The ESS neutron bunker design, materials and timeline.

Introduction

The neutron bunker is the shielding structure outside the monolith shield wall surrounding the target in the centre. The purpose of the bunker is to protect the experimental areas inside the instrument halls from the radiation coming from the monolith and to confine the radiation generated in the first sections of the neutron beam lines. The bunker allows ESS to safely feed neutron beams to the neutron instruments, which are distributed in two wide angle regions on either side of the linac-target area. With each region covering an angular range of 120° there is capacity for up to ≈20 neutron instruments with an angular separation of ≈6°.

An overview of the bunker for one side is shown in figure 1, and it is anticipated that the same design will be used for the other side. Figure 2 shows a side view of the bunker wall and the roof.

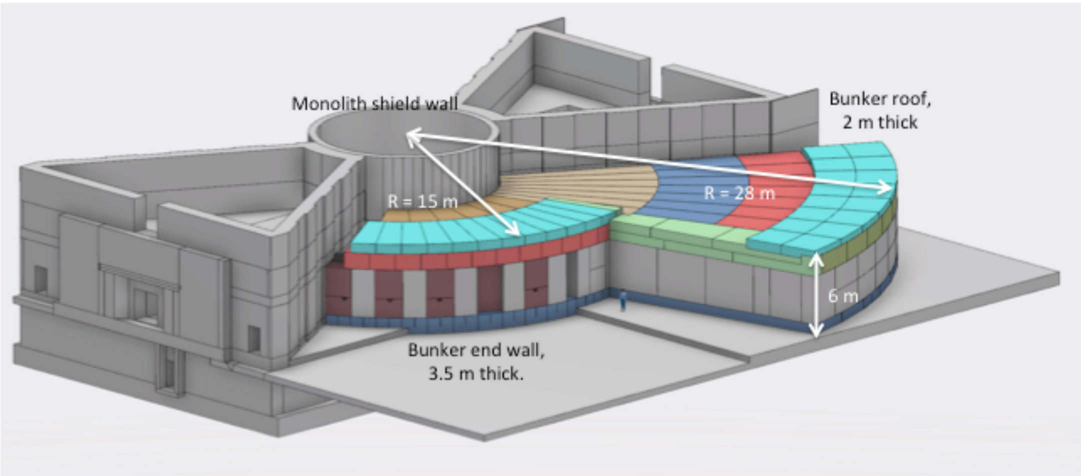

Fig.1. The image shows an overview of one side of the bunker. The scope of the bunker project includes the bunker end wall, the bunker roof from the monolith shield wall up to the bunker end wall and the support structures for the bunker roof.

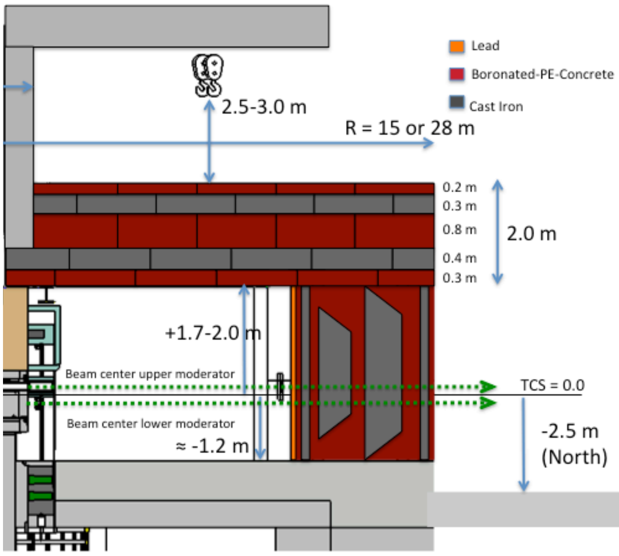

Fig.2. The schematic shows the side view of the bunker wall and the roof.

All instruments share the bunker area, which houses instrument components. For all neutron instruments the components in the bunker include neutron guides (which are housed in metallic vacuum channels) and neutron beam choppers. It will be essential that these components can be removed for maintenance or replacement with a high level of precision. For this purpose it will be necessary to mount the components on kinematic mounts. This will allow access to the components by removing adjacent parts of the bunker roof, and lifting them out with remote handling equipment due to the expected radiation levels.

Each instrument has a guide insert in the monolith shield wall, which feeds neutrons into the neutron guides in the bunker and which in turn feed them through the bunker wall. On the outside of the wall, which is located at 15 m or 28 m for the short and long sectors, respectively, there are openings (beam ports) for the instruments' beam line guides. These beam line guides, including different instrument components, then traverse the experimental hall and end at the instrument cave, which is shown in figure 3.

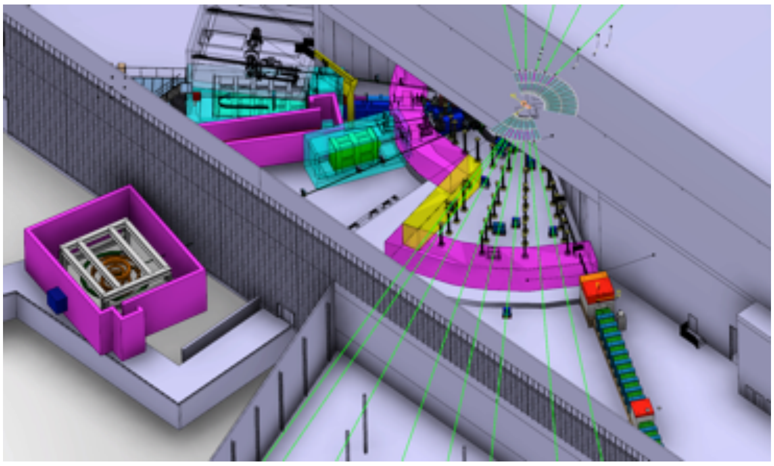

Fig.3. The 3D view shows different instruments beam lines starting at the target monolith shield wall. The beam line at the right of the figure shows the neutron guides and shielding out to the wall, which separates the bunker area from the experimental hall. Green lines indicate all other beam lines.

Unused beam ports will be blocked by beam stops. The bunker is inaccessible during operations (i.e. beam on target), but it must be easy to un-stack during maintenance periods.

The bunker is treated as one single ionizing radiation generating device in the Preliminary Safety Analysis Report (PSAR) to the Swedish radiation protection authorities. The bunker wall and the bunker roof will consist of modular pieces of shielding that are secured in place by engineering controls, e.g. a dedicated Personal Safety System (PSS) will secure the bunker shielding integrity.

In order to comply according to the legislative requirements, the bunker has to be stackable and un-stackable during maintenance in a safe way, which imposes design constraints on the bunker. Several overhead cranes of 20 – 30 tonne lifting capacity will be installed to facilitate movement of bunker parts in the wall and the roof, and for access to the components inside the bunker. Initial designs of the bunker and the blocks are shown in figures 4-7.

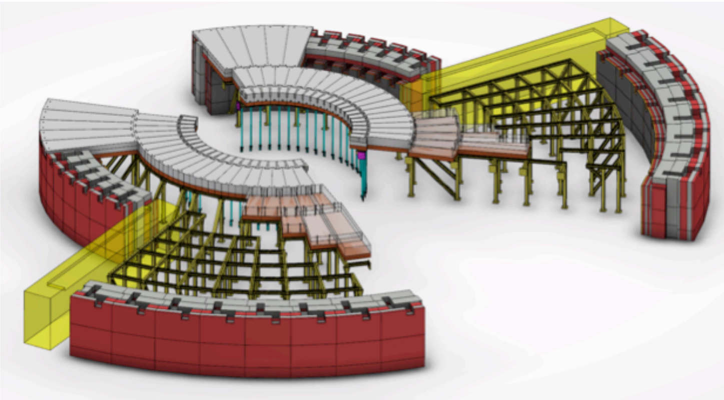

Fig.4. Concept of building the bunker roof and bunker wall utilizing blocks in order to easily un-stack/stack the bunker during maintenance periods. Also shown in the figure are the support structures for the bunker roof.

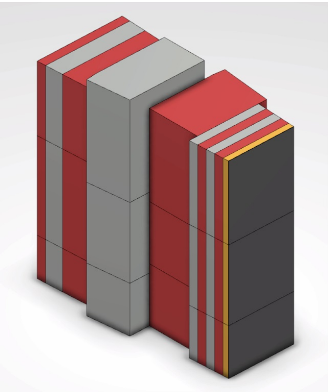

Fig.5. Schematic view of a segment of the bunker wall. The different colors indicate different materials (red=special concrete, grey=cast iron, yellow=lead, dark grey=B_4C coating).

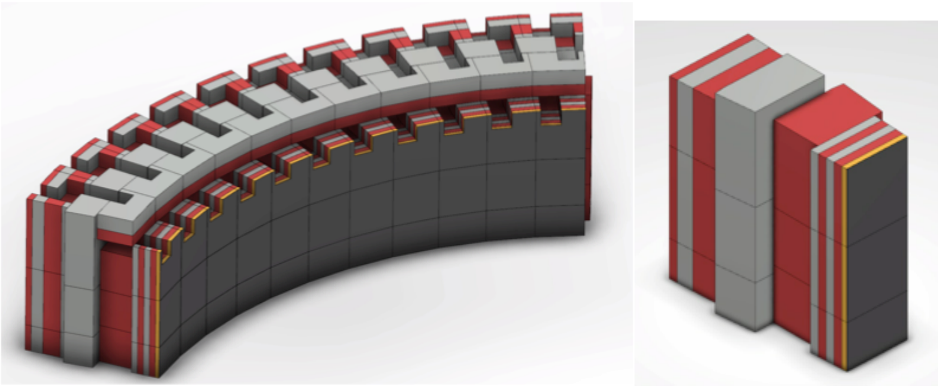

Fig.6. Schematic illustration of the bunker wall and an individual block used to build up the bunker wall.

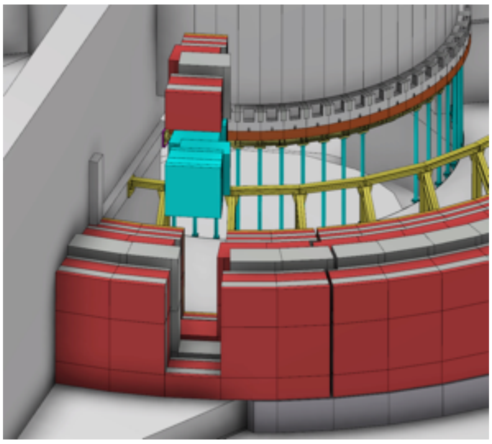

Fig.7. Illustration of a segment block in the bunker wall through which a beam line guide will traverse into the experimental hall.

Materials

The design of the bunker is based on neutronic requirements including safety and performance parameters. The neutronic calculations have taken into account:

- Requirements from both the Swedish legislation and the instruments.
- Dose levels outside the Bunker must be < 3 μSv/h -> simulations require < 1.5 μSv/h to accommodate for difference between simulations and engineering design.
- Floor loading in the bunker: 30 tonnes/m^2.
- Floor loading in the experimental halls: 20 tonnes/m^2.

To meet the neutronic and weight requirements, the materials chosen for the bunker roof and the bunker wall are Polyethylen/Boronated/Concrete (PBC), cast iron, lead and B_4C. The frame supporting the bunker roof consists of steel pillars. The estimated amounts are shown in table 1.

Material	Weight (tonnes)
Polyethylen/Boronated/Concrete	3600
Cast iron	8700
Lead	320
B4C	10
Steel pillars	56
Total	≈12700

Table 1. The materials chosen for the bunker roof and wall.

The special concrete, PBC, is mainly ordinary concrete with the addition of ≈10 wt% PE pellets and ≈0.6 wt% B4C. The simulated neutron attenuation for PBC compared to normal concrete is around a factor of around 10 times better, as is indicated in figure 8. Experimental data is under analysis but indicates a similar attenuation. This, in addition to the lower density of the PBC (≈2 tonnes/m^3) compared to normal concrete, makes it a suitable shielding material to comply with the maximum floor load.

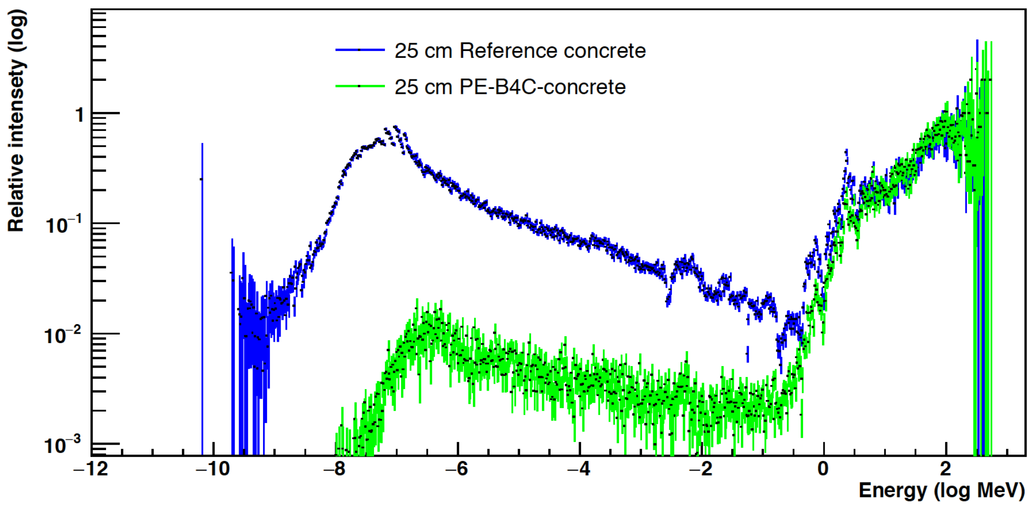

Fig.8. Calculated neutron attenuation for PBC and normal concrete as a function of energy.

Schedule

The delivery of the neutron guide bunker is on the critical path for the ESS project. It is vital for ESS to find partners by mid 2016 in order to start a detailed design together with ESS and to plan for the manufacturing. Currently, it is planned to begin installation of the bunker in 2018, as soon as possible after access is granted to commence work in that part of the facility (D01/D03) and it is anticipated to gain access in the first half of 2018. Figure 9 illustrates the time plan for the delivery of the neutron guide bunker.

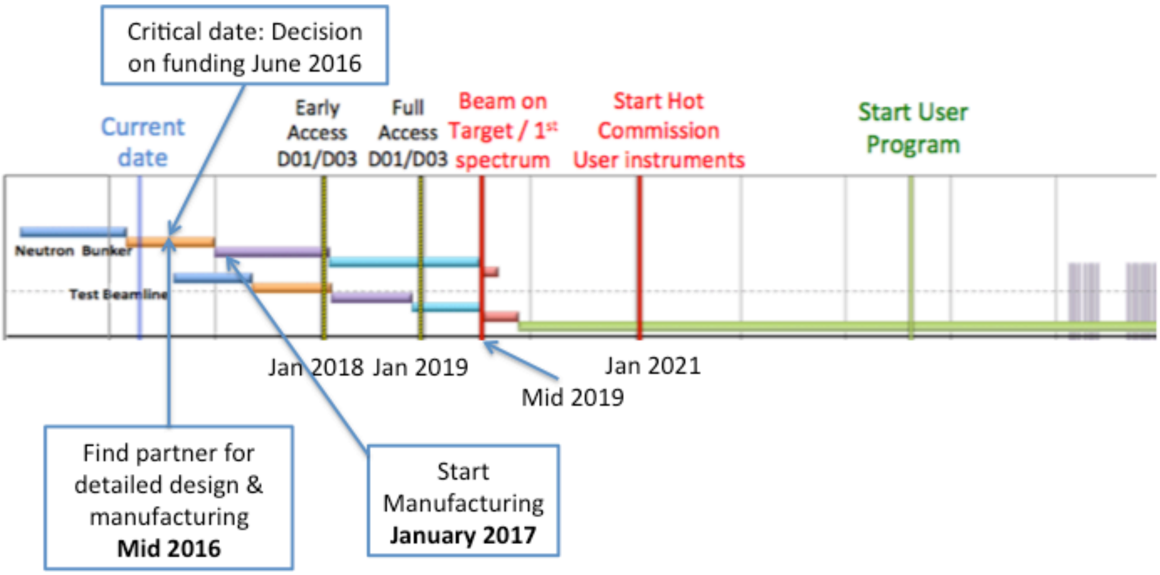

Fig.9. Time schedule for the delivery of the neutron guide bunker.