Working Group on Physics and Disarmament
Arbeitsgruppe Physik und Abrüstung (AGA)

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Zur Abrüstung, der Verhinderung der Verbreitung von Massenvernichtungsmitteln und der Beurteilung neuer Waffentechnologien sind naturwissenschaftliche Untersuchungen unverzichtbar. Auch bei der Verifikation von Rüstungskontrollabkommen werden neue Techniken und Verfahren benötigt und eingesetzt. Schwerpunkte in diesem Jahr bilden Themen wie die nukleare Abrüstung, Verifikation bzw. die Detektion von Nuklearanlagen und Materialien, Raketenabwehr und Zerstörung von Nuklearsprengköpfen, neue militärrelevante Technologien wie Drohnen. Die Fachsitzung wird von der DPG gemeinsam mit dem Forschungsverbund Naturwissenschaft, Abrüstung und internationale Sicherheit FONAS durchgeführt. Die 1998 gegründete Arbeitsgruppe Physik und Abrüstung ist für die Organisation verantwortlich. Die Sitzung soll international vorrangige Themen behandeln, Hintergrundwissen vermitteln und Ergebnisse neuerer Forschung darstellen.

Overview of Invited Talks and Sessions

(Lecture hall KH 00.016)

Invited Talks

AGA 1.1	Wed	14:00–15:00	KH 00.016	**How Missile Defence Works. A Look into Technical Details** — •Markus Schiller
AGA 1.2	Wed	15:00–16:00	KH 00.016	**Technical and Security Aspects of Hypersonic Weapons** — •David Wright
AGA 4.1	Thu	11:00–12:00	KH 00.016	**Quantum Technology Military Applications and Strategic Implications for Defence** — •Michal Krelina
AGA 4.2	Thu	12:00–13:00	KH 00.016	**Risiko Dual-use-Forschung** — •Wolfgang Liebert
AGA 6.1	Thu	15:15–16:15	KH 00.016	**Modeling Nuclear Weapon Effects from Trinity to Nuclear War** — •Sébastien Philippe
AGA 6.2	Thu	16:15–17:15	KH 00.016	**From Local Impacts to Global Risks: New Science on Nuclear War Consequences** — •Friederike Friess

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.

Sessions

AGA 1.1–1.3	Wed	14:00–16:30	KH 00.016	**Missile Defense and Outer Space**
AGA 2.1–2.3	Wed	17:00–18:30	KH 00.016	**Nuclear Fuel Cycle**
AGA 3	Wed	18:30–19:15	KH 00.016	**Members' Assembly**
AGA 4.1–4.2	Thu	11:00–13:00	KH 00.016	**Dual-Use Technologies**
AGA 5.1–5.2	Thu	14:00–15:00	KH 00.016	**Safeguards**
AGA 6.1–6.2	Thu	15:15–17:15	KH 00.016	**Nuclear Weapon Effects**
AGA 7.1–7.10	Thu	17:30–18:30	KH 00.016	**An Overview of Physics and Disarmament Research in Germany – Social Event & Poster Session**
AGA 8.1–8.3	Fri	9:30–11:00	KH 00.016	**Verification**

Members' Assembly of the Working Group on Physics and Disarmament

Mittwoch 18:30–19:15 KH 00.016

- Bericht
- Wahl
- Verschiedenes

AGA 1: Missile Defense and Outer Space

Time: Wednesday 14:00–16:30 Location: KH 00.016

Invited Talk AGA 1.1 Wed 14:00 KH 00.016

How Missile Defence Works. A Look into Technical Details — •Markus Schiller — ST Analytics München

Missile defence has lived through a renaissance over the past few years. With an increased use of missiles in conflicts since the Second Nagorno-Karabakh War 2020, the defence against missile attacks also became an ever more important issue. This is true not only on the tactical level, but also on the greater strategic stage, as America*s plans for a "Golden Dome" vividly illustrate. This presentation will give an overview of conflicts where missiles have played a role, thus pointing out the renewed interest for defence systems, and it will try to offer insights into the physical and technical basics of missile defence systems, to make the problem of missile defence more accessible.

Invited Talk AGA 1.2 Wed 15:00 KH 00.016

Technical and Security Aspects of Hypersonic Weapons — •David Wright — Laboratory for Nuclear Security and Policy, MIT

Hypersonic weapons travel faster than Mach 5 and use atmospheric forces to glide at low altitudes. Boost-glide vehicles (BGV) use rocket boosters to reach high speeds and then glide without powered. Hypersonic cruise missiles (HCM) are also boosted to high speeds but use a scramjet engine to provide power during part of their atmospheric flight.

Hypersonic weapons have gained considerable attention due to their purported advantages over existing missiles - including short delivery times, high maneuverability, and invulnerability to defenses which some proponents have said will "revolutionize warfare". However, technical analysis and computer simulations show that the fundamental physics of hypersonic flight severely constrains their performance. Comparison with existing ballistic missiles shows that many claims about the advantages of hypersonic weapons are overstated or incorrect.

This talk will discuss the physics and technology of BGVs and HCMs and their limitations in terms of speed, range, and maneuverability

AGA 1.3 Wed 16:00 KH 00.016

The Emerging Weaponization of Outer Space and Possible Restraint Measures — •Götz Neuneck — Federation of German Scientists

The challenges of a more congested and weaponized space environment are rising due to geopolitical rivalries of space-faring nations. The leading space powers accuse each other of weaponizing space while testing stealthy satellites and rendezvous and proximity operations (RPOs), direct-ascent ground-based interceptors and preparing space-based interceptors. Armed conflict in space and the deliberate destruction of satellietes can cause much short-term havoc in the space environment causing long-term consequences for different space constellations. Also nuclear weapons in space can not be ruled-out any longer. The arms control history is full confidence building measures and regulations but lack on implementation. The talk summarizes the threat and discusses possible measures of restraint.

AGA 2: Nuclear Fuel Cycle

Time: Wednesday 17:00–18:30 Location: KH 00.016

AGA 2.1 Wed 17:00 KH 00.016

Nuclear archaeology with reprocessing waste: a Bayesian framework for reconstructing reactor operating parameters — •Benjamin Jung — Peace Research Institute Frankfurt (PRIF), Frankfurt, Germany — Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen, Aachen, Germany

In order to verify declarations of fissile material for nuclear disarmament and non-proliferation regimes, nuclear archaeology seeks to reconstruct a state's history of fissile material production by analysing the isotopic composition of samples of material collected at its nuclear facilities. The novel Bayesian Reprocessing Waste Analysis Method (BRAM) aims to use waste from nuclear reprocessing activities as evidence for nuclear archaeology. Through simulation-based case studies, I demonstrate that this Bayesian framework can identify the type of source reactor and reconstruct important parameters such as burnup, cooling time, initial enrichment and power density. Using experimental data from the SFCOMPO database, I have successfully taken the first steps towards validating the framework by correctly reconstructing the operating parameters of a Magnox-type reactor and a pressurised water reactor (PWR). These results demonstrate the framework's potential and encourage further research and development in preparation for real-world applications.

AGA 2.2 Wed 17:30 KH 00.016

China's growing plutonium stockpile: Modelling the new CFR-600 reactors — •Laura Mertes[1], Julien de Troullioud de Lanversin[2], Matthias Englert[3], Friederike Friess[4], and Malte Göttsche[1] — [1]TU Darmstadt, PRIF — [2]The Hong Kong University of Science and Technology — [3]Öko-Institut — [4]BOKU University

China vastly expands the construction of new reactors to reach less dependence on coal. Two of more than 30 reactors under construction are sodium-cooled fast breeder reactors of type CFR-600, that are declared for civilian purposes, and their start of operation seems imminent according to satellite imagery. Fast reactors can be operated to produce more fissile material than they consume and the bred plutonium can be weapons-grade. This leads to proliferation risks typically associated with fast reactors.

Despite the reactors' importance, there are no publicly available studies on the CFR-600's possible plutonium production rates which are necessary for the assessment of the Chinese nuclear modernization campaign.

We present burnup simulation results on the CFR-600 plutonium production using OpenMC and publicly accessible input data. Due to a lack of available data, that are required for the simulation, we resort to an alternative ansatz and include information of similar reactor types which may share significant similarities to the CFR-600. This procedure as well as the adaption to the Chinese fast breeder reactor involves a broad discussion of the role of uncertainties and not-knowing and the impact on the estimation of the plutonium production.

AGA 2.3 Wed 18:00 KH 00.016

Safeguards Monitoring in Geological Repositories - Physics, Systematics, Interfaces, and Constraints — •Matthias Englert — Öko-Institut, Rheinstraße, 95 Darmstadt

We outline a technical framework to integrate safeguards-relevant monitoring into the context of long-term safety for deep geological repositories. The approach maps monitoring measures (e.g., passive seismics, borehole radar, antineutrino detection, myon tomography) to Features-Events-Processes (FEP) catalogues and to safety functions (containment, isolation, retardation) across salt, clay, and crystalline host rocks. Using THMC classification and life-cycle phases (operation, closure, post-closure), we identify influence pathways such as direct paths via installation, heat, or mechanical perturbations, and indirect paths such as signal interpretation and scenario screening. The framework supports completeness and consistency checks by grouping by physics principle, intrusiveness, range, or system coupling and describes trade-offs between verification demands and barrier integrity. Preliminary results emphasize standardised tabulation for comparability, explicit treatment of uncertainties, and criteria for selecting complementary techniques. The aim is a transparent, auditable coupling of safeguards information with safety assessment reasoning rather than a new safety methodology.

AGA 3: Members' Assembly

Time: Wednesday 18:30–19:15 Location: KH 00.016

All members of the Working Group on Physics and Disarmament are invited to participate.

AGA 4: Dual-Use Technologies

Time: Thursday 11:00–13:00 Location: KH 00.016

Invited Talk AGA 4.1 Thu 11:00 KH 00.016

Quantum Technology Military Applications and Strategic Implications for Defence — •Michal Krelina — University of Prague

Quantum technologies are emerging as force multipliers for military and intelligence activities by transforming how information is collected, processed, secured and exploited. Near-term applications are most visible in quantum sensing and communications, with implications for navigation and timing in GNSS-denied environments, enhanced submarine and underground detection, improved ISR performance, and highly secure command-and-control links for strategic and high-value assets. These capabilities promise greater resilience and precision, but also challenge existing assumptions about stealth, survivability and situational awareness. Quantum computing, while longer-term, carries profound intelligence implications through its potential to undermine current cryptographic systems, accelerate code-breaking and pattern analysis, and optimise complex military operations and logistics. The uneven pace of quantum adoption across states may generate new asymmetries, compress decision-making timelines and complicate deterrence and escalation dynamics. As quantum technologies converge with AI, cyber and space systems, their military significance will extend beyond individual capabilities to reshape intelligence advantage, operational planning and strategic stability

Invited Talk AGA 4.2 Thu 12:00 KH 00.016

Risiko Dual-use-Forschung — •Wolfgang Liebert — ISRW, BOKU Wien

Ausgehend von der Frage, um was es geht, wenn von Dual-use die Rede ist, wird die Entwicklung von Dual-use-Forschungskonzepten und ihre aktuelle Renaissance in Europa und Deutschland (zuletzt durch ein Positionspapier des Wissenschaftsrates) dargestellt. Die bislang beachtete Unterscheidung einer zivilen und einer militärischen Wissenschaftskultur soll durch die bewusste Schaffung von Grauzonen und entsprechende Forschungs- und Technologieförderung aufgehoben werden. Diskutiert werden (auch anhand von beispielhaften Entwicklungen) die erwartbaren Folgen — insbesondere für Universitäten und weitere zivile Forschungseinrichtungen. Ein postulierter, aber unreflektierter "Zwang" zur Verteidigungsforschung steht einer anderen Vorstellung von Verantwortungsübernahme in der Wissenschaft gegenüber. Einige Risiken durch Dual-use-Förderstrategien werden diskutiert. Dazu gehören: die schwer revidierbare Verwandlung der Wissenschaftskultur, unerwünschte Folgen für humanitäre und internationale Sicherheit, Herausforderungen für Rüstungskontrolle und Nonproliferation sowie ethische Dilemmata. Dies führt zu weiteren Fragen: Wie könnte eine angemessene individuelle und institutionelle Verantwortungsübernahme aussehen? Kann eine tiefergehende Analyse der wissenschaftlich-technologischen Dynamik den dringlichen Diskurs über Dual-use-Forschung unterstützen?

AGA 5: Safeguards

Time: Thursday 14:00–15:00 Location: KH 00.016

AGA 5.1 Thu 14:00 KH 00.016

Assessing safeguards challenges in compact reactors through antineutrino detection — •Sarah Friedrich, Robin Mentel, Yan-Jie Schnellbach, and Adhitya Sekhar — Technische Universität Darmstadt, Germany

Small Modular Reactors (SMRs) and advanced reactor and fuel types promise enhanced nuclear safety and greater operational flexibility, but they may also introduce new challenges to safeguarding efforts. To support the monitoring of SMRs and the detection of nuclear material diversion, we propose employing antineutrinos, which can be detected by a liquid-organic time-projection chamber outside of the reactor building, allowing non-intrusive, continuous, real-time measurements. The objective is to identify undeclared shutdowns, verify declared operational parameters and detect the diversion of nuclear material.

Our research builds on computational reactor simulations performed with OpenMC and Geant4 for a prototype 300-MWth pressurized water SMR, which allows us to investigate a cluster of several SMRs in close proximity to one another. We analyze how the energy spectrum of detected antineutrinos changes over time with a special focus on the spectrum before and after the declared shutdown of one module, where refuelling takes place. In a further step, we investigate whether the number and spectrum of detected antineutrinos can be used to identify undeclared shutdowns of a module.

AGA 5.2 Thu 14:30 KH 00.016

Developing antineutrino-based safeguards for naval reactors — •Robin Tobias Mentel, Sarah Friedrich, Yan-Jie Schnellbach, and Adhitya Sekhar — Technische Universität Darmstadt

In a world with an increasingly chaotic security landscape, the danger of nuclear proliferation is rising. In recent years, a potential proliferation concern has emerged with the planned employment of nuclear propulsion in submarines by Non-Nuclear Weapon States under the NPT. A prominent example of this is the sale of conventionally armed, nuclear-powered attack submarines by the US and the UK to Australia under the AUKUS agreement. Here, it is important to give safeguards inspectors powerful tools for a comprehensive and reliable safeguards regime, capable of detecting a diversion of weapons-grade nuclear material. We present our research on the development and the detailed simulation of antineutrino monitoring of a few nuclear-powered submarines anchored in the base of a consenting host state. To this aim, we will simulate the antineutrino emission from a naval reactor, simulated by OpenMC, and the subsequent detection in a tonne-scale active medium a few meters away, using Geant4. While focusing on the type of nuclear reactors relevant for the AUKUS-class submarines, we will explore the plausible parameter space of nuclear reactors typically employed in other submarines in terms of enrichment fraction (20 to 97%), reactor power (50 to 150 MW_{th}), burnup, and reactor geometry, like hexagonal and rectangular symmetry. Finally, we explore ways to implement this technique in the context of safeguards, including detector positioning, sensitivity, and integration times.

AGA 6: Nuclear Weapon Effects

Time: Thursday 15:15–17:15 Location: KH 00.016

Invited Talk AGA 6.1 Thu 15:15 KH 00.016

Modeling Nuclear Weapon Effects from Trinity to Nuclear War — •Sébastien Philippe — University of Wisconsin*Madison

The Trinity nuclear test of July 16, 1945 marked the first uncontrolled, large-scale release of radioactive material into the atmosphere. In the decades that followed, more than 500 atmospheric nuclear tests produced fallout at local, regional, and global scales, exposing populations worldwide. Yet the spatial and temporal distribution of this fallout remains only partially characterized. This presentation shows how modern tools - combining high-resolution atmospheric transport models, reanalyzed historical meteorological data, and physics-based nuclear explosion source terms*enable a new generation of fallout reconstructions. These methods yield hour-by-hour deposition estimates at kilometer-scale resolution, improving assessments of radiological exposure from historical testing, including in regions with sparse or absent monitoring data. The same framework scales directly to contemporary nuclear conflict scenarios. When integrated with population, infrastructure, agricultural, ecological, and other prompt nuclear effects, it enables comprehensive assessments of the physical, environmental, and societal consequences of nuclear war.

Invited Talk AGA 6.2 Thu 16:15 KH 00.016

From Local Impacts to Global Risks: New Science on Nuclear War Consequences — •Friederike Friess — BOKU University, Vienna

Heightened geopolitical tensions have renewed attention to the health and environmental consequences of nuclear explosions and war. Reflecting this urgency, WHO has convened a new working group to update its reports on nuclear weapons and health, and the UN Scientific Panel on the Effects of Nuclear War began work last summer, with a comprehensive assessment due by September 2027. Drawing on literature reviews and the authors' participation in the UN panel and respective research, this presentation traces the field's evolution from understanding local impacts to globally integrated monitoring and modeling. We highlight two active areas of research and debate: atmospheric transport of radioactive particles, moving beyond idealized spherical assumptions to more realistic morphologies; and the magnitude of global consequences governed by soot injection from large fires, with implications for climate perturbations and downstream risks to food security and public health.

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.

AGA 8: Verification

Time: Friday 9:30–11:00 Location: KH 00.016

AGA 8.1 Fri 9:30 KH 00.016

Mimicking Nuclear Warhead Signatures via Shielding of Radioactive Material — •Emma Lucke[1], Christopher Fichtlscherer[2], and Moritz Kütt[1,3] — [1]Hamburg Nuclear Disarmament Laboratory, University of Hamburg — [2]Laboratory for Nuclear Security and Policy, Massachusetts Institute of Technology — [3]Program on Science and Global Security, Princeton University

On the road toward reliable gamma spectroscopy-based warhead confirmation systems, ensuring signature uniqueness remains a challenge. If signatures are not unique, this vulnerability could be exploited by presenting hoax objects in place of actual warheads, thereby cheating procedures during nuclear dismantlement. In our previous work we established that combinations of shielded radioactive isotopes can produce gamma emission signatures indistinguishable from those of actual nuclear warheads. However, it remains unclear whether shielded isotope emissions actually offer any advantages over unshielded ones. In addition, earlier results suggest that some shielding configurations may be more effective than others. Our new work focuses on investigating these aspects. We expand the set of considered isotopes to include all long-lived candidates potentially applicable to cheating, which requires new OpenMC shielding simulations at higher photon energies. Additionally, the set of theoretical warhead models is broadened to incorporate further signatures. In a subsequent systematic search for hoax objects within this expanded space, we explore the role of shielding effects in constructing hoax objects that are capable of deceiving gamma spectroscopy based warhead confirmation systems.

AGA 8.2 Fri 10:00 KH 00.016

Modeling, simulations, database, and GUI: Updates on the Digital Twin for Nuclear Verification Project — •Manuel Kreutle[1], Katharina Aymanns[1], and Irmgard Niemeyer[1,2] — [1]Forschungszentrum Jülich, Germany — [2]International Atomic Energy Agency (IAEA), Vienna, Austria

Nuclear non-proliferation and disarmament efforts are centered around technical verification of related activities. This is true for bilateral agreements (e.g. New START, Open Skies, etc.) as well as multilateral treaties (e.g. NPT, CTBT, etc.). Past, present and potential future verification regimes are complex socio-technical systems that produce increasing amounts of data, nowadays usually in digital from. In convergence to that, "Digital Twins" have become a popular concept to monitor, predict or plan the behavior of cyber-physical systems. Hence it is just another step to combining the two.

In this talk, we will give an update on the state of a project on digital twins for safeguards in nuclear waste management. We will present a framework of database-enabled systems modeling, validated simulations, and visualization. The related software can produce realistic measurement and inspection data which can be displayed in a graphical user interface (GUI). In its current state it can be utilized to plan and improve monitoring systems, but we will discuss how it can be extended to allow for data processing of incoming real (live) data. We will close with sharing thoughts on how this project can be extended to create digital twins for nuclear verification in general.

AGA 8.3 Fri 10:30 KH 00.016

MUTOMCA: Muon Tomography for the Re-Verification of Spent Nuclear Fuel Casks — Paolo Andreetto[1], Katharina Aymanns[2], Massimo Benettoni[1], Nicola Bez[1], •Thomas Boland[2], Germano Bonomi[4], Lorenzo Castellani[1], Enrico Conti[1], Johan Dackner[5], Franco Gonella[1], Altea Lorenzon[1], Fabio Montecassiano[1], Marita Mosconi[5], Mentor Murtezi[5], Julia Niedermeier[6], Irmgard Niemeyer[2], Juha Pekkarinen[5], Andrea Rigoni[1], Daniele Scarpa[1], Maik Stuke[3], Matteo Turcato[1], and Gianni Zumerle[1] — [1]INFN Padova and University of Padova, Padova, Italy — [2]Forschungszentrum Jülich GmbH, Jülich, Germany — [3]BGZ Gesellschaft für Zwischenlagerung mbH, Essen, Germany — [4]University of Brescia, Brescia and INFN Pavia, Pavia, Italy — [5]European Commission, Directorate-General for Energy, Luxembourg — [6]Technical University Munich, Garching, Germany

Safeguards inspectors require reliable information to ensure that nuclear material in heavily shielded casks in dry spent fuel storage facilities is not diverted. In the event that all safeguards-related containment and surveillance measures fail, enhanced verification capabilities are needed. The MUTOMCA project aims to address this necessity by exploring muon tomography as a non-destructive assay method for re-verifying spent fuel casks. A detector setup was developed and tested and two algorithms were designed for reconstructing cask contents from muon absorption and scattering data respectively. A field test was performed with two loaded casks. This talk presents the muon detectors, data collection, preliminary results and future prospects.