A Source for Ultra Cold Neutrons at the TRIGA Mainz

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During the last year basic parameters of a source for ultra cold neutrons (UCN) with solid deuterium (sD_2) as converter material at the TRIGA Mainz have been experimentally studied and optimized. The goal of these experiments was to determine the main important parameters for a optimized strong sD_2 source for UCN at the FRMII [1]. These parameters are: The way of freezing the sD_2, the optimal temperature of the sD_2, the lifetime of UCN within the sD_2, the dependence of the UCN production rate on the temperature of the incoming neutron flux and the comparison of measured and calculated UCN production rates.

The UCN source is installed horizontally at a tangential beam tube at the TRIGA reactor, where the heat load to the liquid helium cooled sD_2 converter (max. $V \approx 200\,\text{cm}^3$) is considerably less compared to a radial one. During a reactor pulse the incoming thermal neutron flux at the position of the converter amounts up to $10^{15}\,\text{n}/(\text{cm}^2 \cdot \text{s})$. The UCN produced in the sD_2 converter are guided outside the biological shield and finally are detected.

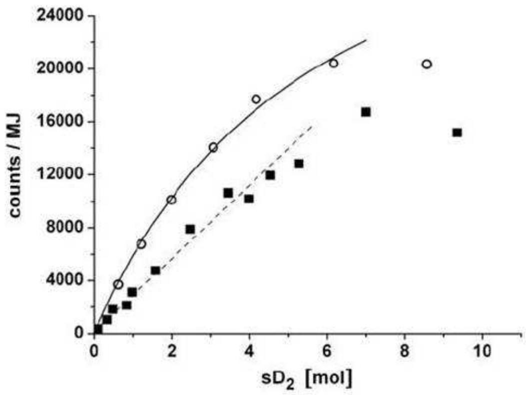

Fig. 1: UCN count rate (normalized to reactor power) as function of sD_2-amount. Open circles: Mesithylene-premoderator. Solid squares: Without premoderator.

In Fig. 1 the measured UCN count rates are shown for two different setups. In one setup the sD_2 was exposed directly to the thermal neutron flux of the reactor. In the second setup the sD_2 was surrounded by a frozen premoderator, in this case Mesithylene at 20 K. The premoderator decreases the temperature of the neutron flux at the converter to the cold regime. The UCN production in sD_2 is most effective for incoming cold neutrons with an equivalent temperature of 30 K [2]. In both setups the amount of sD_2 was varied ($0 - 9$ mol). For smaller quantities the setup with premoderator has roughly a gain of 2 compared to the setup without premoderator. The UCN count rate for the premoderator setup starts to saturate from 4 mol on, whereas this effect has not been seen in the configuration without premoderator. This is explainable by the fact, that sD_2 itself acts also as premoderator, but it isn't as efficient as Mesithylene. From the measurements with premoderator it's also possible to extract the averaged mean free path for UCN inside sD_2, which is about $5 - 6$ cm. At large sD_2 quantities (> 7 mol) the volumetric capacity of the converter vessel is gradually approached, so that cooling becomes difficult. The resulting higher temperature of the sD_2 leads to a decrease in UCN production.

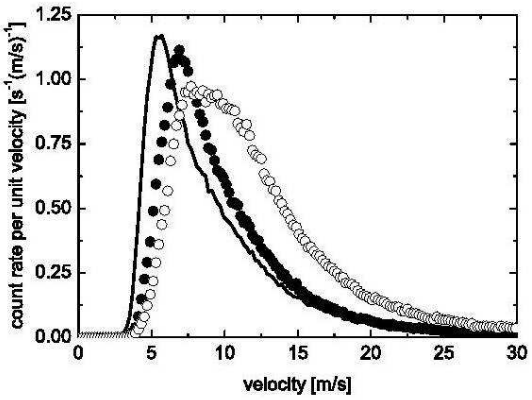

Fig. 2: Velocity spectrum of the UCN-source. Solid line: v-component parallel to beam axis of thermally cycled converter. Solid dots: v-spectrum of thermally cycled converter. Open circles: v-spectrum of thermally uncycled converter.

The UCN velocity spectrum, shown in Fig. 2, which was measured with a chopper setup, was determined with a thermally cycled sD_2 converter and with a not thermally cycled sD_2 converter. Thermal cycling in this sense means periodically ($2 - 5$ times) warming up of the converter to $12 - 14$ K and cooling it down afterwards to 5 K, bevor exposing it to the thermal neutron flux. Thermal cycling showed an increase in UCN count rate of roughly a factor of 2 for sD_2 amounts > 4 mol. Inhomogenities in the crystal structure of sD_2 are removed by such a procedure, resulting in better extraction of the UCN out of the crystal. This assumption is supported by the measured velocity spectrum. The uncycled crystal shows a higher mean velocity of the UCN compared to the cycled crystal. UCN with lower energies are scattered on their way out of the uncycled crystal by the inhomogenities, so that their path inside the crystal increases, and then are lost.

The different measurements performed at this UCN source at the TRIGA Mainz, which can be found in more detail in Ref. [3], have demonstrated, that it's possible to use sD_2 as converter for a strong UCN source. Transforming the results to the situation at the FRMII shows, that a similar source installed there can deliver UCN densities of up to $10^4\,\text{cm}^{-3}$ to typical UCN experiments.

References

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[2] R. Golub and K. Böning, Z. Phys. **B51** (1983) 95
[3] A. Frei *et al.*, Eur.Phys.J. **A34** (2007) 119