Parton Distributions for LHC

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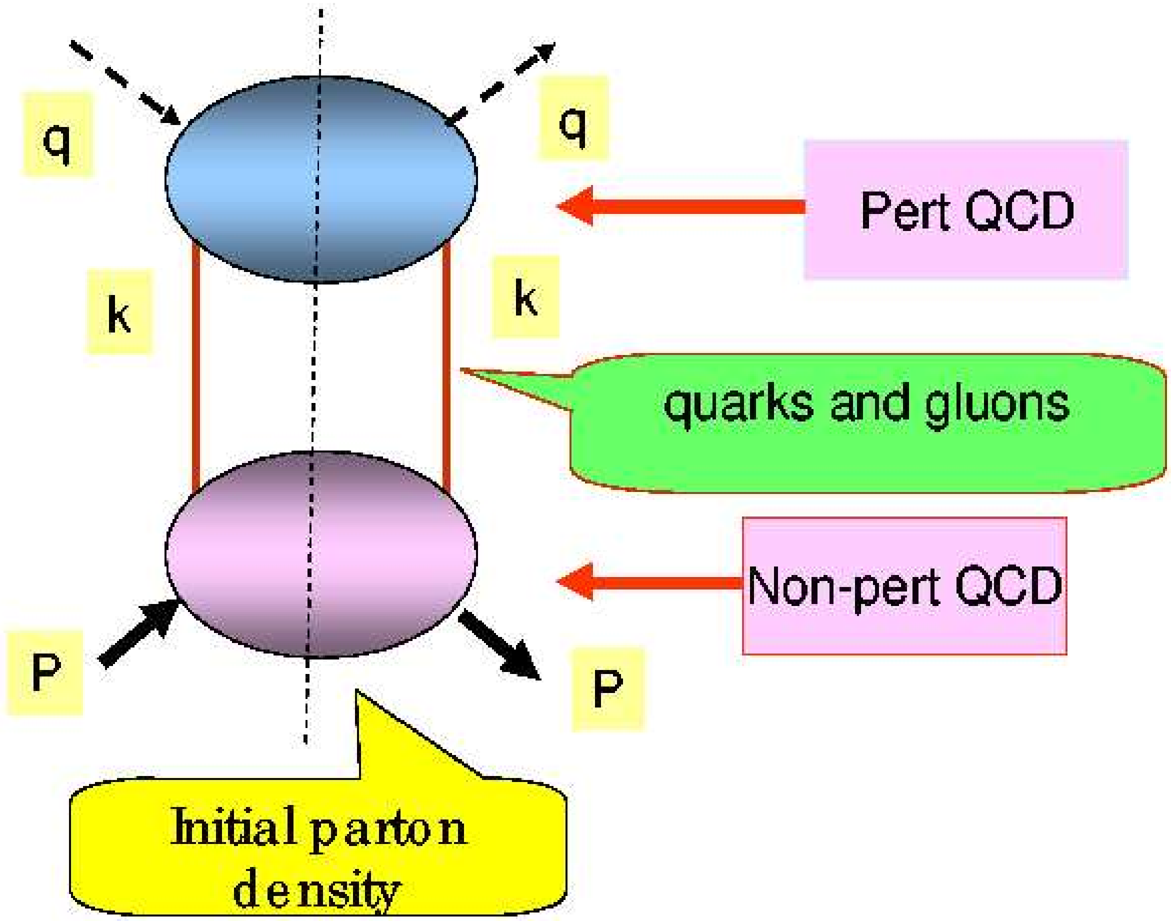
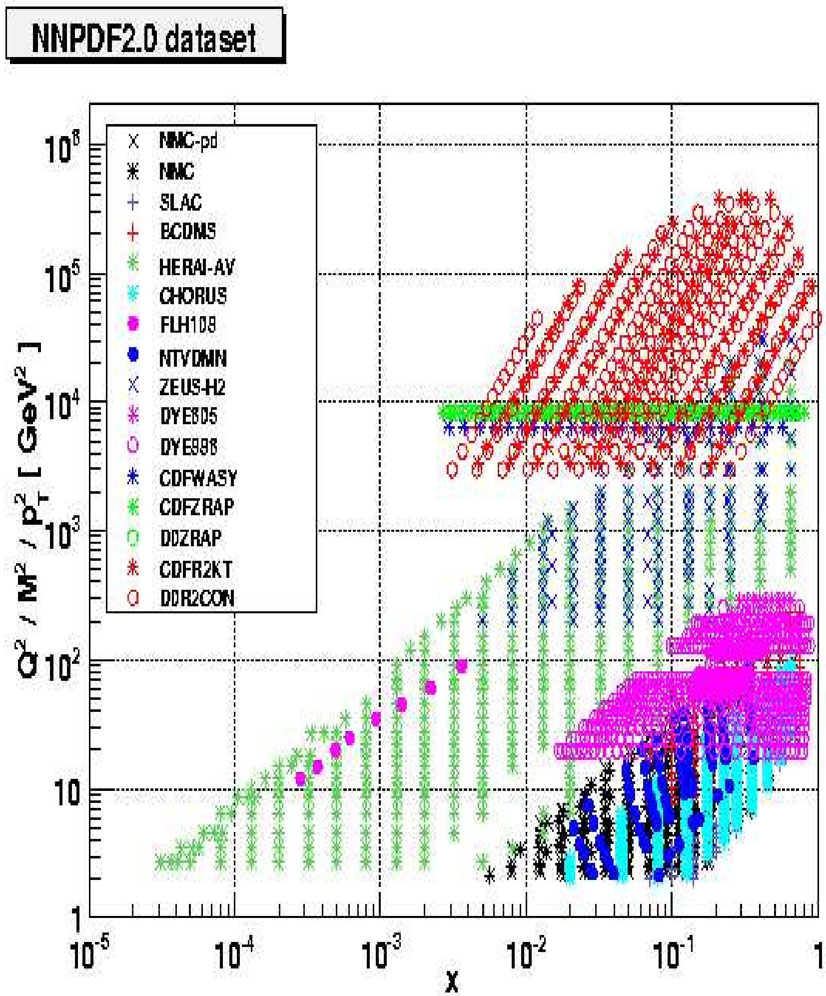
Loops and Legs, Wörlitz, 2010


q
q
Pert QCD
k
k
quarks and gluons
Non-pert QCD
P
P
Initial parton density



- The DIS data constraint sea and gluon at small x and valence quarks at large x.
- The DY data constraint sea at large x.
- The jet data are sensitive to gluons at large x.
- The momentum and fermion number conservation is imposed.
- The fit is sensitive to α_s

Modern PDF sets

- MSTW (DIS+DY+jets, NLO/NNLO, VFNS)

  [arXiV:0901.0002]
- CTEQ (DIS+DY+jets, NLO, VFNS)

  [arXiV:0802.0007]
- NNPDF (DIS+DY+jets, NLO, VFNS)

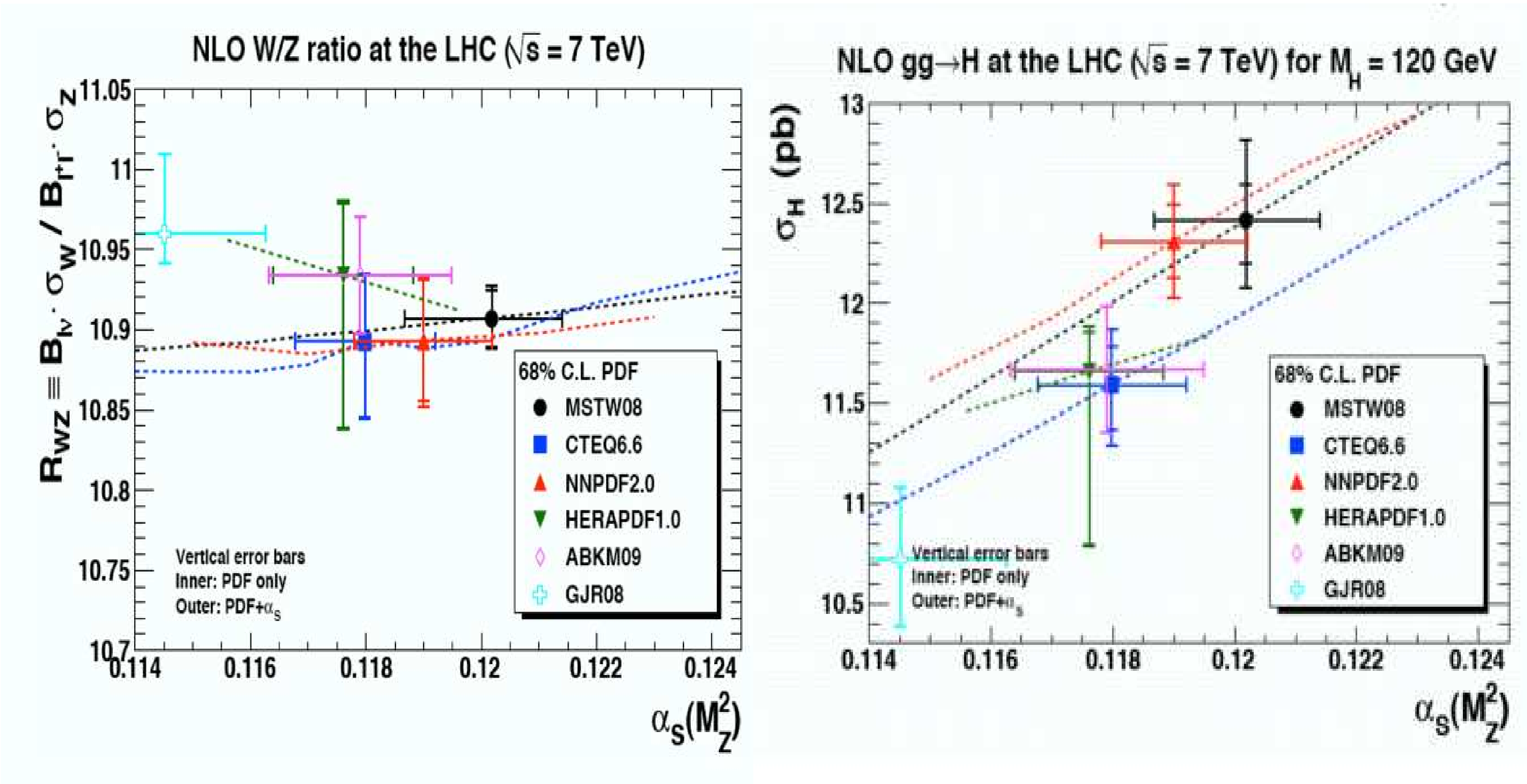
  [arXiV:1002.4407]
- JR (DIS+DY, NLO/NNLO, FFNS)

  [arXiV:0810.4274]
- ABKM (DIS+DY, NLO/NNLO, FFNS)

  [arXiV:0908.2766]
- HERAPDF (DIS, NLO, VFNS)

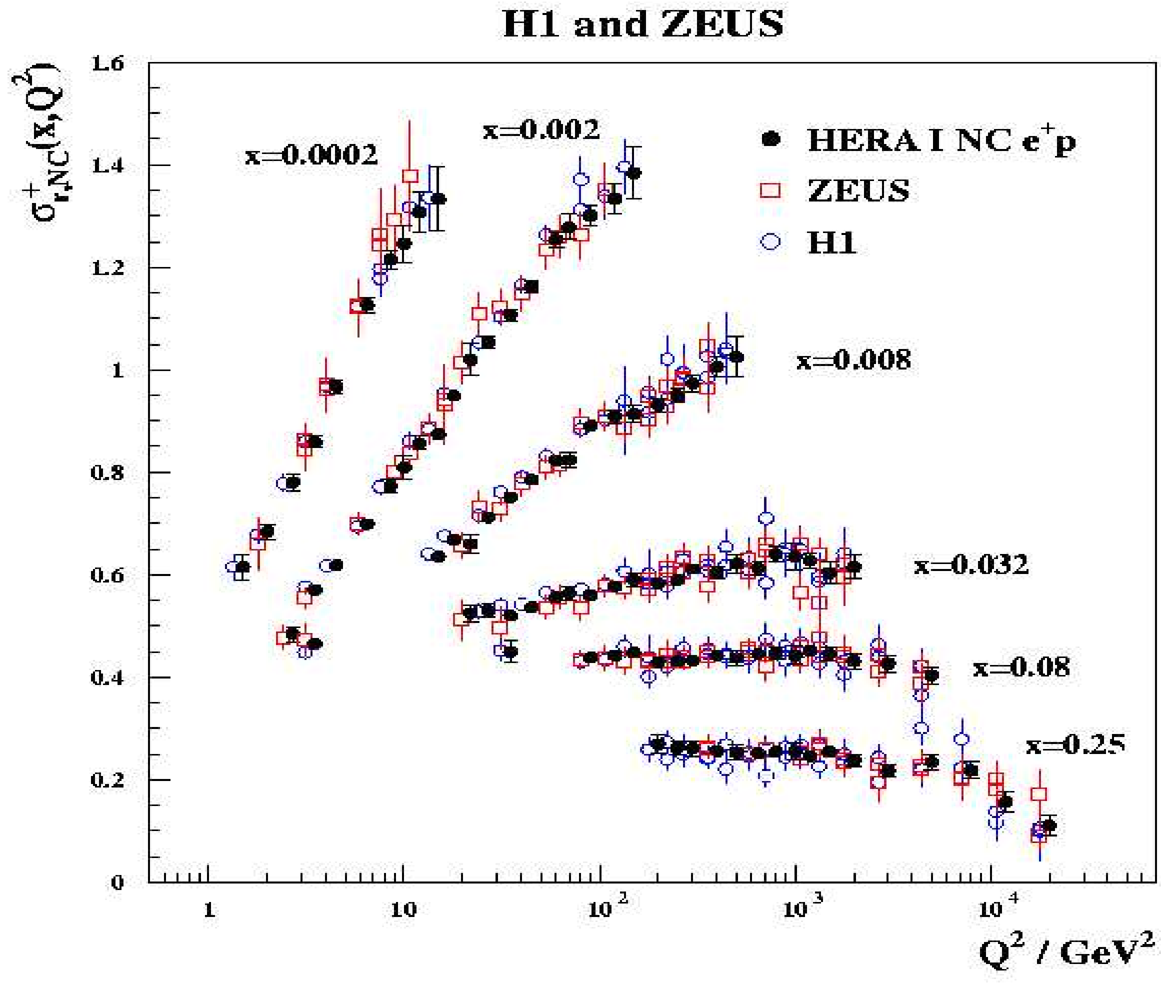
  [arXiV:0911.0884]

LH benchmark

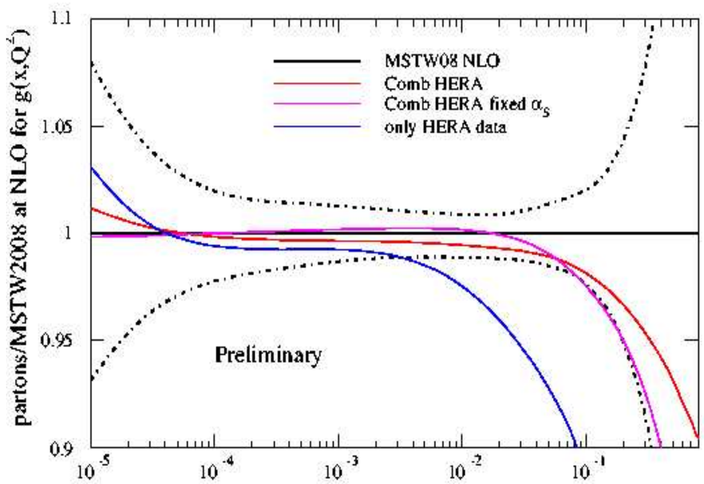


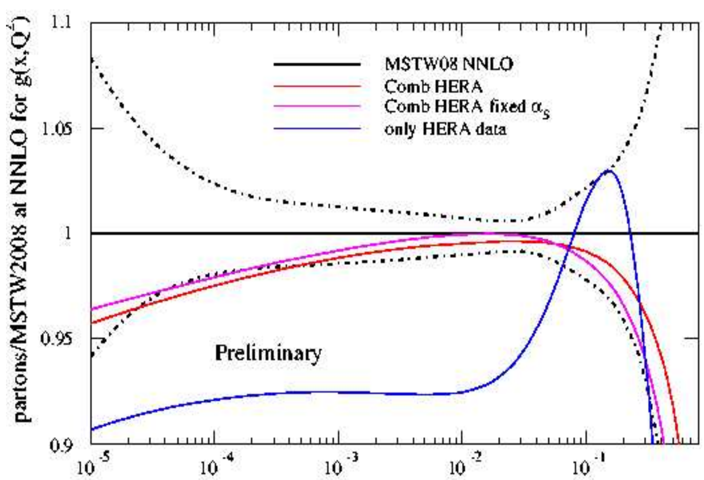
Huston/DIS10

Combined HERA inclusive data



[arXiV:0911.0884]





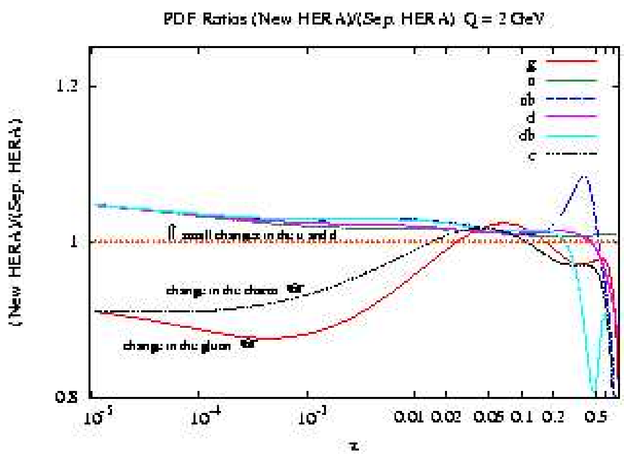
- NLO: Global fit quality: 2610/2471. Significant effect in places, but generally not actually bigger than potential effects from variation of GMVFNS.

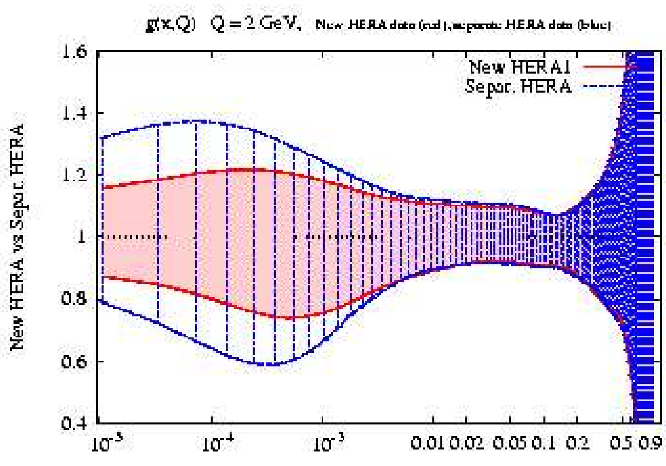
- NNLO: Global fit quality 2505/2387. Significant effect in places. Very little dependence on whether α_s left free.

$$\alpha_s(M_Z) = 0.1215(NLO)$$

$$\alpha_s(M_Z) = 0.1178(NNLO)$$

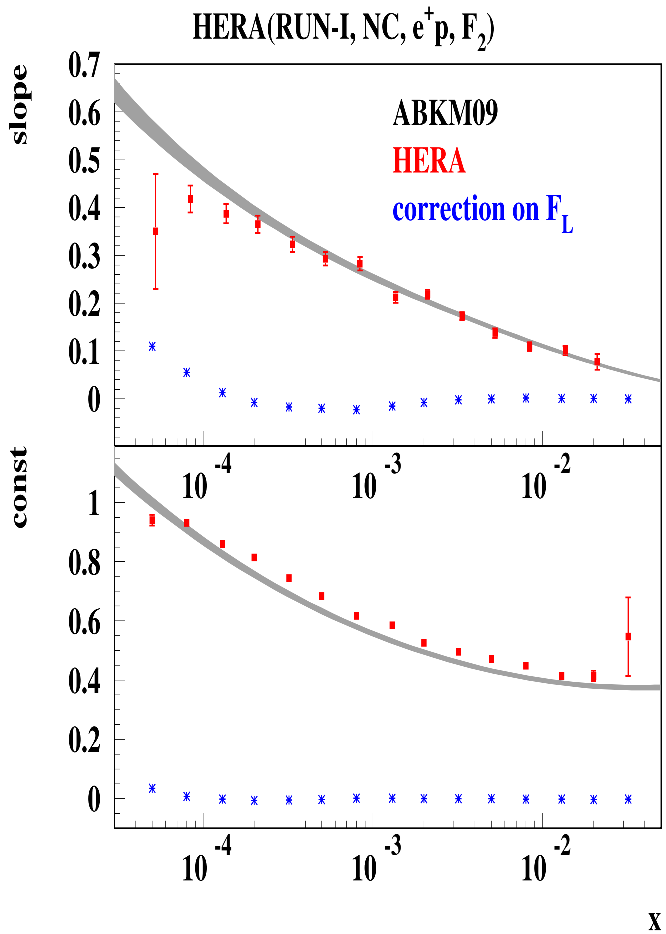
Impact of the HERA combined data CTEQ/DIS10





- For the NLO CTEQ fit the combined HERA data prefer the lower gluon distribution at small x.
- The uncertainty in the gluons at small x is essentially reduced due to inclusion of new data.
- Normalizations are treated as the same footing as the other correlated uncertainties
- The value of α_s is fixed at the world average.

Impact of the HERA combined data   ABKM/DIS10



In general the combined HERA data are above the earlier data sets, however at smallest x the trend is different: The modification of the low-x asymptotic of the singlet distributions is necessary.

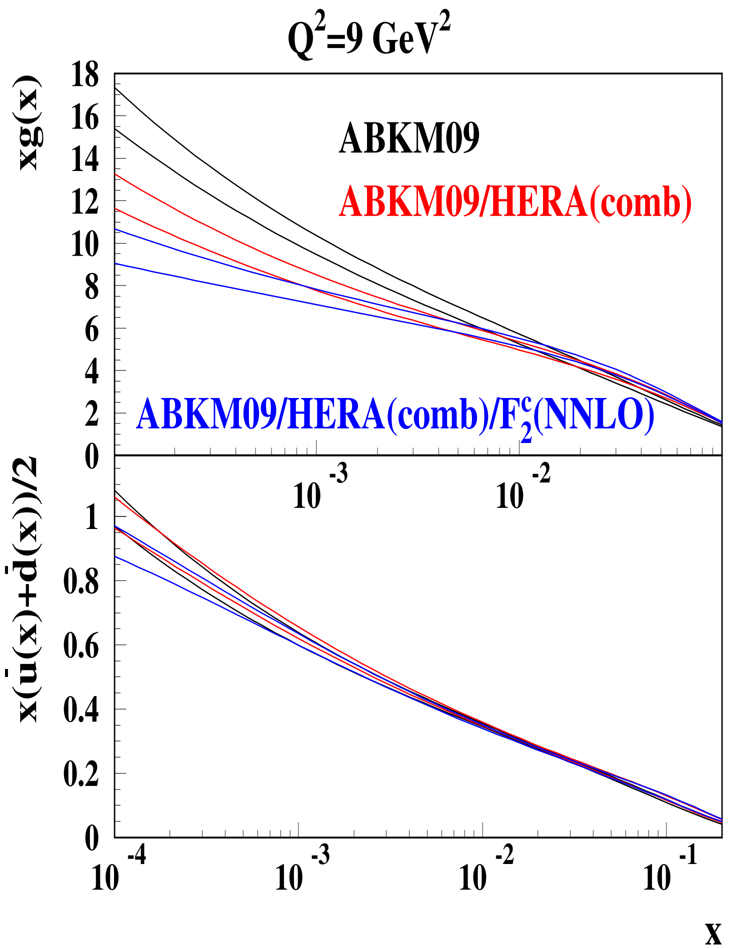
$$q(x) \sim exp\left[a \ln x (1 + \beta \ln x)\right].$$

At $\beta = 0$ it reproduces a conventional shape $q(x) \sim x^a$. The coefficients β allow additional flexibility at small x.

$$\beta^{\rm sea} = 0.035 \pm 0.003$$

Impact of the HERA combined data

ABKM/DIS10

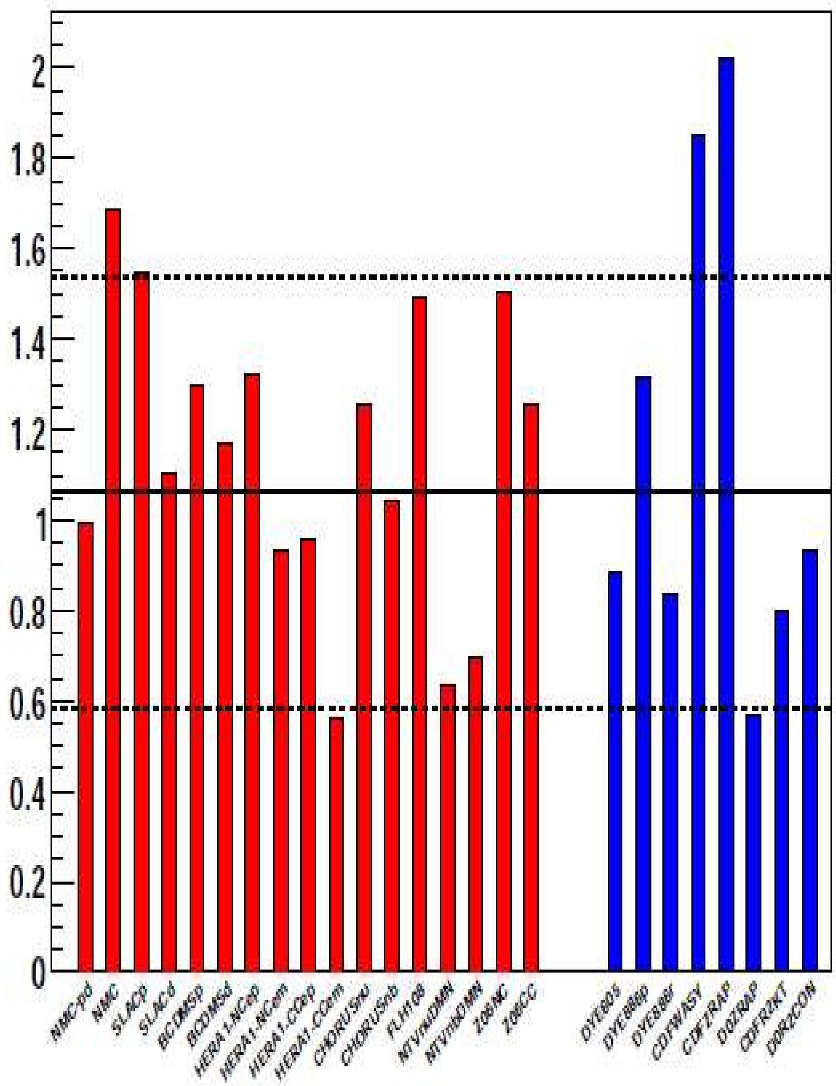


- The gluon distribution at small x goes lower than for the ABKM09 set, however it remains positive down to $\mu^2 \approx 2$ GeV^2.
- The value of $\alpha_s(5, M_Z) = 0.1147(12)$. This is somewhat bigger than the value for the ABKM09 fit $\alpha_s(5, M_Z) = 0.1135(14)$. The difference is within 1σ, however it also signals about some tension.

The NNLO rates for the candle processes

	$W^\pm$ (nb)	Z (nb)	$t\bar{t}$ (pb) (approx.)	H (pb) ($M_H = 150$ GeV)
Tevatron				
ABKM09 (Run-I comb)	26.8 ± 0.3	7.88 ± 0.07	6.72 ± 0.12	0.35 ± 0.02
ABKM09	26.2 ± 0.3	7.73 ± 0.08	6.91 ± 0.17	0.36 ± 0.03
LHC (7 TeV)				
ABKM09 (Run-I comb)	100.9 ± 1.3	29.3 ± 0.4	130.3 ± 5.8	9.4 ± 0.2
ABKM09	98.8 ± 1.5	28.6 ± 0.5	131.3 ± 7.5	8.8 ± 0.3

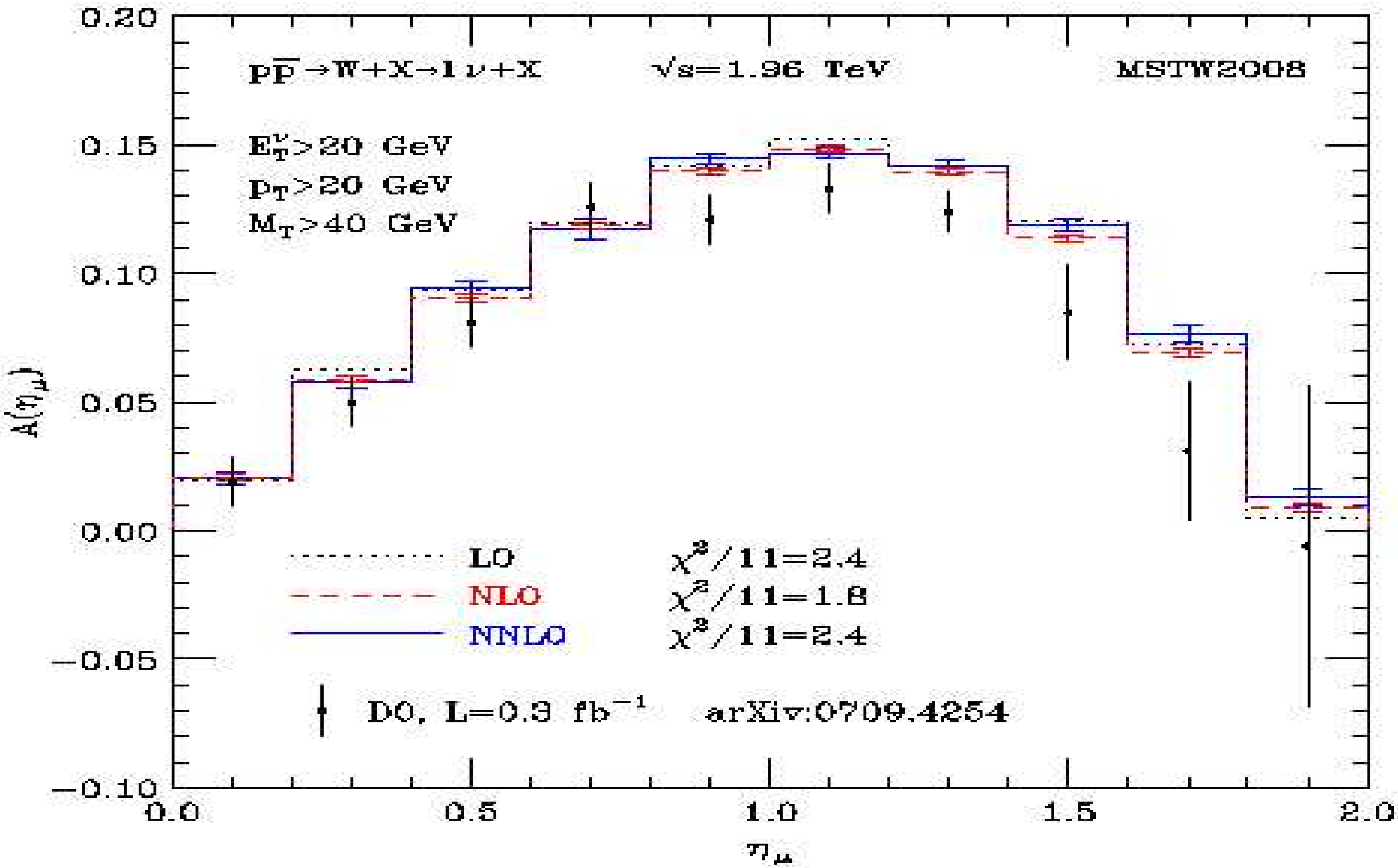
The 5-flavour PDFs generated from the 3-flavour ones are used



NNPDF2.0

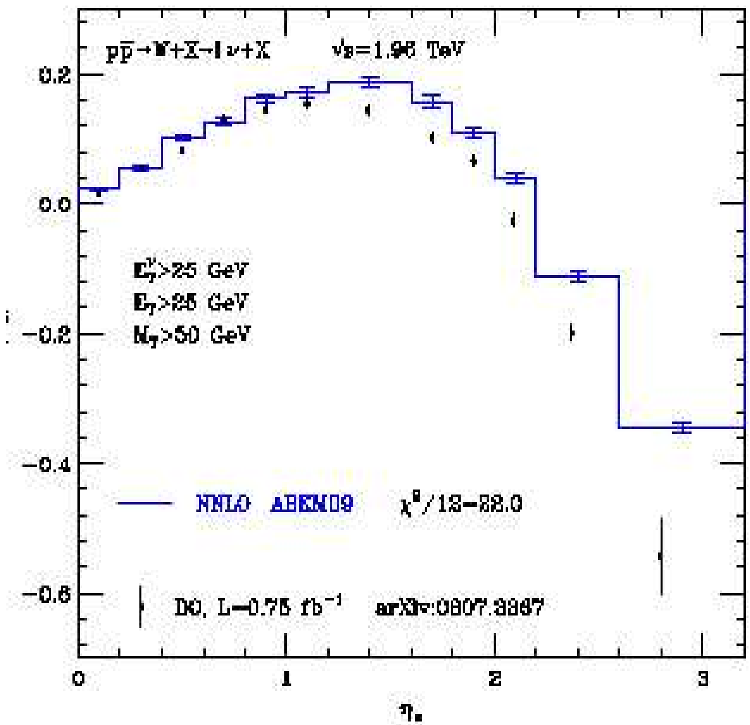
- DIS data combined with the hadronic data (W/Z and inclusive jet production).
- NLO computation of hadronic observables too slow for parton global fits. K-factor depends on PDFs and it is not always a good approximation. Built up FastKernel code for computation of DY observables.
- No obvious tension between hadronic and DIS data, the worst case

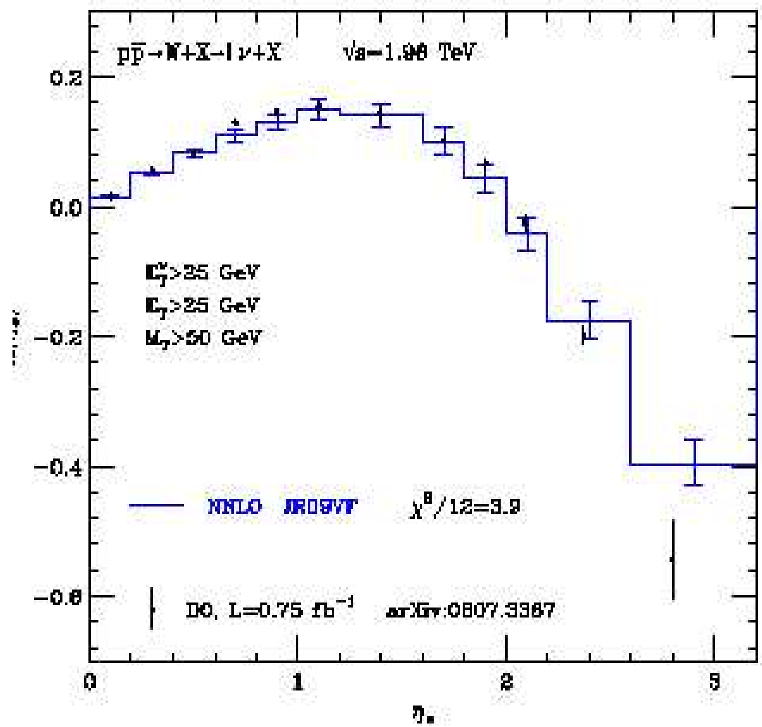
Charge lepton asymmetry Catani-Ferrera-Grazzini



The NNLO predictions overshoot the data on charge lepton asymmetry

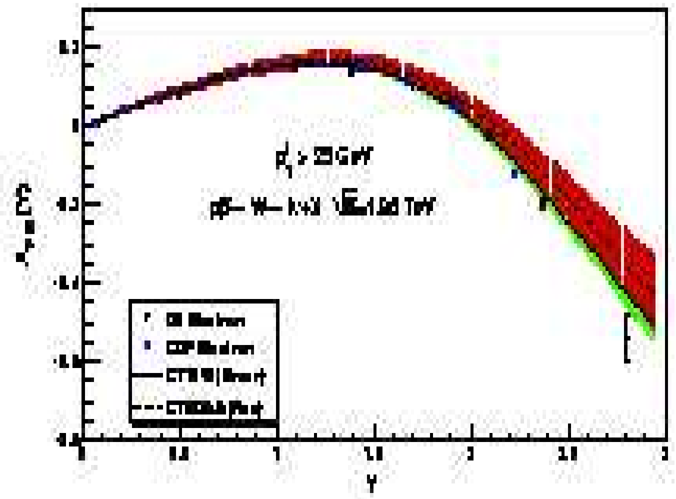
Charge lepton asymmetry   Catani-Ferrera-Grazzini

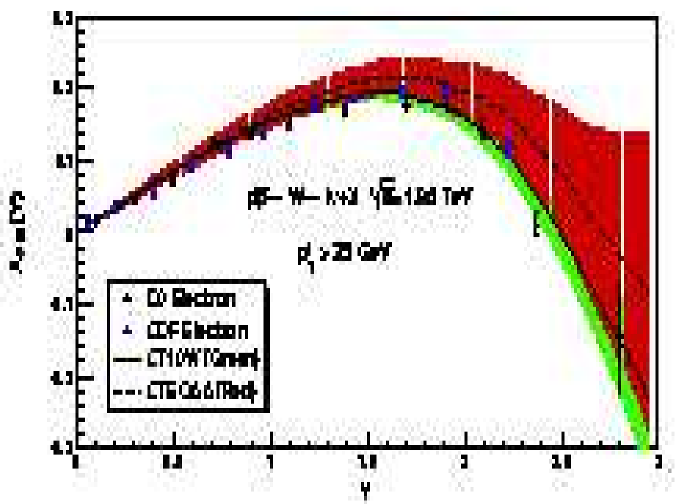




Charge lepton asymmetry

CTEQ/DIS10





- Good fits to electron (e) asymmetry data are possible without NMC and BCDMS; and vice versa. No acceptable fit to D0 II electron asymmetry and NMC/BCDMS data can be achieved. Tension between Run-2 electron asymmetry and D0 Run-2 muon asymmetry.
- Two variants of the fit, CT10 and CT10W, with(out) Tevatron Run-2 data. CT10W agrees better with the W asymmetry data; has smaller uncertainty than CT10.

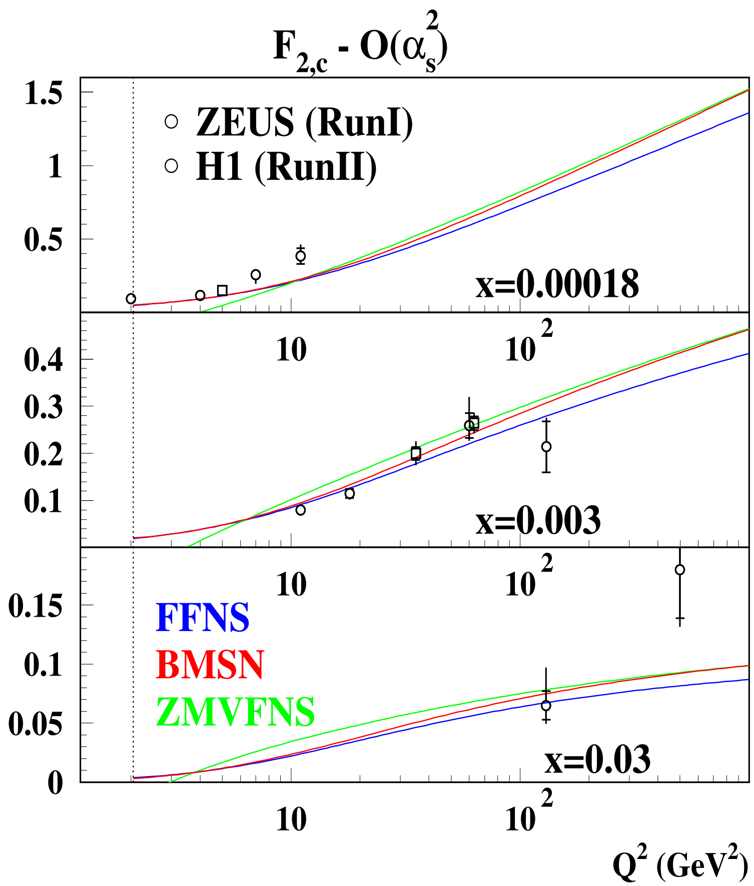
Heavy-quark electroproduction

The heavy-quark electroproduction contributes up to 30% to the inclusive structure functions measured at HERA.

- FFNS (conceptually simple, technically involved ($m_h \neq 0$), fixed order)
- VFNS (technically simple ($m_h = 0$), re-sums large logs, conceptually difficult)

At $Q \sim m_h$ ZMVFNS is clearly irrelevant since the whole concept of heavy-quark PDFs is irrelevant due to the power corrections in $F_{2,c}^{\mathrm{FFNS}}$ spoil the collinear factorization.

A complete definition of the VFNS should include a matching between $F_{2,c}^{\mathrm{FFNS}}$ at small Q^2 and $F_{2,c}^{\mathrm{ZMVFNS}}$ at large Q^2. This matching cannot be derived from the first principles and must be modeled, with a natural requirement of the smooth transition between the large- and small-Q^2 regions.



- With account of the $O(\alpha_s^2)$ corrections (Laenen-Riemersma-Smith) the difference between the FFN and VFN schemes is not too big.
- The smooth VFNS prescription (Buza-Matiounine-Smith-van Neerven) goes very close to FFN for the realistic kinematics.
- With account of the $O(\alpha_s^3)$ corrections (cf. talk by Klein) this difference would be even smaller.

$$F_{2,c}^{\mathrm{BMSN}} = F_{2,c}^{\mathrm{FFNS}}(N_f = 3) + F_{2,c}^{\mathrm{ZMVFNS}}(N_f = 4) - F_{2,c}^{\mathrm{ASYMP}}(N_f = 3)$$

6 extreme variations tried, along with ZM-VFNS

GMVFNS1 – $b = -1, c = 1$.

GMVFNS2 – $b = -1, c = 0.5$.

GMVFNS3 – $a = 1$.

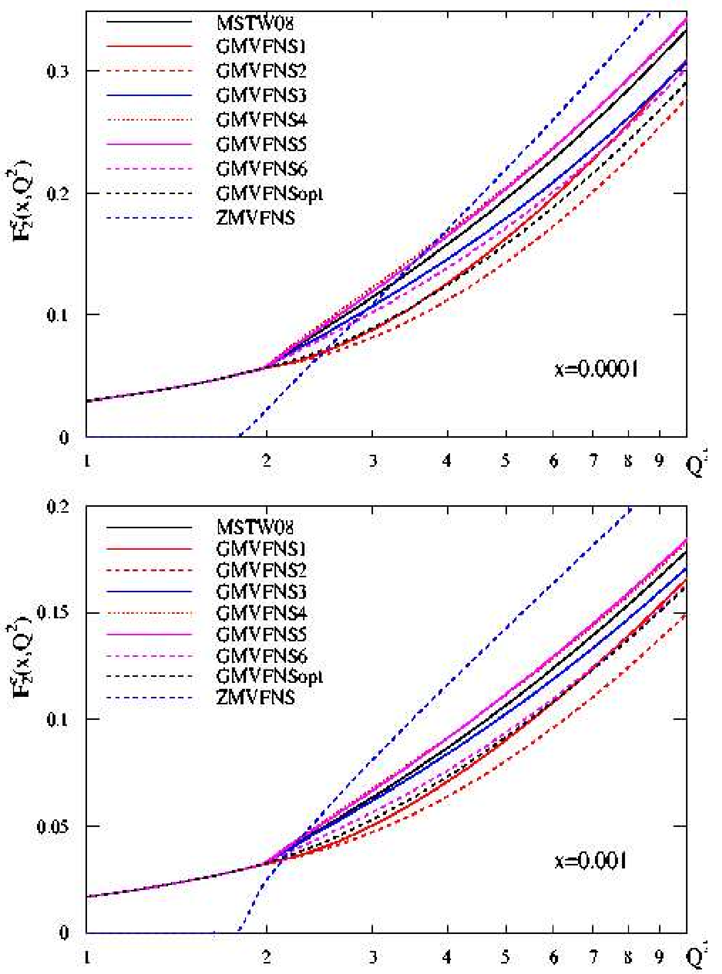
GMVFNS4 – $b = +0.3, c = 1$ – fit.

GMVFNS5 – $d = 0.1$ – fit.

GMVFNS6 – $d = -0.2$ – fit.

Variations in $F_2^c(x,Q^2)$ near the transition point at NLO due to different choices of GM-VFNS.

Optimal, $a = 1, b = -2/3, c = 1$, smooth behaviour.



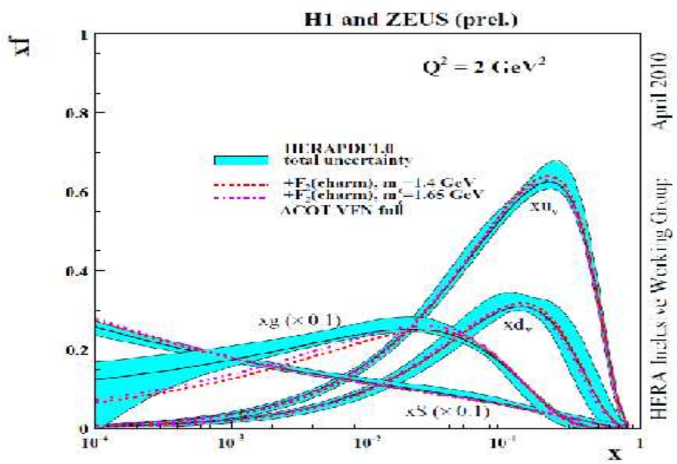
Heavy-quark electroproduction HERAPDF/DIS10

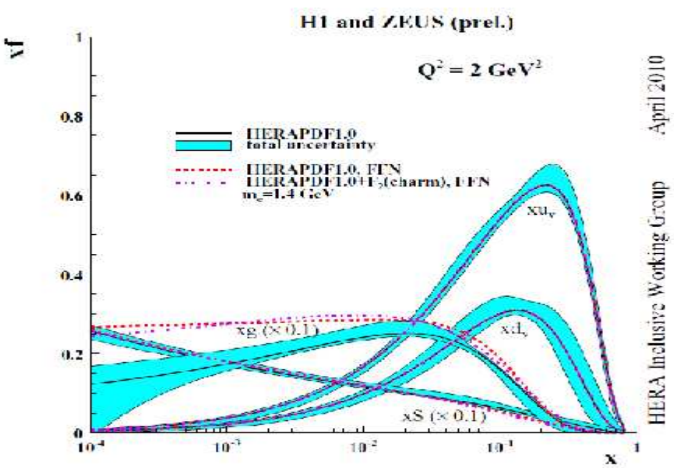
scheme	RT Std m_c=1.4	RT Std m_c=1.65	RT Opt m_c=1.4	RT Opt m_c=1.65	ACOT m_c=1.4	ACOT m_c=1.65	#points
□2	730.7	627.5	644.6	695.4	653.9	605.7	633
$F_2^{(charm)}$ Sub □2	134.5	43.5	64.8	100.1	89.5	41.4	41

scheme	FFN m_c=1.4	FFN m_c=1.65	#points	FFN m_c=1.4 no F_2^c	#points
□2	**567.0**	**852.0**	565	512.9	524
$F_2^{(charm)}$	51.7	248.9	41		0

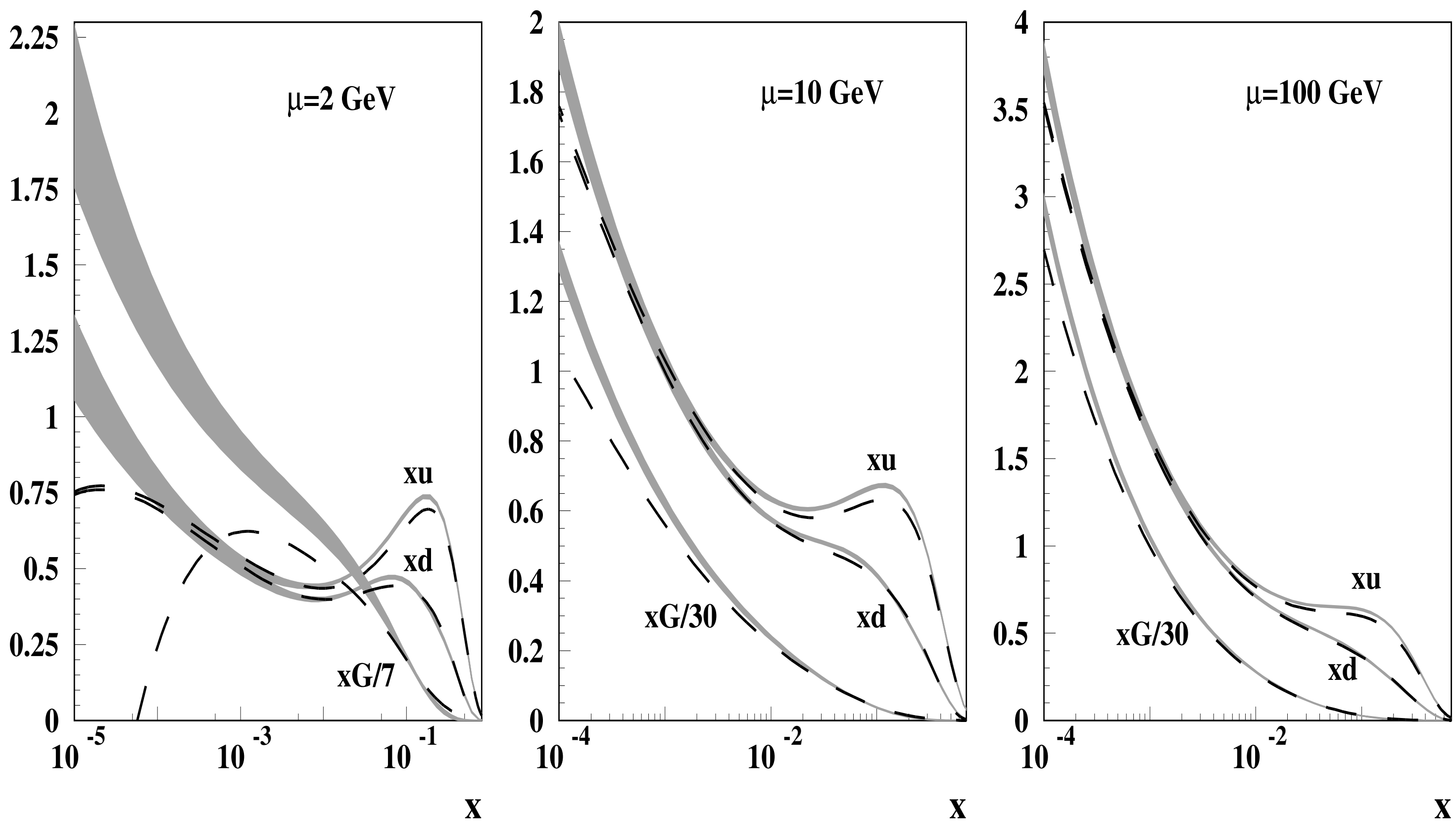
The best values of χ^2 are comparable for the ACOT, RT(Standard), RT(Optimized), and FFN schemes, provided the value of m_c is adjusted too.

Heavy-quark electroproduction HERAPDF/DIS10



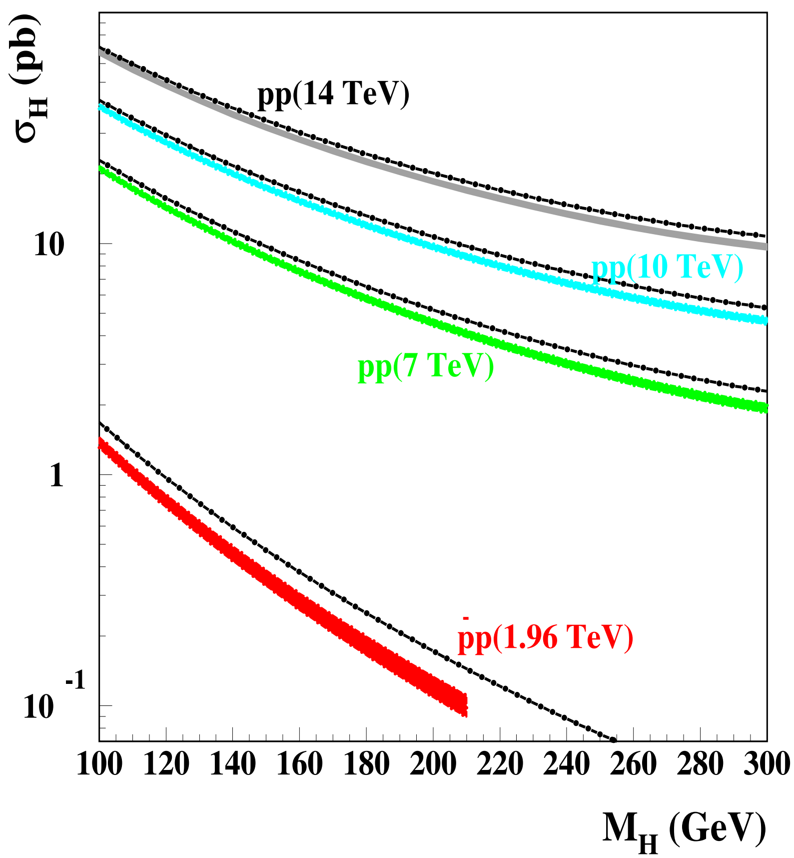


- ACOT gluon shape is suppressed compared to the Standard RT VFN scheme used for HERAPDF1.0
- The FFN gluon shape is VERY different from that of the Standard RT VFN scheme used for HERAPDF1.0.



At small x the NNLO ABKM09 gluons are also go above the MSTW08 ones.

The NNLO Higgs production rates



- The NNLO rate predictions based on the ABKM09 and MSTW09 PDFs are significantly different for the Tevatron case (the same for the $t\bar{t}$ production at LHC, cf. talk by Beneke)
- Taking this difference as an uncertainty, some 40%, one has to release the constraint on the Higgs mass obtained on Tevatron (Baglio-Djouadi)

We have a lot of to do....