First observation of the hyperfine and superhyperfine structure of antiprotonic helium by laser-microwave spectroscopy

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The antiprotonic helium has a remarkable characteristic that it holds some metastable states which keep antiprotons as long as microseconds. With this longevity of the exotic atom lifetime we can perform spectroscopies using laser or even microwave.
Each metastable state of the antiprotonic helium has a level splitting named hyperfine structure, which comes from an interaction between the antiproton orbital angular momentum ($L_{\overline{p}}$) and the electron spin (S_e). Also there are interactions between the antiproton spin ($S_{\overline{p}}$) and $L_{\overline{p}}$ or S_e, which cause further splittings named superhyperfine structures. Since the knowledge of these structures could give insight on the magnetic property of the antiproton, for many years we have designed and prepared for a new scheme of antiprotonic helium spectroscopy using microwave together with lasers.
In this talk we will describe the detail of this laser-microwave experiment and present the first result of the spectroscopy at CERN AD(Antiproton Decelerator) where we successfully observed microwave transitions between hyperfine states and even resolved the superhyperfine splitting (as shown in Fig. 1).

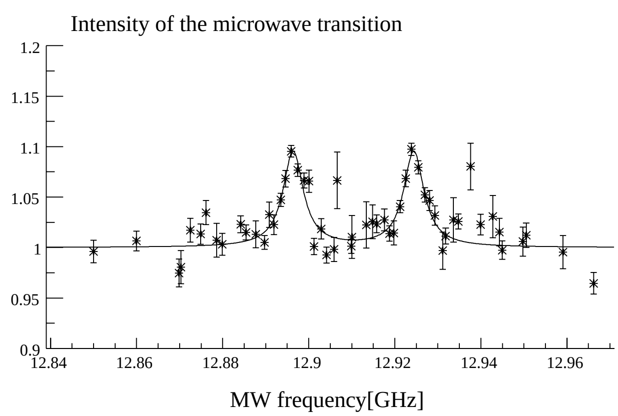

Figure 1: First-observed spectrum of the microwave resonance of the antiprotonic helium $(n, l) = (37, 35)$ state. Microwave transition was caused from one of the hyperfine states with $F \equiv L_{\overline{p}} + S_e = 35 + \frac{1}{2}$ to another state with $F = 35 - \frac{1}{2}$. Due to the superhyperfine interaction among $L_{\overline{p}}$, S_e and $S_{\overline{p}}$ we see the doublet structure.