The Neutron Decay Spectrometer aSPECT

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Measurements of the liftetime τ_{n} and the beta asymmetry A of the free neutron, combined with the muon lifetime, enable us to determine the coupling constants of the weak interaction and the upper left element of the Cabbibo-Kobayashi-Maskawa-Matrix (CKM), V_{ud}. Since the other entries in the top row of the CKM matrix are known from high energy physics, a test of the unitarity is possible. The latest results from measurements of A indicate a deviation from unitarity by 2-3 σ [1].

A different approach to that problem is to measure the electron-neutrino angular-correlation coefficient a. This independent information can be taken together with τ_{n} to determine V_{ud}. Unfortunately, the present knowledge of a is too poor to add anything meaningful to the problem [2,3].

The goal of our collaboration is to use the neutron decay spectrometer aSPECT to improve the precision of the knowledge of a by at least one order of magnitude. Such an experiment would decide the experimental side of the unitarity problem.

The main idea of aSPECT is that the recoil spectrum in neutron decay is sensitive to a. If electron and neutrino are emitted predominantly in the same direction, the proton will have high momentum in the opposite direction, whereas if electron and neutrino are emitted anti-parallel, the proton momentum will be small. As a result, a shows up as a distortion of the proton recoil spectrum (Fig. 1).

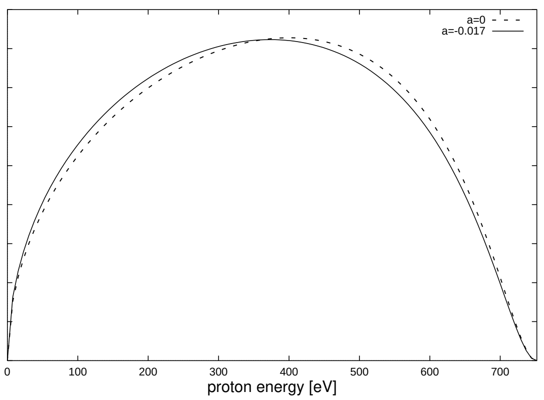

Fig. 1: Dependence of the proton spectrum on a. For comparison, the spectrum for the case of $a = 0$ is given.

aSPECT is a retardation spectrometer which integrates the proton spectrum above an electrostatic barrier. Retardation spectrometers combine a 4π solid angle with high energy resolution and are suitable for precision experiments even if the source strength is low.

We define the ratio r_h as the count rate of decay protons in the proton detector while a barrier voltage U is applied, divided by the total count rate without barrier voltage:

$$r_h = \frac{\int T(E)w(E)dE}{\int w(E)}$$

Here, $w(E)$ is the proton spectrum and $T(E)$ the transmission function of the electrostatic barrier. If all protons were emitted parallel to the magnetic field lines, $T(E)$ would be a simple step function. The extracted value of a depends on r_h in an analytical way.

A sketch of the spectrometer is shown in Fig. 2. Unpolarized neutrons fly through the decay volume of the spectrometer. About one out of 10^8 neutrons decays there; the recoil proton is then guided by the magnetic field lines. Protons emitted in the direction opposite to the detector are reflected by an electrostatic mirror, so that all protons are directed towards the analyzing plane and the detector. The above-mentioned barrier voltage will be applied at the analyzing plane. The protons move from the high field $B_0 \approx 3$ T in the decay volume to the weak field $B_w \approx 0.5$ T. During the flight their momentum is turned close to parallel to the magnetic field lines due to the inverse magnetic mirror effect. This ensures that our transmission function $T(E)$ is close to the ideal step function.

Protons will be detected by a segmented silicon PIN diode. The segmentation has two main advantages: It reduces capacitive noise and suppresses the correlated background which is caused by the electrons from the neutron decay. This is done by applying a $E \times B$ drift field in front of the detector to separate the protons and electrons and then use the spatial information provided by the detector to distinguish between them. The detectors will be tested at the ion source of the Maier-Leibnitz-Laboratory. More detailed information about aSPECT can be found in [4].

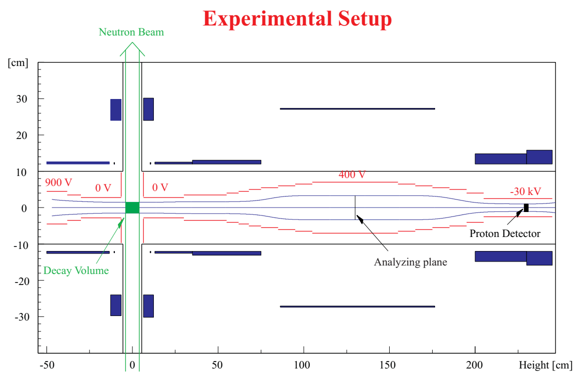

Fig. 2: Setup of the neutron decay spectrometer aSPECT

References

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