Laser Spectroscopy on $\bar{p}^3$He $^\diamond$

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In previous studies of the delayed annihilation time spectra (DATS) of $\bar{p}^3$He and $\bar{p}^4$He at 5.8 K and 400 mbar we had observed a 14 % shorter trapping time of $\bar{p}$ in ^{3}He than in ^{4}He, explained by the different reduced masses. In addition, we found a distinct short-lived component in the case of ^{3}He which was attributed to the existence of at least one state with a lifetime intermediate between the metastable ($\tau \sim 1-2\,\mu$s) and the Auger-dominated ($\tau \lesssim 10$ ns) regime in ^{3}He [1].

With the introduction of laser spectroscopy of the $\bar{p}$He-system, it became possible to determine the lifetimes of individual metastable states and to investigate their dependence on the target conditions, such as temperature, density and impurities. In the case of $\bar{p}^4$He, the lifetime of levels with smaller principal quantum number n was found to be significantly shortened when the target gas density was increased, while states with higher n were almost unaffected. To find out whether this behaviour is also seen in $\bar{p}^3$He and if it might even be responsible for the observed short-lived component, we studied the $(36,33) \to (35,32)$ transition in the $v = n - l - 1 = 2$ cascade (l = angular momentum quantum number) which we found last year at (463.947 ± 0.002) nm [2].

For our investigations, we used the fast extraction mode at CERN's LEAR because this pulsed mode allowed us to find laser resonances very quickly as well as to fire the laser at early times, i. e. within 400 ns after the arrival of the $\bar{p}$. Two different methods were used to obtain information on the level lifetime.

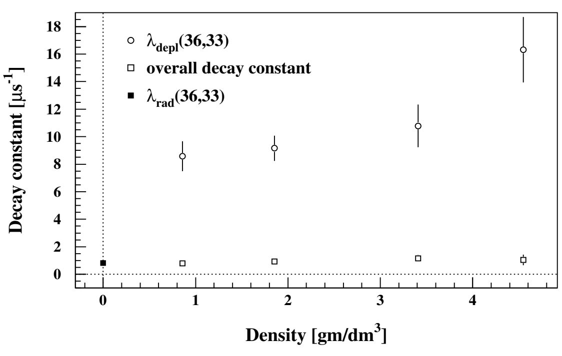

Fig. 1: Overall decay constant for the v=2 cascade and single level decay constant λ_{depl} for the (36,33) state versus density.

One was an "integral" method, with the laser set on resonance and fired with increasing delay with respect to the $\bar{p}$ stop. From a single exponential fit to the peak to background ratio versus the laser delay we get an overall lifetime which does not only reflect the lifetime of the last metastable level but also the feeding effects from higher lying levels. The other method represents a means to determine the lifetime of the last level itself via the "depletion"-lifetime: directly after the laser-induced peak in a time spectrum there is a shallow dip, caused by those $\bar{p}$ which already annihilated when the laser was fired. This "depletion" recovers to the form of a delayed time spectrum without laser with the lifetime of the last-emptied level.

Both methods were carried out for four different densities and the still preliminary evaluation shows that the (36,33) level in $\bar{p}^3$He is even more sensitive to the target density than the corresponding level in $\bar{p}^4$He. On the other hand, the overall decay constant of the v=2 cascade changes only weakly with density (Fig. 1). This means that the upper levels are almost not influenced by density changes. For comparison, we also show the theoretical value of the radiative single level decay constant $\lambda_{\rm rad}(36,33)$ as calculated by Greenland for the isolated atom [3].

This density-induced shortening of the lifetime of the lowest metastable level in the v=2 cascade was used to access a new resonance between two normally metastable levels by increasing the density to 700 mbar. We could detect the $(37,34) \to (36,33)$ transition which we found to be centered at (524.155 ± 0.003) nm (Fig. 2), only 5 ppm below the value predicted by Korobov.

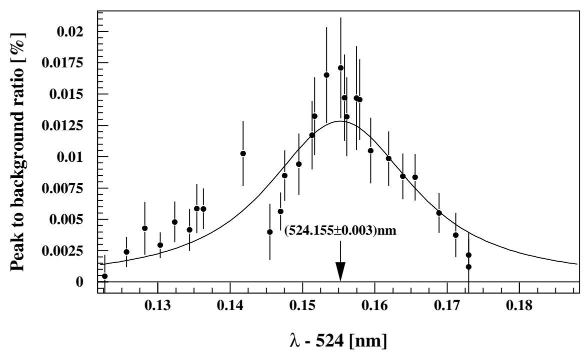

Fig. 2: Resonance profile of the $(37,34) \to (36,33)$ transition fitted by the convolution of a Gaussian with fixed bandwidth and a Lorentzian.

References

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[3] P.T. Greenland, *private communication.*
[4] V.I. Korobov, Phys. Rev. **A54** (1996) 1749; private communication.

$^\diamond$ Supported by the BMBF