PROCEEDINGS OF SCIENCE

Higgs production at NLL accuracy in the BFKL approach

Francesco Giovanni Celiberto,[a,*] **Luigi Delle Rose,**[b,c] **Michael Fucilla,**[d] **Gabriele Gatto,**[b,c] **Dmitry Yu. Ivanov,**[e] **Mohammed M. A. Mohammed**[b,c] **and Alessandro Papa**[b,c]

[a] *Universidad de Alcalá (UAH), Departamento de Física y Matemáticas, Campus Universitario, Alcalá de Henares, E-28805, Madrid, Spain*

[b] *Dipartimento di Fisica, Università della Calabria, Arcavacata di Rende, I-87036, Cosenza, Italy*

[c] *INFN, Gruppo Collegato di Cosenza, Arcavacata di Rende, I-87036, Cosenza, Italy*

[d] *Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405, Orsay, France*

[e] *Sobolev Institute of Mathematics, 630090 Novosibirsk, Russia*

E-mail: `francesco.celiberto@uah.es`, `luigi.dellerose@unical.it`, `michael.fucilla@ijclab.in2p3.fr`, `gabriele.gatto@unical.it`, `d-ivanov@math.nsc.ru`, `mohammed.maher@unical.it`, `alessandro.papa@fis.unical.it`

Precision physics in the Higgs sector has been one of the main challenges of particle physics in the recent years. The pure fixed-order calculations entering the collinear factorization framework, which have been pushed up to next-cube-leading-order, are not able to describe the entire kinematic spectrum. In particular sectors, they have to be necessarily enhanced by all-order resummations. In the so-called semi-hard regime, large energy-type logarithms spoil the perturbative convergence of the series and must be resummed to all orders. This resummation is a core ingredient for a correct description of the inclusive hadroproduction of a forward Higgs boson in the limit of small Bjorken x, as well as for a precision study of inclusive forward emissions of a Higgs boson in association with a backward identified object. A complete resummation for these processes can be achieved at the at next-to-leading logarithmic accuracy thanks to the Balitsky–Fadin–Kuraev–Lipatov approach. In the present work we present and discuss a series of recent phenomenological results within a partial next-to-leading accuracy. They include the analysis of rapidity and azimuthal-angle differential rates for Higgs plus jet and Higgs plus charm reactions in forward and ultraforward directions of rapidity at the LHC.

31st International Workshop on Deep Inelastic Scattering (DIS2024)
8–12 April 2024
Grenoble, France

PoS(DIS2024)101

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[*] Speaker

1. Hors d'œuvre

The *all-order* resummation of high-energy logarithms represents a valuable tool for a precise description of semi-inclusive Higgs-production rates at the LHC as well as the future FCC. In the *semi-hard* regime of QCD, the stringent scale order, $\sqrt{s} \gg \{\mu_i\} \gg \Lambda_{\rm QCD}$, with $\{\mu_i\}$ being a set of process-characteristic hard scales and $\sqrt{s}$ standing for the center-of-mass energy, heightens the weight of energy logarithms. The Balitsky–Fadin–Kuraev–Lipatov (BFKL) approach [1–3] offers us a powerful way to resum those logarithms at the leading-logarithmic (LL) and next-to-leading logarithmic (NLL) level. It also allows us to probe the gluon content of the proton at low x [4–16]. Semi-inclusive hadroproductions of two particles tagged with large transverse masses and a high rapidity separation, ΔY, stand as a promising testing ground of high-energy QCD. To study these two-particle processes, a *multilateral* factorization, where both high-energy and collinear dynamics come into play, is needed. To this scope, a *hybrid* factorization formalism (HyF) was developed [17, 18] (see also [19–21] for single-particle detections). HyF cross sections feature a transverse-momentum convolution of the universal BFKL Green's function with two process-related impact factors. The latters read in turn as a sub-convolution of singly off-shell coefficient functions and collinear parton distributions (PDFs). Phenomenological studies of the HyF formalism within a full or partial NLL accuracy were done through: Mueller–Navelet jet emissions [22–31], Drell–Yan pair [32–35], light [36–43] or heavy-light [44–56] hadron, quarkonium [57–60], and exotic-matter [61–63] detections. In this work we will study the semi-inclusive tag of a forward Higgs boson accompanied by a light-flavored jet [17] (for corresponding next-to-next-to-leading analyses without resummations, or next-to-NLL investigations within the transverse-momentum resummation formalism, see [64, 65] and [66], respectively). We will go with a partial NLL accuracy, which relies upon the NLL Green's function plus leading-order coefficient functions.

2. Higgs production at NLL accuracy

Left panel of Fig. 1 shows the Higgs plus jet hadroproduction rate at 14 TeV, differential in the transverse momentum of the Higgs boson, $|\vec{p}_H|$, and taken at $\Delta Y = 5$. Rapidity ranges are the typical one of CMS or ATLAS studies, with the Higgs boson detected only in the barrel calorimeter ($|y_H| < 2.5$) and the jet reconstructed also by the endcaps ($|y_J| < 4.7$). We observe that, in the BFKL-expected kinematic sector, namely the peak region plus the first part of the distribution tail, where $|\vec{p}_H| \sim |\vec{p}_J|$, resummed predictions are quite stable under energy scale variations, with NLL uncertainty bands (red) almost completely contained inside pure LL ones (blue). This brings clear evidence that the emission of a Higgs boson acts as a *natural stabilizer* of the high-energy resummation [17, 67–69]. Conversely, in the large $|\vec{p}_H|$-tail, NLL BFKL decouples from its LL limit and the corresponding uncertainty band becomes wider and wider with $|\vec{p}_H|$. This happens because, in this kinematic sector, large DGLAP-type as well as *threshold* logarithms, not accounted for by our formalisms, are enhanced. We also note that NLL results are qualitatively close to NLO fixed-order ones from POWHEG [70–72] only in the peak region. This is a clear signal that, to get a precise description of our high-energy observables, a *matching* between the NLL HyF formalism and the NLO background is needed [73–75]. Right panel of Fig. 1 shows the Higgs plus $D^{*\pm}$ NLL azimuthal multiplicity at 14 TeV, for different values of ΔY and with the $D^{*\pm}$ meson detected

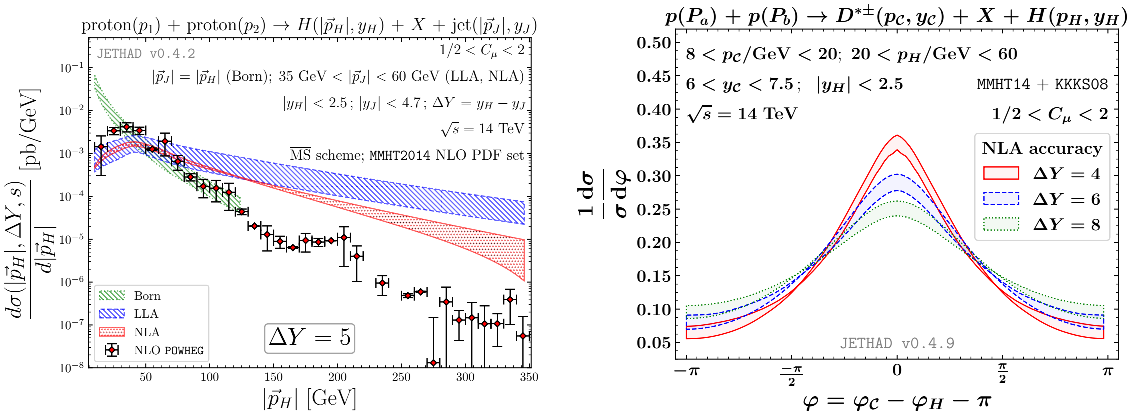

Figure 1: Left panel: Higgs plus jet transverse-momentum spectrum at 14 TeV LHC. Right panel: Higgs plus $D^{*\pm}$ meson angular multiplicity at 14 TeV FPF + ATLAS. Uncertainty bands show $\mu_{R,F}$ variation in the $1 < C_\mu < 2$ range. Text boxes refer to kinematic cuts.

in the ultraforward rapidity directions ($6 < y_C < 7.5$) reachable at the planned Forward Physics Facility [50, 53, 54]. We note that, as ΔY grows, distribution peaks shrink while their widths moderately widen. This is a clear signal of the onset of BFKL dynamics. Indeed, larger and larger values of ΔY heighten the weight of secondary gluons strongly ordered in rapidity, whose effect is caught by the BFKL resummation.

3. Closing statements

We have studied the production of a Higgs boson, accompanied by a jet [17] or a singly charmed hadron [50] in (ultra)forward directions of rapidity at 14 TeV LHC. Future analyses will include: (i) NLO contributions to the Higgs impact factor [76–78], (ii) a *matching* with the fixed-order signal [73–75], and (iii) a phenomenological extension to nominal FCC energies [79, 80].

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