Parton Distribution Functions from JLab to LHC

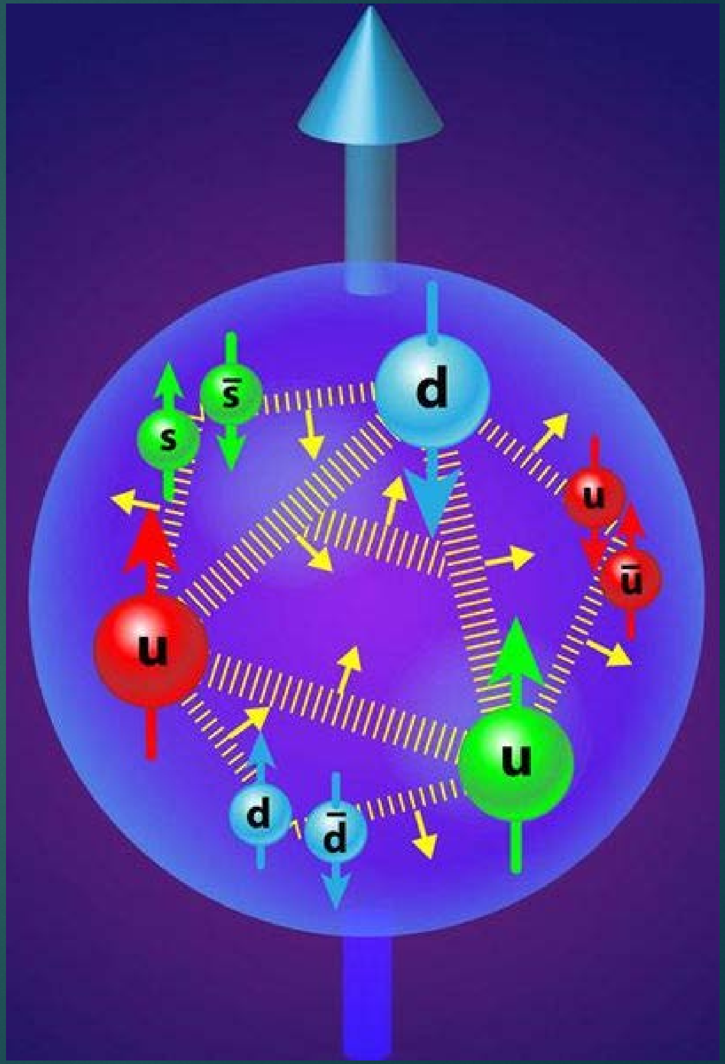
Christopher Cocuzza (Temple University)

Jacob Ethier (Nikhef)
Wally Melnitchouk (Jefferson Lab)
Andreas Metz (Temple University)
Nobuo Sato (Jefferson Lab)

JAM Jefferson Lab Angular Momentum Collaboration

JAM Collaboration

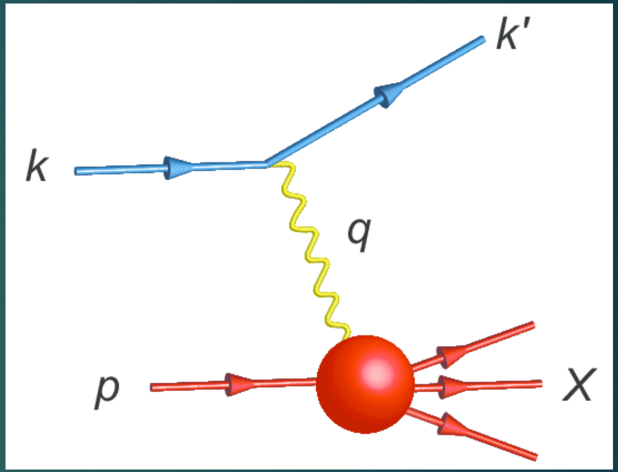
- Understand the 3-dimenstional structure of the nucleons through global QCD analysis of parton distribution functions (PDFs), fragmentation functions (FFs) and transverse momentum dependent (TMD) distributions.
- Use collinear factorization in perturbative QCD to perform simultaneous determinations of PDFs, FFs, TMDs.
- Utilize Monte Carlo methods and modern Bayesian analysis techniques



Spin-Averaged PDF Analysis

Two major goals of this analysis:

1. Examine high-x phenomena ($\frac{x^2 M^2}{Q^2}$) using deep inelastic scattering data
   a) Target Mass Corrections
   b) Higher Twist Corrections
   c) Nuclear Smearing and Off-shell Corrections



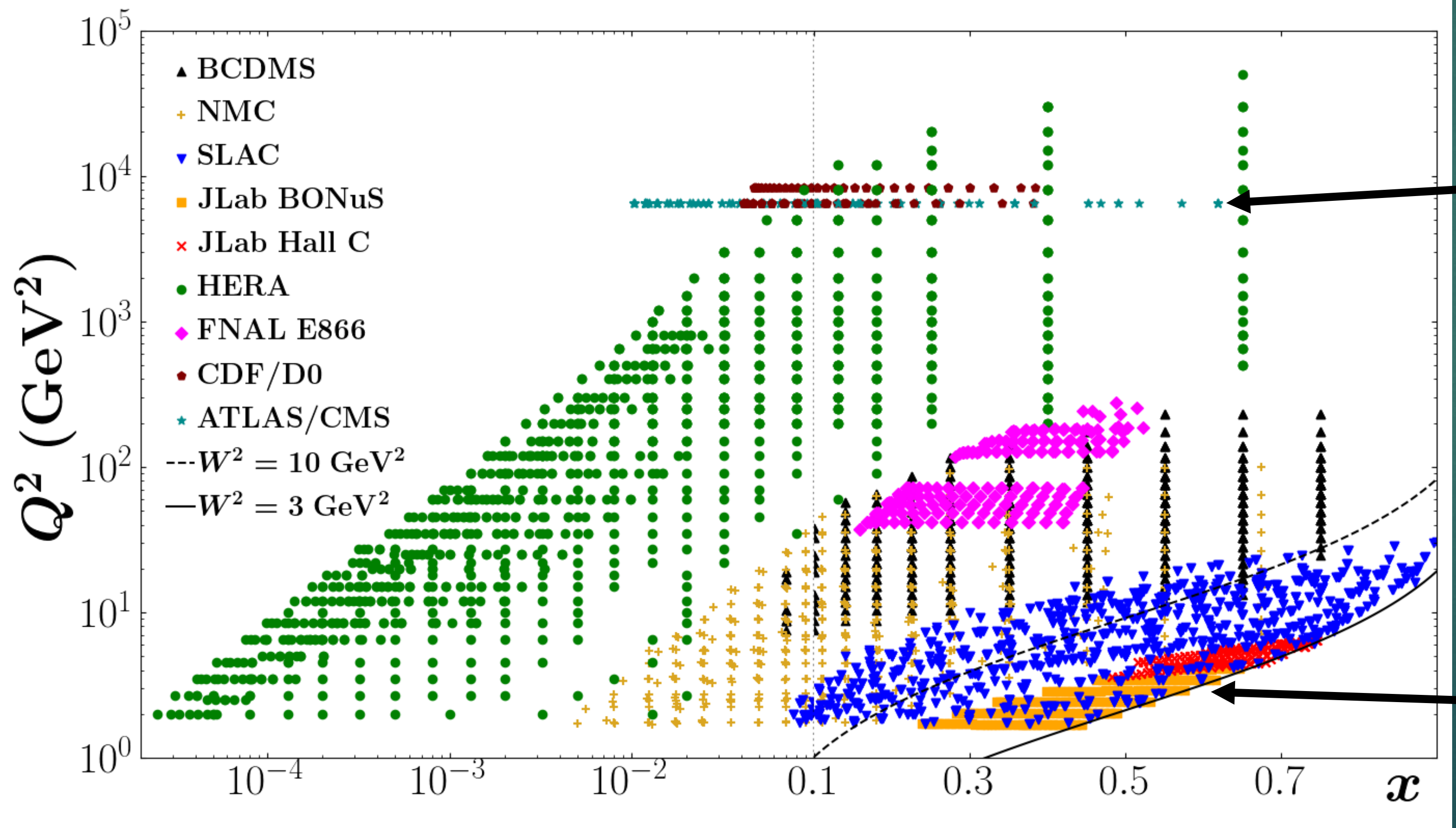
x: Parton momentum fraction

Q^2: Momentum transfer

2. Include new W-boson production data from the LHC and analyze impact on spin-averaged PDFs. Potentially provides important information on valence and light sea quarks.

Data

- **Deep Inelastic Scattering**: BCDMS, NMC, SLAC, HERA, Jefferson Lab (3,863 points)
- **Drell-Yan**: Fermi Lab E866 (250 points)
- **W/Z Boson Production**: Tevatron CDF/D0, LHC ATLAS/CMS (239 points)



New LHC Data

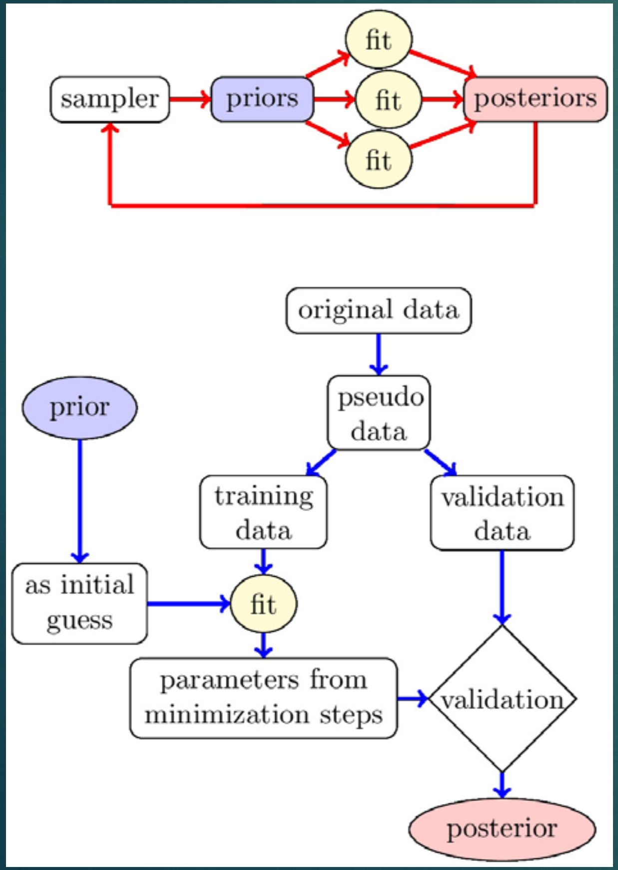
Low W^2 cut allows inclusion of high-x data, particularly from Jefferson Lab

High-x Data

JAM Methodology

- Parameterize PDFs at input scale $Q_0^2 = m_c^2$
- Evolve PDFs using DGLAP and compute observables
- Determine parameters through Bayesian posterior sampling with likelihood function $e^{-\frac{\chi^2}{2}}$

Data Resampling:



$$PDF = a_0 x^{a_1}(1-x)^{a_2}(1+a_3\sqrt{x}+a_4 x)$$

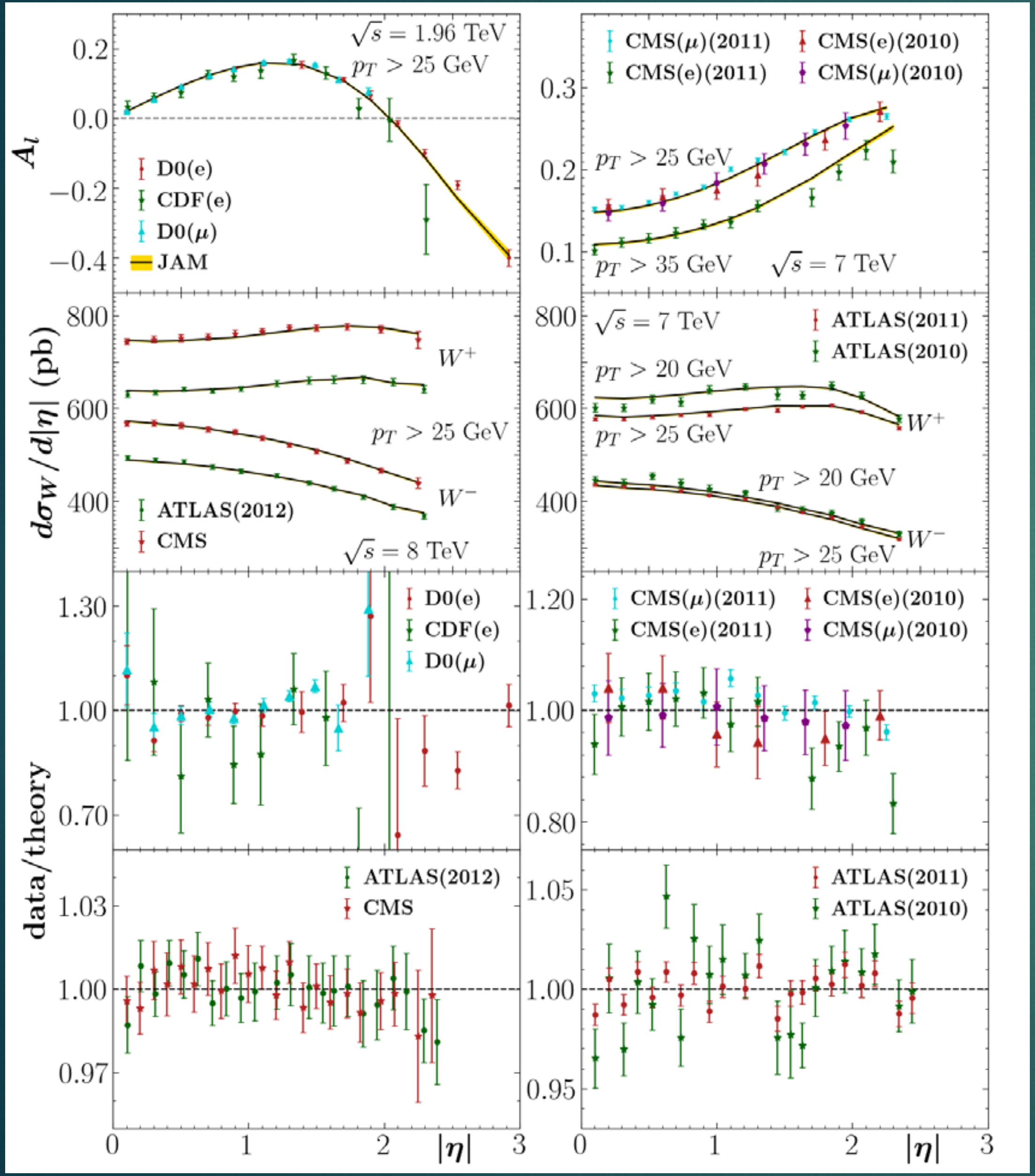
$$\tilde{\sigma} = \sigma + R\alpha$$

$\tilde{\sigma}$: Pseudo-Data
σ: Original Data
R: Random Gaussian number $-1 < R < 1$
α: Quadrature sum of uncertainties

Multi-Step Strategy:

Step	Data	W^2_{cut} (GeV^2)	TMC	a_3, a_4	HT	Offshell
1	Fixed target DIS	10	—	—	—	—
2	+HERA DIS	10	—	—	—	—
3	+JLab DIS	3	—	—	—	—
4	—	3	✓	—	—	—
5	+Drell-Yan	3	✓	—	—	—
6	—	3	✓	✓	—	—
7	+W/Z boson	3	✓	✓	—	—
8	—	3	✓	✓	✓	—
9	+Lepton	3	✓	✓	✓	—
10	—	3	✓	✓	✓	✓

LHC Observables



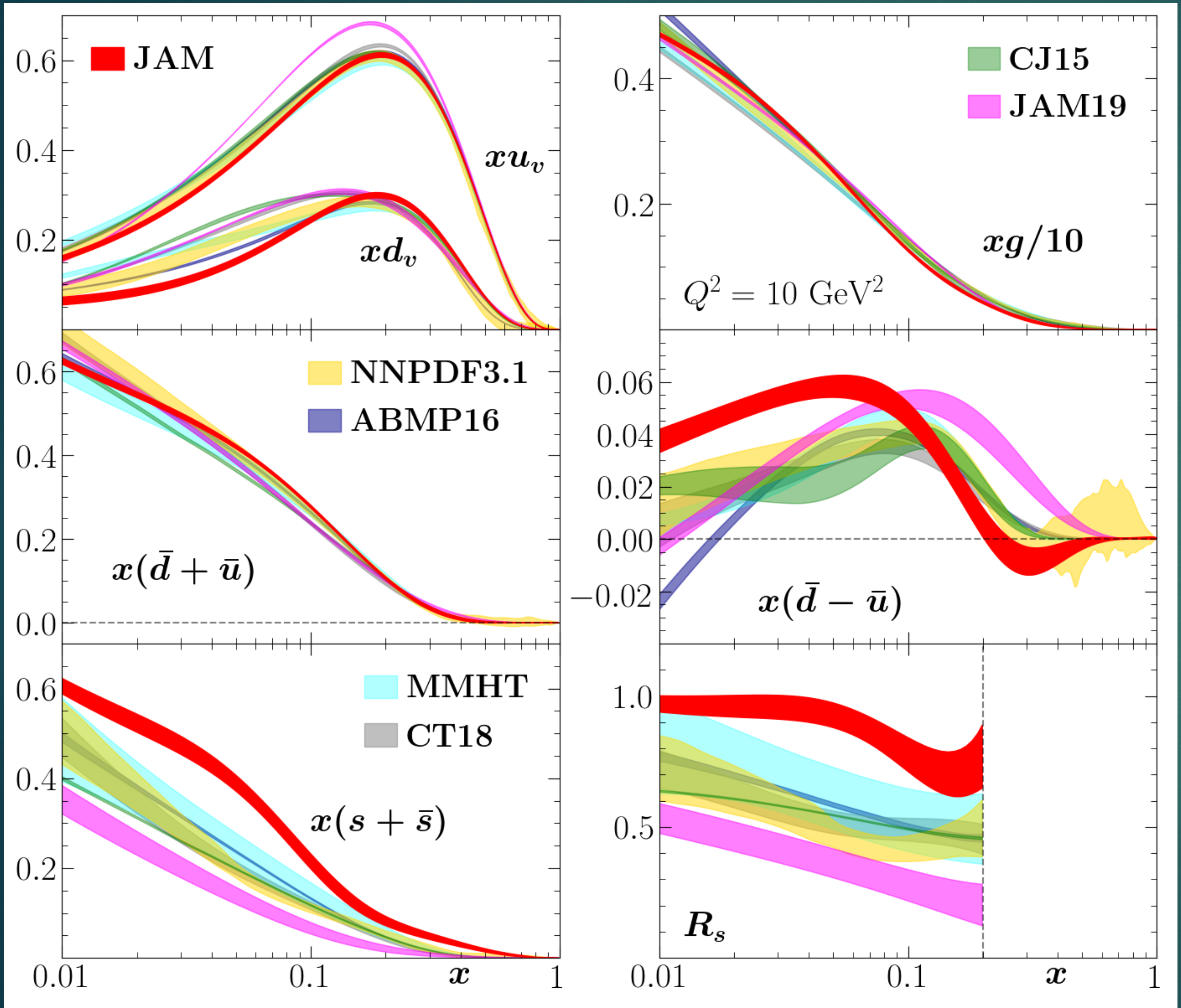
Top left: $p\bar{p}$ data from Tevatron

Everything else: pp data from LHC

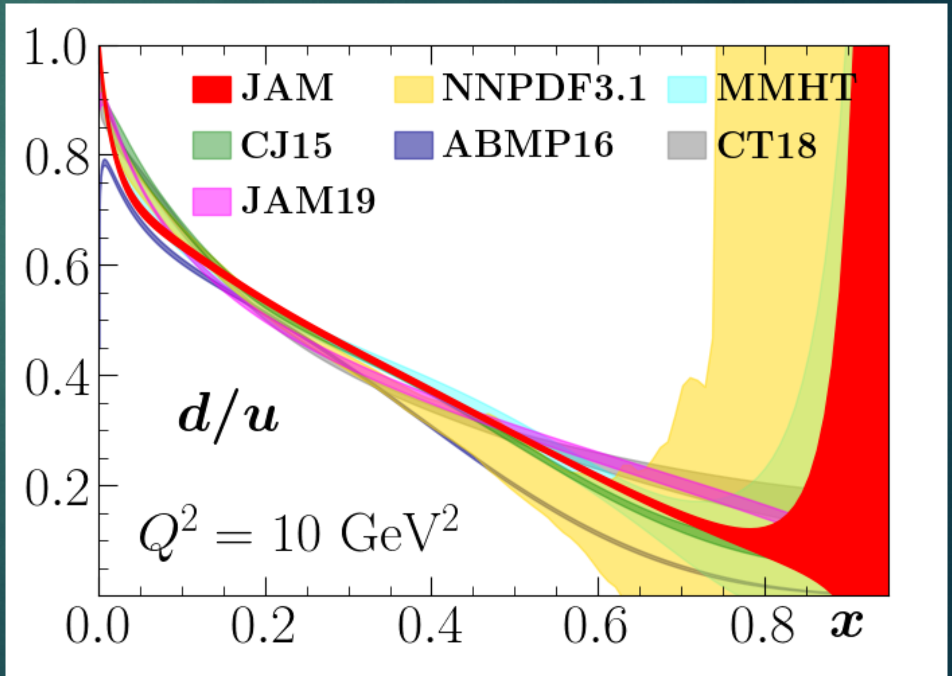
LHC: χ^2/# points = 1.35

Overall: χ^2/# points = 1.11

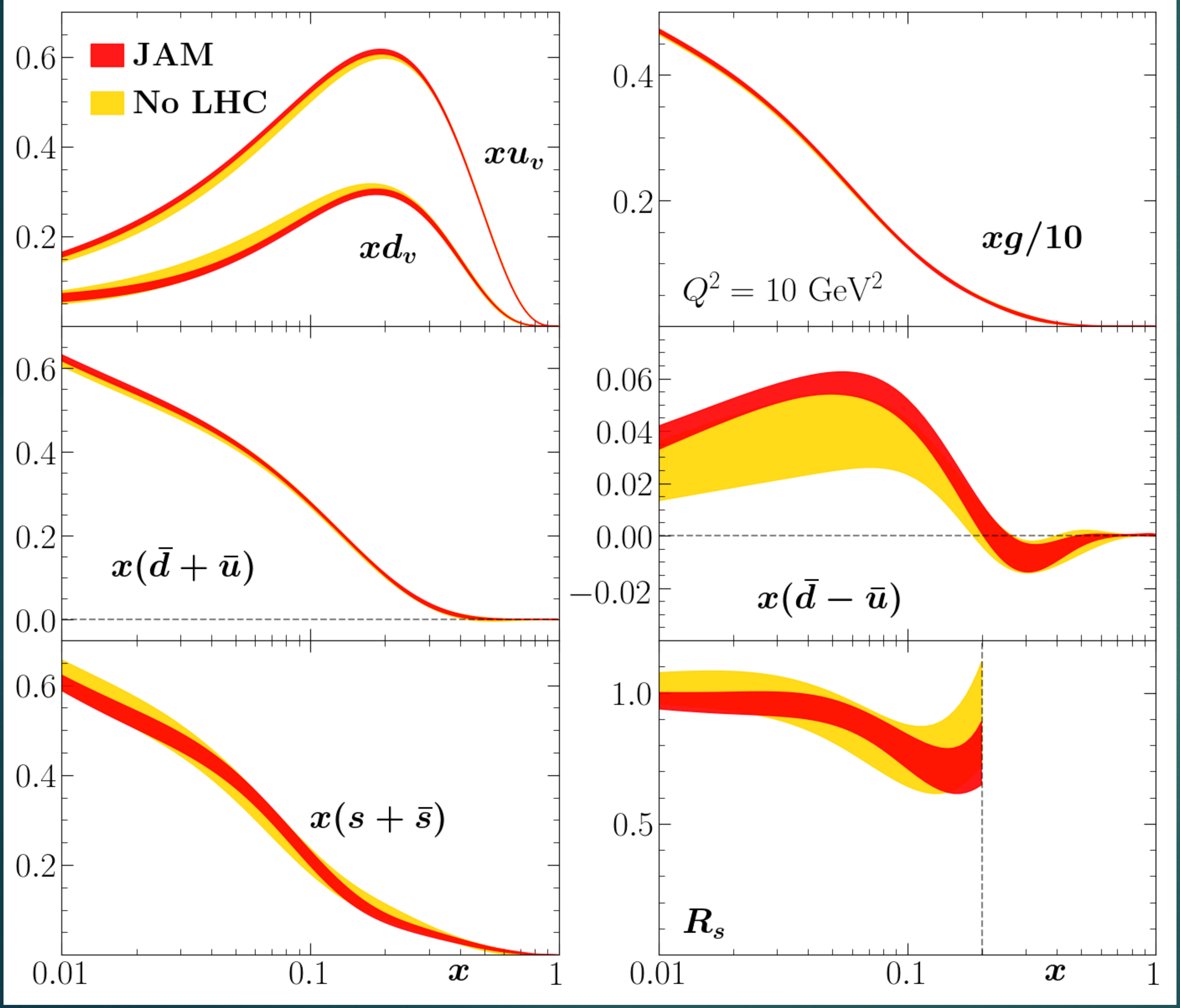
Parton Distribution Functions



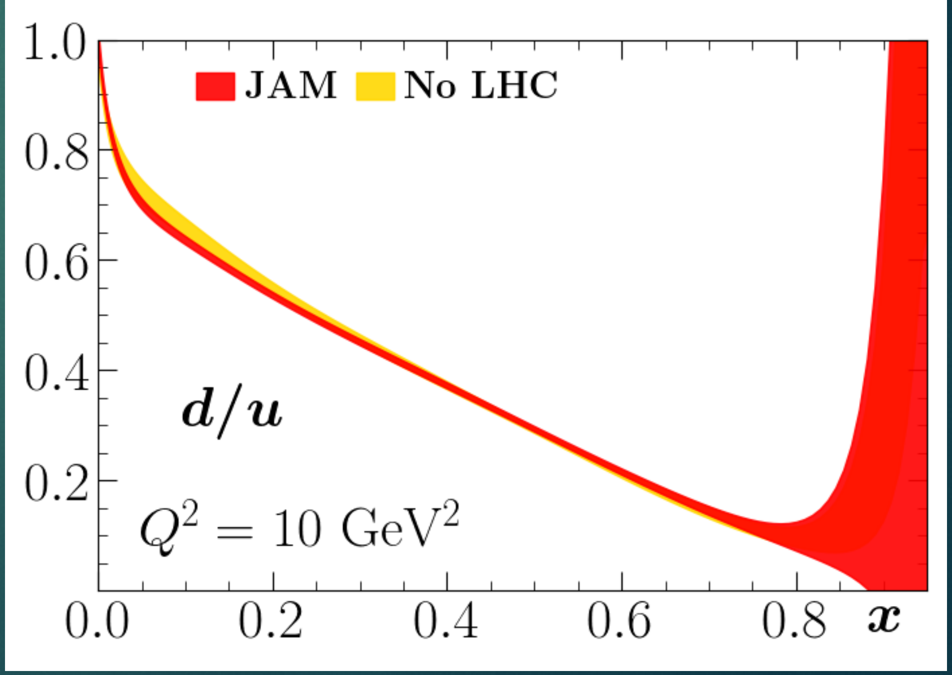
- Suppressed d_v, enhanced s^+
- Large $\bar{d} - \bar{u}$ at low x due to LHC data
- d/u well constrained, except at very high x



Impact of LHC Data

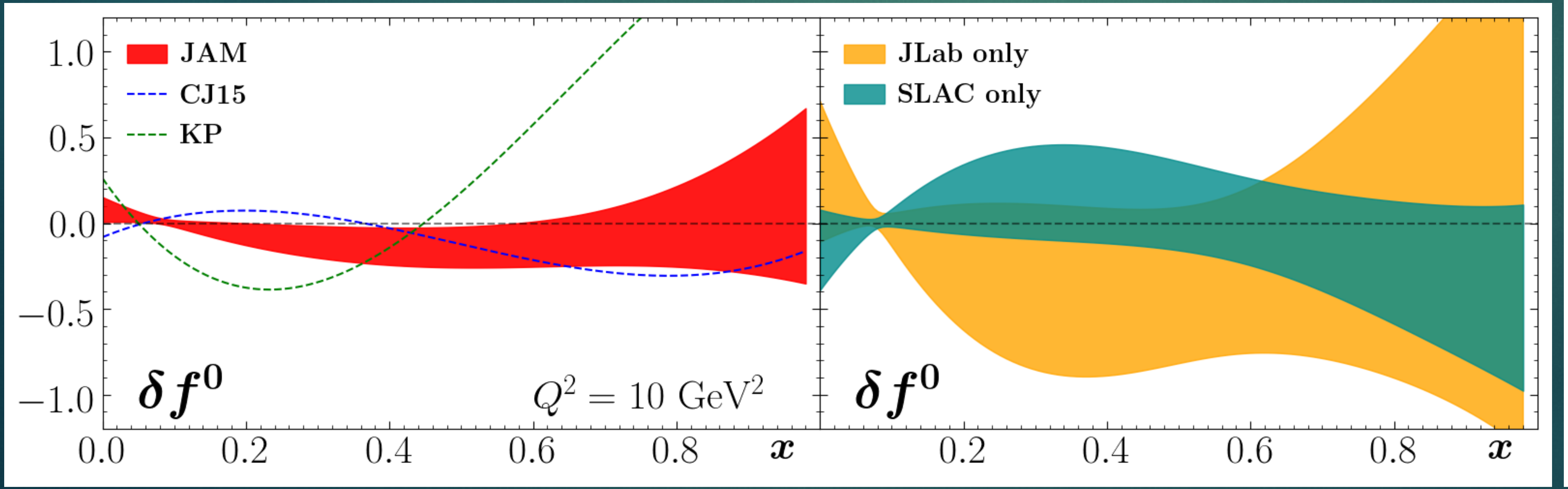


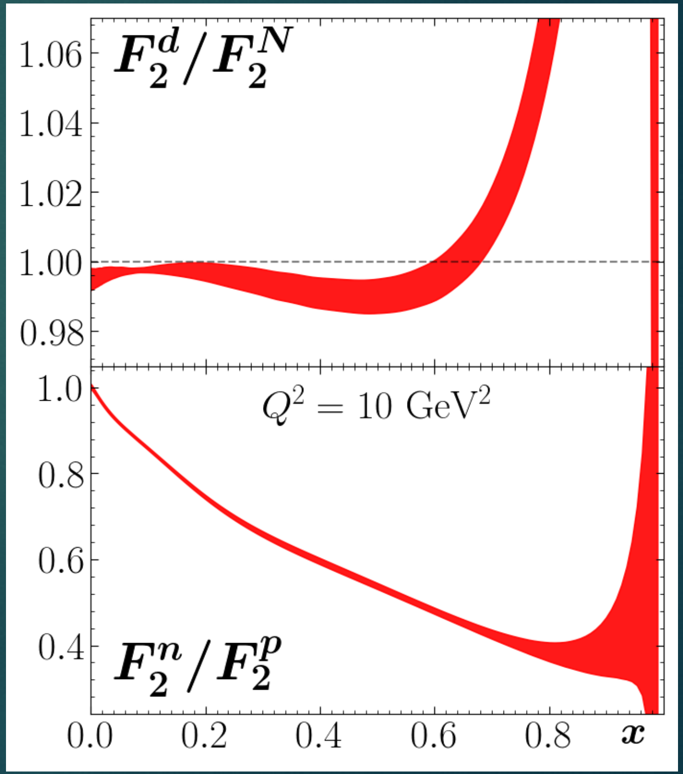
- Constrains u, d quarks at $x < 0.2$
- Constrains and enhances $\bar{d} - \bar{u}$ at $x < 0.2$
- Constrains d/u at $x < 0.3$



Off-shell Corrections

- Consistent with zero, due to tension between Jefferson Lab and SLAC data
- Different than CJ15 and KP results
- Result is consistent regardless of
  - parameterization choice
  - choice of target mass correction (GP, AOT)
  - choice of deuteron wave function (Paris, AV18, CD-Bonn, WJC-1, WJC-2)





Conclusions

- New LHC data provides new constraints at $x < 0.2$ on the valence quarks, sea asymmetry, and d/u ratio.
- Sea asymmetry at low x is found to be larger than previous extractions.
- d_v at low x is found to be smaller, while s^+ is found to be larger.
- Offshell corrections are found to be consistent with zero due to tension in datasets. Result is consistent regardless of parameterization or model choice.

Collaboration

This project was done in collaboration with:

Jacob Ethier

Wally Melnitchouk

Andreas Metz

Nobuo Sato

JAM Jefferson Lab Angular Momentum Collaboration

Thank you to Yiyu Zhou and Patrick Barry for helpful discussions.

Extra: Higher Twist