LHeC and FCC-he: More general explorations (EF 09)

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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. GENERAL CONSIDERATIONS AND AIMS

The ep collider environment offers complementary features compared to the LHC and possible lepton colliders which can be exploited in searches for new particles characterised by non-prompt decays (long-lived). Further studies in addition to the ones performed so far might allow to (1) improve sensitivity in already explored parameters space and scenarios (2) extend to yet to be considered new physics models predicting long-lived particles.

- **The centre of mass energy:** 1.3 and 3.5 TeV for the LHeC and the FCC-he, it is below the LHC's but above most lepton collider energies. BSM particles that are difficult to detect at the LHC (e.g. due to backgrounds) and above the centre-of-mass energy of lepton colliders are therefore natural targets of study, see e.g. the study for heavy sterile neutrinos in ref. [1].

- **Forward detector:** In general, forward processes imply small $|Q^2|$ and target QED and QCD. The forward coverage of the LHeC and FCC-he is up to $\eta < 4.9$ and 5.5, respectively. These are values similar to and exceeding the LHC's forward experiment LHCb and allow studies of QED-like BSM [2]. Moreover, downstream detectors measure hadron fluxes for QCD and luminosity measurements.

- **Particles with long lifetimes:** The recoiling quark and the well controlled electron beam allows for a precise determination of the primary interaction vertex. Together with the absence of pile-up this gives great opportunity in flavor tagging of heavy SM particles, and also to detect long lived BSM particles [3, 4].

- **Lepton flavor:** The initial state having a specific lepton flavor state allows new avenues to new physics that changes lepton flavor. For instance, transitions like $e \to \mu$ or $e \to \tau$ can be well studied due to negligible backgrounds and are complementary to other energy experiments, see e.g. refs. [1, 5]

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 [6].

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