BEER INSTRUMENT

Experimental cave – Technical requirements and design description

Nuclear Physics Institute, CAS
BEER instrument

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LIST OF ABBREVIATIONS

BEER	Beamline for European Engineering Materials Research
Bidder	Party that offers a tender return
CBS	Cost Breakdown Structure
CDR	Comprehensive Design Review
CH	BEER Instrument Experimental Control Hutch
CTV	Call for Tender Verification
EC	BEER Instrument Experimental CAVE
ESS	European Spallation Source
ESS	European Spallation Source ERIC
FAT	Factory Acceptance Test
IRR	Installation Readiness Review
KOM	Kick Off Meeting
NPI	Nuclear Physics Institute of the CAS, v.v.i.
NSS	Neutron Scattering Systems
PSS	Personal Safety System
RFI	Ready For Installation
SAR	Safety Systems Acceptance Review
SAT	Site Acceptance Test
SSDD	Sub-System Design Description
Supplier	Party that is awarded the contract
TA	Technical Annex
TCS	Technical Coordination System
TG	Tollgate

1 INTRODUCTION

This document describes the technical requirements and conceptual design of the experimental cave for the diffractometer BEER at ESS.

1.1 ESS – EUROPEAN SPALLATION SOURCE

The European Spallation Source (ESS) ERIC (European Research Infrastructure Consortium) is a multi-disciplinary research facility based on the world's most powerful neutron source with a vision to enable scientific breakthroughs in research related to materials, energy, health and the environment, and address some of the most important societal challenges of our time. ESS is currently under construction in Lund, Sweden. The initial suite of neutron instruments will consist of 15 instruments and a test beamline with further integration of instruments following to complete the projected suite of 22 instruments. Instruments will include hardware and software necessary to conduct neutron scattering experiments, collect data and distribute them to users and archive all necessary information related to the experiments. In addition, ESS or other partner laboratories will support specific experimental conditions or preparations required by the experimental programs.
Details about the ESS project can be found on https://europeanspallationsource.se/.

1.2 BEER INSTRUMENT

The BEER instrument is one of the instruments built at ESS dedicated to engineering-related research. The main area of research lies in the study of advanced materials under the real processing or application conditions to develop new or adapt existing materials for particular purposes. In addition, BEER will also address the studies dedicated to understanding the internal microstructure of the materials or their change during or after processing. More about the driving ideas behind BEER design can be found in *BEER – Concept of Operations* [1] or on the instrument webpage[1].
The shielded experimental cave is one of the key components that endure radiation safety during experiments. The cave provides shielded space where the neutron scattering experiments take place and prevents neutrons and gamma photons from escaping into the unprotected area of the experimental hall. This document summarises the technical requirements and describes the conceptual design of the instrument cave, which meets these requirements, as well as the ESS standards, technical policies and radiological calculations, which were approved by ESS authorities.

1.3 REQUIREMENT LEVEL INTERPRETATION

The keywords "must", "shall", and "should" in this document are to be interpreted as follows:

1. "must", "shall", or "has/have to" is an absolute requirement of the specification.
2. "should" means that there may exist valid reasons in certain circumstances to ignore a particular item or ease a requirement, but the full implications should be understood and carefully weighed and mutually agreed upon before choosing a different course.

[1] https://europeanspallationsource.se/instruments/beer

2 EXPERIMENTAL CAVE

2.1 GENERAL DESCRIPTION

The experimental cave is a part of the BEER instrument. It is located in the E01 hall at a distance of about 158 m from the neutron source. Figure 1 shows a schematic layout of the BEER instrument, and the experimental cave is represented by the grey rectangle on the far right. The structure of the experimental cave consists of several parts, which can be viewed as separate sub-systems. The following PBS (project breakdown structure) numbers are identified within the experimental cave system, which shall be considered for this construction project. The full PBS three is presented in [2].

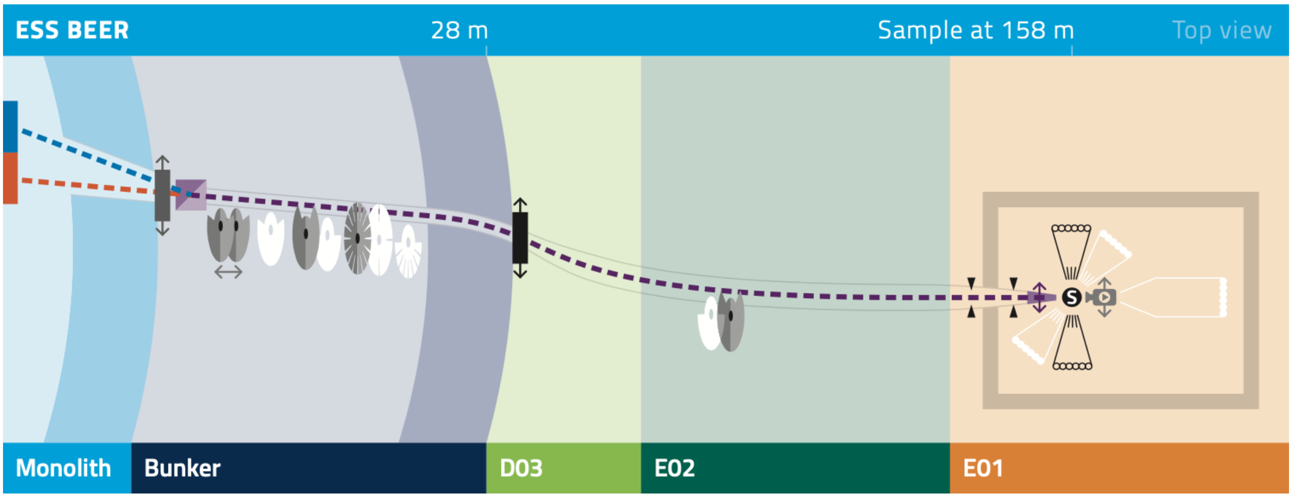


Figure 1: The BEER instrument schematic layout

- PBS 13.6.6.5.4 – Experimental Cave Shielding
- PBS 13.6.6.5.5 – Experimental Cave Structure
- PBS 13.6.6.5.3.10 – Local crane
- PBS 13.6.6.1.8.6 – Beam Stop

The main functions of the experimental cave can be summarised as follows:

- Shield E01 hall from the radiation produced by the neutron beam and its interaction with the sample and the cave interior equipment
- Allow simple access to the sample position (beam height 3.127 m above E01 floor)
- Support the internal cave installations – sample tower, detectors, guide system
- Allow easy transport of the voluminous sample environment or samples in and out of the cave using the entrance door or roof opening
- Allow passage of electrical cables/media pipes in/out of the cave without compromising the shielding of the wall
- Allow manipulation of the heavy and delicate equipment inside the cave
- Block the primary beam using beam-stop
- Allow quick access for personnel and small samples

Further information about the requirement for the cave can be found in *BEER – System Requirements* [3].

3D view of the conceptual design of the experimental cave from the outside and inside is shown in Figure 2 and Figure 3.

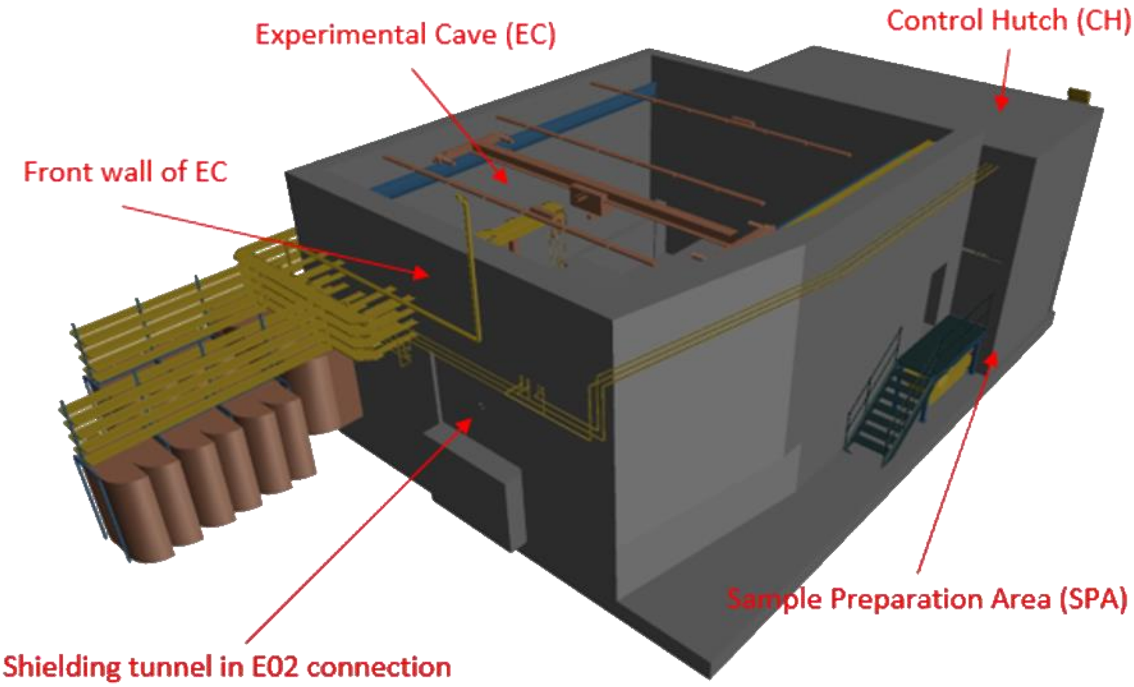


Figure 2: 3D view of the conceptual design of the BEER experimental cave – exterior.

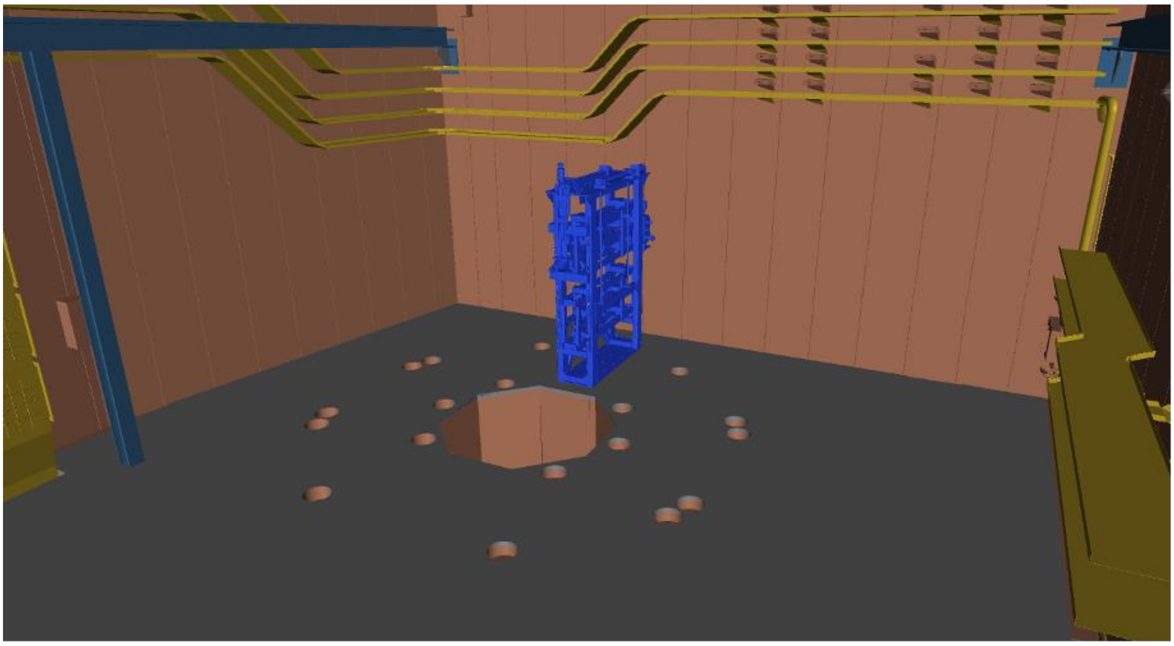


Figure 3: 3D view of the conceptual design of the BEER experimental cave – interior. The structure of the guide exchanger (blue structure) is also shown (not part of this tender).

2.2 INTERFACES

The main interfaces of the experimental cave structure with other systems are described below in Table 1.

Table 1: Experimental cave structure - interfaces

Number	Interface	To component
1	Heavy door end-switches and lock	Personal safety system
2	Personal entry end-switches and lock	Personal safety system
3	Devices (search buttons, blue lights etc.)	Personal safety system
4	Wall Feed-through	Electrical cables/media pipes
5	Cave walls	E01 hall floor
6	Cave front wall	Common shielding
7	Cave front wall	Elevated wall of E02 hall
8	Cave front wall	Support structures in E01
9	Cave front wall	Guide system feed-through
10	Cave front wall	Guide system support structure
11	Cave roof	Overhead crane in E01
12	Elevated floor	Sample tower shaft
13	Elevated floor	Detector support
14	Elevated floor	Guide exchanger

The experimental cave sub-system has the following external interfaces to the subsystems managed mainly by ESS and provided by its partners and suppliers:

1. Personal safety system (PSS) end switches and locks integration (ESS) – interfaces 1 and 2
2. Personal safety system (PSS) devices (search buttons, blue lights etc.) (ESS) – interface 3
3. Utility connection of power, compressed air and other media managed by the common electrical and utilities project (ESS) – interface 4
4. E01 and E02 halls floors and structures (ESS) – interfaces 5, 7 and 8
5. E01 overhead crane (ESS) – interface 11
6. Common shielding project (ESS) – interface 6

The internal interfaces of the experimental cave structure are linked to other internal sub-systems of the BEER instrument, and they are following:

7. A feed-through in the front wall for the guide system (NPI) – interface 9
8. The elevated floor on the E01/E02 boundary for guide support structures (NPI)–interface 10
9. A shaft for the sample tower (Hereon) – interface 12
10. Embedded jars for the kinematics mounts for detectors (Hereon) – interface 13
11. Reinforced floor load for the guide exchanger (NPI) – interface 14

2.2.1 EXTERNAL LIMITATIONS

There is a number of limitations related to the external interfaces. Below is the list of the main limitations or obstacles related to the experimental cave structure, which have to be considered during design. Other relevant information about the ESS interfaces can be found in *ESS – Instrument Technical Interfaces* [4].

- E01 floor load capacity: 20 t/m^2 (see Chapters 4.3.2.2 and 4.3.2.3 in [4])

- E01 overhead crane capacity and coverage: 10 tons (see Chapter 4.4.27 in [4])
- E01 overhead crane max. hook height: 10 m (TCS+7 m)
- E01 maximal structure height 9 m (TCS+6 m)
- E01/E02 support beams, wall structures, ramps clearance

2.3 CONCEPTUAL DESIGN & ASSUMPTIONS

Because the experimental cave needs to fulfil *Radiological requirements and guidelines for instrument shielding design* [5] based on the operation and hazardous scenarios [6] for the BEER instrument, the conceptual design, including the radiological calculation [7], was performed. It was used to define the size of the cave's inner/outer space as well as the material and the thickness of the walls/roof to satisfy all ESS regulations. It also helps to describe the engineering challenges which have to be solved in addition to the basic design (E01 maximum floor load capacity, size of the roof panels, installation of the heavy doors with 10 tons crane, …).
The following chapters describe the conceptual design (documents and drawings available for request) and basic technical requirements that must be followed during the detailed design. The experimental cave structure is divided into four units listed below to describe the sub-system in more detail. Corresponding PBS numbers are also listed.

- Unit 1 – Cave Shielding (PBS 13.6.6.5.4 and PBS 13.6.6.5.5)
- Unit 2 – Cave Sliding Door (part of PBS 13.6.6.5.5)
- Unit 3 – Cave Internal Crane (PBS 13.6.6.5.3.10)
- Unit 4 – Beam Stop (PBS 13.6.6.1.8.6)

3 SPECIFICATIONS AND REQUIREMENTS

3.1 OVERVIEW LAYOUT

The BEER experimental cave is located in the E01 experimental hall on the beam port W02. There are two neighbouring instruments. On the south side, there is NMX, and on the north side, there is C-SPEC. The general layout of the BEER instrument within E01 and adjustment E02 hall is presented in Figure 4.

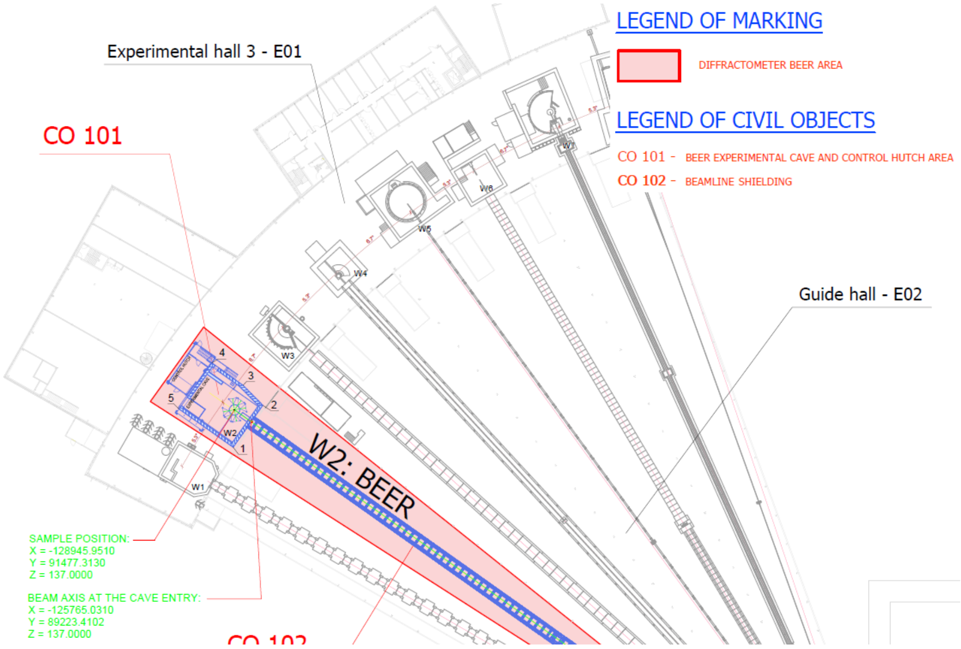


Figure 4: General layout of BEER instrument, BEER Experimental Cave.

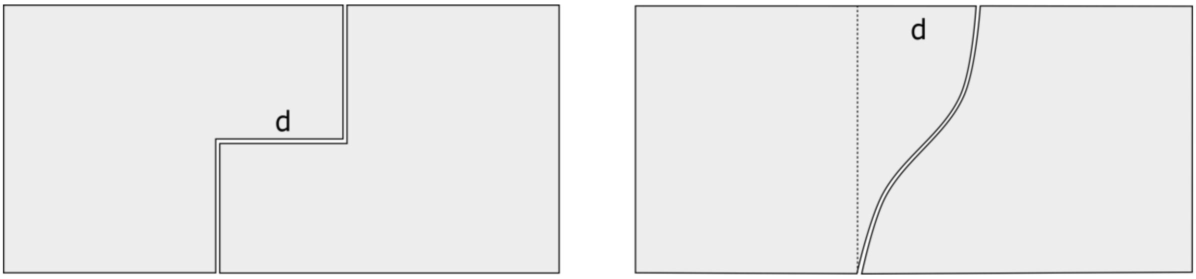
3.2 UNIT 1 – CAVE SHIELDING

3.2.1 RADIATION SAFETY DESIGN

The conceptual design of the cave shielding structure, as summarised in *Technical Report for Civil part* [8], considers all the system requirements [3] and external limitations (Chapter 2.2.1). It was developed and validated with the help of radiation calculations in order to comply with radiation safety requirements. The results of these calculations are summarised in the *Radiation Safety Analysis* [7].

The radiation safety analysis determined minimum requirements for thicknesses and material composition of the cave walls, ceiling and floor. In combination with given spatial constraints and floor load limits, it also determined the requirements for the shape and dimensions of the cave footprint. Consequently, **these requirements must be fulfilled by any future modifications to the conceptual design**. Otherwise, any such modification would require a new radiation safety analysis. Detailed information on these requirements is provided in the next sections.

The further requirements based on the radiation safety calculations are related to the concrete wall or roof structures which have to avoid any direct radiation streaming through the walls. The cave shielding is supposed to be constructed from pre-cast blocks. A chicane geometry for the block junctions is therefore required, the picture below illustrates the allowed geometries of the block chicanes. The displacement of the chicane ends, **d** must be at least 15 cm. The gap width should be minimized and must not exceed 1 cm. Straight gaps should not lie in a plane which intersects with the centre of the sample and within ±35 cm from such a plane.



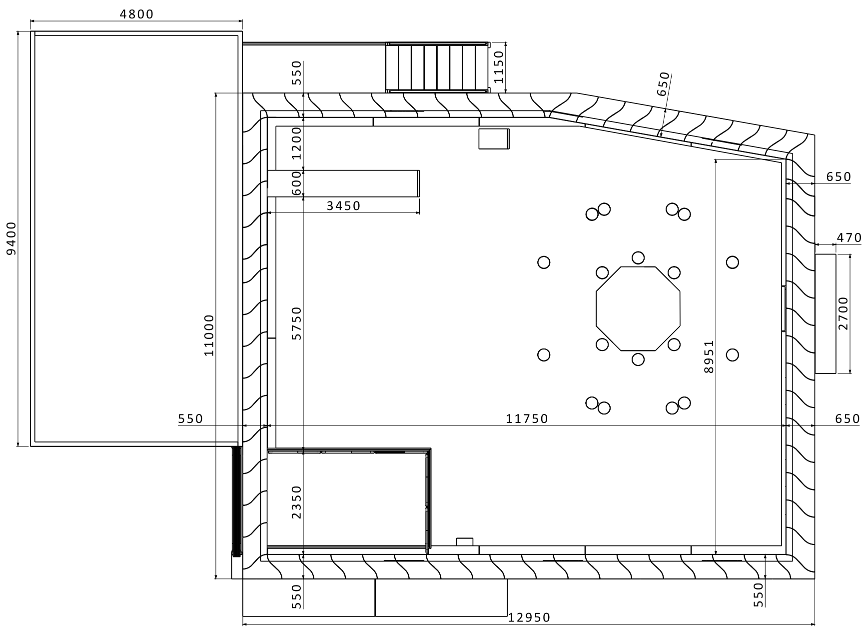
3.2.2 RADIATION SAFETY ASSUMPTIONS

The shielding property of the experimental cave shall provide sufficient protection (dose limit at the outside cave surface < 3 µSv/h) from the radiation, even occurring during an experiment or during hazardous scenarios described in [6]. The inner space of the E01 hall is considered the supervised area [9]. The experimental cave shall shield its surroundings against the radiation produced by the neutron beam to safe levels according to ESS radiation safety regulations as specified in [10]. Access to the cave for sample changes, maintenance, repairs or adjustments is necessary. The surroundings of the cave must be safe for personnel. It can be verified by dose rate measurements.

3.2.3 GEOMETRY AND MATERIAL PROPERTIES

The geometry and dimensions of the cave corresponding to the conceptual design are shown in Figure 5. The model used for the radiation calculations ([7]), together with material thicknesses and properties, is illustrated in Figure 6. The required material properties resulting from the radiation calculations are also summarised below.

- Standard density (2.35 g/cm^3) concrete can be used as a structural material for the cave foundations and roof.
- Heavy concrete (density 3.8 g/cm^3) shall be used for the cave walls, which require strengthened shielding properties.
- The inner walls and roof have to be covered by a layer of B_4C-containing material with an equivalent density of 3 kg of pure B_4C per 1 m^2.



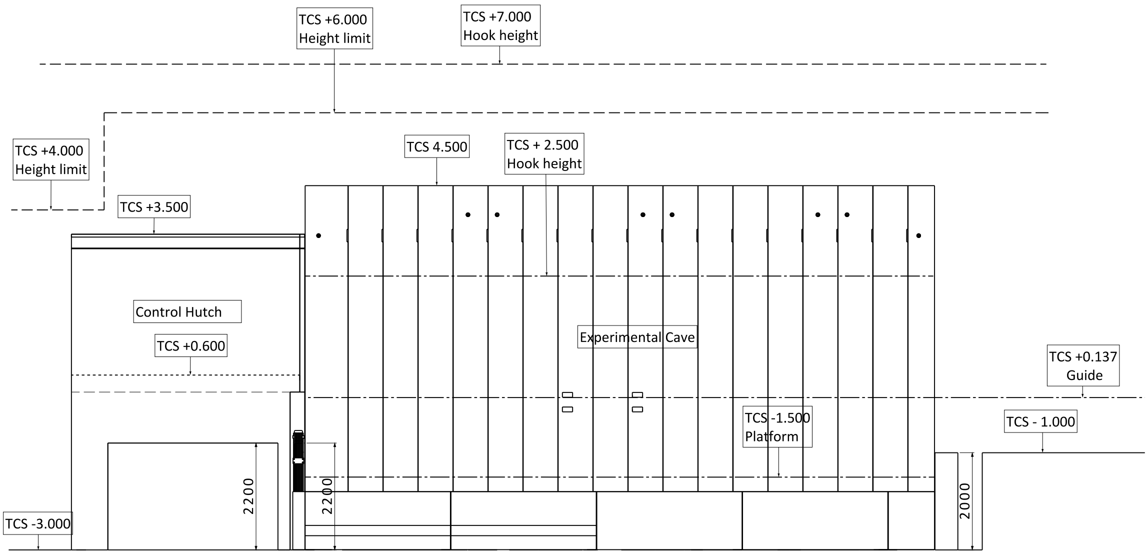


Figure 5: The experimental cave layout drawing with major dimensions.

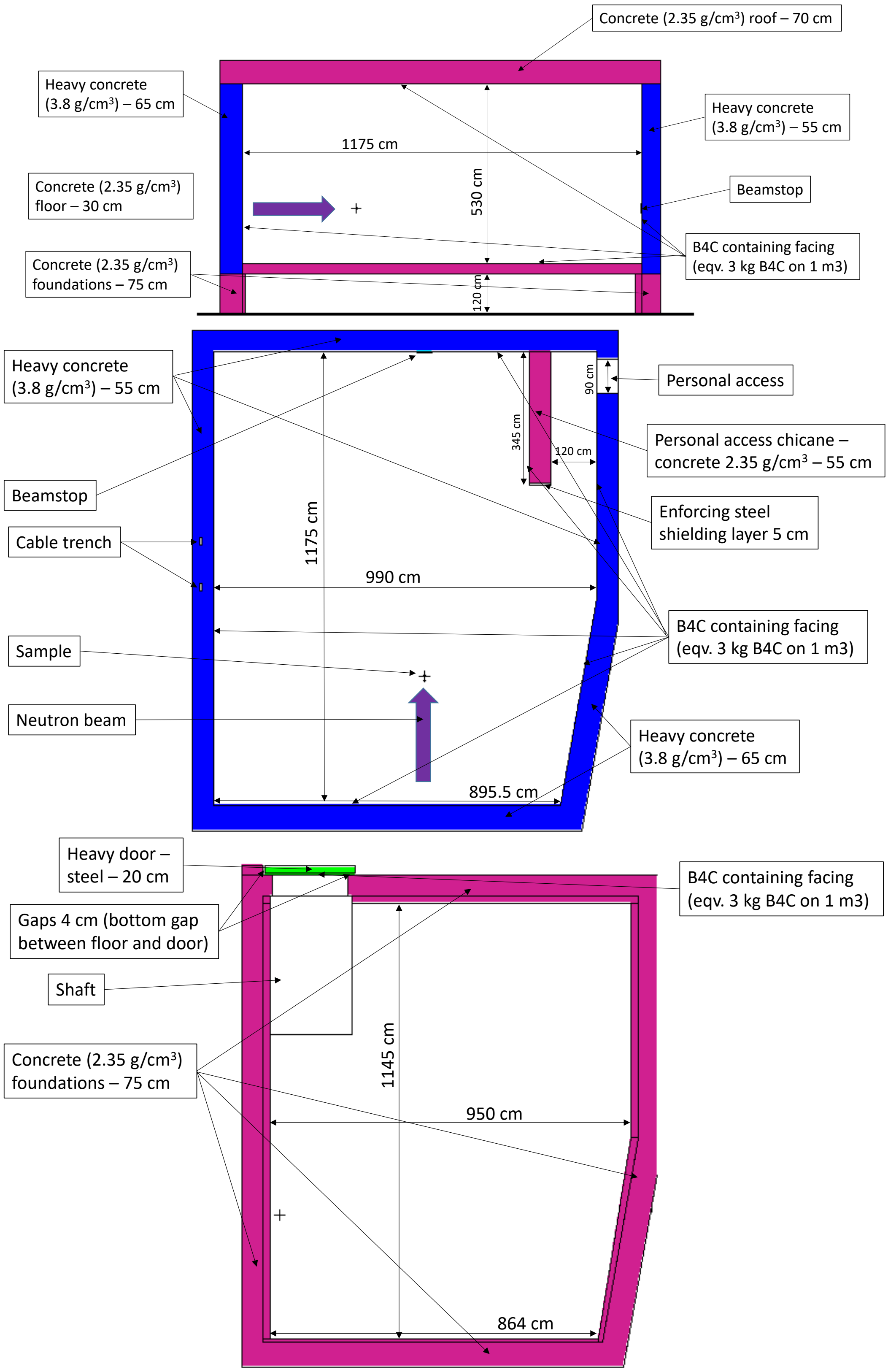


Figure 6: The experimental cave model used for radiological simulations.

3.2.4 IMPORTANT NOTE

Any changes in the cave dimensions, wall thickness, and shielding material composition must be verified by the radiological calculation and approved by ESS.

3.2.5 OVERALL CAVE REQUIREMENTS

The basic outer dimension requirements for the cave structure are listed below:

R1. The external dimensions of the experimental cave shielding shall be 12.95 x 11 m^2 (L x W). The outer dimensions shall not exceed the footprint shown in Figure 5.

R2. The enclosed area of the experimental cave should be maximised.

R3. The cave shall have two door access points. One for equipment access with dimensions 2 x 2.1 m (W x H) and one for personal access with dimensions 0.9 x 2 m (W x H).

R4. The cave shall comply with the radiological calculation in terms of the material, structure, shape and dimensions.

R5. The structure has to be rigid and able to handle all hazards related to the area.

3.2.6 FOUNDATIONS AND FLOOR SUPPORTS

3.2.6.1 REQUIREMENTS

Below are listed the main requirement for the wall foundations and floor support structures.

R6. The wall foundations and floor support structures should use normal concrete with a density of 2.35 g/cm^3.

R7. If a wider foundation is needed, due to the E01 floor load limit (20 t/m^2), the widening shall preferably be into the interior. The outer dimensions shall not be overridden.

R8. The free space for the entry bay should have dimensions of at least 2.1 x 3.6 m (W x L).

R9. The floor support structures should allow the service access and routing of cables/pipes or HVAC system utilities.

3.2.6.2 CONCEPTUAL DESIGN

The detailed description of the conceptual design is summarised in the *Technical report for Civil part* [8]. For the assessment and maximum load on the floor slab in E01, see the static analysis presented in the *Static analysis and technical report* [11]. The above-mentioned reports can be used as the template and guidance for the further analysis needed in the final design. Below is the extract of the design description related to the foundation and floor-supports design.

Requirements for the load capacity in E01 according to the document *ESS – Instrument Technical Interfaces* [4] and *Basis of structural design SS-EN 1990* [12] are fulfilled. The experimental cave peripheral foundations are made of pre-cast reinforced concrete blocks of the primary thickness of 750 mm with an extended bottom (because of load distribution). The foundation block has a height of 1200 mm. These foundation blocks are separated from the E01 floor slab by a strip of heavy bitumen sheet (SBS modified bitumen sheet with a fibreglass support insert) with a thickness of 3.5 mm. The basement walls are also designed at the entry bay, under the crane pillar, and at the placement of the technological equipment to ensure the optimum rigidity and load-bearing capacity of the experimental cave elevated platform (level of TCS-1.5 m). Basement wall thicknesses are 300 mm or 600 mm. Next, there is a designed foundation block (L=1700 mm, W=1000 mm, H=1450mm) between the octagonal foundation blocks and the front peripheral wall of the cave. This block forms the basis for placing the guide exchanger equipment. This massive foundation block of pre-cast reinforced concrete is **separated from other related structures** using an expansion joint with a width of 20 mm. The expansion joint is filled with mineral wool.

At the sample tower shaft, the foundation structure is octagon-shaped. The clear inner width of the octagonal pit is 1900 mm. There are designed two rows of foundation blocks, a thickness of 600 mm. The first is the inner circumference of the octagon pit, and the second is below the detector support outer end. This will prevent the transmission of vibrations from the dynamic load from the sample tower rotary table. The massive foundation blocks are separated from the E01 floor slab by a strip of heavy bitumen sheet in the same way as other foundation blocks. The overview of the pre-cast block foundations is shown in Figure 7.

For service access to the space under the platform (service area), a check opening with a steel inspection door is designed on the side wall of the entry bay. The foundation pre-cast blocks are designed from ordinary concrete (density 2300 kg/m^3) C30/37 - XC1 with B 500B reinforcement.

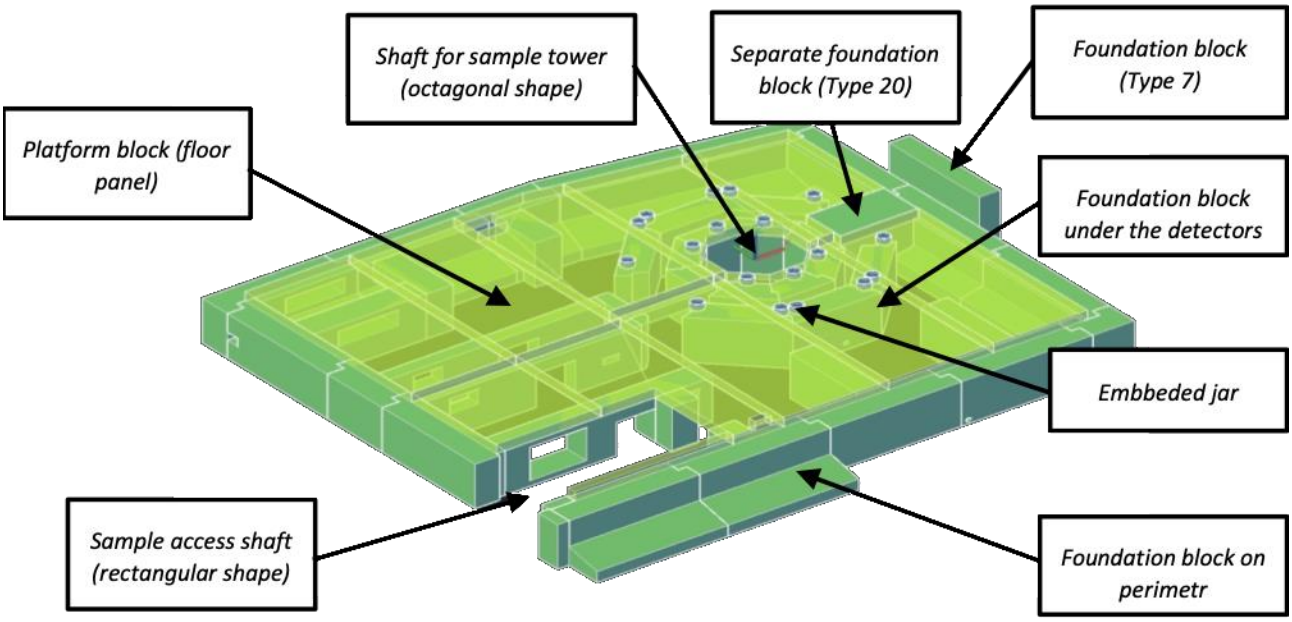


Figure 7: The overview of the foundation pre-cast blocks arrangement.

3.2.7 CAVE WALLS

3.2.7.1 REQUIREMENTS

Below are the basic requirements for the experimental cave walls.

- **R10.** The material of the walls shall be heavy concrete with a density of at least 3.8 g/cm^3.
- **R11.** The walls shall be covered with a boron-containing layer with the equivalent of 3 kg of pure B_4C per 1 m^2.
- **R12.** The front wall shall have a thickness of 65 cm.
- **R13.** The back and left (towards NMX; south) walls shall have a thickness of 55 cm.
- **R14.** The right (towards C-SPEC, north) wall shall have a thickness of 65 cm to the kink (5390 mm from the front wall) and 55 cm from the kink.
- **R15.** Walls shall accommodate the railing system for the inner crane.

R16. The front wall shall be compatible with the common shielding blocks.

R17. The front wall shall accommodate the guide system feedthrough.

R18. The front wall shall create a platform for the last support leg of the guide system.

R19. The front wall shall accommodate the cable and pipes feedthrough chicanes with an overall area of at least 24 dm^2.

R20. The back wall shall accommodate the cable feedthrough chicanes with an overall area of at least 9.6 dm^2.

R21. The front wall shall allow future access and installation of the fire suppression system.

R22. The walls shall not allow direct beam streaming. The block's chicane overlap shall be at least 15 cm.

R23. The back wall shall accommodate the attachment of the beam stop.

R24. The chicane wall (interior) located 120 cm in front of the service/personal entry shall be 55 cm thick, 340 cm in length and 250 cm in height, covered on the front end with a steel plate of thickness of 5 cm.

3.2.7.2 CONCEPTUAL DESIGN

The detailed description of the conceptual design is summarised in the *Technical report for Civil part* [8]. The above-mentioned report can be used as the template and guidance for the further analysis needed in the final design. Below is the extract of the design description related to the cave walls design.

The cave walls are designed as shielding pre-cast reinforced concrete parts with appropriate thickness. An opening with a clear diameter of 150 mm will be made in the front wall of the cave (the axis at the level of TCS+0.137 m) suitable for the neutron guide feedthrough. *The conceptual design of the guide feedthrough is not finalised here due to the lack of interface details at the design time*. The dimensions of an ordinary wall panel are the following, the length of 6300 mm, the width of 720 mm, and the thickness of 550/650 mm. For the service/personal entrance, the shielding partition block (chicane) is designed inside the cave (thickness 550 mm and height 2500 mm). The space between the side wall near the personal entrance and the shielding partition block is 1200 mm. The overview of the pre-cast block wall panel arrangement is shown in Figure 8.

Ordinary wall panels are complemented by the corner and additional panels for peripheral wall connection. Wall panels are installed on foundation blocks (see Chapter 3.2.6). The wall panels are joined to each other by internal steel rods and anchoring plates. The top of the wall panels is shaped to accommodate ceiling panels.

The pre-cast wall parts are designed from reinforced heavy concrete (magnetite-containing concrete - density 3850 kg/m^3), strength class C30/37 - XC1 with B 500B reinforcement. To ensure shielding properties and protects the wall structure from activation, the inside surfaces of the cave will be coated with special boron carbide (B_4C) tiles.

A series of feedthrough for the cables and pipes are designed on the front (5x4), back (4x4) and left (2x2) walls (see Figure 8). They are formed in the pre-casted wall blocks with a cross-section of 60x200 mm^2 (HxW). The passage of the feedthrough is angled (45°) upwards from outside with the surface of the wall to prevent the streaming. The total area of the feedthrough is 24 dm^2 on the front wall, 9.6 dm^2 on the back wall and 4.8 dm^2 on the left wall. On the front wall, there is also separate feedthrough for the sprinkler pipe with a diameter of 40 mm at the same angle as for the feedthrough.

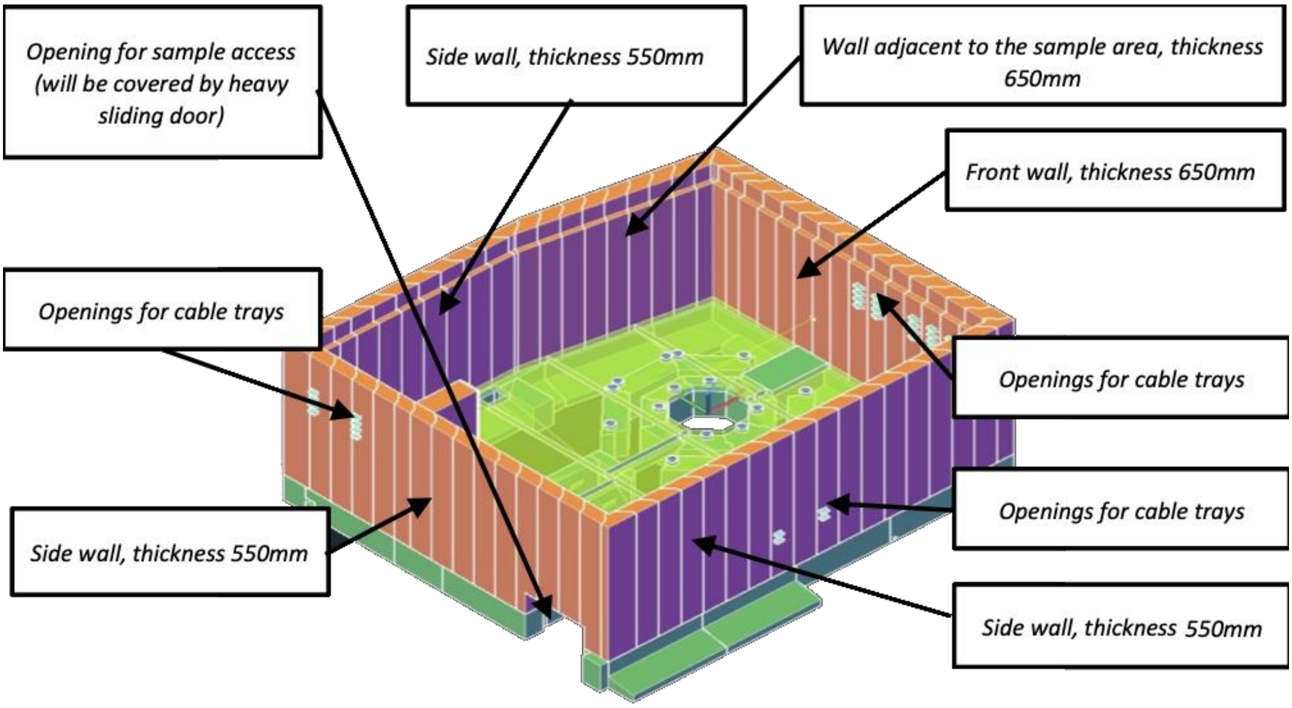


Figure 8: The overview of the wall pre-cast panels arrangement.

3.2.8 CAVE INNER FLOOR AND CEILING

3.2.8.1 REQUIREMENTS

Below are the basic requirements for the experimental cave inner floor (elevated floor above the E01 floor level) and the cave ceiling.

R25. The cave floor and ceiling should use normal concrete with a density of 2.35 g/cm^3.

R26. The cave floor and ceiling shall be covered with a boron-containing layer with the equivalent of 3 kg of pure B_4C per 1 m^2.

R27. The cave floor shall have an upper surface of 1.5 m above the E01 level and a thickness of at least 30 cm.

R28. The cave floor surface finish should be smooth and flat, suitable for air-cushion transport platform access.

R29. The cave floor shall have a load capacity of 4 t/m^2 everywhere with reinforcement to 5 t/m^2 under the incoming beam in the width of at least 1 m.

R30. The cave floor shall include a shaft (octagonal pit) centred at the sample position (TCS coordinates x=-128945.59, y=91477.05) with reinforced walls for the sample tower (design Hereon).

R31. The elevated platform shall accommodate the embedded jars for the kinematics mounts of the detector support structures (design and positions provided by Hereon).

R32. The space of the entry bay shall have a protective fence at the edge of the false floor, but it shall also enable personal access (ladder) on the E01 floor level.

R33. All access paths below false floor area shell be limited by protective fences.

R34. The cave ceiling shall have a thickness of 70 cm.

R35. The ceiling structure shall allow roof opening above the sample position with dimensions at least 2.5x2.5 m and at the rear wall of the cave with dimensions 2.5 x 4.5 m^2 (L x W).

R36. The cave ceiling should be accessible, but no working area is expected there.

3.2.8.2 CONCEPTUAL DESIGN

The detailed description of the conceptual design is summarised in the *Technical report for Civil part* [8]. The above-mentioned report can be used as the template and guidance for the further analysis needed in the final design. Below is the extract of the design description related to the cave floor and ceiling design.

The upper level of the experimental cave floor platform is TCS-1.5 m. The cave floor is designed from pre-cast reinforced concrete panels with a thickness of 250 mm, concrete C30/37, XC1, and a density of 2300 kg/m^3. The floor panels will be laid on the foundation blocks and provided with a concrete screed (30 MPa) of the thickness of 36 mm, levelling layer (if needed) – a self-levelling screed on a cement basis of the thickness of 3 mm and the shielding B_4C tiles. The flatness of the final surface will be provided with an epoxy layer (colour shade provided, thickness 3 mm).

The embedded jar for the kinematic mounts will be placed in the pre-casted platform panels. The process of the placement was not developed yet due to the lack of details from the in-kind partner at the time.

The floor composition with a shielding layer is designed on the upper surface of the platform. The maximum load on the platform is designed at the level of 4 t/m^2 over the entire area, except for the area between the sample tower shaft and the front wall, where the maximum load will be increased to 5 t/m^2 due to the placement of an additional shielding around a guide exchanger. The entry bay with a footprint area of 2150×3650 mm^2 is designed to enable large samples and sample environments handling in and out of the cave using a transport moving on the E01 floor level (TCS-3 m). At the axis of the sample position, the octagonal sample tower shaft with inner dimensions of 1900×1900 mm is designed. The centre of the octagonal pit for the sample tower (sample position) is situated 3350 mm away from the front wall and is aligned with the sample axis (TCS coordinates x=-128945.59, y=91477.05). The edge of the pit is lined at the elevated floor level with a 60×40×5 mm^3 steel L profile fixed to the concrete floor. The overview of the cave floor panel arrangement is shown in Figure 9.

The ceiling above the experimental cave is also designed as a shielding. It consists of pre-cast reinforced concrete – removable ceiling panels (thickness 700 mm) and 3 pcs of fixed ceiling beams. The pre-cast ceiling panels are designed from normal concrete with a density of 2300 kg/m^3, strength class C30/37 - XC1 with B 500B reinforcement.

The ceiling beams are fixed. The ceiling panels are demountable. If necessary, they can be dismantled using the crane in E01 with a maximal load capacity of 10 tons. The ceiling panels are fitted with anchor points for the fall protection system. The anchors with permanent steel rope are designed. The overview of the ceiling panel arrangement is shown in Figure 10.

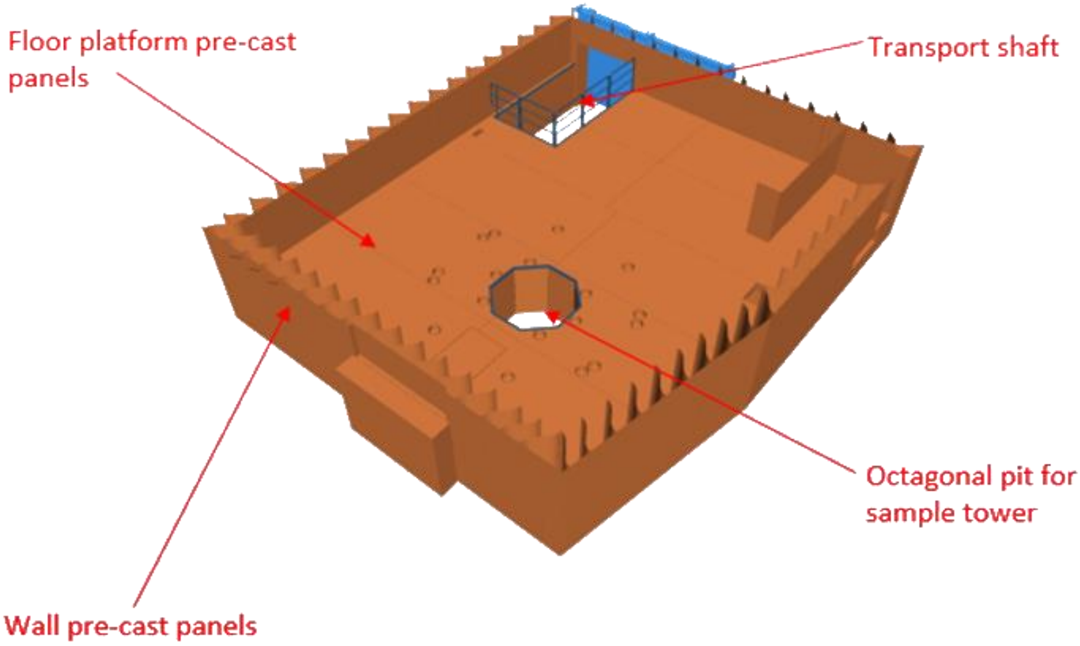


Figure 9: The overview of the cave floor platform (pre-cast panels) arrangement.

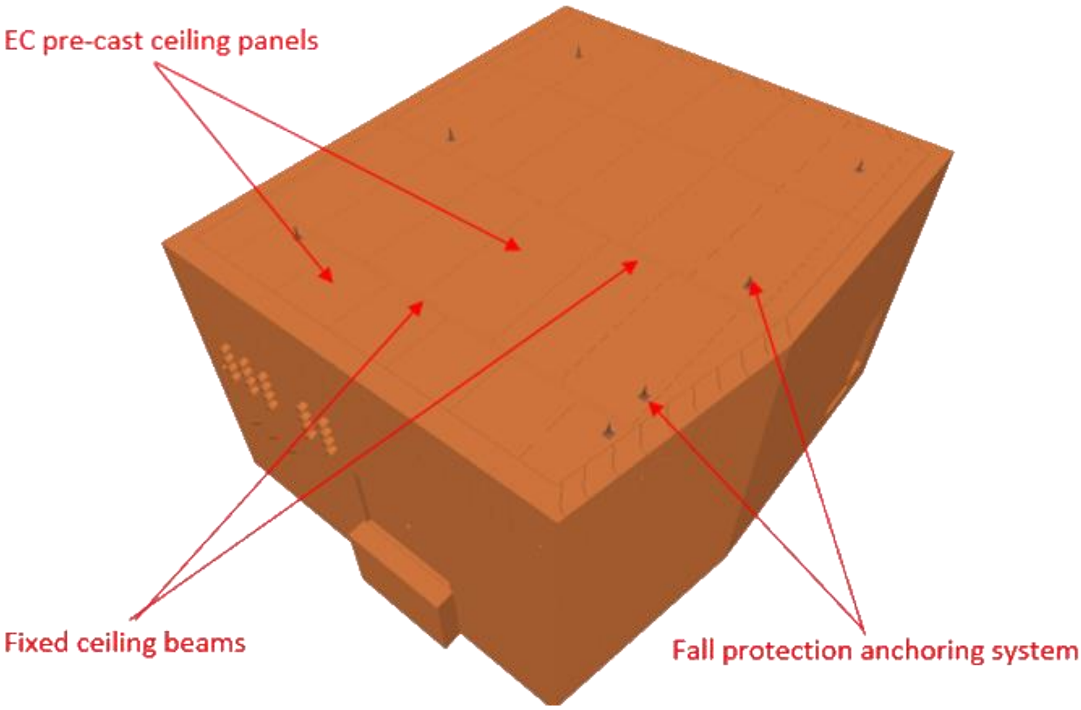


Figure 10: The overview of the ceiling pre-cast panels and beams arrangement.

3.2.9 PERSONAL ENTRY

3.2.9.1 DESCRIPTION

The personal entry at the level of the cave floor will be used for quick access into the cave during the setting up of the experiment. The design of the shielding is done in such a way that the door material doesn’t need to have a shielding property, and even during the running experiment, the door area is safe from radiation exposure. The door must have a lock system and must be equipped with switches monitoring the status in the **close position**. The switches and locking system will be part of PSS, and will be installed and connected by the PSS group at ESS. The design of the personal entry has to be fully compatible with the dedicated types of hardware listed below.

3.2.9.2 REQUIREMENTS

Below are the base requirements for the experimental cave personal entry.

R37. The personal entry into the cave shall be at the height of the cave floor (TCS+1.5 m).

R38. The personal entry shall have easy access from the E01 floor.

R39. The personal entry should allow easy access from the control hutch.

R40. The personal entry shall contain a fence or door-like system to prevent entry.

R41. Two safety switches shall be incorporated in the personal entry door design to monitor the **closed position** of the doors. The specific details are listed below. The hardware will be delivered and connected by the PSS group.

- One safety-classified mechanical switch will be connected to the PSS system and detect the closed position. Due to the ESS safety requirements, the design adaptation **must be fully compatible** with the switch SIEMENS 3SE5112-1QV10[2] or 3SE5212-0QV40[3] with the actuator 3SE5000-0AV07-1AK2[4]. The actuator head shall be extended only when the door is in a closed position. When the door is in the opened position, the actuator head shall be retracted. Guidelines for actuation, travel range and adjustment of the switches are available from the ESS PSS group.
- One safety-classified magnetic switch will be connected to the PSS system and detect the closed position. Due to the ESS safety requirements, the design adaptation **must be fully compatible** with the switch SIEMENS 3SE6604-2BA[5] with solenoid 3SE6704-2BA[6] and the spacer for rectangular block 3SX3260[7] to detect the closed position of the door.

R42. The locking system shall be incorporated in the personal entry door to prevent its opening when locked but allow the emergency escape when needed. The hardware will be delivered and connected by the PSS group.

- The safety lock for the access door to the experimental cave, with escape release from inside, will be installed on the door system and connected to the PSS system. Due to the ESS safety requirements, the design adaptation **must be fully compatible** with the Fortress amGardpro ITM-00230775A178877[8].

3.2.9.3 CONCEPTUAL DESIGN

The detailed description of the conceptual design is summarised in the *Technical report for Civil part* [8]. The above-mentioned report can be used as the template and guidance for the further analysis

[2] Switch body – SIEMENS 3SE5112-1QV10
[3] Switch body – SIEMENS S3SE5212-0QV40
[4] Head part – SIEMENS 3SE5000-0AV07-1AK2
[5] Switch body – SIEMENS 3SE6604-2BA
[6] Solenoid – SIEMENS 3SE6704-2BA
[7] Spacer – SIEMENS 3SX3260
[8] Fortress amGardpro – ITM-00230775A178877

needed in the final design. Below is the extract of the design description related to the personal entry design.
The personal entry to the experimental cave is from the floor of E01 at the level of TCS-3 m, using an external steel staircase. The steel staircase is designed to overcome the height of 1500 mm. The steel staircase is also used for access to the control hutch. The staircase will be provided with a handrail of 1000 mm in height. The overview is depicted in Figure 11.
To enter the experimental cave, at a level of TCS-1.5 m, a single-wing rotary door (aluminium wing and Al frame) is designed - dimensions 900×2000 mm. This door is equipped with a magnetic lock connected to PSS (see **R42**).
The personal entry door will be painted with the colour RAL 6032 - Signal Green, door frame with RAL 9005 - Black.

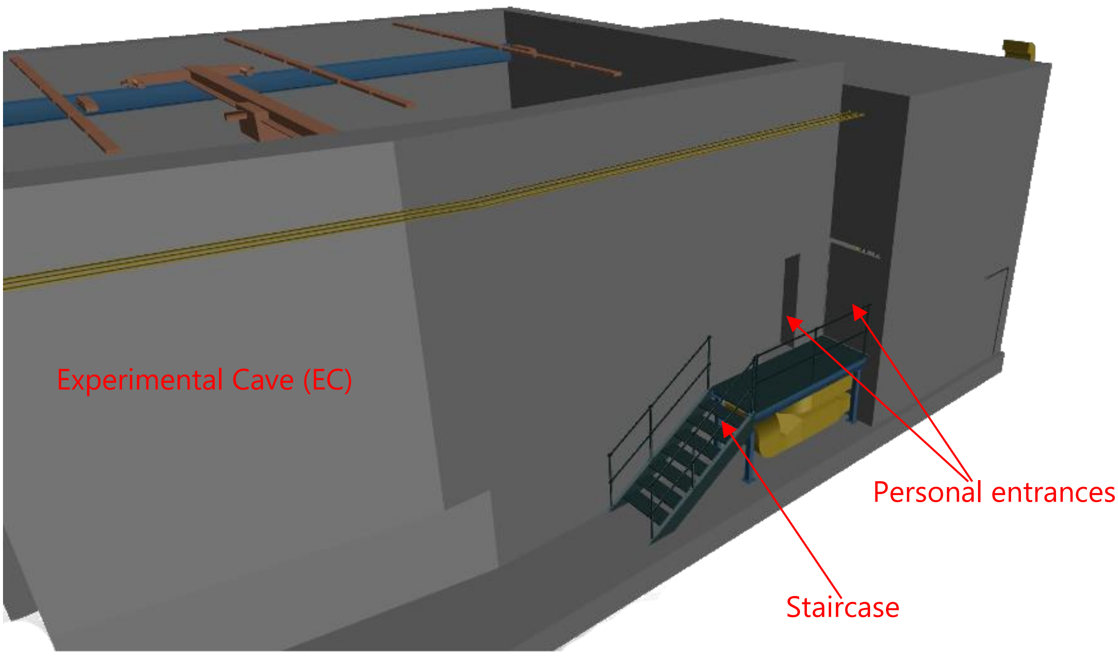


Figure 11: The overview of the access staircase for the personal entrance.

3.3 UNIT 2 – CAVE SLIDING DOOR

3.3.1 DESCRIPTION

The heavy sliding door is used to shield the radiation from inside the cave through the entry bay during the experiment and also to allow access to the voluminous samples and sample environments in the cave. The door shall be equipped with switches which will monitor the status of the door and will be connected to PSS. The mechanism of opening/closing can be motorised or manual, but it needs to fulfil the safety requirement for safe operation for the personnel.
If the operation of the door is motorized, then the PSS shall allow to interlock the main power to the motor. PSS group has to be involved in electrical circuit design. The possibility of manual operation shall be considered (when motor is out of service) and the possibility of locking the manual operation mechanism (mechanical key interlock) should be considered.

3.3.2 REQUIREMENTS

Below are the basic requirements for the experimental cave sliding door system.

R43. The thickness of the door shall be equivalent to 20 cm of steel plus an absorbing layer equivalent to 1 mm of B_4C on the inner side.

R44. The door shall cover the entrance with the dimensions 2 x 2.1 m (W x H) with at least 15 cm overlap.

R45. The doors in the open position shall allow full usage of the entrance space.

R46. The time necessary for the full open/close shall be below 40 seconds.

R47. Two safety switches shall be incorporated in the heavy door design to monitor the **closed position** of the doors. The specific details are listed below. The hardware will be delivered by the PSS group.

- One safety-classified mechanical switch will be connected to the PSS system and detect the closed position. Due to the ESS safety requirements, the design adaptation **must be fully compatible** with the switch SIEMENS 3SE5112-1QV10[9] or 3SE5212-0QV40[10] with the actuator 3SE5000-0AV07-1AK2[11]. The actuator head shall be extended only when the door is in a closed position. When the door is in the opened position, the actuator head shall be retracted. Guidelines for actuation, travel range and adjustment of the switches are available from the ESS PSS group.
- One safety-classified magnetic switch will be connected to the PSS system and detect the closed position. Due to the ESS safety requirements, the design adaptation **must be fully compatible** with the switch SIEMENS 3SE6604-2BA[12] with solenoid 3SE6704-2BA[13] and the spacer for rectangular block 3SX3260[14] to detect the closed position of the door.

R48. If the door is designed with a manual opening mechanism, the locking system shall be incorporated in the personal entry door to prevent its opening when locked but allow the emergency escape when needed. The hardware will be delivered and connected by the PSS group.

- The safety lock for the access door to the experimental cave, with escape release from inside, will be installed on the door system and connected to the PSS system. Due to the ESS safety requirements, the design adaptation **must be fully compatible** with the Fortress amGardpro ITM-00230775A178877[15].

R49. The gap between the door and the cave wall should be as small as technically feasible, but it shall be smaller than 4 cm.

R50. The gap between the door and the E01 floor should be as small as technically feasible, but it shall be smaller than 4 cm.

R51. The door system shall ensure a safe operation for the personnel.

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[9] Switch body – SIEMENS 3SE5112-1QV10
[10] Switch body – SIEMENS S3SE5212-0QV40
[11] Head part – SIEMENS 3SE5000-0AV07-1AK2
[12] Switch body – SIEMENS 3SE6604-2BA
[13] Solenoid – SIEMENS 3SE6704-2BA
[14] Spacer – SIEMENS 3SX3260
[15] Fortress amGardpro – ITM-00230775A178877

3.3.3 CONCEPTUAL DESIGN

The detailed description of the conceptual design is summarised in the *DPS01.07-Sliding door - Technical report* [13]. The above-mentioned report can be used as the template and guidance for the further analysis needed in the final design. Below is the extract of the design description related to the sliding door design.

The shielding part is designed as the sandwich structure of carbon metal sheets in appropriate dimensions – see Figure 12, covered by a 1 mm B_4C layer equivalent for neutron shielding on the inner side (e.g. 2 mm layer of composite 20% resin + 80% B_4C powder). The sheets are made from construction carbon steel S235JR+N with less than 0.2% of cobalt. This content must be confirmed by certificate 3.1 according to EN 10204.

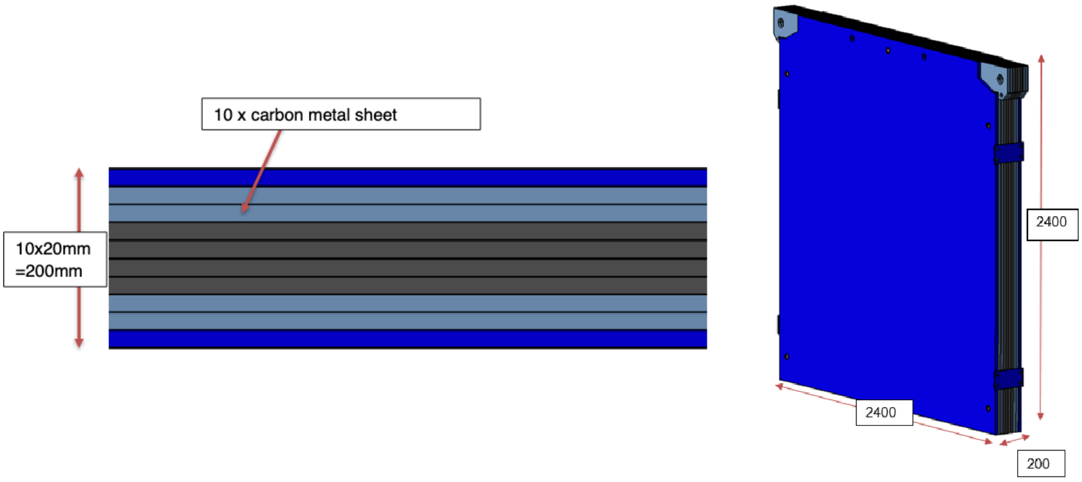

Figure 12: The shielding part of the sliding doors.

The beam is manufactured from the IPE profile according to DIN 1025-5, size 300 mm and length 5400 mm. The material is carbon steel S355J2 with less than 0.2% of cobalt. This content must be confirmed by certificate 3.1 according to EN 10204. On the beam profile are mounted consoles for installation on the experimental cave wall.

As the translation parts are used, the carriages with wheels. These wheels run on the profiles for guidance. In Figure 13, the carriage on the left side is without drive; it is meant to be without an action part. The carriage on the right side includes a drive. The drive consists of a motor, gearbox and pinion.

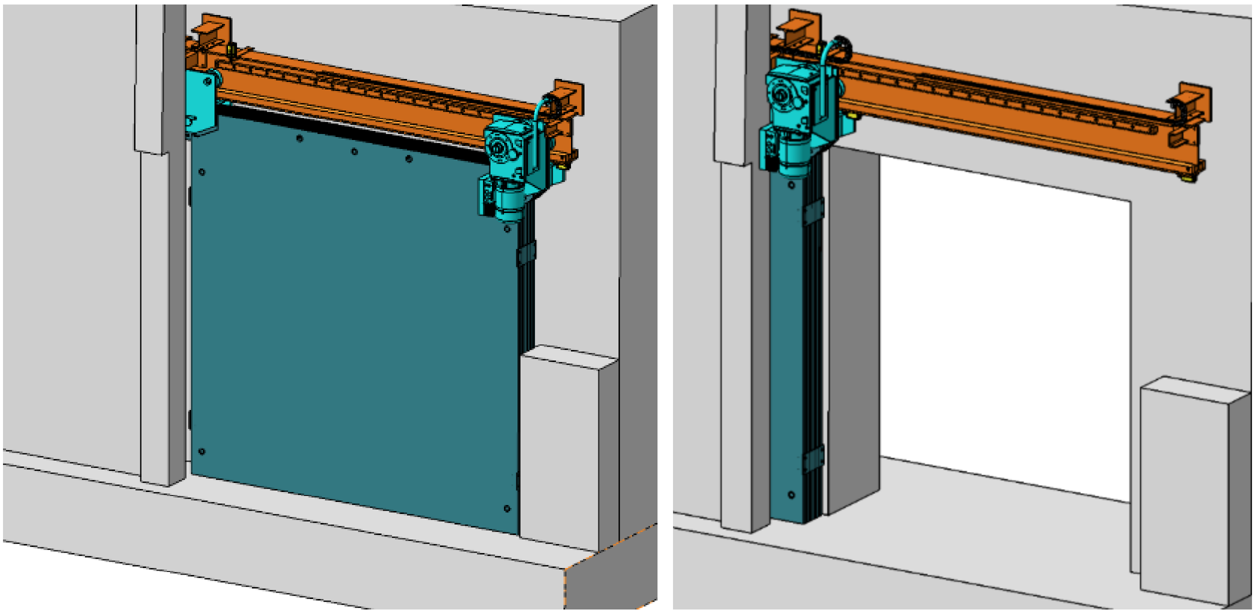

Figure 13: 3D view of the closed (left) and open (right) sliding door of the experimental cave.

3.4 UNIT 3 – CAVE INTERNAL CRANE

3.4.1 DESCRIPTION

The cave internal crane will be used for the manipulation of the voluminous or heavy samples and sample environments from the entry bay onto the sample position or the cave floor. It will also use for the mounting/dismounting of the detectors and the radial collimators assemblies. The detector handling requires smooth acceleration of the crane movements. The hook print should be maximised to allow as large coverage as possible. The same applies to the maximal hook height. The design should allow for maximising the cave height usage.

3.4.2 REQUIREMENTS

Below are the base requirements for the experimental cave interval crane system.

R52. The internal crane shall have a maximal load of at least 4 t.

R53. The crane control shall allow smooth movement acceleration.

R54. The maximum hook height should be at least 4 m above the cave floor.

R55. The hook-print should be maximised, but it shall at least cover the middle points of the roof opening ports (above sample and at the cave rear) and the entry bay.

3.4.3 CONCEPTUAL DESIGN

The detailed description of the conceptual design is summarised in the *Technical report for Civil part* [8]. The above-mentioned report can be used as the template and guidance for the further analysis needed in the final design. Below is the extract of the design description related to the cave's internal crane design.

Below the ceiling will be a crane track for a single-track bridge crane with a load capacity of 4t. The crane tracks will be mounted on brackets and steel anchor plates, with an upper rail level of TCS+3.1 m. One horizontal beam will be supported in the middle by a steel pillar. The crane track span is 8.6 m.

For moving heavier loads inside the cave, a bridge crane with a lifting capacity of 4 t and hook height level TCS+2.3 m (4.0 m above the cave floor) will be used. The bridge crane allows easy movement and positioning of the samples and equipment within the experimental Cave. The bridge crane moves on the track at a level of TCS+3.1 m in the full length of the experimental Cave. The bridge crane has technical parameters listed in Table 2 and the schematic is presented in Figure 14.

Table 2: The crane parameters.

4t CXTS Single Girder Crane			
Bridge span	8 600 mm	Crane control	Radio remote control
Lifting capacity	4000 kg	Main Voltage	3×400V, 50Hz
Runway length	11 800 mm	Control voltage	48V, 50Hz
Lifting height	5.2 m	Operating temperature	+5° to +40° C
Hook type	HBC 2.5	Dead weight	1 660 kg
Hoist travel speed	20 m/min – step-less	Lifting speed	0.11/5.6 m/min – step-less
Bridge travel speed	20 m/min – step-less		

For the crane track and its support, it is proposed to install steel support brackets into the experimental cave walls before concreting, on which the crane beams will be installed. The steel structure of the crane track will be coated – with polyurethane paint, shade 9005 - black.

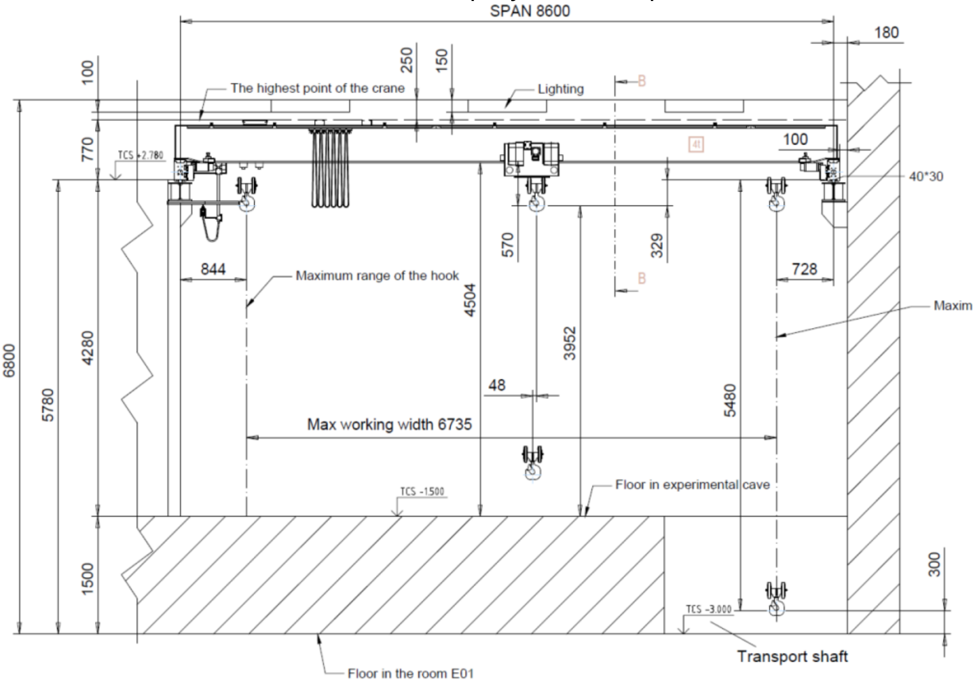

Figure 14: The schematic view of the bridge crane situation within the cave.

3.5 UNIT 4 – CAVE BEAM-STOP

3.5.1 DESCRIPTION

The beam-stop purpose is to stop the primary neutron beam passed through the sample position. The size of the beam-stop has to be big enough to capture diverging neutron beam coming from the neutron guide system at the front part of the cave. It has to prevent back-scattering of the neutrons and reduce gamma radiation produced by neutron capture.

The material design and dimensions of the beam-stop come from the radiological calculations mentioned in Chapter 3.2 and they should not be changed, or new calculations shall be provided.

3.5.2 REQUIREMENTS

Below are the base requirements for the experimental cave beam-stop system.

R56. The beam-stop shall cover the active area of at least 25 x 40 cm (W x H) of the maximally diverged neutron beam.

R57. The beam stop shall be attached to the rear wall with the centre at the axis of the neutron beam.

R58. The beam-stop active area shall contain a 2 cm thick boron-containing plate (material with a minimum of 80% of pure B_4C).

R59. The active area of the beam-stop shall be embedded in a lead dousing with a thickness of at least 3 cm towards the rear wall and at least 1 cm in the lateral directions.

3.5.3 CONCEPTUAL DESIGN

The detailed description of the conceptual design is summarised in the *Technical report for Civil part* [8]. The above-mentioned report can be used as the template and guidance for the further analysis needed in the final design. Below is the extract of the design description related to the cave beam-stop design.

On the back wall of the cave, a beam stop is to be equipped to attenuate the direct neutron beam. The beam stop was modelled as a 20 mm plate of B_4C housed in a lead shell. The detailed beam stop concept is shown in Figure 15.

It will be installed in the experimental cave on its back wall, and it will be an integral part of the wall. The structure of the beam-stop consists of a 20 mm thick plate of B_4C embedded in a lead block. The lead block surrounds the B_4C plate in the perpendicular direction to the neutron beam to shield a prompt γ radiation produced by the interaction of the neutrons with the boron. The size of the beam stop is designed to be able to accommodate the size of the full uncollimated divergent beam.

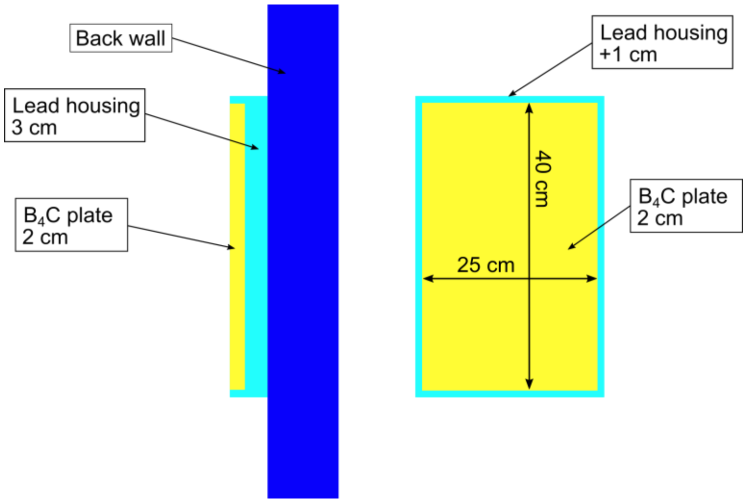

Figure 15: The cave beam-stop detailed description. Left – side view, right – front/along-beam view.

3.6 ADDITIONAL INFORMATION

The conceptual design reports and drawings are available on request. The summarised list of the available documents is presented in Table 3.

Table 3: The list of available documents and drawings from the conceptual design of the cave.

Reports
ESS-0461627 Technical report for Civil part
ESS-0461612 Static analysis and technical report - Steel structures
ESS-1407490 DPS01.07-Sliding door - Technical report
Drawings cave
ESS-0461613 Ground plan level -3,000 m
ESS-0461617 Ground plan level -1,500 m
ESS-0461618 Ground plan level +0,600 m
ESS-0461614 Sections 1-1', 2-2', 6-6'
ESS-0461615 Sections 3-3', 4-4', 5-5'
ESS-0461626 Views
ESS-0461619 Ground plan of the roof
ESS-0461628 Cassette ceiling
ESS-0461625 Details of cable penetrations through EC wall
ESS-0461622 Staircase 8/Z – section, ground plan
ESS-0461623 Staircase 8/Z – section, detail 1,2
ESS-0461624 List of locksmith products
ESS-0462075 Railing 9Z - View - Detail
Drawings sliding door
ESS-0462070 DPS.01.07 – Sliding door - assembly - Drawing
ESS-0462628 DPS.01.07 – Sliding door – Carriages with engine - Drawing
ESS-0462629 DPS.01.07 – Sliding door – Carriages - Drawing
ESS-0462631 DPS.01.07 – Sliding door – Beam - Beam
ESS-0462632 DPS.01.07 – Sliding door – Shielding part - Drawing
ESS-1423178 DPS01.07 - Sliding door - 3D model - STEP
ESS-1423273 DPS01.07 - Sliding door - Bill of quantities
ESS-1423276 BOM - Carriages
ESS-1423279 BOM - Trolley
ESS-1423281 BOM - Beam
ESS-1423282 BOM - Door
ESS-2487562 BOM - Sliding door

4 REFERENCES

[1] BEER - Concept of Operations (ESS-0124310)
[2] BEER PBS (ESS-0135521)
[3] BEER - System Requirements (ESS-0124328)
[4] ESS – Instrument Technical Interfaces (ESS-0403282)
[5] Radiological requirements and guidelines for instrument shielding design (ESS-1108220)
[6] BEER - H1 and H2 scenarios for radiation shielding (ESS-1407242)
[7] BEER – Radiation Safety Analysis (ESS-0432365)
[8] Technical report for Civil part (ESS-0461627)
[9] NSS zoning document - part I (ESS-0051603)
[10] ESS rules for supervised and controlled radiation areas (ESS-0001786)
[11] Static analysis and technical report (ESS-0461611)

[12] Basis of structural design Basis of structural design (SS-EN 1990)
[13] DPS01.07-Sliding door - Technical report (ESS-1407490)