$\mathbf{N \to \Delta(1232)}$ charge quadrupole form factor and proton structure effects in atomic hydrogen

A. J. Buchmann
Institute for Theoretical Physics
University of Tübingen
D-72076 Tübingen
Germany

The $\Delta(1232)$ resonance with spin 3/2 is the lowest lying excited state of the nucleon. In electron scattering it can be excited via magnetic dipole, electric quadrupole, and charge quadrupole transitions. Recent high-precision electron-proton scattering experiments have made it possible to extract the small $p \to \Delta^+(1232)$ charge quadrupole transition form factor from the inelastic electron-proton scattering cross section [1].

Accurate knowledge of this form factor is important because it provides a measure of the deviation of the proton's charge distribution from spherical symmetry [2]. Moreover, the $p \to \Delta^+(1232)$ charge quadrupole transition form factor has interesting consequences for the proton elastic charge form factor [3].

The internal charge distribution of the proton also affects the electronic level spacing in atomic hydrogen. In particular, it contributes to the proton Zemach radius [4, 5] and polarization shift, which are the most important nucleon structure corrections to the hyperfine splitting of the hydrogen atom ground state.

In the present paper we study the effect of the nonvanishing $N \to \Delta(1232)$ charge quadrupole transition form factor on the hyperfine splitting in atomic hydrogen. Previous analyses of this problem have usually focused on the dominant magnetic dipole excitation of the $\Delta(1232)$ resonance.

---

[1] D. Drechsel, S. S. Kamalov, L. Tiator, Eur. Phys. J. **A 34**, 69 (2007).

[2] A. J. Buchmann and E. M. Henley, Phys. Rev. C **63**, 015202 (2001).

[3] A. J. Buchmann, AIP Conf. Proc. 904, 110 (2007); Can. J. Phys. **83**, 455 (2005); Phys. Rev. Lett. **93**, 212301 (2004).

[4] A. Dupays, A. Beswick, B. Lepetit, C. Rizzi, and D. Bakalov, Phys. Rev. A **68**, 052503 (2003).

[5] S. Brodsky, C. Carlson, J. R. Hiller, and D. S. Hwang, Phys. Rev. Lett. **94**, 022001 (2005).