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The ESSνSB Switchyard, Target Station, and Facility Performance

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One of the next challenges in fundamental physics is to understand the origin of matter/antimatter asymmetry in the Universe. Neutrinos could play an important role to elucidate this mystery and better understand the expansion of the Universe. In this context, intense neutrino beams are fundamental tools to study the properties of these particles. The ESSνSB collaboration proposes to use the proton LINAC of the European Spallation Source currently under construction in Lund (Sweden) to produce a very intense neutrino super beam, in parallel with the spallation neutron production. A very challenging part of the proposed facility is the Target Station which will use 5 MW proton beam power. This paper presents an overview of the facility.

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1. An new facility in Europe for discovering the CP violation.

Since the measurement of the last mixing angle θ_{13} by the reactor experiments[1, 2, 3], all the mixing angles of the neutrino mixing matrix have been estimated but with a precision which is not at the same level of the CKM matrix in the quark sector. In addition, numerous questions remain open in particular on the mass hierarchy and on the CP violation in the leptonic sector. In the coming decades, the neutrino community will develop new facilities allowing to bring an answer to these points. In complement with DUNE [4] and HyperK [5] projets, the European Spallation Source (ESS) [6], based in Lund (Sweden), offers the possibility to make a very intense neutrino beam with a proton driver at 5 MW scale with an improve sensitivity on CP violation parameter [7]. The ESSνSB Collaboration will investigated the possibility to realize this superbeam by a design study of all the elements of the facility, including the LINAC upgrade, the Target Station producing the neutrino beam and the detector based on Water Cherenkov detection technique.

2. Design of the ESSνSB facility.

This design of the ESSνSB superbeam will follow the previous study on a superbeam done in the framework of the EUROnu project [8] which has defined the structure of a facility working a Multi Mega Watt proton driver.

2.1 The Multi Mega Watt proton beam based on ESS facility.

An important point of this project remains in the possibility to increase the power of the LINAC from 5 MW to 10 MW by keeping safe the initial working conditions for the neutron users. In running conditions, 5 MW will be dedicated to the neutron experiments and 5 MW to the neutrino superbeam.

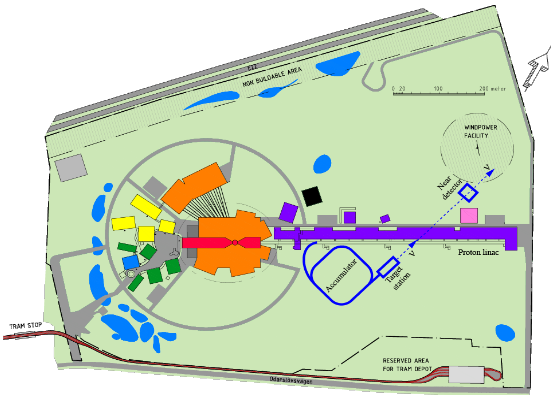


Figure 1: European Spallation Source site with neutrino facility implementation.

An accumulator ring, placed at the end of the ESS LINAC (Fig 1), is required to shorten the proton pulses to μs in order to be compatible with the working condition of the hadronic collector. Due to charge space effect at the entrance of the accumulator an H^- source has to be implemented in complement with the H^+ one for neutron mode.

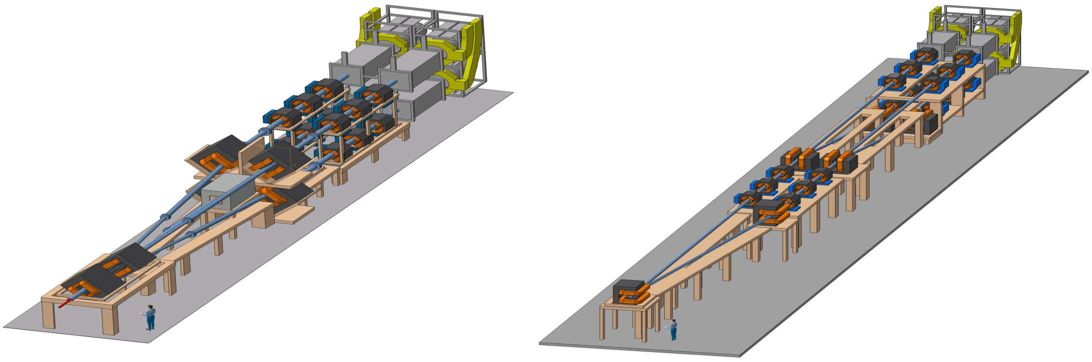


Figure 2: Switchyard option possibilites at the end of the accumulator.

At the end of the accumulator, the 5 MW proton beam is distributed over four beam-lines. The beam is splitted by kicker magnets, bended by dipoles and finally is focused onto the four targets by a system of quadrupoles[9]. Several configurations are under investigation including beam dumps for safety reasons in case of beam defocussing as shown on Fig 2.

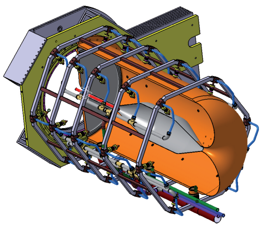
2.2 Target Station concept

The target station of a superbeam consists of a high power target producing a large amount of pions which are focused by system based on magnetic horns. In order to work under reliable conditions, several technical challenges has be solved:

- the target and the horn require an efficient cooling system to remove significant heat load,
- the target concept must withstand with high static and dynamic stress level,
- minimize the material degradation due to high level radiations,
- optimize the target geometry and position inside the horn for efficient pion production,
- remote handling to repair or replace highly activated elements,
- optimize the lifetime of the target which will work without intervention between scheduled maintenance operation,
- the design should provide safe working conditions for personnel and environment,

According to the EUROnu studies, the target station design which accomodate the previous requirements is based on a four horns system allowing to share the total beam power over four solid targets at the level of 1.6 MW proton beam power per target. Each target consists of a packed bed titanium spheres inside a canister whose the dimensions are in the same order than a monolithic one. This design reduces stresses and allow an efficient cooling system with pressurized helium gas (10 bars) circulating inside the canister.

For the four horn system shown in Fig 3, a peak current of 350 kA is pulsed at 14 Hz repetition frequency. About 52 kW are dissipated from resistive heating in the horn structure. In case of one horn is damaged, the beam power will be shared over the three other horns.



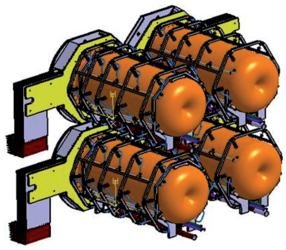


Figure 3: Horn inside view (left) and four horn system (right).

The horn skin is made of aluminium alloy Al 6061 T6 which provides good trade-off between mechanical strength, resistance to corrosion and electrical conductivity. The thickness has to be optimize to maximize physics performance and to limit the energy deposition from secondary particles emitted from the target. The energy deposition has been estimated with a FLUKA [10] simulation for several parts of the horn shown Fig 4 by considering 1.6 MW per target corresponding to the ESSνSB working conditions (compared to 1.3 MW for EUROν study).

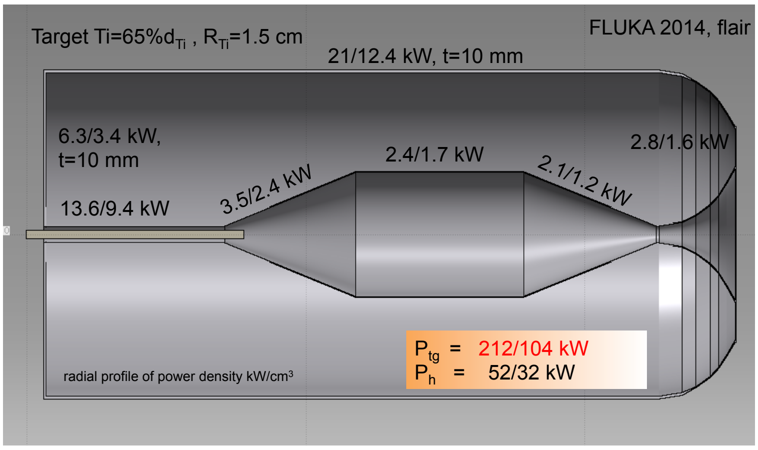


Figure 4: Energy deposition in one horn ESSνSB (1.6 MW) / EUROν (1.3 MW).

In terms of mechanics, a finite element model allows the calculation of the horn stress and deformation due to the magnetic pressure and thermal dilatation minimum stress (< 30 MPa), with a maximal lifetime when the horn has a uniform temperature (around 60^{o}C) maintained by water cooling. The level of activation of the target and the horn, has been estimated and is due to a significant amount of ^{3}H, ^{7}Be, ^{14}C, ^{22}Na and ^{26}Al long lived isotope. The activation is not uniform inside the horn with the most active part close to the target as expected.

3. Facility building

The Four Horn system will work under hard conditions in terms of energy of deposition and radioactive environment as shown in the previous section. The facility concept, inspired form the EUROnu Superbeam design study and shown Fig 5, has been designed to take in account the safety for the workers during running and maintenance mode. One important point remains on

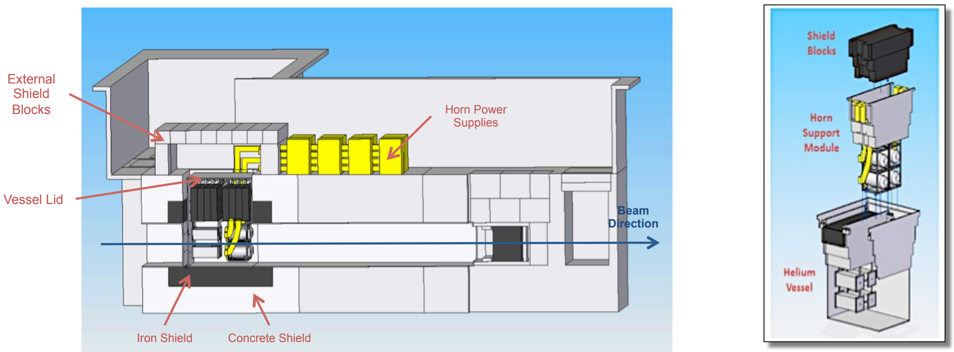


Figure 5: Target Station building (Left) / Extraction of the four horn system (Right).

the handling of the four horn system. The building structure will be equipped with a mechanical moving structure able to remove the iron shielding located above the horn and the full activated four horn system to a hot cell for repairing damages or into a morgue to store radioactive wastes.

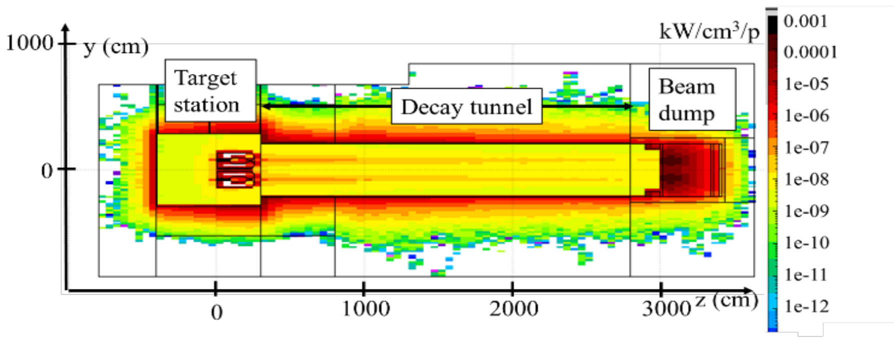


Figure 6: Energy deposition in the facility (left) / Longitudinal and transversal distributions of the power densities in the dump (right).

Location	Absorbed Pover (kW)
Target station (4 targets, 4 horns)	1497 (672, 200)
Decay tunnel (Iron shield)	1566 (640)
Beam dump (Graphite block)	1157 (950)
Whole facility	4220

Table 1: Absorbed power in different parts of the facility.

According to the simulation shown on Fig 6, more than 80% of the beam power is absorbed by the whole structure and required a efficient cooling system, in particular for the beam dump $4 \times 4 \times 3.2\,m^3$ with a core made of graphite which has to dissipated almost 1 MW as indicated in Table 1.

4. Conclusion

the ESSνSB project represents an European opportunity to have a neutrino superbeam with proton driver at 5 MW power in the next decades. With an detector (MEMPHYS) based on the well known technology based on Water Cherenckov technique and located at the second oscillation, this experiment appears to be very competitive for the measurement of the CP parameter. In addition, this superbeam produces also a significant amount of muons which could be used for developping muon beam experiments.

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