aSPECT - a new spectrometer to measure the ratio g_A/g_V of the weak coupling constants

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The weak-quark-mixing CKM-matrix has to be unitary if the standard model of particle physics is correct. In a sensitive test of CKM unitarity one measures the matrix elements of the first row, and tests if their squares sum up to unity. The values of V_{us} and V_{ub} are small, and the least well known for this test is the first element, V_{ud}. Traditionally, it is determined via a comparison of the weak vector coupling constant G_{V}, obtained from superallowed $0^+ \to 0^+$ pure Fermi nuclear transitions, with the Fermi coupling constant obtained from muon decay. Unitarity fails to be fulfilled by more than two standard deviations. An alternative derivation, which is free from corrections due to nuclear structure, employs neutron beta decay data. Taking this mixed transition with exactly known Fermi- and Gamow-Teller matrix elements, G_{V} is determined from the neutron lifetime τ_{n} and the coefficient of an angular correlation, appearing in the differential decay amplitude. Up to now, this has been the beta asymmetry, i.e. the angular correlation between the neutron spin and the electron momentum. It provides a measure of the ratio $\lambda = g_{\mathrm{A}}/g_{\mathrm{V}}$ of the weak axial and vector coupling constants. Combining the world average value of τ_{n} and the most accurate measurement of the beta asymmetry (corresponding to an uncertainty of λ of $2\cdot 10^{-3}$ [1]) leads to a contradiction with CKM unitarity by three standard deviations. The origin of this discrepancy is still unresolved. This situation motivates further theoretical and experimental efforts.

The goal of the aSPECT collaboration is a precise measurement of the antineutrino-electron angular correlation coefficient a in free neutron decay. This is complementary to measurements of the beta-asymmetry with comparably large sensitivity to λ, however, with entirely different systematics. Our minimum aim is to reach an uncertainty of λ of 10^{-3}, using a cold neutron beam at FRM II or at ILL. The experimental technique relies on an integral measurement of the shape of the proton recoil spectrum, which, including order-α radiative corrections, is well-determined by theory with a as the only free parameter. aSPECT is a magnetic spectrometer with an electrostatic retardation potential U as shown in the figure and described in detail in [2]. An important point of the spectrometer design concerns magnetic field homogenity of the strong (B_0) and the weak (B_{w}) field regions, and the form of the transitions between them. With the requirement of adiabaticity of the proton motion in the magnetic and electric fields being fulfilled, the analysis of experimental data becomes nearly independent of the neutron beam distribution in the decay region. Also a precise knowledge of the actual field distributions in the transition regions is then not needed.

In 2001 extensive design studies have been performed. Using a specially developed field calculation and particle tracking code, an arrangement of superconducting coils and electrodes was found, for which deviations from adiabatic motion of any proton from neutron decay can be guaranteed to stay well below the level actually required. The cryomagnet is ordered and shall be delivered before the end of 2002. As a next step, the proton detector shall be developed and tested using a proton source of the MLL accelerator laboratory.

References

[1] J. Reich, H. Abele *et al.*, Nucl. Instr. Meth. **A440** (2000) 535

[2] O. Zimmer, J. Byrne, M.G.D. van der Grinten, W. Heil, F. Glück, Nucl. Instr. Meth. **A440** (2000) 548

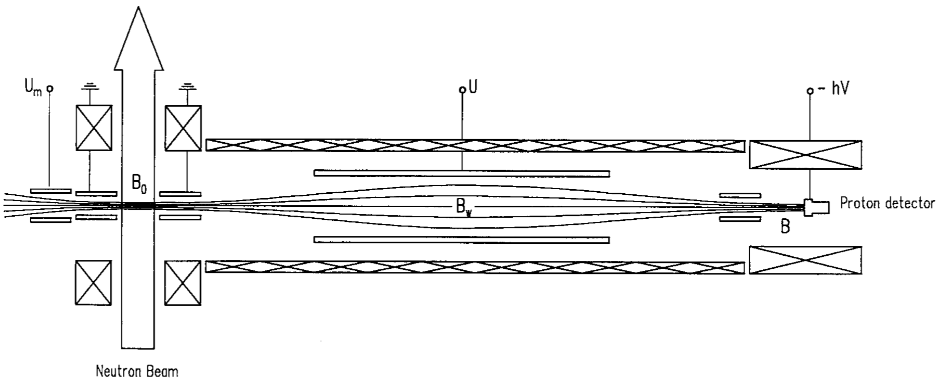

Fig. 1: Schematic sketch of the spectrometer aSPECT [2]