MSTW Updates

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DIS10 - Firenze

Effect of combined HERA data.

Very preliminary – have included combined neutral current data from HERA, with errors added in quadrature for the moment (correlated errors now very small and effect of this previously shown to be small).

Also still including separate H1/ZEUS e^+ charged current data. Combination should be similar since statistics dominate. Normalisations related to NC data correctly. Published e^- NC carry extremely little weight.

Fit to data for $Q^2 \geq 2\mathrm{GeV}^2$ but look also at numbers for $Q^2 \geq 3.5\mathrm{GeV}^2$ to compare to HERA fit results.

Fits at NLO

Simply replace old HERA NC data with combined data.

Global fit quality $\sim 2610/2471$. To HERA NC data $\sim 600/553$ ($Q^2 > 2\mathrm{GeV}^2$) and $\sim 530/524$ ($Q^2 > 3.5\mathrm{GeV}^2$). Latter number compared to $483/524$ (A.M. Cooper-Sarkar) for same treatment of errors. Other data in fit stops equivalently good comparison.

$\alpha_S(M_Z^2) = 0.1215$ – $1 - \sigma$ effect. Quarks generally bigger, sometimes outside $1 - \sigma$ band. Gluon not changed much except some decrease at large x.

Also fit fixing $\alpha_S(M_Z^2) = 0.1202$, i.e. MSTW2008 NLO value. Both global and HERA NC data fit ~ 10 higher. PDF change similar.

Fit only HERA NC and CC cross-section data. 25 free parameters, including α_S. Same as in global fit but strange sector fixed. Now get $\sim 515/553$ ($Q^2 > 2\mathrm{GeV}^2$) and $\sim 445/524$ ($Q^2 > 3.5\mathrm{GeV}^2$). Much better than HERA fit.

$\alpha_S(M_Z^2) = 0.123$, high-x gluon much reduced, quark flavours change dramatically. Comparison to Tevatron jet data – $\chi^2 \sim 1.5$ per point, poor, but not terrible. Comparison to data relying on flavour and quark-antiquark details extremely poor.

Fits at NNLO

Standard fit – global fit quality $\sim 2505/2387$. To HERA NC data $\sim 585/553$ ($Q^2 > 2\text{GeV}^2$) and $\sim 535/524$ ($Q^2 > 3.5\text{GeV}^2$). ~ 15 better than NLO for full data but similar for $Q^2 > 3.5\text{GeV}^2$.

$\alpha_S(M_Z^2) = 0.1178$ – much less than $1-\sigma$ effect. Quarks generally bigger, sometimes outside $1-\sigma$ band, until very low x, then smaller. Gluon not changed much except some decrease at large x, and at lowest x.

Also fit fixing $\alpha_S(M_Z^2) = 0.1171$, i.e. MSTW2008 NNLO value. Both global and HERA NC data fit only $\sim 2-3$ higher. PDF change tiny.

Fit only HERA NC and CC cross-section data. Obtain $\sim 495/553$ ($Q^2 > 2\text{GeV}^2$) and $\sim 465/524$ ($Q^2 > 3.5\text{GeV}^2$). Better than NLO for former, but worse for latter.

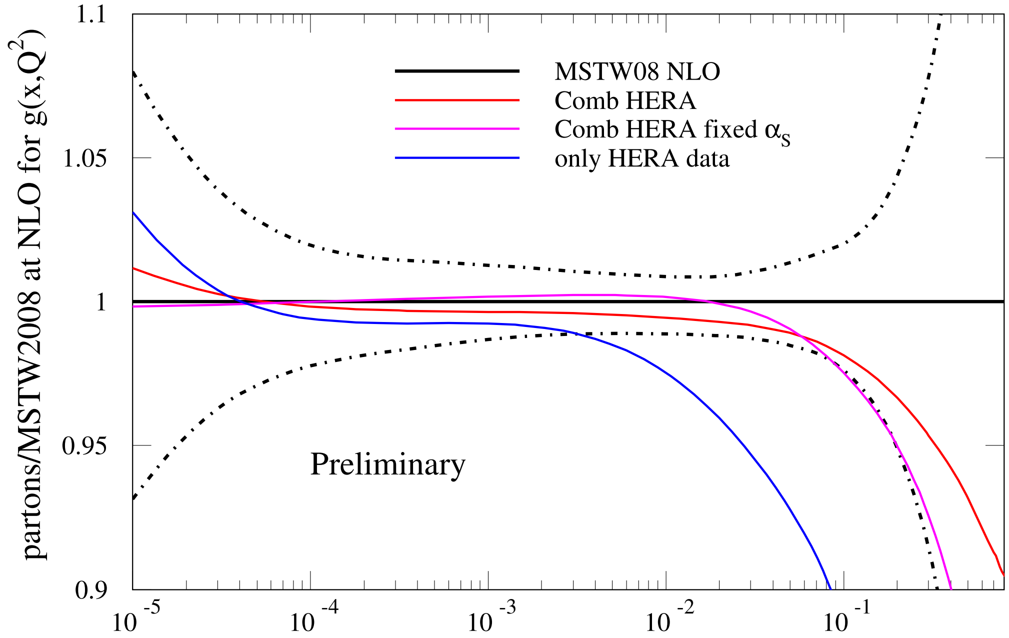
$\alpha_S(M_Z^2) = 0.127$. Gluon generally reduced, quark flavours change dramatically. Comparison to all non HERA data extremely poor.

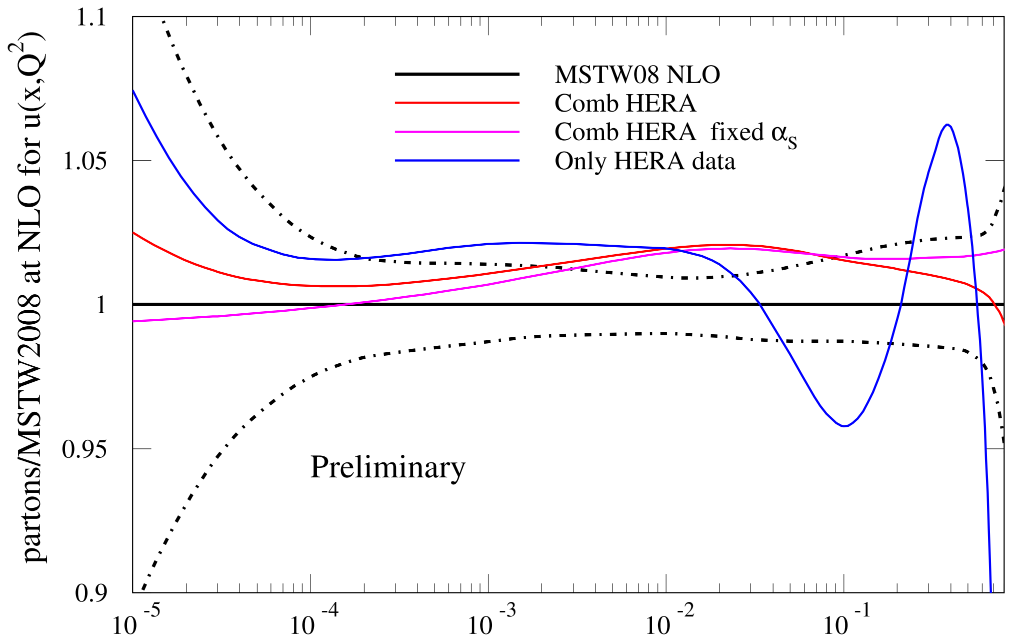
Comparison of gluon and up quark from fits using combined HERA data to MSTW2008 NLO versions with $1-\sigma$, uncertainty shown.

Significant effect in places, but generally not actually bigger than potential effects from variation of GMVFNS - see this afternoon (except for fit to HERA data only).

Most dramatic for quark at about $x = 0.01$, also noticed by NNPDF (Forte).

Only very rough indications of effect on uncertainty. Dynamical tolerance procedure yet to be applied.

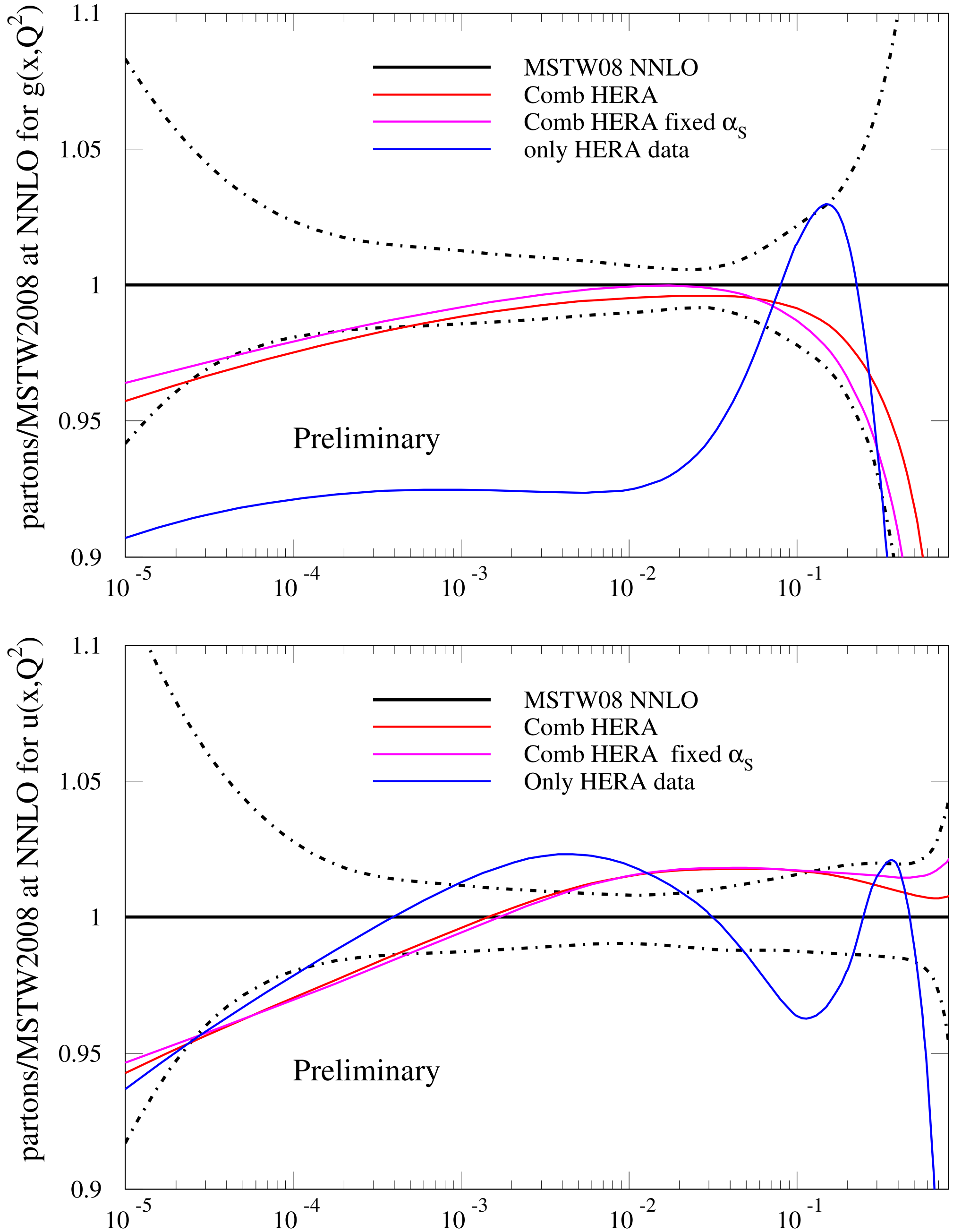




Comparison of gluon and up quark from fits using combined HERA data to MSTW2008 NNLO versions with $1 - \sigma$, uncertainty shown.

Significant effect in places. Very little dependence on whether α_S left free.

Most dramatic for quark at about $x = 0.01$, and PDFs at about $x \sim 0.0001$.



Impact on Cross Sections - NLO.

The values of the predicted cross-sections at NLO for Z and a 120 GeV Higgs boson at the Tevatron and the LHC (latter for 14 TeV centre of mass energy).

PDF set	$B_{l^+l^-} \cdot \sigma_Z$(nb)TeV	σ_H(pb)TeV	$B_{l^+l^-} \cdot \sigma_Z$(nb)LHC	σ_H(pb)LHC
MSTW08	0.2426	0.7462	2.001	40.69
Comb HERA	0.250	0.741	2.05	41.2
fixed $\alpha_S(M_Z^2)$	0.250	0.717	2.04	40.4
only HERA	0.280	0.632	2.21	39.7

For new global fits $2-3\%$ effect on Z (and W) cross sections. Marginally bigger at Tevatron. Similar to $1-\sigma$ uncertainty (including $\alpha_S(M_Z^2)$ variations).

Maximum of little more than 1% for Higgs. Small compared to uncertainties.

HERA-only fit much higher for Z and lower for Higgs though decreasing effect in latter case as sampled x becomes smaller.

Impact on Cross Sections - NNLO.

The values of the predicted cross-sections at NNLO for Z and a 120 GeV Higgs boson at the Tevatron and the LHC (latter for 14 TeV centre of mass energy).

PDF set	$B_{l^+l^-} \cdot \sigma_Z$(nb)TeV	σ_H(pb)TeV	$B_{l^+l^-} \cdot \sigma_Z$(nb)LHC	σ_H(pb)LHC
MSTW08	0.2507	0.9549	2.051	50.51
Comb HERA	0.258	0.954	2.07	50.7
fixed $\alpha_S(M_Z^2)$	0.258	0.931	2.06	50.0
only HERA	0.280	1.12	2.24	55.5

For new global fits $2-3\%$ effect on Z (and W) cross sections at Tevatron, but small change at LHC. Similar to $1-\sigma$ uncertainty in former case.

Maximum of 1% for Higgs, less when α_S changes. Small effect.

HERA-only fit much higher for Z and for Higgs due to very large coupling.

Effect of new Tevatron lepton/W asymmetry.

In MSTW08 fit include D0 muon asymmetry data from 0.3fb^{-1} and $p_T > 20\text{GeV}$ and CDF electron asymmetry from 170pb^{-1} in bins of $25 < p_T < 35\text{GeV}$ and $35 < p_T < 45\text{GeV}$

Use the FEWZ code (Melnikov and Petriello) for NLO QCD with the width of the W taken into account. Have checked fully that this gives very similar results to use of MCFM and even RESBOS.

Is main constraint in one direction on 3 eigenvectors at NLO (5 at NNLO). Mainly constrains d quark distribution since u well known from DIS.

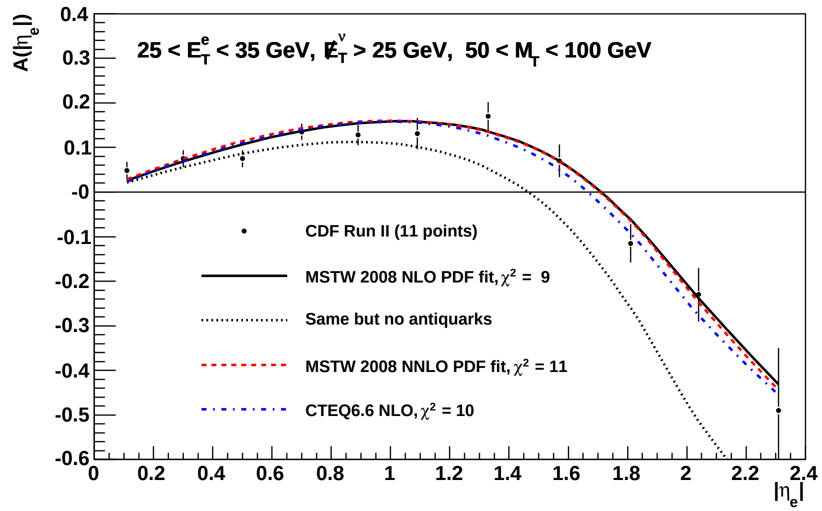
Main d constraint from deuterium DIS subject to uncertainty from nuclear corrections. Currently the uncertainties due to these corrections not accounted for.

In both cases fit is not very good, particularly for D0. At NLO $\chi^2 = 25/10$ for D0 data and $\chi^2 = 29/22$ for CDF data.

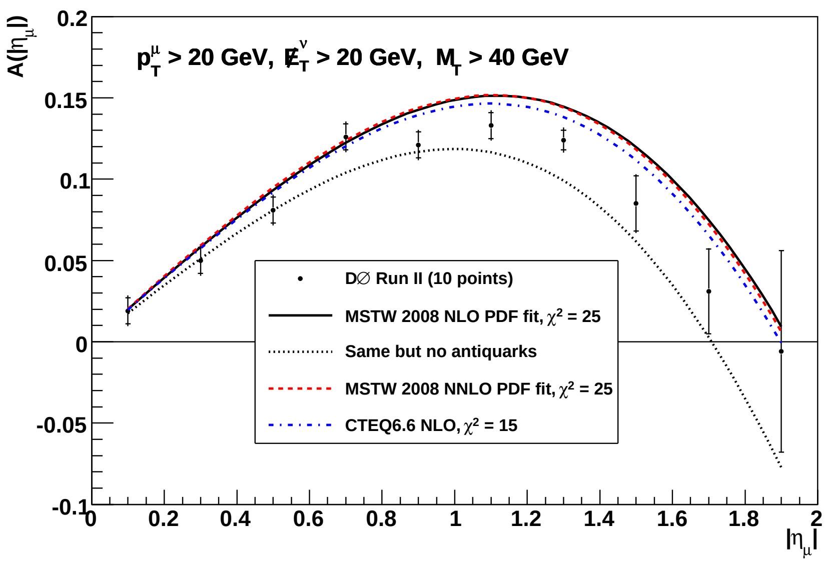
Left out D0 data on electron asymmetry in two p_t bins with 0.75fb^{-1} since fit $163/24$ in p_T bins or $116/12$ for $p_T > 25\text{GeV}$ combined data.

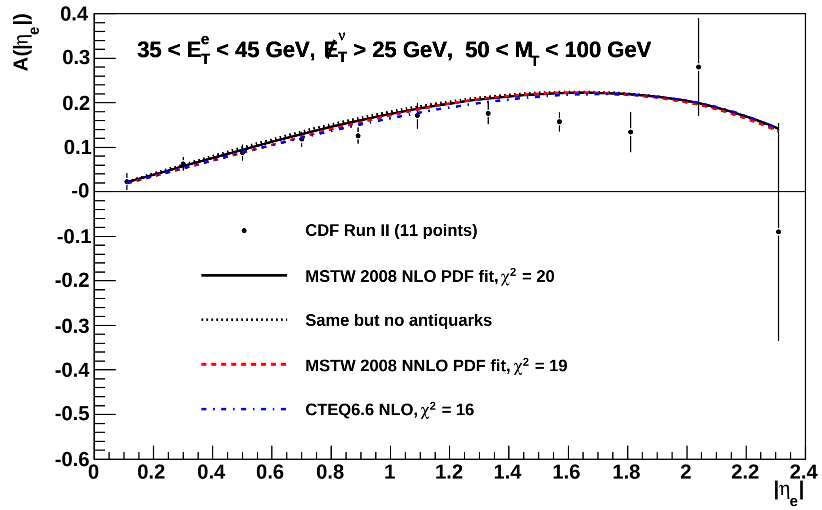
Comparison to prelim CDF W-asymmetry data about $28/13$ (depending on details), i.e. ok but needs tuning.

CDF data on lepton charge asymmetry from $W \to e\nu$ decays



D∅ data on lepton charge asymmetry from $W \to \mu\nu$ decays





Standard fits give very poor comparison to both D0 electron data from 0.75fb^{-1} and D0 muon data from 4.9fb^{-1}.

Try a wide variety of alternative fits first by weighting asymmetry data and/or making cuts on other data fit.

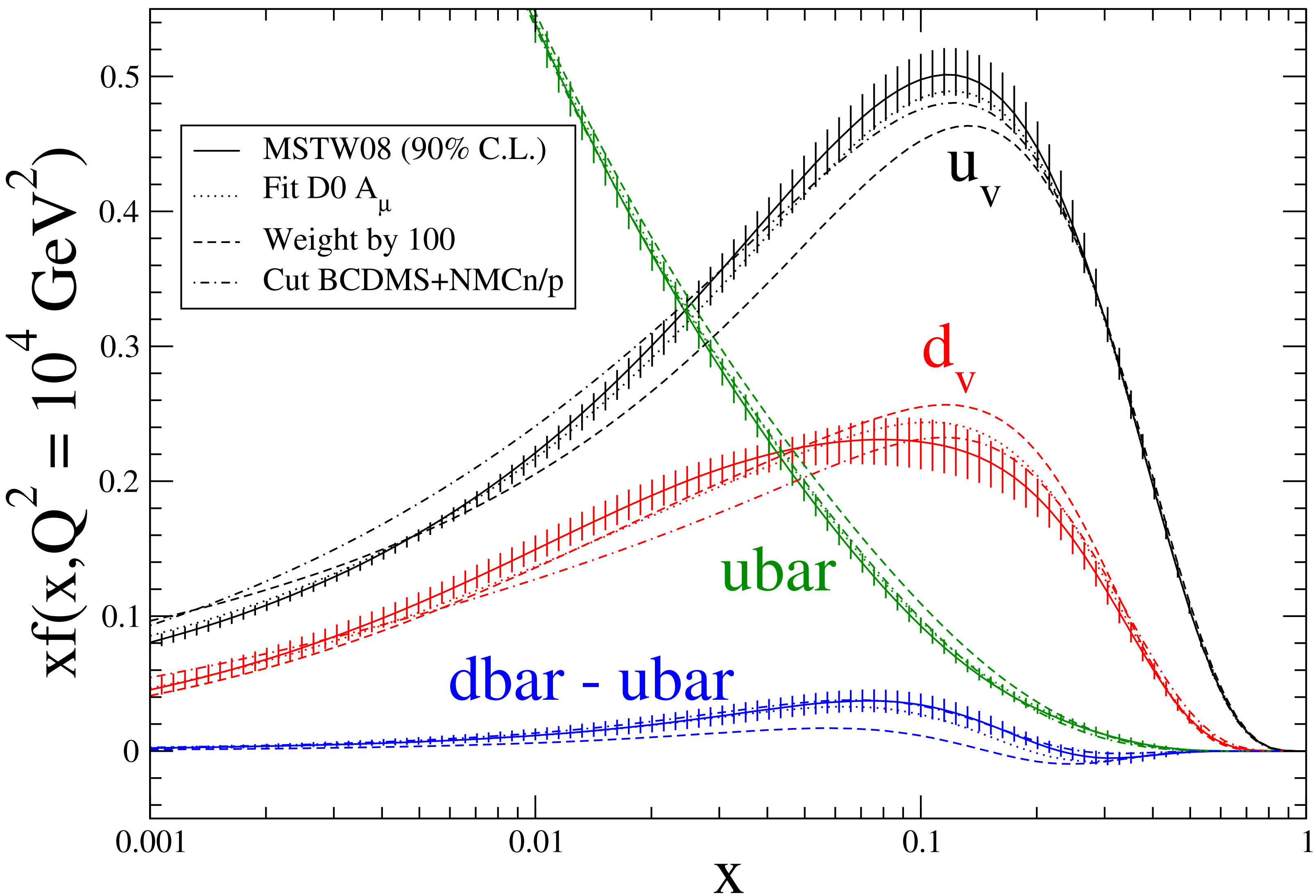
Fit to D0 e and μ data and other data. w denotes high weight D0 data set.

Cut – omit BCDMS, NMCn/p from fit.

Cut data have $\chi^2 = 1222/462$. Other (not D0$_\mu$) data $\chi^2 = 48$ lower (mainly Drell-Yan and F_2^d).

fit	$\chi^2/12$ D0$_e$ $p_T > 25$	$\chi^2/12$ D0$_e$ $25 < p_T < 35$	$\chi^2/12$ D0$_e$ $35 < p_T < 45$	$\chi^2/2689$ non-D0	$\chi^2/16$ D0$_\mu$ both p_T
Standard					
MSTW08	116	19	144	2518	542
fit D0$_e$	71	23	81	2551	358
fit D0$_e$ (w)	25	10	23	2942	183
fit D0$_\mu$	26	55	88	2640	119
fit D0$_\mu$ (w)	33	79	88	3131	10
fit D0$_\mu$ (w) cut	33	52	55	3190	26

Change in PDFs when fitting W -> μν data with 4.9 fb^{-1} from D0



Change in partons for good fits much larger than uncertainties.

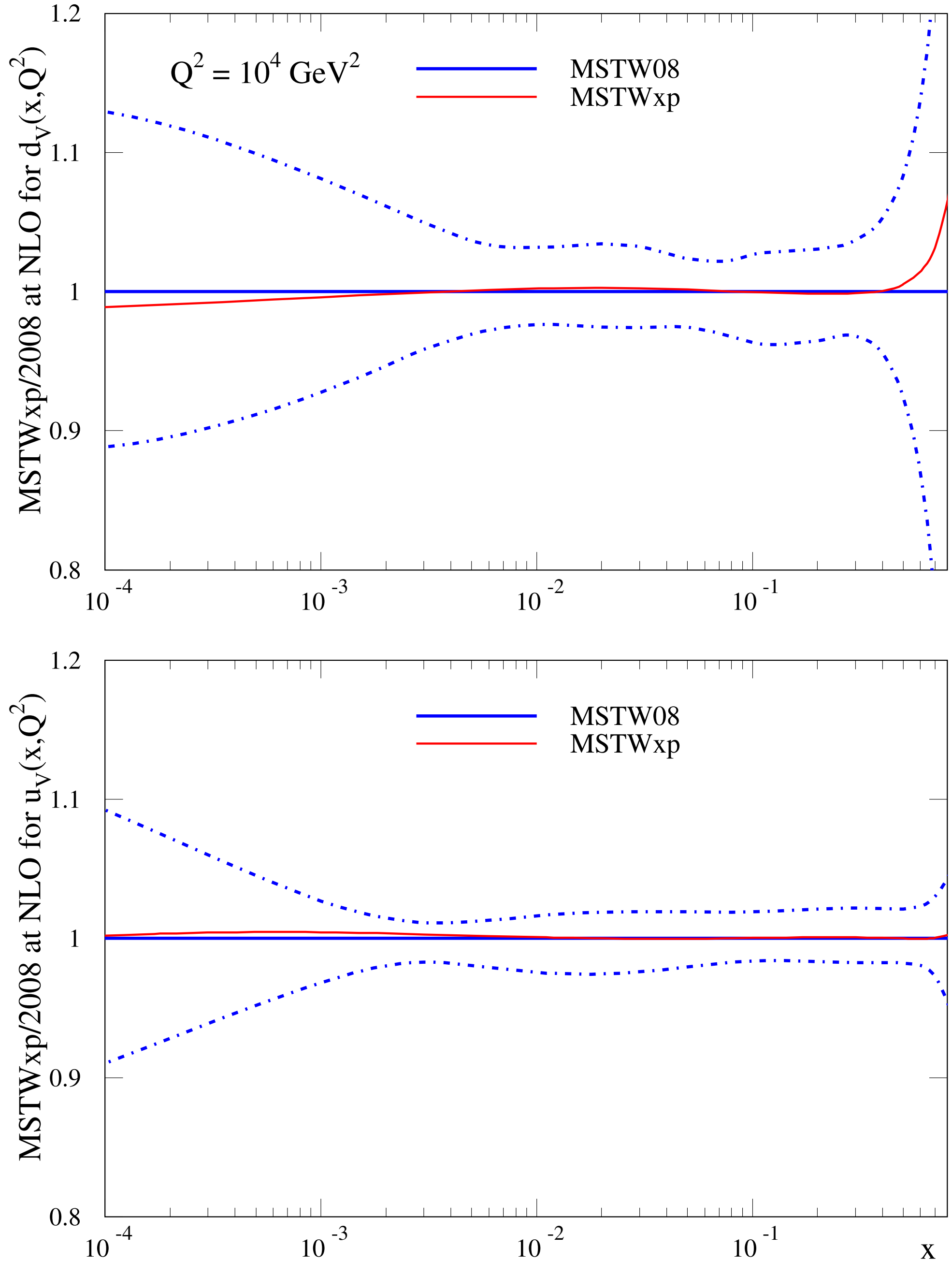
Previously tried adding x^2 terms to standard $(1+\epsilon x^{0.5}+\gamma x)$ polynomial multiplying $A_V(1-x)^\eta x^\delta$ in two valence parameterisations.

Fit quality improved by 2 units.

Change in partons negligible.

Tried also in fits with new asymmetry data.

Again very little effect indeed.



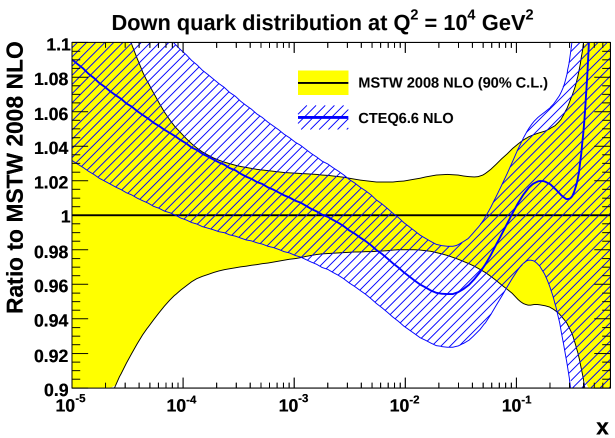
In standard fit data corrected for shadowing at small-x, but not for any high-x effects.

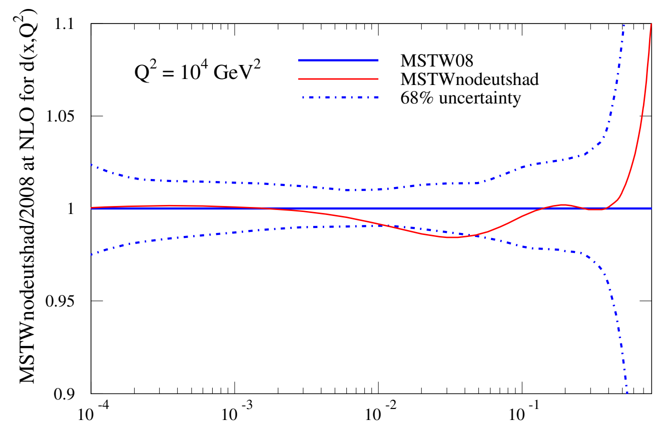
CTEQ apply no corrections. Leads to slightly better comparison to asymmetry data when we try this, (smaller $d(x)$ at $x \sim 0.01$) but quite small effect.

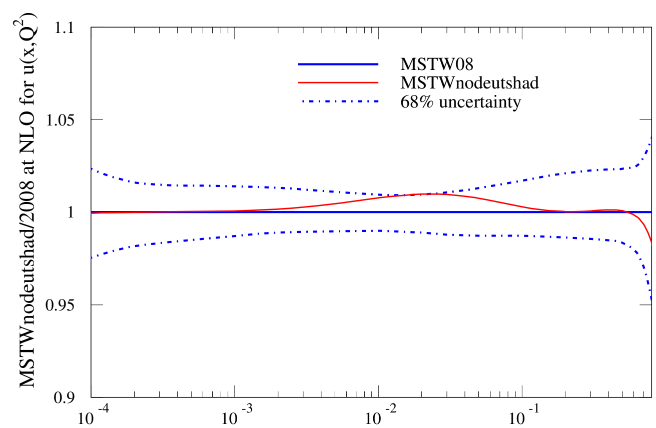
Using standard MSTW08 data $\chi^2 = 19/10$ (from $\chi^2 = 25/10$) for D0 data and $\chi^2 = 25/22$ (from $\chi^2 = 29/22$) for CDF data.

Partons only change by fairly small amounts, but can approach 68% uncertainty band for $u(x, Q^2)$ and $d(x, Q^2)$ in expected region $0.01 < x < 0.1$.

Dip in $d(x, Q^2)$ indeed reminiscent of comparison to CTEQ, but smaller. (Effect on this in recent Pumplin paper arXiv:0909.5176.)







Also try more sophisticated approach to corrections for deuterium data.

Try alternative Q^2-independent deuterium corrections for all x applied to theory corrected by means of a smooth function with 4 free parameters.

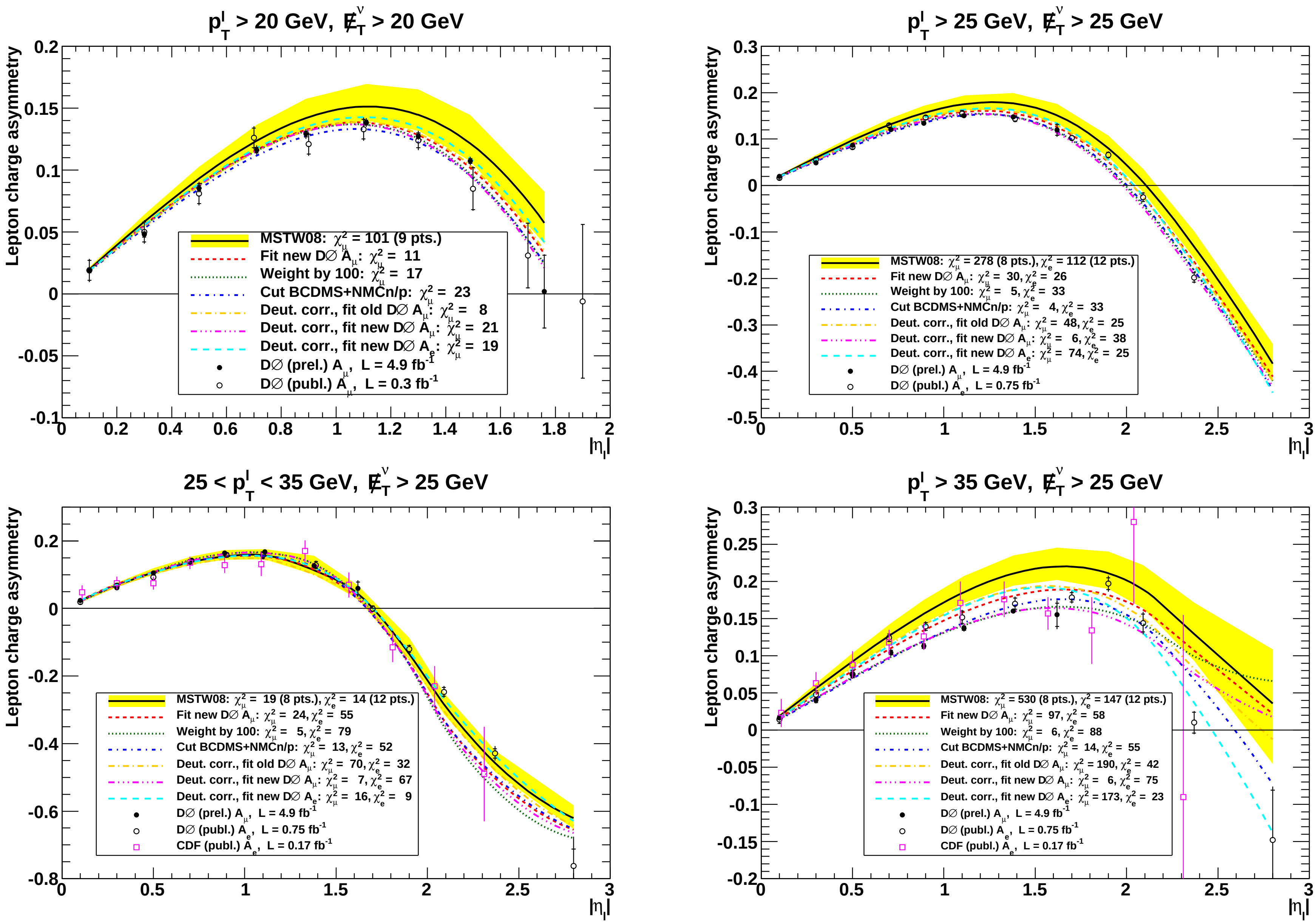
Improves quality of fit to non-asymmetry data significantly. Also ...

Using standard MSTW08 data $\chi^2 = 6/10$ (from $\chi^2 = 25/10$) for D0 (PRD 77) data and $\chi^2 = 21/22$ (from $\chi^2 = 29/22$) for CDF data (PRD 71).

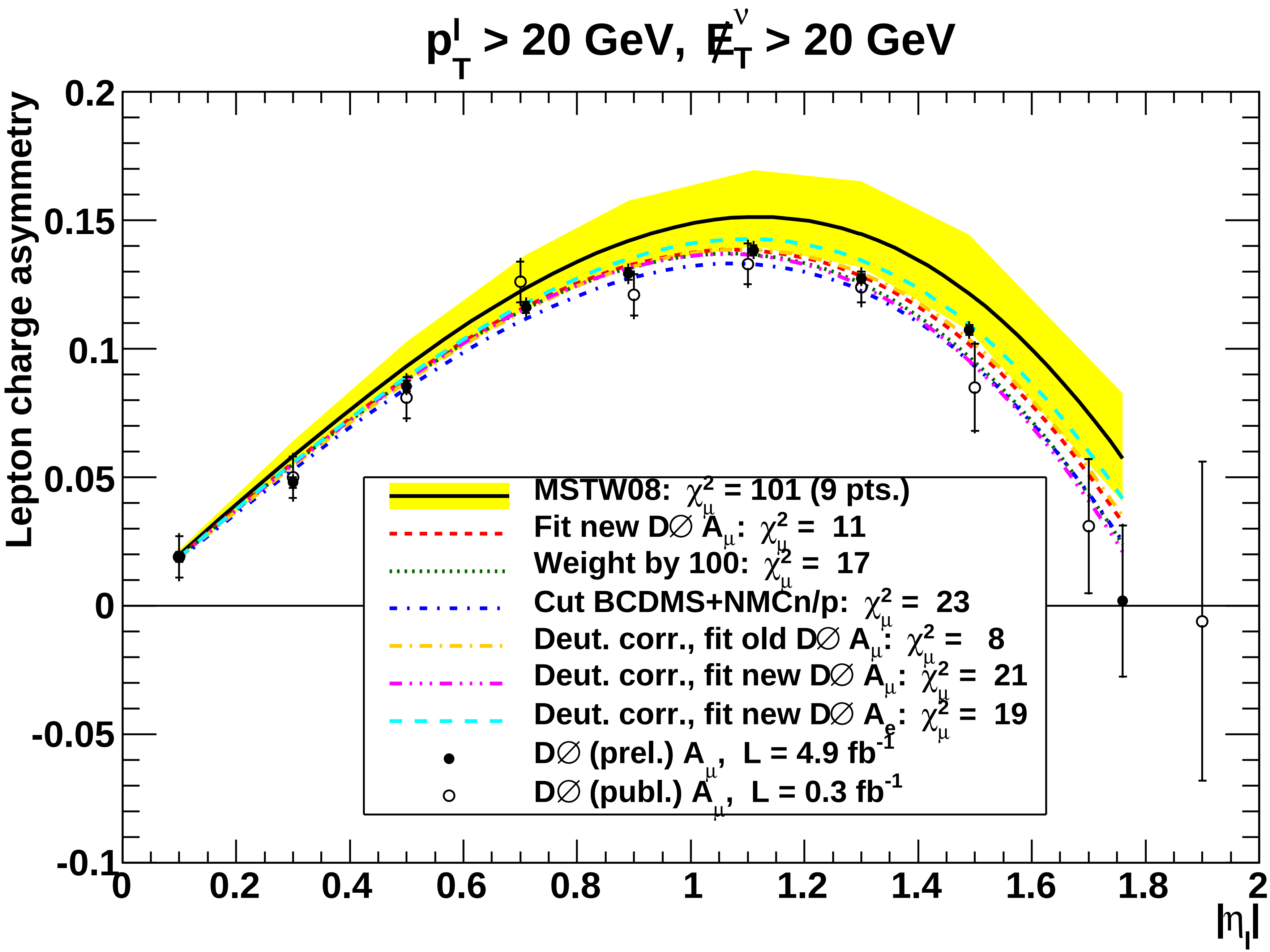
Fit to D0 e and μ data and other data. w denotes high weight D0 set.

fit	$\chi^2/12$ D0$_e$ p_T >25	$\chi^2/12$ D0$_e$ $25<p_T<35$	$\chi^2/12$ D0$_e$ $35<p_T<45$	$\chi^2/2689$ non-D0	$\chi^2/16$ D0$_\mu$ both p_T
Deut. Corr.					
MSTW08 data	25	32	42	2455	140
fit D0$_e$ (w)	25	9	23	2551	192
fit D0$_\mu$ (w)	38	67	75	2649	11
fit D0$_{e+\mu}$ (w)	24	16	40	2848	42
fit D0$_e$ $p_T>25$	23	38	32	2454	229

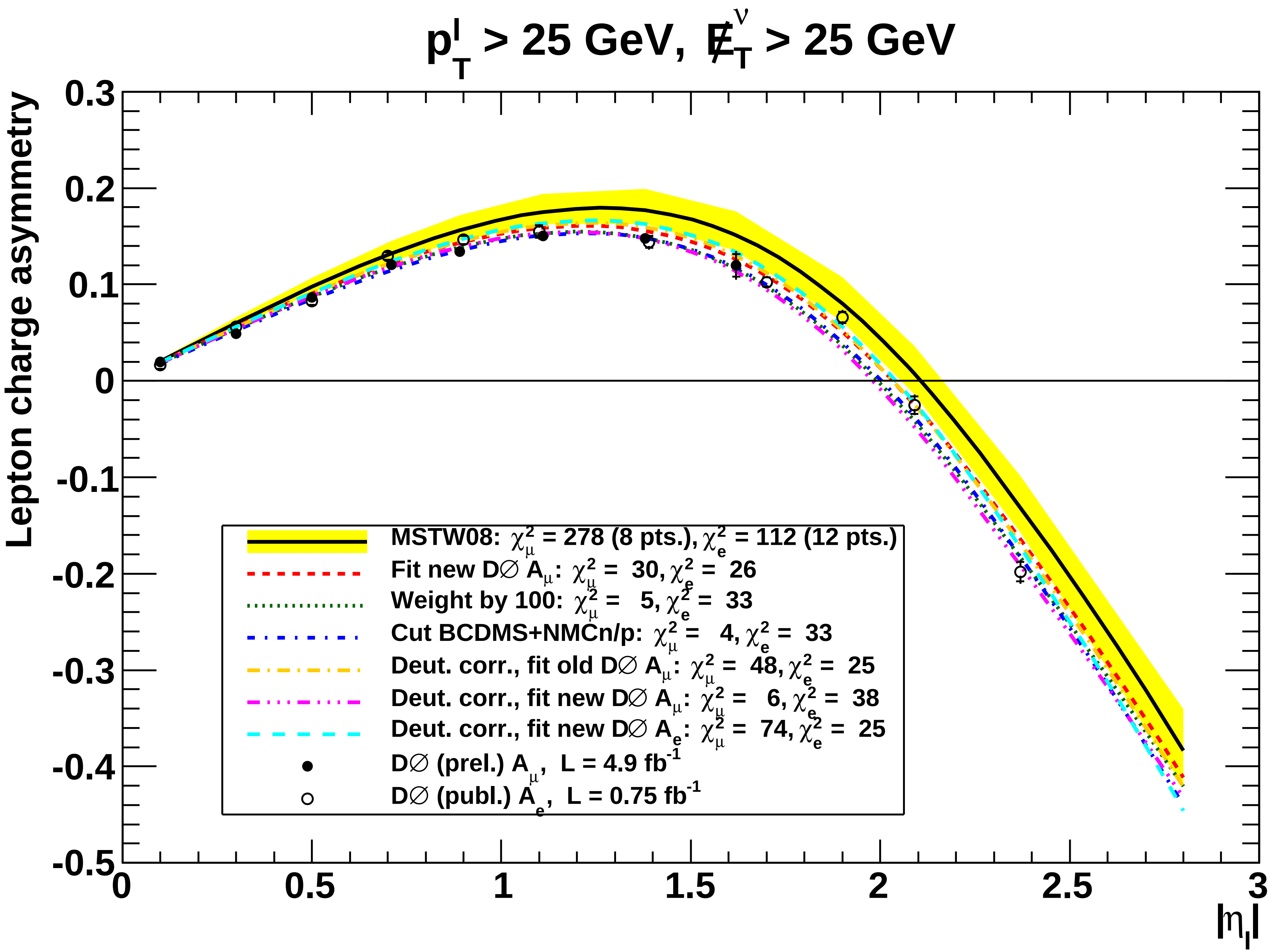
Deuterium corrections help significantly.



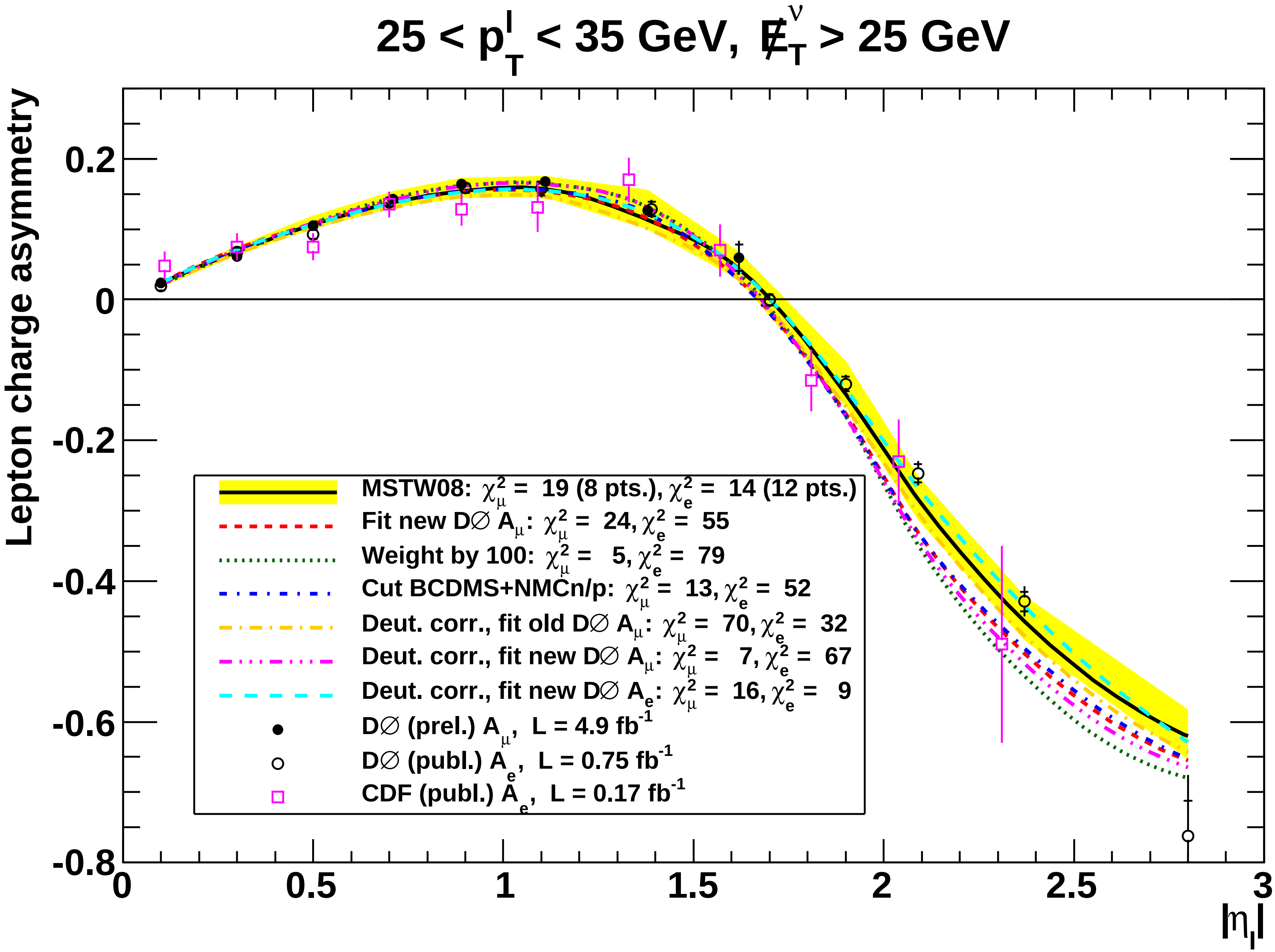
Comparison between various fits and both D0 electron data from $0.75\mathrm{fb}^{-1}$ and D0 muon data from $4.9\mathrm{fb}^{-1}$.



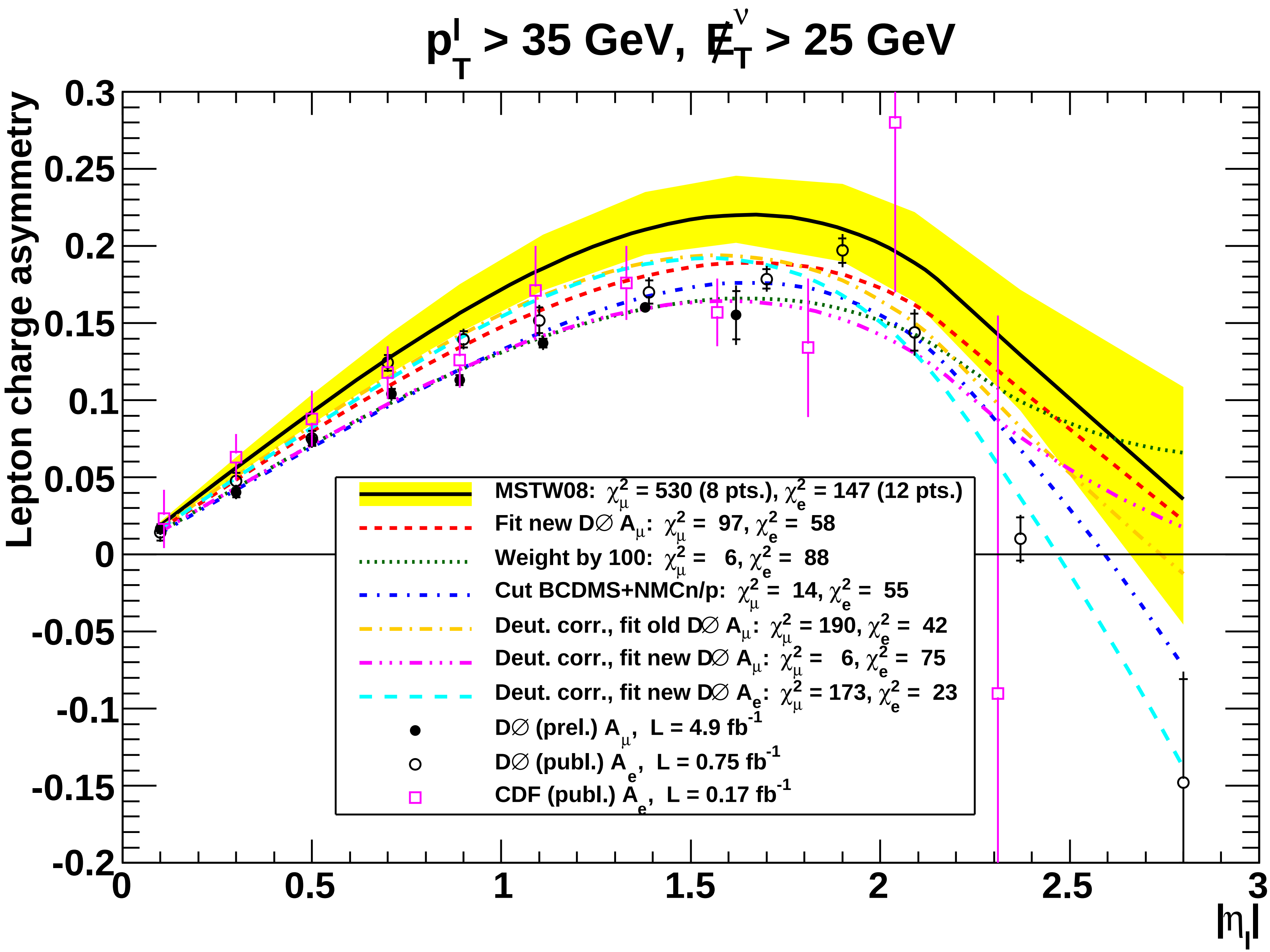
p_T^l > 20 GeV, $\not{E}_T^\nu$ > 20 GeV
Lepton charge asymmetry
0.2
0.15
0.1
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
$|\eta_l|$
MSTW08: χ^2_μ = 101 (9 pts.)
Fit new D∅ A_μ: χ^2_μ = 11
Weight by 100: χ^2_μ = 17
Cut BCDMS+NMCn/p: χ^2_μ = 23
Deut. corr., fit old D∅ A_μ: χ^2_μ = 8
Deut. corr., fit new D∅ A_μ: χ^2_μ = 21
Deut. corr., fit new D∅ A_e: χ^2_μ = 19
D∅ (prel.) A_μ, L = 4.9 fb^{-1}
D∅ (publ.) A_μ, L = 0.3 fb^{-1}



$p_T^l > 25$ GeV, $\not{E}_T^{\nu} > 25$ GeV
Lepton charge asymmetry
$|\eta_l|$
MSTW08: $\chi^2_\mu = 278$ (8 pts.), $\chi^2_e = 112$ (12 pts.)
Fit new DØ A_μ: $\chi^2_\mu = 30$, $\chi^2_e = 26$
Weight by 100: $\chi^2_\mu = 5$, $\chi^2_e = 33$
Cut BCDMS+NMCn/p: $\chi^2_\mu = 4$, $\chi^2_e = 33$
Deut. corr., fit old DØ A_μ: $\chi^2_\mu = 48$, $\chi^2_e = 25$
Deut. corr., fit new DØ A_μ: $\chi^2_\mu = 6$, $\chi^2_e = 38$
Deut. corr., fit new DØ A_e: $\chi^2_\mu = 74$, $\chi^2_e = 25$
DØ (prel.) A_μ, L = 4.9 fb^{-1}
DØ (publ.) A_e, L = 0.75 fb^{-1}



25 < p_T^l < 35 GeV, E̸_T^ν > 25 GeV
Lepton charge asymmetry
|η_l|
MSTW08: χ²_μ = 19 (8 pts.), χ²_e = 14 (12 pts.)
Fit new D∅ A_μ: χ²_μ = 24, χ²_e = 55
Weight by 100: χ²_μ = 5, χ²_e = 79
Cut BCDMS+NMCn/p: χ²_μ = 13, χ²_e = 52
Deut. corr., fit old D∅ A_μ: χ²_μ = 70, χ²_e = 32
Deut. corr., fit new D∅ A_μ: χ²_μ = 7, χ²_e = 67
Deut. corr., fit new D∅ A_e: χ²_μ = 16, χ²_e = 9
D∅ (prel.) A_μ, L = 4.9 fb^-1
D∅ (publ.) A_e, L = 0.75 fb^-1
CDF (publ.) A_e, L = 0.17 fb^-1



p_T^l > 35 GeV, $\not{E}_T^\nu$ > 25 GeV
Lepton charge asymmetry
$|\eta_l|$
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
0.5
1
1.5
2
2.5
3
MSTW08: χ^2_μ = 530 (8 pts.), χ^2_e = 147 (12 pts.)
Fit new D∅ A_μ: χ^2_μ = 97, χ^2_e = 58
Weight by 100: χ^2_μ = 6, χ^2_e = 88
Cut BCDMS+NMCn/p: χ^2_μ = 14, χ^2_e = 55
Deut. corr., fit old D∅ A_μ: χ^2_μ = 190, χ^2_e = 42
Deut. corr., fit new D∅ A_μ: χ^2_μ = 6, χ^2_e = 75
Deut. corr., fit new D∅ A_e: χ^2_μ = 173, χ^2_e = 23
D∅ (prel.) A_μ, L = 4.9 fb^{-1}
D∅ (publ.) A_e, L = 0.75 fb^{-1}
CDF (publ.) A_e, L = 0.17 fb^{-1}

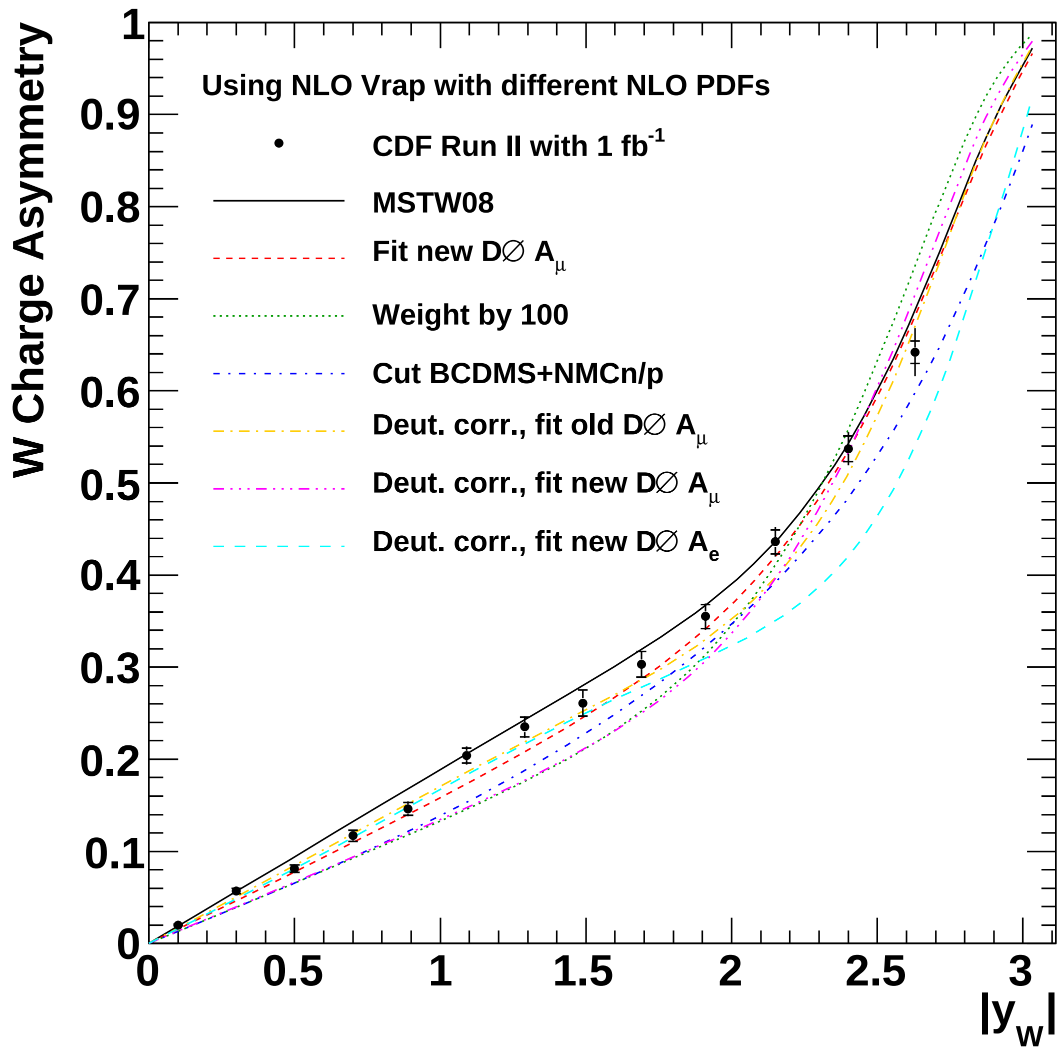
Compare various MSTW predictions to the published CDF data on W-asymmetry.

Standard MSTW fit gives reasonable comparison as does standard fit with allowed deuterium corrections.

Approx χ^2 is $28/13$ and $24/13$ respectively.

Only unweighted (and poor) fit to $\mathrm{D0}_\mu$ data is at all similar. All others $\chi^2 > 100$.

All others show some region of clearly too much suppression for some region of rapidity.

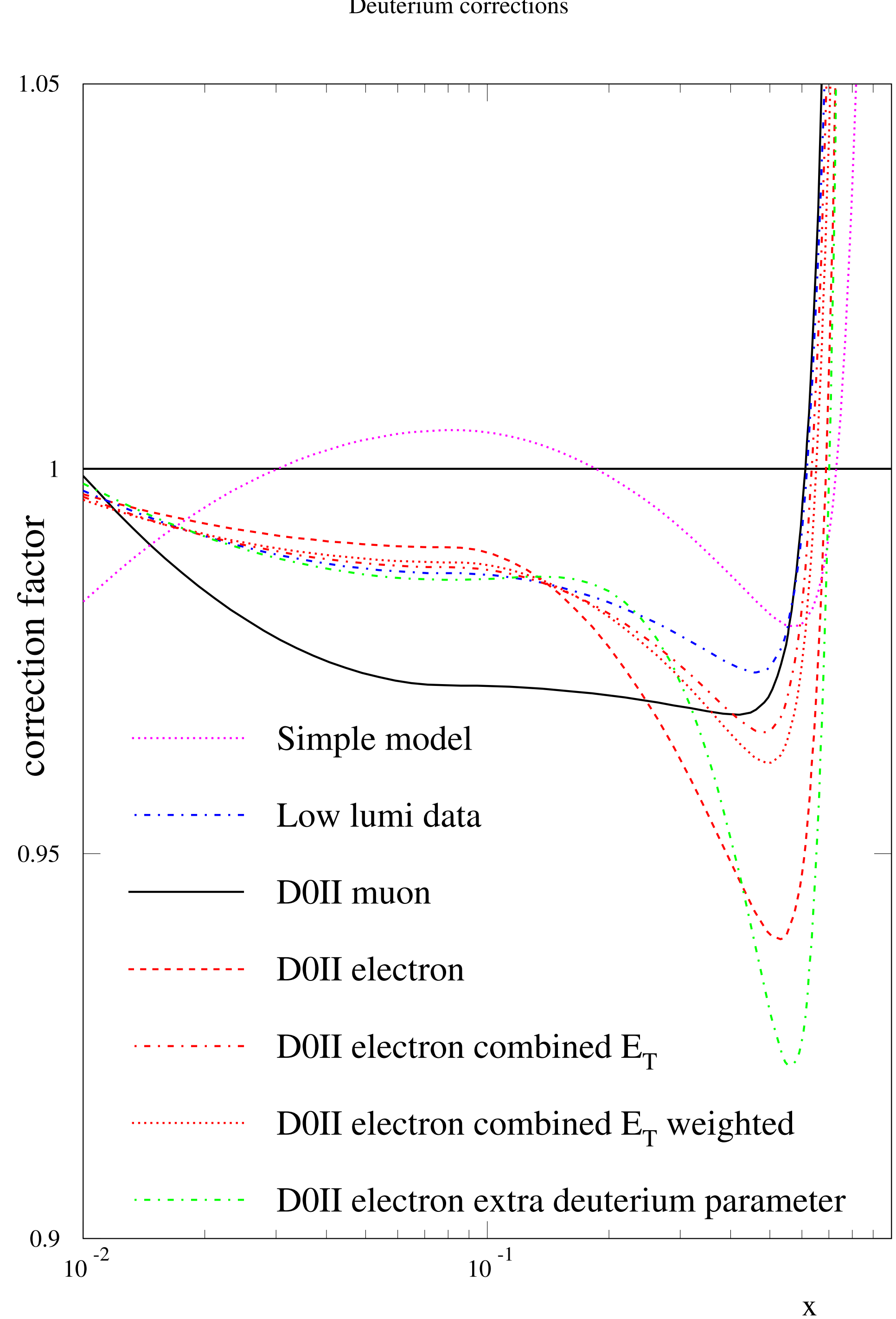


Deuterium corrections help significantly but are very large/unusual for best fits to muon or electron asymmetry in both p_T bins.

All dip at $x \sim 0.6$ (binding effects) and rise quickly at very high x (Fermi motion), but dips to less than ~ 0.97 not expected.

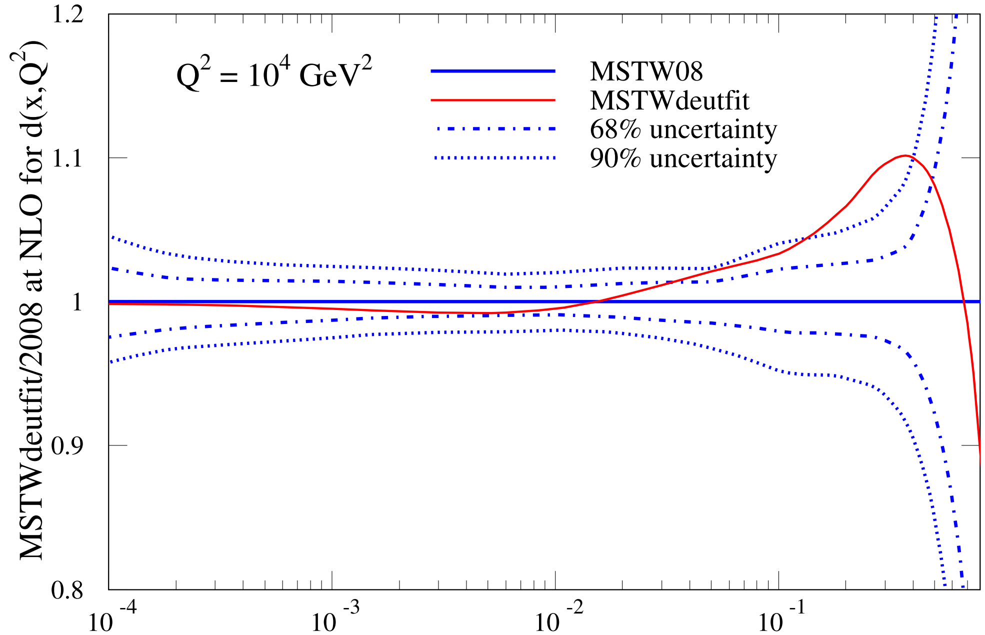
Tendency to rise (and go above 1 for $x < 0.01$) for lowest x not strong, and driven by deuterium data rater than asymmetry data, so low x shadowing corrections roughly consistent with expected shadowing.

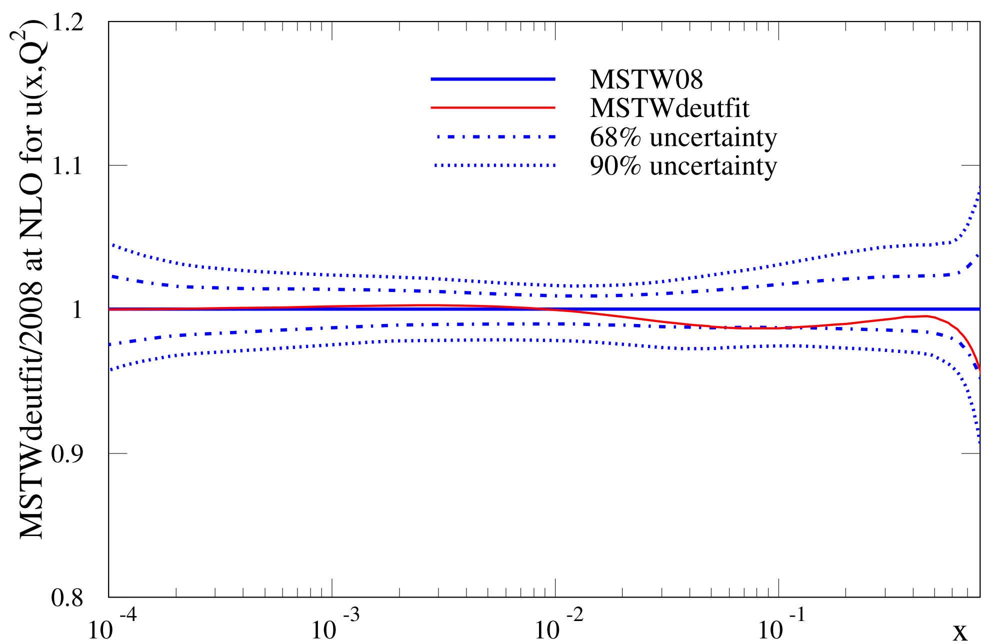
Suppression even at $x \sim 0.1$ (anti-shadowing region) unexpected. Particularly needed for $D0_\mu$ data.

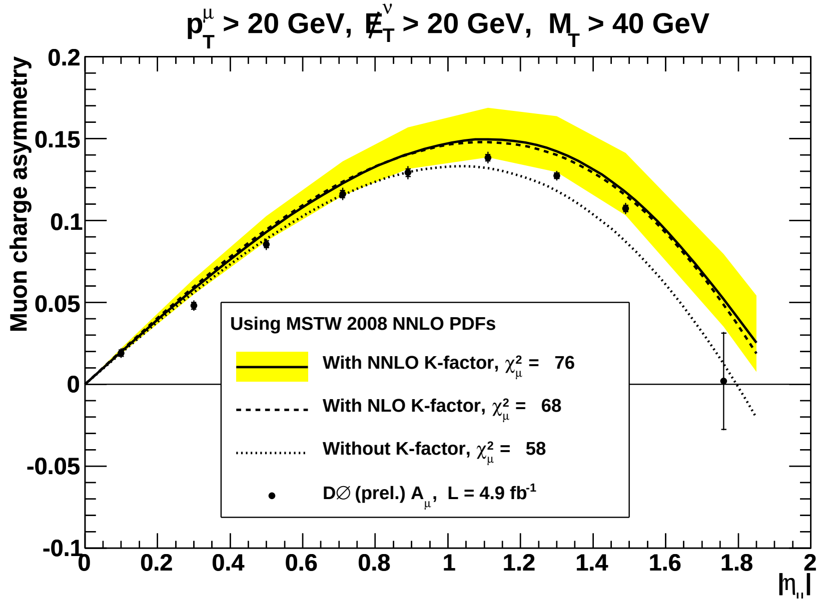


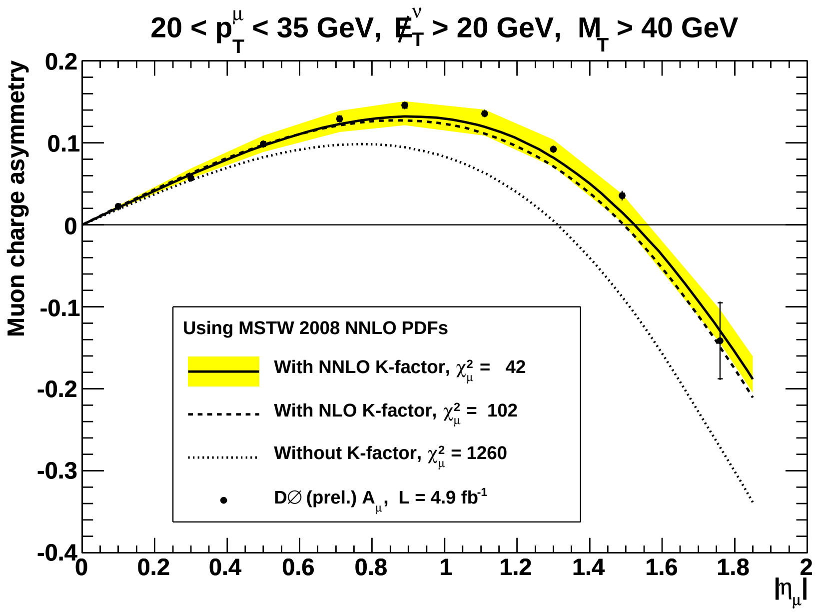
Refit with free deuterium corrections results in a change of the PDFs often at the level of the 68% uncertainty band.

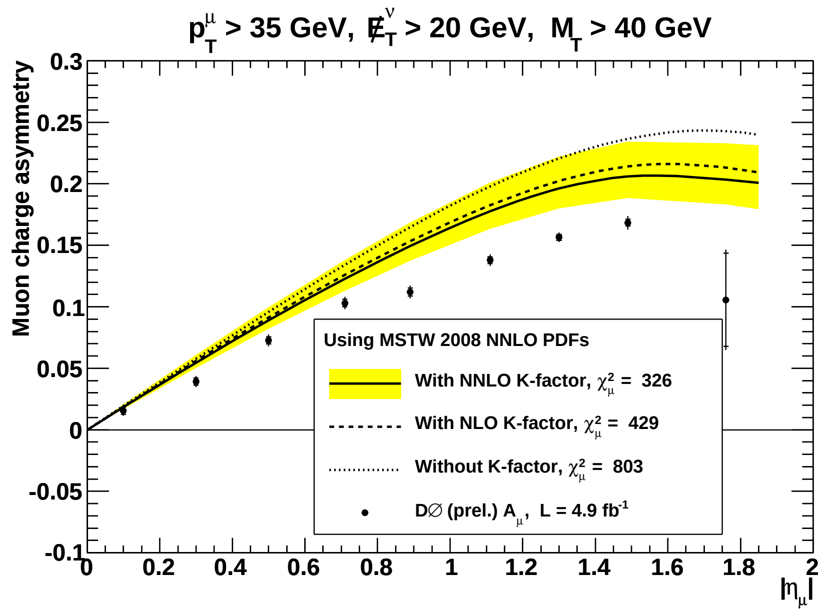
For $d(x, Q^2)$ for $0.2 < x < 0.4$ can even be outside 90% uncertainty.











NNLO corrections (Grazzini et al) are in the correct direction to help resolve discrepancies with D0 data but are too small to fully account for them.

Conclusions

Have looked at effect on central fits when including new combined HERA neutral current data. In some places alters partons, and $\alpha_S(M_Z^2)$, by $1-\sigma$ or a bit more.

Total fit better at NNLO. Global fit worse than HERA fit. Can do better than HERA fit when only fitting HERA data. Big decrease in χ^2 when other data removed.

Can be a $1-\sigma$ effect on Z and W cross-sections, more so at Tevatron. Less for Higgs cross sections. More variation at NLO than at NNLO.

Have difficulty fitting some recent lepton/boson asymmetry data at NLO. NNLO seems to help, but not very much. Deuterium corrections help, both with normal fit and asymmetry data. Improve asymmetry data fit in MSTW08 a lot.

Without deuterium corrections reasonable fit to CDF W-asymmetry possible without high penalty. All D0 sets bad.

With deuterium corrections can fit CDF W-asymmetry and D0 electron asymmetry for combined p_T with no problems. D0 electron asymmetry for separate p_T not too bad, but large deuterium assumption. **D0 muon data impossible without high penalty.**

Maximally self consistent sets seem to be CDF W-asymmetry and D0 electron asymmetry for combined p_T.

Observation on Relationship Between Gluon and $\alpha_S(M_Z^2)$

In study of α_S within global fit noticed that within full fit HERA cross-section data prefer large $\alpha_S(M_Z^2) \approx 0.125$ at NLO (0.121 at NNLO). Due to presence of other data?

Fitting only to these data using NLO find $\alpha_S(M_Z^2) = 0.127 \pm 0.005$ (using $\Delta\chi^2 = 1$) and $\chi^2 = 57$ lower than in global fit for 839 points.

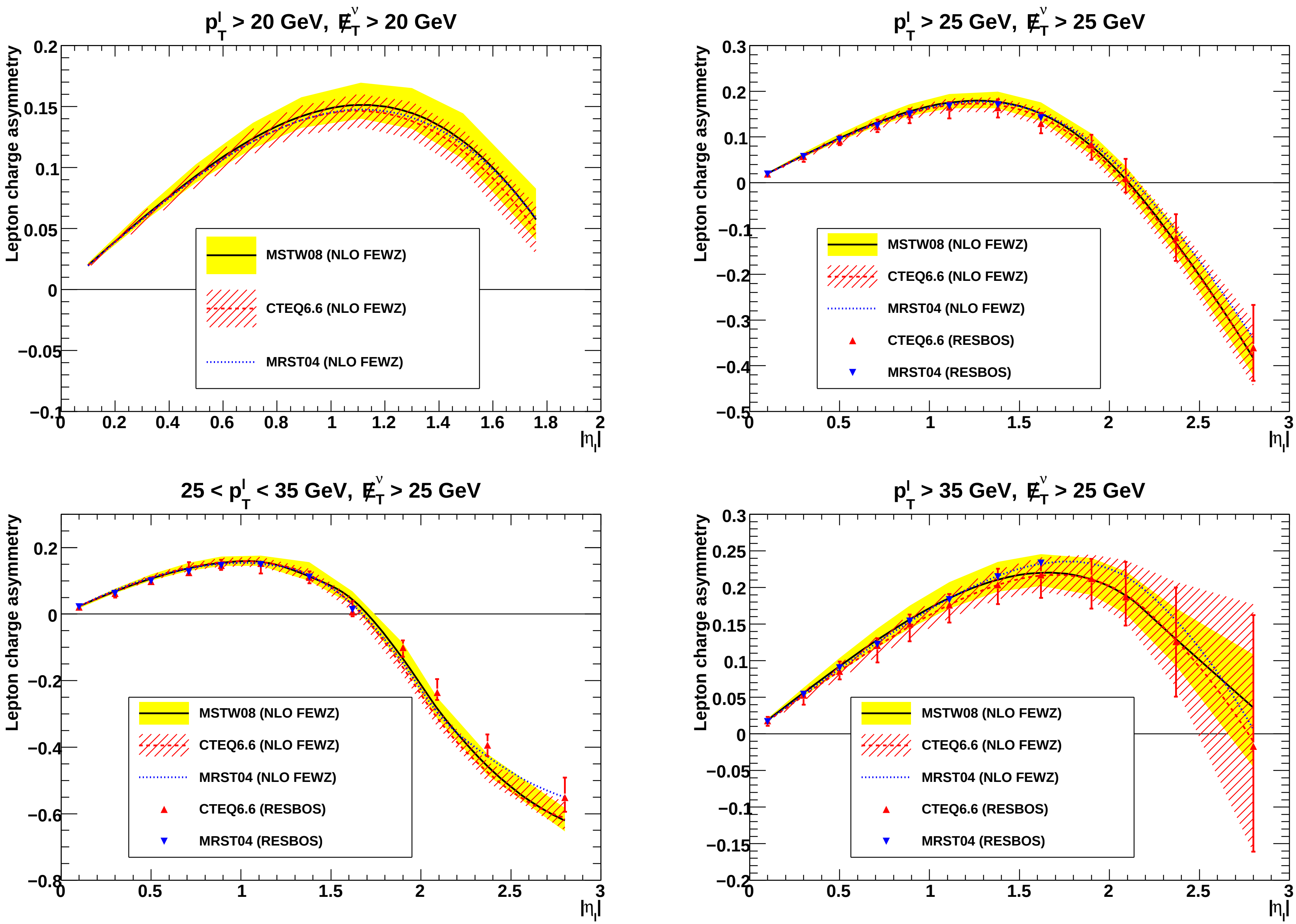
However, repeated fit removing second term from

$$xg(x, Q_0^2 = 1\text{GeV}^2) = A_g(1-x)^{\eta_g}(1+\epsilon_g x^{0.5} + \gamma_g x)x^{\delta_g} + A_{g'}(1-x)^{\eta_{g'}}x^{\delta_{g'}}.$$

Obtain instead $\alpha_S(M_Z^2) = 0.110 \pm 0.002$ with χ^2 now 17 higher.

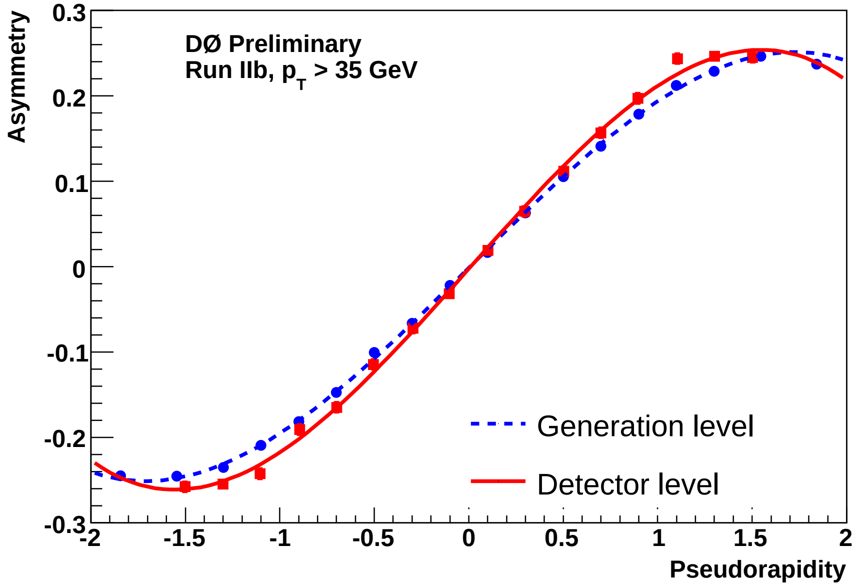
Use restricted parameterisation at $Q_0^2 = 1.5\text{GeV}^2$. Now χ^2 only 4 higher than best fit. Data *happy* with positive input gluon - similar to other single power gluon fits? Obtain $\alpha_S(M_Z^2) = 0.117 \pm 0.0025$. (Find $\alpha_S(M_Z^2) = 0.132 \pm 0.006$ with free parameterisation.)

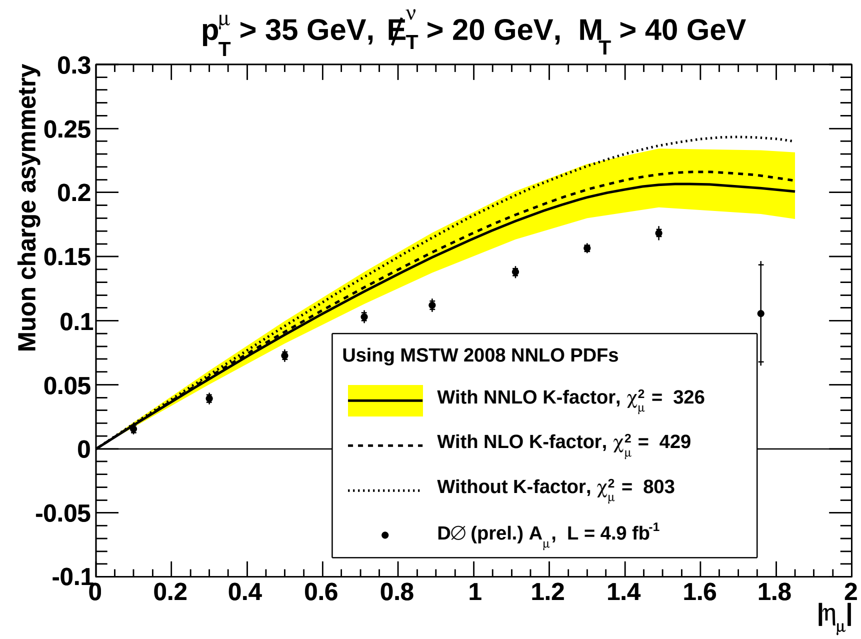
Both extracted $\alpha_S(M_Z^2)$ and its uncertainty (obtained from careful scan - higher value otherwise) sensitive to limited gluon parameterisation. Both become lower.



Comparison between use of FEWZ and RESBOS for CTEQ6.6 and MRST04

Notice that Monte Carlo for D0 muon data (fig. 2 of D0 note 5976-CONF) much bigger than data, particularly for high p_T. Influence on detector corrections?





Monte Carlo data more than 50% greater than actual data.

Effect on size of detector corrections?