Contribution ID: **73** Type: **Poster**

Direct Coulomb De-excitation as the Dominant Mechanism of Quenching the Metastable 2s-state of Muonic Hydrogen

Tuesday, 6 September 2011 16:45 (20 minutes)

The cross sections of the elastic, Stark and Coulomb de-excitation processes in the collisions of muonic hydrogen with hydrogen atom have been calculated in the close-coupling approach taking into account both the closed channels and vacuum polarization shifts of the ns states. In particular, the cross sections of the elastic $2s-2s$ scattering and Coulomb $2s-1s$ de-excitation below the $2p$ threshold which determine the destiny of a metastable $2s$ state in muonic hydrogen have been calculated for the first time. The convergence of the cross sections with increasing the number of the basis states has been investigated.

The obtained cross sections are used as the input data in the detailed studies of the atomic cascade kinetics. The new version of the extended standard cascade model taking into account the initial distributions in the quantum numbers and kinetic energy. In the wide density range a number of characteristics of the atomic cascade have been calculated and compared with the known experimental data: the relative yield of K_α-line, the arrival population of $2s$-state, the population of the $2s$ metastable fraction (i.e. muonic atom in $2s$-states with kinetic energy below $2p$ threshold), the yield of high-energy (0.9 keV) component of the $1s$ muonic hydrogen, and the lifetime of the metastable $2s$ fraction.

The results of the present study prove that the direct Coulomb de-excitation is the dominant mechanism of quenching the metastable $2s$ fraction. This mechanism quantitatively explains the formation of the hot $1s$ muonic hydrogen and leads to the perfect agreement of the calculated and experimental values for lifetime of the metastable $2s$ fraction.

This work has been partially supported by Russian Foundation for Basic Research (Grant No. 10-02-01096).

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Session Classification: Poster Session

Track Classification: Other exotic atoms and rare decays