Electromagnetic Corrections to πN Scattering Lengths from Pionic Hydrogen

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The scattering length $a_{\pi^- p}$ is presently extracted from the energy shift in the pionic hydrogen atom to a few % in a nearly model independent way[1]. At this level a number of effects associated with the electromagnetic field begin to affect the analysis. It is important to extract the amplitude correctly in the absence of such terms with controlled errors, both for a proper understanding of isospin breaking at threshold in chiral perturbation theory[2] and, from a purely practical viewpoint, for a precise determination of the πN coupling constant from the GMO sum rule, where an important source of uncertainty comes from that of the πN scattering lengths[3]. The state of the art analysis is that of Sigg et al.[4] which uses a coupled channel approach for the effective πN potentials and includes the mass splittings and the Coulomb field. While this approach emphasizes the magnitude of the corrections its πN interactions are not numerically consistent with the low energy expansion of the pion-nucleon amplitudes. This raises questions about its accuracy. In particular, their analysis would partly describe inconsistently contributions implied by gauge invariance. Our aim is to elucidate the different contributions and their behavior using both numerical and analytical models. We use for this purpose a coupled channel potential approach, a separable interaction approach as well as perturbation theory. This allows us to bring out the variation with the amount of mass splitting as well as the dependence on the finite charge distribution separately from that of the effective interaction range. The results will be presented with emphasis on the physical mechanisms and magnitudes and compared to terms in the chiral effective field theory expansion.

References

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