Recent Developments in Neutron Metrology, Neutron Dosimetry and Related Areas at the Physikalisch-Technische Bundesanstalt (PTB)

R. Nolte, for the staff of departments 6.4 and 6.5 of PTB

1. Neutron Metrology

The PTB uses a recoil proton proportional counter (RPPC) filled with hydrogenous gases and a recoil proton telescope (RPT) with tristearin radiators as reference instruments for the measurement of the neutron fluence below and above 1.2 MeV, respectively. Neutron fluence measurements using RPTs depend on availability of hydrogenous radiators with traceable hydrogen content. The two radiators still in use at PTB are more than 20 years old. Hence, there is an urgent need to procure new polyethylene or tristearin radiators with a more optimal selection of areal masses. In this respect the decline in sample preparation facilities in Europe is a major obstacle. Negotions with the manufacturer of our present radiators were not successful so far.

To reveal possible instabilities of the RPT radiators, the two PTB reference instruments were compared during the last two years between 1 MeV and 2 MeV where the RPT with the thin radiator and the RPPC can both be used. The two radiators were compared in a second measurement at 5 MeV. The results of these comparisons are presently under analysis. Further investigations using admixtures with higher stopping powers in the RPPC are planned to increase the energy range where RPT and RPPC can be compared.

To increase the number of reference instruments at its disposal for consistency checks, the PTB participated in an informal comparison of long counters organized by the NPL. The results of the comparison showed that the relative efficiencies of the two de Phanger long counters operated by the NPL and the PTB are identical within the range of the measurement uncertainties. In future, the de Phanger long counter of PTB will be included in the regular internal consistency checks.

The development of a realistic calibration field at the PTB was continued within the diploma thesis of K. Schäler, who investigated the stability of thick water-cooled lithium targets for use inside a moderator sphere made from graphite and polyethylene. The work resulted in a target design and manufacturing procedure, which allows the repeated use of the target without problems due to corrosion of the lithium layer.

The neutron reference fields realised at the PTB accelerator facility were used for several calibrations of Bonner sphere spectrometers. During these measurements potential problems with the subtraction of room-return neutrons were identified. At present the background subtraction procedures are investigated in collaboration with an external group by measurements and Monte Carlo simulations.

The activities of the PTB in the metrology of high-energy neutrons at the iThemba Laboratories (TLABS) in Cape Town / South Africa will be significantly reduced by the end of this year. The know-how and part of the equipment will be transferred to the South African colleagues to guarantee the availability of this unique facility for use by external groups in future without PTB involvement. The PTB is currently negotiating a co-operation agreement with TLABS, University of Cape Town and the South African NMI NMISA.

As in earlier years, PTB provided beam time at the thermal reference neutron beam at the GKSS research reactor FRG1 during two periods per year. This facility will be available until 2010 but only for one period per year. The operation of the FRG1 reactor will stop by end of 2010. The need for a new thermal reference field at one of the German research reactors will be investigated in 2009.

The PTB is pilot laboratory for the CCRI(III)-K8 key comparison of thermal neutron fluence measurements. This comparison is still running. The consistency checks of the two circulating SP9 proportional counters showed no evidence for instabilities. The final report for the supplementary comparison EUROMET.R(III)-S2 of neutron fluence measurements for energies of 15.5 MeV, 16 MeV, 17 MeV and 19 MeV was drafted and is presently discussed among the participants.

2. Neutron dosimetry

There has been one measurement campaign at the University clinic of Essen in order to calibrate the neutron therapy beam in units of absorbed dose to water. The data obtained with a water calorimeter and ionisation chambers is still under investigation.

3. Applications of fast neutrons in science and technology

During the last two years the PTB accelerator facility (PIAF) was used for three projects supported by the European infrastructure project 'European Facilities for Nuclear Data Measurements' (EFNUDAT) and more experiments are still to be carried out. The focus of the experiments ranged from the calibration of organic scintillation detectors at the TOF spectrometer over the investigation of the neutron sensitivity of novel inorganic scintillators such as $LaBr_3$(Ce), to the measurements of the emission beta-delayed neutrons after the fission of thorium nuclei.

The doctoral thesis of E. Pönitz on the measurement of inelastic neutron scattering on elemental lead and on bismuth in the energy range between 2.2 MeV and 4 MeV was successfully finished and revealed interesting discrepancies between the results obtained with (n,n') method (detection of scattered neutrons) used at the PTB and the (n,n'γ) method (detection of the de-excitation photons) employed at the GELINA photoneutron source of the IRMM.

Within the EFNUDAT project, the neutron metrology group participated in the characterisation of two upcoming neutron beam facilities. The spectral neutron distribution of the photoneutron source nELBE of Forschungszentrum Dresden (FZD) was measured using the PTB ^{235}U fission ionisation chamber H19. The ^{238}U fission chamber H21 was employed for the characterisation of the high-energy white beam facility ANITA at the Gustav Werner cyclotron of the The Svedberg Institute (TSL) in Uppsala. At this facility, a high-intensity neutron beam with continuous energy distribution is produced by a 178 MeV proton beam impinging on a stopping-length tungsten target. Due to the moderate time resolution of about 5 ns and the lack of a pulse selector, the standard TOF measurement procedures had to be modified. The neutron spectrum above 10 MeV was inferred form several measurements at different flight distances between 2.5 m and 10 m using an analytical model for the spectral shape. The parameters of the model and their uncertainties were determined consistently from the total set of data using the WinBUGS software, which employs the Markov chain Monte Carlo method for parameters estimation.

4. Technical development of the accelerator facility

The performance parameters of the PTB accelerator facility did not deviate significantly from those of the earlier years. A system for millisecond beam switching using fast steerers was developed for applications in nuclear data measurements and for testing the count rate response of instruments.

It is planned to replace the aging 3.7 MV Van-de-Graaff accelerator by a state-of-the-art tandem accelerator with a maximum terminal voltage between 4 MV and 5 MV. The main reasons for this are difficulties in the procurement of replacement parts such as belts expected for the future as well as problems related to the operation of the present accelerator in pulsed mode. In addition to an ion source for constant-current and pulsed light-ion beams, the machine will also be equipped with a heavy-ion source to serve the microbeam with high-LET projectiles. At present, the details of the machine parameters and the beam transport system are discussed with a potential manufacturer.

For the mid to long-term future the procurement of a superconducting 200 MeV - 400 MeV cyclotron is envisaged to serve application in proton and heavy ion therapy, material science, radiation hardness testing etc. A workshop on this topic will be held at PTB in 2009 to identify the potential applications and external interest.