Extracting Neutron Structure Functions from World DIS Data with CJ15 Nuclear Corrections

Shujie Li
on behalf of the CTEQ-Jefferson Lab Collaboration

CTEQ Workshop @ JLab, Nov. 2018

Overview

World unpolarized DIS proton and deuterium datasets with new data from Jefferson Lab 6 GeV experiments

+

nuclear corrections from CJ15 [1] global QCD analysis

=

F2 neutron "Data"

Why neutron?

- Neutron excess correction
  - EMC effect
  - Neutrino experiment
- Flavor separation
  - d/u
  - Nucleon structure / confinement at large x
- Sum rules and moments
  - Gottfried Sum Rule (d_bar - u_bar)
  - Compare non-singlets to lattice ($\int F_2^p - F_2^n \, dx$)
- Scaling at small x with future EIC/LHeC
  - Reggie, BFKL, saturation,...

The CJ DIS Database

SLAC (Whitlow, E140, E140x)

JLab (JLCEE96, E06-009, E94-110, E03-103, E99-118, E00-116, CLAS6, BoNus)

- *2000+ new data points*

NMC, BCDMS, HERMES, HERA, E665 …

Revisited correlated systematics for NMC, SLAC, etc

A = data is available but not collected 10001-10070 = data ID in JAM databsae

Experiment	σ_r	F2	R
SLAC-Whitlow	p: 10014	p: 10010	p: 10064
	d: 10015	d: 10011	d: 10065
	d/p: 10034	d/p (*): 10034	
SLAC-E140			d: 10066
SLAC-E140x	p: 10037	p: 10035	p: 10067
	d: 10038	d: 10036	d: 10068
NMC	p: 10022	p: 10020	
	d: 10040	d: 10039	
	d/p:10021	d/p (*):10021	
BCDMS	p: 10018	p: 10016	p: 10069
	d: 10019	d: 10017	d: 10070
JLab E06-009	d: 10042	d: 10041	

The full database will come to public soon …

The CJ DIS Database

SLAC (Whitlow, E140, E140x)

JLab (JLCEE96, E06-009, E94-110, E03-103, E99-118, E00-116, CLAS6, BoNus)

- *2000+ new data points*

NMC, BCDMS, HERMES, HERA, E665 …

Revisited correlated systematics for NMC, SLAC, etc

JLab BoNuS F2 Neutron Data with 4.223 and 5.262 GeV beam

Data files:

xlsx: neutron csv: neutron

Source:

https://userweb.jlab.org/~narbe/BoNuS/analysis/deut-fit/checks/tables/resnr/v1/

References:

1-- S. Tkachenko et al. (CLAS Collaboration), Phys. Rev. C 89, 045206 – Published 24 April 2014

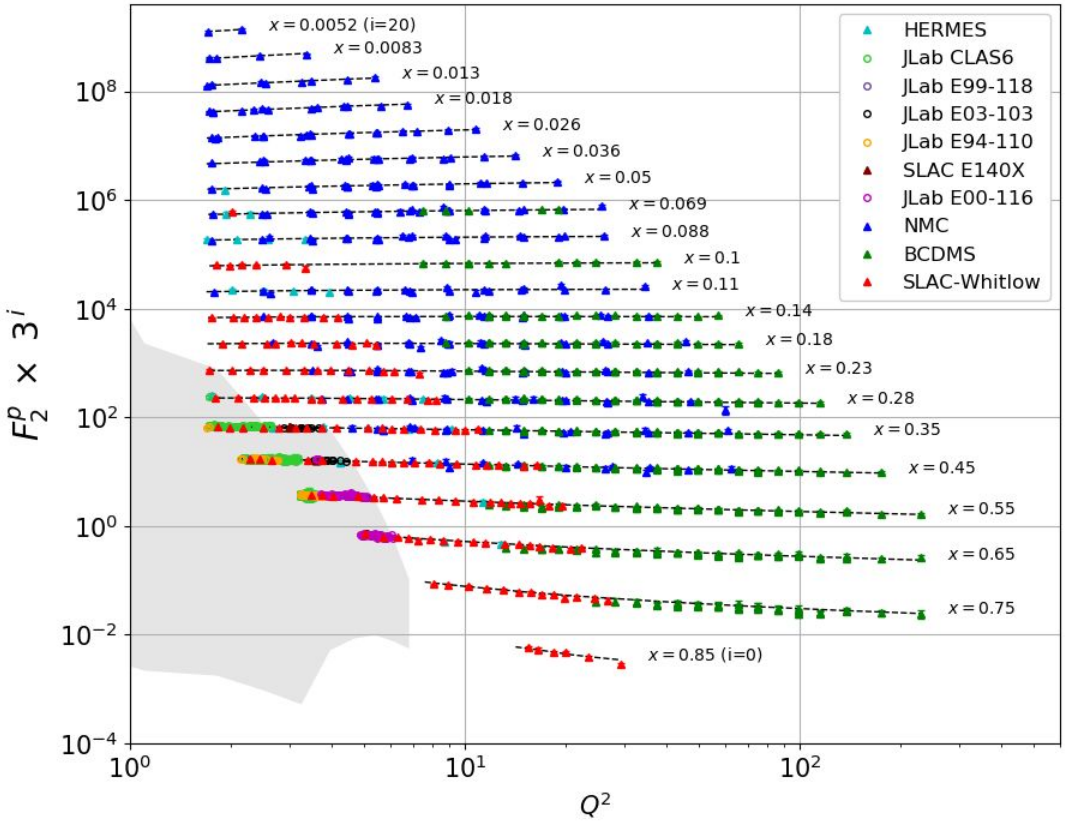
2-- K. A. Griffioen et al., Phys. Rev. C 92, 015211 – Published 21 July 2015

Uncertainties:

The full database will come to public soon …

F2 p kinematics

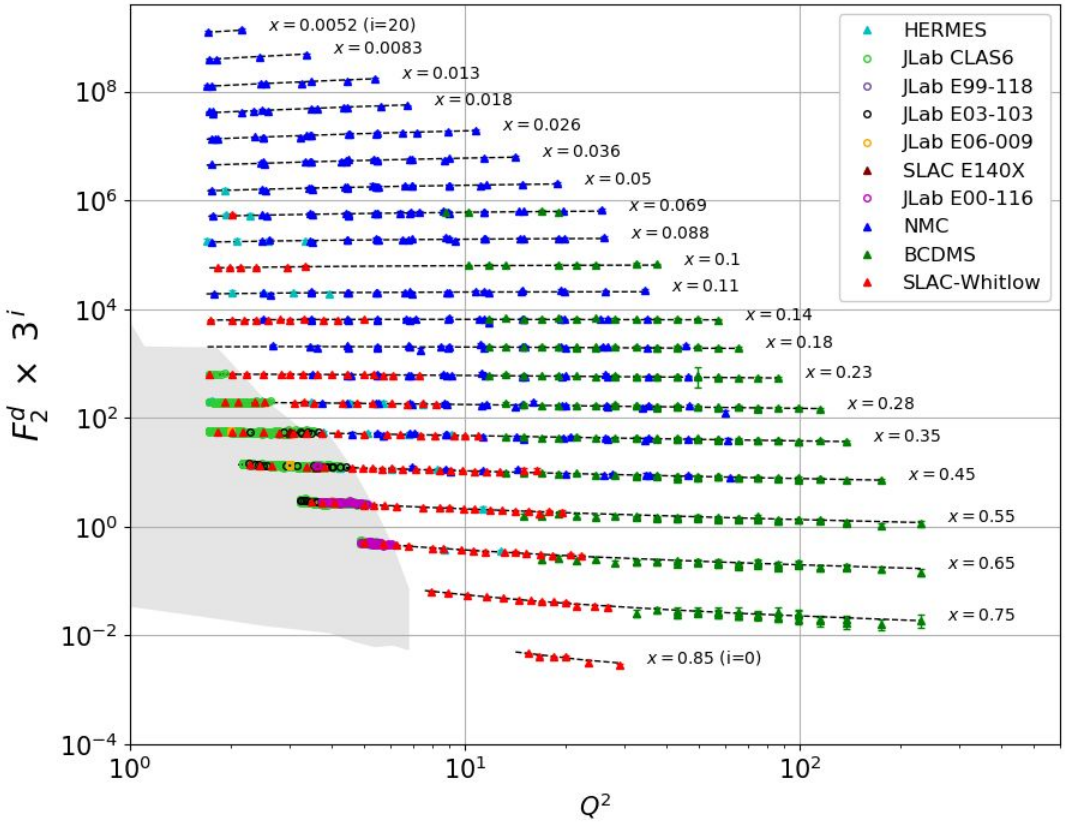
Markers: DIS data after rebinned in x_bj. Shaded area: JLab data.
Dashed line: CJ15 calculation



F2 d kinematics

Markers: DIS data after rebinned in x_bj. Shaded area: JLab data.

Dashed line: CJ15 calculation



Data Selection

1. **Pass DIS cuts:**
   a. $Q^2 > 1.691\ GeV^2/c^2$
   b. $W^2 > 3.5\ GeV^2$

2. **Within each experiment**, we match the proton and deuteron data points by requiring:
   a. same beam energy,
   b. $|x_{proton} - x_{deuteron}| < 0.01$,
   c. $|Q^2_{proton} - Q^2_{deuteron}| < 1\%$.

Experiments	# of Proton F2 Data Points	# of Deuteron F2 Data Points	# of Constructed Neutron Points
SLAC-Whitlow[2]	564	582	470
BCDMS	351 [3]	254 [4]	254
HERMES [5]	45	45	45
JLab E-00-116 [6]	136	136	120
NMC [7]	275	275	258
SLAC-E140x [8]	9	13	9
JLab E-03-103 [9]	37	69	37
JLab CLAS6	609 [10]	1723 [11]	0
JLab E-94-110 [12]	112	0	0
JLab E-06-009 [13]	0	79	0
JLab E-99-118 [14]	2	2	2

F2 Neutron Extraction

we use CJ15 to remove nuclear effects in F_2 deuteron data. The free nucleon (proton + neutron) F_2

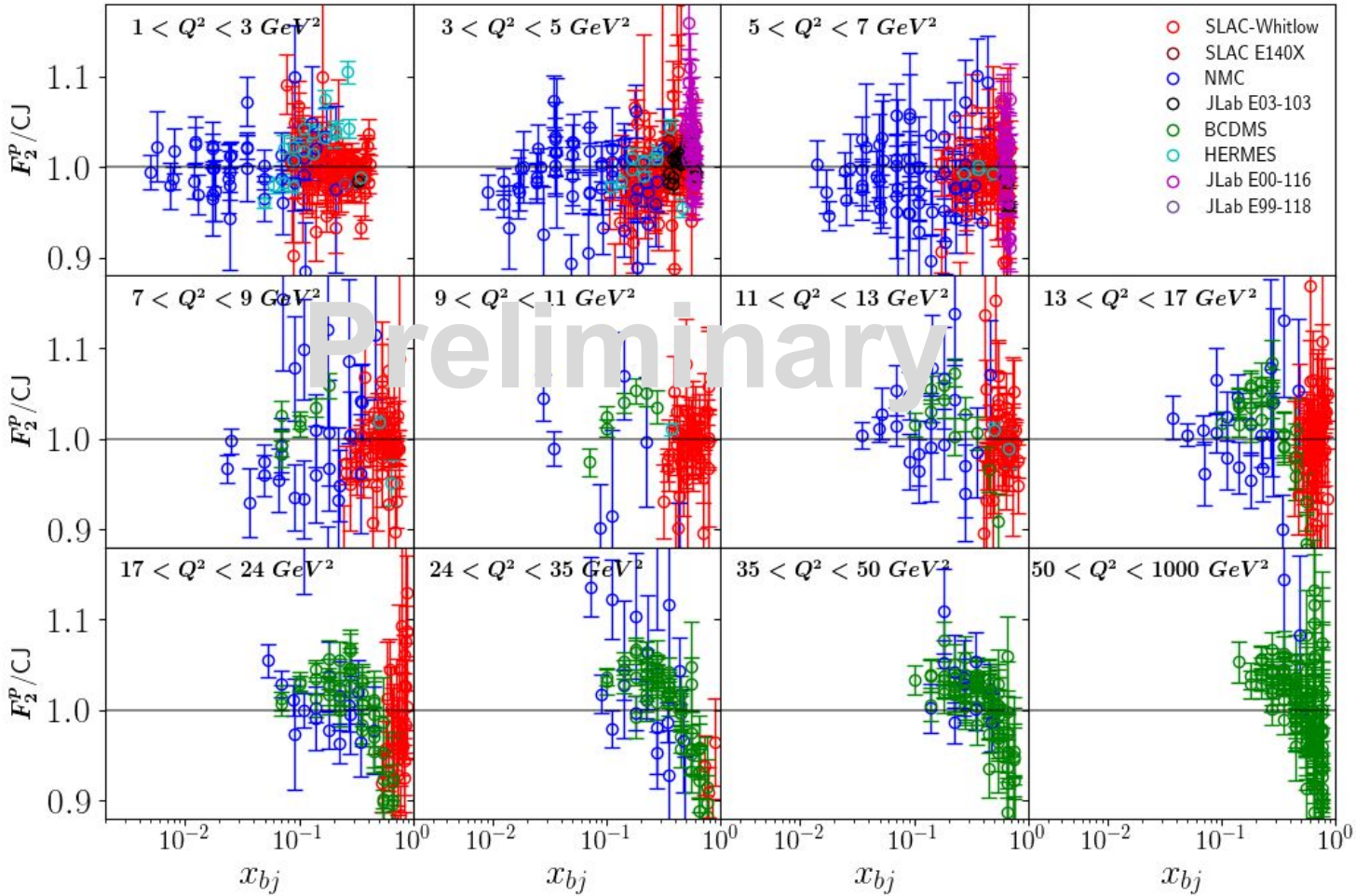
$$(p+n)_{data} = d_{data} * (p+n)_{cj} / d_{cj}$$

Then The F_2 neutron are constructed as:

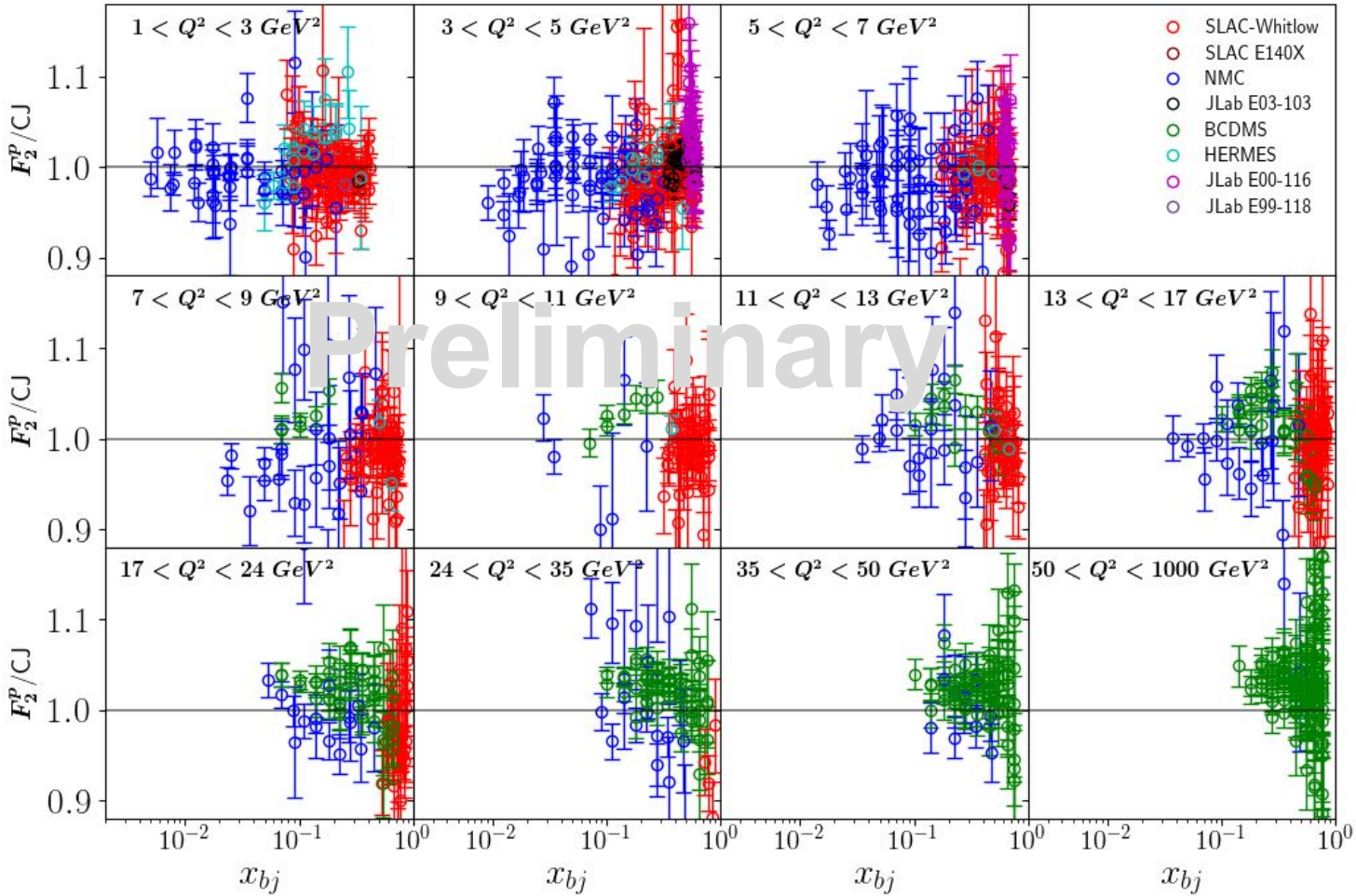
$$n_{data} = (p+n)^*_{data} - p^*_{data} = d^*_{data} * (p+n)_{cj}/d_{cj} - p^*_{data}$$

Where d^*_{data} is the original F2 data being shifted within their correlated and normalization uncertainties (decided by CJ15 fit) so that it's cross-normalized and ready for use.

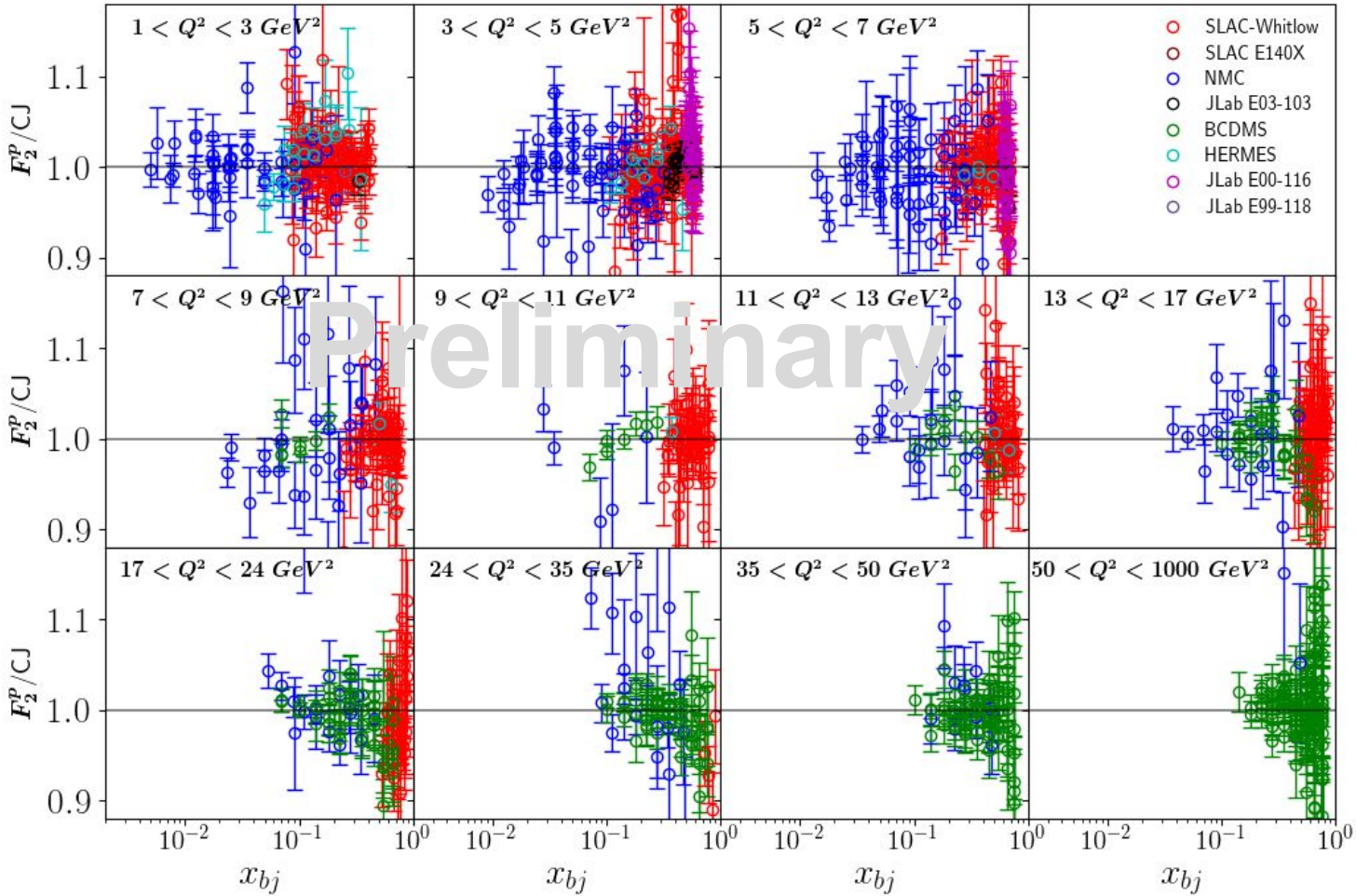
raw F_2^p Data/CJ



modified F_2^p Data/CJ



modified+normed F_2^p Data/CJ



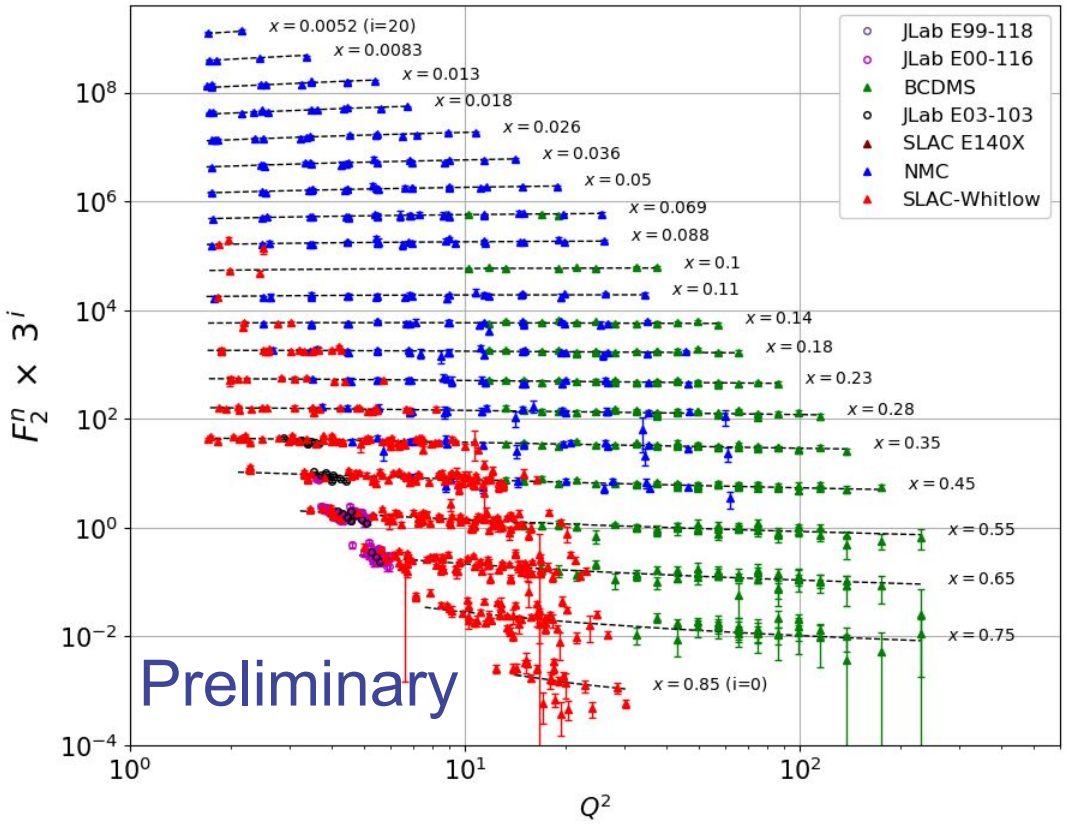
Uncertainties

- Experimental uncertainties
  - Statistical
  - uncorrelated systematics

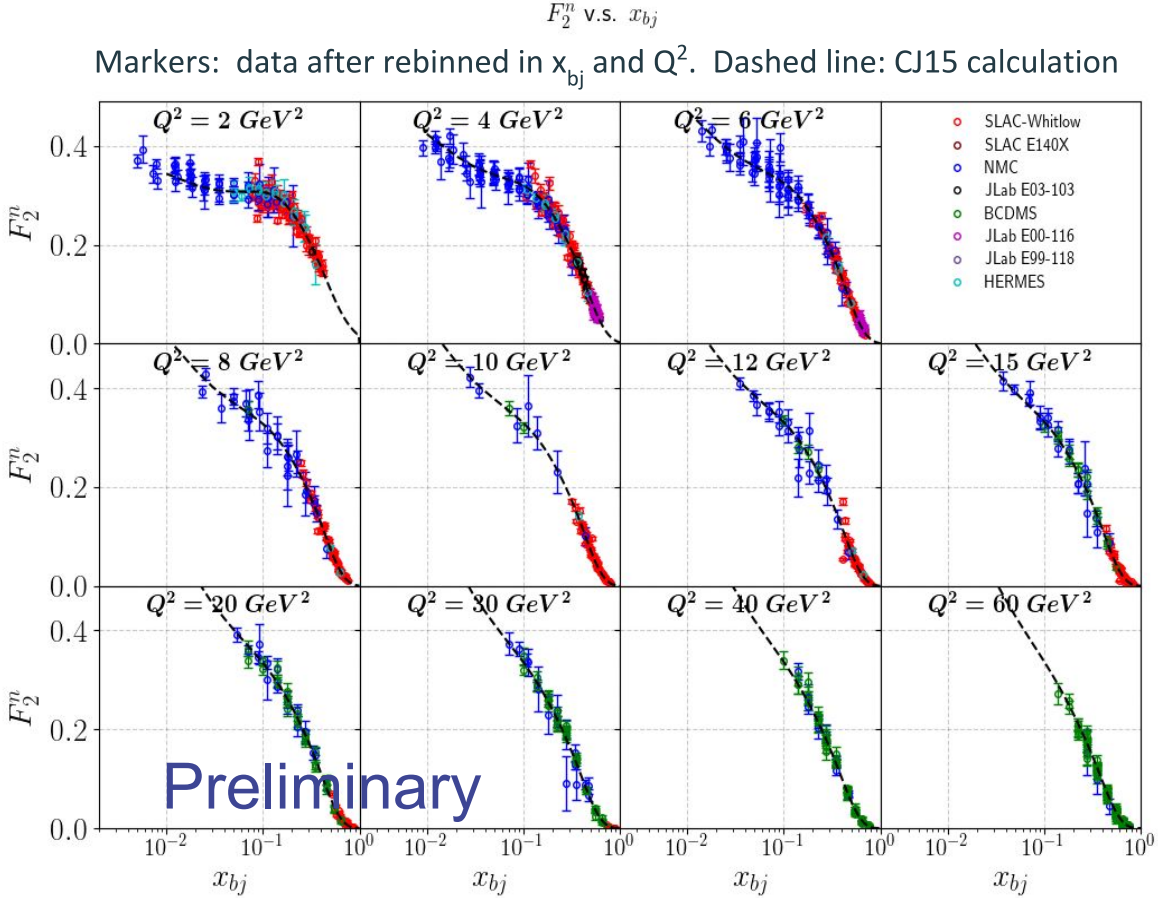
- theoretical systematics (PDF uncertainties) using 2* 24 (=19 PDF + 2 off-shell + 3 higher-twist parameters) eigen-PDF sets:
  - Normalization + correlated shifts uncertainties
  - Nuclear correction (d/(p+n)) uncertainties

F2 Neutron Results!

Markers: DIS data after rebinned in x_bj. Dashed line: CJ15 calculation



F2 Neutron Results!

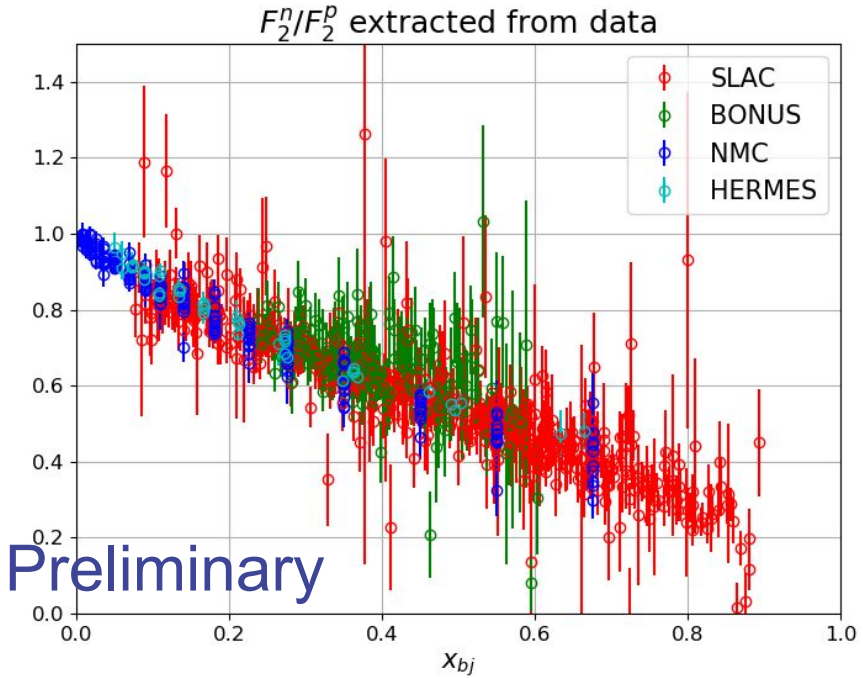


F2 n/p from Data

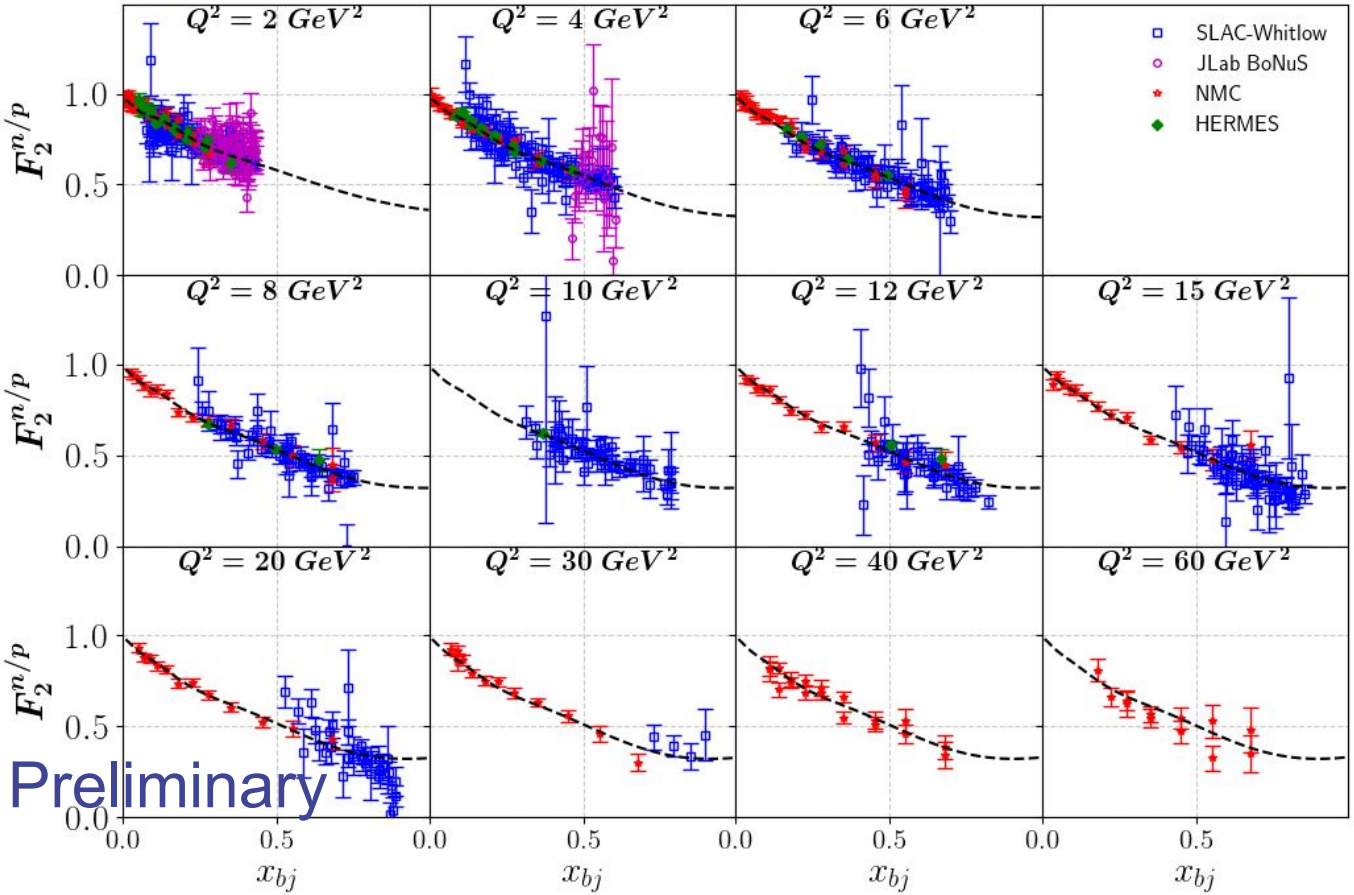
$n/p = (d/p)_{data} - (d/(n+p))_{CJ}$

$n/p = 1/\{1/[(n/d)_{data} (d/(n+p))_{CJ}] - 1\}$

Leverages precisions d/p data (NMC, HERMES, SLAC) and spectator tagged n/d (BoNuS)



$F_2^{n/p}$ v.s. x_{bj} (Q^2 rebinned)



Preliminary

F2 n/p Models

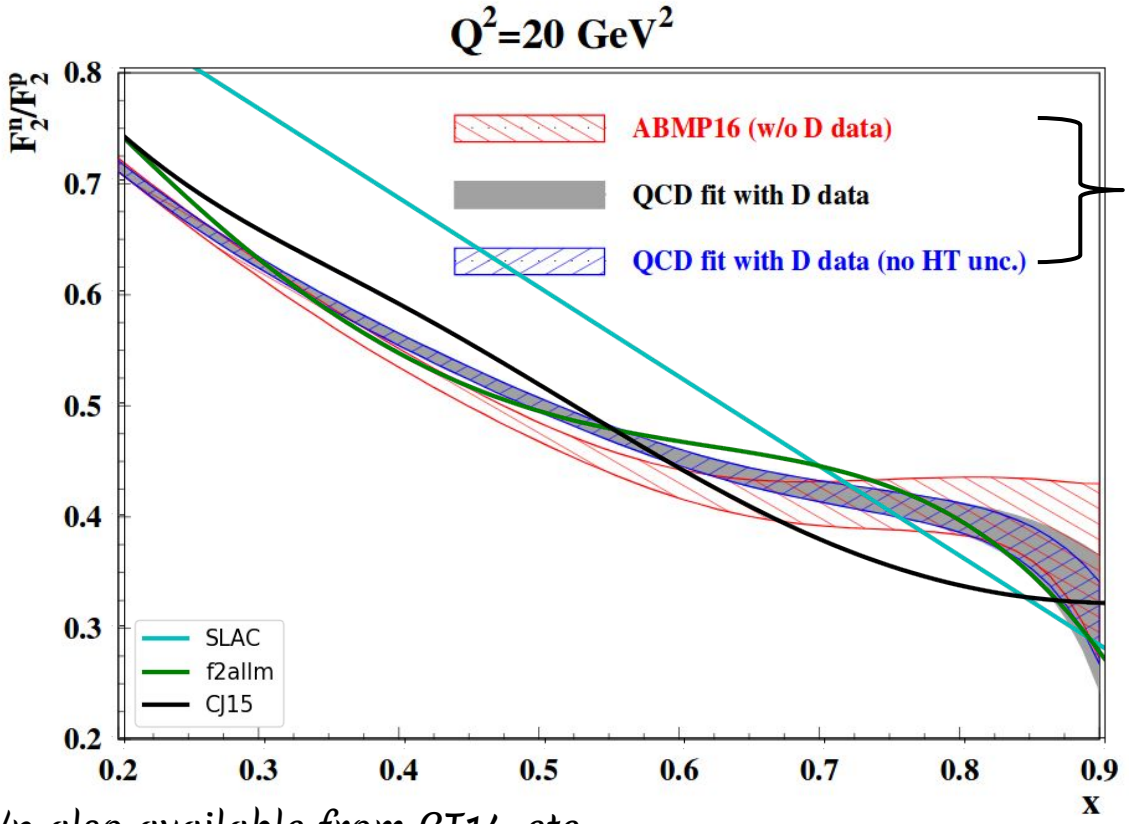


Fig 10 from S. I. Alekhin, S. A. Kulagin, and R. Petti

Phys. Rev. D 96, 054005(2017)

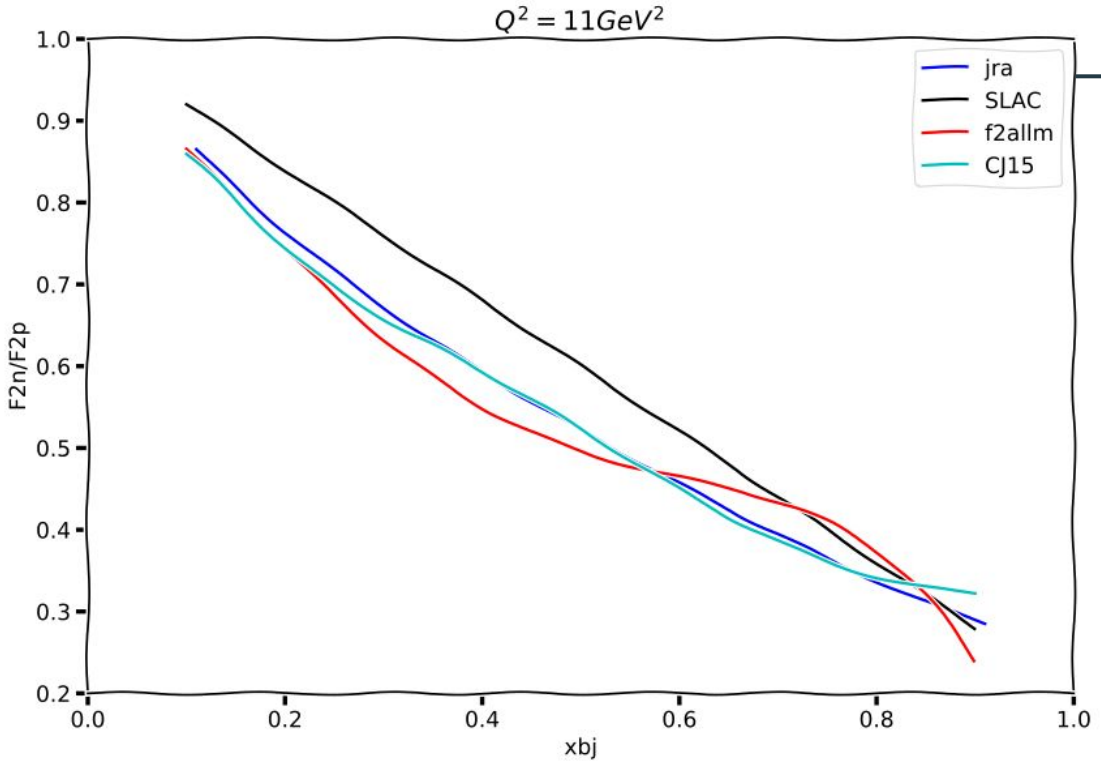
n/p also available from CT14, etc …

References

[1]A. Accardi, L.T. Brady, W. Melnitchouk, J.F. Owens, N. Sato, Phys. Rev. D **93** 114017 (2016)
[2] http://www.slac.stanford.edu/exp/e140/
[3] BCDMS Collaboration, Physics Letters B, Volume 223, Issues 3–4, 1989, Pages 485-489
[4] BCDMS Collaboration, Physics Letters B, Volume 237, Issues 3–4, 22 March 1990, Pages 592-598
[5] The HERMES Collaboraton, Journal of High Energy Physics, 2011, Volume 2011, Number 5, Page 1
[6] S. P. Malace et al, Phys. Rev. C 80, 035207
[7] New Muon Collaboration, Nucl.Phys. B483 (1997) 3-43
[8] L. Tao, Ph.D. Thesis, The American University, 1994
[9] J. Seely et al.Phys. Rev. Lett. 103, 202301
[10] M. Osipenko et al. (CLAS Collaboration)Phys. Rev. C 73, 045205
[11] M. Osipenko et al. (CLAS Collaboration)Phys. Rev. C 73, 045205
[12] The Jefferson Lab Hall C E94-110 Collaboration, arXiv:nucl-ex/0410027
[13] Ibrahim Albayrak, JLAB-PHY-11-1417, Ph.D. Thesis, Hampton University, 2011
[14] V. Tvaskis et al.Phys. Rev. C 81, 055207

Thanks Alberto Accardi, Cynthia Keppel, Wally Melnitchouk, Jeff Owens, Nobuo Sato for their help.

F2 n/p Models



J. Arrington, J. G. Rubin, and W. Melnitchouk

Phys. Rev. Lett. 108, 252001(2012)

n/p also available from CT14, AKP, etc …