ENP: Exploring New Physics

G. Corcella (Resp.), E. Bagnaschi, V. Del Duca, D. Sengupta (Ass. Cabibbo)

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 investigated the possibility that light new physics in the top-quark sample at the LHC can be found by employing well known kinematical distributions like the invariant mass b-jet+lepton (m_{bl}) in the dilepton channel of $t\bar{t}$ events. In particular, we demonstrated that new physics can be probed in the rising part of the m_{bl} spectrum and, as a case study, we considered a supersymmetric scenario with light stops, charginos and neutralinos. The conclusion of Ref. [1] is that one should recast public data on searches for new physics and identify models that are not yet excluded.
- We contributed to the ATLAS analysis [2] on the top mass measurement in the dilepton channel by using the $m_{l\mu}$ distribution, where l is a lepton from W in $t \to bW$ decay and μ is a muon from a B-hadron decay. The measured value of the top-quark mass is $m_t = 174.41 \pm 0.39$ (stat.) $\pm\, 0.66$ (syst.) $\pm\, 0.25$ (recoil) GeV, where the third uncertainty arises from changing the PYTHIA Monte Carlo parton shower gluon-recoil scheme.
- We delivered a new code for Higgs boson pair production at NLO in the POWHEG Monte Carlo framework, based on analytic results for the two-loop virtual corrections, including full top-mass dependence. We studied the uncertainties due to the top-mass renormalization scheme, allowing the trilinear Higgs self coupling to vary around its Standard Model value and including parton shower effects. The results were obtained for both inclusive and differential observables [3].
- One of the most important mechanisms of production of the pseudoscalar Higgs in the MSSM is the loop-induced gluon fusion $gg \to A$, which exhibits large NLO SUSY-QCD corrections, computed in the past in large-mass approximation. We re-calculated such corrections with full mass dependence and treated the effective top and bottom Yukawa couplings in terms of effective low-energy theories, where the heavy degrees of freedom are decoupled. The results were also applied to the decays of A into gluon or photon pairs at NLO [4].
- Still on supersymmetry, models with low electroweak fine-tuning are expected to be more prevalent on the string landscape than fine-tuned models. Such models are characterized by light Higgsinos in the $\mathcal{O}$ (1 GeV) range and top squarks about 1–2.5 TeV, with large trilinear soft terms. We evaluated the prospects for top squark discovery at HL-LHC in this scenario and found a 5σ reach out to a stop mass $m_{\tilde{t}_1} \simeq 1.65$ TeV and a 95% CL exclusion reach to $m_{\tilde{t}_1} \simeq 1.95$ TeV [5].
- We computed the tree-level current for the emission of a soft quark-antiquark pair in association with a gluon, which is the last missing ingredient in NNNLO QCD computations and allows one to understand colour correlations induced by the soft emission of a quark pair and a gluon. We also studied the behaviour of collinear splitting amplitudes in the triple-soft approximation, and obtained the corresponding factorization formula [6].

- We calculated QCD corrections to the Higgs transverse momentum distribution for production in association with a jet in gluon fusion. The exact dependence on the mass of the quark circulating in the loops was taken into account for both bottom and top quarks. Besides the usual on-shell mass scheme, a running mass was implemented in the computation [7].

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

[1] E. Bagnaschi, G. Corcella, R. Franceschini and D. Sengupta, e-Print: 2312.09794 [hep-ph], submitted to Phys. Rev. Lett.

[2] G. Corcella and ATLAS Collaboration, 'Measurement of the top-quark mass using a leptonic invariant mass in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector', JHEP 06 (2023) 019.

[3] E. Bagnaschi, G. Degrassi and R. Gröber, 'Higgs boson pair production at NLO in the POWHEG approach and the top quark mass uncertainties', Eur. Phys. J. C83 (2023) 1054.

[4] E. Bagnaschi, L. Fritz, S. Lieber, M. Mühlleitner and T.T.D. Nguyen, 'Pseudoscalar MSSM Higgs Production at NLO SUSY-QCD', JHEP 03 (2023) 124.

[5] H. Baer, V. Barger, J. Dutta and D. Sengupta, 'Top squarks from the landscape at high luminosity LHC', Phys. Rev. D108 (2023) 075027.

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

[7] 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', Phys. Lett. B843 (2023) 137995.