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 H8)

Max von Laue Lecture

PV XVI	Thu	18:30–19:30	MVL	**Max von Laue Lecture: What physicists can do to improve international security?** — •Steve Fetter

Invited Talks

AGA 2.1	Thu	11:15–12:00	H8	**TPNW Verification: Domains, Boundary Conditions, Priorities & Problems** — •Thomas E. Shea
AGA 2.2	Thu	12:00–12:45	H8	**International Partnership for Nuclear Disarmament Verification: Current Status and Future Prospects** — •Irmgard Niemeyer, Gerald Kirchner, Götz Neuneck
AGA 3.1	Thu	13:30–14:15	H8	**Denuclearization of the Korean Peninsula** — •Tariq Rauf
AGA 3.2	Thu	14:15–15:00	H8	**The DPRK's SLBMs and SRBMs - A Brief Update on North Korea's Missile Activities** — •Markus Schiller
AGA 3.3	Thu	15:15–16:00	H8	**One Size does not Fit All: Greatly Different Mandates for Denuclearizing Nuclear States** — •Robert Kelley
AGA 4.1	Thu	16:00–16:45	H8	**The Space Debris Challenge and ESA's Space Safety Programme** — •Holger Krag

Sessions

AGA 1.1–1.2	Thu	10:00–11:15	H8	**Disarmament Verification I**
AGA 2.1–2.2	Thu	11:15–13:30	H8	**Disarmament Verification II**
AGA 3.1–3.3	Thu	13:30–16:00	H8	**North Korea: Denuclearization**
AGA 4.1–4.1	Thu	16:00–16:45	H8	**Space Security**
AGA 5	Thu	17:00–18:00	MVAGA	**Annual General Meeting**
AGA 6.1–6.2	Fri	10:00–11:15	H8	**Non-Proliferation and Nuclear Verification**
AGA 7.1–7.2	Fri	11:15–12:30	H8	**Nuclear Archeology**
AGA 8.1–8.2	Fri	12:30–13:30	H8	**Preventive Arms Control**

Annual General Meeting of the Working Group on Physics and Disarmament

Thursday 17:00–18:00 MVAGA

1. Report of the activities 2020/2021
2. Election of the speakers
3. Future Activities

AGA 1: Disarmament Verification I

Time: Thursday 10:00–11:15 Location: H8

AGA 1.1 Thu 10:00 H8

Zur Validierung von Monte-Carlo-Simulationen mit GEANT4 im Rahmen nuklearer Abrüstungsverifikation — •Manuel Kreutle[1], Alessandro Borella[2], Riccardo Rossa[2], Celine Scholten[1], Gerald Kirchner[1] und Claas van der Meer[2] — [1]Carl-Friedrich von Weizsäcker-Zentrum für Naturwissenschaften und Friedensforschung, Universität Hamburg — [2]Belgian Nuclear Research Centre SCK CEN, Mol, Belgien

Im Rahmen der Arbeit der Internationalen Partnerschaft zur Verifikation nuklearer Abrüstung (IPNDV) wurde eine internationale Übung im Kernforschungszentrum SCK CEN in Mol, Belgien, durchgeführt. Zusätzlich zu den Messungen wurden Monte-Carlo-Simulationen durchgeführt, um die Neutronensignaturen der verschiedenen vorhandenen Aufbauten zu rekonstruieren. In diesem Beitrag werden Simulationsergebnisse zum effektiven Neutronenmultiplikationsfaktor k_{eff}, zu Neutronenflussdichten und zur räumliche Verteilungen von Neutronenwechselwirkungsprozessen vorgestellt, welche mit Hilfe von GEANT4 berechnet wurden. Im Vergleich von k_{eff}-Ergebnissen mit MCNP- und KENO-Simulationen konnte die gute Leistung von GEANT4 nachgewiesen werden. Auch die Flussdichten für epithermische und schnelle Neutronen, welche mit GEANT4 und KENO berechnet wurden, stimmen in zufriedenstellendem Maß überein. Die vorliegenden Daten tagen somit zur Validierung der GEANT4-Neutronenphysik in Systemen mit spaltbarem Material, so wie z.B. im Rahmen von nuklearer Abrüstungsverifikation, bei.

AGA 1.2 Thu 10:30 H8

Einfluss von Betonwänden auf Neutronenstrahlung — •Svenja Sonder und Gerald Kirchner — Universität Hamburg, Carl Friedrich von Weizsäcker-Zentrum für Naturwissenschaft und Friedensforschung (ZNF), Beim Schlump 83, 20144 Hamburg

Neutronenmessungen spielen sowohl bei der Abrüstungsverifikation von nuklearen Waffen als auch bei zivilen Safeguards eine wichtige Rolle. Dabei haben die Größe des Raumes und die Beschaffenheit der Wände einen deutlichen Einfluss auf die Neutronenflussdichten, sodass begleitende Simulationen ohne Berücksichtigung der Wände die Realität nicht adäquat abbilden. Daher wurden am ZNF Simulationen durchgeführt, um den Einfluss von Betonwänden auf die Neutronenmessungen zu untersuchen.

Zur Simulation wurde das am CERN entwickelte Programm GEANT4 verwendet, welches aufgrund seiner Vielseitigkeit in verschiedensten Bereichen der Physik – von Hochenergiephysik bis zur medizinischen Bildgebung – eingesetzt wird. Dabei wird mithilfe von Monte-Carlo-Simulationen der Teilchentransport simuliert.

In diesem Vortrag soll der Einfluss von Betonwänden auf die Messungen innerhalb eines Raumes quantifiziert werden. Dabei wird ein besonderer Fokus auf die Änderung der Neutronenflussdichten und deren Energieverteilungen in räumlicher Nähe zu den Wänden gelegt. Darüber hinaus werden die verschiedenen Wechselwirkungsprozesse zwischen Neutronen und Beton beleuchtet.

15 min. break

AGA 2: Disarmament Verification II

Time: Thursday 11:15–13:30 Location: H8

Invited Talk AGA 2.1 Thu 11:15 H8

TPNW Verification: Domains, Boundary Conditions, Priorities & Problems — •Thomas E. Shea — Vienna

The TPNW provides a potential framework for eliminating existing arsenals in all nine nuclear-armed states, eliminating critical nuclear weapons infrastructure, and detecting any attempts to rearm in the future. The TPNW will require a verification system tailored to each nuclear-armed state reflecting its nuclear programs and respecting its laws governing nuclear safety and security. Each verification system should address eleven pursuits. Full verification will be costly, sometimes controversial, and will likely require prolonged periods before a state can be declared to be disarmed. Finding hidden weapons and clandestine manufacturing and support facilities will require the use of information obtained by the verification authorities together with information provided by states and other parties. Cybersecurity considerations will govern which verification technologies will be approved by each nuclear-armed state to prevent espionage and approved by the verification authorities to assure scientific authenticity

Invited Talk AGA 2.2 Thu 12:00 H8

International Partnership for Nuclear Disarmament Verification: Current Status and Future Prospects — •Irmgard Niemeyer[1], Gerald Kirchner[2], and Götz Neuneck[3] — [1]Forschungszentrum Jülich — [2]ZNF Universität Hamburg — [3]IFSH Universität Hamburg

The International Partnership for Disarmament Verification (IPNDV) includes technical experts and government representatives from Nuclear Weapon States and Non-Nuclear Weapon States to work jointly on procedures and technologies that would allow for effective verification of nuclear disarmament. In Phase I (2016-2017), IPNDV identified 14 key steps in the nuclear weapons dismantlement lifecycle. In Phase II (2018-2019), IPNDV broadened its work to consider wider aspects of nuclear disarmament verification while at the same time deepen the work on specific elements of verification. In moving from paper to practice, five practical exercises and technology demonstrations were conducted, including the Nuclear Disarmament Verification (NuDiVe) Exercise, co-hosted by Germany and France. Phase III (2020-2025) builds on current working methods and engages in further hands-on activities, including scenario-based discussions, practical exercise, such as NuDiVe 2021, and technology demonstrations. The talk will discuss the Partnerships' achievements so far and give an outlook to the next steps.

45 min. lunch break

AGA 3: North Korea: Denuclearization

Time: Thursday 13:30–16:00 Location: H8

Invited Talk AGA 3.1 Thu 13:30 H8

Denuclearization of the Korean Peninsula — •Tariq Rauf — Vienna

Tariq Rauf (former Head of Verification and Security Policy, International Atomic Energy Agency, responsible for the Director General's report on Application of Safeguards in the Democratic People's Republic of Korea). Nuclear weapons were first introduced into the Korean Peninsula in January 1958 by the US through its defence alliance with South Korea. During the inter-Korean war, the US threatened three times to use nuclear weapons against DPRK. There was no DPRK nuclear weapon programme until decades later.

South Korea's nuclear weapons research programme was wound up in 1975 with its ratification of the Non-Proliferation Treaty (NPT). In August 2004, the IAEA cited South Korea for previously undeclared nuclear activities involving the reprocessing of nuclear material. Between 9 October 2006 and 3 September 2017, the DPRK carried out six nuclear weapon tests and more than 100 missile tests. Until very recently, annual US-South Korea military exercises had been expanding both in their scope and numbers of troops, including decapitation strikes, and invasion and occupation of major military and other strategic locations in North Korea.

After early mutual threats and insults, DPRK leader Kim Jong Un and US President Donald Trump have held three bilateral summits but as yet no agreement has been possible on denuclearization of the Korean peninsula.

This presentation will cover developments regarding the DPRK's nuclear and missile programmes, and assess the prospects and possible measures for achieving the denuclearization of the Korean Peninsula.

Invited Talk AGA 3.2 Thu 14:15 H8

The DPRK's SLBMs and SRBMs - A Brief Update on North Korea's Missile Activities — •Markus Schiller — ST Analytics GmbH, München, Germany

After having successfully launched the Hwasong-15 road-mobile ICBM in November 2017, the Democratic People*s Republic of Korea (DPRK) apparently adhered to a self-imposed missile launch moratorium for almost 18 months. In May 2019, though, North Korea started to launch missiles again; about two dozen were fired over the summer months of 2019. However, contrary to 2017, these launches were limited to Short Range Ballistic Missiles (SRBMs) and a Submarine-Launched Ballistic Missile (SLBM), and relied on technologies that had nothing in common with the previous ICBM activities.

This presentation will give an update on the observed North Korean missile activities since 2018, including an attempt to distill some possible strategic motives for these activities.

15 min. break

Invited Talk AGA 3.3 Thu 15:15 H8

One Size does not Fit All: Greatly Different Mandates for Denuclearizing Nuclear States — •Robert Kelley — Vienna

The International Atomic Energy Agency (IAEA) has dealt with nuclear materials verification inspections in many states. In only a few cases has the IAEA actually had to deal with extensive programs, nuclear weapons components, and very sensitive nuclear weapon design information. In three significant cases, Iraq (1991-2003), Libya (2004) and South Africa (1993) there were very sensitive nuclear investigations required. All three had widely varying mandates, discoveries and constraints. Future investigations of actual weaponization activities can learn many lessons from these cases. A third, denuclearization active, Project Sapphire in Kazakhstan provided yet another model for extracting dangerous weaponization materials. Hopefully these cases will be studied in preparations for another denuclearization campaign, possibly in the DPRK.

AGA 4: Space Security

Time: Thursday 16:00–16:45 Location: H8

Invited Talk AGA 4.1 Thu 16:00 H8

The Space Debris Challenge and ESA's Space Safety Programme — •Holger Krag — ESA/ESOC Darmstadt

In line with EU and ESA's 'Shared vision and goals for the future of Europe in space', ESA has prepared a new programme that aims for Europe to ensure European autonomy in accessing and using space in a safe and secure environment. The primary goal of this programme is the protection of our planet, humanity and assets in space and on Earth from hazards originating in Space. The major hazards from space to be tackled by the programme have been identified as the Space Weather originating from our Sun, Planetary Defence from Asteroids and Space Debris. The talk will concentrate on the space debris-related aspects of the programme and provide details on ESA*s plans to develop sensor technology for debris monitoring in the area of laser, ground- and space-based optical telescopes and radar. One of the flagships of the programme will be an element entitled CREAM (Collision Risk Estimation and Automated Mitigation), which is a series of activities for the development of automated collision avoidance capabilities and alternate fast commanding option for public and private entities coping with enhanced space traffic, including a demonstration of such capabilities by 2023. The most prominent cornerstone will be the first ever active debris removal mission as an enabler of European industrial capability to conduct in-orbit servicing. The goal is to remove an ESA-owned space debris target object >100kg before the end of 2025 on orbit in a service approach, building on the industrial interest in gaining access to the rising in-orbit servicing market.

AGA 5: Annual General Meeting

Time: Thursday 17:00–18:00 Location: MVAGA

Annual General Meeting

AGA 6: Non-Proliferation and Nuclear Verification

Time: Friday 10:00–11:15 Location: H8

AGA 6.1 Fri 10:00 H8

Nuclear Weapon or Hoax Object? Imitating Gamma Spectra in Verification Measurements — •Christopher Fichtlscherer[1,2] and Moritz Kütt[2] — [1]Nuclear Verification and Disarmament Group, RWTH Aachen, Aachen, Germany — [2]Arms Control and Emerging Technologies, IFSH, Hamburg, Germany

Nuclear weapon authentication often relies on the passive gamma spectrum of a warhead. Measurement systems for such authentication need to provide sufficient information to judge whether the measured object is a warhead. At the same time, they need to protect information considered sensitive. Authentication is only possible if the measured spectrum is unique to a specific warhead type for a given measurement system. If it were possible to produce hoax objects whose emissions create the same measured signal, states could present those in verification processes, effectively undermining disarmament efforts. To determine the uniqueness of warhead spectra, we attempted to replicate detector responses of a notional warhead model with mixtures of radioactive isotopes. In the talk, we present simulation results for existing warhead authentication prototypes.

AGA 6.2 Fri 10:30 H8

Simulation Calculations for the Conversion of FRM-II — •Matthias Englert and Christoph Pistner — Institute for Applied Ecology, Rheinstr. 95, 64295 Darmstadt

Minimization of the civil use of highly enriched uranium (HEU) is one of the cornerstones of international nonproliferation efforts to prevent access to fissile material suitable to build nuclear weapons. The only reactor in Germany still using HEU is the FRM-II at the Technical University in Munich (TUM). Since almost 20 years there is a push to convert the reactor to lower enrichment. The extremely compact design of the fuel element, made possible by new uranium silicide fuel, has made the conversion of the reactor into a demanding task ever since. In a series of papers, new promising conversion options were published in recent years by TUM scientists. Especially conversion with the current uranium silicide fuel - an option that was almost neglected in the first 15 years - has seen new interest. We present complementing results from our simulation calculations regarding uranium silicide conversion with the burnup routine VESTA, the latest version of the neutron transport code MCNPX 6.2 and updated evaluation and core design tools implemented in Mathematica 12. For the new simulation environment, a benchmark was performed against older results on the HEU reference model. A new reactor geometry was modeled according to a design choice published by TUM with uranium silicide fuel with a density of 6 gU/cm3 at an enrichment of 35% and burn calculations will be presented. Since the results were promising we investigated whether the uranium silicide fuel qualified for LEU enrichment at 4.8 gU/cm3 would be suitable for use with up to 50% enrichment. Uranium silicide fuel has been used for 16 years at a density of 3.0 gU/cm3 with a high enrichment of 93% in FRM-II. Two strategies were identified to explore the possibilities of a uranium silicide fuel with higher density than 3.0 gU/cm3 (1.5 gU/cm3) with lower enrichment: First, to operate with fuel >4.8 gU/cm3 with as few changes in fuel assembly geometry as possible; second, to operate with the current fuel at a density of 3.0 gU/cm3. Further analysis focused on an investigation of the purely geometrical changes with the current fuel of a density of 3.0 gU/cm3. The dependence on enrichment was investigated and an enrichment of 50-60% was found to be promising. However, the burnup calculations showed that an enrichment of 50% leads to a reduction of the cycle length. Subsequently, the same model was used to investigate the effect of varying the length of the fuel element. We finally present an outlook for further optimizations such as a change in the density jump (or cancellation by using neutron absorbers) or other geometrical changes, such as a reduction in the number of plates and an increase in the cooling channel width.

15 min. break

AGA 7: Nuclear Archeology

Time: Friday 11:15–12:30 Location: H8

AGA 7.1 Fri 11:15 H8

Forensic measurements for nuclear archaeology - A new approach — •Lukas Rademacher and Malte Göttsche — Nuclear Verification and Disarmament, RWTH Aachen

The availability of effective and widely accepted verification tools is an essential prerequisite for any lasting and successful effort towards nuclear disarmament. One such verification toolbox is nuclear archaeology - it aims to reconstruct the production and removal history of weapons-usable fissile materials. A central method of nuclear archaeology is the deduction of a shut-down reactor's lifetime plutonium production using samples taken from within its core. Specific isotopic ratios are measured to assess neutron fluence and thus estimate plutonium production.

We will present a new approach aiming to strengthen the potential of the method by analyzing a larger set of measured isotopic ratios. This allows for the reconstruction of operational histories of the considered reactor in more detail , therefore providing more information to cross-check declarations. However, this requires a considerably more complex analysis. A feasibility study for this new approach using state-of-the-art mathematical and computational methods has been conducted and will be presented, showing that it is indeed possible to reconstruct additional information.

AGA 7.2 Fri 11:45 H8

Uncertainty Quantification of Plutonium Production Estimates Using the Isotope Ratio Method — •Benjamin Jung and Malte Göttsche — RWTH Aachen University, Aachen, Germany

An understanding of fissile material production histories is essential to enable nuclear disarmament. The Isotope Ratio Method is a technique to estimate the lifetime plutonium production of shut-down reactors. Robust uncertainty assessments are crucial to determine whether these plutonium estimates are consistent with a state's declaration. With Monte Carlo methods and sensitivity analysis techniques, we examine which impact different magnitudes of various uncertainty sources have, using a CANDU 6 and the graphite-moderated Yongbyon reactors as models. The results show that, in particular, uncertain burnup values and, to a lesser degree, nuclear data uncertainties impact the overall uncertainty. To appropriately consider this, we propose a new sequence of applying the Isotope Ratio Method, which calculates tolerance intervals (as opposed to mean values with a standard deviation). The scenarios considered here result in intervals of approximately +/- 10% around the plutonium estimate, suggesting possibly larger uncertainties of the Isotope Ratio Method than previously assumed.

15 min. break

AGA 8: Preventive Arms Control

Time: Friday 12:30–13:30 Location: H8

AGA 8.1 Fri 12:30 H8

Small Armed Aircraft and Missiles - Technology Assessment and Preventive Arms Control — •Jürgen Altmann, Mathias Pilch, and Dieter Suter — Exp. Physik III, TU Dortmund University, Dortmund, Germany

Numerous countries are deploying armed uninhabited aerial vehicles (UAVs), with wingspans of many metres and payloads of hundreds of kg. But work for and deployment of smaller systems have intensified. We have created a database of technical information on small (size <= 2 m) and very small (<= 0.2 m) UAVs (https://url.tu-dortmund.de/pacsam-db). In May 2021 the UAV database contains 152 types from 27 countries, among them 24 armed types from 10 countries. The database of small and very small missiles (diameter <= 70 m and 40 mm, respectively) counts 12 entries in July 2021 (4 of which date back several decades, 4 newer ones are <= 40 mm).

Because of limited payloads, small UAVs and missiles would bring limited weapon effects, but due to low cost they could be produced in high numbers, and attacks against soft spots or in swarms could be militarily relevant. Vertical and horizontal proliferation could endanger military stability and international security; preventive arms control is needed.

AGA 8.2 Fri 13:00 H8

Renaissance of Directed Energy Weapons? — •Götz Neuneck — IFSH University of Hamburg

The call to introduce Directed Energy Weapons on the battlefield goes back to Ronald Reagan's Strategic Defense Initiative, but is renewed from time to time. Russia's President Putin introduced a new ground-based combat laser (Peresvet)and U.S. President Trump's Missile Defense Review calls for new laser weapons for defense purposes. The development of high-power lasers for research and industrial purposes has been improved significantly. The talk analyses the current state ofthe art for laser sources, their dual-use potential and possible solutions for arms control. Esp. in the era of emerging power rivalry it is utmost important to organize dialogues with conflicting states.