First JAM results on the determination of polarized parton distributions

2013 Fall Meeting of the APS DNP
Oct 26th, Newport News, USA

Pedro Jimenez-Delgado

Jefferson Lab

The JAM collaboration

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About JAM

The **JAM (Jefferson Lab Angular Momentum)** Collaboration is an enterprise involving theorists and experimentalists from the Jefferson Lab community to study the quark and gluon spin structure of the nucleon by performing global fits of spin-dependent parton distribution functions (PDFs).

Because of the unique capabilities of Jefferson Lab's CEBAF accelerator in measuring small cross sections at extreme kinematics, the JAM spin PDFs are particularly tailored for studies of the **large Bjorken-*x*** region, as well as the resonance-deep inelastic transition region at low and intermediate values of W and Q^2.

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updated March 21, 2013

Parallel effort to our unpolarized PDFs: CJ and JR

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Collaboration

The JAM Collaboration consists of the following members:

Theory

- Pedro Jimenez-Delgado (*Jefferson Lab*)
- Alberto Accardi (*Hampton University*)
- Wally Melnitchouk (*Jefferson Lab*)

Database Working Group

- Peter Bosted (*Jefferson Lab / College of William and Mary*)
- Jian-ping Chen (*Jefferson Lab*)
- Keith Griffioen (*College of William and Mary*)
- Sebastian Kuhn (*Old Dominion University*)
- Yelena Prok (*Old Dominion University*)
- Oscar Rondon (*University of Virginia*)
- Brad Sawatzky (*Jefferson Lab*)

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contact Wally Melnitchouk
updated June 4, 2013

To start with, open to further contributions

The JAM database

Public database with all data on polarized scattering experiments (DIS for now)

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EXPLORING THE NATURE OF MATTER

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U.S. DEPARTMENT OF ENERGY

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Experiments

- All data
- proton
- deuteron
- 3He

JAM database - Experiments

Experiment	Description
COMPASS	proton and deuteron A1, g1
EMC	proton A1, g1
HERMES	proton, deuteron, and 3He A_par, neutron A1
HERMES2012	proton A2 and g2
JLab Hall A (E01-012)	3He A_par, A1, g1
JLab Hall A (E97-103)	3He (and neutron) asymmetries, g1, g2
JLab Hall A (E99-117)	3He (and neutron) asymmetries, g1, g2
JLab Hall B (EG1b)	proton and deuteron A1
JLab Hall C (E01-006 "RSS")	proton and deuteron A_par and A_perp (resonance region)
SLAC E142	3He A1, A2, g1, g2
SLAC E143	proton and deuteron A_par, A_perp
SLAC E154	3He A_par, A_perp
SLAC E155	proton and deuteron A1, A2, g1, g2
SLAC E155x	proton and deuteron A2, g2
SLAC E80/E130	proton A_par
SMC	proton and deuteron A1, g1

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Data considered at this stage

World data on polarized DIS (for $Q^2 \geq 1\ \mathrm{GeV}^2$, $W^2 \geq 3.5\ \mathrm{GeV}^2$)

experiment	reference	observable	target	N_{data}	$\chi^2(\mathrm{LT})/N_{\mathrm{dat}}$	$\chi^2(\mathrm{JAM})/N_{\mathrm{dat}}$
EMC	[1]	A_1	p	10	0.42	0.39
SMC	[29]	A_1	p	12	0.36	0.36
	[29]	A_1	d	12	1.59	1.66
	[30]	A_1	p	8	1.37	1.35
	[30]	A_1	d	8	0.54	0.56
COMPASS	[31]	A_1	p	15	0.95	0.97
	[32]	A_1	d	15	0.57	0.51
SLAC E80/E130	[33]	$A_\parallel$	p	23	0.52	0.54
SLAC E142	[34]	A_1	^{3}He	8	0.58	0.70
	[34]	A_2	^{3}He	8	0.70	0.70
SLAC E143	[35]	$A_\parallel$	p	85	0.85	0.81
	[35]	$A_\perp$	p	48	0.95	0.91
	[35]	$A_\parallel$	d	85	1.05	0.85
	[35]	$A_\perp$	d	48	0.92	0.91
SLAC E154	[36]	$A_\parallel$	^{3}He	18	0.43	0.42
	[36]	$A_\perp$	^{3}He	18	1.00	1.00
SLAC E155	[37]	$A_\parallel$	p	73	1.00	0.92
	[37, 38]	$A_\perp$	p	66	1.00	0.96
	[39]	$A_\parallel$	d	73	0.98	0.97
	[38, 39]	$A_\perp$	d	66	1.51	1.49
SLAC E155x	[40]	$\tilde{A}_\perp$	p	117	2.17	1.64
	[40]	$\tilde{A}_\perp$	d	117	0.90	0.84
HERMES	[41]	$A_\parallel$	p	37	0.38	0.39
	[41]	$A_\parallel$	d	37	0.86	0.85
	[42]	A_1	"n"	9	0.29	0.30
	[43]	A_2	p	20	1.07	1.16
JLab E99-117	[44]	$A_\parallel$	^{3}He	3	0.62	0.06
	[44]	$A_\perp$	^{3}He	3	1.08	0.87
COMPASS	[48]	$\Delta g/g$	p	1	5.27	2.71
total				1043	1.07	0.98
JLab E97-103*	[45]	$A_\parallel$	^{3}He	2	—	—
	[45]	$A_\perp$	^{3}He	2	—	—
JLab EG1b*	[47]	A_1	p	766	—	—
(prelim.)	[47]	A_1	d	767	—	—

Mainly on *measured* asymmetries:

$$A_\parallel = D(A_1 + \eta A_2)$$

$$A_\perp = d(A_2 - \xi A_1)$$

D, d depend on

$$R = \frac{F_L}{(1+\gamma^2)F_2 - F_L}$$

$$\gamma^2 = 4\frac{M^2}{Q^2}x^2$$

We *consistently* develop our own unpolarized analysis in parallel (JR NLO)

Dedicated analyses of the impact of *individual* data sets from JLab

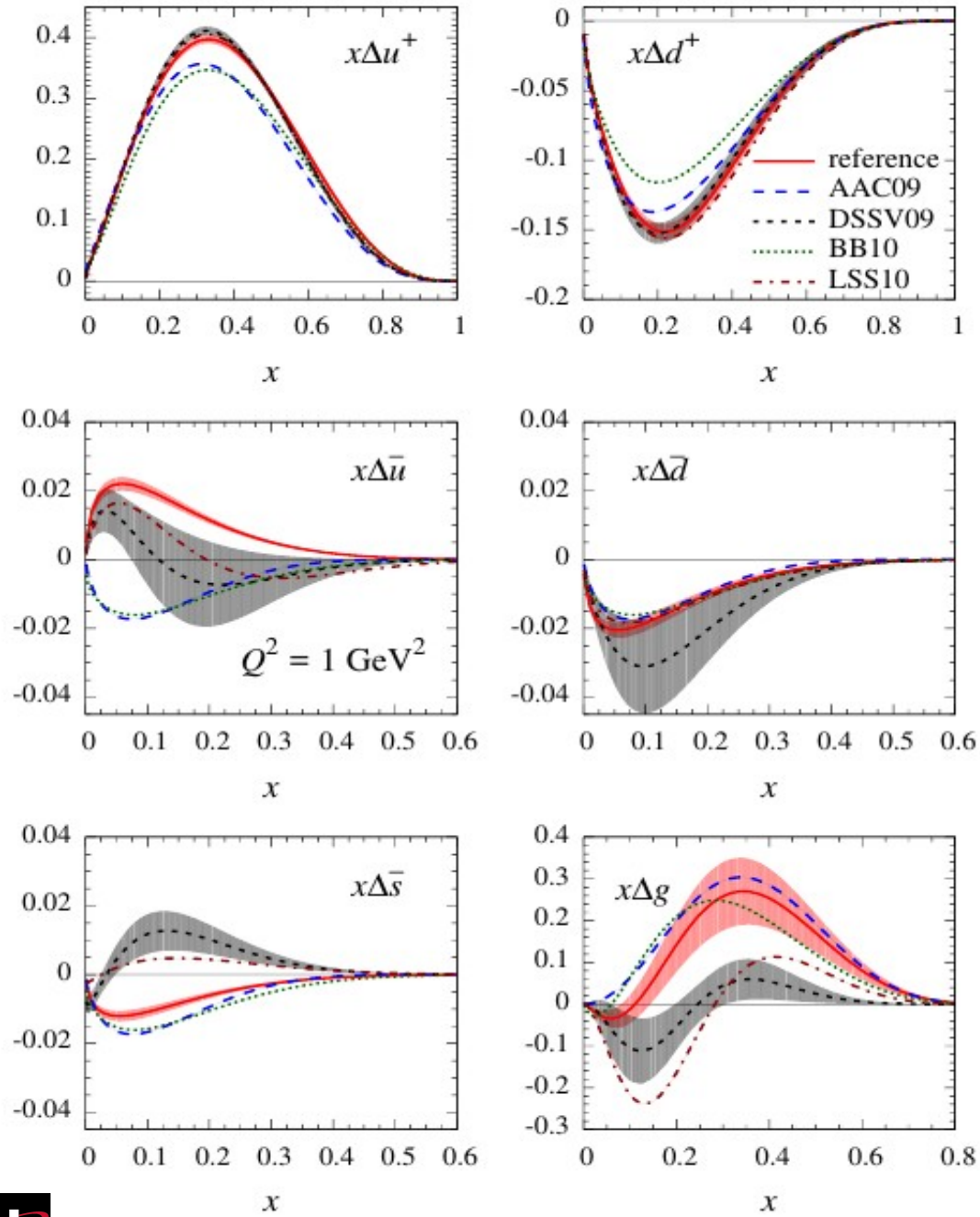
Data and theory comparison with other groups

	DIS	SIDIS	hadron collider	nuclear smearing	TMCs	HT g_1	HT g_2
DSSV 09	✓	✓	✓				
AAC 09	✓		✓				
BB 10	✓				✓	✓	~
LSS 10	✓	✓			✓	✓	
NNPDF 13	✓				✓		
JAM 13	✓			✓	✓	✓	✓

Presently concentrated on improvements in the theoretical description of DIS

Long-term objective is to tick all the boxes (include SIDIS and RHIC data)

Current status of polarized PDFs



Worse known than the unpolarized:

$$\Delta u^+ = \Delta u + \Delta\bar{u} \quad \text{and}$$

$$\Delta d^+ = \Delta d + \Delta\bar{d} \quad \text{better known}$$

- Sea distributions $\Delta\bar{u},\ \Delta\bar{d}$ do not enter in DIS asymmetries

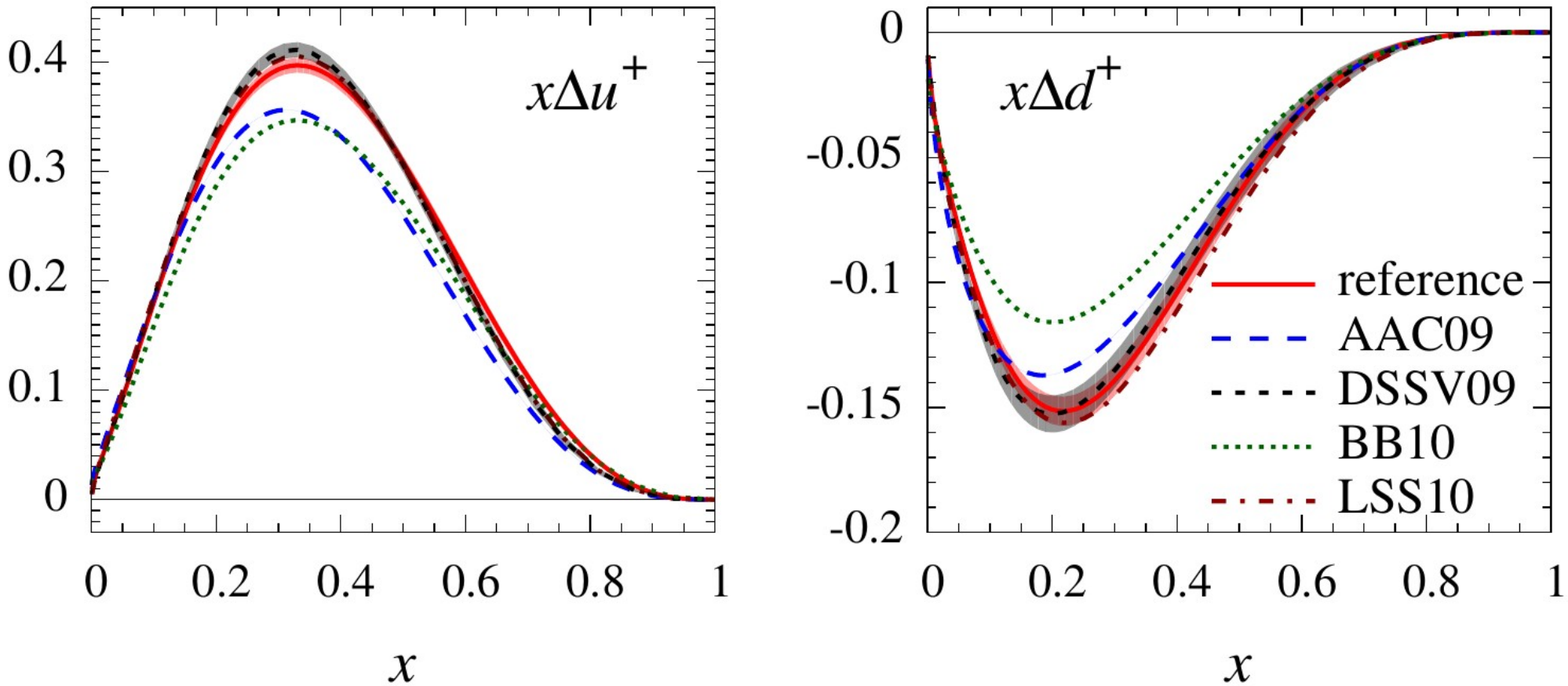
- Rather weak constraints on $\Delta\bar{s}$

- Δg less known, determined mainly from RHIC data (also COMPASS)

Simple fit without further corrections: reference

Nuclear targets treated with the "effective polarization" approximation:

$$g_1^d = (1 - \tfrac{3}{2} w_d)(g_1^p + g_1^n) \qquad g_1^{\mathrm{He3}} = P_n\, g_1^n + P_p\, g_1^p$$



More similar to DSSV, LSS than to others

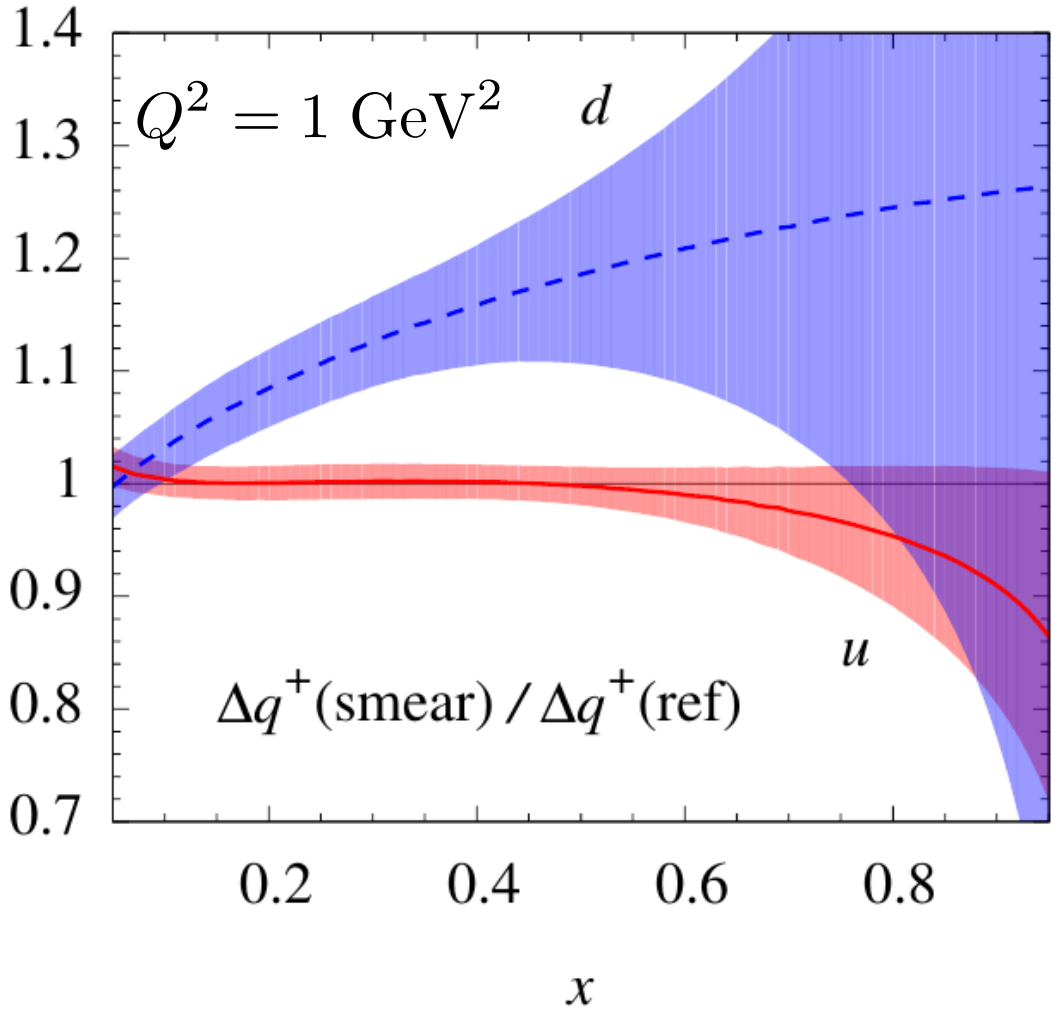
Baseline for assessing the impact of additional corrections

Improved description of nuclear targets

Improved by using "smearing functions" derived from nuclear wave functions:

$$g_i^A(x) = \sum_{j=1,2} \int \frac{dy}{y}\, f_{jN}(y,\gamma)\, g_j^N\left(\frac{x}{y}\right) \qquad \gamma^2 = 1 + 4\frac{M^2}{Q^2}x^2$$

[Kulagin, Petti 06]



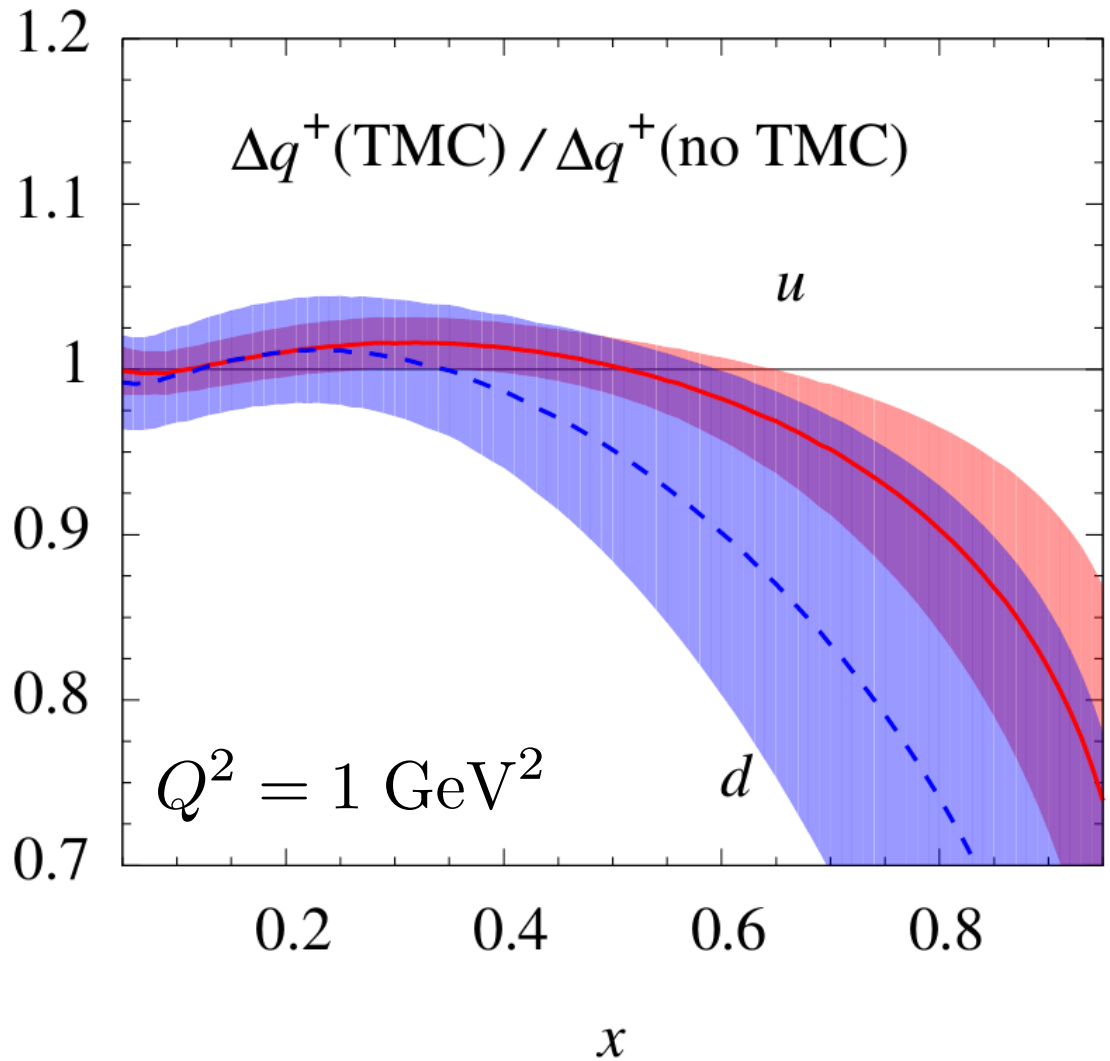
Most *significant* for Δd in the medium- and large-x region

Target-mass corrections

Power corrections from finite target mass calculated in the OPE approach:

$$g_1^{\mathrm{TMC}}(n) = g_1(n) + \frac{M^2}{Q^2}\frac{n^2(n+1)}{(n+2)^2}g_1(n+2) + \frac{M^4}{Q^4}\ldots + \mathcal{O}(\frac{M^8}{Q^8})$$

[Bluemlein, Tkabladze 99]



Relevant for both Δu and Δd in the large-x region

Higher twist contributions

We consider also corrections from higher twist contributions:

$$g_1 = g_1^{\tau=2} + g_1^{\tau=3} + g_1^{\tau=4}$$

$$g_2 = g_2^{\tau=2} + g_2^{\tau=3}$$

The Bluemlein-Tkabladze relation: $g_1^{\tau=3}(x,Q^2) = 4x^2 \frac{M^2}{Q^2}\left(g_2^{\tau=3}(x,Q^2) - 2\int_x^1 \frac{dy}{y} g_2^{\tau=3}(y,Q^2)\right)$

[Bluemlein, Tkabladze 99]

With a phenomenological parametrization :

$$g_2^{\tau=3} = A[\ln x + (1-x) + \tfrac{1}{2}(1-x)^2] + (1-x)^3[B + C(1-x) + D(1-x)^2 + E(1-x)^3]$$

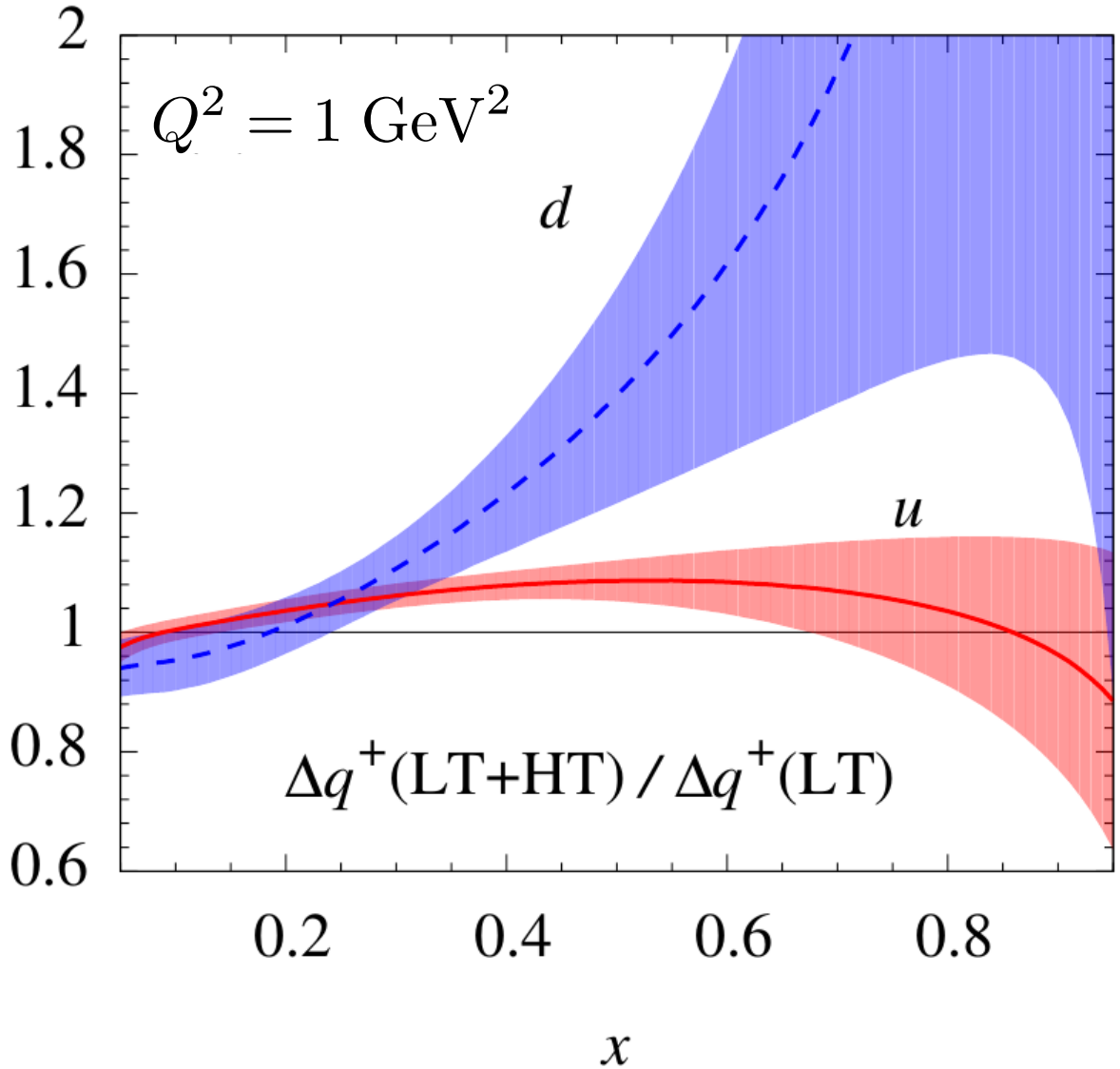
[Braun *et al.* 09]

And a splines approximation for: $g_1^{\tau=4} = \dfrac{h(x)}{Q^2}$

Possible scale dependence in h and $g_2^{\tau=3}$ has been neglected (for now)

Higher twist contributions

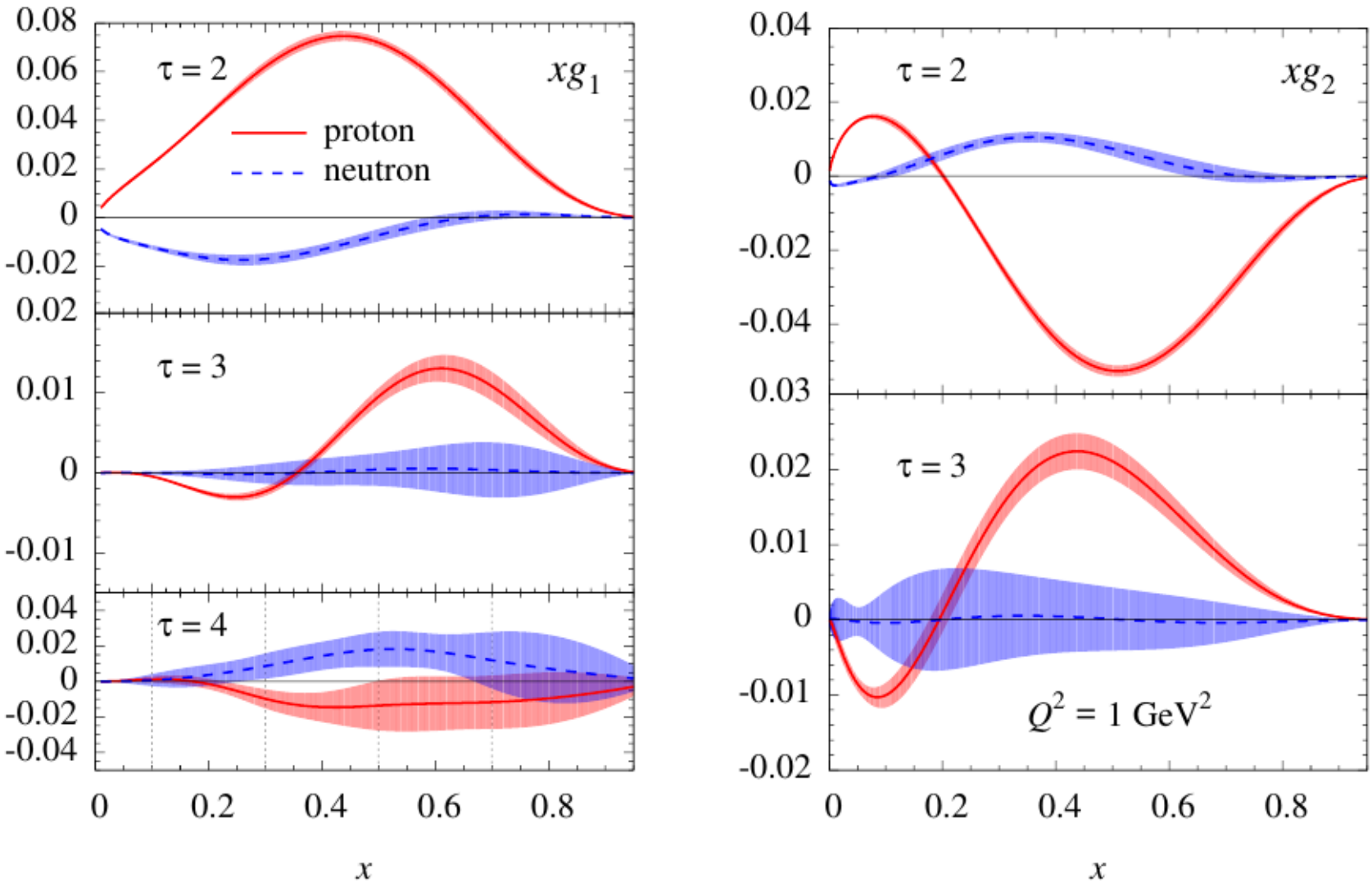
Considerable improvement of χ^2 for some sets (globally $1.07 \to 0.98$, 3σ)



Very large changes in Δd

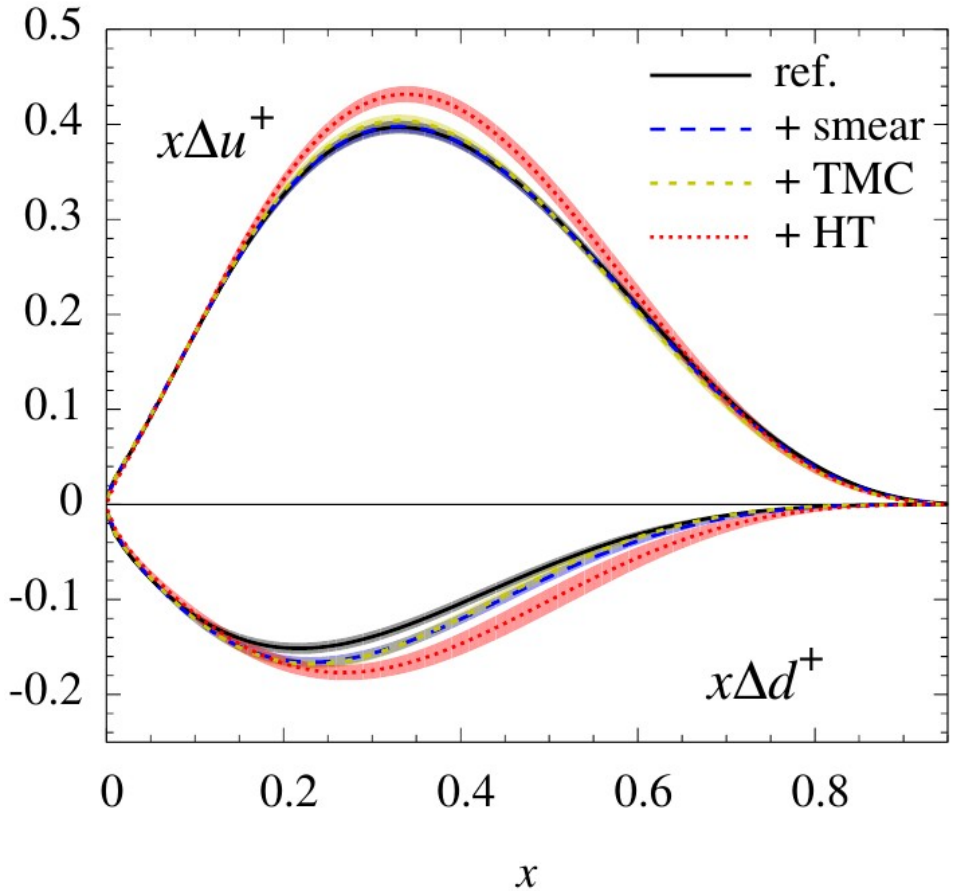
Higher twist contributions

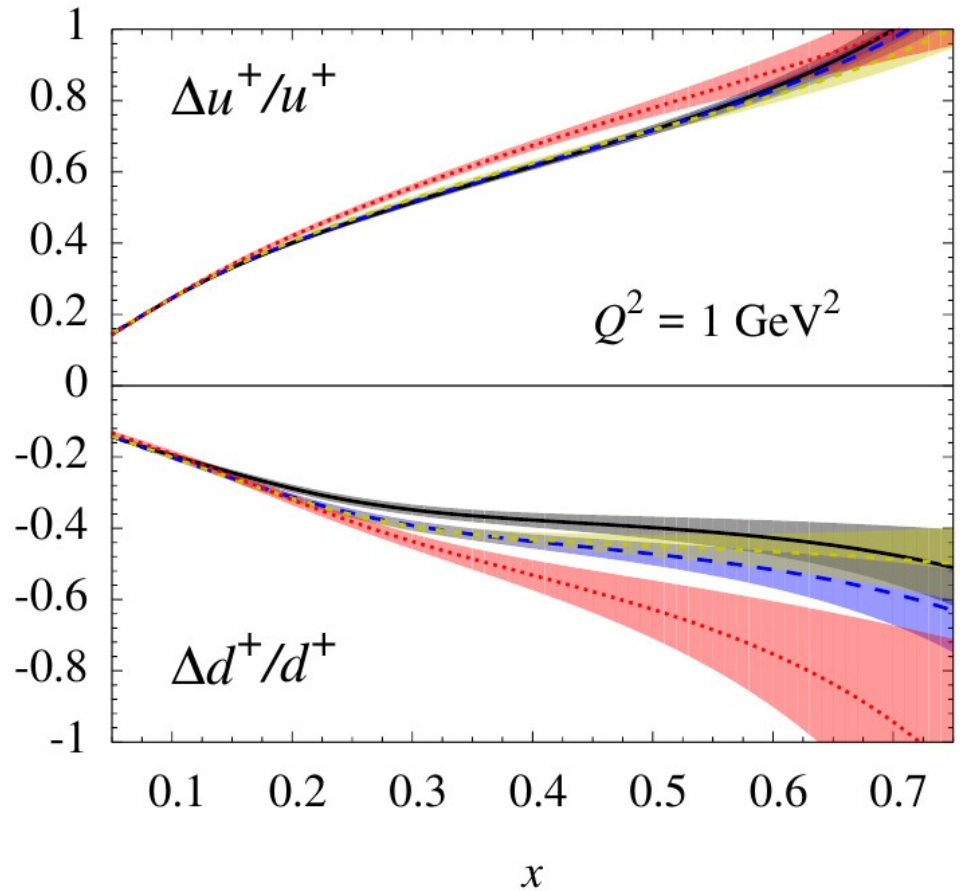
Possible to determine *simultaneously* higher-twist contributions for g_1 and g_2



Qualitative agreement with previous (separated) determinations

Cumulative impact





These corrections are *manifestly important* for PDF extractions

Summary and outlook

First JAM results on the determination of polarized parton distributions:

- More accurate nuclear corrections
- Target mass corrections
- Complete inclusion of higher-twist

These corrections are ***manifestly important*** for PDF extractions

Impact of hadronic and nuclear corrections on global analysis of spin-dependent parton distributions

arXiv:1310.3734 [hep-ph]

Dedicated analysis of the impact of JLab data

Other developments in progress or planned: OAM, SIDIS, RHIC …

Thank you for your attention!