LHeC and Improved **PDF determinations** for the **Nucleon** and **Deuteron**

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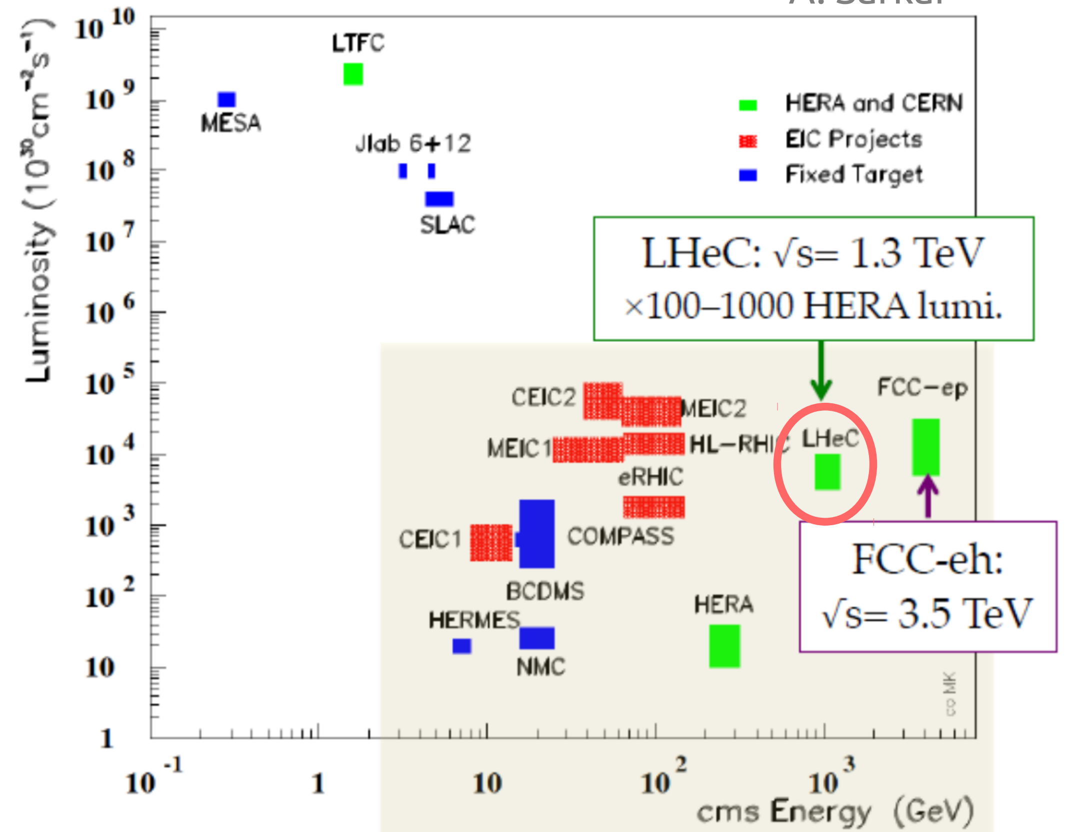
PDFs and Low x at LHeC / FCC-he — **CERN** — **November 15th 2017**

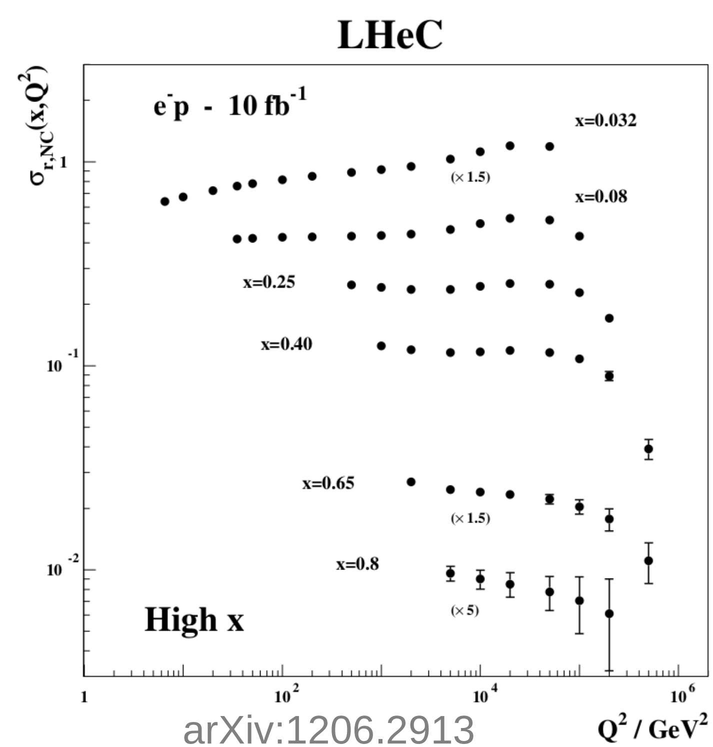
LHeC promises ~$10^2 - 10^3$ enhancements over HERA **luminosities**

- the corresponding increase in statistics will allow precise PDF extractions and SM predictions



→ will drive *sharp* improvements in PDF relative uncertainties, e.g., for low-x **gluon** :

$$\delta^{rel.}[xg(x,\mu^2 = 1.9\,\mathrm{GeV}^2)]$$



arXiv:1206.2913

- in particular, we will move closer to **parametrization independent determinations of proton PDFs**, i.e., weak dependence on starting-scale choices like

$$x f_a(x, Q_0) = x^{a_1}(1-x)^{a_2} P_a(x) \longrightarrow \text{[Bernstein polynomial]}$$

T.J. Hou et al., Phys. Rev. D95 (2017), 034003.

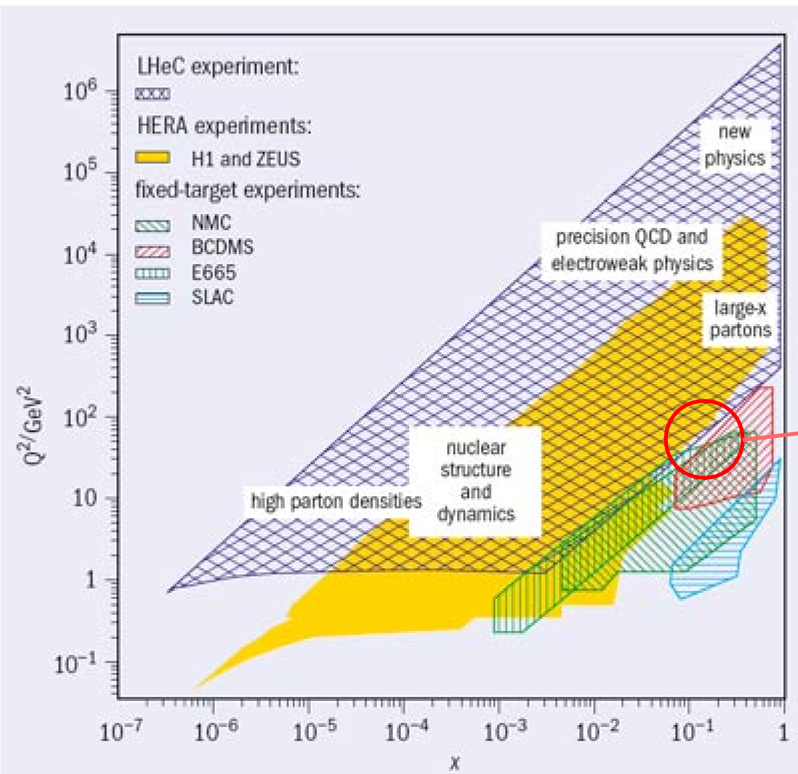
this greatly enhanced precision will unlock physics $\lesssim 1\%$ effects

- e.g., may help settle the **intrinsic heavy quarks** question (esp. charm) :

$$c(x, Q^2 = m_c^2) \stackrel{?}{\neq} \bar{c}(x, Q^2 = m_c^2) \stackrel{?}{\neq} 0$$

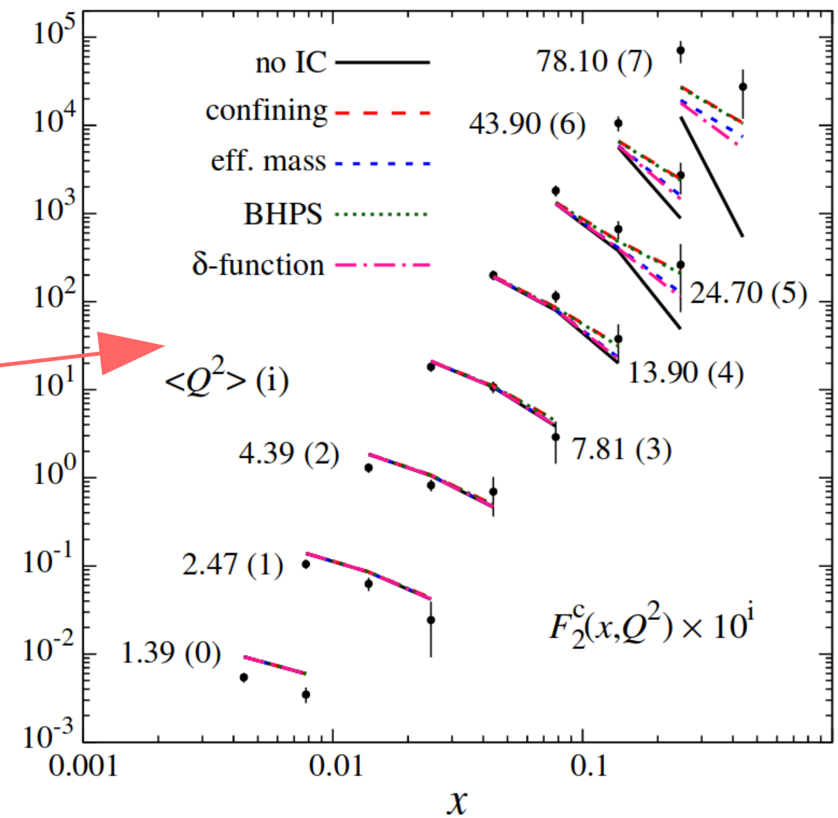
→ canonically, a valencelike *excess* at high x, and intermediate Q^2 in $F_2^c(x, Q^2)$

- while targeted at low x, LHeC can access the high x region, albeit at $Q^2 \gtrsim 100\, GeV^2$



M. Klein & P. Newman, CERN Courier, April 2009.

P. Jimenez-Delgado, TJH, J. T. Londergan, and W. Melnitchouk, PRL**114**, 082002 (2015).



- ultimately, evolution couples high x/low Q^2 ↔ low x/high Q^2 !

→ **high precision data, even at low x could be decisive in global analyses**

these improvements can be extended to the deuteron/light nuclei

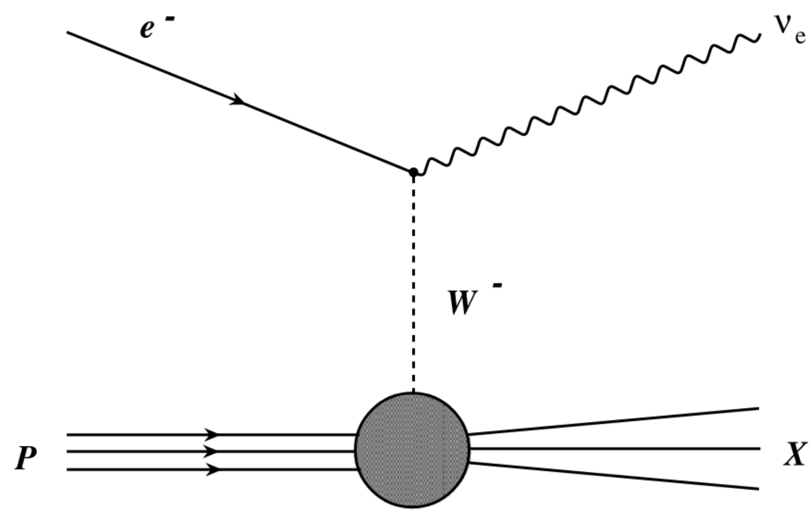
- the deuteron system is rich in still-untangled QCD dynamics (both partonic and nuclear)

  → natural place to look for parton-level **charge symmetry violation** (CSV) :

$$P_{cs} = e^{i\pi T_2} \quad : \quad P_{cs}|u\rangle = -|d\rangle; \quad P_{cs}|d\rangle = |u\rangle$$

TJH, Londergan, Murdock and Thomas, Phys. Lett. B698 (2011), 123.

- given the deuteron's isoscalarity, CSV would be observable in **CC e±D scattering**!



$$R^-(x) \equiv \frac{2(F_2^{W^-D}(x) - F_2^{W^+D}(x))}{F_2^{W^-p}(x) + F_2^{W^+p}(x)}$$

↓ quark-parton model

$$R^-(x) = \frac{x[-2s^-(x) + \delta u^-(x) - \delta d^-(x)]}{x[u^+(x) + d^+(x) + s^+(x) + 2c(x)]}$$

$$\delta u^-(x) = u_p^-(x) - d_n^-(x)$$

- wave function and dynamical effects generate $\delta u^-(x),\ \delta d^-(x) \neq 0$
  - electromagnetic effects: photon distribution; $e_u \neq e_d$
  - mass effects: $\delta\tilde{m} = m_{dd} - m_{uu} \sim 4\,\mathrm{MeV} \neq 0$

the evolution properties of CSV PDFs in R^- grow it at larger Q^2

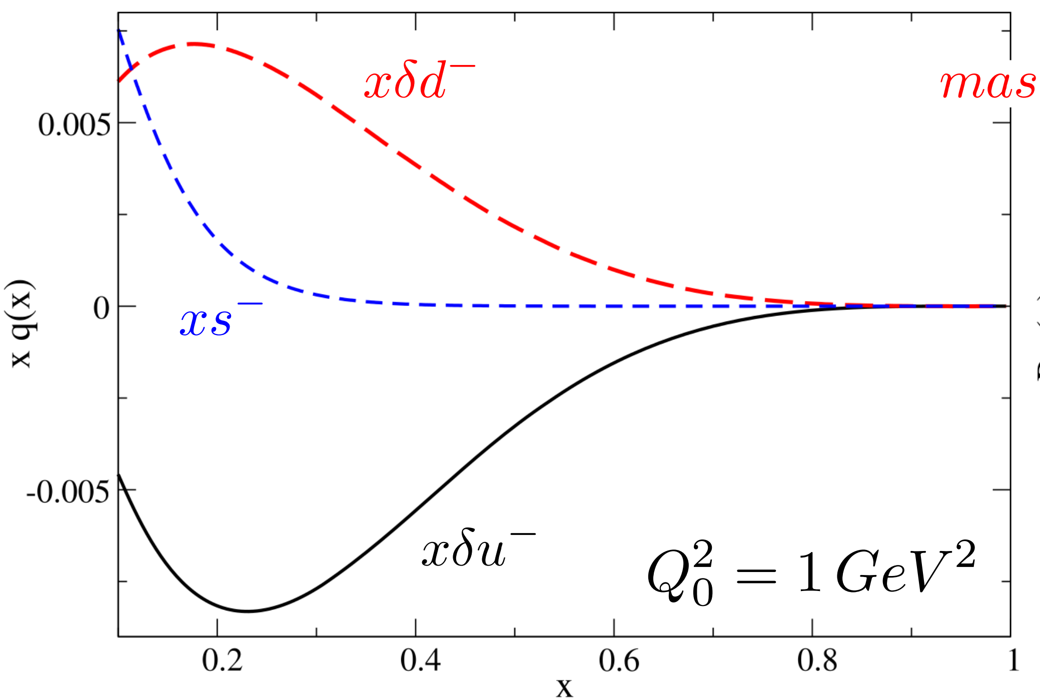
- for coupled QCD-QED DGLAP equations, the α_s contributions largely cancel in the CSV PDFs

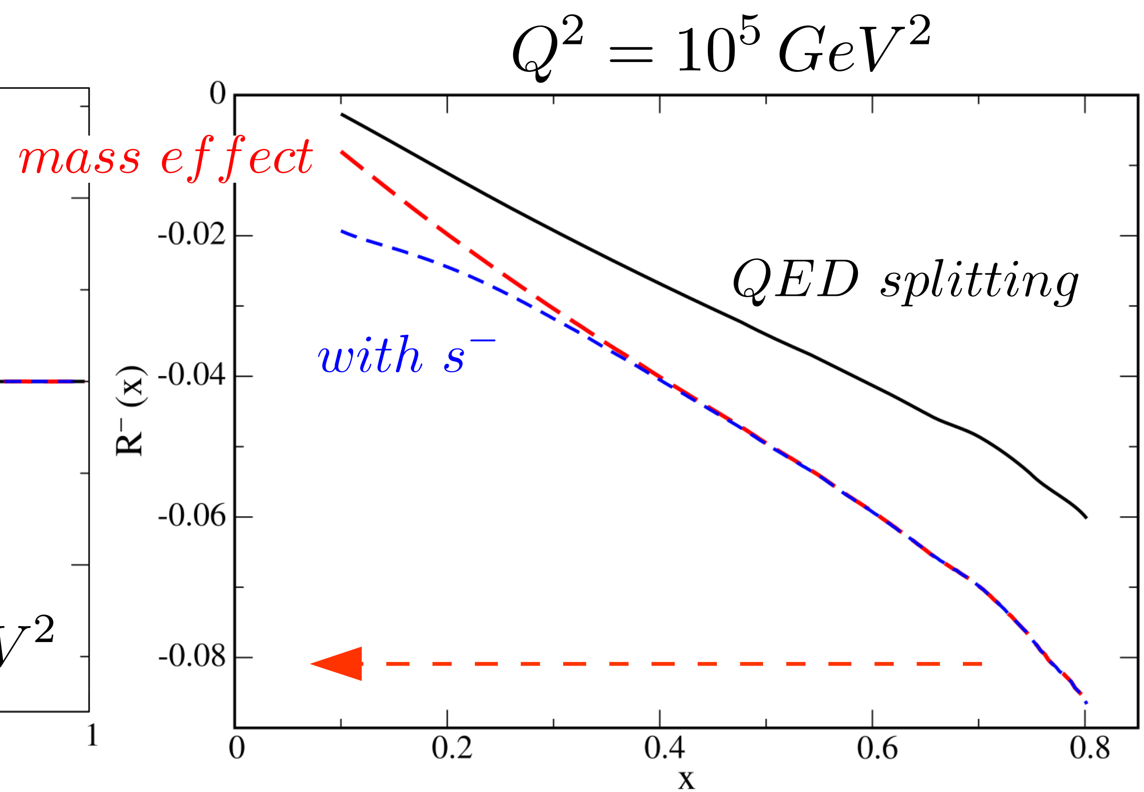
coupled QCD – QED evolution

singlet denom. $\sim \quad \dfrac{\partial q_i(x,\mu^2)}{\partial \ln \mu^2} = \dfrac{\alpha_s}{2\pi}\left[P_{qq}\otimes q_i + P_{qg}\otimes g\right] + \dfrac{\alpha}{2\pi} e_i^2 \widetilde{P}_{qq}\otimes q_i$

QED evolution

NS CSV numer. $\sim \quad \dfrac{\partial[\delta u^-(x,\mu^2)]}{\partial \ln \mu^2} \approx \dfrac{\alpha}{2\pi}(e_u^2 - e_d^2)\widetilde{P}_{qq}\otimes u^-$





- a < 1% effect in the appropriate observable can become a ~5 – 10% effect at high Q^2 !

challenges and opportunities

- LHeC will provide unprecedented access to nucleon and nuclear PDFs with **high precision**
  - on the one hand, sources of uncertainty like PDF/model errors in global analyses will be radically reduced
  - at the same time, there will be an increased need for improved theoretical technology (e.g., pQCD corrections, low x resummation) to aid PDF extractions

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- for the proton, we have the prospect of resolving long-standing ambiguities in the structure function (**heavy quark contributions**; strangeness)
  - understanding the possibilities requires a detailed analysis of the putative LHeC data's sensitivity to PDFs (in progress!)

- similarly, for the deuteron, new insights can be made regarding parton-level operations like **charge symmetry**
  - this would aid knowledge of the nucleon's **photon content** and flavor structure (e.g., **down quark** PDF), with a reciprocal benefit to the proton