LHeC Physics Case for Positrons

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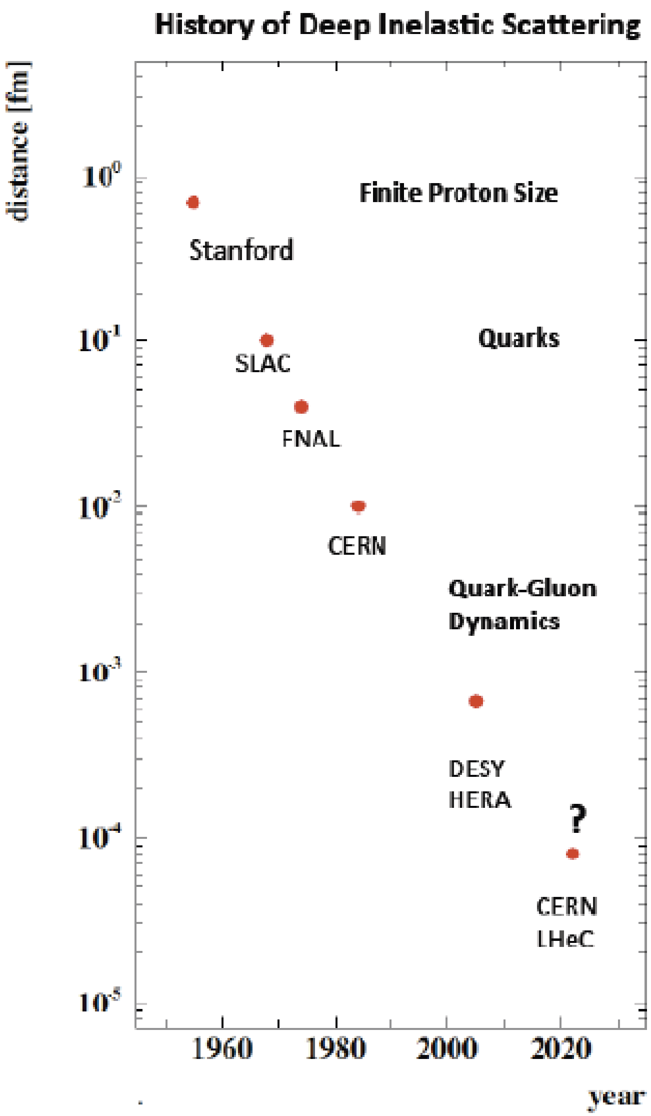
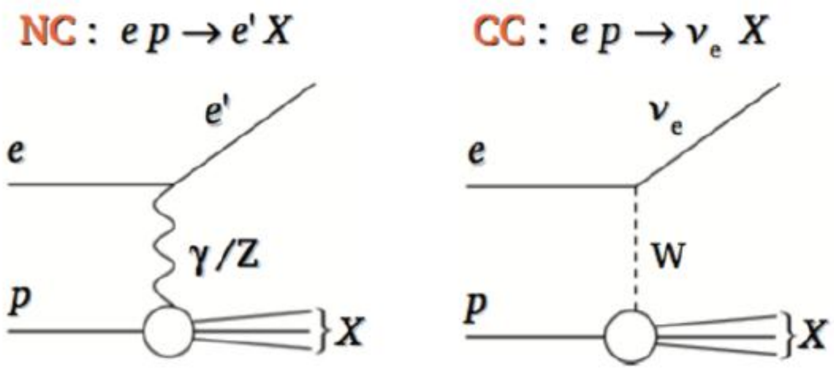
(with many thanks to Max Klein, University of Liverpool and the LHeC study group)

Introduction to LHeC Physics



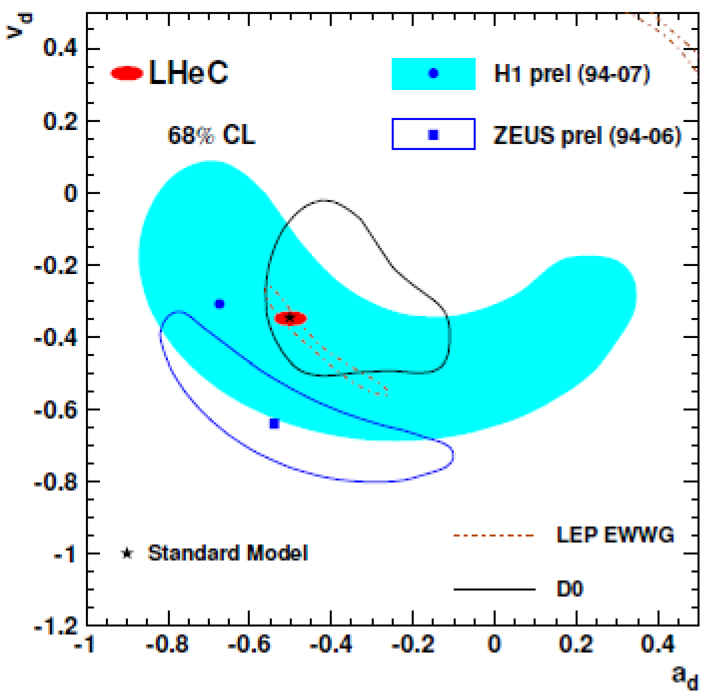


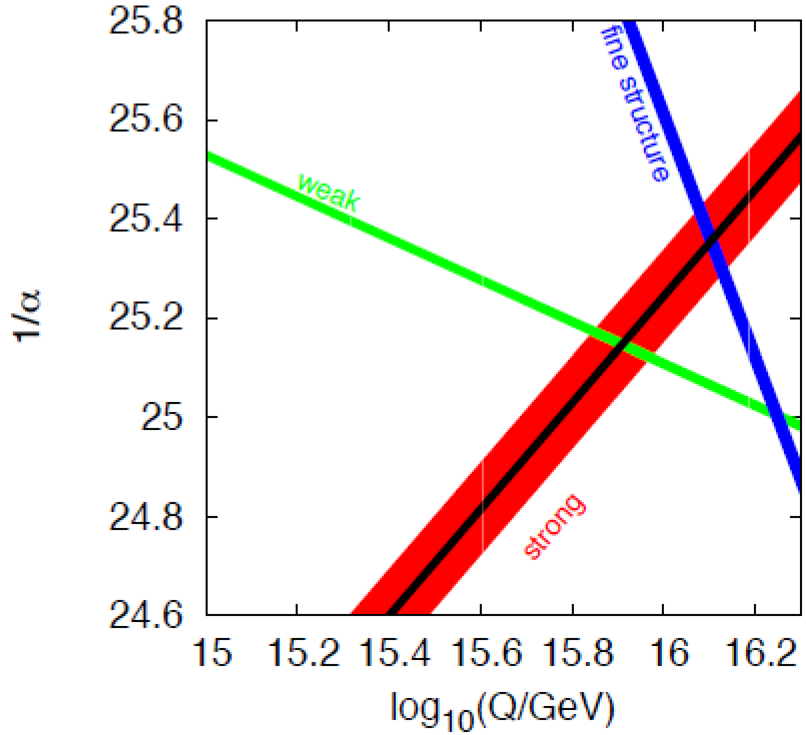
ep physics goals:

- Nucleon parton density functions / QCD
  - E.g. quark/gluon composition of proton as a function of Q^2 and x
- New physics
  - E.g. Higgs quantum numbers, leptoquarks, R-parity violating SUSY...
- Strong / electroweak precision measurements
  - E.g. $\Delta\alpha_s(M_Z^2)$~0.1%

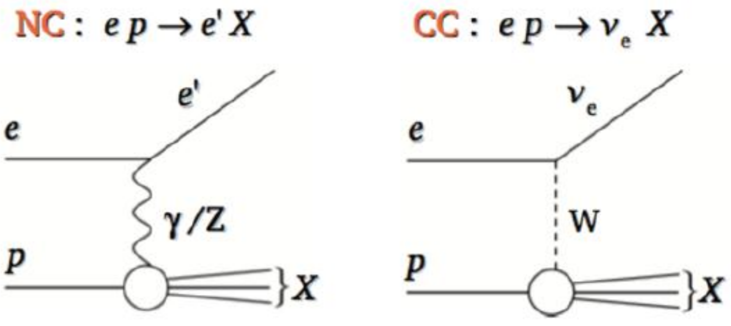
LHeC physics (II)

- $Q^2 \sim 1 TeV^2$
- $X_{min} \sim 10^{-6}$
- $L \sim 10^{33} cm^{-2} s^{-1}$





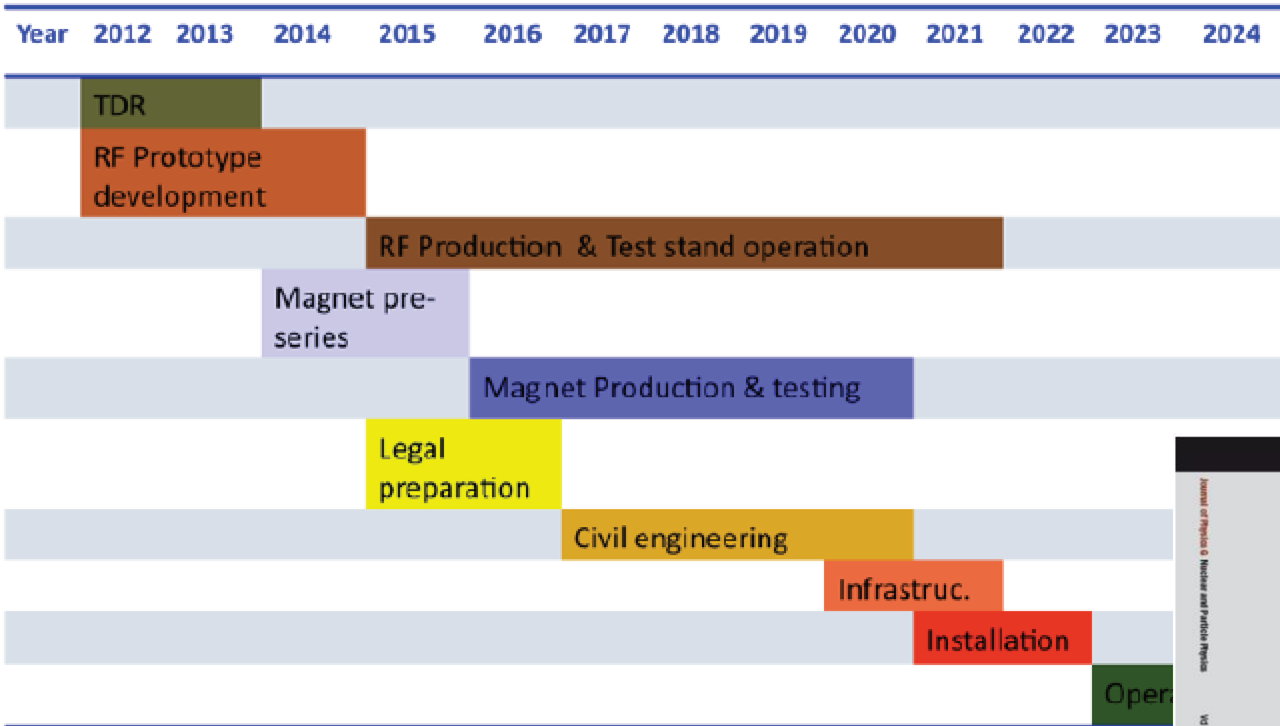
Role of Positrons in ep physics



Charged-current process – lepton beam charge selects up and down and anti-quarks. Requires high Q^2.

Neutral-current process – lepton beam charge and polarisation probes vector and axial-vector couplings of the Z.

LHeC Timeline



CDR published
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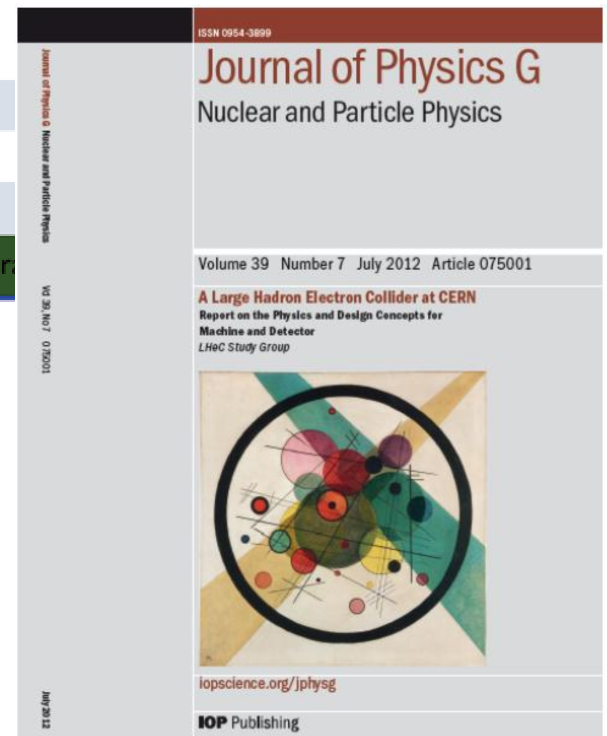
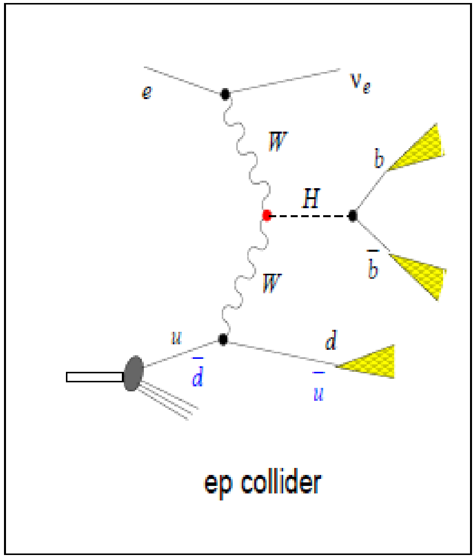
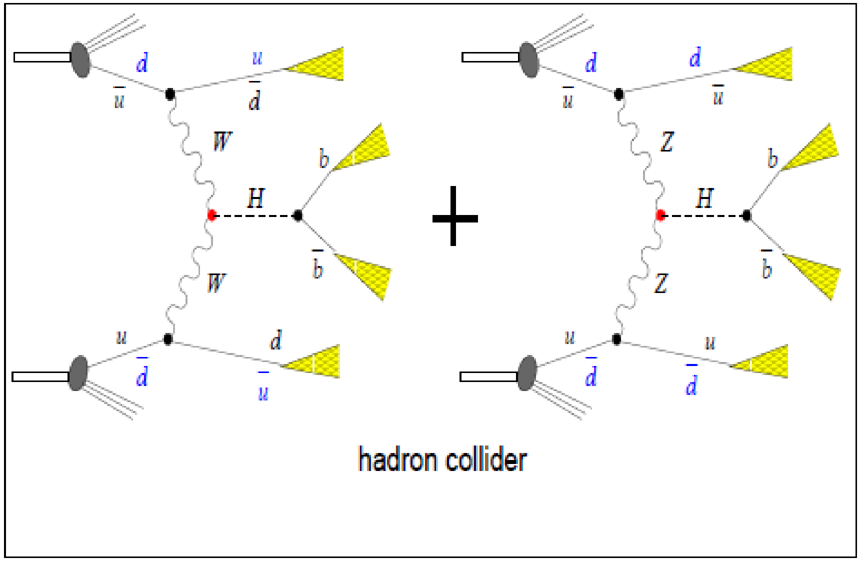


- Operate in parallel with HL-LHC
- 100 MW power budget

Higgs Studies at LHeC



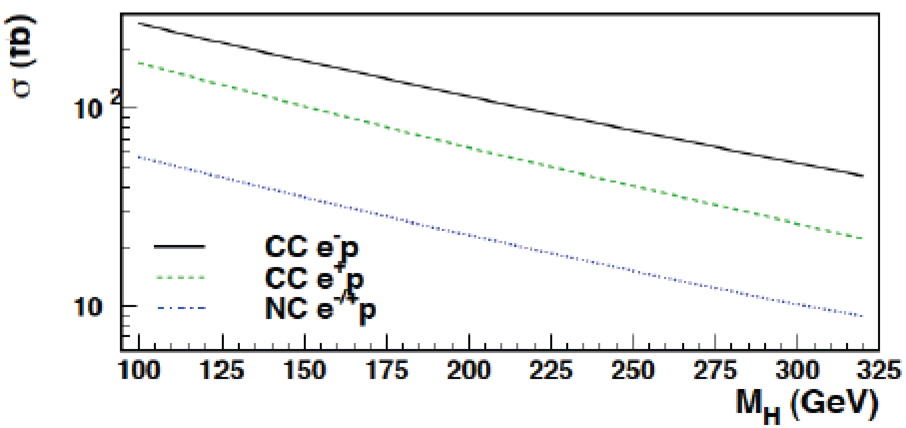
ep collider



hadron collider

- Dominant decay mode of ~126GeV Higgs is bb
- Hbb coupling statistical precision ~ 4%
- ep collider ⇒ HWW and HZZ couplings

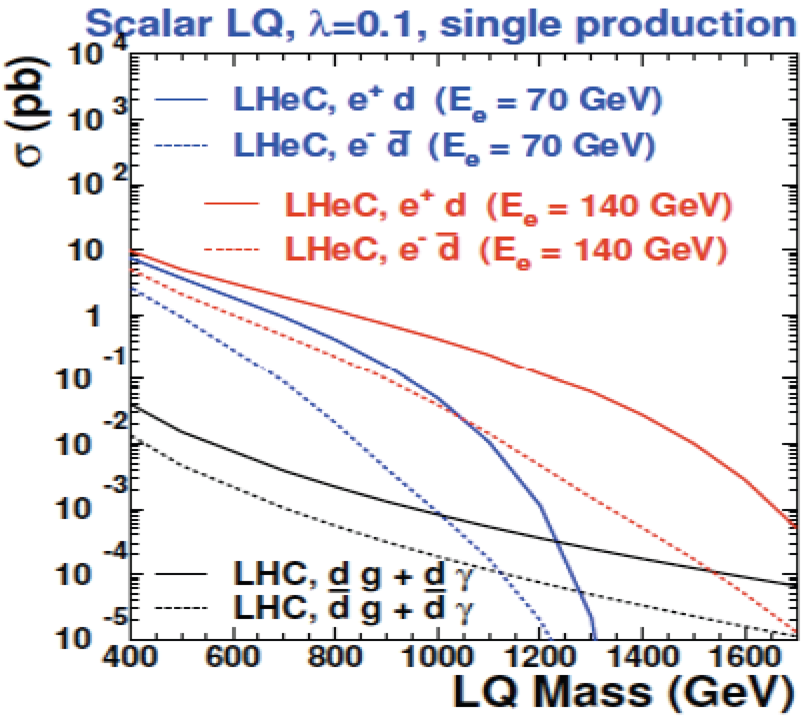
- Useful for identifying CP state of 'Higgs'
- No need for positrons here?



Positron Physics at LHeC

- Observation of saturation of the gluon density at low x
- LeptoQuark spectroscopy
- eeqq contact interactions
- Quark / anti-quark composition of sea
- Full unfolding of partonic content of proton
- Top factory
- Generalised Parton Distributions via Deeply Virtual Compton Scattering
- Electroweak coupling at per cent level

LeptoQuark Sensitivity

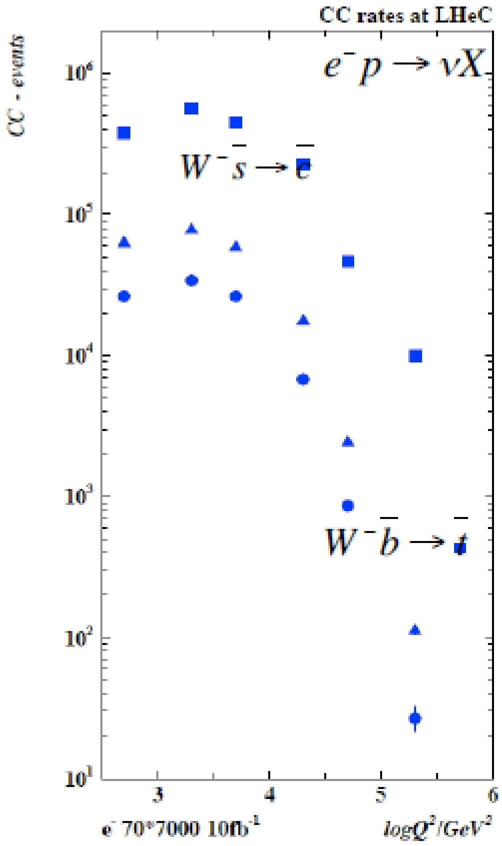


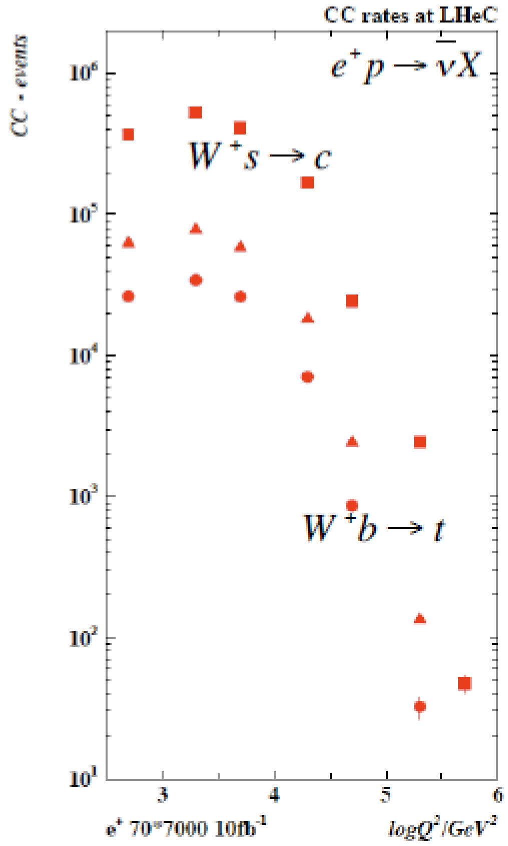
Discovery at LHC.

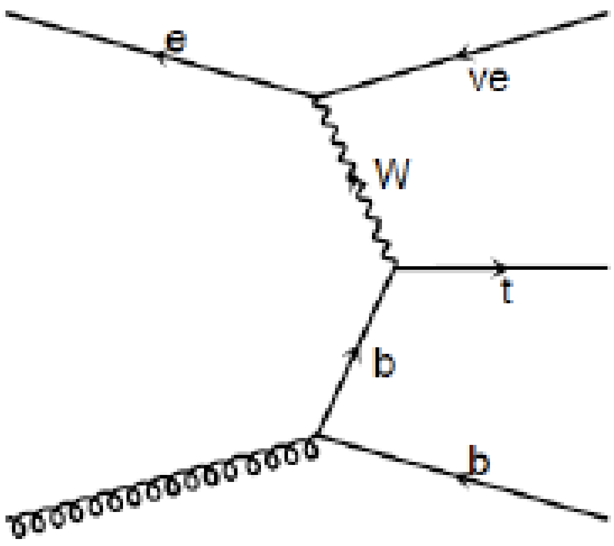
LHeC used for e.g. Probing LQ-e-q couplings.

Leptoquarks with fermion number F = 0 would require polarised positron beam to determine whether it couples to left or right-handed lepton current.

Top Production







Conclusion

→**There is a strong demand from physics to maximize the positron luminosity too**
(with probably less emphasis to the e^+ beam polarisation which is yet another complication)
→ **A setup with 100 fb-1 electrons and 1 fb-1 positrons is tolerable but requires L+ = O(L-/10)**

If the positron luminosity was much lower than for electrons, one would be tempted not to "waste" running time on positrons and thus the integrated luminosity came out to be even lower, relatively to electrons

Backup

QCD Discoveries Higgs Substructure New and BSM Physics Top Quark	$\alpha_s < 0.12$, $q_{sea} \neq \overline{q}$, instanton, odderon, low x: (n0) saturation, $\overline{u} \neq \overline{d}$ WW and ZZ production, $H \to b\overline{b}$, $H \to 4l$, CP eigenstate electromagnetic quark radius, e^*, ν^*, W?, Z?, top?, H? leptoquarks, RPV SUSY, Higgs CP, contact interactions, GUT through α_s top PDF, $xt = x\overline{t}$?, single top in DIS, anomalous top
Relations to LHC	SUSY, high x partons and high mass SUSY, Higgs, LQs, QCD, precision PDFs
Gluon Distribution Precision DIS	saturation, $x \approx 1$, J/ψ, Υ, Pomeron, local spots?, F_L, F_2^c $\delta\alpha_s \simeq 0.1\,\%$, $\delta M_c \simeq 3\,\mathrm{MeV}$, $v_{u,d}$, $a_{u,d}$ to $2-3\,\%$, $\sin^2\Theta(\mu)$, F_L, F_2^b
Parton Structure Quark Distributions QCD	Proton, Deuteron, Neutron, Ions, Photon valence $10^{-4} \lesssim x \lesssim 1$, light sea, d/u, $s = \overline{s}$?, charm, beauty, top $\mathrm{N^3LO}$, factorisation, resummation, emission, AdS/CFT, BFKL evolution
Deuteron Heavy Ions Modified Partons	singlet evolution, light sea, hidden colour, neutron, diffraction-shadowing initial QGP, nPDFs, hadronization inside media, black limit, saturation PDFs “independent” of fits, unintegrated, generalised, photonic, diffractive
HERA continuation	F_L, xF_3, $F_2^{\gamma Z}$, high x partons, α_s, nuclear structure, ..