LHeC and FCC-he: Model specific explorations (EF 08)

G. Azuelos, M. D'Onofrio, O. Fischer, for the LHeC/FCC-eh Study Group

I. INTRODUCTION

The LHC was originally envisioned as the ultimate machine to search for physics beyond the Standard Model at the TeV scale. Since electrons and quarks share only electroweak interactions, an electron-proton collider could allow to measure the same phenomena in a different environment with generally higher precision. It could add complementary search channels or lead to the discovery of a weak signal. The possibility of undiscovered New Physics (NP) below the TeV scale could thus be also addressed by the LHeC, to be operated when the LHC will be in its high luminosity phase, and its potential higher energy successor, the FCC-eh.

A most notable and distinctive feature of electron-proton collisions compared to *pp* collisions is the absence of color exchange between the electron and proton beams, which leads to a reduced level of background from SM processes and negligible pileup. The LHeC and FCC-eh colliders will thus provide new opportunities for tests of Beyond the Standard Model physics, with a clean collision environment allowing for detailed and precision studies of many scenarios. Furthermore, the vastly improved parton distribution functions obtained at these colliders will considerably reduce the theoretical uncertainties of BSM signals and SM backgrounds.

II. AIM: FURTHER EXPLORATIONS OF NEW PHYSICS MODELS

Exotic phenomena that can be studied at *ep* colliders have been reviewed, for example, in [1], and reported in various papers. Further studies should be targeted to explore new models and improve existing analyses. Targets of interest are listed below.

- **Extensions of the SM Higgs Sector:** Possible extensions of the Higgs sector have been proposed and can be studied at the *ep* colliders with results often complementary to those of *pp* colliders and other future facilities. Preliminary studies presented in [1] have a large margin for improvements. As an example, further studies should be performed on: modifications of the Top-Higgs interaction; modification of Higgs self-couplings; and on potential exotic decays of the Higgs boson into a pair of light spin-0 particles, of long-lived particles of different nature, or of axions.

- **Searches for supersymmetry:** Several SUSY scenarios might remain still elusive in searches performed at *pp* colliders. Studies performed on weakly-produced SUSY particles could be extended to dedicated searches for sleptons, including tau sleptons. R-parity violating interactions are also particularly interesting in electron-proton collisions, where single superpartners might be produced resonantly, and detected via the corresponding $2 \to 2$ process.

- **Anomalous Gauge Couplings:** Triple gauge boson couplings (TGC) W^+W^-V, $V = \gamma, Z$ are precisely defined in the SM and any significant deviation from the predicted values could indicate new physics. Investigations carried out so far could be extended to more final state events and new techniques based on machine-learning could be used to boost the sensitivity.

- **Theories with heavy resonances and contact interaction:** In recent years, leptoquarks (LQ) have re-gained in theoretical interest, as they have been proposed as a solution to B-anomalies, excesses or deficiencies observed in ratios of branching ratios between different generations. Electron-proton colliders are uniquely sensitive to the detection of LQs, produced cleanly in an s-channel process. If discovered, precision studies of LQ properties could be carried out (e.g. $\ell - q - LQ$ coupling strength, fermion number, spin). Despite the stringent constrains from LHC, some regions of phase space remains unexplored, i.e. if the branching ratio to a charged lepton is small. FCC-eh can extend the reach to LQ of mass of ~ 3 TeV. Furthermore, if LQs exist at masses much higher than the c.o.m energy of the collider, the process can be interpreted as contact interaction. Additional studies at the LHeC and FCC-eh are sought in this proposal.

III. TECHNICAL SUPPORT AND IMPLEMENTATION

Realistic predictions of the exploration by LHeC and FCC-eh of BSM phenomena require a good understanding of theoretical and experimental systematic uncertainties. For high-Q^2 processes, parton-level simulations must account for the proton remnants in the highly asymmetric beam configurations (60 GeV e x 7 TeV p or 60 GeV e x 50 TeV p). Also, the detector must allow for good reconstruction of particles, such as b-jets, in the forward region. Supporting documentation on software relevant for e-p analyses can be found in [2].

[1] P. Agostini *et al.* [LHeC and FCC-he Study Group], [arXiv:2007.14491 [hep-ex]].
[2] https://twiki.cern.ch/twiki/bin/viewauth/LHeC/LHeCFCCehBSM