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Neutron Detector Requirements

One of the objectives of the work package 7 “Joint development of detector technologies” is to develop beyond state-of-the-art detector technology for the neutron scattering instruments at ESS. As a result of discussion between detector group and instrument scientists at European Spallation Source (ESS) a MultiBlade detector (Boron-10-based gaseous detector) is planned to be built for the Test Beam Line (TBL) by the ESS detector group. The main focus of this deliverable is to verify the implementation of the MultiBlade detector as a suitable technology in accordance with the TBL detector requirements.

1. Test Beam Line Detector Requirements at ESS

The primary objective of TBL at ESS is the continuous and precise monitoring of the moderator performance as the pulsed neutron beam characteristics (neutron flux, time structure, spatial distribution etc.) varies. TBL will also serve as a testing facility to support the user program by characterizing and aligning samples and performing simple imaging experiments during ESS commissioning and test operations. In order to achieve these objectives TBL will need to be ready by Beam on Target (BOT) with a fairly simple and robust system. The TBL (Figure 1-1) is in direct line of sight to the moderator and its experimental cave will be directly attached to the bunker wall (Figure 1-2). These conditions require that TBL be equipped with a range of detectors to fulfil different needs.

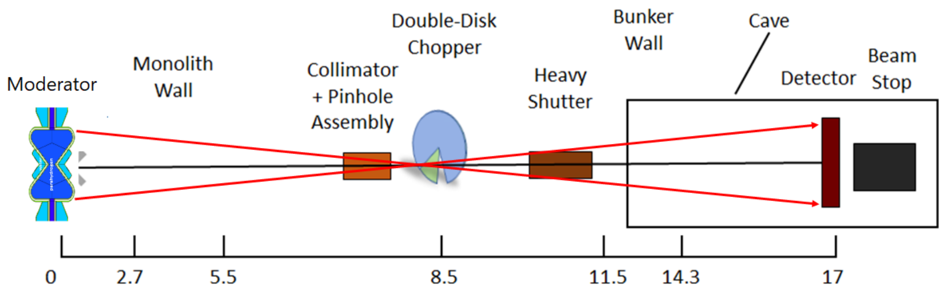

Figure 1-1. Schematic top view of TBL with the main components (image:TBL).

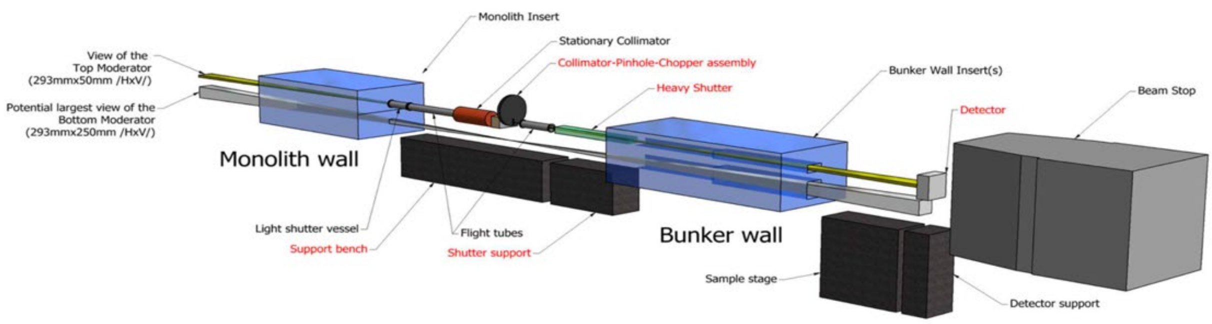

Figure 1-2. Schematic overiew of TBL apparatus at ESS (image:TBL).

The moderator characterization at ESS is an important task and consists of two major deliverables:

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- The characterization of the neutron energy (wavelength) distribution across the entire visible moderator surface
- The characterization of the pulse shape itself that is emitted by the moderator

The ‘pinhole imaging concept’ allows to image the moderator at the detector position with 1:1 magnification. The simulation of ‘pinhole imaging’ of the moderator at the detector position is shown in (Figure 1-3).

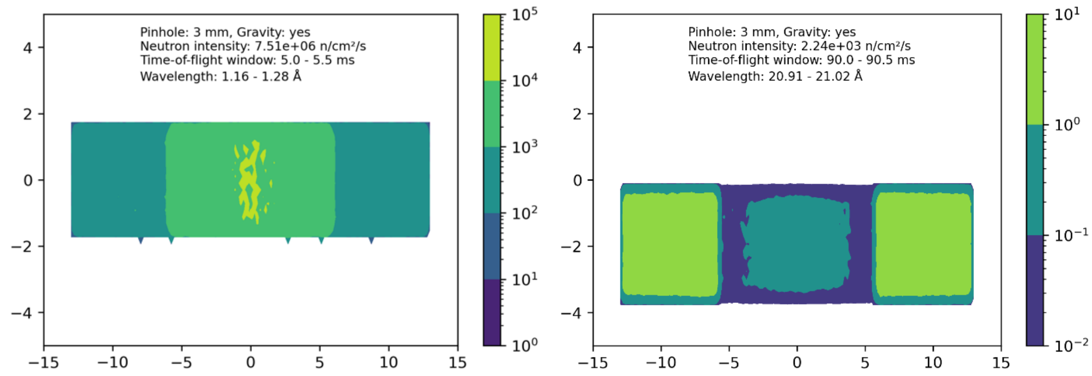

Figure 1-3. Expected neutron intensity distribution at the detector position of 17m for two different wavelength ranges (McStas simulation). Unit in cm’s on x- and y-axis (Courtesy of T. Chulapakorn,TBL).

The MultiBalde detector can spatially characterise the intensity of the moderator along with the associated neutron energy (wavelength) distribution via Time-of-Flight. Apart from the imaging purposes the current MultiBlade detector specification is also suitable for high-temporal resolution measurements in order to characterize the shape of the ESS neutron pulse for certain wavelengths. According to TBL requirements the detector will have a high spatial resolution (~ 0.5 mm (FWHM)) along the vertical direction of the expected neutron intensity distribution (height) and about (~ 3.5 mm (FWHM)) resolution along the horizontal direction of the expected neutron intensity distribution (width); with an active area that will allow to image the entire moderator at once, ideally composing an active area > 300 mm (W) x 100mm (H). The height (H) of the detector is determined by the trajectory of neutrons with large wavelengths due to gravity effect. The detector must provide a sufficiently large dynamic range in order to cope with the different flux conditions. The desirable specifications of the MultiBlade detector for TBL are summarized in Table 1-1.

Table 1-1. Test Beam Line desirable specifications

Active area coverage	≈ 300 (W) x ≈ 100 (H)	mm^2
Spatial resolution (V) (FWHM) Spatial resolution (H) (FWHM)	≈ 0.5 ≈ 3.5	mm mm
Instantaneous rate capability	≈ 10	kHz/mm^2
Time resolution for imaging Time resolution for neutron pulse shape measurement	< 100 < 30	µs µs

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2. MultiBlade Detector Specification

The MultiBlade detector is a stack of Multi Wire Proportional Chambers (MWPC) operated at atmospheric pressure with a continuous gas flow (Ar/CO_2 80/20 mixture). The detector is made up of identical units, the so-called 'cassettes'. Each cassette holds a 'blade' (a flat substrate coated with $^{10}B_4C$) which consists of a plane of 32 wires and a plane of 64 strips resulting into a two-dimensional readout system. This detector technology has been tested and characterized in the past years and a detailed description where the results are discussed are listed below.

- Demonstration of proof of concept and test of the first prototype at the ILL in 2013 [1].
- A detailed characterization of detector at the Budapest Neutron Centre in 2015 [2–5].
- A full characterization of detector including specular and off-specular reflectivity measurements on several samples at the neutron reflectometer CRISP at the ISIS neutron and muon source in the UK in 2017 [6-9].
- Background studies, in particular the response of the detector to fast neutrons and gamma-rays at Source Test Facility (STF) at Lund university in 2018 [10].
- Installation and test of MultiBlade demonstrator at AMOR reflectometer at Paul Scherrer Institute (PSI) in 2018 [11].

A fully functional MultiBlade detector unit and DAQ system comprised of eleven cassettes was permanently installed at the AMOR reflectrometer at PSI in May 2022 and the in-beam performance of the detector was tested. The MultiBlade detector is chosen for the TBL because of its desirable characteristics and reliability proven at PSI. Following this successful test, the final modifications to improve the design of the detector were implemented and a MultiBlade detector unit comprised of 4 cassettes was built which is currently installed at STF for background studies and detector uniformity test (Figure 2-1). This is the detector design that the ESS detector group intends to build for TBL. In Table 2-1 the verified key characteristics of MultiBlade detector is summarized.

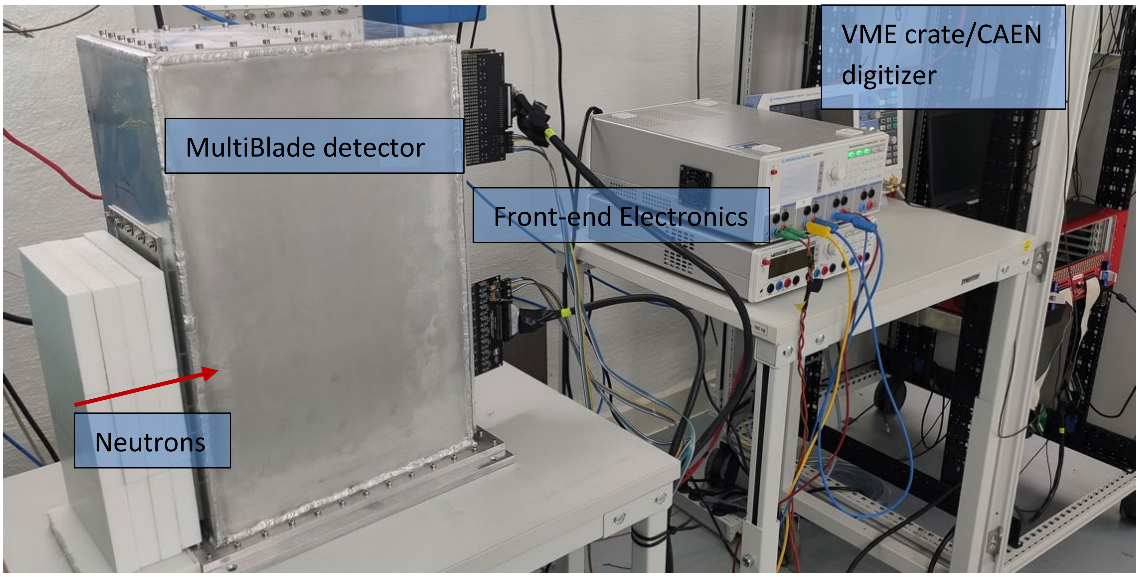

Figure 2-1. MultiBlade unit currently being tested by ESS at Source Test Facility (STF), Lund (photo: F.Ghazi Moradi).

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Table 2-1 MultiBlade detector specification

Active area /one cassette	260 x 10	mm^2
Spatial resolution (FWHM) y Spatial resolution (FWHM) x	0.55 4	mm mm
Maximum instantaneous pixel rate at 2% dead time	10	kHz/mm^2
Gamma ray-sensitivity	$< 10^{-6}$	
Time resolution	< 5	µs
Efficiency	45% @ 2.5 60% @ 4.2 75% @ 6	Å Å Å

As outlined in Table 2-1, a cassette subtends approximately 10 mm toward the sample centre because of its 5 degrees inclination. The required dimension and resolution which are summarized in Table 1-1 implies that 11 blades (10 cassettes) are needed to match TBL requirement which will offer an active area of 260 x 100 mm^2.

3. Conclusion

In conclusion the MultiBlade detector design and performance has proven to be a reliable choice in terms of fulfilling the needed specifications for TBL in the following respect:

- Proven functionality and reliability of MultiBlade referenced in various publications
- Matching the MultiBlade detector specification in terms of global rate, temporal and spatial xsresolution with TBL requirements
- Clear service and maintenance interface description provided by the detector group at ESS

4. References

[1] F. Piscitelli, et al., "Study of a high spatial resolution 10 B -based thermal neutron detector for application in neutron reflectometry: the Multi-Blade prototype", Journal of Instrumentation, vol. 9, no. 03, p. P03007, 2014.

[2] F. Piscitelli, et al., "The Multi-Blade Boron-10-based neutron detector for high intensity neutron reflectometry at ESS", Journal of Instrumentation, vol. 12, no. 03, p. P03013, 2017.

[3] "Budapest neutron centre", http://www.bnc.hu.

[4] L. Rosta, "Cold neutron research facility at the budapest neutron centre", Applied Physics A, vol. 74, pp. s52–s54, 2002.

[5] L. Rosta and R. Baranyai, "Budapest research reactor – 20 years of international user operation", Neutron News, vol. 22, no. 3, pp. 31–36, 2011.

[6] "CRISP instrument manual 2010" , https://www.isis.stfc.ac.uk/Pages/crisp-instrument-manual-nov-2010.pdf.

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[7] C. C. Wilson, "A guided tour of isis - the uk spallation neutron source", Neutron News, vol. 6, no. 2, pp. 27–34, 1995.

[8] F. Piscitelli, et al., "Characterization of the Multi-Blade ^{10}B-based detector at the CRISP reflectrometer

at ISIS for neutron reflectometry at ESS", Journal of Instrumentation, vol. 13, P05009, 2018.

[9] G. Mauri, et al., " Neutron reflectometry with the Multi-Blade 10B-based detector", Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences 474, 2216, 2018

[10] G. Mauri, et al., "Fast neutron sensitivity of neutron detectors based on Boron-10 converter layers", Journal of Instrumentation, vol. 13, no. 03, p. P03004, 2018.

[11] G. Mauri et al., "The Multi-Blade Boron-10-based neutron detector performance using a focusing reflectometer", Journal of Instrumentation, vol. 15, P03010, 2020.