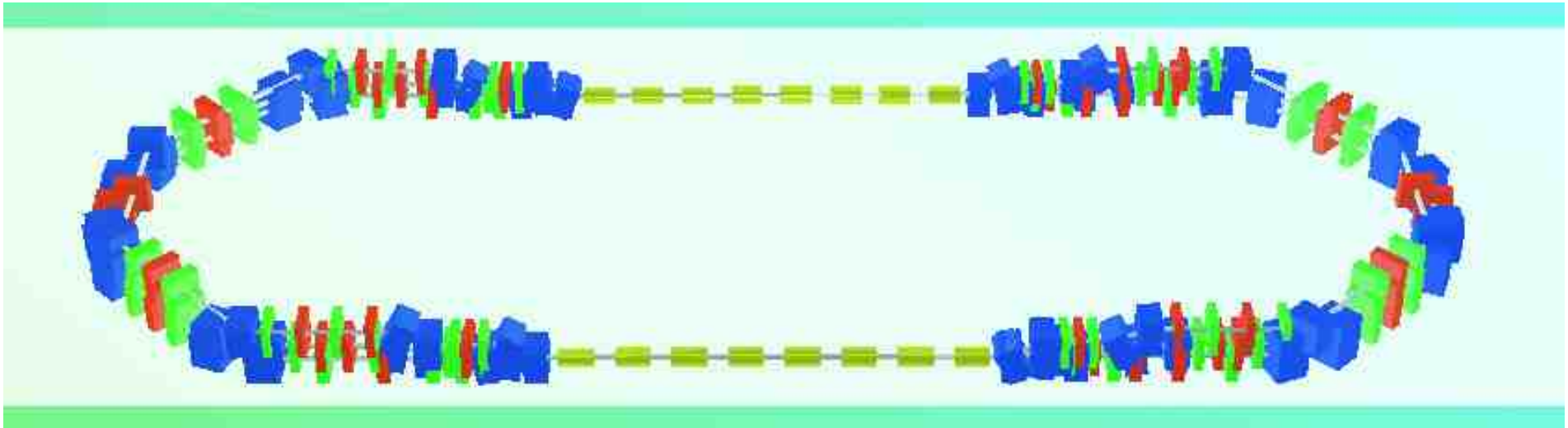


# Nuclear PDFs

*the synergy of the HL-LHC and LHeC*



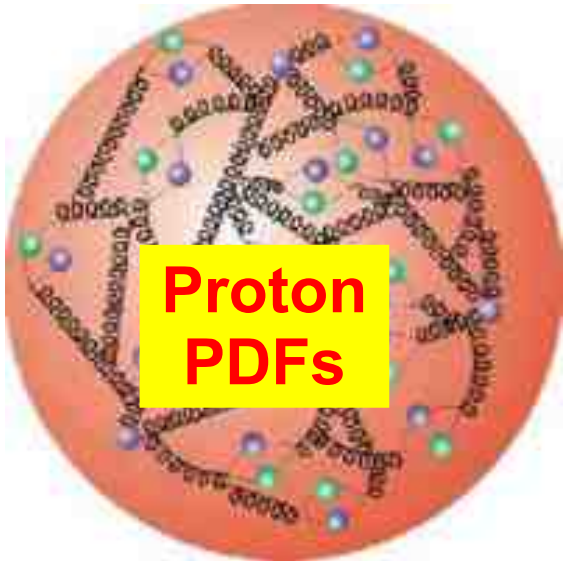
Fred Olness

SMU

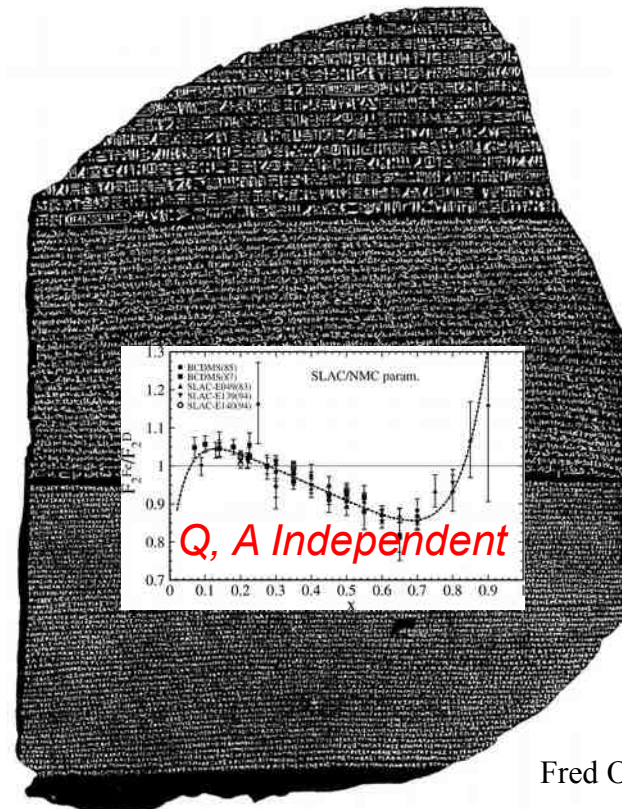
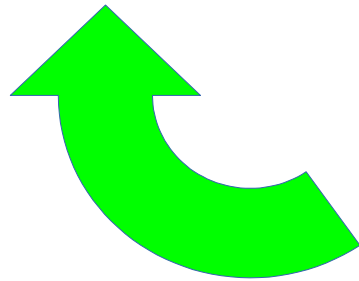
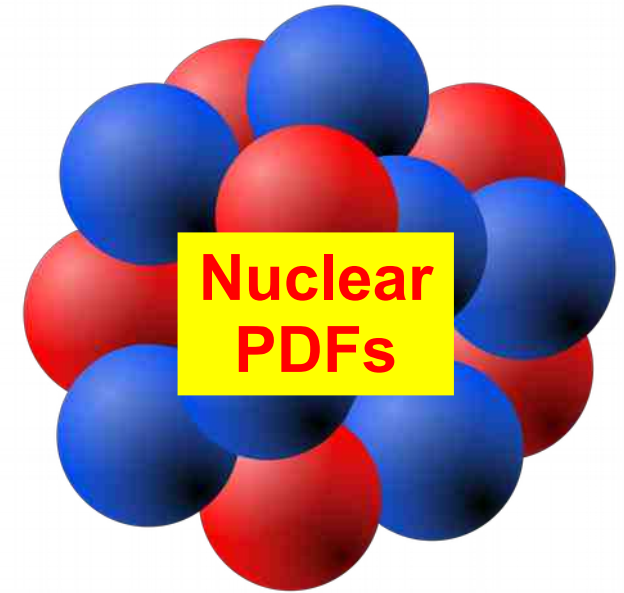


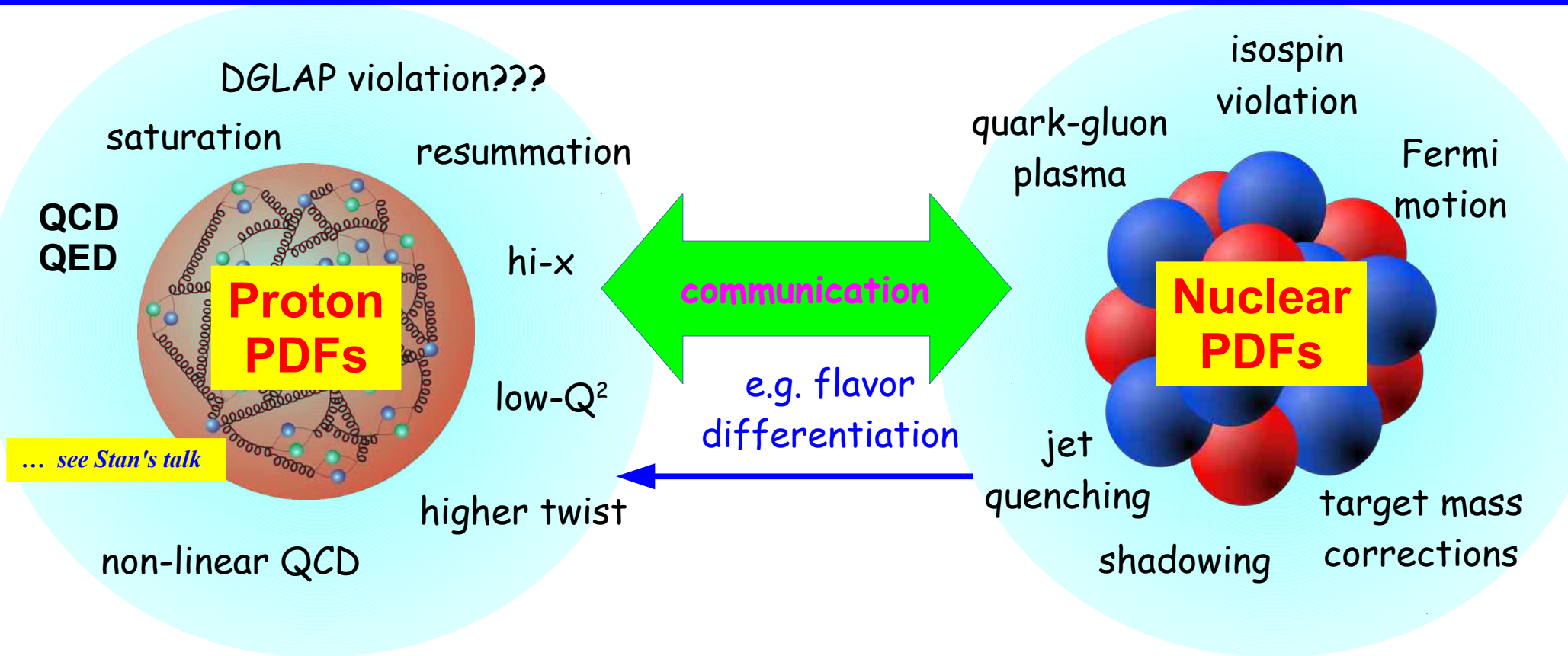
Workshop on the **LHeC**

Chavannes-de-Bogis  
24-26 June 2015



... there was a time when nuclear corrections were carved in stone ...

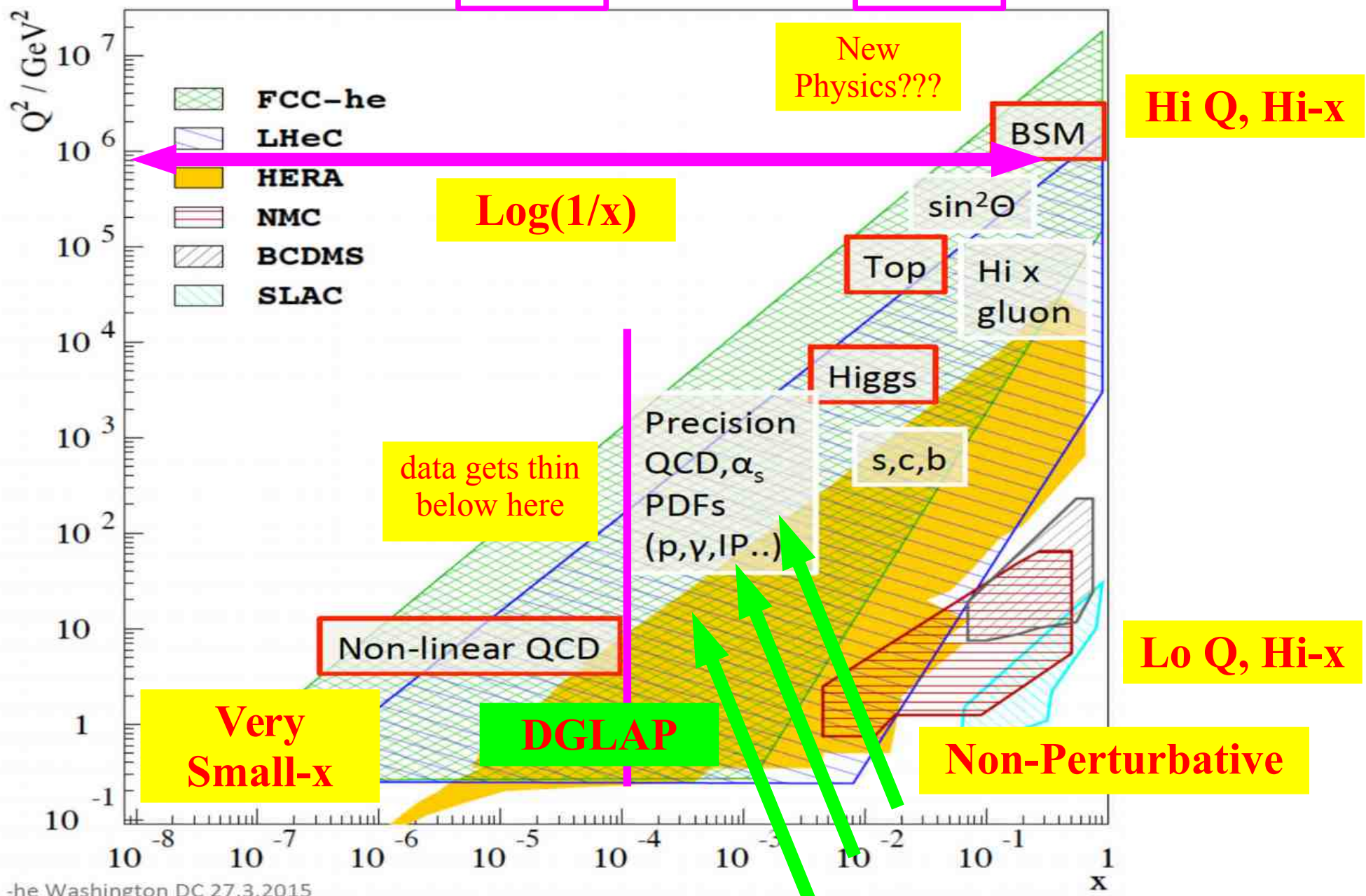




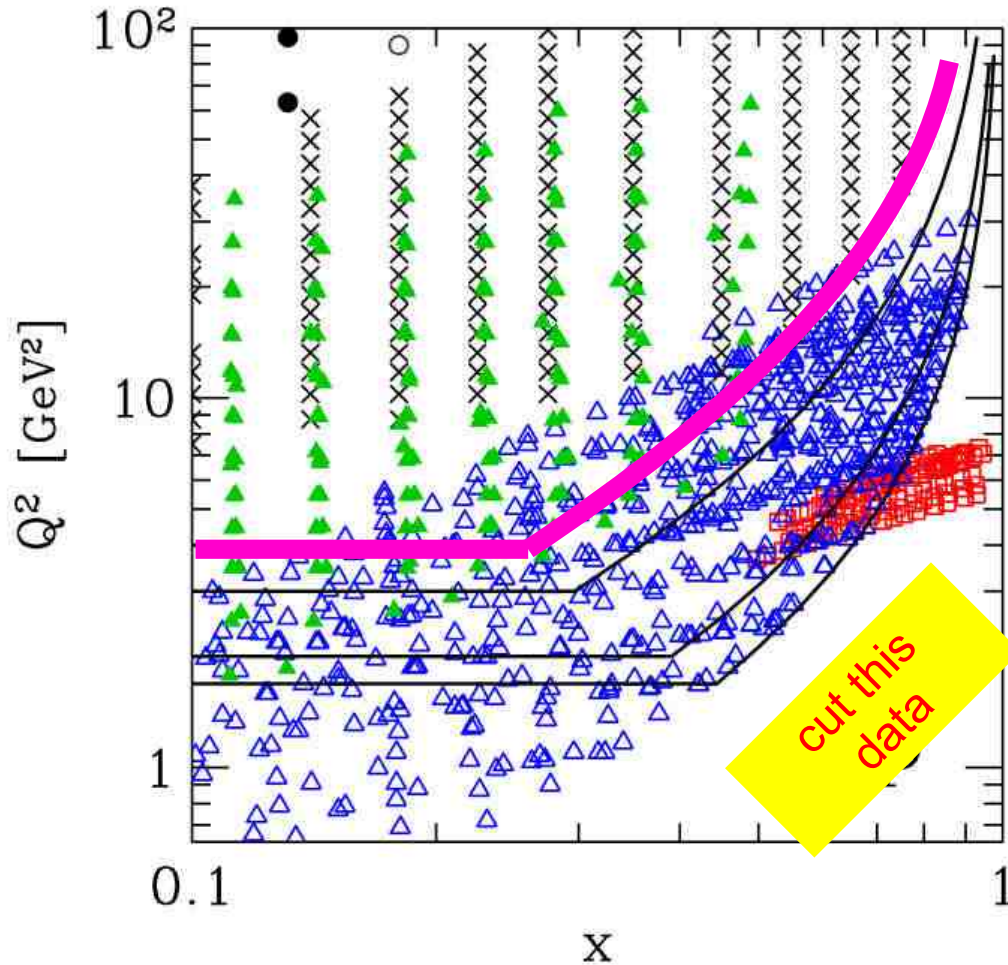
**“... indeed the LHeC would considerably sharpen the hadron collider potential in terms of theoretical control and precision”** *Altarelli*



$$\sigma_{hh \rightarrow X} = f_{h \rightarrow a} \otimes \hat{\sigma}_{ab \rightarrow X} \otimes f_{h \rightarrow b}$$



CTEQ-CJ PRD 81, 034016 (2010)



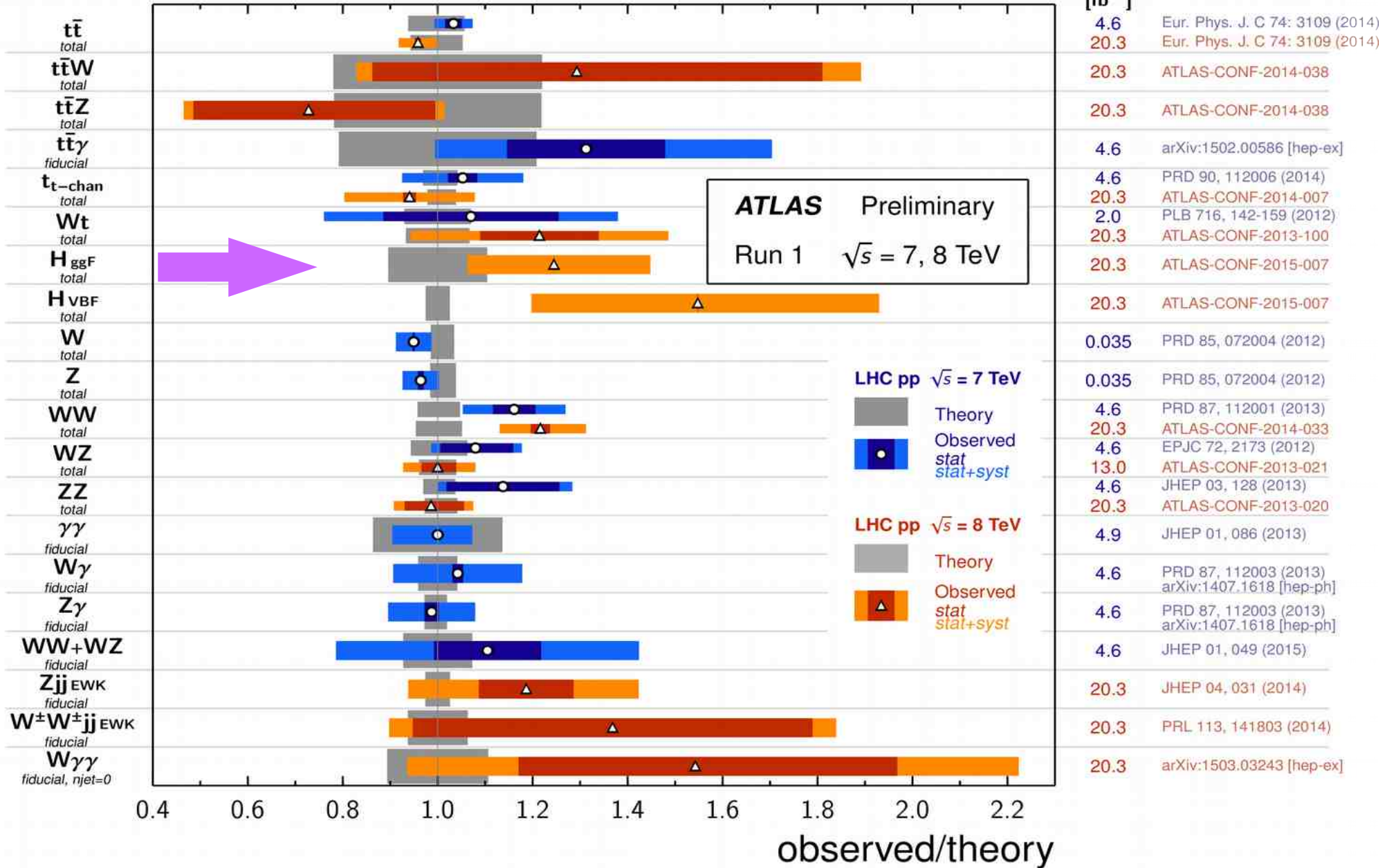
Common Cuts  
 $Q^2 > 4 \text{ GeV}^2$   
 $W^2 > 12 \text{ GeV}^2$

## Standard Model Production Cross Section Measurements

Status: March 2015

$\int \mathcal{L} dt$   
[fb<sup>-1</sup>]

Reference



Much of theory error from PDFs

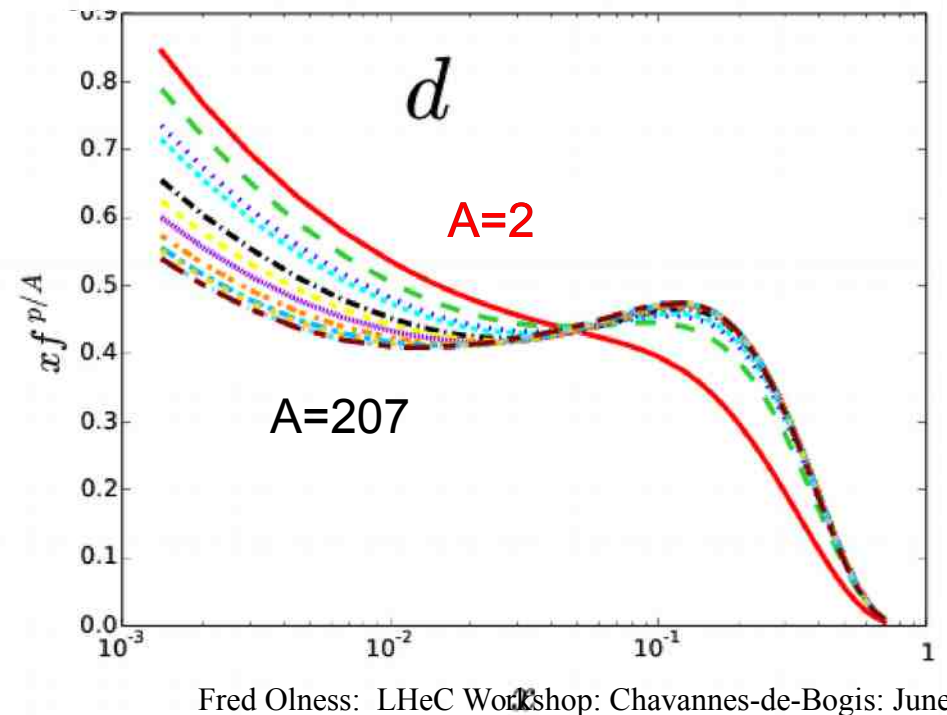
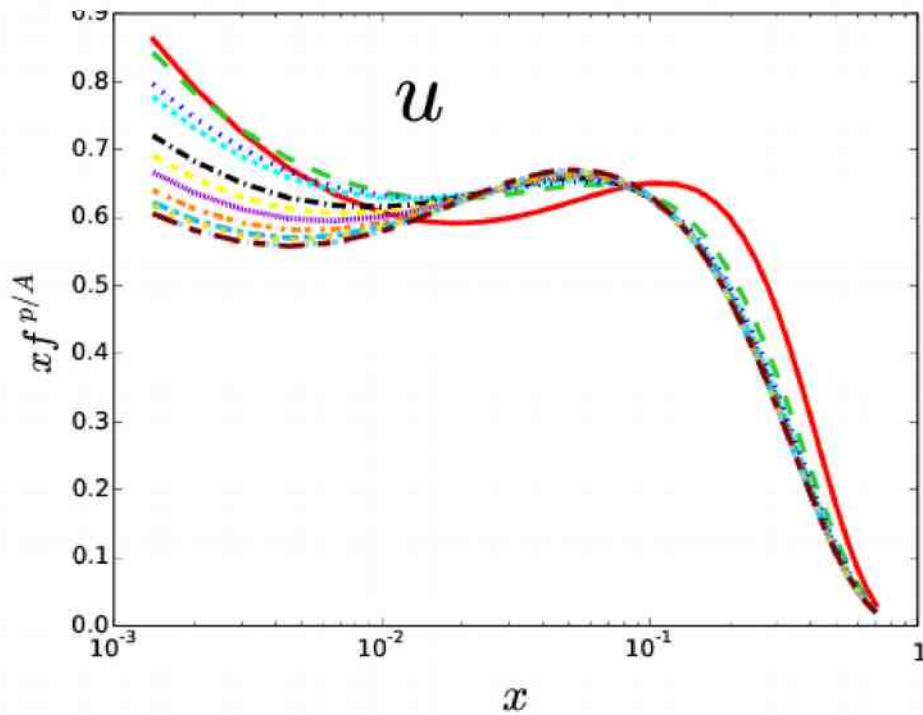
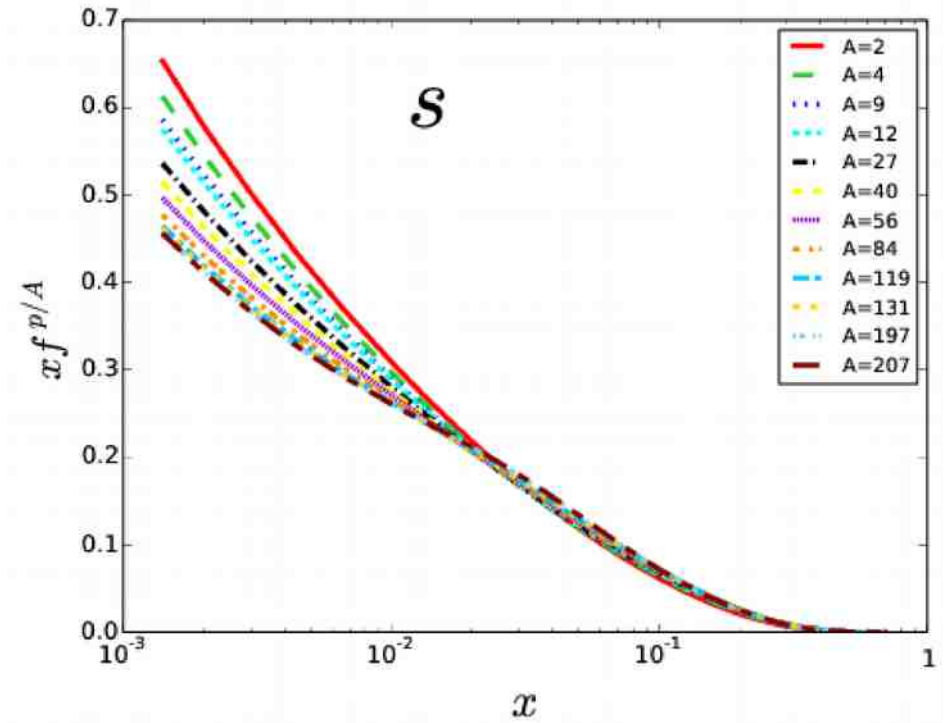
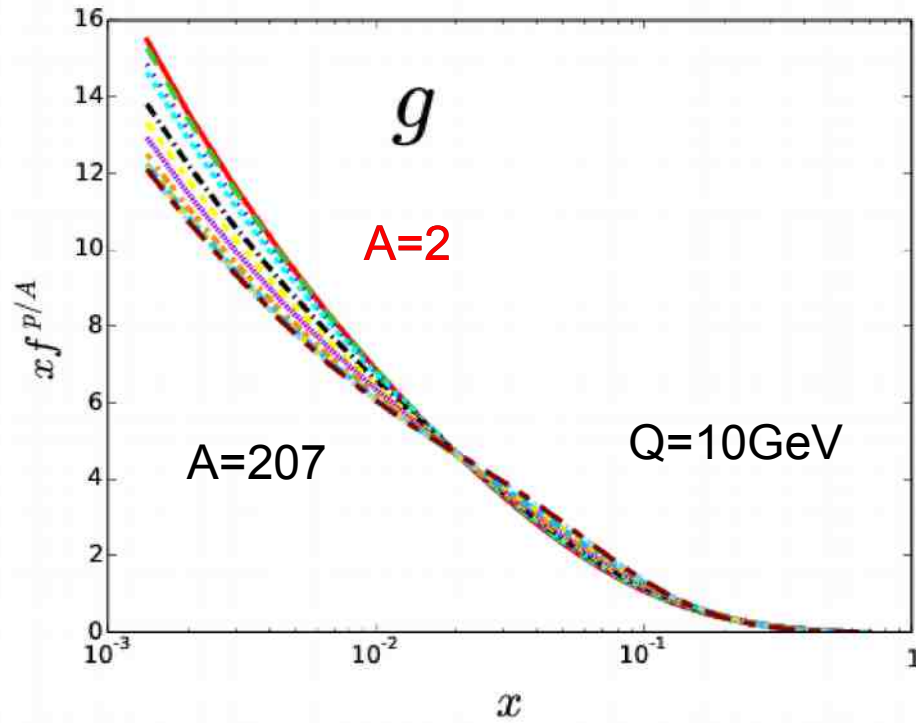
N<sup>3</sup>LO gg->H

PDF error 2x of Theory Error

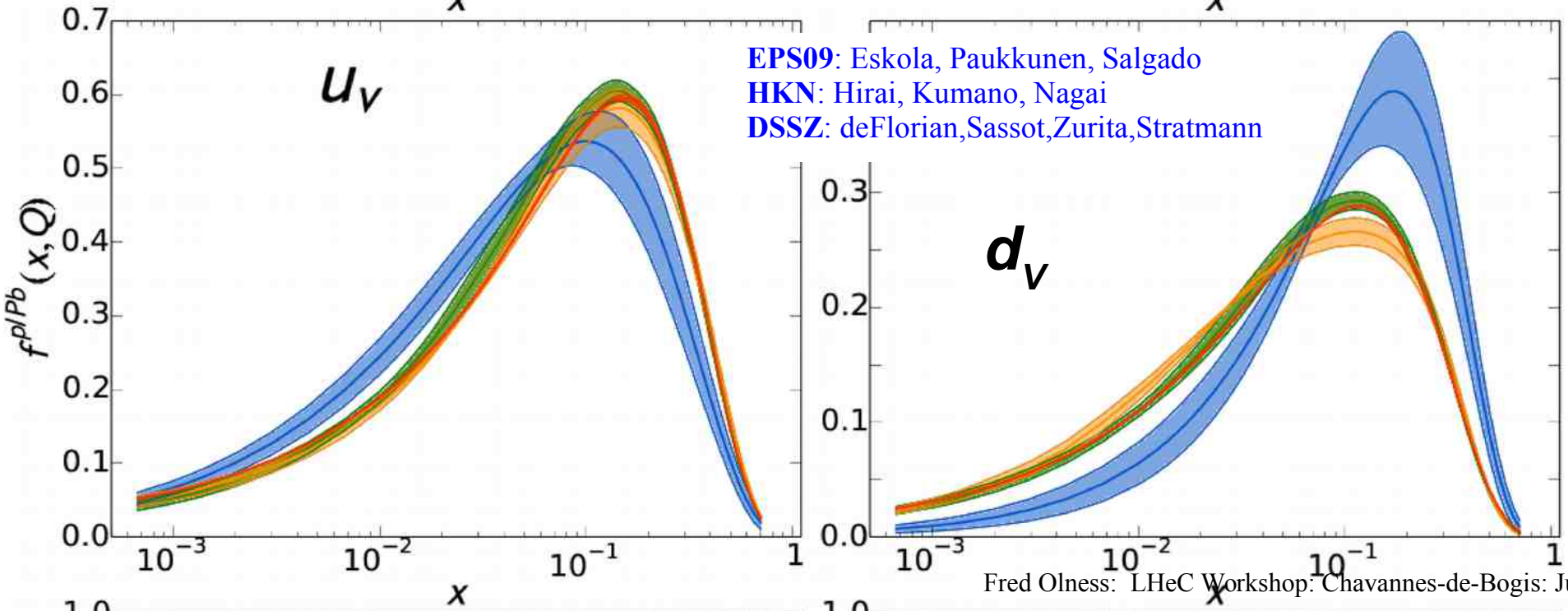
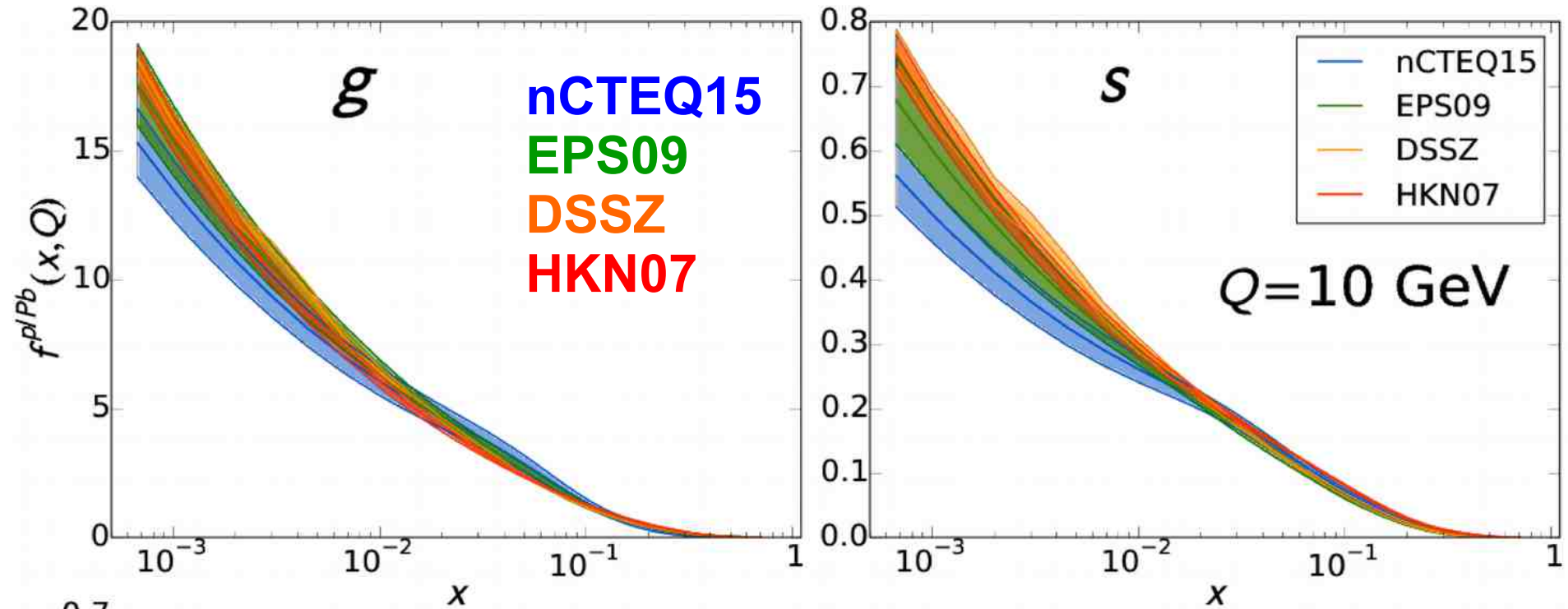
# nPDFs

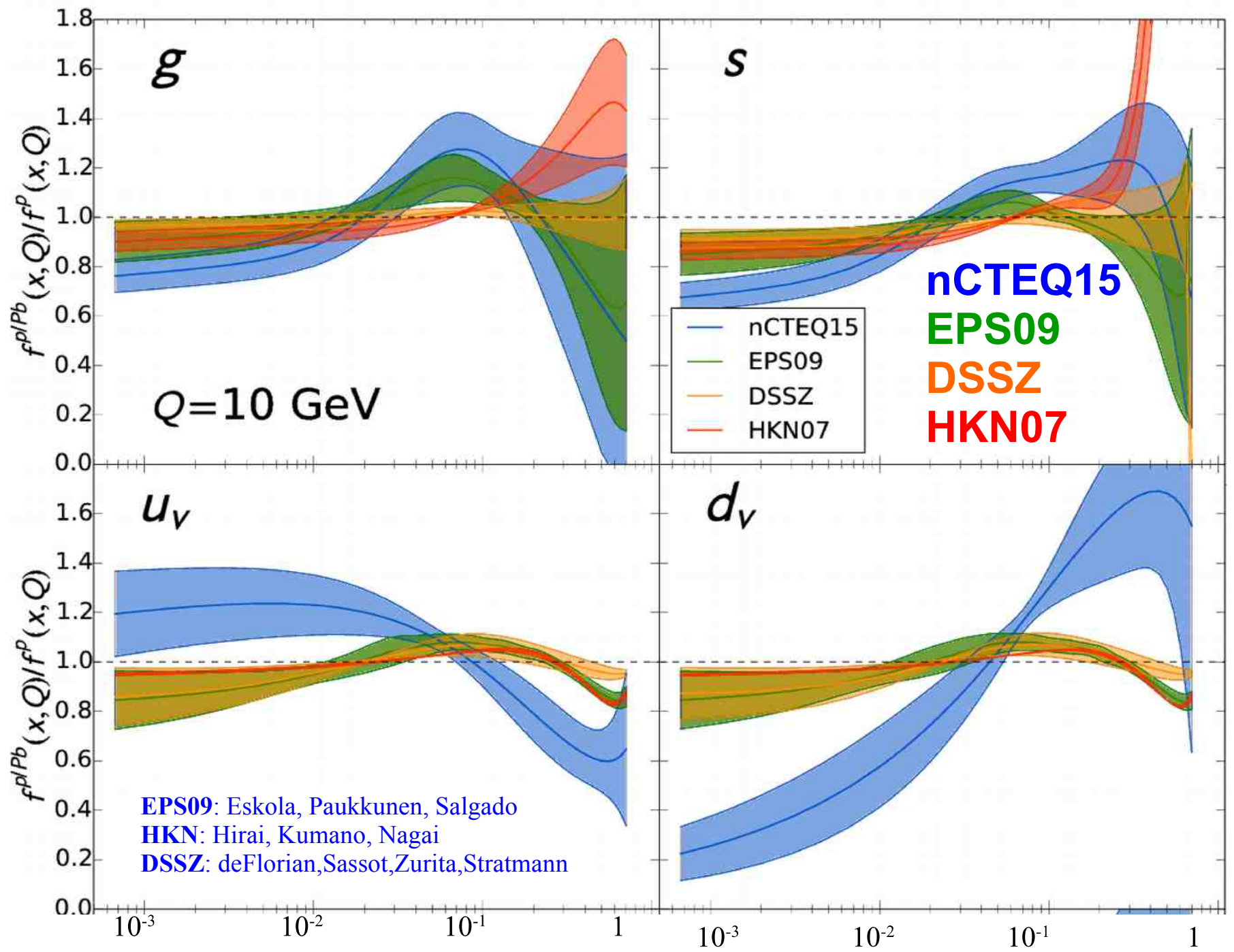
*nCTEQ15* first presented at DIS2015

Hepforge.org

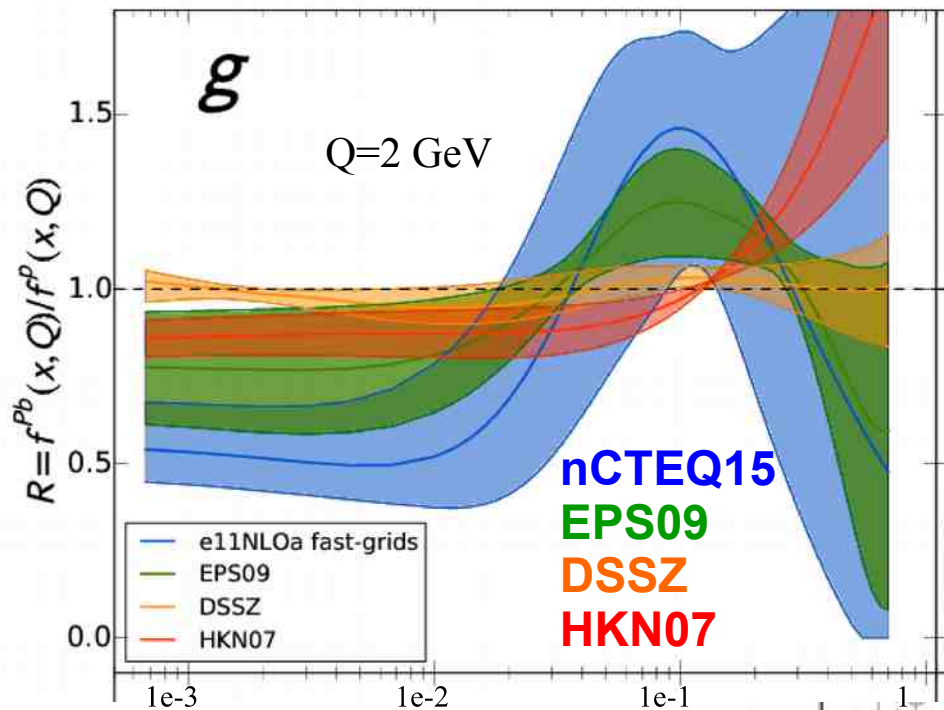




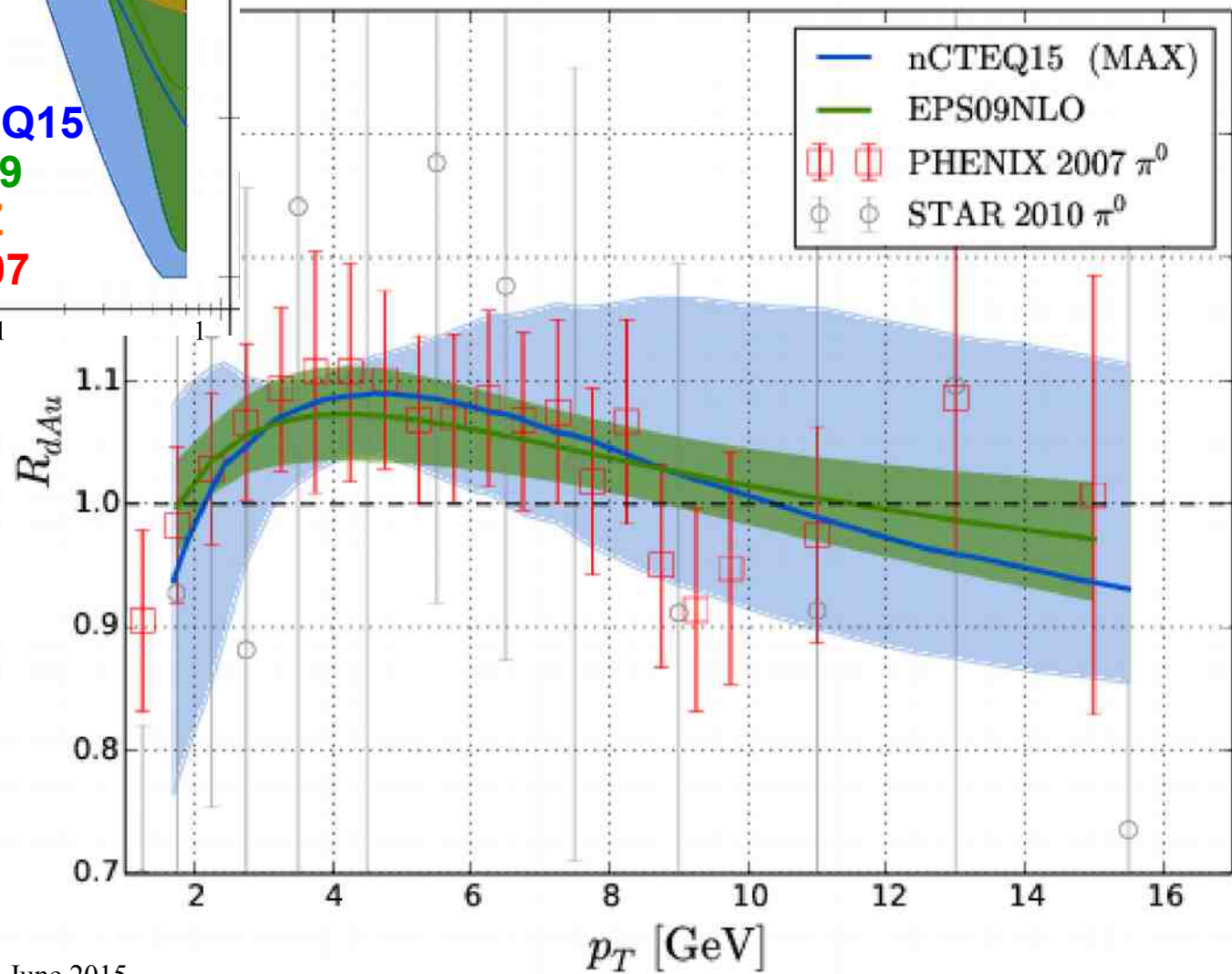




# Gluon



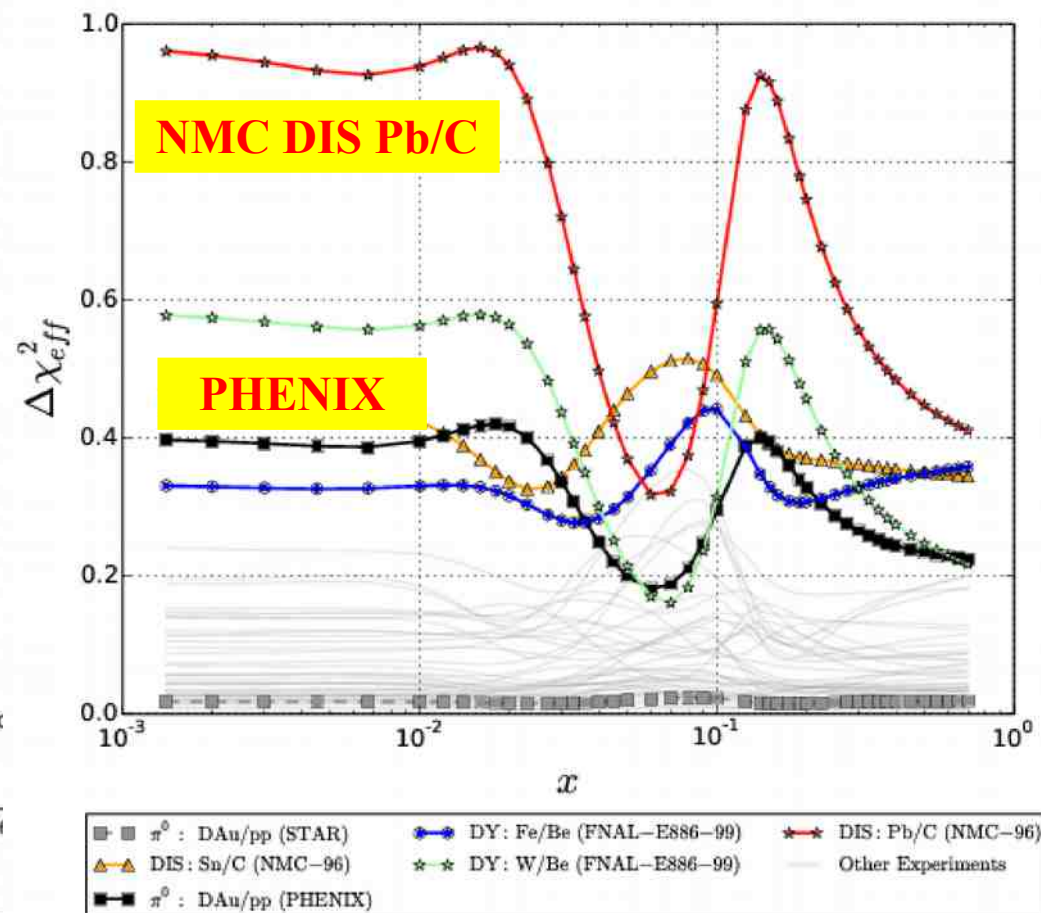
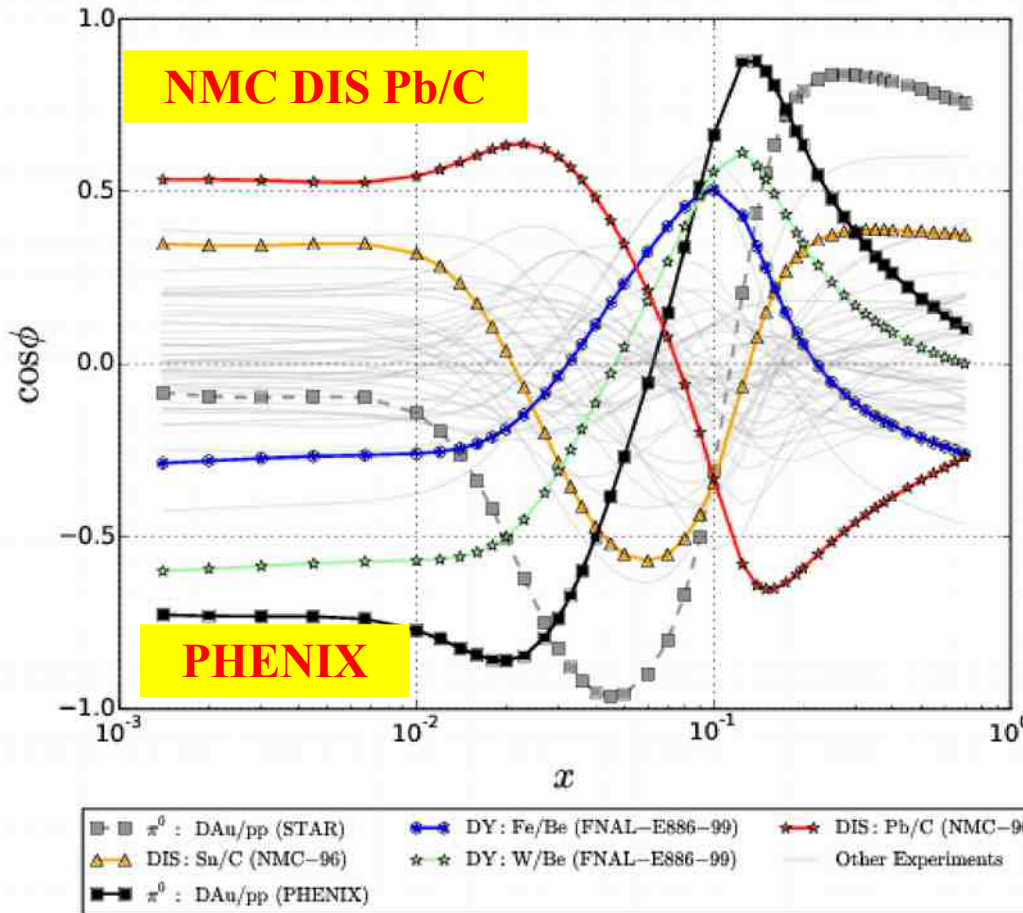
## RHIC Pion Production Data



## Correlation Cos

lead @ Q=10 GeV

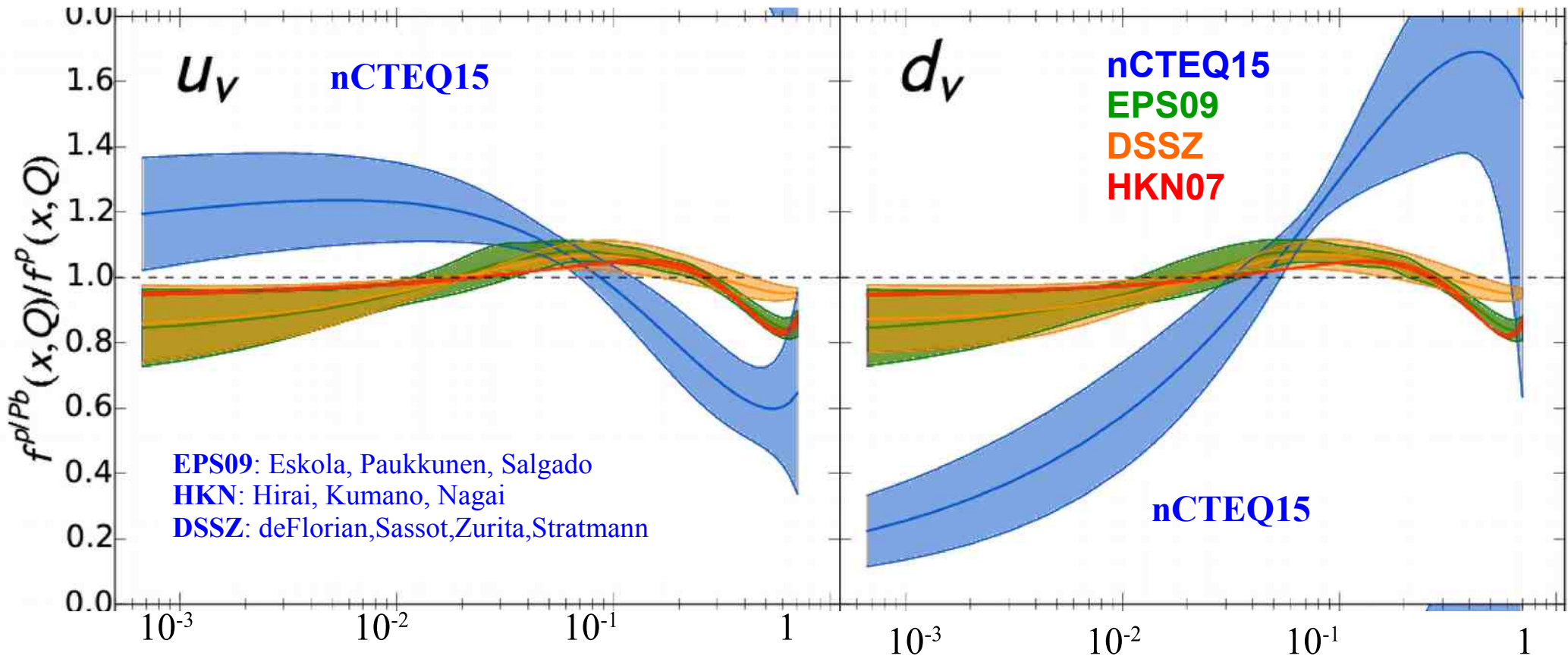
## Effective $\chi^2$



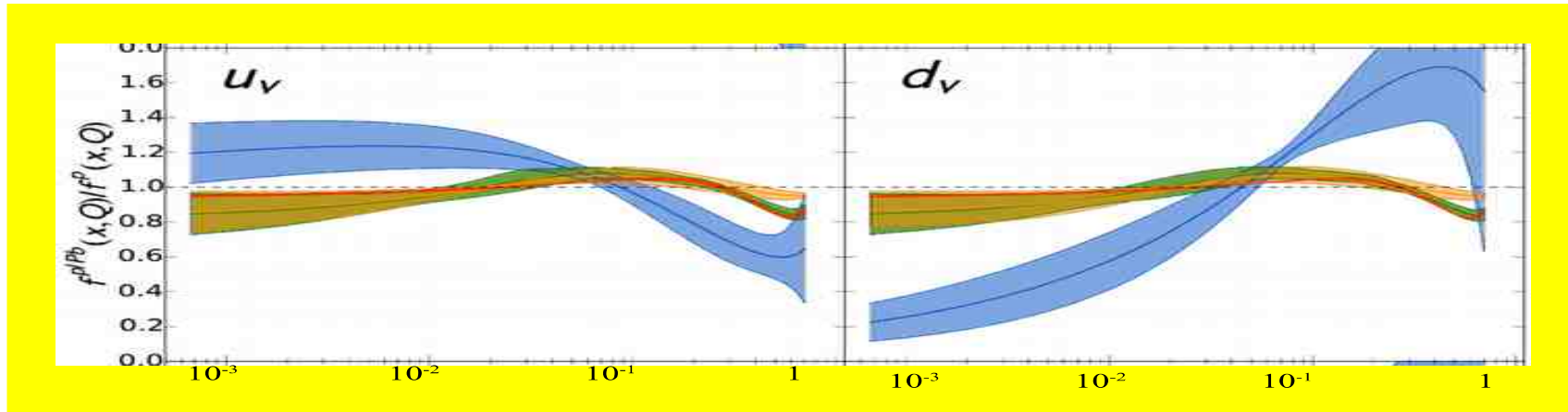
**PHENIX: dAu  $\pi^0$  Production**

*... can use more data*

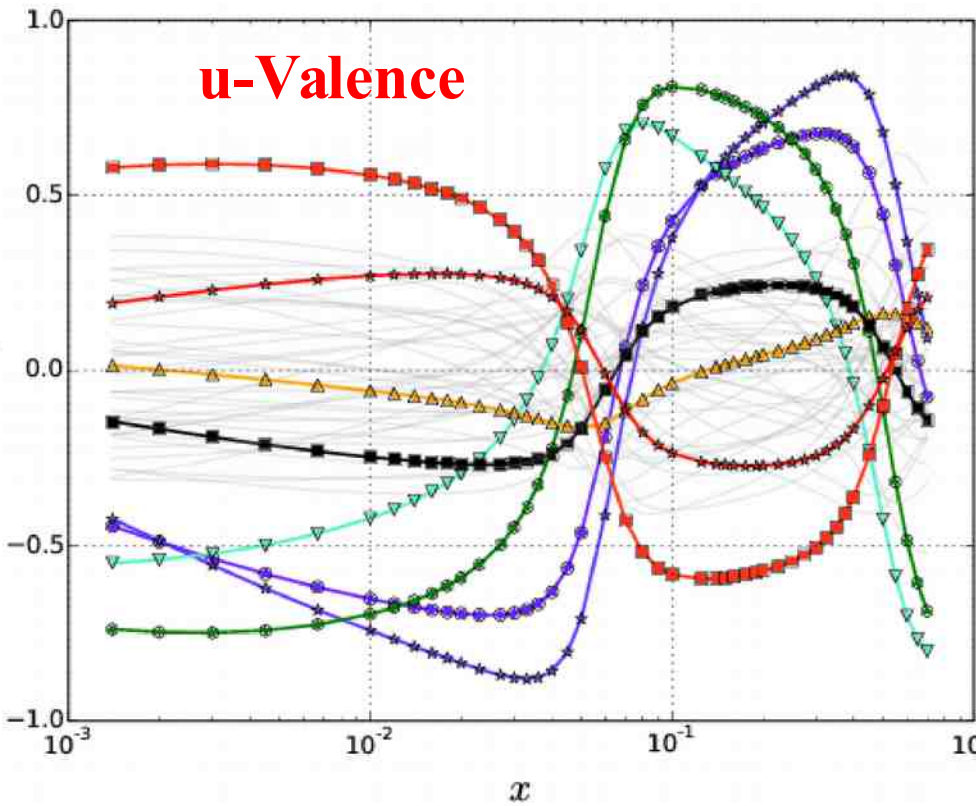
U & D



*... nCTEQ15 agrees on average, but ...*

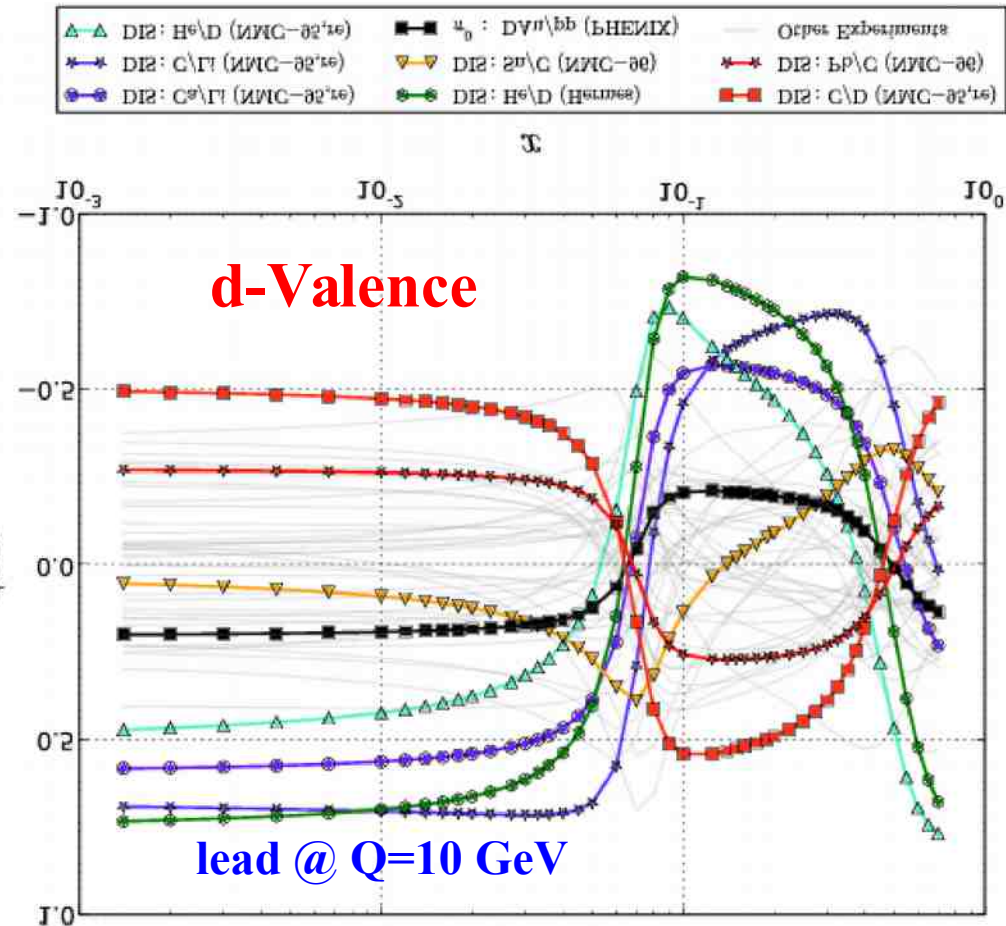


**u-Valence**



- DIS: Ca/Li (NMC-95, re)
- DIS: C/Li (NMC-95, re)
- DIS: He/D (NMC-95, re)
- DIS: He/D (Hermes)
- DIS: Sn/C (NMC-96)
- $\pi^0$ : DAu/pp (PHENIX)
- DIS: C/D (NMC-95, re)
- DIS: Pb/C (NMC-96)
- Other Experiments

**d-Valence**

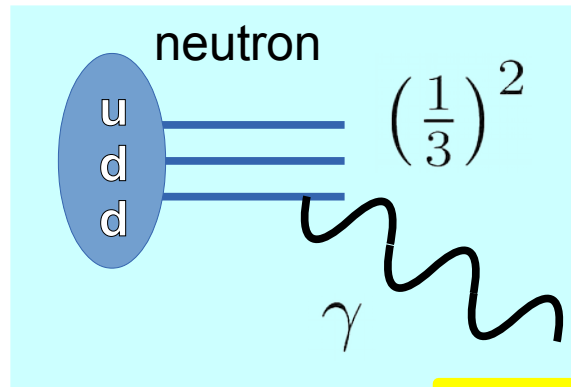
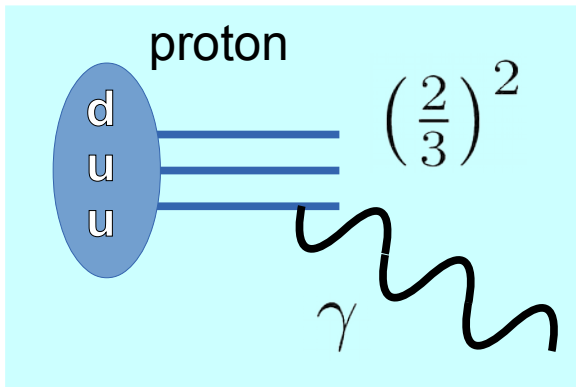


- DIS: He/D (NMC-95, re)
- DIS: C/Li (NMC-95, re)
- DIS: C^e/Li (NMC-95, re)
- $u_p$ : DVN/bb (BHEMIX)
- DIS: Sn/C (NMC-96)
- DIS: He/D (Hermes)
- Other Experiments
- DIS: Pb/C (NMC-96)
- DIS: C/D (NMC-95, re)

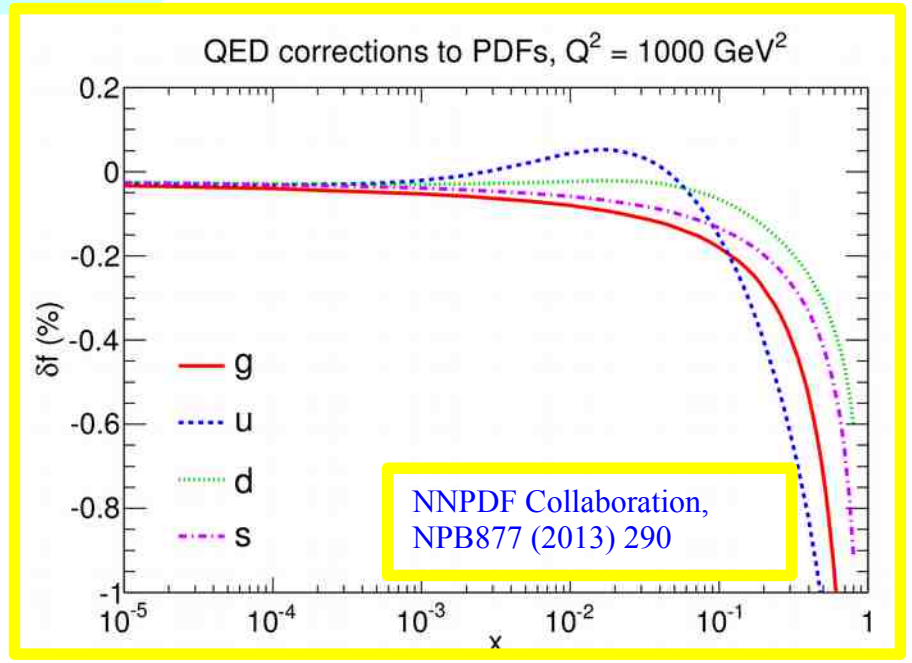
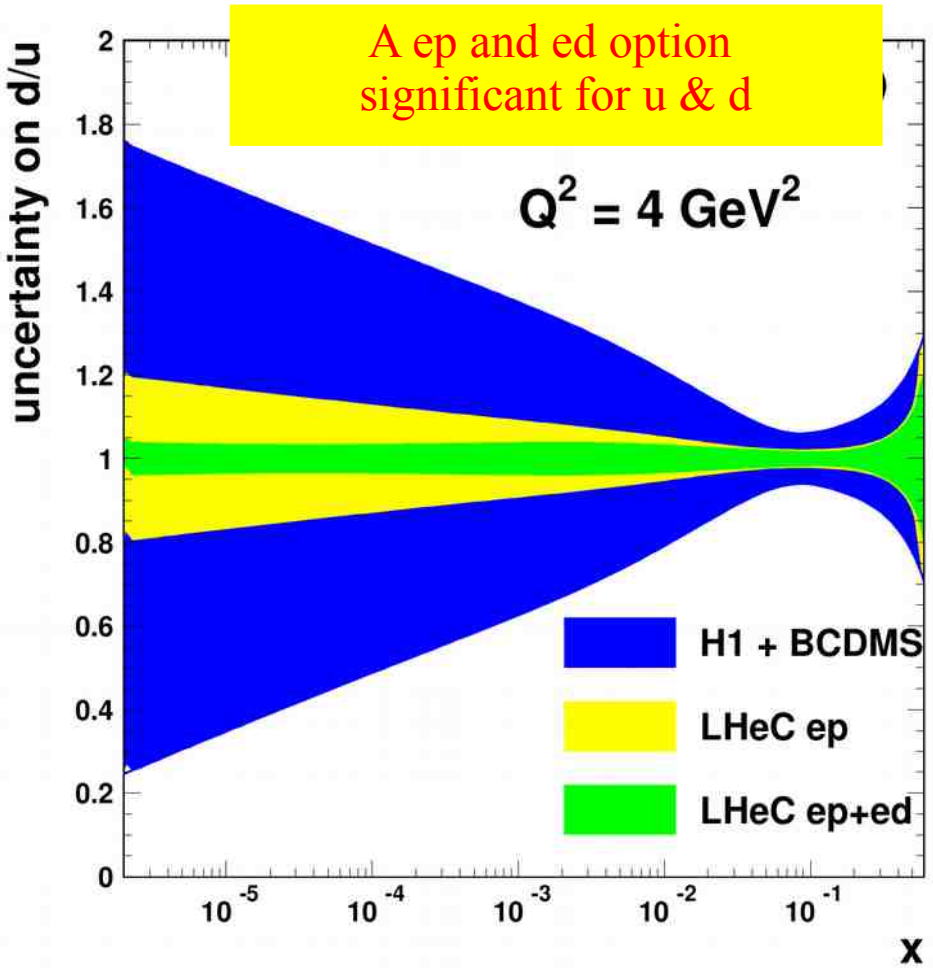
lead @ Q=10 GeV



# IsoSpin Violation



QED Evolution yields Isospin violating terms.  
Comparable to NNLO QCD



... and beyond:  
Need to introduce PDFs for  $\gamma$  W and Z

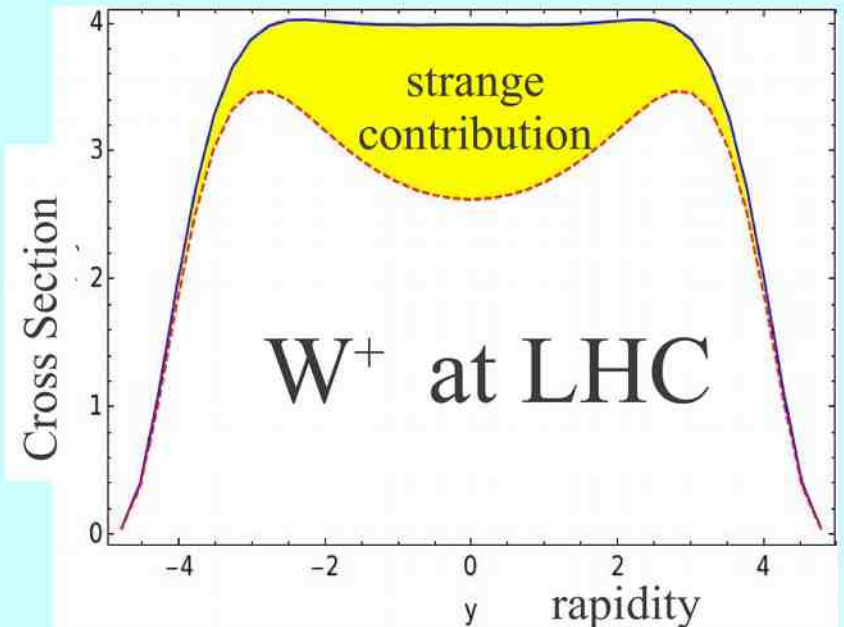
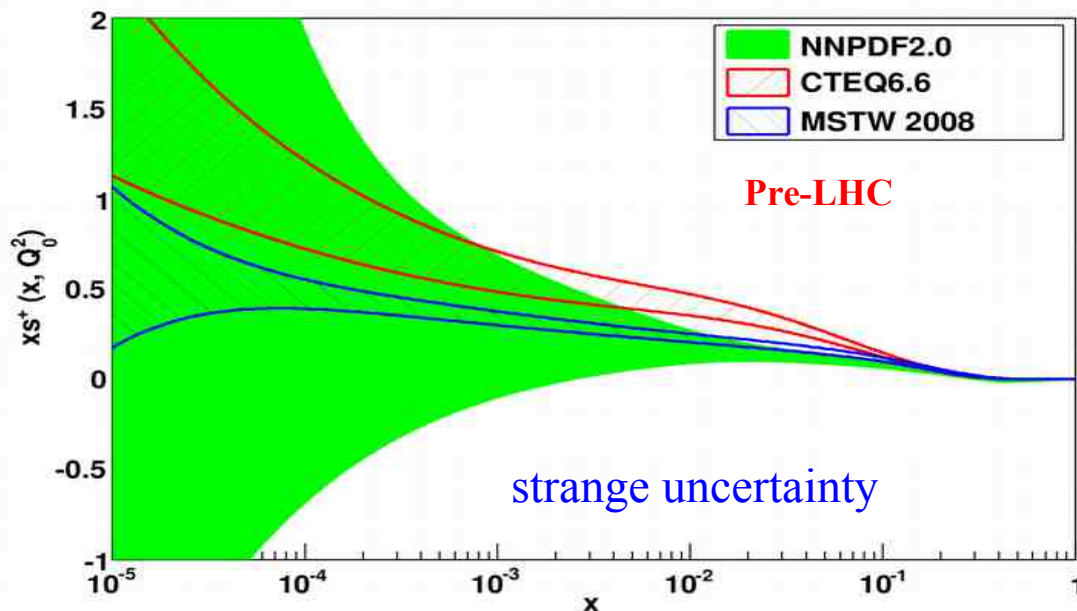
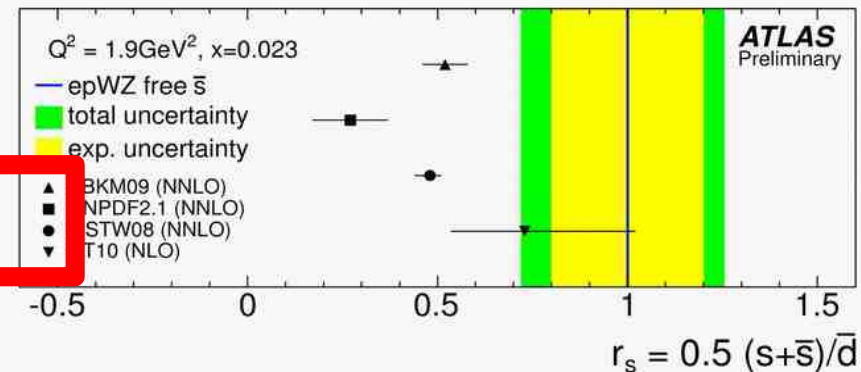
# Strange

## W, Z data sensitivity to strange sea

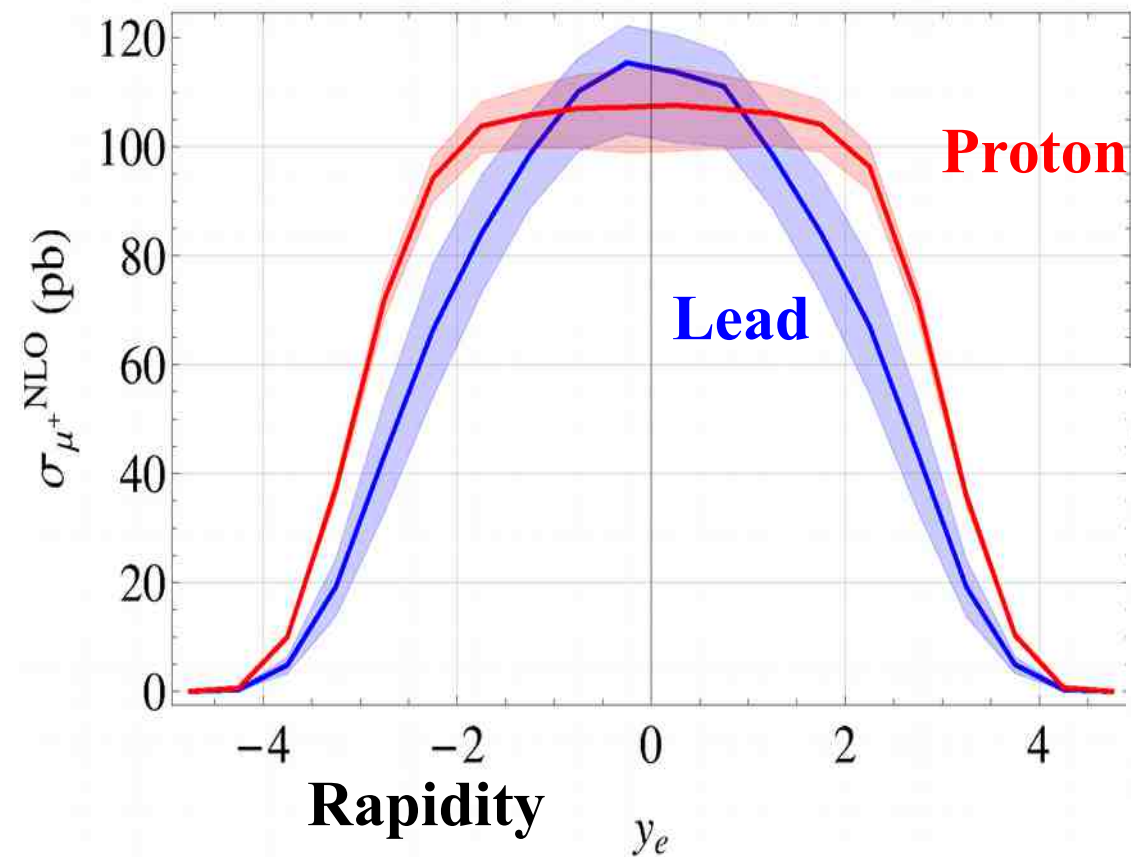
Suggests SU(3) symmetry in contrast to low Q measurements

- ATLAS performed NNLO QCD fit to  $Z, W^+, W^-$  + HERA  $ep$  DIS cross sections: significant tension for  $Z$  observed when suppressing strange by 50% at low scale  $1.9 \text{ GeV}^2$
- Fit with free strange sea gives no suppression

$$r_s = 1.00 \pm 0.20_{\text{exp}} \begin{matrix} +0.16 \\ -0.20 \text{ sys} \end{matrix}$$

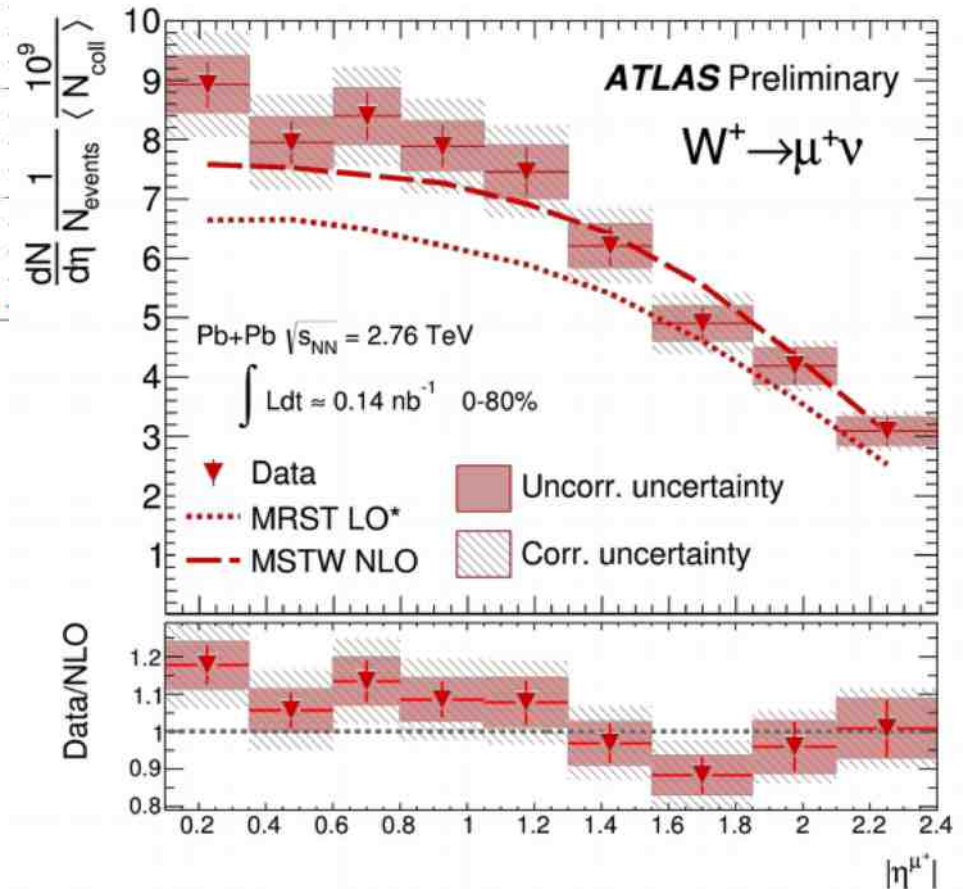


FEWZ  $\mu^{+,NLO}$  at 2.76 TeV



This is a shape measurement

$$W^+ \rightarrow \mu^+ \nu$$



# Final Thoughts

# Nuclear Parton Distributions

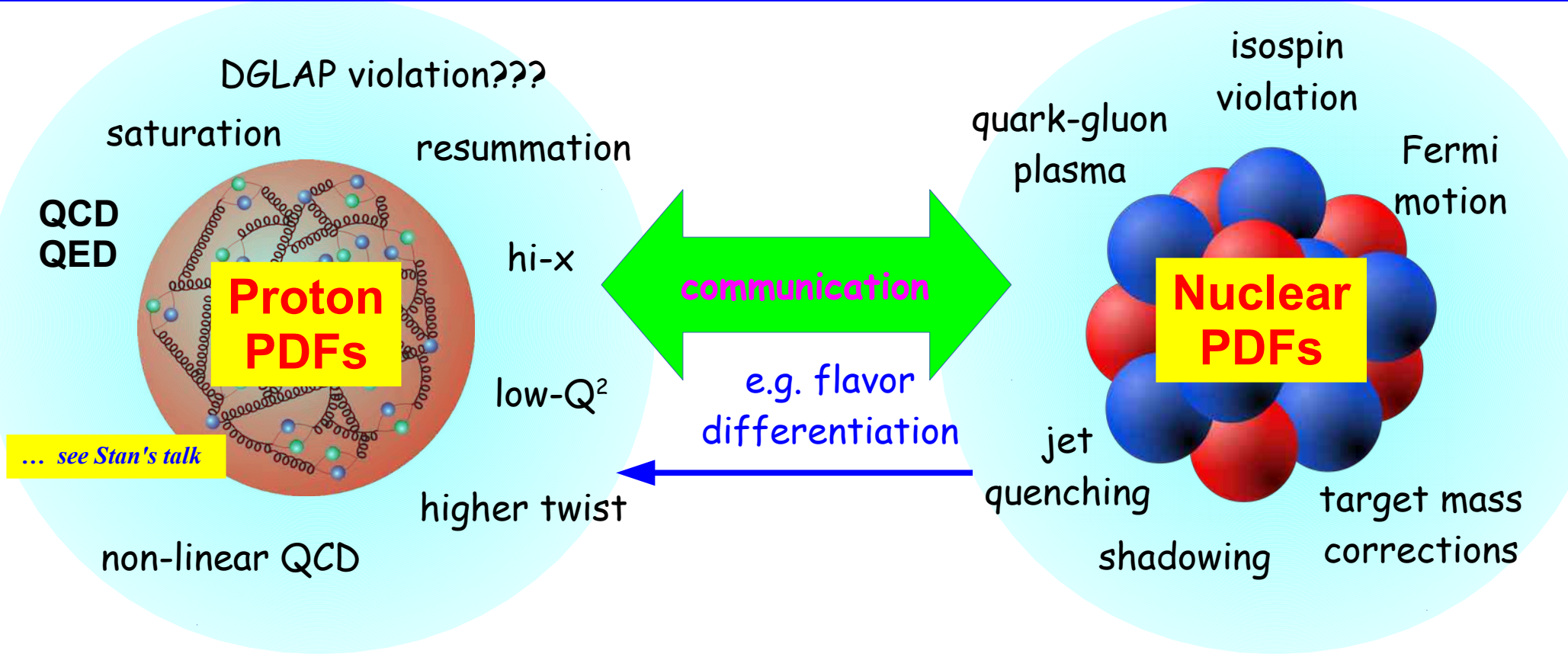
Photo credit: <http://justinsomnia.org/>

## LHeC Program:

- ⇒ tremendous reach for New Physics Searches
- ⇒ new opportunities *and* challenges

## LHeC: Complement HL-LHC

Maximize discovery potential at highest energy  
Study QCD extremes in  $\{x, Q^2\}$  plane



**“... indeed the LHeC would considerably sharpen the hadron collider potential in terms of theoretical control and precision”** *Altarelli*

