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Book of Abstracts

XXIV International School On Nuclear Physics, Neutron Physics and Applications

13-18 September 2026, Nessebar, Bulgaria

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CONFERENCE PROGRAM

XXIV International School on Nuclear Physics, Neutron Physics and Applications 2026

13–18 September 2026, Sol Nessebar Resort, Nessebar, Bulgaria

Day 1: Sunday, 13 September 2026

- **10:00 – 17:00** Registration

Day 2: Monday, 14 September 2026

09:00 – 09:30 CONFERENCE OPENING

09:30 – 12:05 Session 1

Chairperson: Dimitar Tonev

09:30 – 10:00 **Giacomo de Angelis**
EXOTIC STRUCTURES AND DOUBLE-MAGICITY AT THE EDGE OF STABILITY
National Institute for Nuclear Physics (INFN)– Legnaro National Laboratories, Legnaro, Italy

10:00 – 10:30 **Gilles De France**
STUDIES OF ISOSCALAR PAIRING AT GANIL
GANIL, Caen, France

10:30 – 10:55 **Diana Carbone**
HEAVY-ION INDUCED SINGLE AND DOUBLE CHARGE EXCHANGE REACTIONS IN A MULTI-CHANNEL APPROACH: NEW RESULTS FROM THE NUMEN PROJECT
Laboratori Nazionali del Sud, Catania, Italy

10:55 – 11:10 Coffee Break

Chairperson: Yu Zhang

11:10 – 11:40 **Dimitar Tonev**
ADVANCED DOPPLER-SHIFT METHODS AND NUCLEAR CHIRALITY
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

11:40 – 12:05 **Alessandro Compagnucci**
PROBING THE 10B+A REACTIONS AT LUNA FOR NUCLEOSYNTHESIS IN PRIMORDIAL STARS
SUPA, School of Physics and Astronomy, University of Edinburgh, UK

12:30 – 14:00 Lunch Break

15:00 – 17:20 Session 2

Chairperson: Giovanni De Gregorio

15:00 – 15:25 **Giuseppe D'Agata**
ANC METHOD: STANDARD USAGE AND RECENT UPDATES
Dipartimento di Fisica e Astronomia "Ettore Majorana," Università di Catania, Italy

15:25 – 15:50 **Angel Demerdjiev**
NEUTRON IRRADIATION OF SHIELDING STRUCTURES IN THE INRNE-BAS TR-24 CYCLOTRON FACILITY
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

15:50 – 16:15 **Jeongsu Ha**
ABRUPT STRUCTURAL TRANSITION IN 84MO AND 86MO: AN ISOSPIN-SYMMETRIC ISLAND OF INVERSION

Center for Exotic Nuclear Studies, Institute for Basic Science, Korea

16:15 – 16:30 Coffee Break

Chairperson: Gilles De France

16:30 – 16:55 **Antonino Pitronaci**
DETECTION CHALLENGES WITH THE NEW MAGNEX GAS TRACKER: PRELIMINARIES AND PERSPECTIVES
Department of Physics and Astronomy "E. Majorana", UniCT, Italy

16:55 – 17:20 **Radoslav Simeonov**
IMPACT OF MIRROR MISALIGNMENT ON THE POINT SPREAD FUNCTION IN A SIMPLIFIED OPTICAL MODEL
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

18:30 – 19:30 Welcome drink

19:30 – 21:30 Dinner – Italian Restaurant

Day 3: Tuesday, 15 September 2026

09:30 – 12:05 Session 3

Chairperson: Jie Meng

09:00 – 09:30 **Peter Ring**
BRUECKNER HARTREE-FOCK THEORY AS AN AB-INITIO APPROACH FOR NUCLEAR DENSITY FUNCTIONAL THEORY
TU Munich, Germany

09:30 – 10:00 **Baohua Sun**
DEDUCING CHARGE RADII OF UNSTABLE

ISOTOPES USING HADRONIC PROBES
School of Physics, Beihang University, China

10:00 – 10:25 **Yiping Wang**
CONFIGURATION-INTERACTION TIME-DEPENDENT DENSITY FUNCTIONAL THEORY FOR NUCLEAR DYNAMICS
State Key Laboratory of Nuclear Physics and Technology,School of Physics, Peking University, China

10:25 – 10:50 **Nikolay Goutev**
AN EFFICIENCY EXTRAPOLATION METHOD FOR TRUE COINCIDENCE SUMMING CORRECTION
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

10:50 – 11:10 Coffee Break

Chairperson: Qibo Chen

11:10 – 11:40 **Takaharu Otsuka**
QUANTUM MECHANICAL ROTATIONS OF NUCLEAR ELLIPSOIDS AND CLUSTERS
The University of Tokyo, Japan

11:40 – 12:05 **Qiang Zhao**
EXACT-EXCHANGE RELATIVISTIC DENSITY FUNCTIONAL THEORY FOR ATOMIC NUCLEI
China Institute of Atomic Energy, China

12:30 – 14:00 Lunch Break

15:00 – 17:20 Session 4

Chairperson: Giacomo de Angelis

15:00 – 15:30 **Giovanni De Gregorio**
NEUTRINOLESS DOUBLE-BETA DECAY WITHIN A CONSISTENT CHIRAL EFT SHELL-MODEL FRAMEWORK
Università della Campania "Luigi Vanvitelli" & Istituto Nazionale di Fisica Nucleare, Italy

15:30 – 15:55 **Gennaro Nunziata**
QUANTUM ANNEALING FOR NUCLEAR MANY-BODY EIGENVALUE PROBLEMS
Università degli Studi della Campania "L. Vanvitelli", Italy

15:55 – 16:20 **Mariana Petris**
IMPLEMENTATION OF MSMGRPCS WITH AGING EFFECT SUPPRESSION IN LARGE SCALE HIGH INTERACTION RATE EXPERIMENTS
Horia Hulubei National Institute of Physics and Nuclear Engineering, Romania

16:20 – 16:35 Coffee Break

Chairperson: Nikolay Goutev

16:35 – 17:00 **K. Chakarova, Ventzislav Rusanov**
MÖSSBAUER, X-RAY FLUORESCENCE AND XANES MEASUREMENTS ON COUNTERFEITED DOLLAR MONEY PAPER AND PIGMENTS
American College of Sofia, Bulgaria

17:00 – 17:20 **Hristo Hristov**
NUCLEAR PHYSICS IN CLINICAL PRACTICE: FROM MEDICAL RADIONUCLIDE PRODUCTION TO DIAGNOSTIC IMAGING IN ONCOLOGY

Medical University "Prof. Dr. Paraskev Stoyanov",
Clinic of Nuclear Medicine and Metabolic Therapy,
University Hospital "St. Marina", Bulgaria

Day 4: Wednesday, 16 September 2026

09:00 – 12:05 Session 5

Chairperson: Peter Ring

09:00 – 09:30 **Jie Meng**
RECENT ADVANCES IN NUCLEAR CHIRALITY: STRUCTURE AND REACTIONS
Peking University, China

09:30 – 10:00 **Qibo Chen**
ENTANGLEMENT IN NUCLEAR CHIRAL ROTATION
East China Normal University, China

10:00 – 10:30 **Yu Zhang**
ALGEBRAIC MODEL ANALYSIS OF CHIRAL DOUBLET BANDS
Liaoning Normal University, China

10:30 – 10:55 **Elena A. Stefanova**
THE DECAY OF THE HEAD OF THE FIRST H11/2 NEGATIVE-PARITY BAND IN 105Ru
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

10:55 – 11:15 Coffee Break

Chairperson: Y. P. Wang

11:15 – 11:45 **Zhengxue Ren,**
DYNAMICS OF ROTATION IN CHIRAL NUCLEI
School of Physics, Nankai University, China

11:45 – 12:05 **Galina D. Dimitrova**
EVALUATION OF PROMPT AND RESIDUAL RADIATION FIELDS INDUCED BY BEAM LOSSES IN A TR-24 CYCLOTRON FACILITY
Institute for Nuclear Research and Nuclear Energy, Bulgarian of Academy of Sciences, Sofia, Bulgaria

12:20 – 12:30 Conference Photo

12:30 – 14:00 Lunch Break

15:00 – 15:50 Session 6

Chairperson: Angel Demerdjiev

15:00 – 15:25 **Liliana Panteleev-Simeonova**
SEMICONDUCTOR DETECTORS PARAMETERS INVESTIGATIONK
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

15:25 – 15:50 **Mladen Mitev**
INFLUENCE OF THE OF NUCLEAR FUEL ISOTOPIC COMPOSITION ON THE ACTIVATION OF REACTOR INTERNALS
Technical University of Sofia, Bulgaria

15:50 – 16:15 Coffee Break

16:30 – 17:30 Poster Session

1. **Rositsa Palakarcheva-Ivanova, Kalin Filipov*, Mladen Mitev**
   FUNCTIONAL RESONANCE ANALYSIS METHOD AS AN ANALYTICAL TOOL FOR ASSESSING THE IMPACT OF ACCIDENT TOLERANT FUEL IMPLEMENTATION ON FUNDAMENTAL NUCLEAR SAFETY FUNCTIONS IN LIGHT WATER REACTORS
   Technical University of Sofia, Sofia, Bulgaria

2. **Boyan Bonchev**
   PYROPHORIC IRON NANOPARTICLES FORMED BY SELECTIVE EXTRACTION FROM FE–AL ALLOYS: A MÖSSBAUER STUDY
   Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

3. **Nikolay Petrov**
   LOW-BACKGROUND GAMMA SPECTROMETRY SYSTEM FOR RADIOECOLOGICAL STUDIES
   Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

4. **Elena Geleva**
   APPLICATION OF NUCLEAR PHYSICS METHODS FOR THE DETERMINATION OF RADIONUCLIDES IN NATURAL WATERS
   Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

18:30 – Conference Dinner

Day 5: Thursday, 17 September 2026

09:30 – 11:25 Session 7

Chairperson: Mladen Mitev

09:30 – 09:55 **Kristina Hadzhiyska**
DATA GAPS IN ENERGY SYSTEM MODELING: IMPLICATION FOR SCENARIO RELIABILTY
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

09:55 – 10:20 **Srebrin Kolev**
PRACTICAL AND USER EXPERIENCE FROM UTILISING THE BEACON CORE MONITORING SYSTEM AND THE APA H CODE PACKAGE AT KOZLODUY NPP UNITS 5 AND 6
Kozloduy Nuclear Power Plant, Bulgaria

10:20 – 10:45 **Nikolay Karaivanov** *State Enterprise Radioactive Waste, Bulgaria*

10:45 – 11:05 Coffee Break

11:05 – 11:25 **Petya Vryashkova**
ASSESSMENT OF THE ACCIDENT PROGRESSION IN CASE OF SBLOCA WITH DIFFERENT BREAK SIZES ALONG WITH SBO
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

12:30 – 13:30 Lunch Break

14:00 – Excursion

Day 6: Friday, 18 September 2026

09:30 – 10:35 Session 8

Chairperson: Elena Stefanova

09:30 – 09:50 **Vlad-imir Silvestrov**
COMMISSIONING OF THE NATIONAL DISPOSAL FACILITY
State Enterprise Radioactive Waste, Bulgaria

09:50 – 10:15 **Kalin Filipov**
CHARACTERIZATION OF THE ISOTOPIC COMPOSITION OF SPENT NUCLEAR FUEL IN LIGHT WATER REACTORS
Technical University of Sofia, Bulgaria

10:15 – 10:35 **Desislava Dimitrova**
MONITORING OF 226Ra in BULGARIAN DRINKING WATERS
Institute for Nuclear Research and Nuclear Energy, BAS, Sofia, Bulgaria

10:35 – 11:15 CLOSING CEREMONY

ABSTRACTS

SESSION 1

EXOTIC STRUCTURES AND DOUBLE-MAGICITY AT THE EDGE OF STABILITY

Giacomo de Angelis[1]

[1]*National Institute for Nuclear Physics (INFN-LNL) – legnaro National Laboratories, legnaro, Italy*

Abstract

Magic numbers, corresponding to specific numbers of protons or neutrons, are fundamental to understanding single-particle nuclear shell structure. Nuclei exhibiting one or two magic numbers are characterized by large energy gaps between single-particle orbitals, which confer enhanced stability. Doubly magic nuclei are particularly robust: they are difficult to excite, and their neighboring nuclei can often be described as a few valence nucleons outside a closed core. This effectively reduces a complex quantum many-body problem to a more tractable few-body system. It is now well established that magic numbers can evolve in exotic nuclei far from stability. This raises important questions regarding how shell closures behave at the proton drip line and to what extent shell strength is modified by the weak binding and continuum effects characteristic of systems at the edge of stability [1]. In this context, nuclear structure information obtained through γ-ray spectroscopy plays a crucial role [2,3]. In this talk, I will present recent results from the AGATA LNL experimental campaign, together with high-precision mass measurements of loosely bound nuclei at the proton drip line performed using the newly developed Bp-IMS technique at the storage ring facility in Lanzhou [4,5]. Evidence

for isospin-symmetry breaking has revealed the formation of exotic nuclear structures in near-threshold states. In particular, results support a doubly magic character for ^{22}Si, featuring a more spatially extended proton distribution [5]. Gamow shell-model calculations indicate that this structure arises from an enhanced occupation of the unbound $s_{1/2}$ orbital, driven by continuum coupling effects. The interplay of continuum dynamics and non-Hermitian features makes ^{22}Si a rare and compelling example of a doubly magic open quantum system.

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contract № КР-06-МНФ/8, 18.05.2026.

References:

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[2] L. Lalanne et al., Physical Review Letters 129, 122501 (2022).
[3] J.J.Valiente Dobon et al., Physical Review C **98**, 011302(R) (2018).
[4] Y. Yu et al., Phys. Rev. Lett. 133, 222501 (2024).
[5] Y.M. Xing et al., Phys. Rev. Lett. 135, 012501 (2025).

Studies of isoscalar pairing at GANIL

Gilles de France[1]

[1]*GANIL, Caen, Ffrance*

Abstract

Isoscalar pairing in nuclei is an elusive component of pairing which concentrates the efforts from several teams of experimentalists and theoreticians all the world. It is expected to play a crucial role in the structure of nuclei but it is difficult to establish clear evidence of effects associated to it. Since many years several attempts have been made looking for specific, yet not definite, impact of isoscalar pairing in the structure of specific nuclei. In this talk, I will present the GANIL facility and its future. I will then introduce in some pedagogical way nuclear pairing and present the various experiments we performed to highlight some predicted effects of isoscalar pairing. I will then finish by some conclusions and perspectives.

HEAVY-ION INDUCED SINGLE AND DOUBLE CHARGE EXCHANGE REACTIONS IN A MULTI-CHANNEL APPROACH: NEW RESULTS FROM THE NUMEN PROJECT

Francesco Cappuzzello[1,2*], Diana Carbone[1]

[1]*Laboratori Nazionali del Sud, Catania, Italy*

[2]*Istituto Nazionale di Fisica Nucleare, Catania, Italy,*

E-mail of the Corresponding Author: cappuzzello@lns.infn.it

Abstract

In order to get quantitative information on neutrino absolute mass scale from the possible measurement of the 0νββ decay rates, the Nuclear Matrix Elements (NME) involved in such transitions are required. Recently, heavy-ion induced double charge exchange (DCE) reactions have been proposed in Italy [1-2] and Japan [3,4] as tools to get information about 0νββ NMEs. The basic point is that there are important similarities between the two processes, mainly that the initial and final states are the same and the transition operators have a similar structure, including in both cases a superposition of Fermi, Gamow-Teller and rank-two tensor components [5].

The NUMEN project at INFN-LNS laboratory in Italy proposes to explore the whole network of direct nuclear reactions connecting the initial and final nuclear states of the ββ-decay. This includes DCE, Single Charge Exchange (SCE), multinucleon transfer reactions, elastic and inelastic scattering. A key aspect is the consistent investigation of all the above reaction channels. This multi-channel approach demands that: i) the cross sections for all the relevant reaction channels are measured under the same experimental conditions; ii) the data analysis is performed in the framework of the microscopic quantum reaction theory in a model space large enough to include all the reaction channels and adopting consistent nuclear

structure inputs. Experimental campaigns have been performed at INFN-LNS in order to explore heavy ion induced reactions on target of interest for 0νββ decay. These studies are complemented by a strong activity on the theoretical side, especially tailored to give a detailed description of the challenging DCE reaction mechanisms [6-7]. An overview of recent activity performed in Catania in this field will be presented at the ISNP2026 Conference.

References:

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[4] Sakaue, A. et al., Prog. Theor. Exp. Phys. 123D03 (2024)

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[6] Lenske, H. et al., Prog. in Part. and Nucl. Phys. 109 103716 (2019)

[7] Cappuzzello, F. et al., Prog. in Part. And Nucl. Phys., 128 103999 (2023)

ADVANCED DOPPLER-SHIFT METHODS AND NUCLEAR CHIRALITY

Dimitar Tonev[1]*

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Bulgaria

E-mail of the Corresponding Author: dimitar.tonev@inrne.bas.bg

Abstract

Advanced Doppler-shift methods for lifetime analysis in the femtosecond and picosecond time regions will be presented in details. Improvements in the procedure for analysis in recoil distance Doppler-shift methods will be underlined with a special attention on the case when the gates is set on the shifted portion of the transition directly feeding the level of interest. It is shown that a successful reproduction of the data requires to take into account the emission of gamma-rays during the slowing-down of the ions in the stopper if the investigated lifetime is shorter than or comparable to the slowing-down time [1]. Similarly, a method for describing gamma-ray line-shapes observed in coincidence lifetime measurements using the Doppler-shift attenuation method will be illustrated, with particular attention to scenarios where the gate targets a transition directly feeding the level of interest [2].

Extensive applications of the advanced Doppler-shift methods to determine the lifetimes of excited nuclear states in the chiral candidates nuclei ^{134}Pr [3], ^{102}Rh [4] and ^{136}Pm will be presented. The angular correlations and the electromagnetic character of some of the gamma-ray transitions observed were investigated in detail. Reduced transition probabilities in ^{134}Pr are compared to the predictions of the two quasiparticle-triaxial rotor and interacting boson fermion-fermion models. A new chiral candidate sister band was found. Lifetimes of exited states in both chiral candidate bands of ^{102}Rh were measured for the first time in the A ~ 100 mass region by means of the Doppler-shift

attenuation technique. The derived reduced transition probabilities are compared to the predictions of the two quasiparticles plus triaxial rotor model.

Additionally, new data for the investigation of ^{136}Pm nucleus will be reported.

In memory of Prof. Pavel Petkov!

Acknowledgment: The research was supported by the Bulgarian Science Fund under Contract № KP-06-N77/1, 28.11.2023 and by the Ministry of Education and Science of the Republic of Bulgaria through the National Programme D01-99: Qualification improvement in the field of nuclear technologies and nuclear engineering.

Key words: Lifetime measurements**;** transition probabilities**;** nuclear chirality.

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Probing the 10B+α reactions at LUNA for nucleosynthesis in primordial stars

Alessandro Compagnucci[1]*, Marialuisa Aliotta[1], Rhys Bonnell[1], Lavinia Dalla Vedova[1], Thomas Davinson[1]

[1]SUPA, School of Physics and Astronomy, University of Edinburgh, Peter Guthrie Tait Road, Edinburgh EH9 3FD, UK

E-mail of the Corresponding Author: alessandro.compagnucci@ed.ac.uk

Abstract

The synthesis of CNO elements is a critical milestone in the chemical evolution of massive primordial stars, since the CNO cycle required to halt their gravitational collapse cannot operate without them. Formed exclusively from the H and He and traces of light elements produced during Big Bang nucleosynthesis, these stars must therefore generate their own supply of CNO nuclei in situ. While the triple-alpha process is generally invoked for the initial production of carbon, alpha-induced reactions on light nuclei, such as ^{10}B, have been proposed as competitive alternatives in these low-metallicity environments [1]. Such reactions, however, are only viable if the corresponding cross sections are significantly enhanced by alpha-clustering effects near the α-separation threshold in their compound nuclei. In the case of the ^{10}B+α system, existing literature data suggest the presence of such cluster-enhanced cross sections, but the relevant low-energy astrophysical regimes remain largely unexplored and poorly constrained [2,3].

As part of the ERC NUCLEAR project [4], a programme of precise measurements of the ^{10}B(α,p)^{13}C, ^{10}B(α,d)^{12}C and ^{10}B(α,n)^{13}N reaction cross sections is being carried out at the Laboratory for Underground Nuclear Astrophysics (LUNA). Taking advantage of the deep underground environment of the Gran Sasso National Laboratories to suppress cosmic-ray induced backgrounds, these measurements achieve new and noteworthy results at a beam energy range of 290–

400 keV, directly in the Gamow window for these primordial environments [5]. The experiments are conducted using two distinct detection setups: a set of silicon detectors placed at 135° to measure charged particle channels, and a high-efficiency 4π BGO detector array to measure the $^{10}B(\alpha,n)^{13}N$ channel via the activation technique, and the $^{10}B(\alpha,p\gamma)^{13}C$ channel through prompt gamma-ray detection.
This talk presents preliminary results from these experimental campaigns, highlighting the status of the data analysis for all three reaction channels. We will discuss the associated experimental challenges, alongside the rigorous characterization and monitoring of the solid boron-10 carbide targets under intense alpha-beam irradiation. Finally, we outline the ongoing efforts to constrain the reaction cross sections at even lower energies, probing the full stellar temperature regime relevant for first-generation stars.

Key words: Primordial nucleosynthesis, CNO cycle, alpha-induced reactions, boron-10, underground nuclear astrophysics

References:

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2. Q. Liu et al. *Low-energy cross-section measurement of the 10B(α, n)13N reaction and its impact on neutron production in first-generation star,* Phys. Rev. C 101, 025808 (2020).
3. A. Gula et al. *$^{10}B + \alpha$ reactions at low energies,* Phys. Rev C 107, 025805 (2023)
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SESSION 2

ANC method: standard usage and recent updates

G. D'Agata[1,2], G. L. Guardo[2], L. Lamia[1,2,3], D. Vescovi[8,9], J. P. Fernández-García[2,6,7], V. Burjan[8], R. J. deBoer[9], M. La Cognata[2], S. Palmerini[4,10], D. Lattuada[2,11], J. Mrazek[8], A. A. Oliva[2], R. G. Pizzone[1,2], G. G. Rapisarda[1,2], S. Romano[1,2,3], M. L. Sergi[1,2], R. Spartá[2,11], and A. Tumino[2,11]

[1]Dipartimento di Fisica e Astronomia "Ettore Majorana," Università di Catania, Catania, Italy
[2]INFN-Laboratori Nazionali del Sud, Catania, Italy
[3]Centro Siciliano di Fisica Nucleare e Struttura della Materia (CSFNSM), Catania, Italy
[4]INFN—Sezione di Perugia, Perugia, Italy
[5]Istituto Nazionale di Astrofisica—Osservatorio Astronomico d'Abruzzo, Italy
[6]Departamento de FAMN, Universidad de Sevilla, Apartado 1065, 41080 Sevilla, Spain
[7]Centro Nacional de Aceleradores, Universidad de Sevilla, Junta de Andalucía-CSIC, 41092 Sevilla, Spain
[8]Nuclear Physics Institute of Czech Academy of Sciences, 250 68 Ř ež, Czech Republic
[9]Joint Institute of Nuclear Astrophysics, University of Notre Dame, Notre Dame, USA
[10]Dipartimento di Fisica e Geologia, Università di Perugia, Perugia, Italy
[11]Università degli Studi di Enna "Kore," Enna, Italy

E-mail of the Corresponding Author:giuseppe.dagata@dfa.unict.it

Abstract

One of the biggest problems for nuclear astrophysics has always been to experimentally retrieve the cross section at astrophysical energies: the presence of the Coulomb barrier strongly decreases the overall cross section in the range of interest (usually between some keV and some MeV). Also, many reactions involve radioactive nuclei with a small half-life in the entrance channel, making a direct measurement sometimes almost unfeasible. For this reason, many indirect methods have been developed in the last decades, and among these the Asymptotic Normalization Coefficient (ANC) [1,2] one is useful to extract the direct capture cross section for (p, γ) [3], (n,γ) [4] and (α,γ) [5] reactions of astrophysical interest from a suitable one-particle transfer. In the case of highly unstable nuclei with small half-life, an extension to the method has been developed involving mirror reactions [6,7]. Furthermore, the ANC method can be used in conjunction with the Trojan Horse Method (THM) to better assess the strenght of several resonances [8].
In this work, several examples of ANC applications will be explored: the first represents a standard use of the method and employs mirror nuclei to have information on the the $^{26}Si(p,\gamma)^{27}P$ reaction [9], while the second studies the ^{17}O+p system, with the aim to extract information on low-lying resonances [8].

Key words: nuclear astrophysics, nuclear reactions, indirect methods

References:

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NEUTRON IRRADIATION OF SHIELDING STRUCTURES IN THE INRNE-BAS TR-24 CYCLOTRON FACILITY

A. Demerdjiev[1]*, G. Dimitrova[1], D. Tonev[1], N. Goutev[1], E. Geleva[1] , K. Terziev[1], A. Klisurski[1]

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, blvd. Tzarigradsko Chaussee 72, Sofia, BG-1784, Bulgaria

E-mail of the corresponding author: angeld@inrne.bas.bg

Abstract

Neutron irradiation of shielding structures in medical-cyclotron bunkers can depend strongly on the spatial distribution of the radiation source term. In the present work, this effect is investigated for the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences (INRNE-BAS) TR-24 cyclotron facility using a refined FLUKA model [1, 2] that includes the cyclotron body, Y-shaped beamline, target station and central bunker door. Three irradiation scenarios are considered: proton beam target irradiation, distributed beam losses in the cyclotron vacuum chamber and localised losses in the extraction region.

The analysis focuses on the neutron spectra scored at the target-facing wall and the central bunker door. The results show that the neutron irradiation is strongly source- and position-dependent. Target irradiation primarily affects the wall behind the target station with a broad neutron spectrum containing a fast component. While beam-loss sources, couple more efficiently to this region than the target source. For the extraction-loss scenario at the central-door surface, the integrated thermal, epithermal and fast neutron fluence fractions are comparable. These results indicate that target-only calculations are not

sufficient to characterise the neutron irradiation of all critical shielding structures in the facility.

Key words: TR-24 Cyclotron, Radiation Shielding, FLUKA, Neutron Spectra, Monte Carlo Simulations

Acknowledgments: The research has been supported by the Bulgarian Science Fund under Contract № KP-06-N77/1, 28.11.2023 and by the Ministry of Education and Science of the Republic of Bulgaria, through the National Program D01-99: Qualification improvement in the field of nuclear technologies and nuclear engineering.

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Abrupt structural transition in ^{84}Mo and ^{86}Mo: an Isospin-Symmetric Island of Inversion

J. Ha[1,2,3,4], F. Recchia[2,3*], S. M. Lenzi[2,3], H. Iwasaki[5,6], D. D. Dao[7], F. Nowacki[7], and the e19034 collaboration

[1]*Center for Exotic Nuclear Studies, Institute for Basic Science, Daejeon, Korea*
[2]*Dipartimento di Fisica e Astronomia, Univeristà Degli Studi di Padova, Padova, Italy*
[3]*Sezione di Padova, Istituto Nazionale di Fisica Nucleare, Padova, Italy*
[4]*Instituut voor Kern- en Stralingsfysica, KU Leuven, Leuven, Belgium*
[5]*Facility for Rare Isotope Beams, Michigan State University, East Lansing, MI, USA*
[6]*Department of Physics and Astronomy, Michigan State University, East Lansing, MI, USA*
[7]*Universitè de Strasbourg, CNRS, IPHC UMR7178, Strasbourg, France*

E-mail of the Corresponding Author: francesco.recchia@unipd.it

Abstract

The shell structure is the backbone of nuclear theory. A large energy gap with the completely filled spherical orbitals defines shell closure and magic number. The disappearance of the "normal" filling at certain neutron (N) or proton (Z) numbers, which is not predicted from the classical shell model, has been discussed for a long time since its discovery [1]. This Island of Inversion (IOI) is successfully explained through the shell model with variants of dynamical SU(3) symmetry [2]. The present work introduces a new IOI observed at the $N = Z$ nuclide ^{84}Mo.

The experiment was conducted at the NSCL (now FRIB), Michigan State University. The ^{86}Mo secondary beam was produced from in-flight fragmentation of a ^{92}Mo primary beam. The HPGe tracking

array GRETINA and the TRIPLEX plunger [3] were used to measure the lifetime of the first 2^+ state of ^{84}Mo and neighboring nuclides in the nuclear chart. The measured $B(E2; 2_1^+ \rightarrow 0_1^+)$ shows a striking difference between ^{84}Mo and ^{86}Mo. Interestingly, the results depart from a similar $B(E2)$ trend of other $N = Z$ and $N = Z + 2$ nuclides. We employed the DNO-SM [4] and other theoretical approaches to explain the large difference in the $B(E2)$ values. The study revealed that an abrupt change of collectivity between ^{84}Mo and ^{86}Mo is attributed to an increase in the energy gap between the $g_{9/2}$ and $d_{5/2}$ orbitals, leading to different particle-hole configurations. The experimental finding and the interpretation point to an Isospin-symmetric IOI, lying on the $N = Z$ line for the first time [5].

Key words: shell model, nuclear structure, isospin symmetry, island of inversion

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DETECTION CHALLENGES WITH THE NEW MAGNEX GAS TRACKER: PRELIMINARIES AND PERSPECTIVES

A. Pitronaci [1]*, M. Cavallaro[2], D. Torresi[2], N. Added[3], C. Agodi[2], V.A.P. Aguiar[3], A. Boiano[4], G. Brischetto[2], D. Calvo[5], F. Cappuzzello[1,2], D. Carbone[2], I. Ciraldo[2], C. Garofalo[1,2], M.A. Guazzelli[6], Y. Kucuc[7,8], R. Linares[9], C. Lombardo[2], N.H. Medina[3], K. Palli[10,11], D. Pierroutsakou[4], D. Sartirana[5], O. Sgouros[2], V. Soukeras[2], A. Spatafora[2], and V.A.B. Zagatto[9]

[1]Department of Physics and Astronomy "E. Majorana", UniCT, 95123 Catania, Italy
[2]INFN, Laboratori Nazionali del Sud, 95125 Catania, Italy
[3]Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo 05508-090, Brazil
[4]INFN, Sezione di Napoli, 80126, Napoli, Italy
[5]INFN, Sezione di Torino, 10125 Torino, Italy
[6]Centro Universitario FEI, Sao Bernardo do Campo 09850-901, Brazil
[7]Turkish Accelerator and Radiation Laboratory (TARLA), Ankara, 06830, Turkey
[8]Akdeniz University, Department of Physics, Antalya, 07058, Turkey
[9]Instituto de Fisica, Universidade Federal Fluminense, Av. Litoranea s/n, Gragoata, Niteroi, R.J., 24210-340, Brazil
[10]Department of Physics and HINP, The University of Ioannina, 45110 Ioannina, Greece
[11]Department of Chemistry, National and Kapodistrian University of Athens and HINP, 15771 Athens, Greece

E-mail of the Corresponding Author: antonino.pitronaci@dfa.unict.it

Abstract

The NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) project is developing new detection technologies to put constraints on the neutrinoless double beta ($0\nu\beta\beta$)-decay nuclear

matrix elements by measuring Heavy-Ion-induced Double Charge Exchange (HI-DCE) reactions [1,2]. In fact, HI-DCE reactions represent a promising source, but they are characterized by tiny cross-sections [3]. In this regard, a substantial upgrade of the CS superconducting cyclotron at the INFN- LNS is currently underway: it will enable the production of high intensity ion beams. The current R&D activity is focusing also on the MAGNEX facility [4], requiring a new focal plane detector (a low-pressure gas tracker based on MTHGEM [5,6] and a telescope array of SiC–CsI(Tl) [7] for particle identification) and a scintillator array of $LaBr_3$(Ce) [8]. These new devices must cope with extremely high rate of reaction products (up to MHz of ions) and should be sufficiently radiation-hard (up to fluencies of 10^{13} ions/cm^2), preserving in turn the good performance of the previous ones (to resolve mass ΔA/A$\sim$1/300, angles $\Delta\theta/\theta$ $\sim$0.2° and energy ΔE/E $\sim$1/1000) [9]. Within this characterization measurements, the novel gas tracker underwent its first in-beam characterization during the IRRAD4 experiment at IFUSP in Sao Paulo (Brazil) [10]. Medium-heavy ion beams (^{7}Li at 24 MeV, ^{12}C at 45 MeV and ^{16}O at 64 MeV) were delivered along the SAFIIRA beam line, allowing a small beam-spot (300 μm) and a small angular divergency (0.2° FWHM) [11]. The position resolutions were investigated, and the detector response was studied at different energies and rates of the impinging beam. Under specific working conditions, the detector can achieve sub-millimetre position resolutions, regardless of the irradiation rate. These encouraging results, in terms of position resolution and detector performance in generale, support the predicted design specifications and may guide the way for new use of such a high-resolution detector in experiments at high-intensity ion beams.

Key words: Gaseous detector – MPGDs – MTHGEMs – Heavy-Ion detectors – Magnetic spectrometers

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Impact of Mirror Misalignment on the Point Spread Function in a Simplified Optical Model

Radoslav Simeonov[1]*

[1]*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria*

E-mail of the Corresponding Author:
radoslav.simeonov@inrne.bas.bg

Abstract

The point spread function (PSF) is a fundamental characteristic of optical systems and a key diagnostic for mirror alignment and focusing quality in modern gamma-ray telescopes. Its shape and width determine the system response to point-like sources and provide an effective measure of focusing quality and optical tolerances. In this work, we present simplified Monte Carlo models for PSF studies, designed to capture the effect of small angular misalignments on the focal-plane distribution of reflected photons. The approach allows systematic investigation of how alignment errors propagate into the PSF shape and width, and provides a practical framework for linking optical tolerances to observable image degradation.

Key words: astroparticle, optical systems, gamma-ray telescopes

SESSION 3

Brueckner Hartree-Fock Theory as an Ab-initio Approach for Nuclear Density Functional Theory

P. Ring[1]*

[1]Physics Department, Technical University Munich

85748 Garching, Germany

E-mail of the Corresponding Author: peter.ring@tum.de

Abstract

In recent years, significant progress has been made in ab-initio calculations for nuclear structure. Most of them are restricted to relatively light nuclei. Studies of medium-heavy and heavy nuclei are based on nuclear density functional theory. Today, very successful phenomenological density functionals are available. Therefore, studying the connection between such functionals to ab-initio nucleon-nucleon forces is essential. Non-relativistic Brueckner-Hartree-Fock theory was a starting point of ab-initio investigations in nuclear structure in the 1950s and 1960s. However, it failed because three-body forces were not included at that time. Later, it was found that the relativistic Brueckner-Hartree-Fock (RBHF) theory can reproduce the saturation properties of nuclear matter. We discuss recent developments of RBHF theory for infinite nuclear matter and finite nuclei.

Key words: Ab-initio approaches, Nuclear Density Functional Theory

Deducing charge radii of unstable isotopes using hadronic probes

Baohua Sun[1*],

[1]School of Physics, Beihang university, China

E-mail of the Corresponding Author: bhsun@buaa.edu.cn

Abstract

Charge-changing reactions (CCRs) at intermediate energies are an experimentally simple yet valuable tool for exploring the complex reaction mechanisms and exotic structures of rare isotopes. Based on years of experimental studies at RIBLL2/HIRFL and FRS/GSI, our collaboration has studied CCRs of more than 60 p-sd shell nuclei on various targets at incident energies of about 300 and 900 MeV/nucleon. Leveraging this extensive and systematic dataset, we have demonstrated the indispensable role of charge-particle evaporation following neutron removal in CCR. We found an empirical yet robust method to deduce the charge radii of p-shell isotopes and suggest a heavy-isotope target as the optimal choice. I will present selected new results from our CCR studies, including the Mirror-difference charge radii and odd-even staggering in the charge radii of the lightest isotopes.

Acknowledgment: This work was partly supported by the National Natural Science Foundation of China (Grant Nos. 12325506).

Key words: Charge radii, charge-changing cross section, mirror nuclei, odd-even staggering

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Configuration-interaction time-dependent density functional theory for nuclear dynamics

Y. P. Wang[1], B. Li[1], D. Vretenar[2,1]*, T. Nikšić[2,1], P. W. Zhao[1]*, and J. Meng[1]*

[1]State Key Laboratory of Nuclear Physics and Technology,

School of Physics, Peking University, Beijing 100871, China

[2]Physics Department, Faculty of Science,

University of Zagreb, 10000 Zagreb, Croatia

E-mail of the Corresponding Author:
vretenar@phy.hr
pwzhao@pku.edu.cn
mengj@pku.edu.cn

Abstract

The time-dependent density functional theory (TDDFT) is a fundamental framework to describe the nuclear collective time-dependent processes, from small-amplitude collective oscillations to large-amplitude processes such as fission and heavy-ion reactions. However, due to the mean-field approximation, it only includes the one-body dissipation effect and cannot describe the spreading widths of one-body observables.

In this work, a configuration-interaction time-dependent density functional theory (CI-TDDFT) for nuclear dynamics is developed. In this framework, the correlated nuclear many-body wave function is expanded in terms of time-dependent many-particle configurations built from a common set of orthonormal single-particle states. The equations of motion for both the expansion coefficients and the single-particle states are derived self-consistently using the Dirac-Frenkel time-dependent variational principle. This formulation extends conventional time-dependent density functional theory (TDDFT) by incorporating configuration mixing and beyond-mean-

field correlations, while preserving energy and particle-number conservation.

As an illustrative application, the method is implemented using the relativistic point-coupling functional PC-PK1 in the particle-hole channel and a monopole pairing interaction in the particleparticle channel, and is applied to the study of isoscalar giant monopole resonance in 58Ni and 60Ni. Numerical tests show that both the total energy and particle number are conserved, with relative deviations within $4 \times 10{-}4$ during the time evolution. Compared with conventional TDDFT, CITDDFT yields broader strength distributions for giant monopole resonances while keeping the main peak positions close to those from TDDFT. This broadening is associated with configuration mixing in the valence space and suggests a coupling of the monopole oscillation to additional collective degrees of freedom. These results demonstrate the potential of CI-TDDFT as a quantum, microscopic beyond-mean-field framework for nuclear dynamics.

Key words: nuclear dynamics, giant resonances, time-dependent density functional theory, configuration interaction

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AN EFFICIENCY EXTRAPOLATION METHOD FOR TRUE COINCIDENCE SUMMING CORRECTION

N. Goutev[1]*, D. Tonev[1], M. Ganchev[1], Ch. Chukov[1], A. Demerdjiev[1], G. Dimitrova[1], E. Geleva[1], Tz. Marinov[1]

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, blvd. Tzarigradsko Chaussee 72, Sofia, BG-1784, Bulgaria

E-mail of the Corresponding Author: nikolay.v.goutev@inrne.bas.bg

Abstract

An empirical method is presented for the correction of true coincidence summing (TCS) effects and the simultaneous estimation of the activity of γ-γ cascade-emitting nuclides using a single high-purity germanium (HPGe) detector without prior absolute efficiency characterization or Monte Carlo modelling. The method uses the true coincidence sum peak itself as an internal tracer of source-detector coupling. The observed near-linear dependence of *Isum^(-1/4)* on source-to-detector distance provides an independent diagnostic supporting the use of $X = \sqrt{Isum}$ as an internal first-order efficiency coordinate. The observed cascade photopeak rates are then described by the second-order model $Iobs(X) = CX - KX^2$, where the quadratic term represents coincidence-summing losses and the linear term gives the restored summing-free response. The source activity is obtained from the restored cascade responses and the sum-peak response using the relevant emission probabilities and angular-correlation factor [3]. The approach adapts the principle of efficiency extrapolation used in radionuclide metrology [1] to single-detector γ-γ coincidence spectrometry and is closely related to modified sum-peak extrapolation methods [2]. Validation with a calibrated ^{60}Co source yielded an activity of 5.89(25) kBq, compared with a reference value of 6.00(18) kBq. Application to a thorium-bearing ceramic sample containing ^{208}Tl yielded a ^{208}Tl activity of 2.06(11) kBq under secular-

equilibrium conditions. The results demonstrate the practical potential of the method for TCS correction and activity determination without a prior absolute efficiency calibration. The method is further applied to a ^{152}Eu source to assess its extension to multi-energy efficiency calibration.

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Key words: TCS; HPGe; efficiency extrapolation; activity determination; internal standard.

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Quantum Mechanical Rotations of Nuclear Ellipsoids and Clusters

Takaharu Otsuka[1]*

[1]*The University of Tokyo, Tokyo, Japan*

[2]*RIKEN Nishina Center, Wako-shi, Saitama, Japan*

E-mail of the Corresponding Author: otsuka@phys.s.u-tokyo.ac.jp

Abstract

The rotational motion is one of the most fundamental modes of the objects at all scales. It is quite visible in classical mechanics. However, the rotational mode is much richer in quantum mechanics: there are dual modes for the rotation of quantum mechanical objects including atomic nuclei, as shown below.

Many nuclei are deformed into ellipsoidal shapes with substantial triaxiality, contrary to Aage Bohr's axial symmetry dominance hypothesis. The triaxial shape is like an almond, and the prevailing triaxiality is the first point I will make with two major origins: symmetry restoration and nuclear forces. Such triaxial ellipsoids show rotational excitation energies with J(J+1) dependence very well. This beautiful feature is due to practically conserved *K* quantum number, which is a consequence of the robust coupling between intrinsic degrees of freedom (shapes) and extrinsic degrees of freedom (rotational symmetry), contrary to traditional belief that these two are separate. The members of a given rotational band arise from the angular momentum projection of a common intrinsic state, and rotational excitation energies are obtained also by the same calculation. What I emphasize here is that rotational excitation energies are NOT due to rotational kinetic energies BUT due to the loss of binding energy, which shows a J(J+1) dependence. The binding energy includes contributions from single-particle energies, *NN* interaction, 3N interaction, *etc*. All of them contribute. This is the

feature of the rotational mode of ellipsoidally shaped nuclei. This mode is called “compact-object rotation”.

Nuclear states made from clustering show a different rotational mode, called “distant-object rotation”. The basic formulation is the same between the two modes, but different parts of the Hamiltonian matter. Each cluster is already internal eigenstate of the Hamiltonian, and what contributes to the rotational excitation energy is the kinetic energies of the centres of mass of cluster. The distant-object rotation has a link to the rotation in classical mechanics, whereas the compact-object rotation does not.

The practically conserved K quantum number also holds with cluster configurations, although the axial symmetry is completely gone. The K quantum number is a symmetry emerging better with larger number of participating particles.

I think these are main points I would like to make. Some of them can be applied atomic clusters, too.

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Key words: Rotation, quantum mechanics, triaxiality, cluster, K quantum number

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SESSION 4

NEUTRINOLESS DOUBLE-BETA DECAY WITHIN A CONSISTENT CHIRAL EFT SHELL-MODEL FRAMEWORK

Luigi Coraggio[1], Giovanni De Gregorio[1*], Nunzio Itaco[1], Songlin Lyu[1]

[1]Università della Campania "Luigi Vanvitelli" & Istituto Nazionale di Fisica Nucleare[2]

E-mail of the Corresponding Author: giovanni.degregorio@na.infn.it

Abstract

In this talk, I will present the first shell-model calculation of neutrinoless double-beta decay nuclear matrix elements performed within a fully consistent framework in which both the nuclear Hamiltonian and the decay operators are derived from chiral effective field theory. The effective shell-model Hamiltonian and the relevant transition operators are constructed within many-body perturbation theory and subsequently employed to study the nuclei involved in the decays of 48 Ca, 76 Ge, and 82 Se. The reliability of the theoretical framework is assessed through the calculation of selected spectroscopic properties and electromagnetic observables. The same consistently derived interactions and operators are then used to evaluate the neutrinoless double-beta decay nuclear matrix elements. Particular attention will be devoted to the convergence properties of the many-body perturbative expansion, providing a basis for estimating the associated theoretical uncertainties.

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QUANTUM ANNEALING FOR NUCLEAR MANY-BODY EIGENVALUE PROBLEMS

Gennaro Nunziata[1]*, Francesco Antonio D`Aniello[2], Giovanni De Gregorio[3], Carmine De Lucia[2], Radek Floprecht[4], František Knapp[5], Nicola Lo Iudice[6], Angelo Martone[2], Petr Vesely

[1]*Università degli Studi della Campania "L. Vanvitelli"*

[2]*CIRA – Centro Italiano Ricerche Aerospaziali, Capua, Italy*

[3]*Università della Campania "Luigi Vanvitelli" & INFN*

[4]*Charles University of Prague*

[5]*Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic*

[6]*Department of Physics "Ettore Pancini", Università degli Studi di Napoli Federico II*

[7]Nuclear Physics Institute, Czech Academy of Sciences, Řež, Czech Republic

*E-mail of the Corresponding Author:*gennaro.nunziata@unicampania.it

Abstract

The solution of large-scale eigenvalue problems is a central task in nuclear many-body theory, where Hamiltonian matrices may become extremely large even after physically motivated truncations. In this contribution, we present a hybrid quantum-classical strategy to address standard and generalized eigenvalue problems arising from the Equation-of-Motion Phonon Method (EMPM). The method recasts the eigenvalue search into a sequence of quadratic unconstrained binary optimization problems suitable for D-Wave quantum annealers, while classical deflation is used to iteratively remove the previously computed eigenvectors and access excited states. This makes it possible to go beyond ground-state targeting and reconstruct several eigenpairs of the nuclear Hamiltonian.

The approach is benchmarked on EMPM matrices relevant for nuclear-structure calculations, comparing quantum annealing on real D-Wave hardware with classical reference solutions and simulated annealing. We analyze the role of binary precision, matrix size, convergence behavior, and the accuracy of the reconstructed eigenvalues and eigenvectors. The results show that quantum annealing can reproduce the low-lying eigenspectrum in controlled nuclear test cases, while also highlighting the present limitations associated with finite precision, embedding constraints, and hardware noise. This work provides a concrete example of how near-term quantum annealers can be integrated into nuclear many-body workflows, opening a route toward hybrid quantum-classical algorithms for large-scale eigenvalue problems in nuclear structure.

IMPLEMENTATION OF MSMGRPCS WITH AGING EFFECT SUPPRESSION IN LARGE SCALE HIGH INTERACTION RATE EXPERIMENTS

Mariana Petris[1]*

[1]*Horia Hulubei National Institute of Physics and Nuclear Engineering (RO)*

E-mail of the Corresponding Author: mpetris@nipne.ro

Abstract

For the next generation high interaction rate experiments or for the upgrade at higher luminosities of the running ones, the development of detectors with high counting rate capabilities and aging mitigation is a paramount topic in the detector research field. A long time

operation of gas detectors in a high counting rate environment could lead to aging effects reflected in an increase of the dark current and dark counting rate (higher noise), with impact on the detector performance. Moreover, a higher noise rate leads to an artificial increase of the data volume in a free-streaming data acquisition operation used nowadays in high counting rate experiments.
For the mitigation of aging effects observed in Multi-Strip Multi-Gap Resistive Plate Chambers (MSMGRPCs) exposed to high irradiation doses, produced by the the decomposition of the working gas molecules, a new MSMGRPC architecture was designed. Prototypes with a direct flow of the gas mixture through the gas gaps defined by a new type of discrete spacers were designed and assembled. The aging investigations of the chambers with the new design demonstrated negligible aging effects. The obtained results in an in-beam test performed at the SIS18 accelerator of GSI Darmstadt. demonstrated the performance of the prototypes in terms of efficiency (>95%) and time resolution (~55 ps). Therefore, such direct flow MSMGRPCs will be implemented in the low polar angle region of the TOF system (Inner Wall) of the CBM experiment at FAIR, where challenging counting rates up to 50 kHz/cm2 are anticipated. The MSMGRPCs will be installed in a staggered architecture on 4 levels in the CBM-TOF inner wall modules, in order to avoid dead zones. The modular design encompasses 12 modules also staggered in space, such to assure an uniform detection area. Details about the implementation of the direct flow MSMGRPCs of different granularities in the most complex module of CBM-TOF inner wall, whose assembling is in progress, will be discussed.

Key words: high interaction rate, high time resolution MSMGRPC, aging

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Mössbauer, X-Ray Fluorescence and XANES Measurements on Counterfeited Dollar Money Paper and Pigments

K. Chakarova[1], V. Rusanov[2*], D. Tonev[2], K. Appel[3]

[1]American College of Sofia, P. B. 873, 1000 Sofia, Bulgaria

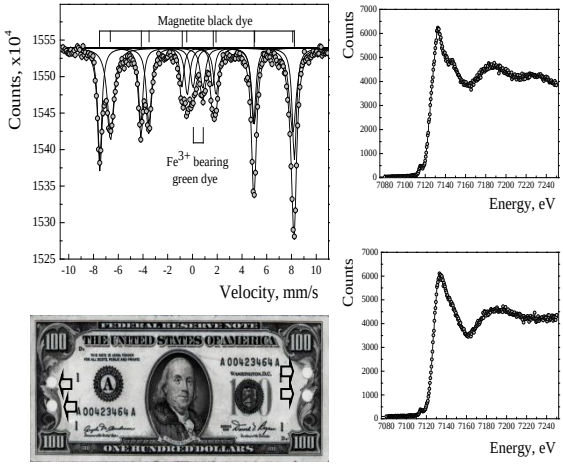
[2]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 72 Tsarigradsko Shose Blvd., 1784 Sofia, Bulgaria

[3]European X-Ray Free-Electron Laser, 22869 Schenefeld, Holzkoppel 4, Hamburg, Germany

E-mail of the Corresponding Author: rusanov@phys.uni-sofia.bg

Mössbauer spectroscopy, X-ray fluorescence (XRF) [1–4], and X-ray Absorption Near-Edge Structure (XANES) studies of counterfeit dollar banknote paper, printing pigments, and artists' pigments demonstrate that combining these three techniques is highly useful in forensic science. Two of these methods—Mössbauer spectroscopy and XANES—are element- and isotope-sensitive. They are also sensitive to the oxidation state and coordination environment of ^{57}Fe atoms. The parameters measured in the papers and pigments used to produce counterfeit banknotes provide distinctive fingerprints that enable the unambiguous identification of counterfeits and forgeries.

The figure shows, on the left, the Mössbauer spectrum of a single counterfeit old-series USD 100 banknote, together with a photograph of the banknote. On the right, it shows XANES spectra at the iron K-edge obtained from regions covered with black pigment (top) and green pigment (bottom).



EDXRF analysis of the unprinted paper and the black and green pigments indicate that a new roll of paper was used to print each new group of counterfeit banknotes. High-quality paper was used to produce counterfeit old-series USD 100 banknotes, whereas lower-quality paper was used for counterfeit new-series USD 100 and USD 50 banknotes. The lowest-quality counterfeits were printed on ordinary photocopy paper.

Mössbauer investigations show that thirteen counterfeit banknotes from both the old and new series have remarkably stable and nearly identical pigment properties. This consistency is not observed in genuine banknotes printed in different years. These findings provide additional evidence that, even if the counterfeit banknotes themselves did not all originate from a common source, their printing pigments probably did.

X-ray fluorescence analysis of unprinted banknote paper and three randomly selected counterfeit USD 50 banknotes provide sufficient information to clarify certain aspects of dollar counterfeiting and the sources involved in its distribution. The specific characteristics observed in the investigated dollar forgeries may, however, be typical

only of southeastern Europe, where the counterfeit banknotes examined in this study were collected.

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contracts № KP-06-N77/1, 28.11.2023 and KP-06-МНФ/8, 18.05.2026.

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NUCLEAR PHYSICS IN CLINICAL PRACTICE: FROM MEDICAL RADIONUCLIDE PRODUCTION TO DIAGNOSTIC IMAGING IN ONCOLOGY

Hristo Hristov[1,2]*, Dimitar Tonev [1], Aneliya Klisarova[2]

[1] *Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Bulgaria*

[2] *Medical University "Prof. Dr. Paraskev Stoyanov", Clinic of Nuclear Medicine and Metabolic Therapy, University Hospital "St. Marina", Varna, Bulgaria*

E-mail of the Corresponding Author: hristo.yordanovx@gmail.com

Abstract

An overview of the development of on-site cyclotron production of medical radionuclides and the expanding clinical applications of the resulting radiopharmaceuticals, based on the long-term experience of the Clinic of Nuclear Medicine and Metabolic Therapy at University Multiprofile Hospital for Active Treatment "Sveta Marina", Varna, is presented. In 2013, the hospital commissioned Bulgaria's first hospital-based medical cyclotron for positron emission tomography (PET) radionuclide production. The self-shielded 7.5 MeV ABT BG-75 cyclotron enabled on-site ^{18}F production via the $^{18}O(p,n)^{18}F$ nuclear reaction and routine synthesis of [^{18}F]fluorodeoxyglucose ([^{18}F]FDG), substantially improving the availability of positron emission tomography/computed tomography (PET/CT) imaging.

Annual production data and more than a decade of operational experience are reviewed, documenting a program supporting over 7000 PET/CT examinations annually, together with the requirements for reliable operation, specialized maintenance and technological renewal.

The program has since expanded beyond [^{18}F] FDG to include an ^{18}F-labelled prostate-specific membrane antigen (PSMA)-targeting

radiopharmaceutical synthesized from locally produced ^{18}F, broadening access to PSMA PET/CT for prostate cancer in Bulgaria.

To ensure production continuity, the clinic is installing a new BEST ABT B-100 cyclotron, which, once commissioned, will provide backup during the phased replacement of the existing BG-75 and enable production of new ^{18}F-labelled radiopharmaceuticals. Together, these developments illustrate how hospital-based cyclotron complexes can establish a complete pathway from radionuclide production and radiopharmaceutical synthesis through quality control to PET/CT diagnosis, while supporting the long-term integration of nuclear physics into clinical practice.

Acknowledgment: The research was supported by Medical University "Prof. Dr. Paraskev Stoyanov" – Varna; University Hospital "St. Marina" – Varna.

Key words: medical cyclotron; ^{18}F production; PET/CT; radiopharmaceuticals; PSMA

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SESSION 5

Quantum chirality in Relativistic density functional theory

Jie Meng[1*]

[1]*School of Physics, Peking University*

E-mail of the Corresponding Author:*mengj@pku.edu.cn*

Abstract

The concepts of chirality and quantum chirality in nuclear physics are explained. Recent progresses are briefly reviewed, including MχD, the chiral rotation induced by superfluidity, Chirality-Parity (ChP) violation, K-plot and the A-plot. The microscopic description of the nuclear quantum chirality without any parameters beyond the well-defined relativistic density functional theory in 3D lattice are introduced. The three-dimensional tilted axis cranking relativistic density functional theory predict the yarest state and the excitation energy for the yare state of the experimental nearly degenerate bands are reproduced by the time-dependent relativistic density functional theory.

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contract № KP-06-МНФ/8, 18.05.2026.

Key words: Quantum chirality，MχD, K-plot， A-plot，Relativistic density functional theory

Entanglement in nuclear chiral rotation

Qibo CHEN[1*]

[1]East China Normal University

E-mail of the Corresponding Author:qbchen@phy.ecnu.edu.cn

Abstract

Nuclear chirality occurs in a rapidly rotating nucleus with triaxially deformed core alongside high-*j* valence particle(s) and hole(s). Strong coupling between the angular momenta of the particle, hole, and core, leading to significant angular momentum entanglement. We investigate the entanglement in particle rotor model for the particle-hole configuration $\pi(1h11/2)1 \otimes \nu(1h11/2)-1$ for different values of the triaxiality parameter [1] and the influence of the pairing gap is studied [2]. The entanglement between the angular momenta of the two quasiparticles and the total angular momentum is quantified by the three bipartite concurrences of one type of angular momentum with the other two angular momenta and the area of the triangle formed by the bipartite concurrences. A distinctive interchange in the spin dependent concurrence triangle of chiral partners is identified as a hallmark of chiral rotation onset. Moreover, it is revealed that the entanglement in the doublet bands increases with the pairing gap.

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Algebraic Model Analysis of Chiral Doublet Bands

Yu Zhang[1*]

[1]*Liaoning Normal University, China*

E-mail of the Corresponding Author: dlzhangyu_physics@163.com

Abstract

Compared with even-even nuclear systems, odd-odd nuclei exhibit significantly more complex dynamical structure, posing substantial greater theoretical challenges. The interacting boson-fermion-fermion model (IBFFM) provides a well-established framework for capturing the collective and single-particle structural properties of such systems. Within this algebraic framework, we analyse the dynamical condition required for the emergence of chiral doublet bands, employing a simple IBFFM Hamiltonian that incorporates quadrupole-quadrupole coupling between the bosonic core and two unpaired fermions. Our analysis reveals that chiral-like rotational patterns can persist over a wider range of structural parameters than previously assumed. This enhances the viability of chiral doublet bands as a general spectroscopic feature in odd-odd nuclei.

The decay of the head of the first $h_{11/2}$ negative-parity band in ^{105}Ru

E.A. Stefanova[1]*, S. Lalkovski[2], A. Korichi[3], et. al

[1]*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 1784 Sofia, Bulgaria*

[2]*Faculty of Physics, University of Sofia "St. Kliment Ohridski", 1164 Sofia, Bulgaria*

[3]*Université Paris-Saclay, Gif-sur-Yvette, France*

E-mail of the Corresponding Author: elenas@inrne.bas.bg

Abstract

Excited states of the nucleus ^{105}Ru, were populated in an induced fusion-fission reaction channel of the reaction ^{30}Si + ^{168}Er. The value of L = 5 was obtained in (d,p) experiments [1,2] for the 209 keV state in ^{105}Ru. Based on this result and the corresponding systematics, an assignment of $11/2^-$ was previously made for this state. The sequence of levels built on the 209-keV state observed in [3] was consequently interpreted as the first h11/2 band in 105Ru. In the present experiment, it was observed that the transitions within the level sequence on top of that state, previously observed in [3], are in coincidene with the 143 keV transition, depopulating the 164 keV state for which L =2 was obtained in a (d,p) experiment [2]. That observation revealed that the 209 keV state is not a long-lived isomer as expected and as was measured for the analogous state in ^{103}Ru, but the decay through it is rather prompt. Based on that, an 44 keV transition can be assigned as depopulating the 209 keV state with an assignment of $11/2^-$ to the 164 keV state with an assignment of $5/2^+$. In addition, it is presently revealed that this transition cannot be M2 or E3. Consequently, the L-value assignments of L=5 for the 209-keV state and L=2 for the 163-keV state obtained in the previous (d,p) experiments are inconsistent with the present observations. Thus, at least one of the previous L-

value assignments must be reconsidered, or an additional parallel decay path may be present.

Acknowledgment: This research is supported by the Bulgarian National Science Fund contract numbers KP-06-N98/2 and KP-06-N68/8.

Key words: high-spin level scheme and structure

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Dynamics of rotation in chiral nuclei

Z. X. Ren[1*]

[1]*School of Physics, Nankai University, Tianjin 300071, China*

E-mail of the Corresponding Author: zxren@nankai.edu

Abstract

The dynamics of chiral nuclei is investigated with the time-dependent and tilted axis cranking covariant density functional theories on a three-dimensional space lattice in a microscopic and self-consistent way. The experimental energies of the two pairs of the chiral doublet bands in Nd-135 are well reproduced without any adjustable parameters beyond the well-defined density functional. A novel mechanism, i.e., chiral precession, is revealed from the microscopic dynamics of the total angular momentum in the body-fixed frame, whose harmonicity is associated with a transition from the planar into aplanar rotations with the increasing spin. This provides a fully microscopic and dynamical view to understand the chiral excitations in nuclei.

Key words: chiral rotation, time-dependent cranking covariant density functional theories, tilted axis cranking covariant density functional theories

EVALUATION OF PROMPT AND RESIDUAL RADIATION FIELDS INDUCED BY BEAM LOSSES IN A TR-24 CYCLOTRON FACILITY

Galina D. Dimitrova[1]*, Dimitar Tonev[1], Anguel Demerdjiev[1], Nikolay Goutev[1], Elena Geleva[1], K. Terziev[1]

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, blvd. Tzarigradsko Chaussee 72, Sofia, BG-1784, Bulgaria

E-mail of the Corresponding Author: galinadd@inrne.bas.bg

Abstract

The Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences (INRNE-BAS) [1] is currently designing a new accelerator facility based on a TR-24 cyclotron. As part of the preliminary radiation shielding assessment, we are performing a Monte Carlo simulations using the FLUKA transport code [2, 3].

In the present study we implemented a simplified model of the cyclotron and its shielding bunker developed in our previous work [4, 5]. The aim was to evaluate the prompt radiation fields during cyclotron operation and the residual radiation fields at different cooling times. The radiation fields were induced by beam losses inside the cyclotron vacuum chamber under conditions corresponding to the production of ^{18}F. Two cyclotron operating regimes were considered: normal operation with 0.1% beam losses and abnormal operation with 3% losses. We also studied a bunker configuration in which parts of the inner walls were replaced with low-sodium concrete. The results show that this configuration significantly lowers the residual dose rates inside the bunker after an irradiation session for ^{18}F production.

Key words: TR-24 cyclotron**,** Radiation shielding, Simulations, Beam Losses;

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contract № KP-06-N77/1, 28.11.2023 and KP-06-MNF/8, 18.05.2026.

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Semiconductor detectors parameters investigation

Liliana Panteleev-Simeonova[1*], Nikolay Petrov1, Svetozar Arabadzhiyski[1] et. al.

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian of academy of sciences, Sofia, Bulgaria

Abstract

A spectroscopy characteristics of semiconductor detectors are investigated. The change in the characteristics of the detectors as a result of many years of operation was studied. The main noise sources limiting the energy resolution of spectrometers with semiconductor detectors have been identified. For good energy resolution and high count rate capability, an optimal signal shaper has been proposed. The experimental results are in agreement with the theory of optimal signal shaping.

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contract № КР-06-МНФ/8, 18.05.2026 and by the Ministry of Education and Science of the Republic of Bulgaria, through the National Program D01-99: Qualification improvement in the field of nuclear technologies and nuclear engineering.

Key words: Semiconductor detectors; Optimal shaping; spectroscopy characteristics

INFLUENCE OF THE OF NUCLEAR FUEL ISOTOPIC COMPOSITION ON THE ACTIVATION OF REACTOR INTERNALS

Mladen Mitev[1]*, Krasimir Kostov[1]

[1]*Technical University of Sofia*

E-mail of the Corresponding Author: mrmitev@tu-sofia.bg

Abstract

The reactor pressure vessel and the internal components are an integral part of the reactor unit and are among its most important components. The service life of the entire NPP depends on their service life. In terms of the "defense in depth" principle, the RPV is one of the most important barriers protecting the environment from radioactive fuel and fission products. The integrity of the RPV and the internal components is one of the main conditions for the safe operation of any NPP. Their safety must be guaranteed not only during operation, but also under all accident conditions. For sustainable management of their resources, knowledge of their damage is necessary, and for the purposes of operational maintenance and decommissioning, knowledge of their activity is necessary. It is well known that during operation, the RPV and internal components are damaged by radiation resulting from the operation of the reactor, especially the effect of high-energy neutrons on the mechanical properties of the RPVDuring operation, under the influence of operating temperature and neutron irradiation, neutron embrittlement and temperature ageing processes occur, leading to a transformation of the structural-phase state and mechanical properties of the RPV and internal components steels. In recent decades, it has become common practice to place spent fuel assemblies, i.e. those with the highest burn-up, in the outermost part of the reactor core, which means that their radiation has the greatest impact on the reactor pressure vessel and its internal components. It is important to assess this impact. Due to factors such as the planned

quantitative increase in NPPs, the practice of extending the operating life of existing NPPs, the increase in the specified operating life of new generation NPPs, and the high cost of burying radioactive waste, it is necessary to conduct new computational studies on the problem of the activation of structural and protective materials. Each of these isotopes and their effects on the reactor pressure vessel and its internal components are analyzed separately using the MCNP code, which provides a comprehensive understanding of their impact on the safety and lifetime of reactors of this particular type. An assessment has been made of the integral neutron fluxes and the activation of steels by the reactions $^{54}Fe(n,p)^{54}Mn$ and $^{63}Cu(n,\alpha)^{60}Co$. The results show that steel containing Cu becomes more activated due to the conversion of the ^{63}Cu isotope to ^{60}Co. The spectra of the plutonium isotopes ^{239}Pu and ^{240}Pu isotopes, which occure in the spent fuel assemblies, lead to a higher activation of iron by the $^{54}Fe(n,p)^{54}Mn$ reaction by about 20%. This shows that these isotopes have significant contribution to the RPV an reactor internals activation and should be considered in NPP lifetime management. This becomes important with the increase in operating time and burnup depths in pressurized water reactors.

Acknowledgment: This research was funded by the Ministry of Education and Science of the Republic of Bulgaria, through the National Program D01-99: Qualification improvement in the field of nuclear technologies and nuclear engineering.

Key words: RPV, Reactor Internals, spent nuclear fuel, activation

POSTER SESSION

FUNCTIONAL RESONANCE ANALYSIS METHOD AS AN ANALYTICAL TOOL FOR ASSESSING THE IMPACT OF ACCIDENT TOLERANT FUEL IMPLEMENTATION ON FUNDAMENTAL NUCLEAR SAFETY FUNCTIONS IN LIGHT WATER REACTORS

Rositsa Palakarcheva-Ivanova[1], Kalin Filipov[1]*

[1]*Technical University of Sofia*

E-mail of the Corresponding Author: filipov@tu-sofia.bg

Abstract

This study investigates the applicability of the Functional Resonance Analysis Method (FRAM) as a systems-level approach for assessing the influence of accident tolerant fuel (ATF) implementation on the fundamental safety functions of light water reactors (LWRs). The analysis is structured around the three fundamental safety functions defined by the IAEA and develops them into a nine-function FRAM architecture representing reactor monitoring and diagnosis, reactivity control, core coolability, heat removal, cladding oxidation and hydrogen generation, fuel geometry and fission-product retention, confinement, and electrical, instrumentation and accident-management support. Each function is characterized using the six standard FRAM aspects—Input, Output, Preconditions, Resources, Control, and Time—and their functional couplings are examined with particular emphasis on those directly affected by fuel and cladding behaviour.

Representative loss-of-coolant accident and station blackout conditions are considered as qualitative instantiations of the proposed model. The analysis indicates that ATF does not introduce new safety

functions or substitute for engineered safety systems; rather, it modifies the propagation of functional variability by increasing the tolerance of selected fuel-related functions to adverse accident conditions. The most direct effects are associated with reduced high-temperature cladding oxidation and hydrogen generation and with delayed degradation of fuel geometry and fission-product retention, while the resulting benefit to confinement is predominantly indirect. Under scenarios involving prolonged loss of heat removal or electrical support, the model also demonstrates that the additional coping margin provided by ATF remains dependent on successful cooling recovery and accident-management actions. The results support the use of FRAM as a complementary method to deterministic safety analysis and probabilistic safety assessment for examining the system-level implications of introducing ATF into operating LWRs, particularly where technological, operational and time-dependent interactions must be considered simultaneously.

Acknowledgment: This research was funded by the Ministry of Education and Science of the Republic of Bulgaria, through the National Program D01-99: Qualification improvement in the field of nuclear technologies and nuclear engineering.

Key words: Accident Tolerant Fuel (ATF), Functional Resonance Analysis Method (FRAM), light water reactor (LWR), fundamental safety functions, nuclear safety, station blackout, loss-of-coolant accident, accident management, functional variability, fuel integrity.

Pyrophoric Iron Nanoparticles Formed by Selective Extraction from Fe–Al Alloys: A Mössbauer Study

B. Bonchev[1], V. Rusanov[1], D. Tonev[1]

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract

Pyrophoric iron nanoparticles were unexpectedly obtained during selective extraction of aluminium from Fe–Al alloys originally prepared for applications in resonance Mössbauer detectors. Aluminium was removed using dilute NaOH, leaving aggregates of ultrafine iron particles that exhibit rapid self-heating and spontaneous ignition with sparks upon exposure to air.

The precursor Fe–Al alloy was characterized by scanning electron microscopy, X-ray fluorescence analysis and ^{57}Fe Mössbauer spectroscopy, whereas the pyrophoric iron and its long-term oxidation products were studied by Mössbauer spectroscopy at room temperature, 77 K and 4.2 K. Direct electron-microscopic or X-ray diffraction characterization of the highly reactive product was impractical under conventional conditions.

The Mössbauer spectra reveal a heterogeneous nanostructure consisting of crystalline α-Fe cores, a structurally disordered or partially amorphized surface layer, and an intercrystalline fraction. The characteristic particle size was estimated to be approximately 7–8 nm, with a disordered surface layer of about 4–5 atomic monolayers. Paraffin-protected samples stored for more than 20 years retain a substantial metallic α-Fe fraction, while slow oxidation leads predominantly to magnetite formation. The results demonstrate the long-term metastability and potential fire and explosion hazard of pyrophoric iron nanoparticles.

Key words: pyrophoric iron; iron nanoparticles; Mössbauer spectroscopy; self-ignition; magnetite

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contracts № KP-06-N77/1, 28.11.2023 and KP-06-МНФ/8, 18.05.2026.

Low-Background Gamma Spectrometry System for Radioecological Studies

Nikolay Petrov[1], Liliana Simeonova-Pantaleev[1], Svetozar Arabadzhiyski[1] et. al.

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract

A low-background gamma spectrometry system is designed, manufactured and put into operation at the Laboratory of Nuclear Spectroscopy of INRNE-BAS. Multilayered protection from lead, copper, cadmium and plexiglass provides reduction of the radiation background and improved signal-to-noise ratio. Gamma spectra can be measured with two replaceable HPGe detectors of medium and large efficiency. Radon elimination is achieved by passive nitrogen ventilation of the sample chamber. Plastic scintillators antimuon protection system is designed and tested. The system allows measurement of gamma spectra of environmental samples with very low concentration of radionuclides in the field of radioecology, geology, nuclear energy and nuclear safety.

Keywords: Gamma spectroscopy; Low-background; HPGe detectors

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contracts № KP-06-N77/1, 28.11.2023 and KP-06-МНФ/8, 18.05.2026.

APPLICATION OF NUCLEAR PHYSICS METHODS FOR THE DETERMINATION OF RADIONUCLIDES IN NATURAL WATERS

Elena Geleva[1]*, Dimitar Tonev[1], Nikolay Goutev[1], Desislava Dimitrova[1], Bozhidar Slavchev[1], Anguel Demerdjiev[1], Galina D. Dimitrova[1]

[1]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences,

72 Tzarigradsko Shousse Blvd., 1784 Sofia, Bulgaria

E-mail of the Corresponding Author: elenag@inrne.bas.bg

Abstract

Naturally occurring radionuclides in drinking and mineral waters are important indicators of water quality and potential radiological exposure of the population. This study presents the application of nuclear physics methods to the characterization of natural radioactivity in water samples. Alpha spectrometry was applied for the determination of the activity concentrations of three key alpha-emitting radionuclides: ^{238}U, ^{234}U and ^{210}Po in drinking water samples. A state of radioactive disequilibrium between ^{234}U and ^{238}U was observed in the water samples investigated. The obtained results were used to assess the radiological status of the investigated waters and to estimate the annual effective dose resulting from their ingestion.

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Key words: Nuclear physics methods, natural waters, radionuclides

SESSION 7

DATA GAPS IN ENERGY SYSTEM MODELING: IMPLICATION FOR SCENARIO RELIABILTY

Kristina Hadzhiyska*[1]

[1]*Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences*

E-mail of the Corresponding Author: khadjiiska@inrne.bas.bg

Abstract

Energy scenario modelling is a critical tool for planning national energy systems and assessing policy impacts. However, the reliability of scenario outputs strongly depends on the availability and granularity of input data. This study analyses data gaps in Bulgaria's energy statistics, using the National Energy Balance and Eurostat sectoral data as reference points. By comparing the data required for medium-resolution energy models (including household, industrial, and transport sectors, as well as technological parameters of production units) with what is available in public statistics, we identify critical gaps that limit robust scenario development. Key missing information includes temporal resolution, sectoral detail at household and transport levels, device-level consumption patterns, and technological characteristics of power plants. The analysis highlights the implications of these gaps for policy evaluation, demonstrating that scenarios based solely on aggregated national data may overestimate system reliability or misrepresent sector-specific impacts. Recommendations for improving data collection and integration are discussed to enhance the credibility of energy modelling and support informed decision-making.

Key words: energy, scenario modelling, data gaps.

Acknowledgment: The research has been supported by the Bulgarian Science Fund under Contract № КР-06-МНФ/8, 18.05.2026.

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Abstract title: Practical and User Experience from Utilising the Beacon Core Monitoring System and the APA-H Code Package at Kozloduy NPP Units 5 and 6

Srebrin Toshkov Kolev[1*]

[1]Kozloduy NPP EAD, 3321, Kozloduy, Bulgaria

E-mail of the Corresponding Author: STKolev1@npp.bg

Abstract

With the introduction of RWFA fuel assemblies at unit 5 of Kozloduy NPP, the BEACON core monitoring system and the APA-H nuclear design code package were employed as complementary alternatives to the already long-term established native options at Kozloduy. The main talk of the presentation would include results and impressions of the experience regarding the BEACON core monitoring system and the APA-H code package for the past 2 years at units 5 and 6 from a practical and also user standpoint. A brief summary of comparisons between results from the different systems is provided. Some ideas for a better overall user experience with APA-H are also considered.

Key words: BEACON, APA-H, practical results, user experience

SIZE REDUCTION AND DECONTAMINATION WORKSHOP

N. Karaivanovov[1]*

[1]State Enterprise Radioactive Wastes, 3000 NPP Kozloduy Site SD NDF

E-mail of the Corresponding Author:Nikolay.Karaivanov@dprao.bg

Abstract

The Size Reduction and Decontamination Workshop (SRDW) was constructed as part of the new infrastructure required for the decommissioning of Units 1–4 of Kozloduy Nuclear Power Plant. It is intended for the decontamination of radioactive materials generated during the dismantling of systems and equipment in the Turbine Hall and Reactor Hall.

The presentation describes the main size-reduction machines, as well as the equipment used for mechanical and chemical decontamination. Finally, the results achieved during operation of the facility and the lessons learned are presented.

Assessment of the accident progression in case of SBLOCA with different break sizes along with SBO

Petya Vryashkova[1]*, Pavlin Groudev[1]

[1]*Institute for Nuclear research and Nuclear energy, Bulgarian of academy of sciences, Bulgaria, Sofia, 1784*

E-mail of the Corresponding Author: pivryashkova@inrne.bas.bg

Abstract

This paper investigates the influence of break size on the severe accident progression in case of a Small Break Loss-of-Coolant Accident (SBLOCA) combined with a Station Blackout (SBO) event in a VVER-1000/V-320 reactor. Four accident scenarios with equivalent break diameters of 30, 40, 50, and 60 mm in the cold leg of the Reactor Coolant System (RCS) were analyzed.

The simulations were performed using the integral severe accident code ASTEC V2.1.1.6, developed by ASNR and GRS. The reference nuclear power plant is Unit 6 of the Kozloduy Nuclear Power Plant (NPP), equipped with a VVER-1000/V-320 reactor. The ASTEC input deck for this reactor was developed by the Institute for Nuclear Research and Nuclear Energy (INRNE-BAS).

Since the loss of AC and DC power occurs simultaneously with the initiating event of SBLOCA, the active safety systems became unavailable. The passive hydro - accumulator system is assumed to be the only emergency core cooling system available during the accident progression. The hydro -accumulators provide coolant injection until their water inventory is depleted.

The study focuses on the in-vessel phase of severe accident progression, including loss natural circulation, core uncover, core heat-up, hydrogen generation, fuel cladding failure, core degradation, melting and relocation of molten materials to the lower plenum, and

reactor pressure vessel lower-head failure. A comparative analysis is performed to evaluate the effect of break size on the timing and progression of the investigated transients.

The study provides valuable insights into the behaviour of VVER-1000/V320 reactors under combined SBLOCA and SBO conditions and contributes to the assessment of the severe accident management strategies.

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Key words: nuclear safety, loss of coolant, severe accident, hydrogen production, vessel failure.

SESSION 8

Commissioning of the National Disposal Facility

Vladimir Silvestorov[1]
[1]*State Enterprise Radioactive waste, Bulgaria*

E-mail of the Corresponding Author: Vladimir.Silvestrov@pprao.dprao.bg

Abstract

National Disposal Facility (NDF) – General information

- Multibarrier near-surface engineering facility
- Low- and Intermediate-level short-lived Radioactive Waste (RAW) resulting from:
  - Operation of Units 1 to 4 of Kozloduy NPP and their subsequent decommissioning
  - New Build – Units 7 and 8
  - Nuclear applications
- Phase 1 of NDF – disposal of RAW from decommissioning of Units 1-4 of Kozloduy NPP
- National project according to the State Property Act & project of national importance according to the Spatial Development Act
- A strategic project important for national security
- Operational period – 60 years
- Closure period – 15 years
- Institutional control period – 300 years

Key words: Commissioning of the National Disposal Facility

CHARACTERIZATION OF THE ISOTOPIC COMPOSITION OF SPENT NUCLEAR FUEL IN LIGHT WATER REACTORS

Kalin Filipov[1]*, Tsvetan Yovov[1]

[1]*Technical University of Sofia*

E-mail of the Corresponding Author: filipov@tu-sofia.bg

Abstract

Globally, approximately 14–16% of the total electricity production is generated through the fission of ^{235}U and ^{239}Pu nuclei. The objective of this study is to perform a detailed characterization of the isotopic composition of spent nuclear fuel discharged from light water reactors. To achieve this objective, comprehensive depletion simulations were carried out using the Monte Carlo transport code Serpent MC, which enables accurate modelling of fuel burnup and isotopic evolution. A detailed characterization of the isotopic composition of spent nuclear fuel was performed using the Serpent MC code, demonstrating its significance for the overall strategy of spent nuclear fuel management. A comparative assessment employing the ENDF/B-VII and JEFF-3.1 nuclear data libraries showed that the predicted inventories of uranium and plutonium isotopes are in close agreement, with differences generally within the statistical uncertainty of the calculations (typically below 10%, and in most cases considerably smaller). In contrast, more pronounced discrepancies were identified for isotopes present in low concentrations. Accurate characterization of spent nuclear fuel enables detailed evaluation of the evolution of uranium, plutonium, and other actinides, as well as the accumulation of fission products throughout reactor operation. This information is essential for reliable assessment of the neutronic and radiological characteristics of irradiated fuel. Consequently, the obtained results provide a sound basis for determining optimal

conditions for the transportation, interim storage, and long-term management of spent nuclear fuel.

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Key words: Transuranic Elements, Nuclear Data Comparison, Spent Nuclear Fuel

MONITORING OF Ra-226 in BULGARIAN DRINKING WATERS

D. Dimitrova[1*], D. Tonev[1], N. Goutev[1], S. Krastevski[1], Z. Zahariev[1], B. Slavchev[1]

[1]*Institute for Nuclear research and Nuclear energy, Bulgarian of academy of sciences, Sofia, Bulgaria*

E-mail of the Corresponding Author: dessy-d@inrne.bas.bg

Abstract

Radium-226 is naturally occurring in the environment because it is part of the uranium decay series.
Some drinking water sources can contain radionuclides at activity concentrations that can present a human health risk. The World Health Organization (WHO) recommends to routinely monitor radioactivity in drinking waters and to take proper actions when needed to minimize the health risk. Radioactivity in drinking waters in Bulgaria is regulated by the Ministry of Environment and Water. Ra-226 is prepared by co-precipitation with barium sulphate. The precipitate is then dissolved with EDTA and NaON and counted with an alpha spectrometry. The method has been applied to samples of drinking waters of different regions of Bulgaria. In all samples, the specific activity of Ra-226 varies a lot, but it was lower than 500 mBq/L. Radioactivity concentrations of Ra-226 in drinking waters depends on local geological characteristics and climatic conditions.

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Key words: Drinking water, Ra-226