ENP: Exploring New Physics

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The research activity carried out within the ENP project deals with the phenomenology of particle physics at present and future colliders. In particular, we performed precision tests of the Standard Model (SM), in both electroweak and strong sectors, as well as investigation of signals of physics beyond the Standard Model at the LHC and future accelerators.

- We studied the so-called 331 model, based on a $SU(3)_C \times SU(3)_L \times U(1)_X$ gauge symmetry, whose striking feature is the prediction of doubly-charged vectors and scalars, so-called bileptons, with lepton number $L = \pm 2$, as well as exotic quarks, with charge 4/3 or 5/3. In particular, we investigated hadronic decays of vector bileptons, i.e. in pairs of an exotic and a Standard Model quark, and found that they can give a detectable signal at a future 100 TeV hadron collider (FCC-hh), while the LHC statistics are too low, even in the high-luminosity phase [1].

  We reconsidered past work on the fragmentation of bottom quarks in top-quark decays $t \to bW$, whose state of the art is next-to-next-to-leading order (NLO) in QCD, provided with soft and collinear resummation in the next-to-leading-logarithmic (NLL) approximation, with the goal to extend it NNLL and explore the impact of the higher-order corrections on the top-mass determination. Furthermore, we addressed the long-standing issue of the interpretation of the top-quark mass measurements, based on Monte Carlo simulations, in terms of well-posed field-theory definitions like the pole mass. For this purpose, a possible strategy consists in simulating fictitious top-flavoured hadrons and compare final-state distributions, such as the b-jet+lepton invariant mass in the dilepton channel, with those obtained from the simulation of standard top events, wherein the top quark decays before hadronizing. The advantage of this method is that the so-called Monte Carlo mass is a hadron mass, which can be related to any field-theory definition, such as the pole mass, by means of lattice or Non Relativistic QCD.

  We also worked on a review paper on heavy-quark fragmentation, taking particular care about bottom- and charm-quark production in electron-positron annihilation and the inclusion of non-perturbative corrections by means of phenomenological parameter-dependent models or by an effective strong coupling constant [2].

  (G. Corcella and D. Sengupta)

- We worked on improving the accuracy of the Balitsky–Fadin–Kurayev–Lipatov (BFKL) equation to NNLL accuracy by calculating the one-loop central emission vertex (CEV) for two gluons which are not strongly ordered in rapidity. The computation was undertaken in the next-to-multi-Regge kinematic (NMRK) and it was shown that the colour structure and the kinematic dependence capture much of the complexity of the six-gluon amplitudes in general kinematics [3].

  Still on higher-order computations, it was calculated the tree-level current for the emission of a soft quark-antiquark pair in association with a gluon, the last missing ingredient to understand the infrared behaviour of NNNLO amplitudes. Besides, collinear splitting amplitudes in the triple-soft limit were computed and a factorization formula was derived [4].

Furthermore, we calculated QCD corrections to the Higgs transverse momentum distribution in Higgs production in association with a jet via gluon fusion at the LHC, accounting for the exact dependence on the mass of the quark circulating in the heavy-quark loops and for both bottom and top quarks. Besides the usual on-shell mass scheme, for the first time a running mass was implemented in the computation [5].

(V. Del Duca)

The main achievements of the members of the ENP team are summarized in the following publications:

1. G. Corcella, C. Corianò, A. Costantini and P.H. Frampton, 'Non-leptonic decays of bileptons', Phys. Lett. B826 (2022) 136904.

2. G. Corcella, 'Selected results in heavy-quark fragmentation', Universe 8 (2022) 9.

3. E.M. Byrne, V. Del Duca, L.J. Dixon, E. Gardi and J.M. Smillie, 'One-loop central-emission vertex for two gluons in $\mathcal{N} = 4$ super Yang–Mills theory', JHEP 08 (2022) 271.

4. V. Del Duca, C. Duhr, R. Haindl and Z. Liu, 'Tree-level soft emission of a quark pair in association with a gluon', JHEP 01 (2023) 040.

5. R. Bonciani, V. Del Duca, H. Frellesvig, M. Hidding and V. Hirschi, 'Next-to-leading-order QCD corrections to Higgs production in association with a jet', e-Print: 2206.10490 [hep-ph].