First JAM results

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(for the collaboration)

Jefferson Lab

Data considered at this (first) stage

World data on polarized DIS

PROTON	**SLAC E80/E130:** G. Baum et al., Phys. Rev. Lett. **51**, 1135 (1983)
	EMC: J. Ashman et al., Nucl. Phys. **B328**, 1 (1989)
	SMC: B. Adeva et al., Phys. Rev. D **58**, 112001 (1998)
	Phys. Rev. D **60**, 072004 (1999)
	Erratum-ibid. Phys. Rev. D **62**, 079902 (2000)
	COMPASS: M.G. Alekseev et al., Phys. Lett. B **690**, 466 (2010)
	SLAC E143: K. Abe et al., Phys. Rev. D **58**, 112003 (1998)
	SLAC E155: P.L. Anthony et al., Phys. Lett. B **493**, 19 (2000)
	Phys. Lett. B **458**, 529 (2000)
	SLAC E155x: P.L. Anthony et al., Phys. Lett. B **553**, 18 (2003)
	HERMES: A. Airapetian et al., Phys. Rev. D **75**, 012007 (2007)
	JLab Hall B (EG1b): Y. Prok et al., Phys. Lett. B **672**, 12 (2009)
	HERMES: A. Airepetian et al., Eur. Phys. J. C **72**, 1921 (2012)
DEUTERON	**SMC:** B. Adeva et al., Phys. Rev. D **58**, 112001 (1998)
	Phys. Rev. D **60**, 072004 (1999)
	Erratum-ibid. Phys. Rev. D **62**, 079902 (2000)
	COMPASS: V.Yu. Alexakhin et al., Phys. Lett. B **647**, 8 (2007)
	SLAC E143: K. Abe et al., Phys. Rev. D **58**, 112003 (1998)
	SLAC E155: P.L. Anthony et al., Phys. Lett. B **463**, 339 (1999)
	Phys. Lett. B **458**, 529 (2000)
	SLAC E155x: P.L. Anthony et al., Phys. Lett. B **553**, 18 (2003)
	HERMES: A. Airapetian et al., Phys. Rev. D **75**, 012007 (2007)
	JLab Hall B (EG1b): Y. Prok et al., Phys. Lett. B **672**, 12 (2009)
HELIUM-3	**SLAC E142:** P.L. Anthony et al., Phys. Rev. D **54**, 6620 (1996)
	SLAC E154: K. Abe et al., Phys. Rev. Lett. **79**, 26 (1997)
	Yu. Kolomensky, Ph.D. thesis, U. Massachusetts (1997),SLAC-Rep-503
	HERMES: K. Ackerstaff et al., Phys. Lett. B **404**, 383 (1997)
	JLab Hall A (E99-117): X. Zhang et al., Phys. Rev. Lett. **92**, 012004 (2004)
	Phys. Rev. C **70**, 065207 (2004)
	JLab Hall A (E97-103): K. Kramer et al., Phys. Rev. Lett. **95**, 142002 (2005)
	K. Kramer, Ph.D. thesis, Coll. of William & Mary (2003)
	JLab Hall A (E01-012): P. Solvignon et al., Phys. Rev. Lett. **101**, 182502 (2008)

Mainly on *measured* asymmetries:

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

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

D, d depend on

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

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

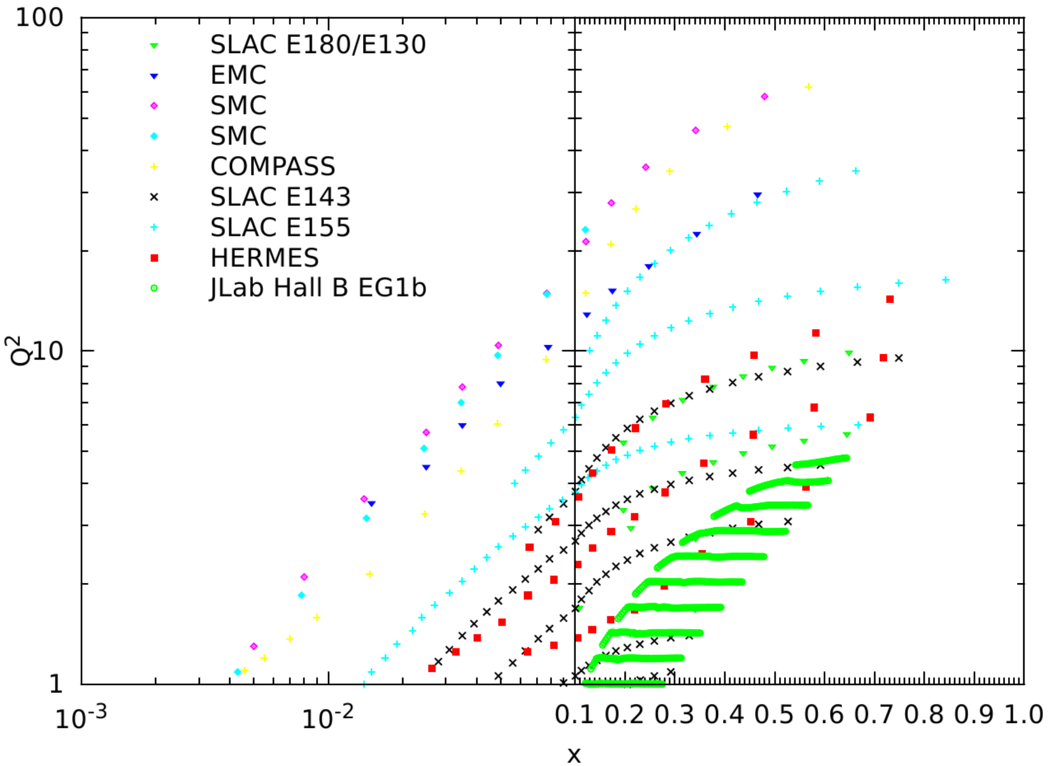
We consistently develop our own unpolarized analysis in parallel (JR)

Dedicated analyses of (some) JLab data: HALLAk, HALLAs, HALLB

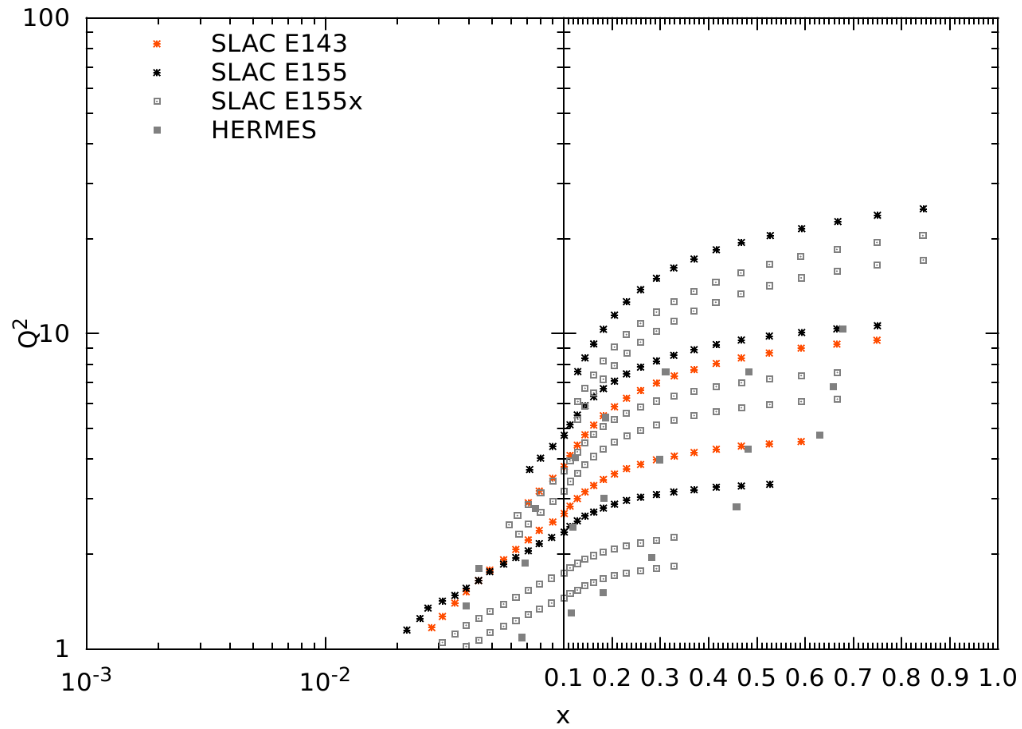
Data considered at this (first) stage

Minimal kinematic cuts imposed: $Q^2 \geq 1\ \mathrm{GeV}^2$ $\qquad W^2 \geq 3.5\ \mathrm{GeV}^2$

$A_{\|}^{p}$ or A_{1}^{p}



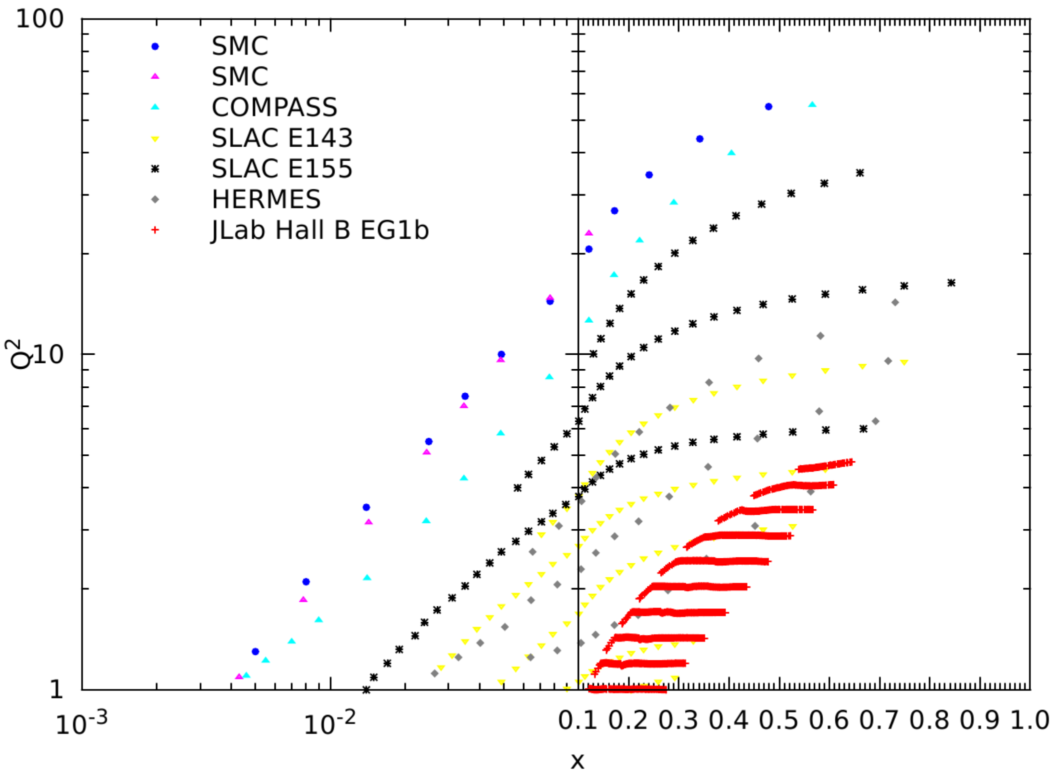
$A_{\perp}^{p}$ or A_{2}^{p}



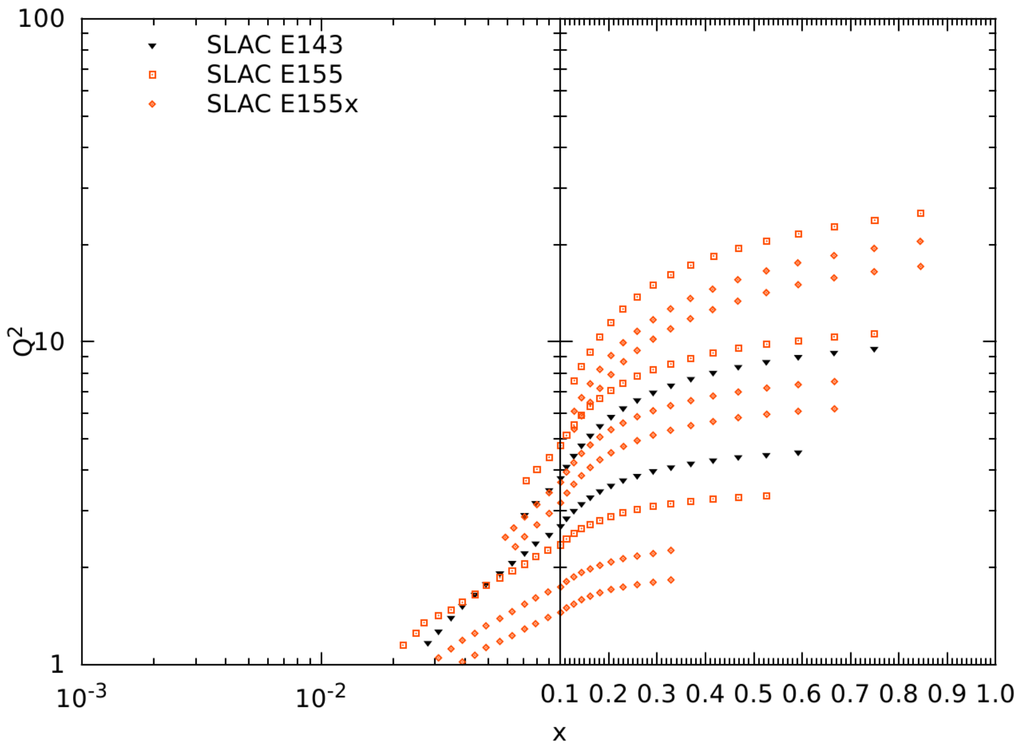
Data considered at this (first) stage

Minimal kinematic cuts imposed: $Q^2 \geq 1\ \mathrm{GeV}^2$ $\quad W^2 \geq 3.5\ \mathrm{GeV}^2$

$A^d_{\|}$ or A^d_1



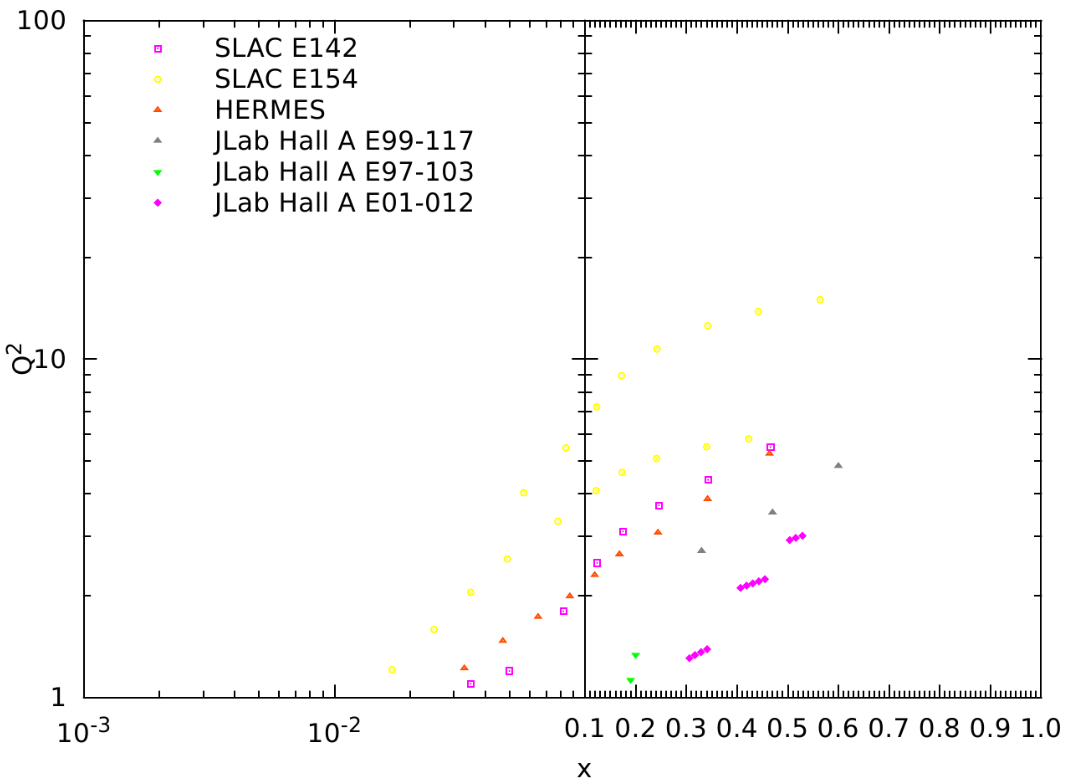
$A^d_{\perp}$ or A^d_2



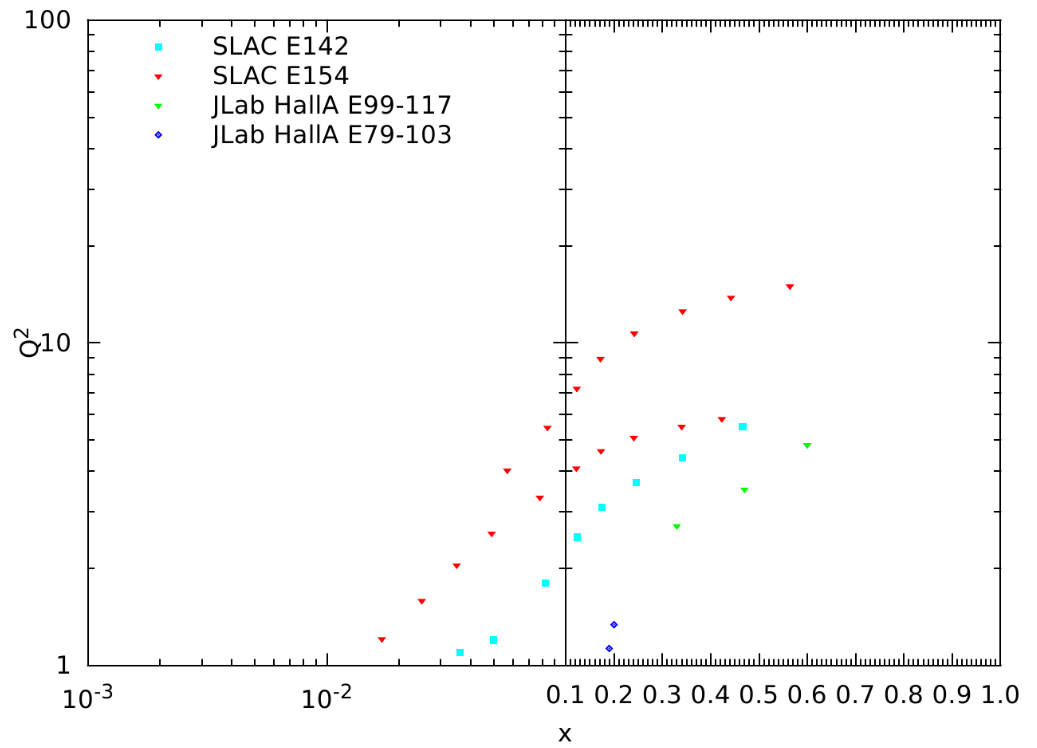
Data considered at this (first) stage

Minimal kinematic cuts imposed: $Q^2 \geq 1\ \mathrm{GeV}^2$ $W^2 \geq 3.5\ \mathrm{GeV}^2$

$A_{\|}^{3\mathrm{He}}$ or $A_1^{3\mathrm{He}}$



$A_{\perp}^{3\mathrm{He}}$ or $A_2^{3\mathrm{He}}$



Underlying QCD description

$$A_1 = (g_1 - \gamma^2 g_2)\frac{2x}{(1+\gamma^2)F_2 - F_L} \qquad A_2 = \gamma(g_1 + g_2)\frac{2x}{(1+\gamma^2)F_2 - F_L}$$

NLO QCD calculation of (twist two) structure functions in Mellin space:

$$g_1(n, Q^2) = \frac{1}{2}\sum_{q,\bar{q}} e_q^2 \left(\Delta C_{qq}^1 \Delta q + \Delta C_g^1 \Delta g\right)$$

$$g_2(n, Q^2) = g_2^{WW} = -\frac{n-1}{n} g_1(n, Q^2)$$

RGE evolution of helicity parton distributions implemented as well in the space of complex moments (truncated solutions)

$$f(n) = \int_0^1 dx\, x^{n-1} f(x)$$

Parametrization

Only *two* independent combinations of quark distributions contribute:

$$x\Delta u^+(x,\mu_0^2) = N_u\, x^{a_u}(1-x)^{b_u}(1+B_u\, x)$$

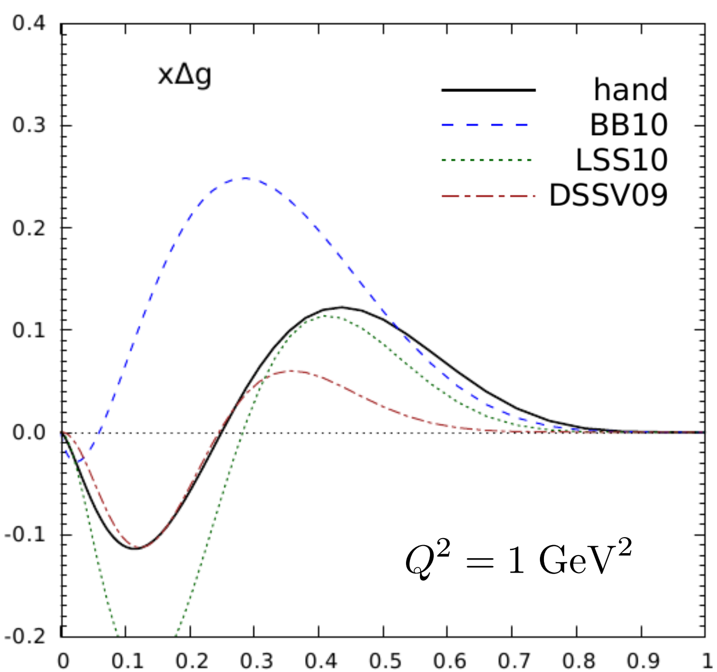
$$x\Delta d^+(x,\mu_0^2) = N_d\, x^{a_d}(1-x)^{b_d}(1+B_d\, x)$$

$\Delta q^+ \equiv \Delta q + \Delta \bar{q}$

Constrains from hyperon decays relate N_u and N_d, and fix N_s:

$$\int_0^1 (\Delta u^+ - \Delta d^+)dx = 1.269 \pm 0.003 \qquad \int_0^1 (\Delta u^+ + \Delta d^+ - 2\Delta s^+)dx = 0.586 \pm 0.031$$

The *x*-dependence of the sea has been fixed by hand (e.g. counting rules)



Formally Δg enters at second order, but in practice our fits are *insensitive*:

$$\Delta\chi^2 \ll \Delta\chi^2_{1\sigma}$$

It has been fixed to a reasonable function (hand)

Statistical estimation

Least-squares estimator with a complete treatment of the systematic uncertainties (equivalent to the standard correlation matrix approach) [CTEQ]:

$$\chi^2 = \sum_{i=1}^{N} \frac{1}{\Delta_i^2} \left(D_i + \sum_{j=1}^{M} r_j \Delta_{ji} - T_i \right)^2 + \sum_{j=1}^{M} r_j^2$$

Here the systematic shifts are calculated *analytically*

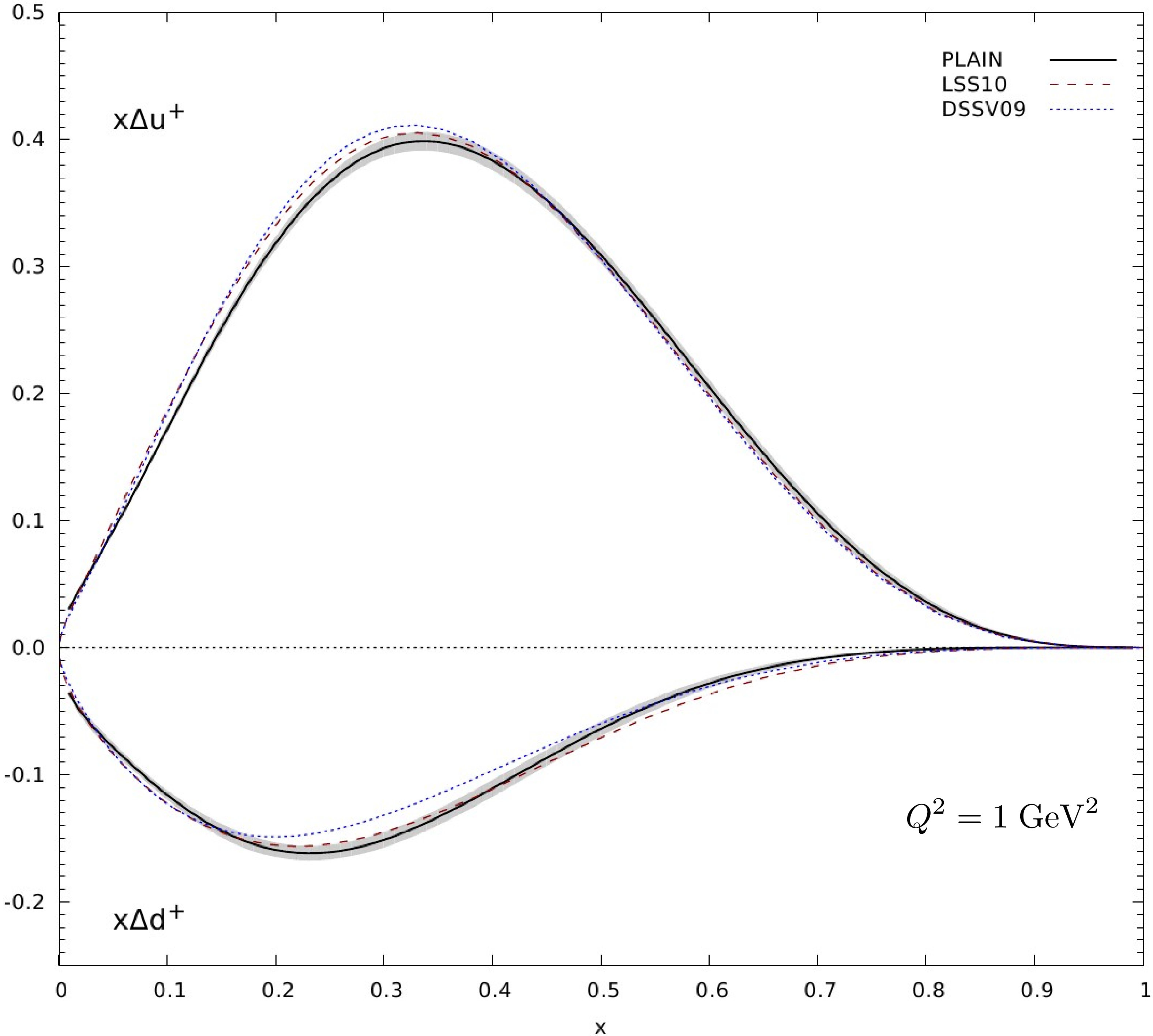
Unfortunately many experiments do not provide enough information

Errors estimated with the *Hessian* approach (linear propagation):

"Vicinity" of the minimum (tolerance) characterized by:

$$\Delta\chi^2 = \chi^2(p) - \chi^2(p^0) \leq T^2 = 1$$

Simple fit without further corrections: PLAIN



Improved description of nuclear targets: NSMEAR

In PLAIN the "effective polarizations" approximation have been used:

$$g_1^d = (1 - \tfrac{3}{2}0.06)(g_1^p + g_1^n) \qquad g_1^{He3} = 0.86\ g_1^n - 0.059\ g_1^p$$

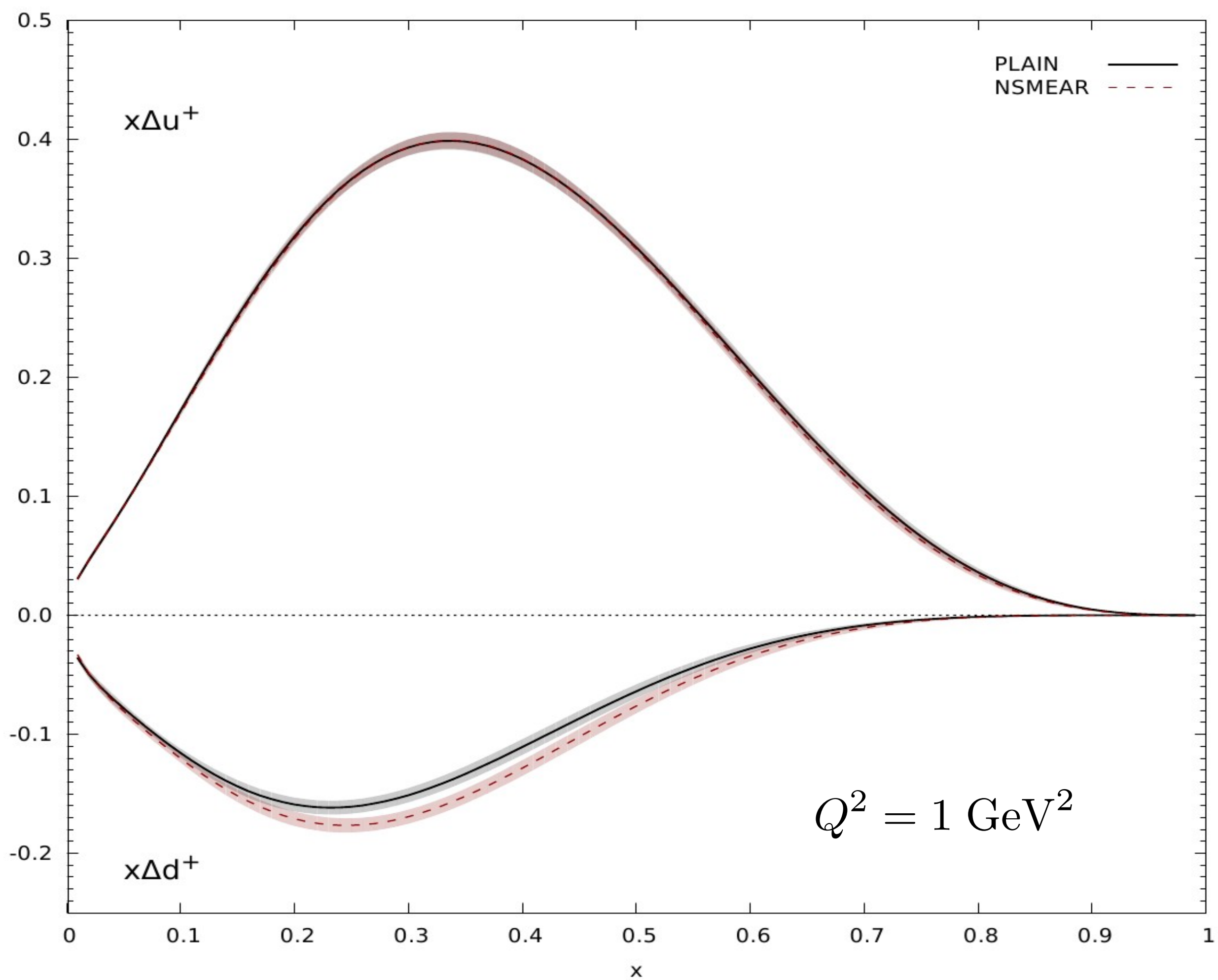
An improvement over this is to consider "smearing" functions derived from the nuclear wave functions

$$g_i^A(x) = \sum_{\substack{j=1,2 \\ N=p,n}} \int dy\ f_{jN}(y,\gamma)\ g_j^N(\tfrac{x}{y})$$

$$\gamma^2 = 1 + 4\frac{M^2}{Q^2}x^2$$

Relevant for Δd in the medium- to large-x region

(This approach is also used in the unpolarized part)



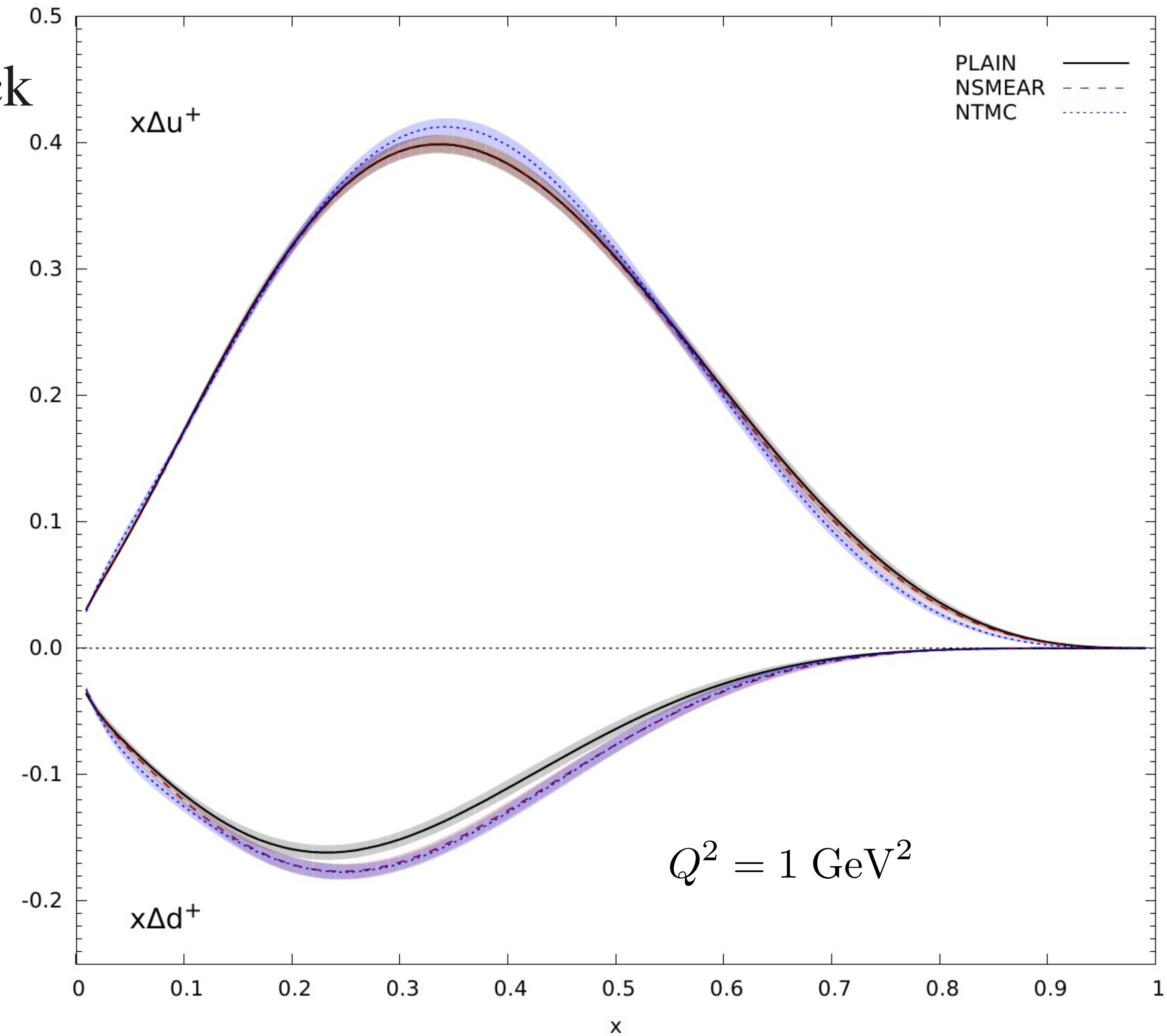
Plus target-mass corrections: NTMC

We use power corrections from finite target mass calculated in the OPE approach:

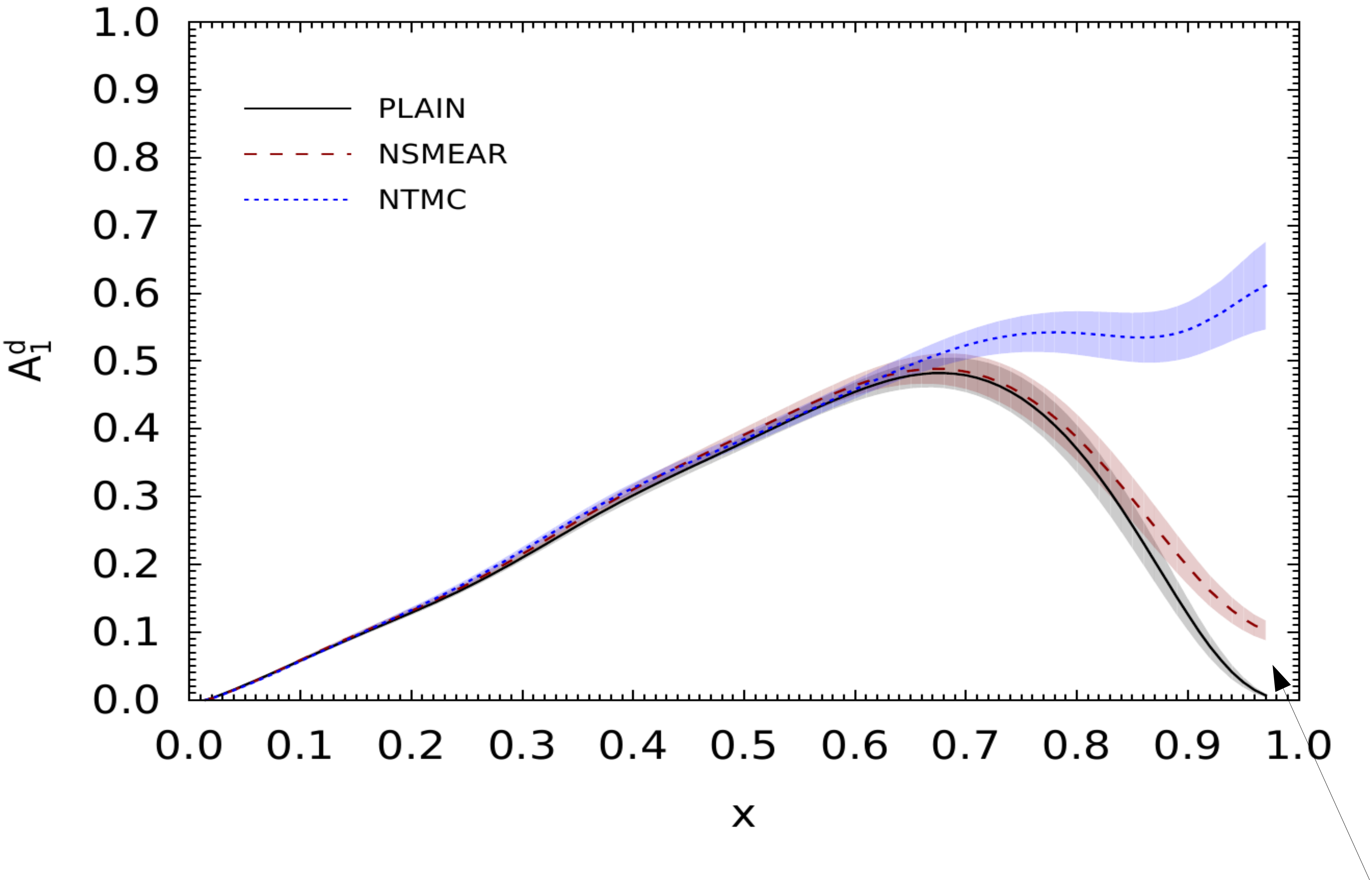
$$g_1^{\mathrm{TMC}}(n) = g_1(n) + \frac{M^2}{Q^2}\frac{n^2(n+1)}{(n+2)^2} g_1(n+2) + \frac{M^4}{Q^4}\ldots + \mathcal{O}(\frac{M^8}{Q^8})$$

where the Wandzura-Wilzceck relation holds also after TMCs [Bluemlein, Tkabladze 99]

These are relevant for Δu in the medium- to large-x region



Plus target-mass corrections: NTMC



Clearly they are needed for the asymmetries (TMCs included in the unpolarized SFs!):

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

With a phenomenological parametrization [Braun *et al.* 09] :

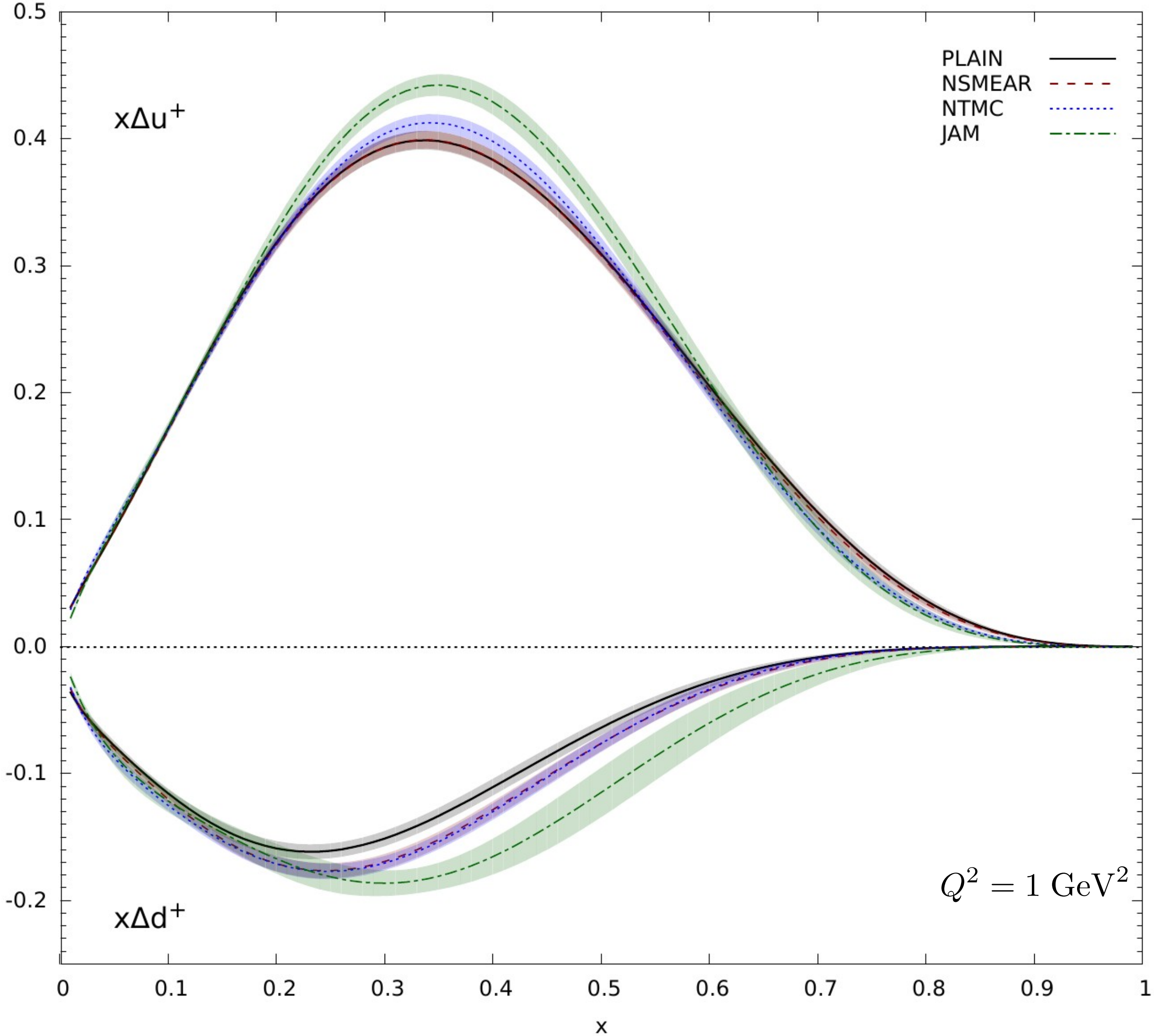
$$g_2^{\tau=3} = A[\ln x + (1-x) + \tfrac{1}{2}(1-x)^2] + (1-x)^3[B + C(1-x) + D(1-x)^2 + E(1-x)^3]$$

$$\int_0^1 dx\, g_2^{\tau=3} = 0$$

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

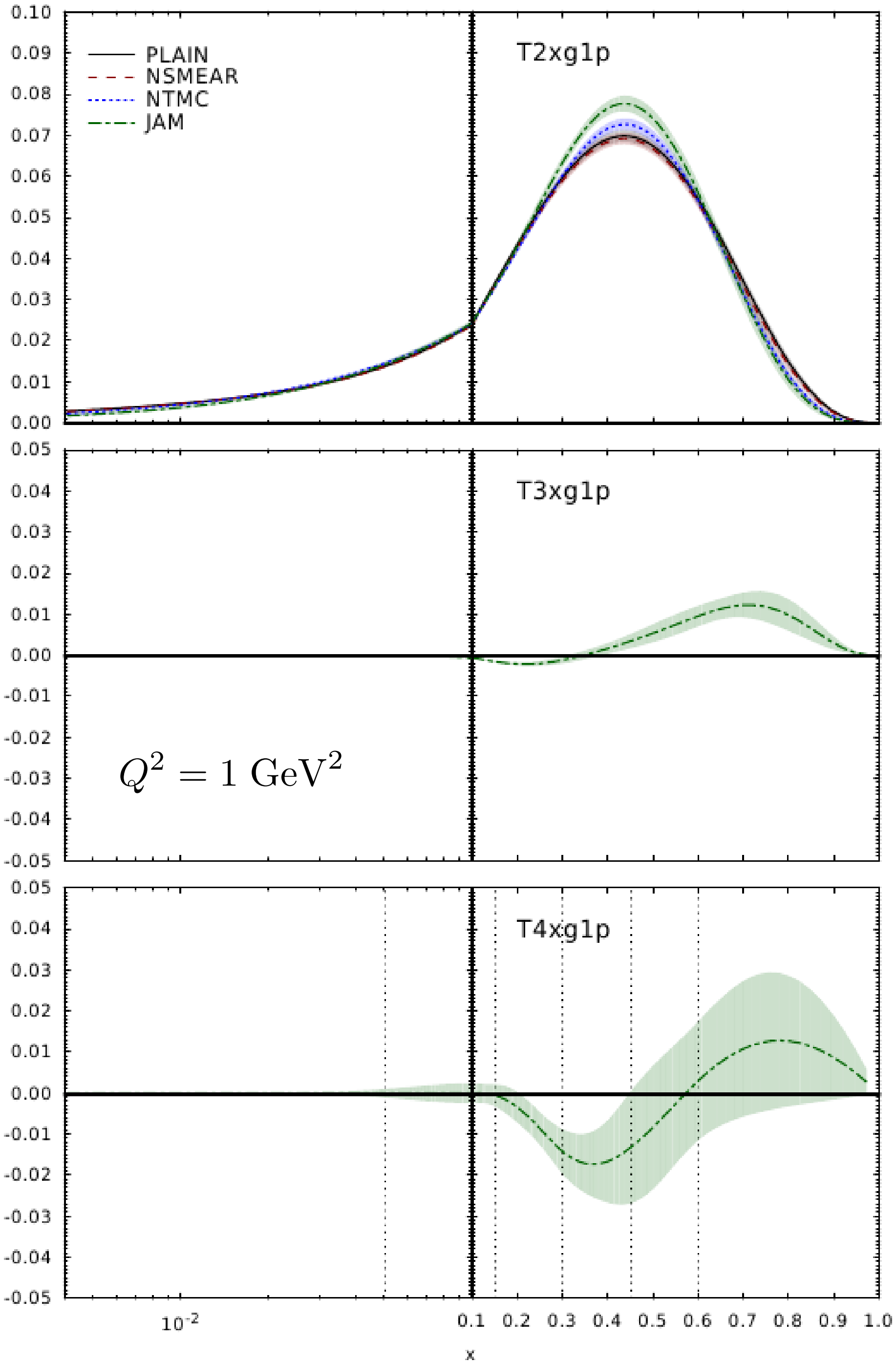
Possible scale dependence in h and $g_2^{\tau=3}$ have been neglected

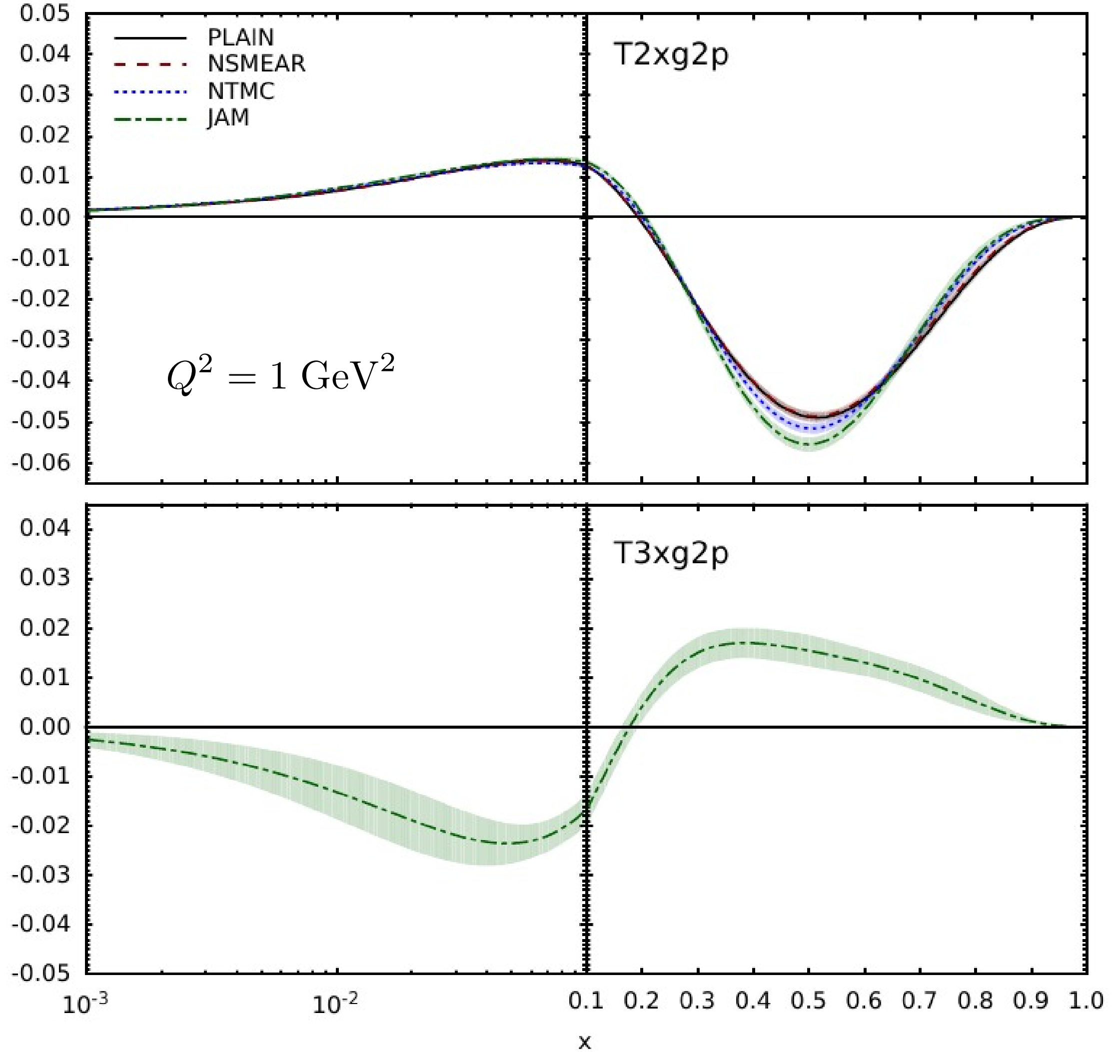
Including all these corrections: JAM



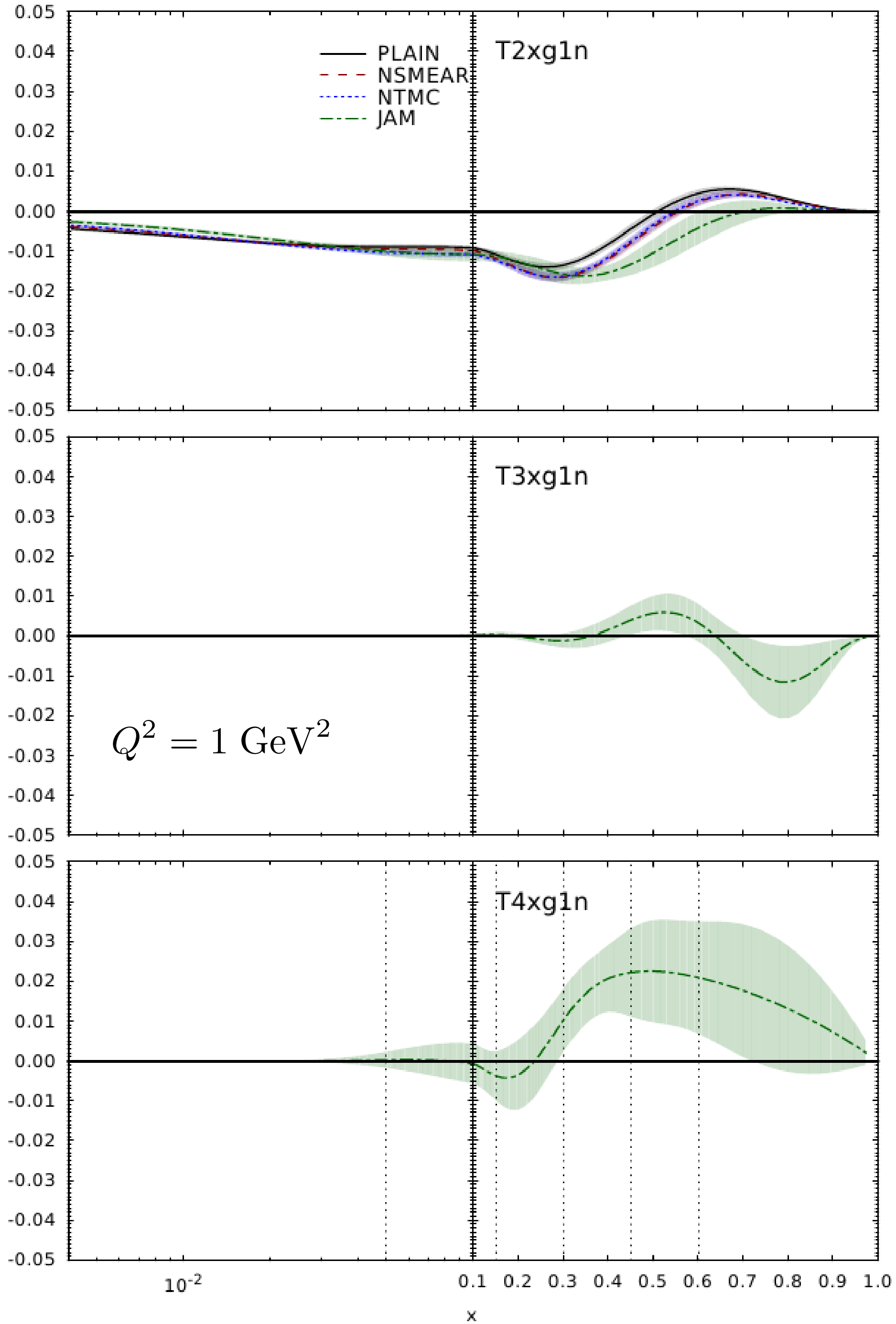
Manifest importance of higher twist contributions

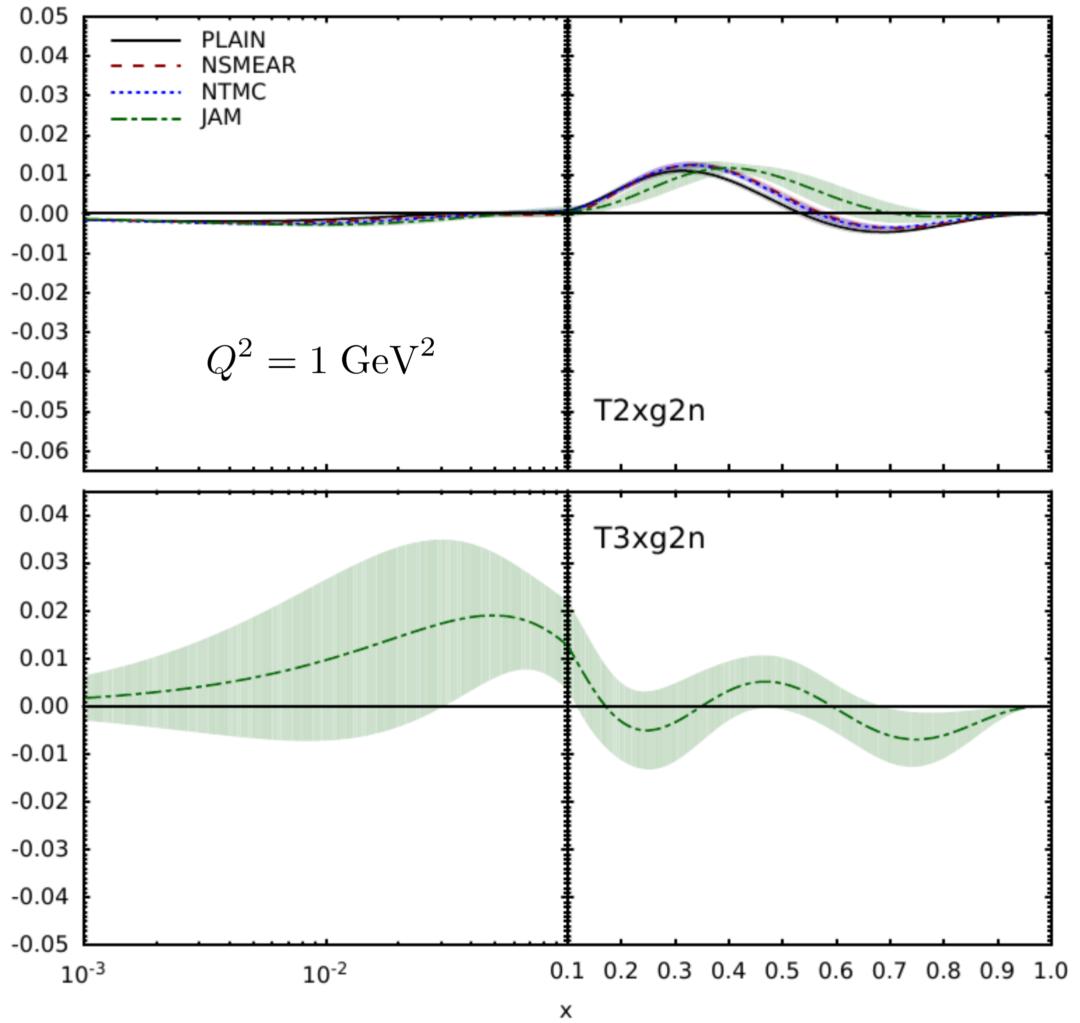
Including all these corrections: JAM



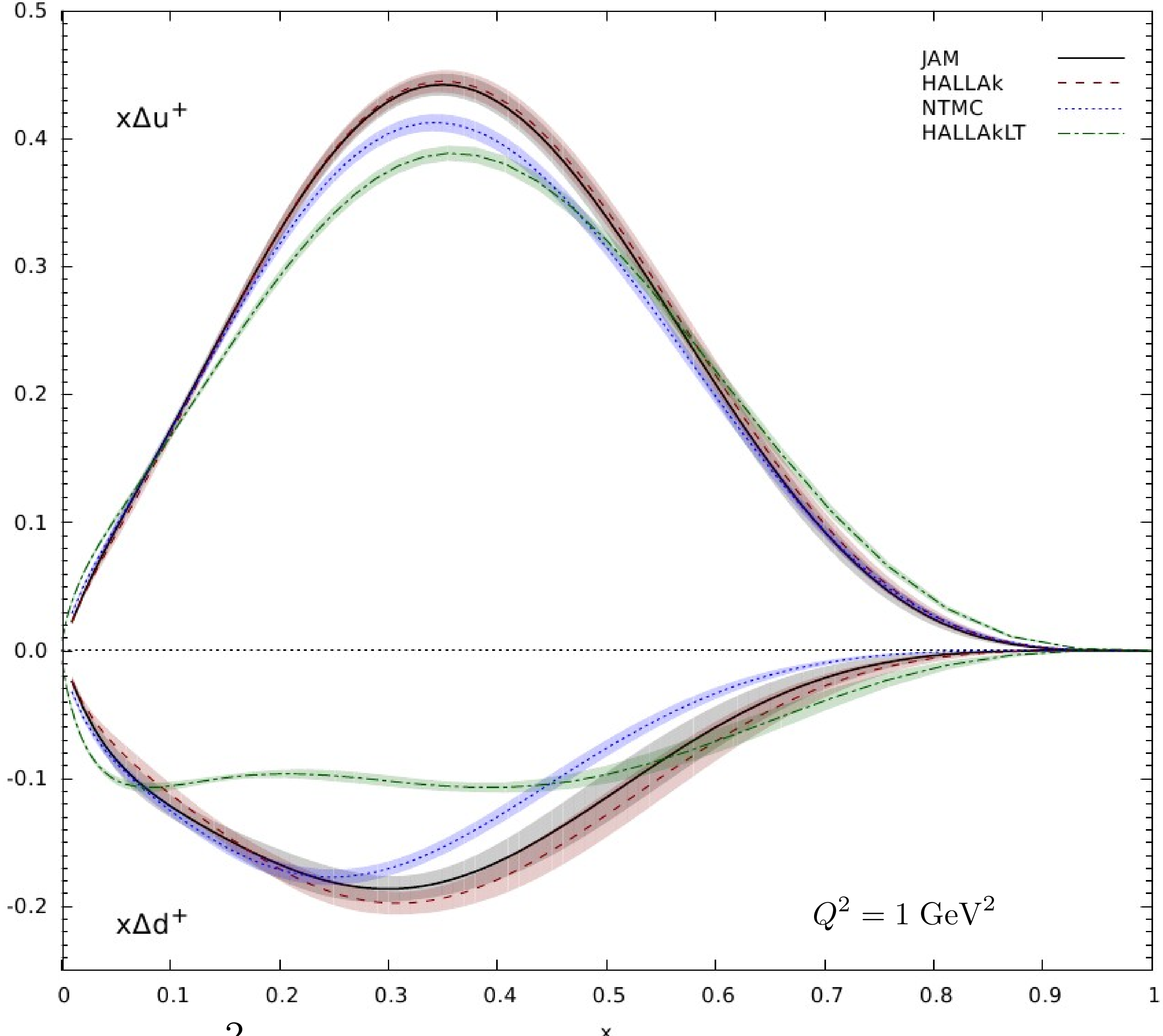


Including all these corrections: JAM



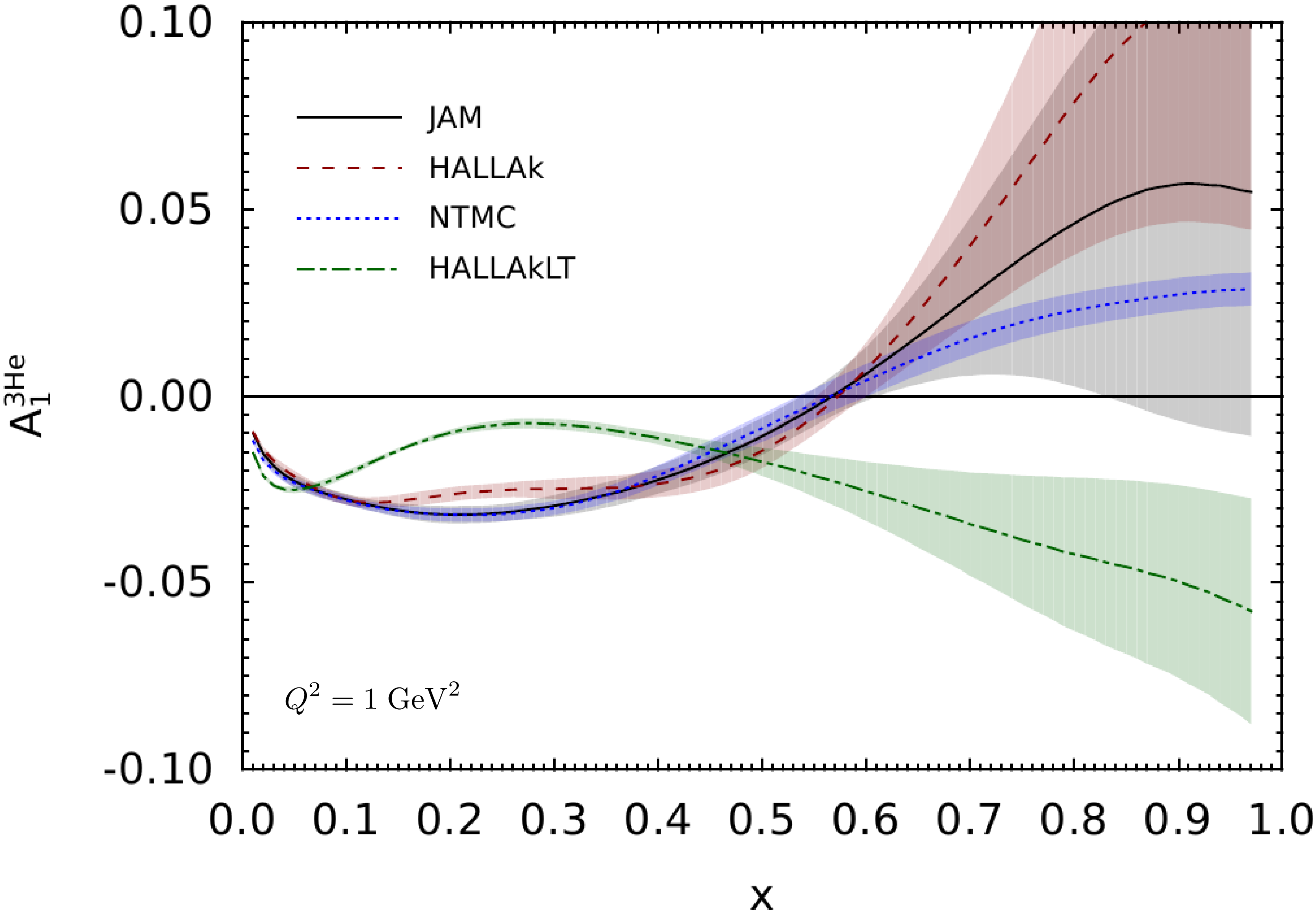


Including Jlab Hall A E97-103: HALLAk

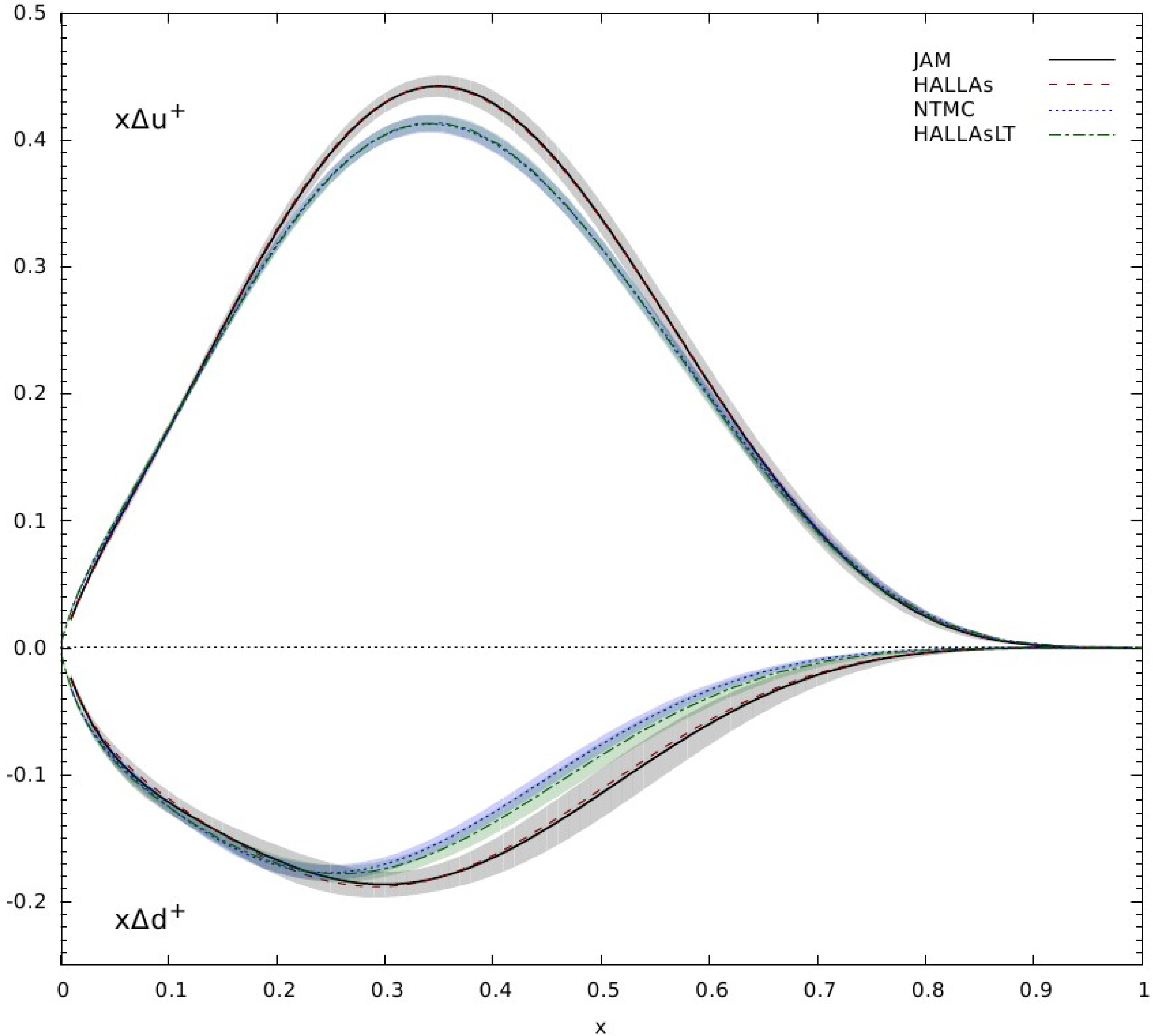


Better with HT, but χ^2 very large (for $A_{||}$ LT about 15, HT about 4)

Including Jlab Hall A E97-103: HALLAk



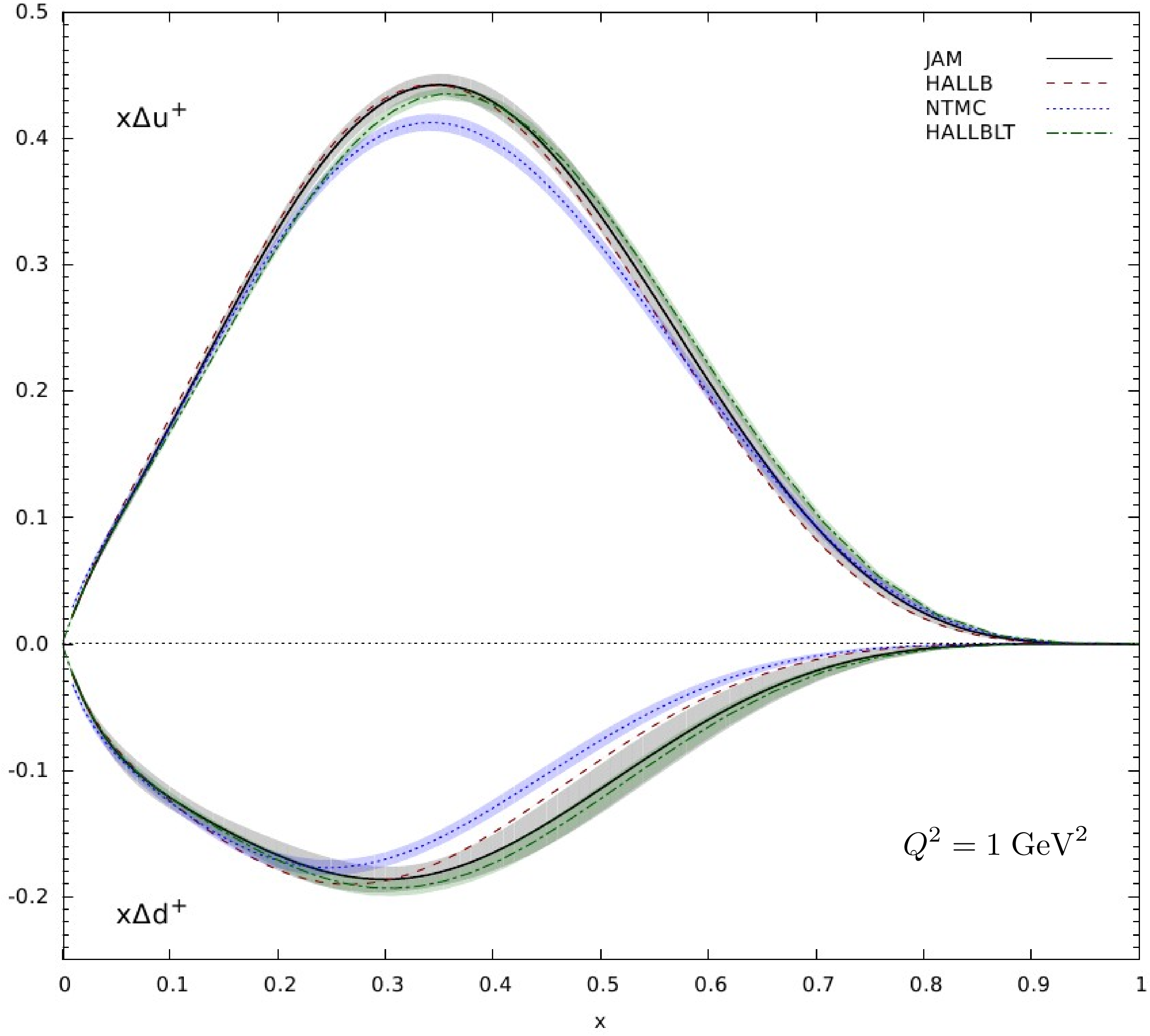
Including Jlab Hall A E01-012: HALLAs



Central values do not move that much, but χ^2 rather large (LT about 3, HT about 2.5)

Including Jlab Hall B: HALLB

Are they ready? A combination of the data points would be great



Summary and outlook

First JAM results practically *ready*

Some things still to be done: $x \to 1$ studies, OAM, symmetric sea,...

We will present them in the meetings in Denver (GHP + APS) , and in DIS 2013 (Alberto)

It is time to write our first paper!

Some tasks to which you could contribute?

- Help preparing tables and figures, e.g. comparisons with $A_{||}$ and $A_{\perp}$, combinations of data, and such (I can provide you with our predictions)
- Help with the text? Especially in what refers to your own data (if it applies)
- Suggestions and comments are also welcome