AGA 7: An Overview of Physics and Disarmament Research in Germany – Social Event & Poster Session

This session offers an overview of physics research focusing on disarmament issues in Germany. Different research groups will introduce themselves and present brief summaries of their current work. In addition, posters covering a range of related topics will be on display. The session also provides opportunities for discussion and networking with the researchers.

Time: Thursday 17:30–18:30 Location: KH 00.016

AGA 7.1 Thu 17:30 KH 00.016

Nuclear archaeology with normalizing flows: Learning about past plutonium production from reprocessing waste — •Fabian Unruh[1] and Malte Göttsche[1,2] — [1]Peace Research Institute Frankfurt — [2]TU Darmstadt

Plutonium, a material used in nuclear weapons, is produced in nuclear reactors. In reprocessing, plutonium is separated from the fuel rod—a crucial procedure for weaponization—producing highly radioactive waste. Being very informative about operational reactor parameters, an analysis of the waste could be an asset for verifying declarations on plutonium production for an arms control agreement.

In this *nuclear archaeology* approach, the isotopic composition of the waste is analyzed with normalizing flow-based invertible neural networks, which unlike many Deep Learning (DL) techniques output probability density functions rather than point-estimates. The obtained posterior distributions for burnup and time since irradiation can represent multiple modes corresponding to mixtures of waste from several irradiation campaigns. Knowing only true parameter values, but not true posterior distributions, for test data renders validation challenging and requires specific approaches. First, *coverages* of posterior distributions, i.e. the fraction of instances where a confidence region covers the true value, are compared to expectations. Second, clustering algorithms partition multimodal distributions and the probability mass of individual modes is related to the corresponding campaign's share in the total waste. The presented results contribute to developing sound and trustworthy DL techniques for nuclear archaeology.

AGA 7.2 Thu 17:30 KH 00.016

Analysis of Human Intrusion Scenarios in the context of Site-Marking Concepts for Deep Geological Repositories — •Yannick Vogt and Friederike Friess — Universität für Bodenkultur Wien, Institute of Safety and Risk Sciences, Department of Landscape, Water and Infrastructure, Peter-Jordan-Straße 76, 1190 Vienna, Austria

Scientific consensus suggests the disposal of high-level radioactive waste in deep geological repositories. Such repositories are to be protected against human intrusion. Here, a differentiation can be made between intentional and unintentional intrusion scenarios. Where unintentional intrusion describes intrusion by accident, intentional intrusion scenarios refer to the deliberate locating of a storage site, to recover the resource materials contained within, e.g. plutonium or copper.

Based on a comprehensive literature review, pathways are studied by which a repository might be entered. These pathways include drilling and mining activities, infrastructure projects, archaeological excavations, or military operations. Additional methodological approaches are explored, helping to broaden the horizon of scenario development, such as incorporating thematically related literary works or conducting a creative tabletop workshop.

This work aims to present a comprehensive overview of human intrusion scenarios. The presented results are part of a larger project on site-marking concepts for deep geological repositories.

AGA 7.3 Thu 17:30 KH 00.016

Advancements in Radioxenon Monitoring with the new German SAUNA Q_b Systems — •Steffen Ludwig[1], Sofia Brander[1], J. Ole Ross[2], Sabine Schmid[1], Martina Konrad[1], Andreas Zehr[1], Andreas Bollhöfer[1], and Moritz Kütt[3] — [1]Bundesamt für Strahlenschutz (BfS) — [2]Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) — [3]Hamburg Nuclear Disarmament Laboratory (HaNDL), University of Hamburg

Since 1997, the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization has been monitoring nuclear weapon tests globally through the International Monitoring System. Radioxenon isotopes are produced in characteristic ratios during nuclear fission processes and can be indicators for nuclear explosions. They can even escape from deep underground nuclear tests.

As part of my PhD project in the Atmospheric Radioactivity and Trace Analysis group at BfS and at HaNDL, I will present first data from the new SAUNA Q_b systems deployed in Freiburg and the Bavarian Forest. These compact systems automatically sample and analyze radioxenon from the atmosphere. Thus, they improve the ability to characterize known radioxenon sources, evaluate Atmospheric Transport and Dispersion Models and identify unknown radioxenon emitters. In particular, traces of Xe-131m, which presumably originate from hospital emissions, will be investigated. Further, I will discuss ideas to combine SAUNA Q_b data, other radioxenon monitoring data and available emission data to improve source localization within the new European Q_b network.

AGA 7.4 Thu 17:30 KH 00.016

Opportunities for Natural-Science and Technical Peace Research — •Jürgen Altmann[1], Matthias Englert[2], Friederike Friess[3], Manuel Kreutle[4], Moritz Kütt[5], Christoph Pistner[2], Lukas Rademacher[6], and Max Schalz[7] — [1]TU Dortmund University — [2]Öko-Institut Darmstadt — [3]BoKu University Vienna — [4]Forschungszentrum Jülich — [5]University of Hamburg — [6]Peace Research Institute Frankfurt/TU Darmstadt — [7]RWTH Aachen University

FONAS, the Research Association Science, Disarmament and International Security, is the German professional organisation of scientists who conduct peace research based on natural science, engineering, computer science or mathematics. A wide variety of topics is being investigated: consequences of (nuclear) war, escalation potential and strategic stability; monitoring of (military) research and development; assessment of potential new weapon systems; military uses of new technologies under viewpoints of peace and international security and options for preventive arms control; verification technologies for actual and future disarmament, arms control and non-proliferation; proliferation risks from civilian/dual-use technologies. The poster will present examples from present research, with a main focus on research groups in Germany, to raise awareness about such research and to encourage (young) physicists to participate.

AGA 7.5 Thu 17:30 KH 00.016

nuSENTRY: Safeguards monitoring of future compact reactors using antineutrino detectors — •Yan-Jie Schnellbach, Sarah Friedrich, Robin Mentel, and Adhitya Sekhar — Technische Universität Darmstadt, Darmstadt, Germany

Current developments in the nuclear industry foresee a growth in the number of nuclear power plants, especially driven by a new class of reactor types with < 300 MW_e power, called Small Modular Reactors (SMRs). The planned decentral deployment of SMRs, combined with technically more integrated and compact designs, present new challenges for safeguards. Antineutrino detectors offer a potential new way of monitoring the fissile material in SMRs. Active reactors produce an unique neutrino fingerprint based on the fissioning isotopes and reactor power. Unlike other radiation, neutrino emissions penetrate any shielding and can therefore allow continuous monitoring at a stand-off distance of up to tens of metres. Furthermore, these detectors are highly sensitive to other radiation, including atmospheric muons and reactor neutrons, allowing further characterisation of facility operations. The nuSENTRY project studies the feasibility of using such a detector to characterise SMRs with antineutrinos and complementary radiation signatures as well as the potential for verifying reactor operations in the naval reactor context. This is done by using OpenMC-based reactor simulation to extrapolate reactor designs to SMR or naval designs, while different detection technologies are compared using GEANT4-based simulations to determine energy resolution and measurement times with respect to sensitivity.

AGA 7.6 Thu 17:30 KH 00.016

A muon detector concept for non-destructive imaging and material distinction for verification of nuclear items — •Nicolas Schwarz, Yan-Jie Schnellbach, and Sarah Friedrich — Technische Universität Darmstadt, Darmstadt, Germany

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) aims to ensure the exclusively peaceful civilian use of fissile material and nuclear technology in energy generation and disarmament. They are implemented by state parties and controlled by the International Atomic Energy Agency (IAEA). This contribution presents a conceptual muon detector as a safeguard for the purpose of (re-)verification. Ideally, such detectors could look inside closed compartments, advantageous for radioactive contents that pose a hazard for human safety, when opened. Muography is already established in structure analysis of civil engineering, archeology and geological research of volcanoes. Cosmic muons are naturally emerging as secondary rays in the atmosphere and are therefore suitable probes for passive measurements. They belong to minimum ionizing particles (MIPs) and thus the mean energy loss is a function of the momentum alone in the Bethe region. The proposed detector concept studied in this work is a two-sided hybrid muon detector, that uses a PVT scintillator hodoscope for muon track reconstruction, and a liquid organic TPC for calorimetric energy loss measurement. Simulation-based feasibility studies have been conducted to yield density images and show that a differentiation of heterogeneous materials is possible. A final disposal container will be used as a Spent Nuclear Fuel test subject to apply the insights gained from this analysis.

AGA 7.7 Thu 17:30 KH 00.016

Forensic Measurements for Nuclear Archaeology — •Lukas Rademacher — Technical University of Darmstadt, Darmstadt, Germany — Peace Research Institute Frankfurt, Frankfurt am Main, Germany

Reliable verification, conducted using universally accepted tools, is an integral part of lasting efforts towards nuclear disarmament. And the further such efforts progress, the more important it will become that this verification focusses not only on warheads, but also on existing stocks of fissile materials. 'Nuclear Archaeology' is a toolbox providing verification methods for these stocks. One of its most established methods, the 'Isotope Ratio Method' (IRM), revolves around isotopic measurements of samples taken from structural reactor elements, such as a graphite moderator or fuel channel tubes. Specific isotopic ratios in these samples can be used to deduce the neutron fluence in the reactor and create an estimate of the total plutonium production. We present a further development of this established methodology, aiming to strengthen its potential. Breaking down the deduced information about past operation in more detail becomes possible when analyzing several isotopic ratios in parallel. However, this deduction can no longer be performed analytically, and a numerical approach is applied instead. Suitable ratios and deduced operational history information are presented for two example cases. They are based on simulations of two different reactor types, the graphite moderated Trawsfynydd Unit II as well as a generic heavy water moderated CANDU 6 model, showcasing the framework's potential as well as wide applicability.

AGA 7.8 Thu 17:30 KH 00.016

Research on Nuclear Safeguards and Disarmament at Forschungszentrum Jülich — •Manuel Kreutle[1,2], Thomas Boland[1,2], Lisa Laumen[1], Kim Westerich-Fellner[1], Neslihan Yanikömer[1], Phillip Kegler[1], Katharina Aymanns[1], and Stefan Neumeier[1] — [1]Forschungszentrum Jülich, Germany — [2]RWTH Aachen University, Germany

With this poster we want to provide insight to physicists with interest in society and policy on working in interdisciplinary research in the nuclear area. We will give an overview of the physics-related work on nuclear safeguards and disarmament currently conducted in the 'Nuclear Safeguards and Security' division at the Institute for Fusion Energy and Nuclear Waste Management (IFN-2) at Forschungszentrum Jülich. We will present safeguards research projects on muon-based measurements to confirm the presence of nuclear material in storage casks or the absence of undeclared tunnels in a deep geological repository for nuclear waste, the development of digital twins for monitoring nuclear waste management facilities under safeguards, or the creation of a virtual reality (VR) training platform for education and training in nuclear safety and safeguards. We will further discuss work on nuclear disarmament, including practical tabletop and roleplay exercises.

AGA 7.9 Thu 17:30 KH 00.016

Mentorship program for scientific peace research — •Robin Tobias Mentel[1] and Martin Bernhard Kalinowski[2] — [1]Technische Universität Darmstadt — [2]Peace Science Collaboration

This poster presents the AGA's new mentorship program for students and young scientists, aiming to support young researchers to grow their career and skills, while also developing the network of junior and senior people in this complex and multidisciplinary field of physics and disarmament and other topics of science and peace research. The mentorship will help them not just to plan their career, but also develop relevant skills and prepare for job searches and applications. The Frühjahrstagung offers a great opportunity to introduce this initiative to a broad audience. We invite interested students and potential mentors to approach us and contribute to a growing community dedicated to responsible scientific peace and conflict research. This poster will also present the scope of the work and the current initiatives of the AGA. Specifically, we will introduce the research groups that are active in the field of nuclear arms control in Germany. Our goal is to show the diversity of research, ranging from technical verification methods to policy analysis. Further, the poster will outline engagement opportunities for students, early-career researchers, and senior scientists. There are a number of opportunities to become active, including public outreach, participation in interdisciplinary working groups, and contributions to the dialogue between science and society.

AGA 7.10 Thu 17:30 KH 00.016

Development of a novel antineutrino monitor prototype for nuclear safeguards — •Adhitya Sekhar[1], Nick Thamm[2], Sarah Friedrich[1], Robin Mentel[1], Stefan Roth[2], and Yan-Jie Schnellbach[1] — [1]Technische Universität Darmstadt — [2]RWTH Aachen University

In recent years there has been growing interest in antineutrino-based nuclear safeguards for monitoring reactor operation and spent fuel containment through the low-MeV antineutrinos emitted in beta-decay of fission fragments. Following previous promising simulations, a prototype for a novel antineutrino detection concept utilising a liquid organic time projection chamber (LOr-TPC) is now being developed. This study presents the initial phase of this project, showcasing investigations into the amplification properties of gaseous tetramethylsilane (TMS). A first test was conducted using a single-wire proportional counter in a ∼5mL cylindrical chamber and a ^{55}Fe source. A second test is being planned using a Thick Gaseous Electron Multiplier (THGEM). The results of these tests will be shown, along with comparisons made to previous measurements of amplification in other standard gases using the same setup, and their implications on the antineutrino monitor prototype development pipeline.