# MATTER-ANTIMATTER INTERACTIONS INVOLVING ANTIHYDROGEN

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The ATHENA and ATRAP projects are continuing their work on antihydrogen at CERN after their successful preparation of antihydrogen in 2002. See, for example, [1,2]. This has opened up the prospect of a whole new area of investigation in atomic and molecular physics, in addition to tests of the CPT invariance of relativistic quantum field theory and Einstein's principle of equivalence.

The simplest interaction to consider is between atomic hydrogen and antihydrogen. We have already carried out calculations of cross sections for very low-energy hydrogen antihydrogen ($H\bar{H}$) scattering [3,4].

There is currently considerable interest in the interaction of antihydrogen with the next simplest atom, helium, both as a possible means of cooling $\bar{H}$ and as a way of determining the $\bar{H}$ loss rate due to the presence of He as an impurity. We are currently carrying out calculations of very low-energy cross sections for $He\bar{H}$ scattering. We have calculated wave functions and energies for $He\bar{H}$ in the Born–Oppenheimer approximation using basis sets that contain Hylleraas-type functions that correlate the interaction of the positron in $\bar{H}$ with the electrons in He [5].

These calculations give accurate results for the energy but not as accurate as the values obtained by Strasburger and Chojnacki using a basis set made up of explicitly correlated Gaussian functions [6]. Work is currently being carried out on the inclusion of Hylleraas-type functions that correlate the interaction between the electrons. This will bring about an improvement in the accuracy of the energy.

As Strasburger and Chojnacki's energy values are more accurate, we used them to obtain the potential that we required to calculate elastic scattering cross sections. However, our wave functions made it possible to carry out calculations for rearrangement processes. Cross section values for the antiprotonic He + Ps channel will be presented at the conference. These have been calculated using the distorted wave T-matrix approach used by Jonsell et al. in their calculations on $H\bar{H}$ [4]. A progress report will be given on calculations on the $He\bar{p} + e^+$ channel.

Our $He\bar{H}$ calculation will form the starting point for a wide range of applications. The T-matrix approach can be extended to make possible calculations on $He\bar{H}$ scattering using the Kohn variational method, as in the case of $H\bar{H}$ [3]. In addition, our $He\bar{H}$ calculation can be adapted and extended to make it possible to carry out a Kohn calculation of $e^+H_2$ scattering with inclusion of the Ps formation channel which was not possible in earlier calculations [7].

Together with R-matrix calculations [8], these calculations will be used to make a detailed study of the very high positron annihilation rates that have been observed in positron scattering by some molecules [9,10]. This is supported by EPSRC (UK). One of the smallest target molecules for which the very high annihilation rates have been observed is acetylene, HCCH. A key question is how to represent accurately the short range interaction between the positron and the target electrons in such molecules, for which it is not possible to use Hylleraas-type basis functions.

One possibility is to use Gaussian basis functions. As an indication of what might be expected from such an approach, we will conclude with a comparison between $\delta$-function expectation values for positron-electron coincidence for $He\bar{H}$ calculated using our wave functions containing Hylleraas-type functions and those obtained by Strasburger [11] using explicitly correlated Gaussian functions.

## References

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