Minutes ATS Seminar – 9th February 2024
In hybrid format

ESS target systems design and construction: lessons learnt

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12 participants in presence and 24 by remote.

Introduction

ESS (https://europeanspallationsource.se/) is a spallation neutron source operating with a proton Linac at 2 GeV, pulsed at 14 Hz. Its initial phase will operate with a beam power of 2MW, with future ramp-up plans and design compatible with 5MW beam power operation. Its initial phase will comprise 15 instruments and a development beamline. Up to 22 beam lines will be able to host instruments if funding becomes available. The construction budget of the full project is estimated at over 3 BiEuros in 2023. The facility aims at delivering neutrons and attract users that perform experiments at other neutron sources, notably at Institut Laue Langevin in Grenoble.

Design

A “rebaseline” exercise was performed in 2022. The construction had already started in 2013. The Linac accelerator is now completed, as well as the target building. 3 experimental halls can receive neutrons at different distances, at 15m for the shortest and 150m for the longest to exploit different time of flights characteristics. The target station will be ready to receive beams for commissioning in mid-2025, with a predictable shift of up to 6 months. The target is composed of a rotating cylindrical wheel containing cassettes with tungsten bricks. The target monolith is of 11m diameter and 8m height. The shielding is composed of heavy concrete blocks, of stainless steel for the inner part, and of iron cast blocks for the rest. The target wheel itself presents 36 independent sectors on a 2.5 m diameter, rotating at 23.3rpm synchronized with the 14Hz beam. Each sector is made of bricks for a total of 3.5t tungsten, and cooled with high pressure He circuit (3kg He at 11Bar, T-in 40deg C, T-out 240deg C).

2 moderators have been designed for neutrons moderated at 17K made of liq H2 and at a different level moderated at 300K with H2O. The beam instrumentation is handled with a dedicated plug in front of the station, while the vacuum is maintained in the proton beam line with a cooled Al window.

The Beam safety system is based on the monitoring of the following 5 parameters : Cooling flow, temperature, pressure, Vacuum, wheel rotating speed. The handling requires different shielded casks for transport through a high bay located on top of the target. Finalization of the target monolith and hot cells facility is underway to perform safety analysis

Installation and commissioning

The commissioning of the “neutron factory”, part of the station producing neutrons is planned for 2024, while hot cells will follow up. Procurement of spares is meanwhile proceeding. Commissioning with beam is planned in 2025. In 2026, 2027 regular target station operation is foreseen.

The target station has significantly benefited from in-kind contributions of institutes across Europe, such as DTU / CNS / Juelich : Moderator/Reflector Plug and Cryo Moderator System / CER (Hungary) : cask / STFC-RACE : hot cells /Czech consortium: cooling systems : both He-H2O and HVAC / ESS Bilbao : essentially all target components, except the moderator and reflector. Significant delay arose from some of the subcontractors that got bankrupted, while few key components are still missing, such as the connectors from static to rotating assemblies.

The facility documentation is being completed, which notably comprises drawings, as-commissioned-systems, verified reports, operational maintenance procedures. The facility licensing is progressing, with 4th licensing meeting in autumn, accelerator before the beam dump, Beam on dump foreseen in November, and a safety readiness review foreseen during 1st half 2025, while the first 5 instruments will be installed along the neutron beam lines.

All neutron beam port tubes have been welded, with related challenges in alignments and quality (notably for those perceived as straightforward, not part of the primary circuit, in some unexpected manner). Vessel was cleaned, to get ready for installation of the outer shielding and tungsten core. **All was installed in 10 days only, showing the planning was well done.** The ring and services were connected (gas, water, electrical supply, signal/communication cabling), and the neutron beam port inserted. The target wheel itself, with 36 sectors/cassettes, each comprising ca 200 bricks of size 8x3x1 cm^3.

The beam window was finalized with a flame sprayed luminescent coating, part of beam monitoring; moderator / reflector plug was installed. Shaft 4m and aperture for the beam wheel, with moderator inside.

Mock up and test stand have been used, as well as test luminescent coating tested spinning of wheel in situ. ESS moderator lowering + target wheel interaction with support structure, and free movement tested equally. This let the pumping commission of the target monolith last summer as all vacuum boundaries could be installed in place (monolith, connecting ring, neutron port tubes and windows). Leak testing online pointed out towards 2 neutron windows that was rapidly corrected, and no contamination was to be found. The precision of the neutron beam extraction beam line and of the position moderator.

Lessons learned

The main issue arose with both turbo He circulator that failed while no spare was yet available. 2 types of failure were witnessed in Aug 2022, with one issue found at bottom on the bearing, while the other failed on top, the origin not fully identified with a suspected debris in the circuit. To mitigate additional risks on schedule for start-up, alternative designs are developed in parallel with the 2 turbo He circulators being recovered.

The welding of pipes of inner shielding were very bad . Advanced welding is generally good. but the “easy” welding was missed because of lack of quality insurance in place seen in many suppliers

License

Remote handling does not require license, but is required to run the facility with minimum risks (subcontractor is bankrupted : at least + 6months delay and high risk of further delay)

Q&A:

Thierry : Is the radiation and contamination monitoring part of the machine protection.
A: The safety system is split into 4 independent systems : machine protection system (MPS), the personnel safety system (PSS), the target safety system (TSS) and Radiation and Emission Monitoring System (REMS).