PN IV: 5.9.2

CERN Research Programme/ Experiment:
Neutrino Platform/ NP-02- proto-DUNE-DP and DRD2

Project title / Acronym:

Romanian contribution to CERN to DUNE experiment/ RO-DUNE 3
RO-DUNE-3

University of Bucharest

Team members:

1. Prof. Ionel Lazanu - Senior Researcher I
2. Prof. Alexandru Jipa - Senior Researcher I
3. Dr. Mihaela Parvu – Researcher III
4. Dr. Leonard Gebac – Researcher
5. Ioana Lalau - PhD Student
6. Denis Barbu – PhD Student
7. Valentin Bugaescu – Master Student

28 November 2025

Specific scientific activities focus of UoB group in 2025:

1+3. Low-Energy Physics: contributions to radiopurity & radioactive background mitigation at protoDUNEs and DUNEs, DUNE -phase II, DRD2 (* Results of the MC simulations using FLUKA code: **1 oral talk** at DUNE General Meeting; **2 oral talks** at DRD2 Meetings; * Preparation stage of neutron attenuation measurements with a set-up built at UoB for protoDUNEs and DUNEs, DUNE -phase II, as well as in DRD2; * Analysis of current knowledge for (alpha, n) reactions and urgent resolution needs - published paper; * Improvement and upgrade of the SOURCES4 code for (alpha, n) reactions - available code and published article.)

2. Searches for exotic particles using DUNE or protoDUNE. The work about hypothetical detection of ALPs produced by $A\bar{Q}Ns$ captured in the core of the Earth is in progress and will be posted in arXiv.

4. Consolidation of participation in collaboration (by participating in 2 weeks of online meetings of WGs of interest: Low energy, protoDUNE, DUNE -phase 2, DRD2/Tasks 4.1 and general; participation at in-person meetings.)

5. Dissemination of results and outreach activities and achieving synergies with other groups
(*** 11** activities @ DUROCERN with **372** middle school and high school students, as well as students.; * Participation in the Science and Technology Summer School 2025)

Highlights of accomplishments during 2025 in the collaboration

ProtoDUNE@Neutrino Platform Two 750 t LAr TPC prototypes at EHN1 in the CERN North Area exists.
NP02 Vertical Drift: • demonstrator installed in 2023-24, and **is operational from 2025**. • DUNE **Physics program** with NP02 **is completed**. • A plan of the NP02 post beam run activities was agreed. • The plan covers all the requested tests. • Plan to be completed by the end of March '26. • In parallel, continue the feasibility study (supported by data) of **BSM searches with ProtoDUNEs as beam dump experiment** • Liquid argon will be kept (clean) in NP02 • Interest in maintaining NP02 operational with minimal supervision

Priority of the Neutrino Platform in the next 2-3 years: [from F. Lanni's talk at nuSCOPE Workshop, oct. 2025]:... • Continue to **support the existing approved experiments**. • Possible **synergies and common R&D activities with the DRD2 Collaboration.**

ProtoDUNE NP02 and their role in the DUNE - Phase II: The DUNE Collab. has identified the NP02 cryostat as the natural infrastructure for validation of detector technologies for DUNE Phase II Far Ddetector modules. **VD is the reference starting point for the DUNE FD 3&4**.

Results obtained by UoB team in 2025

Studies for (α, n) Reactions

Motivation: * The neutrons from the (α, n) reactions are an important component of the radioactive background of the experiments. The calculations and measurements depend on accurate nuclear data to support the analysis. * However, much of the relevant data was measured in the 1980s and earlier and has not been updated. * The current uncertainties in the cross sections and neutron emission spectra are unacceptably large. * Those uncertainties, coupled with the computational power now available to utilize any improved data, prompted a scoping study of (α, n) reaction data.

The interest in (alpha, n) reactions has been analysed for a wide range of applications: neutrino physics, searches for dark matter and neutrinoless double beta reactions, astroparticles, nuclear reactions, reactors, to medical applications.

SOURCES4 code has been updated including: * Revised cross-sections derived from experimental data where available, and from nuclear reaction models using TALYS 1.96, EMPIRE 2.19/3.2.3, and the JENDL-5 evaluated library when data were scarce. * The implementation also incorporates an extended set of excited nuclear levels from RIPL-3, providing a more complete treatment of final-state transitions.

After an effort of over 2 years these 2 works were completed and published:

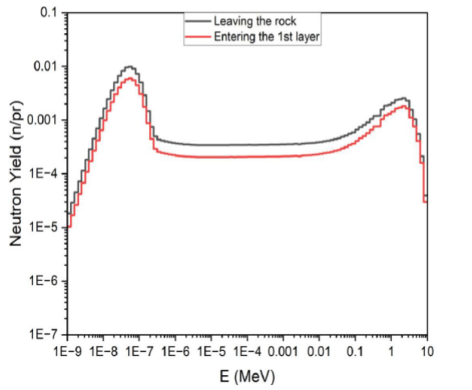
Review of Neutron Yield from (α, n) Reactions: Data, Methods, and Prospects,
J. Phys. G, 2025, https://doi.org/10.1088/1361-6471/
Optimized neutron yield calculations from (α, n) reactions with the modified SOURCES4 code,
Appl.Radiat.Isot. 225 (2025) 112035, https://doi.org/10.1016/j.apradiso.2025.112035

Radiopurity & background mitigation (WG – Low energy physics in DUNE and Task 4.1 in DRD2)

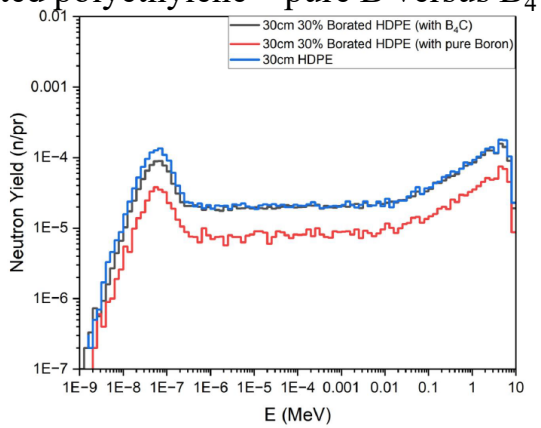
- **Modelling the radioactive sources of background using MC codes or other methods;**
- **Radioassay techniques at required sensitivity for next generation of rare-event search experiments**
- **Mitigation through material selection/treatment and clean manufacture**
- **Development of novel materials for background suppression**
- **Tools for the evaluation of backgrounds**

Shielding materials **Seven materials as potential supplementary shielding layers were studied: water, HDPE, borated HDPE with: 2%, 5%, 10% and 30% as well as boron carbide.**

FLUKA simulation of neutrons generated in 40 cm of rock surrounding the cavern – neutrons are highly surpressed due to the two reasons pointed before.



Borated polyethylene – pure B versus B_4C



- Based on the simulations (FLUKA) for a simplified geometry, 30 cm of HDPE can reduce the number of neutrons that enter in the LAr by more than 3 order of magnitude. Borated polyethilene is found to have similar performances but is more expensive.

Work in progress

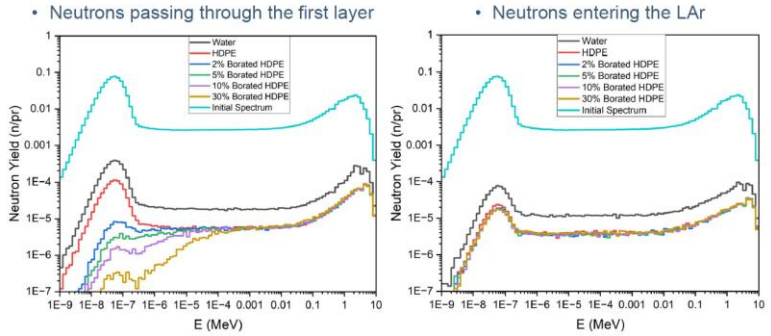
Simulations for optimizing neutron and gamma radiation shielding

Work in progress

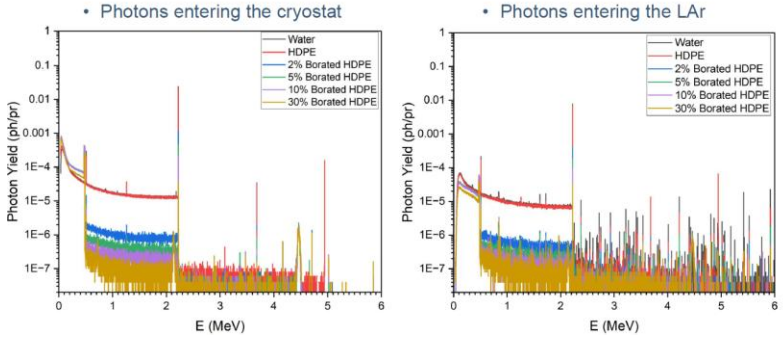
* The wall of rock is practically infinite. In the simulations, **a rock thickness of 40 cm** was found to give approximatively the constant spectrum **as the case of 100 cm** (the relative differences between the normalized yields are less than 1%).

* Preliminary results on neutron and gamma shieldings

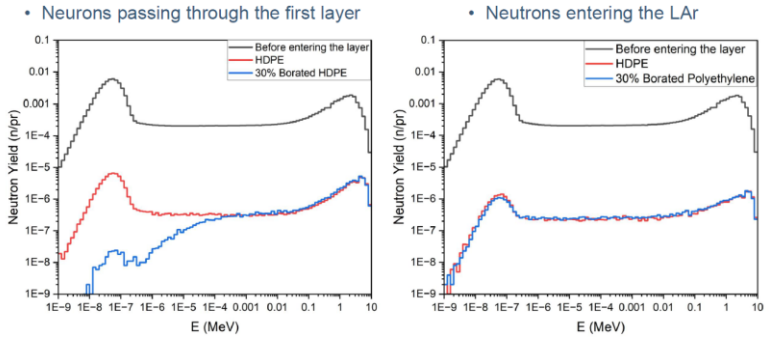
Preliminary results – 30 cm layers in the simplified geometry



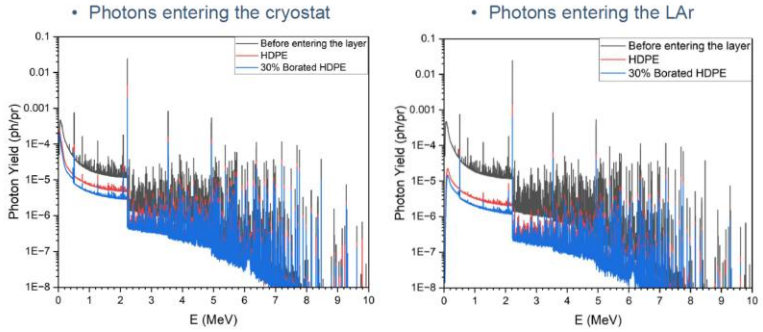
Preliminary results – 30 cm layers in the simplified geometry



Preliminary results – 30 cm layer in a real geometry



Preliminary results – 30 cm layer in a real geometry



Denis Barbu , Talks done at: DUNE - General Meeting, Valencia September 2025, DRD2 Meeting, February 2025, DRD2-Task 4.1 Meeting, October 2025

BSM Physics

quarks and gluons form baryons such as protons and neutrons

nuclei

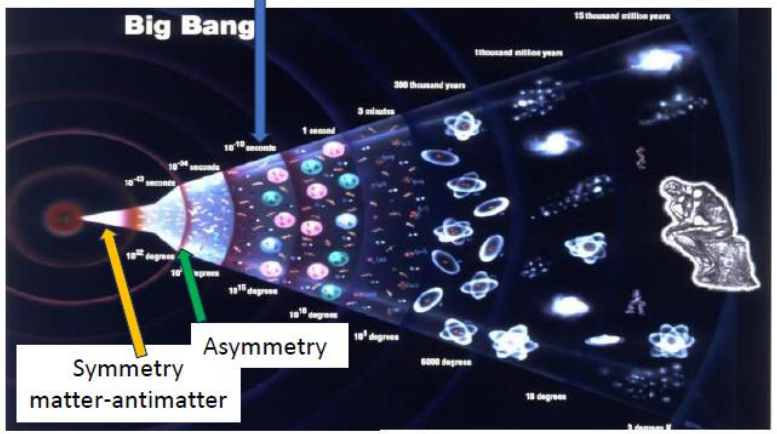
atoms

macroscopic matter, planets, etc.

Standard Model

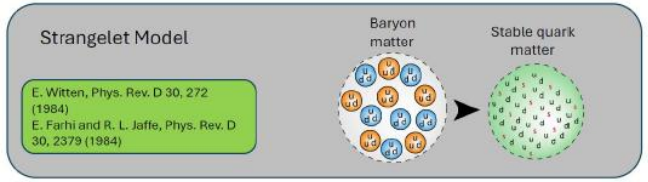
6 quarks+6 antiquarks
6 leptons+6 antileptons

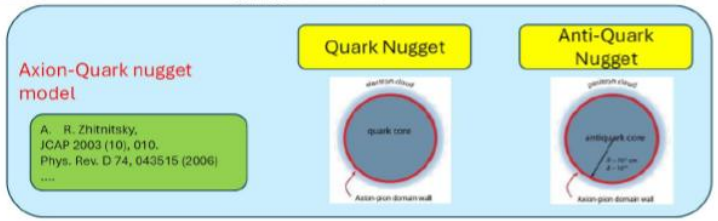
Higgs
3 interactions:
Colour + em + weak
+
gravity



Are additional exotic particles needed?

WIMPs ...? Others?



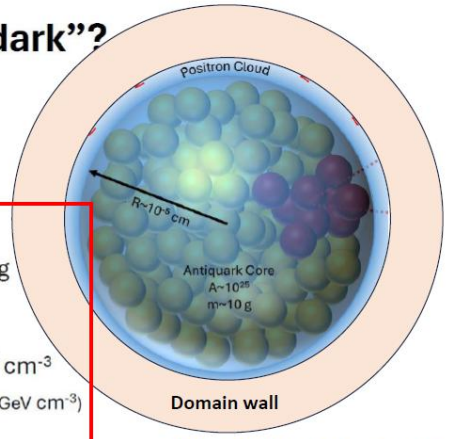


Usually, in hadronic interactions $\frac{\sigma}{M} \sim 10^{-2\div 3} \frac{cm^2}{g}$

Why are Quark Nuggets "dark"?

- Typical **mass number**: $\langle A \rangle \simeq 10^{25}$
- Typical **mass**: $\langle M \rangle = Am_p \simeq 10\,\mathrm{g}$
- Typical **size**: $\langle R \rangle \simeq A^{1/3} \times 1\,\mathrm{fm} = 10^{-5}\mathrm{cm}$

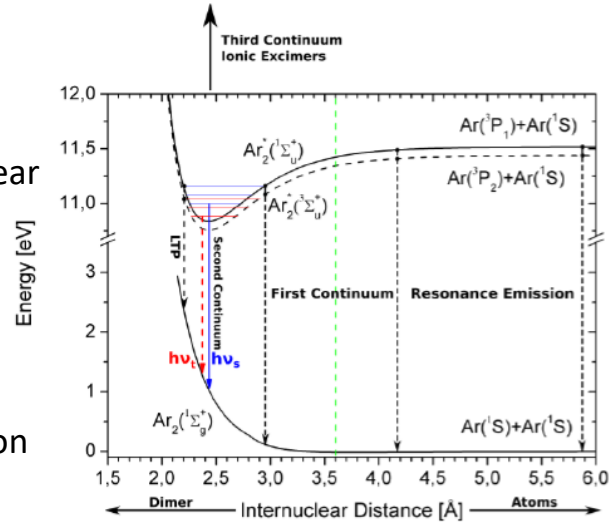
- **Cross-section to mass ratio:**
$$\frac{\sigma}{M} \sim 10^{-9}\ \mathrm{cm^2/g}$$
- **Number density:**
$$\langle n \rangle = \frac{\rho}{\langle M \rangle} \lesssim 10^{-26}\ \mathrm{cm^{-3}}$$
(Local DM density, $\rho = 0.3\,\mathrm{GeV\,cm^{-3}}$)
- **Rate on Earth:**
$$\frac{\langle \dot{N} \rangle}{4\pi R_\oplus^2} \simeq 4 \times 10^{-2}\ \mathrm{km^2\ yr^{-1}}$$



their oscillations generate a new type of particles - axions

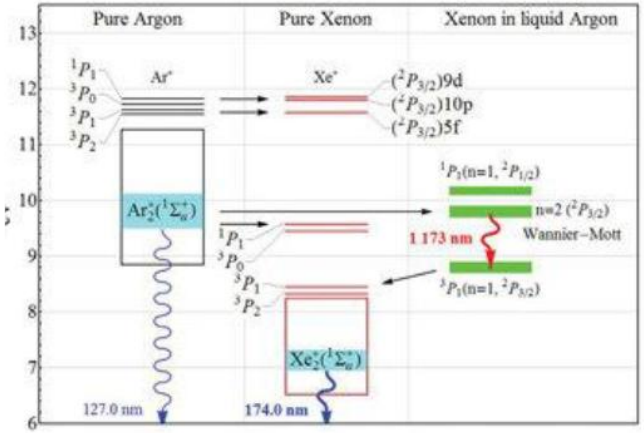
Detection using liquid noble gases

The molecule potentials are dependent on the internuclear distance. The lower black curve exhibits the repulsive ground state potential.
The green dashed vertical line denotes the mean internuclear distance of argon atoms in the liquid phase.



The argon excimer molecule potentials and the corresponding emission processes.

Energy levels in the liquid argon-xenon mixture which are important for the excitation scheme



Work is in progress.

Papers and talks

Journals / arxiv in the last year

Papers using ProtoDUNE

1. Spatial and temporal evaluations of the liquid argon purity in ProtoDUNE-SP
JINST 20 (2025) 09, P09008, e-Print: 2507.08586 [physics.ins-det]
2. The track-length extension fitting algorithm for energy measurement of interacting particles in liquid argon TPCs and its performance with ProtoDUNE-SP data
JINST 20 (2025) 02, P02021, e-Print: 2409.18288 [physics.ins-det]
3. Identification of low-energy kaons in the ProtoDUNE-SP detector
e-Print: 2510.08380 [hep-ex]

Papers with a short number of authors

1. Nuclear effects in proton decay
D Barbu, M Parvu, I Lazanu, *Mod.Phys.Lett.A* 40 (2025) 13n14, 2550038, e-Print: 2502.13981 [hep-ph]
2. Optimised neutron yield calculations from (α, n) reactions with the modified SOURCES4 code
M Parvu, Piotr Krawczun, Vitaly A. Kudryavtsev,
Appl.Radiat.Isot. 225 (2025) 112035, e-Print: 2408.10910 [nucl-ex]
3. Review of Neutron Yield from (α, n) Reactions: Data, Methods, and Prospects, D. Cano-Ott, …V. A. Kudryavtsev, **I. Lazanu**,…, **M. Parvu**, ..
J.Phys.G (2025), e-Print: 2405.07952 [nucl-ex]

Papers using DUNE

1.Neutrino interaction vertex reconstruction in DUNE with Pandora deep learning, *Eur. Phys. J. C* 85 (2025) 697, 697, e-Print: 2502.06637 [hep-ex]
2. DUNE Phase II: scientific opportunities, detector concepts, technological solutions, *JINST* 19 (2024) 12, P12005, e-Print: 2408.12725 [physics.ins-det]
3. Supernova pointing capabilities of DUNE
Phys.Rev.D 111 (2025) 9, 092006, e-Print: 2407.10339 [hep-ex]
4. Towards mono-energetic virtual ν beam cross-section measurements: A feasibility study of ν-Ar interaction analysis with DUNE-PRISM
e-Print: 2509.07664 [hep-ex]
5. Operation of a Modular 3D-Pixelated Liquid Argon Time-Projection Chamber in a Neutrino Beam, e-Print: 2509.07012 [physics.ins-det]
6. European Contributions to Fermilab Accelerator Upgrades and Facilities for the DUNE Experiment, e-Print: 2503.23744 [physics.acc-ph]
7. DUNE Software and Computing Research and Development
e-Print: 2503.23743 [physics.data-an]
8. The DUNE Science Program, e-Print: 2503.23291 [hep-ex]
9. The DUNE Phase II Detectors, e-Print: 2503.23293 [physics.ins-det]

Talks at international meetings

1. Studies on neutron shielding from (alpha,n) reactions in the rock
Denis Barbu,
DUNE Collaboration Meeting – Valencia, Spain, Sep 8 – 12, 2025
2. Aspects on neutron shielding and simualtions, Denis Barbu,
DRD2 Collaboration Meeting (11-13 February)
3. Neutron shielding studies for underground large detectors,
Denis Barbu,
Carpathian Summer School of Physics 2025
4. Neutron shielding studies – updates,
Denis Barbu,
7 oct. 2025, DRD2 WP4.1 Meeting

Talks at national meetings

Talks at National Conferences: (Bucharest University Faculty of Physics 2025 Meeting; see:

1. The study of B8 and hep solar neutrinos, Valentin BUGAESCU, Mihaela PÂRVU, Ionel LAZANU
2. Neutron background studies for rare event searches,
Denis BARBU, Mihaela PARVU, Ionel LAZANU
3. Open problems in Dark Matter searches,
Ionel LAZANU, Mihaela PARVU, Denis BARBU, Valentin BUGAESCU
4. Studies on neutron shielding for underground detectors through FLUKA simulations, Denis Barbu
Dialoguri Doctorale in Fizica 2025
5. Noi idei de căutare a Materii Intunecate în Univers,
Ionel Lazanu, Mihaela Parvu şi Denis Barbu,
Conferința Anuală de Comunicare a Rezultatelor Cercetării la Universitatea din București, ediția a IV-a 26-29 noiembrie 2025

Collaborations, local synergies

Within the DUNE and DRD2 collaboration, two ad-hoc groups were formed to collaborate in deepening the theoretical and experimental situation related to (alpha, n) reactions which are of major interest in the analysis of the radioactive background in these areas of interest. A computational code has been updated and is currently available to the scientific community.

Education

The field of neutrino physics is correlated with the academic studies in all cycles of education: **undergraduate** through the 2 semesters of the course and laboratory of Nuclear Physics and elementary particles and one course of Detectors; at **master studies** there is a specialization in Physics of the atom, nucleus, elementary particles, astrophysics and applications, and for **doctoral studies** through personalized courses addressed to doctoral students.

In the last 5 years, 8 students have had bachelor's theses, 1 Master Thesis and 2 PhD Thesis in this subject .

Outreach (http://ro-dune.unibuc.ro)

* **Activities @ DUROCERN: 372** middle school and high school students, as well as students from Ovidius Univ. visits the exhibition and interactive spaces within DUROCERN during in **11 activities**

* **Participation in the Science and Technology Summer School 2025**, August - September with the theme: Particle Hunters! The participating team won the 2nd prize

Thank you very much for your attention!