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Commissioning gamma detector array by imaging evolution of a pulse of >10^4 positrons in a dipole trap: efficient injection, toroidal homogenization, and radial diffusion to the wall

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We present techniques for diagnosing magnetically confined electron-positron pair plasma [1]. Direct and positronium-mediated annihilation result in overlapping volumetric γ sources, and the 2-γ emission from these volumetric sources can be tomographically reconstructed from coincident counts in multiple detectors. Transport processes result in localized annihilation where field lines intersect walls and limiters. These localized sources can be identified by the fractional γ counts on spatially distributed detectors. In order to demonstrate the effectiveness of annihilation-based techniques, we present measurements from a gamma detector array imaging injection, toroidal homogenization, and radial diffusion of a pulse of >10^4 positrons in a permanent magnetic dipole trap. An annihilation-gamma array consisting of 21 detectors placed in reentrant ports 1cm from the trap electrode wall, detects ~1000 gammas per shot. FPGA processing of the detector signals timestamps detections to 24ns accuracy and identifies ~100 coincident lines of response per shot. The efficiency of injection is characterized by the absence of a prompt annihilation signal. The toroidal homogenization of the positron pulse during the first 100μs is characterized by pile-up annihilation signals generated by dumping all remaining positrons. The radial diffusion and confinement time are characterized by counting annihilations over the confinement time. [1] von der Linden et al. (2023) J. Plasma Phys.

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