n_TOF

A THE FACILITY

A.1 The neutron time-of-flight infrastructure at CERN

CERN is the European Organization for Nuclear Research, the world's largest particle physics laboratory, situated on the border between France and Switzerland. It is also notorious for being the birthplace of the World Wide Web. Its main function is to provide the particle accelerators needed for high energy physics research, and numerous experiments have been constructed at CERN by international collaborations to make use of them. The main site at Meyrin also has a large computer centre containing very powerful data processing facilities primarily for experimental data analysis, and because of the need to make them available to researchers elsewhere.

The CERN accelerator complex has six main accelerators: Two linear accelerators; the PS Booster; the 28 GeV Proton Synchrotron (PS); the Super Proton Synchrotron (SPS); and Isotope Separator On-line (ISOLDE). Most of the activities at CERN are currently directed towards building a new collider, the Large Hadron Collider (LHC) and its experiments, due to start operation in 2007.

The neutron Time of Flight (n_TOF) facility at CERN is an intense source of a wide energy range from thermal up to 250 MeV flux of neutrons, generated by the spallation mechanism of 20 GeV/c protons from the PS accelerator onto a solid lead target. The goal of the n_TOF is to provide unprecedented precision in neutron kinetic energy determination, which will in turn bring the much-needed precision in neutron-induced cross-section measurements.

The beam, 20 GeV/c momentum with a time resolution of 6 ns (r.m.s.) is transported to the n_TOF spallation module via a transport line. There are two operation modes for the proton beam for n_TOF i) a dedicated mode, in which a full bunch of protons with intensity up to 7×10^{12} is delivered to the n_TOF target; ii) a parasitic mode in which a bunch of lower intensity, normally delivered to the East Experimental Area is shared with intensity of the order of 4×10^{12} protons.

The lead spallation module has been designed in order to obtain the highest figure of merit (ratio between the neutron flux and a time resolution parameter squared). This resulted into a $60\times80\times80$ cm^3 lead block with a 20 cm deep niche in the entrance face. The target is water cooled. The water also acts as moderator for the outgoing neutron beam, strongly enhancing the neutron flux at low energies. At present n_TOF neutron beam have two operational modes, one for capture and another for fission cross section measurements. This is achieved by interchanging the second collimator, located just in front of Experimental Area (EAR-1). This collimator can have a diameter of Ø 1.8 cm for the capture setup or Ø 4.0 cm for fission measurements in which the maximum fluence in the experimental area can be distributed on a larger surface.

The unique features of the n_TOF facility (instantaneously very intense neutron flux, low duty cycle, high resolution and low background) makes possible the measurement of highly radioactive isotopes usually available in small quantities. Such measurements are vital for a range of studies in fields as diverse as nuclear technology, astrophysics and fundamental nuclear physics.

The neutron beam line is equipped with a wide variety of detectors that was used for monitoring and neutron induced cross section measurements. Namely there are ^{6}Li-Si-monitors, BF_3 chambers; Fission Ionization chambers; Parallel Plate Avalance counter ; C6D6 detectors and a large 4π BaF total absorption calorimeter and two data acquisition systems i) an innovative DAQ based on fast digitizers 1Gs ii) a VME based DAQ using commercial TDC's and 40MHz FADC.

The high instantaneous neutron flux at n_TOF, represents a great advantage especially for the measurements of small mass and radioactive samples as in our case, but it poses relevant problems on signal processing and acquisition due respectively to pile-up events and large dead times. To

overcome these problems, an innovative data acquisition (DAQ) system based on fast digitizers has been set-up. The main feature of this system consists in the possibility to sample and record the full analogue waveform of the detector signal. The sampling is performed by means of fast Flash Analogue to Digital Converter (FADC), with sampling rates up to 1 Giga Samples/s. The FADC are plugged into a Compact-PCI crate interfaced to a PC by a controller and a standard DMA cable. The raw data, consisting in a series of pulses preceded and followed by some samples for baseline determination, are later analyzed via software to extract the required information on time-of-flight, charge, amplitude, particle identification. For the operation of the fission detectors and of the n_TOF TAC, a total of 64 FADC channels have been operational at n_TOF during the experimental campaigns.

Presently there is only one experimental area (EAR-1) where all the measurements take place, but there are a few improvements and/or upgrades of the facility which are under study. We list them here with a note on the fact that the details of the setting in operation of these will require dedicated actions which can be performed during the course of 2005 and the 2006 winter shutdowns: i) Upgrade of the target area (ventilation system); ii) Possibility of using heavy water in place of normal de-mineralized water to eliminate the 2.2 MeV prompt gamma's by the neutron capture on Hydrogen from the cooling water circuit; iii) Modification of EAR-1 in order to allow for measurements of unsealed samples; iv) Construction of an additional experimental area in front of EAR-1 for parallel measurements of fission and capture; v) Construction of an additional vertical & shorter flight-path of 20 m and a new spallation target optimized for both flight paths ensuring also higher radiation safety. The construction of an additional flight-path could change drastically the possibilities of measurements at n_TOF. In fact, the gain in higher flux would allow for measurements of extremely low mass samples, thus also improving significantly the safety conditions.

A.2 Quality of research

During the first 3 years of operation the facility allowed the systematic and accurately study of neutron induced reactions in the energy range from 1 eV to 250 MeV. The unique features of the n_TOF facility and the high performance detectors used provided quality measurements of neutron induced cross sections of radioactive samples of modest quantities. The measured data supersedes that of the presently available nuclear data and satisfies thus the demanding requests in frontier research and industrial requirements.

The n_TOF project objectives includes measurements of neutron induced cross sections needed for the design of innovative ADS applications like transmutation of nuclear waste, energy production radio-isotope production for medical applications and basic science subjects in particular astrophysics.

The measurements so far performed at n_TOF have covered capture and fission cross section measurements on a large number of samples. The full list is given in the table below. Most of the measurements have been performed for the n_TOF-ND-ADS Project, within the EC FP5 initiative. The motivations and physics cases of the various measurements have been given in great detail in the proposal for measurements submitted to the CERN INTC Committee. Here we will show the results of a few of the measurements performed.

TABLE 1. Isotopes Measured at n_TOF during the 2002-2004 experimental campaign

Capture	Fission
^{151}Sm, ^{204,206,207,208}Pb ^{209}Bi, ^{232}Th, ^{139}La ^{24,25,26}Mg $^{90,91,92,\mathbf{93},94,96}Zr$ ^{186,187,188}Os, ^{240}Pu $^{233,234}U$, ^{237}Np, ^{243}Am	$^{233,234,236}U$ ^{232}Th ^{237}Np $^{241,243}Am$ ^{245}Cm
Relative to: ^{197}Au	*Relative to*: $^{235,238}U$

A.3 New opportunities for access

The unique research capabilities offered at the n_TOF facility provide an excellent opportunity for trans-national collaborations in the field of transmutation research and innovative nuclear energy systems. Measurements related to transmutation research, ADS and fundamental physics will highly benefit from the n_TOF facility and related infrastructure. In the framework of EFNUDAT, the CERN/n_TOF can place in the disposal of EFNUDAT about 300 data-taking hours per year (see below D.1) provided that all the conditions are respected (proposal accepted by the INTC committee and all safety issues are fulfilled).

B MANAGEMENT OF THE ACCESS PROVIDED

B.1 User access to the infrastructure

The CERN/n_TOF facility currently offers only one measuring station (EAR-1) with a flight path of 185 m where fission and capture measurements can take place in parallel. A second measuring station with a vertical and shorter flight path 20 m is under study and most probably will be operational in the coming years. Moreover a rabbit system is envisaged for activation of elements using delayed-gamma spectroscopy. The facility is operational 24h/day, 7 days/week for the period that the accelerator complex of CERN is running typically 6 months/year.

Single scientists or research groups can apply by submitting a proposal to the local INTC committee (ISOLDE and n_TOF committee). The INTC committee makes 4 calls per year, where the spokes person of the proposal presents orally the experiment (scientific motivations, technical details and specific features related to the experiment) and makes a request for the necessary beam-time. The decision of the INTC committee will be based mostly on the scientific motivations and feasibility of the project.

A typical experiment involves two weeks for preparation of the experimental set-up, performing the experiments, and dismantling the equipment. The major part of the data processing and analysis shall be performed at the home institute. The minimum requirement is that 3 persons are always present for the 3 shifts/day. Always one person is in the control room and one on call in case of emergency.

Users of the facilities who are supported by the Euratom Transnational Access Programme should disseminate the results of their work through publications, seminars and other public presentations. Publications should preferentially be in peer-reviewed international scientific journals. The experimental data should be submitted to the EXFOR database at the NEA databank.

B.2 Scientific, technical and logistic support

CERN has a well-developed scientific staff, local technical team for support/maintenance of the facility, and logistic infrastructure in place to support and accommodate external researchers. External users will have full access to the facilities and their state-of-the-art neutron cross-section measurement set-ups dedicated for capture, fission and scattering experiments. The experimental set-ups are fully equipped with a wide variety of sophisticated detectors, and data acquisition and analysis systems.

External visitors performing experiments at our facilities will be assigned office space and receive all administrative and computing support that is adequate for their needs. They have access to the same services as the CERN staff (e.g., telephone, fax, internet access, library, meeting rooms and restaurant). The Social Service of the institute can be contacted for administrative or personal problems, such as lodging, contacts with local administration, schools and hospitals.

Support laboratories and workshops are available on site for small mechanical work, and for special sample handling and mounting.

All users of the facility, at the time of their first entry at CERN must follow a 2 half-days seminar on radiation safety issues to be eligible to access the installation. They may also participate in seminars and lectures organised on site.

B.3 Peer review procedure

The peer review procedure, common for all Transnational Access Activities within EFNUDAT, is described under Activity NA1-Management of the I3, part B.3.2.4. However, at CERN there are specific procedures to perform experiments at n_TOF, requiring an evaluation by the INTC committee. It is foreseen that proposals for experiments at n_TOF that are approved by the PAC of EFNUDAT will be defended at the INTC. Support from EFNUDAT to these experiments at n_TOF will only be given after approval by INTC.

Experiments at the n_TOF facility usually require much more resources as provided by EFNUDAT. For example, the user groups are generally much larger. Therefore, in this TA proposal only 20% of the real costs will be charged for the user fees within EFNUDAT. For a typical experiment with a duration of 2 weeks, EFNUDAT will normally support travel and subsistence for 2 researchers staying about 21 days at CERN.

C EUROPEAN ADDED VALUE: European interest in the infrastructure

C.1 Community interest in the infrastructure

Over the first 3 years, a multinational collaboration consisting of 40 institutes 150 scientists from 15 countries was operating non-stop the n_TOF facility mainly for neutron induced capture and fission measurements. The total amount of beam time used was of the order of 2500h/year in the form of 6 pulses out of a super-cycle of 14.4s for a total period of 7 months. After the successful end of the n_TOF collaboration phase 1, there is a strong demand to continue the program. There are also several other institutes that have shown their interest in submitting proposals to the INTC committee.

C.2 Expected impact

The research possibilities at all EFNUDAT facilities together will be advertised internationally in a common and systematic way, using different modern methods and media. In addition the publicity within the framework of n_TOF/Phase2 will also refer to the EFNUDAT Transnational Access programme. A special web-page will be created for EFNUDAT (see network Activity NA5). This web-page will be linked to the web-page of n_TOF, to the home-page of the CERN. CERN's annual report should clearly advertise the access opportunities and the web-route to the EFNUDAT web-page. A concerted EFNUDAT action on advertisement may also be envisaged, using 'cross-linked' institutes web-pages with a description of the consortium of facilities and their research opportunities.

C.3 Attracting potential new users

Making available the unique features of the n_TOF facility to a wider scientific community will increase the number of running projects. A wider transnational access will strengthen the present experimental program and will result in a more optimum exploitation of the infrastructure. Merging new initiatives with present know-how will create around the facilities a fertile and innovative environment. Moreover, existing research ideas that presently cannot be realised, due to a lack of manpower, can acquire the necessary critical mass with an additional intellectual input. The impact also on the nuclear community will be indispensable, by allowing the dissemination of the know-how and knowledge of the users of the facility. The users also will benefit from the 50 years experience of CERN on the accelerator domain and high energy physics.

D ACCESS OFFERED BY THE INFRASTRUCTURE

D.1 Annual implementation plan

The implementation plan covers a project with duration of 48 months. If the proposal can be accepted a reasonable estimate is that we can offer each year a minimum of 3 experiment-weeks. The accelerators are operating continuously on a 7 days/week basis 24 h/day, with maximum 6 cycles of 1.2s period over a super-cycle of 14.4s for a total period of about 25 weeks/year corresponding to 168 h/week. The average duration of an experiment is estimated to be two weeks, so that researchers will spend 14 days at the infrastructure. For a visiting experimental group access will be financed for 2 users.

D.2 Activities connected with access

Access offered to the external users will include user training, scientific and technical support during the experiment, office services, computers and administrative and logistic support. The costs (on the basis of user fees) are justified in detail in part D.3. Also costs for travel and subsistence related to the visits of users will be borne by the contract. All starting projects at n_TOF are subject to approval of the Safety commission/Radioprotection department (SC/RP). Special training sessions are organised for newcomers on health and safety at work, including radiation protection issues for activities in controlled areas. Young researchers can also benefit from other lectures organised within CERN.

Users will get access to the same services as the CERN staff e.g. office space, standard office services (telephone, fax, internet services) and meeting rooms, library and restaurant. The Social Service of the institute can be contacted for administrative or personal problems, such as lodging, contacts with local administration, schools and hospitals.