

## RAPORT ȘTIINȚIFIC FINAL

### Program 4 - Cercetare fundamentală și de frontieră

#### Tip proiect: Proiecte de cercetare exploratorie

Proiect: *De la o metoda promitatoare la o intelegere deplina a reactiilor induse de deuteroni*

Acronim: Protodeep

Contract nr: PCE 7 /2022 (PN-III-P4-PCE-2021-0642)

Perioada de raportare: 01.06.2022 – 31.12.2024

Coordonator: Institutul National de Cercetare-Dezvoltare pentru Fizica si Inginerie Nucleara „Horia Hulubei” (IFIN-HH)

Pagina web: <https://www.nipne.ro/proiecte/pn3/60-proiecte.html>

Director de proiect: Dr. Marilena Avrigeanu ([https://www.nipne.ro/1505-staff\\_info.html](https://www.nipne.ro/1505-staff_info.html))

### 1. Obiectivele prevăzute/realizate

Realizarea integrala a obiectivelor prevazute ale acestui proiect este prezentata in articolele publicate<sup>1,2,3,4,5,6,7</sup> (autor corespondent fiind directorul proiectului de fata), dintre care cele mai relevante<sup>3,4</sup> justifica indeplinirea obiectivului major reprezentat si de titlul proiectului, obiectiv definit in propunerea de proiect cu ajutorul unui citat<sup>8</sup> de referinta pentru nivelul comparativ al studiilor fenomenologice si al celor microscopice: *‘Deviations between the results of direct measurements and*

---

<sup>1</sup> M. Avrigeanu and V. Avrigeanu, *Optical potential for incident and emitted low-energy alpha particles. III. Non-statistical processes induced by neutrons on Zr, Nb, and Mo nuclei*, Phys. Rev. C **107**, 034613 (2023), <https://doi.org/10.1103/PhysRevC.107.034613> [AIS Q2]

<sup>2</sup> M. Avrigeanu and V. Avrigeanu, *Structural material nuclear data basic research*, Front. Phys. **11**, 1172697 (2023), <https://doi.org/10.3389/fphy.2023.1172697> (part of the *Research Topic on Nuclear Data for Fusion Technology from Basic Research to Full-Scale Applications*, <https://www.frontiersin.org/research-topics/39045/nuclear-data-for-fusion-technology-from-basic-research-to-full-scale-application>) [AIS Q2]

<sup>3</sup> M. Avrigeanu, E. Simeckova, J. Mrazek, C. Costache, and V. Avrigeanu, *Modeling of deuteron-induced reactions on molybdenum at low energies*, Journal of Fusion Energy **43**, 15 (2024), [10.1007/s10894-024-00407-w](https://doi.org/10.1007/s10894-024-00407-w) [AIS Q1]

<sup>4</sup> E. Simeckova, M. Avrigeanu, J. Mrazek, J. Novak, M. Stefanik, C. Costache, and V. Avrigeanu, *Deuteron-induced neutron emission on molybdenum at low energies*, Journal of Fusion Energy [AIS Q1] (to be submitted, Dec. 2024) [[https://users.euro-fusion.org/repository/pinboard/EFDA-JET/journal/116700\\_ife20241.pdf](https://users.euro-fusion.org/repository/pinboard/EFDA-JET/journal/116700_ife20241.pdf), EUROfusion Pinboards No. 942/20 Nov. 2024]

<sup>5</sup> M. Avrigeanu and V. Avrigeanu, *Role of direct interactions in (d,p) and (d,2p) reactions*, EPJ Web of Conf. **284**, 03006 (2023) [oral talk at 15<sup>th</sup> International Conference on Nuclear Data for Science and Technology (ND2022), July 25-29, 2022, Sacramento, California, US]; <https://doi.org/10.1051/epjconf/202328403006>

<sup>6</sup> M. Avrigeanu and V. Avrigeanu, *Due consideration of the breakup and direct reaction mechanisms within (d,p), (d,2p), (d,xn2p), and (d,xn) reactions*, EPJ Web of Conf. **292**, 06001 (2024) [main oral talk at 16<sup>th</sup> Varenna Conference on Nuclear Reaction Mechanisms (NRM2023), Varenna, Italy, June 11-16, 2023, F. Cerutti and T. Kawano (Eds.), <https://indico.cern.ch/event/1132769/>]; [10.1051/epjconf/202429206001](https://doi.org/10.1051/epjconf/202429206001)

<sup>7</sup> M. Avrigeanu and V. Avrigeanu, *Deuteron-induced reaction cross sections for 93Zr up to 200 MeV*, oral talk at [7<sup>th</sup> Int. workshop on Compound-Nuclear Reactions and Related Topics \(CNR\\*24\)](https://www.cnr.it/it/7th-international-workshop-on-compound-nuclear-reactions-and-related-topics-cnr-24), 8-12 July 2024, Vienna, Austria, EPJ Web of Conf. (submitted, Oct. 2024), [https://conferences.iaea.org/event/368/papers/31731/files/12849-MAvrigeanu\\_CNR\\_2024.pdf](https://conferences.iaea.org/event/368/papers/31731/files/12849-MAvrigeanu_CNR_2024.pdf),

<sup>8</sup> J.J. Cowan, C. Sneden, J.E. Lawler, A. Aprahamiam, M. Wiescher, K. Langanke, G. Martinez-Pinedo, and F.-K. Thielemann, Rev. Mod. Phys. **93**, 15002 (2021)

*surrogate reaction studies may reflect insufficient treatment and separation between different reaction mechanisms, such as direct transfer and breakup components (Avrighianu and Avrighianu, 2016). While this method is promising, a deeper understanding of the reaction mechanism seems to be necessary (Potel, Nunes, and Thompson, 2015).'* Daca la momentul respectiv a fost majora implicarea definitorie in aceasta paralela a grupurilor<sup>9,10</sup> IFIN-HH si LLNL, atingerea obiectivului propus al proiectului poate fi cel mai corect argumentata prin primul paragraf al referentului *Journal of Fusion Energy* (AIS Q1) pentru principala lucrare<sup>3</sup> de sinteza a proiectului: *'This paper presents an extensive systematic analysis of the interaction between deuterium and molybdenum, using a large number of experimental data and state-of-the-art phenomenological theoretical models to evaluate the activation cross sections concerned. The evaluation methodology is consistent and clear, and the analysis is found to be as systematic as possible. In most cases, the results of the evaluation well reproduce the latest NPI measurements and thus are considered to be highly accurate. I would commend the authors for this amazing and tremendous work. I believe it is very worthwhile that detailed results and discussion are written for each reaction channel. Even for channels for which there is insufficient experimental data to derive spectroscopic coefficients for a particular channel, for which there is a lack of experimental data to compare, or for which there are some differences from experimental data, such details given would help to resolve problems as they arise in future activation analyses. I find the originality and scientific quality of the paper is high and therefore worthy of publication'* (J. Fusion En. MS. No. 10894, 1<sup>st</sup> Referee, March 6, 2024).

In fapt, obiectivele proiectului prevazute si realizate integral au fost evidentiate de etapele de raportare, pe ani:

- 2022: Perfectionarea modelului de rupere ('breakup', BU) al deuteronilor si analiza consistenta a rolului interactiilor directe in reactii induse de deuteroni pe izotopii stabili <sup>98,100</sup>Mo la energii de pana la 50 MeV,
- 2023: Perfectionarea modelului de rupere al deuteronilor si analiza consistenta a rolului interactiilor directe in reactii induse de deuteroni pe izotopii stabili <sup>95-97</sup>Mo la energii de pana la 50 MeV, si
- 2024: Analiza comparativa de modele nucleare pentru functiile de excitatie ale reactiilor directe induse de deuteroni pe 92,94,natMo la energii incidente de pana la 50 MeV.

Cu toate acestea a fost necesara si realizarea unor actiuni suplimentare specifice, descrise in continuare.

## **2. Prezentarea rezultatelor obținute**

**2.1** Elementul introdus pentru prima data in evaluarile actuale ale datelor nucleare pentru reactii induse de deuteroni, determinand si includerea sa in ultima versiune a codului de calcul TALYS-2.0<sup>11</sup> de larg uz international, il reprezinta luarea in considerare suplimentara ("enhancement") a sectiunilor eficace ale reactiilor initiate de neutronii si protonii proveniti din 'ruperea' ('breakup', BU)

---

<sup>9</sup> M. Avrighianu and V. Avrighianu, *On deuteron interactions within surrogate reactions and nuclear level density studies*, J. Phys. Conf. Ser. **724**, 012003 (2016)

<sup>10</sup> G. Potel, F.M. Nunes, and I.J. Thompson, *Establishing a theory for deuteron-induced surrogate reactions*, Phys. Rev. C **92**, 34611 (2015)

<sup>11</sup> A.J. Koning, S. Hilaire, and S. Goriely, *TALYS & Related Software - Nuclear reaction model code*, <https://nds.iaea.org/talys/>

deuteronului<sup>12</sup>. Problema majora in acest caz consta intr-o adaugare a incertitudinilor privind valorile sectiunilor eficace ale acestor reactii suplimentare la cele ale reactiilor initiate de insasi deuteronii. O analiza a reactiilor induse si de neutroni pe izotopii stabili ai elementului Mo a devenit astfel necesara si s-a realizat in contextul Ref.<sup>1</sup> orientata initial pe problematica potentialului de model optic pentru particule alfa dar finalizata cu accentul pe necesitatea cunoasterii detaliate a interactiunilor neutronilor rezultati din procesul BU, publicata cu urmatorul 'Abstract':

**Background:** The reliability of a previous  $\alpha$ -particle optical-model potential (OMP) on nuclei with mass number  $45 \leq A \leq 209$  was proved for emitted  $\alpha$  particles as well, for proton-induced reactions on Zn isotopes [Phys. Rev. C **91**, 064611 (2015), Paper I]. However, the same was not the case of neutrons on Zr stable isotopes [Phys. Rev. C **96**, 044610 (2017), Paper II]. **Purpose:** A recent assessment of this potential also for nucleon-induced  $\alpha$  emission on  $A \approx 60$  nuclei, including pickup direct reaction and eventual giant quadrupole resonance (GQR)  $\alpha$  emission, was completed for neutrons incident on Zr, Nb, and Mo stable isotopes. **Methods:** Consistent sets of input parameters, determined through analysis of independent data, are involved while no further empirical rescaling factors of the  $\gamma$  and nucleon widths have been involved. **Results:** A suitable account of all competitive reaction channels is confirmed by careful uncertainty analysis, to avoid parameter ambiguities and/or error compensation. Additional validation of this potential is also supported by recently measured  $(\alpha, \gamma)$  and  $(\alpha, n)$  cross sections of Zr and Mo nuclei. **Conclusions:** An increase of the  $\alpha$  emission beyond the statistical predictions, through consideration of additional reaction channels of the pickup direct interaction and GQR-like decay, makes possible the description of both absorption and emission of  $\alpha$  particles by the same optical potential."

**2.2** Un segment al rezultatelor mentionate mai sus, privind in particular reactiile  $(d,p)$  si  $(d,2p)$ , a format si obiectul unei prezentari<sup>5</sup> orale la editia din 2022 a conferintei de referinta in domeniul datelor nucleare, cu urmatorul 'Abstract':

"Accurate cross sections of deuteron-induced reactions within an enlarged energy range up to 50 MeV are definitely involved by demands of on-going strategic research programs (ITER, IFMIF, SPIRAL2-NFS) using deuteron beams. Among them, the  $(d,p)$  and  $(d,2p)$  reaction cross sections leading to hydrogen-gas bubble accumulation in the structural materials are very important for radiation damage studies. In contrast to the case of neutrons, systematics of deuteron activation cross sections, including those leading to hydrogen, triton, and helium-gas accumulation, is modest while even the newest evaluations show apparent discrepancies. Thus, the present work is devoted to the comparative analysis of measurements, model calculations, and evaluation corresponding to  $(d,p)$ , and  $(d,2p)$  activation cross sections, to improve the description of existing data and to provide trustful predictions where no measured data exist."

**2.3** Analiza de modele nucleare considerata necesara in vederea evaluarii avansate a sectiunilor eficace ale reactiilor induse de deuteroni pe izotopii stabili <sup>92,94-98,100</sup>Mo a inclus luarea in considerare a tuturor datelor experimentale disponibile pentru izotopii stabili vizati, pentru energiile incidente de pana la 50 MeV. S-a acordat atentie contributiilor tuturor mecanismelor de reactie implicate mentionate mai sus, incluzand si emisia la preechilibru (PE) si 'nucleu compus' (CN), precum si

---

<sup>12</sup> M. Avrigeanu and V. Avrigeanu, Phys. Rev. C **92**, 021601(R) (2015); ibid. C **95**, 024607 (2017)

analizei sistematice a distribuțiilor unghiulare folosind o versiune actualizată a codului SCAT2. Similar, au fost implicate modelul BU inclus recent<sup>13</sup> în codul de calcul de larg uz internațional TALYS<sup>11</sup>, și codul FRESCO<sup>14</sup> asociat analizei microscopice a reacțiilor directe (DR) 'stripping' și 'pick-up', analiza spectrelor energetice ale emisie de neutroni/protoni, și a distribuțiilor unghiulare ale particulelor emise. În final s-a realizat astfel și considerarea consistentă a BU, DR, PE, și CN, și a seturilor de parametri de modele nucleare. Rezultatele acestei analize de ipoteze și parametri de model, în cadrul proiectului de față, au fost prezentate<sup>15,16,17</sup> odată cu secțiunile eficiente ale reacțiilor respective obținute în vederea actualizării îmbunătățite a evaluărilor de uz internațional extins TENDL-2021<sup>18</sup> în secțiunile I-II ale lucrării<sup>3</sup> cu următorul 'Abstract':

"The activities of the EUROfusion consortium on the development of high quality nuclear data for fusion applications include evaluations of deuteron induced reactions and related data libraries for needs of the DEMO fusion power plant and IFMIF-DONES neutron-source nuclear analyses. Molybdenum is one of the major constituents of the reference stainless steels used in critical components of these projects. While the TENDL deuteron data library was the current reference used by EUROfusion, need of its further improvement has already been pointed out. The weak binding energy of the deuteron is responsible for the high complexity of its interaction with nuclei, involving also a variety of reactions initiated by the nucleons following the deuteron breakup. Their analysis completed that of the deuteron interactions with Mo and its stable isotopes, from elastic scattering to pre-equilibrium and compound–nucleus reactions, up to 50 MeV. A particular attention has been paid to the breakup, stripping, and pick-up direct interactions which amount to around half of the deuteron total–reaction cross section. The due account of most experimental data has validated the present approach, highlighted some prevalent features, and emphasized weak points and consequently the need for modeling/evaluation upgrade."

**2.4** Pe de altă parte, o analiză avansată a secțiunilor eficiente izomerice ale reacțiilor induse de deuteron pe izotopii Mo a fost inițiată odată cu descrierea corectă a contribuțiilor tuturor mecanismelor de reacție implicate. A fost urmărită descrierea corespunzătoare a funcțiilor de excitație măsurate pentru starea fundamentală și starea izomerică ale reacțiilor induse de deuteronii incidenti pe izotopii stabili ai Mo în cadrul calculelor TALYS de ultimă generație prin modificarea parametrului de limitare a distribuției de spin a densității de nivele nucleare ('nuclear-level density' -

---

<sup>13</sup> M. Avrigeanu, D. Rochman, A.J. Koning, U. Fischer, D. Leichtle, C. Costache, V. Avrigeanu, *Advanced breakup nucleon enhancement of deuteron-induced reaction cross sections*. Eur. Phys. J. A 58, 3 (2022)

<sup>14</sup> I.J. Thompson, *Comput. Phys. Rep.* 7, 167 (1988); computer code v. FRES 2.9 (2011)

<sup>15</sup> M. Avrigeanu and V. Avrigeanu, *Analysis of deuteron-induced reactions on structural materials*, EFFDOC-1487, OECD/NEA Data Bank, Nov. 24, 2022, Paris, [https://www.oecd-neo.org/dbdata/nds\\_effdoc/effdoc-1487.pdf](https://www.oecd-neo.org/dbdata/nds_effdoc/effdoc-1487.pdf)

<sup>16</sup> M. Avrigeanu and V. Avrigeanu, *Analysis of deuteron-induced reactions on structural materials*, EFFDOC-1504, OECD/NEA Data Bank, April 24, 2023, Paris, [https://www.oecd-neo.org/dbdata/nds\\_effdoc/effdoc-1504.pdf](https://www.oecd-neo.org/dbdata/nds_effdoc/effdoc-1504.pdf)

<sup>17</sup> M. Avrigeanu and V. Avrigeanu, *Analysis of deuteron-induced reactions on structural materials*, EFFDOC-1519, OECD/NEA Data Bank, Nov. 27, 2023, Paris, [https://www.oecd-neo.org/dbdata/nds\\_effdoc/effdoc-1519.pdf](https://www.oecd-neo.org/dbdata/nds_effdoc/effdoc-1519.pdf)

<sup>18</sup> A. J. Koning and D. Rochman, TENDL-2021: TALYS-based evaluated nuclear data library, [https://tendl.web.psi.ch/tendl\\_2021/tendl2021.html](https://tendl.web.psi.ch/tendl_2021/tendl2021.html)

NLD) cu un factor<sup>3</sup> de 0,25. De fapt, aceste rezultate sunt în concordanță cu cea mai recentă analiza a rapoartelor izomerice ale reacțiilor induse nucleoni [At. Data Nucl.Data Tables **153**, 101583 (2023)], în timp ce autorii TALYS au subliniat cel mai recent că „*au existat destul de multe dezbateri cu privire la distribuțiile corecte de spin pentru reacțiile la preechilibru*”, în timp ce „*versiunile actualizate vor fi rezervate pentru viitoarele modele de pre-echilibru care iau în considerare în mod constant spin-ul de-a lungul întregului formalism*” [Eur. Phys. J. A (2023) **59**:131]. Rezultatele obținute, utilizând cele mai recente opțiuni ale codului TALYS-1.97, de exemplu „**preeqspin 4**”, au fost discutate în acest sens, în timp ce sunt în curs investigații suplimentare privind efectele opțiunii „**preeqspin Y**” asupra tranzițiilor izomerice. în lucrarea<sup>4</sup> ce urmează a fi transmisă spre publicare cu urmatorul ‘Abstract’:

“The activation cross sections of <sup>91-96,97m,99m,101</sup>Tc nuclei in deuteron-induced reactions on Mo were measured by the stacked-foil technique and high-resolution gamma spectrometry using U-120M cyclotron of CANAM infrastructure of NPI CAS, at energies up to 20 MeV, and NFS facility at SPIRAL-2 at energies between 20 and 40 MeV. Their extended analysis, together with all available data for deuteron interactions with Mo isotopes up to 50 MeV, has then included every process from elastic scattering and deuteron breakup (BU), until stripping and pickup direct reactions (DRs) besides pre-equilibrium emission (PE) and fully equilibrated compound nucleus (CN) decay. The newly measured activation excitation functions proved essential for deuteron database, while analysis of all available data strengthens their consistent account, while molybdenum is one of the major constituents of the reference stainless steels used in critical components of the DEMO fusion power plant and IFMIF-DONES neutron-source nuclear analyses.”

**2.5** O contribuție rezumativă a principalelor aspecte specifice reacțiilor induse de deuteroni, privind în particular reacțiile (d,p), (d,2p), (d,xn2p) și (d,xn), a format și obiectul unei prezentări<sup>6</sup> orale principale la ediția din 2023 a “16<sup>th</sup> Varenna Conference on Nuclear Reaction Mechanisms”<sup>19</sup> de referință în domeniul mecanismelor de reacții nucleare, în deschiderea sesiunii ‘Deuteron and nucleon induced reactions’, cu urmatorul ‘Abstract’:

“Suitable account of available excitation-function of deuterons in-interaction with target nuclei components of candidates materials for the ITER fusion reactor, the European DEMO fusion reactor, and the IFMIF-DONES Ir-radiation Facility has been proved by consistent analysis of the reaction mechanisms involved in the complex deuteron-nucleus interaction. In this work the attention has been focused on the analysis of the deuteron activation cross sections related to the gas accumulation, (d, p), (d, 2p), (d, xn2p), and to the strong neutron emission, (d, xn), interaction processes of interest for the radiation damage and shielding design studies devoted to the structural materials selection. The key role of direct interactions, i.e., breakup, stripping and pick-up processes is stressed out by the comparison of data with theoretical and evaluation predictions.”

**2.6** În contextul unui ‘ResearchTopic’<sup>20</sup> inițiat de directorul acestui proiect împreună cu alți patru colegi din Germania (2), Anglia și Suedia, la propunerea editorilor **Frontiers-in-Physics**

---

<sup>19</sup>F. Cerutti and T. Kawano (Eds.), *Proc. 16th Varenna Conference on Nuclear Reaction Mechanisms (NRM2023)*, Varenna, Italy, June 11-16, 2023, <https://indico.cern.ch/event/1132769/>, EPJ Web of Conf. **292** (2024)

<sup>20</sup>. Avrigeanu, I. Kodeli, D. Leichtle, A. Prokofiev, and U. Fischer (Eds.), *Frontiers-in-Physics Research Topic on Nuclear Data for Fusion Technology from Basic Research to Full-Scale Applications*,

(<https://www.frontiersin.org/>), a publicat de asemenea cu rol rezumativ o lucrare<sup>2</sup> cu urmatorul 'Abstract':

"The nuclear data evaluation for deuteron-induced reactions and  $\alpha$ -particle emission by neutron interactions is addressed within "Nuclear data for fusion technology, from basic research to full-scale applications." The status and open questions related to these subjects in the area of nuclear data for fusion technology, specifically for the nuclear design of the ITER fusion device, the European DEMO fusion reactor, and the IFMIF-DONES Irradiation Facility, are briefly reviewed. A firm demand for accurate cross-sections of reactions induced by neutrons and deuterons exists, in this respect, within a more enlarged energy range up to 50 MeV than for fission applications. The current requirements are closely met by the TENDL Evaluated Nuclear Data Library, settled using the TALYS nuclear model code, which is one of the most widely used codes in basic research and applications including nuclear fusion technology. However, further improvement of this data library has recently been suggested, while, with respect to fission applications, not only the aforementioned energy range but also the diversity of nuclear data for fusion technologies is plainly stretched. Consequently, the progress of nuclear data activities conducted more recently on deuteron-induced reactions and  $\alpha$ -emission by neutron interactions, throughout the European Fusion Program and subsequent to previous achievements within F4E and EUROfusion programs, is wholly summarized."

### 3. Prezentarea indicatorilor de rezultat realizați

Corespunzător celor 3 articole în reviste cotate ISI și 6 contribuții la conferințe/manifestări internaționale indicate ca „Rezultate estimative verificabile ale activității” în „Plan de realizare a proiectului” (Anexa II la Contractul de finanțare nr. PCE 14 / 2022), au fost realizate:

- 3 articole publicate în reviste având AIS Q1 (Ref.<sup>3</sup>) și Q2 (Refs.<sup>1-2</sup>),
- 3 contribuții la conferințe internaționale și publicate în reviste indexate ISI (Refs.<sup>5-7</sup>), și
- 3 contribuții la manifestări internaționale „Nuclear Data Week”, OECD/NEA Data Bank, Paris, și disponibile pe pagina [https://www.oecd-neo.org/dbdata/nds\\_effdoc/](https://www.oecd-neo.org/dbdata/nds_effdoc/) (Refs.<sup>15-17</sup>).

### 4. Prezentarea nerealizărilor înregistrate față de rezultatele estimate prin cererea de finanțare

Un obiectiv major nerealizat îl reprezintă angajarea unui masterand/doctorand/post-doc deși disponibilitatea poziției vacante a fost anunțată public la adresele din interior/exterior IFIN-HH, inclusiv pe pagina proiectului (<https://www.nipne.ro/proiecte/pn3/60-proiecte.html>), din 26.05.2022):

- <https://www.euraxess.gov.ro/jobs/814405>
- <https://jobs.research.gov.ro/anunt.php?id=5138>
- [https://www.nipne.ro/jobs/01082022/asistent\\_cercetare\\_PCE-2021-0642.doc](https://www.nipne.ro/jobs/01082022/asistent_cercetare_PCE-2021-0642.doc)
- [https://www.nipne.ro/proiecte/pn3/20220510\\_gqrpav\\_avrigeanu/OpenPosition\\_MSc-PhD\\_ASC\\_PCE-2021-0642.pdf](https://www.nipne.ro/proiecte/pn3/20220510_gqrpav_avrigeanu/OpenPosition_MSc-PhD_ASC_PCE-2021-0642.pdf)
- oferta tematică în cadrul Scolii Doctorale de Fizică (UB, 2023), disponibilă pe pagina <https://www.fizica.unibuc.ro/Doctorat/Prezentare/Conducatori/>, cu includerea 'link'-

urilor publicatiilor din ultimii 3 ani, din zona 'rosie/galbena' ISI/WoS, avand directorul proiectului de fata ca autor corespondent si reprezentand exemple de lucrari realizabile in cursul unui stagiu doctoral/post-doctoral.

##### **5. Impactul estimat al rezultatelor obținute, cu sublinierea celui mai semnificativ rezultat obținut.**

Cel mai semnificativ rezultat al proiectului de fata il reprezinta publicarea lucrarii Ref.<sup>3</sup> intr-o revista de marca a domeniului fuziunii nucleare (AIS Q1). In acest mod s-a obtinut o atestare la cel mai inalt nivel a originalitatii si consistentei studiului respectiv. De asemenea este de mentionat si aprecierea unui al doilea referent al *Journal of Fusion Energy* pentru principala lucrare<sup>3</sup> de sinteza a proiectului: *'The paper details extensive efforts in producing accurate cross sections for deuterium induced reactions on natural and isotopic Mo targets to contribute to nuclear data libraries. These are of fusion relevance as they are used the design and commissioning of the IFMISDONES and similar deuterium beam facilities. Mo is a component in structural materials and its behaviour under deuterium irradiation needs to be accurately predicted. The modeling approach used (with explicit contributions from direct and break up reaction channels) gives improved agreement with available experimental data compared to current evaluations. The paper shows that high fidelity calculations of this nature are required to accurately predict deuterium induced activation cross sections for Mo targets.'* (J. Fusion En. MS. No. 10894, 2nd Referee, March 6, 2024).

In acelasi timp, importanta analizei optime a reactiilor induse de deuteroni in instalatii de fuziune nucleara a condus si conduce in continuare la sustinerea<sup>21</sup> acestor studii si in cadrul programului **EUROfusion Consortium** (*European Consortium for the Development of Fusion Energy*, <https://www.euro-fusion.org/eurofusion/>). Astfel, toate lucrarile mentionate si in acest raport au un dublu obiectiv: unul orientat intr-o prima parte a lucrarii asupra aspectelor de cecetare fundamentala (ipoteze si parametri de modele nucleare, raportate in principal la obiectivele acestui proiect), si altul realizat in a doua parte a lucrarii prin rezultatele calculelor de sectiuni eficace de reactie ce urmeaza a fi preluate de *EUROfusion*.

Director Proiect,

(Nume, Prenume, Semnatura)

Avrigeanu Marilena

---

<sup>21</sup> <https://www.nipne.ro/proiecte/pn3/57-proiecte.html>