Precision QCD at the LHeC and FCC-eh

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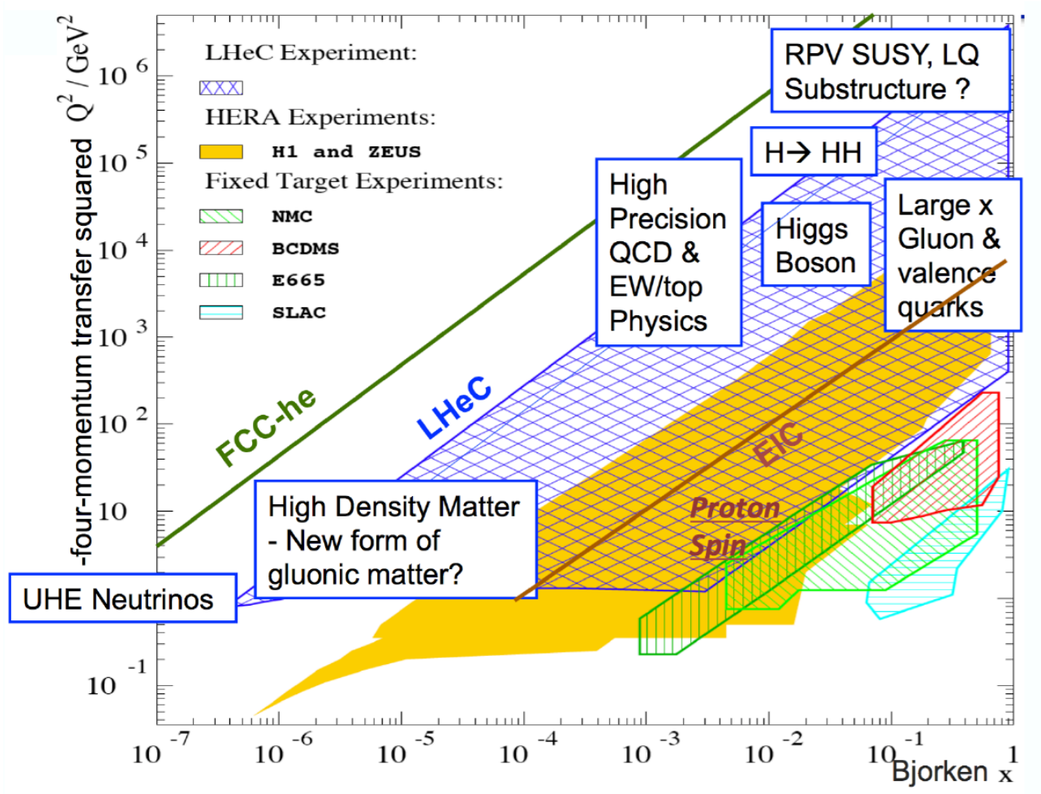
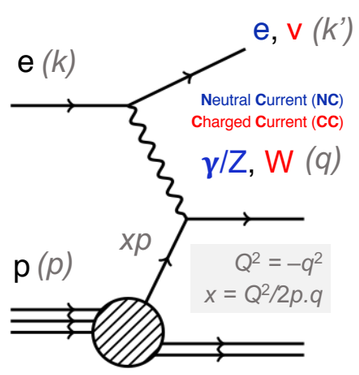
The **L**arge **H**adron-**e**lectron **C**ollider (LHeC) and the **F**uture **C**ircular **C**ollider in electron-hadron mode (FCC-eh) will provide electron-proton collisions with centre-of-mass energies in the range $\sqrt{s}$=1.3–3.5 TeV, and instantaneous luminosities larger than 10^{34} cm^{-2}s^{-1}. This contribution presents new, expected results on the precise determination of proton **P**arton **D**ensity **F**unctions (PDFs) at both small and large x; the study of both NC and CC processes allows a complete flavour decomposition of parton densities in the proton, for the first time. Results on the strong coupling constant, α_s, which could be determined to per mille precision, are also discussed.

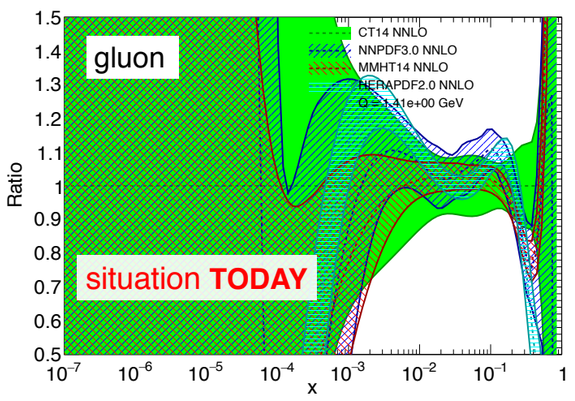
1. LHeC and FCC-eh: Super-Microscopes

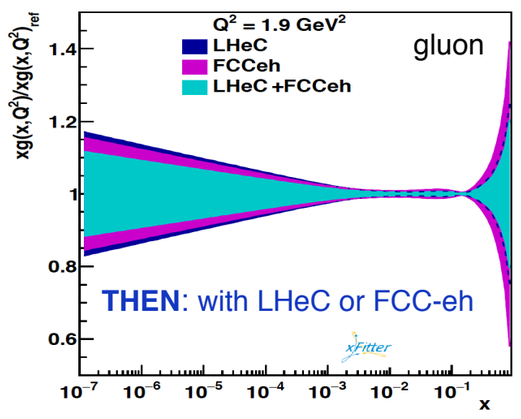


The **LHeC** and **FCC-eh** have unique physics programmes of **D**eep **I**nelastic **S**cattering (DIS), over a hugely extended kinematic reach with respect to HERA. Designed to run concurrently with the HL-LHC or FCC, they have their own unique physics capabilities while, at the same time, transforming the energy frontier machines into high precision facilities, via precise measurements of **proton PDFs** and **α_s**, as well as nuclear, photon and diffractive structure.

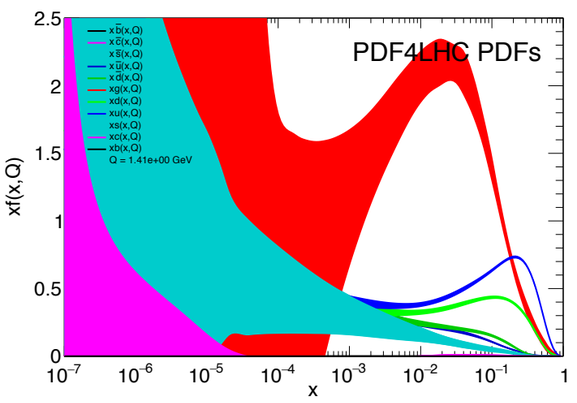


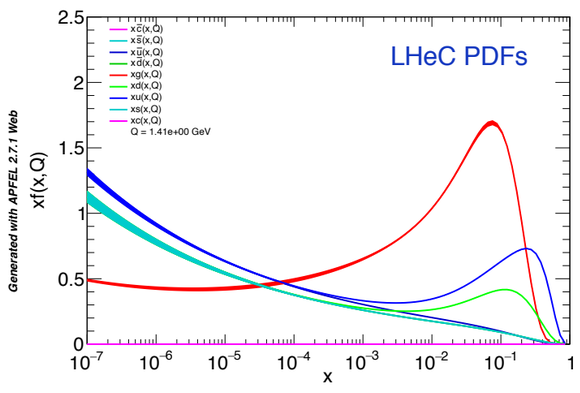
2. Proton PDFs from the LHeC and FCC-eh





The **LHeC** (**FCC-eh**) provides a single, precise and unambiguous dataset:– strongly constraining both **quark** and **gluon** (shown) parton densities at large x (relevant for searches), and at small x below 10^{-5} (10^{-6}), compared to current data which extends down to x≃10^{-4}. The latter will allow exploration of low x QCD (DGLAP vs BFKL, non-linear evolution, gluon saturation; and with impact on ultra high energy CRs).

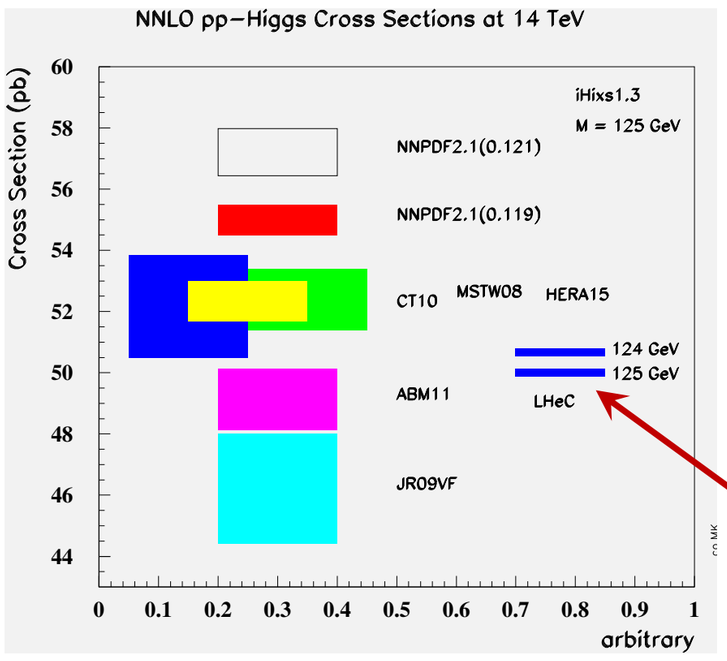


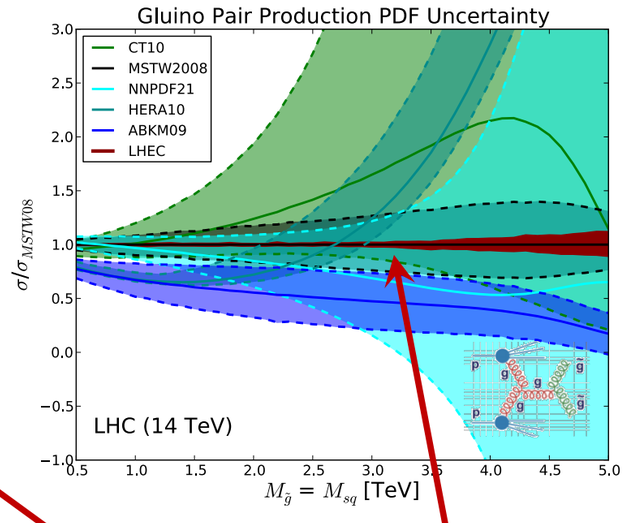


All **parton flavours** can be disentangled, with precise measurements of charm and beauty structure functions, the strange density (via charm tagging in CC), and with direct sensitivity to the top PDF. The **LHeC PDFs** are shown in the Figure above (right), compared to the situation today (left).

[LHeC and FCC-eh PDFs based on new, simulated NC and CC inclusive DIS datasets for latest running scenarios; extracted using xFitter]

3. Impact for the LHC and FCC

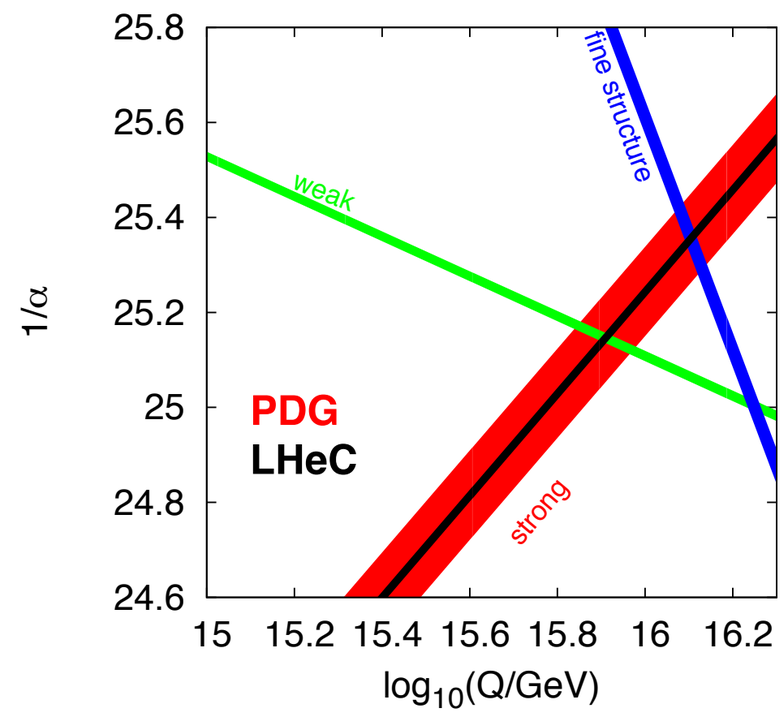




LHeC PDFs

A precise knowledge of **proton structure** is critical for maximising the physics potential of the LHC and future hadron colliders, such as the HE-LHC or FCC. Of particular topical importance are the theory uncertainties on Higgs production (currently dominated by PDFs+α_s), and limitations on searches for new particles at high mass. Two examples are shown in the Figures, indicating the dramatic improvement expected from **LHeC PDFs**. The per mille **α_s** precision expected from the LHeC or FCC-eh (see Box 4) will also feed directly into improved cross section predictions.

4. Strong Coupling (α_s)



α_s is the least well known of the coupling constants, and is critical for precise hadronic cross section predictions, and for constraining GUT scenarios. With the LHeC, **per mille precision** on **α_s** can be achieved, to N^{3}LO, from QCD analysis of NC and CC inclusive DIS data. LHeC jet data can also provide further constraints. Such ultra-high precision is necessary to challenge lattice QCD calculations.

http://lhec.web.cern.ch

LHeC CDR: "A Large Hadron Electron Collider at CERN": Report on the Physics and Design Concepts for Machine and Detector, LHeC Study Group, arXiv:1206.2913v2 [physics.acc-ph]
other references: arXiv:1211.4831, arXiv:1211.5102, arXiv:1305.2090