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# Distinguishing signal from background for a direct measurement of antihydrogen's Lamb shift

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It is predicted that after the Big Bang equal amounts of matter and antimatter should have been created, however the universe is dominated by matter and there is much less of its counterpart. Antihydrogen is created and analyzed by the ALPHA (Antihydrogen Laser Physics Apparatus) collaboration at CERN to look for asymmetries by comparing its spectra with hydrogen's. The Lamb shift is an important transition in hydrogen, it is traditionally defined as the splitting of the 2S1/2 and 2P1/2 states at zero magnetic field. Presently it has been only indirectly measured in antihydrogen using data from two separate laser spectroscopy experiments. ALPHA's goal is to make a more precise direct measurement of this transition, where contrasting measurements of the Lamb shift in hydrogen and antihydrogen will provide insight as to the differences between the two. To measure this, a trapped antihydrogen atom must be excited from 1S (ground state) to 2S with a laser. Next, microwave radiation will be applied to cause a transition to 2P. The 2P state has a high probability of undergoing a positron spin flip transition to an untrapped state, resulting in the anti-atom annihilating on the surrounding apparatus walls. There are two types of annihilations occurring, those from a 2S-2P transition followed by a spin flip decay, the desired signal, and those from the ionization of the 2S state by the excitation laser, an undesired background. It is critical to distinguish between the two to complete a Lamb shift measurement. This is done by examining existing laser spectroscopy datasets categorized into those with and without ionizations. Those without ionizations are from experiments where the excitation was directly from 1S to 2P, followed by a spin flip decay down and detected annihilation. Contrasting these datasets allows ionization and spin flip annihilation position distribution variations to be determined. A statistical analysis of position distribution variations gives the information necessary to distinguish between the desired and undesired background signal. It also provides insight as to how various experimental modifications impact the location of annihilations. Knowing this is critical in determining the viability of a direct lamb shift measurement and the appropriate laser and microwave parameters. From here ALPHA can design an experiment to make the first direct measurement of this important transition in antihydrogen which could lead to a discovery in the matter/antimatter asymmetry problem.

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