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## Concept of operations for the ESS Test Beamline

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	Name	Role/Title
<b>Owner</b>	Robin Woracek	TBL Instrument Lead Scientist
	Gabor Laszlo	TBL Engineer and NSS Lead Instrument Engineer
<b>Reviewer</b>	Andrew Jackson	Head of Neutron Instruments Division
	Luca Zanini	Target Physics Group representative
<b>Approver</b>	Jon Taylor	NSS Project Leader

Document Type	Description
Document Number	ESS-1400197
Date	Dec, 09, 2020
Revision	
State	Preliminary
Confidentiality Level	Internal

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## 1. INTRODUCTION

The purpose of this Concept of Operations (ConOps) is to provide a brief description of the NSS Test Beamline (TBL). The basic instrument concept is introduced; this includes both a high level introduction to the science case of the instrument as well as the framework and context within which the instrument will be designed, operated and maintained through its life-cycle.

The intended audience for this document includes everyone involved in the construction and operation of the TBL. It will also serve the function as a quick overview of the instrument's purpose, construction and operation.

The ConOps is intended to be updated several times to ensure its actuality.

## 2. SCIENTIFIC CASE

The primary purpose of the TBL is to verify that the ESS has successfully achieved the milestone of producing slow neutrons from its spallation target and moderator-reflector system. It will characterize the target and moderator systems and determine to what extent the design performance has been achieved.

After that, it will serve to monitor the moderator performance as the source power is increased and the operating conditions (e.g. time structure, beam rastering, moderator parameters, etc.) are varied.

During ESS commissioning and operations, it will serve a variety of additional purposes in support of technical developments and commissioning and also more directly supporting the user program by characterizing and aligning samples and performing simple imaging experiments.

The TBL will not be available through the ESS user program.

It is expected that ESS will have access to test beamlines at other, lower flux, facilities. Priority for beamtime at the ESS test beamline will thus be given to applications which benefit from being performed there, such as the following:

- Characterization of the ESS moderator system
- Support for experiments scheduled on instruments in the ESS user program
- Measurements which need the particular properties of the ESS TBL
- Time-critical measurements in support of ESS instrument construction

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### 3. SYSTEM CHARACTERISTICS

#### 3.1 System purpose

The TBL will be the first beamline to become operational. Its primary purpose is to characterize the ESS moderator system in order to support the performance of the instruments in the user program. Its full purpose is defined as:

- Verification that the project has successfully delivered a source of slow neutrons with the expected characteristics
- Characterization of the pulsed neutron beam emitted from the upper moderator: time structure, spatial distribution, energy dependence, stability
- Characterization of the moderator system for the purpose of calibration of the neutron beam instruments
- Provision of data to inform the development of detectors and data processing systems
- Provision of data for moderator and accelerator development over the operating life of the ESS

In addition, the TBL must be upgradeable for the following purposes:

- Support for the development of key neutron technologies, such as optical components and detector systems
- Provision of white-beam and low-wavelength-resolution imaging capability to support the scientific program of ODIN and other beamlines
- Alignment and characterization of single-crystal samples for the ESS user program
- Characterization of the moderator system below the spallation target (in case it will be installed)
- Allowing for the principal possibility to extend the length of the beamline for installation of a second experimental end station with a longer flight path

#### 3.2 High Level System Requirements

In order to fulfill the main purposes of the TBL, the following high level requirements need to be met:

1. The system shall be able to characterize the moderator spectra over the wavelength range from 0.5 Å to 30 Å over both the thermal and the cold moderator surfaces (purpose: verification and characterization of the neutron source with respect to the relevant wavelength range)
2. The system shall provide an adjustable wavelength resolution, ranging between the natural resolution determined by the total flight path of 17 m and down to 3 % for 0.5 Å neutrons (correspondingly better for lower wavelengths) by using an adjustable chopper at a distance of 8.5 m (purpose: enabling to measure the pulse shape from the neutron source by time of flight pinhole imaging for single wavelength across the

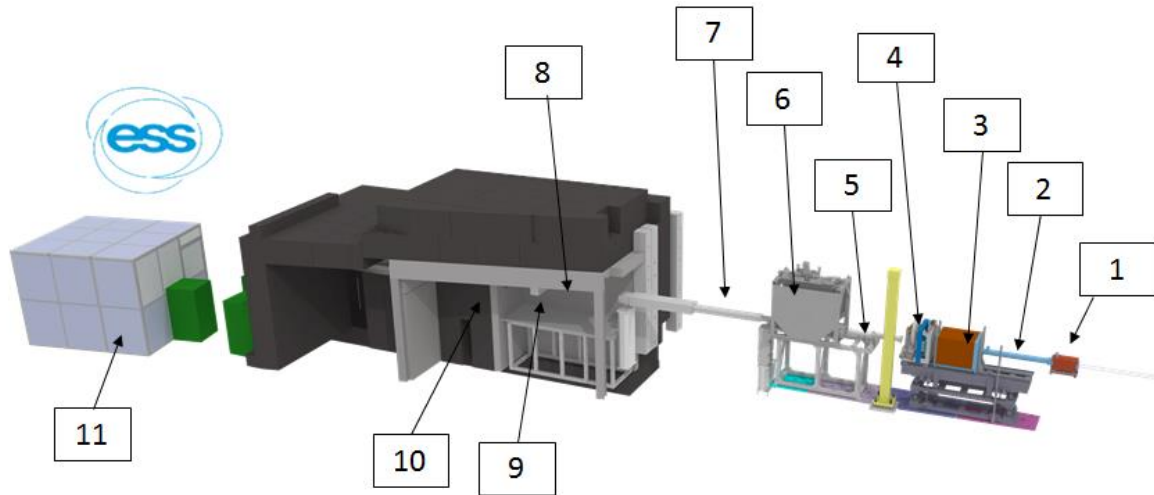
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- wavelength band identified above, while allowing other applications that require higher flux by parking the chopper in open position)
3. The system shall deliver the full image of the top moderator and the pre-moderator surfaces ( $\approx 300\text{mm} \times 30\text{mm}$ ) to the detector in a single setting (purpose: verification and characterization of the neutron source with spatial resolution for the same and time without the need of scanning)
  4. The system shall allow for variable spatial resolutions using variable pinhole settings, at least 1 mm or better concerning the moderator characterization. (purpose: verification and characterization of the neutron source with high spatial resolution while allowing to adjust the flux to prevent detector saturation as well as enabling higher flux for kinetic studies of the moderator performance)
  5. The system shall be able to trade flux for resolution; both spatial resolution and wavelength resolution (purpose: verification and characterization of the neutron source with high spatial and medium to high wavelength resolution while allowing to adjust the flux to prevent detector saturation as well as enabling higher flux for kinetic studies of the moderator performance)
  6. The signal to noise (S/N) ratio should be better than 10 (intensity with shutter open divided by intensity with shutter closed) over the full moderator image and over the full measurable wavelength range (purpose: verification and characterization of the neutron source with reliable statistics)
  7. The system should allow to operate the beamline with the chopper parked open (purpose: allow the beamline to be utilized for higher flux applications; allow the characterization of the neutron source by diffraction from powder or monochromator crystals)
  8. The system shall be able to attenuate the beam when needed to avoid detector saturation (purpose: verification and characterization of the neutron source utilizing an array of possible detector technologies)
  9. The system shall be able to absorb different parts of the neutron and gamma spectrum, including the possibility to absorb all slow neutrons while allowing fast neutrons and gamma radiation to reach the detector, by optional filters (purpose: characterization of the neutron source concerning fast neutrons and gamma radiation)
  10. The system shall allow access to the instrument cave while the proton beam is on within 1 hour (or less) of closing the shutter (purpose: allowing to make physical adjustments to the experimental setup inside the cave within reasonable time during operations)
  11. The system shall allow the provision of a moveable monochromator crystal to be placed in the beam at the sample position for characterization of the moderator pulse shape of certain wavelengths (purpose: providing an additional characterization method of the neutron source, namely the pulse shape, in addition to the characterization using the time of flight pinhole option).



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The principal layout of the Test Beamline is depicted in Figure 2 with key components listed in table 1. Components that pose implications for operation of the TBL are detailed in the following.



**Figure 2 Key components of the TBL.**

**Table 1 Key components of the TBL.**

NR.	COMPONENT NAME
1.	Bridge Beam Guide (BBGOA)
2.	Flight Tube 1
3.	Fixed Collimator
4.	Chopper and Adjustable Collimator (Pinhole Selector)
5.	Flight Tube 2 and position of filter/attenuator stage
6.	Heavy Shutter
7.	Bunker Wall Feedthrough
8.	Experimental Cave
9.	Detector
10.	Beam Stop
11.	Control Hutch

### 3.4.2 Fixed Collimator

The fixed collimator will reduce the contribution from fast neutron and gamma radiation into the experimental cave. The material composition under considerations foresees it to be manufactured from copper with a tapering hole, but the final design is still pending.

Possible upgrade option: The design of the beamline should allow the installation of a fixed collimator with larger aperture dimension or the modification of the existing collimator to fulfil the requirement of enlarging the opening. Such a major change needs to be verified with additional simulations/analytical calculations so that the shielding still fulfils its requirements.

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### **3.4.3 Chopper and Adjustable Collimator**

This unit has already been manufactured and is being used at the BNC. The chopper is a double-disk chopper. The collimator is mounted a motion stage for the purpose of remote alignment. The unit also includes a set of changeable attenuators with four positions (upstream) and a set of changeable pinholes with five positions (downstream).

### **3.4.4 Filter/attenuator stage**

Two motorized stages will allow different combinations of beam filters and attenuators. They serve the purpose of shaping the beam for the purpose of its own characterization and attenuation (e.g. to avoid detector saturation). Materials that serve the main purpose of attenuating the beam uniformly beam across the energy range are referred to as beam attenuators and materials that serve the purpose of attenuating (suppressing) parts of the spectrum are referred to as beam filters. Placing these materials on two independent stages will allow to choose different combinations of beam attenuators as beam filters. Materials that are planned to be installed include perforated B4C plates, Bi, Pb, Cd, W, Be and Polymethyl methacrylate (some of them in different thicknesses).

### **3.4.5 Experimental cave and Shielding**

The instrument operates with an intense beam and in direct line of sight. The shielding serves two purposes. Firstly, it limits the radiation levels outside the instrument to safe levels for personnel access and to minimize background for neighbouring instruments. Secondly it shields the detectors from any radiation not emanating from the moderator.

In case of the test beamline, the experimental cave is directly attached to the common bunker wall and is the place where the detector will be positioned. It shields the surrounding hall from the radiation generated by these systems as well as shielding the detector system from external radiation. The experimental cave can be entered when the beamline shutter is closed.

The cave structure will be assembled from steel and concrete and possibly covered on the inside with HDPE/ borated shielding. The material and thickness specifications are being finalised in a design study carried out by contractor Millennium. Materials are chosen for low activation to permit personnel access to the cave with only a short delay after the shutter has been closed. A cave beam-stop is installed on the inner side of the downstream wall of the cave to absorb the neutrons that are not absorbed by the detector.

An immediate upgrade path foresees motorized stages for positioning possible samples, potential equipment and also detectors within the neutron beam.

### **3.4.6 Support infrastructure**

AC power lines 230V 50 Hz and 400V 50Hz will be installed at different positions inside the experimental cave to supply power inside the cave.

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An EPICS network and a generic Ethernet network will be available outside the cave in order to offer e.g. connections for different detector and sample environment options.

Artificial Illumination is foreseen inside the cave. It should be possible to turn off the light during measurements as e.g. some detector technologies might be affected by this.

Network cameras will be installed in the experimental cave to monitor the experiment. A public address (PA) System might be installed inside the cave.

A cable feedthrough is foreseen to have the possibility to connect auxiliary equipment (such as detector electronics) from outside the cave to the experimental endstation.

### **3.4.7 Detectors**

In order to fulfil the main scope of the test beamline, i.e. characterisation the neutron emission of the moderator surfaces with spatial and wavelength resolution, the instrument will need to be equipped with at least one position sensitive time of flight detector, ideally composing an active area  $> 300 \text{ mm} \times 30 \text{ mm}$ . The detector must provide a sufficiently large dynamic range in order to cope with the different flux conditions.

The PDR in 2017 has concluded that the minimal set of detectors for the test beamline consist of the subset from the BrighnESS project and a test detector from the BNC-Wigner part of the project. The suitability of these detectors still need to be assessed. From these detectors, the MultiBlade detector is currently deemed the most suitable to will fulfil several of the requirements. This detector type is currently being tested by ESS at the SINQ neutron source at the PSI in Switzerland. All requirements to the detector performance that are desirable for the purpose of the test beamline (e.g. high spatial resolution, high timing resolution, high count rate capabilities and large active area) can however not be realized with a single detector and hence several different kind of detectors are intended to be used, suitable for each condition/purpose. In all cases, the detectors must be synchronized to the ESS timing system and ideally be integrated into the ESS DAQ chain. The user must be able to visualize the data without further data processing. Besides the MultiBlade detector, a n-GEM and a scintillator-camera based detector are planned to be available on 'day one'.

Two beam monitors are planned, one inside the bunker (behind the chopper-pinhole assembly) and one inside the cave (behind the bunker wall). Au foil measurements are to be carried out in addition in order to compare the dedicated neutronics simulation for the practica condition of the different operating parameters.

The instrument must also be able to accommodate detectors and corresponding auxiliary equipment for the testing and characterisation of those technologies itself. These detectors may be positioned in the direct or scattered (if a sample is placed in the beam) geometry.

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### 3.4.8 Support systems

The main part of the support system for the Test Beamline is the control hutch. Moreover, a transit area in E02 for storing of activated parts and components (that were exposed at the TBL during previous experiments) needs to be foreseen.

### 3.4.9 Integrated control and monitoring system

The instrument control software framework, data acquisition (DAQ), and beamline monitoring system will be standardised across the ESS instrument suite and instrument specific functionalities will be implemented in that framework. This will allow also the beamline staff to access the monitoring systems needed for the safe operation of the instrument. The TBL will, however, present a special case concerning the DAQ and workflow, since not all detectors will be integrated to the same level. This section will hence be updated when subject is progressing further.

In either case, the instrument control software should be able to control all main functionalities of the instrument as it will on the other ESS instruments (including a graphical (GUI) and command line (CLI) interface), such as motor positions, chopper phases, detector functionalities among others and will provide the following capabilities to allow the user:

- to control and display the status of the beamline components (detectors, motor stages, choppers, slit systems)
- to process and display the recorded data from the range of available detectors as well as the meta-data (motors, chopper system, etc.)
- to display the detector data in x-y (spatial) and z (time) domains with conversion to wavelength (in order to allow for the moderator characterization).
- to control auxiliary equipment that will be tested/used at the beamline (by providing a high degree of flexibility)

The control software interfaces with the Experimental Physics and Industrial Control System (EPICS) framework, which is used to control the individual hardware components. Appropriate network connections will hence be provided inside and outside the experimental cave and hutch.

### 3.4.10 Control Hutch

A control hutch will host remote control equipment, computers and the experimentalists during measurement times. The hutch will be adjacent to the cave.

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## 3.5 Key System Interfaces

There are several key interfaces to other parts of the ESS facility:

### 3.5.1 Target systems

The beam extraction system is physically located inside the target monolith. In case of the TBL the Monolith Insert does not contain optics. There is a simple tapering hole in the insert that is designed to contain the beam. The atmosphere of the insert is the same as the target environment ( $p=1 \times 10^{-3}$  mbar). The TBL monolith insert will be provided by the target division according to the interface drawing.

### 3.5.2 Bridge Beam Guide (BBG) of the TBL

The BBG assembly is located downstream of the Monolith Insert, before the first Flight Tube. It is mounted in the copper collar of the Light Shutter structure. The TBL BBG does not contain optics, only an evacuated flight tube, with neutron beam windows.

The tube is pumped down through a pinch-off tube and that is permanently sealed after the pumping. In case of a leak the vessel can be pumped down again through the pinch-off tube once. Internal pressure can be checked via the pressure indicator on the top of the chamber. Details are provided in ESS-0265772 (TBL - System Design Description).

### 3.5.3 Buildings (Conventional facilities)

The design of the building defines parameters like the floor and ceiling heights, floor loading capacity, crane access, space for paths and infrastructure of the instrument *etc.* All of these will have a large impact on the construction, operation and maintainability of the system. The instrument power consumption and heat release budget is also defined by this interface. The infrastructure includes electrical power and network used for the detector readout.

### 3.5.4 Integrated Controls System (ICS)

The ICS network transmits the control signals from the instrument control software to electronic hardware components. In the case of the TBL, this are namely the motion controllers as well as timing synchronization to the chopper and detector system. The interface to ICS includes both hardware and software interfaces, which are standardized across instruments.

### 3.5.5 Data Management and Software Centre (DMSC)

Instrument control and data visualization and reduction software are provided by the DMSC. Close collaboration between the instrument team and DMSC is required to ensure requirements are formulated and met in a timely manner.

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### **3.5.6 Test beamline at the Budapest Neutron Centre (BNC)**

The chopper and pin-hole system has been designed, built and installed at the BNC TBL. It will be commissioned and operated there, prior to being moved to ESS for installation and use.

## **4. SYSTEM STAKEHOLDERS**

The first group of important stakeholders is NSS project management who fund and manage the project. The TBL serves the main purpose of demonstrating successful production of slow neutrons, following beam on target and of characterizing the moderator performance from the beginning of operations throughout the lifetime of the facility. The Target division is thus the second important group of stakeholders. The Wigner institute which is responsible for the BNC TBL is another important stakeholder.

All the stakeholders are described in detail on the confluence page of the TBL:  
<https://confluence.esss.lu.se/display/SPD/ESS+Test+Beamline>

It should be noted here that a collaborative meeting series has been formed between Target, Accelerator, ICS and the Neutron Instrument Division/NSS to discuss and plan the commissioning of the facility and where the TBL plays an important role:

<https://confluence.esss.lu.se/x/zaL1FQ>

## **5. OPERATIONAL CONCEPTS**

### **5.1 General**

The main purpose of the TBL is to verify that the ESS neutron source has successfully achieved the milestone of producing slow neutrons from its spallation target and moderator-reflector system as well as the characterization of the source itself. The latter is especially important during the start-up phase of the facility. Additionally it will serve several additional purposes, some of which are possible from the beginning and some only after upgrades have been implemented. These operational scenarios are described below.

### **5.2 Operational environment**

The ESS will be a user facility that provides several different neutron (scattering) instruments for experiments that are conducted by scientists (academic or industrial). The design of the facility is novel and some key technologies related to the neutron production have never been implemented at other facilities (e.g. rotating tungsten target, moderator concept). While all other neutron instruments will be made available to external users through a proposal system, the TBL will be the only beamline where beam time is allocated and planned by ESS staff. It can hence be used on a regular basis to characterize the neutron source under the same or different operation conditions. The beamline will also be made available to support the user programme and development of

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key neutron technologies (such as detectors, optical devices, sample environments, etc.). Main limitations of the beamline in its initial design concerning the latter purposes include the relatively small experimental cave and the relatively low flux of slow neutrons (compared to the other neutron instruments).

Since the functionality of the TBL is crucial from the beginning of operations, its operational phases shall be subdivided as follows since the operational environment is changing between and even during these phases.

### **5.2.1 Sub mode Construction**

During construction, no ionizing radiation is allowed in the instrument. In this sub-mode technical components, shielding, media and infrastructure are installed. The main hall cranes are used for most of the construction activities to carry and position components inside the cave. Forklifts and overhead crane are used to bring the construction elements to the installation position.

### **5.2.2 Sub mode cold commissioning**

This phase has partly already started as some components are already in use at the BNC (e.g. the double-disk chopper). The alignment and functionality of all systems however will be needed to be tested when they are installed at their final position. This can partly be done in parallel to the sub mode construction. Cold commissioning does not require neutrons and takes place before the production of first neutrons. This phase should result in verification that remote control of components that have this requirement is possible and reliable (especially but not exclusively those in the bunker). The neutron detector should also be installed and communication be tested in this phase. It will require corresponding personnel from ICS, MCAG, DG and DMSC. (PSS will be dealt with separately, but the corresponding system verification will take place in the same time frame.)

### **5.2.3 Sub mode hot commissioning**

This phase starts with the production of first neutrons at ESS. The verification that the system complies with radiation safety is not part of this document, but needs to be considered at any time. The hot commissioning of the TBL entails to verify that the individual neutronic components work. In order to do so, the functionality of the neutron detector needs to be verified. When this has been done, then the functionality of the shutter, the chopper, pinhole exchanger and attenuates/filtered can be tested as well. It should be noted that the hot commissioning phase will be complicated by the fact that neutron production might be irregular in the beginning. Nonetheless, basic functionality of individual components should be tested at this stage. It should furthermore be noted that this phase needs to be partly repeated any time the power of the neutron beam is increased (or alternatively can be considered as ongoing and to run in parallel to normal operations until ESS reaches steady operations).

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#### **5.2.4 Sub mode normal operation (shutter closed)**

Once the basic functionalities of the beamline components have been verified, the normal operation mode of the TBL starts. A distinction can be made between the scenarios when the shutter is open vs closed. During the operation modes, the neutron beam is on target and access to the instrument is limited to the components outside the bunker, downstream of the heavy shutter (i.e. the experimental cave). The PSS controls the access to the cave and allows or prevents the opening of the door. When the beamline operator closes the shutter, the PSS allows entry to the cave. This allows to set up the experiment itself, e.g. positioning of the detector and/or any sample that should be measured at the TBL.

#### **5.2.5 Sub mode normal operation (shutter open)**

In order to do perform a measurement on the TBL, the experimental cave needs to be closed and entry be prevented by PSS. Only afterwards it is possible to open the shutter. This mode allows to perform different experiments that are detailed in the next section.

### **5.3 Operational scenarios**

It is crucial for the immediate goal of the TBL to perform safe experiments with all required components working as needed. The moderator characterization presents the task with the highest priority. All main operation scenarios are described as follows:

#### **5.3.1 Instrument preparation and cold verification**

This operational task is not to be confused with the cold commissioning phase above and should be considered to be undertaken before conducting any experiment on the TBL. This operation is typically performed before the experiment itself:

- can be done with the source (accelerator) on or off, the shutter closed and cave accessible
- serves the purpose of setting the primary instrument parameters for a specific experiment including the choppers and the pinhole (remotely via control computer and software)
- can be used for installing the specific required detector solution at the specific required position
- optionally required auxiliary equipment can be set up and connected
- all functions can be tested as far as possible without beam

Required equipment:

- depends on the desired experiment

Required staff:

- instrument scientist & technical staff as required

Access frequency:

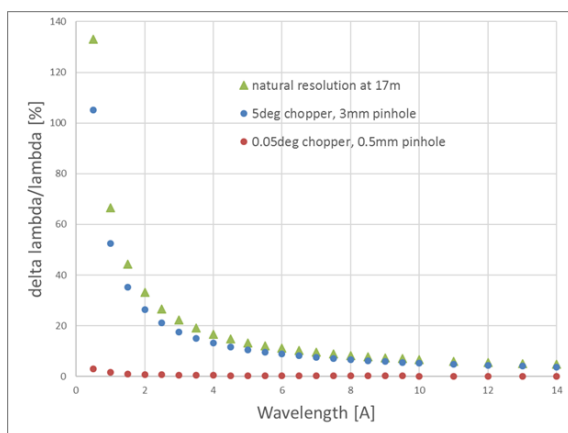
- before any experiment (several times a day during operations)

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### 5.3.2 Moderator Characterization by pinhole imaging

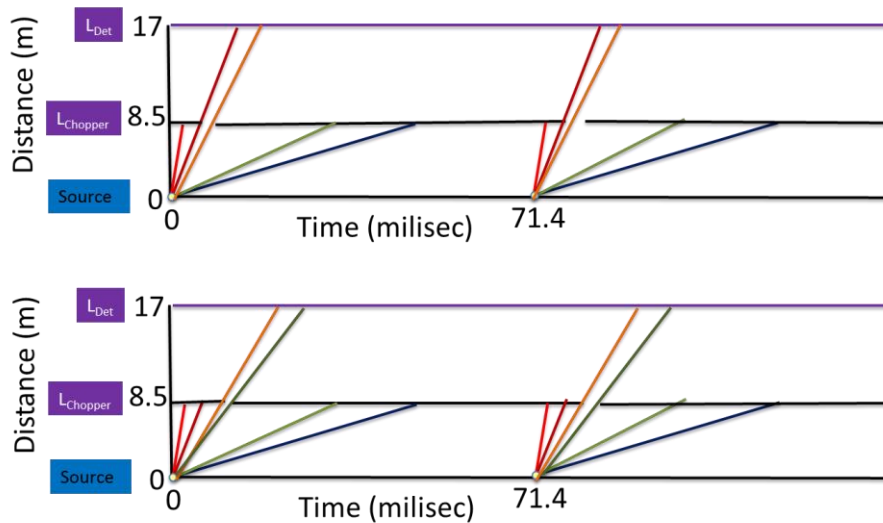
This operational task represents the main purpose of the test beamline which is the characterization of the neutron pulse and pulse shape that is emitted by the moderator. This information should be available with spatial resolution across the surface of the moderator. The following concepts apply:

- The pin-hole aperture is positioned near the midway point between the neutron moderator and the neutron detector (i.e.~ 8.5 m from the moderator).
- This allows to view the whole width of the moderator(s) (~ 30 cm) with magnification 1 at an image plane of 17 m (i.e. 2 - 3 m beyond the outer wall of the bunker) without moving the pinhole.
- The pinhole size can be adjusted remotely to reach the required spatial resolution and count rate.
- An attenuator can be inserted remotely to avoid detector saturation.
- A slow-neutron absorber can be inserted remotely to determine the background from fast neutrons and gamma radiation from the moderator system.
- The performance of the moderator system is measured by monitoring data from the neutron position sensitive detector (PSD) remotely.
- The neutron emission can be measured at different wavelengths using the time-of-flight method. The double disk chopper will allow the wavelength resolution to be adjusted by creating windows smaller than the largest opening of 5° (see examples in Figure 3).
- The pulse shape that is characteristic to ESS (with a plateau region and a long tail) can be measured by choosing a high wavelength resolution setting. This mode can also be described as using a ‘pinhole in time of flight’, where the recorded pulse shape will need to be inverted in analogy to the pinhole camera principle.
- Personnel access to the instrument will be needed for adjusting the detector at regular intervals. The shutter will be closed for these operations, followed by a short waiting time to allow for deactivation. (see above)



**Figure 3 Wavelength resolutions at the TBL at a detector position of 17m using different chopper settings. When using the double-disk chopper, only a single wavelength (wavelength band within the resolution) is accessible at one setting. Parking the chopper open allows to access a wider wavelength band at the natural resolution (limited by gravity however).**

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**Figure 4 Schematic time-distance diagram to show how the double disk chopper can be used to measure different parts of the neutron spectrum. The wavelength bandwidth is significantly reduced compared to when the chopper is parked in open position. By choosing a smaller opening angle of the chopper, the wavelength resolution can be increased. Top and bottom show a different chopper phase, exemplifying how to choose a different wavelength.**

**Required equipment:**

- a time of flight neutron detector with 2D spatial resolution
- a positioning or alignment device (e.g. kinematic mount) for the detector (ensuring repeatability in position precision when repeating the same measurement at a later stage).

**Required staff:**

- instrument scientist & technical staff as required

**Performance frequency:**

- ~ daily during the start of operations (with frequent access to the external cave) until successful measurements are obtained for selected operation conditions.
- regular measurements at given operational conditions of the accelerator and target (~ between once per week to once per month) with decreasing frequency as the facility matures.

**5.3.3 Moderator Characterization by diffraction from a monochromator crystal**

As an alternative to the characterization of the neutron source by pinhole and ‘time of flight pinhole’ imaging, it should also be possible to install a monochromator crystal in the beam at the sample position. This allows to measure the moderator pulse shape of certain wavelengths (determined by crystal and diffraction condition). The neutron detector needs to be installed at an angle with respect to the direct beam, either to the side or downwards. This method does not provide a spatial image of the moderator surface (at least to straight forward), but focuses on the pulse shape emitted from an integrated area of the moderator surface.

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#### Required equipment:

- a simple TOF detector (no PSD necessary)
- a positioning device for the monochromator crystal (ensuring repeatability in position precision when repeating the same measurement at a later stage), including a rotation stage and liner state to move the crystal within the beam.
- a positioning device for the detector (ensuring repeatability in position precision when repeating the same measurement at a later stage).
- Shielding material, such as B4C and/or Cd in order to protect sample holders and stages from radiation.

#### Required staff:

- instrument scientist & technical staff as required

#### Performance frequency:

- regular measurements at given operational conditions of the accelerator and target (~ between once per week to once per month) with frequency decreasing as the facility matures.

## 5.4 Operational scenarios following upgrade

The TBL will be designed to be upgradeable for a number of additional operational scenarios. Some of them should be possible to be carried out even without additional major upgrades. All operational scenarios that do not concern the characterization of the neutron itself are described herein.

### 5.4.1 Testing of components

One operational scenario foresees to place items in the direct beam (which is not the case for the moderator characterization). The purpose in this case is the characterization of these items itself in terms of the neutronic performance, its neutron transmission, etc.. Such items could be neutron optical components, such as guide sections, mirrors, lenses or polarizers. The detector could be positioned in the direct or scattered beam position for such tests. Mechanical holders and support frames will need to be prepared for this and will likely be assembled from standard mounting systems, like provided by ITEM or Bosch-Rexroth. The chopper settings will be adjusted to yield the desired wavelength resolution and wavelength band. One example of such a test setup includes parts of the Neutron Optics Test Bench (NOTB).

The main limitation of such tests concerns the physical size of the TBL cave and the achievable wavelength resolution/flux condition.

#### Required equipment:

- a neutron detector matching the experimental needs (likely a time of flight neutron detector)
- Connections (electric, maybe gases, maybe vacuum)
- Positioning equipment and hardware for the device. Additional motorized axis.

#### Required staff:

- instrument scientist & technical staff as required

Performance frequency: t.b.d.

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#### 5.4.2 Testing of detectors

The test of neutron detectors is another possible operation mode of the test beamline. The testing can concern different aspects of the detector, including one or a combination of the following: count rate capability, position sensitivity, timing sensitivity, testing of DAQ electronics, wavelength dependent efficiency, etc. While the focus is related to testing of detectors in support of the user program at the other instrument, possible detectors to be tested also include those from future particle physics beamline that could be potentially installed at the same beam port as the TBL.

The main limitation of such tests concerns the physical size of the testbeamline cave.

Required equipment:

- Mounting hardware for the detector.
- Connections (electric, maybe gases, maybe vacuum)
- Power supplies for the detector(s)
- Shielding material, such as B4C and/or Cd in order to protect sample holders and stages from radiation.

Required staff:

- instrument scientist & technical staff as required

Performance frequency:

- t.b.d., but possibly frequently during the construction of the other neutron instruments.

#### 5.4.3 Neutron imaging of samples or components

One obvious opportunity is to perform neutron based transmission imaging at the TBL. Such experiments will be useful to characterize the transmission properties of e.g. sample environment devices. It can also concern scientific experiments and as such complement measurements at other ESS beamlines in the user program. While the TBL is limited in maximum flux and minimum wavelength resolution, some applications benefit from low wavelength resolution measurements and the test beamline is suited to address these in its day 1 design.

Required equipment:

- Time of flight imaging detector.

Required staff:

- instrument scientist & technical staff as required

Performance frequency:

- t.b.d.

#### 5.4.4 Characterization and alignment of single-crystal samples

Users will often bring single-crystal samples for measurement at other instruments which need to be characterized by neutron Laue diffraction to determine their crystalline quality, or to be aligned so as to bring particular crystallographic planes into alignment with the neutron beam. This will require the installation of a goniometer with rotation

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and translation stages for the samples, all remotely controlled through the instrument control system, as well as an appropriate detector. The detector will need to have TOF capability and position sensitivity. It will be mounted in scattering geometry, with the exact setup t.b.d. (close to backscattering, to the side or below), preferably adjustable using appropriate mounting systems.

Required equipment:

- Time of flight detector with suitable mounting
- Sample goniometer

Required staff:

- instrument scientist & technical staff as required

Performance frequency:

- t.b.d., possibly frequently in support of the user program at the other instruments
- 

## 5.5 Maintenance Concepts

### 5.5.1 Levels of maintenance

Within ESS there are three identified levels of maintenance, see ref [ESS-0003640]:

1. Organizational maintenance: maintenance performed on site where the element is normally being operated.
2. Intermediate maintenance: maintenance performed on site at a dedicated workshop.
3. Supplier maintenance: maintenance performed off site at the supplier premises.

### 5.5.2 Maintenance categories

Maintenance can be divided into two categories: Corrective and Preventative. By utilizing condition-based monitoring, taking into account the overall ESS operational schedule, preventative maintenance on instruments is aimed to be conducted during the planned facility shutdown periods unless instrument reliability and availability are sacrificed. This will minimize disruption to user operation.

Preventative maintenance is part of scheduled maintenance which also includes maintenance work to be conducted on equipment where condition-based monitoring cannot be achieved. Performed instrument reliability analysis, part of RAMI work, aims to ascertain that preventative maintenance on this type of equipment can be limited to periods of scheduled shutdown of the facility. Maintenance and monitoring requirements of critical components will be taken into account in design and procurement of equipment from the beginning.

Corrective maintenance will mainly apply when an event happens forcing maintenance to be done unscheduled. This occurs either when a component fails or when an issue is

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detected that requires immediate action. The instrument will have to stop operations for the duration of repairs or maintenance.

Another key categorisation of maintenance is the distinction regarding to access requirements and limitations. Components can hence be categorized into easy maintenance access, limited maintenance access and difficult maintenance access devices. In the first category all devices and components can be placed in areas which are located outside the radiation shield of the primary instrument, including such devices placed outside the cave (e.g. control cabinets). These devices can be serviced anytime when required, though downtimes are used for preventive maintenance in order not to interfere with the operation of the instrument. In the second category are the limited number of hardware components installed in the cave and which are hence downstream of the heavy shutter system of the instrument. These components shall be accessible during source operation in case of required corrective maintenance. The third category are components installed in the bunker area where access currently appears to be possible only during source downtimes and through remote handling. Access to components within this category requires removal of shielding with the corresponding implications of crane use, space requirement and scheduling and additionally might also involve a required cool down time of components due to activation, which increases times required for the maintenance.

As yet another category of practically no access the components of the extraction system in the monolith could be defined, which are practically non-accessible, as access requires removal of significant parts of the instrument and its neighbours. Hence no moving parts and components requiring maintenance can be placed there and the design of the components installed there has to be especially robust.

### **5.5.3 Maintenance philosophy**

Robustness and maintainability are key design objectives for the test beamline and hence the number of components in limited or difficult access areas is minimized as far as possible. The components inside the common shielding bunker are designed to be especially robust. All equipment will be standardized as much as possible with other parts of the organization, which makes it feasible for the Instrument Technology groups to have spares on site in case of a breakdown.

## **6. CONSEQUENCES OF THE CONCEPTS**

### **6.1 General design considerations**

#### **6.1.1 Upgrade options**

The test beamline is built with a limited scope and budget in the beginning. It is designed to be modular in order to allow for staged instrument upgrades. Upgrades only requiring minor adjustments/investments include enlarging the pinhole diameter (allowing higher neutron flux for a range of applications, including imaging; requiring new shielding

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verifications), expanding the detector suite and expanding the available motion axis. More involved upgrades include extending the length, width or height of the beamline and potentially even adding additional choppers.

### 6.1.2 Robust design

The test beamline design has several features that make it robust. Firstly the beam delivery system is simple and contains pre-tested components by the partners at Wigner. Secondly there are relatively few moving parts and they are all accessible for maintenance and repairs.

## 6.2 Training of personnel

Training of personnel will be further developed in future releases of this document. Training will in general build on the basic ESS access requirements and safety Glossary

Term	Definition
NSS	Neutron Scattering Systems
SPL	Scientific Project Leader
LE	Lead Engineer
CIS	Chief Instrument Scientist
CIE	Chief Instrument Engineer
PM	Project Manager
DS	Director for Science
GL	Group Leader
CDR	Critical Design Review
ICS	Integrated Control Systems (group at ESS)
DMSC	Data Management and Software Centre (groups at ESS)
MCAg	Motion Control and Automation Group (group at ESS)
DG	Detector Group (group at ESS)
ConOps	Concepts of Operations
IRR	Installation Readiness Review
ORR	Operational Readiness Review
PDR	Preliminary Design Review
PSS	Personnel Safety System
SAR	Safety System Acceptance Review
TG	Toll gate

Document Type            Description  
Document Number        ESS-1400197  
Date                        Dec, 09, 2020  
Revision  
State                       Preliminary  
Confidentiality Level    Internal

## 7. REFERENCES

- [1]            Process for Neutron Instrument Design and Construction: ESS-0051706
- [2]            Concepts of Operations for the ESS system: ESS-0003640
- [3]            Concepts of Operations for the NSS system: ESS-0005817

## DOCUMENT REVISION HISTORY

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<b>Revision</b>	<b>Reason for and description of change</b>	<b>Author</b>	<b>Date</b>
0.01	First draft	Robin Woracek	05 Aug 2020
0.02	Minor edits before starting review in CHESS	Robin Woracek	09 Dec 2020

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