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Tabletop Tests of the Standard Model and Beyond: A Tale of Two Electron Dipole Moments[1]

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The standard model of particle physics – a set of particles, interactions and symmetries knitted together by field theory – is the great triumph and the great frustration of modern physics. The great triumph is its ability to predict the outcome of laboratory tests with exquisite precision. The great frustration is its inability to account for basic features of the universe, like how it survives annihilation after the big bang, why it is made of matter rather than antimatter, why does gravity not fit well, what is dark matter, etc. The magnetic and electric dipole moments of the electron, measured using completely differently methods, illustrate the crucial role of tabletop measurements for testing the standard model and beyond. The electron's magnetic moment, determined to 3 parts in 10 /13, is the most precisely determined property of an elementary particle. The measurement with a one-electron quantum cyclotron tests the most precise prediction of the standard model. A ten times more precise measurement is currently being pursued in light of an intriguing 2.4 standard deviation discrepancy that has recently emerged between the measurement and the prediction. A positron measurement at the new precision should provide a 200 times improved test of the standard model's fundamental CPT symmetry invariance with leptons. The electron electric dipole, measured using the incredibly strong internal field on valence electrons within cold molecules in a cold beam, is an extremely sensitive probe for physics beyond the standard model. The standard model requires 4th order perturbation theory to produce the CP violation needed for an electric dipole, while supersymmetric models and other proposed beyond-the-standard-model improvements predict much large electric dipoles moments from first order perturbation theory. Following two previous order-of-magnitude improvements in sensitivity, a new measurement seeks to improve the sensitivity by another order of magnitude.

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