Recent progress in validation of the PDFs

(S.Alekhin, IHEP, Protvino)

Very often the bottleneck in validation of the PDFs is calculation of the high-order QCD corrections: With better theoretical background we can use more data without risk of uncontrolled theoretical uncertainties.

Recent milestones in the hard QCD calculations

- The NNLO corrections to the Drell-Yan c.s.

  (Anastasiou-Dixon-Melnikov-Petriello 03)

- The NNLO splitting functions

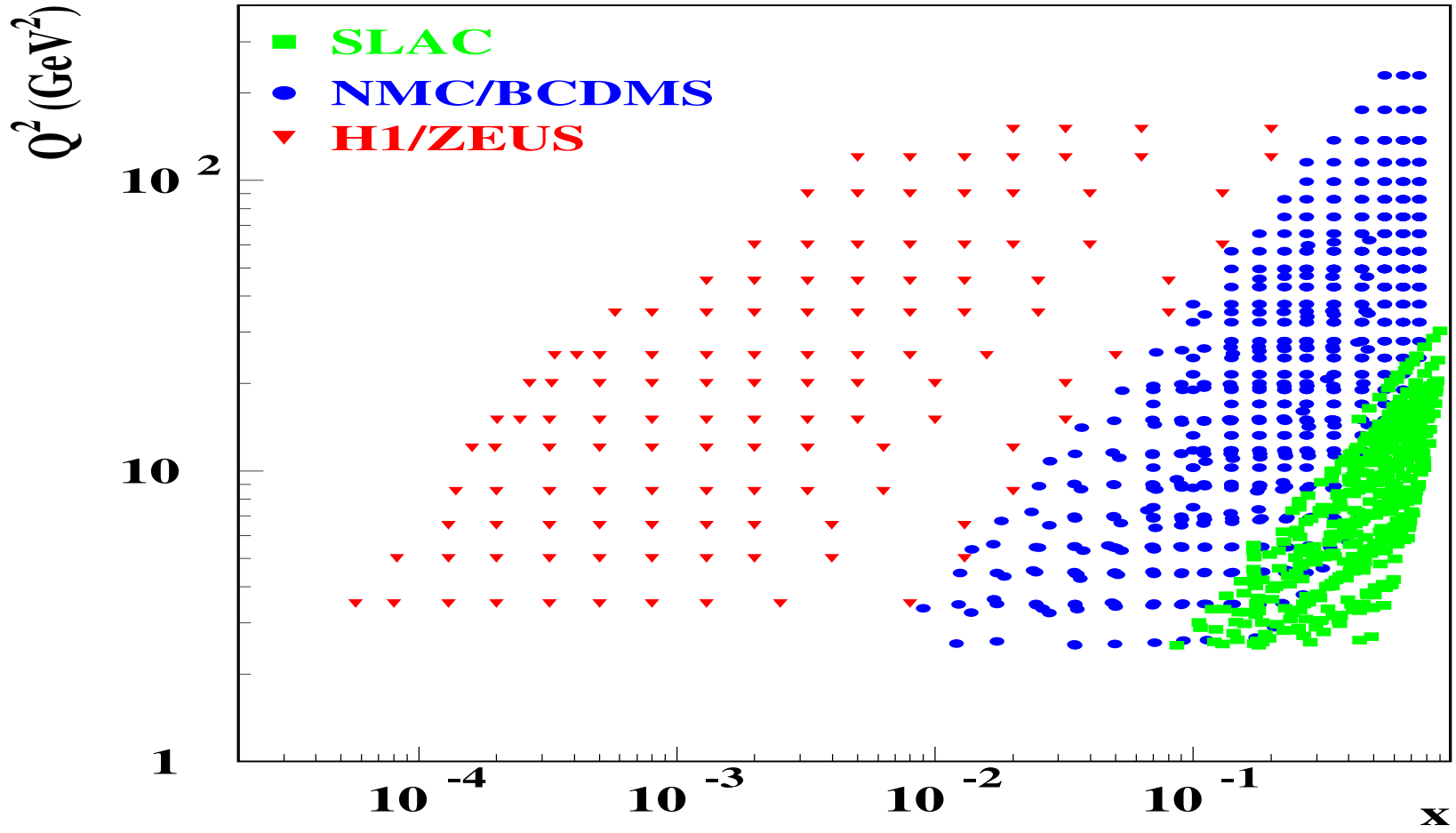
  (Moch-Vermaseren-Vogt 04)

- The $O(\alpha_s^3)$ coefficient functions for the charged-leptons DIS c.s.

  (Moch-Vermaseren-Vogt 05)

Extract the PDFs with the NNLO(N3LO?) accuracy, add the DY data to the high-order QCD fit, try to use the DIS data at low Q,...

Kinematics of the global DIS data



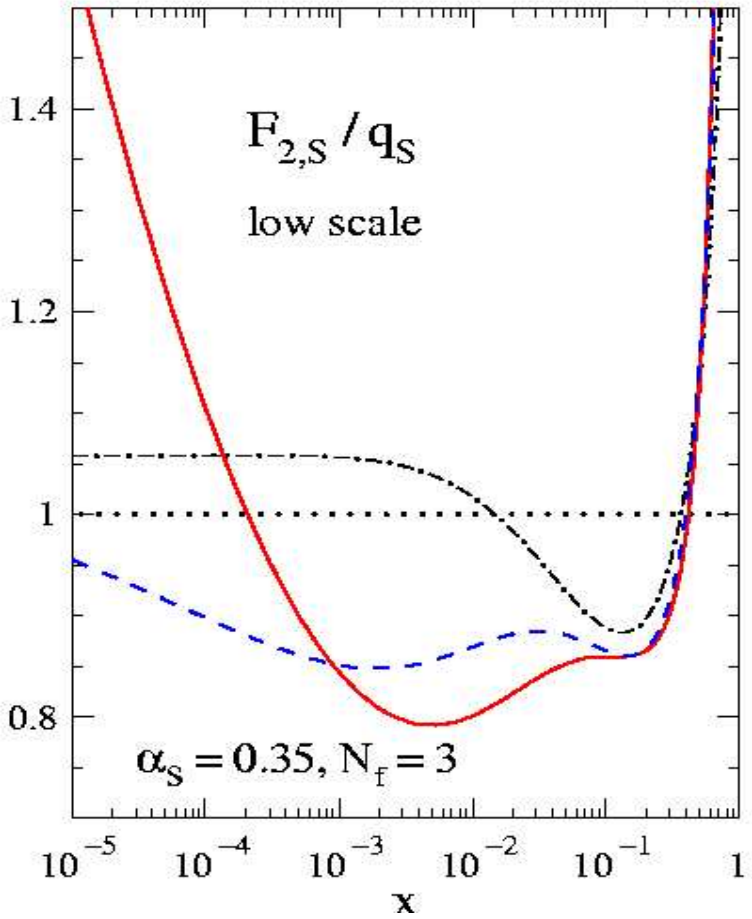
The regular cuts $Q^2 > 2.5$ GeV^2 and $W > 1.8$ GeV are applied.

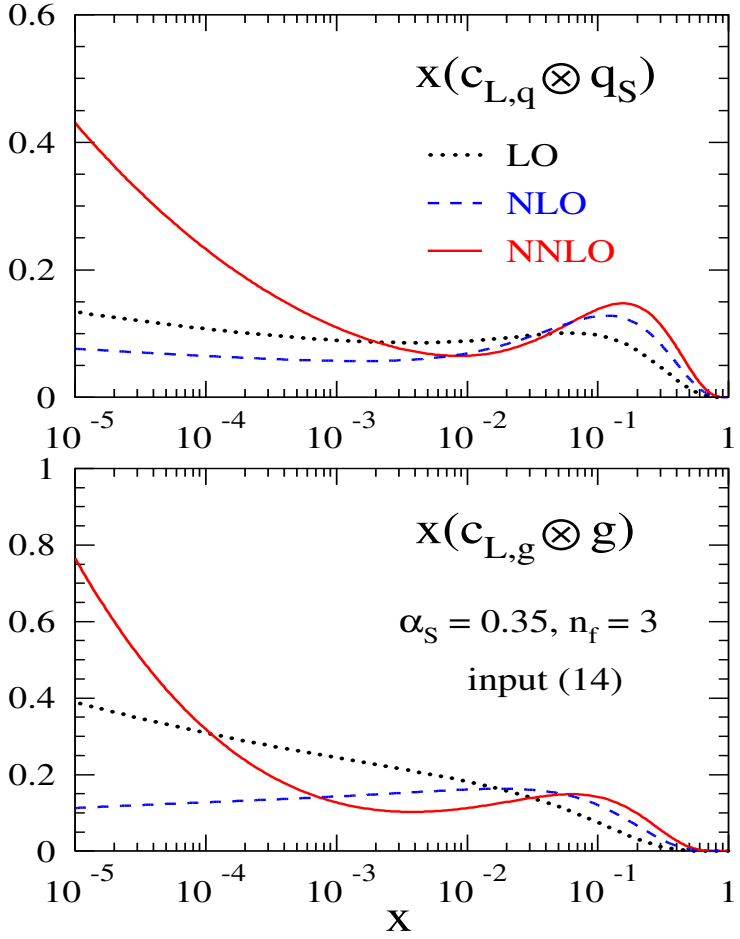
Theoretical input to the global DIS fit

- The massless NNLO QCD corrections for the light quarks and gluons (splitting and coefficient functions).
- Account of the heavy quarks contributions up to $O(\alpha_s^2)$ by Laenen-Riemersma-Smith-van Neerven.
- Account of the target-mass corrections by Georgi-Politzer, correction for the Fermi-motion in deuterium, and the twist-4 terms.
- *The massless $O(\alpha_s^3)$ corrections to the coefficient functions*

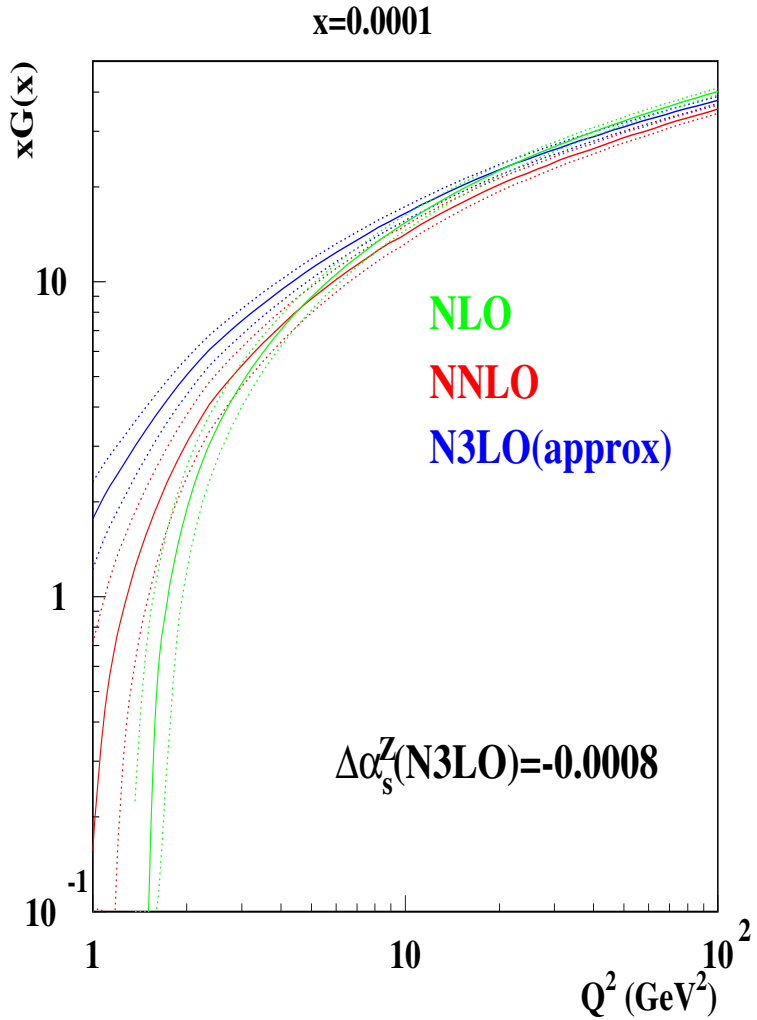
The $O(\alpha_s^3)$ corrections to the DIS coefficient functions

(Moch-Vermaseren-Vogt 04-05)





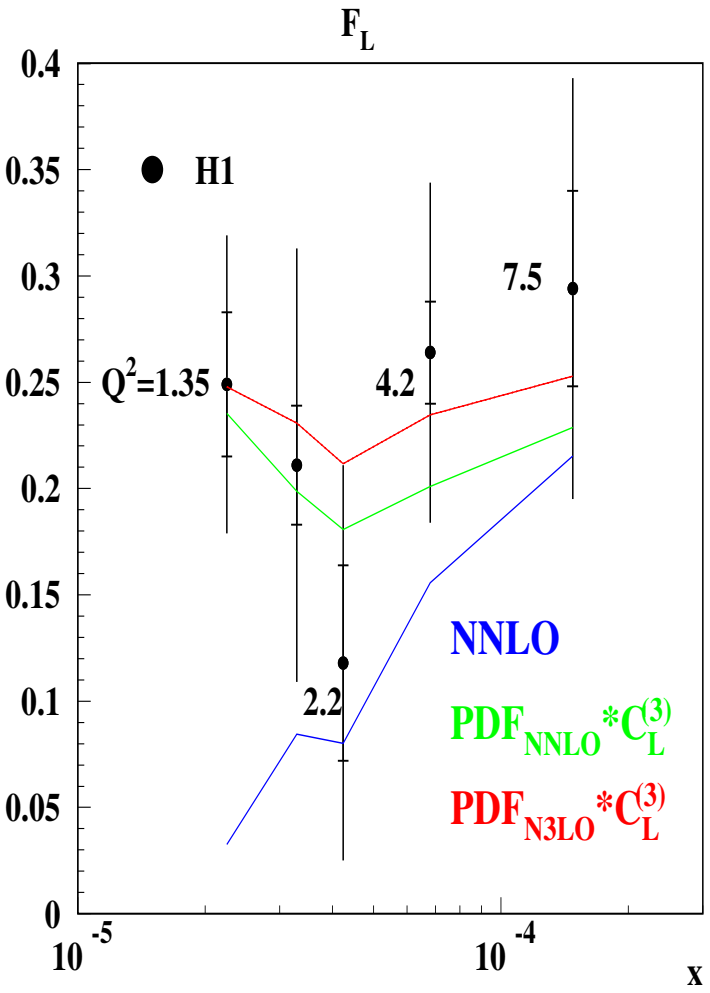
Perturbative stability of the PDFs



In the approximate N3LO fit the $O(\alpha_s^3)$ coefficient functions are combined with the NNLO evolution kernel. Successive account of the HO QCD correction makes gluon distribution at small x/Q bigger; this must be essential for modeling the underlying events at the LHC. Further validation of the evolution kernel in this region might be important

(Altarelli-Ball-Forte 03)

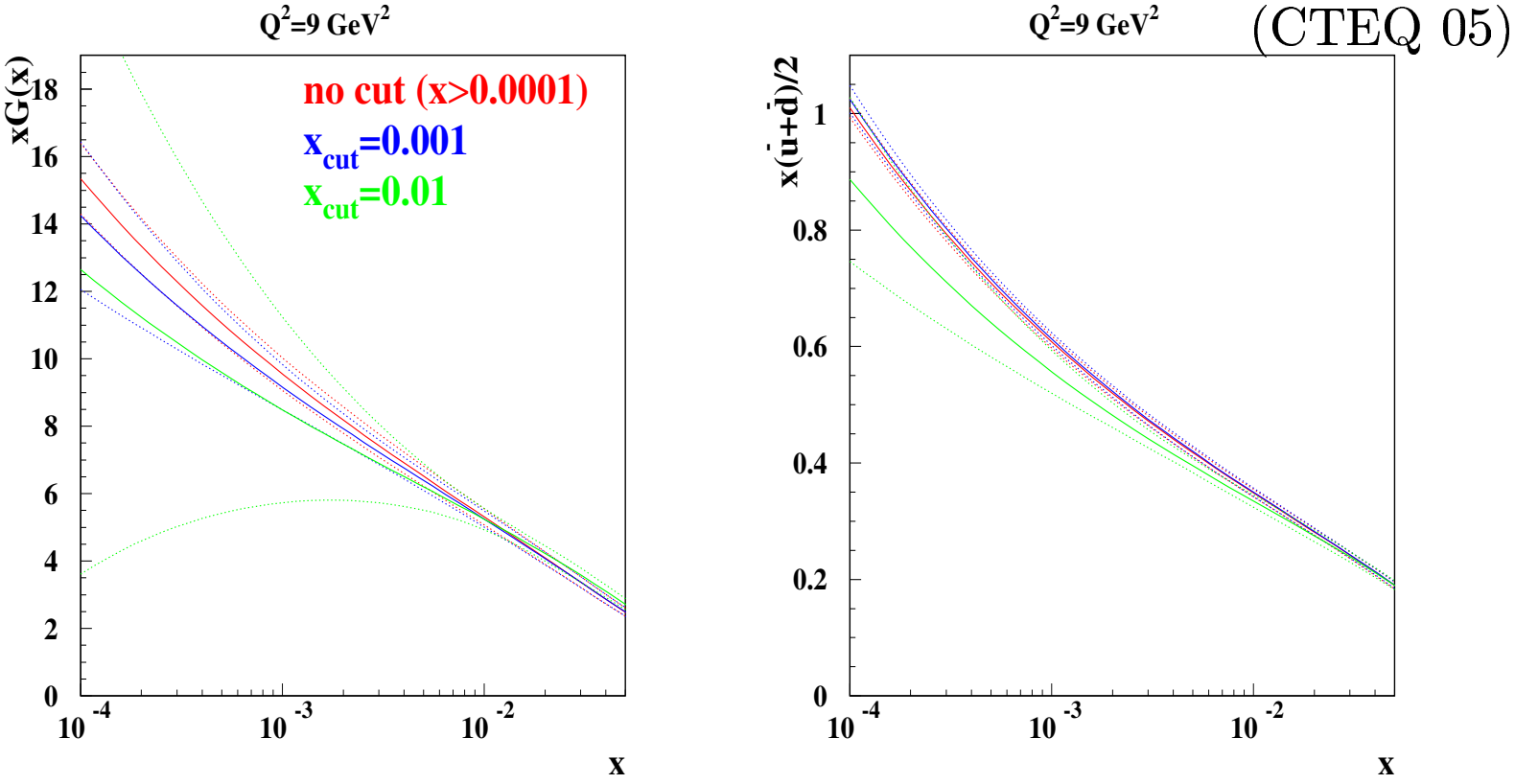
Impact of the HO QCD corrections on F_L



The $O(\alpha_s^3)$ corrections clearly improve agreement to the data, however at the same time it raises the question about perturbative stability of the predictions (check the k_T re-summation results for $C_L^{(3,4,5)}$ by Catani-Hautmann).

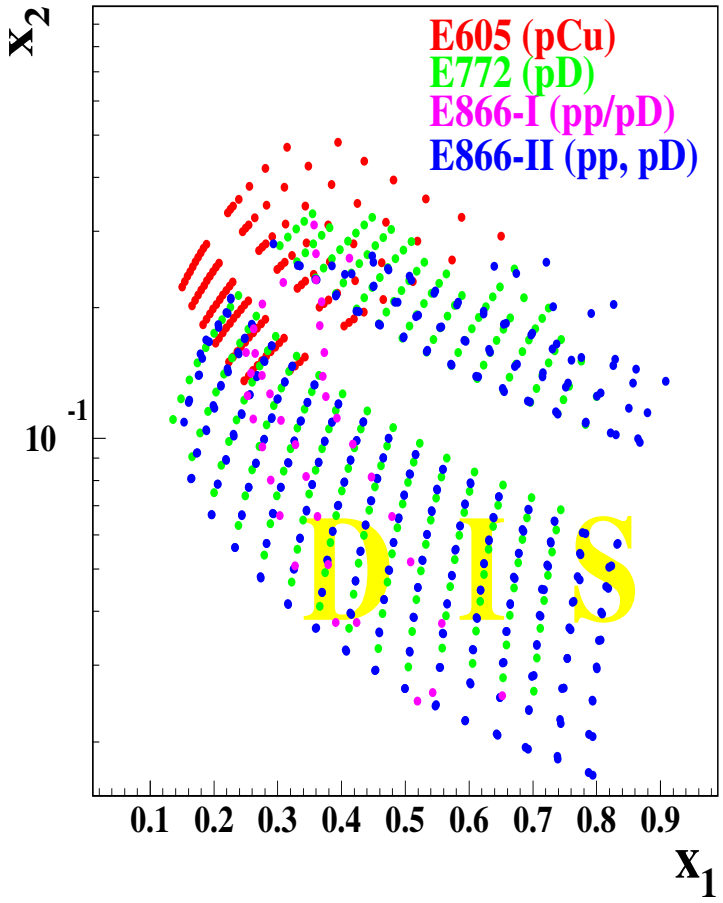
Sensitivity of fit to the low-x cut

(MRST 04)
(CTEQ 05)



The PDFs are stable with respect to the low-x cut, possible impact of the HO corrections is within the errors (agrees to the CTEQ NLO results).

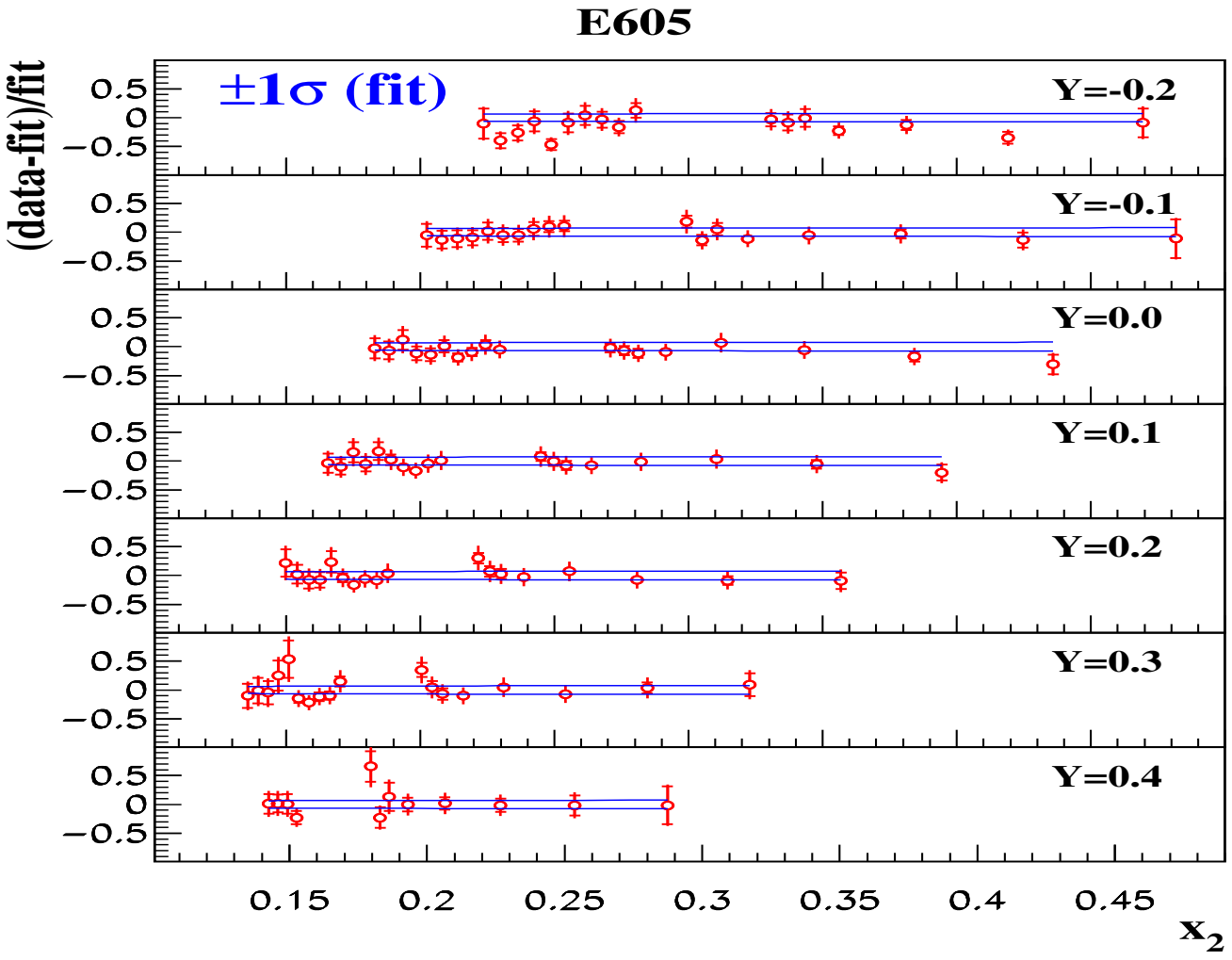
The NNLO fit to the combined DIS and DY data

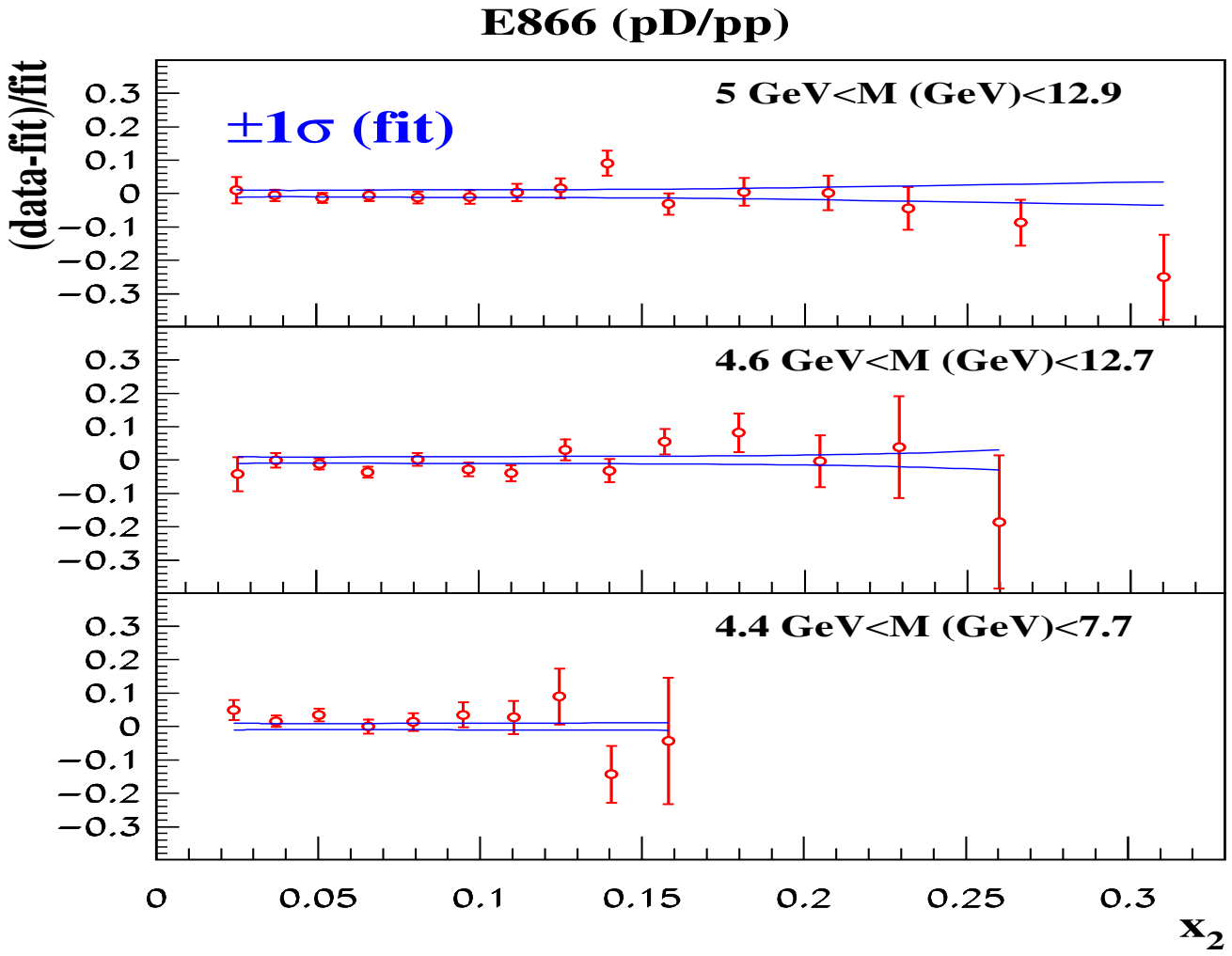


- The DIS data are combined with the DY data on isoscalar target (pCu) and with the data on ratio (pD)/(pp) to constraint both isospin- symmetric and asymmetric combinations of the sea distributions at large x.
- The NNLO corrections to the DY c.s. are calculated *iteratively* providing self-consistency of the fit.

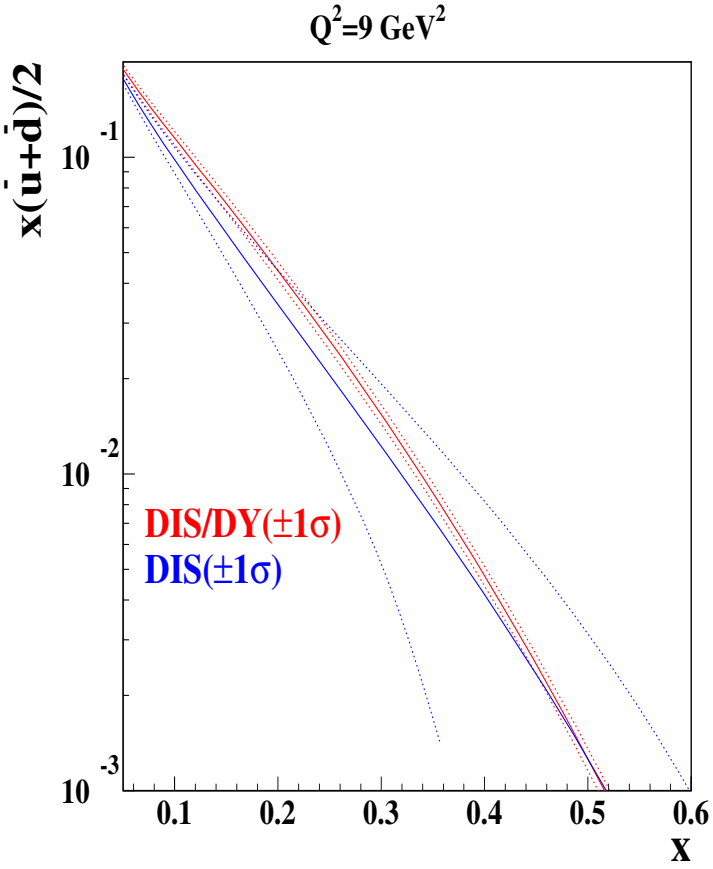
Table 1: The number of data points (NDP) and the values of χ^2/NDP for each experiment used in the fit.

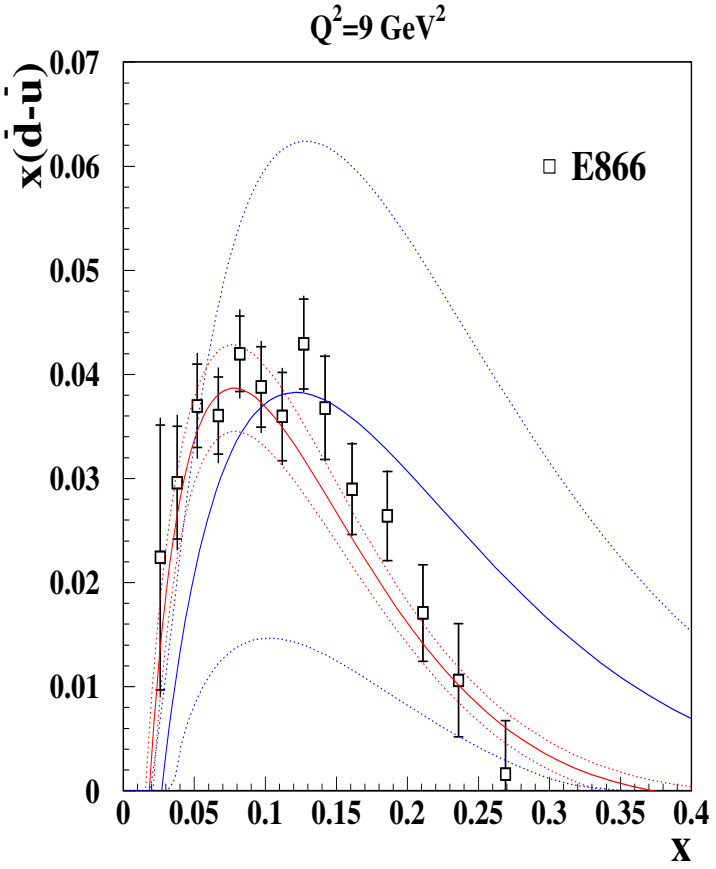
Experiment	NDP	χ^2/NDP	Experiment	NDP	χ^2/NDP
SLAC-E-49A	118	0.56	BCDMS	605	1.10
SLAC-E-49B	299	1.18	NMC	490	1.26
SLAC-E-87	218	0.94	H1(96-97)	135	1.13
SLAC-E-89A	148	1.42	ZEUS(96-97)	161	1.28
SLAC-E-89B	162	0.80	FNAL-E-605	119	1.49
SLAC-E-139	26	1.03	FNAL-E-866	39	1.13
SLAC-E-140	17	0.47	Total	2537	1.13

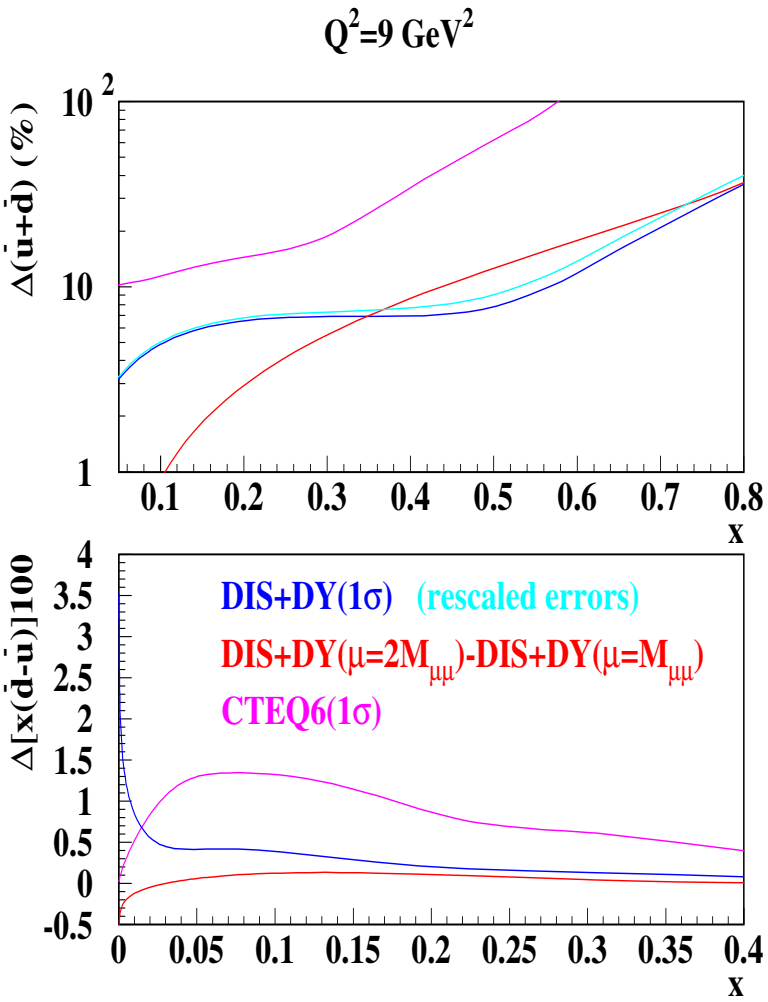

E605
±1σ (fit)
(data-fit)/fit
Y=-0.2
Y=-0.1
Y=0.0
Y=0.1
Y=0.2
Y=0.3
Y=0.4
0.5
0
−0.5
0.15
0.2
0.25
0.3
0.35
0.4
0.45
x2


E866 (pD/pp)
(data-fit)/fit
±1σ (fit)
5 GeV<M (GeV)<12.9
4.6 GeV<M (GeV)<12.7
4.4 GeV<M (GeV)<7.7
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
0
0.05
0.1
0.15
0.2
0.25
0.3
x2

Sea in the nucleon

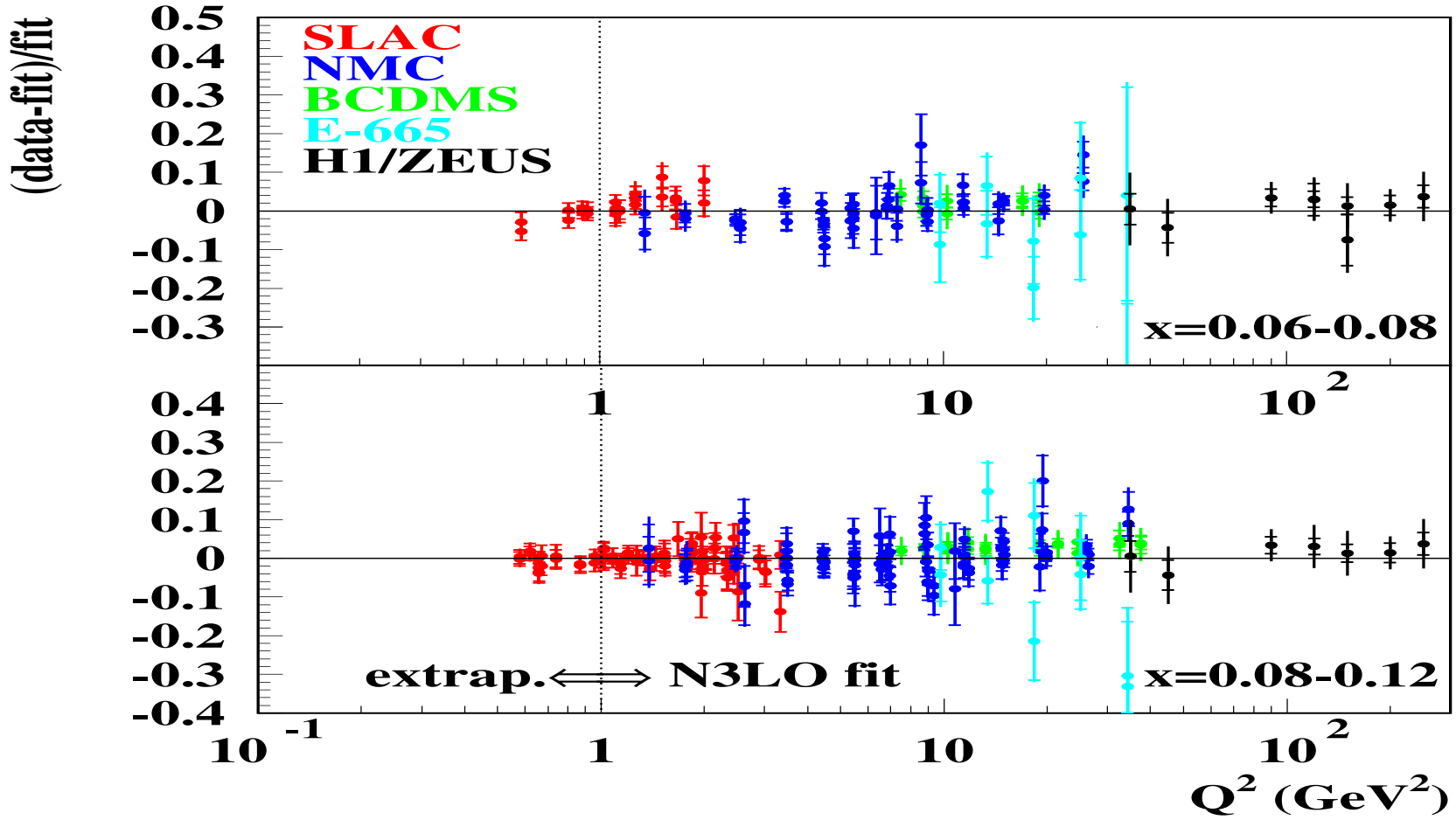






- We need not big rescaling factor for the errors in data in order to bring them into **ideal** agreement to the fit (such factor is 10 for CTEQ6).
- Suppression of the errors in sea down to 20 % at $x \lesssim 0.7$
- The errors in PDFs due to variation of the DY scales are comparable to the experimental ones.

Modeling the low-Q DIS data

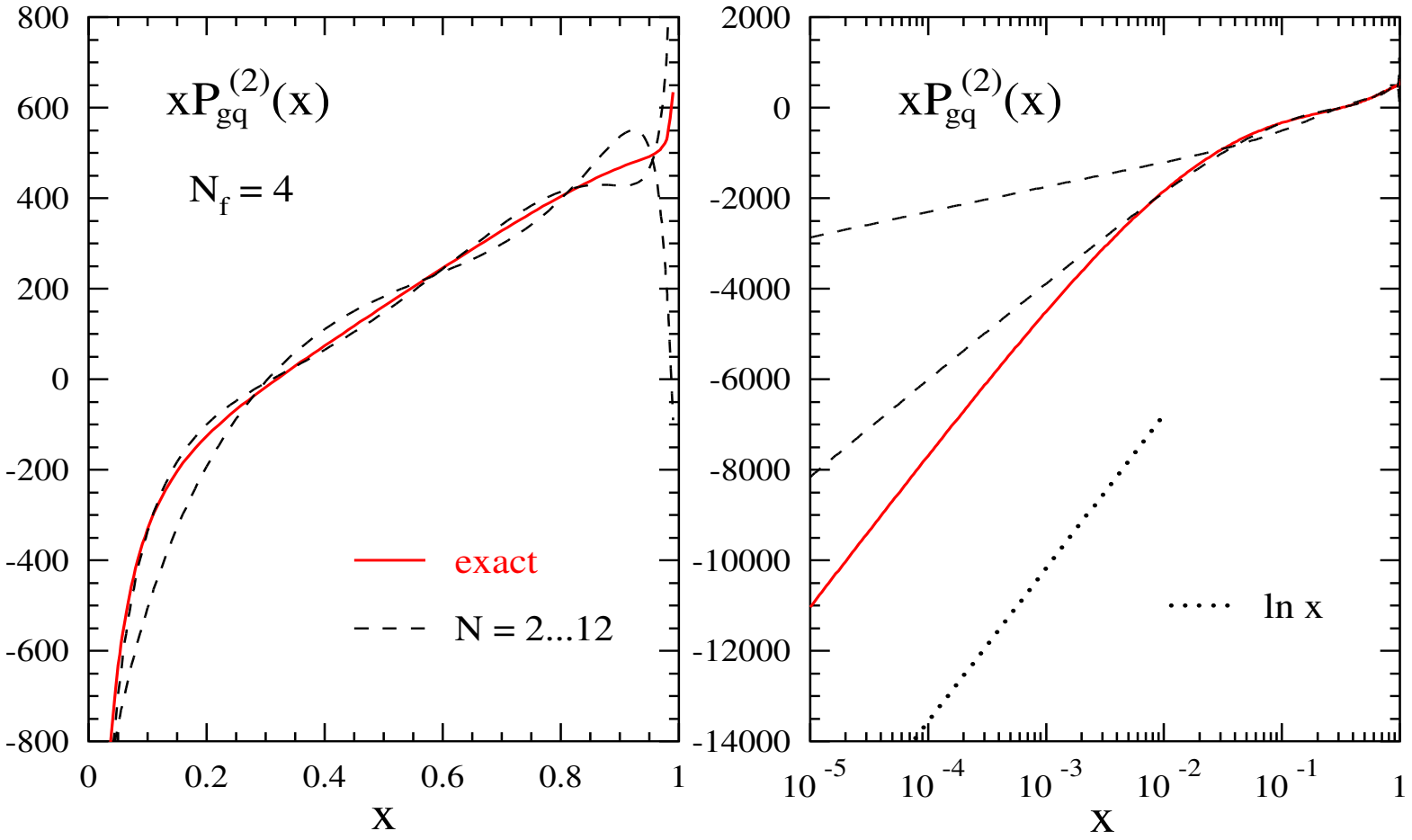


Summary

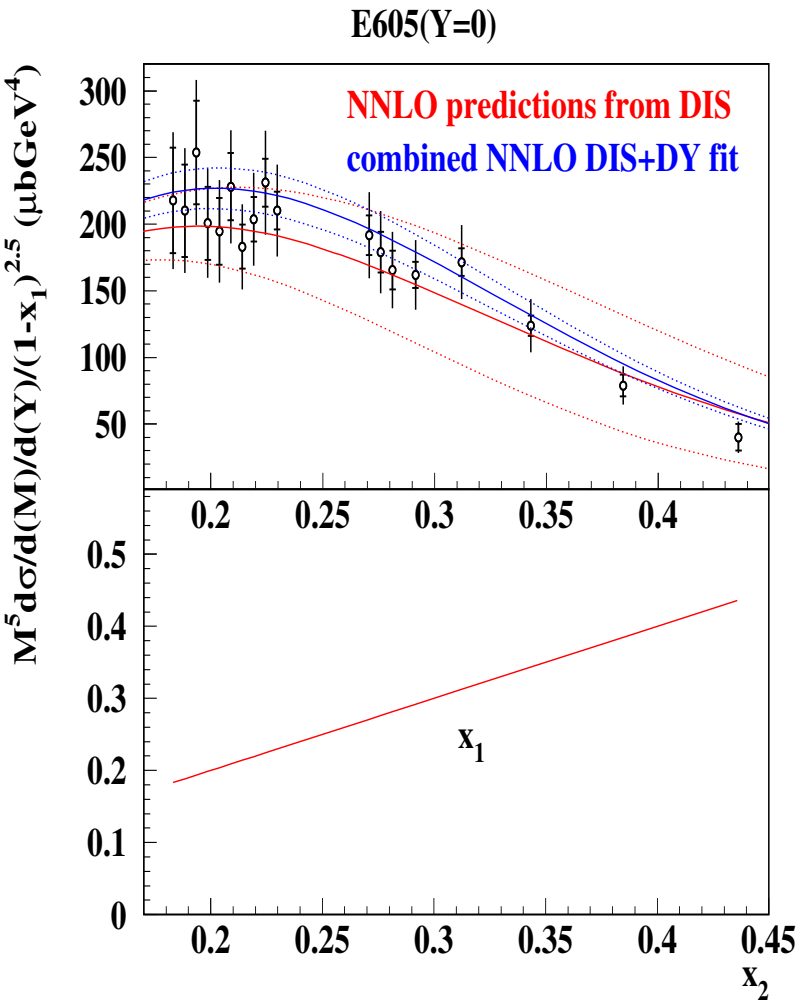
- Recent progress in the HO QCD calculations allows to extract the NNLO PDFs from the DIS and DY data providing a good constraint on the PDFs except the gluon distribution at large x. The total error in sea is suppressed down to 30% at $x < 0.7$ (*big impact on the searches of new physics at the LHC*).
- Account of the $O(\alpha_s^3)$ corrections is important for the PDFs and SFs at low-x/low-Q. Especially interesting is comparison of the data on F_L to the HO pQCD calculation (*check of the pQCD limitations*).
- With the HO QCD corrections satisfactory description of the fixed-target charged-leptons DIS data down to $Q^2 \approx 0.5$ GeV^2 can be obtained (*due to universality of the approach it can be applied for modeling neutrino c.s. at low energies*).

Addendum

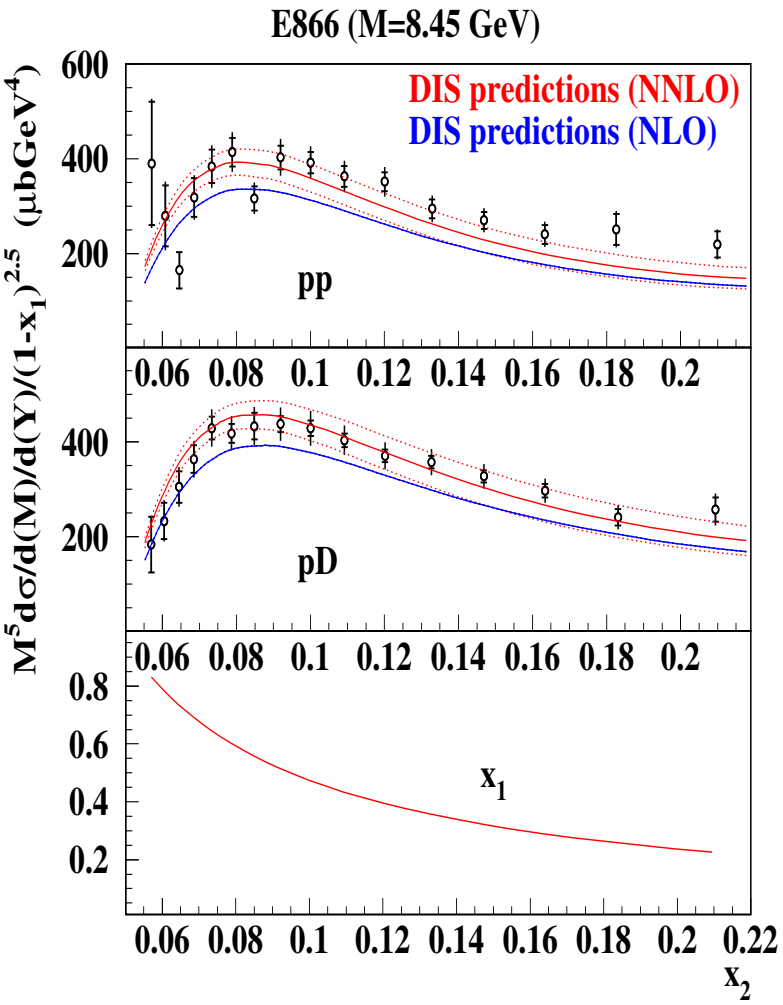
Precise evolution kernels by Moch-Vermaseren-Vogt



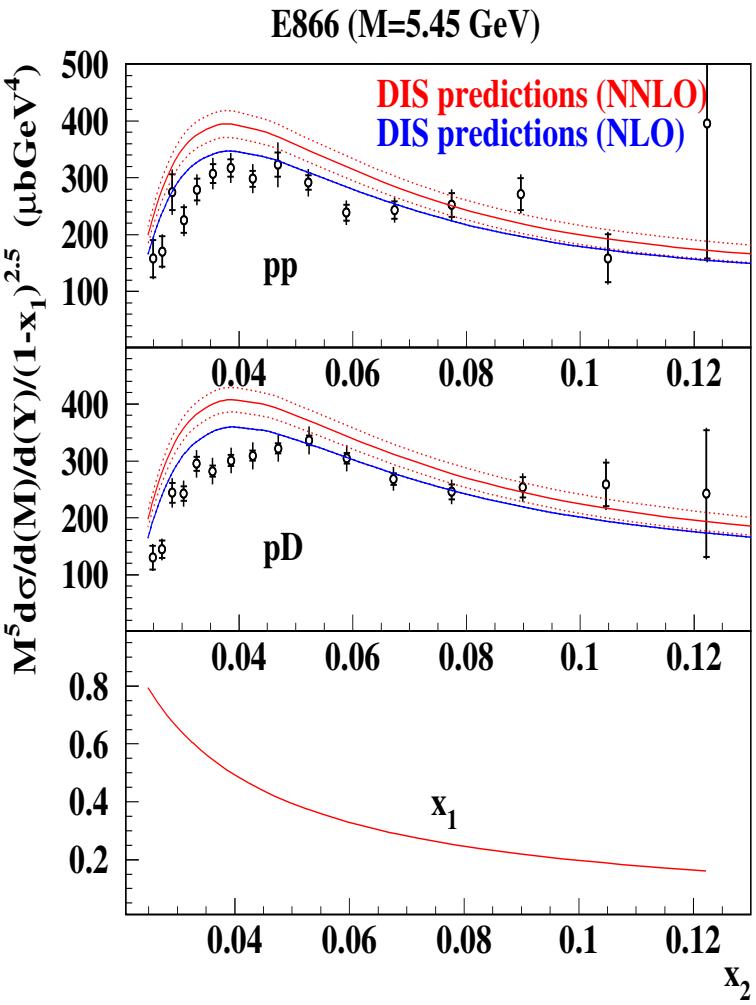
In the worst case the exact expressions are about the uncertainty band estimated for the approximate ones.



The E605 data are in good agreement to the DIS ones within the errors

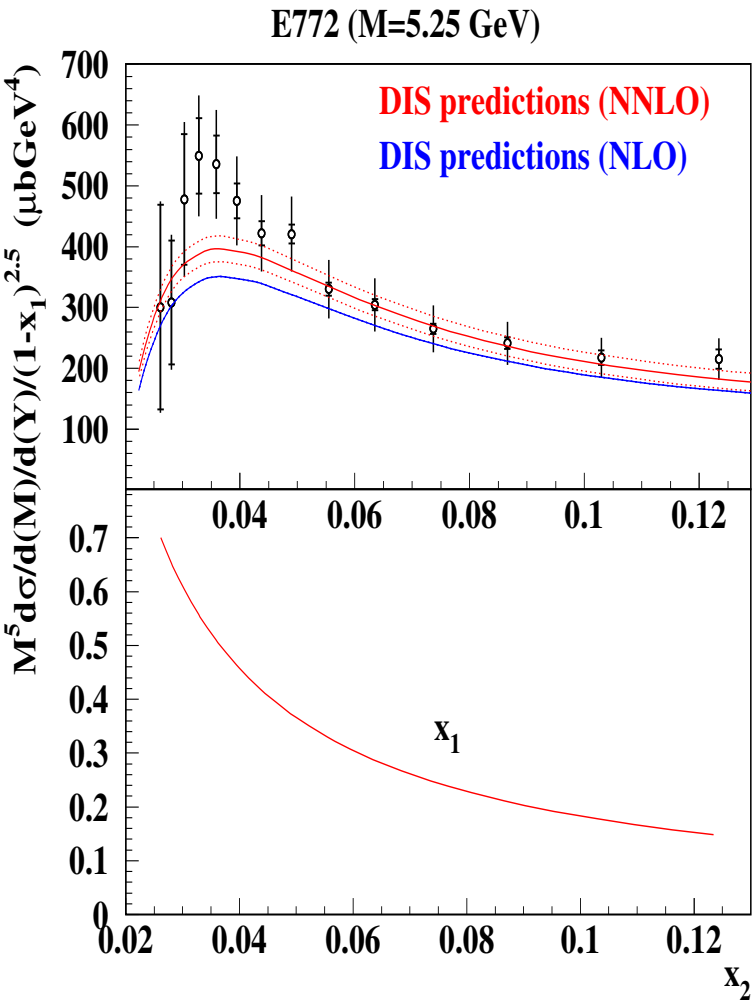


The E866 data are in agreement to the DIS ones in the region of the overlap with the E605 experiment, however...



....the E866 data are in disagreement to the DIS ones at low M, where the latter constraint sea with a good precision.

The NLO predictions are in better agreement with data than the NNLO ones.



The trend of E772 data at low M is different from E866 case, therefore one can expect uncontrolled systematic effects in the Drell-Yan data.

The NNLO rates for the W/Z production