BSM Physics with LHeC and FCC-eh

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The LHeC/FCCeh and PERLE Workshop
Orsay
26/10/22

The Large Hadron-Electron Collider at the HL-LHC

LHeC and FCC-he Study Group

P. Agostini *et al.*, [arXiv:2007.14491 [hep-ex]]

LHeC $E_e = 50$ GeV, $\sqrt{s} \simeq 1.2$ TeV, $\mathcal{L}_{int} = 1$ ab^{-1}, parallel to HL-LHC

FCC-he $E_e = 50$ GeV, $\sqrt{s} \simeq 3.2$ TeV, $\mathcal{L}_{int} = 3$ ab^{-1}, parallel to FCC-hh

The Large Hadron-Electron Collider at the HL-LHC – chapter 8

Beyond the Standard Model studies at *ep*

- **Electron-proton collider** ideal laboratory to study common features of electrons and quarks with EW / VBF production, Leptoquarks, multi-jet final states, forward objects
- **Upside:**
  - Small background (no QCD interaction between e and p)
  - Very low pileup, low trigger thresholds.
- **Downside:** low production rates for new physics processes due to 'small' $\sqrt{s}$
- Increased engagement from theory community in recent years, summarised in "chapter 8" (almost 100 articles).

Here: brief overview over some "post-update" contributions.

Works beyond the CDR update

Searching for charged lepton flavor violation at ep colliders

S. Antusch, A. Hammad and A. Rashed, JHEP **03** (2021), 230 [arXiv:2010.08907 [hep-ph]].

Exotic Higgs decays into displaced jets at the LHeC

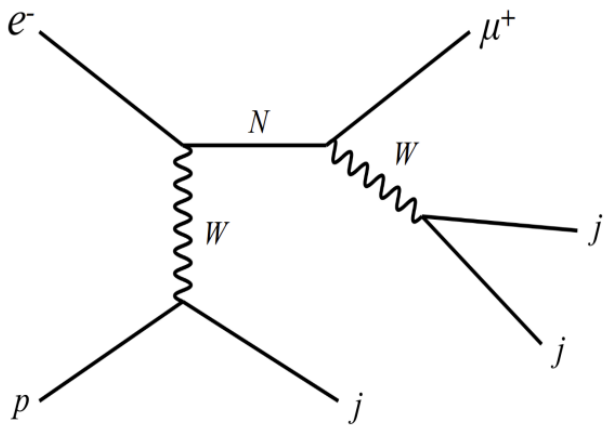
K. Cheung, OF, Z. S. Wang and J. Zurita, JHEP **02** (2021), 161 [arXiv:2008.09614 [hep-ph]].

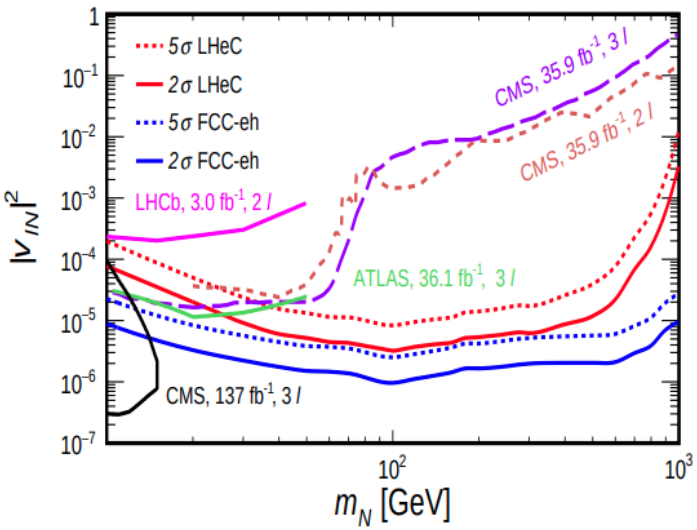
Displaced Neutrino Jets at the LHeC

G. Cottin, OF, S. Mandal, M. Mitra and R. Padhan, JHEP **06** (2022), 168 [arXiv:2104.13578 [hep-ph]].

Search for heavy Majorana neutrinos at ep colliders

H. Gu and K. Wang, Phys. Rev. D **106** (2022) no.1, 015006, [arXiv:2201.12997 [hep-ph]].





- Majorana neutrinos: lepton number violating signatures.
- No SM background at parton level.

cf. Antusch *et al.*, "Sterile neutrino searches at future e^-e^+, pp, and e^-p colliders"

- Analysis at detector level with boosted decition tree.
- Sensitivity similar to lepton-number conserving signatures,

$\Rightarrow$ Background free to excellent approximation.

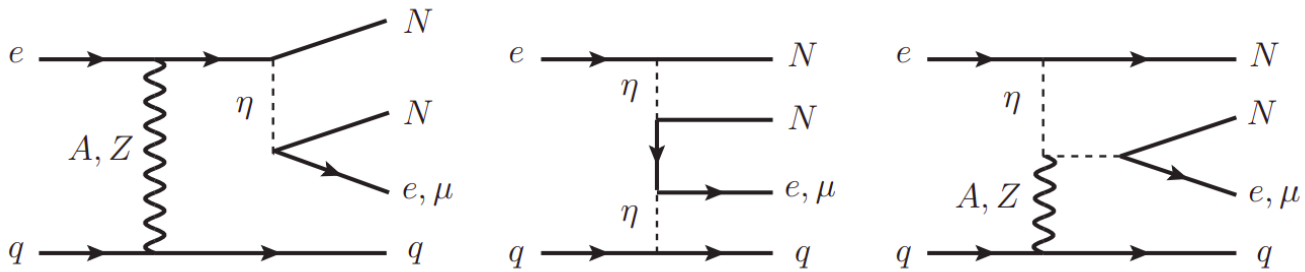
Search for Leptophilic Dark Matter at the LHeC

G. y. Huang, S. Jana, A. S. de Jesus, F. S. Queiroz and W. Rodejohann, [arXiv:2207.01656 [hep-ph]].

- Yukawa-like interaction with dark fermion and dark scalar:

$$\mathcal{L}_Y = y_{N\ell}\eta\bar{N}L_\ell, \qquad \ell = e, \mu$$

- Representative for several models with a dark sector.



- Signals: $ej + E_{miss}$, $\mu j + E_{miss}$, considering backgrounds.

See Farinaldo's talk!

Other recent articles

- A. Jueid, J. Kim, S. Lee and J. Song, **"Studies of nonresonant Higgs pair production at electron-proton colliders,"** [arXiv:2102.12507 [hep-ph]].
- K. Cheung and Z. S. Wang, **"Physics potential of a muon-proton collider,"** [arXiv:2101.10476 [hep-ph]].
- G. D. Kribs, D. McKeen and N. Raj, **"Breaking up the Proton: An Affair with Dark Forces,"** Phys. Rev. Lett. **126** (2021) no.1, 011801 [arXiv:2007.15655 [hep-ph]].
- A. Gutiérrez-Rodríguez, M. A. Hernández-Ruíz, E. Gurkanli, V. Ari and M. Köksal, **"Study on the anomalous quartic $W^+W^-\gamma\gamma$ couplings of electroweak bosons in e^-p collisions at the LHeC and the FCC-he,"** Eur. Phys. J. C **81** (2021) no.3, 210 [arXiv:2005.11509 [hep-ph]].

Conclusions

- BSM in electron-proton generated a lot of interest in the pheno community in recent years.
- Driving factor: complementary to pp and ee colliders.
- Overlap, BSM and precision:
  - ⋆ Top factory!
    (Couplings to γ, Z, W, and FCNC.) interactions.
  - ⋆ Higgs properties.
- Opportunities for BSM that is hidden at the LHC:
  - ⋆ Displaced vertices from long lived particles;
  - ⋆ Lepton flavor violation (electron-tau);
  - ⋆ Not-too-heavy scalars;
  - ⋆ GeV-scale bosons.