High-precision spectroscopy of antiprotonic helium atomcules

E. Widmann

Physics Department, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan

The study of $\bar{p}He^+$ atomcules carried out by the PS205 collaboration at CERN-LEAR revealed many facets of this unusual 3-body system. Its structure was first examined using a laser spectroscopy technique where it could be shown that the antiprotons occupy highly excited metastable states with principal quantum number $n = \sqrt{(m/M)}$ and orbital angular momentum quantum number $l = n - 1$ as predicted by the Condo- Russel model. Successive improvements of both the experimental precision in measuring laser-induced transitions between such highly-excited states and the theoretical accuracy in calculating the $\bar{p}$ energy levels in this three-body system have led to a remarkable agreement between theory and experiment on the ppm level.

The next logical step in studying the structure of $\bar{p}He^+$ is to try to measure the level splitting arising from magnetic interactions of its constituents. Due to the very large angular momentum $l = 35$ of the antiptoton, the three magnetic monents associated with the $\bar{p}$ angular momentum and the $\bar{p}$ and e^- spins couple in a very unusual way. Each level is split into a doublet by the interaction of the $\bar{p}$ angular momentum with the electron spin which we call a "hyperfine" splitting (HFS) because it arises from the interaction of different particles. Each doublet is split into another doublet with by a factor 100 smaller separation due to the interaction of the $\bar{p}$ spin with the moments of the other particles (named "super-hyperfine" splitting, SHFS).

The level splitting leads to a splitting of laser transitions between adjacent levels. In 1996 for the first time a doublet splitting (HFS) of $\Delta\nu = 1.70 \pm 0.05$ GHz could be observed in the $(n, l) = (37, 35) \rightarrow (38, 34)$ transition [1] (see Fig. 1), in accordance with theoretical predictions. The smaller SHFS splitting cannot be resolved with the pulsed laser system used. For an more precise measurement of the level splitting, direct transitions between the sublevels have to induced. An experiment planned for the forthcoming Antiproton Decelerator AD at CERN will be described which has the potential of determinig the magnetic moment of the $\bar{p}$.

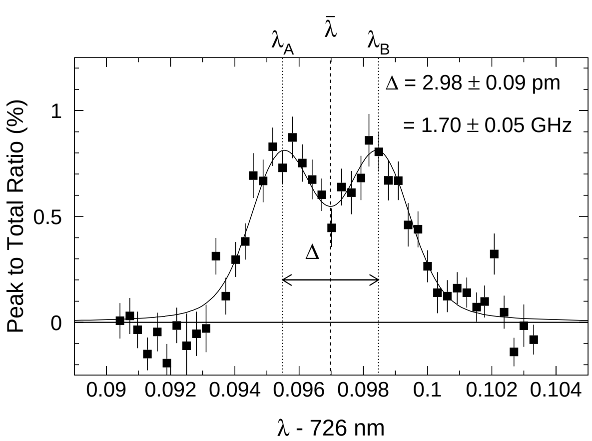

Fig.1 Observed HFS splitting in the $(n, l) = (37, 35) \rightarrow (38, 34)$ transition of antiprotonic helium [1].

[1] E. Widmann et al., Phys. Lett. **B404** (1997) 15.