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The LHC as a Neutrino-Ion Collider

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Proton-proton collisions at the LHC generate a high-intensity collimated beam of neutrinos in the forward direction, characterized by energies of up to several TeV. The recent observation of LHC neutrinos by FASERν and SND@LHC signals that this hitherto ignored particle beam is now available for scientific inquiry. Here we quantify the impact that neutrino deep-inelastic scattering (DIS) measurements at the LHC would have on the parton distributions (PDFs) of protons and heavy nuclei. We generate projections for DIS structure functions for FASERν and SND@LHC at Run III, as well as for the FASERν2, AdvSND, and FLArE experiments to be hosted at the proposed Forward Physics Facility (FPF) operating concurrently with the High-Luminosity LHC (HL-LHC). We determine that up to one million electron- and muon-neutrino DIS interactions within detector acceptance can be expected by the end of the HL-LHC, covering a kinematic region in x and Q2 overlapping with that of the Electron-Ion Collider. Including these DIS projections into global (n)PDF analyses reveals a significant reduction of PDF uncertainties, in particular for strangeness and the up and down valence PDFs. We show that LHC neutrino data enables improved theoretical predictions for core processes at the HL-LHC, such as Higgs and weak gauge boson production. Our analysis demonstrates that exploiting the LHC neutrino beam effectively provides CERN with a "Neutrino-Ion Collider"without requiring modifications in its accelerator infrastructure.

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