TG5/SAR Meeting

ODIN: Scientific Overview of Instrument – High Level Requirements

R. Woracek, A. Tartaglione, R. Ammer, S. Athanasopoulos, S. Schmidt,
T. Chulapakorn, S. Xu, M. Morgano, M. Schulz, M. Strobl, V.M. Monge, B. Peric, E. Luca, E. Calzada
+ support groups

LUND
17 DEC 2025

Scientific Overview of Instrument – High Level Requirements

- ❑ ODIN team & legwork
- ❑ ODIN overview
- ❑ ODIN High Level Requirements
- ❑ ODIN System Requirements

ODIN Team

Michael Lerche (TUM)
Philipp Schmackat (TUM)
Burkard Schillinger (TUM)
& many more...

Aureliano Tartaglione
Scientist

Manuel Morgano
Scientist

Elbio Calzada
Lead Engineer

Jan Hovind
Technician

Virginia Martinez Monge
Installation Engineer

Michael Schulz
Head of Imaging group

Markus Strobl
Head of Imaging group


Shuqi Xu
Post-Doc (LU)

Robin Woracek
Scientist

Bojan Peric
Lead Engineer


Søren Schmidt
Data Scientist


Caroline Curfs
Sample Environment

Egla Luca
Installation Engineer

Stefanos Athanasopoulos
Scientist (LU)


Richard Ammer
Operation Engineer

+ the many ESS colleagues from Choppers, Detectors, Motion, PSS. ECDC, ICS, Integration Support, Vacuum. SAM, Vacuum, CEP, Sample Environment, RP, CUP, NSS support, Rigging, Workshops, Admin, Procurement, in-kind,...

ODIN – legwork

Started over a decade ago…

EUROPEAN SPALLATION SOURCE

MXType.Localized
Document Number MXName
Project Name <<ODIN>>
Date
rinted

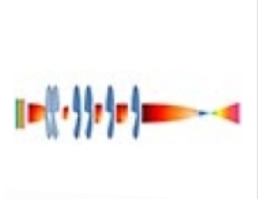
Available online at www.sciencedirect.com
ScienceDirect
Physics Procedia
Physics Procedia 69 (2015) 18 – 26
10 World Conference on Neutron Radiography 5-10 October 2014
The Scope of the Imaging Instrument Project ODIN at ESS
Markus Strobl*

NIUS2012 - ESS Neut
Apr 15 – 18, 2012
Hotel zur Therme, Bad Zurzach
Europe/Zurich timezone
Home
Timetable
Registration
Venue / Accommodation
Home

Meeting Report
OPEN ACCESS
NEUWAVE-12 at ESS: Workshop Series on Wavelength Dependent Neutron Imaging Back in Full Swing

Contents lists a… le
Nuclear Inst. and M…ods i
journal hom…ge: www.elsev
ELSEVIER
Wavelength frame multiplicati… chopper system … neutron-imaging instrument … IN at the Europ…
P. Schmakat [a,b], M. Seifert [a,f], M. S…z [a,b,*], A. Tartaglione [b]
P. Böni [a], M. Strobl [d,c]

Optics Express Vol. 23, Issue 1, pp. 301-311 (2015) • https://doi.org/10.1364/OE.23.000301



Neutron guide optimisation fo… imaging instrument at the Eur…
A. Hilger, N. Kardjilov, I. Manke, C. Zendler, K. Lieutenant, K
Find other works by these authors

ESS Lund …

The NEUWAVE-5 participants met on the ESS-AB (Lund) site expecting positive signs to initiate building the European Spallation Source and neutron imaging facilities in particular.

The 5th Meeting of the NEUWAVE series, promoting energy-selective neutron imaging, took place in Lund, Sweden, in April 2013 coinciding with the acceptance of the neutron imaging instrument project ODIN at the upcoming European … mented at state-of-the-art neutron imaging stations, as well as method development has seen considerable progress. In this framework, pulsed spallation sources become especially attractive for neutron imaging. The time-of-flight (TOF) approach has … beamlines is a central task of workshop. Four different projec… pulsed spallation sources have b… initiated meanwhile resulting in … beamline initiatives:

- ERNIS at J-PARC (Japan)
- IMAT at ISIS-TS 2 (UK)

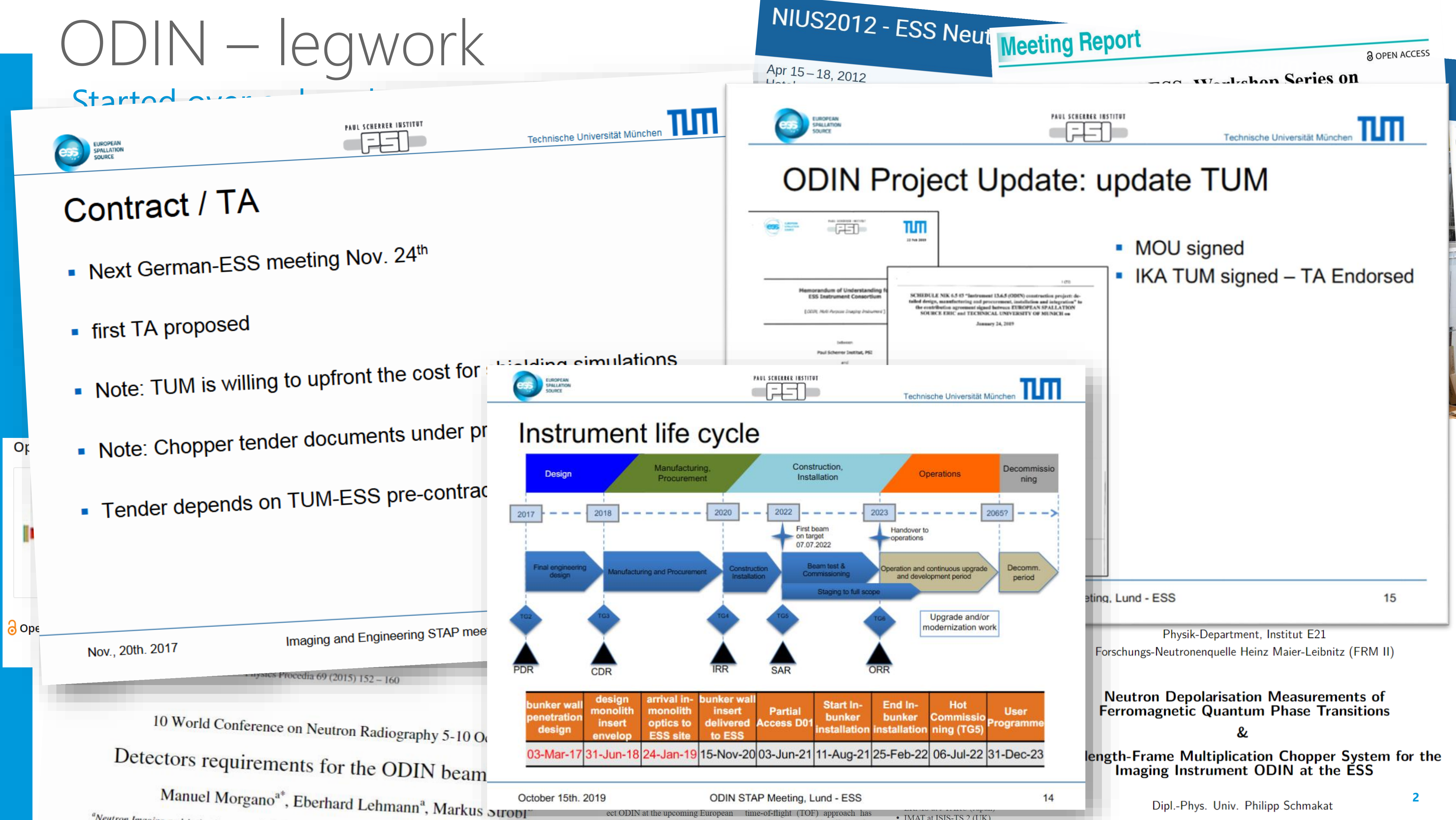
Available online at www.sciencedirect.com
ScienceDirect
Physics Procedia 69 (2015) 152 – 160
Physics Pr…
10 World Conference on Neutron Radiography 5-10 October 2014
Detectors requirements for the ODIN beamline at ES…
Manuel Morgano [a*], Eberhard Lehmann [a], Markus Strobl [b]

Technische Universität München
Physik-Department, Institut E21
Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II)

Neutron Depolarisation Measurements of Ferromagnetic Quantum Phase Transitions & Wavelength-Frame Multiplication Chopper System for the Imaging Instrument ODIN at the ESS

Dipl.-Phys. Univ. Philipp Schmakat

ODIN – legwork

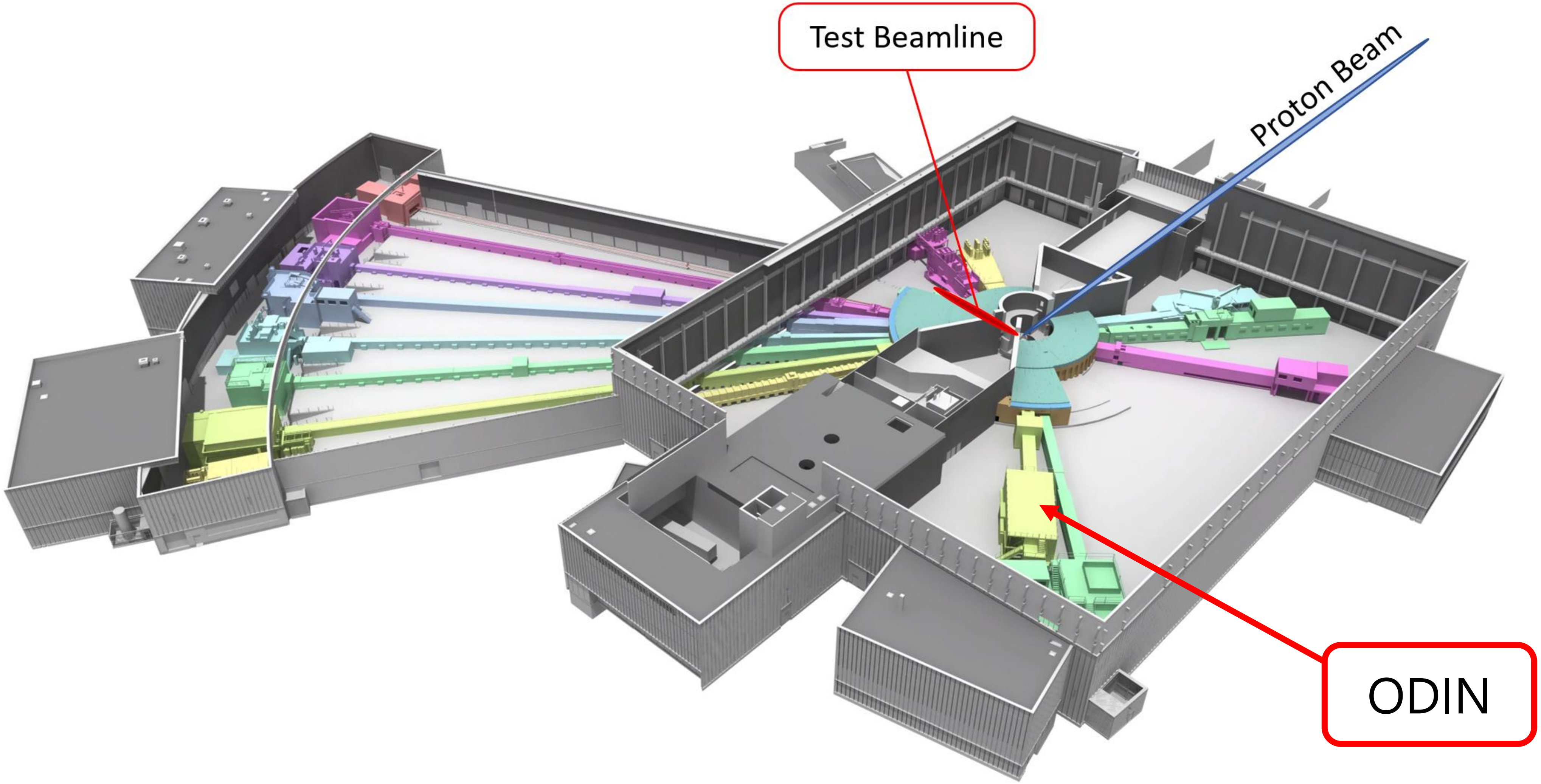


Scientific Overview of Instrument – High Level Requirements

- ❑ ODIN team & legwork
- ❑ ODIN overview
- ❑ ODIN High Level Requirements
- ❑ ODIN System Requirements

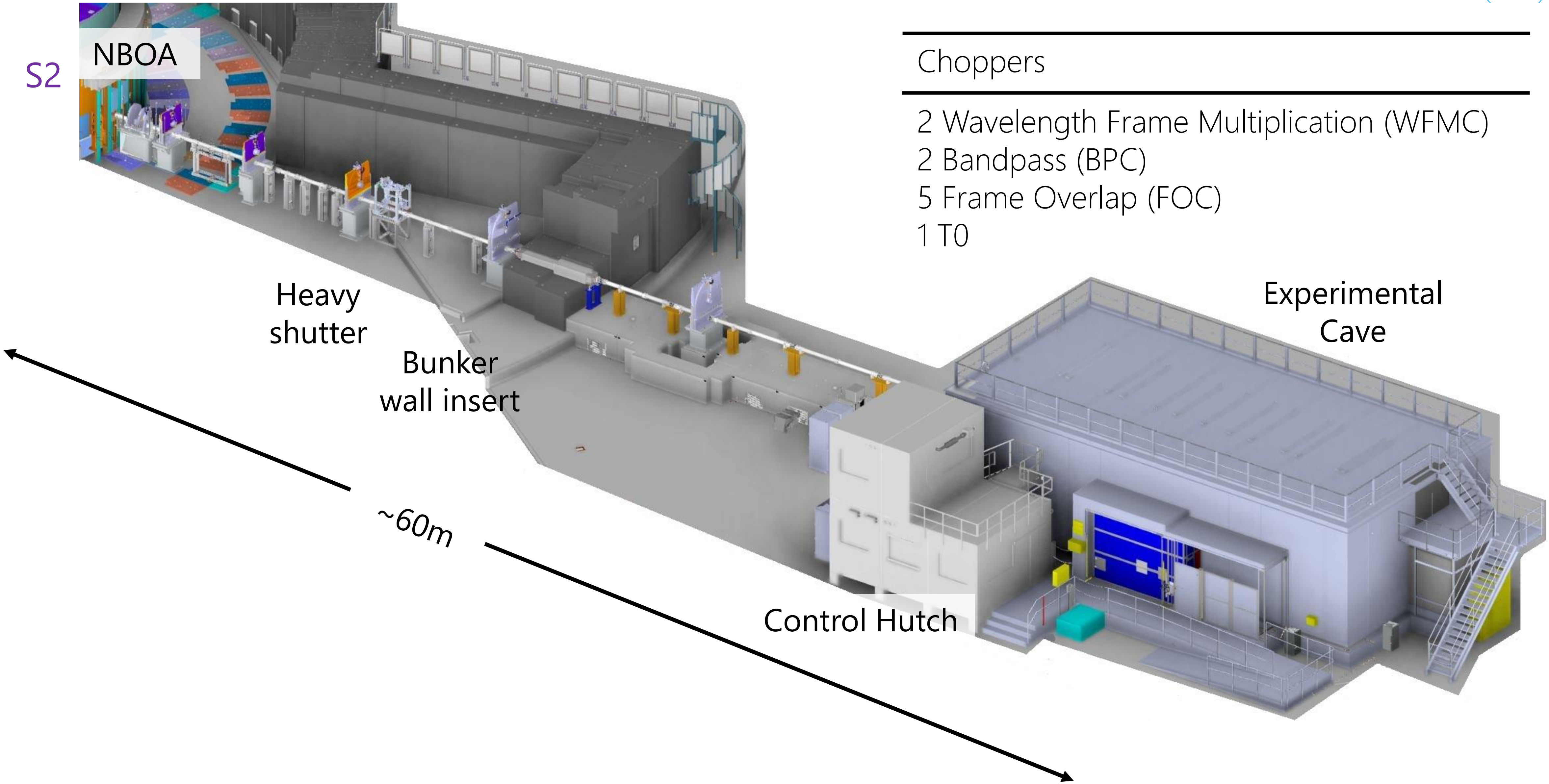
Overview

Location in Facility: S2 (D01)



ODIN

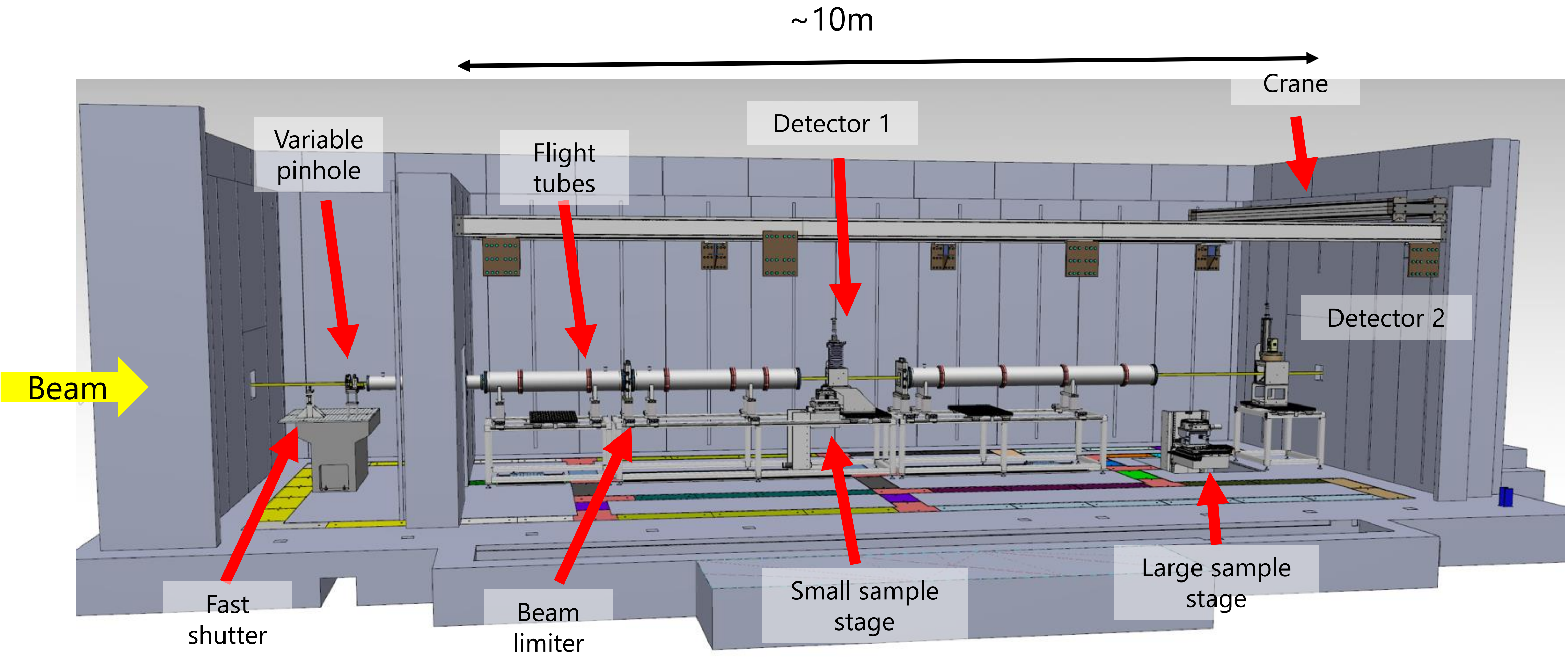
Layout



Choppers
2 Wavelength Frame Multiplication (WFMC)
2 Bandpass (BPC)
5 Frame Overlap (FOC)
1 T0

ODIN

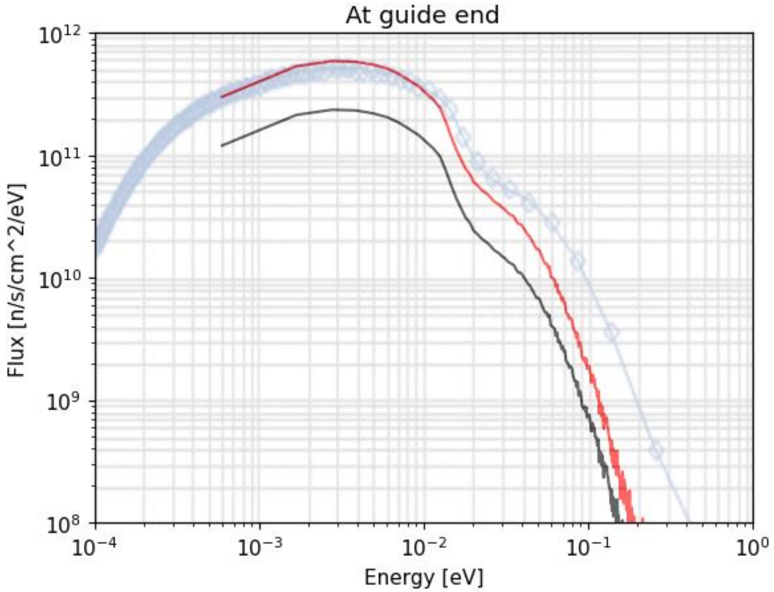
Experimental Cave



ODIN

In brief

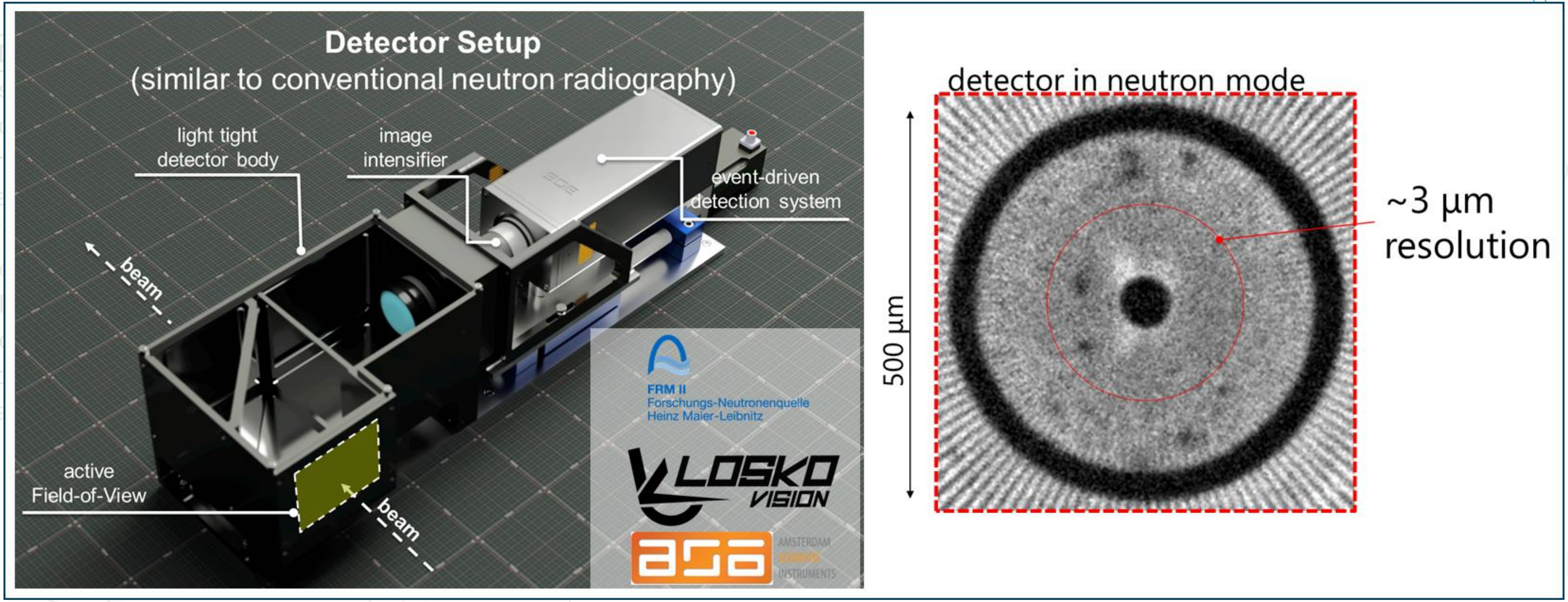
ODIN Quick Facts	
Instrument Class	Imaging
Moderator	Bispectral
Primary Flightpath	50 m (to pinhole)
Secondary Flightpath	2 – 14 m (pinhole to detector)
Wavelength Range	1 – 10 Å
Field of View	20 x 20 cm^2
L/D Ratio	Tunable 300 – 10000
Incident Beam Polarisation	Optional
Polarisation Analysis	Optional
Bandwidth at 14 Hz	4.5 Å

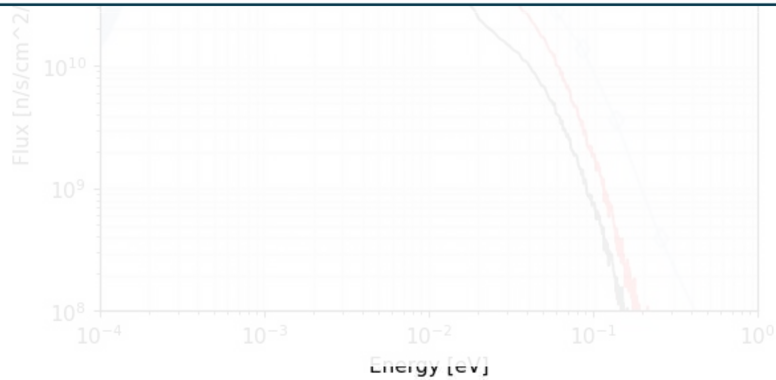


- **Large space**
  - ➢ sample environments
  - ➢ setups *(e.g. polarization, grating interferometry)*
- Bi-spectral extraction
- Direct line-of-sight (T0 chopper)
- **Three main modes:**
  - ➢ White beam
  - ➢ high flux wavelength dispersive (basic ToF)
  - ➢ high resolution wavelength dispersive (WFM)

ODIN

In brief





- **Detectors** (scope of instrument team):
  - ➢ Scintillator CMOS (+optional gating)
  - ➢ LumaCam (Scintillator event mode)
  - ➢ + *Users bring own detectors*

Scientific Overview of Instrument – High Level Requirements

- ❑ ODIN team & legwork
- ❑ ODIN overview
- ❑ ODIN High Level Requirements
- ❑ ODIN System Requirements

2. HIGH LEVEL SCIENTIFIC REQUIREMENTS

2.1. Background

The science case and hence the high-level scientific requirements are based on the imaging modalities that shall be supported by ODIN. The chosen modalities are scientifically most advanced and promising while being able to best exploit the specific strengths of the ESS source. The basic scope that the instrument will fulfil in accordance with the scope setting meeting will not enable all envisioned imaging modalities. However, modalities not available in the basic scope will be implemented at a later point (staging). Therefore, all modalities, basic and staged, are presented here. In addition to staged modalities, which are an integral part of the instrument, some potential upgrade options are described briefly as well.

I. White Beam Imaging with highest spatial and temporal resolution. ESS will provide a time averaged flux comparable to or outperforming current neutron sources. Therefore, ODIN can be enabled to provide the highest resolution for this most common and conventional form of neutron imaging. This will further widen the already broad range of applications in general and in industry in particular.

II. Time of Flight Imaging with adjustable wavelength resolution down to unprecedented accuracy and with adjustable wavelength range: The outstanding brightness of ESS combined with its tuneable time structure allows for tailoring the resolution of time-of-flight (ToF) imaging to specific applications. These techniques, as far as developed, are the main drivers for imaging at pulsed sources so far. This will enable advanced and in-situ studies of materials currently not amenable by any other technique or instrument.

High Level Requirements

2.1.1. Basic Scope

White Beam imaging for various scientific or industrial applications as outlined in *Internal Review – ESS Instrument Construction Proposal – ODIN – Optical and Diffraction Imaging with Neutrons* (ESS-0001483) [1]. The high flux at ESS will enable the study of fast, even non-periodic processes.

Bragg edge imaging for (1) strain mapping, (2) crystalline phase studies, (3) preferred orientation investigations, (4) microstructure studies and (5) grain mapping, which may be combined with diffraction (a potential update): The versatility in wavelength range and the achievable high wavelength resolution will enable advanced and *in-situ* studies of, among others, engineering and functional materials with unprecedented accuracy and detail.

High Level Requirements

2.1.2. Full Scope

I. Polarized neutron imaging (staged) for the investigation of magnetic fields and structures and phenomena in bulk materials: The required wavelength resolution provides ESS with a significant advantage as compared to short pulsed and continuous sources, and the ToF mode enables otherwise not amenable quantifications, potentially up to the full reconstruction of magnetic vector fields in 3D. This will enable the characterisation of magnetic features, which are currently not amenable by any other technique or instrument in bulk condensed-matter.

II. Dark-Field neutron imaging (staged), which enables the observation of (ultra) small angle scattering features of structures beyond direct spatial resolution combined with image resolution: The required wavelength resolution provides ESS with a significant advantage as compared to short pulsed and continuous sources and the ToF mode enables otherwise not amenable small angle scattering quantification of microscopic structures. Two promising methodical approaches are envisaged with the potential to together cover structures from the nanometer to the micrometer scale in addition to the imaging resolution range. This will enable material science characterisations of a vast variety of materials from hard matter to soft matter even in the context of real systems and devices where these length scales and in particular variation of those is not amenable today.

III. Diffraction (potential upgrade) combining imaging with diffraction has the potential to enable advanced *in situ* studies as mentioned 2.1.2 above. However, given the high complexity and cost for a diffraction detector system, this technique is foreseen as a potential upgrade to be considered later.

High Level Requirements

2.2. Top-level requirements for ODIN

Corresponding to 2.1.1 above, the top-level requirements for the basic scope are[1]:

1) ODIN shall be capable of a direct spatial resolution down to 10 µm (3D).
2) ODIN shall allow for time resolutions below 70 ms in kinetic measurements, with a spatial resolution down to 50 µm.
3) ODIN shall allow time resolutions of the order of 1 µs in quasi-stroboscopic mode, with a spatial resolution down to 55 µm.
4) ODIN shall allow measurements of sample areas of up to 20×20 cm^2 at once.
5) ODIN shall allow the detection of contrast equivalent to 10 ppm H_2 in steel, with a spatial resolution down 100 µm.
6) ODIN shall be able to detect relative lattice distortions of the order of 10^{-5}.
7) ODIN shall be capable of visualising crystalline phases with a 3D resolution of at least 100 µm.
8) ODIN shall be able to observe structural phase transitions with a 2D resolution down to 300 µm with a time resolution of 10 s of seconds.
9) ODIN shall be able to observe grains and their orientations with a 3D resolution of at least 100 µm
10) The System's design shall provide the space and flexibility necessary to host and drive future developments in the Neutron Imaging field, including the potential upgrade with diffraction detectors.
11) ODIN should serve the user and science community without interruptions during source operation; all components' service-cycles should be adaptable to the ESS maintenance cycle.

High Level Requirements

Additional top-level requirements for ODIN corresponding to staged imaging modalities, 2.1.2 above, are:

12) ODIN shall be able to detect and quantify structural features down to 10 nm from dark-field contrast imaging with direct spatial resolution of at least 1 mm.
13) ODIN shall be able to characterise magnetic fields and structures with accuracy better than 1 mT.
14) ODIN shall be able to provide complementary x-ray contrast with similar spatial resolution (10 µm) relatable to the neutron data with according accuracy.

What does this mean in practice – for the Science that ODIN can address?

ODIN

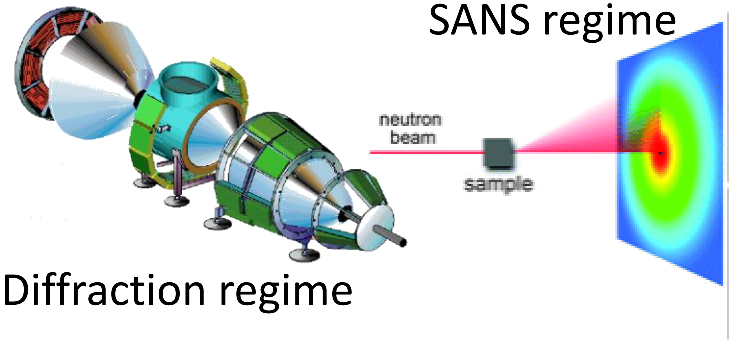
High Level Requirements

Reflectometry

Diffraction — SANS — Imaging

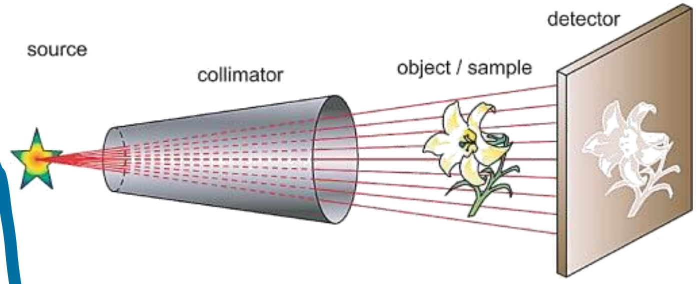
- ‘Contrast’ due to small spatial features
- Usually averaged over several mm^3

SANS regime



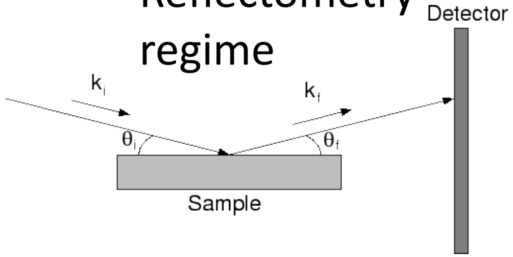
Diffraction regime

Imaging regime



- ‘Contrast’ from larger features resolved in real space with spatial resolution

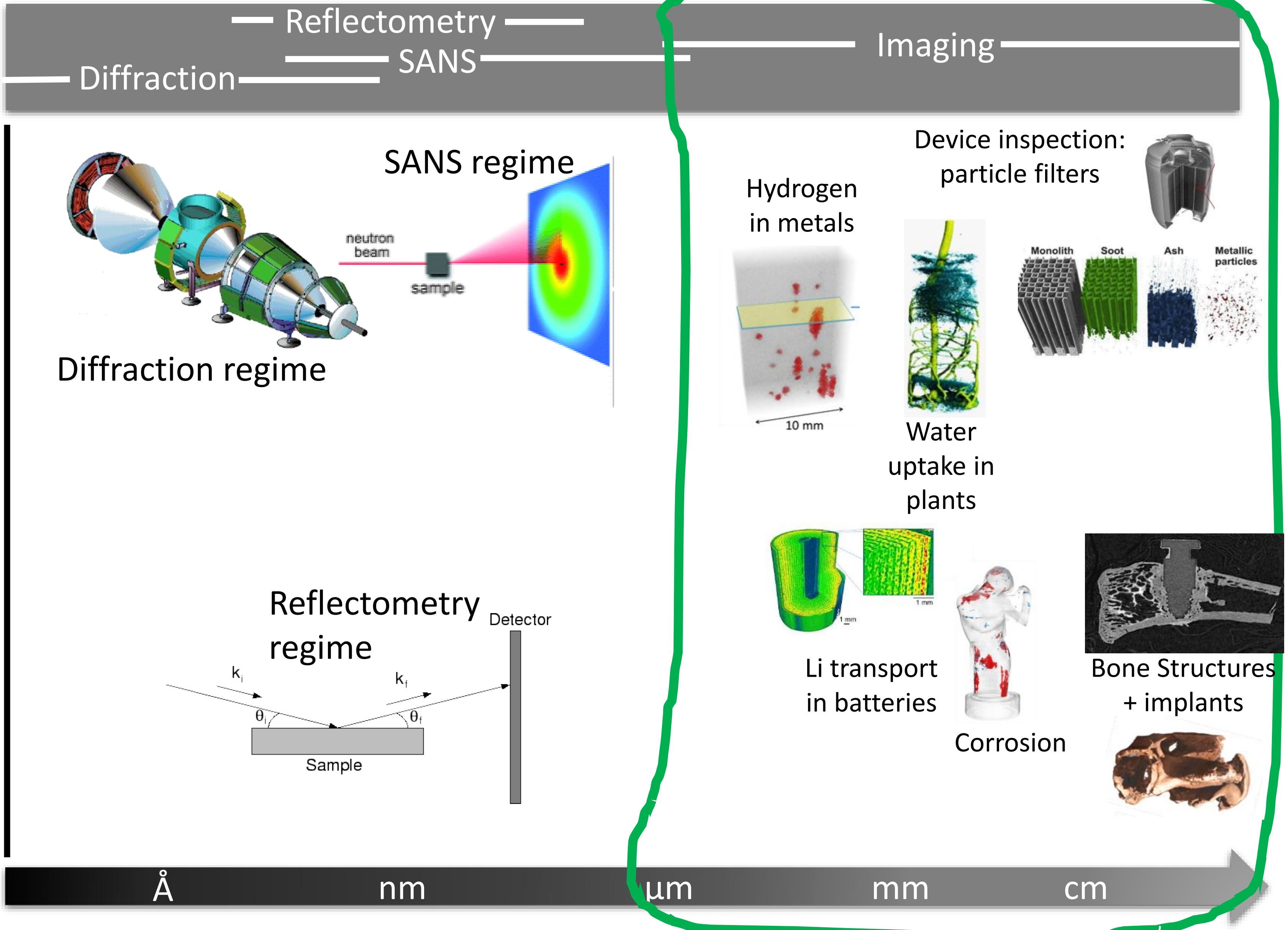
Reflectometry regime



Å — nm — µm — mm — cm

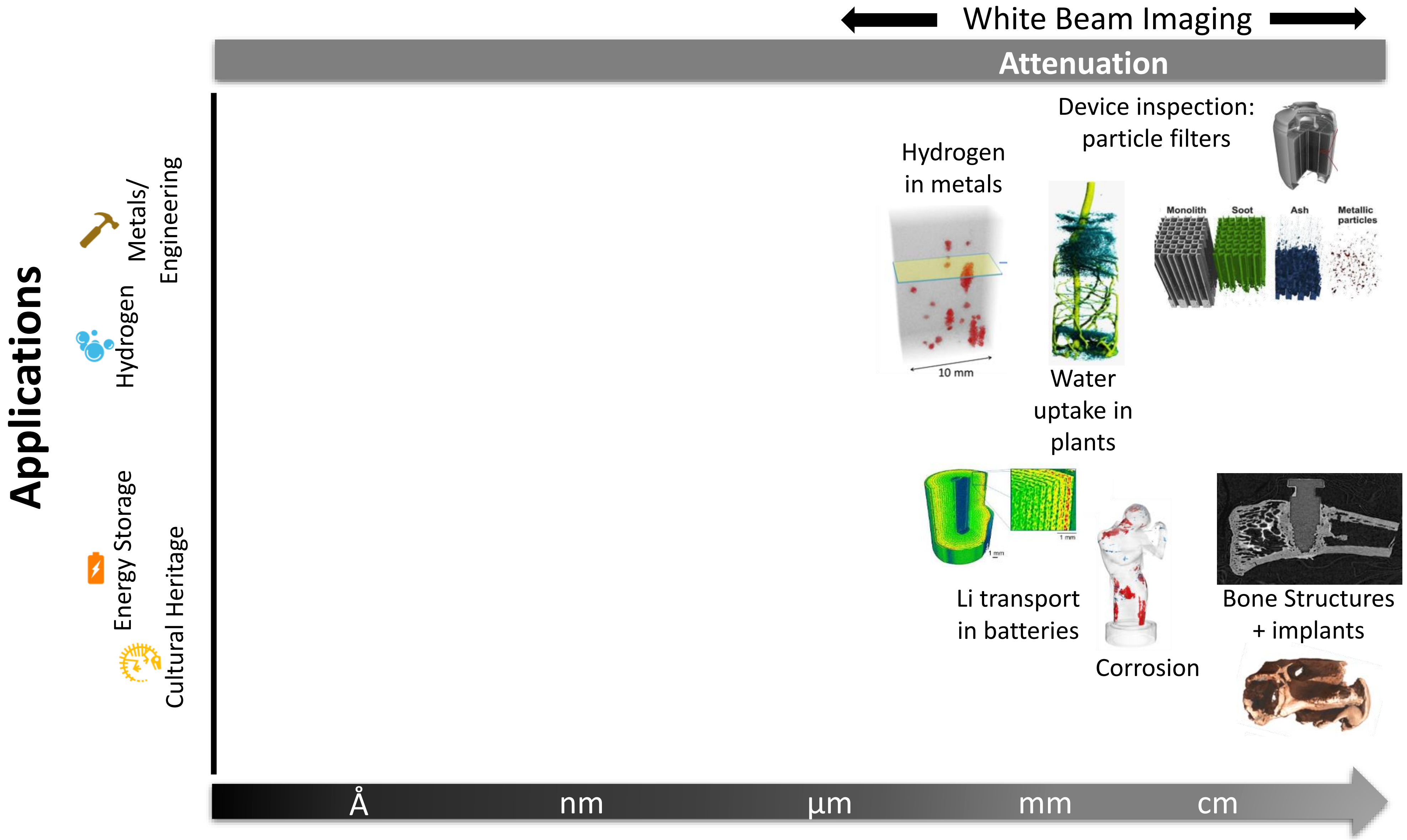
ODIN

High Level Requirements



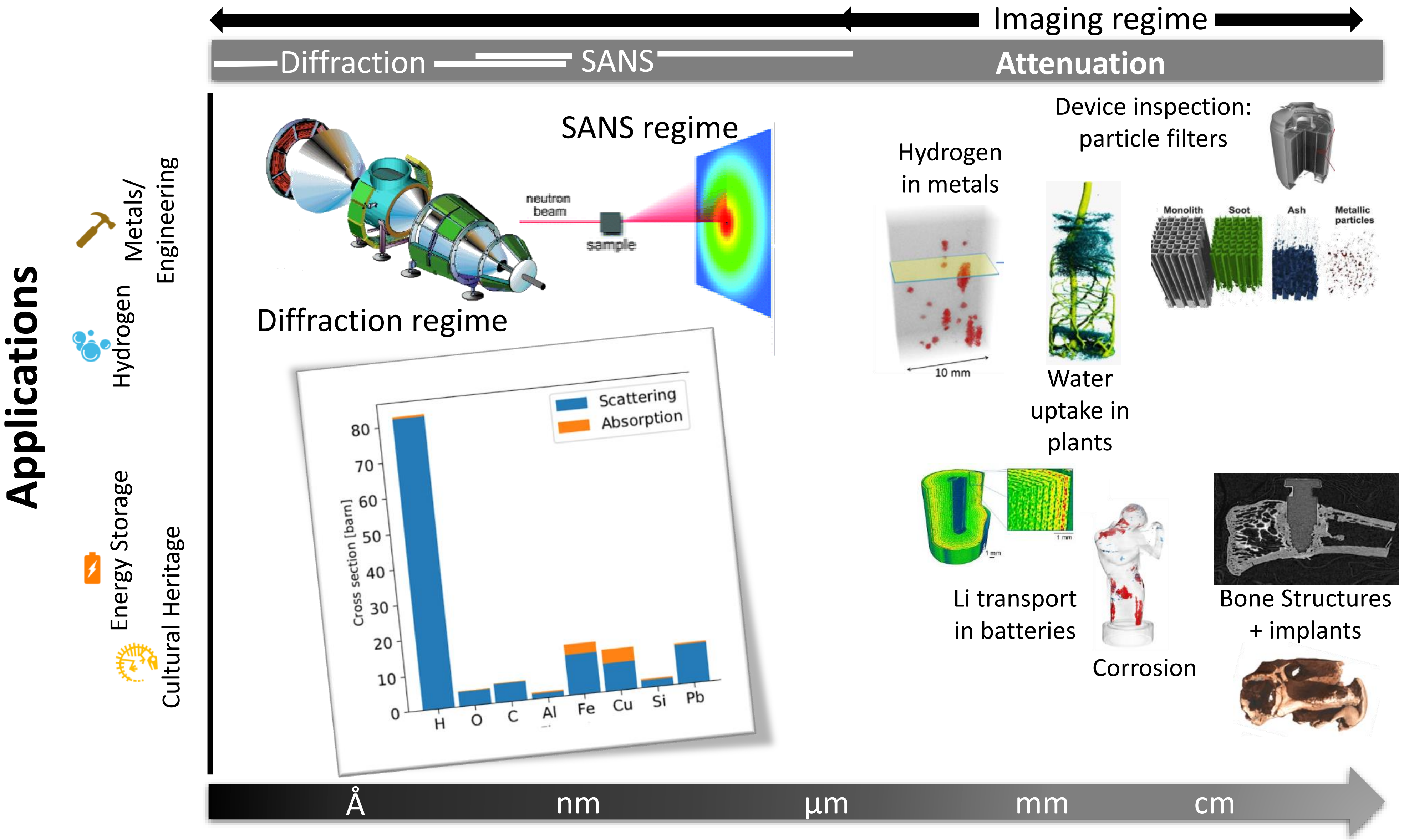
2.1.1. Basic Scope

White Beam imaging for various scientific or industrial applications as outlined in *Internal Review – ESS Instrument Construction Proposal – ODIN – Optical and Diffraction Imaging with Neutrons* (ESS-0001483) [1]. The high flux at ESS will enable the study of fast, even non-periodic processes.



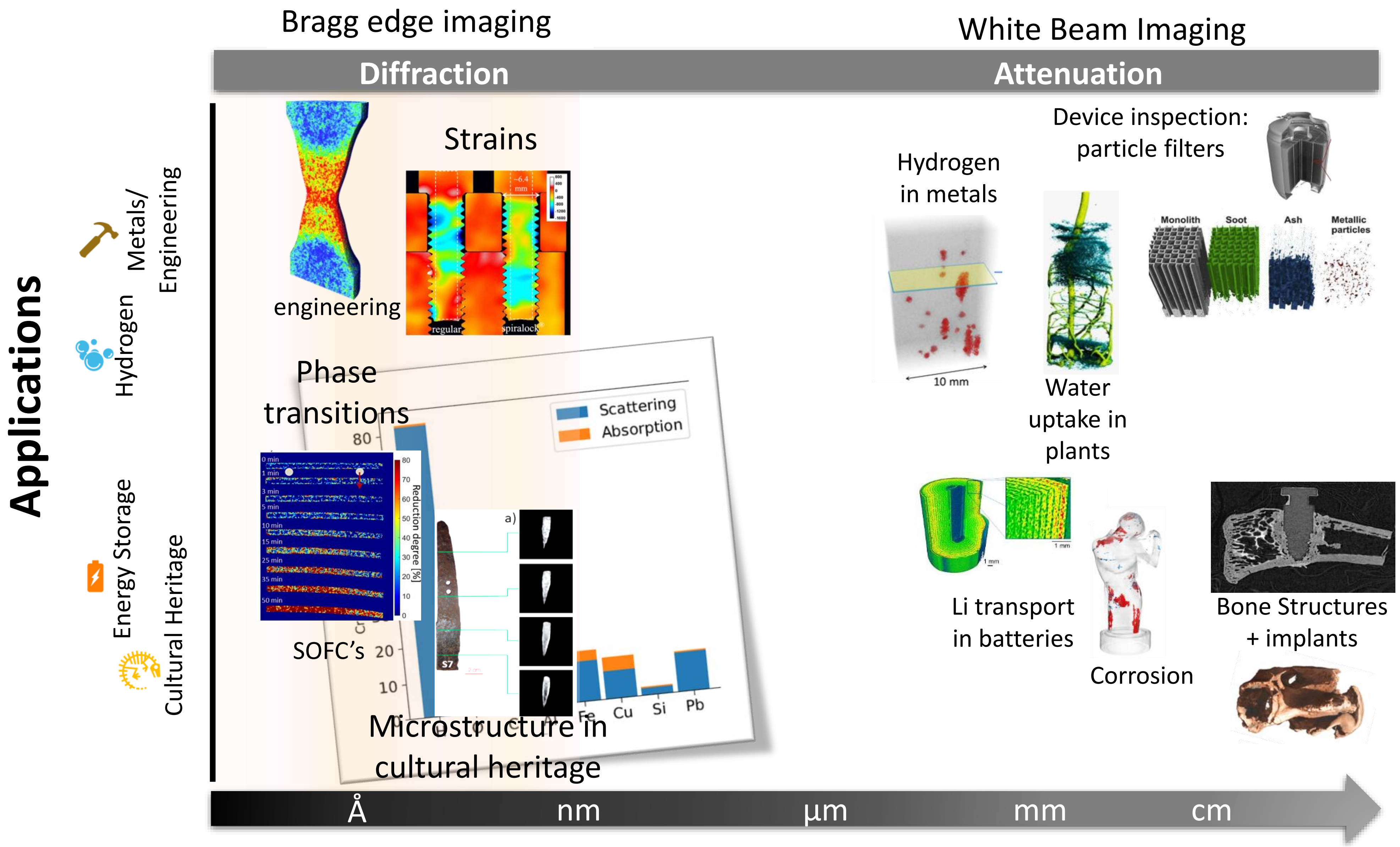
ODIN

High Level Requirements



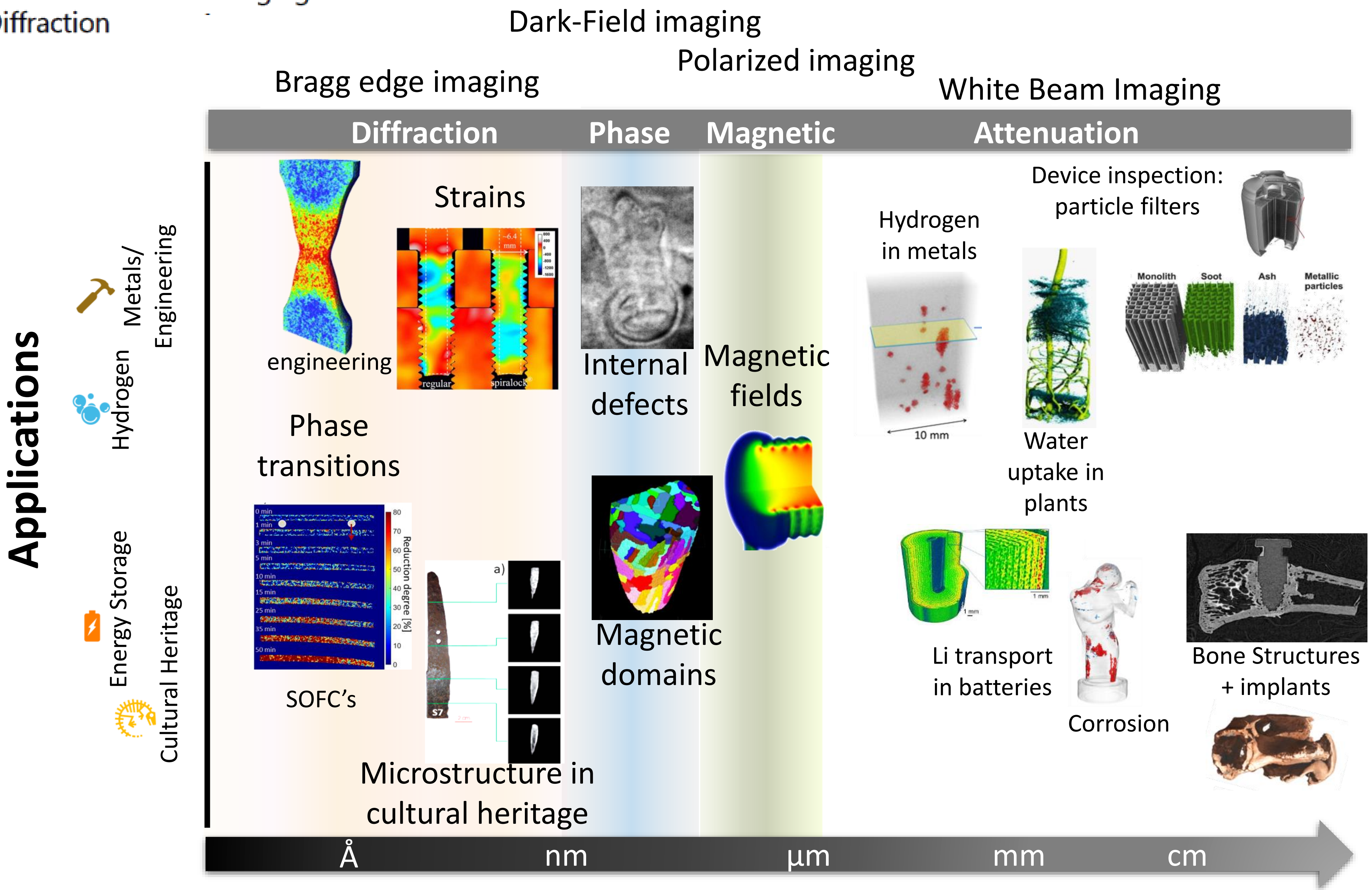
2.1.1. Basic Scope

Bragg edge imaging for (1) strain mapping, (2) crystalline phase studies, (3) preferred orientation investigations, (4) microstructure studies and (5) grain mapping, which may be combined with



2.1.2. Full Scope

I. Polarized neutron imaging
II. Dark-Field neutron imaging
III. Diffraction



What does this mean in practice – What components are needed?

3.4. System overview

3.4.1. General

The conceptual ODIN instrument, see Figure 2, is subdivided into the following generic main functional blocks:

- Neutron guide
- Prompt pulse suppression
- Shielding
- Chopper system
- Shutters
- Cave interior
- Beam manipulation and analysis equipment
- Detectors
- Beam stop
- Personnel Safety System, PSS
- Control hutch
- Instrument control

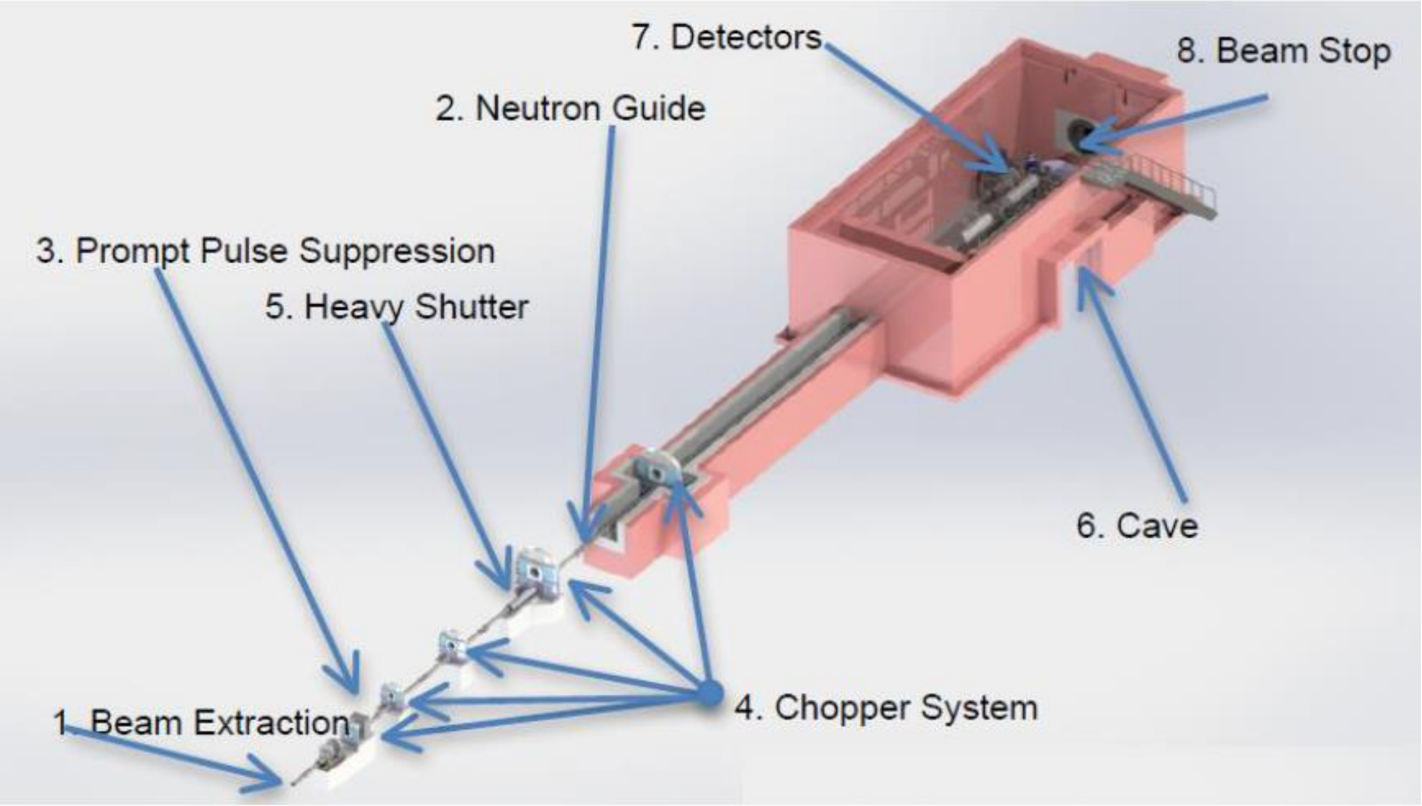


Figure 2 - ODIN conceptual layout

Scientific Overview of Instrument – High Level Requirements

- ❑ ODIN team & legwork
- ❑ ODIN overview
- ❑ ODIN High Level Requirements
- ❑ ODIN System Requirements

ODIN

System Requirement Specification (ESS-0129650)

- **13.6.5 ODIN (Imaging)**
  - 13.6.5.0 ODIN Instrument Integration
  - 13.6.5.1 Beam Transport and Conditioning System
  - 13.6.5.2 Sample Exposure System
  - 13.6.5.3 Scattering Characterization System
  - 13.6.5.5 Experimental Cave
  - 13.6.5.6 Control Hutch
  - 13.6.5.7 Sample Preparation Area
  - 13.6.5.8 Utilities Distribution
  - 13.6.5.9 Support Infrastructure
  - 13.6.5.10 Control Racks
  - 13.6.5.11 Integration Control and Monitoring

2.1.1 Requirements Categories

ESS has organized system requirements in three categories. Ideally they can be separated as follows:

- Functional requirements – generally answering to the "what" is performed by the system
- Constraint requirements (or non-functional requirements) – generally answering to the "how" a function is performed by the system
- Performance requirements – generally answering to the "how well" a function has to perform or "to what extent" a constraint affects the system design

What does this mean in practice –

116 Functional and Constraint Requirements

ODIN

System Requirement Specification (ESS-0129650)

Example: Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

33	Medium ToF Resolution Imaging (MtoFR, 1% wavelength resolution) – FOV for polarized and polarimetric imaging The MtoFR Imaging shall allow for polarized and polarimetric imaging with a FOV at least of 5×5 and 7.5×7.5 cm^2 for different spatial resolutions respectively and polarisation with a wavelength average of 70% between 1 and 10 Å.	ConOps 2.1.: II 2.2.: 13 3.2. & 3.4.9
34	Medium ToF Resolution Imaging (MtoFR, 1% wavelength resolution) – Detector coverage in diffraction geometry The MtoFR Imaging shall allow for additional detector coverage in diffraction geometry (a planned future upgrade).	ConOps 2.1.: II 2.2.: 9 3.2. & 3.4.9
35	High ToF Resolution Imaging (HtoFR, <1% wavelength resolution) – Detector coverage in diffraction geometry The HtoFR Imaging shall allow for additional detector coverage in diffraction geometry.	ConOps 2.1.: II 2.2.: 6,9,10 3.2. & 3.4.9

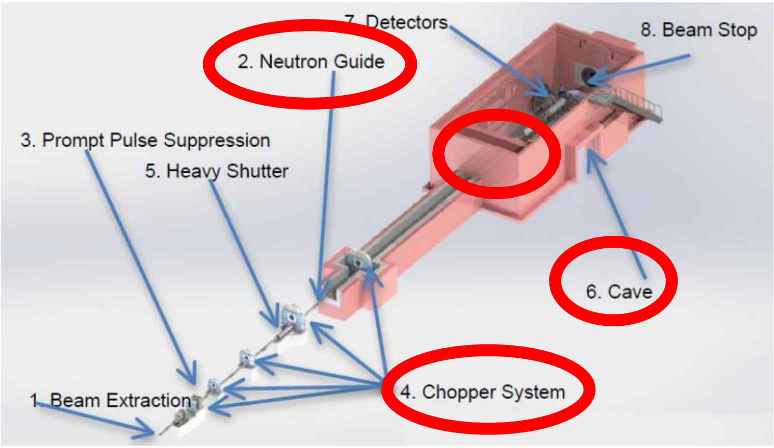


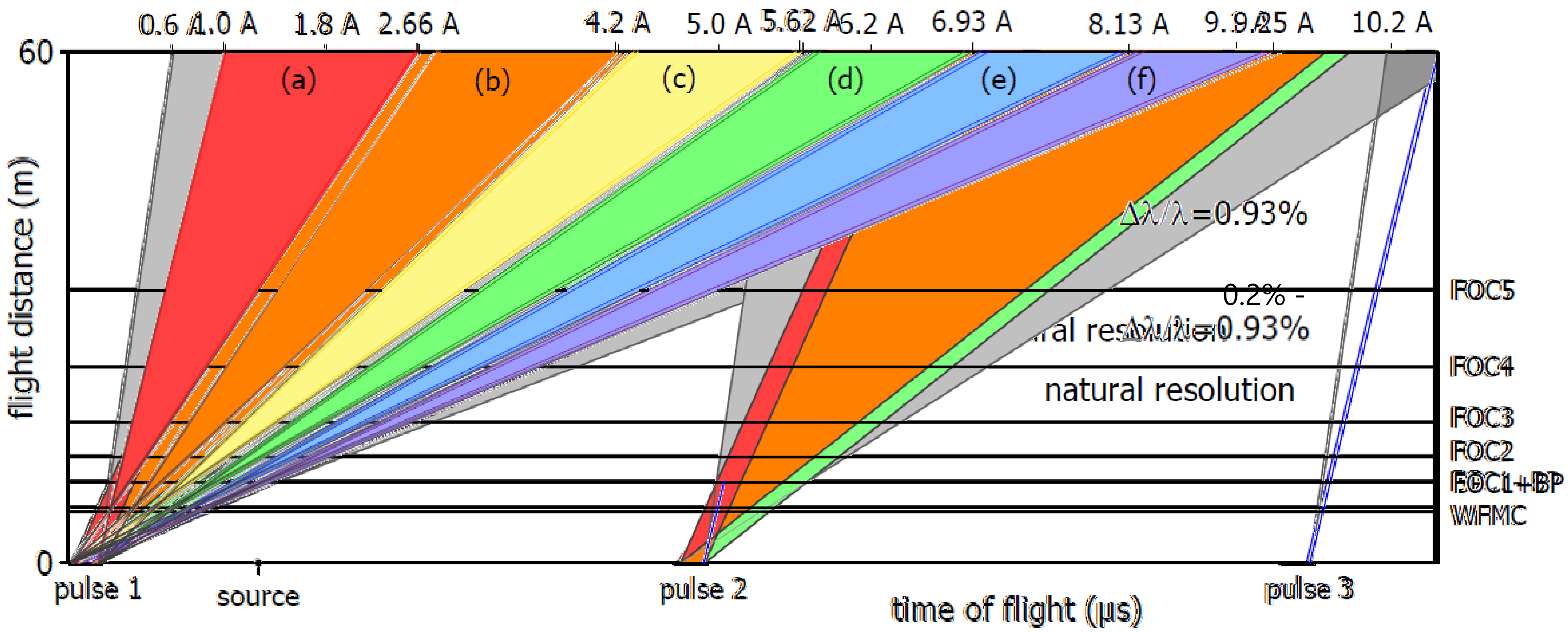
Figure 2 - ODIN conceptual layout

+ Cave Interior

ToF @ ODIN

Possibilities with the long-pulsed source

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1



ODIN

System Requirement Specification (ESS-0129650)

Examples: Sample Exposure System, SES – PBS 13.6.5.2

39	SES Tomography axis alignment The SES shall offer the capability to align the rotation axis within the image resolution requirements, ideally about 1 μm.	ConOps 2.1. & 3.2. 3.4.7. & 5.
40	SES longitudinal positioning The SES shall offer the possibility to perform corresponding measurements along the positions foreseen for sample exposure, i.e. from about 1 m to up to 14 m from the pinhole position, with mm accuracy.	ConOps 2.1. 3.2. 3.4.7. & 5.
41	SES maximum weight capacity The SES shall be able to handle samples up to 1000kg.	ConOps 2.1. & 3.2. 3.4.7. & 5.
42	SES control All remotely controlled alignment of the SES shall be possible from the control hutch but also from within the cave, i.e. in close vicinity (visual control) of the SES.	ConOps 2.1. & 3.2. 3.4.7. & 5.

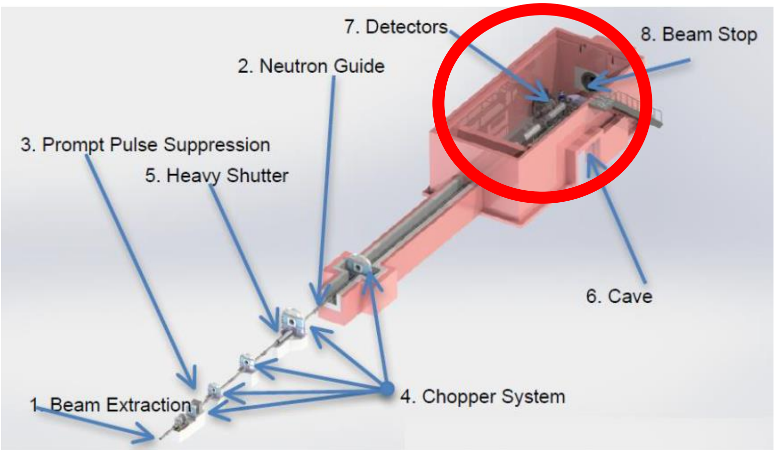


Figure 2 - ODIN conceptual layout

Cave Interior

Was long discussion topic and now will be possible via laptop/tablet -> *NIT-611 to track*

THANK YOU!

ODIN

System Requirement Specification (ESS-0129650)

2.2 Functional Requirements

The following sections breakdown the high-level scientific requirements to requirements that the major subsystems need to fulfil.

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

Id	Text	Trace up to
1	Wavelength Transportation – Range The BTCS shall be optimised [1] to transport neutrons with wavelength from 1 Å to 20 Å from the thermal and cold moderator surfaces (a wavelength-averaged brilliance transfer higher than 40% as compared to the benchmark of an optics-less pinhole set-up with 6.5 m source to pinhole and L=10 m pinhole to detector)	ConOps 2.1.: I-II; 2.2.: 2,5-10, 12,13 3.2., 3.4.2
2	Field of View – Transported Divergence The BTCS shall be able to illuminate an area up to 20×20 cm^2 at L=14 m	ConOps 2.1.: I; 2.2.: 4,11 3.2. & 3.4.2
3	Beam Divergence – Profile The wavelength dependent divergence transported by the BTCS shall allow for homogeneous (75%) illumination of the FOV.[1]	ConOps 2.1.: I; 2.2.: 1,2,4,5, 11 3.2. & 3.4.2

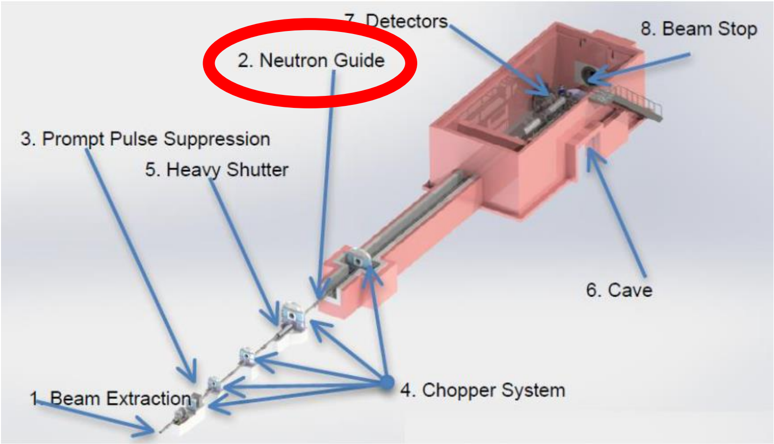


Figure 2 - ODIN conceptual layout

ODIN

System Requirement Specification (ESS-0129650)

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

4	Wavelength Resolution and Selection – Wavelength Range The BTCS shall be able to provide various selectable wavelength resolutions from smaller than 0.4% to bigger than 10%.	ConOps 2.1.: II; 2.2.: 6-13 3.2.
5	Wavelength Resolution and Selection – Natural Resolution A standard detector position shall be at 60m from the moderator to profit from a “natural resolution” [2] of 10% at 2 Å.	ConOps 2.1.: II; 2.2.: 7,8, 10-12 3.2.
6	Wavelength Resolution and Selection – Pulse Shaping For the detector position of 60m the BTCS shall allow pulse shaping to tune the wavelength resolution constantly for all wavelengths between 1 and 9 Å continuously from 1% to ≤ 0.4%	ConOps 2.1.: II; 2.2.: 6-13 3.2. & 3.4.7

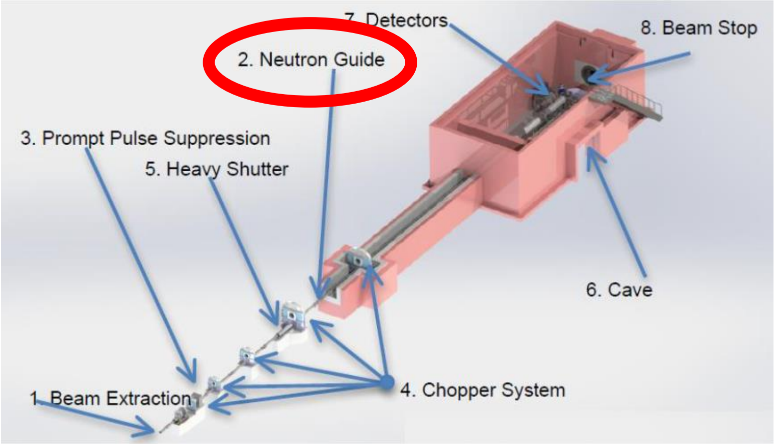


Figure 2 - ODIN conceptual layout

ODIN

System Requirement Specification (ESS-0129650)

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

Id	Text	Trace up to
7	Collimation - Flight Path (L) The BTCS shall allow for a collimation path L from pinhole (D) to detector of up to at least 10m extendable up to 14m while avoiding air scattering.	ConOps 2.1.: I-II; 2.2.: 8-12 3.2. & 3.4.7.
8	Collimation – Pinhole Position The BTCS shall have a pinhole at 50 m.	ConOps 2.1.: II; 2.2.: 7,8, 10-12 3.4.2 & 3.4.7
9	Collimation – Pinhole Size, fixed The BTCS shall have at least 6 settings of the pinhole size covering 0-30 mm range.	ConOps 2.1. & 2.2. 3.2 & 3.4.7
10	Beam Collimation – L/D Ratio The BTCS shall allow for collimation ratios (L/D; L and D being pinhole to detector distance and pinhole diameter, respectively) to be chosen between 100 and 10000.	ConOps 2.1. & 2.2. 3.2. & 3.4.7 5.

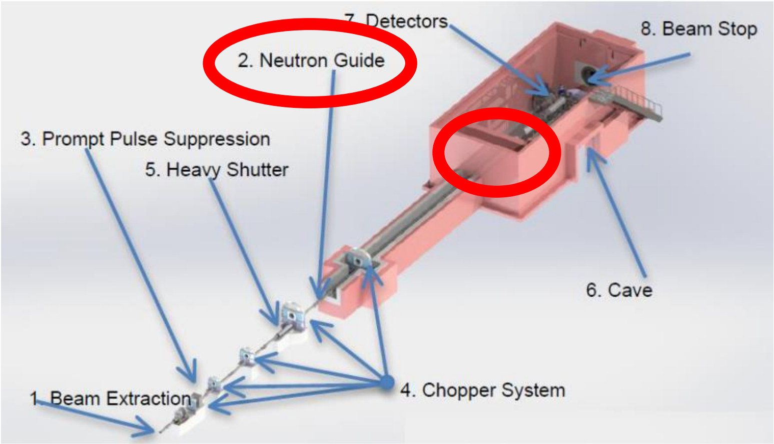


Figure 2 - ODIN conceptual layout

+ Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

11	Beam Size Selection – continuous variation BTCS shall be able to continuously reduce the maximum beamsize at any given distance of L.[3]	ConOps 2.1. & 2.2. 3.2. & 3.4.7
12	Bandwidth Selection The “natural” usable wavelength bandwidth at the 60 m detector position is about 4.5 Å. The BTCS shall be able to use an unlimited bandwidth allowing frame overlap as well as at least the double natural bandwidth without frame overlap.	ConOps 2.1. & 2.2. 3.2.
13	Operation Mode Changes – Remote Mode Switching Modes of operation concerning components upstream of the pinhole (and the pinhole system itself) shall be remotely configurable (during operation).	ConOps 2.2.: 15 3.2. & 3.4.5. 3.4.7. & 5.
14	Operation Mode changes – BTCS access requirements during switching The BTCS downstream of the pinhole shall be accessible for configuration during protons on target (target operation).	ConOps 3.2. & 3.4.6., 3.4.7. 3.4.11. & 5
15	White Beam Imaging – FoV The BTCS shall allow white beam imaging using the full range of sizes of the field of view.	ConOps 2.1.: I 2.2.: 4,10 3.2.1 & 3.4.7

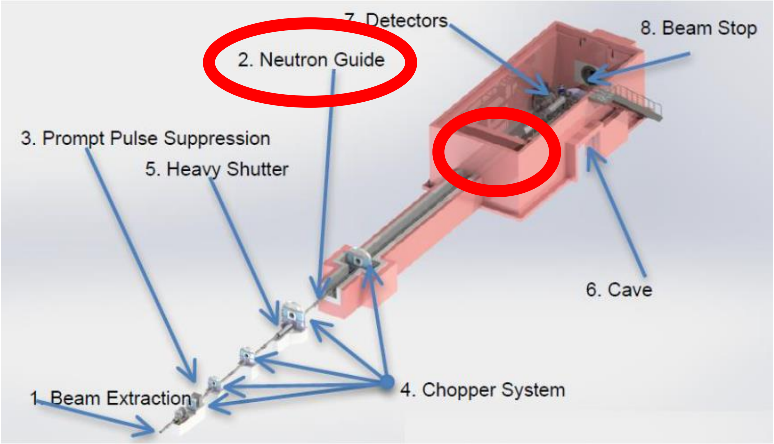


Figure 2 - ODIN conceptual layout

+ Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

Id	Text	Trace up to
16 ✓	White Beam Imaging – Spectrum range White beam imaging shall be possible utilising the full beam spectrum transported and any selected fraction of it.	ConOps 2.1.: I 2.2.: 4,10 3.2.1
17 ✓	White Beam Imaging – Spatial resolution White beam imaging shall be possible with spatial resolutions down to at least 10 µm on a limited field of view (approximately 5×5 cm^2 for best resolution).	ConOps 2.1.: I 2.2.: 4,10 3.2.1
18 ✓	Low ToF Resolution Imaging (LtoFR, natural wavelength resolution) – Maximum Field of View/resolution The BTCS shall allow LtoFR imaging using a maximum field of view of at least 5×5 cm^2 with high spatial resolution.	ConOps 2.1.: II 3.2. & 3.4.8
19 ✓	Low ToF Resolution Imaging (LtoFR, natural wavelength resolution) – FOV/resolution The BTCS shall allow LtoFR imaging using the full range of sizes of FOV with a spatial resolution relaxed to the mm range.	ConOps 2.1.: II 3.2. & 3.4.9
20 ✓	Low ToF Resolution Imaging (LtoFR, natural wavelength resolution) – Bandwidth The BTCS shall allow LtoFR Imaging to be possible using the natural bandwidth, double the natural bandwidth anywhere between wavelengths of 1 and 20 Å	ConOps 2.1.: II 2.2.: 7,8,12 3.2. 3.4.2 & 3.4.5

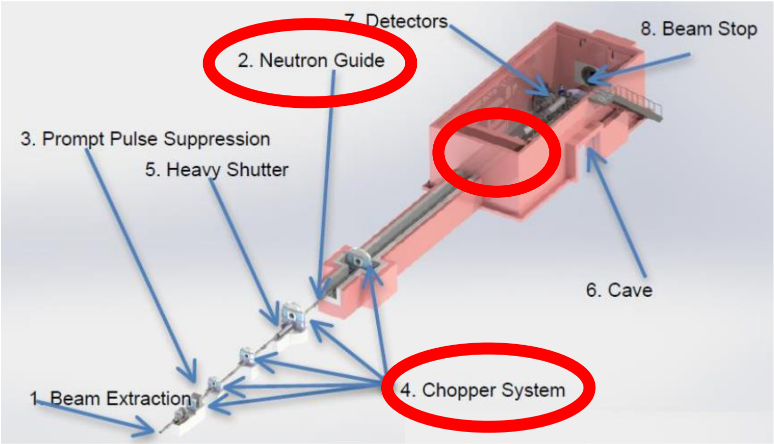


Figure 2 - ODIN conceptual layout

+ Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

21	Low ToF Resolution Imaging (LtoFR, natural wavelength resolution) – Spatial Resolution The BTCS shall allow LtoFR Imaging with spatial resolution at least 100 µm on a limited field of view (approximately 5×5 cm^2).	ConOps 2.1.: II 2.2.: 7,8,12 3.2 & 3.4.9
22	Medium ToF Resolution Imaging (MtoFR, 1% wavelength resolution) – Maximum Field of View The BTCS shall allow MtoFR imaging using a maximum field of view of at least 5×5 cm^2 with high spatial resolution of at least 100 mm and using the full range of sizes of FOV with a spatial resolution relaxed to the mm range.	ConOps 2.1.: II 2.2.: 7-11,13 3.2. 3.4.9
23	Medium ToF Resolution Imaging (MtoFR, 1% wavelength resolution) – Bandwidth, shortest wavelength The BTCS shall allow MtoFR Imaging being possible using the natural bandwidth and double the natural bandwidth starting at 1 Å.	ConOps 2.1.: II 2.2.: 7-11,13 3.2. & 3.4.5
24	Medium ToF Resolution Imaging (MtoFR, 1% wavelength resolution) – Spatial Resolution The BTCS shall allow MtoFR Imaging with spatial resolution at least 100 µm on a limited field of view (approximately 5×5 cm^2).	ConOps 2.1.: II 2.2.: 7-11,13 3.2. & 3.4.9

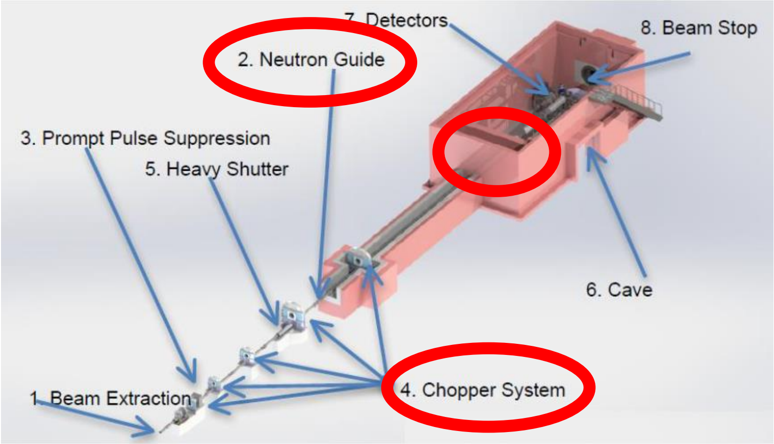


Figure 2 - ODIN conceptual layout

+ Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

2.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

Id	Text	Trace up to
25	High ToF Resolution Imaging (HtoFR, <1% wavelength resolution) – Maximum Field of View The BTCS shall allow HtoFR imaging using a maximum field of view of at least 5×5 cm^2 with high spatial resolution or using the full range of sizes of FOV with a spatial resolution relaxed to the mm range.	ConOps 2.1.: II 2.2.: 6,9 3.2. & 3.4.9
26	High ToF Resolution Imaging (HtoFR, <1% wavelength resolution) – Bandwidth, shortest wavelength The BTCS shall allow HtoFR Imaging shall be possible using the natural bandwidth starting between 1 Å and 3 Å.	ConOps 2.1.: II 2.2.: 6,9 3.2. & 3.4.5
27	High ToF Resolution Imaging (HtoFR, <1% wavelength resolution) – Spatial Resolution The BTCS shall allow HtoFR Imaging with spatial resolution at least 100µm on a limited field of view (approximately 5×5 cm^2).	ConOps 2.1.: II 2.2.: 6,9 3.2. & 3.4.9
28	Beam Monitoring The BTCS shall allow for monitoring the beam flux with a wavelength resolution of <0.3% at 9, 33 and 50 m downstream the moderator under any operation condition.	ConOps 2.1.: I, II 2.2.: 2,3,5,8, 10,11 3.2.
29	Background The fast neutron and gamma background shall not exceed signal to background values in the white beam mode and shall not exceed a 1% level in any time channel for the best HtoFR with an MCP detector from UC Berkeley. The latter can be relaxed if reliable background correction is possible. Background level refers to measured background assuming current state of the art detectors.	ConOps 2.1.: I, II 2.2.: 2,3,5,6, 8-10 3.4.3. 5.3.3

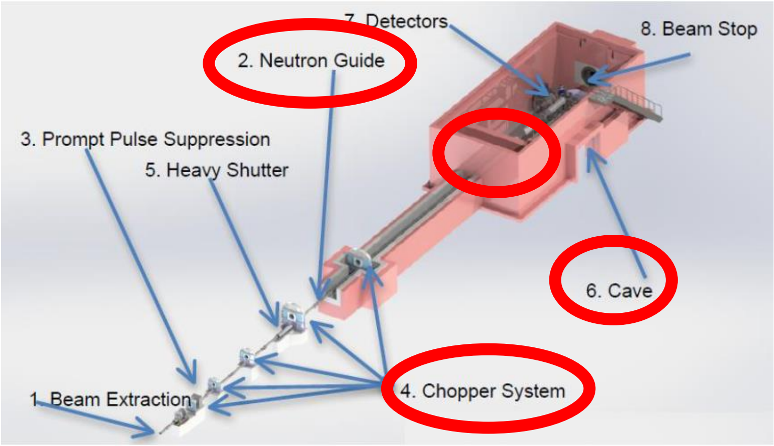


Figure 2 - ODIN conceptual layout

+ Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

BTCS requirements below refer to imaging modalities foreseen for staging. In order to ensure an instrument that can host these imaging techniques in a straightforward fashion, corresponding requirements are listed.		
Id	**Text**	**Trace up to**
30	White Beam Imaging – Depolarisation imaging The White beam Imaging shall allow for depolarisation imaging and polarisation and analyser efficiencies with a wavelength average of 70% between 1 and 20 Å.[4]	ConOps 2.1.: I 2.2.: 13 3.2.1 & 3.4.8
31	Low ToF Resolution Imaging (LtoFR, natural wavelength resolution) – FOV for grating interferometry The LtoFR Imaging shall allow for grating interferometry with a FOV of at least 5×5 and 7.5×7.5 cm^2 for different spatial resolutions respectively.[4]	ConOps 2.1.: II 2.2.: 12 3.2. 3.4.8 & 3.4.9
32	Low ToF Resolution Imaging (LtoFR, natural wavelength resolution) – FOV for SEMSANS imaging The LtoFR Imaging shall allow for SEMSANS Imaging with a FOV of at least 5×5 cm^2.[4]	ConOps 2.1.: II 2.2.: 12 3.2. 3.4.8 & 3.4.9

In NSS-Polarization WP

1st Science Post-Doc in collaboration with FRM2

VR ISIS grant awarded

ODIN

System Requirement Specification (ESS-0129650)

2.2.2 Sample Exposure System, SES – PBS 13.6.5.2

Id	Text	Trace up to
36	SES – Alignment The SES shall have the capability to align small and large samples including their sample environment for measurements with the respective required size and resolution of a study (i.e. down to 1 µm).	ConOps 2.1. 3.2. 3.4.7. 5.
37	SES Positioning The SES shall offer the capability to perform positioning across the beam remotely for scans with a precision of up to 1 µm.	ConOps 2.1. & 3.2. 3.4.7. & 5.
38	SES Tomography The SES shall offer the capability for remotely controlled tomographic scans, i.e. rotations around the z axis (360°) with the accuracy of the image resolution requirements: 0.005°	ConOps 2.1. 3.2. 3.4.7. & 5.

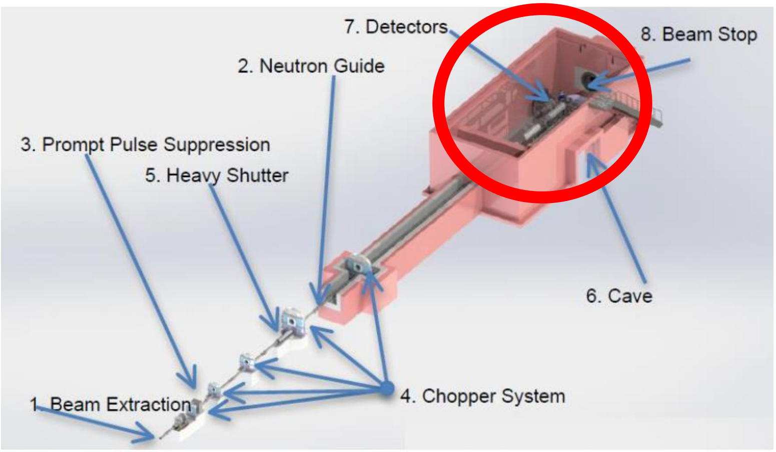


Figure 2 - ODIN conceptual layout

Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

2.2.3 Scattering Characterization System, SCS – PBS 13.6.5.3

Id	Text	Trace up to
43	The SCS system shall enable the fulfilment of the High-level scientific requirements for the instrument. It shall detect the beam according to the beam transport and condition requirements defined for the BTCS in terms of size, spatial resolution, time resolution, instrument configurations and modes etc. As no one detection system can fulfil all requirements the instrument shall include a number of detectors that best fulfil all the above requirements. The detector suite shall satisfy the minimum requirements as defined below.	ConOps 2.1. 3.2. 3.4.9. 5.
44	Detector Area The SCS shall provide detector areas of up to at least 20×20 cm^2.	ConOps 2.1.& 2.2: 4,11 3.2.
45	Spatial resolution The SCS shall provide effective resolutions of down to at least 10 µm but should reach values of the order of 1 µm.	ConOps 2.1. 2.2: 1,10,11 3.2.

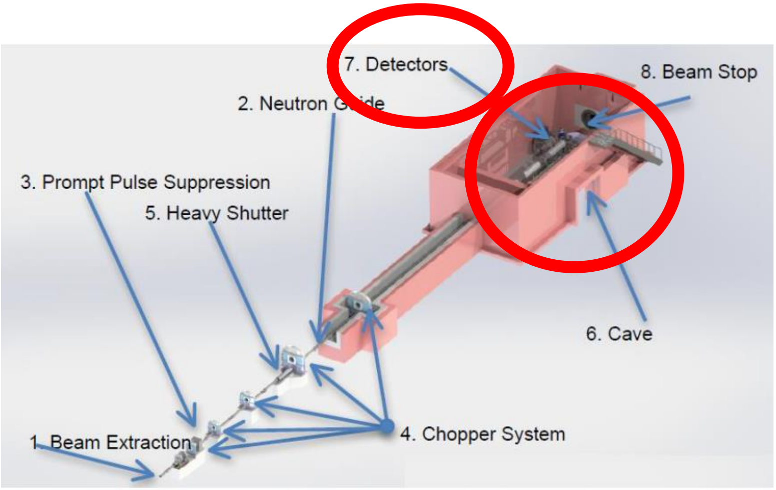


Figure 2 - ODIN conceptual layout

Cave Interior

Detectors at RADEN-JPARC

Counting type (µNID, nGEM, LiTA) (see Table IV)
Camera-type (^{6}LiF + ZnS scintillator + CCD, EM-CCD, sCMOS)

ODIN

System Requirement Specification (ESS-0129650)

46	Time resolution – ToF Imaging The SCS shall provide detector time resolutions down to the ns range (sub-μs range) for ToF imaging measurements.	ConOps 2.1.: II 2.2: 3,6-13 3.2. & 3.4.9.
47	Time resolution – Kinetic Imaging The SCS shall provide detector time resolutions down to ~70 ms for kinetic imaging applications.	ConOps 2.1. & 2.2: 2 3.2.
48	Time resolution – Stroboscopic measurements The SCS shall provide detector time resolutions of at least 10ns to allow stroboscopic measurements with time resolutions around 1 μs.	ConOps 2.1. & 2.2: 2 3.2.
49	Efficiency – Lower acceptable limit Detection efficiency of the SCS shall not fall below 30% at 4 Å for any specific detector system.	ConOps 2.1. 3.2. & 3.4.9.
50	Efficiency – Optimal minimum Detection efficiency of the SCS shall in optimum case reach at least 90% at 4 Å.	ConOps 2.1. 3.2. & 3.4.9.
51	Efficiency – Ambition The detection efficiency of the SCS shall be optimum according to the state of the art available in 2019/20.	ConOps 2.1. 3.2. & 3.4.9.

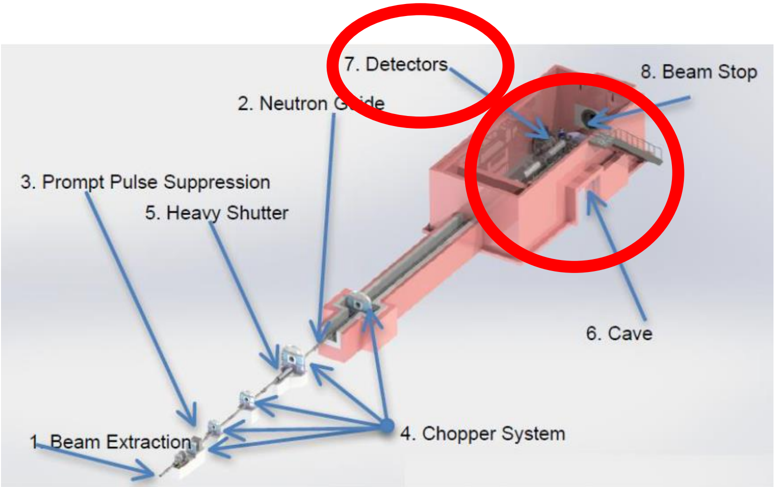


Figure 2 - ODIN conceptual layout

Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

52	**Count rate – Limitation and Decay** The detectors should have no count rate limitation and corresponding efficiency decay.	ConOps 2.1. 3.2. & 3.4.9.
53	**Count rate – Local minimum** Detectors shall reach values of $10^8 cm^{-2}s^{-1}$, for local count rates and corresponding integrated count rates over their respective detection area. That should even apply for systems used for ToF	ConOps 2.1. 3.2. & 3.4.9.
54	**Count rate – Local optimum** Detectors should in optimum case allow for local count rates and corresponding integrated count rates over their respective detection area of higher than $10^{10} cm^{-2}s^{-1}$.	ConOps 2.1. 3.2. & 3.4.9.
55	**Gamma Sensitivity** The gamma sensitivity of SCS systems shall be at least as low as the state of the art of specific currently used systems for corresponding applications. (A minimum requirement should potentially be defined for each specific system based on the current choice and the corresponding state of the art.)	ConOps 2.1. 3.2. 3.4.9.

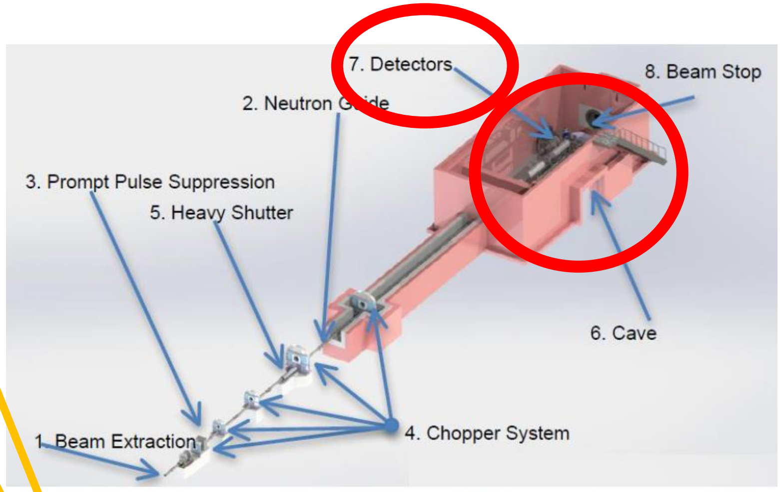


Figure 2 - ODIN conceptual layout

Cave Interior

Highly dependent on the detector settings and configuration.

ODIN uses the best available technology. To fulfill these requirements, a range of detectors is needed.

ODIN

System Requirement Specification (ESS-0129650)

56 ✓	Background Noise The background noise (read out noise) of specific SCS detection systems shall be at least as good as the state of the art of specific currently used systems for corresponding applications.	ConOps 2.1. 3.2. & 3.4.9.
57 ✓	Space requirement The active detection area of every SCS detection systems shall be possible to be placed not more than 10 mm from the closest surface of a sample or any sample environment respectively at very foreseen position of the SES.	ConOps 2.1. 3.2. 3.4.9.
58 ✓	Alignment – Hot Alignment Live view mode of imaging detectors shall allow quick alignment (hot alignment).	ConOps 2.1. & 3.2. 3.4.9. & 5.
59 ✓	Beam Stop – Attenuation The beamstop of the SCS shall be able to attenuate a direct beam to a level below 3 μSv/hr outside the Experimental Cave	ESS-0001786 "Supervised area" versus 3rd safety area

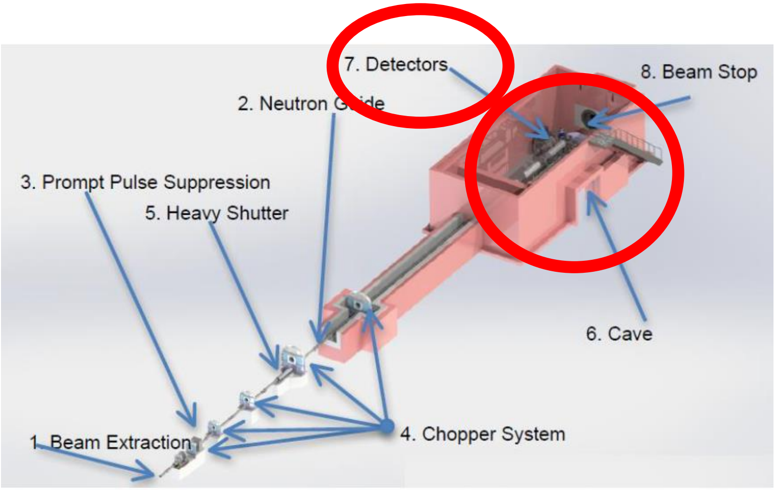


Figure 2 - ODIN conceptual layout

Cave Interior

ODIN

System Requirement Specification (ESS-0129650)

2.2.4 Experimental Cave, EC – PBS 13.6.5.5

Id	Text	Trace up to
60	The Experimental Cave – access to pinhole components The Experimental Cave shall provide access to all components downstream the pinhole – part of BTCS, SES and SCS (including the pinhole)	ConOps 3.& 5.
61	The Experimental Cave – Flexible support structure Shall house the flexible support structure for all components downstream the pinhole.	ConOps 3.& 5.
62	The Experimental Cave – Utilities access The Experimental Cave shall have access to a variety of utilities including various power outlets (10A, 15A, 20A 32A), chilled water, compressed Instrument air and gas supplies.	ConOps 3.& 5.
63	The Experimental Cave – Utilities removal The Experimental Cave should allow for removal of exhaust gases and cooling water etc.	ConOps 3.& 5.
64	Biological shielding, Experimental Cave – Access to SES while proton beam on Target The Experimental Cave shall allow the user to access the SES while the proton beam is on target but only while systems are in place to ensure the dose level in the Experimental cave is acceptable.	ConOps 3.& 5.

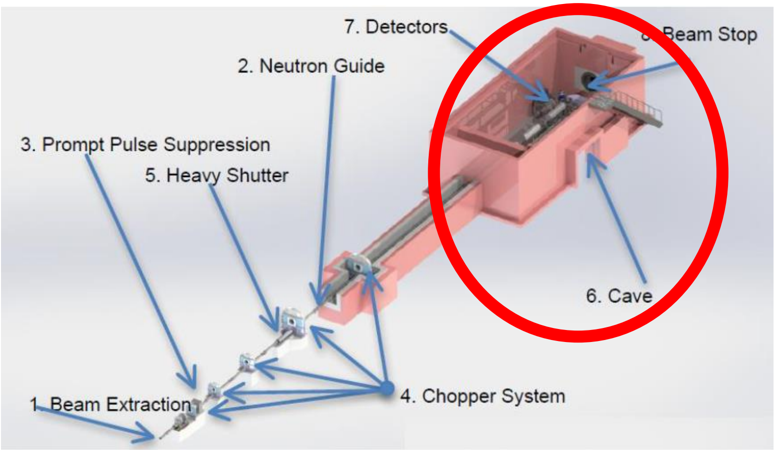


Figure 2 - ODIN conceptual layout

ODIN

System Requirement Specification (ESS-0129650)

65	Biological shielding, Experimental Cave – Access SES while proton be on Target, acceptable dose level The dose level in the Experimental Cave when accessing SES in it, with shutters closed, shall be 3 μSv/h in accordance with ESS-0001786 & ESS-0051603.	ConOps 3.& 5. ESS-0001786 ESS-0051603
66	Biological shielding, Experimental Cave – Access to SES during irradiation Experimental Cave shall prevent access to the SES while a sample irradiation is occurring.	ConOps 3.& 5.
67	Biological Shielding, Experimental Cave – dose attenuation The Experimental Cave shall attenuate the dose rate emanating from the SES and SCS during a sample irradiation , i.e shutter open, to 3 μSv/h, in accordance with ESS-0001786 & ESS-0051603,	ConOps 3.& 5. ESS-0001786 ESS-0051603
68	Experimental Cave – manual alignment of objects Laser equipment shall allow aligning detectors and samples to the beam manually.	ConOps 3.& 5.
69	Experimental Cave – Laser equipment remote removability Laser should be removable from beam remotely.	ConOps 3.& 5.

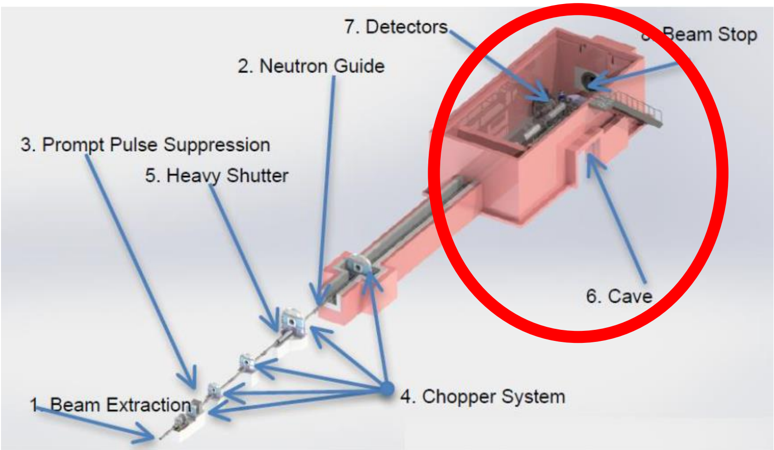


Figure 2 - ODIN conceptual layout

ODIN

System Requirement Specification (ESS-0129650)

70	Experimental Cave – Visual monitoring of cave Live CCTV shall allow for visual control of movements in cave.	ConOps 3.& 5.
71	Experimental Cave – Floor Space The Experimental Cave shall provide a floor space > 70 m^2	ConOps 3.& 5.
72	Experimental Cave – Beam access height The Experimental Cave shall have a floor to beam axis height of 1.25±0.1 m (at least along beam for manual manipulations).	ConOps 3.& 5.
73	Experimental Cave – Object accommodation Entry to the Experimental cave shall allow for the movement of apparatus up to 1m wide × 1m thick × 2m tall.	ConOps 3.& 5.
74	Experimental Cave – SES accessibility It should be possible to access the SES and the cave through the entire area of the roof. The SES shall be accessible with	ConOps 3.& 5.
75	Experimental Cave – Accessibility It should be possible to access the cave directly from the loading dock to allow easy installation of heavy, sensitive equipment e.g. environment chambers.	ConOps 3.& 5.

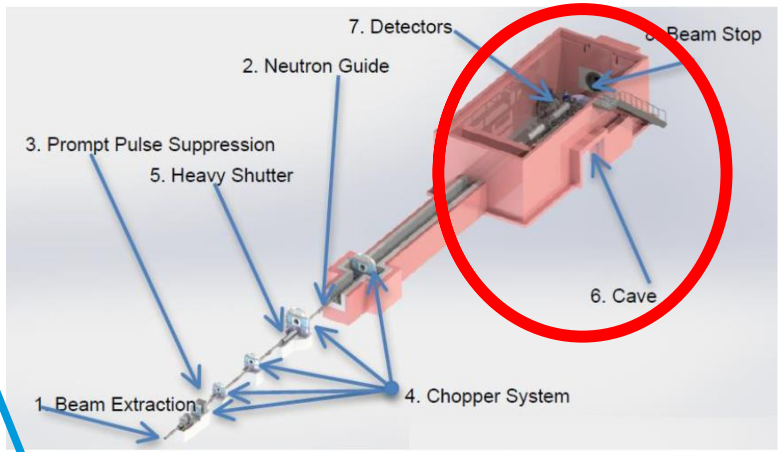


Figure 2 - ODIN conceptual layout

Mitigation in place:

- ODIN can use the 'GOLUMN' cameras
- Web-cams will be procured as well

ODIN

System Requirement Specification (ESS-0129650)

2.2.5 Control Hutch, CH – PBS 13.6.5.6

Id	Text	Trace up to
7[illegible]	Control Hutch – Instrument control terminal(s) The control hutch shall allow the user to remotely control the technical components from dedicated computer terminals	ConOps 3.& 5.
77	Control Hutch – Detector terminals The control hutch shall allow the user to remotely control detector systems from dedicated computer terminals and view live streams of detectors and CCTV.	ConOps 3.& 5.
78	Control Hutch – Data reduction terminal The control hutch shall allow the user to process the neutron data	ConOps 3.& 5.
79	Control Hutch – Comfort The control hutch should be a comfortable working environment for up to 6 users. ISO 11064-6 provides good guidelines for defining comfort and should be followed where possible.	ConOps 3.& 5.

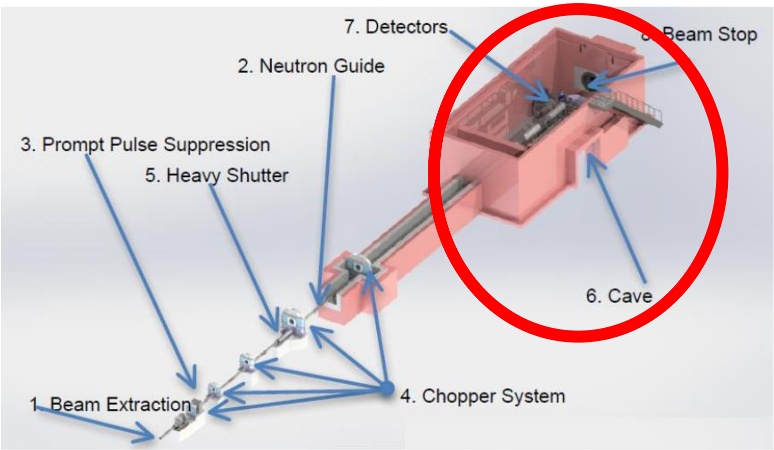


Figure 2 - ODIN conceptual layout

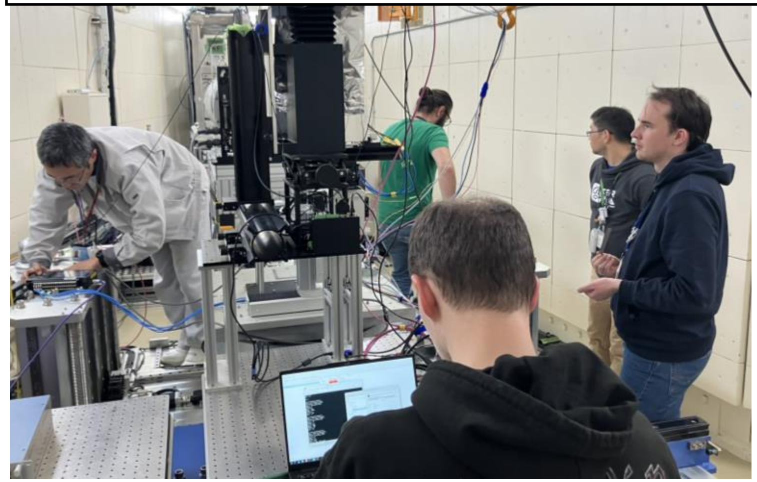
ODIN

System Requirement Specification (ESS-0129650)

2.2.6 Integration Control and monitoring, IC&M – PBS 13.6.5.12

Id	Text	Trace up to
79	IC&M – Instrument Control and Automation All motorized axes and electronic driven systems shall be remotely controllable with the instruments computer system	ConOps 3.& 5.
80	IC&M – Monitoring All viable systems shall be monitored electronically and feed back into the control system	ConOps 3.& 5.
81	IC&M – Source pulse synchronizing A signal, (ideally NIM) synchronized with the source pulse, shall be available to the system	ConOps 3.& 5.
82	IC&M – ODIN Standalone mode All electronic systems shall be configured such that the instrument can be controlled and utilized in a standalone mode independent of the ICS.	ConOps 3.& 5.
83	IC&M – Personal Safety System (PSS) The PSS shall be fully integrated into the Instrument control such that the Instrument can be operated safely.	ConOps 3.& 5.

Example @JPARC: User equipment controlling RADEN motion stages



ESS systems are inherently not designed for the flexibility typically required at imaging beamlines at operating facilities

ODIN

System Requirement Specification (ESS-0129650)

2.3 Constraint Requirements

2.3.1 Operational constraint requirements

Id	Text	Trace up to
84	Operation Mode Changes – Mode Redundancy Maintenance or failure issues of one mode shall have a minimum impact on other modes (That choppers are removable or can be set to an open position is more important than repair and maintenance times that still should be kept to a minimum).	ConOps 5.3.3 6.1.2
85	Operation mode changes – BTSC access, configuration time No configuration mode change requiring access in the area downstream the pinhole shall take longer than 8 hours (including alignment).	ConOps 3.& 5.
86	BTCS Ergonomics The beam and BTCS components downstream of the pinhole shall be accessible at a comfortable height. (125±10 cm)	ConOps 3.& 5.
87	Detector exchange – As the SCS shall include a number of detectors, any change of detector configuration and system shall be a smooth standard operation carried out within 15 min (not including hot alignment, i.e. requiring beam).	ConOps 3.& 5.

Ok for 'ODIN standard detectors', not for others however: ESS systems are inherently not designed for the flexibility typically required at imaging beamlines at operating facilities