Preliminary calculations for ESS-Bilbao low energy Target

Revision 1.1

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1. Introduction: Accelerator Description

An accelerator facilty south of the Pyreness 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, EUROTANS, 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 founding of 180 M€ in order to build a facility in Bilbao that contribute to ESS proyect and I should have its “own life”. We are going to build and accelerator base on ESS parameters and we are also planing 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, ect.)

• Sources of potential applications of proton/light-ion and neutron beams.

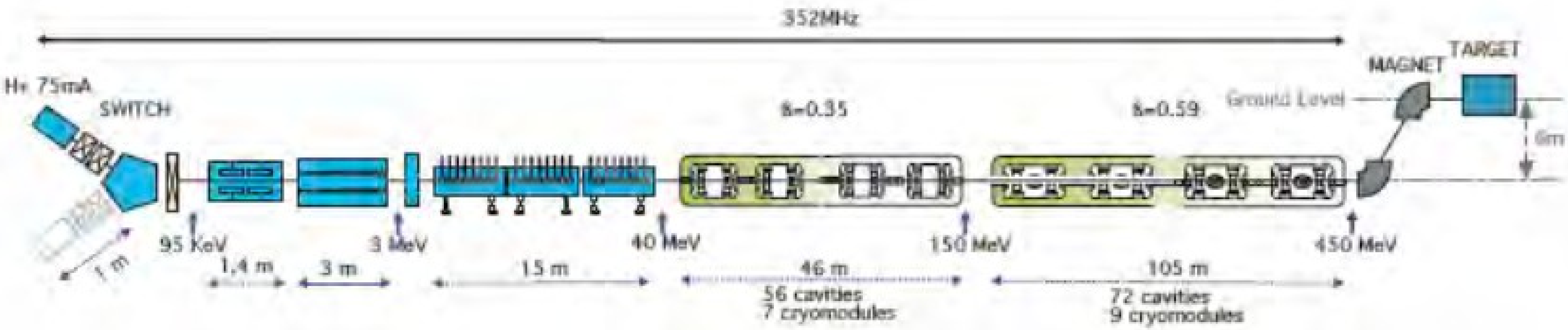
Things under construction:

• 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

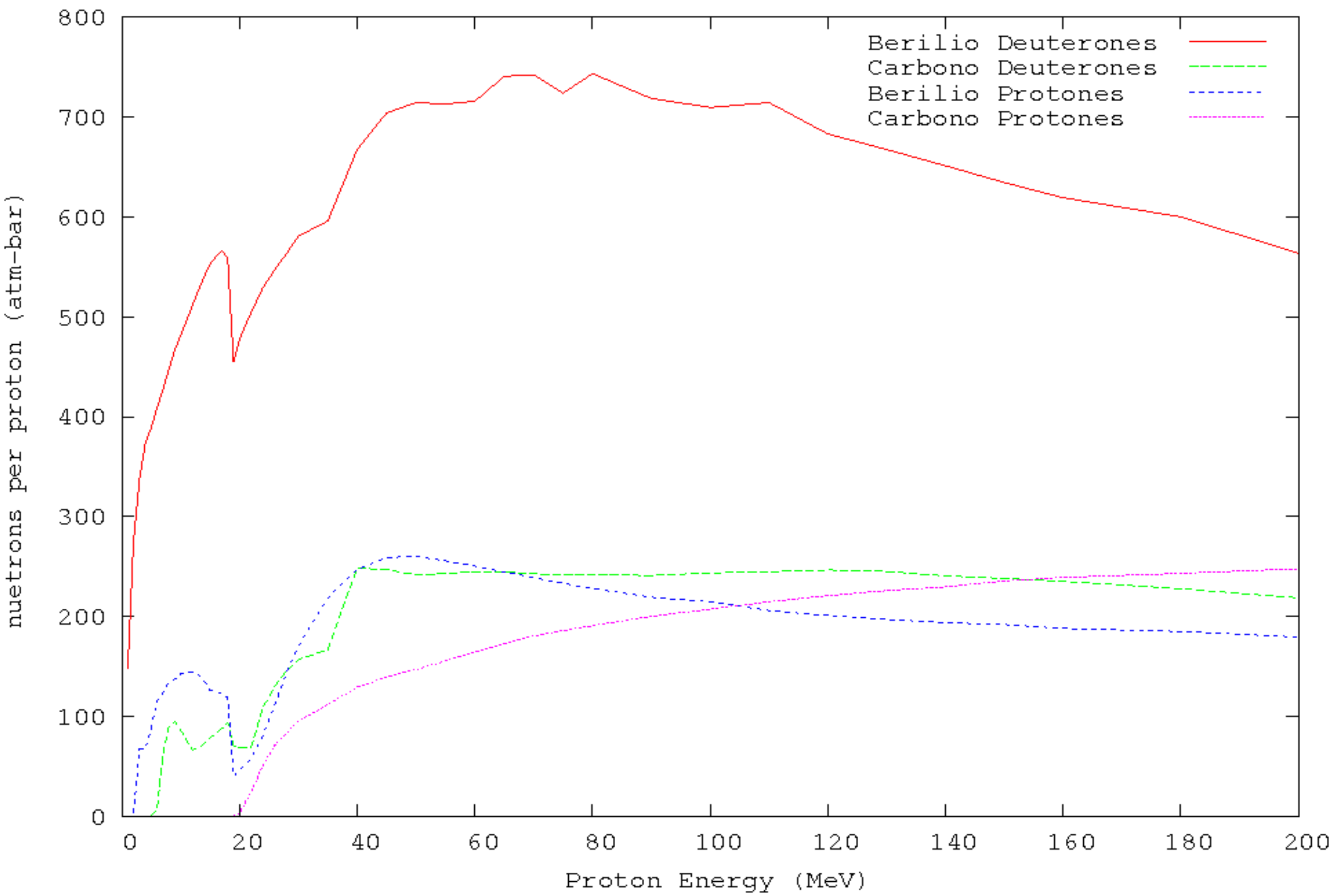


Basic parameters for the accelerator

Max. Proton current	75-100 mA
Max. Final Energy	300-450 MeV
Energy on first extraction	40 MeV
Max. Rep. Rate	20-50 Hz
Pulse Length	1.5 ms
Bunch Freq.	352.2 MHz
Max. Cav Grad	9 MV/m
Max Power on first extraction	80-100 kW
Max final Power	1MW

2. Neutron Source

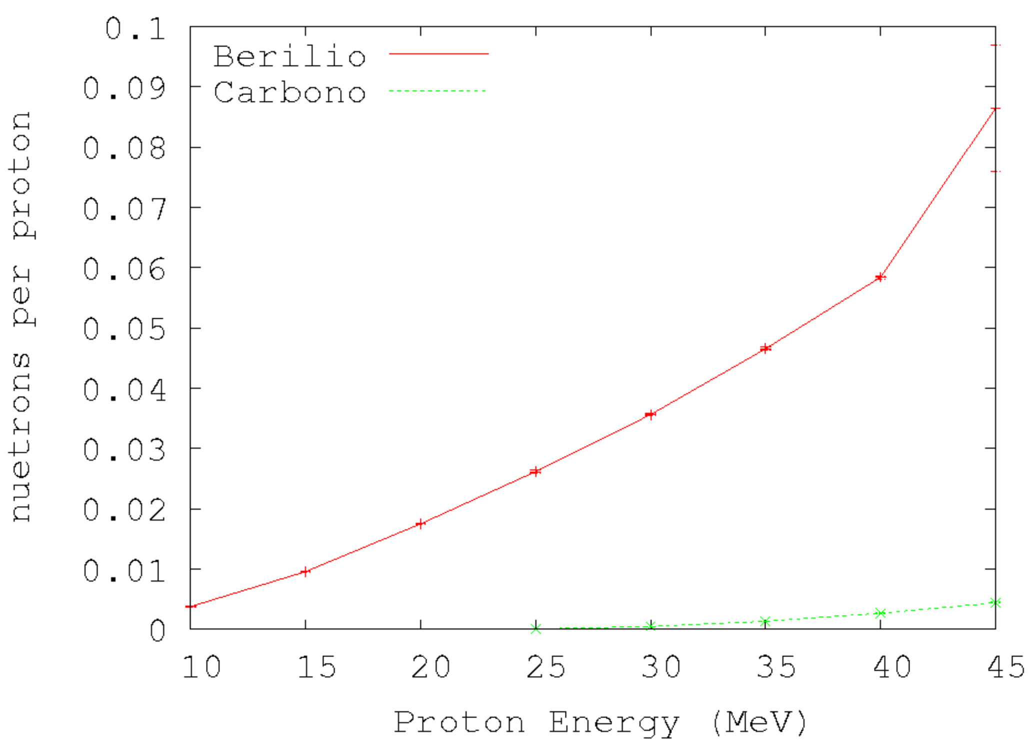
This Figure shows the neutron generation cross section for tow target materials: Carbon and Beryllium In both cases, for deuterons and protons beryllium production is larger that carbon up to 100 MeV energy. Thus, in our energy range (~40 MeV) beryllium target is recommended.

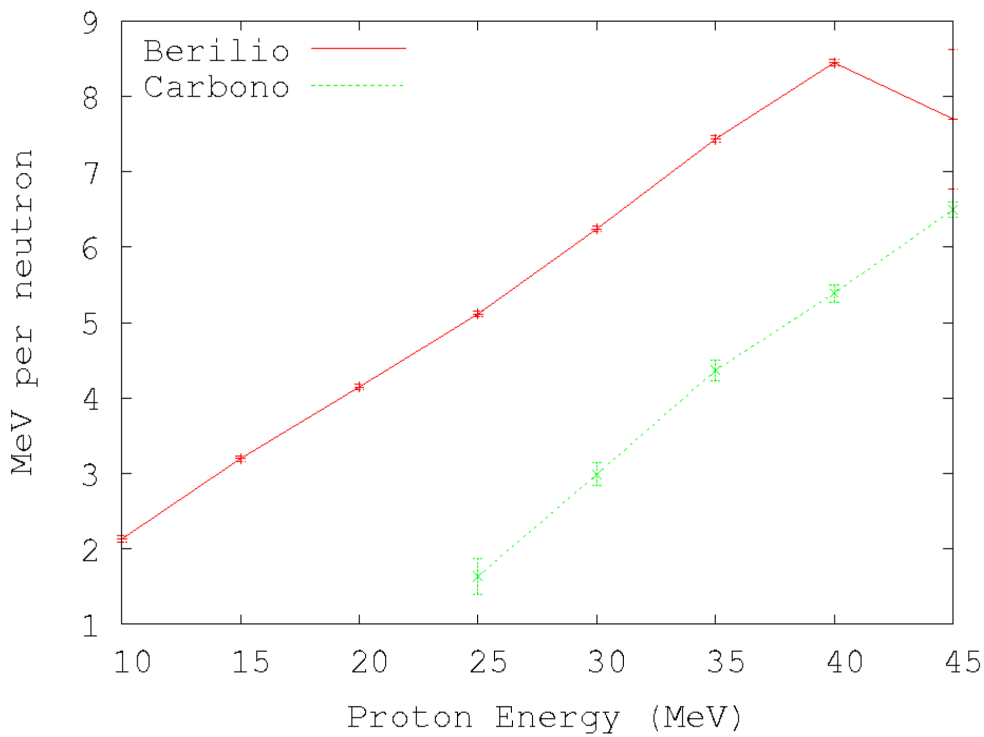


2. Neutron Source

These Figures show neutron production and average energy for beryllium and carbon targets. In both parameters: energy and production, beryllium is clearly better.

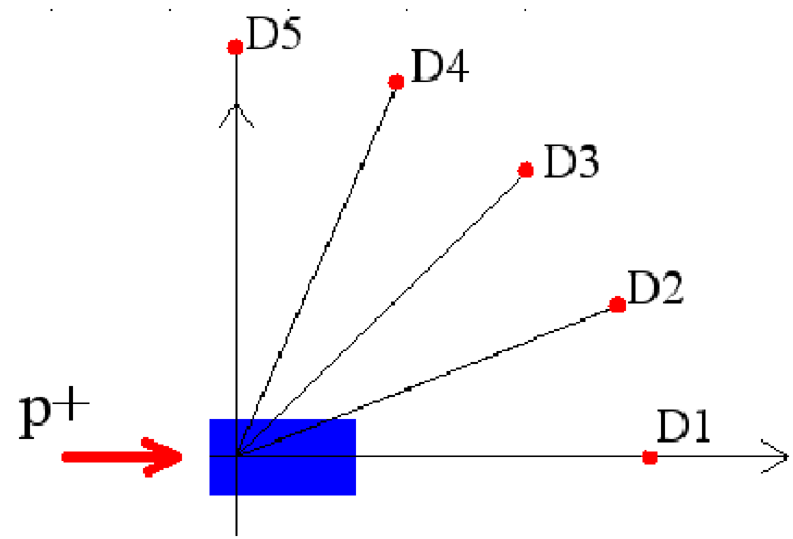
Considering a beryllium target, the neutron production in our energy range (~40 Mev) will be around 1 neutron per 10 protons, with and average energy of 8 MeV.

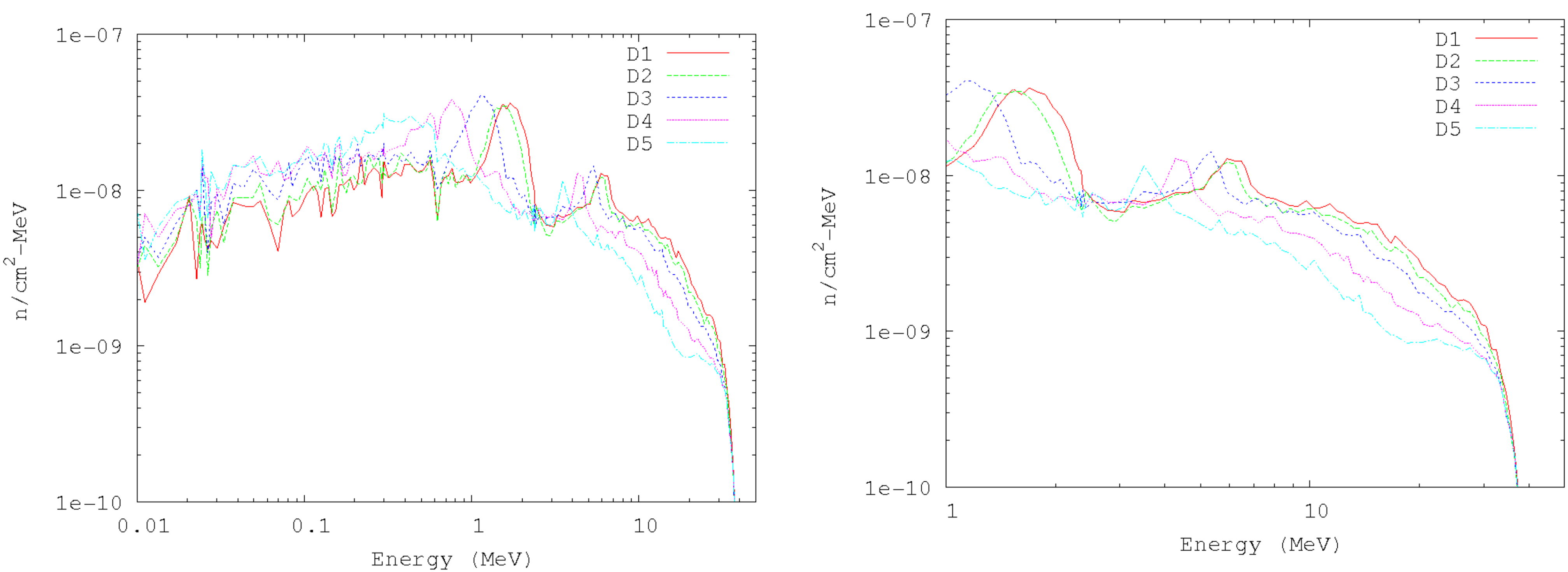




2. Neutron Source

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.



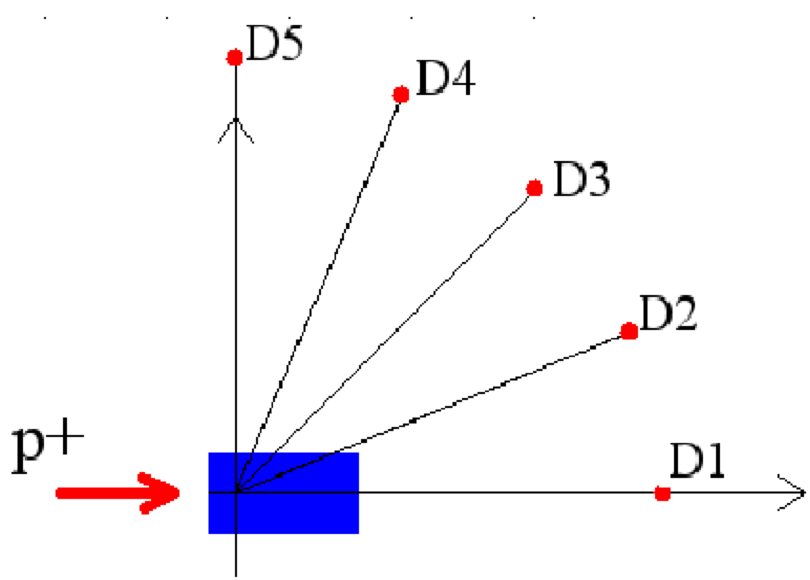


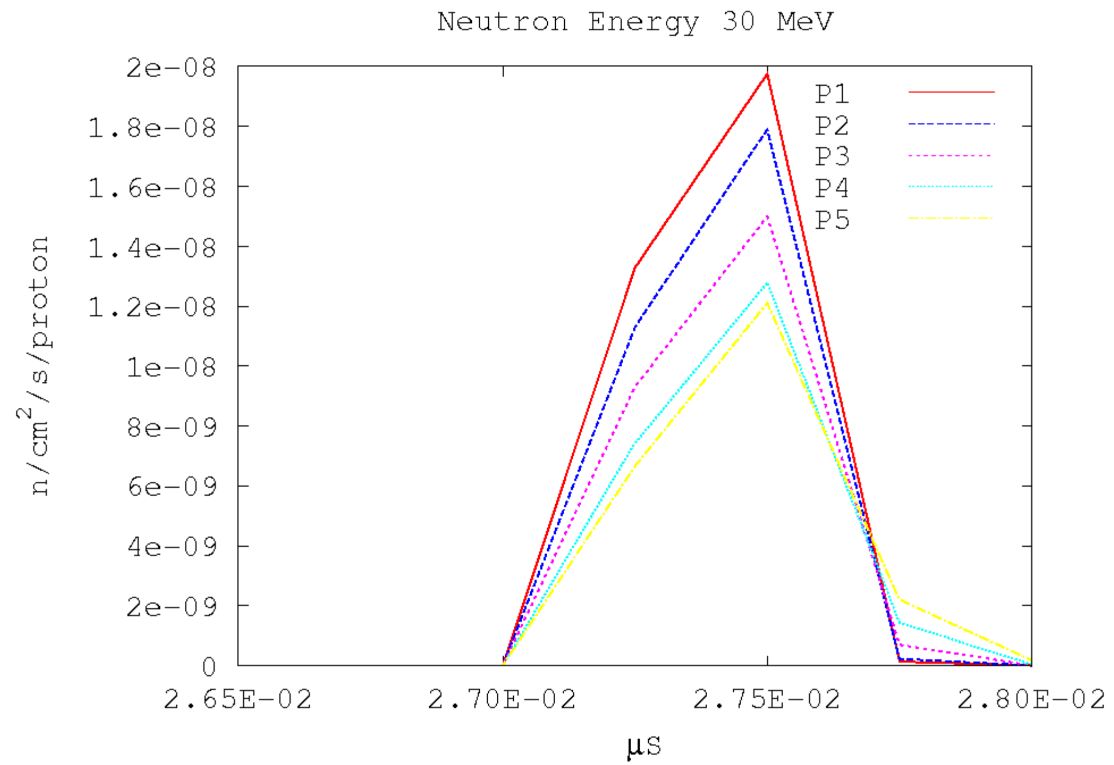
Neutron Energy espectra

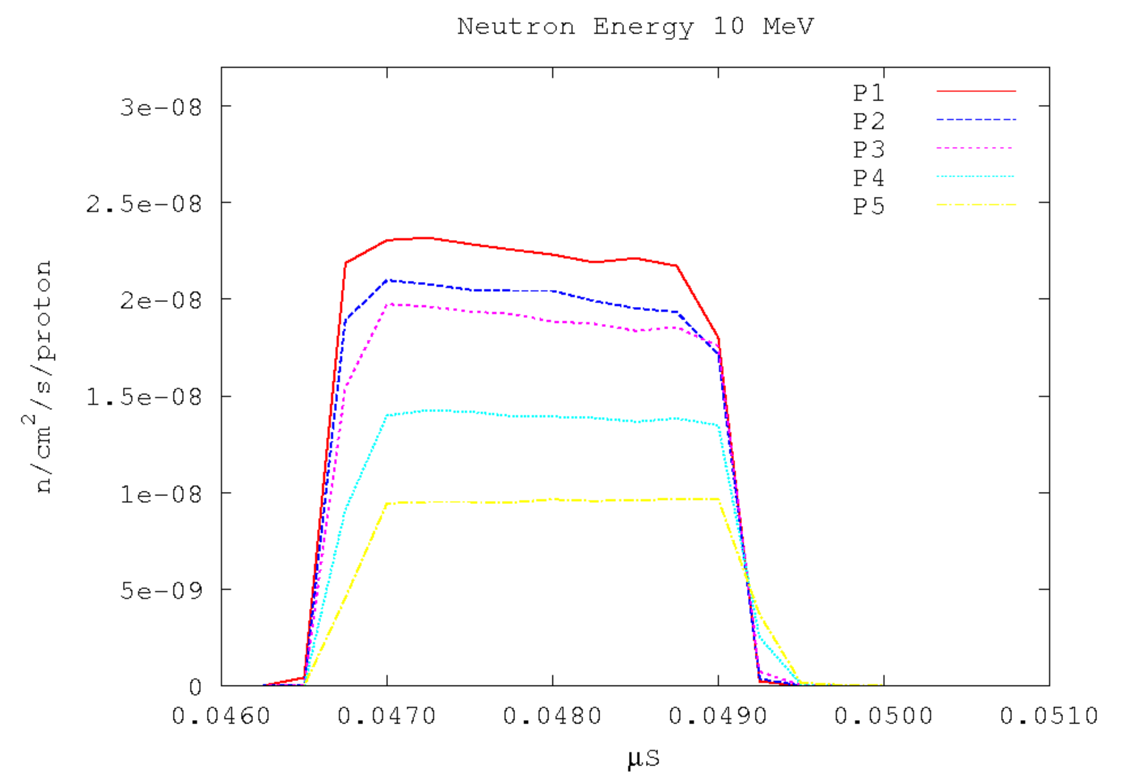
2. Neutron Source

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 form the beryllium target

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



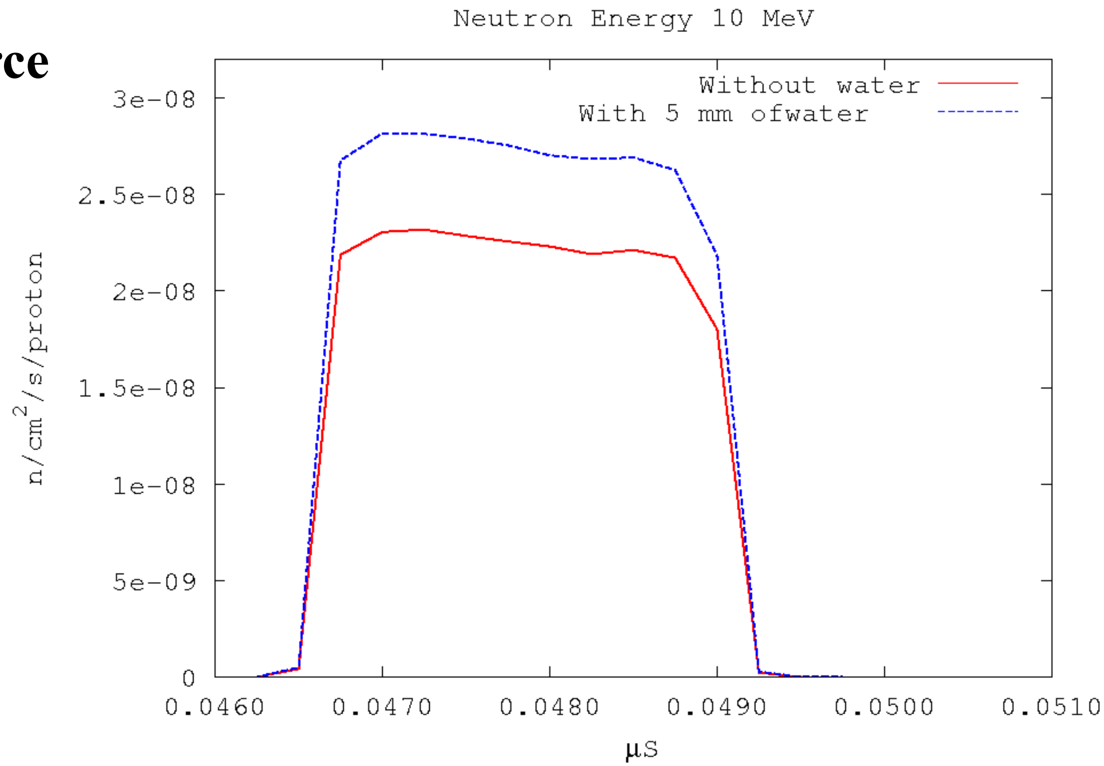


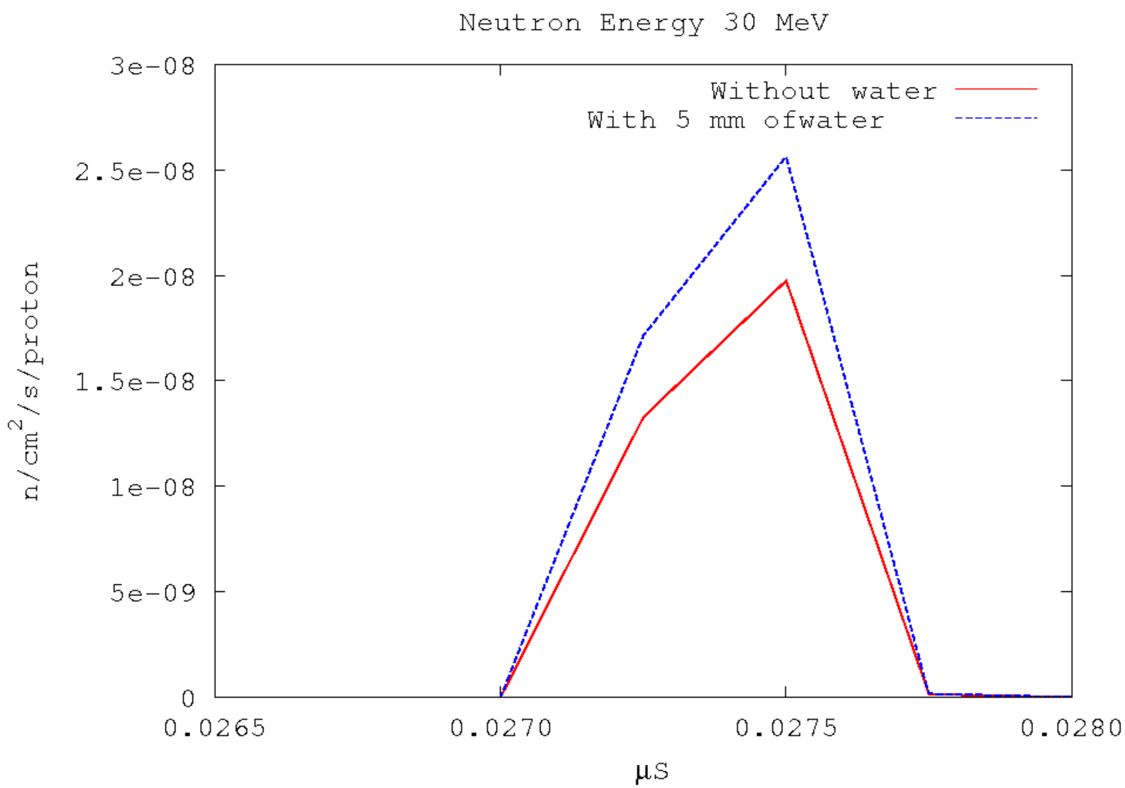


2. Neutron Source

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.



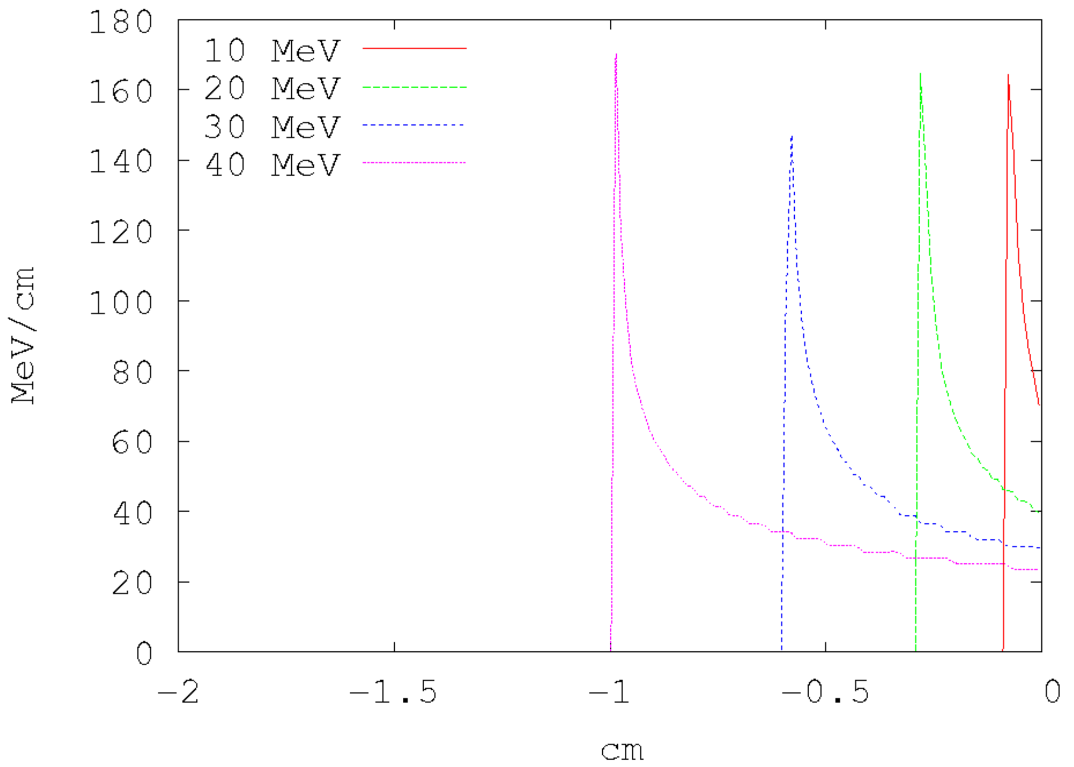


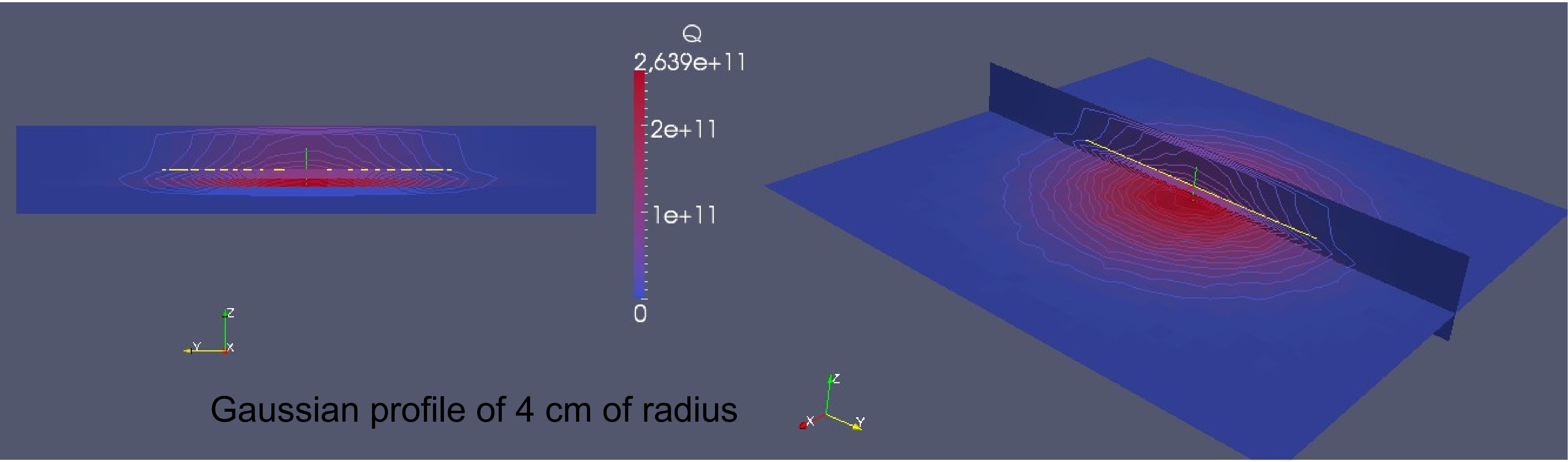
3. Thermomechanical conditions

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.



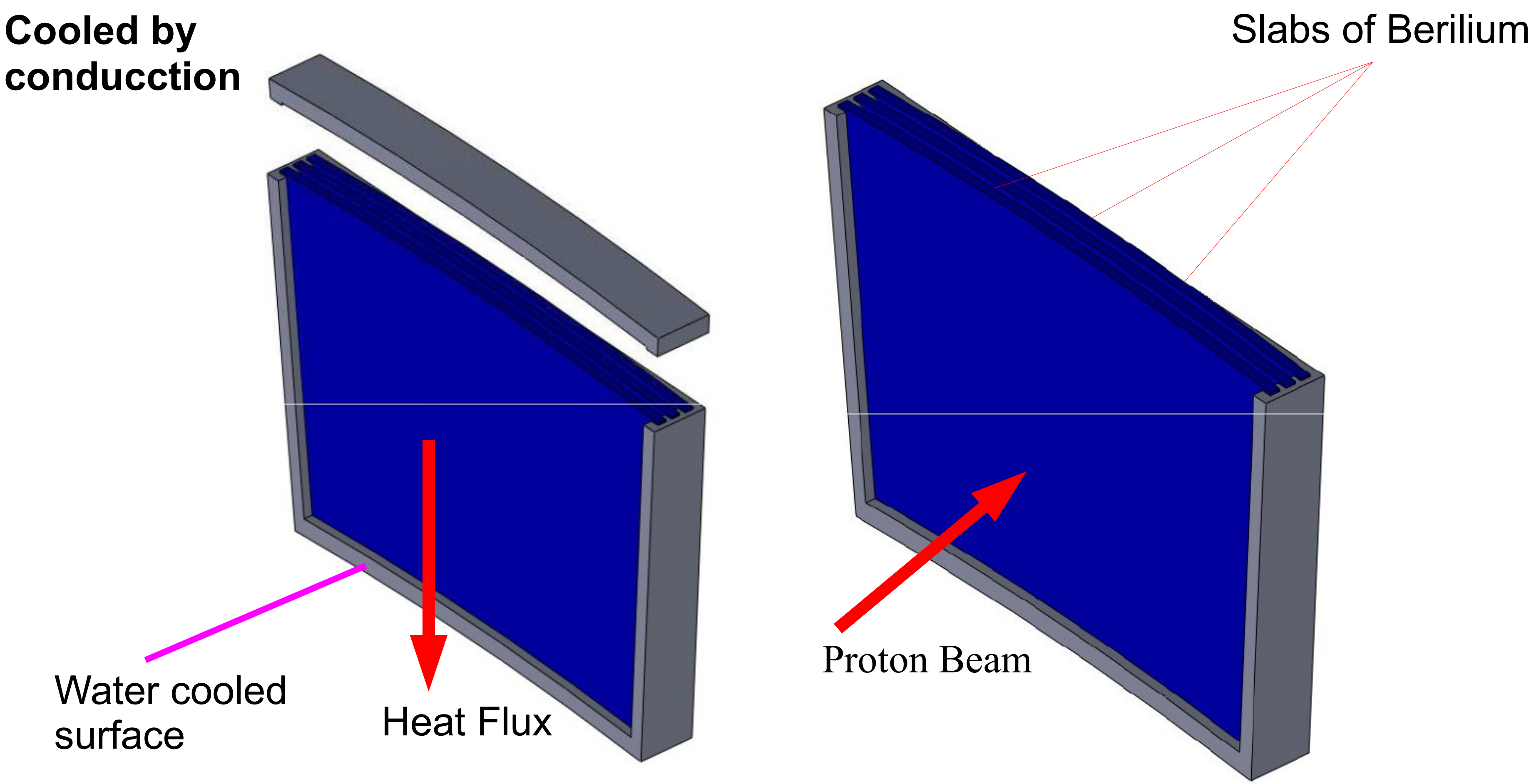


Gaussian profile of 4 cm of radius

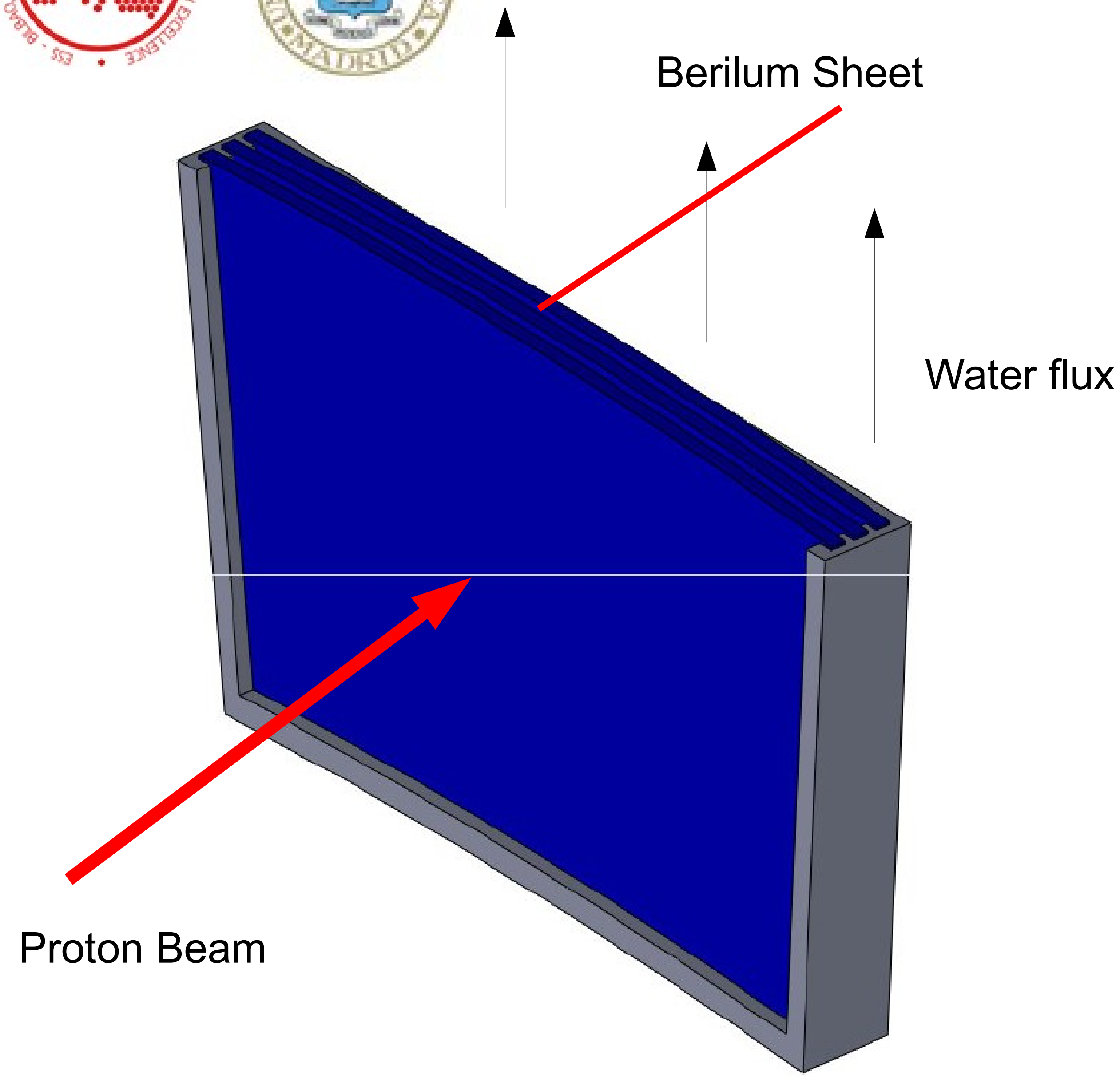
3. Thermomechanical conditions

Due to the effect of he 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



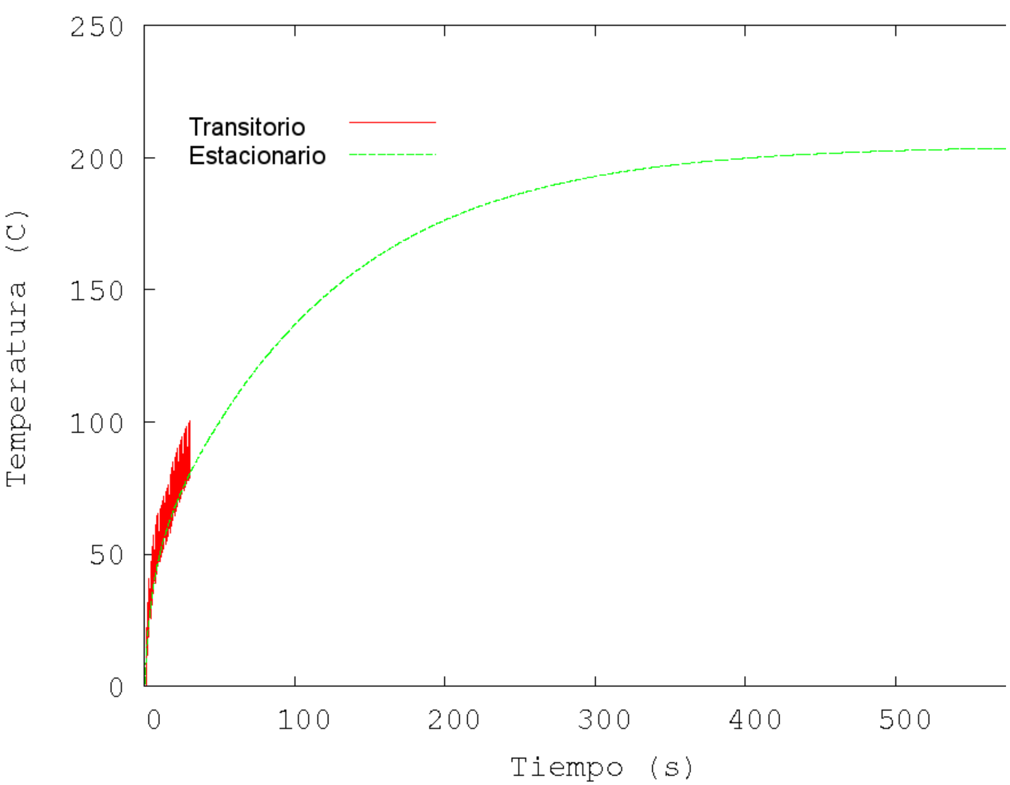
The second scheme to explore is cooled by a layer of water opposite to the beam.

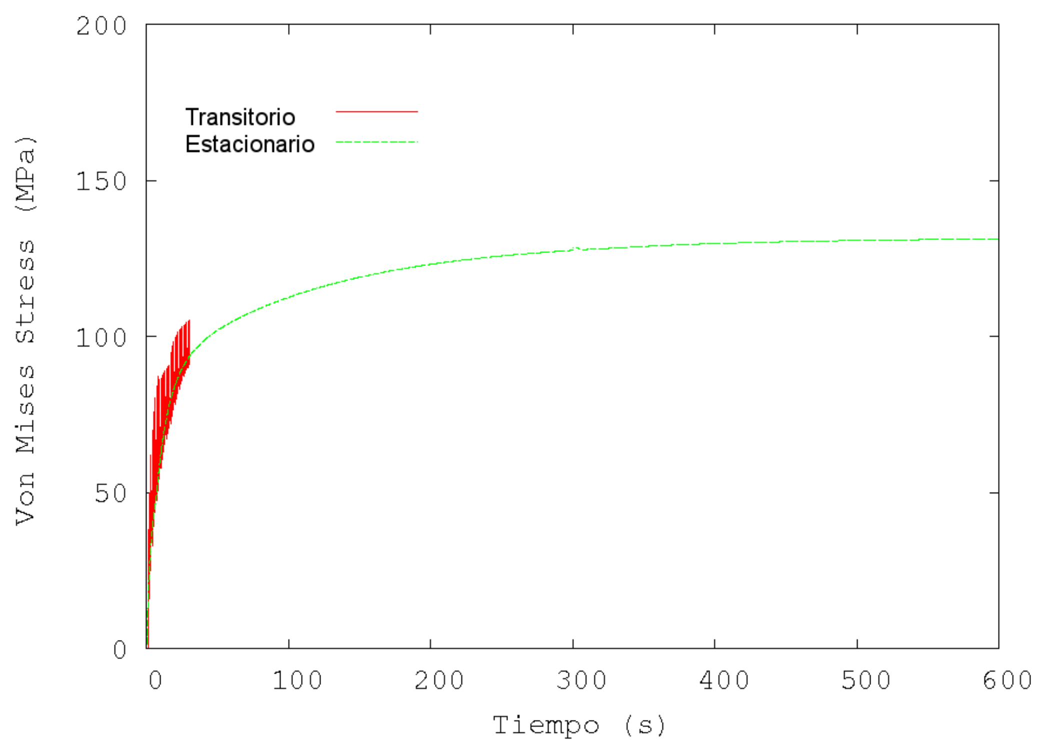
Obviously the cooling capability is higher that the previous scheme, but we will lose high energy neturons due to the water.

Nevertheless, as we are only interesting in moderated neutrons the effect of this layer will be negligible

3. Thermomechanical conditions: Conduction

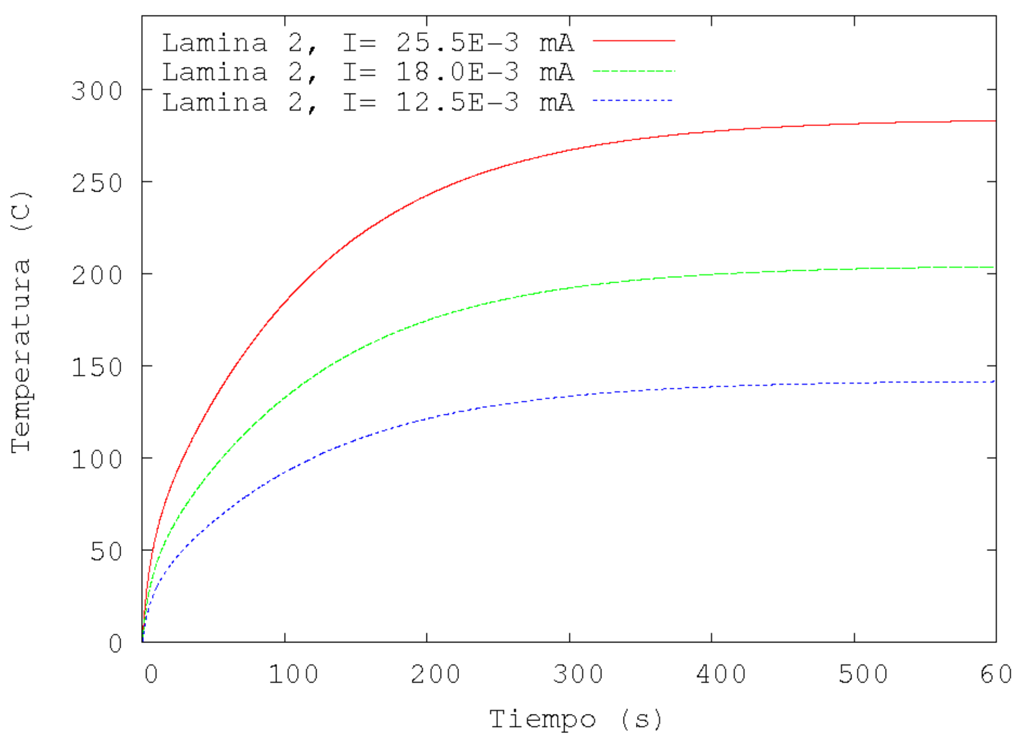
Time distribution effect is not really important in this scheme because the main component of the stress proceeds from temperature distribution as this Figures shows, so we can analyze this problem considering only the average energy of the beam in order to find the stationarity temperature distribution and after that introducing the time dependent beam.

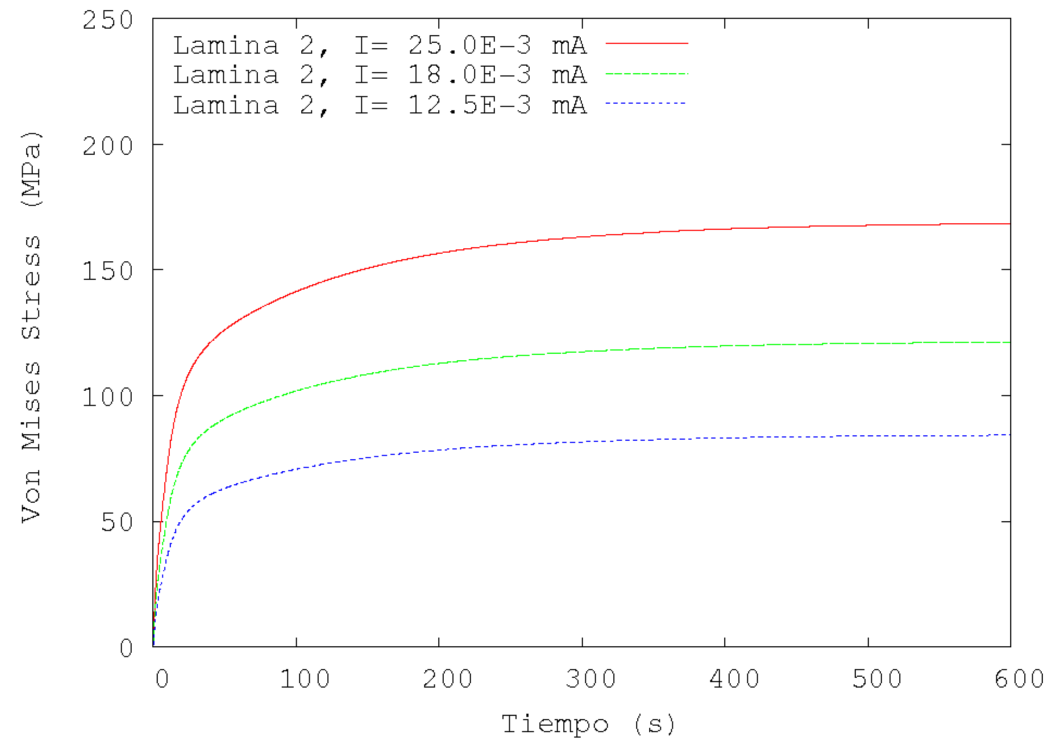




3. Thermomechanical conditions: Conducction

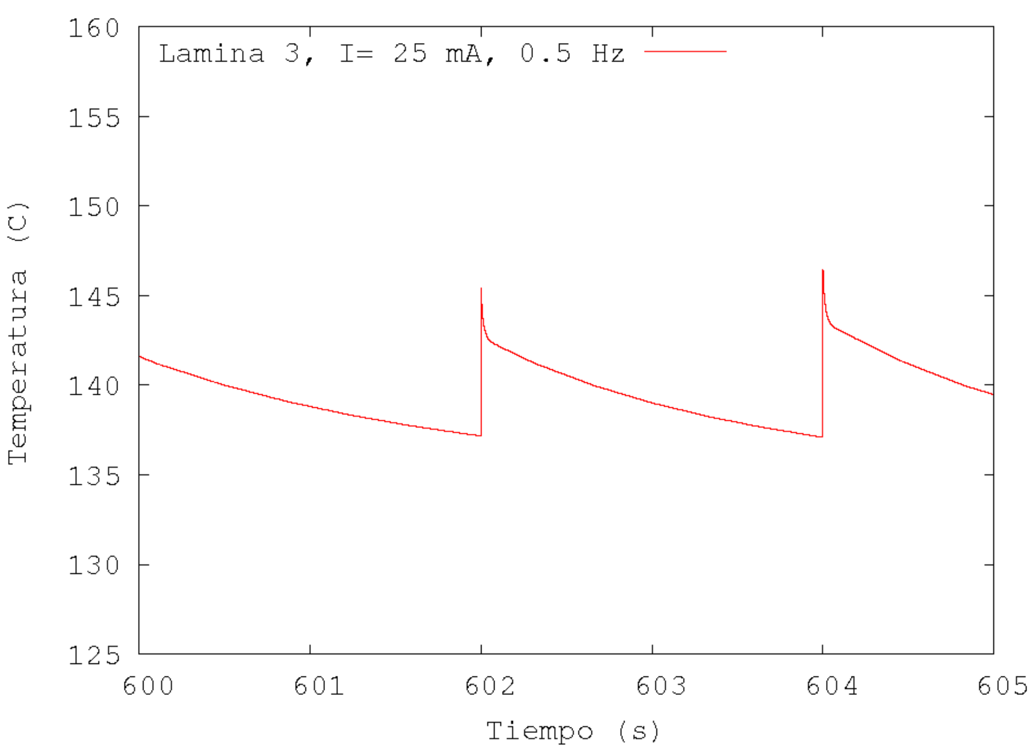
This Figures shows maximum temperature and stress for a target of 3 sheets of 3 mm of thickness cooled by conductivity. In order to guarantee the integrity of the target, the maximum beam intensity per “sheet” is 0.125 mA. This value is equivalent to a a beam of 25 mA@0.5Hz@1ms.

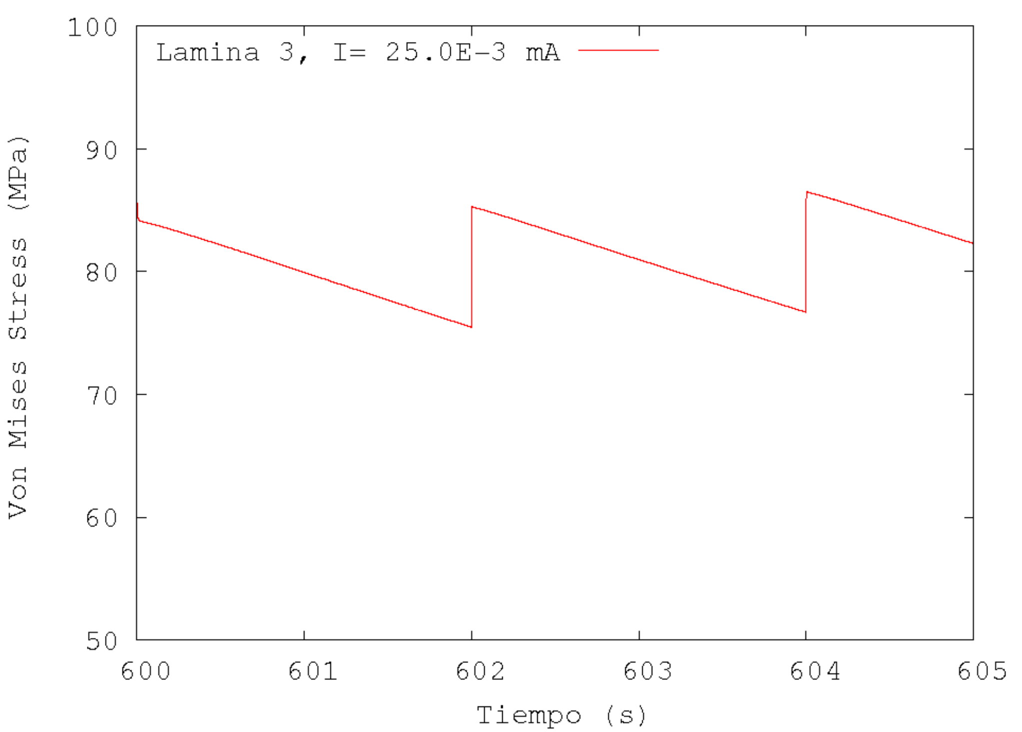




3. Thermomechanical conditions: Conducction

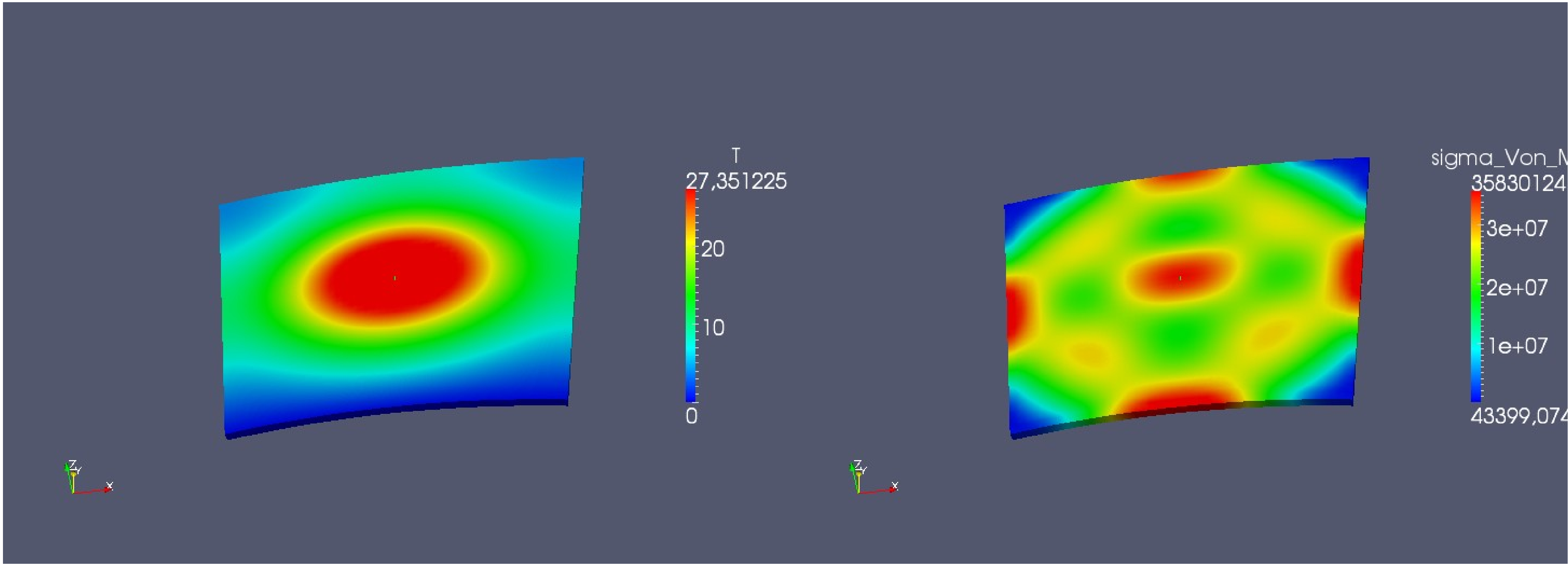
Starting from the stationary conditions estimated in previous simulation we can estimate the effect of the pulse (1ms and 0.5 Hz). We can see that temperature and stress effect is around 10º and 20 Mpa, so the operation conditions are safe.





3. Thermomechanical conditions: Conducction

Rising transitory in the third sheet for 0.5 Hz beam frequency Time = 14s.

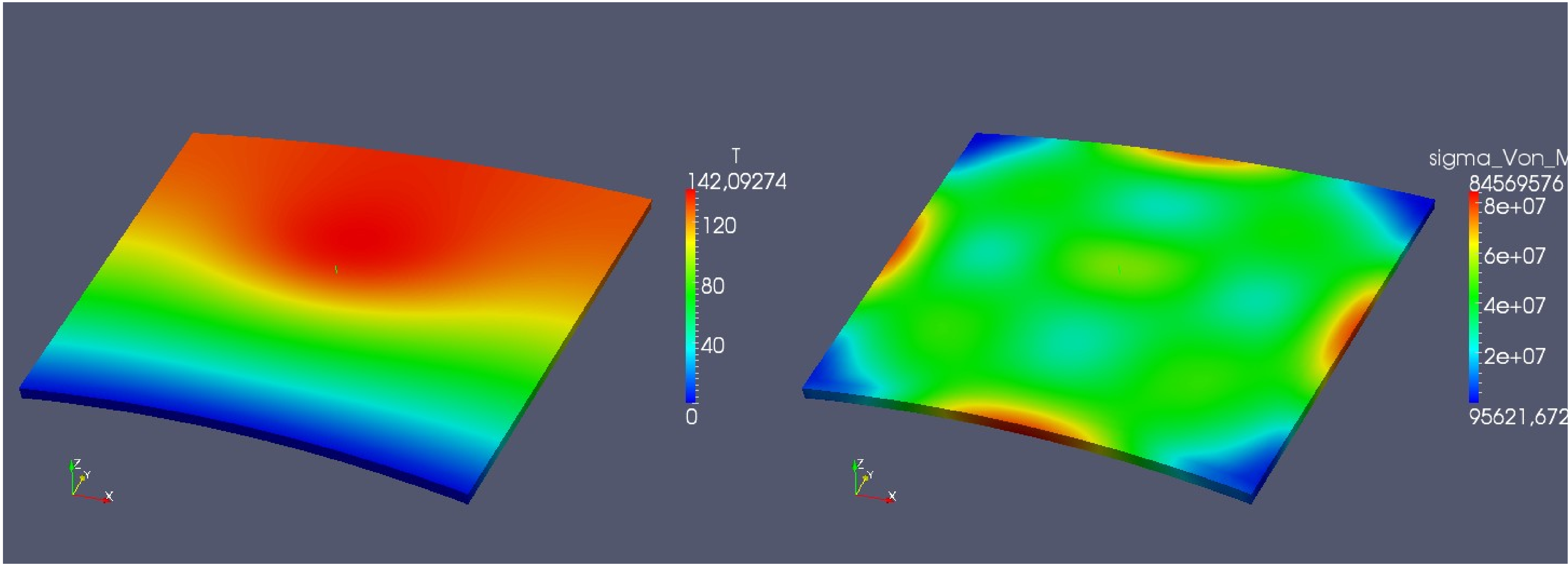


Relative temperature

Von Misses stress (MPa)

3. Thermomechanical conditions: Conducction

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



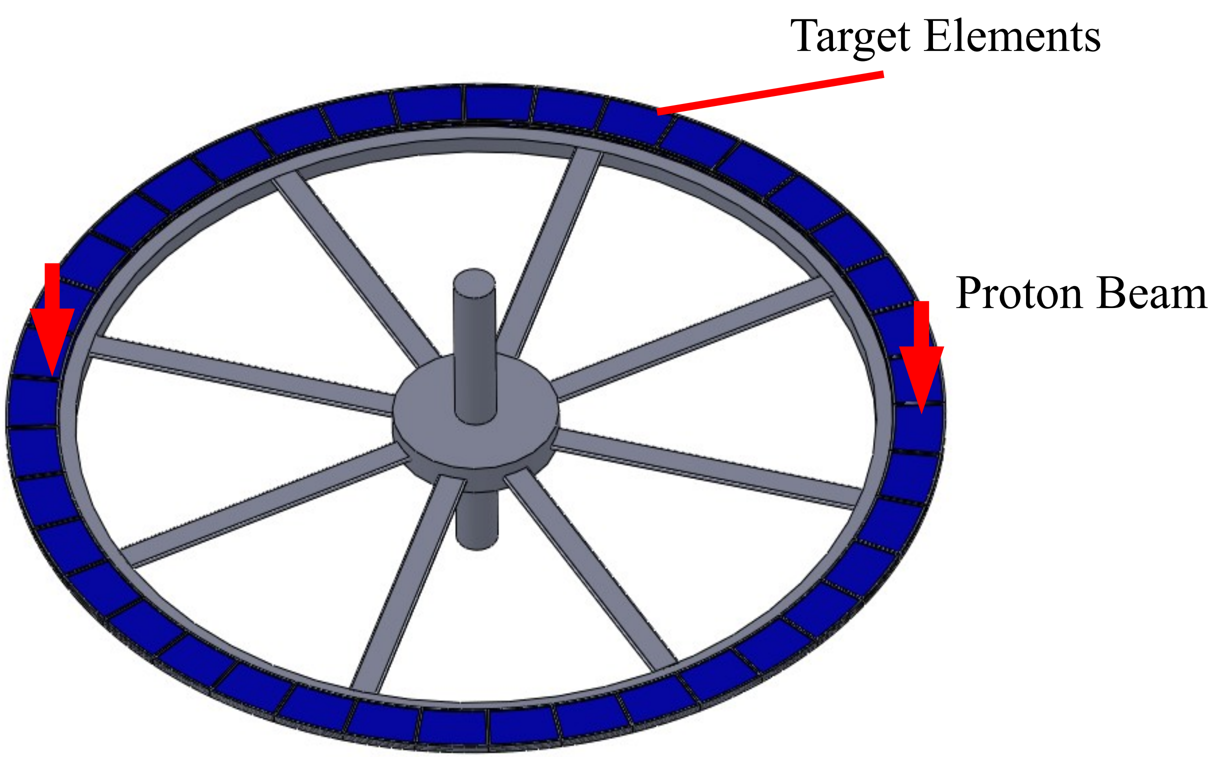
Temperatura

Tensión (MPa)

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 weel so the radius is 80 cm.



Target main parameters

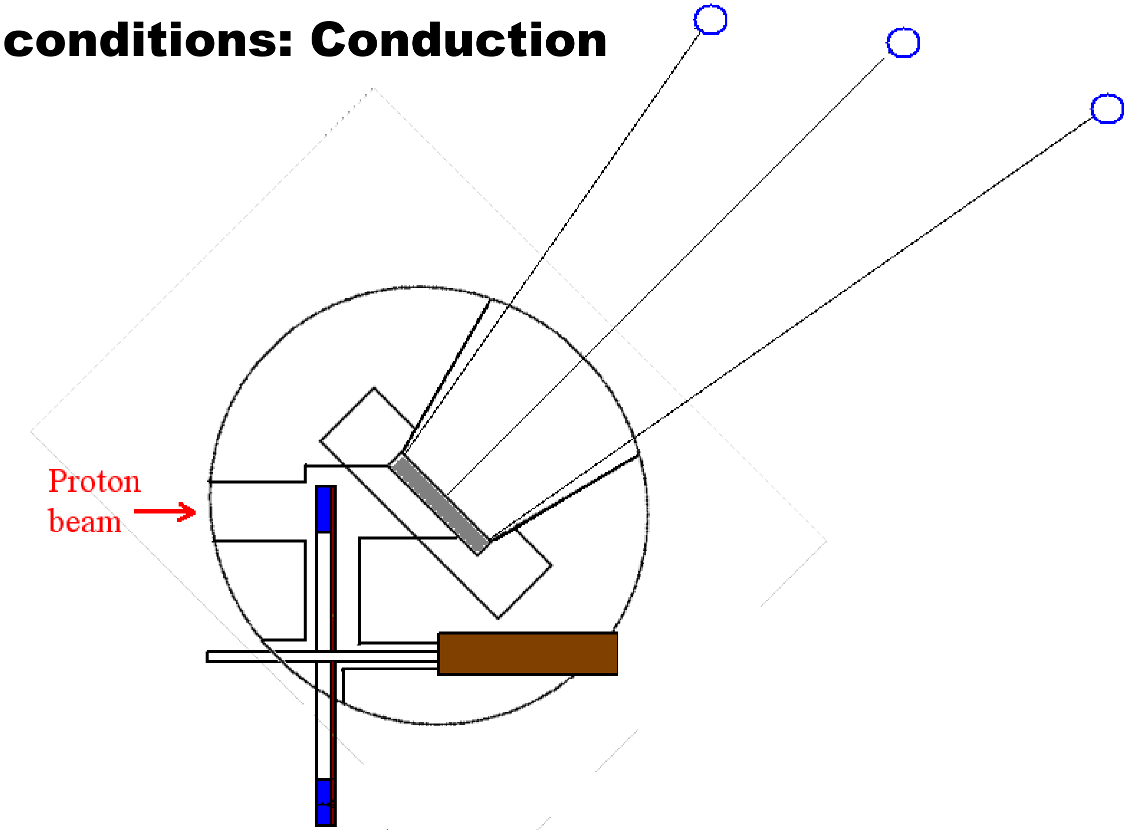
25 mA
20 Hz
1 ms
40 MeV

TOTAL POWER: 20 kW

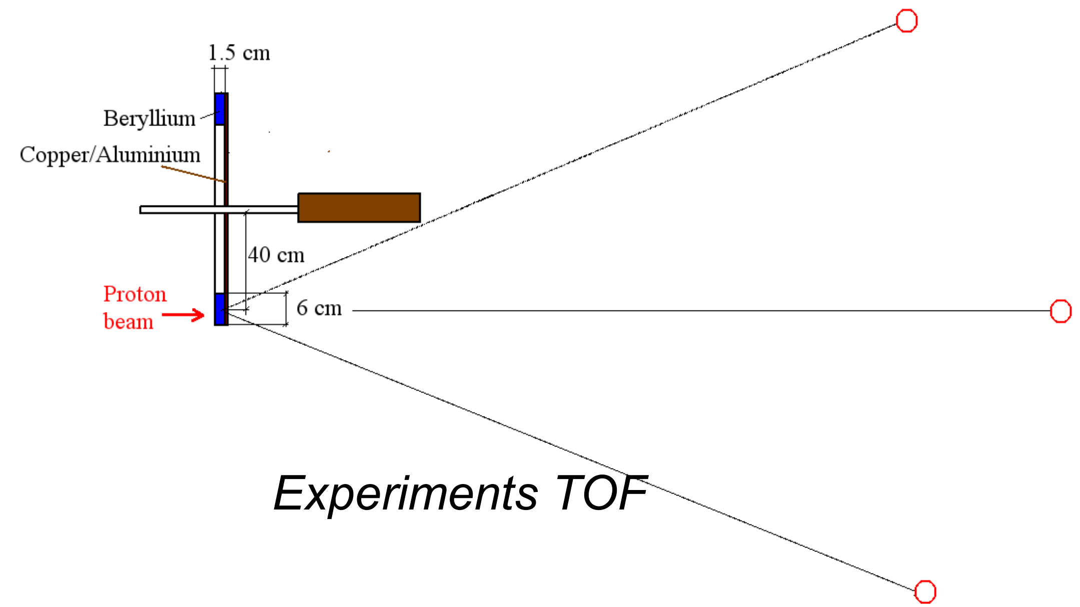
3. Thermomechanical conditions: Conduction

The idea of low energy target coled 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”.



Cold neutrons experiments

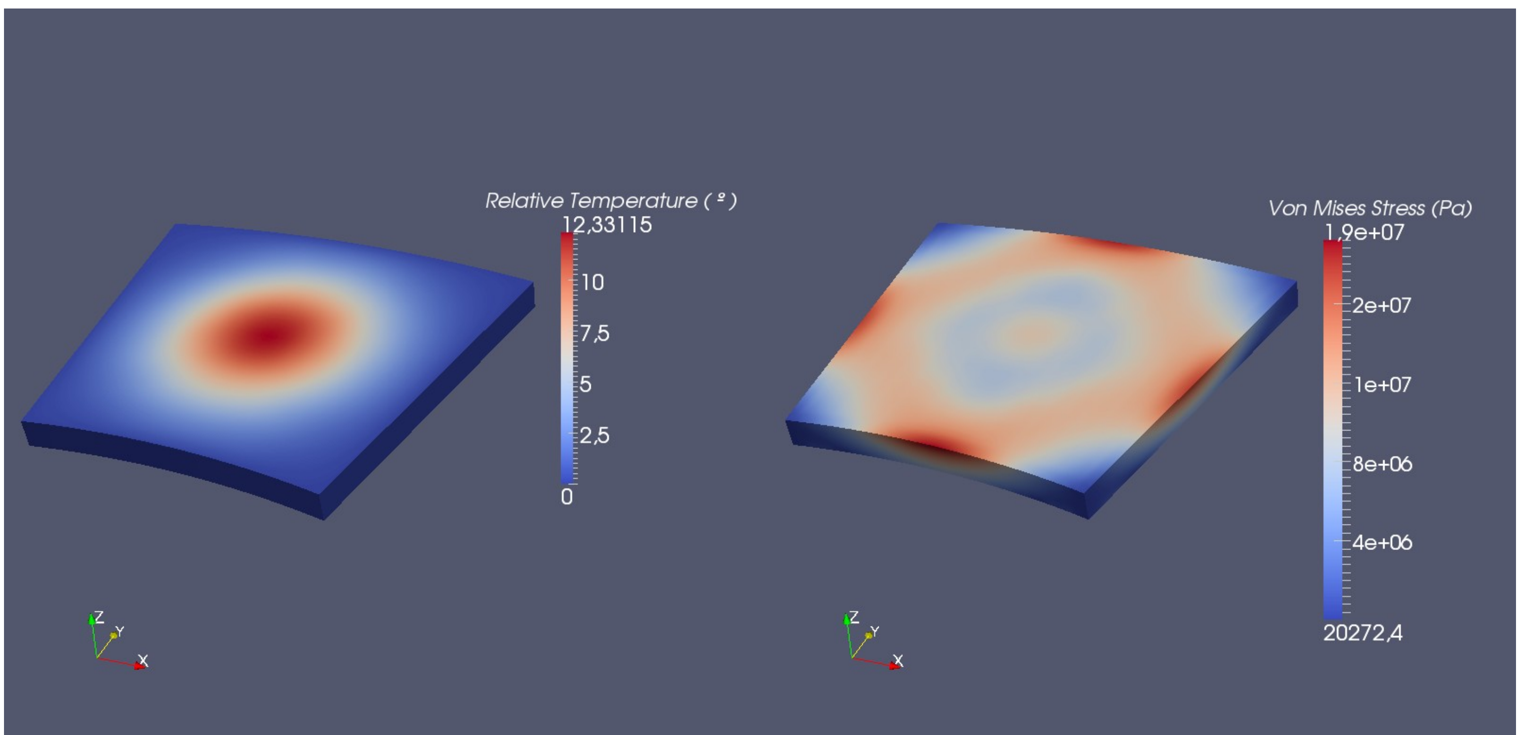


Experiments TOF

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.



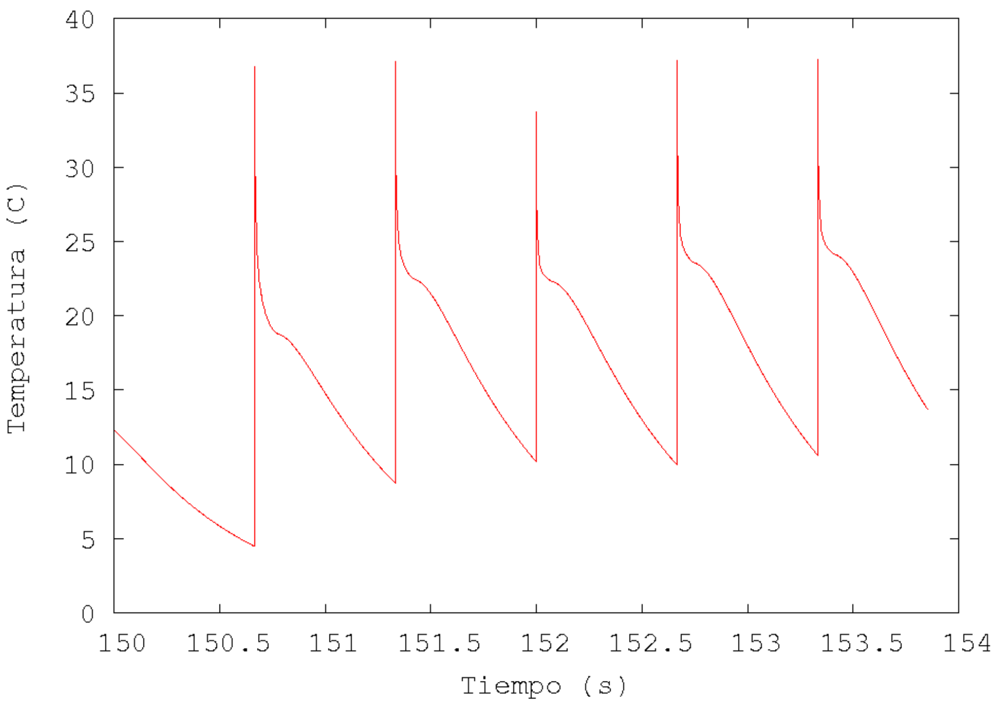
Temperature and stress

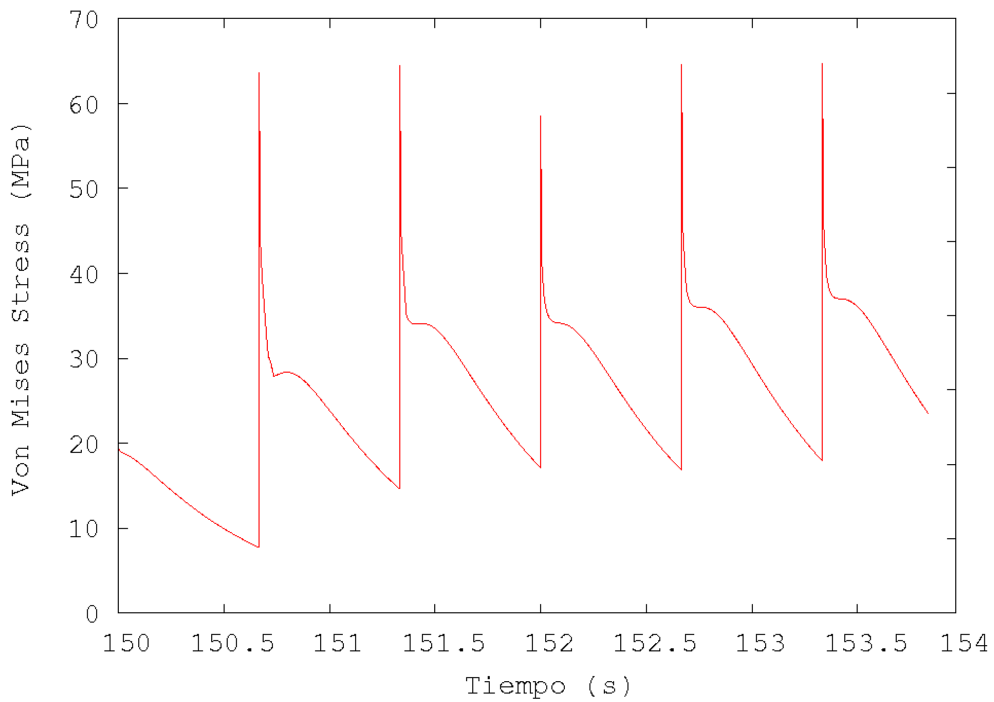
Beam Parameters

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

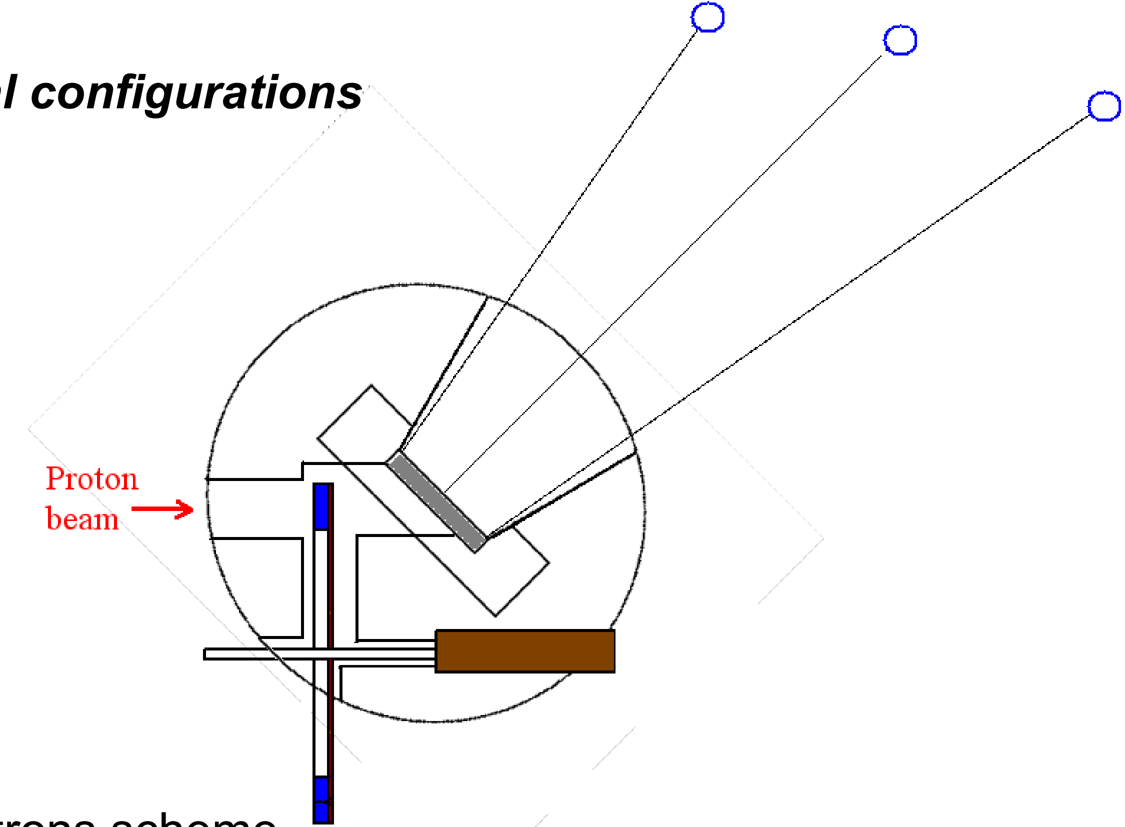
Depending on the experiments to perform, our configuration could be based on two different targets with common auxiliary elements:

→ Cooling system

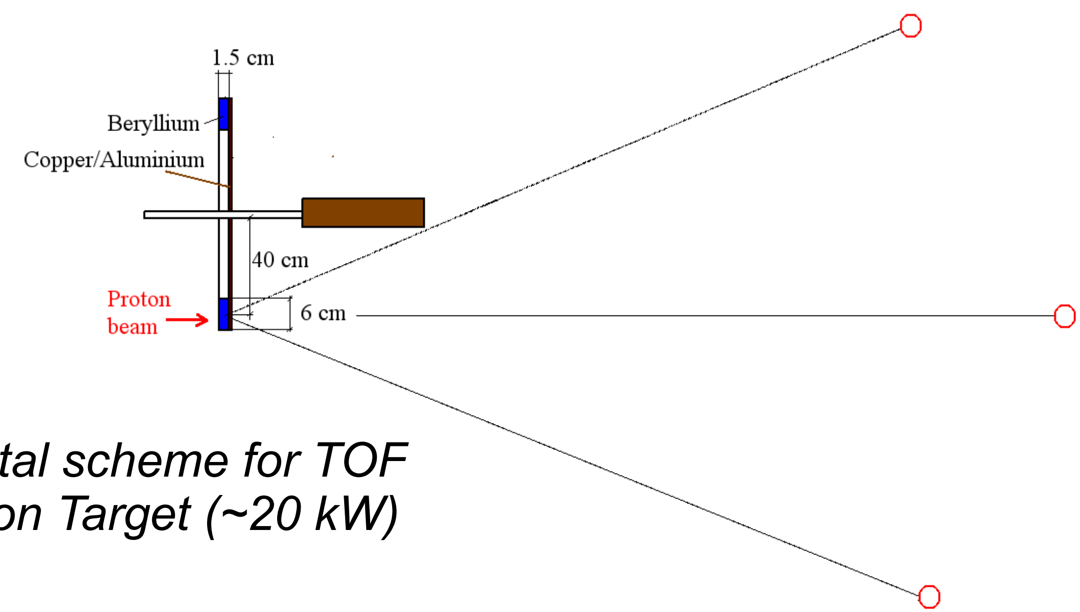
→ Engine

→ Remote handling system

"So we only have to change the weel"



Cold Neutrons scheme
Water cooled target (~90 kW)



Experimental scheme for TOF
Conducction Target (~20 kW)

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