible for at least 90% of the total reaction cross section. However, this is not the case of the deuteron-induced reactions, due to specific noncompound processes that are yet considered negligible for neutron spectra measured at backward angles and then multiplied by 4. Thus, in spite of finding that about 76% of the total reaction cross sections of 5 to 8 MeV deuterons on ⁸⁹Y are determined by CN and the rest is due to direct interaction (DI) and pre-equilibrium emission (PE), in rough agreement similar results for deuteron beams on ²⁷Al, ⁵⁶Fe, and ^{63,65}Cu targets, numerical calculations with

² M. Avrigeanu and V. Avrigeanu, *On deuteron interactions within surrogate reactions and nuclear level density studies*, in Proc. [XXI Int. School on Nuclear Physics, Neutron Physics and Applications, 6 - 12 September 2015, Varna, Bulgaria](http://www.inrne.bas.bg/international-school-varna/), Journal of Physics: Conference Series (in press); <http://www.inrne.bas.bg/international-school-varna/>

³ M. Avrigeanu and V. Avrigeanu, *Role of the direct mechanisms in the deuteron-induced surrogate reactions*, Proc. [14th Int. Conf. on Nuclear Reaction Mechanisms, 15-19 June 2015, Varenna, Italy, CERN Proceedings-2015](http://www.fluka.org/Varenna2015/) (in press); <http://www.fluka.org/Varenna2015/>

⁴ M. Avrigeanu and V. Avrigeanu, *On the level density models analysis based on deuteron-induced reactions*, [5th Workshop on Nuclear Level Density and Gamma Strength, Oslo, May 18-22, 2015](http://tid.uio.no/workshop2015/); <http://tid.uio.no/workshop2015/>

deuteron-induced reactions have been considered beyond our current capabilities. This is why we present in this work an unitary analysis of the mechanisms responsible for the deuteron interactions with the above-mentioned target nuclei, namely the breakup (BU), stripping and pick-up DIs, and PE and CN processes.”

Stadiul implementarii proiectului

Ca urmare a interesului pe care il prezinta subiectul acestui proiect pentru cercetarile de fuziune nucleara pe plan mondial, rezultate obtinute in cadrul proiectului de fata au fost preluate si introduse in formatul specific al bibliotecilor de date nucleare, in cadrul a doua rapoarte^{5,6} prezentate in cadrul *NEA Nuclear Data Weeks, 27-30 Aprilie 2015 si 30 Nov.-4 Dec. 2015*, organizate de catre OECD/NEA (Issy-les-Moulineaux, France). Aprecierea acordata acestor lucrari a asigurat continuarea activitatii echipei de cercetare a proiectului de fata in cadrul acordului cu nr. F4E-FPA-168/2011 (2012-2016) de tip „*Framework Partnership Agreement*” (FPA) al unui consortiu, incluzand grupul din IFIN-HH, cu agentia ***Fusion for Energy*** (F4E, <http://fusionforenergy.europa.eu/>) a Comisiei Europene. Finantarea acestui consortiu este insa mai mult simbolica datorita costurilor majore ale realizarii ITER, astfel incat nu a existat o dubla finantare nationala/internationala ci una complementara a componentelor lucrarilor de cercetare fundamentala care formeaza si obiectul raportului de fata. Participarea la consortiu respectiv garanteaza, pe de alta parte, orientarea corespunzatoare a activitatii IFIN-HH inclusiv pe tematica proiectului de fata.

Referintele [1-6] reprezinta lucrarile realizate cu finantarea integrala la nivel national in cadrul proiectului de fata, avand inclusa in sectiunea „*Acknowledgement*” si mentiunea acestei finantari unice la nivel national prin acest proiect. Acesta mentiune este inclusa si in sectiunile corespunzatoare ale paginii proprii a proiectului, avand adresa http://tandem.nipne.ro/~dante/projects/PN2P3_0450/index.html. Absenta unei suprapuneri cu rezultatele altor proiecte realizate anterior de acelasi grup poate fi constata prin comparatie cu paginile tuturor acestor proiecte PN-II, reunite in pagina <http://tandem.nipne.ro/~dante/projects.html>, precum si cu pagina proiectului PN-09-37-01-05 al departamentului propriu (DFN) din cadrul IFIN-HH. In cadrul proiectului PN mentionat pot fi constatate rezultatele distincte^{7,8,9,10}, obtinute la un nivel comparabil, pe tematica unei propuneri de proiect PN-II-ID-

⁵ M. Avrigeanu, *Progress on the analysis of deuteron-induced reaction mechanisms at low energies*, [EFFDOC-1251](http://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1251.pdf) (http://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1251.pdf), [NEA Nuclear Data Week, 27-30 April 2015](http://www.oecd-nea.org/dbdata/meetings/april2015/) (<http://www.oecd-nea.org/dbdata/meetings/april2015/>), OECD/NEA, Issy-les-Moulineaux, France.

⁶ M. Avrigeanu, *Progress on the analysis of deuteron-induced reaction mechanisms at low energies*, EFFDOC Report, [NEA Nuclear Data Week, 30 Nov. - 4 Dec. 2015](http://www.oecd-nea.org/dbdata/meetings/nov2015/) (<http://www.oecd-nea.org/dbdata/meetings/nov2015/>), OECD/NEA, Issy-les-Moulineaux, France.

⁷ V. Avrigeanu and M. Avrigeanu, *Consistent optical potential for incident and emitted low-energy α particles*, *Phys. Rev. C* **91**, 064611 (R) (2015). DOI: [10.1103/PhysRevC.91.064611](https://doi.org/10.1103/PhysRevC.91.064611).

⁸ V. Avrigeanu and M. Avrigeanu, *Realistic radiative strength functions within α -particle induced reactions and emission in the mass range $A\sim 70$* , *5th Workshop on Nuclear Level Density and Gamma Strength, Oslo, May 18-22, 2015*; <http://tid.uio.no/workshop2015/>

⁹ V. Avrigeanu, *Progress on the analysis of alpha-particle optical potential at low energies*, [EFFDOC-1252](http://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1252.pdf) (http://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1252.pdf), [NEA Nuclear Data Week, 27-30 April 2015](http://www.oecd-nea.org/dbdata/meetings/april2015/) (<http://www.oecd-nea.org/dbdata/meetings/april2015/>), OECD/NEA, Issy-les-Moulineaux, France.

¹⁰ V. Avrigeanu, *Progress on the analysis of alpha-particle optical potential at low energies*, EFFDOC Report, [NEA Nuclear Data Week, 30 Nov. - 4 Dec. 2015](http://www.oecd-nea.org/dbdata/meetings/nov2015/) (<http://www.oecd-nea.org/dbdata/meetings/nov2015/>), OECD/NEA, Issy-les-Moulineaux, France.

PCE-2011-3/4 nefinantate in final dar primind o apreciere si finantare complementara in cadrul acordului F4E-FPA-168/2011 (2012-2016).

Resurse

O precizare importanta priveste imposibilitatea de a urma si in anul 2015 recomandarea de „intensificare a activitatii de publicare cu implicarea tinerilor cercetatori”, care a reprezentat singura deficientea consemnata in „Fisa de evaluare intermediara a stadiului implementarii” proiectului, disponibila¹¹ si pe pagina proprie a proiectului, pentru care s-a acordat calificativul B⁺ si s-a recomandat proiectul pentru prezentarea publica a rezultatelor in vederea „clarificarii contributiei tinerilor cercetatori la activitatea de publicare” (punctul de vedere al directorului de proiect privind evaluarea respectiva, disponibil si pe pagina proprie a proiectului¹², in dezacord cu aspectele critice mentionate mai sus, a fost inclus integral si in prezentarea¹³ publica a rezultatelor care a avut loc in cadrul sedintei publice¹⁴ din 18.06.2014.).

In fapt recomandarea mentionata a fost oricum satisfacuta prin listele de autori ale lucrarilor realizate in perioada 17.06.2013-19.06.2014, perioada in care pozitia de post-doc vacanta in cadrul echipei proiectului a fost ocupata de catre Dr. C. Manaiescu, in urma anuntului public¹⁵ pe site-ul www.euraxess.ro.

Insa in conditiile reducerii cu 50% a suportului financiar prevazut pentru perioada 01.01-30.09.2014¹⁶ in cadrul propunerii de proiect, fondurile disponibile in cadrul proiectului - distribuite in mod egal intre principalii membri ai echipei de cercetare, in conformitate cu nivelurile de salarizare mentionate de asemenea in propunerea de proiect (respectiv nivelul PD/POSDRU in cazul Dr. C. Manaiescu) - au acoperit numai perioada 01.01.-19.06.2014, data de la care sustinerea financiara a angajarii Dr. C. Manaiescu nu a mai fost posibila. In concluzie, pierderea in fapt a angajarii cercetatorului post-doc, ca urmare a reducerii sustinerii financiare aprobate initial, precum si absenta sa din lista de autori a lucrarilor realizate ulterior nu sunt imputabile echipei proiectului.

Director proiect,


Marilena Avrigeanu

¹¹ http://tandem.nipne.ro/~dante/projects/PN2P3_0450/rapoarte/Fisa_de_evaluare_AM-2013.pdf

¹² http://tandem.nipne.ro/~dante/projects/PN2P3_0450/rapoarte/Punct_vedere_Eval-Int_ID-PCE-2011-0450.pdf

¹³ http://tandem.nipne.ro/~dante/projects/PN2P3_0450/rapoarte/ID_0450_2014-UEFISCDI.ppt

¹⁴ <http://uefiscdi.gov.ro/articole/3752/Sedinte-publice-de-prezentare-a-rezultatelor-obtinate.html>

¹⁵ <http://ec.europa.eu/euraxess/index.cfm/jobs/jobDetails/33772294> .

¹⁶ http://tandem.nipne.ro/~dante/projects/PN2P3_0450/resources.html