PRECISION CALCULATIONS IN PARTICLE PHYSICS
(group Thomas Gehrmann)

Bachelor thesis project

Modern jet algorithms for electron-positron colliders

The next major collider project at CERN is the FCC-ee (future circular collider), an electron-positron collider that will allow precision studies of the Higgs boson and the electroweak interaction. Data from previous generations of electron-positron colliders have been preserved, and are currently being re-analysed with modern methods to optimise the physics potential of the FCC-ee. In this project, we aim to focus on the physics of hadronic jets in e^+e^- collisions, examining the impact of modern jet clustering algorithms and of preprocessing techniques (grooming, pruning) aiming to improve the identification of jet kinematics with primary quarks and gluons produced in the hard interaction. The work will be performed in an already existing numerical framework, and will combine numerical and analytical aspects.

Master thesis projects

Axial-vector contributions in the Drell-Yan process

Electroweak vector bosons couple differently to left-handed and right-handed fermions. The resulting combination of vector and axial-vector couplings is an essential prediction of the electroweak Standard Model. In lepton pair production at hadron colliders (the Drell-Yan process), the axial-vector couplings result in non-trivial asymmetries in the kinematical distribution of the leptons. These asymmetries are now being measured to high accuracy at the CERN LHC and they are very sensitive to the coupling parameters of the Standard Model. To enable precision physics studies with these observables, we plan to compute the second-order QCD corrections to the axial-vector contributions in the Drell-Yan process with an associated jet in the final state. The project combines analytical work on the subprocess amplitudes with numerical developments for the cross section predictions.

Operator product expansion for the gluon operator

The operator product expansion is a systematic procedure to separate long-distance and short-distance contributions in quantum field theory. One of its most important applications is the computation of initial state QCD radiation off incoming quarks or gluons at hadron colliders, which are described by the quark and gluon operators and their renormalization. While the operator product expansion for the quark operator is well-understood to all orders in perturbation theory, the gluon operator poses novel challenges due to its gauge-dependence and its mixing with Fadeev-Popov ghosts in QCD. Its operator product expansion could up to now only be understood for the first terms in the perturbative expansion. The aim of this project is to establish a fully consistent operator product expansion for the gluon operator, and to determine its renormalization conditions. The project addresses the foundations of quantum field theory, requiring conceptual and analytical work.