

RAPORT ȘTIINȚIFIC INTERMEDIAR

ETAPA DE EXECUTIE NR. 1

CU TITLUL Completari la validarea emisiei de particule alfa indusa de neutroni rapizi pe materiale structurale in particular la ~10 MeV, si analiza avansata a sectiunilor eficace ale izomerilor in reactii induse de deuteroni pe nuclee cu A=90-100 (Supplementary material on the assessment of particular alpha-particle emission induced by fast-neutrons on structural materials around 10 MeV and advanced analysis of isomeric cross sections of deuteron-induced reactions on A=90-100 nuclei)

Raportul științific intermediar va cuprinde următoarele documente:

1. Raportul de cercetare *in extenso*, conform modelului din Anexa 1.A;
2. Indicatori de realizare intermediară, vor fi completați în platforma IFA-PROMPT;
3. Proces verbal de avizare internă, conform modelului din Anexa 1.C;
4. Procese verbale de recepție a lucrărilor realizate de terți – fără format impus;

RAPORT ȘTIINȚIFIC FINAL

Raportul științific final va cuprinde următoarele documente:

1. Rezumat publicabil în limbile română și engleză (maxim 3 pagini) din care să rezulte principalele rezultate, activități, gradul de noutate și impactul preconizat asupra mediului științific, tehnic, economic, social și didactic;
2. Indicatori de realizare finală, conform modelului din Anexa 1.B – reprezintă suma tuturor indicatorilor din rapoartele intermediare;
3. Protocol de finalizare a proiectului, conform modelului din Anexa 1.D.

Detailed research report

1. Project title: Romanian cooperation to EUROfusion WPBB2 and complementary research / WPBB2-RO (Participarea Romaniei la EUROfusion WPBB2 si cercetari complementare / WPBB2-RO)
2. List of deliverables covered in the present report:
 - 1 research report
 - 2 articles (see item 5 below)
 - 2 conference (meeting) contributions (see item 5 below)

3. Summary (max. 1 page)

An additional analysis of the most recent measurement and analysis of (n,α) reaction cross sections has included the eventual role of the alpha-emission decay of nuclei excited just at the isoscalar Giant Quadrupole Resonance (ISGQR) energies within (n,α) reactions below and around the incident energy of 14 MeV. Former EUROfusion/WPBB similar analyses [Eur. Phys. J. A **57**, 54 (2021), **58**, 189 (2022), Phys. Rev. C **107**, 034613 (2023)] has been completed in this respect also by comparison of the corresponding Energy Weighted Sum Rule (EWSR) data with the available systematics. The results are published in Phys. Lett. B **858** (2024) 139078, with a Supplementary Material requested by the paper referee, entitled „*The ISGQR systematics' widths and Lorentzian shapes use within neutron-induced alpha-emission analysis*”.

At the same time, an advanced analysis of isomeric cross sections of deuteron-induced reactions on Mo stable isotopes nuclei has been initiated following the proper account of all involved mechanisms contributions as the breakup (BU), stripping and pick-up direct reactions (DRs), pre-equilibrium (PE) and compound –nucleus (CN) processe, and amending the nuclear-level density (NLD) spin distribution cut-off parameter by a factor of 0.25 [M. Avrigeanu *et al.*, J. Fusion Energy **43**:15 (2024)]. The results obtained for the neutron emission within the deuteron-induced reactions on Mo isotopes have been discussed using the latest options of TALYS-1.97, i.e. ‘**preeqspin 4**’ in addition to ‘**preeqspin 3**’. This goal is customary with respect to the previous conclusion that reduced values of the spin cut-off parameter, obtained from isomeric cross-section analysis, was artificial and resulted from the use of an improper PE spin distribution, namely CN one.

4. Detailed report, highlighting the results obtained during the reporting period and the objectives fulfilment, conclusions

Further validation of the alpha-particle optical model potential (OMP) developed within F4E/EUROfusion deliverables, for a sound description of the alpha-emission in neutron-induced reactions, has concerned the most recent measurement and analysis of (n,α) reaction cross sections. Measured data larger by $\sim 100\%$ than actual evaluations (TENDL-2023) led firstly to changes of the above-mentioned OMP (also the actual default option of the code-system TALYS-2.0 used to provide TENDL), however at variance with other recent measurements. Consequently, an additional analysis

of these data has been carried out, including the eventual role of the alpha-emission decay of nuclei excited just at the isoscalar Giant Quadrupole Resonance (ISGQR) energies within (n,α) reactions below and around the incident energy of 14 MeV. Former EUROfusion/WPBB similar analyses [Eur. Phys. J. A **57**, 54 (2021), **58**, 189 (2022), Phys. Rev. C **107**, 034613 (2023)] has been completed in this respect also by comparison of the corresponding Energy Weighted Sum Rule (EWSR) data with the available systematics. An additional ‘isotope effect’ has been proved for the ISGQR fractions of the EWSR, corresponding to the (γ,α) and (n,α) reactions, at variance to the systematics of the previous (α,α') results. This supplementary analysis is providing further support of the above-mentioned alpha-particle, made possible only by the correlation between the measured error bars of the primary data used to fix the consistent input parameters, and the final uncertainty bands of the calculated results. The results are published in Phys. Lett. B **858** (2024) 139078, with a Supplementary Material requested by the paper referee, entitled „*The ISGQR systematics' widths and Lorentzian shapes use within neutron-induced alpha-emission analysis*” [1].

At the same time, an advanced analysis of isomeric cross sections of deuteron-induced reactions on Mo stable isotopes nuclei has been initiated following the proper account of all involved mechanisms contributions as the breakup (BU), stripping and pick-up direct reactions (DRs), pre-equilibrium (PE) and compound–nucleus (CN) processes. It has been obtained similarly to the suitable modeling of the measured ground and isomeric state excitation functions of deuteron-induced reactions on Cr, Fe, Ni, Zr, and Nb stable isotopes within actual state-of-art by TALYS calculations and amending the nuclear-level density (NLD) spin distribution cut-off parameter by a factor of 0.25 [J. Fusion Energy **43**:15 (2024)]. Actually these results are in line with the most recent compilation of isomeric ratios of light particle induced reactions [At. Data Nucl. Data Tables **153**, 101583 (2023)]. The results obtained for the neutron emission within the deuteron-induced reactions on Mo isotopes have presently discussed using the latest options of TALYS-1.97, i.e. ‘**preeqspin 4**’ in addition to ‘**preeqspin 3**’ [2]. They represent a former phase of a comparative analysis of them and the large amount of measured isomeric cross sections of reactions induced by deuterons on Nb [Phys. Rev. C **88**, 014612 (2013)] as well as neutrons on Mo [Phys. Rev. C **71**, 044617(2005)] already well described using no spin cut-off adjustment but an advanced particle-hole state density [Comp. Phys. Comm. **112**, 191 (1998)] including a PE spin cut-off [Nucl. Sci. Eng. **92**, 440 (1986)]. This goal is customary with respect to the previous conclusion that reduced values of the spin cut-off parameter, obtained from isomeric cross-section analysis, were artificial and resulted from the use of an improper PE spin distribution, namely CN one [Phys. Rev. C **80**, 044612 (2009)].

The above-mentioned results have been presented within the EUROfusion WPBB-S.05.02-T007 Monitoring meeting on Nov 25, 2024, at OECD/NEA Data Bank [3,4].

5. Publications list, conference presentations, list of attended meetings.

[1] M. Avrigeanu and V. Avrigeanu, Phys. Lett. B **858**, 139078 (2024) *Supplemental Material: The ISGQR systematics' widths and Lorentzian shapes use within neutron-induced α -emission analysis*, <https://www.sciencedirect.com/science/article/pii/S0370269324006361#se0090> [AIS Q1], [EUROfusion Pinboards No. 410/2024, Figs. 1-2 and 4-5.

[2] 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) [EUROfusion Pinboards No. 942/20 Nov. 2024], Secs. 4-5.

[3] M. Avrigeanu and V. Avrigeanu, *Progress report on deuteron-induced reaction analysis*, Report EFFDOC-1546, OECD/NEA JEFF (Nov 25-28, 2024) & EUROfusion WPBB-S.05.02-T007

Monitoring meeting, Nov 25, 2024, https://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1546.pdf, Secs. 3-4.

- [4] V. Avrigeanu and M. Avrigeanu, *Progress report on neutronn-induced alpha-particle emission analysis*, Report EFFDOC-1547, OECD/NEA JEFF (Nov 25-28, 2024) & EUROfusion WPBB-S.05.02-T007 Monitoring meeting, Nov 25, 2024, https://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1547.pdf, Secs. 3-4.

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CU TITLUL Completari la analiza si validarea ipotezelor si parametrilor de modele nucleare pentru evaluarea datelor de reactii induse de deuteroni pentru materiale structurale, si a potentialului de model optic al particulelor alfa relevant pentru evaluarea producerii de gaze si defecte de iradiere (Supplementary material on nuclear-model assumption/parameter analysis and validation for evaluation of deuteron-induced reaction data of structural materials and alpha-particle optical model potential relevant for evaluation of gas production and radiation damage data)

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A particular action concerned the completion at the very beginning of this project of its web page with the address <https://www.nipne.ro/proiecte/pn4/5-projects.html> . The main goal of this prompt advertising activity has been the immediate announcement of the open position for a research-assistant physicist to be hired for the project period, as a first note on this page (http://www.nipne.ro/proiecte/pn4/WPBB2-RO/Asistent_Cercetare_WPBB2.pdf). Moreover, the same announcement has been made available also the national level:

https://www.nipne.ro/jobs/10122024/asistent_cercetare_WPBB2rev2.doc ,
http://jobs.research.gov.ro/docs/Asistent_Cercetare_Proiect_EURATOM_RO_WPBB2_8949.doc ,
<https://euraxess.ec.europa.eu/jobs/298794#work-locations> .

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- [2] 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) [[EUROfusion Pinboards](#) No. 942/20 Nov. 2024], Secs. 1 and 3.
- [3] M. Avrigeanu and V. Avrigeanu, *Progress report on deuteron-induced reaction analysis*, Report EFFDOC-1546, OECD/NEA JEFF (Nov 25-28, 2024) & EUROfusion WPBB-S.05.02-T007 Monitoring meeting, Nov 25, 2024, https://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1546.pdf, Secs. 1-2.
- [4] V. Avrigeanu and M. Avrigeanu, *Progress report on neutron-induced alpha-particle emission analysis*, Report EFFDOC-1547, OECD/NEA JEFF (Nov 25-28, 2024) & EUROfusion WPBB-S.05.02-T007 Monitoring meeting, Nov 25, 2024, https://www.oecd-nea.org/dbdata/nds_effdoc/effdoc-1547.pdf, Secs. 1-2.