1

Radiation Safety

H1/H2 Scenarios

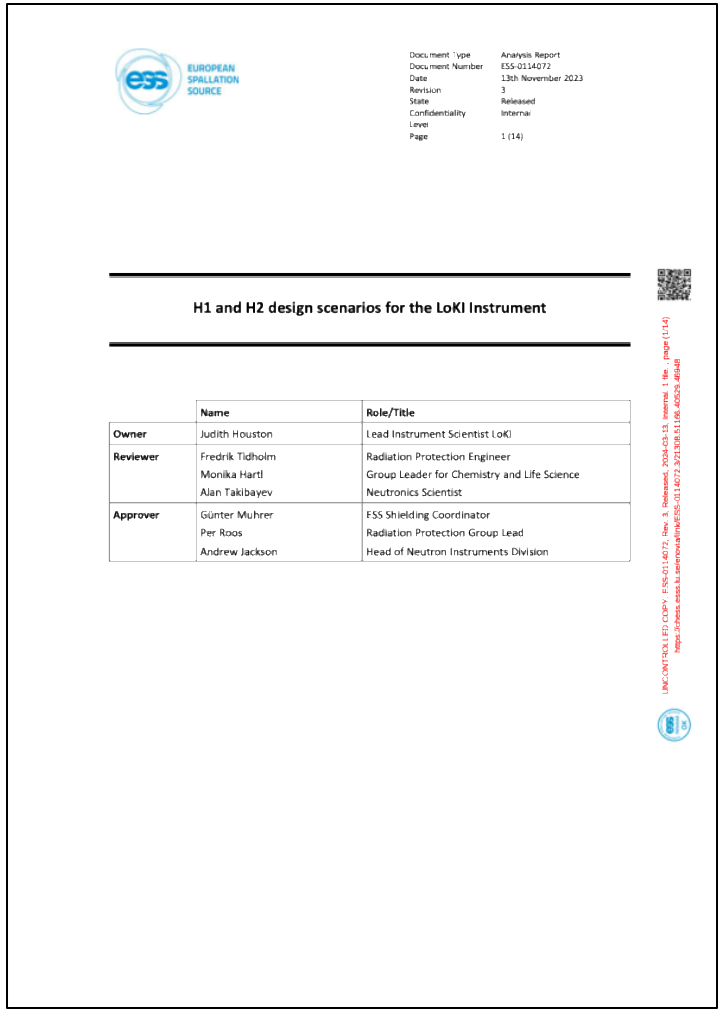
Design Basis for Radiation Safety

Summary

From simulation:
Maximum neutron current at bunker wall exit : 5.24×10^{10} n/s
Maximum neutron current at sample position : 1.0×10^{10} n/s

15 H1 events identified – 11 taken forward for analysis
7 H2 events identified – 3 taken forward for analysis

#	Cause
H1-1	Instrument shutter is closed
H1-3	Chopper 2 is closed
H1-4	Collimator jaws closed in beam
H1-7	Gd in beam at sample position
H1-8	Water in beam at sample position
H1-9	Fast shutter closed
H1-10	Steel equipment in beam at sample position
H1-11	Roof plug removed
H1-12	Cd in beam at sample position
H1-13	Cd in scattered beam within detector tank
H1-15	Boron in beam within detector tank
H2-1	Full beam on back wall of detector vessel
H2-2	Strongly isotropic scattering sample left in beam
H2-5	Misaligned/damaged snout



EUROPEAN SPALLATION SOURCE

Document Type Analysis Report
Document Number ESS-0114072
Date 13th November 2023
Revision 3
State Released
Confidentiality Level Internal
Page 1 (14)

H1 and H2 design scenarios for the LoKI Instrument

	Name	Role/Title
Owner	Judith Houston	Lead Instrument Scientist LoKI
Reviewer	Fredrik Tidholm	Radiation Protection Engineer
	Monika Hartl	Group Leader for Chemistry and Life Science
	Alan Takibayev	Neutronics Scientist
Approver	Günter Muhrer	ESS Shielding Coordinator
	Per Roos	Radiation Protection Group Lead
	Andrew Jackson	Head of Neutron Instruments Division

Radiation Safety Report

Shielding Analysis

6. ACCEPTANCE CRITERIA

The acceptance criteria are based on the different scenario hazard level and the area classifications around the beam line as detailed in Guideline and rules for instrument shielding design [2].

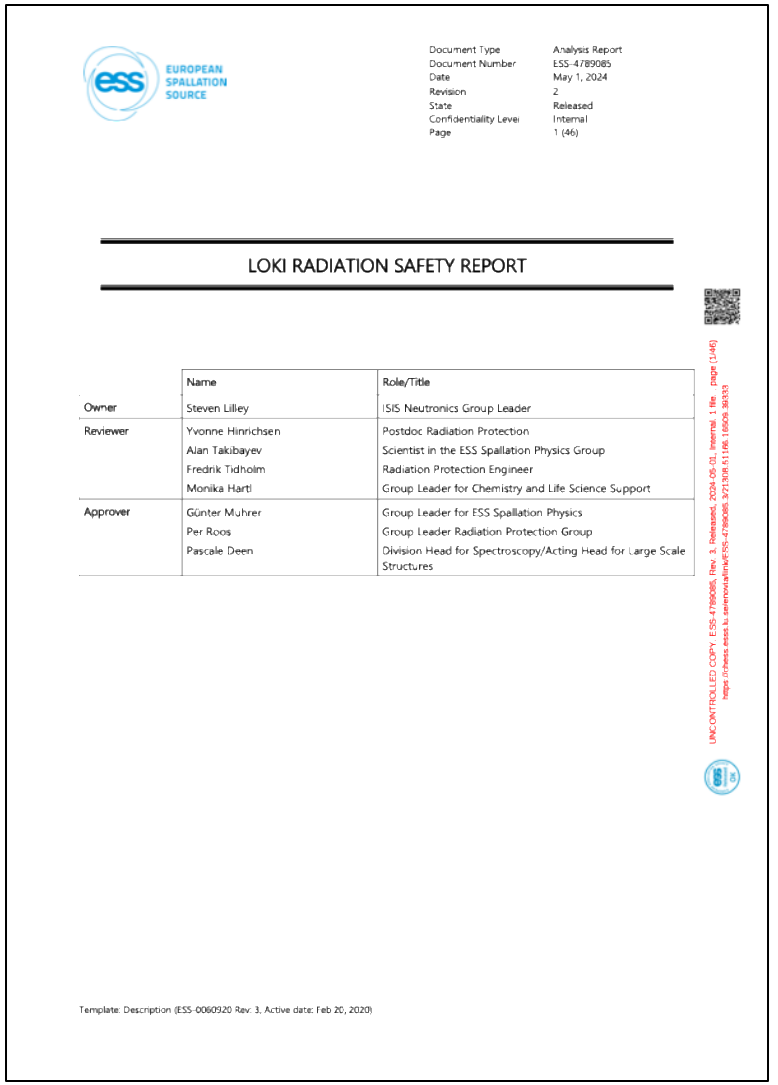
Hence the shielding will be designed so that for all H1 conditions:

- "The dose rate on the outer surface of the instrument shall not exceed 3 µSv/h. To test for compliance, the calculated dose rate needs to be averaged over a 20×20 cm^2 area and multiplied by the appropriate safety factor."
- The calculated area-average dose rate from any of the four vertical faces of the instrument cave (consider each separately) does not exceed 0.5 µSv/h.
- The calculated area-average dose rate from any 10 m long section of guide shielding does not exceed 0.5 µSv/h.
- The guide section roof may be given a higher designation as controlled area in which case the upper dose rate limit averaged over 20 x 20 cm^2 area would be 25 µSv/h.

and for all H2 conditions:

- The dose does not exceed 1 mSv per event (which is expected to occur less than once per year), otherwise the H1 criteria are used.

An appropriate safety factor is considered in all calculations reducing the acceptance criteria for the simulation results. In the ESS guidance this safety factor is given as a factor of two from Monte Carlo simulations [2]. This means that for the H1 scenarios the target dose rate outside the shielding around the LoKI instrument is 1.5 µSv per hour.



EUROPEAN SPALLATION SOURCE

Document Type	Analysis Report
Document Number	ESS-4789085
Date	May 1, 2024
Revision	2
State	Released
Confidentiality Level	Internal
Page	1 (46)

LOKI RADIATION SAFETY REPORT

	Name	Role/Title
Owner	Steven Lilley	ISIS Neutronics Group Leader
Reviewer	Yvonne Hinrichsen	Postdoc Radiation Protection
	Alan Takibayev	Scientist in the ESS Spallation Physics Group
	Fredrik Tidholm	Radiation Protection Engineer
	Monika Hartl	Group Leader for Chemistry and Life Science Support
Approver	Günter Muhrer	Group Leader for ESS Spallation Physics
	Per Roos	Group Leader Radiation Protection Group
	Pascale Deen	Division Head for Spectroscopy/Acting Head for Large Scale Structures

Template: Description (ESS-0060920 Rev: 3, Active date: Feb 20, 2020)

Reference : ESS-0019931, "ESS Procedure for designing shielding for safety"

Radiation Safety Report

Shielding Analysis

14. CONCLUSIONS AND RECOMMENDATIONS

This report summarises the shielding considerations for the LoKI instrument at the ESS compared against the H1 and H2 scenarios.

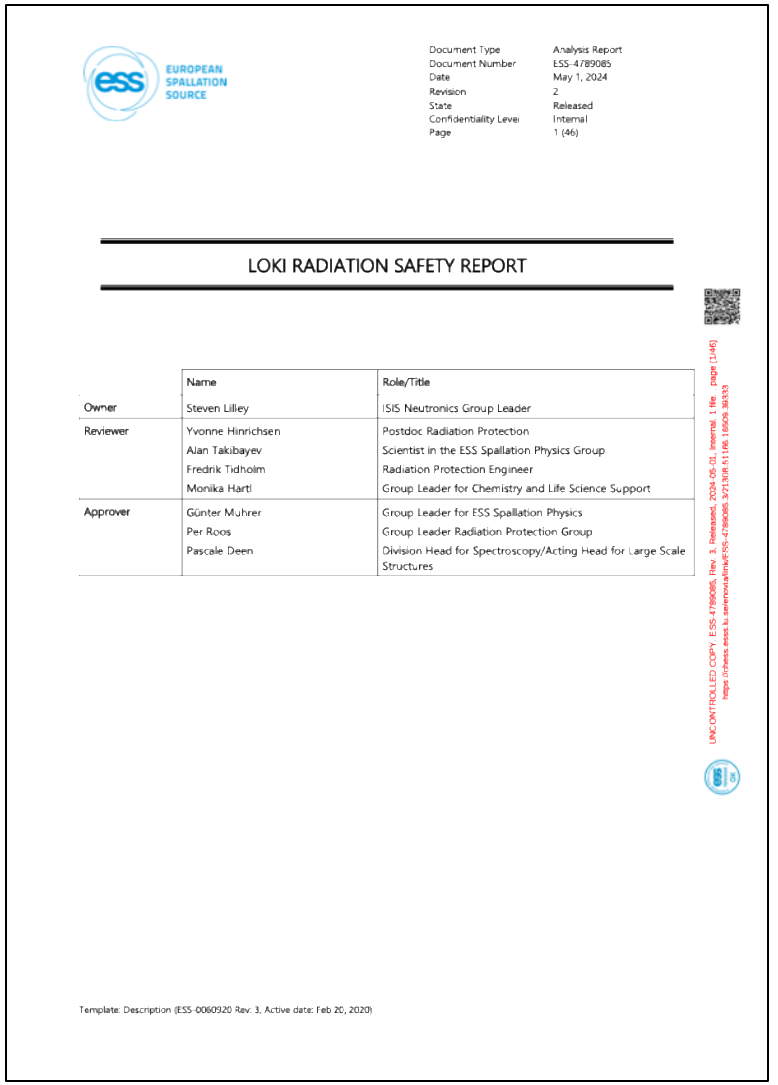
Consideration has been made of both highly scattering and highly absorbing scenarios which test both the neutron and gamma shielding design. High energy and guide transported neutrons have both been considered where relevant as has photo-neutrons from the prompt photons and prompt photons from neutron capture in the guide coatings.

The calculations are conservative, taking the full 5 MW ESS design as a starting point, simplifying the geometry to only include key parts of the design and maximising penetrations and tolerance gaps. In addition, only absorbing material such as B4C has been included where absolutely needed for shielding purposes e.g. around some penetrations. It is highly likely that for science and background reduction purposes there will be more than considered in this analysis.

In each H1 scenario the shielding is sufficient to reduce the dose rates to below 1.5 μSv/h outside of the shielding in the majority of locations.

A few specific areas may need to have localised shielding or access restricted and a boron-based beam stop has now been included to prevent direct irradiation of the steel tank.

A few small hotspots around the interfaces between the bunker wall, the sample area door and smaller penetrations do exist but less than the 20 x 20 cm area. The majority of these hotspots are due to the conservative nature of the calculations with maximum tolerance gaps included. The installation process should ensure that the tolerance gaps are not larger than those specified. Some scenarios are bounded by others and have not been investigated in detail or are an activation rather than shielding hazard.



EUROPEAN SPALLATION SOURCE

Document Type	Analysis Report
Document Number	ESS-4789085
Date	May 1, 2024
Revision	2
State	Released
Confidentiality Level	Internal
Page	1 (46)

LOKI RADIATION SAFETY REPORT

	Name	Role/Title
Owner	Steven Lilley	ISIS Neutronics Group Leader
Reviewer	Yvonne Hinrichsen	Postdoc Radiation Protection
	Alan Takibayev	Scientist in the ESS Spallation Physics Group
	Fredrik Tidholm	Radiation Protection Engineer
	Monika Hartl	Group Leader for Chemistry and Life Science Support
Approver	Günter Muhrer	Group Leader for ESS Spallation Physics
	Per Roos	Group Leader Radiation Protection Group
	Pascale Deen	Division Head for Spectroscopy/Acting Head for Large Scale Structures

Template: Description (ESS-0060920 Rev: 3, Active date: Feb 20, 2020)

2

LoKI Shielding documentation overview

Documentation overview

LoKI Instrument

LoKI Shielding Verification report ESS-5806458

4. VERIFICATION OF DESIGN

Shielding system	FBS Tag	Calculation Report	Installation Inspection report
Shielding Bunker to cave	ESS.NSS.H01.LOKI.A01.F01	(ESS-4789085) (ESS-5248311)	ESS-5723871 ESS-5765648
Shielding for Instrument cave	ESS.NSS.H01.LOKI.U01	(ESS-4789085) (ESS-5248311)	ESS-5768841 ESS-5768861

EUROPEAN SPALLATION SOURCE

Document Type	Report
Document Number	ESS-5806458
Date	Sep 7, 2025
Revision	1
State	Released
Confidentiality Level	Internal
Page	1 (4)

LOKI SHIELDING VERIFICATION REPORT

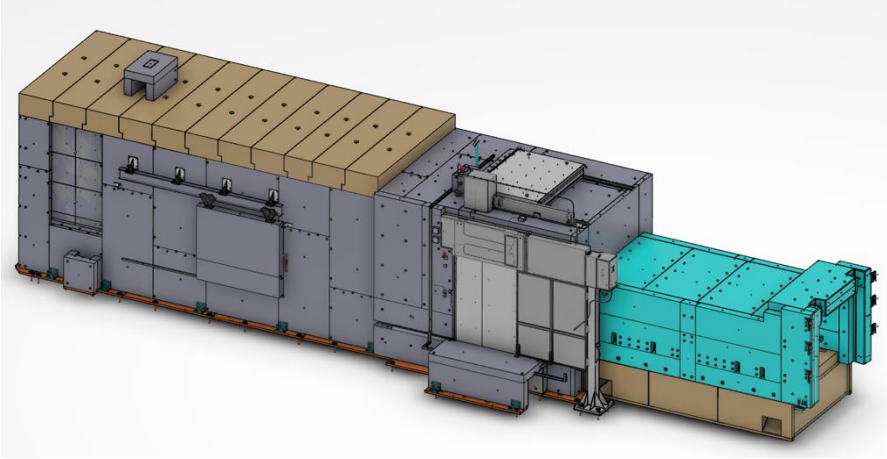
	Name	Role/Title
Owner	Clara Lopez	Installation package leader/Integration Engineer
Reviewer	Ana Cintas	RP Protection Expert
Approver	Per Roos	Group Leader, Radiation Protection

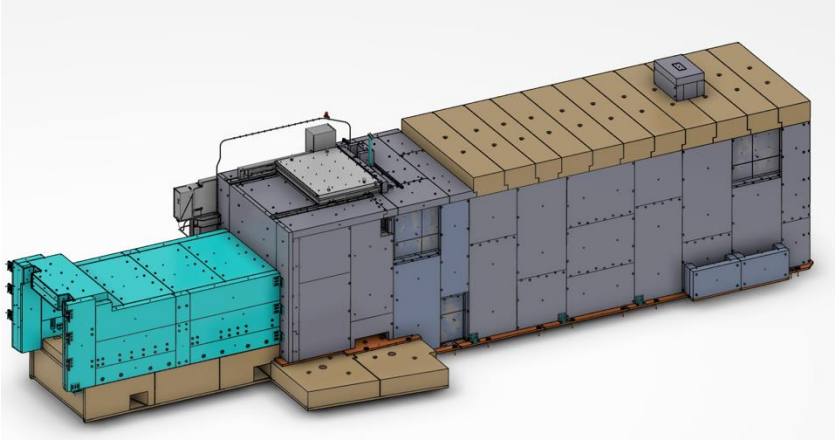
5-09-07, Internal, 1 file, , page (1/4)
L308:51166.7379.26493

SAT based on Installation documentation
System design description

Design documentation approved in TG3

- ESS-4789085 LoKI Radiation safety report
- ESS-5248311 LoKI Activation Analysis Report





3

Bunker to cave =ESS.NSS.H01.LOKI.A01.F01

LoKI Bunker to cave shielding

LoKI Instrument

- ESS-5723871 LoKI Shielding Bunker to Cave SAT
- ESS-5765648 LoKI Shielding Bunker to cave location checklist
- ESS-1108661 Sub System design Description for Shielding bunker to cave

EUROPEAN SPALLATION SOURCE

Document Type	Site Acceptance Test
Document Number	ESS-5723871
Date	Aug 20, 2025
Revision	1
State	Released
Confidentiality Level	Internal
Page	1 (10)

LOKI SHIELDING BUNKER TO CAVE

	Name	Role/Title
Owner	Clara Ines Lopez	Senior Engineer/Integration Engineer for Instruments
Reviewer	Ana Cintas Jim Nightingale Stefan Pacoste	Radiation Protection Expert Lead Engineer/Project manager for ESS Instruments-STFC QC Engineer
Approver	Gabor Laszlo	Section Leader for Instrument Engineering

LoKI Bunker to cave shielding

LoKI Instrument

- ESS-5723871 LoKI Shielding Bunker to Cave SAT

3. VERIFICATION OF GAPS BETWEEN BLOCKS AND AGAINST MAIN INTERFACES.

Ensure gaps between blocks are less than 10 mm and less than 50 mm against the bunker wall

Passing condition: Completed.

Achieved condition: Measurements done during installation and verified by RP personnel, See ESS-5765648 LoKI shielding bunker to cave installation location checklist signed. The figure 1 and 2 show the requirement values and, Photo 1a, 1b and 2 with the achieved distance

☐ N/A ☒ Pass ☐ Fail ☐Remark:

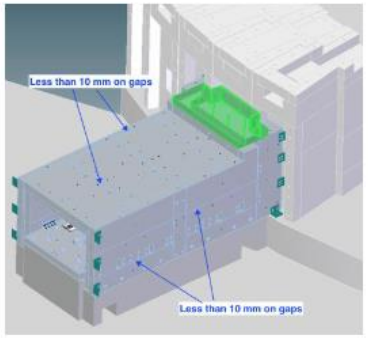


Figure 1 Gaps between blocks for shielding

Photo 1a and 1b both sides o shielding bunker to cave

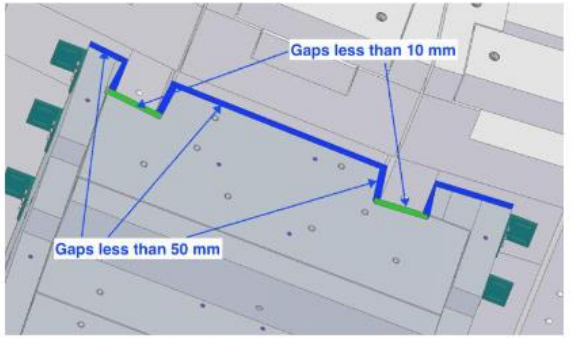
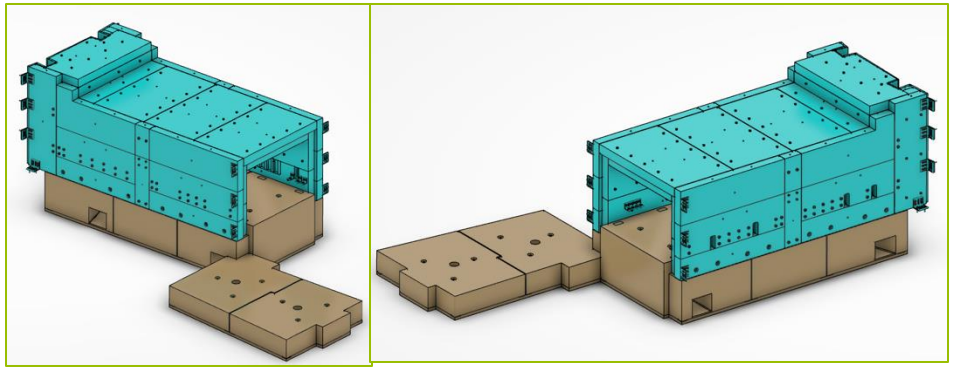


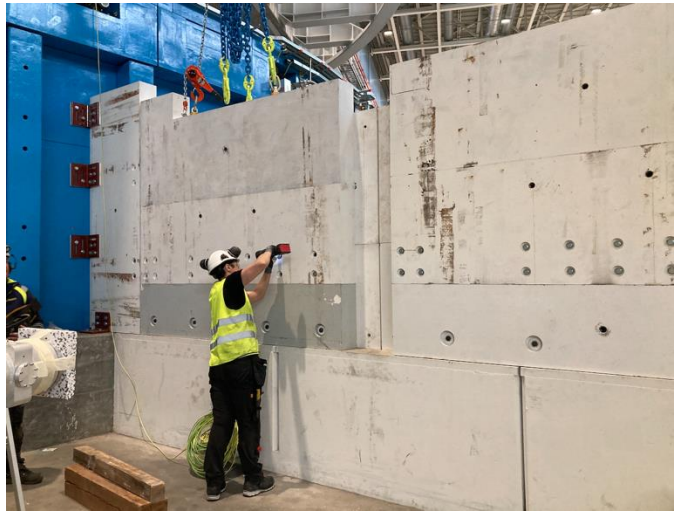
Figure 2 Gaps between shielding and bunker wall

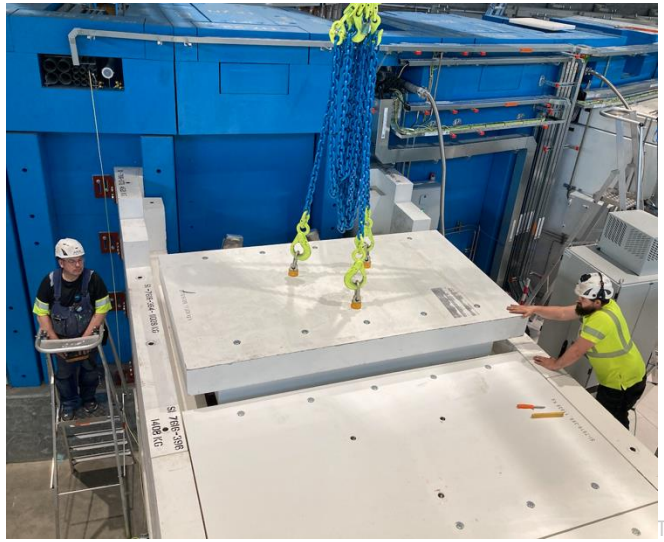
Photo 2 Interface LoKI shielding against bunker wall

Bunker to cave Installation

LoKI Instrument







4

Shielding on cave =ESS.NSS.H01.LOKI.U01.F01

LoKI Shielding on cave

LoKI Instrument

- ESS-5768841 LoKI Cave Site Acceptance Test
- ESS-5768861 LoKI Cave Installation location Checklist
- ESS-1108664 Sub-System design description for End Station

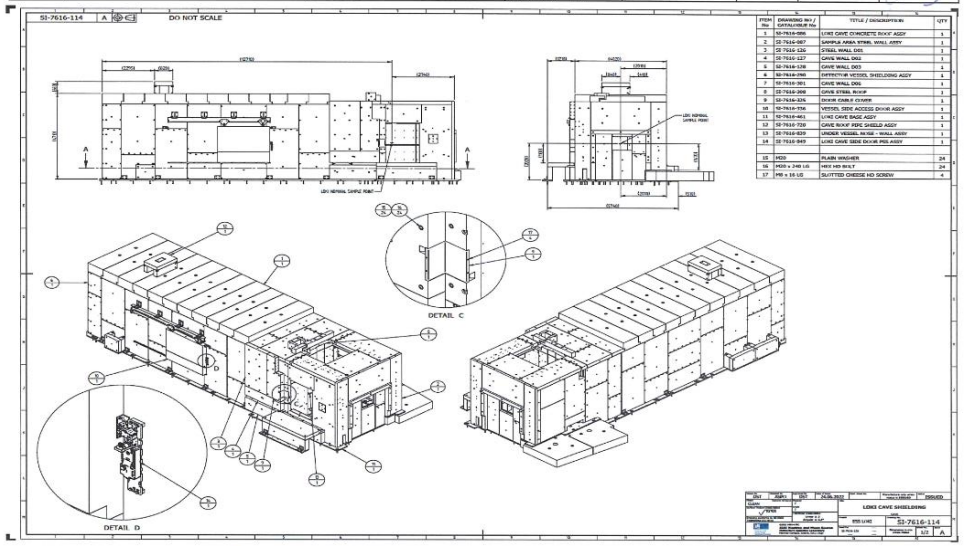
EUROPEAN SPALLATION SOURCE

Document Type	Site Acceptance Test
Document Number	ESS-5768841
Date	Sep 8, 2025
Revision	1
State	Released
Confidentiality Level	Internal
Page	1 (7)

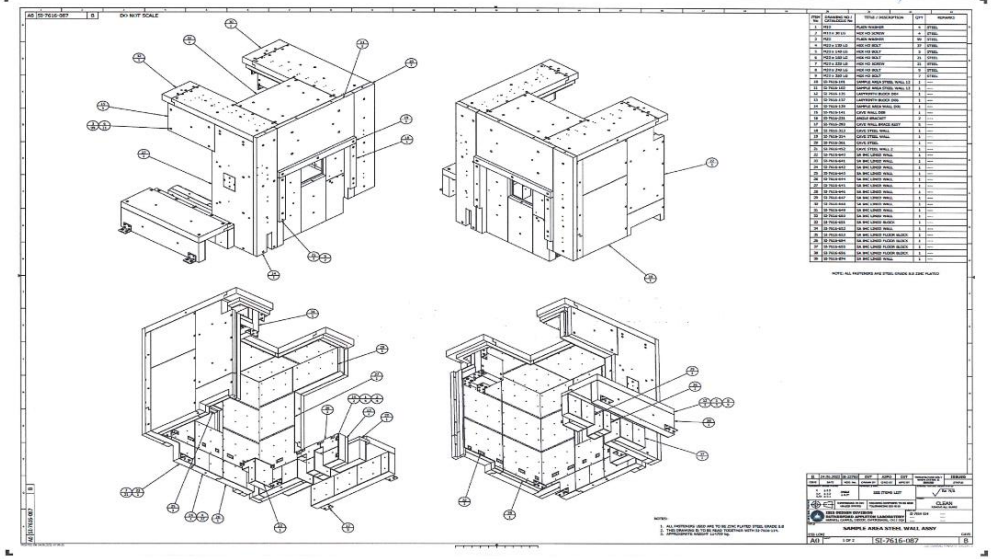
LOKI Cave Assembly shielding

RP representative: Ana Cintas Date: August 28/25

item	FBS	Assembly	Drawing	CAD model	Binder	Installed	Signed
	ESS.NSS.LOKI.U01.F01	Cave Shielding	ESS-4130147 / SI-7616-114	ESS-3819617	ib115	Yes	



item	FBS	Assembly	Drawing	CAD model	Binder	Installed	Signed
C		Sample Area steel wall	ESS-4130148 / SI-7616-087	ESS-4028030	ib115	Yes	



CAVE SITE ACCEPTANCE TEST

	Name	Role/Title
Owner	Clara Ines Lopez	Senior Engineer/Integration Engineer for Instruments
Reviewer	Jim Nightingale Ana Cintas Clara Ines Lopez	Lead Engineer/Project manager for ESS Instruments-STFC Radiation Protection Expert Senior Engineer/IPL for LoKI Instrument
Approver	Andrew Jackson	Head of Large Scale Structure Division

LoKI Bunker to cave shielding

LoKI Instrument

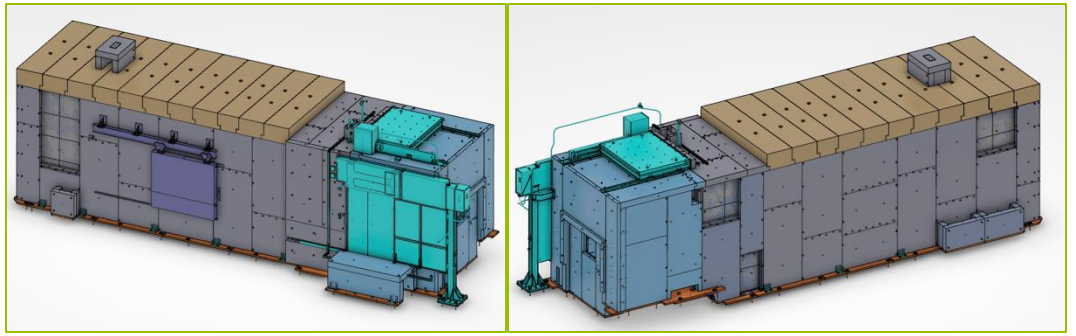
- ESS-5723871 LoKI Shielding Bunker to Cave SAT
- ESS-5765648 LoKI Shielding Bunker to cave location checklist

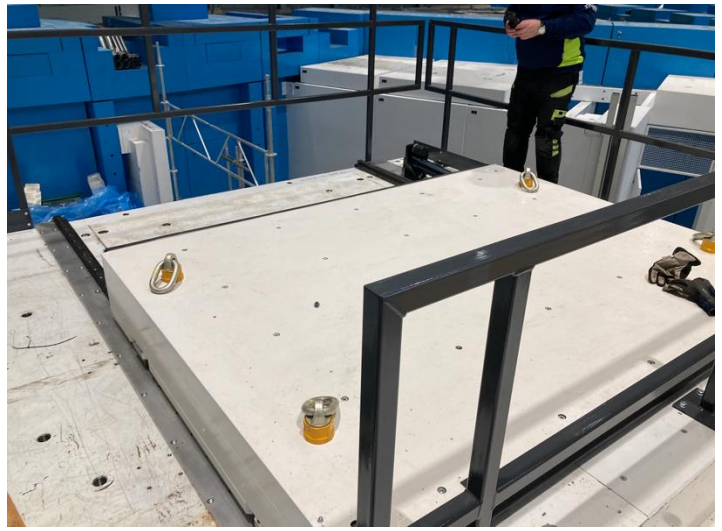
Verification of Gaps between blocks and against main interfaces

Ensure gaps between blocks are less than 10 mm.

Cave Shielding installation

LoKI Instrument





5

Radiation Safety Assessment

Radiation Safety Assessment

Implementation of Safety Functions

LoKI is within the radiation safety envelope of a generic instrument as defined in SSM submissions

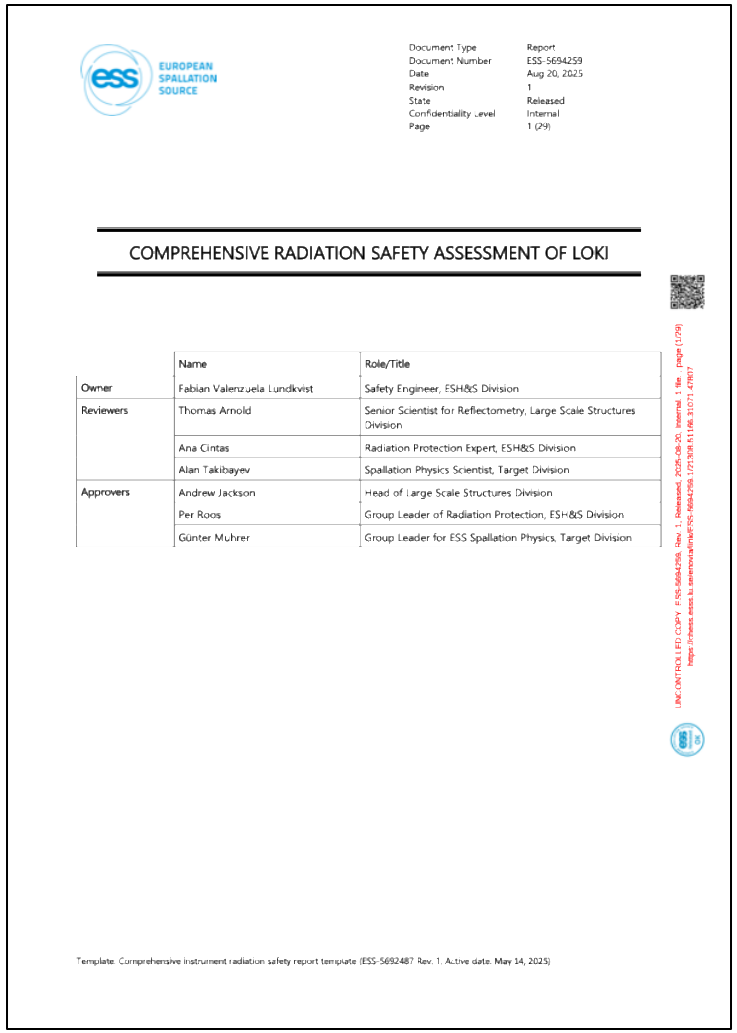
All relevant RSFs and WRSFs are satisfied.

8. CONCLUSIONS

From the conclusions in Chapter 7, the radiation safety requirements for LoKI are met.

With respect to the shielding, the underlying analysis utilizes a 5 MW beam which is the maximum beam power possible and thus the shielding is sufficient for phases which has a lower beam power. Hot spots will be treated as such and given clear indication to prevent workers from standing next to them for a prolonged period of time.

The activation calculations have highlighted that sufficient cool down times are necessary before access to caves or components such as the choppers or collimator (see Section 7.5.2 and Section 7.6.2).



EUROPEAN SPALLATION SOURCE

Document Type	Report
Document Number	ESS-5694259
Date	Aug 20, 2025
Revision	1
State	Released
Confidentiality Level	Internal
Page	1 (29)

COMPREHENSIVE RADIATION SAFETY ASSESSMENT OF LOKI

	Name	Role/Title
Owner	Fabian Valenzuela Lundkvist	Safety Engineer, ESH&S Division
Reviewers	Thomas Arnold	Senior Scientist for Reflectometry, Large Scale Structures Division
	Ana Cintas	Radiation Protection Expert, ESH&S Division
	Alan Takibayev	Spallation Physics Scientist, Target Division
Approvers	Andrew Jackson	Head of Large Scale Structures Division
	Per Roos	Group Leader of Radiation Protection, ESH&S Division
	Günter Muhrer	Group Leader for ESS Spallation Physics, Target Division

Template: Comprehensive instrument radiation safety report template (ESS-5692487 Rev. 1, Active date: May 14, 2025)