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State space models for Project 8 event reconstruction

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The Project 8 experiment aims to directly probe the neutrino mass by precisely measuring the energy spectrum of beta electrons emitted in the decay of tritium. The collaboration has pioneered the cyclotron radiation emission spectroscopy technique (CRES), which measures the energy of single electrons by detecting the cyclotron radiation they emit in a magnetic field. Traditional methods for event reconstruction rely on detecting tracks in a spectrogram after transforming the voltage output into the frequency domain. With the goal of achieving 0.3 eV root mean square (rms) energy resolution in the next prototype, these frequency-based methods face challenges, such as how to determine the electron's location in the detector volume. State space models (SSMs) have shown promise for performing well on long time series data with good computational efficiency. In this work, we will demonstrate that the diagonal structured state space architecture (S4D) shows potential for reconstructing event parameters directly from the voltage time series in high-fidelity Project 8 simulations. The architecture's minimal operations and good efficiency also opens the possibility for real-time reconstruction at the 400 MHz sampling frequency.

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