UCN Detector Development

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A detector for ultracold neutrons(UCN) has been developed, which can be operated in superfluid helium at 0.4 K.

In all UCN experiments up to now(neutron life time, EDM etc.), the UCN were detected with ^{3}He or BF_3 gas counters outside the storage volume after having fallen down a gravitational tube in order to gain enough energy (102.5 neV/m) to pass a window. However, in experiments, where the absolute detection efficiency is essential, it is better to measure UCN in the storage volume, i.e., in the case of Mark 3000, in superfluid helium. Silicon PIN diodes [1], operated with a reverse voltage and a charge sensitive preamplifier, can be used as a charged particle detector even at very low temperature(cf. fig.2 of [2]). Figs 1 and 2 show a β and an α spectrum from ^{192}Ir and ^{252}Cf, respectively, measured at room temperature with a 3 x 3 cm^2 diode. A UCN detector with close to one intrinsic efficiency is obtained with a layer on top of the PIN diode which contains ^{6}Li, using the ^{6}Li(n,α)t reaction, where either the 2.06 MeV α particle or the 2.73 MeV t is measured. The UCN reflectivity R of the layer must be small, that UCN can penetrate into the layer to be detected. R can be reduced, e. g., by double layers consisting of materials with positive and negative scattering potentials, respectively. In our case, double layers of ^{6}LiF and ^{62}Ni were used. On the 0.1 μm Al film covering the PIN diode p layer, a 90 Å thick titanium film, a 880 Å reflector from ^{58}Ni and 150 double layers consisting each of 60 Å of ^{6}LiF and 30 Å of ^{62}Ni, were evaporated. Fig. 3 shows the calculated R vs UCN energy T_{UCN} using an optics program, where the reflected amplitude and, thus, R, is obtained by matrix multiplication [3]. In fig. 4 R vs T_{UCN} is drawn measured with cold neutrons(CN) at the FRM QRII beam guide, where the CN were reflected at 5° from a glass substrate with the identical multilayer yielding UCN momentum transfers and thus the shown T_{UCN}. R is 20 % at maximum corresponding to a UCN detection efficiency of at 80%.

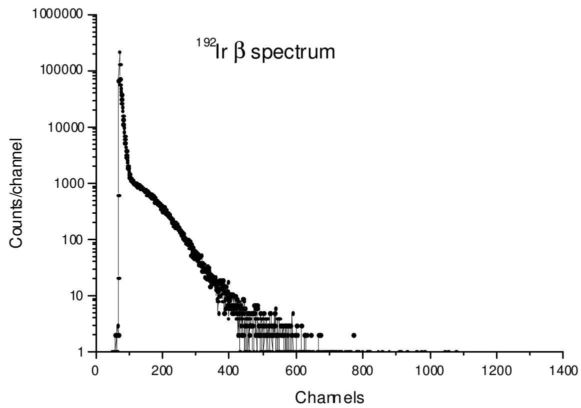

Fig. 1: ^{192}Ir β spectrum measured with the UCN detector at room temperature. The maximum β energy is 0.67 MeV.

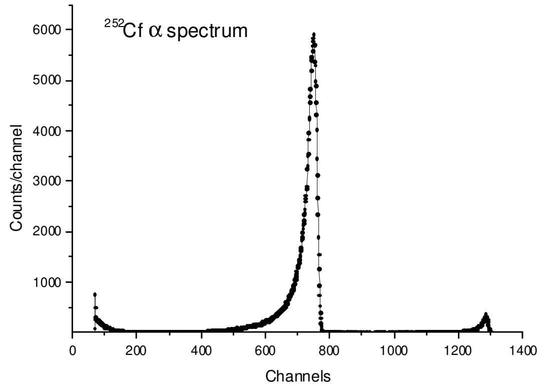

Fig. 2: ^{252}Cf α spectrum measured with the UCN detector at room temperature. The α energy is 6.12 MeV. The small peak at the right side is due to pileup

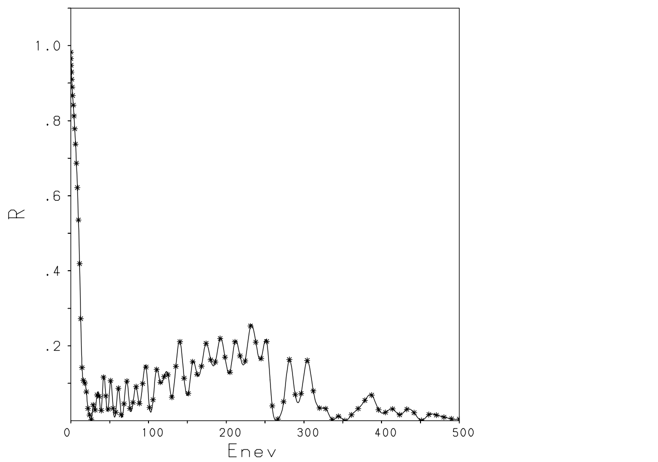

Fig. 3: Calculated reflectivity for UCN vs UCN energy

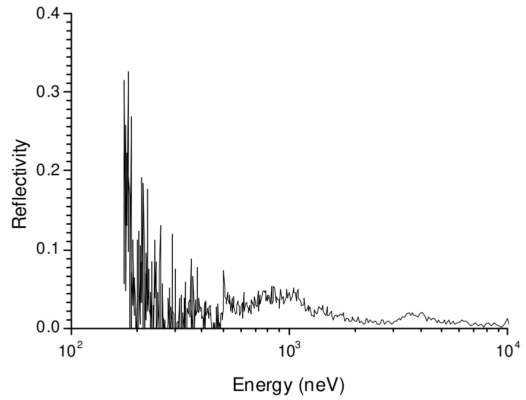

Fig. 4: Measured reflectivity for UCN vs UCN energy

References

[1] PIN diode, manufactured by Siemens AG.
[2] I. Altarev *et al.*, this report, p.111
[3] F.Herrmann, diploma thesis, TU München, 1990