

Overcoming Plasma-Induced Noise: Statistical Optimization of α -Particle Detection in EXL-50U p-B Reactions

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Accurate measurement of charged fusion products in magnetically confined plasmas faces significant challenges due to plasma radiation exposure, electromagnetic interference, thermal loads, and background bombardment by electrons/ions, which generate substantial noise while yielding sparse signals. To address these issues, advanced solutions are required beyond conventional detector design and calibration, including signal discrimination techniques, machine learning-based noise suppression for enhanced signal-to-noise ratios, and statistical analysis to improve signal significance. This study focuses on the detection simulation of α -particles generated by proton-boron (p-B) fusion reactions in the ENN-operated ST-type device EXL-50U. By employing Monte Carlo simulations, we systematically evaluate the expected α -particle signals, reducible backgrounds (e.g., electromagnetic interference, plasma fluctuations, and energetic protons/electrons/photons), and irreducible backgrounds (e.g., high-energy proton pileup events and fortuitously energized helium impurities). The signal significance of measurable fusion products is quantified using statistical metrics, providing critical insights for optimizing α -particle diagnostics in p-B fusion experiments under high-background conditions.

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