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First Commisioning Results from the nTOF Facility at CERN

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A new high-flux spallation neutron source, the neutron Time-of-Flight facilty (nTOF), recently became operational at CERN. The neutron energy ranges from the thermal to the GeV range. Performance results from the commisioning are reported.

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Abstract. A new high-flux spallation neutron source, the neutron Time-Of-Flight facility (nTOF), recently became operational at CERN. The neutron energy ranges from the thermal to the GeV range. Performance results from the commissioning are reported.

INTRODUCTION

The aim of the neutron Time-Of-Flight (nTOF) facility at CERN is the measurement of cross-sections needed for the design of innovative Accelerator Driven System (ADS) applications such as incineration of nuclear waste, energy production, radioisotope production for medical applications and for many other basic science subjects, in particular astrophysics. A complete overview of the physics potential is given in Refs. [1, 2]. Therefore, a nTOF facility has been built at the CERN PS, delivering a maximum intensity of 3×10^{13} protons in four pulses within a 14.4 s supercyle at a momentum of 20 GeV$/c$. The source is followed by a 182 m flight basis. This allows neutron cross-sections of almost any element to be studied systematically and with excellent resolution using targets of very modest mass — necessary for unstable or otherwise expensive materials — in the interval from 1 eV to 250 MeV.

THE nTOF FACILITY

The simulation of the detailed geometry of the lead target has been performed to estimate the neutron flux at 200 m. Two Monte Carlo codes were used successively: FLUKA [3] and the EA-MC Monte Carlo code [4]. FLUKA generates the spallation neutrons and transports them from high energies down to 19.6 MeV. The neutrons from FLUKA simulations with kinetic energy lower than 19.6 MeV are further transported by the EA-MC code using the same geometry as in previous simulations.

Following an overall optimisation between neutron flux and $\Delta\lambda$ resolution (λ = effective neutron path), the spallation target was chosen to be a lead block of $80 \times 80 \times 40$ cm^3, followed by a water moderator of 5 cm thickness [2]. In the final design [5] the neutron emission takes place at an angle of 10° with respect to the proton beam direction and the target is made of pure lead blocks already used in the TARC experiment [6]. A thin single metallic window (aluminium alloy) of 1.6 mm thickness is the interface between the moderator and the vacuum in the nTOF tube [5].

The time-of-flight tube (Fig. 1) starts directly behind the window and ends where the sloped floor of the TT2A tunnel

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(1.18% gradient) touches the tube, thus allowing a length of 200 m. The pressure in the vacuum tube is $\approx$ 1 mbar. The tube is made up of four different sectors, the first one ($\text{Ø} = 80$ cm), closest to the target, is made of aluminium alloy whereas the others ($\text{Ø} = 80$, 60 and 40 cm) are made of stainless steel [5].

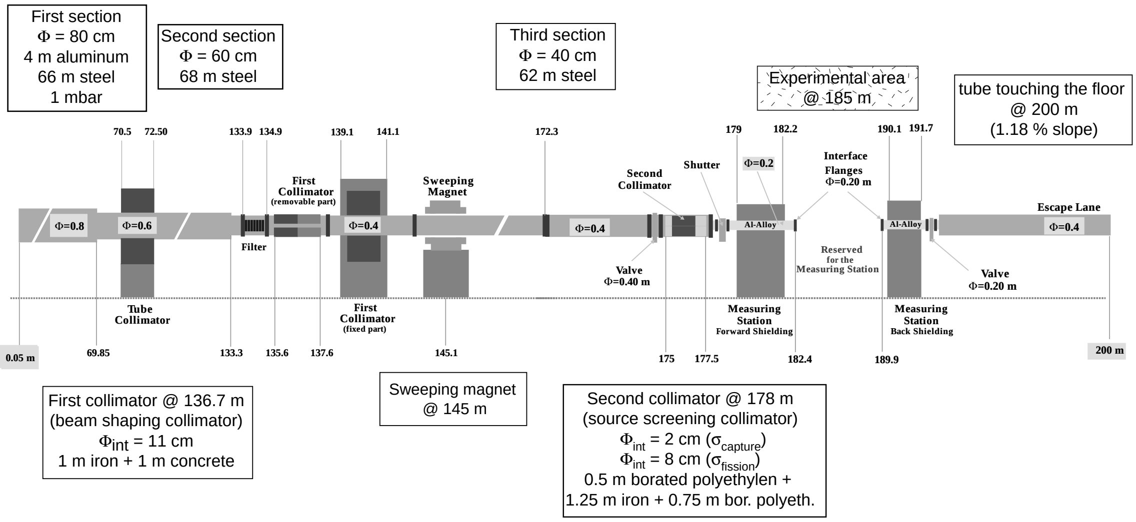

FIGURE 1. Time-of-flight tube sections up to the end of the TT2A tunnel (200 m).

Two collimators were installed to reduce the radius of the neutron beam. The first one, 2 m in length (beam shaping collimator), is located at 136.7 m and is made of 1 m of iron and 1 m of concrete; its inner diameter is 11.5 cm. The second collimator (source screening collimator) with 1.8 cm inner diameter is placed at 178 m with 50 cm of 5% borated polyethylene, 125 cm of iron, and 75 cm of 5% borated polyethylene.

In spite of the 10° angle between the time-of-flight tube and the proton beam, some charged particles will remain and contaminate the neutron flux. Therefore, a 2 m long dipole magnet, located at 145 m, is used to sweep away these unwanted secondary particles. Detailed simulations were made of the production of charged particles and photons [7] appearing after the magnet.

THE COMMISSIONING

Two commissioning phases took place, one in November 2000 and another one at the beginning of April 2001, aimed at checking the performance of the facility and at comparing the data with the simulation. While the main interest was concentrated on the physical parameters of the installation, the target behavior and various safety-related aspects were also monitored. The incident proton beam delivered by the PS was monitored in intensity by current transformers accurate to 1% for nominal intensities of 7×10^{12} protons per burst increasing to 5% at 10^{11} protons. In the second commissioning phase the shape of the proton beam was continuously monitored via CCD cameras and digitised. Both set of information were continuously recorded per pulse. Additional measurements were related to safety aspects, namely the temperature of the target, the temperature of the cooling water and the activity of the resin filters, and different positions inside the tunnel.

In the first commissioning phase a BC702 detector from BICRON, with an active diameter of 38 mm, was used for neutron energies below about 200 keV. This detector contains a mixture of ^{6}LiF and ZnS(Ag) powders, fixed in a transparent plastic matrix attached to a photomultiplier tube.

For high-energy neutrons a BC404 plastic detector enriched with ZnS(Ag) was used. Two bunches of optical fibers were attached on two adjacent sides of the plastic to conduct the light to two photomultipliers. The plastic is fast enough to avoid long-term blinding by the prompt gamma flash and to allow time-of-flight measurements for fast neutrons. Measurements were done with these detectors at 173 m downstream from the target, first without and then with the first collimator. The final measurements were made after the second collimator at 182.5 m.

In the second commissioning period, two parallel-plate ionisation chambers with fissile deposits, one with ^{235}U and another with ^{238}U, were used. These detectors are inter-comparison instruments and were provided by PTB Braunschweig [8]. The fissile deposit size was much larger than the beam size ($\text{Ø} = 76$ mm compared to less than

30 mm for the beam). The fission chambers have been used many times in the past and careful simulations have evaluated their efficiency. The detection efficiency is practically constant and equal to 95% up to neutron energies of 10 MeV.

In both commissioning phases pairs of gold foils were irradiated, followed by their gamma activation measurement.

The data acquisition system [9] recorded each event in a flash ADC and a multi-hit TDC together with the beam information.

RESULTS FROM THE COMMISSIONING

Figure 2 shows the preliminary results of two measurements from the first commissioning phase. The efficiency curve obtained in different facilities has been used to unfold the measured time-of-flight spectrum. The shape of the measured spectral function is essentially unchanged in the two measurements and therefore, as the first measurement is renormalised for the distance of 182.5 m, one can deduce a reduction factor of 7.3 for the flux due to the first and second collimators.

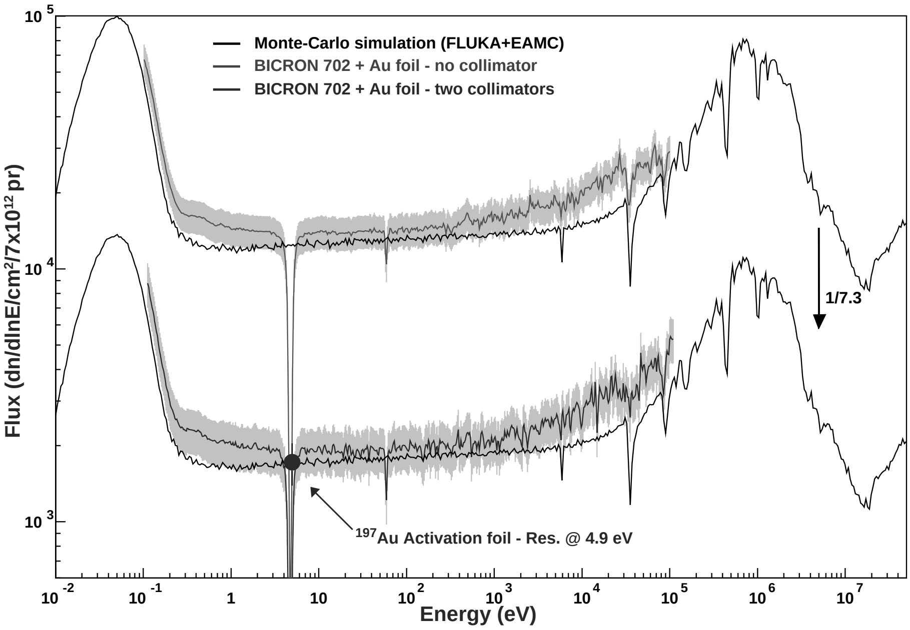

FIGURE 2. Preliminary neutron spectrum measurements with no collimator (upper curve) and with two collimators (lower curve).

Some systematic deviations from the simulated spectral function appear both for low- and high-energy regions, most probably for the following reasons: saturation effect in the photomultipliers due to the prompt γ flash, a yet missing calibration of the detector, or a detector defect which needs to be understood.

The above described effects did not appear (or were less in the case of the γ flash) in the two fission detectors. The raw time-of-flight spectrum was corrected run by run for small shifts in the t_0 value, since the PS timing signal was sometimes not constant. Next the contributions from α particles and other charged particles produced by high-energy neutrons were eliminated by cutting in the flash ADC spectrum where a very clear separation was observed from the fission products.

An additional correction had to be applied owing to the presence of tantalum, on which the ^{235}U is evaporated, and of platinum, which is the material of the electrodes. The resulting spectrum is shown in Fig. 3 where the data are in perfect agreement with the ENDF expectation [10].

After all these corrections, the neutron fluence was obtained by dividing the data with the expected values from the ENDF database. The preliminary result is shown in Fig. 4 for the ^{235}U and ^{238}U fission detector.

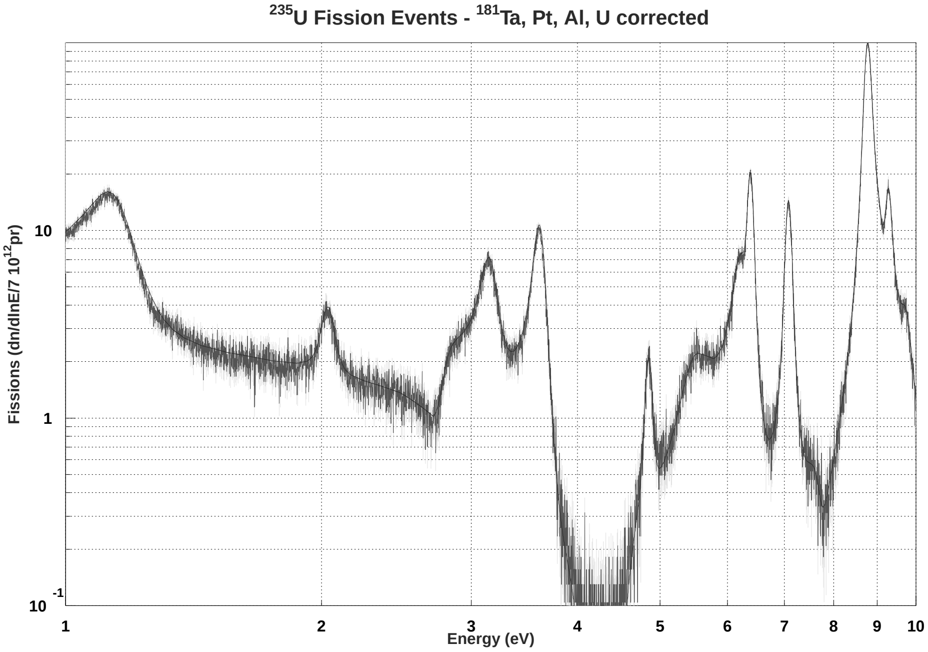

FIGURE 3. Number of fissions (corrected for Ta and Pt contributions) in the ^{235}U fission detector between 1 and 10 eV together with the expectation (preliminary).

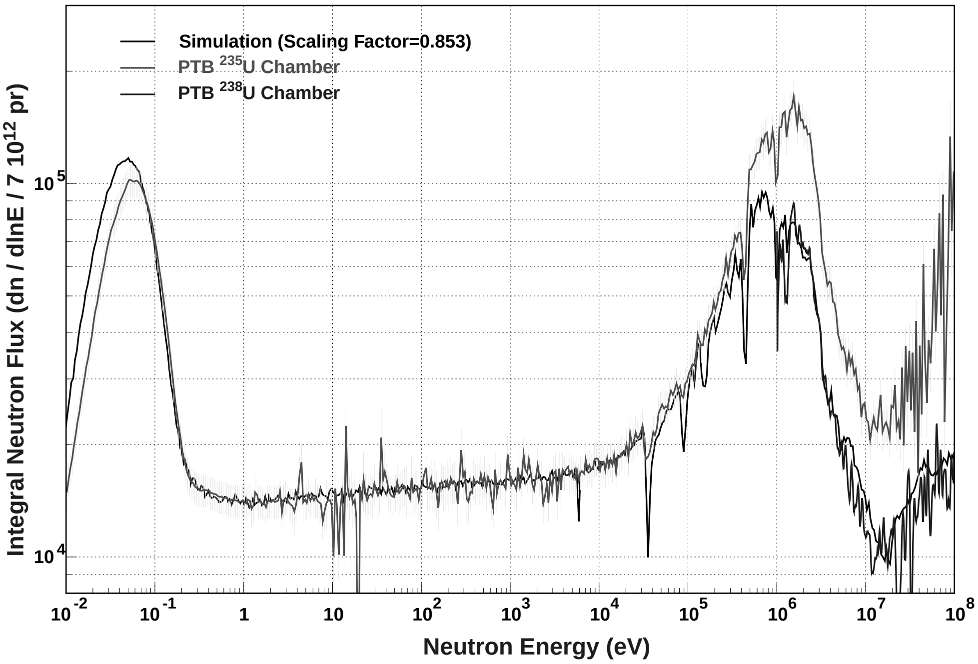

FIGURE 4. Preliminary integrated neutron fluence from the ^{235}U (upper data curve) and ^{238}U (lower data curve) fission detector together with the expectation.

In the case of the ^{235}U detector a clear disagreement with the expectation is observed at the highest energies, whereas for the ^{238}U detector, which is only sensitive to high-energy neutrons, the agreement is good. Recent measurements in the experimental zone revealed the presence of a γ background, presumably coming from the slowing down of fast neutrons with subsequent capture and for which the origin is not yet known. These background neutrons are outside of the beam area but within the sensitive surface of the ^{235}U detector. They give a signal in the ^{235}U detector but with the wrong time, therefore faking high-energy neutrons whereas the ^{238}U detector is insensitive to these neutrons. An additional contribution might come from (n,xn) reactions inside the collimator.

The few peaks pointing downwards come from wrong ENDF data [10] on Ta and Pt. The few peaks pointing upwards (for $E_\mathrm{n} < 10$ keV) are probably due to the same neutron background since we have observed that valleys at some resonances were filled.

CONCLUSION

The preliminary results from the commissioning measurements show a good agreement between the data and expectation. More measurements and calculations, mainly concerning the background, are now being performed before the facility is ready to make precise physics measurements.

REFERENCES

1. Proposal for a Neutron Time Of Flight Facility, CERN/SPSC 99-8, SPSC/P 310, 17 March 1999.
2. C. Rubbia et al., ‘A High Resolution Spallation Driven Facility at the CERN–PS to Measure Neutron Cross Sections in the Interval from 1 eV to 250 MeV’, CERN/LHC/98-02 (EET), Geneva, 30 May 1998. C. Rubbia et al., ‘A High Resolution Spallation Driven Facility at the CERN–PS to Measure Neutron Cross Sections in the Interval from 1 eV to 250 MeV: a Relative Performance Assessment’, CERN/LHC/98-02 (EET)-Add. 1, Geneva, 15 June 1998.
3. A. Fasso et al., in ‘Intermediate Energy Nuclear Data: Models and Codes’, Proceedings of a Specialists Meeting, Issy les Moulineaux (France) 30 May – 1 June 1994, p.271, published by OECD, 1994 and references therein.
4. F. Carminati et al., ‘TARC General Purpose Monte Carlo’, CERN Internal Report CERN/LHC/EET 96-011, Geneva, 17 April 1996.
5. Neutron TOF Facility (PS 213) Technical Design Report, CERN/INTC/2000-004, 11 February 2000.
6. H. Arnould et al., ‘Neutron-Driven Nuclear Transmutation by Adiabatic Resonance Crossing’, CERN-SL-99-036 EET, also as final report to the European Commission, Contract No F141-CT96-0009, EUR 19117 EN, ISBN 92-828-7759-0.
7. V. Vlachoudis et al., ‘Particle distribution entering the vacuum tube from a $80 \times 80 \times 60$ cm^3 lead target’, SL-Note-2000-029 (EET), 30 March 2000. V. Vlachoudis, presented at the MC 2000 Conference, Lisbon, 23-26 October 2000.
8. D. B. Gayther, Metrologia 27 (1990) 221.
9. V. Vlachoudis, ‘A multi purpose DAQ system developed and used for the nTOF commissioning’, EET Int. Note 2001–03, 26 July 2001
10. ENDF/B-VI, OECD NEA Data bank (1996).