Measurement of the neutron lifetime in a Penning trap

W.M. Snow, Z. Chowdhuri, G. Hansen
Indiana University Cyclotron Facility, Bloomington, IN

The neutron lifetime τ is important for weak interaction theory, where it helps to determine the CKM matrix element V_{ud}, and also as input for Big Bang nucleosynthesis (BBN) calculations of ^{4}He abundance [1]. The 2.2 σ deviation from unitarity for the CKM matrix using the Particle Data Group (PDG) value of V_{ud} from 0^+ to 0^+ nuclear decays [2] has motivated a number of new measurements to determine V_{ud} and V_{us} from neutron and kaon particle decays, and the current experimental situation is in a period of rapid flux [3]. The precision of τ and the baryon-to-photon ratio in the universe dominate the uncertainties in the BBN prediction for the primordial ^{4}He abundance [1,4]. The recent results from WMAP [5] and future satellite measurements [6] should render the error from the baryon-to-photon ratio negligible; however, the astrophysical measurements of ^{4}He are still dominated by uncontrolled systematic effects.

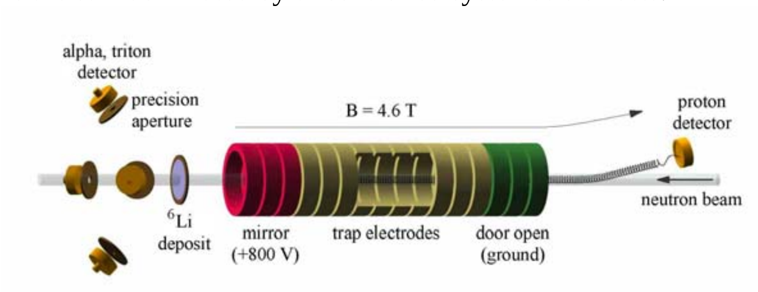

Figure 1. *Conceptual outline of the Penning trap neutron lifetime apparatus.*

We recently completed a precision measurement of the neutron lifetime using a proton trap (see Fig. 1) at NIST [7]. The fluence from a highly collimated beam of cold neutrons was continuously monitored while the decay protons were trapped and subsequently counted. The result τ=886.8±3.4 s represents the most precise measurement of τ via an in-beam technique. It is in good agreement with the world average (see Fig. 2) as compiled by the PDG [8], which is dominated by bottle-type measurements using ultracold neutrons. The agreement is particularly significant because these two experimental techniques have very different systematic uncertainties. The primary impact of this measurement is thus as an independent check on the accepted PDG value. The error on this measurement can be reduced to approximately 2 seconds with an improved calibration of the neutron flux monitor used in the experiment with a cryogenic

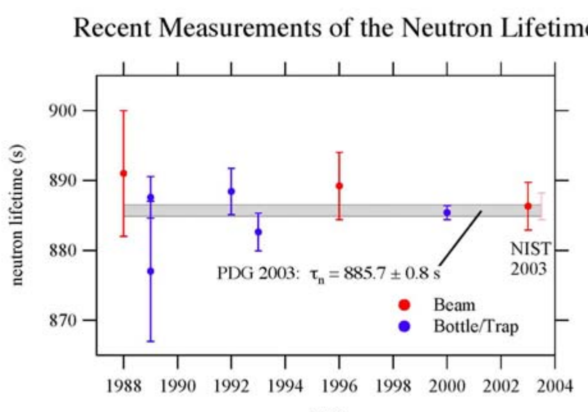

Figure 2. *Recent history of neutron lifetime measurements using in-beam methods (red symbols) and ultracold neutron traps (blue), including the current NIST result.*

neutron radiometer. We have already carried out a calibration with 0.1% absolute accuracy with a ^{6}Li target [36] and a measurement using a liquid ^{3}He target is in progress at NIST.

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