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Jet-Origin Identification and Its Application at an Electron-Positron Higgs Factory

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Future high-luminosity electron–positron colliders such as the CEPC and FCC-ee, with a circumference of around100 km, will produce predominantly hadronic events, offering a rich environment to study jet physics. A central focus of this work is jet origin identification (JOI), a general framework extending beyond traditional jet flavor tagging. JOI distinguishes among 11 categories, including five quark flavors, their antiquarks, and gluons, by combining flavor tagging, jet charge, s-tagging, and gluon tagging. Using the CEPC CDR geometry and full simulation, a graph-based neural network model (ParticleNet) was employed to exploit jet substructure with graph convolutions.

The results demonstrate strong performance, with flavor tagging efficiencies of 67–92% for bottom, charm, and strange jets, and charge-flip rates of 7–24% across quark species.

Applied to Higgs decays, JOI enables stringent constraints on rare processes. Upper limits on branching ratios of H⟶ss, uu, dd and flavor-violating modes such as H⟶sb,db,uc,ds are projected at the level less than 0.1% at 95% confidence, with H⟶ss the upper bound reaching about three times the Standard Model expectation.

In the electroweak sector, JOI significantly improves the determination of CKM elements. For example, in the measurement of |Vcb| using semi-leptonic W decays at the CEPC, boosted decision tree classifiers achieve statistical uncertainties of 0.91% (muon channel) and 1.2% (electron channel), improving by ~40% compared to conventional flavor tagging.

Vertex detector optimization further enhances sensitivity based on fast simulations, showing that reducing layer radii improves the significance for H⟶ss decays by ~12%. Subsequent CEPC TDR updates with smaller inner radii, higher resolution, and improved PFA contribute additional gains, alongside better feature engineering and calibration strategies.

Overall, JOI with state-of-the-art neural networks successfully integrates flavor tagging, jet charge, s-tagging, and gluon identification into a single model, delivering advances in Higgs and W physics measurements. Ongoing studies are refining the influence of detector geometry, PID, and simulation schemes, while AI-powered PID and broader channel applications are being developed.

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