First experimental verification of neutron acceleration by the material optical potential of solid deuterium.

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A consequence of the material optical potential is that the energy of neutrons produced within a sample will be boosted as they cross the material boundary, leading to a shift in energy; a measurement of this shift will give a model independent value of the material optical potential but requires (a) a material that produces significant quantities of very low energy neutrons and (b) measurement of the lower energy limit of the external neutron spectrum. This is possible, and has been carried out, by measuring for the first time the spectrum of UCNs produced in a solid deuterium moderator.

The experiment was performed at the TRIGA Mark II reactor of the Mainz University in a pulsed mode with an energy release of about 6.7 MWs. At this reactor, a new UCN source with a solid deuterium converter operating at 5 K was recently installed.

In order to determine the UCN energy spectrum from the superthermal solid deuterium converter, we used a gravitational spectrometer, see Fig. 1. Ultracold neutrons leave the 5 K solid deuterium converter, pass through a 0.1 mm thin aluminium foil with material optical potential of 54 neV installed for safety reasons. The neutrons are guided through the biological shielding of the reactor strictly horizontally in electropolished stainless steel tubes of 66 mm inner diameter and about 4 m length. Outside the reactor core shielding, the neutrons enter an U-shaped chicane built from the same material.

The “U” uses gravity to determine the minimum energy of throughgoing UCNs; its height and hence the minimum UCN energy may be adjusted by rotation around the neutron guide axis. Passing neutrons are registered in a gas counter containing 18 hPa ^{3}He and 12 hPa CO_2 in about 1070 hPa Ar. The detector with its 0.1 mm aluminium entrance window was mounted 60 cm below the beam axis. In this way, gravitation accelerates UCNs such that all of them can penetrate the detector entrance window with a material optical potential of 54 neV. Figure 2 shows the registered neutrons normalized to the reactor power.

To the left of the data shown in Fig. 2, one can see a flat distribution over increasing height of the spectrometer. Above about 100 cm, corresponding to ~100 neV neutron kinetic energy, the spectrum decreases. This can be compared to the material optical potential of solid deuterium at 5 K calculated to be about 106 neV. For the analysis, we have fitted a constant *A* to the flat distribution and a straight line, $y = Bx + C$, to the beginning of the slope at height values above 100 cm, see Fig. 2. From the crossing of these two functions, we deduce the minimal UCN energy, i.e. the material optical potential of solid deuterium at 5 K to be (99 ± 7) neV in agreement with theory.

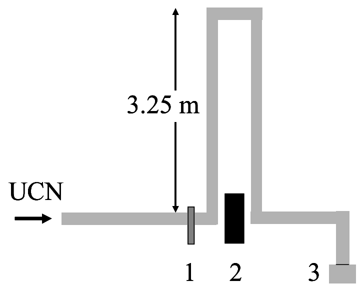

Fig.1: Sketch of the gravitational spectrometer; 1: vacuum shutter; 2: 10 cm borated polyethylene; 3: UCN detector with 0.1 mm aluminium entrance window. The detector was shielded against background in a box of 10 cm borated polyethylene (not shown).

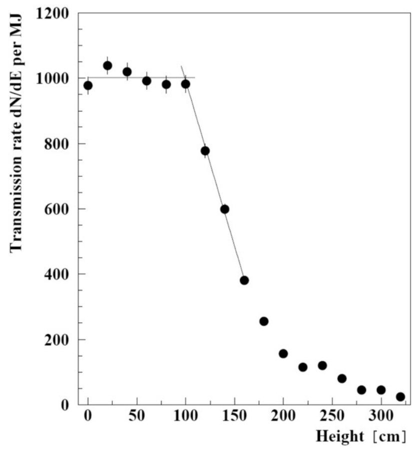

Fig. 2: Data taken with the gravitational spectrometer. The UCN transmission rates per megajoule of the reactor power are plotted against the vertical height of the gravitational spectrometer. The two lines represent the fit to the data, see text.

1. A.Frei et al., Eur.Phys.J.A34,119–127(2007)
2. Z-Ch.Yu et al., Z.Phys. B62, 137-142 (1986)