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Volumetric and Localized Annihilation Signatures of a Magnetically Confined Electron-Positron Pair Plasma

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The APEX collaboration aims to magnetically confine electron-positron pair plasma and diagnose the plasma with FPGA-processing of annihilation detections from an array of 48 Bismuth-Germanate (BGO) scintillators. Direct annihilation of pairs and the annihilation of positronium (Ps), formed through radiative and three-body recombination produce a volumetric source of gammas. Back-to-back two-gammas from direct or para-Ps annihilation can be detected in coincidence, allowing for tomographic reconstruction of the volumetric source. Three-photon decay, on the other hand, signifies the self-annihilation of ortho-Ps. Ionization of drifting Ps and collisions with neutrals and charged particles drive cross-field transport, which results in localized sources of two-gamma annihilation at the wall and magnet. The rates of the various annihilation mechanisms depend on the plasma temperature and density and the partial pressures of background gases. Triangulation, distance-attenuated single-photon counting, and the ratio between localized and volumetric decays will provide diagnostics for the properties and evolution of the plasma. We are developing techniques to differentiate between volumetric and localized gamma-ray sources and have conducted measurements with β+ emitters placed on rotating turntables to emulate pair plasma
distributions.

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