Thursday Morning, November 12, 2026

Vacuum Technology
Room 321 - Session VT-ThM

Vacuum Technology Big Vacuum Systems and Accelerators

Moderators: Prof. Dr. Sefer Avdiaj, University of Prishtina, **Eleni Marshall**, STFC Daresbury Laboratory

8:00am **VT-ThM-1 Ultra-High Vacuum Systems for Next Generation Gravitational Wave Detectors**, ***Jordan Vanosky***, LIGO Laboratory, California Institute of Technology **INVITED**

LIGO, the Laser Interferometer Gravitational-wave Observatory consists of two, 4-kilometer long, L-shaped interferometers, which operate under Ultra High Vacuum conditions in order to detect gravitational waves from cosmic sources. The next generation of gravitational wave detector, Cosmic Explorer, targets a 10x increase in sensitivity and will consist of two 40 kilometer long beamtubes, a potential 90 million liter UHV system. Cosmic Explorer will enable a greater survey of the universe for gravitational wave sources, but this scale brings unique challenges for fabrication and qualification of the ultra-high vacuum system. Improving on the methods and techniques that built LIGO is essential in order for an 80-kilometer long vacuum system to be feasible. New materials, fabrication methods, installation procedures, and bakeout techniques must be considered in order to reduce costs and installation time.

8:30am **VT-ThM-3 New Method for Bake-Out of Large Vacuum Systems**, ***Freek Molkenboer****, Corné Rijnsent, Thom Oosterveer, Han Velthuis, Herman Bekman, Andrey Ushakov, Dirk van Baarle,* TNO Science and Industry, the Netherlands

Thermal bake-out is a well-known and commonly used method for removing contaminants from the inner surface of a vacuum system. However, the economic and practical scalability of this method for very large systems or systems with a high thermal mass poses quite some challenges.

The Einstein Telescope will be the largest vacuum system on Earth and will require the removal of water and other contaminates after installation underground. The currently foreseen method is thermal bake-out using Joule heating of the beam tube. The beam-pipes have a diameter of 1 meter, and due to the layout of the Einstein Telescope, a total of over 120 kilometers of beam-pipe is needed.

TNO will investigate the technical feasibility of using plasma techniques to remove water and other contaminates from the inner surface of the beam tube. For this study, a dedicated setup has been designed and built to assess whether plasma assisted cleaning can achieve the low partial pressure requirements as are needed for the Einstein Telescope.

During the presentation, we will discuss the realization of the experimental setup, as well as the outcome of the first half year of experiments.

8:45am **VT-ThM-4 in-Situ Bakeout of Beam Line Assemblies Under Project Constraints: A Measurement-Driven Approach Validated on the LCLS-II He Installation Campaign**, ***Pierre Ribault****, Giulia Lanza, TC Chen, Dale Gill, Dentell Reed, Robert Coy,* SLAC National Accelerator Laboratory

The LCLS-II High Energy upgrade installation at SLAC uses a specific bake procedure for its beam line assemblies (BLAs): in-situ heating at 50 °C for eight hours, with an additional in-situ heating step on the BLA ceramic. The reason is practical. We want to desorb more water during the in-situ pumping phase, so that the total pump-down time of the full line stays within the project budget. This abstract describes how the bake parameters were chosen, the measurements that supported them, and the fleet-scale validation we are running on the HE installation.

Water dominates the outgassing budget at room temperature on stainless steel and ceramic surfaces, and it sets the in-situ pump-down time. Heating the BLA accelerates water release from the metal surfaces. The ceramic is harder to bake through bulk heating because of the thermal coupling in the integrated assembly, so we added a dedicated heating step for it. Both steps were sized so that the per-BLA outgassing fits within the budget for the full line.

We measured the outgassing of representative HE BLAs before installation rather than relying on extrapolated values. These measurements were used to refine the predictive model and to set the duration and temperature of the in-situ ceramic heating step. The 24-hour per-BLA pumping target was derived from the assembly time and the post-bake pumping requirement, set against the line-level pump-down budget defined by the project.

About twenty-three identical BLAs will be installed and baked over the course of one year. Each is monitored continuously by a SLAC particle-free turbo cart, which provides residual gas analysis with networked acquisition and a common time base across stations. The campaign gives us a chance to compare nominally identical units baked under the same procedure, and to look at the spread between them.

The presentation will cover four points. The engineering reasoning behind the bake parameters and the ceramic heating step. The outgassing measurement campaign and how it fed into the model. The first comparisons between predicted and observed bake trajectories on the BLAs installed by the time of the symposium, including the disagreements. And what the fleet data tells us about the spread between BLAs that should, on paper, behave the same way.

We submit this work as a documented case of a project-driven bake procedure: how it was designed, what data supported the design choices, and how the campaign is being monitored. The intent is to share the approach and the dataset with the community.

9:00am **VT-ThM-5 ESS Vacuum System Commissioning for Beam on Target**, ***Marcelo Juni Ferreira***, European Spallation Source ERIC, Sweden; *Artur Gevorgyan, Laurence Page, Adrien Besson, Hilko Spoelstra,* European Spallation Source, Sweden

The European Spallation Source (ESS) is a multidisciplinary research infrastructure and neutron source facility based on a 2 GeV, 5 MW proton linear accelerator (LINAC). The facility uses superconducting radio-frequency (SRF) cavities assembled under particle-free conditions to accelerate the proton beam, which produces neutrons through spallation on a helium-cooled tungsten wheel. The facility can host up to 42 neutron instruments.

The ESS Vacuum Group is responsible for all technical vacuum systems across the Accelerator, Target, and Neutron Scattering Instruments (NSS).

This presentation will provide an overview of the installed vacuum systems for the commissioning phase of the proton accelerator and monolith target systems for Beam-On-Target in Q1 2027. It will cover the vacuum hardware, the EPICS-based vacuum control interface, and the system's early performance, including the first beam to the tuning beam dump. The presentation will also describe the Target monolith vacuum system and comment on the installation of neutron instruments.

9:15am **VT-ThM-6 Engineering and Validating Vacuum Systems for the Spallation Neutron Source Second Target Station**, ***Austin Chaires***, Oak Ridge National Laboratory

The Second Target Station (STS) project at the Spallation Neutron Source (SNS) requires specialized vacuum systems to support particle transfer, inert experiment environments and safety requirements. This work outlines the engineering responsibilities and validation methodologies used to design vacuum environments across the STS target and instrument systems. Various vacuum systems must fulfill diverse functional needs, including clearing proton and neutron flight paths, isolating the inert environments of instruments, managing hazardous hydrogen gas concentrations under National Fire Protection Association (NFPA) safety standards, and providing thermal insulation for liquid hydrogen target cooling. Additionally, vacuum is used to safely remove water from highly active, radioactive components destined for disposal. To mitigate radiation exposure and ensure system robustness, the engineering approach leverages twenty-five years of SNS operational lessons learned to integrate As Low As Reasonably Achievable (ALARA) principles, modular common pump stations, and redundant pumping pathways. Design validation is achieved through a multi-faceted analytical approach combining empirical formulas, vendor consultation, and software modeling via ANSYS APDL and VacTran. For novel configurations, multiple parallel analytical methods are cross validated to guarantee compliance. This comprehensive design and validation framework ensures system readiness as the STS target and instrument vacuum systems approach final design reviews this year in anticipation for the Department of Energy (DOE) project milestone critical decision (CD) 2/3 approval to proceed to procurement.

9:30am **VT-ThM-7 Gas Dynamic Modeling of an Upgraded Titanium Arc-Gettering Neutral Beam Pumping System**, ***Alan Van Drie***, TAE Technologies

Fusion Neutral Beam Injection (NBI) systems impose demanding vacuum pumping requirements due to the need to maintain gas pressures in the 2–3 mTorr range within the beam neutralizer section while simultaneously reducing downstream pressures to the 10^{-5} Torr range to minimize beam re-ionization losses and cold gas bleed into the main fusion vessel.

This work presents modeling and prototype testing of an upgraded multi-scale finned titanium arc-gettering pumping system developed in support of higher-voltage and longer-duration upgrades to the NORMU neutral beams. The objective of the pumping upgrade is to increase effective pumping speed and gas capacity within the restricted geometric envelope of the neutral beam vessel. Gas modeling across both transitional and molecular flow regimes was used to evaluate pressure and density distributions, gas transport, and pumping effectiveness within complex neutral beam geometries. The distributed finned geometry was developed to improve hydrogen isotope pumping performance while addressing engineering integration and conductance constraints associated with upgraded neutral beam architectures.

Author Index

Bold page numbers indicate presenter