Measurement of the differential neutron/deuteron scattering cross section in the energy range from 100 keV to 600 keV by means of a recoil-proton proportional count

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Besides the nucleon-nucleon scattering, the scattering of a neutron on a deuteron – i.e. on a nucleus of the heavy hydrogen atom ^2H consisting of a neutron and a proton – is one of the fundamental processes in quantum-mechanical few-body systems. Furthermore, the neutron-deuteron scattering is of considerable technical importance in nuclear reactors that are moderated by means of heavy water (^2H_2O). The analysis of experiments with heavy-water-moderated critical and subcritical reactor models has led to variations of the angular distributions of the scattered neutrons between the nuclear data libraries ENDF/B-VI and ENDF/B-VII which, however, could not explain all measurement results. Therefore, the differential cross section for the neutron/deuteron scattering has been included in the High-Priority Request List (HPRL) for nuclear data measurements which is supervised by the Nuclear Energy Agency (NEA) of the OECD. In spite of its obvious technical and scientific importance, only relatively few – and partly inconsistent – measurements from the 1950s and 1960s are available for the neutron/deuteron scattering in the energy range below 1 MeV. More recent experimental data are thus still required to clarify the questions that have arisen.

For these reasons, a first series of measurements has been carried out using PTB's proportional counter P2 in cooperation with IRMM in Geel/Belgium. Instead of the mixture of light hydrogen ($^1H_2$) and methane (C^1H_4), which is usually used as a counter gas to measure the neutron fluence, a gas mixture of heavy hydrogen (deuterium, $^2H_2$) and deuterated methane (C^2H_4) was used. Thereby, the counter gas in the proportional counter is used both as a scattering target and for the detection of the recoil deuterons generated during the scattering of neutrons on deuterium. In an ideal detector, the pulse height distribution would directly reflect the differential scattering cross section in the centre-of-mass frame. In a real detector, however, mainly the finite pulse height resolution and the so-called edge effects – i.e. the incomplete energy deposition of deuterons at the edge of the counting volume – as well as the background of parasitic photons lead to distortions of the pulse height distribution. In a new experiment, the photon background was suppressed as far as possible by electronic discrimination as well as by shielding. The edge effects as well as the contribution of carbon recoil nuclei from the neutron-carbon scattering have been modelled as accurately as possible by means of a new Monte Carlo simulation program.

Figure 1 shows the experimental pulse height distribution of the proportional counter for a neutron energy of 498 keV as well as simulated pulse height distributions which have been calculated by means of various data sets for the differential cross section. The data used for the differential cross section in the centre of mass are represented below as a function of the scattering angle of the neutron in the centre-of-mass frame.

The results of the new measurements seem to confirm the data from the more recent library ENDF/B-VII, whereas the angle distributions from the Japanese library JENDL 4 and from the older library ENDF/B-VI show clearly too high an anisotropy at large scattering angles.

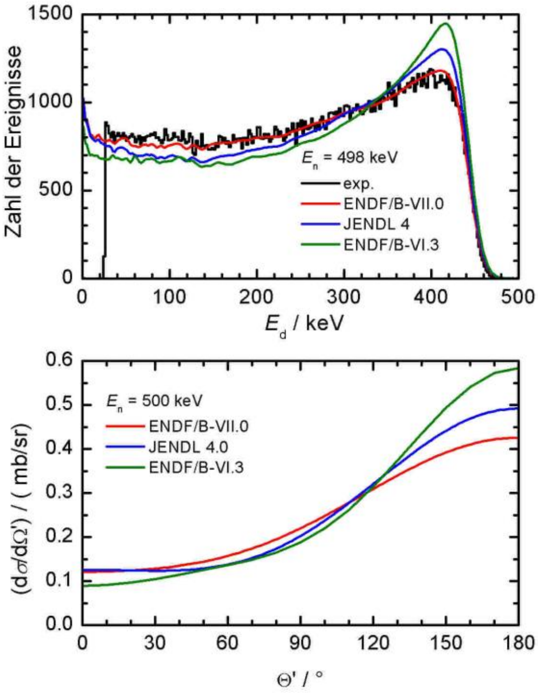

Fig.: Experimental (histogram) and simulated (coloured lines) pulse height distributions for a neutron energy of 498 keV (top) and cross sections used for the simulation as a function of the neutron scattering angle in the centre of mass (bottom).

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