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Calculation of integration and disintegration processes of antihydrogen positive ions in collisions with positronium

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Antihydrogen positive ions ($\bar{\mathrm{H}}^+$) consisting of an antiproton and two positrons are utilized to produce cryogenic antihydrogen atoms. The $\bar{\mathrm{H}}^+$ can be collected with an electric field, sympathetically cooled by lasers with Be^+ ions, and subsequently neutralized by stripping off one of the positrons. The $\bar{\mathrm{H}}^+$ is integrated in the mixture of antihydrogen ($\bar{\mathrm{H}}$) and positronium (Ps), but disintegrated by the collisions off Ps. Experiments producing the $\bar{\mathrm{H}}^+$ ions using laser-excited Ps targets are under development in the GBAR project at CERN.

In this study, we calculate the integration and disintegration processes of antihydrogen positive ions by a coupled-rearrangement-channel approach with a Gaussian expansion method. We investigate scattering cross sections between the antihydrogen atom and excited positronium for the integration processes, and those between the antihydrogen positive ion and positronium for the disintegration processes. The state-to-state reaction cross sections are obtained by S-matrix elements for all allowed scattering processes, namely both in forward and reversed directions, without the assumption of the detailed balance.

For the integration reaction, we include all possible inelastic processes: Ps excitation, Ps deexcitation, and Ps polarization where only the angular momentum of Ps changes without kinetic energy change [1]. The threshold behavior of these cross sections is also investigated [2]. For the disintegration reaction which is a five-body scattering problem consisting of an antiproton, three positrons, and an electron, we introduce a model potential to describe the interaction between an antihydrogen atom and leptons (electron and/or another positron) and adopt a model four-body calculation to calculate the formation cross section of the positronium antihydride and positronium positive ion [3]. The model potentials are optimized to reproduce the binding energy of antihydrogen positive ion and positronium antihydride.

[1] T. Yamashita et al., New J. Phys. 23, 012001 (2021).
[2] T. Yamashita et al., Phys. Rev. A 105, 052812 (2022).
[3] P. Froelich, T. Yamashita and et al., (submitted).

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