Non-global logarithms at finite $N_C$ beyond leading order

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Introduction

As the beam energy of the LHC reaches record levels wide regions of the phase space are being probed which could potentially uncover new physics signals. The exploitation of the data from such phase space necessitates ever more accurate comparisons between theoretical predictions and experimental measurements of cross-sections.

The distributions of exclusive observables in general suffer from several towers of large logarithms that require a resummation, and which arise from the cancellation of real and virtual infrared/collinear singularities in the matrix element-squared. Besides the so-called global logarithms which are typically present in calculations of exclusive observables being sensitive to emissions in the entire angular phase-space, another tower of large logarithms that was discovered some time ago emerges starting from two gluon emission, and is commonly known as non-global logarithms [3]. These logarithms emerge in the calculation of observables whose definition depends on angular configurations of emissions (see fig 3).

Large logarithms in exclusive cross-sections

In this section we proceed with the calculation of non-global logarithms at finite $N_C$. We compute non-global logarithms at finite $N_c$, up to four-loop to single logarithmic accuracy and discuss the possibility of their exponentiation to all orders.

Non-global logarithms

Currently work is in progress for the calculation of the four-gluons amplitudes but our preliminary result for the three-loop hemisphere mass distribution is expressed as:

$$S(\rho) = e^{\rho \psi} \left(1 - \frac{1}{3} C_4 C_4 L^2 \zeta(2) + \frac{1}{3} C_4 C_4 L^4 \zeta(4)\right),$$

with $\zeta$ the Riemann-Zeta function and $C_4$ and $C_4$ the fundamental and adjoint Casimir operators of SU($N_c$), which at large $N_c$ become $C_4 \rightarrow C_4/2 = N_c/2$. Our result up to this order is consistent with analytical calculations made in the large $N_c$ approximation [6]. Our result opens the door for studying the possibility of exponentiation of non-global logarithms beyond leading order.

To illustrate the calculation we consider the simple process of $e^+e^- \rightarrow q\bar{q}$ and pick a simple observable, namely the hemisphere mass. We consider strongly energy-ordered soft emissions $Q \gg k_1 \gg k_2 \gg \cdots$ associated with this process, which is the centre-of-mass energy.

For non-global logarithms, we compute the cumulant integrated hemisphere-mass distribution normalised to the born cross-section, defined by:

$$S(\rho) = 1 + S_1(\rho) + S_2(\rho) + \cdots$$

with

$$S_n(\rho) = \int \prod_i d\Phi_i \bigg| M_{\text{ew}}(k_i)\bigg|,$$

where $M_{\text{ew}}$ is the matrix element-squared for the production of $n$ gluons (summed over real or virtual contributions) of the $q\bar{q}$ pair at $n$th order, normalised to the born cross-section and $\prod_i d\Phi_i$ is the corresponding phase-space factor. The measurement function $\eta$ (which either equals one or zero) has the role of excluding emission events for which the total jet mass $\rho$ is greater than some $\rho_0$, so one has $\eta = \Theta(\rho - \rho_0)$.

Framework

To calculate non-global logarithms we use the eikonal Feynman rules for soft gluon emissions, which is sufficient to capture non-global single logarithms. Furthermore with help from the Mathematica package ColorMath [4] we are able to calculate all necessary color algebra for the matrix element squared up to four loops. In order to check the consistency of our results (which are found at finite $N_c$) we write them in the large $N_c$ approximation and compare them with those obtained at large $N_c$ by analytical solution to the BMS equation.

Future research

Our aim in the future (after completing the four gluon calculation), is of course to study the possibility of the exponentiation of non-global logarithms, or the resummation into a different function. We then plan to extend our work to include the effect of clustering on non-global logarithms by calculating them analytically in the presence of various jet algorithms such as the $k_t$, CA and SISCone algorithms.

References

[1] https://cern.ch

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