PIAF (PTB Ion Accelerator Facility)

A. THE FACILITY

A.1 The Accelerator Infrastructure at PTB

The PTB is the German National Metrology Institute with about 1500 employees in 9 scientific and technical divisions. Major tasks of research and development are the improvement of the national measurement standards, e.g. by exploitation of quantum effects for realizing the SI units, and the precise determination of fundamental constants and material properties. Division 6 "Ionising Radiation" deals with radioactivity as well as photon and neutron metrology and dosimetry. A great variety of well characterised radiation reference fields is available for experiments.

Department 6.4 operates two particle accelerators for the production of charged particles, an ion-microbeam as well as neutron and high-energy photon reference fields. One of the main tasks is the production of mono-energetic neutron reference fields according to the international standard ISO 8529 for the characterisation and calibration of detectors and dosimeters. In addition, the department can provide high-intensity 'white' neutron beams with fluence or dose rates at therapeutic levels.

The department also deals with various aspects of dosimetry for radiobiology, radiotherapy and radiation protection and has a long tradition and expertise in the measurement of nuclear data.

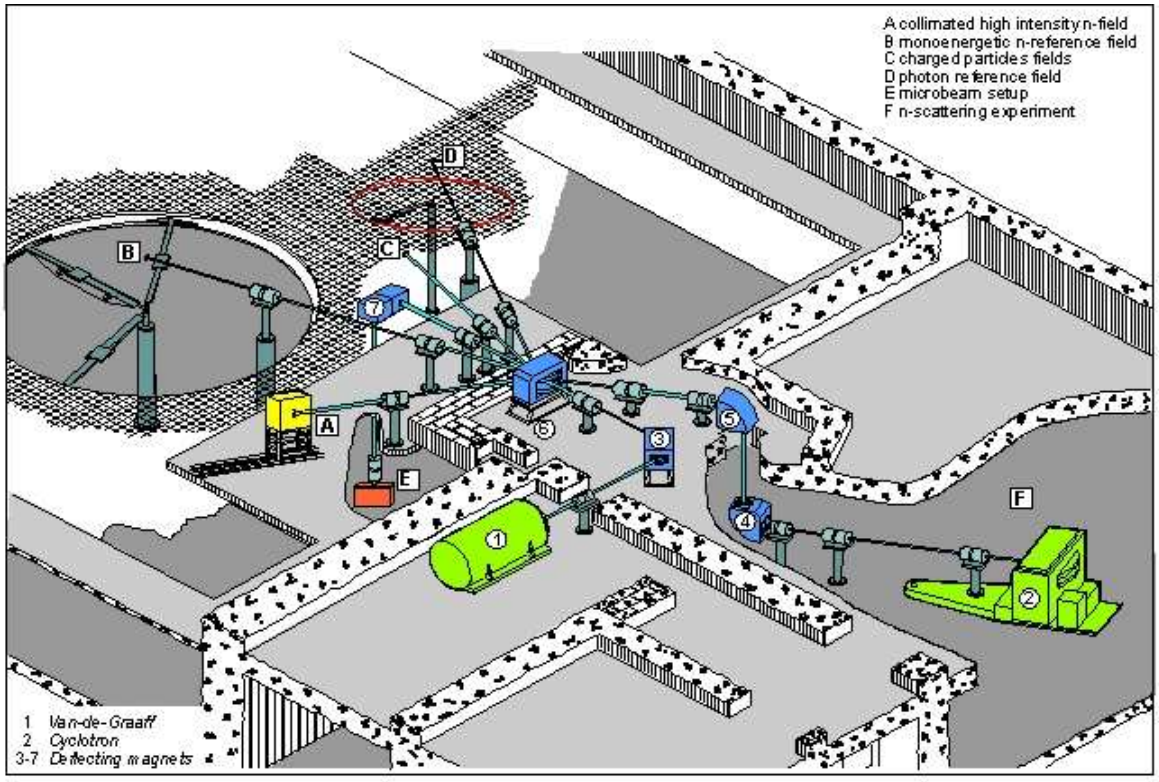

Fig. 1: Accelerator facility of PTB in Braunschweig

Department 6.4 operates a TCC CV-28 variable-energy cyclotron, which provides beams of protons (< 19 MeV, < 80 µA), deuterons (< 13.5 MeV, < 80 µA) and alpha particles (<28 MeV, < 20 µA). Complementary, the same ion beams are available with energies up to 3.75 MeV in the low energy region and with similar currents from a Van de Graaff linear accelerator. Experiments with almost mono-energetic neutrons in the energy region of 20 keV < E_n < 20 MeV are performed in the center of

a very large experimental hall in open geometry, in this way providing low levels of backscattered neutrons. In addition, high-intensity, collimated neutron beams with average neutron energies up to 5.5 MeV are available (see Figure 1).

Five (of eight) beamlines in the large experimental hall are dedicated to:

- the production of high-energy photon reference fields
- the direct use of ions in vacuum
- the ion microbeam
- the mono-energetic neutron reference fields
- the high-intensity, collimated neutron beams with white spectra

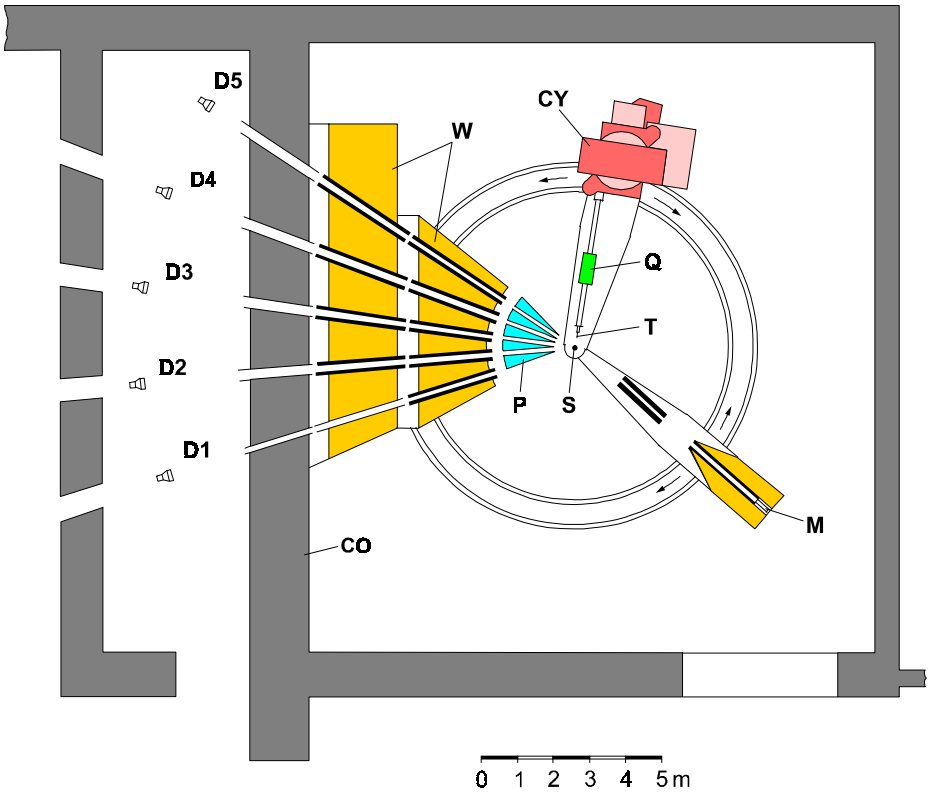

Fig. 2: Multi-detector time-of-flight spectrometer for the measurement of neutron scattering and activation cross sections.

A multi-detector time-of-flight (TOF) spectrometer is connected to the main beam line of the cyclotron (see Figure 2). This instrument offers unique opportunities for the measurement of angular differential elastic and inelastic neutron scattering cross sections as well as neutron emission cross sections by detection of the scattered neutrons. This technique is largely complementary to the technique applied at white sources where the photons resulting from inelastic scattering are detected for the measurement of angular integrated cross sections for inelastic scattering. Using the D(d,n) reaction with a Deuterium gas target, the TOF spectrometer covers at present the energy region from 6 MeV to 15 MeV where monoenergetic neutron sources are not available. The in-depth characterization of the instrument resulted in cross section data of unprecedented accuracy. It is foreseen to extend the energy range of the instrument by developing a $^{15}N_2$ gas target. With the $^{15}N(p,n)$ reaction, neutrons with energies between 5 MeV and 2 MeV will be available for the measurement of elastic and inelastic scattering cross sections.

In addition, various other neutron production targets may be used at the main beamline of the cyclotron and these neutron sources can then be characterised by means of a high-precision time-of-flight (TOF) spectrometer for yield and spectral distribution. This makes this instrument a very valuable tool for the development of new targets.

The accelerator facility of PTB is unique in Europe, and even in the world. While well characterized mono-energetic neutron fields at ISO-recommended energies can also be provided by the NPL (UK) using a linear accelerator, no other neutron metrology laboratory in Europe uses a cyclotron to produce neutrons in the energy range from 6 MeV to 14 MeV which are required for the measurement of cross sections. The PTB infrastructure and instrumentation available for determination of the spectral neutron fluence by means of a great variety of spectrometric techniques is indispensible for reliable neutron experiments and will be extremely valuable for the EFNUDAT transnational user groups. Polyenergetic neutron fields can also be reliably specified for external users at both accelerators.

A.2 Quality of research

PTB developed the national primary standard instruments for the determination of the spectral neutron fluence of these reference fields. For quality assurance, PTB successfully took part in international key comparisons for the determination of the fluence of monoenergetic neutrons in the energy range from 144 keV to 14.8 MeV.

The well-specified mono-energetic neutron fields have been used for more than 25 years to characterise neutron detectors, spectrometers and dosimeters, partially in the framework of EU-supported projects and concerted actions. Part of this work was carried out in collaboration with external partners from NPL (UK), GSF (D), CMI (CZ), IRSN (F), UAB (E), LANL (USA), FZK (D), PSI (CH), DIMNP (I), Berthold(D).

An important feature of the infrastructure is the nano-second pulsing option at both accelerators, which is used for neutron spectroscopy by time-of-flight. A successful long-term programme uses neutron TOF in combination with a dedicated collimator and detector system to measure neutron scattering and activation cross sections of selected elements. The present focus is on materials which are of relevance for fusion applications but the facility is also well suited for measurements of samples relevant for other emerging nuclear systems like ADS or GenIV reactors. The only principal limitation is the required minimum sample mass and the restriction to samples which are not highly radioactive.

So far, cross sections for the following materials were measured with high precision at the PTB accelerator facility:

- elastic and inelastic scattering section (DX): ^{14}N, ^{16}O, ^{nat}Si, ^{nat}Ti, ^{41}V, ^{nat}Cr, ^{nat}Fe, ^{nat}Cu, ^{nat}Pb
- neutron emission cross sections (DDX): ^{nat}Ti, ^{41}V, ^{nat}Cr, ^{nat}Cu, ^{nat}Pb
- activation cross sections: ^{19}F, ^{24}Mg, ^{27}Al, ^{28}Si, ^{29}Si, ^{30}Si, ^{46}Ti, ^{48}Ti, ^{51}V, ^{52}Cr, ^{54}Fe, ^{56}Fe, ^{59}Co, ^{58}Ni, ^{63}Cu, ^{65}Cu, ^{64}Zn, ^{93}Nb, ^{103}Rh

All finally analyzed cross section data were submitted to the NEA data bank with full documentation of uncertainties for inclusion in the EXFOR data bank. In addition to the work carried out at the PTB facility, considerable experience has been acquired in high-energy neutron metrology and cross section measurements at external neutron beam facilities.

A.3 New opportunities for access

The unique accelerator facility of PTB is best suited for experiments with fast neutrons. The particular options of the accelerators (nanosecond-pulsing with a desired repetition frequency), the excellent infrastructure with all necessary instruments and state-of-the art data-acquisition systems as well as the support of the skilled PTB staff enable the user groups easily to perform their experiments at optimal conditions. It is highly complementary to other EFNUDAT TA facilities, and the proposal/peer-review scheme of the I3 will provide an excellent opportunity for EU research groups to access the unique facilities.

B. MANAGEMENT OF THE ACCESS PROVIDED

B.1 User acess to the infrastructure

PTB in Braunschweig is located in the north of Germany and easy to reach by car, train or airplan (via Hanover). The accelerators are usually run in two shifts by experienced operators. On request, the accelerators may also be used around the clock (3 shifts for four days a week).

It is expected, that the user groups set up and perform their experiments at PTB taking into consideration the safety regulations for installations with potential radiation hazards. Technical and metrological support will be provided by PTB-staff. The TOF spectrometer with the cyclotron can be used by external user, either with the existing detector and associated hardware and data acquisition systems or with detectors and electronics supplied by the users.

According to long-time experience in collaboration with external groups we recommend to run the experiments with a team of four experimenters, both for set-up and testing in advance and for the experiments with the accelerator. Depending on the type of experiments different groups may share the one-week beamtime which will be dedicated for EFNUDAT-TA four times a year. The user groups may alternatively agree with PTB-staff to perform irradiations of materials or instruments according to their instructions.

The laboratories and equipment available for use by EFNUDAT I3 transnational user groups will be:

- the well characterised neutron reference fields
- the cyclotron in combination with the neutron tof-spectrometer for the investigation of any neutron-producing targets and the determination of neutron cross sections
- a well-characterized and shielded HPGe detector for activation measurements.
- multiparameter data acquisition systems for experiments at the TOF spectrometer and at the beamlines in the low-scatter area.
- access to the PTB underground laboratory UDO in the Asse salt mine in about 30 km distance from Braunschweig which can be used for the measurements of very small activities.
- access to the internet, but only limited access from outside due to the PTB-firewall

The output expected from the TA user groups is additional scientific knowledge, which shall be published in the general scientific literature. Summaries of their work shall be included in the yearly EFNUDAT TA-report

A small panel of our department regularly discusses the user requests and decides on the beamtime for the next quarter of the year. At least the minimum required beamtime described here will be reserved for EFNUDAT transnational users, and the EFNUDAT peer review process will be coordinated with the PTB scheduling activity.

User research will be independent of PTB research, but in many cases the accessing user groups will benefit from developing a more collaborative relationship with PTB scientists and engineers, due to their knowledge and expertise in the research fields mentioned above.

B.2 Scientific, technical and logistical support

A team of one engineer and four technicians maintain and operate the two accelerators. The operators also support the guest groups in setting up and aligning the experiments.

The neutron metrology working group with three scientists, one engineer and one technician maintains the primary standard instruments and is responsible for characterising the field parameters at the reference point and the corresponding monitor systems. All relevant information will be provided to the guest groups. The calculation of the user fee is therefore based on 0.5 person years for a scientist and a technician, respectively, in addition to the personnel of the accelerator group. The accelerator facility of PTB may be used in different ways. Irradiations in the specified neutron fields will be

performed in the large experimental hall. The users equipment will be installed in a low scatter environment in order to ensure irradiations at low 'room return' neutron background. The ns-pulsing option of both accelerators may be used for TOF-spectrometry.

The cyclotron in combination with the neutron TOF-spectrometer allows high-precison measurements with the well characterized PTB neutron sources (D(d,n) with a Deuterium gas-target, $^{15}N(p,n)$ with a $^{15}N_2$ gas target under development) as well as user-designed neutron sources. Samples or detectors supplied by the users may be installed at the target and detector stations of the TOF spectrometer and used for measurements of nuclear data.

The guests can be accommodated on-site in the PTB guest house or in hotels close to PTB. An on-site canteen is serving breakfast and lunch on working days. Logistical assistance and transport arrangements are usually provided for external users.

PTB's radiation protection service will ensure appropriate radiation protection and personal dosimetry. The visitors will be instructed in the local regulations in advance.

C. EUROPEAN ADDED VALUE

C.1 Community Interest in the Infrastructure

C.1.1 International users in the past

For almost 30 years now, the PTB accelerator facility has been used by a large number of external users, either in bilateral scientific collaboration or in the framework of projects with many partners, supported by the EU in recent framework programs.

In recent years, national and transnational external groups used the accelerator facility for various purposes, e.g. for

- investigation of the energy-dependent response of neutron detectors, spectrometers and dosimeters (IRSN/France, DIMNP/Italy, IPNE/Romania, FZ/Karlsruhe, Siemens/UK, ENEA/Italy, FOI/Sweden, IKTP/TU Dresden, IKP/TH Darmstadt, CMI/Czech Republic, SMU/Slovak Republic),
- cross section measurements (FZ/Karlsruhe, LMU/München, CIAE Bejing),
- determination of the relative radiobiological effectiveness of neutrons with respect to Co-60 photons or X-rays (U/Münster, U/Bremen, U/Göttingen, LMU/München)
- development and chacterization of liquid scintillation detectors for neutron diagnostics at the fusion experiment JET (ENEA)

These investigations were partially performed in the framework of scientific cooperations when PTB was also interested in the subject. In case of such bilateral contracts the partners had to cover their travel costs only, while PTB contributed with the beamtime and the metrological infrastructure. The collaborations in general resulted in joint publications which are highly respected in the community.

The well-specified monoenergetic neutron and high-energy photon fields of PTB were extensively used in the last two years by the partners of two large projects supported within EU-FP5, namely for:

- the characterisation of the energy-dependent fluence or dose response of most of the detector systems used to determine the personal dose which the air crew is exposed to during intercontinental flights (project DOSMAX)
- the characterisation of electronic personal neutron dosimeters and spectrometers applied for measurements at workplaces of nuclear installations to determine the personal dose (project EVIDOS)
- the irradiation of passive personal dosimeters which then had to be analysed by various secondary standard dosimetry laboratories (SSDL). This comparison exercise was initiated and supported by the IAEA in Vienna.

In the case that an external group wishes to take advantage of the PTB measurement capability for investigations not of direct research interest for PTB, the experiments are routinely carried out with the

help of our skilled staff and the customer is charged for this service. However, in some cases this has inhibited external groups from using this unique facility and expertise. We are convinced that many groups which have not had financial support in the past will apply for beamtime and use of the metrological infrastructure if the TA is approved. Thus transnational access will increase at the PTB.

Approval of this I3-TA provided, we will encourage European research groups to use the PTB accelerators with the unique infrastructure, in particular the expertise and instrumentation in the field of nuclear data measurements. We expect an increase in transnational use of the facilities, and a corresponding impact on certain important areas of EU research.

C.2 Expected impact

Making available the unique features of the PTB accelerator facility, in particular the TOF spectrometer, to a wider scientific public will increase the number of running projects in a particularly difficult energy region where monoenergetic neutron sources are not available. It will also strengthen the coooperation with other facilities, e.g. 'white' neutrons sources, which offer complementary opportunities to the present facility. Hence a considerable impact on the progress of nuclear data work for a broad range of applications is to be expected from an integration of the PTB facilitiy into EFNUDAT. In view of the unfortunate age structure in the nuclear data community, training of young researchers and transfer of knowledge from experienced staff will be an important issue which will benefit from the oppurtunities offered by the Integrated Infrastructure Initiative.

C.3 Attracting new potential users

Opportunities for transnational access of the PTB accelerator facility shall be published on the EFNUDAT and the PTB websites. The information will also be distributed to potentially interested laboratories and user groups, e.g. the European Metrology Group (EUROMET). In the first year concerted publicity will be made for access to PTB together with all EFNUDAT TA facilities, and information distributed to major European research organisations.

D Access offered by the infrastructure

D.1 Annual implementation plan

The PTB may offer 2 times one week (equal to 120 hours in total) per year beamtime including the metrological infrastructure for external users (as specified in section 2.1. As for all other EFNUDAT I3 facilities the unit of access being offered by PTB is one hour. This is the time the beam is at the disposal of the user group and includes the time needed to adapt the experiment to the accelerator. Setting up and testing of the users equipment will not be taken into account if carried out outside of the normal beamtime scheduling periods, e.g. at the weekend.
For an efficient use of the accelerator facility we recommend to run the experiments at least in two shifts per day (around the clock with 3 shifts on request). Different groups may share one week of beamtime offered in the framework of I3 TA, respecting however the minimum quantity of access to be provided and the requirements of the user proposals for beamtime. This is the standard mode of operation at the facility.

D.2. Activities connected with the access

External can be trained in using the dedicated simulation and data analysis codes available for the PTB TOF spectrometer. Such acitivities were already carried out in a collaboration with the CIAE / Bejing. If needed by external user, specific training will also be available for the unfolding code package UMG which was developed in the PTB.