Investigation of the Metastability of the $2s$ State in Muonic Hydrogen

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In view of a new experiment proposed at PSI to measure the rms proton charge radius by determining the Lamb shift in muonic hydrogen μp, it is of vital importance to have good knowledge about population *and* lifetime of the metastable μp($2s$) state. In order to obtain this information we performed an experiment to investigate the muon transfer to neon in a mbar gas mixture of hydrogen with several percent of neon.

Our setup is shown in fig. 1. The πE5 muon beam is compressed in the inhomogeneous stray field of a 5-Tesla superconducting solenoid. The muons are slowed down to kinetic energies below 100 keV, detected in the PPAC and pass the stack of six ultra-thin carbon foils. In the stack the muons are on the one hand cooled by 'frictional cooling' [1], on the other hand they eject electrons which are detected in the MSP. The stack thus also serves as a second entrance detector. Afterwards the muons are stopped in a 15 cm long cylindrical target with diameters of 7, 12 and 16 mm, respectively. The target is filled with 4, 8, or 16 mbar of hydrogen at 3, 6, 12, 25, or 50% of neon admixture.

We measured the muonic neon K-series x rays following the transfer reaction

$$\mu\mathrm{p}(1s \text{ or } 2s) + \mathrm{Ne} \longrightarrow \mathrm{p} + \mu\mathrm{Ne}^*, \qquad (1)$$

exploiting the fact that the transfer signal of μp($2s$) to neon is enhanced by two effects: The transfer rate of μp($2s$) to neon is about an order of magnitude larger than the one for μp($1s$) [2,3], and the μp($1s$) vanish into the walls of the target chamber quickly due to the small elastic cross section for scattering of μp($1s$) on H_2.

We also recorded the signal of the μp($1s$) arriving at the target chamber walls, which were coated with a thin layer of gold,

$$\mu\mathrm{p}(1s) + \mathrm{Au} \longrightarrow \mathrm{p} + \mu\mathrm{Au}^*. \qquad (2)$$

In this way we obtained valuable information on the time evolution of the μp($1s$).

The time spectra of both the neon and the gold transfer reactions were compared with detailed Monte-Carlo simulations including knowledge of the initial kinetic energy distributions of muonic hydrogen [4], scattering of μp($1s$) on H_2 and the measured rate for the transfer from μp($1s$) to neon at near-thermal energies. We find a number of excess events at late times which can neither be attributed to $1s$ transfer nor to background (which we measured carefully in pure H_2, He, and Ne gas). The various pressures, concentrations and target diameters give the opportunity for multiple cross-checks of the hypothesis that these excess events have to be attributed to the presence of long–lived metastable μp($2s$). A lower limit (95% C.L.) of 0.4% for the fraction of long-lived metastable μp($2s$) (per formed muonic hydrogen atom) results. A more detailed analysis of the data is presently performed.

References

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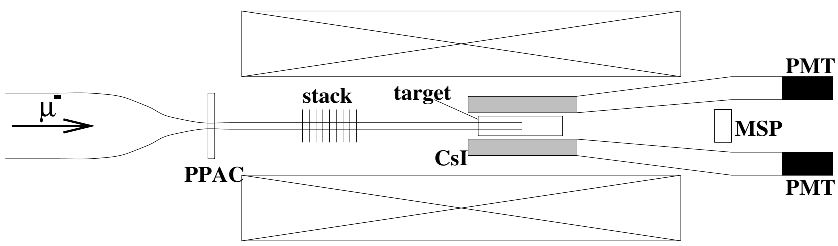

Fig. 1: Setup of the experiment. PPAC: parallel plate avalanche counter, MSP: micro–sphere plate, PMT: photomultiplier tube.