Is a measurement of the W/lepton asymmetry with 100pb^{-1} of data useful?

-A M Cooper-Sarkar

There is NOT great agreement between PDF providers on the predictions for the W/lepton asymmetry-

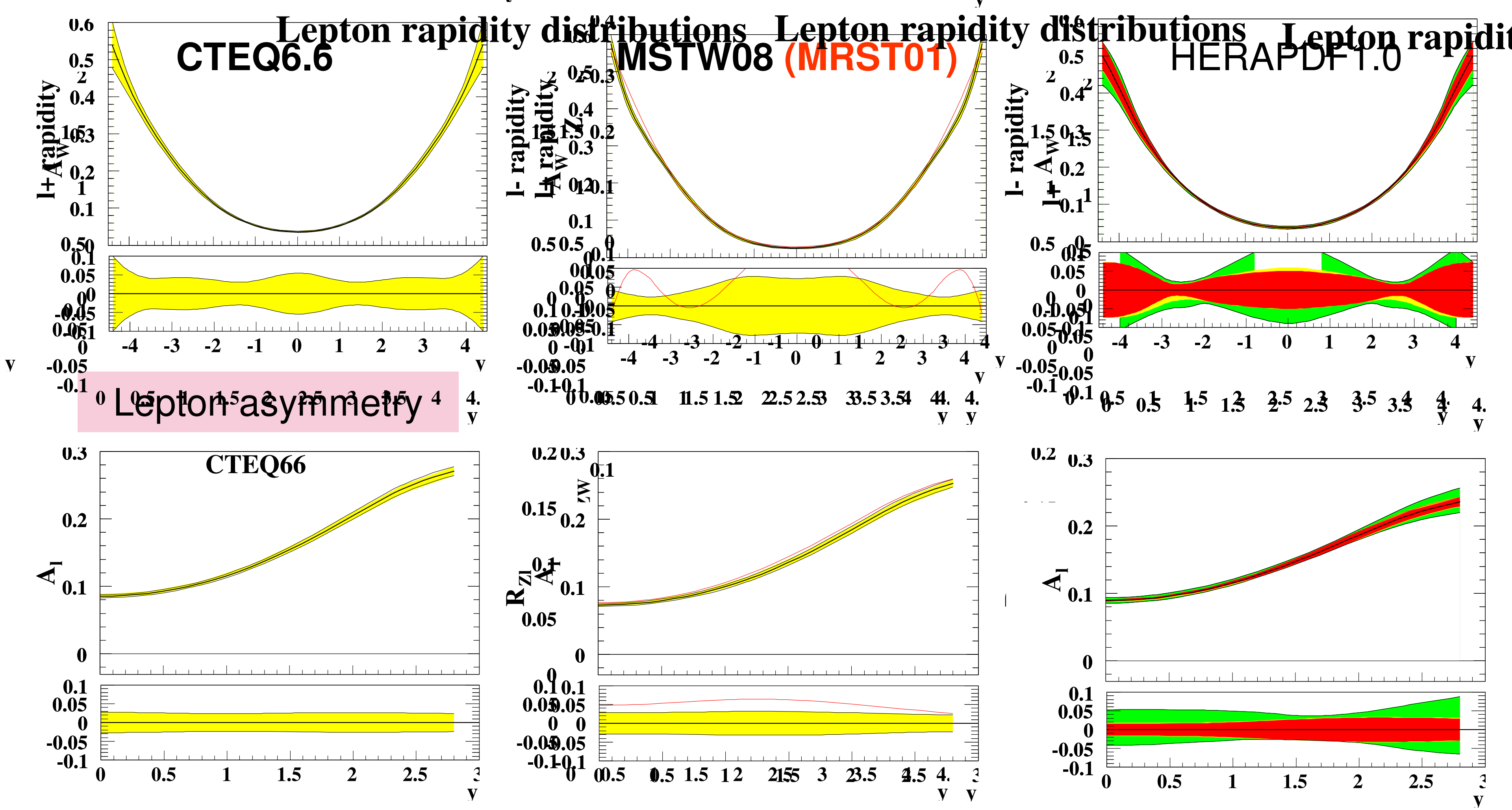
The differences lie outside the nominal error bands…

Note: I'm going to show error bands at 68%CL not 90% CL- you can all multiply by 1.645 if you want to

Hence even a measurement at 100pb-1 could be useful

This study is done using Kristin Lohwasser's estimates of systematic and statistical errors and hence for now it is done at 14 TeV

In the W asymmetry – there is NOT fanatastic agreement (14TEV)



The differences at central rapidity are quite striking, but maybe that needs highlighting……..

exp uncert.

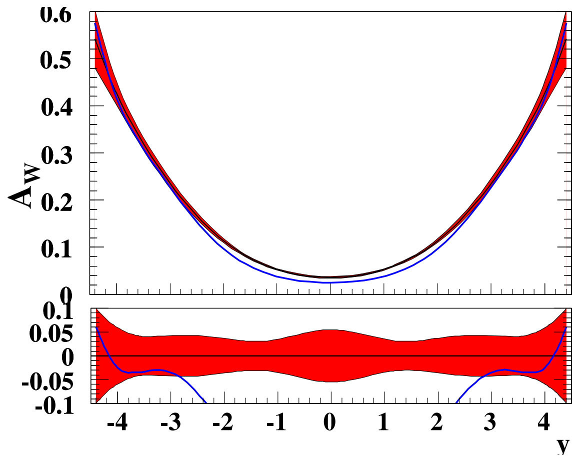
exp uncert.

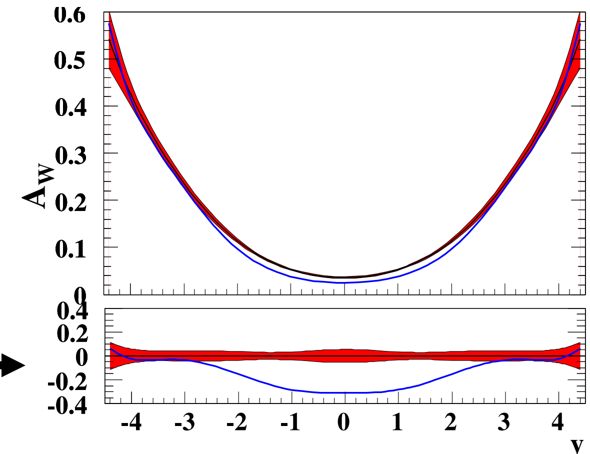
MRST01

The biggest difference is MSTW08 to CTEQ66

(and this has been true of historic CTEQ and MRST sets as well)

The difference doesn't look much until you home in on the discrepancy of the MSTW08 prediction to the CTEQ66 error band





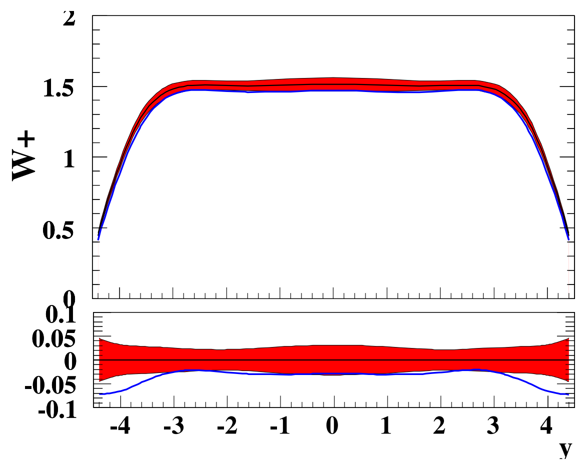
It exceeds my standard 10% scale

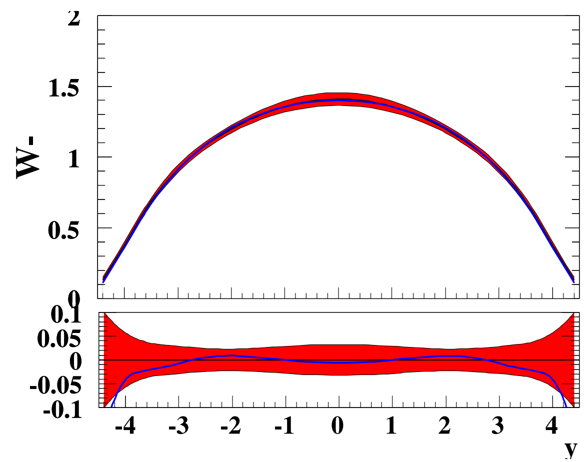
Turns out to be~35% discrepancy!

W and Z rapidity distributions

Where is it coming from?- compare W+ and W- distributions

It looks like the W- agrees fairly well but the W+ is lower for MSTW





We can trace this difference back to the different valence PDFs of CTEQ66 and MSTW08

Predictions for AW are different in the central region- because predictions for valence distributions at small-x are different

Dominantly, at LO $$A_W = \frac{u(x_1)\,\bar{d}(x_2) - d(x_1)\,\bar{u}(x_2)}{u(x_1)\,\bar{d}(x_2) + d(x_1)\,\bar{u}(x_2)}$$

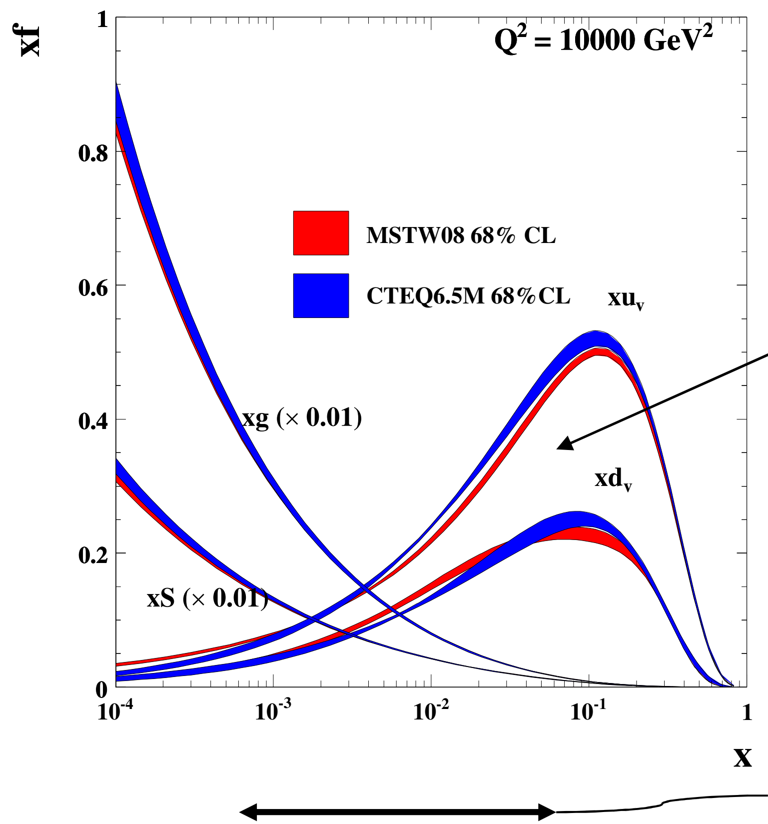
And at central rapidity $x_1 = x_2$

and ubar ~ dbar ~ qbar at small x

So $$A_W \sim \frac{(u - d)}{(u + d)} = \frac{(u_v - d_v)}{(u_v + d_v + 2\,\bar{q})}$$

Actually this LO approx. is pretty good even quantitatively
The difference in valence PDFs you see here does explain the difference in A_W between MRST and CTEQ

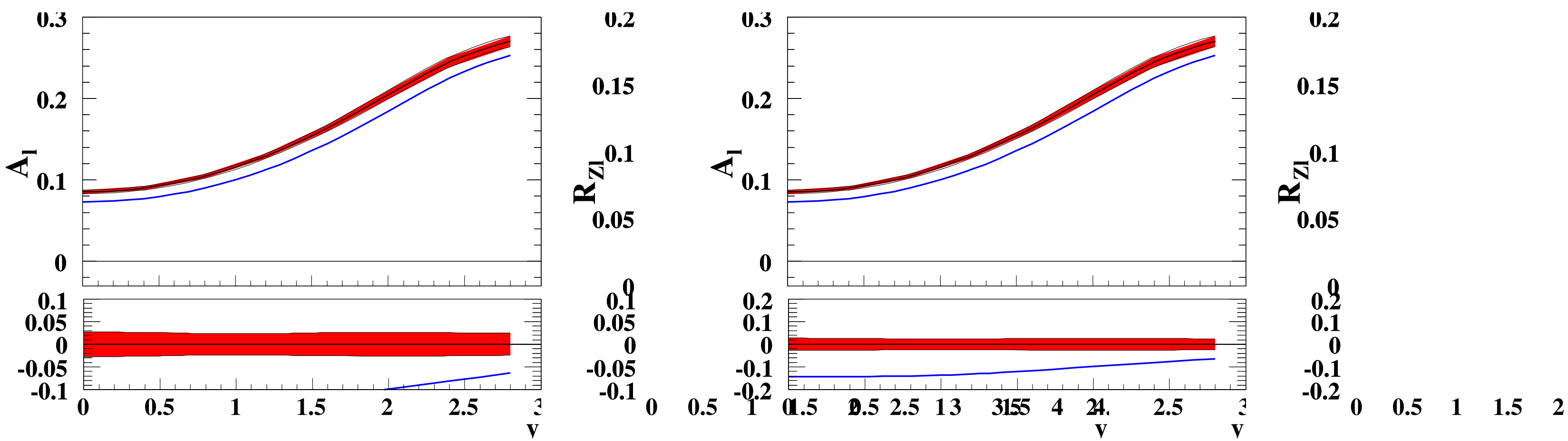
As we move away from central rapidity: as x_1 increases (decreases) the larger (smaller) difference is weighted by larger (smaller) sea distributions at smaller x_2



Why are these valence PDFs so different?
Well there's really no data that constrains valence at these low-x values

x- range affecting W asymmetry in the measurable rapidity range at ATLAS (14TeV)

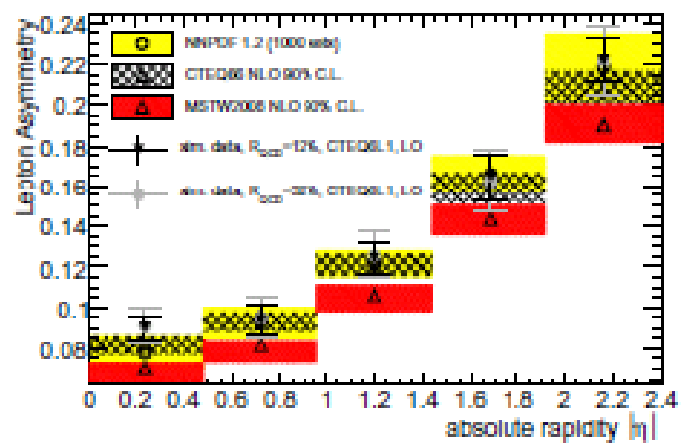
But does this large discrepancy CTEQ66 to MSTW08 apply to the lepton asymmetry?



YES it does- once more you see it better if you blow up the scale- → Its~15% at central rapidity

Now for an aside: If there's no data to constrain the valence PDFs at these low-x values then the predictions must be largely dependent on the parametrisation. In that case does the NNPDF have a larger uncertainty and cover both MSTW and CTEQ predictions?

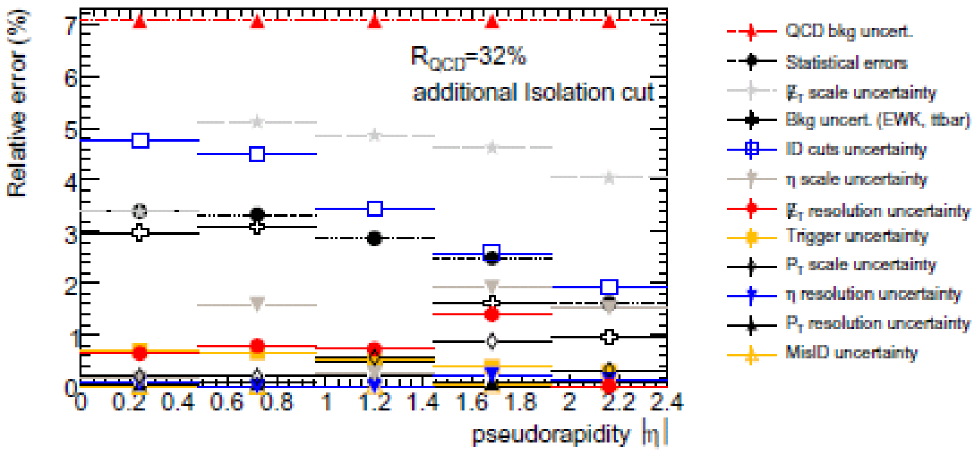
The answer for NNPDF1.2 would seem to be 'not quite' →

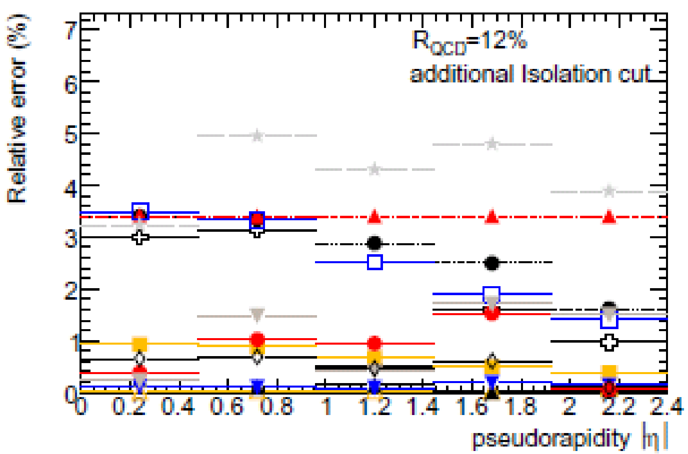


So how well can we measure the lepton asymmetry?

We need to consider backgrounds, scale uncertainties, resolution uncertainties trigger uncertainties…

Recent study by K.Lohwasser shows that the background from QCD di-jets is out biggest problem





In these plots the statistical errors are for 100pb-1 at 14 TeV.

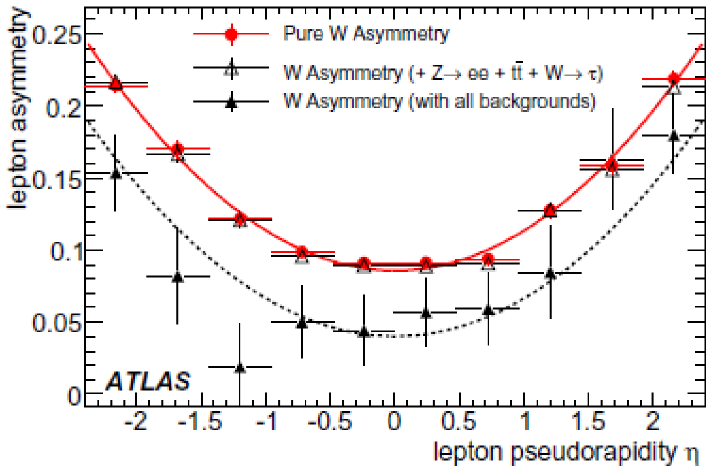
This will get better

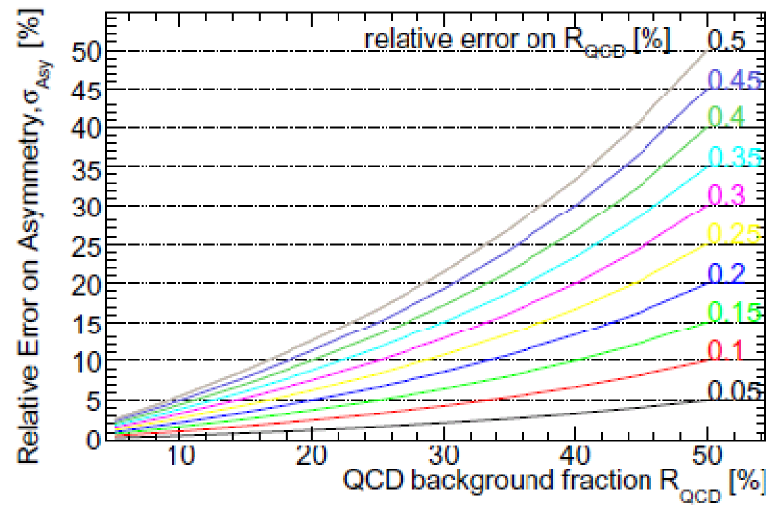
Even the missing Et scale uncertainty may be better understood in time

But the QCD di-jet background is a tough one. There are two estimates here one of 32% and one of 12% QCD di-jet background. The latter comes from assuming that we can reduce it using an isolation cut around the fake electron.

What does this background do?- it changes the shape of the asymmetry- flattening it, and we have to correct for this

And our problem is not just how big is this background, but how well do we know how big it is



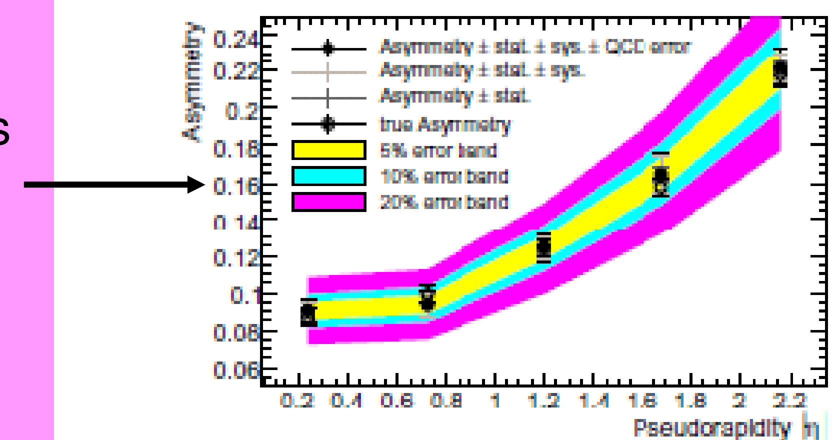


The upshot is that if we assum12% QCD background known to ± 3%

We can achieve a measurement like this

And note that the statistical errors are uncorrelated but the systematics are correlated

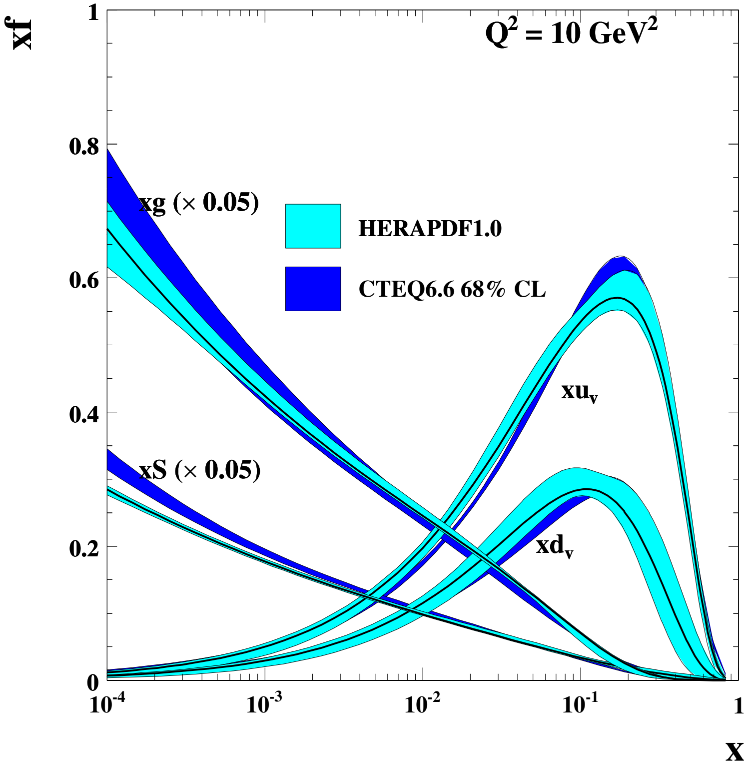
It seems that one could discriminate a 15% discrepancy

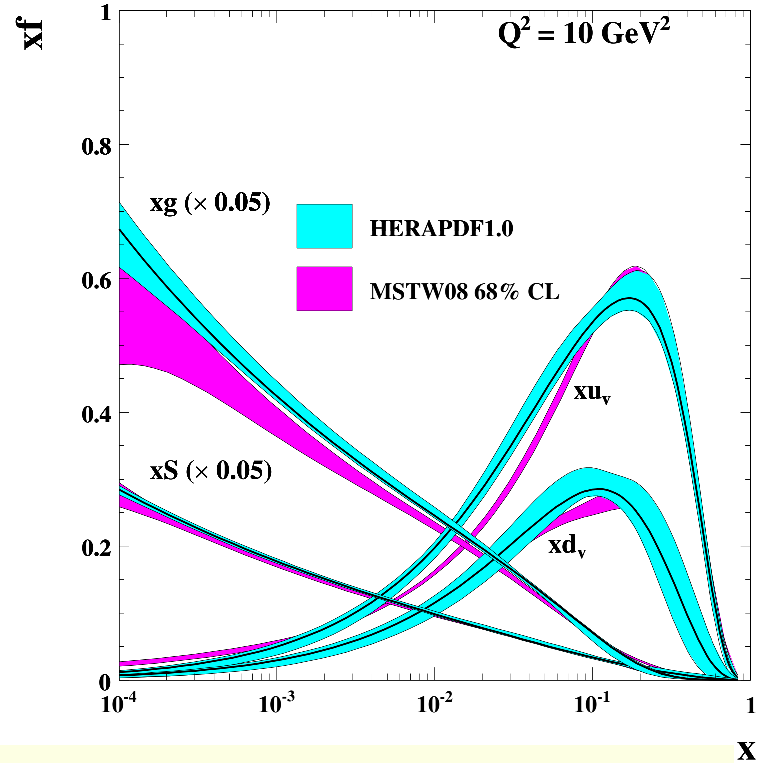


To look into this further I have taken Kristin's estimates for statistical (uncorrelated) and systematic errors (100%correlated) and applied them to central predictions according to 3 different PDFs:

HERAPDF1.0, CTEQ66, MSTW08

Then I feed this pseudo-data into the HERAPDF fit



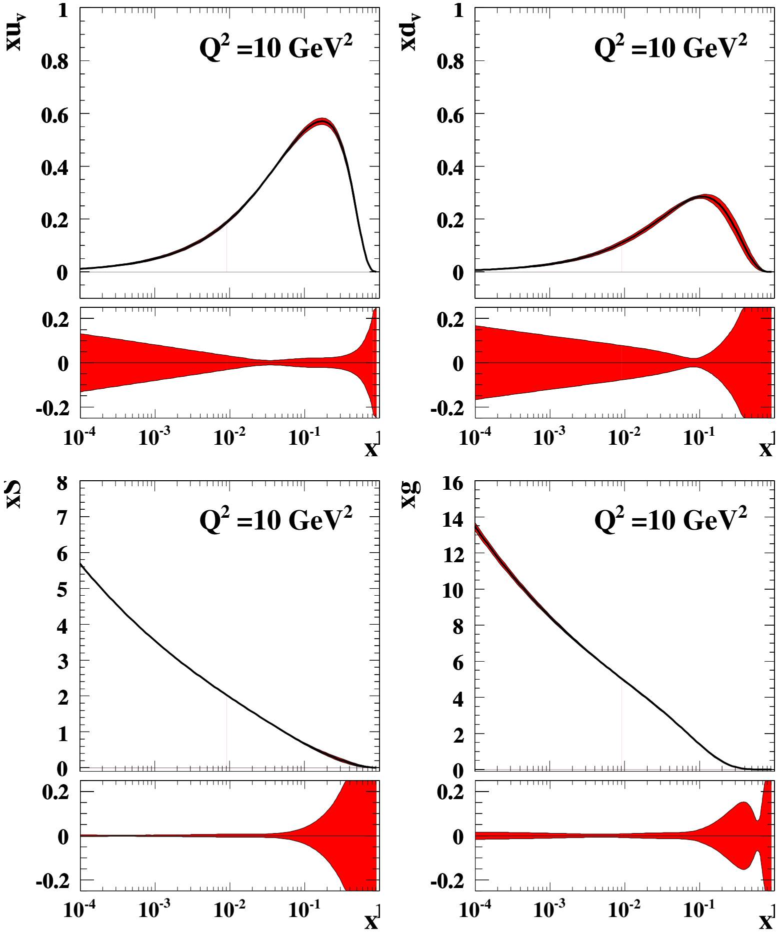


The HERAPDF is based on the new HERA data combination. Its valence PDFs agree better with CTEQ66 than with MSTW08

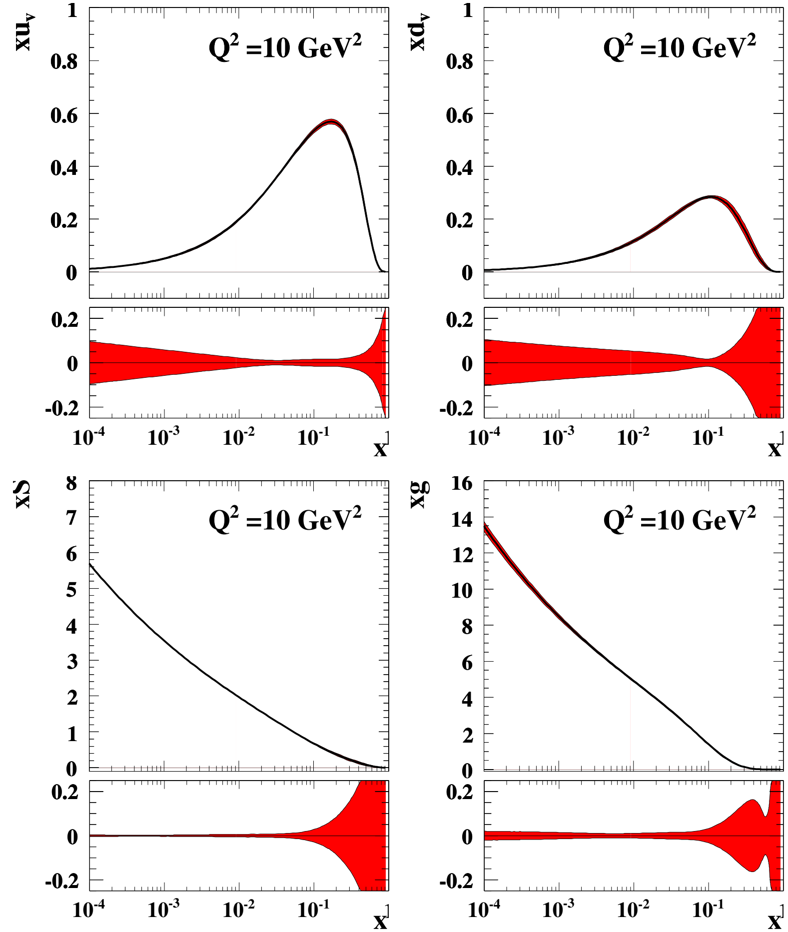
First HERAPDF1.0 pseud-data: the asymmetry has HERAPDF1.0 central values and Kristin's errors. What is the effect of adding this asymmetry data?

This is the HERAPDF uv and dv BEFORE adding any lepton asymmetry pesudo-data

The $\chi 2$/ndf is 574/582



And this is what it looks like if we add the lepton asymmetry pseudo-data.
The chisq/ndf is 579/587.. $\chi 2$/ndf=1 for the extra data points by construction

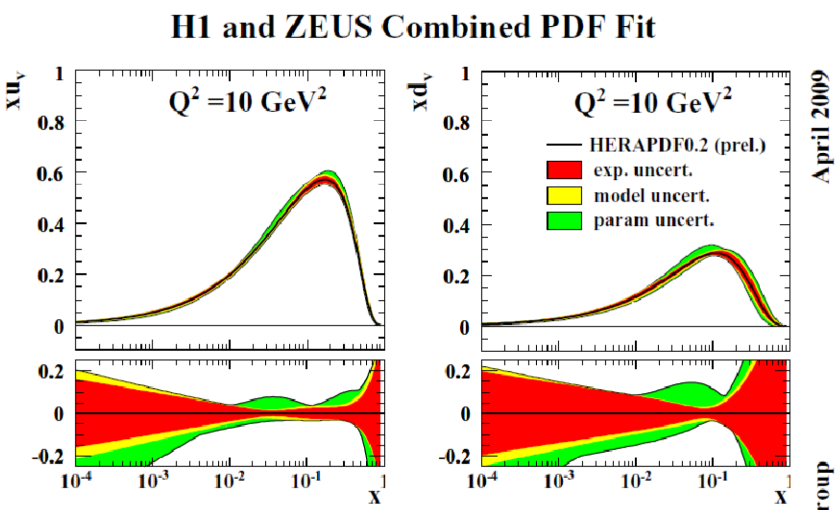


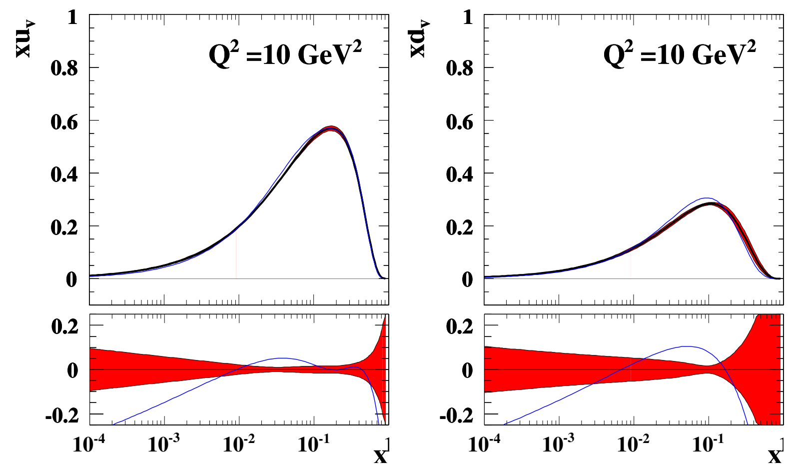
This shows only the experimental uncertainties on the PDFs: there is improvement by ~50% in the valence PDF uncertainties

But PDF uncertainties come from more than just the experimental sources.

Let's not dwell on the treatment of correlated errors, increased χ2 tolerances etc.

Just consider the parametrisation uncertainties





This is there HERAPDF1.0 with an envelope in green which covers uncertainties due to differing choices of the input parametrisation

Does the addition of lepton asymmetry pseudo-data help to reduce the size of this envelope?

NO

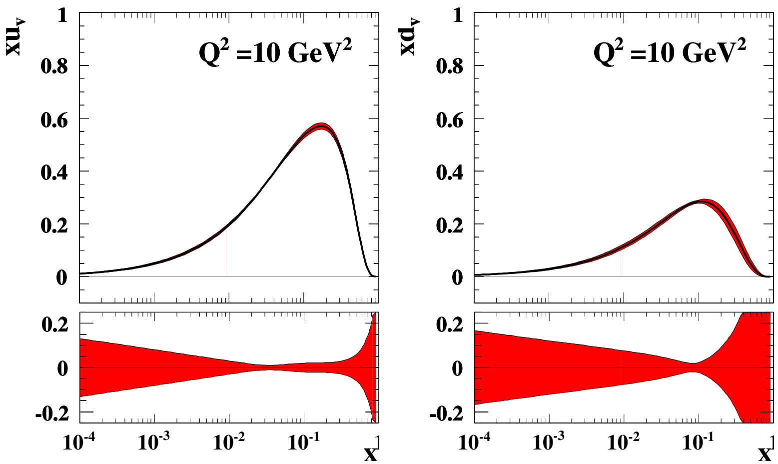
This is the PDF fit after including lepton asymmetry pseudo-data, with HERAPDF1.0 central values

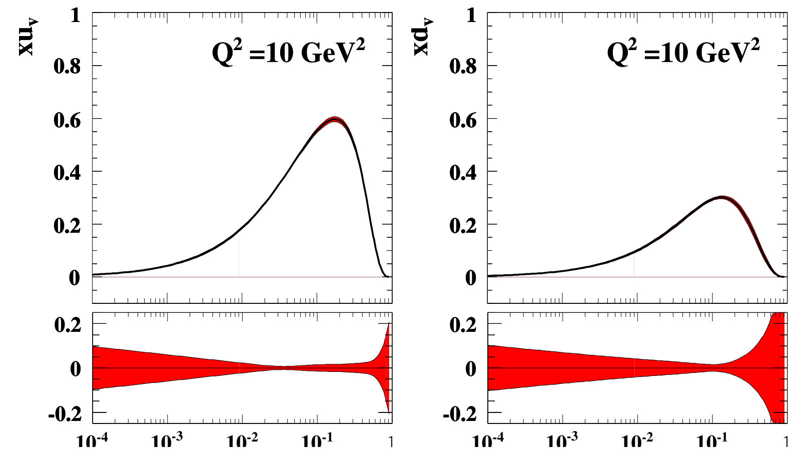
The blue line shows an extreme parametrisation variation. In this case it seems that the size of the envelope due to differing choices of parametrisation would not be reduced

Second CTEQ6.6 pseudo-data: the asymmetry has CTEQ6.6 central values and Kristin's errors. What is the effect of adding this asymmetry data?

This is the HERAPDF uv and dv BEFORE adding lepton asymmetry pseudo-data
The χ2/ndf is 574/582

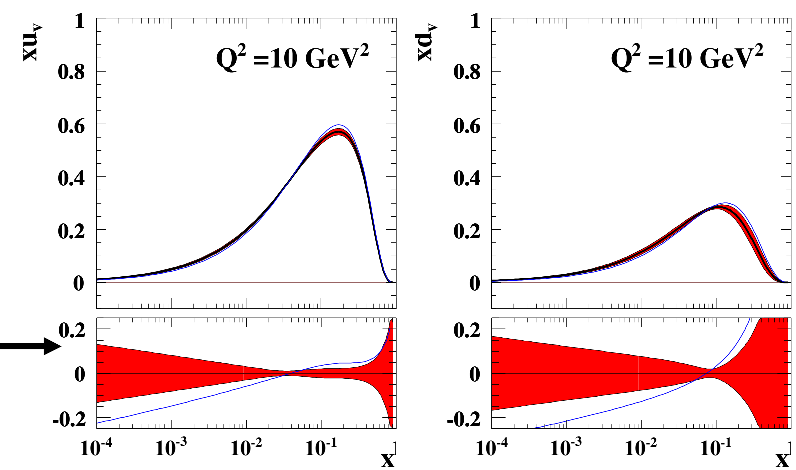
And this is what it looks like if we add the lepton asymmetry pseudo-data.
The χ2/ndf is 584/587.. χ2/ndf=6/5 for the extra data points, 578/582 for the old ones



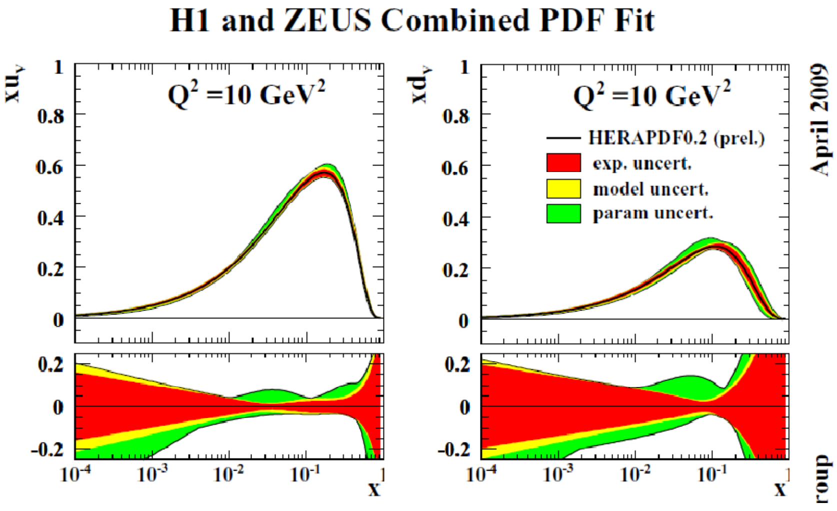


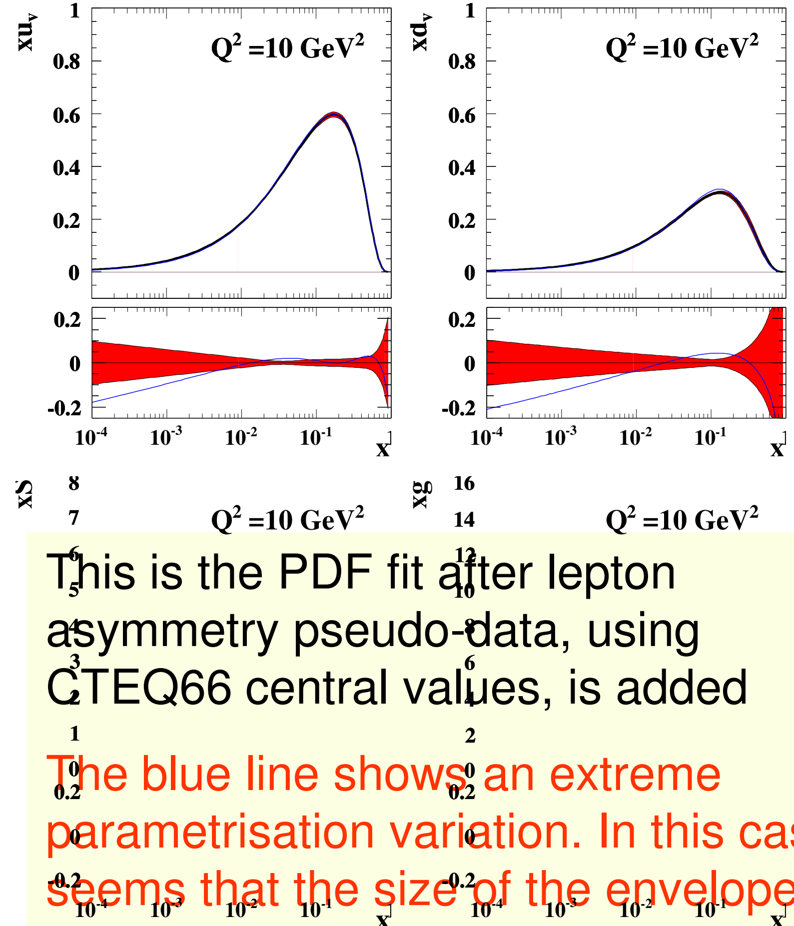
The experimental uncertainties on the valence PDFs decrease (just as they did for the HERAPDF pseudo-data).

But the fit has moved to a new central value, which is shown compared to the old central values as a blue line. It is outside the experimental error band but NOT outside the broader parametrisation uncertainties of the HERAPDF.



Let's consider the parametrisation uncertainties again





This is there HERAPDF1.0 with an envelope in green which covers uncertainties due to differing choices of the input parametrisation

Does the addition of lepton asymmetry pseudo-data help to reduce the size of this envelope?

YES

This is the PDF fit after lepton asymmetry pseudo-data, using CTEQ66 central values, is added

The blue line shows an extreme parametrisation variation. In this case it seems that the size of the envelope due to differing choices of parametrisation would be reduced

CONCLUSION

So the conclusion is that even with conservative estimates of systematic errors an 100pb^{-1} measurement of the W asymmetry should be useful.

But its not clear how much better it can get with more statistics because we are already becoming systematics limited- we ‘ll need to improve our knowledge of the QCD background

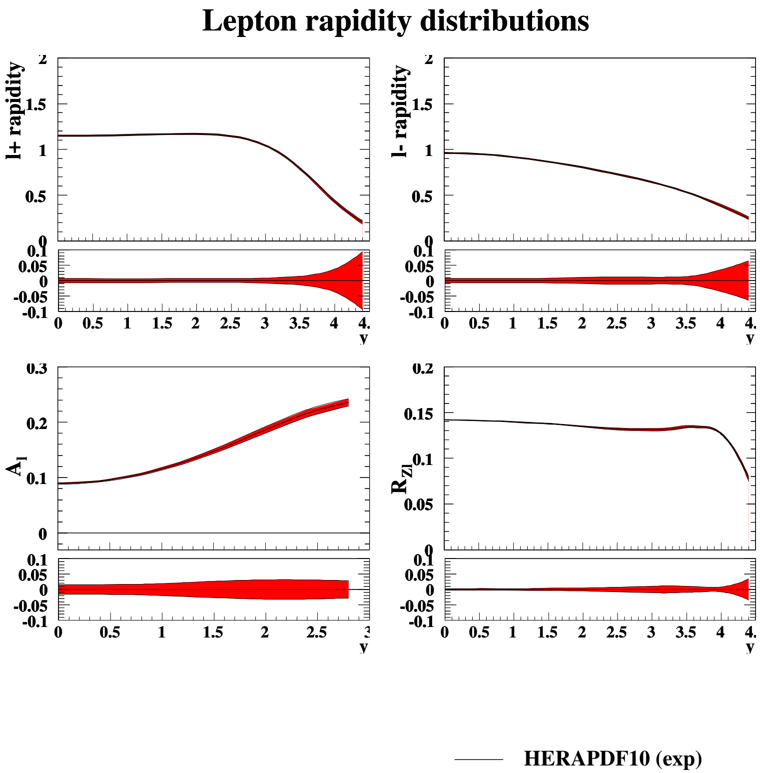
And as an aside:

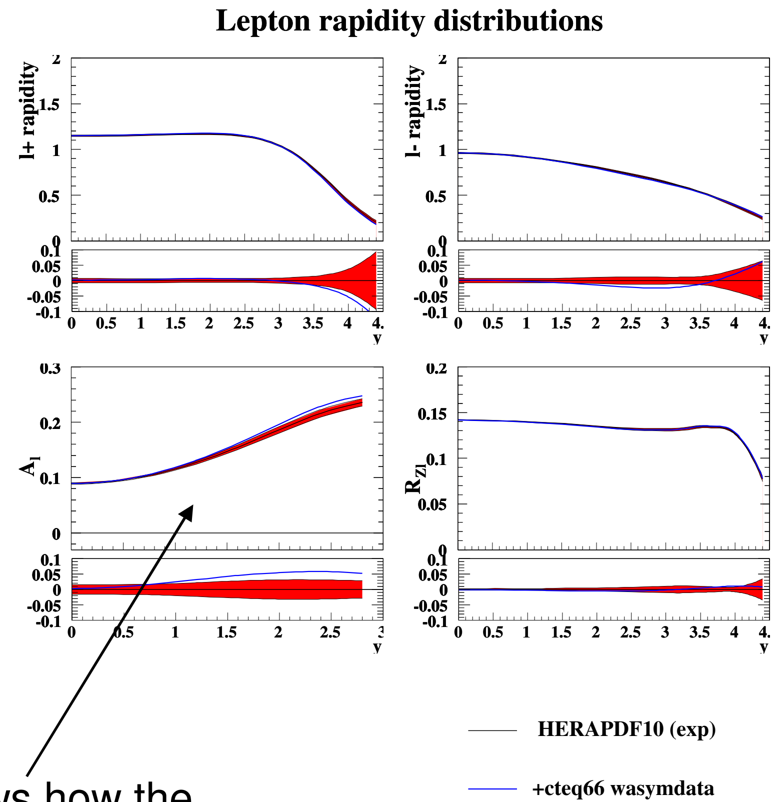
Why haven’t I shown you the results with MSTW08 based pseudo-data?

Because I can’t fit it with better than $\chi 2$/ndf=2

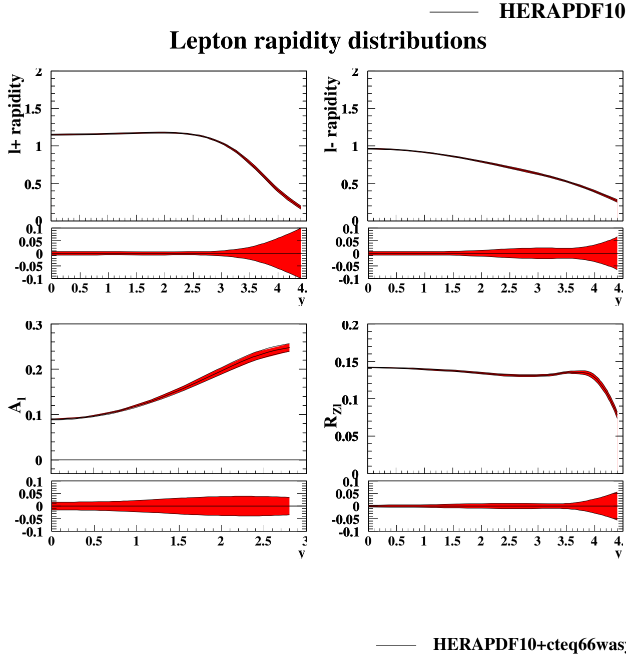
Even with 16 parameters in the fit!

extras





This shows how the CTEQ66 asymmetry data pulls the prediction of the HERAPDF up at large rapidity



Predictions for the lepton asymmetry from the before and after fits

But perhaps we need to look more closely at the difference in Δ=dbar-ubar . It is noticeable at high-x but there is still a small Δ at x~0.006 (ie y=0 for LHC at 14TeV)

Could this play a role?

Without assuming dbar=ubar but still LO

And still at y=0,

$$Aw = \frac{\bar{d}\,(u_v - d_v) + d_v\,\Delta}{\bar{d}\,(u_v + d_v + 2\bar{d}) - 2\bar{d}\Delta - d_v\Delta}$$

Where Δ=0.016 for CTEQ

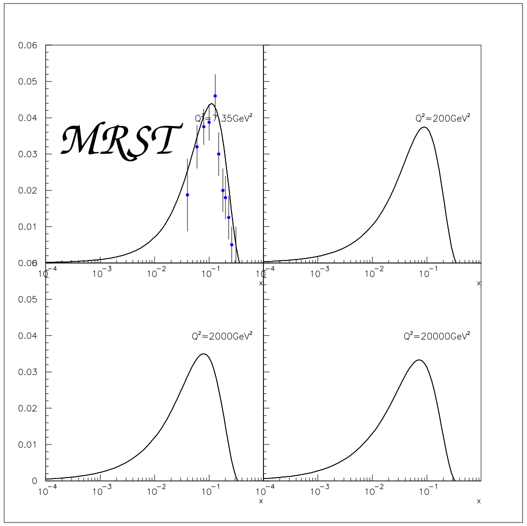
$$Aw = \frac{0.7x(0.06) + 0.11x0.016}{0.7X(1.68) - 2x0.7x0.016 - 0.11x0.016}$$

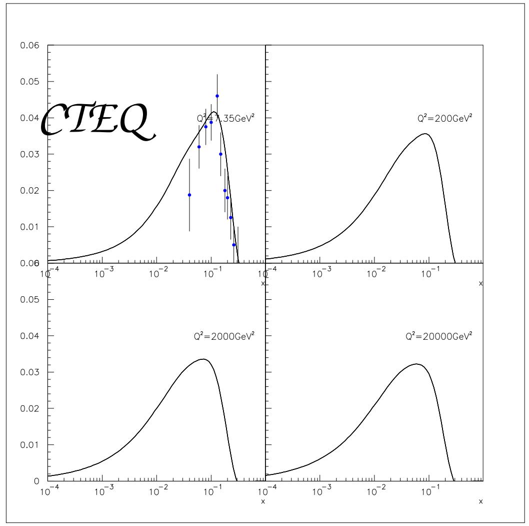
And Δ=0.010 for MRST

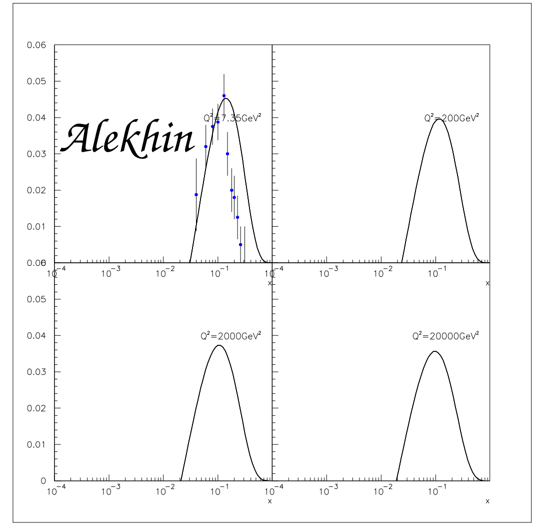
$$AW = \frac{0.7x(0.045) + 0.11x0.011}{0.7x(1.665) - 2x0.7x0.011 - 0.11x0.011}$$

The terms involving the difference of ubar and dbar are simply too small to matter compared to the terms involving the valence difference.

But it is possible that dbar and ubar could be more different for other PDFs

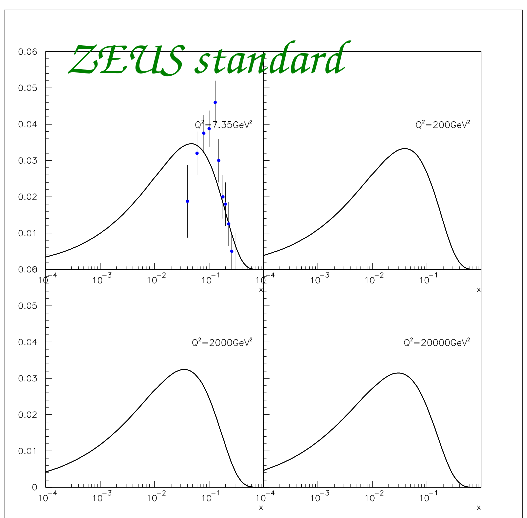


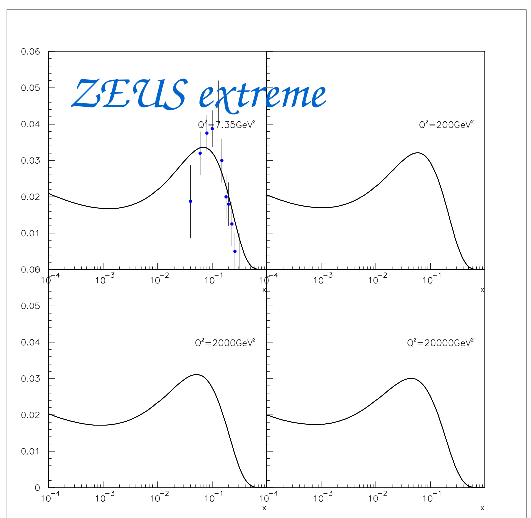




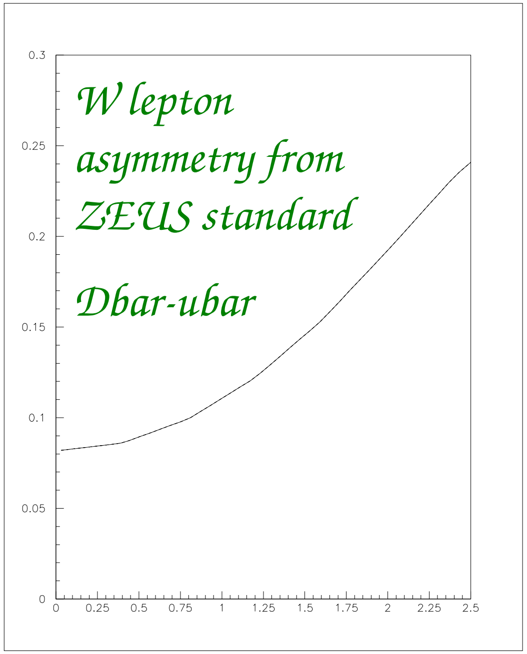
There are many difference between these PDF sets so I have made two toy PDFs (based on ZEUS-S) in which the only difference is dbar-ubar as $x \rightarrow 0$. Standard dbar-ubar = $0.24\, x^{0.5} (1-x)^9$ at $Q^2_0 \sim 7$ GeV2 and

Extreme dbar-ubar = 0.005x-0.16(1-x)13 (1+100x) at Q20 ~ 7 GeV2





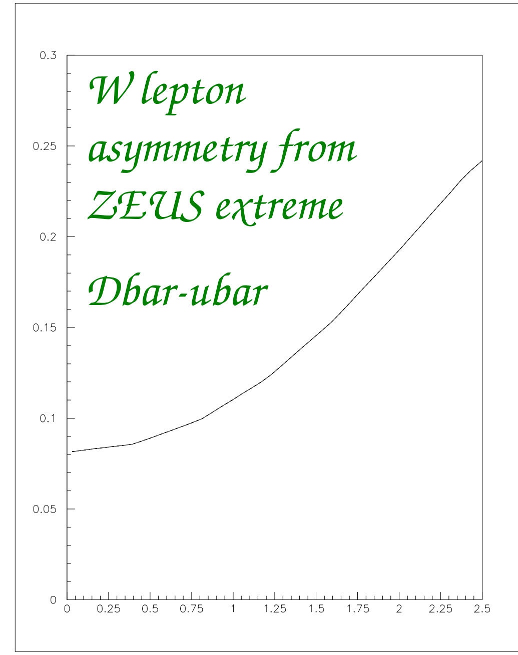
ALL with E866 dbar-ubar data superimposed

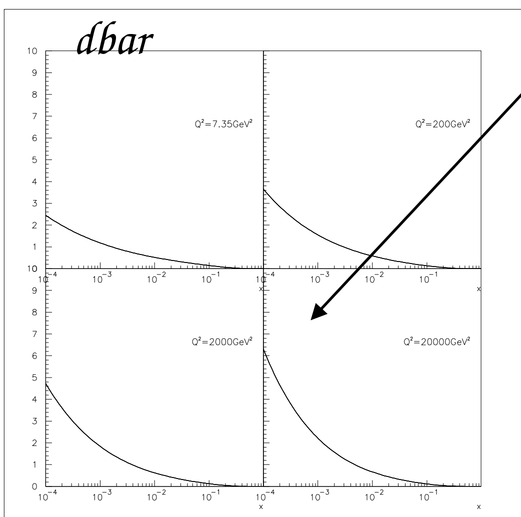


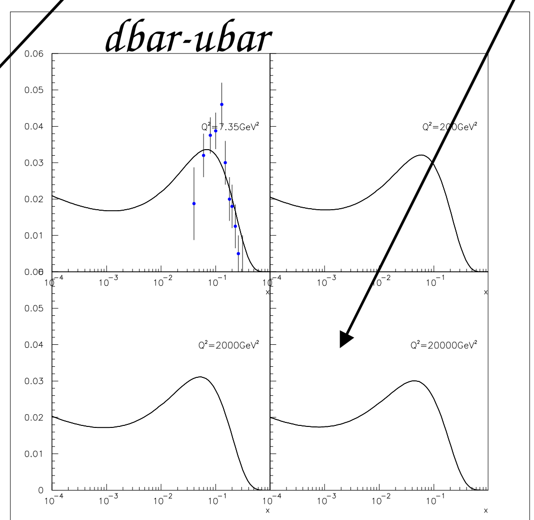
Clearly even this more extreme difference in dbar-ubar has had no visible impact on the lepton asymmetry

The basic reason is that dbar and ubar are themselves quite large ~ O(1) at x=0.006 and $Q2=M_W^{2}$- since they have evolved from small values at low Q2 BUT

The difference dbar-ubar has become relatively negligible - $O(10^{-2})$ because it does NOT evolve – we could only see it if we could measure at the sub percent level of accuracy-







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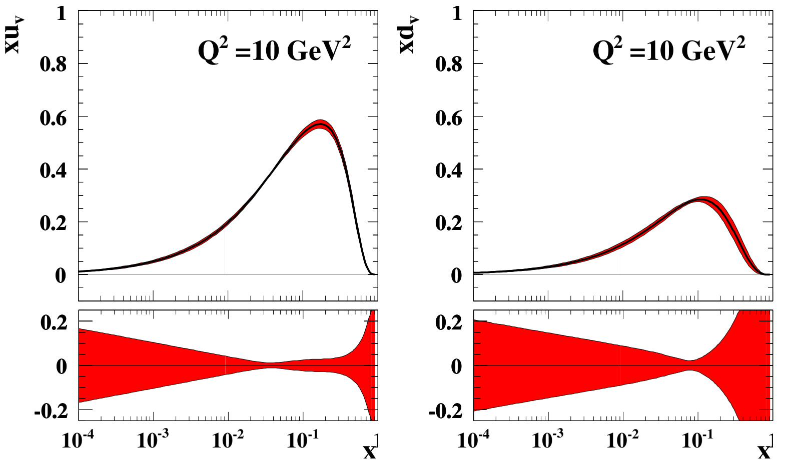
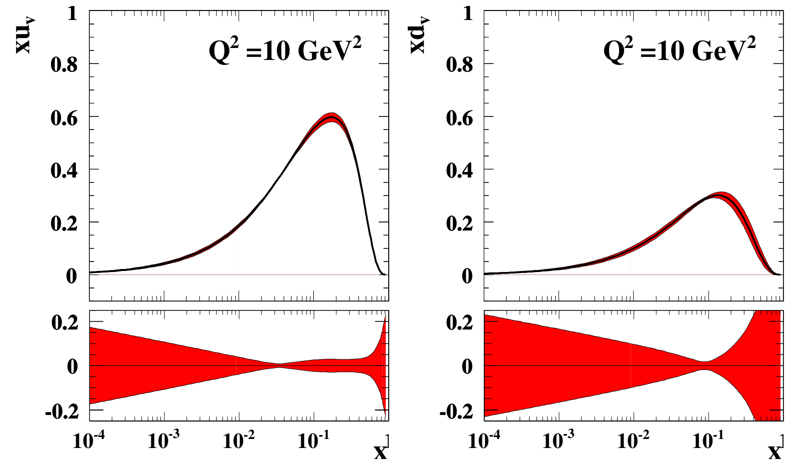
A large difference in dbar-ubar at $Q2=MW^2$ would involve putting it in as similarly large at the starting scale Q2~ 7 GeV2 –incredible fine tuning

For ZEUS- extreme

Without asymmetry pseudo-data



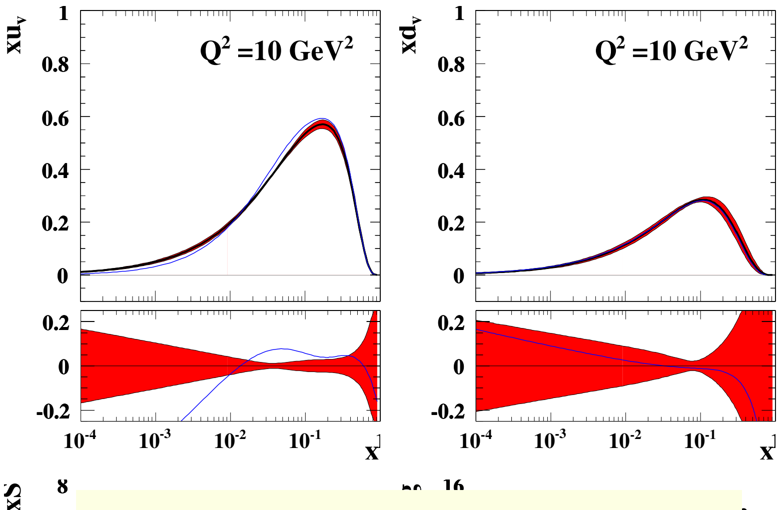
With asymmetry pseudo-data



In this comparison the correlated experimental errors of the asymmetry measurement have been OFFSET. Then the improvement due to this data is not so clear. BUT still it is interesting to consider parametrisation uncertainty.

Alternative parametrisation

Used for the fit to CTEQ66 asymmetry pseudo-data



4 extra free params in valence- get chisq 566 for old and 6 for new