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Machine learning-assisted measurement azimuthal angular asymmetry of soft gluon radiation in positron-proton collisions

At leading order in positron-proton collisions, a lepton scatters off a quark through virtual photon exchange, producing a quark jet and scattered lepton in the final state. The total transverse momentum of the system is typically small, but deviations from zero can be attributed to perturbative initial and final state radiations in the form of soft gluon radiation when the transverse momentum difference, $|\vec{P}_\perp|$, is much greater than the total transverse momentum of the system, $|\vec{q}_\perp|$. The soft gluon radiation comes exclusively from the jet, and should result in a measurable azimuthal asymmetry between $|\vec{P}_\perp|$ and $|\vec{q}_\perp|$. Quantifying the contribution of soft gluon radiation to this asymmetry should serve as a novel test of perturbative QCD as well as an important background estimation for measurements of the lepton-jet imbalance that have recently garnered intense investigation. The measurement is performed in positron-proton collisions from HERA Run-II measured with the H1 experiment. A new machine learning method is used to unfold eight observables simultaneously and unbinned. The final measurement, the azimuthal angular asymmetry, is then derived from these unfolded and unbinned observables. Results are compared with parton shower Monte Carlo predictions as well as soft gluon radiation calculations from a Transverse Momentum Dependent (TMD) factorization framework.
Additionally, a multi-differential measurement of the momentum imbalance between outgoing jets and the scattered positron is reported, which provides a useful test of pQCD in the regime where collinear and transverse-momentum-dependent frameworks overlap.

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