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Event-Adaptive FARICH Reconstruction under Unknown Dark-Count Rates with a Track-Conditioned Transformer

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Focusing aerogel ring-imaging Cherenkov (FARICH) detectors require the reconstruction of sparse photon patterns in the presence of background caused by a photosensor dark count rate. We present the Track-Conditioned Ring Assignment Transformer (TCRAT), an attention-based model that simultaneously assigns photon hits, reconstructs the particle velocity, and performs particle identification in a FARICH detector.

Each event is represented as an unordered set of pixelized hits. A track-conditioned query identifies hits compatible with the charged-particle trajectory, while a separate background query models unassigned hits. The method does not impose a circular or elliptical ring shape on the photodetector plane, allowing it to account for angle-dependent distortions caused by refraction at the aerogel-air boundary.

The method was evaluated using simulated single-particle events in the FARICH detector concept for the future Super Charm-Tau Factory, including track and momentum measurement uncertainties and dark-count rates ranging from zero to 1 MHz/mm². When trained across the full background range without an explicit dark-count-rate input, TCRAT maintained an RMS90 β resolution of about (4.6×10^{-4}) and a balanced particle-identification accuracy of about 94% across the studied noise conditions. Providing the dark-count rate explicitly did not improve the reconstruction quality, indicating that the model can infer the relevant background conditions directly from the event hit pattern.

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