Novel Technology Advances as Budapest Neutron Centre Leads Optimisation of ESS Moderator

THE MODERATOR. The European Spallation Source will be the first spallation neutron facility to operate a low-dimensional moderator as part of its target systems. Hungary’s Wigner Research Centre at BNC is building a prototype of the ESS moderator test beamline to optimise the novel technology.

BUDAPEST—One of the keys to maximising neutron brightness at the European Spallation Source (ESS) is also one of the more unassuming components of the facility. About the dimensions of a movie theatre film canister, the significance of the ESS low-dimensional moderator (LDM) is easily lost in the massive scale of the ESS Target Station. As a component of the moderator-reflector system, this roughly 3 x 70 cm aluminium alloy cylinder, consisting of separate channels containing water and liquid hydrogen, plays a key role in determining the scientific impact of the world-leading research instruments designed for ESS.

The prototype moderator test beamline under construction at the Budapest Research Reactor. At center is a 3He 2D detector on a 2D stage, that allows detector positioning to cover the moderator image and its reflections on mirrors of the beam extraction system; and at right a mask with pinhole and chopper assembly on a 2D stage that allows scanning over the 4 cm-wide, 10 cm-high beam cross section. PHOTOS: BNC-Wigner

The moderator is the central point of neutron extraction for all beamlines at ESS. Its basic geometry, material composition and operating methods must all be optimised to maximise the number of neutrons that can be used for scientific research at ESS. The Hungarian Wigner Research Centre for Physics at the Budapest Neutron Centre (BNC-Wigner) has...
The European Spallation Source (ESS) carried out a series of experiments to develop new moderator geometries, and to develop a conceptual design of an advanced liquid hydrogen moderator based on the ESS concept.

It is important that the performance of the ESS moderator is fully characterised as soon as neutron production starts at ESS. In collaboration with the EU’s BrightnESS project, BNC-Wigner is designing and building a prototype ESS moderator test beamline to be used for this purpose. BrightnESS is an EU-funded project that supports ESS in a variety of areas, including the innovation of key neutron technologies such as detectors and moderators.

**New Observations Mean Increased Brightness for Spallation and Reactor Sources**

“We have obtained very promising experimental results, which will make a great contribution to the modelling of the ESS moderator, including its design, fabrication and operation,” says László Rosta, Scientific Coordinator at BNC-Wigner and a delegate for Hungary on the ESS Council. “The results have also elaborated a simplified scheme for a new CNS [Cold Neutron Source] system for a reactor case.”

The Budapest Neutron Centre hosts the 10 MW Budapest Research Reactor (BRR), a cold neutron facility that is one of the largest and most important research infrastructures in Hungary. While ESS will produce neutrons via spallation rather than a nuclear reaction, the BRR’s beamline serves as a testing ground both to characterise the ESS moderator as well as to develop reactor-based applications of the novel moderator concept.

Experiments began by observing the average brightness of the cold moderator at BRR in different condensation and cooling-down scenarios of the liquid hydrogen moderating material. As a novelty, these scenarios included the option of cooling down the moderator for a few days before the neutron source was switched on.

“Surprisingly, this systematically led to clearly higher moderator brightness,” says ESS Technical Coordinator Feri Mezei. “One of the goals in the testing of the prototype moderator test beamline is to try to understand by observing all details this curious phenomenon that might be also relevant to other neutron moderators at other sources.”

Mezei is the lead author on the paper that introduced the innovative LDM geometry in 2014, along with ESS Target Division co-authors Luca Zanini, Alan Takibayev, Konstantin Batkov, Esben Klinkby, Eric Pitcher and Troels Schönfeldt. The European Spallation Source developed the novel concept—previously described in different incarnations as the ‘flat’,
‘pancake’ and ‘butterfly’ moderator—and will be the first to apply it for enhanced source brightness. The pioneering innovation was validated on a spallation source beamline at the Japan Proton Accelerator Research Complex in 2015. It will increase neutron brightness by a factor of 2-3 compared to existing moderators, for the benefit of those instruments able to exploit such high neutron flux.

ESS Technical Coordinator Feri Mezei. PHOTO: ESS

Middle-Ages Technique is Model for Moderator Test Beamline
The principle of moderator testing is the imaging of the neutron luminosity of the neutron-emitting surface of the moderator. Like in a film, the images taken one after the other will allow to fully characterise the intensity, homogeneity, energy spectrum and time structure of the neutron emission to the ESS beamlines.

‘The main components of the set-up are a set of pin-holes for image projection to a position-sensitive area detector, a chopper defining the neutron energy with the help of the time-of-flight to the neutron detection, and a neutron beam shutter to offer accessibility for adjustments,” explains Mezei. ‘The testing technique follows the time-honoured camera obscura principle from the Middle Ages, and has already been used several times at BNC-Wigner, for example to optimize the beam take-off for their recently installed split-guide.”

Laszlo Rosta, Scientific Coordinator at BNC-Wigner, at an ESS Council meeting in Malmö.

The BrightnESS project provides support not only to develop the test beamline concept at BNC-Wigner, but to test prototype components and prepare for the installation of the moderator test beamline at ESS.

János Füzi, head of the Neutron Spectroscopy Department at Wigner, explains: ‘The current experiment allows us to explore the ortho-para [liquid hydrogen] behaviour of our working moderator. We also gather new useful data for the design of the test beamline equipment to be used at ESS, by measuring and extrapolating, for example, neutron transmission or radiation shielding features of components.”

Critical Step in Commissioning of ESS
The complete set-up at BRR will be operational in 2018. At the time of first beam on target at ESS, the moderator test prototype will be available for immediate characterisation of the ESS moderator, including the complete testing of the method in an environment of a high-power pulsed source, after routine operation on a medium-power continuous source.

This is a critical step in the commissioning of ESS as a whole. It will make possible early testing of many critical source features, such as background, shielding and shutters, and will serve as a training ground for beamline handling work.

The test beamline’s full experimental characterisation of the trailblazing ESS moderator design will signal the inception of a new generation in neutron source efficiency and performance.

Studies Continue at BNC-Wigner

Further engineering work is needed to optimise use of the moderator. Studying the geometry of the moderator’s chamber, reducing temperature inhomogeneity, and refining the quality of the moderator’s alloy are common engineering realities that directly influence neutron intensity.

Tests at BNC-Wigner have already demonstrated that monitoring the homogeneity of the moderator as well as the beam take-off system have crucial importance.

More work is also needed to calculate heat loads on the moderator chamber and its thermo-hydraulic properties, while further investigation of the ortho-para conversion features is also in progress.

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