



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Quantum Chromodynamics (QCD), the theory of the strong interaction, is an essential component of the Standard Model (SM) of particle physics. Precision predictions within QCD are necessary for interpreting collider data and for testing the SM against experimental observations. In recent years, the demands for theoretical precision has grown due to the increasing accuracy of measurements at the Large Hadron Collider (LHC). In this thesis, we address this challenge by performing higher-order perturbative QCD calculations and threshold resummation for a class of processes at the LHC. These include both Standard Model processes and those sensitive to potential extensions beyond it.

A central focus of this work is on soft-gluon threshold resummation—a technique used to account for the dominant logarithmic corrections that arise when partonic processes are near threshold. Such logarithms, if left untreated, can spoil the convergence of the perturbative expansion. We perform the threshold resummation in the Mellin-space to systematically resum these logarithms to next-to-next-to-next-to-leading logarithmic (N^3LL) accuracy, matched with the available next-to-next-to-next-to-leading order (N^3LO) fixed-order results. This provides the state-of-the-art precision for hadronic cross-section predictions.

In Chapter 3, we study the threshold resummation of Drell-Yan-like processes at N^3LO+N^3LL accuracy. Drell-Yan processes serve as clean probes of QCD dynamics due to their relatively simple final states and have played a critical role in precision studies at hadron colliders. We perform the resummation for neutral and charged Drell-Yan, V H production and Higgs production through bottom quark annihilation and present phenomenological results relevant to current LHC energies.

In Chapter 4, we extend threshold resummation to the associated production of a Higgs boson with a Z boson (ZH production) through gluon fusion. This is a loop-induced process in the Standard Model and sensitive to new physics effects. We perform soft-virtual (SV) and next-to-soft-virtual (NSV) resummation for this process in born-improved theory at the LHC, achieving improved theoretical control over uncertainties from unknown higher-order corrections.

In Chapter 5, we investigate the threshold resummation of ZZ production at the LHC up to NNLO + NNLL accuracy. Diboson production processes like ZZ are crucial both as precision SM measurements and as backgrounds to Higgs and new physics searches. We make use of the resummation formalism developed for $2 \rightarrow n$ type processes involving colorless final states and tailor it to the ZZ production process for performing the resummation. We notice that these improved predictions reduce the scale uncertainties, particularly in the high invariant mass region.

In Chapter 6, we shift focus to the computation of two-loop virtual amplitudes for the decay of a pseudo-scalar Higgs boson to three partons, within an effective theory approach. These amplitudes are relevant for understanding pseudo-scalar Higgs production in association with a jet at hadron colliders, especially in scenarios beyond the Standard Model such as the Minimal Supersymmetric Standard Model (MSSM). We compute the amplitudes to NNLO accuracy, including the terms beyond the positive power in the dimensional regulator ϵ , which are essential for the computation of three-loop pseudo-scalar production cross sections.

Finally, the results presented in this thesis represent significant advances in precision QCD calculations, enhancing our ability to interpret LHC data and to test the boundaries of the Standard Model. The resummation techniques and multi-loop calculations studied herein are not only relevant for the processes studied but also provide a framework that can be extended to a broad class of observables in collider physics.

