Proposal for the Direct Measurement of the Zero-Point Energy

Tufail Khan[1†], Pallavi[4], Avnish Ola[3], Veena C.P.[1], Kedar Mal [1], C.P. Safvan [1], W. Quint[2], M. Vogel[2], and Sugam Kumar[1]

[1]Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India

[2]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

[3]University of Delhi, New Delhi, India

[4]Jawahar Lal Nehru University, New Delhi, India

Synopsis We propose a direct measurement of the electron zero-point energy through photodetachment of trapped H^- ions. In a magnetic field, the detached electron occupies quantized cyclotron states, shifting the lowest threshold by $\hbar\omega_+/2$. Progress on trap commissioning, ion production,trapping and detection using CEM through time of flight technique is reported.

The non-zero ground-state energy of the quantum harmonic oscillator, $E_0 = \hbar\omega/2$, is a fundamental consequence of quantum mechanics. We propose a direct measurement of electron's zero point energy using laser photodetachment of H^- anions confined in a Penning trap [1]. The detached electron remains confined by the trap fields rather than entering a three-dimensional free-particle continuum, so that the lowest threshold is shifted, to leading order, to $h\nu_{\rm th} = E_{\rm A} + \hbar\omega_+/2$, where $E_{\rm A}$ is the hydrogen electron affinity and ω_+ is the reduced cyclotron frequency. Magnetic-field-dependent threshold shifts associated with the electron cyclotron zero-point energy have previously been observed in negative-ion photodetachment [2].

We report progress toward implementing this scheme with the Delhi Penning Trap (DPT) at the Inter-University Accelerator Centre, New Delhi. For the proposed zero-point-energy measurement, operation of the cryogenic trap within a 1 T superconducting magnet is proposed. Its open geometry provides particle injection, extraction and optical access, related open-access cylindrical Penning-trap concepts have been developed for precision experiments [3].

Commissioning has established electron-gun ion production, trapping, extraction and time-of-flight detection using a channel electron multiplier (CEM). The detection and data-acquisition chain is being optimized for stable ion counting and reproducible measurement cycles.

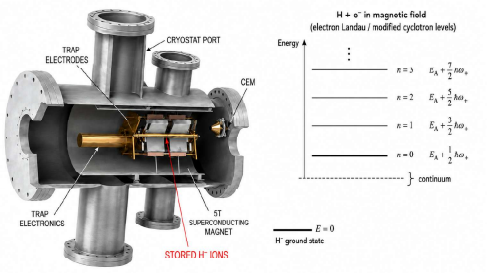

Figure 1. Proposed cryogenic Penning-trap configuration in a 5 T superconducting magnet and Landau levels of the detached electron and the zero-point shifted photodetachment threshold.

The next steps are reliable production and confinement of H^- ions, narrow-linewidth laser scans across the photodetachment threshold and controlled counting of the photodetachment products. Systematic effects relevant to the threshold resolution are being evaluated, including ion temperature, motional broadening, Zeeman structure, magnetic-field inhomogeneity, electrostatic anharmonicity and final-state interactions. These developments define the experimental requirements for resolving the zero-point contribution through precision threshold spectroscopy.

References

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†E-mail: tufail2246@gmail.com