nPDFs towards EIC

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Outline

Current State of nuclear PDFs

Impact of LHC pA data on nuclear PDFs

Why can EIC be a game-changer for nuclear PDFs

nPDF - current status

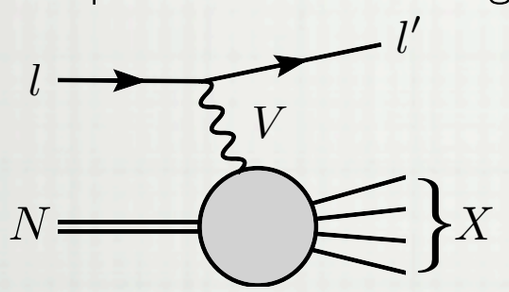
- Data used in current nPDF analyses

	HKN07	EPS09	DSSZ	nCTEQ15
order	NLO	NLO	NLO	NLO
eDIS	✓	✓	✓	✓
Drell-Yan	✓	✓	✓	✓
νDIS	✗	✗	✓	✗
π^0	✗	✓	✓	✓
Data points	1241	929	1579	740

nPDF - current status

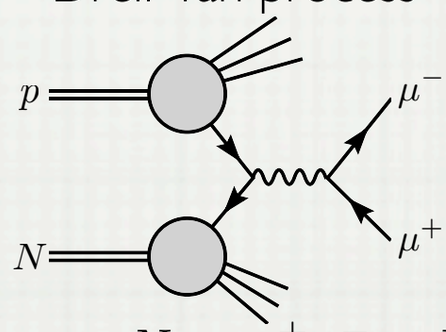
- Data used in current nPDF analyses

Deep Inelastic Scattering



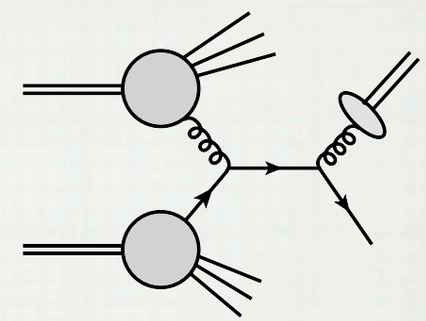
$l + N \to l' + X$

Drell-Yan process



$p + N \to \mu^+\mu^- + X$

Single pion production



$d + N \to \pi^0 + X$

RHIC - PHENIX & STAR

$\mathrm{N} = \mathrm{Au}$

CERN BCDMS & EMC & NMC

$N = (\mathrm{D}, \mathrm{Al}, \mathrm{Be}, \mathrm{C}, \mathrm{Ca}, \mathrm{Cu}, \mathrm{Fe}, \mathrm{Li}, \mathrm{Pb}, \mathrm{Sn}, \mathrm{W})$

FNAL E-665

$N = (\mathrm{D}, \mathrm{C}, \mathrm{Ca}, \mathrm{Pb}, \mathrm{Xe})$

DESY Hermes

$N = (\mathrm{D}, \mathrm{He}, \mathrm{N}, \mathrm{Kr})$

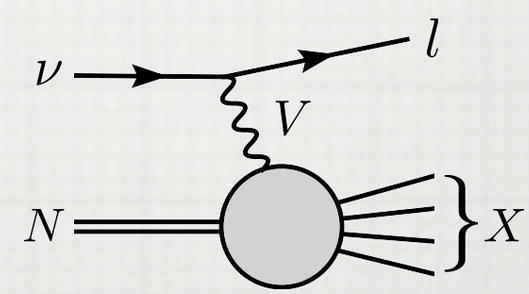
SLAC E-139 & E-049

$N = (\mathrm{D}, \mathrm{Ag}, \mathrm{Al}, \mathrm{Au}, \mathrm{Be}, \mathrm{C}, \mathrm{Ca}, \mathrm{Fe}, \mathrm{He})$

FNAL E-772 & E-886

$N = (\mathrm{D}, \mathrm{C}, \mathrm{Ca}, \mathrm{Fe}, \mathrm{W})$

Neutrino Deep Inelastic Scattering



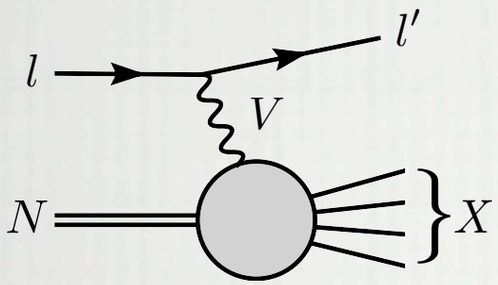
$\nu(\bar{\nu}) + N \to l + X$

CHORUS

CCFR & NuTeV

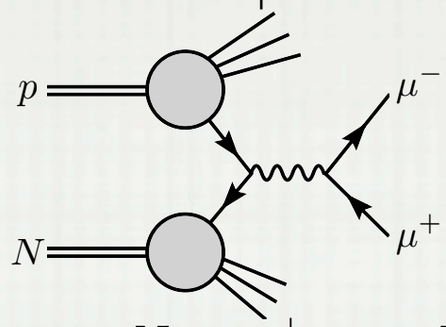
nPDF - current status

Deep Inelastic Scattering



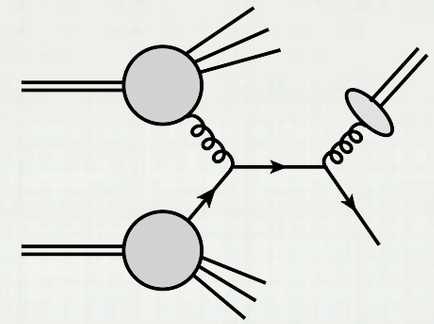
$$l + N \to l' + X$$

Drell-Yan process

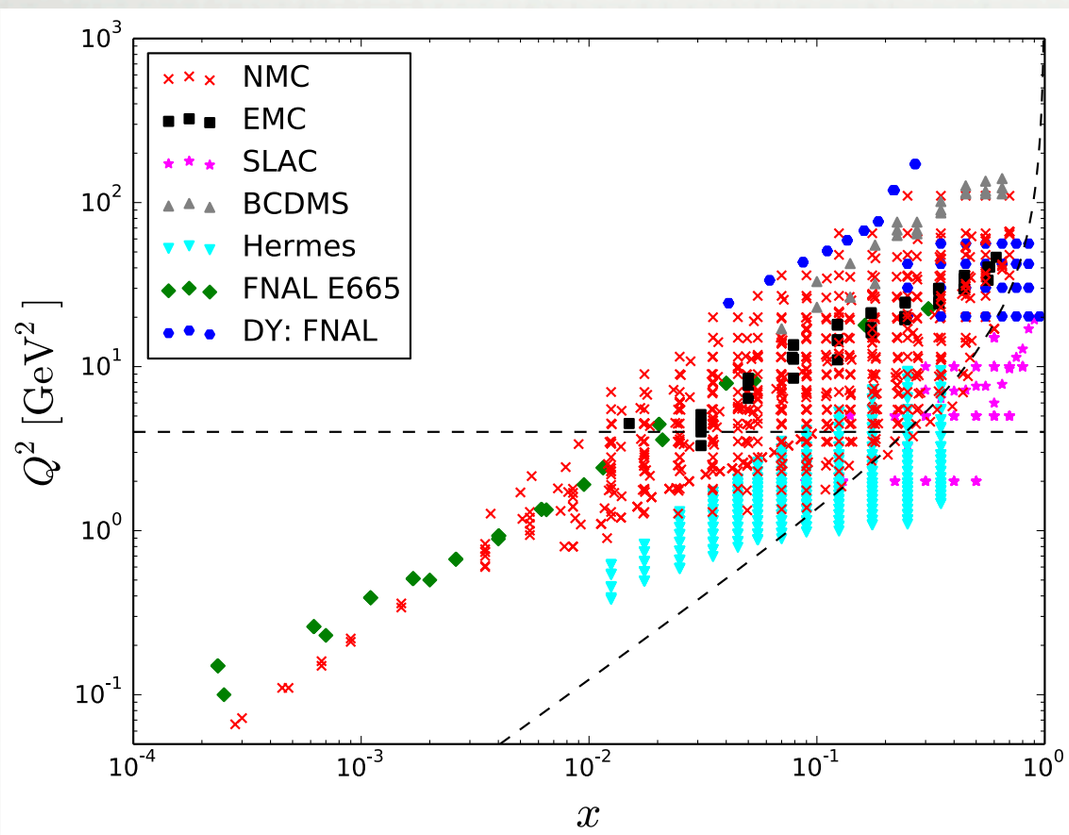


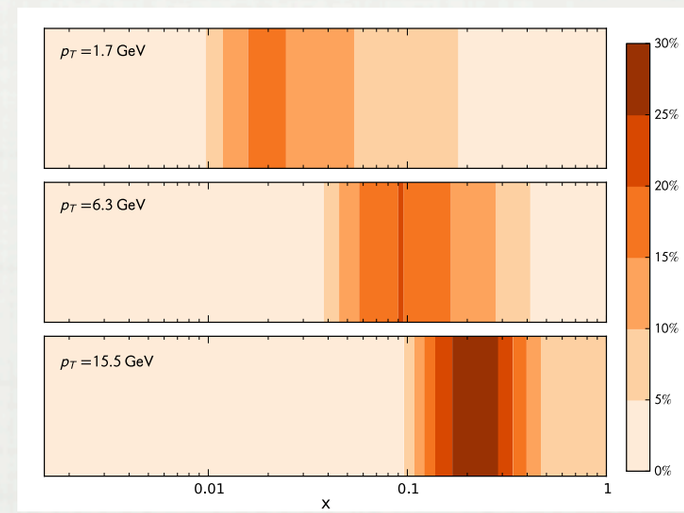
$$p + N \to \mu^+\mu^- + X$$

Single-pion production

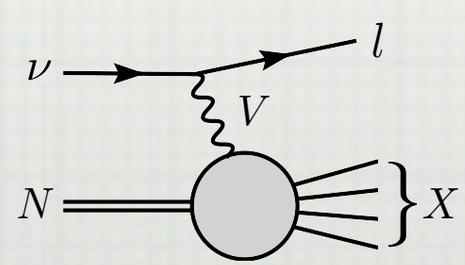


$$d + N \to \pi^0 + X$$

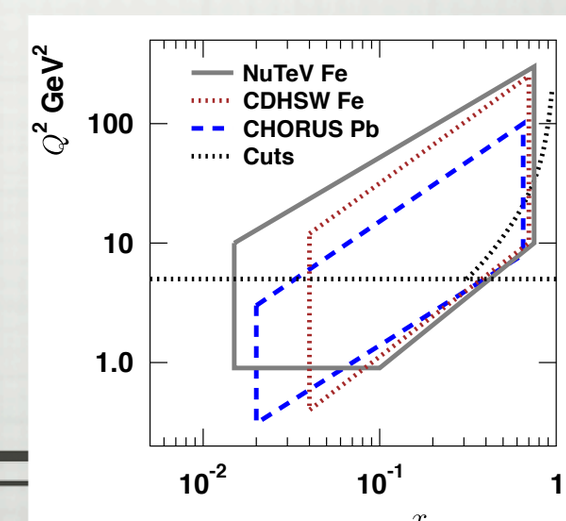




Neutrino DIS



$$\nu(\bar{\nu}) + N \to l + X$$

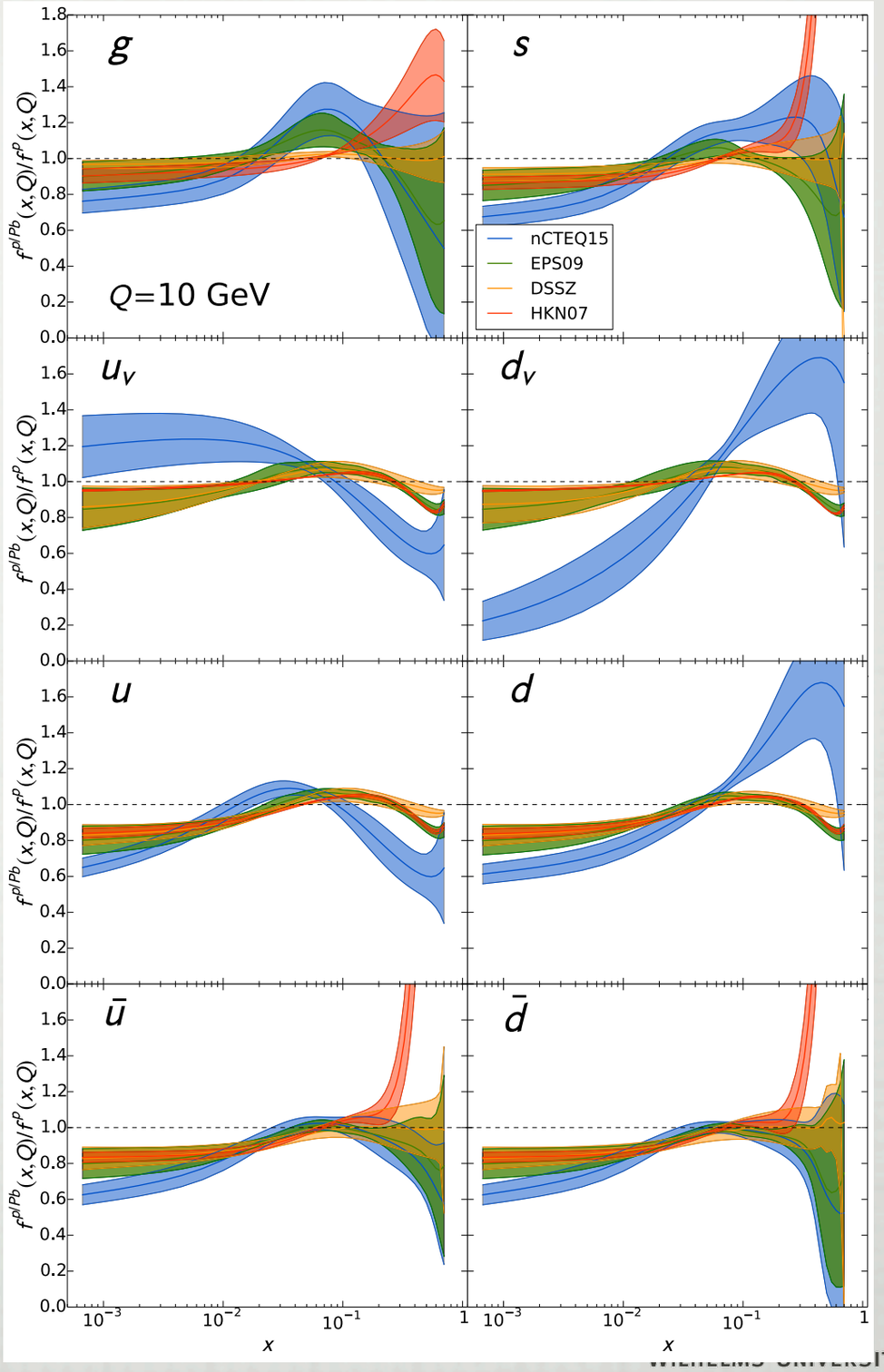


nPDF - current status

- Uncertainties of current nPDF analyses

$$R_i(\mathrm{Pb}) = \frac{f_i^{Pb}(x,Q)}{f_i^{p}(x,Q)} \quad @ \quad Q^2 = 100\ \mathrm{GeV}^2$$

  - larger uncertainty @ gluon nuclear correction factor & large low-x suppression
  - different solution for d-valence & u-valence
  - similar sea quark nuclear correction factors
  - nuclear correction factors depend largely on underlying proton baseline



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$$R_i(\mathrm{Pb}) = \frac{f_i^{Pb}(x,Q)}{f_i^{p}(x,Q)} \quad @ \quad Q^2 = 100\ \mathrm{GeV}^2$$

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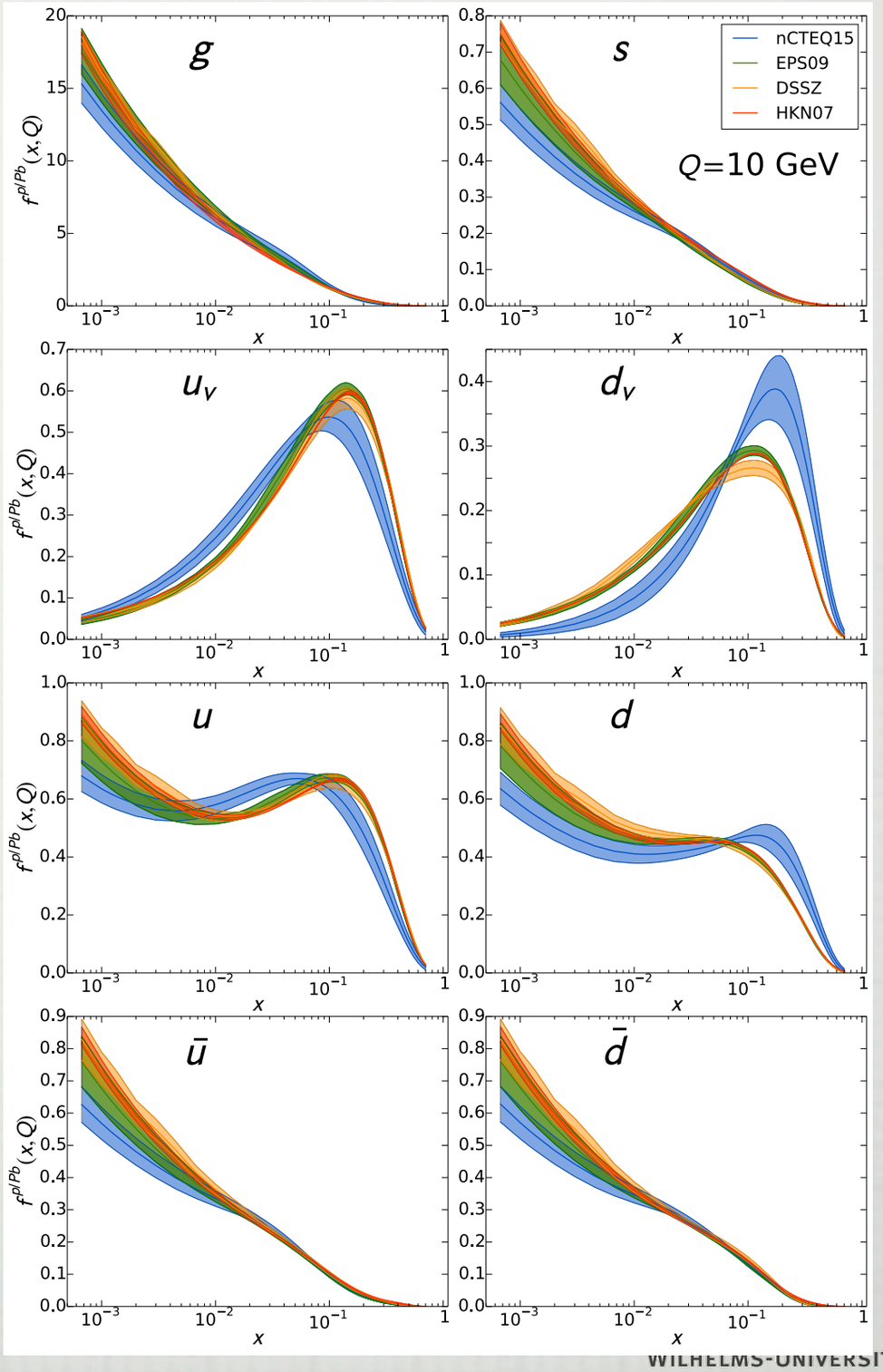
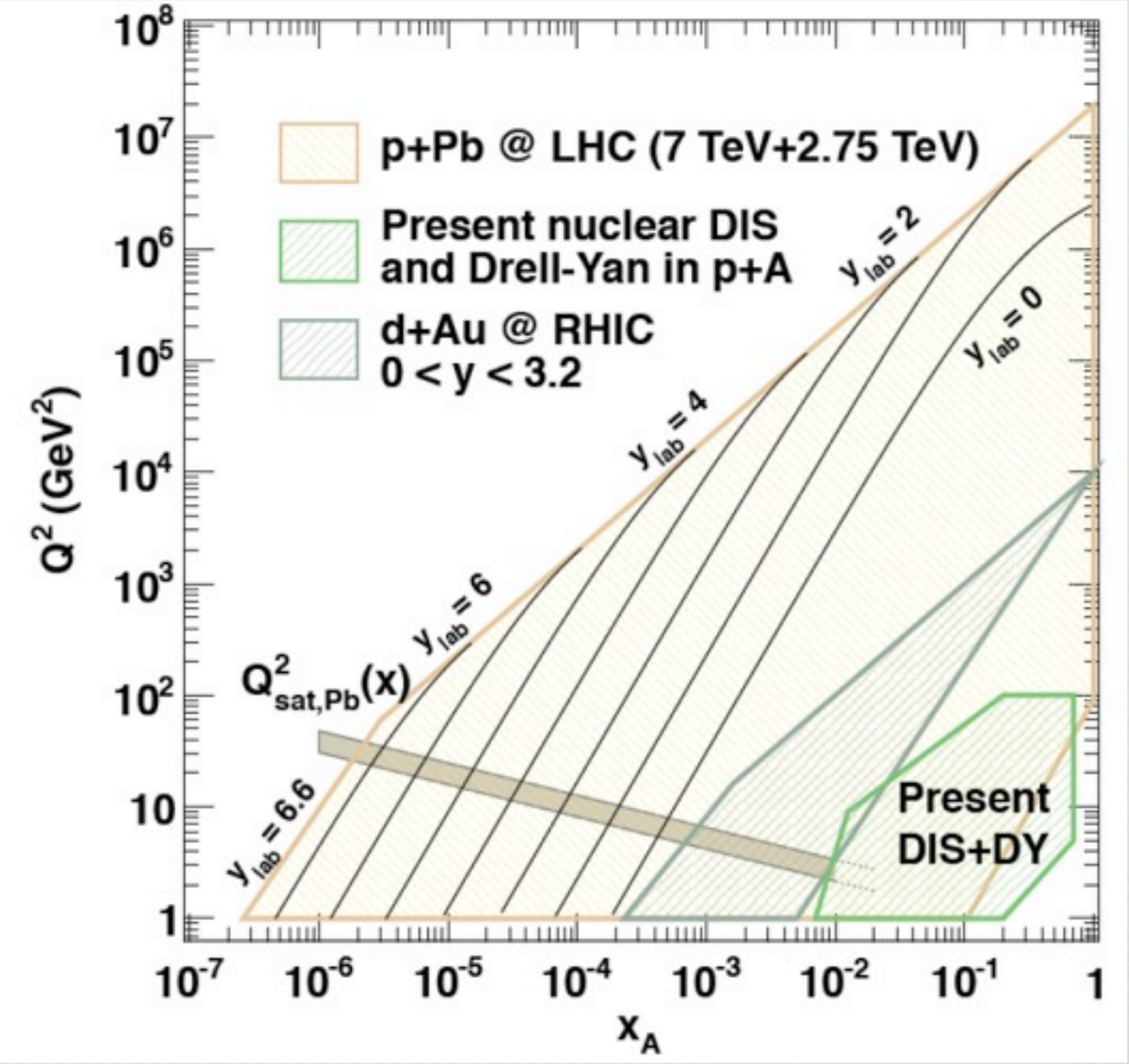
- similar sea quark nuclear correction factors
- nuclear correction factors depend largely on underlying proton baseline
- PDF (not ratios) should be compared between fits



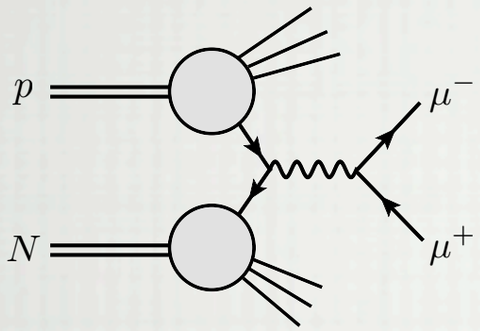
nPDF - preview of LHC p+Pb

- LHC data x-Q^2 coverage
  - large kinematic reach of LHC data - especially in the forward direction
  - even with possible large kinematic reach the effect of LHC data probably limited
  - theoretically clean observables challenging
  - only Pb target - constraints of other nuclei only through A-dependence



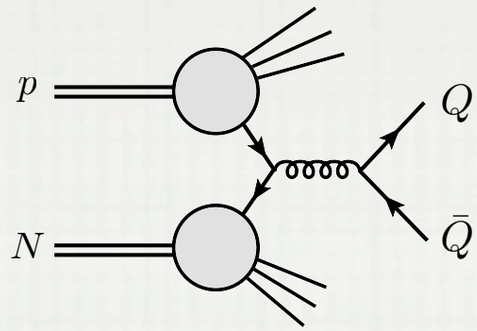
nPDF - preview of LHC p+Pb

Drell-Yan process (W,Z)



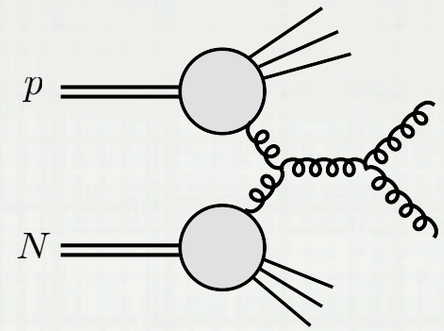
$$p + N \to \mu^+\mu^- + X$$

Heavy-quark production



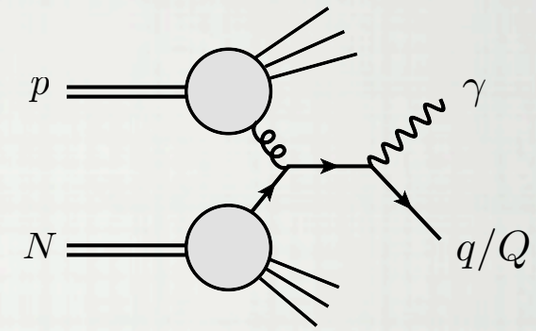
$$p + N \to Q\,\bar{Q} + X$$

Di-jet production

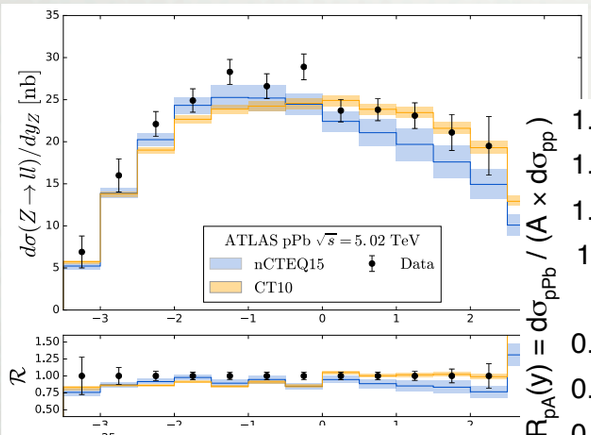


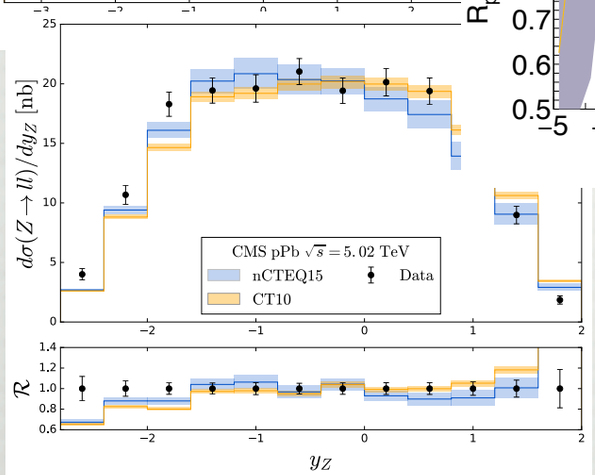
$$p + N \to 2 \text{ jets} + X$$

Direct photon production

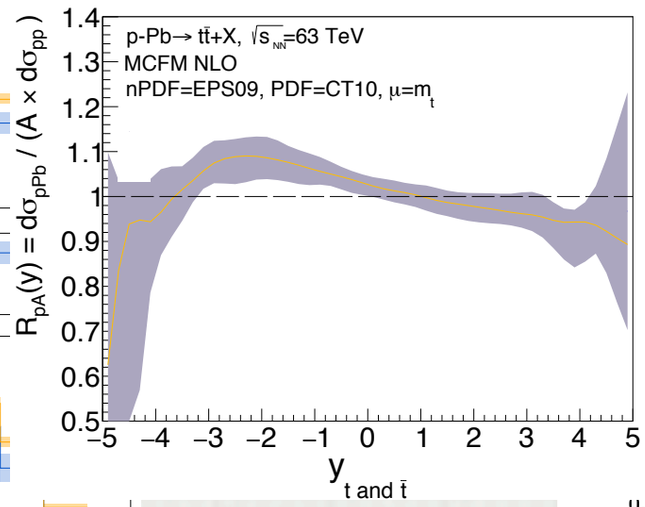


$$p + N \to \gamma\; q/Q + X$$

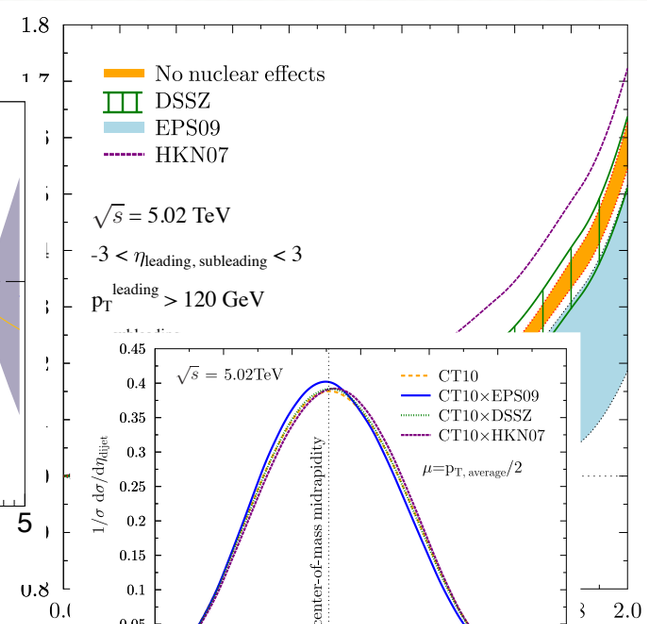


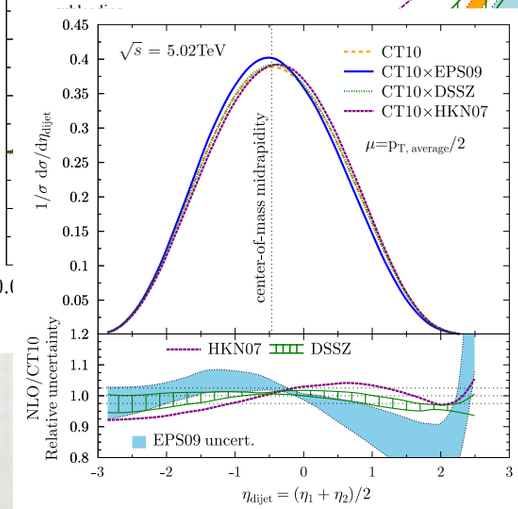


arXiv: 1610.02925

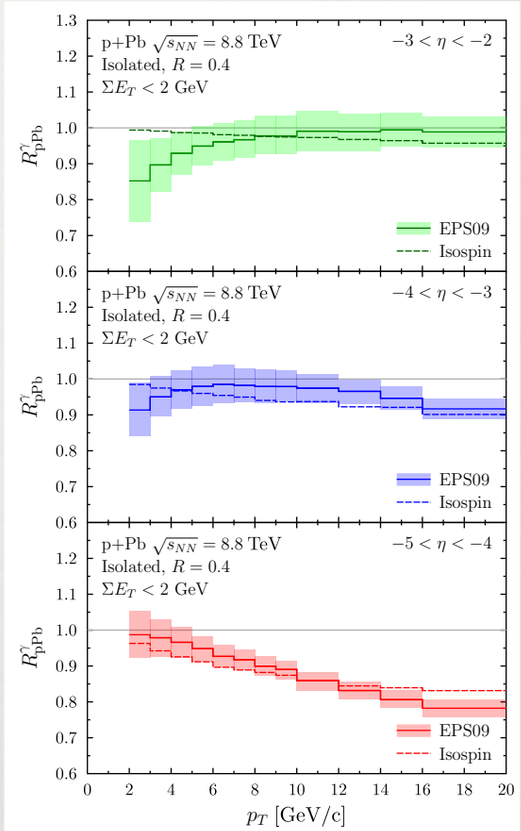


arXiv: 1501.05879





arXiv: 1308.6733



arXiv: 1406.1689

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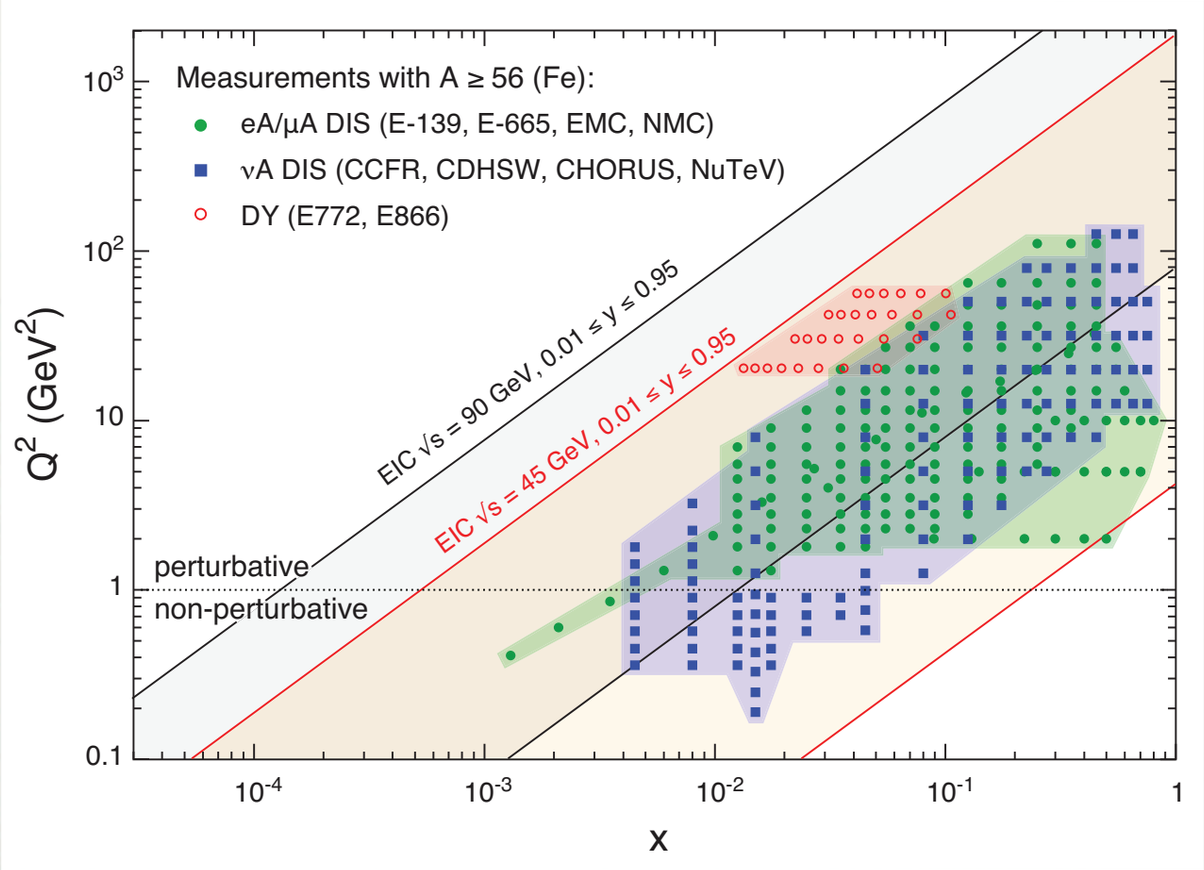
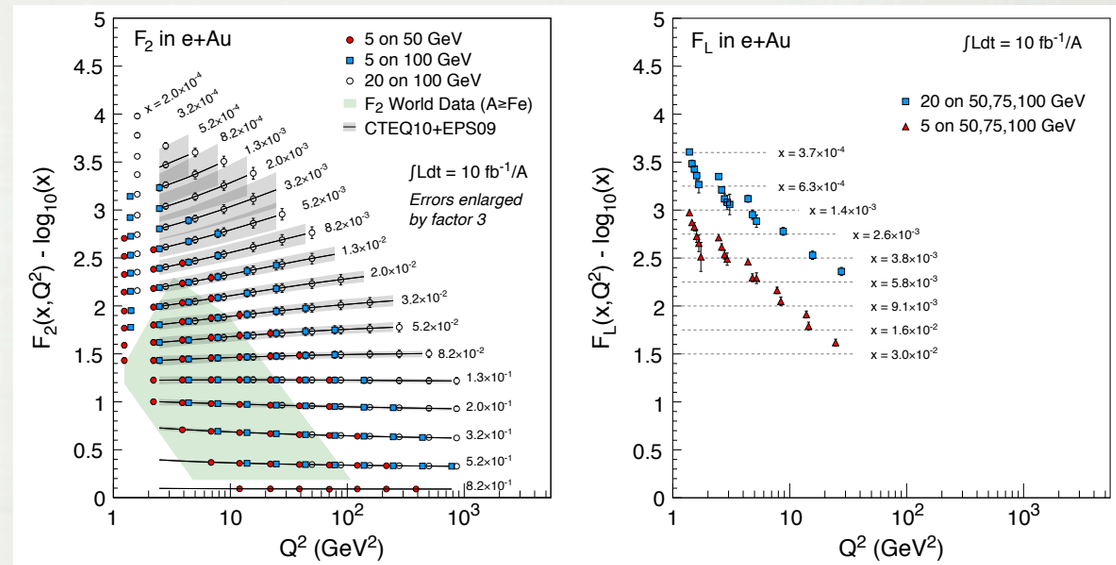
EIC - game-changer for nPDF

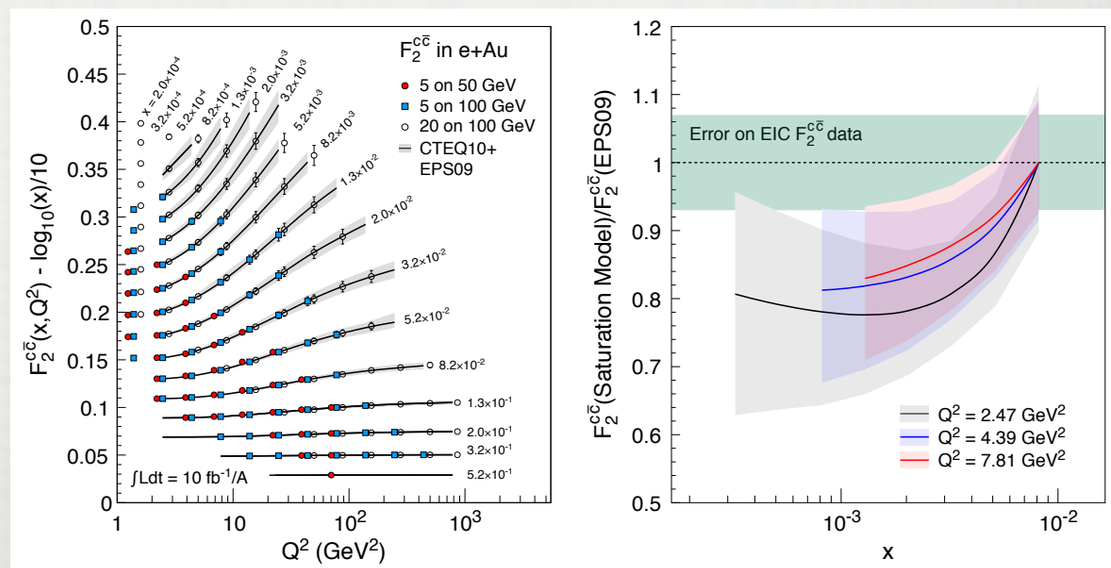
- EIC data x-Q^2 coverage
  - smaller coverage than LHC but much cleaner observables
  - high-precision to determine even the nuclear gluon down to $x=10^{-3}$
  - multiple targets essential - nPDF for single nucleus possible
  - charge current DIS - settling the neutrino problem once and for all

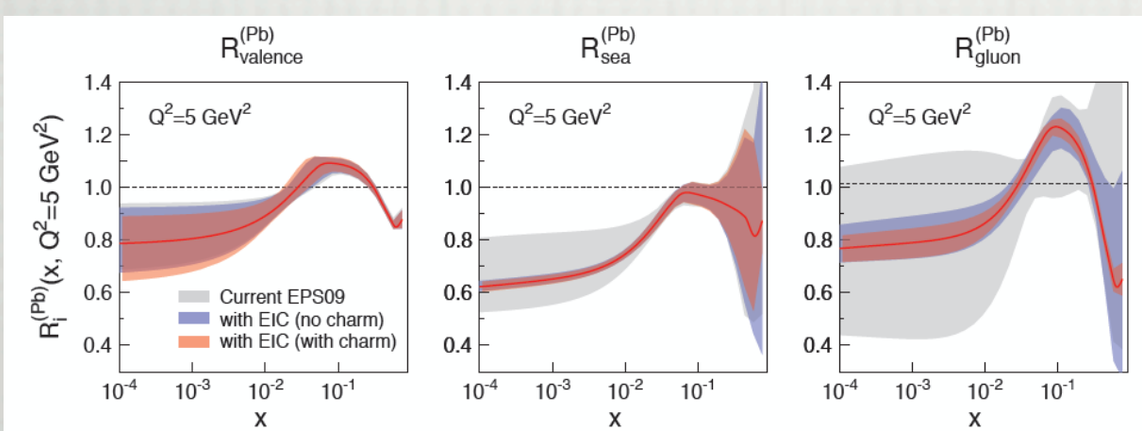


EIC - game-changer for nPDF

- EIC data impact on nPDFs
  - multiple handles on the the nuclear gluon PDF
  - flavor separation in nPDFs possible
  - even some constraints on intrinsic charm in nPDF







THANK YOU