

# Long-Term Multi-Grid Trial at SNS Validates Detector's Use for CSPEC and T- REX

AUG 25, 2017

**Large-Area Detectors.** Seven years of R&D, first based at ILL and now at ESS, with critical work done in Linköping, have produced the first Boron film-based large-area detector prototype validated for use by ESS instruments. The integration project now enters the detailed design phase.

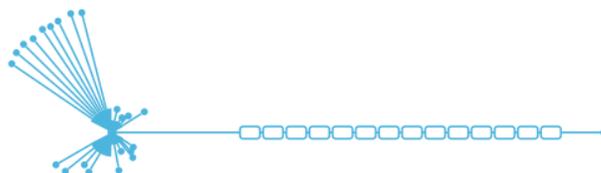
OAK RIDGE, LUND and GRENOBLE—For one year now, a Boron-10 Carbide (10B4C) film-based large-area detector prototype built at the European Spallation Source (ESS) has been collecting data at the Spallation Neutron Source (SNS) in Oak Ridge, Tennessee. The 1.4-metre-high solid-state detector is installed within an SNS instrument's detector chamber, directly adjacent to its existing Helium-3 detector. The setup has allowed for real-world scientific results from the two very different detector technologies to be collected and directly compared while the instrument remains in use for scientific experiments.



The ESS Multi-Grid team at SNS following installation of the demonstrator next to the CNCS large-area Helium detector. From left, Fatima Issa, Isaak Lopez Higuera, Michelle Everett (SNS), Anton Khaplanov and Richard Bebb. PHOTO: Courtesy of A. Khaplanov

## Parallel Experiment Data Provide Validation

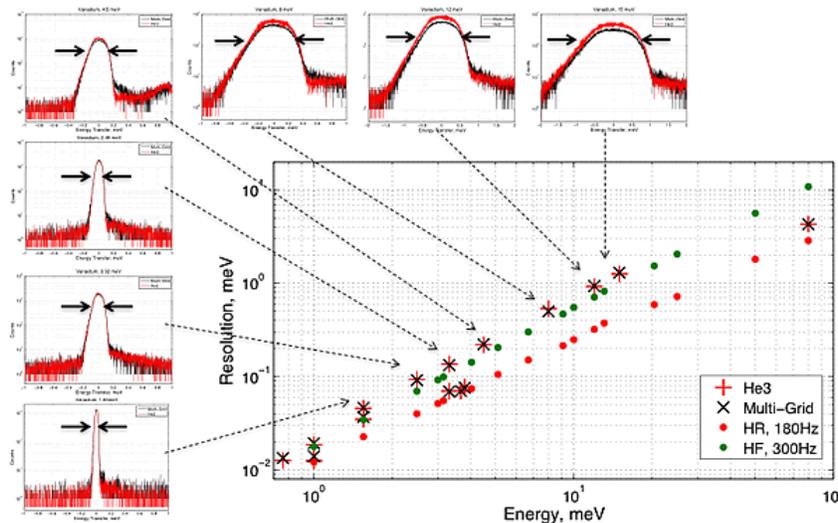
The Boron-10 and Helium-3 detectors have been gathering parallel data since July 2016 over the course of the spectrometer's normal operations. An analysis of that data by the ESS Detector Group, with the help of the instrument teams for [CSPEC](#) and [T-REX](#), two



direct-geometry spectrometers under construction for ESS, has led to the large-area detector's formal adoption as the baseline detector technology for these two instruments. The technology will also be required by the later instrument, [VOR](#).

'We completed the characterisation on test beams and test sources, and one short experiment on a time-of-flight instrument, that all indicated the Multi-Grid would perform as expected. Now we have confirmed this with results on an instrument that is operating for a very long time in very different conditions, with different samples, and at different neutron energies,' says ESS detector scientist Anton Khaplanov, who leads the development of the Multi-Grid detector for ESS instruments.

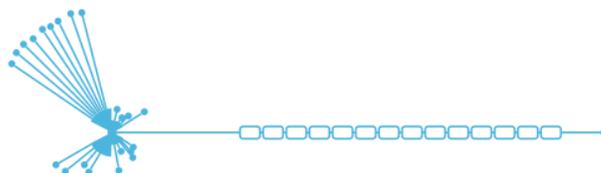
## Elastic Energy Resolution



"The black and the red are Multi-Grid and Helium-3, respectively," explains ESS detector scientist Anton Khaplanov. "So the time of flight is different, because the two detectors have a different depth, a different geometry all around. But when you calculate Energy, you see that the data points are exactly the same. The figure is showing how these kinds of measurements have been made for several different wavelengths and several different instrument settings at CNCS. And what we find is that—at these crosses—the measurements all coincide. So you get exactly the same resolution from both detectors." IMAGE: ESS

It was during the 2015 ESS Annual Review that a member of the review committee, Ken Herwig of the SNS Instrument and Source Design Division, suggested that the SNS instrument CNCS (Cold Neutron Chopper Spectrometer) would be the ideal host for battle-testing ESS's new detector technology. Like the ESS facility design, SNS is a high-power, pulsed spallation source. The ESS Multi-Grid detector prototype (MG.CNCS) was then built to the specifications of CNCS, a cold neutron spectrometer like CSPEC, under the guidance of the instrument's lead scientist Georg Ehlers of SNS.

Building on R&D originating at France's Institute Laue-Langevin (ILL), and with funding delivered through the [European Union's BrightnESS project](#), [the ESS Detector Group](#) is



working to develop better detector technologies, including the Multi-Grid, for six of the ESS instruments.

'In the last 15 years, the most important developments in our understanding of materials from neutron diffraction and spectroscopy have emerged due to improvements in the technology of large-scale detectors," says ESS Detector Group Leader Richard Hall-Wilton, who also serves as Deputy Head of Instrument Technologies. 'Especially important are refinements in position sensitivity, counting rate capability, and signal-to-noise separation, areas where the Multi-grid demonstrator shows great potential.'

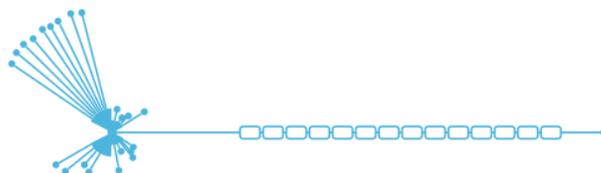
### Counting Neutrons: Better Performance Through R&D

A scientific instrument is only as good as the data it produces, and in the case of neutron instruments the data are only as good as the instrument's detector. As researchers work to model the physical properties of materials, films and tissues using neutrons, it is the detectors that serve as both the lens and the photographic paper for the [software-generated visualisations](#) that are produced.



The MG.CNCS demonstrator under construction at ESS. Clockwise from top left: Anton Khaplanov; Isaac Lopez Higuera; Khaplanov explaining the MG concept at the opening of the ESS Utgård workshop in Lund; and the final assembly at the ESS EMBLA detectors workshop. PHOTOS: ESS

In a neutron scattering experiment, the neutrons encounter the sample as a focused particle beam and collide with the sample's atomic nuclei, which scatters them in as many directions as there are neutrons. Acting as the backstop to the area surrounding the experiment's sample location, the detector absorbs the scattered neutrons.



Neutrons, however, are particles without a charge, and detecting them can be a challenge. When a neutron ‘hits’ a detector, the event is in fact a reaction between the neutron and a mediating compound, which converts the neutron to an electric pulse. That pulse is counted, time-stamped, converted into position in three-dimensional space, and transmitted as a data point to a computer.

Taken together with an instrument’s known metadata and constants including the distance between the ESS Target and the sample, and the distance between the sample and the detector, the data are compiled to develop a two-, three-, or four-dimensional model of the interactions between neutron and sample. This can be a structural analysis of the sample, but will also include magnetic phenomena and real-time changes in physical properties stimulated by the experiment’s conditions.

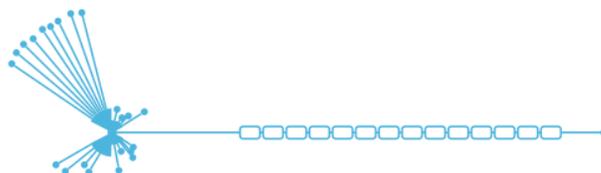
At ESS there will be more neutrons coming off a sample than a detector can handle. The facility will sport [the most powerful linear proton accelerator ever built](#), and will be capable of producing up to two orders of magnitude more neutrons than existing facilities. So the number of neutrons that an instrument’s detector can count before being overwhelmed with data will be critical in delivering on the promise of the extraordinary brightness of ESS. Scientists at ESS and its partner labs must therefore work [to build detectors](#) that are as innovative as [the facility’s world-leading instruments](#) in order to leverage this high neutron flux.

‘Our testing has shown that the count-rate capability—how many neutrons can be counted in conditions of very high flux—for Boron-10 Multi-Grids is better than for Helium-3 position-sensitive counters,’ says Khaplanov. ‘The problem [for He3] is in the gas itself. If there are many pulses at the same time they will create a continuous signal in the gas of the detector preventing further neutrons from being detected. You do not have the same limitation with the Multi-Grid because you have many layers of detection over which you are dividing the flux.’

### **Beyond Helium-3**

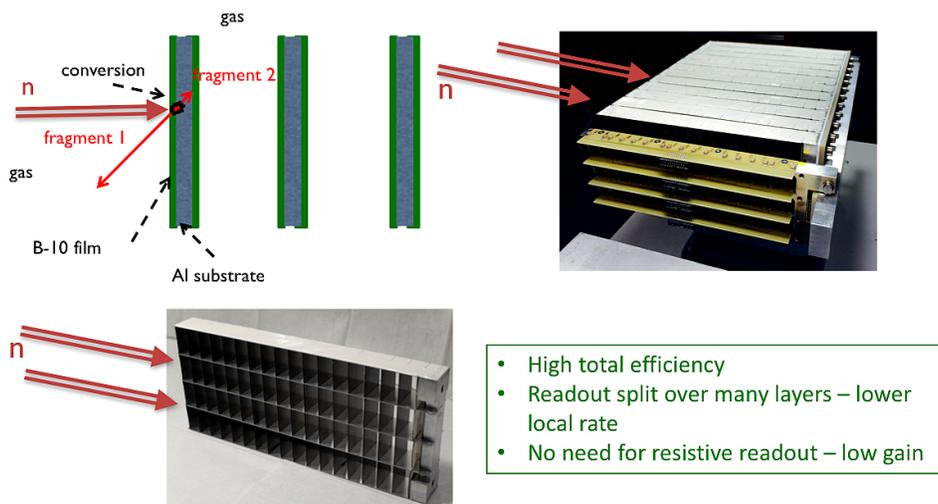
Better performance, however, is only one of the BrightnESS project’s motivating factors. Another concerns a shortage of Helium-3, the current basis medium for neutron detectors around the world.

Primarily stockpiled as a by-product of nuclear weapons development, the once-plentiful supply has been dwindling. The cost of building hundreds of square metres of conventional neutron detectors for ESS grew to prohibitive amounts and future availability remains uncertain. The Detector Group’s R&D is therefore focused on using the alternative, solid-state technology: aluminum alloy substrates coated with a  $^{10}\text{B}_4\text{C}$  thin film. The coating is applied through an innovative sputtering process developed by Linköping University’s Thin Films Physics division. This process is now standardised and executed by [the ESS Detector Coatings Workshop established in Linköping in 2014](#).



Apart from ensuring that each instrument will be built with as much detector coverage as possible, the new Boron-10 technology will open up the range of experiments possible with neutron instruments.

‘Since Helium-3 has become prohibitively expensive, the development of B10 detectors offers new possibilities for neutron scattering instrumentation,’ says Pascale Deen, lead scientist for the CSPEC instrument project. ‘The recent developments will make it feasible to develop spectroscopic instruments that probe thermal excitations in materials. This allows us to continue studying materials that, for instance, reveal magneto-thermal properties necessary to reduce the noxious gasses currently ejected by refrigeration devices, or understand high-temperature superconductivity with the aim to develop zero-energy-loss electric transmission.’



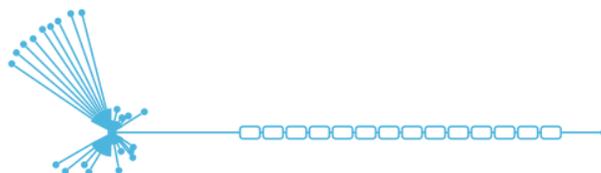
Multi-Grid concept explained. IMAGE: ESS

### 2010-2014: The CRISP Detectors Subproject

Led by researchers at ILL in Grenoble, the world’s flagship neutron science facility for nearly five decades, the European Strategy Forum on Research Infrastructures (ESFRI) was already seeking an alternative to Helium-3 gas detectors based on the promise of the Boron-10 films technology. It was at ILL that the Multi-Grid concept and its early prototypes were developed.

From 2010 to 2014, the Cluster of Research Infrastructures and Synergies in Physics (CRISP) developed common solutions in the fields of Accelerators, Detectors, Instruments and Experiments, as well as Information Technology and Data Management. The collaboration among the 11 ESFRI institutions was funded in part by the European Commission.

‘The Multi-Grid detector development was the first technical collaboration between ESS



and ILL,” explains Bruno Guérard, head of ILL’s detector group. ‘The joint venture has brought this technique to maturity, and there has been a very good complementarity of competence—ILL for the Multi-Grid technology on one side, and ESS and Linköping University for the thin convertor films on the other.’”

Guérard led the CRISP Detectors Subproject to its crowning achievement, the development of a full-scale demonstrator of the Multi-Grid. This prototype was modelled for the IN5 spectrometer at ILL, but also served to demonstrate a production capability on a scale similar to that required for large chopper spectrometers, such as those now being designed for ESS.

‘The principle of the detector is that you have a series of grids, placed in a stack,” explains Khaplanov, who worked with Guérard at ILL for three years before coming to ESS to continue the Multi-Grid project. ‘This can be a stack of 12 or 16, for a smaller detector, such as a testing detector, or 100-plus grids for a full-scale detector for a spectrometer. Grids are similar, but of course tackling integration of a few grids is not the same as that of hundreds.’”

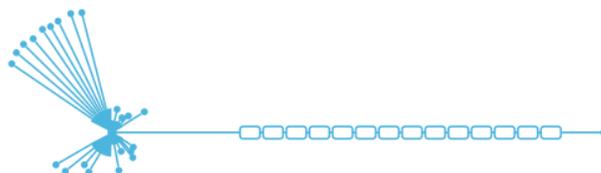
Or a thousand—ILL’s IN5 demonstrator, which is now kept in a workshop at ESS, has 1,024 of these metal grids, coated in Boron-10 film at Linköping and wired for detection at ILL.



The IN5 Multi-Grid demonstrator at the ILL detector workshop in Grenoble, France. The detector features 1,024 sets of grids and was developed as part of ESFRI's CRISP project. From left, Mathieu Ferraton and Jean-Claude Buffet of ILL. PHOTO: ILL

#### **2014-2018: BrightnESS Work Package 4**

The CRISP collaboration developed and extensively characterised four prototypes of the detector’s design, and it is this work that the BrightnESS project has built on. In addition to

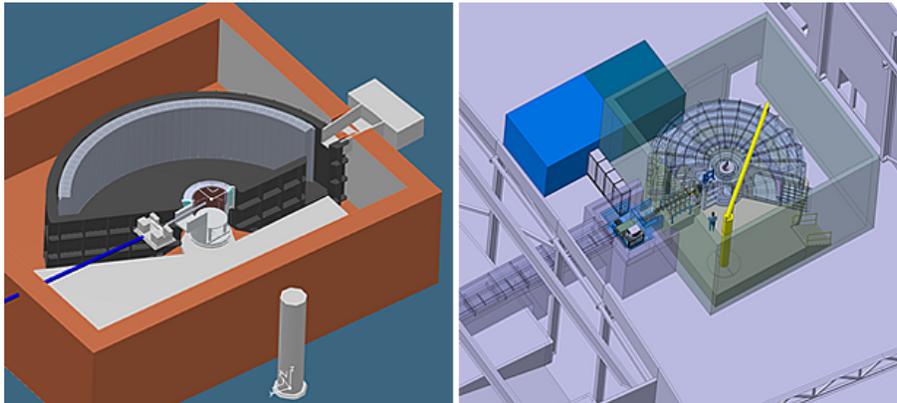


Khaplanov, Francesco Piscitelli, a detector scientist also now at ESS, was part of ILL's work under CRISP. Piscitelli now leads the development of [another Boron-based detector](#) for ESS that has its origins at ILL, the Multi-Blade.

The Multi-Grid CNCS prototype will continue to collect data at SNS for now, but there is plenty of work left to do.

'There are two questions left untested after SNS,' says Khaplanov. 'How well the Multi-Grid will perform on a thermal [higher energy] instrument similar to T-REX, and how to operate it in vacuum, which has implications for how this vessel is manufactured and how it is operated practically.'

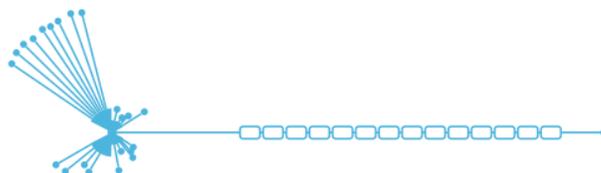
Guérard's team at ILL is investigating the latter, how best to circulate the detector gas from a high-pressure to a low-pressure environment and back again. Continuing to work on the Multi-Grid through BrightnESS, another focus at ILL is to prototype a different geometry for the detector that will eliminate the dead spaces at each grid's very small margins. Multiplied over a large area, these uncounted neutrons can add up to a significant performance factor.



Models of the CSPEC (l) and T-REX large-area detector chambers. The spectrometers under construction for ESS will both use the Multi-Grid technology. IMAGES: ESS

'We're also doing some new detectors,' says Khaplanov of his team at ESS. 'At the moment we are ordering parts for one that is optimised for T-REX, which measures at higher energies. To do this, we will increase the number of  $B_4C$  layers from 32, as in the CNCS prototype, to 40, and also increase their thickness.'

'But the biggest challenge at the moment is to make a design for the entire large-scale detector. Over the past years it was to demonstrate the performance and to characterise everything, to have answers about efficiency, background sensitivity, gamma ray sensitivity, time resolution, how you optimise it for different spectra, etc. Now we have to integrate it into the instrument design.'



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## FURTHER READING:

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