Preliminary calculations for ESS-Bilbao low energy Target

Revision 1.1

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1. Introduction: Accelerator Description

An accelerator facility south of the Pyrenees is a long overdue since ...

- There is a pressing need to build a base for support of activities on accelerator physics carried out by a variety of communities involved in international/bilateral collaborations (CERN, IFMIF/EVEDA, ESRF, ISIS, CFEL, EUROTRANS, ISOL-like, etc.)

- An emergent group of small/medium firms have identified a number of opportunities within this niche of activity

- An agreement with ESS-Scandinavia commits us to carry out accelerator research in support of the ESS project once it gets off the ground.

- There is funding of 180 M€ in order to build a facility in Bilbao that contribute to ESS project and I should have its “own life”. We are going to build and accelerator base on ESS parameters and we are also planning possible applications on neutron science.
1. Introduction: Accelerator Description

Basic tenets of the effort under development

The facility under construction should provide means to gain expertise in design, construction and operation of high power light-ion machines aimed as:

- Drivers of future neutron sources such as ESS
- A test ground for components and subsystems developed within a variety of collaborations (i.e. Linac4/SPL, IFMIF, ISIS, FAIR, etc.)
- Sources of potential applications of proton/light-ion and neutron beams.

**Things under construction:**

- A Penning H- ion source test-stand (testing): ITUR
- A 2.7 GHz klystron-driven ECR proton sources with this parameters
  - Extraction energy 95 keV
  - Total current 75 mA -- 100 mA
  - Proton Fraction > 90 %
  - Pulse length 1.5 ms
  - Duty Factor 0.04
  - Sought Emittance < 0.2 \(\pi\) mm mrad
### 1. Introduction: Accelerator Description

#### Basic parameters for the accelerator

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Proton current</td>
<td>75-100 mA</td>
</tr>
<tr>
<td>Max. Final Energy</td>
<td>300-450 MeV</td>
</tr>
<tr>
<td>Energy on first extraction</td>
<td>40 MeV</td>
</tr>
<tr>
<td>Max. Rep. Rate</td>
<td>20-50 Hz</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>Bunch Freq.</td>
<td>352.2 MHz</td>
</tr>
<tr>
<td>Max. Cav Grad</td>
<td>9 MV/m</td>
</tr>
<tr>
<td>Max Power on first extraction</td>
<td>80-100 kW</td>
</tr>
<tr>
<td>Max final Power</td>
<td>1 MW</td>
</tr>
</tbody>
</table>
2. Neutron Source

This Figure shows the neutron generation cross section for two target materials: Carbon and Beryllium. In both cases, for deuterons and protons, beryllium production is larger than carbon up to 100 MeV energy. Thus, in our energy range (~40 MeV) beryllium target is recommended.
These Figures show neutron production and average energy for beryllium and carbon targets. In both parameters: energy and production, beryllium is clearly better.

Considering a beryllium target, the neutron production in our energy range (~40 Mev) will be around 1 neutron per 10 protons, with an average energy of 8 MeV.
In order to estimate neutron flux distribution, we have used several point detectors (MCNPX) located 2 m away from the target. As we can see in the figures the highest neutron emission will be produced on a narrow around the beam direction.

2. Neutron Source

*Neutron Energy spectra*
2. Neutron Source

Time source distribution will be also a critical parameter for TOF experiments, and thus we need a good characterization of the source. We have repeated the previous procedure with point detectors 2m and 1cm away from the beryllium target.

Pulse length for high energy neutrons (10-30 MeV) will be between 1 and 2 ns, as shown in the figures.
2. Neutron Source

One important consideration previous to the thermomechanical analysis is the effect of the cooling water in the neutronics. Figure shows the effect of water in neutron flux at 10 and 30 MeV.

In average we will lose a 30% of the brightness by introducing the water channel.
Protons at 40 MeV produce a very high heat deposition (Brag peak) 1 cm deep in beryllium.

Figures shows heat deposition profile produced by a Gaussian beam (2 sigma) of 4 cm of radius.

Optimum depth in order to reduce thermal stress and guarantee the interaction of almost all protons is ~ 1 cm.
3. Thermomechanical conditions

Due to the effect of the water over neutronics of the system, we are going to explore two different cooling schemes:

- Several slabs of beryllium cooled by conduction
- One slab of 1 cm of beryllium cooled by water in the internal surface.
3. Thermomechanical conditions

The second scheme to explore is cooled by a layer of water opposite to the beam. Obviously the cooling capability is higher than the previous scheme, but we will lose high energy neutrons due to the water. Nevertheless, as we are only interested in moderated neutrons the effect of this layer will be negligible.
Time distribution effect is not really important in this scheme because the main component of the stress proceeds from temperature distribution as this Figures shows, so we can analyze this problem considering only the average energy of the beam in order to find the stationarity temperature distribution and after that introducing the time dependent beam.

3. Thermomechanical conditions: Conduction
This figure shows maximum temperature and stress for a target of 3 sheets of 3 mm of thickness cooled by conductivity. In order to guarantee the integrity of the target, the maximum beam intensity per "sheet" is 0.125 mA. This value is equivalent to a beam of 25 mA@0.5Hz@1ms.
Starting from the stationary conditions estimated in previous simulation we can estimate the effect of the pulse (1ms and 0.5 Hz). We can see that temperature and stress effect is around 10º and 20 Mpa, so the operation conditions are safe.
3. Thermomechanical conditions: Conduction

Rising transitory in the third sheet for 0.5 Hz beam frequency Time = 14s.
3. Thermomechanical conditions: Conduction

Final conditions of the sheet in the maximum temperature and thermal stress conditions for previous beam. We can conclude that the mechanical conditions for this power level are adequate.
3. Thermomechanical conditions: Conduction

The operational frequency of the target will be between 20-30 Hz so in order to reduce the beam power over the elements we propose a rotating target presented in the figure.

The rotating velocity will be 60 Hz so that each element will support only 0.5 Hz, and we need 40 elements in the wheel so the radius is 80 cm.

Target main parameters

- 25 mA
- 20 Hz
- 1 ms
- 40 MeV

TOTAL POWER: 20 kW
3. Thermomechanical conditions: Conduction

The idea of low energy target cooled by conduction allows switching between two configurations for experiments without modifying the target, but it does not allow to use the full power of the accelerator.

Nevertheless it is very adequate to experiments were the beam has to be “cutted”.
3. Thermomechanical conditions: cooled by water

The main parameter of the accelerator is that it generates a total power of 90 kW so it is not possible to cool it only by conduction. In order to design a full power target we have considered the option of cooling it by a layer of water in one side of the sheets. Due to this, it is not possible to divide the target in several layers because we only can cool the last one.

Figures show temperature and stress maps for the new cooling scheme. We can see that thermal stress in the steady state is very low so the main component for the stress in this case will came form the pulse distribution.

Temperature and stress

Beam Parameters

75 mA
1.5 ms
0.5 Hz
40 MeV
3. Thermomechanical conditions: cooled by water

Previous figures show very low temperature and stresses for the same target diameter (80 cm) as the “conduction target”, so it is possible to reduce the target dimensions, but in order to design a common layout for both targets we will continue with a radius of 80 cm (40 sheets under a beam frequency of 0.5 Hz).
4. Experimental configurations

Depending on the experiments to perform, our configuration could be based on two different targets with common auxiliary elements:

→ Cooling system
→ Engine
→ Remote handling system

“So we only have to change the weel”
5. Conclusions

As summary main conclusions we could remark

- We have two concepts for target design depending on the energy level
- We propose two experimental configurations so that we are able to operate with and without moderator.

Next steps

- Analysis of the life time of the target: H implantation and corrosion
- Activity and residual heat
- Layout of the system
- Moderator system and TOF experimental configuration
- Shielding