Progress in validation of PDFs and the high-twist terms in deep-inelastic scattering

(S.Alekhin, IHEP, Protvino)

in collaboration with

S.Kulagin (INR, Moscow)

R.Petti (CERN & South Carolina U.)

Uncertainty in the extraction of the Weinberg angle sine (s_W) due to PDFs

(Kulagin 03)

$$R^- = \frac{\sigma^\nu_{\rm NC} - \sigma^{\bar\nu}_{\rm NC}}{\sigma^\nu_{\rm CC} - \sigma^{\bar\nu}_{\rm CC}} \approx \frac{1}{2} - s_W^2 + \delta R^-_{\rm tot}$$

$$\delta R^-_{\rm tot} = \left(\frac{x_1^-}{x_0^-}\right)_A \left(1 - \frac{7}{3}s_W^2 + \mathcal{O}(\alpha_S)\right) \approx \frac{Z-N}{A}\left(\frac{x_1^-}{x_0^-}\right)_p \left(1 - \frac{7}{3}s_W^2\right)$$

$$x^-_{0,1} = \int {\rm d}x\, x(u_{\rm val} \pm d_{\rm val})$$

For the iron target magnitude of δR^- is about 10 times the error in the NuTeV measurement of R^-, hence the uncertainty in $(x_1^-/x_0^-)_p$ must be $\ll$ 10% ($\ll$ 0.04 by absolute value).

PDFs	$(x_1^-/x_0^-)_p$
CTEQ6(NLO)	0.42 ± 0.03
MRST01(NLO)	0.43 ± 0.02
A02M(NNLO)	0.43 ± 0.03

The ways to improve the A02M determination of $(x_1^-/x_0^-)_p$

- **add the fixed-target Drell-Yan data** – better separation of the sea and valence quarks distributions and hence better determination of both.
- **add low-Q charged-leptons data** – good statistical significance of the data at low Q; *validation of the operator product expansion at small Q and control of uncertainties due to the high-twist contributions (particularly important for NOMAD with $< Q^2 > \sim 5\ GeV$).*

Theoretical input of the NNLO QCD fit

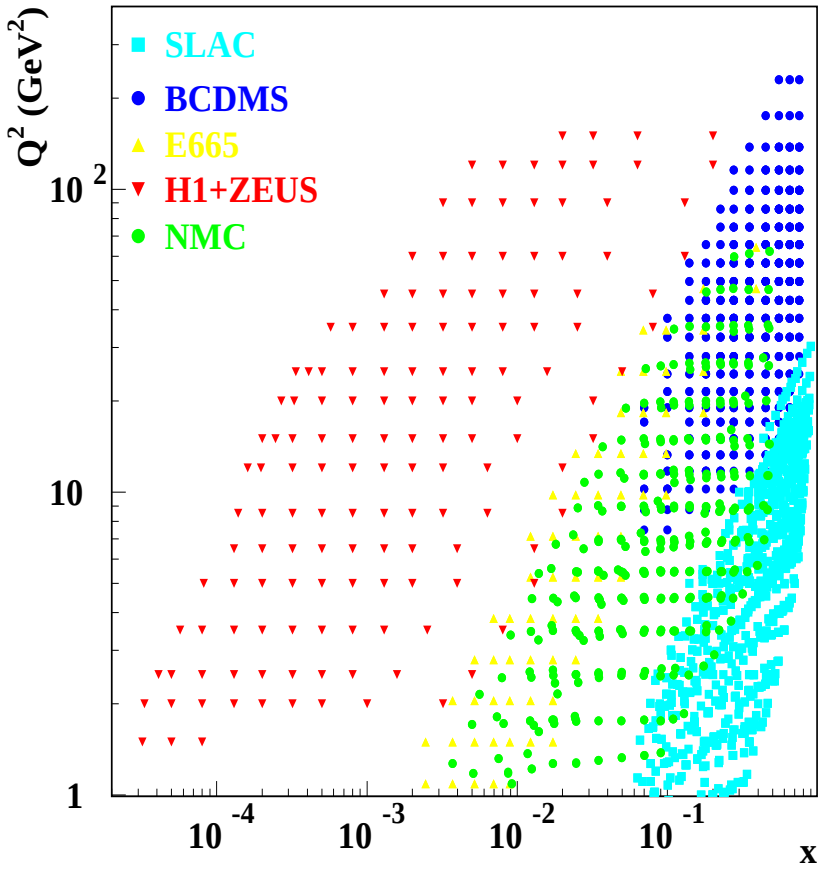
- The PDFs are evolved using three-loop, $O(\alpha_{\rm s}^3)$, splitting functions in the $\overline{MS}$ scheme.
- The DIS structure functions are calculated using OPE

$$F_{2,\rm T}(x,Q) = F_{2,\rm T}^{\rm LT}(x,Q) + \frac{H_{2,\rm T}^{(2)}(x)}{Q^2} + \left(\frac{H_{2,\rm T}^{(4)}(x)}{Q^4}\right)$$

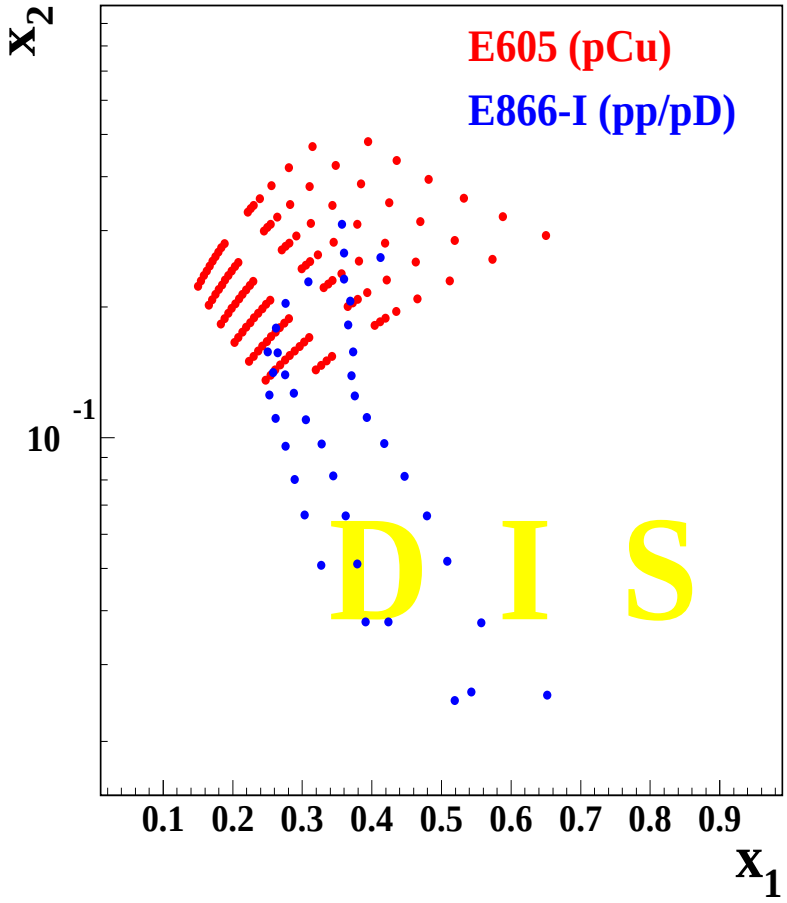
  The leading-twist terms (entirely dominant at $Q^2 \gtrsim 10$ GeV^2) are calculated with the the two-loop, $O(\alpha_{\rm s}^2)$, coefficient functions for massless partons and with the one-loop, $O(\alpha_{\rm s}^2)$, coefficient functions for the heavy quarks. The twist-4 terms (contributes at $Q^2 \lesssim 10$ GeV^2) and the twist-6 terms (might contribute at $Q^2 \lesssim 3$ GeV^2) – no QCD evolution.
- The Drell-Yan cross sections are calculated using the two-loop, $O(\alpha_{\rm s}^2)$, coefficient functions.

Experimental input of the fit

DIS



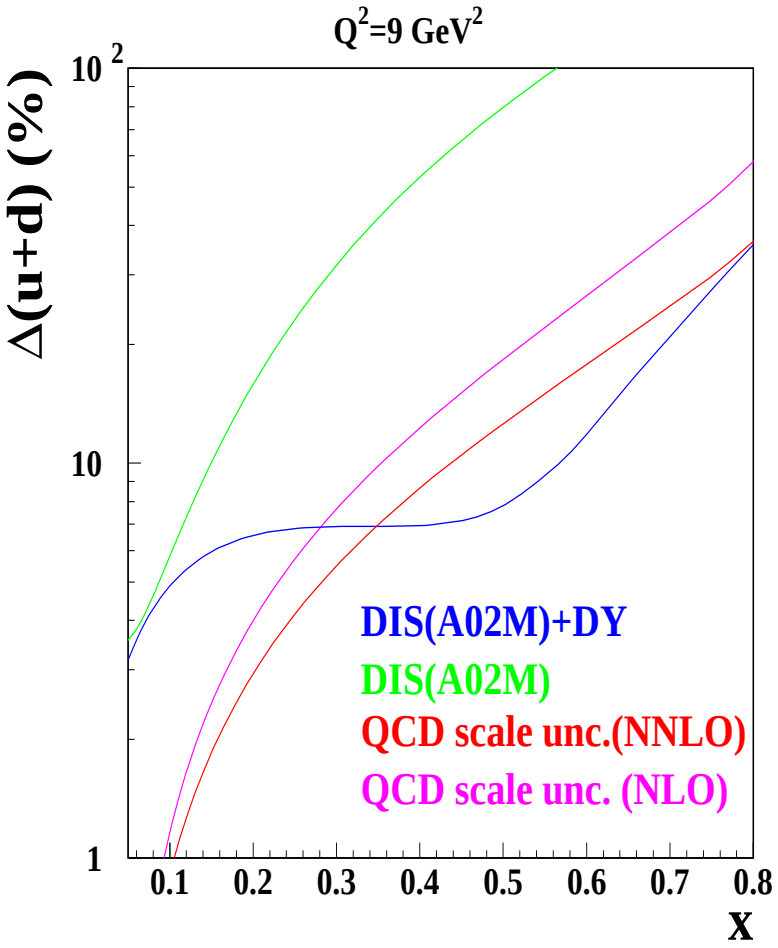
DY



JLAB data are not used

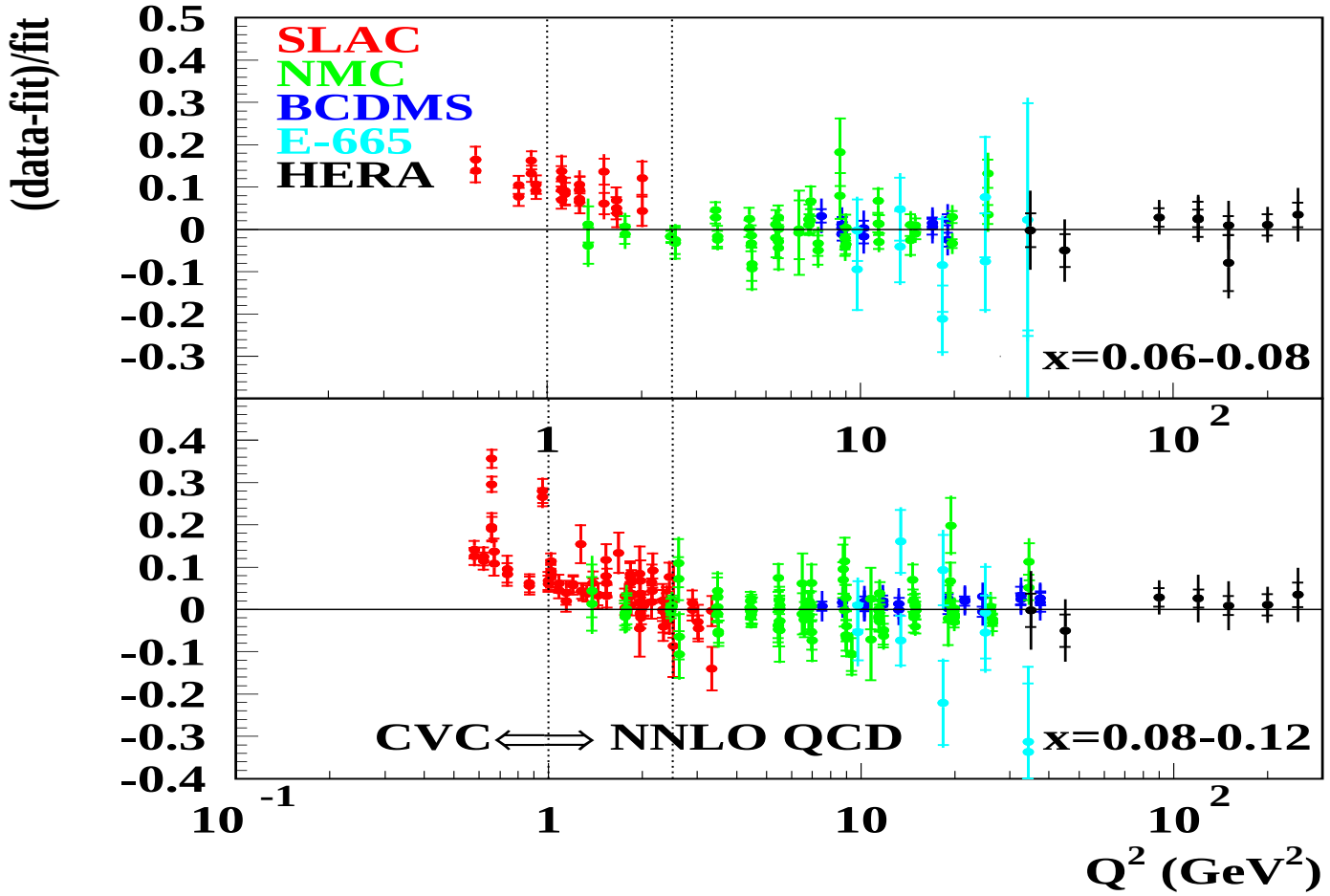
Impact of the DY data on the sea distribution

(sa-Melnikov-Petriello 06)



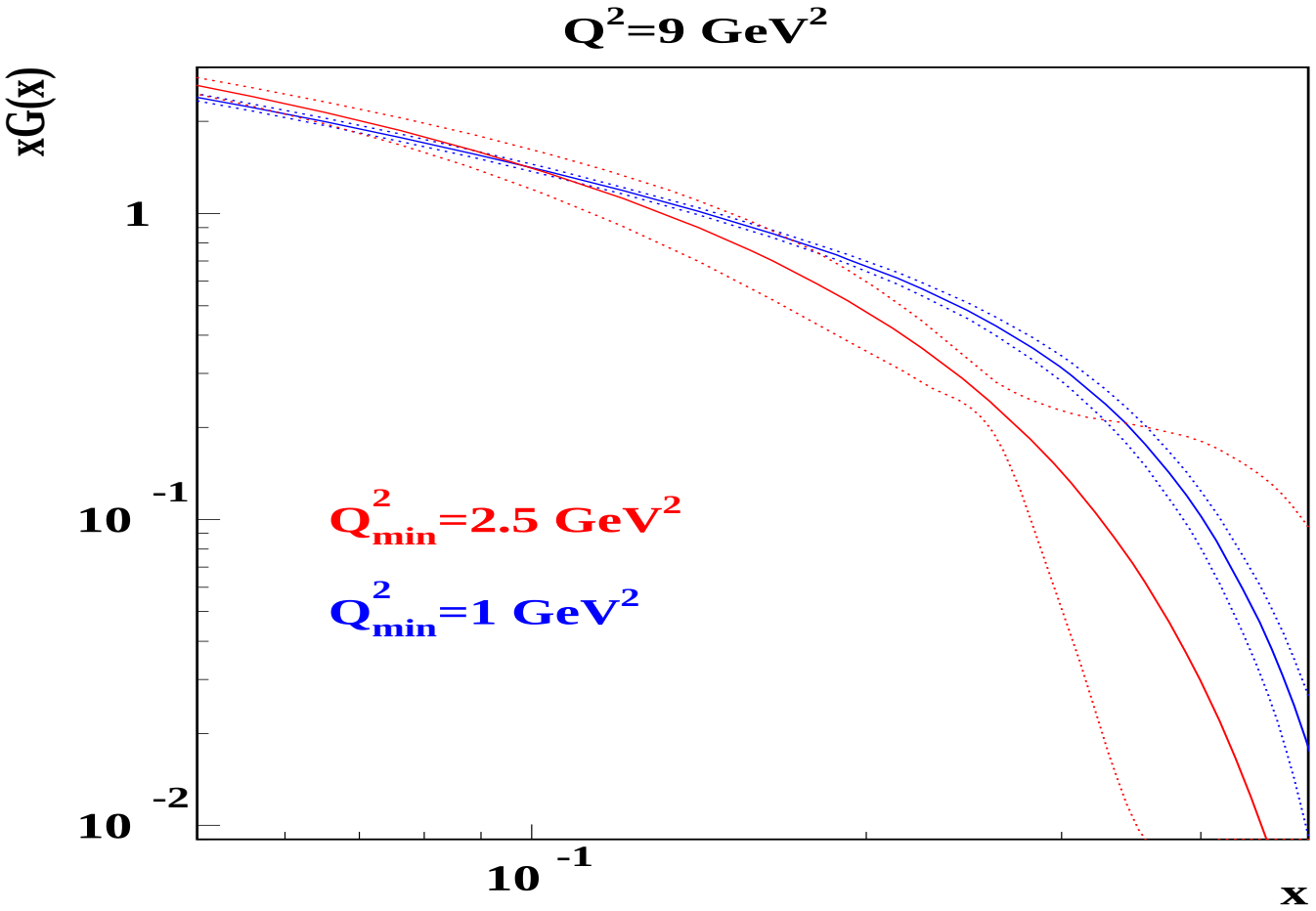
- Experimental errors in the sea is < 20 % at $x \lesssim 0.7$.
- The errors in PDFs due to variation of the DY scales are comparable to the experimental ones (*the NNLO corrections are crucial at this point*).
- The error in $(x_1^-/x_0^-)_p$ goes from 0.03 for A02M to 0.01 for A02M with the DY data included.

Extrapolation of the fit to $Q^2_{\rm DIS} < 2.5$ GeV^2



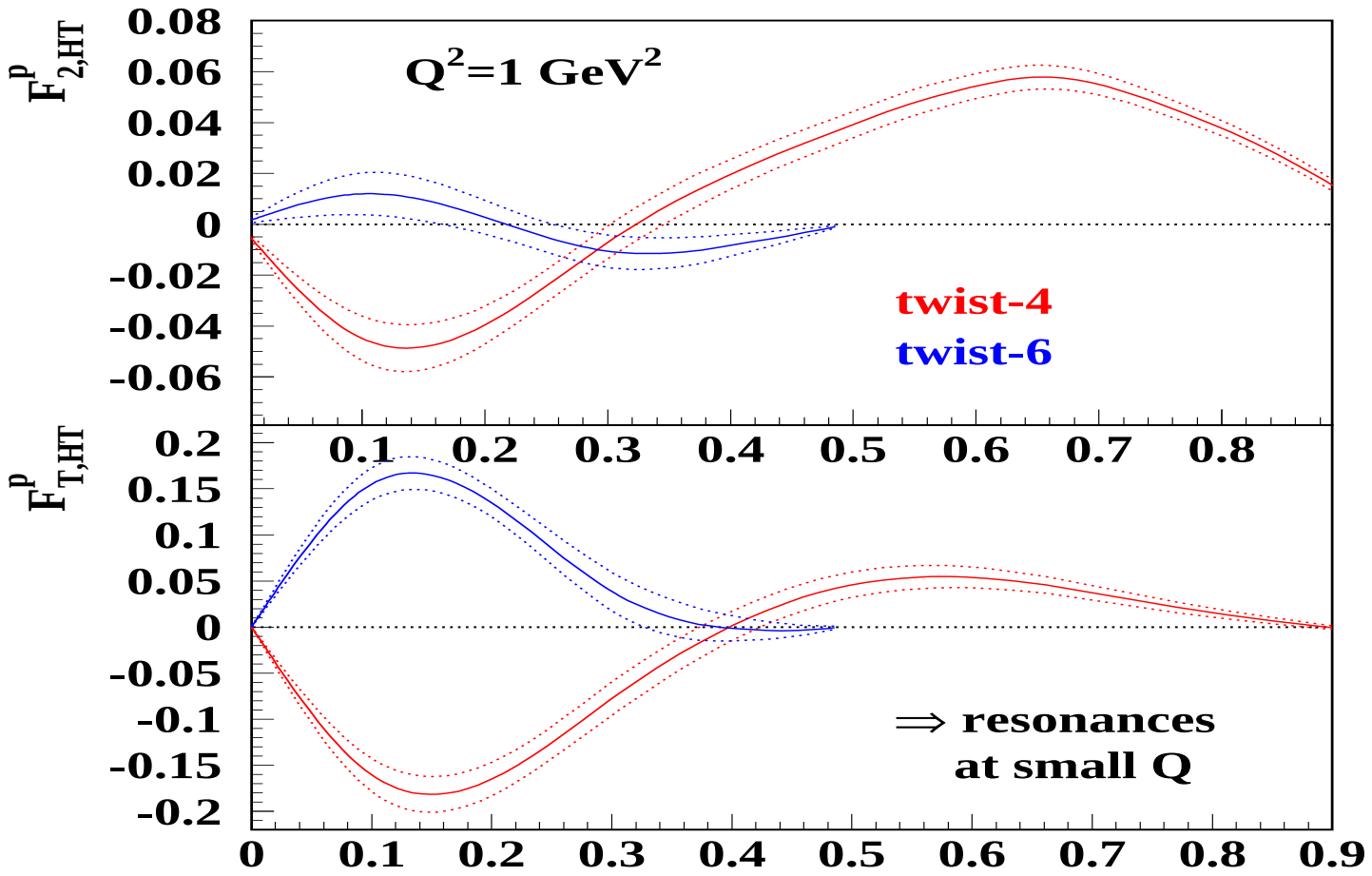
Extrapolation of the high-Q fit to $Q \sim 1$ GeV does not work.

Gluons in the low-Q DIS fit



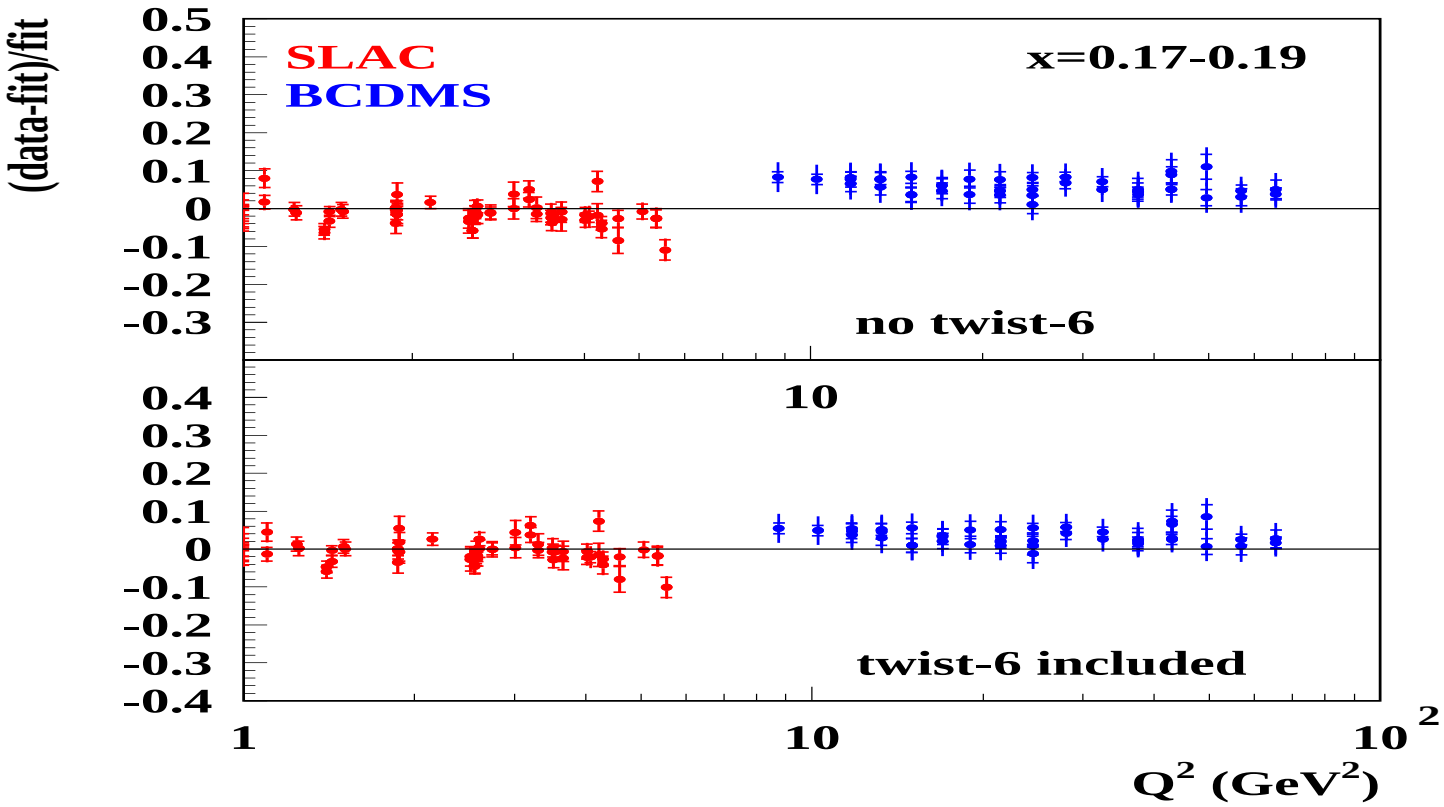
The change in G(x) due to the low-Q data looks unnatural.

High-twist terms in the fit with $Q^2 > 1$ GeV^2

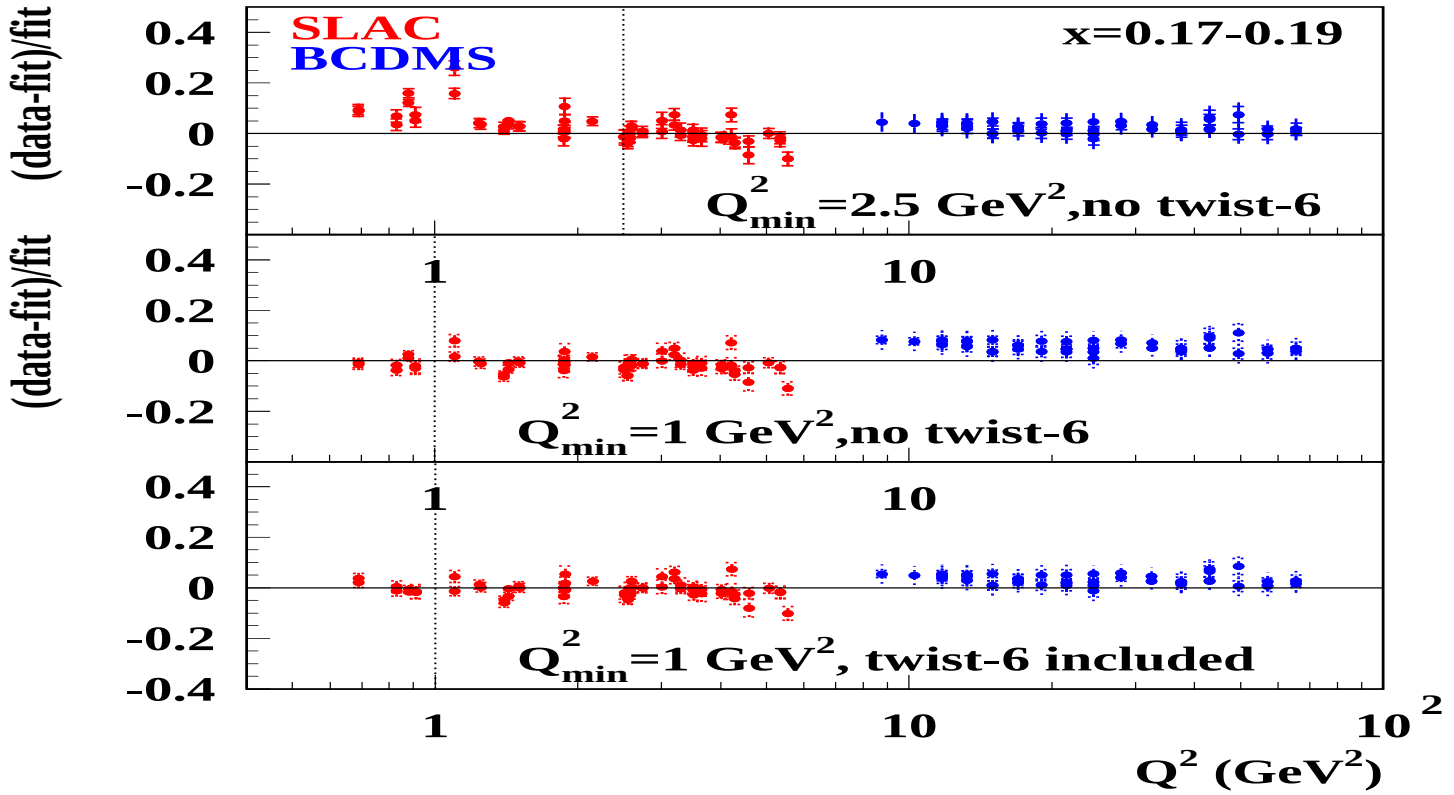


The twist-6 terms in $F_{\rm T}$ demonstrate strange behavior.

Impact of the twist-6 terms on pulls of the fit



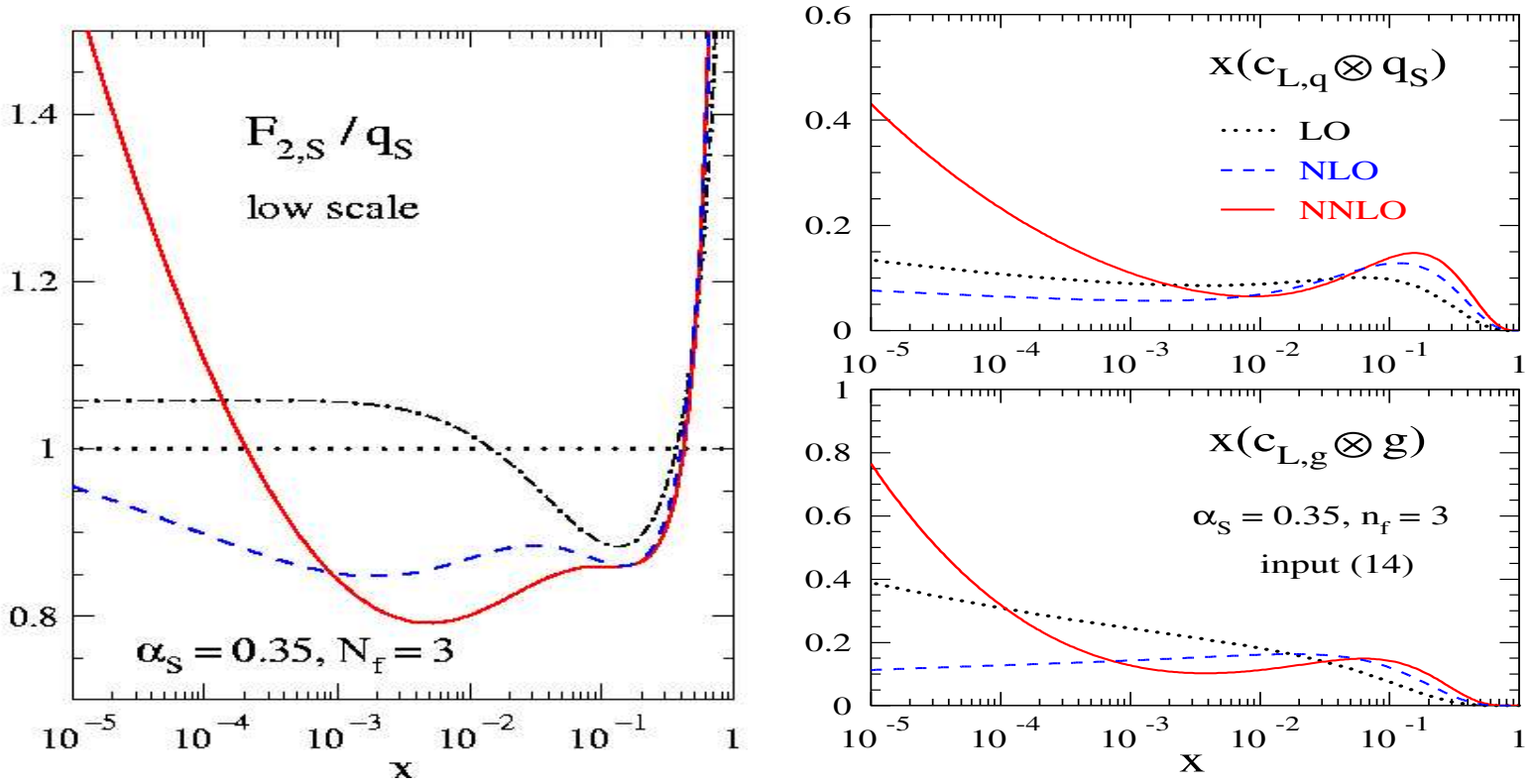
The origin of twist-6 terms is rather due to mismatch of the SLAC and BCDMS data at $Q^2 = 5 \div 10$ GeV^2.



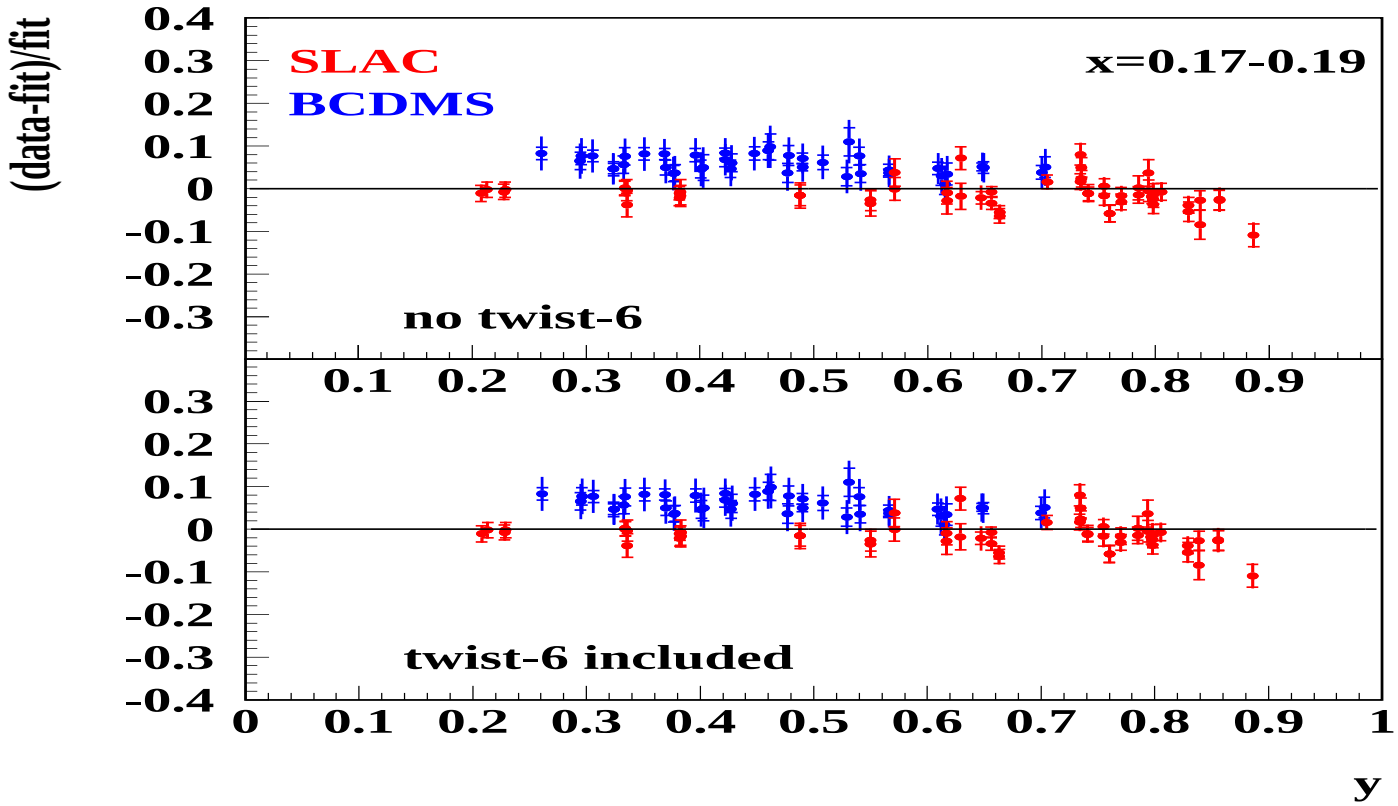
Details of the SLAC/BCDMS matching depends on the Q-cut.

The $O(\alpha_s^3)$ corrections to the DIS coefficient functions

(Moch-Vermaseren-Vogt 04-05)

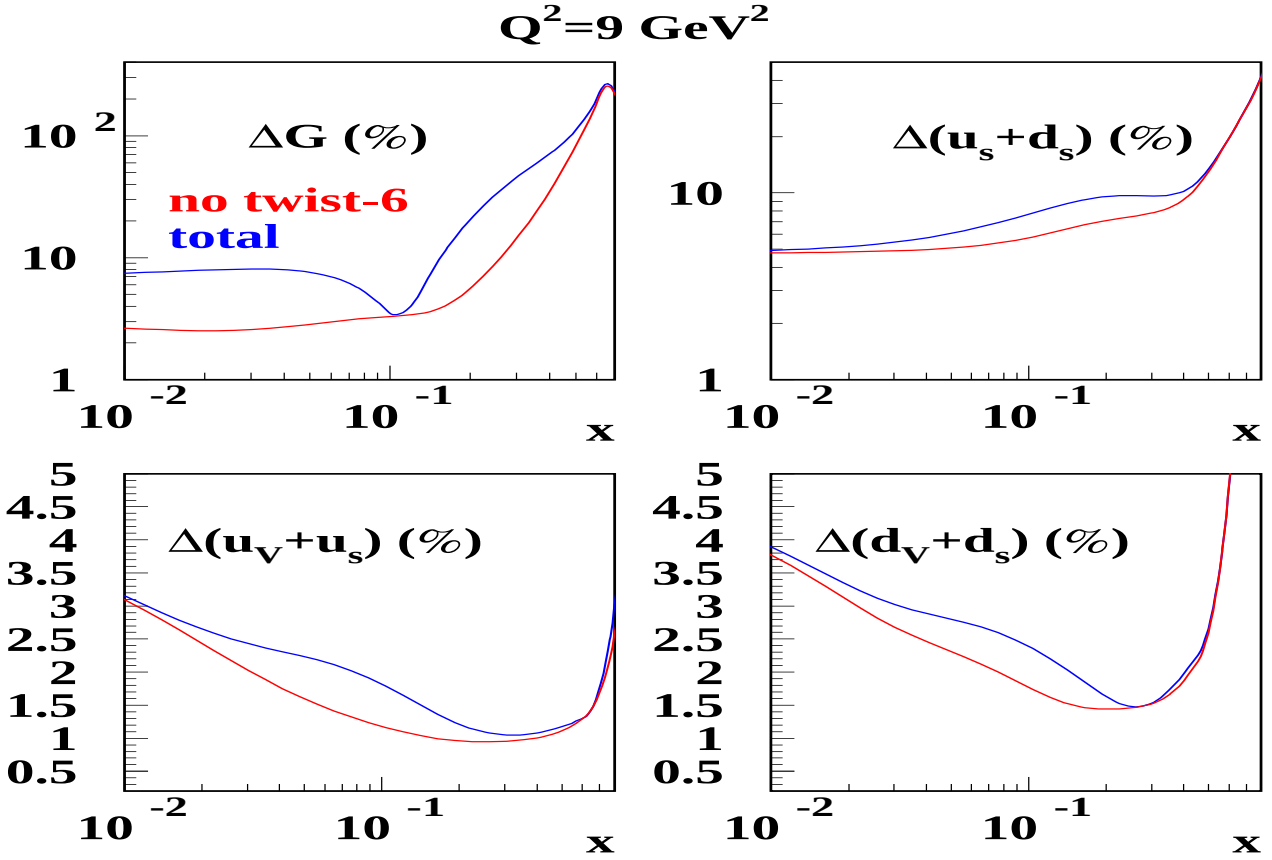


This correction doesn't change fitted twist-6 terms



The electro-weak corrections seems not to be responsible for the SLAC/BCDMS discrepancy too.

The twist-6 uncertainty and the PDFs errors



The uncertainty due to twist 6 is half of difference between the results of fits with/without twist-6 included.

Results and outlook

PDFs	$(x_1^-/x_0^-)_p$
CTEQ6(NLO)	0.42 ± 0.03
MRST01(NLO)	0.43 ± 0.02
A02M(NNLO)	0.43 ± 0.03
AKP06(NNLO)	$\mathbf{0.4268 \pm 0.0056 \pm 0.0026(tw6)}$

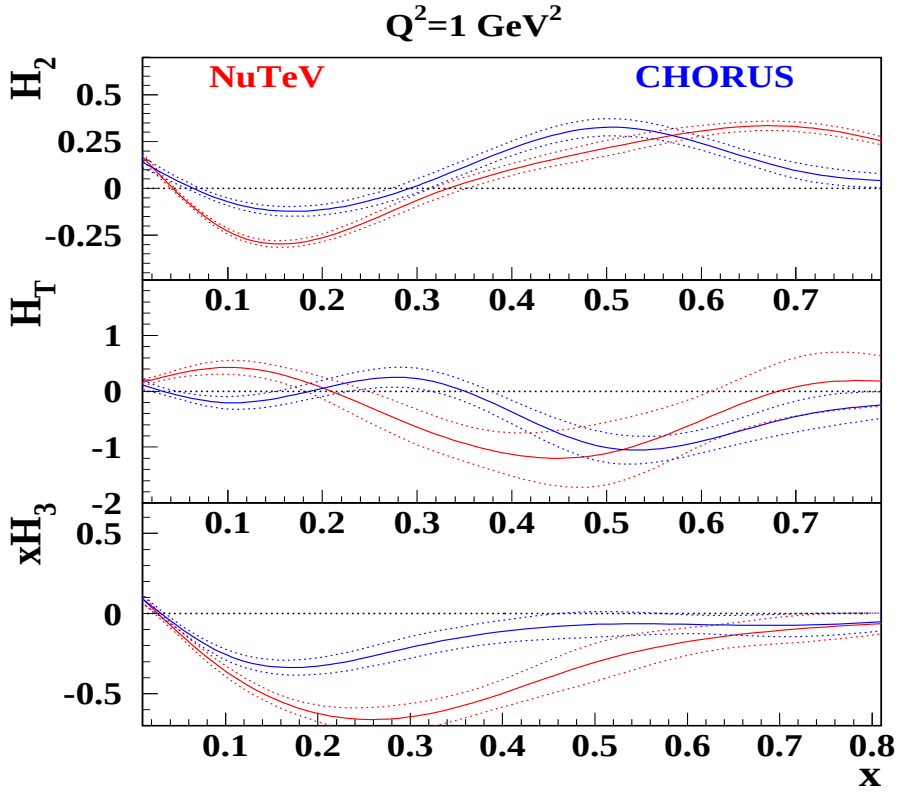
Factor of 5 improvement in the uncertainty of $(x_1^-/x_0^-)_p$

Uncertainty in the strange sea must be re-assessed in view of the recent NuTeV dimuon data.

	$\alpha_s(M_Z)$
A02M(NNLO)	0.11280 ± 0.00150
AKP06(NNLO)	$0.11102 \pm 0.00078 \pm 0.00170(tw6)$

The error in α_s has not been improved.

Status of the inclusive νN data and fits with $Q^2 > 1$ GeV^2



- the PDFs from the DIS+DY fit
- the nuclear corrections by Kulagin-Petti
- the EW corrections by Arbuzov-Bardin

χ^2/NDP=1451/1144=1.27 (CHORUS), 2768/2618=1.06 (NuTeV)

Summary

- Tuning of PDFs has been basically finished; the only missing point is validation of the strange sea.
- The values of high-twist terms in the νN DIS are still unclear, mainly due to the contradiction between the CHORUS and NuTeV data interplayed with the nuclear effects (talk by Sergey K.).