KIT
Karlsruhe Institute of Technology

Tritium Laboratory Karlsruhe

30 years

23rd May 2023
ceremonial act

24th & 25th May 2023
symposium on tritium science & technology

Book of abstracts

Preface

We are delighted to present this abstract book of the symposium on the 30th anniversary of the Tritium Laboratory Karlsruhe (TLK) that will take place on 24th and 25th May 2023. Many different presenters have contributed.

TLK, operated by the Institute for Astroparticle Physics (IAP), stands as a semi-technical scale facility that has contributed in advancing our understanding of tritium, the radioactive hydrogen isotope, and its technical use for applications in nuclear fusion, astroparticle physics and beyond. With three decades of experience, TLK has gained a wealth of knowledge and expertise. Distinguished features are its license to handle up to 40 grams of tritium and a closed cycle which allows reprocessing of any tritium-bearing gases. Continuous maintenance and upgrading efforts have allowed that TLK is a state-of-the-art infrastructure despite its three decades of existence.

As a major facility of the German Helmholtz-Association (HGF), TLK is entrusted with two critical missions. Firstly, TLK has been dedicated to advancing the fuel cycle for nuclear fusion, a vital pursuit with far-reaching implications for global energy challenges. Important milestones were the development of Tokamak Exhaust Processes and the proposal for the ITER fuel cycle. Secondly, TLK has focused its efforts on the measurement of neutrino mass.

Here, a crucial achievement of TLK is its role as the host of the KATRIN experiment, a world-leading endeavor investigating direct neutrino mass based on tritium beta decay. This groundbreaking experiment performed by an international collaboration has captured the attention of the scientific community and holds the potential to further explore our understanding of neutrinos and their properties.

Looking ahead, TLK remains resolute in its dedication to contributing to fundamental research and offers opportunities for technology development in the pursuit of nuclear fusion. With a highly skilled and motivated team, TLK is poised to achieve great strides in these areas of scientific inquiry.

The abstracts presented in this book showcase the ongoing research, discoveries, and collaborative efforts in the field of tritium science and technology by leading international researchers in the fields of

- Neutrino physics with tritium (incl. atomic tritium source technologies)
- Tritium-material interactions
- Fusion R&D on fuel cycle & blanket
- Tritium processing experiences
- Tritium analytics
- Tritium in industry incl. fusion start-ups

It is our hope that this symposium serves as a source of inspiration, fostering dialogue and collaboration within these exciting fields.

Beate Bornschein (Head of TLK) and Magnus Schlösser (Deputy head of TLK).

Sponsoring

We are very grateful to our sponsors who kindly support our 30th anniversary.

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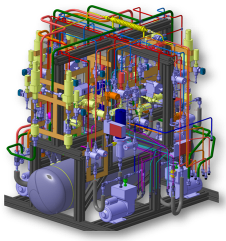

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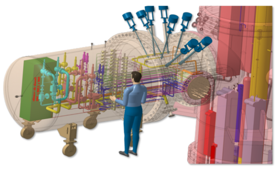

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Our services include, but are not limited to, cryogenic technical support throughout the entire project, from procurement, to design, to installation and operation. We can help you with technology projects, such as isotope separation or ion separation facilities.

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Congratulations on 30 years TLK, which we accompany since the beginning.

Stable long-term measurements of the anti-neutrino mass via the beta-decay of tritium require a constantly high activity and thus accurate tritium gas output and purity. The closed loop tritium retention system at KIT enables a permanent throughput of 40g tritium/day with a purity of more than 95%.

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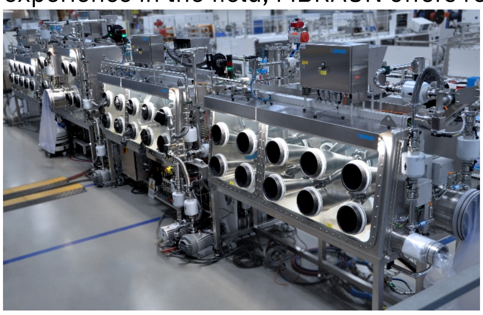

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With decades of experience in the practical handling of tritium, the team of smolsys ltd, founded in 2014, has made it their mission to provide the market with the safest, most flexible, and modern tools for its tasks in handling hydrogen isotopes. In collaboration with the customer and external specialist partners, an optimal solution is found for the task at hand. Here, our own tritium laboratory proves an asset. After a "Design Qualification" by the customer, we manufacture, assemble, and test all goods, ready for a Factory Acceptance Test. In addition to designing and building automated machinery and equipment, we also offer our own smolsys line of products for tritium handling, such as special face sealed all-metal bellow valves and other high vacuum components, magnetic driven syringe pumps for high pressure applications, or our new in-line tritium concentration sensor.

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Important information

Talks and posters

Talks

During the symposium we have a total of 21 talks. To keep on schedule we would like to ask all presenters to keep on time. The durations in the time table (cf. section 4) are always given with a discussion time of 5 minutes included.

Indico upload

We would like to collect the talks on the Indico platform on a voluntary basis. If you like, upload it yourself orsend it to rodenbeck@kit.edu.

Posters

We have 23 poster submissions. Many thanks for this great number. All posters will be fixed to individual poster walls which will be present in the conference room during the two days of the symposium. Ideally, you fix the posters once you arrive at the venue or in one of the first coffee breaks. In case you arrive at the campus earlier, then you can hang up your poster already from Monday 3 PM on.

We have scheduled two poster sessions of each one hour of duration (`https://indico.scc.kit.edu/event/3418/`). All posters can be presented in one of the sessions or even in both. This allows for best engagement with the ≈100 participants at our workshop as certain discussions will develop only during the meeting. Also it allows you as poster presenter to visit the posters of others. We will have individual poster walls at which you could use needles for fixing.

Venue

The events take place on Campus North (CN). Here, you find general directions to KIT CN. The three important buildings (FTU, TLK and B. 401) are marked on the map on page 56.

Entrance to KIT Campus North (CN)

The access to the perimeter of KIT is restricted to non-KIT members. We describe the foreseen paths to access during the TLK anniversary below.

Access during the ceremonial act (23rd May)

The transfer from the FTU (talks) to the TLK (lunch, guided tours and barbecue) is organized together with guides from TLK. You can either use a shuttle bus or walk together with a larger guided group. These groups form outside of the FTU building. We encourage you to spend less time at FTU, but chat, discuss, argue with friends and colleagues either during transfer to TLK or there during lunch.

Entrance during the symposium (24th and 25th May)

The most convenient way to enter the campus during the symposium is to due this without our chartered shuttle-busses or taxis which commute from Karlsruhe and Bruchsal / Büchenau to the Campus North (CN) of KIT. In case you use other means of transportation to arrive at CN, you can “hop” into the bus just before it enters the perimeter. The bus schedule is found below.

Entrance without shuttle bus

In case you arrive earlier, later or at an otherwise inconvenient without the chance by hopping in to the shuttle bus. Then you can still get access to CN. In this case you need to enter the Reception ”Anmeldung” at the southern gate of KIT and get a visitor's passport. Your name will be noted on a list there. Please bring your ID or passport to identify yourself. With is visitor's pass you can enter / leave at any time.

Public transportation

General information and tickets by KVV (`http://en.kvv.de/`). See also bus schedules on page 56.

1. **From Karlsruhe City**
   Tram (S1 or S11) to Leopoldshafen - Leopoldsstraße
   Change to Bus 195 (one stop to KIT-Campus Nord Südtor)

2. **From Karlsruhe Central station**
   Regional train to Blankenloch Bahnhof
   Change to Bus 195 (four stops to KIT-Campus Nord Südtor)

3. **KIT Shuttle bus - between Campus North and South**
   Regular shuttle service between both campi: `https://www.kit.edu/downloads/Fahrplan_Shuttle.pdf`

Shuttle schedules

For everyone that requested transportation during their registration, we offer the following shuttles. The bus will have a “30 Year TLK” sign.

23rd May 2023

9:15 h Bus from bus parking at Hauptbahnhof (central station) Karlsruhe (find location here).
9:30 h Bus from Schlossbezirk (find location here).
9:45 h Cab from Hotel Plaza, Am Mantel 1A, 76646 Bruchsal.
9:45 h Cab from Hotel Ritter in Büchenau.
20:00 h Bus and cabs will drive back to Hauptbahnhof, Schlossbezirk, Hotel Plaza and Hotel Ritter.

24th May 2023

8:00 h Bus from bus parking at Hauptbahnhof (central station) Karlsruhe (find location here).
8:15 h Bus from Schlossbezirk (find location here).
8:45 h Bus will stop at bus station in front of KIT Campus North.
If you hop on the bus you don’t need to register on your own at the gate.
8:30 h Cab from Hotel Plaza, Am Mantel 1A, 76646 Bruchsal.
8:35 h Cab from Hotel Ritter in Büchenau.
21:00 h Bus and cabs will drive back to Hauptbahnhof, Schlossbezirk, Hotel Plaza and Hotel Ritter.

25^{th} May 2023

8:00 h Bus from bus parking at Hauptbahnhof (central station) Karlsruhe (find location here).
8:15 h Bus from Schlossbezirk (find location here)
8:45 h Bus will stop at bus station in front of KIT Campus North.
If you hop on the bus you don't need to register on your own at the gate.
8:30 h Cab from Hotel Plaza, Am Mantel 1A, 76646 Bruchsal
8:35 h Cab from Hotel Ritter in Büchenau
18:00 h Bus and cabs will drive back to Hauptbahnhof, Schlossbezirk, Hotel Plaza and Hotel Ritter.

Hybrid access

Hybrid access to the symposium is made available via zoom (link).

Meeting ID: 990 9625 5880

Password: 30years

Guided tours on 23rd May

On May 23th between 2 and 4 pm, there is the possibility to visit the TLK or the KATRIN spectrometer hall. At the TLK and the spectrometer hall, the guided tours will start on demand, as soon as groups of about eight to twelve people have gathered.

Since the **TLK** is a surveillance area, we are obliged to keep track of everyone entering the lab. If you opted for a guided tour during the registration process, you will receive a TLK tour voucher at FTU in the morning. You need to hand over the voucher at the entrance at TLK

Additionally, the number of visitors allowed in the lab is limited to about five groups (each of about ten people) at a time. Please have a look at the entrance how long the queue is and bring some patience or take a cup of coffee in between.

No registration is needed for the visit of the **KATRIN spectrometer hall**. Just visit there during the time slot between 2 pm and 4 pm if you like and join a guided tour.

Timetable

Tuesday, May 23rd

10:00	**B 101**	**Aula**	**Ceremonial act**
10:00			Coffee and Get-Tougether
10:30			Welcome and Greetings
10:45	Beate Bornschein		30 Years of TLK
11:05	Thomas Giegerich		Challenges in the Tritium Fuel Cycle for the DEMO Reactor
11:35	Susanne Mertens		Measurement of Neutrino Mass with Tritium Beta Decay - Where do we stand, where can we go?
12:05	Magnus Schlösser		The Tritium Future
12:30			**Transfer to TLK**
13:00	**B 451**	Tent	**Lunch at TLK**
14:00	**B 451**		**Guided tours**
16:00	**B 451**	Tent	**Barbecue**

Wednesday, May 24th

09:00	**B 401**	**R 410**	**Welcome**
09:10	**B 401**	**R 410**	**Neutrino physics with Tritium and atomic sources: Session 1**
09:10	Hamish Robertson		Tritium and the Mass of the Neutrino
09:45	Sebastian Böser		Towards an atomic tritium source for Project 8
10:10	Michael Sturm		Operation of the KATRIN molecular tritium source
10:35	B 401	R 410	Coffee break
10:55	**B 401**	**R 410**	**Neutrino physics with Tritium and atomic sources: Session 2**
10:55	Ruben Saakyan		Determination of absolute neutrino mass using quantum technologies
11:20	Nicolo de Groot		Tritium for cosmic neutrino detection with Ptolemy
11:45	Marco Röllig		Paving the Way: Towards an Atomic Tritium Source for KATRIN
12:10	Alec Lindman		Practicalities of Atomic Tritium for Project 8
12:35			Discussion / Perspectives
13:00	**Casino**		**Lunch break**
14:00	**B 401**	**R 410**	**Poster session**
15:00	B 401	R 410	Short break

15:15	**B 401**	**R 410**	**Tritium and dark matter experiments**
15:15	Michelle Galloway		Tritium traces in rare-event search experiments
15:40	B 401	R 410	Short break
15:50	**B 401**	**R 410**	**Fusion R&D – Fuel Cycle/Materials: Session 1**
15:50	Francisco Alberto Hernandez Gonzales		The Breeding Blanket, the Core of a Thermonuclear Fusion Reactor. Technology, EU Concepts and Perspective
16:25	George Ana		Activities in support of ITER/DEMO
16:50	Alessia Santucci		ENEA activities in tritium recovery and processing for DEMO fuel cycle and blanket
17:15	B 401	R 410	Coffee break
17:35	**B 401**	**R 410**	**Fusion R&D – Fuel Cycle/Materials: Session 2**
17:35	Christoph Kirchlechner		The Tritium Research in the Fusion Materials Laboratory
18:00	Knut Amis		The Research Training Group GRK 2721: Hydrogen Isotopes
18:25	Florian Priester		Sieverts' constant for $H_2/D_2/T_2$ in eutectic PbLi
18:50			Discussion / Perspectives
19:15			**Walk to Dinner**
19:30	**B 451**	Tent	**Dinner**

Thursday, May 25th

09:00	**B 401**	**R 410**	**Tritium processing (experience and lessons learned)**
09:00	Xavier Lefebvre		Experience/Lessons learnt during DTE2 in AGHS
09:30	Ian Castilo		Tritium Processing Experience at Canadian Nuclear Laboratories (CNL)
10:00	Stefan Welte		Development & Operation of the TLK tritium loop
10:30	Robert Michling		The ITER Tritium Plant – Operation and Analytical Needs
11:00	B 401	R 410	Coffee break
11:20	**B 401**	**R 410**	**Tritium analytics and application**
11:20	Robin Größle		Tritium Analytics in the powers of ten
11:45	Christian Grisolia		Outcomes of the TRANSAT (Transversal actions for tritium) EU project
12:10	Yuji Hatano		Tritium Research Activities in Hydrogen Isotope Research Center, University of Toyama
12:35	Helmut Telle		Raman spectroscopy of tritiated molecules: the Good, the Bad and the Ugly
13:00	**Casino**		**Lunch break**
14:00	**B 401**	**R 410**	**Poster session**
15:00	B 401	R 410	Short break
15:10	**B 401**	**R 410**	**Discussion & Perspectives**

15:30	**B 401**	**R 410**	**Fusion start up and tritium**
15:30			Introduction
15:35	Andrew Holland		Overview of Private Fusion Efforts
15:45	Brandon Sorbom		Development of fuel cycle systems for D-T fusion power plants
16:10	Sandra Romanelli		Commercialization of Fusion Reactors
16:35	Francesco Volpe		Renaissance Fusion: Nuclear fusion concept and tritium related issues
17:00	Magnus Schlösser		Tritium Laboratory Karlsruhe – opportunities for tritium research
17:15			Discussion & Perspectives
17:35	**B 401**	**R 410**	**Tritium Manual Revelation**
18:00	**B 401**	**R 410**	**Goodbye**

Wednesday, 24th May

Neutrino physics with Tritium and atomic sources

B. 401 R. 410 09:00 – 13:00

Tritium and the Mass of the Neutrino

Hamish Robertson (University of Washington)

For 75 years the shape of the beta spectrum of tritium has been our clearest window on the most mysterious property of the neutrinos, their mass. The discovery of neutrino oscillations gave us proof that neutrinos have mass, which is a direct contradiction of the minimal standard model of particle physics. But how much mass? Oscillations cannot give a number for the mass, other than that the average of the three masses must be at least 0.02 eV. The mass is needed to build the new standard model, and to help pin down such things as the equation of state of dark energy and the evolution of structure in cosmology. KATRIN, the first new laboratory experiment on the beta spectrum of tritium in more than 20 years, has now shown the mass to be no greater than 0.8 eV. KATRIN continues toward its sensitivity goal of 0.2 eV. If the mass is not in this range, a very different approach called “Project 8” has passed proof-of-concept tests with a scheme that might have even greater sensitivity.

Towards an atomic tritium source for Project 8

Sebastian Böser (Johannes Gutenberg Universität Mainz / PRISMA)

Highest precision electron spectroscopy is required to determine the neutrino mass from tritium beta-decay. In molecular tritium, initial and final state excitations limit the achievable resolution on the neutrino mass to 100meV. Trapping tritium atoms magnetically at high purity will avoid this systematic effect and allow to surpass the sensitivity limit. Towards this goal, Project 8 will use CRES technology, which is compatible with such a source concept. However, providing such an atomic source at the number density and size required to achieve the required event statistics constitutes a major challenge. In this talk, I will present a conceptual design towards producing, cooling and trapping an atomic tritium flux meeting our requirements.

Operation of the KATRIN molecular tritium source

Michael Sturm (Karlsruhe Institute of Technology)

The objective of the KArlsruhe TRItium Neutrino (KATRIN) experiment is the direct measurement of the effective mass of the electron antineutrino with an expected sensitivity of 0.2 eV/c^2 (90% CL) on the neutrino mass. As β-particle source KATRIN uses molecular tritium which decays in a "Windowless Gaseous Tritium Source" (WGTS). This kind of source consists of a gas dynamic system with a source tube of 90 mm in diameter and 10 m in length. The source tube is placed in a magnetic field of approx. 3 T and is pumped with differential pumping stages at both ends. In total, 26 turbomolecular pumps (TMP) are continuously operated within the KATRIN tritium handling system (loop system). After pumping down by the TMP's and compressing to approx. 250 hPa by the transfer pumps, the tritium is purified with a palladium membrane filter and re-injected into the middle of the source tube ("closed loop operation"). This talk will give an overview over the KATRIN tritium system, its commissioning and the measurement phases so far culminating in a total throughput of 22 kg over the WGTS.

Determination of absolute neutrino mass using quantum technologies

Ruben Saakyan (University College London)

Quantum Technologies for Neutrino Mass (QTNM) is a project recently funded in the UK by the Quantum Technologies for Fundamental Physics programme. Its goal is to harness recent breakthroughs in quantum sensors to assess the feasibility of a positive neutrino mass measurement with a sensitivity in the 0.01 - 0.1 eV range. It will use the Cyclotron Radiation Emission Spectroscopy (CRES) technique to measure the energy of electrons emitted in the beta-decay of atomic tritium. To accomplish this goal QTNM is developing a number of quantum technologies such as quantum noise limited microwave amplifiers and Rydberg atoms magnetometry. I will review the status of the QTNM project, the technological developments pursued by the collaboration, and will give an outlook into the project's future.

Tritium for cosmic neutrino detection with Ptolemy

Nicolo de Groot (Radboud University and Nikhef)

The Ptolemy experiment plans to observe the cosmic neutrino background through neutrino capture on a tritium target. It is currently in the R&D phase. We present an overview of the design and the current state of the experiment and more recent results on the tritium target.

Paving the Way: Towards an Atomic Tritium Source for KATRIN

Marco Röllig (Karlsruhe Institute of Technology)

KATRIN, the KArlsruhe TRItium Neutrino experiment, is leading the charge in measuring the mass of electron neutrinos with an unprecedented sensitivity through the beta-decay of tritium. However, it is ultimately limited by systematic uncertainties like the molecular final state distribution. New technologies must be developed to surpass the experiment's current sensitivity limits. One promising but challenging technology is an atomic tritium source for KATRIN. In this presentation, we outline our strategy towards achieving this goal, including new test experiments developed at the Tritium Laboratory Karlsruhe (TLK) that pave the way towards an atomic tritium source. We discuss the development of a high-luminosity atomic tritium source, as well as crucial aspects such as beam cooling, beam shaping, and the use of analytical tools for beam characterization.

Practicalities of Atomic Tritium for Project 8

Alec Lindman (Johannes Gutenberg Universität Mainz)

Atomic tritium promises to circumvent the major systematic limitation on direct neutrino mass experiments, enabling Project 8 to reach a sensitivity of 40 meV. Building such an apparatus requires splitting copious quantities of tritium into atoms, and no existing atom source that is compatible with tritium can reach our required flux. In Mainz, we have built a high-flow hydrogen/deuterium test facility and measured the output of a commercial tungsten-capillary atom source to a flow 20 times larger than previously published. Combined with supporting efforts across the Project 8 collaboration, we have developed new experimental methods to study intense atom sources. Our latest test stand now permits stable, long-duration experiments with outstanding signal to noise. I will recount the progression of the test stand, discuss some of the methods we have designed, and show recent results. We are using these results to map out previously unknown shortcomings of the existing atom-source theory at high flow, and to guide the design of a new generation of custom atom sources to achieve high efficiency, high atom flux, and reliable operation with tritium. Such a source will support the Project 8 Atomic Tritium Demonstrator, including its full-flux cold atom beamline and cubic-meter atom trap.

Tritium traces in rare-event search experiments

Michelle Galloway (University of Zurich)

Underground astroparticle observatories designed to observe new physics and rare processes require ultra-low backgrounds at the keV energy scale. With increasing sensitivity, cosmogenically-produced isotopes are likely to appear and present new challenges for background minimisation. Tritium, in particular, has already surfaced in several semiconductor-based experiments and was suspected as a new background in the XENON1T experiment. For the latter, a trace ^{3}H:Xe amount at the level of 10^{-24} mol/mol would have been enough to obscure a potential signal. This talk will focus on the possible sources and sinks of tritium for noble-liquid detectors as well as the mitigation and measurement strategies deployed within the context of the XENON dark matter project.

Fusion R&D – Fuel Cycle/Materials

B. 401 R. 410 15:50 – 19:15

The Breeding Blanket, the Core of a Thermonuclear Fusion Reactor. Technology, EU Concepts and Perspective

Francisco A. Hernandez Gonzalez (Karlsruhe Institute of Technology)

Near-term fusion reactor concepts are based on the fusion of deuterium-tritium in a magnetic confinement configuration. While deuterium is abundant in nature, tritium is virtually non-existent and it is, at the moment, only a man-made by-product of some specific types of fission reactors. The current global inventory of man-made tritium is very scarce and keeps diminshing in time due to the decaying nature (half-life of around 12 years) of this isotope. Therefore, tritium has to be bred in-situ in a fusion reactor in order to guarantee its fuel self-sufficiency. The tritium breeding is one of the key functions of the Breedign Blanket (BB), which constitutes the core of a D-T fusion reactor. Other key functions of the BB is the production of high grade heat for electricity production and the contribution to shielding of the vacuum vessel and superconducting magnets.

This contribution gives an overview on the key role of the Breeding Blanket in a fusion reactor, its possible architectures, associated Tritium Extraction and Removal (TER) systems technologies and describes the main EU candidate BB concepts being considered for the EU DEMOnstration fusion reactor.

Activities in support of ITER/DEMO

George Ana (National Research and Development Institute for Cryogenics and Isotopic Technologies – ICSI Rm. Valcea), *Ion Cristescu (KIT)*

The design of ITER/DEMO tritium processing systems should benefit from experimental data and process validation on experimental facilities that are relevant from size and operational parameters point of view. Several rigs and experimental facilities have been developed or are under development in order to characterize different materials and components for some ITER and DEMO Tritium Plants like packings for ITER WDS (Water Detritiation System) or zeolites for DEMO Helium Cooled Pebble Bed Tritium Extraction and Recovery system. Beside the experimental activities, several design activities have been performed with respect to the two systems. The main achievements concerning the R&D and design activities with contribution from ICSI and KIT are introduced.

ENEA activities in tritium recovery and processing for DEMO fuel cycle and blanket

Alessia Santucci (ENEA), *Vincenzo Narcisi (ENEA), Alessandro Venturini (ENEA Brasimone)*

Tritium self-sufficiency is one of the big challenges of a DEMO power plant. This means that the efficiency of all the aspects related to tritium production, recovery and processing must be improved and, at the same time, all possible losses and inventories must be reduced. The nuclear fusion technologies division of the ENEA FSN department is very active on these topics. This talk illustrates some of the activities currently carried out at ENEA Frascati and Brasimone mainly inside EUROfusion work packages named WPTFV and WPBB. In the WPTFV, most of the work is dedicated to the design of the so-called DEMO outer tritium plant loop (OUTL). Compare with the others two loops of DEMO fuel cycle, the direct (DIRL) and the inner (INTL), the OUTL is the one that has most similarities with the processes inside the ITER fuel cycle since contains the systems to detritate water, to separate the hydrogen isotopes and process the exhaust gases prior their release. However, significant differences arise due to the presence of the blanket and the coolant. Referring to the coolant, the talk addresses the problem of tritium permeation and the activities carried out to mitigate this issue. Inside the WPBB, ENEA leads the activities related to the development of the water cooled lithium-lead (WCLL) blanket. In this regard, the talk shows the experiments dedicated to study the hydrogen properties inside the lead-lithium alloy and the activities to realize efficient technologies for tritium extraction from lead lithium.

The Tritium Research in the Fusion Materials Laboratory

Christoph Kirchlechner (Karlsruhe Institute of Technology (KIT)), *Regina Knitter (KIT), Pavel Vladimirov (KIT), Vladimir Chakin (KIT), Xufei Fang (KIT), Rolf Rolli (KIT), Hans-Christian Schneider (KIT), Julia Leys (KIT)*

The Fusion Materials Laboratory (FML) is a unique facility providing experimental techniques for the investigation of radioactive and toxic materials. Its main purpose is the development and qualification of functional and structural materials for fusion power plants. Consequently, the interaction of tritium with these material classes is one of the core research topics at the FML. The talk will start with a short introduction to the instrumentation at the FML. Subsequently, examples for the global measurement of the tritium release of lithium orthosilicate-based breeder pebbles and the local measurement of tritium adsorption and segregation with near-atomic resolution will be presented. Finally, in an outlook we will shine light on the future of tritium research in the ERC funded Consolidator Grant "TRITIME" as well as currently envisaged future characterization techniques for tritium research.

The Research Training Group GRK 2721: Hydrogen Isotopes

Knut Asmis (Leipzig University)

Hydrogen's three naturally occurring isotopes, protium (H), deuterium (D) and tritium (T) lie at the focus of the DFG Research Training Group ^{1,2,3}H (RTG 2721), which combines the expertise of Leipzig University, the Helmholtz-Zentrum Dresden-Rossendorf/Research Site Leipzig, and the Leibniz Institute of Surface Engineering in the fields of laser spectroscopy, materials science, lab-on-a-chip technology, advanced organic synthesis and radiochemistry. Our research and training programme is aimed at gaining an atomic-level understanding of nuclear quantum effects in nanostructured materials and ^{i}H-bonded networks in order to develop enabling technologies for H/D/T separation using porous materials, electrocatalytic D/T labelling and microscale T detection.

Sieverts' constant for $H_2/D_2/T_2$ in eutectic PbLi

***Florian Priester (Karlsruhe Institute of Technology (KIT))**, Robin Größle (KIT)*

We have designed and build a new setup at the Tritium Laboratory Karlsruhe (TLK) for the measurement of the Sieverts-constant of lithium-lead (PbLi) with tritium. To reduce the systematic impact of hydrogen solubility in different materials, we used aluminium and glass parts for the majority of the setup choosing stainless steel only where no alternatives are available. Combined with a careful design and layout of all internal volumes and variable buffer vessel sizes combined with a flexible PbLi amount of 100 g or 1000 g, the setup provides high-sensitivity access to a broad range of possible Sieverts-constants. The symmetric layout of the feed and extraction side aims for both, adsorption and desorption measurements with high sensitivity in a wide range of Sieverts-constants mentioned in literature. A second key feature for a successful determination of the Sieverts-constant is the handling of the lithium lead. Impurities such as oxides can have a great impact on the performance of the facility as well as on the Sieverts-constant itself. Therefore, methods for cleaning, storage and transfer have to be tested and defined. In this contribution we will present the current status of the experiment including details on the design considerations. In addition, we show the efforts made to obtain best possible sample preparation for the lithium-lead used. This will be accompanied by an extensive series of commissioning measurements with hydrogen which are an absolute necessity to gain a deep understanding of the systematic effects of the facility prior to contamination with tritium.

Thursday, 25th May

Tritium processing (experience and lessons learned)

B. 401 R. 410 09:00 – 11:00

Experience/Lessons learnt during DTE2 in AGHS

Xavier Lefebvre (UK Atomic Energy Authority (UKAEA)), *The AGHS shift team members*

JET has recently completed the second Deuterium/Tritium Campaign at JET (DTE2). Initiated in September 2020, it was the first experimental campaign since 2003, and the first major one since DTE1 in 1997. This has induced a lot of challenges for the Tritium Innovation Unit members, in charge of the recommissioning and operation of the Active Gas Handling System (AGHS). This presentation will present these challenges as well as some lessons learnt.

Tritium Processing Experience at Canadian Nuclear Laboratories (CNL)

Ian Castillo (Canadian Nuclear Laboratories (CNL)), *Don Ryland (CNL)*

The presentation will provide a general overview of CNL, what we do and the recent major investments happening in the laboratories. An overview of the tritium and heavy water management, process and separation experience will follow, including an exciting description of the newly proposed Heavy Water Detritiation Facility. The HWDF is expected to be built in the next 2 to 3 years, using CNL hydrogen isotopes technology. A short description of new initiatives to separate deuterium and tritium gases using cryogenic distillation of thermal cycling absorption will also be given. Finally, the presentation will conclude with the newest program of work that incorporates tritium in the fusion fuel cycle and the opportunities that CNL is pursuing with its partners, showing its first-of-a-kind fully integrated fuel cycle demonstration facility.

Development & Operation of the TLK tritium loop

Stefan Welte (Karlsruhe Institute of Technology (KIT)), *Jürgen Wendel (KIT), David Hillesheimer (KIT), Joshua Kohpeiß (KIT)*

Since starting operation in 1993 the Tritium Laboratory Karlsruhe (TLK) has developed into a unique pilot scale isotope laboratory focused on tritium handling and processing to conduct a variety of scientific experiments and development tasks. While TLK was initially focused to develop technical tritium handling techniques and processes in view of the fuel cycle in future fusion power plants (development of processes and components for detritiation of gases expected from tokamak exhaust, development of a combined water detritiation and cryogenic distillation system and the application of different methods for tritium analytics), the current mission is to host the tritium source of the Karlsruhe Tritium Neutrino experiment (KATRIN), which will use tritium for direct measurement of the absolute mass of the electron (anti)neutrino, employing precise spectroscopy of the tritium β-spectrum close to the maximum energy of 18.6 keV. In order to fulfil this mission, TLK currently operates a dedicated semi-technical-scale tritium- infrastructure for reliable and modular tritium confinement and processing. This system is comprising of tritium storage & delivery, isotope recovery and isotope separation, housed in 15 glove boxes of $125\mathrm{m}^3$ total volume. A set of regulations is applied as a basis for the operation of TLK, resulting in a regulatory framework of operation in view of licensing as well as administrative and technical regulations, that ensure a both safe and flexible environment, to legally and reliably operate an isotope laboratory of this scale. This contribution will give an overview of both the past and current state of the TLK tritium infrastructure operations, as well as lessons learned.

The ITER Tritium Plant - Operation and Analytical Needs

Robert Michling (ITER Organization)

Robert MICHLING, Ian BONNETT, David DEMANGE, Wataru SHU, Peter SPELLER, Scott WILLMS ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, 13067 St Paul Lez Durance Cedex – France Corresponding author: Robert.michling@iter.org

ITER is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power. When ITER uses the real fusion fuel during operations — a mixture of deuterium and tritium — part of this fuel will not be burned. This leads to an exhaust mixture of fusion fuel, helium and other impurities, which needs to be processed at unprecedented flow rates by the Tritium Plant within the Fuel Cycle, with measures necessary for the confinement and safe handling of tritium. The ITER Tritium Plant systems are a complicated and complex collection of small scale chemical plant subsystems, utilising specialist technology with multiple confinement barriers. It uses well-proven fusion technologies and equipment (catalytic reactors, permeators, cryogenic distillation, chemical exchange columns, electrolysers, gas distribution, etc.), deployed at a larger scale than previously used. For the operation and safety aspects the Tritium Plant systems have specific needs of analytical capabilities in view of hydrogen isotope measurements (absolute/relative) for online process control functions, as well for precise composition measurements linked to accountancy tasks within the facility. The detection of impurities in the hydrogen gas streams are also crucial for indication of healthy process conditions and off-sets events. The range of hydrogen isotope fractions to be analysed within gases or of water stretch from pure to ppt levels, which can only be covered by the implementation of different analytical technologies and measurement conditions to fulfil the needs of the Tritium Plant. The presentation will give an overview of the different Tritium Plant systems under the most common operating conditions linked to individual analytical requirements. Also it will highlight available analytical technologies and identify areas of missing analytical performances to be resolved in future for a successful and safe operation of the Fuel Cycle of ITER.

Tritium analytics and application

B. 401 R. 410 11:20 – 13:00

Tritium Analytics in the powers of ten

Robin Größle (Karlsruhe Institute of Technology (KIT))*, Dominic Batzler (KIT), Beate Bornschein (KIT), Simon Niemes (KIT), Florian Priester (KIT), Marco Röllig (KIT), Magnus Schlösser (KIT), Michael Sturm (KIT), Helmut Telle (Universidad Autonoma de Madrid), Stefan Welte (KIT), Johanna Wydra (KIT), Genrich Zeller (KIT)*

The focus of the Tritium Laboratory Karlsruhe (TLK) is tritium R&D in support of a wide field of applications like neutrino mass measurement with KATRIN and the Fusion fuel cycle. One key aspect is tritium analytics, a broad and multifaceted field that can be sorted in many different ways. One useful way to group the analytic tools is by the properties of the tritium sample like its state of aggregation, the molecular state (e.g. elemental, water, tritiated carbon hydrogens and so on) or composition (like tritium traces in water or helium, pure hydrogen istopologues and so on). Another grouping is by the gathered information, e.g. total activity, total heat of decay, molecular composition etc. This kind of sorting will always be difficult, because this will open up many side conditions for a proper screening. In this contribution we are sorting by the order of magnitude of tritium density that the analytic tool can handle. Starting from a very high density with IR spectroscopy, that can be used for elemental solid and liquid Tritium like it is used in pellet production for fusion fuelling and isotope separation by cryogenic distillation. Passing several orders of magnitude with techniques like Raman spectroscopy and beta induced X-ray spectroscopy; which are for example used in inline process monitoring of KATRIN. Down to rare traces of tritium measured with scintillation counting like it is required in dual phase xenon time projection chambers in the search of ultra-rare physics.

Outcomes of the TRANSAT (Transversal actions for tritium) EU project

Christian Grisolia (Commissariat à l'énergie atomique et aux énergies alternatives (CEA), Institute for Magnetic Fusion Research (IRFM))*, D. Combs (United Kingdom Atomic Energy Authority (UKAEA)), I. Cristescu (Karlsruhe Institute of Technology), T. Gilardi (CEA), A. Jha (School of Biological and Marine Sciences), K. Liger (CEA), V. Malard (CEA), S. Markelj (Jožef Stefan Institute), C. Moreno (Centro de Investigaciones Energéticas (CIEMAT)), R. Vale (UKAEA) and the TRANSAT contributors*

In the framework of H2020 Euratom research and innovation programme, TRANSAT (TRANSversal Actions for Tritium) is a 54 months multidisciplinary project built to contribute to Research and Innovation on cross-cutting activities required to improve and disseminate knowledge on tritium management in fission and fusion facilities. TRANSAT has started in 2017 and was built to answer the main following challenges:

- tritium release mitigation strategies,
- waste management improvement,
- refinement of the knowledge in the field of radiotoxicity, radiobiology and dosimetry,
- promote the knowledge dissemination about tritium management.

To evaluate the scientific tasks to be covered in TRANSAT, all the open issues at each step of the tritium life cycle that have not yet been addressed within European research programs or in previous studies have been analyzed. This general landscape has been focused on crosscutting activities on fusion and fission. The aim of this presentation is to give a general overview of the major outcomes of the technical topics that have been covered by the eighteen partners of the project.

- particular, this paper will focus on:
- the development and test of new permeation barriers,
- the control of online tritium effluents by innovative technical solution,
- the development of new diagnostics for tritiated Low Level Wastes characterization
- the improvement of the modelling tools of tritium migration in fusion/fission reactors.

In addition, part of the project deals with radiotoxicity, radioecology, radiobiology and dosimetry on tritiated particles produced during dismantling, whose impacts have never been addressed before. The results of these activities will be also presented.

Tritium Research Activities in Hydrogen Isotope Research Center, University of Toyama

Yuji Hatano (University of Toyama), *Masanori Hara (University of Toyama), Masao Matsuyama (University of Toyama)*

Hydrogen Isotope Research Center (HRC), University of Toyama, Japan has been licensed to use 8 TBq of tritium per day. This handling capability of tritium allows to perform investigations on tritium measurements, tritium-material interactions and preparation of tritiated targets for nuclear reaction studies. The objective of this presentation is to introduce several tritium measurement techniques developed in HRC together with recent activities on tritium target fabrication.

β-ray induced x-ray spectrometry (BIXS) has been developed in HRC [1]. The escape depth of β-rays from tritium in a solid are just a few hundred nanometers to a few micrometers, depending on density of the solid. Hence, it is difficult to measure tritium content in a solid and that in gas and liquid phases from outside of a container by β-ray counting. Nevertheless, interactions between β-rays and matters result in generation of bremsstrahlung and characteristic x-rays. Because of far larger escape depths of x-rays than β-rays at the same energy, tritium content in a solid sample can be evaluated by x-ray measurements. Non-destructive depth profiling is possible by analysing x-ray spectrum with consideration of generation and attenuation of x-rays in a sample. A thin beryllium windows covered by high-Z material layer allows the evaluation of tritium content in gas and liquid phases from outside of the container.

HRC also developed a high sensitivity calorimeter capable to evaluate the amount of tritium as low as 40 MBq [2]. In Japan, the amount of tritium allowed to handle without control by regulations is limited to be less than 1 GBq. However, it is difficult to evaluate and control tritium content in imported products. This calorimeter is helping the security authority of Japan via non-destructive measurement of tritium content in imported products.

Dr. K. Miki in Tohoku University, Japan, has proposed to study multi-neutron systems using nuclear reactions of tritium. A self-standing Ti tritide target was prepared in HRC through the collaboration of Dr. Miki and researchers in HRC. Ti tritide targets supported by Cu plates were also prepared for 14 MeV neutron generator. HRC is currently the sole provider of tritide targets in Japan.

[1] M. Hara et al., Fusion Eng. Design 119 (2017) 12-16 and references there in. [2] M. Matsuyama and M. Hara, Fusion Sci. Technol. 54 (2007) 16–21.

Raman spectroscopy of tritiated molecules: the Good, the Bad and the Ugly

Helmut Telle (Universidad Autonoma de Madrid)

Raman spectroscopy has become one of the cornerstones of laser analytical methods to identify, and quantify, chemical compounds, and for use in determining material composition. Its great advantages are that (i) only one a single, fixed-wavelength laser is required; (ii) any molecular compound can be investigated, even in multi-component mixtures; (iii) any type of material can be probed, irrespective of aggregate state – gaseous, liquid or solid; and (iv) the analysis can be carried out contactless, in situ and with spatial resolution, if required. After a brief introduction into the principles of Raman spectroscopy, a few key examples from operations at TLK will be discussed – ranging from fundamental science to chemical process control, and applications to surface science.

Fusion start up and tritium

B. 401 R. 410 15:30 – 17:35

Overview of Private Fusion Efforts

Andrew Holland (Fusion Industry Association)

There is growing excitement about fusion energy as an option to contribute to the world's low-carbon energy supply. Increasing numbers of private companies are aiming to deliver commercial fusion and are producing significant breakthroughs in the science and technology that will lead to a commercial power plant.

The Fusion Industry Association (FIA) is the unified voice of the fusion industry, working to transform the energy system with commercially viable fusion power. Founded as an initiative in 2018, the FIA has already made its mark in Washington and around the world. As it expands, the FIA will support the creation of a new industry that will change the world.

Development of fuel cycle systems for D-T fusion power plants

Brandon Sorbom (Commonwealth Fusion Systems)

Decades of worldwide, government-sponsored research in fusion science have established the tokamak-based configuration as the leading approach to confining fusion-grade plasmas with strong magnetic fields. Yet, in the past, even state-of-the art superconducting magnet technology required tokamaks to be enormous to produce net fusion energy. Recently, a new high temperature superconductor has reached industrial maturity. CFS is using these high temperature superconductors to build smaller and lower-cost tokamak fusion systems. CFS will build first-of-its-kind high temperature superconducting magnets, followed by the world's first net energy-producing fusion machine, called SPARC. SPARC will pave the way for the first commercially viable fusion power plant, called ARC. CFS has assembled a world-class team working to design and build fusion machines that will provide limitless, clean, fusion energy to combat climate change.

Commercialization of Fusion Reactors

Sandra Romanelli (Tokamak Energy)

Public funded fusion experiments have stalled in recent years for several reasons. ITER is around 10 years away and Demo around 30 years. This timeline brings commercial fusion power plants to the grid by the end of this century. Private fusion companies closing this gap and their mission is to provide commercial clean, sustainable and low carbon energy to the grid much earlier. Tokamak Energy was founded in 2009 and has a road map to a pilot power plant in the 2030s.

Renaissance Fusion: Nuclear fusion concept and tritium related issues

Francesco Volpe (Renaissance Fuison)

At Renaissance Fusion we build stellarators (from ‘stella’, Latin for ‘star’) - the most efficient, steady, and stable fusion reactors on earth.
With unique High Temperature Superconducting (HTS) magnets and liquid metal shields, we bring stellarators out of the lab and onto the grid.

Tritium Laboratory Karlsruhe – opportunities for tritium research

Magnus Schlösser (Karlsruhe Institute of Technology)

The Institute for Astroparticle Physics (IAP) operates the European Tritium Laboratory Karlsruhe (TLK), a semi-technical scale facility for processing tritium, the radioactive hydrogen isotope. Its license to handle up to 40 grams of tritium, its present site inventory of about 30 grams of tritium, and its extensive infrastructure and experimental apparatus, make it a favorable location to contribute to research and developments for nuclear fusion research.
More than 20 glove box systems, total volume of about 190 m^3, are operated in an area of 1600 m^2 for experiments and infrastructure facilities. The TLK can look back on a history of more than 30 years of safe operation and experience with tritium.
In this talk we will summarize possible opportunities by the TLK for the public-private R&D initiatives in the field of nuclear fusion.

Announcement for the tritium manual publication

Ralf-Dieter Penzhorn

A new Tritium Manual will shortly be made available on the Internet. While the Manual is primarily focussed on the tritium-related needs of fusion machines, its content extends much beyond that.

Primary goal of the Manual is to provide expedient and broad introduction into very many tritium-linked topics to experienced scientists and engineers active in the field of tritium technology or to technical personnel and newcomers involved either in the operation or the design, construction and manufacture of advanced tritium-compatible components and installations. The Manual may also be of assistance to scientists engaged in tritium-related research.

The Manual recapitulates on the physical properties, synthesis and self-radiolysis of tritium-bearing species relevant to the fusion fuel cycle. Chemical reactions taking place between tritiated molecular hydrogen or water with oxygen and potential impurities of the fusion fuel cycle constitute another subject. Addressed is the interaction of tritiated hydrogen with metals and alloys in view of tritium handling, tritium storage, tritium compression or catalysed reactions with other molecules. Equally weighty is information on the interaction of gaseous tritiated species with materials employed for primary containments (includes a variety of tritium-resistant polymers) or materials constituting the plasma-exposed wall of fusion machine vessels. The large evolution during the past few years of materials selected for the first wall of ITER (CFC, Be, W, B, Si, SS) has been duly considered.

A chapter of the Manual is dedicated to basic components and design principles of key tritium processes of the fusion fuel cycle. Some typical components in direct contact with tritiated species are:

i) all kinds of different pumps, ii) permeators, iii) simple or sophisticated storage vessels equipped with incorporated calorimetry, iv) technical scale cryogenic traps for the retention of water or hydrogen, v) electrolysers, vii) separation columns, viii) analytical instruments like conventional and micro GC, laser Raman spectrometer, IR spectrometer, calorimeter, BIXS, accelerator mass spectrometer, autoradiography, bremsstrahlung counting, PIN diode, NRA, liquid scintillation counting, etc., ix) process control equipment like hygrometers, flow meters, ion chambers, etc., xii) radiation monitors, and many others.

Components are described and discussed from the perspective of the experience gained during the course of decades in several prominent tritium installations all over the world. While it is impossible to keep up with the continuous evolution of a rapidly developing component and instrumentation market, it can be argued that their basic technical principles remain mostly the same. This also holds for the tritium-compatible materials employed for their manufacture. Consequently, the technical properties of many components and instruments together with the knowledge acquired during their extended testing with tritium in small and large facilities often employing very large tritium inventories remains applicable. Innovative equipment on the other hand, must still undergo ample parameter assessing with hydrogen followed by prolonged demonstration with tritium under compliance with high safety standards in one of merely few facilities worldwide before becoming recommendable for tritium service.

Extensively treated are containment and confinement concepts. Whereas confinement covers type of glove box atmosphere and corresponding tritium removal system, leak rates, materials for gloves and windows, regeneration of molecular sieves, monitoring of oxygen and tritium, etc., in case of containment the subjects are supply of non-radioactive and radioactive gases, interlocks, alarms, protective measures against over-pressure and over-temperature, component failure analysis, etc.

The analytics of tritium-bearing gases, liquids and solids is a subject of considerable rank. Concepts for the sporadic and continuous analysis of complex mixtures are compared.

The Manual provides a description, evaluation and comparison of the safety philosophy prevailing in several small and larger conspicuous installations. This approach was chosen because every major tritium installation has its own tritium handling and safety idiosyncrasy comprising licensing, technical delivery and acceptance terms, manufacturing codes, rules regulating work in controlled areas, concepts for the implementation of automated control systems, procedures for measurement of process parameters, basic way of conduct during the operation of tritium systems, etc. The collected information may serve as source of ideas for existing as well as for future tritium handling facilities.

Typical solid, liquid and gaseous waste arisings in research laboratories as well as in key large technical facilities handling tritium are presented. The approach adopted in some of these installations for the decontamination of getters, adsorber beds, structural materials, service waste, walls and floors of buildings, etc. is described. A related topic is sentencing and packaging of wastes.

A few less-common topics dealt with in the Manual are extraction of tritium from blankets, natural and man-made sources of tritium, applications of tritium other than for fusion, hot atom chemistry, continuous monitoring of aqueous tritium, molecular sieve membranes, the KA-

TRIN experiment at TLK, etc. A brief introduction into “cold fusion”, which has recently experienced a tremendous evolution, is given.

Awareness of the state of the art is particularly important when new research activities are initiated or advanced components are designed. Prototypes constructed without sufficient knowledge of the literature, may result in unnecessary experimental and technical efforts. In case manufacture has already progressed, subsequent modifications and re-design can lead to considerable loss of time, effort, and resources.

While in the past several Tritium Manuals like for example

- Safe Handling of Tritium, Review of Data and Experience, Technical Reports Series No. 324, IAEA Vienna (1991).

- Primer on Tritium Safe Handling Practices, DOE Handbook (DOE-HDBK-1079-1994).

- DOE Handbook - Radiological training for Tritium Facilities, DOE-HDBK-1105-2002.

- DOE Handbook – Tritium Handling and Safe Storage, DOE-HDBK-1129-2008 and DOE-STD-1129-2015.

- Sissingh R.A.P. and Gordon S.C.

TFTR Tritium Systems Course, Vol. 1 and 2, Office of Certification and Training, March (1994). have been published, these publications have mostly dealt with specific subjects like for instance safety aspects during tritium handling, safe tritium storage, radiological training for work in a specific Tritium Facility. In view of this, the present Manual is not in competition with those already existing ones nor is it superseded. It is rather of supplementary character.

Easy access to the original scientific and technical literature comprising many technical reports only available to a restricted community is possible from more than thousand references.

Postersession

B. 401 R. 410	Wednesday, 24th May 14:00 – 15:00
B. 401 R. 410	Thursday, 25th May 14:00 – 15:00

DEMO Coolant Purification Systems: design status, needs and perspective

Vincenzo Narcisi (ENEA), *Alessia Santucci (ENEA)*

Tritium permeation from Breeding Blanket (BB) towards Primary Heat Transfer System (PHTS) is an issue for operation of DEMO machine since, once permeated into PHTS, tritium can migrate to working areas and environment via permeation and leaks. In order to control radioactive release two strategies was individuated to keep tritium concentration within primary coolant below fixed limits: the use of anti-permeation barriers and/or the adoption of the Coolant Purification System (CPS). Nowadays, two BB concepts are under investigation for DEMO, namely the Helium-Cooled Pebble Bed (HCPB) and Water-Cooled Lithium Lead (WCLL). The first one relies on helium as heat transport media whereas the latter involves water as primary coolant. Depending on the coolant medium, the proper technology must be selected to fulfill the CPS objective. For the HCPB case, the reference configuration relies on copper oxide (CuO) beds, to oxidize all the hydrogen isotopes present in the helium coolant, and Zeolite Molecular Sieve (ZMS) beds for the adsorption of tritiated water formed in the CuO beds. For the WCLL BB concept, Water Distillation (WD) is the most promising technology, due to its simplicity and intrinsic safety. The present work deals with the presentation of the ongoing design and optimization activity for both the CPS technologies. Regarding the helium CPS, emphasis is posed on the experimental activity programmed for the near future, whereas for the water CPS the main assumption and an optimization procedure to reduce energy consumption are presented.

Development of atomic beam sources, confinement methods and detection techniques for neutrino mass measurements with atomic tritium

Markus Fleck (University College London), *Vincenzo Monachello (University College London), Stephen Hogan (University College London), Emilia Sedzielewski (University College London), Junwen Zou (UCL), QTNM collaboration*

To measure the absolute neutrino mass by Cyclotron Radiation Emission Spectroscopy (CRES) following beta-decay of atomic tritium, it is essential to generate dense atomic beams, implement methods for state-selection and magnetic confinement of ground-state atoms, and perform high-precision in-situ magnetometry and electrometry. These represent some of the aims of the UK Quantum Technologies for Neutrino Mass (QTNM) project. Here we report advances in each of these areas in preliminary studies with atomic hydrogen. The techniques used can be transferred to experiments with tritium.

We present the operation and initial characterisation of a pulsed supersonic beam of atomic hydrogen. This is based on a DC discharge of H_2. Detection of the ground-state atoms in this beam is implemented by resonance-enhanced multi-photon ionisation via the 2S intermediate state. The resulting H^+ ions are collected at a microchannel plate detector.

In parallel with this, we have designed and simulated the operation of a magnetic state selector for the ground state atoms in this beam. The construction of this is underway and its design and operation will be presented. After state-selection, we plan to inject the atoms into a magnetic storage ring for long-term confinement. This ring comprises 120 permanent hexapole Halbach array magnets that guide the beam using inhomogeneous magnetic fields. Ultimately, we plan to install CRES measurement modules within this ring. The detailed design of this magnetic storage ring, and the results of numerical particle trajectory calculations for hydrogen and tritium atoms will be presented.

To allow in-situ measurement of magnetic and electric fields in the CRES modules within this apparatus, we have recently demonstrated the use of circular Rydberg states for absolute magnetometry, magnetic gradiometry and vector electrometry. Results from this work will also be summarised.

ELECTRON - High Resolution Electron Spectroscopy of a Novel Tritium Source, Using Next Generation Metallic Microcalorimeters

Neven Kovac (Institute of Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT))*, Tamara Elisa App (IAP, KIT), Fabienne Bauer (Institute of Micro- and Nanoelectronic Systems (IMS), KIT), Ferenc Glück (IAP, KIT), Sebastian Kempf (IMS, KIT), Rudolf Sack (IAP, KIT), Magnus Schlösser (IAP, KIT), Markus Steidl (IAP, KIT), Kathrin Valerius (IAP, KIT)*

Metallic Magnetic Calorimeters (MMCs) are low temperature single particle detectors, whose working principle is based on quantum technology. Due to their excellent energy resolution, near linear detector response, fast signal rise time and close to 100% quantum efficiency, MMCs outperform conventional detectors by several orders of magnitude, making them interesting for a wide range of different applications. The aim of the ELECTRON project is to demonstrate, for the first time, that MMC based detectors can be employed for a high resolution spectroscopy of external electron sources, namely electron-gun, Kr-83m and tritium. As MMC-based detectors have never been used for measurements of light charged particles, understanding the interplay between the detector and the external electrons is of crucial importance. To this end, electron-gun, which offers a possibility to easily adjust the rate and the energy of the electrons, and Kr-83m, with its well defined spectral lines, will allow for a proper characterisation and calibration of the detectors. Once the detector behaviour is well understood and characterised, newly developed tritium sources will be employed for the first ever measurements of the tritium β-decay spectrum with a cryogenic microcalorimeter. Technology and methods developed within the context of the ELECTRON project will pave a way for the next generation neutrino experiments with tritium, employing a differential detector based on quantum technology. Possible future applications include the potential next phase of the KATRIN neutrino mass experiment, aiming at sub-200 eV sensitivity to electron (anti-)neutrino mass, as well as the detection of the cosmic neutrino background. Undoubtedly, application scope of such technology goes well beyond neutrino physics and will allow for completely new and ground-breaking experiments in both particle and in astroparticle physics.

eV scale sterile neutrino sensitivity analysis in KATRIN

Shailaja Mohanty (Karlsruhe Institute of Technology), *Xaver Stribl (Technical University of Munich)*

KATRIN has recently reported a direct sub-eV upper bound on the neutrino mass from tritium beta-decay spectrum measurements. Along with the neutrino mass search, KATRIN has published recent results on searching for a fourth neutrino with a mass in the eV-range using the precision beta-decay spectra. The fourth neutrino mass-eigenstate introduces an additional branch into the tritium β-spectrum which manifests as a kink in the differential spectrum. The position and amplitude of this kink correspond to the sterile neutrino mass m_4 and effective mixing angle $\sin^2(\theta) = |U_{e4}|^2$, respectively. In this work sensitivity studies to light sterile neutrinos based on new science runs and the effect of systematic uncertainties are presented. A grid scan is performed in the [m_4^2, $\sin^2(\theta)$] 2-D plane using the fitting tool ”KaFit” and neural network ”Netrium” and sensitivity contours are calculated within this parameter space. The obtained sensitivity is compared to current results and anomalies in the field of light sterile neutrinos.

UKAEA H3AT Facility Overview

Sarah Bickerton United Kingdom Atomic Energy Authority (UKAEA)), Nathanya Platt (UKAEA), Tamsin Jackson (UKAEA), Stephen Reynolds (UKAEA), ***Xavier Lefebvre (UKAEA)***

An overview of the UKAEA Tritium Advanced Technology (H3AT) facility whose assembly will soon take place at UKAEA Culham after the successful completion of the detail design.

UKAEA H3AT Research Overview

*Rachel Lawless (United Kingdom Atomic Energy Authority (UKAEA)), Lyn McWilliam (UKAEA), **Xavier Lefebvre (UKAEA)***

An overview of the tritium research strategy in the UKAEA Tritium Advanced Technology (H3AT) division. Based on tritium Quantification, Inventory minimisation and Containment, a four-year roadmap is presented.

First Sensitivity Studies on the potential implementation of a high-resolution detector into the KATRIN setup

Svenja Heyns (Karlsruhe Institute of Technology)

The Karlsruhe Tritium Neutrino (KATRIN) experiment is designed to probe the neutrino mass with a sensitivity of 0.2 eV/c² (90% C.L.). The measurement principle relies on an integral measurement of the tritium beta spectrum at the kinematic endpoint of T_2 by a high-pass MAC-E-type filter. Switching to a differential measurement of the beta-electron spectrum with eV-scale resolution would increase statistics and allow improved discrimination of background events. The KATRIN collaboration continuously works on improvements on and better understanding of the current setup, while also having an increasing interest in future adjustments by planning the next decades. Being versatile and adaptable, a focus is put on investigating options of switching the source of the neutrinos, as well as the electron detector. Without the need of specific knowledge on particular hardware, conceptual studies can be performed and on the other hand are used to draft the demands on hardware and planning a new setup to benefit the most from the KATRIN facilities and gain as much in neutrino mass sensitivity as possible. The simulation and first sensitivity studies will be presented by this work.

In-situ tritium decontamination of the KATRIN Rear Wall

Max Aker (Karlsruhe Institute of Technology)

The KATRIN collaboration aims to determine the neutrino mass with a sensitivity of 0.2 eV/c² (90% CL). This will be achieved by probing the endpoint region of the β-electron spectrum of gaseous tritium with an electrostatic spectrometer. A gold-coated stainless steel disk defines the reference potential for the high precision neutrino mass measurement and it terminates the β-electron flux as the physical boundary of the tritium source. This so-called Rear Wall is exposed to tritium, which leads to ad- and absorption. This in turn leads to systematic uncertainties for the neutrino mass measurements that need to be understood and mitigated. In maintenance phases, during which the gaseous tritium source was emptied (<10^{-5} of nominal gas density), the activity accumulated on the Rear Wall during normal operation was monitored using β-induced X-ray spectrometry (BIXS) and direct observation of emitted β-electrons with a silicon detector. The dependency of the observed activity increase on the integral tritium throughput was investigated and found to converge from a limited exponential growth to a continuous linear growth. This poster gives an overview of the results we obtained using several methods of in-situ decontamination of the Rear Wall while continuously monitoring the activity. The decontamination methods included heating during continuous evacuation, flushing the system with nitrogen, deuterium or air with residual humidity at different pressures and illumination of the Rear Wall with UV-light. These well-known methods led only to a small ($approx$ 15%) decrease in the observed activity. However, a decrease of the surface activity by three orders of magnitude in less than a week was achieved by combination of different methods using UV light, a heated surface and a low (5 mbar–100 mbar) pressure of air inside the chamber, leading to the production of highly reactive ozone. This proved to be by far the most efficient method, drastically reducing the contribution of the Rear Wall surface activity to the β-spectrum of the gaseous source.

Investigation of ozone properties for the decontamination of tritiated surfaces

***Dominic Batzler (Karlsruhe Institute of Technology (KIT))**, Max Aker (KIT), Robin Größle (KIT), Daniel Kurz (KIT), Florian Priester (KIT), Michael Sturm (KIT), Peter Winney (KIT)*

A major focus of the research at Tritium Laboratory Karlsruhe (TLK) is to develop key technologies needed both for fusion and for the operation of the KATRIN experiment. One important consideration towards maintenance and decommissioning of tritium experiments is the development of suitable decontamination procedures. These could also be applied to reduce tritium memory effects, e.g. of analytic tools used in process monitoring. In the case of the KATRIN experiment, adsorbed tritium is regularly removed from the "Rear Wall" located inside its tritium source, since it contributes to the systematic uncertainty on the tritium β-spectrum. This is done insitu via UV/ozone cleaning, which is a method that has been mentioned in literature multiple times. However, the underlying mechanism leading to the decontamination effect is not yet well understood. To investigate this mechanism systematically and to optimise the decontamination procedure, the UV ozone (UVO) experiment was set up. Carried out in a controlled environment, its purpose is to explore the production and depletion rates of ozone, as well as chemical processes between contaminated surfaces, ozone, and flushing gases like N2, H2, D2 and others with spectroscopic tools. This poster gives an overview of the UVO experiment and presents first quantitative results of the pressure dependence of ozone production and depletion rates in synthetic air.

KATRIN like MINI MAC-E Filter with a tritium source for the advanced physics lab course

Sarah Untereiner (Karlsruhe Institute of Technology)

The KATRIN experiment at the Karlsruhe Institute of Technology (KIT) aims to determine the effective neutrino mass using the kinematics of electrons from the tritium β-decay. The integral energy spectrum of the electrons is measured by a electrostatic high-pass filter, using the MAC-E filter principle (Magnetic Adiabatic Collimation and Energy filter). Only electrons with energies above the retarding potential of the filter are counted at the detector at the end of the MAC-E spectrometer. In order to give students the opportunity to learn more about the experimental principles behind KATRIN, a smaller version of the MAC-E filter setup, called MiniMACE, has been built, which will be used in the advanced physics lab course at KIT. With a scale of approximately 1:20 the MiniMACE experiment includes all the major components of KATRIN: a tritium source, the spectrometer with adjustable high voltage, a high resolution detector and the magnetic guiding field. Other than KATRIN, the source uses two implanted disks with tritium and ^{83m}Kr that can be exchanged inside the ultra-high vacuum source chamber. This poster shows the design of the physics lab setup and reports on first results. This project has been supported by RIRO (Research Infrastructure in Research- Oriented teaching), which is part of the ExU project at KIT.

KATRIN neutrino mass analysis - Insight into the neural network approach

Christoph Wiesinger (Technical University of Munich), *Alessandro Schwemmer (Max-Planck-Institute for Physics, Munich), Susanne Mertens (Max-Planck-Institute for Physics, Munich)*

KATRIN is probing the effective electron anti-neutrino mass by a precision measurement of the tritium beta-decay spectrum near the kinematic endpoint. Based on the first two measurement campaigns a world-leading upper limit of 0.8 eV (90% CL) was placed. New operational conditions for an improved signal-to-background ratio, the steady reduction of systematic uncertainties and a substantial increase in statistics allow us to expand this reach. Our poster displays the KATRIN neutrino mass analysis and provides insight into the neutral network approach used to perform the computationally challenging analysis.

Measurement of the energy-dependent energy-loss function of electrons in molecular tritium gas

Volker Hannen (University of Münster), *Sonja Schneidewind (University of Münster), Rudolf Sack (Karlsruhe Institute of Technology), Richard Salomon (University of Münster), Christian Weinheimer (University of Münster)*

The KATRIN experiment aims at the direct measurement of the neutrino mass scale via precision endpoint spectroscopy of β-electrons produced in the decay of molecular tritium with a target sensitivity of 0.2eV/c² (90% C.L.). An important systematic effect entering the analysis are energy-losses of β-electrons due to scattering off tritium molecules inside the source. The energy-loss function can be determined by measuring integral (standard spectrometer mode) or differential (time-of-flight mode) transmission spectra using a monoenergetic electron beam which is guided through the whole tritium source. The electron beam is produced by a recently upgraded photo-electron source providing energies up to 27 keV, with an energy resolution of <100 meV. The poster presents measurements for the determination of the energy-dependent energy-loss function in molecular tritium gas with high purity which were recently taken with the new photo-electron source at KATRIN. *This work is supported by BMBF under contract number 05A20PMA and Deutsche Forschungsgemeinschaft DFG (Research Training Group GRK 2149) in Germany.*

Measuring the viscosity of tritium

Johanna Wydra (Karlsruhe Institute of Technology (KIT)), *Michael Sturm (KIT), Robin Größle (KIT), Florian Priester (KIT), Simon Gentner (KIT)*

Experimental values for the viscosity of tritium are still unknown in literature. Values to be found are ab initio calculated values, which are only valid for 300 K and higher. For lower temperatures, only values extrapolated from hydrogen and deuterium exist, with an uncertainty of 5-10 %. The viscosity of tritium is an important parameter, needed for gas dynamics simulations, for example in fusion science and particle physics experiments. We have now developed a Cryogenic Viscosity Measurement Apparatus (Cryo-ViMA), based on a spinning rotor gauge (SRG), with which we are able to measure the viscosity of tritium between 77 K and 300 K, with an uncertainty of 2 % without any systematic corrections. By including systematic corrections concerning the temperature and the pressure, the uncertainty on the measurements can even be reduced down to 1 %. This poster presents the final setup, the measurement procedure and first results from the cold commissioning in a narrow temperature range.

TRISTAN: A novel detector for searching keV-sterile neutrinos at the KATRIN experiment

Korbinian Urban (Technical University of Munich)

Sterile neutrinos are a possible extension of the Standard Model of particle physics. If their mass is in the keV range, they are a suitable dark matter candidate. One way to search for sterile neutrinos in a laboratory-based experiment is via tritium beta decay. A sterile neutrino with a mass up to 18.6 keV would manifest itself in the decay spectrum as a kink-like distortion. The Karlsruhe Tritium Neutrino (KATRIN) experiment currently investigates the endpoint region of the tritium beta-decay spectrum to measure the effective electron anti-neutrino mass. The main objective of the TRISTAN project is to extend this energy range to measure the entire beta-decay spectrum. To this end, a novel multi-pixel silicon drift detector and readout system is currently being developed which enables the search for sterile neutrinos in the keV-mass range. This poster will give an overview on the design and development of the new detector and show first test measurements of a detector module.

Preliminary safety assessment of a fusion engineering test facility in accidental conditions

Gérald Degreef (Kyoto Fusioneering), *Paul Barron (Kyoto Fusioneering), Takashi Ino (Kyoto Fusioneering), Reuben Holmes (Kyoto Fusioneering, University of Tokyo), Colin Baus (Kyoto Fusioneering, Kyoto University), Richard Pearson (Kyoto Fusioneering), Satoshi Konishi (Kyoto Fusioneering, Kyoto University)*

The UNITY (Unique Integrated Testing Facility) is currently under construction in Japan. The facility will be capable of performing integrated testing of components necessary for the primary and secondary thermal cycles used in power generation and fuel cycle of early fusion power plants. The thermal section of the facility will have heating capacity for blanket modules up to 0.1 m^2 of plasma-facing surface area. Of the three liquid coolants supported (Li, LiPb, FLiBe), the LiPb loop will be connected first, with an inventory of 100 litres. A uniform magnetic field of up to 4 T can be generated with a pair of NbTi magnets for liquid metal magneto hydrodynamics testing. A plasma exhaust pumping system for the inner fuel cycle, direct internal recycling, a fuel clean-up system, tritium extraction from the coolant, and storage will be integrated into one system, using deuterium as a proxy for tritium. As future iterations of UNITY will use tritium for fuel cycle demonstration, we conduct a safety evaluation of a hypothetical tritium release in accidental conditions, assuming the use of deuterium and tritium instead of only the deuterium proxy. The safety assessment goal for UNITY is to demonstrate that it can be easily sited in Japan (or another country), without public health and environmental concerns, or the need for any emergency planning. We employ proven risk assessment methodologies to select the most representative accident scenario in terms of potential consequences. From this scenario, we estimate the quantity of radioactive materials that could be released from a simplified loop. We also undertake a literature review of the likely tritium release fraction that is then used in the assessment. Finally, we perform a sensitivity analysis to identify the most impactful parameters, enabling us to make design-impacting decisions and proportionate safety systems.

Separation of ortho para hydrogen by cryogenic distillation

***Daniel Kurz (Karlsruhe Institute of Technology (KIT)**, Robin Größle (KIT), Stefan Welte (KIT)*

Not only the isotopologues of hydrogen can be separated by cryogenic distillation but also the nuclear spin isomers of H2, D2 and T2 (ortho, para). One application of the ortho para distillation is the measurement of the separation performance of a distillation column quantified by the height equivalent of theoretical plates (HETP). Compared to isotope mixtures the relative volatility of the isomers is much smaller than that of different isotopologues and therefore the concentration gradients along a distillation column are way smaller. Therefore, this can be used for high accurate measurement of the HETP of distillation column. In addition, this also enables to produce high purity ortho or para samples. Typically, only the ground state can be achieved in high purity by cooling down and catalysing. The room temperature equilibrium of 75% ortho H2 and T2 (66% para for D2) can not be exceeded by this procedure, but the application of cryogenic distillation enables the generation of such unique samples. Those samples above the thermal equilibrium come to interest when investigating the fundamental properties like molecular interaction and thermodynamic properties in dependence of the ortho para ratio of H2, T2 and D2. This contribution shows the current state of simulation and experiments of ortho para distillation at TLK.

Setup and characterization of a confocal Raman imaging microscope built for the measurement of tritiated samples

Genrich Zeller (Karlsruhe Institute of Technology (KIT)), *Deseada Diaz Barrero (Universidad Autonoma de Madrid (UAM) & KIT), Magnus Schlösser (KIT), Simon Niemes (KIT), Paul Wiesen (KIT), Beate Bornschein (KIT), Helmut Telle (UAM)*

In recent years, there has been a growing interest in conducting in-situ Raman measurements on tritium-loaded graphene or graphene-like samples due to proposals in neutrino physics programs like KATRIN and PTOLEMY. A confocal Raman microscope (CRM), which can used for spatio-chemical analysis of these samples, could become radioactive contaminated due to post-loading desorption of tritiated species. Therefore, a suitable CRM has to (i) comply with tritium-safety regulations, (ii) should have a minimal number of parts exposed to contamination, and (iii) can allow for future integration into a tritium glovebox system. In this work, the setup and the design of a self-built CRM are presented, as well as selected characterization and Raman imaging measurements. Additionally, the status of a graphene-loading chamber with in-situ resistivity and temperature measurements is shown.

Simulations for the QTNM project

Seb Jones (University College London)

The Quantum Technologies for Neutrino Mass (QTNM) project aims to utilise Cyclotron Radiation Emission Spectroscopy, along with unique quantum breakthroughs, to make measurements of the effective neutrino mass at the sub-eV level. In order to design this experiment, bespoke simulation tools have been developed which allow various options to be evaluated. These tools allow us to effectively simulate many areas of our proposed experiment, from the motion of electrons in electric and magnetic fields, to signal identification amongst a variety of noise backgrounds.

Studies towards atomic tritium sources for future neutrino mass experiments

*Beate Bornschein (Karlsruhe Institute of Technology (KIT)), Caroline Rodenbeck (KIT), **Leonard Hasselmann (KIT)**, Magnus Schlösser (KIT), Michael Sturm (KIT), Tim Sandmann (KIT), Sebastian Koch (KIT), Robin Größle (KIT), Marc Thiel (KIT)*

The current best limit on the anti-electron neutrino mass of $m_\nu < 0.8\,\mathrm{eV\,c^{-2}}$ $(90\,\%\,\mathrm{CL})$ was published by the KATRIN collaboration in 2021. For this, spectroscopy of electrons from the decay of molecular tritium is used. Due to molecular excitation states however, the sensitivity of experiments using molecular tritium is limited to $\approx 0.1\,\mathrm{eV\,c^{-2}}$. One approach to overcome this molecular barrier is to use atomic tritium sources for future experiments.

This poster presents studies and developments with the aim to determine how an atomic hydrogen source can be operated, characterized, and scaled up. In the first iteration, an off-the-shelf source (Tectra H-flux) is commissioned in a test setup. With this, a basic understanding of the system behavior and atomic hydrogen production was developed. In addition, the status of design and implementation of a system which is capable to handle tritium is presented.

Tritium operation of the Karlsruhe Tritium Neutrino Experiment (KATRIN) at TLK

David Hillesheimer (Karlsruhe Institute of Technology (KIT)), *Alexander Marsteller (University of Washington), Florian Priester (KIT), Marco Röllig (KIT), Michael Sturm (KIT), Stefan Welte (KIT), Johanna Wydra (KIT), Lutz Bornschein (KIT), Tobias Falke (KIT), Tobias Weber (KTI), Nancy Tuchscherer (KIT), Thanh-Long Le (KIT), Simon Niemes (KIT)*

The Karlsruhe Tritium Neutrino experiment (KATRIN) measures the tritium β-spectrum close to the maximum decay energy to achieve the value of the electron-antineutrino mass with a sensitivity of 0.2 eVc^{-2} (90% C.L.). Since only a small fraction of the decay electrons carries nearly all the energy, a high luminous tritium source, with its supporting infrastructure facilities, is necessary. Since the start of the tritium operation of KATRIN back in May 2018, more than 700 days of 24/7 measuring campaigns with a total tritium throughput of more than 22 kg and a tritium concentration > 95 % were conducted. Despite several technical challenges occurring during the runtime, the necessary reliable supply of tritium was provided. This contribution will give an overview of the current operational conditions of the Tritium Laboratory Karlsruhe (TLK) tritium facilities involved, as well as an overview of selected technical challenges we faced during the runtime.

Sub-Doppler ro-vibrational spectroscopy on HT

Valentin Hermann (Karlsruhe Institute of Technology (KIT)), *Frank Cozijn (Vrije Universiteit Amsterdam (VU)), Meissa Diouf (VU), Wim Ubachs (VU), Magnus Schlösser (KIT)*

Tests of molecular quantum electrodynamics in the hydrogen benchmark species have predominantly targeted stable isotopes such as H_2, HD, and D_2. Accurate dissociation energy measurements [1] have shown remarkable agreement with theoretical predictions [2,3]. While various cavity-enhanced techniques have been employed to measure vibrational splittings, particularly in HD [4,5], these endeavors have encountered challenges due to dispersive line shapes with multiple interpretations [6,7], restricting the precision of determining molecular vibrational level splittings. However, comparisons of numerous P and R lines have enabled the determination of highly accurate rotational level splittings [7].

Incorporating tritium-containing isotopologues in QED tests of hydrogen species provides new perspectives and deepens our understanding of these systems. Coherent Anti-Stokes Raman spectroscopy (CARS) has recently been utilized to measure vibrational splitting in T2, HT, and DT [8], albeit with an accuracy limited to a few MHz. We aim to significantly enhance the accuracy by employing our developed NICE-OHMS technology to measure the HT overtone spectrum. We have developed a specialized setup for HT spectroscopy under radiation safety conditions. Loading and handling the HT gas is done by employing an non-evaporable getter. We present the newest results from this nowel setup.

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THE GENERATION AND ANALYSIS OF TRITIUM-SUBSTITUTED METHANE

Deseada Diaz Barrero (Karlsruhe Institute of Technology (KIT) & Universidad Autonoma de Madrid (UAM)*, Thanh-Long Le (KIT), Simon Niemes (KIT), Stefan Welte (KIT), Magnus Schlösser (KIT), Beate Bornschein (KIT), Helmut H. Telle (UAM)*

Abstract — An unavoidable category of molecular species in large-scale tritium applications, such as nuclear fusion, are tritium-substituted hydrocarbons, which form by radiochemical reactions in the presence of (circulating) tritium and carbon (mainly from the steel of vessels and tubing). Tritium substituted methane species, CQ4 (with Q = H,D,T), are often the precursor for higher-order reaction chains, and thus are of particular interest. Here we describe the controlled production of CQ4 carried out in the CAPER facility of the Tritium Laboratory Karlsruhe, exploiting catalytic reactions and species enrichment via the CAPER integral permeator. CQ4 was generated in substantial quantities (>1000 cm^3 at 850 mbar, with CQ4content of up to 20%). The samples were analyzed using laser Raman and mass spectrometry to determine the relative isotopologue composition and to trace the generation of tritiated chain hydrocarbons. Keywords — Tritium-substituted methane, mass spectrometry, Raman spectroscopy, measurement and monitoring.

The Process of Setting Up Experiments at TLK

Joshua Kohpeiß (Karlsruhe Institute of Technology (KIT)), *Stefan Welte (KIT), David Hillesheimer (KIT)*

Since 30 years tritium experiments and facilities are being set up at Tritium Laboratory Karlsruhe (TLK). This is done in a framework of technical and administrative rules to ensure that during all operation, the requirements set by the TLK tritium licence is upheld and a safe and reliable operation is guaranteed, while the environment in which science is performed has a maximum of flexibility. With the collected experience as well as the existing present infrastructure, TLK is very adapt competent in setting up tritium experiments. All facilities built at TLK need have dto go through an administrative- and technical- documentation process aiding and accompanying design, setup and commissioning. This contribution shows the typical steps involved in the setup of a tritium facility at TLK.

Development of a tritium-compatible electrolyzer for water detritiiation

***Immanuel Müller (Karlsruhe Institute of Technology (KIT))**, Simon Niemes (KIT), Stefan Welte (KIT)*

The radioactive hydrogen isotope tritium is becoming increasingly important in research and industry. Since tritium has a very low availability, a closed tritium cycle is essential for applications on a technical scale, e.g. electricity generation from nuclear fusion. The physical properties of tritium present a particular challenge for safe handling. These include its (i) good permeability through pipe walls, (ii) high corrosivity, and (iii) difficult detection due to low decay energy.

A closed tritium cycle is being operated for over 25 years at Tritium Laboratory Karlsruhe (TLK) [1] to test and develop technologies for safe handling and containment of tritium. The various experiments or decontamination carried out at TLK produce tritiated water (HTO), from which tritium needs to be recovered. One possibility for this is the Combined Electrolysis Catalytic Exchange Process, which was implemented on a technical scale with the TRENTA-facility at TLK [2].

A central element of TRENTA is the electrolyzer, which splits HTO into oxygen and hydrogen isotopologues. Initially, commercial electrolysis units where used as a proof of concept. However, they were not designed for tritium operation and subsequently showed significant deficiencies during operation [3]. For that reason, a dedicated electrolyzer plant was designed specifically for tritium operation. This electrolyzer is based on Proton Exchange Membrane (PEM) Electrolysis and fulfills both (i) the process requirements, which serve the fulfillment of operation parameters and component protection, and (ii) safety-related requirements for radiation protection. Because the plant will be setup in a glove box, emphasis was given to good accessibility, sufficient space for maintenance and a compact construction design.

In this poster, we will present our implementation of a tritium-compatible electrolyzer. The focus lies on the compliance of process and safety requirements for tritium operation, as well as designing a facility with good handleability and easy maintenance.

Organization

Local organization committe

- Dominic Batzler
- Beate Bornschein
- Lutz Bornschein
- Adalbert Braun
- Deseada Diaz Barrero
- Robin Größle
- Leonard Hasselmann
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Please note the PCO website at KIT with overview of services.
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- Official website: `https://www.iap.kit.edu/tlk/index.php`

- TLK Twitter profile: `https://twitter.com/tritiumlab`

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Fahrplan

Leopoldshafen – KIT-Campus Nord – Brücke L559 – Blankenloch

Montag – Freitag																					
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Leopoldshafen, Leopoldstr. S		13:58	14:18	14:58	15:18	15:38	16:12	16:30	16:51	17:10	17:30	17:50	18:10	18:25	18:40	19:20	20:00				
KIT-CN Südtor		14:04	14:24	15:04	15:24	15:44	16:18	16:36	16:57	17:16	17:36	17:56	18:16	18:31	18:46	19:26	20:06				
Blankenloch Kreisel / L559			14:28		15:28	15:48	16:22	16:40	17:01	17:20	17:40	18:00	18:20	18:35	18:50	19:30	20:10				
– Brücke L559			14.29		15:29	15:49	16:23	16:41	17:02	17:21	17:41	18:01	18:21	18:36	18:51	19:31	20:11				
Blankenloch Nord S			14:32		15:32	15:52	16:26	16:44	17:05	17:24	17:44	18:04	18:24	18:39	18:54	19:34	20:14				
Blankenloch Bahnhof R			14:33		15:33	15:53	16:27	16:45	17:06	17:25	17:45	18:05	18:25	18:40	18:55	19:35	20:15				
S2 Blankenloch Nord	ab					16:02	16:32	16:52	17:12	17:32	17:52	18:12	18:32	18:42	19:02						
S2 Karlsruhe Markplatz	an					16:29	16:59	17:19	17:39	17:59	18:19	18:39	18:59	19:09	19:29						

Bei Verspätungen können die dargestellten Anschlüsse nicht immer eingehalten werden

BUS 195

Fahrplan

Blankenloch – Brücke L559 – KIT Campus-Nord – Leopoldshafen

Montag – Freitag																				
S2 Karlsruher Marktplatz	ab		05:36	05:48	05:58	06:28	06:48	07:08	07:28	07:48		08:18								
S2 Blankenloch Nord	an		06:02	06:15	06:25	06:55	07:15	07:35	07:55	08:15		08:45								
S2 Blankenloch Bahnhof R		05:33	06:02		06:33	07:02	07:16	07:39	08:02	08:16	08:41			09:44		10:44		11:44		12:44
Blankenloch Nord		05:35	06:04	06:21	06:35	07:04	07:18	07:41	08:04	08:18	08:43	08:52		09:46		10:46		11:46		12:46
– Brücke L559		05:38	06:07	06:24	06:38	07:07	07:21	07:44	08:07	08:21	08:46	08:55		09:49		10:49		11:49		12:49
– Kreisel / L559		05:39	06:08	06:25	06:39	07:08	07:22	07:45	08:08	08:22	08:47	08:56		09:50		10:50		11:50		12:50
KIT-CN Südtor		05:43	06:12	06:29	06:43	07:12	07:26	07:49	08:12	08:26	08:51	09:00	09:14	09:54	10:14	10:54	11:14	11:54	12.14	12:54
Leopoldshafen, Leopoldstr. S		05:47	06:16	06:33	06:47	07:16	07:30	07:53	08:16	08:30	08:55	09:04	09:18	09:58	10:18	10:58	11:18	11:58	12:18	12:58
S1 S11 Leo'hafen, Leopoldstr.	ab		06:24	06:35	06:55	07:24	07:35		08:24		09:04		09:24	10:04	10:24	11.04	11:24	12:04	12.24	13:04
S1 S11 Karlsruhe Marktplatz	an		06:55	07:05	07:25	07:55	08:05		08:55		09:35		09:55	10:35	10:55	11:35	11.55	12.35	12:55	13:35
Montag – Freitag																				
S2 Karlsruhe Marktplatz	ab		13:08						15:28	15:58	16:18	16:38	16:58	17:18	17:38	17:58	18:38	19:18	19:38	
S2 Blankenloch Nord	an		13:35						15:55	16:25	16:45	17:05	17:25	17:45	18:05	18:25	19:05	19:45	20:05	
S2 Blankenloch Bahnhof R			13:44		14:44		15:24	15:44	16:04	16:27	16:46	17:06	17:26	17:46	18:06	18:26	19:06	19:46	20:15	
Blankenloch Nord			13:46		14:46		15:26	15:46	16:06	16:29	16:48	17:08	17:28	17:48	18:08	18:28	19:08	19:48	20:17	
– Brücke L559			13:49		14:49		15:29	15:49	16:09	16:32	16:51	17:11	17:31	17:51	18:11	18:31	19:11	19:51	20:20	
– Kreisel / L559			13.50		14:50		15:30	15:50	16:10	16:33	16:52	17:12	17:32	17:52	18:12	18:32	19:12	19:52	20:21	
KIT-CN Südtor		13:14	13:54	14:14	14:54	15:14	15:34	15:54	16:14	16:37	16:56	17:16	17:36	17:56	18:16	18:36	19:16	19:56	20:25	
Leopoldshafen Leopoldstr. S		13:18	13:58	14:18	14:58	15:18	15:38	15:58	16:18	16:41	17:00	17:20	17:40	18:00	18:20	18:40	19:20	20:00	20:29	
S1 S11 Leo'hafen, Leopoldstr.	ab	13:24	14:05	14:24	15:04	15:24	15:44	16:04	16:24	16:45	17:05	17:25	17:45	18:05	18:24	18:44	19:24	20:04		
S1 S11 Karlsruhe Marktplatz	an	13:55	14:35	14:55	15:35	15:55	16:15	16:35	16:55	17:15	17:35	17:55	18:15	18:35	18:55	19:15	19:55	20:35		

Bei Verspätungen können die dargestellten Anschlüsse nicht immer eingehalten werden

In case of emergency

- For the conference: Magnus Schlösser, +49 175 2256873
- For a real emergency on campus: **3333 from KIT-phone, +49 721 608-3333 from mobile phone**