PSR21 - Parton Showers and Resummation

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Book of Abstracts

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The role of NLP threshold corrections in dQCD and SCET

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Cross-sections in perturbative QCD are plagued by large corrections from soft and collinear radiation. The most singular terms are known to be universal, which allows their resummation to all orders in the coupling. In this talk, I will discuss the recent progress on understanding the structure of next-to-singular (NLP) contributions, and show the non-negligible phenomenological impact of these for Drell-Yan and single-Higgs production. In addition, I will perform an analytical and numerical comparison between the NLP resummation frameworks in direct QCD and soft-collinear effective theory.

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Transverse momentum resummation on the azimuthal spectra of the final leptons in the Drell-Yan processes

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To propose an alternative portal to the $W^{\pm}/Z$ correlations, the azimuthal opening angle ϕ_L between the final leptons is investigated in the DY processes. In the fixed-order context, the calculation on the ϕ_L distribution is not straightforward, as the soft and collimated beam radiations in the regime of $\phi_L \to \pi$ or $q_T \to 0$ GeV give rise to large logarithms bringing down the perturbativity. Hence, it is essential to carry out the all-perturbative order resummation over those singular behaviors, more specifically, the $\ln^m[q_T^2/M_V^2]/q_T^2$ terms. To accomplish this goal, the soft-collinear effective theory is utilized in this work for the factorization and exponentiation. Thanks to the rapid developments of the fixed-order studies, the beam and soft ingredients for this method have been computed up to the three-loop level, which permits us to access the N^{3}LL$'$ evaluations. In tacking the hard sectors, not only are the non-singlet amplitudes comprised in the calculation, the singlet influences are also addressed for the neutral DY process particularly. To this end, we make use of the axial-vector effective field theory to integrate out the top-quark influences and then recast the hard functions in terms of the Wilson coefficients and 5-flavour amplitudes. Their anomalous dimensions and perturbative expressions are extracted from the anomaly-dependent quark form factors.

For the numerical outputs, the comparisons between the singular and QCD contributions are presented first of all to demonstrate the validation of the asymptotic expansion. Their manifest agreements are observed in the vicinity of $q_T = 0$ GeV. Furthermore, the resummation-improved results from NLL$'$ to N^{3}LL$'$ are exhibited in the q_T and ϕ_L spectra. It is seen that within the asymptotic domains ($\phi_L \to \pi$ or $q_T \to 0$ GeV), the N$^{3(2)}$LL$'$ results are well situated in the N$^{2(1)}$LL$'$ error bands, and with the increase in accuracy, the theoretical uncertainties are diminished substantially.

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Jet Substructure overview

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Dynamical grooming

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Dynamically grooming a jet (1) amounts to isolate the hardest splitting in the branching story. The properties of the branching tagged by dynamical grooming can be computed using resummation techniques. In this talk, based on (2), I'll present the resummation structure of dynamically groomed observables, some of them infra-red and collinear safe and others Sudakov safe only, up to next-to next-to-double logarithm accuracy including a matching to leading order in α_s. After including non-perturbative corrections, determined through Monte-Carlo, this theoretical calculation provides a very good description of the preliminary ALICE data (3,4).

(1): arXiv/hep-ph/1911.00375
(2): arXiv/hep-ph/2103.06566

(3): arXiv/nucl-ex/2009.07172
(4): arXiv/nucl-ex//2009.12247

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Next-to-leading non-global logarithms in QCD

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We present a new formalism for the resummation of non-global QCD observables beyond leading-logarithmic accuracy. We describe the derivation of a set of integro-differential equations that govern the dynamics of soft radiation in the planar limit, using which we perform a fixed-order calculation of the out-of-jet energy and transverse energy distributions at lepton colliders. We finally comment on the solution of the system of equations by means of Monte Carlo methods and the resummation of non-global corrections at all orders.

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Fiducial Higgs and Drell-Yan distributions at N3LL'+NNLO with RadISH

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We present state-of-the-art predictions for the transverse momentum of
the colour singlet in gluon-fusion Higgs production and in neutral Drell-Yan
lepton-pair production, as well as the phistar observable in Drell Yan.
We resum such observables at N3LL' accuracy in momentum space with the RadISH formalism, thus consistently including in our prediction all constant terms of relative order α_s^3 with respect to the Born.
We supplement our results with a transverse-recoil prescription, accounting for dominant classes of subleading-power corrections in a fiducial setup.
The resummed predictions are then matched with fixed-order differential spectra at NNLO accuracy and compared with 13 TeV LHC data relevant to the Higgs to di-photon channel, as well as to neutral Drell-Yan lepton-pair production.

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Spin correlations in the PanScales parton showers and jet observables

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In this talk, I will describe the adaptation of the well-known Collins-Knowles spin-correlation algorithm to the PanScales dipole and antenna showers. Furthermore, I discuss several spin-sensitive observables, such as a Lund-declustering based azimuthal measure and the 3-point energy correlator that was resummed recently by Chen, Moult and Zhu. The Collins-Knowles algorithm implementation in the PanScales showers is validated by comparing with leading order matrix elements at fixed order. Validation at all orders proceeds through the application of a number of novel numerical techniques, which allows us to run the PanScales showers up to extremely small scales, isolating the single-logarithmic collinear terms. The predictions for the spin-sensitive observables are compared with analytic resummation, as well as with the MicroJets collinear resummation code, extended to also include spin correlations. Finally, I comment on the potential phenomenological applications of these observables.

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Non-global Logarithms Beyond Leading Colour

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High-precision all-order calculations can only be performed for a narrow class of observables, which are sensitive to radiation over the entire final state phase-space. When phase-space boundaries are introduced, the resummation is affected by so-called non-global logarithms, which have an intricate all-order structure. In this talk, we present a first-principle calculation for the leading-order non-global logarithms in large-N_c limit, and some improvements for higher-order and resummed results are proposed with artificial neural networks, which can dramatically speed up needed theory calculations. And the impact of the finite-N_c corrections is discussed in the end.

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Subleading colour effects in the PanScales parton showers and beyond

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It is known that standard dipole showers yield incorrect subleading-colour contributions already at leading-logarithmic level for certain observables. In this talk, I will present two new, simple

prescriptions to palliate this issue. I will show how the resulting colour-corrected matrix elements are cured at fixed order in the appropriate limits. I will then demonstrate how the two algorithms allow us to achieve full-colour next-to-leading logarithmic accuracy for various observables (global observables and multiplicities). I will conclude by commenting on the comparison to full-colour NLL-resummed results for non-global observables.

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Parton-Shower Effects in Higgs Production via Vector-Boson Fusion

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We present a systematic investigation of parton-shower and matching uncertainties of perturbative origin for Higgs-boson production via vector-boson fusion. To this end we employ different generators at next-to-leading order QCD accuracy matched with shower Monte Carlo programs, `PYTHIA8`, and `HERWIG7`, a next-to-next-to-leading order QCD calculation.
We thoroughly analyse the intrinsic sources of uncertainty within each generator, and then compare predictions among the different tools using the respective recommended setups. Within typical vector-boson fusion cuts, the resulting uncertainties on observables that are accurate to next-to-leading order are at the $10 We further more show how a specific recoil scheme is needed when PYTHIA8 is employed, in order
We conclude that for vector-boson fusion processes an assessment of the uncertainties associated with an NLO+
PS simulation at next-to-leading order matched to parton showers based only on the variation of renormalisation, factor$

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Quenching effects in the jet spectrum at various cone sizes

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The strong suppression of high-pT jets in heavy-ion collisions is a result of elastic and inelastic energy loss, suffered by the jet multi-prong collection of color charges that are resolved by medium interactions. We develop a novel analytic framework to study the quenched jet spectrum in which we include many energy-loss-related effects, such as resummation of soft and hard medium induced emissions, broadening, elastic scattering, jet fragmentation, cone size, coherence effects, etc. We present the first predictions for the nuclear modification factor and the quantile procedure with cone size dependence. We compare dijet and boson+jet events to unfold the spectrum bias effects and improve quark-, and gluon-jet classification in heavy-ion jets. Besides pointing out its flexibility, we show our formalism relevance in pp jets modeling non-perturbative effects.

The talk is based on arXiv:2101.01742 and arXiv:2103.14676

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Groomed jet mass as a direct probe of collinear parton dynamics

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Jet grooming techniques have proved efficient in mitigating hadronization and pile-up effects in jet observable measurements at the LHC. We study the link between parton dynamics in the collinear limit and the logarithmically enhanced terms of the groomed jet mass distribution, for jets groomed with the modified mass-drop tagger (mMDT). While the leading-logarithmic (LL) result is linked to collinear evolution with leading-order splitting kernels, here we derive the NLL structure directly from triple-collinear splitting kernels. The calculation we present is a fixed-order calculation in the triple-collinear limit, independent of resummation ingredients and methods. It therefore constitutes a powerful cross-check of the NLL results previously derived using the SCET formalism and provides much of the insight needed for resummation within the traditional QCD approach. This work also provides direct insight into the connection between higher-order splitting kernels and NNLL structure of rIRC safe observables, and is part of a larger program to develop new more accurate parton showers.

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Sector showers with fixed-order corrections

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Fixed-order corrections to parton showers often build upon the construction of “shower histories“, accounting for all possible branching sequences to arrive at a given parton configuration. Constructing these histories at high particle multiplicities mandates fairly complex and resource-intensive algorithms.

In this talk, I will introduce the concept of so-called sector showers as implemented in the Vincia antenna shower. Sector showers divide the branching phase space into distinct “sectors”, each of which only receives contributions from a single branching kernel. As a consequence, only a single branching history exists per colour-ordered state.
On the one hand, this allows to assign a unique scale to each parton configuration. On the other hand, it reduces the factorial scaling of the number of contributing histories to an effective linear scaling with the number of final-state particles.
I will discuss how these features can be utilised in efficient matching and merging techniques and present ongoing efforts to include higher-order corrections in Vincia.

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Interplay between perturbative and non-perturbative effects with the ARES method

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We present a new method to compute leading hadronisation corrections to two-jet event shapes in e^+e^- annihilation. Interplay between perturbative and non-perturbative effects is accounted for with the ARES method.

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Evolution of Track functions at order alpha_s^2

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Using the tracking system at the LHC, one can efficiently suppress pile-up contamination and improve angular resolution. Observables that only depend on charged particles (tracks) are not infrared safe in perturbation theory, so any calculation of track-based observables must account for hadronization effects. This can be done by matching the partonic cross section onto perturbative objects that absorb the infrared divergences, called track functions. These track functions describe the energy fraction of a hard parton which is converted into charged hadrons. We demonstrate the validity of the track function approach at order alpha_s^2 by calculating its renormalisation group evolution at this order, using two different approaches: The first uses analytic results for the projected Energy-Energy Correlator to extract the evolution for moments of the track function. The second involves a calculation of a track-based jet function in Soft-Collinear Effective Theory. This result is also an important input for higher-order calculations of track-based observables.

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Next-to-leading power two-loop soft functions for the Drell-Yan process at threshold

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In this talk, I will discuss the two-loop calculation of the bare next-to-leading power soft functions appearing in the Drell-Yan process in the threshold kinematics. These soft functions are the last missing ingredient needed to verify the next-to-leading power Drell-Yan factorization formula to NNLO. I will briefly review the derivation of the bare factorization theorem and introduce the relevant basis of the power suppressed soft functions. The talk will be dedicated to the discussion of the technical

aspects of the calculation. In particular, I will focus on the evaluation of the master integrals using the differential equations method.

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Azimuthal decorrelation in V+jet production with the WTA axis

Authors: Yang-Ting Chien[1]; Rudi Rahn[2]; Solange Schrijnder van Velzen[None]; Dingyu Shao[3]; Wouter Waalewijn[4]; Bin Wu[None]

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The azimuthal decorrelation in vector boson+jet production due to soft and collinear QCD effects can be calculated to high precision by using recoil-free jet axes, such as the Winner-Takes-All (WTA) axis, alongside Soft-Collinear Effective Theory (SCET) methods.
We present theoretical predictions at next-to-next-to-leading logarithmic accuracy for the azimuthal decorrelation, and demonstrate that this result is robust when using charged tracks instead of calorimetry, and in the presence of large backgrounds, due to the features of the WTA axis.
We further find contributions to the process from linearly-polarised gluon transverse momentum distributions (arising from spin superposition effects of a single incoming or outgoing parton), in both the initial and final state.

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Automating the calculation of jet and beam functions

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We present a novel framework to streamline the calculation of jet and beam functions to next-to-next-to-leading order in perturbation theory. By exploiting the infrared behavior of the collinear splitting functions, we factorize the singularities with suitable phase-space parametrizations and perform the observable-dependent integrations numerically. We have implemented our approach in the publicly available code PySecDec and present the first results for sample jet and beam functions.

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NLP resummation and the endpoint divergent contribution in DIS

Authors: Leonardo Vernazza[1]; Martin Beneke[2]; Mathias Garny[2]; Sebastian Jaskiewicz[3]; Robert Szafron[4]; Jian Wang[5]

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The off-diagonal parton-scattering channels $g+\gamma^*$ and $q+\phi^*$ in deep-inelastic scattering are power-suppressed near threshold $x \to 1$. In my talk I will discuss the next- to-leading power (NLP) resummation of large double logarithms of $1-x$ to all orders in the strong coupling, which are present even in the off-diagonal DGLAP splitting kernels. The appearance of divergent convolutions prevents the application of factorization methods known from leading power resummation. Employing d-dimensional consistency relations from requiring $1/\epsilon$ pole cancellations in dimensional regularization between momentum regions, I will show that the resummation of the off-diagonal parton-scattering channels at the leading logarithmic order can be bootstrapped from the recently conjectured exponentiation of NLP soft-quark Sudakov logarithms. In particular, I will illustrate how the result for the DGLAP kernel in terms of the series of Bernoulli numbers found previously by Vogt can be derived directly from algebraic all-order expressions. I will show that the off-diagonal DGLAP splitting functions and soft-quark Sudakov logarithms can be identified as inherent two-scale quantities in the large-x limit. I will conclude by showing that the conjectured soft-quark Sudakov exponentiation formula can be derived in the context of a refactorization of these scales and renormalization group methods inspired by soft-collinear effective theory.

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The parton branching method for TMDs in Monte Carlo calculations

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The parton branching (PB) method is recently developed for the evolution of transverse momentum dependent (TMD) parton distributions to be used within Monte Carlo calculations. With PB TMDs, soft-gluon resummation is fulfilled and a mismatch in the treatment of transverse momentum in MC event generators can be avoided. In this talk I show PB TMD results for Drell-Yan transverse momentum spectra and present a comparison with results from the CSS analytical resummation approach obtained via the program reSolve.

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Groomed jet mass as a direct probe of collinear parton dynamics

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Dynamical grooming

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Semi-analytic resummation in the Sherpa framework

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Next-to-leading non-global logarithms in QCD

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Non-global Logarithms Beyond Leading Colour

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Interplay between perturbative and non-perturbative effects with the ARES method

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Electroweak corrections and multijet merging

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Boosted Higgs Production in Vector Boson Fusion

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Parton-Shower Effects in Higgs Production via Vector-Boson Fusion

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Spin correlations in the PanScales parton showers and jet observables

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Subleading colour effects in the PanScales parton showers and beyond

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Sector showers with fixed-order corrections

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The PanScale shower approach

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Improved dipole showers

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Subleading effect in parton showers

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The Geneva framework

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qT subtraction/resummation at N3LO/N3LL

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Transverse momentum resummation on the azimuthal spectra of the final leptons in the Drell-Yan processes

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Fiducial Higgs and Drell-Yan distributions at N3LL'+NNLO with RadISH

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Azimuthal decorrelation in V+jet production with the WTA axis

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kT factorisation and TMDs

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The parton branching method for TMDs in Monte Carlo calculations

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NLP resummation and the endpoint divergent contribution in DIS

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The role of NLP threshold corrections in dQCD and SCET

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