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The Cold Molecule Nuclear Time-Reversal Experiment (CeNTREX)

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Observations of time-reversal symmetry (T) violation outside the Standard Model could shed light on the most pressing questions in physics such as the origins of the asymmetry between matter and antimatter in the universe. Experiments searching for such mechanisms can also set stringent constraints on theories that include sources of T violation. The Cold Molecule Nuclear Time-Reversal Experiment (CeNTREX) collaboration uses modern techniques of molecular quantum state control to search for a T-violating nuclear Schiff moment (NSM). A beam of cold TlF molecules traverses an interaction region where a nonzero NSM would drive the Tl nuclear spin precession about an applied electric field. This precession can be detected as an asymmetry between the spin state populations. CeNTREX maximizes the intrinsic sensitivity to new physics by relying on heavy Tl nuclei as constituents in polar molecules. The statistical sensitivity is enhanced by using a bright cryogenic-buffer-gas cooled molecular beam source along with electrostatic focusing, achieving a long spin precession time, and utilizing optical cycling in molecules for a near-unity detection efficiency. The control of TlF quantum states is essential to the experimental scheme, including rotational cooling of the molecules that is carried out with ultraviolet laser light and microwaves and concentrates the molecular population in a single quantum state.