The Present Status of the n_TOF Facility at CERN

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The main aim of the n_TOF facility at CERN is to provide precise neutron cross-section data relevant to the R&D of accelerator driven systems, nuclear astrophysics, etc. It is composed of a spallation neutron source, a 187.5-m flight path, a variety of detectors, a data acquisition system, etc. A 20 GeV proton synchrotron is employed together with a lead target for the spallation neutron source. The measurement of capture and fission cross sections started in 2002 and had been performed until the mid of November in 2004. The capture and fission measurements were performed for 28 and 7 isotopes, respectively. The brief history, present status, and future plan of the n_TOF facility are reported.

1. Introduction

C. Rubbia et al. proposed “The Energy Amplifier: A Solid-Phase, Accelerator Driven, Sub Critical, Th/233U Breeder for Nuclear Energy Production with Minimal Actinide Waste”[1]. However, more accurate neutron cross-section data in a wide energy range were necessary for the R&D of the energy amplifier. Thus, C. Rubbia et al. proposed the idea of the n_TOF facility at CERN in 1998[2].

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The n_TOF facility was commissioned in 2001. Then, the background in the experimental areas was investigated and it was larger than the simulated result by about 50 times. After adding an iron shield with a thickness of 3 m and a shadow bar, the measurement of capture and fission cross sections started in 2002. The work packages from nTOF1 to nTOF10 had been performed until the mid of November in 2004. In these packages, capture and fission experiments were performed for 28 and 7 isotopes, respectively.

The brief history, present status, and future plan of the n_TOF facility are reported mainly based on the presentation at ND2004 by P. Cennini[2].

2. Neutron Source of the n_TOF Facility

A 20 GeV proton synchrotron was employed together with a $80\times80\times60$ cm^3 lead target as a spallation neutron source. One 20 GeV/c proton can produce about 300 neutrons in the lead target. A proton pulse was delivered to the lead target every 2.4 s. The width and intensity of proton pulse depended on the operation modes of the synchrotron. In the Dedicated Mode, the width was 6 ns (rms) and the intensity was 7×10^{12} protons. The performances of the n_TOF facility are shown in Table 1. The main characteristics are (1) the wide neutron-energy range, (2) the high neutron flux, and (3) the high energy resolution. The flight time of 1 eV neutron for the 187.5 m path is about 0.014 s, so only 0.006 (=0.014/2.4) of real time is the measuring time. Therefore, (4) the low duty cycle is favorable for the measurements of cross sections of radioactive samples.

Table 1 Performances of the n_TOF facility

Nominal Energy Spectrum	1 eV to 250 MeV
Neutron Flux	6.2×10^{5} n/cm^{2}/7×10^{12} p
Flight Path	187.5 m
Duty Cycle	$<$1%
Energy Resolution	0.02% at 1 keV, 0.2% at 1 MeV, 1% at 100 MeV
Intrinsic in-beam Contamination	Gamma Rays: 10%
Outside-beam Contamination	$<10^{-6}$ relative

3. Detectors and Data Acquisition System

Parallel Plate Avalanche Counters (PPACs) and a Fast Induction Chamber (FIC) were developed for fission cross-section measurement. Four C_6D_6 detectors and a 4π BaF_2 spectrometer were developed for capture cross-section measurement.

The n_TOF data acquisition (DAQ) system is a general purpose one using flash analog-to-digital converters (FADC). The DAQ system was designed based on the proton beam repetition rates, expected event rates and detector channels, and characteristics of the detector signals. The sampling rate of FADC was usually 500 MHz and the full analogue waveform of each output of detector was stored during 16 ms for each proton pulse. Therefore, there was no dead time in measurement and the DAQ system could manage a huge data rate of 45 Mb/s. In fact, 2 Tb data were stored every day.

4. Cross Section Measurement at the n_TOF

Since the first measurement with the C_6D_6 detectors for the capture cross section of ^{151}Sm, capture and fission experiments were performed for 28 and 7 isotopes, respectively, as shown in Table 2. In 2004, the capture experiments were performed with the 4π BaF_2 spectrometer and 25-400 mg samples. Each of radioactive samples was encapsulated in a Ti case due to the regulation of CERN.

Table 2 Capture and fission experiment performed at the n_TOF facility

Capture (28 Isotopes)		
	2002	^{151}Sm, ^{204,206,207,208}Pb, ^{209}Bi, ^{232}Th
	2003	^{24,25,26}Mg, ^{90,91,92,93,94,96}Zr, ^{139}La, ^{186,187,188}Os
	2004	^{79}Se, ^{233,234,236}U, ^{237}Np, ^{240,242}Pu, ^{243}Am
Fission (7 Isotopes)		
	2002	^{232}Th, ^{234}U
	2003	^{232}Th, ^{233,234,235,236,238}U, ^{237}Np, ^{241,243}Am, ^{245}Cm
	2004	^{233,235,236,238}U, ^{241,243}Am, ^{245}Cm

5. Research Members at the n_TOF Facility

In 2004, the experiments at the n_TOF facility were performed by 114 researchers from 40 institutions. Most of researchers were from European institutions, but researchers from non-European institutions also participated. From Japan, M. Oshima (JAERI) and the author officially participated in the n_TOF experiments. The Maintenance and Operation (M&O) cost of the n_TOF facility was shared by all the researchers except for post-doc researchers and doctor course students.

6. Future Plan at the n_TOF Facility

The water coolant of lead target produced 2.2 MeV gamma-ray background in the time region corresponding to the keV neutron region. To reduce this background, the addition of 0.2-1% B to the coolant water or the usage of heavy water has been investigated. The usage of heavy water has another advantage: it could drastically increase the neutron flux in the keV region.

The second measuring station will be installed at about 150 m in a class A room, where one can use unsealed targets. Moreover, the second flight path will be installed to obtain higher (×100) neutron flux. This flight path will be 20-25 m and orthogonal to the lead target.

All researchers hope that the next measurement will start in the summer of 2006.

References

[1] C. Rubbia, Proc. Int. Conf. on Nuclear Data for Science and Technology, 1994, Gatlinburg, USA, pp. 1065-1071 (1994).

[2] P. Cennini, Int. Conf. on Nuclear Data for Science and Technology, 2004, Santa Fe, USA.