The Neutronic Applications Laboratory for ESS-Bilbao

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Abstract.
The ESS-Bilbao Accelerator Center site at the Lejoa UPV/EHU campus, will be provided with a proton accelerator up to 50-80 MeV. In the first construction phase, a beam extraction will be set at the end of the DTL, producing a 50 MeV proton beam with 75 mA of intensity, 1.5 ms pulses at a frequency of 20 Hz. These beam characteristics allow to configure a low intensity neutron source based in the Be (p, n) reaction, which enables neutronic experimentation similar to that of the Low Energy Neutron Source (LENS) at Indiana University. The total beam power will be 112 kW, so the configuration of the neutron production target will be based on a rotating disk of beryllium slabs facing the beam on one side and a cryogenic methane moderator on the other, with the target-moderator system surrounded by a beryllium reflector. Two cold neutrons extraction lines, will be placed, as well as a fast neutron extraction line with the facility allowing the switch between the two configurations.

A review of the desing of this small neutron facity at ESS-BILBAO is presented in this paper, along with the neutron performance for different temperatures of methane moderator, shielding, activation of components and dose rate out of the operation

1. Introduction

The strategy of building a MW-range, accelerator-based spallation neutron source as the next generation neutron facility for Europe is at present under scrutiny on the basis of experience gained during commissioning of the SNS[6] in the US and the JPARC[2] facility in Japan as well as from current operational experience achieved by high throughput installations such as the ISIS source at the U.K. The underlying technology has however advanced since the time when previous generation facilities reached final design stages, and therefore, time is now ripe to learn from ongoing experience and define the development areas which would allow the European Spallation Source (ESS)[1] to benefit from recent advances in technology while maintaining a reliable, low risk, design.

Within the current European context, ESS-Bilbao (ESS-B) has entered a new endeavor within which while being a partner of the ESS project aims to develop significant in-house capabilities needed to support the country participation in a good number of accelerator projects worldwide (IFMIF/EVEDA, LINAC4, FAIR, XFEL, ESRF upgrades, ISIS-FETS etc.). On such grounds

ESS-B has started the construction of a modular, multipurpose research accelerator which should serve as a benchmark for components and subsystems relevant for the ESS project as well as to provide the Spanish science and technology network with hands-on experience on power accelerators science and technology, a task long overdue.

The present document reports on the development of ongoing projects which basically comprise the construction of the room temperature accelerating structures plus some prototyping of a first demonstration cryomodule comprising two superconducting spoke resonators, as well as some foreseen applications of the generated proton and neutron beams. The current design parameter values are to be considered as a basis for a feasibility assessment of the ESS linac components and consist of 75 mA of proton current, 20 Hz repetition rate using 1.5 ms proton pulses and two 352/704 MHz bunch frequencies with a single frequency jump (Table **??**). The accelerator structures either planned or under development at present are meant to satisfy such stringent demands. A number of applications of proton and neutron beams have already been envisaged. Here we report on the state of our design for the Neutron Applications Laboratory which consists of a rotating beryllium target, a multimaterial reflector (lead, water or beryllium), two low energy neutrons lines and one hight energy neutron line.

Table 1. Accelerator main parameters

Proton Energy	$50-60MeV$
Peak Current	$75mA$
Frequency	$20-50Hz$
Pulse Length	$0.3-1.5ms$
Average Current	$2.25mA$
Neutron source	$9.25 \cdot 10^{14}n/s$

2. The neutron source

The neutron source is the main parameter of the neutron science laboratory. The energy level of 50 MeV indicates that the more efficient way to produce neutrons will be the reaction $^{9}Be(p,n)$. On previous works [8] a comparison between codes and experiments [9] indicates that Isabel model produces the more accurate results. The table 2 shows the neutron yield produced by several target materials evaluated with MCNPX code [5] and Isabel intranuclear cascade model [10]. Beryllium will produce the highest neutron yield and due to that it will be our main option for target material.

Material	**N/p**	**Av. Energy (MeV)**
Carbon	$7.54 \cdot 10^{-3}$	8.04
Lithium	$4.27 \cdot 10^{-2}$	13.15
Beryllium	$6.49 \cdot 10^{-2}$	7.76

Table 2. Target material selection

The neutron production of $^{9}Be(p,n)$ reaction characterized by a significant anisotropy in the neutron emission [3]. The hight energy neutrons will be mainly produced in the forward direction, and due to that the hight energy applications should be oriented in this direction. In order to reduce fast neutron induced background, thermal and cold neutrons experiments should be placed at 45^o direction.

3. Applications

The ESS-BILBAO neutron Science Laboratory will configure an small neutron source that could give support to the develops required for the high intensity sources. A prove of that are the experiments that SNS is performing in the LENS facility along last years [7]. In this line, the desing of this laboratory is focused on the evaluation of ESS components and the develop of moderators but, some other applications has been identified:

- Cold neutrons line for ESS components test
- Instruments and experiments for ESS
- High energy neutron line and Aerospace irradiations
- Material irradiations for Fusion (FI)

The main application of ESS-BILBAO Neutron Source is the production of thermal and cold neutrons. In order to produce cold neutrons a methane moderator will be introduced in the target area. This methane moderator will have a view surface of 10x10 cm and 2 cm of thickness, similar to LENS configuration (slab box type of 12x12x1) [4], but with an increased thickness to accommodate the higher source neutrons energy. Figure 1 shows the neutron distribution of < 5 meV neutrons on moderator surface for long proton pulses using different reflector materials. Beryllium reflector will produce the highest integrated cold neutron flux. Nevertheless, lead reflector will produce a lower tail distribution so both of them could be interesting for experimental applications. These neutron fluxes are around 4 orders of magnitude below ESS neutron flux, nevertheless they will be useful to test components such as neutron guides, moderators and instrument.

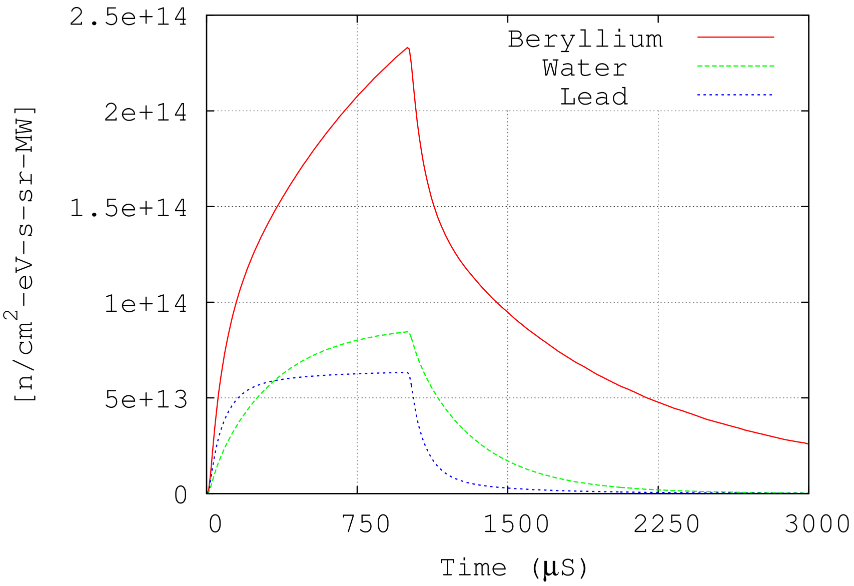

Figure 1. Long pulse for 5 meV neutrons

The cold neutron production of ESS-BILBAO laboratory could be increased by the reduction of the moderator temperature. The Figure 2 shows the effect of the moderator temperature in the brightness for neutrons at 1 meV. The moderator at $4K$ produces twice the number of neutrons at $1meV$. Due to this effect ESS-BILBAO moderator have to be able to control the operation temperature in order to optimize the operation of the source.

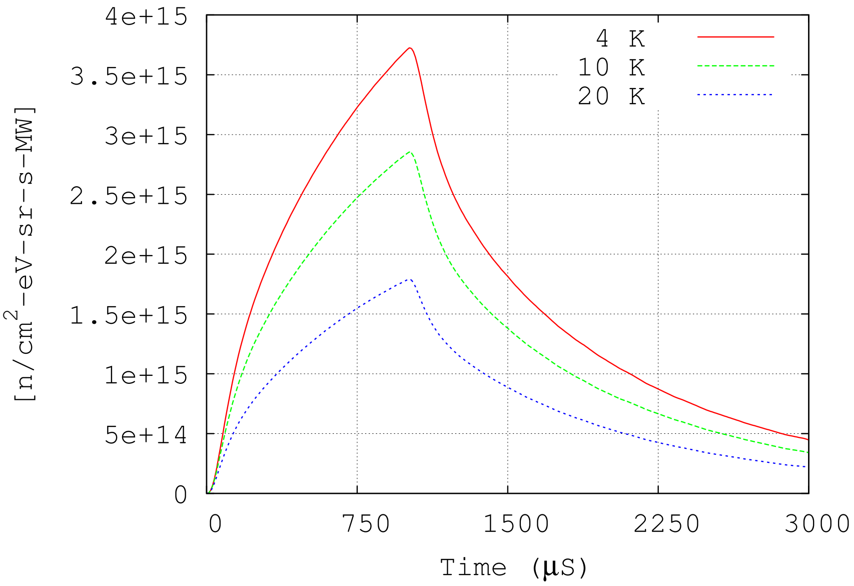

Figure 2. Long pulse for 1 meV neutrons

4. Layout and target assembly

The layout of the installation is related with the neutron source. As it can be show on Figure 3 three lines are proposed, one in the forward direction dedicated to high energy neutrons production and two at 45^o for cold and thermal neutrons. The handling of the neutron target has to be done in a controlled environment so a hot cell close to the target is required.

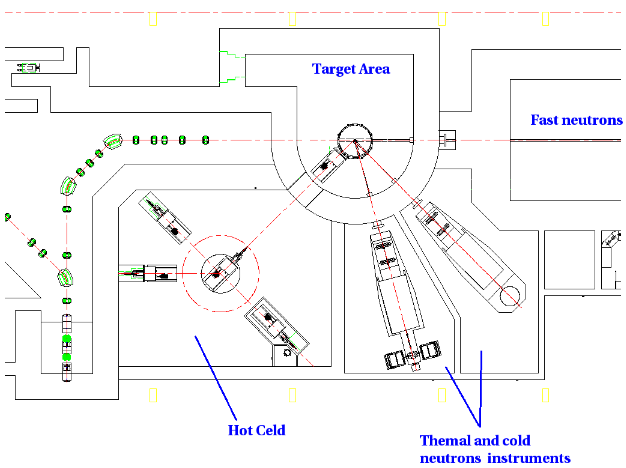

Figure 3. Layout of the Laboratory

The target-moderator-reflector assembly (TMR) is shown on figure 4. There are three main componentes: the rotating target, the moderator an the vessel. The target is a rotating component with 20 beryllium sheets in which protons produced by the accelerator interacts (see [**?**]). In the forward direction is placed the methane moderator and both components are surrounded by reflector. The reflector is inserted in the shielding vessel in order to configure the system.

The moderator will be extract in the vertical direction meanwhile target will be extract by a rail system in horizontal direction. The main goal of this system is to provide a flexible system to change the moderator without interaction with target system. It should be taken into account that the change of target will be done ones per year meanwhile moderator substitution will be required each several weeks of operation. The operation in the moderator will be done by a remote handling system due to the high activation level of the component.

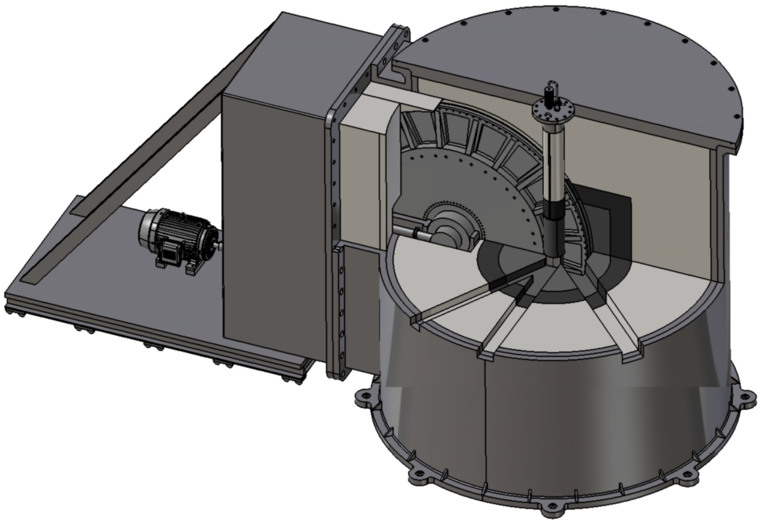

Figure 4. Target moderator reflector assembly

5. Shielding and activation proposal

In order to quarantine a safe operation of the TRM a multimaterial shielding is required. The first layer is made by lead (15 cm) in order to adsorb source photons and to reduce the energy of neutrons. A large thickness of borated polyethylene (60 cm) is required to thermalize and absorb the neutrons. Finally the absorption of neutrons on ^{10}B produce a medium energy gamma (0.45 MeV), this secondary radiation will be shield by 10 cm of steel.

This high volume of shielding reduce the activation of the vessel and due to that the dose rates around the vessel one day after the shutdown (200 h of full power operation) is the level on 1 mSv/ h. This means that hand operation is possible in the vessel environment. The Figure 5 shows the dose rate level.

The most activated element is the moderator with produces a contact dose rate of 30 Sv/h one day after the shutdown and 85 mSv/h after one year of decay. The Figure 6 shows the evolution of the activity in the moderator covers after 2000 h of full power operation. Due to this, the manipulation of moderator have to be done mean a remote handling system. The target produce a dose rate significantly lower (3 Sv/h) after shutdown. After one year of decay

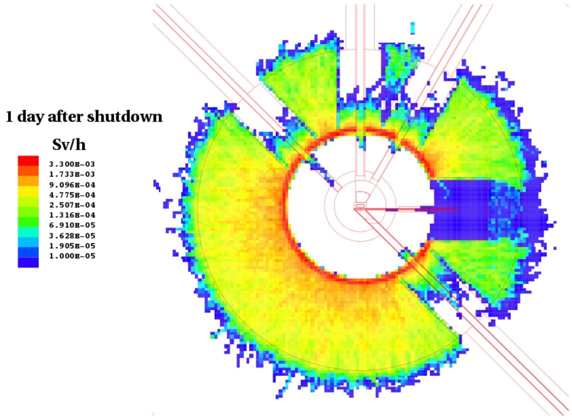

Figure 5. Dose rate in the TRM area after 2000 h of operation and 1 day of decay

the target contact dose rate level is 30 mSv/h so it can be manipulated hands on but an storage time is mandatory.

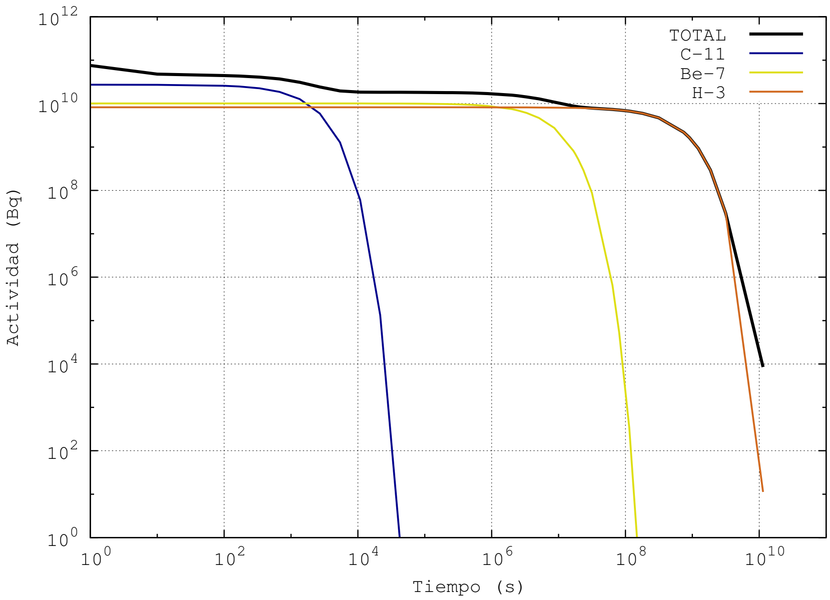

Figure 6. Activity of the moderator vessel

6. Conclusions

The ESS-BILBAO facility will have a LENS-type neutron source focused on components testing that could support the develops in larger European facilities like ESS. As a conclusion of ESS-BILBAO works on the Neutron Science Laboratory, the following ideas can be remark:

- ESS-BILBAO will have a LENS-type facility for testing components.
- The TMR for ESS-BILBAO will allow the study and test of ESS moderators
- Large remote handling capabilities are not required in the laboratory

- This facility will increase radically the in-house capabilities for Spanish Neutron Science

Acknowledgments
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