Description of doctoral project
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Electroweak Effects in Boosted Top Quark Production

The top quark is a unique particle in the Standard Model (SM) of Particle Physics, since besides strong, electromagnetic and weak interactions it also has a large coupling to the Higgs field, resulting in a mass of roughly 170 GeV/c^2, the largest of any fundamental particle discovered to date. The top quark mass m_t is thus a key ingredient for precision tests of the SM as well as searches for beyond-the-SM physics.

This project focuses on determinations of the top quark mass from differential jet cross section measurements at colliders. In Quantum Chromodynamics (QCD) jets are coherent states of QCD emissions that manifest themselves as collimated sprays of hadrons in the detectors. Since the top quark is unstable and very short-lived due to its large mass, the notion of a top jet has to be refined when electroweak radiative effects are considered to coherently treat its decay products in aforementioned jet cross sections, which is one of the main goals of this work. Of special interest is the case of so-called boosted top jets, i.e. jets produced with large jet energies $E_J \gg m_t$ but invariant mass close to the top mass, $p_J^2 \sim m_t^2$. The jet distributions typically show a peaked structure in this regime. For these suitably constructed observables the peak position is very sensitive to the top quark mass, allowing for high-precision extractions of m_t from the distributions in the peak region. Furthermore the large scale separation in this regime allows to establish powerful factorization formulae for these observables on the theory side, considerably facilitating the systematic inclusion of the various radiative effects contributing at those different physical scales, all while allowing us to stay fully analytic in the calculations. Large logarithmic corrections due to soft and collinear radiation, which are traditionally tamed by numerical methods (Monte-Carlo event generators) can be summed to all orders in perturbation theory in a very elegant and transparent way by Renormalization Group evolution equations.

Concretely, my work aims to systematically incorporate electroweak effects into these factorized calculations and consistently combine them with exisiting results from pure QCD. Special focus lies on corrections to the decay of the top quark that go beyond a simple Breit-Wigner approximation for resonant top propagators. We use the powerful tool of Effective Field Theories (EFT), in particular the Soft-Collinear Effective Theory (SCET). SCET has been devised for QCD applications in processes involving jets, and its consistent extension to the electroweak theory, i.e. a gauge theory with a Brout-Englert-Higgs effect, poses a string of interesting challenges. Concrete examples in this context are EFT Feynman loop integrals with nonzero boson masses, the notion of "isospin" (which in contrast to "color" is observable) and, closely related, the concepts of local and global symmetry breaking.