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Organized by the French Atomic Energy Commission (CEA),
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First results of the new n_TOF spallation target commissioning


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Abstract: The Neutron Time of Flight facility n_TOF located at CERN started to take data in 2001. Due to an increase of radioactivity released in the cooling water the experiment was stopped by end of 2004. In 2008 a new spallation target has been installed. In 2009 the collaboration has performed the full commissioning of the facility, consisting in the determination of the fluence, the beam profile, and the energy resolution of the neutron beam. After a brief description of the new target assembly, very preliminary results concerning the shape of the neutron fluence and its absolute value will be given. Measurements of the neutron beam profile will also be shown.

Introduction

The Neutron Time of Flight facility n_TOF [1] located at CERN has been used since 2001 for measurements of neutron cross sections relevant for nuclear technology and astrophysics. A 20 GeV/c proton beam coming from the PS complex and impinging on a lead spallation target is used to produce neutrons. Using a water moderator, a wide neutron energy range spectrum spanning about 10 orders of magnitude is available. Thanks to the combination of this wide spectrum, together with a high flux per pulse and an advanced data acquisition system, a large set of high quality capture and fission data has been obtained. Up to 2004 the target consisted of a lead block of 80x80x40 cm³ cooled by water. Due to an increase of radioactivity released in the water the experiment was stopped by end of 2004.

In 2008 a new spallation target has been installed. It consists of a cylindrical Pb block of 60 cm diameter and 40 cm length, cooled by a forced flow of water. The water is chemically controlled in order to minimize its dissolution capacity. The water and Pb are enclosed in an aluminum container fitting into the old target container, which acts as a secondary containment vessel. At the target level, the cooling and moderator circuit are separated, offering the possibility to use different compositions for the moderator.

During the commissioning phase that started last May, we investigated the shape and intensity of the neutron fluence, the neutron beam profile, and the energy resolution of the facility by using a wide range of materials and detectors system.

After having briefly described the new n_TOF spallation target, this contribution will present the measurements and very preliminary results concerning the intensity and energy distribution of the neutron beam, together with its spatial profile.

The new n_TOF spallation target

After a three year’s long stop due to activation of the cooling water by spallation products, a new lead target was designed and constructed as well as new systems to fulfill the safety requirements before the restart of the facility. In particular a ventilation system has been installed to maintain the primary area depressurized with respect to the adjacent galleries. An optimized cooling system was developed allowing to control the chemical parameters of the water, in particular its oxygen content, and to reliably filter the activation products from the water. An extensive study of the corrosion mechanism has been performed to improve the long-term stability of the target.

In order to optimize the cooling efficiency, without loosing in neutron production, the new target was shaped as a cylinder of 60 cm in diameter and 40 cm in length. The vessel surrounding the target has been designed to optimize the water circulation around the target, particularly at the proton beam impact spot. This later has also been significantly increased compared to the previous situation to avoid thermal stress on the target.

Another improvement was achieved by the separation of the target cooling and of the moderator circuit. This enables the use of different moderator composition, providing greater
Neutron fluence shape measurements

In order to investigate the energy distribution of the neutron beam several measurements have been performed:

- A five plate fission chamber calibrated at PTB [4] containing 201.4(5) mg of $^{235}\text{U}$. The neutron fluence is determined from the counting rate, taking care of the well-known detector efficiency and the expected fission yield computed from a detailed MCNP simulation [5].

- A neutron monitor SiMon [6], consisting of 4 silicon detectors measuring tritium emitted by the $(n,\alpha)$ reaction from a thin (300 $\mu$g/cm$^2$) $^6\text{Li}$ foil.

- A neutron monitor MGAS [7], consisting of two MicroMegas detectors containing a $^{10}\text{B}$ deposit for measuring low energy neutrons and a $^{235}\text{U}$ deposit for measuring high energy neutrons.

Results, expressed in isolethargic units, are shown in figure 2. The black curve is the result from the PTB fission chamber. The red curve shows the results from the SiMon detector, while the green curve corresponds to the MGAS detector with the $^{10}\text{B}$ deposit. The SiMon and MGAS results are scaled to the PTB fission chamber results in the neutron energy range below 1 eV. The results from the PTB fission chamber are shown only below and above the resonance region, since the analysis in this region still need some improvements. Data for the MGAS above 200 keV are not shown, since other reactions than the $^{10}\text{B}(n,\alpha)$ are contributing to the detector's counting rate above this energy. Data from the SiMon detector are also cut at 200 keV due to the large uncertainties in the angular distribution of the reaction products. As can be seen from figure 2, the flux shape of the n_TOF facility presents a peak in the thermal region. From 1 eV to few tens of keV the flux is almost isolethargic. In the MeV region one can see the peak associated with evaporation neutrons. Because of the presence of thick aluminum windows at the spallation target station, the flux presents big dips at 5.9, 35 and 86 keV. A dip at about 300 eV is also present due to the presence of manganese inside the
aluminum alloy.

Figure 2. Neutron fluence shape, in isolethargic units, resulting from the analysis of the PTB fission chamber (in black), SiMon in (in red) and MGAS with the $^{10}$B deposit (in green).

As can be seen from figure 2 there is a very good agreement between the 3 measurements. Thanks to these measurements an overall uncertainty of 3% will be achievable in the flux shape determination.

Intensity of the neutron beam

Although the absolute intensity of the neutron beam is not so critical for cross section measurements, since the normalization of the reaction yields is obtained otherwise, this number is of importance to have a good knowledge of the facility performance and the predictive power of the simulations. Since the PTB fission chamber is a very well known apparatus, one can obtain, in addition to the fluence shape, a precise determination of its intensity. The SiMon and MGAS detectors can also be used to reach this goal, but with a lower accuracy.

<table>
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<tr>
<th>Table 1. Comparison of the neutron fluence with respect to PTB fission chamber measurement.</th>
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<td>PTB</td>
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<td>Average ratio over PTB</td>
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<td>Accuracy in the absolute value</td>
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</table>

In addition to these previous measurements the flux intensity has also been determined at 4.9 eV by using the activation technique and the Saturated Resonance Method (SRM), performed with the n_TOF Total Absorption Calorimeter (TAC) [8]. For the activation two gold foils with 25 μm thickness each and 45 mm in diameter (i.e. bigger than the beam spot) were placed back to back in the neutron beam. From the difference in counts, associated with the decay of $^{198}$Au, between the two foils on can estimate with an accuracy of about 10% the neutron fluence around the 4.9 eV resonance of gold [5]. Finally, the combination of the saturated resonance method with the high detection efficiency of the n_TOF TAC also allowed us to determine the neutron fluence in the energy region of the first resonance of gold.
Figure 2 shows the absolute neutron fluence determined using the PTB fission chamber. The ratio of this measurement and its associated uncertainty to the other measurement is summarized in the table 1. All the measurements are well in agreement within their associated uncertainties. Nevertheless one should note that the measured fluence is 16% lower than the one predicted by the simulations [2].

**Neutron beam profile**

The neutron beam at n_TOF is shaped by means of two collimators located at respectively 135 and 175 m from the lead spallation target. The second collimator determines the spatial distribution of the beam in the experimental area. The knowledge of the beam profile, as well as its dependence with neutron energy is of primary importance for capture measurements, where the samples are smaller than the beam spot. The beam profile has been investigated by means of two position sensitive detectors, a MEDIPIX [9] and a bidimensional MicroMegas detector (XY-MGAS) [10].

For the MEDIPIX detectors two neutron converters have been used, $^6$Li for low energy neutrons (up to 1 keV) and polyethylene for fast neutrons. Measurements have been performed in four neutron energy intervals: $0.01-1$ eV, $1-10^3$ eV, $0.08-1$ MeV, $0.08-200$ MeV.

The XY-MGAS detector, based on the bulk technology, consisted of a $6\times6$ cm$^2$ active area, made of $106\times106$ strips read by two 96 channel Gassiplex cards allowing to obtain the beam profile as a function of neutron energy. A $^{10}$B converter has been used with two different thicknesses: 20 nm to investigate low neutron energies, and 2 μm to study the profile for neutron energies up to 1 MeV.

![Figure 3](image)

**Figure 3.** Results from XY-MGAS detector. Left: spatial distribution of neutrons below 1 eV. Right: vertical profile compared with simulation (see text)

The left panel of figure 3 shows the spatial distribution of neutrons below 1 eV measured with XY-MGAS. Symbols on the right panel of figure 3 correspond to a slice along the vertical axis for horizontal values between -0.28 and +0.28 cm. The blue curve corresponds to the simulated profile under similar conditions. If one assumes a 2 mm tilt in the second collimator one can reproduce very well the experimental data as shown by the red curve in figure 3. This small misalignment in the collimator system may also explain, at least partially, the discrepancy between the absolute neutron intensity and the measured one, as shown in the previous section.

**Conclusion and perspectives**

After a 3 years stop, a new lead spallation target has been installed and commissioned at the n_TOF facility at CERN. A lot of effort has been spent to fulfill the safety requirements and ensure the long-term stability of the target. The first measurements of the 2009 campaign aimed to fully characterize the neutron beam in terms of spatial profile, neutron energy distribution, intensity and resolution in energy. A very preliminary analysis shows that 3% accuracy in the neutron energy shape is achievable, using the combination of various measurements and several standard reactions. The neutron flux shape is very similar to the past, but presents a stronger structure due to several thick aluminum windows close to the target. The neutron spatial distribution has been investigated.
with the use of a MEDIPIX and a 2D-MicroMegas detectors. A first comparison in the thermal energy region with a simulation of the optical transport of neutrons up to experimental area may indicate a small misalignment of our collimation system. This work still needs to be completed in the full neutron energy range. If confirmed it could partially explain the neutron intensity 16% lower than expected. The analysis of the resolution in energy using the shape analysis of well-known iron resonances is ongoing.

The decoupling of the moderator and the cooling circuit allows to use borated water as a moderator in the near future. This should lower by almost one order of magnitude the background in capture measurements due to the in-beam gammas, without affecting significantly the neutron flux above 1 eV.

In order to measure with radioactive samples without the ISO2919 sealing certification, it is foreseen to transform the experimental area in a work sector of type A. Since substantial backgrounds from sample canning can be avoided in this way, a whole class of new experiments will become feasible in a near future.

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