Brief CTEQ update

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New from CTEQ-TEA (Tung et al)->CT10 PDFs

- Combined HERA-1 data
- CDF and D0 Run-2 inclusive jet data
- Tevatron Run 2 Z rapidity from CDF and D0
- W electron asymmetry from CDFII and D0II (D0 muon asymmetry) (in CT10W)
- Other data sets same as CTEQ6.6
- All data weights set to unity (except for CT10W)
- Tension observed between D0 II electron asymmetry data and NMC/BCDMS data
- Tension between D0 II electron and muon asymmetry data
- Experimental normalizations are treated on same footing as other correlated systematic errors
- More flexible parametrizations: 26 free parameters (26 eigenvector directions)
- Tolerance: look for 90% CL along each eigenvector direction
  - within the limits of the quadratic approximation, can scale between 68% and 90% CL with naïve scaling factor
- Two series of PDF's are introduced
  - CT10: no Run 2 W asymmetry
  - CT10W: Run 2 W asymmetry with an extra weight
- See arXiv:1007.2241

Impact of new HERA data on fit

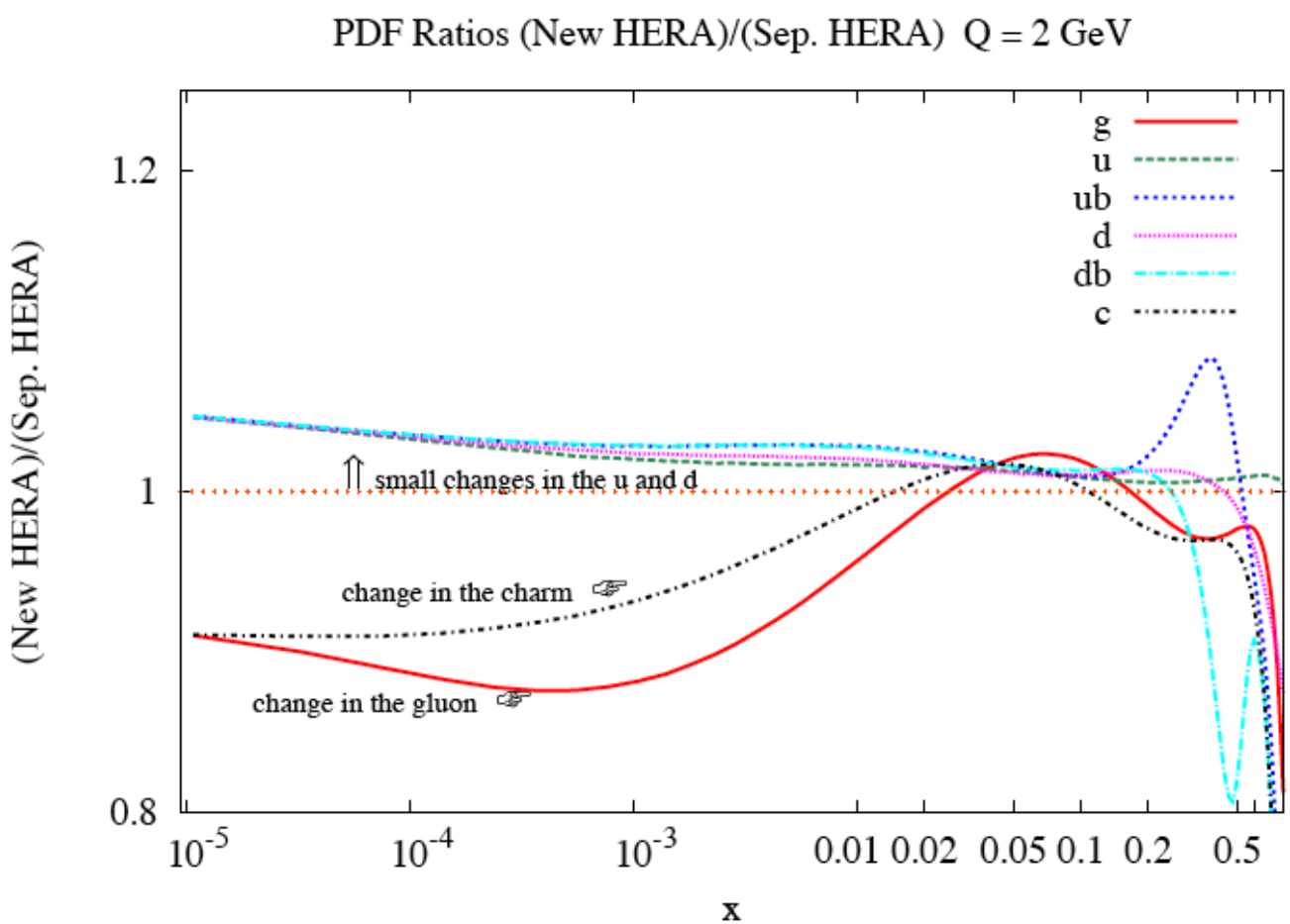
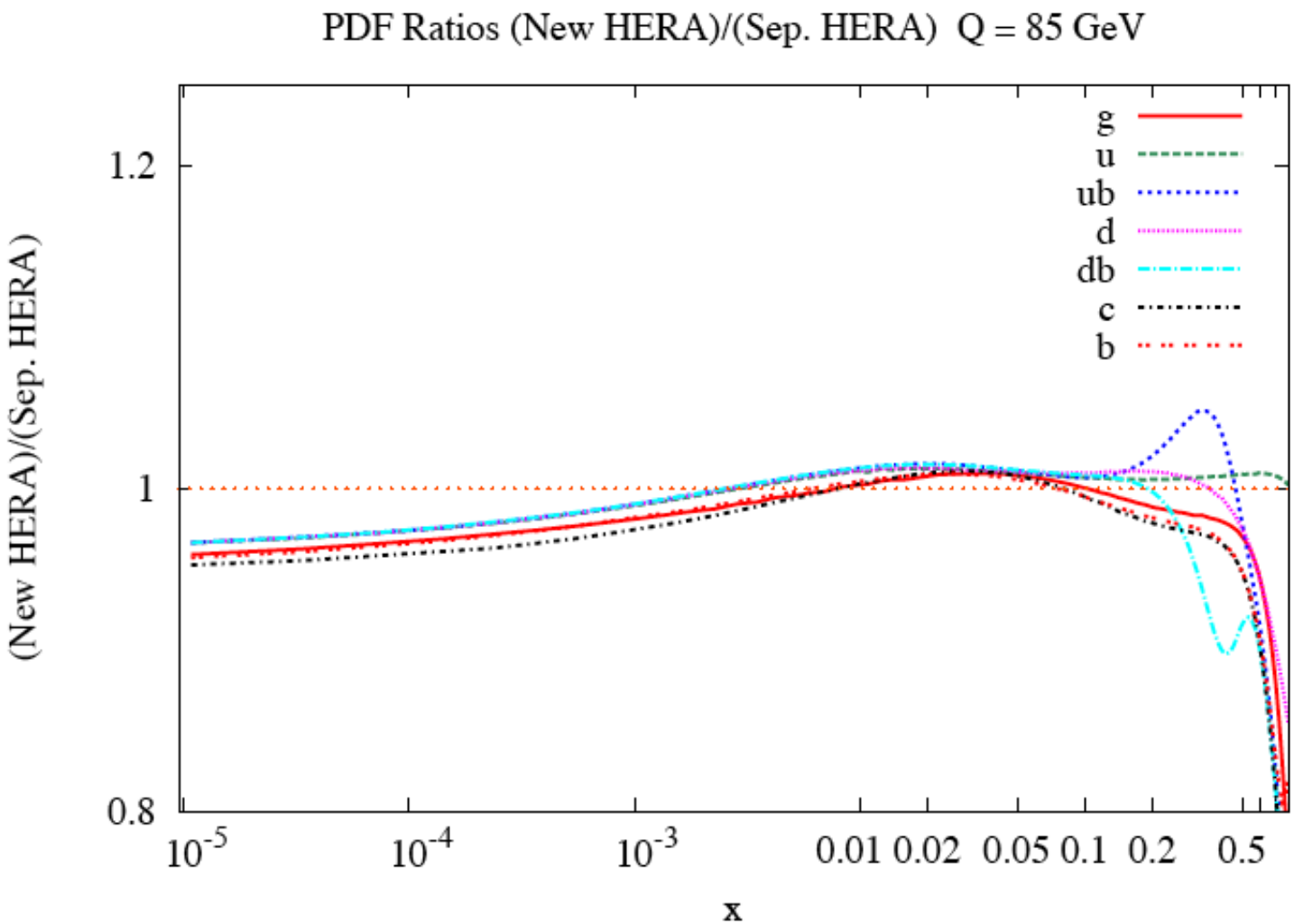


Figure: PDF Ratios: (CT10 with the new HERA Run I data vs (CT10 with the separate HERA data)) for $Q = 2$ GeV.



Smaller changes at 85 GeV

Impact of HERA data on gluon uncertainty

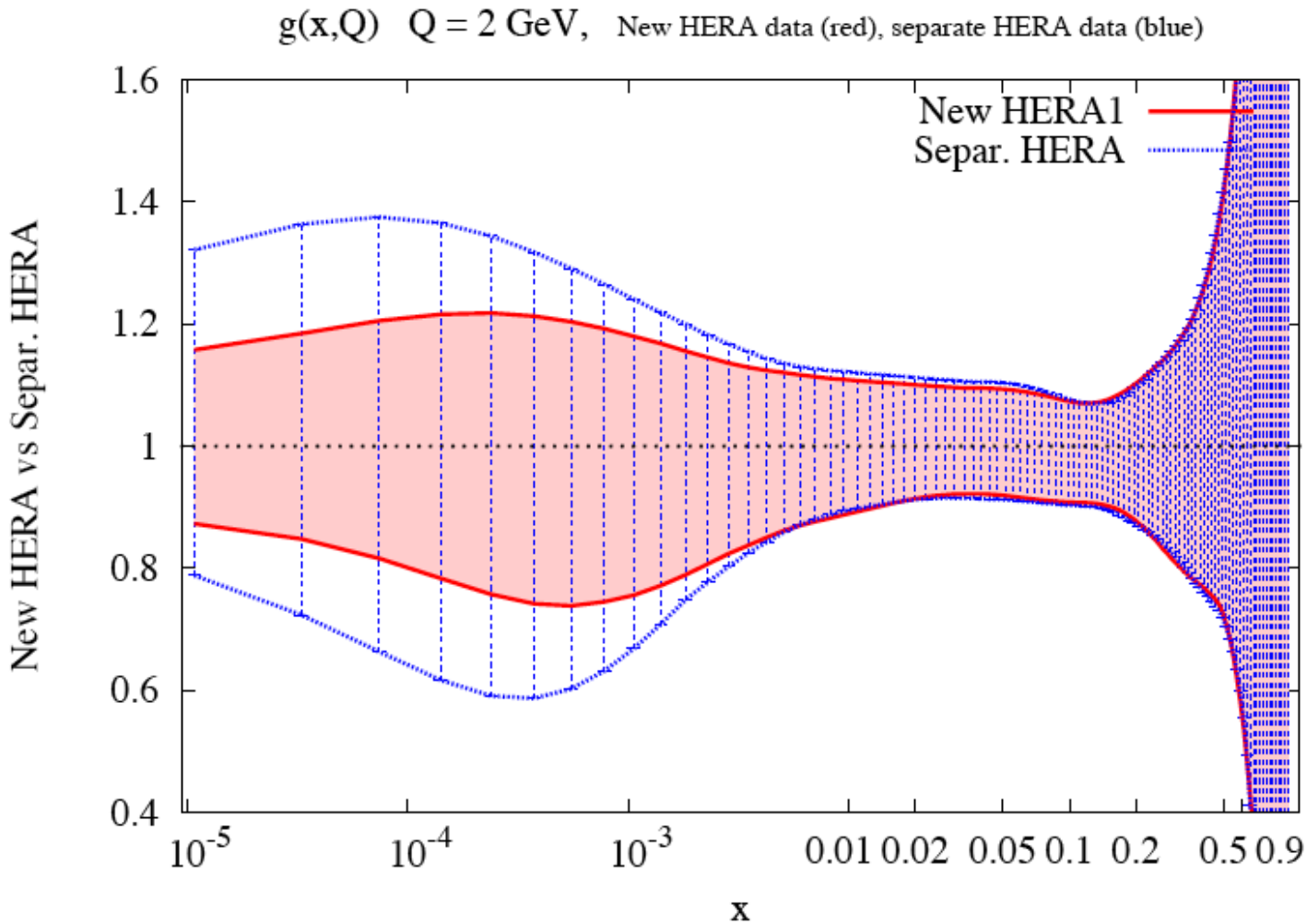
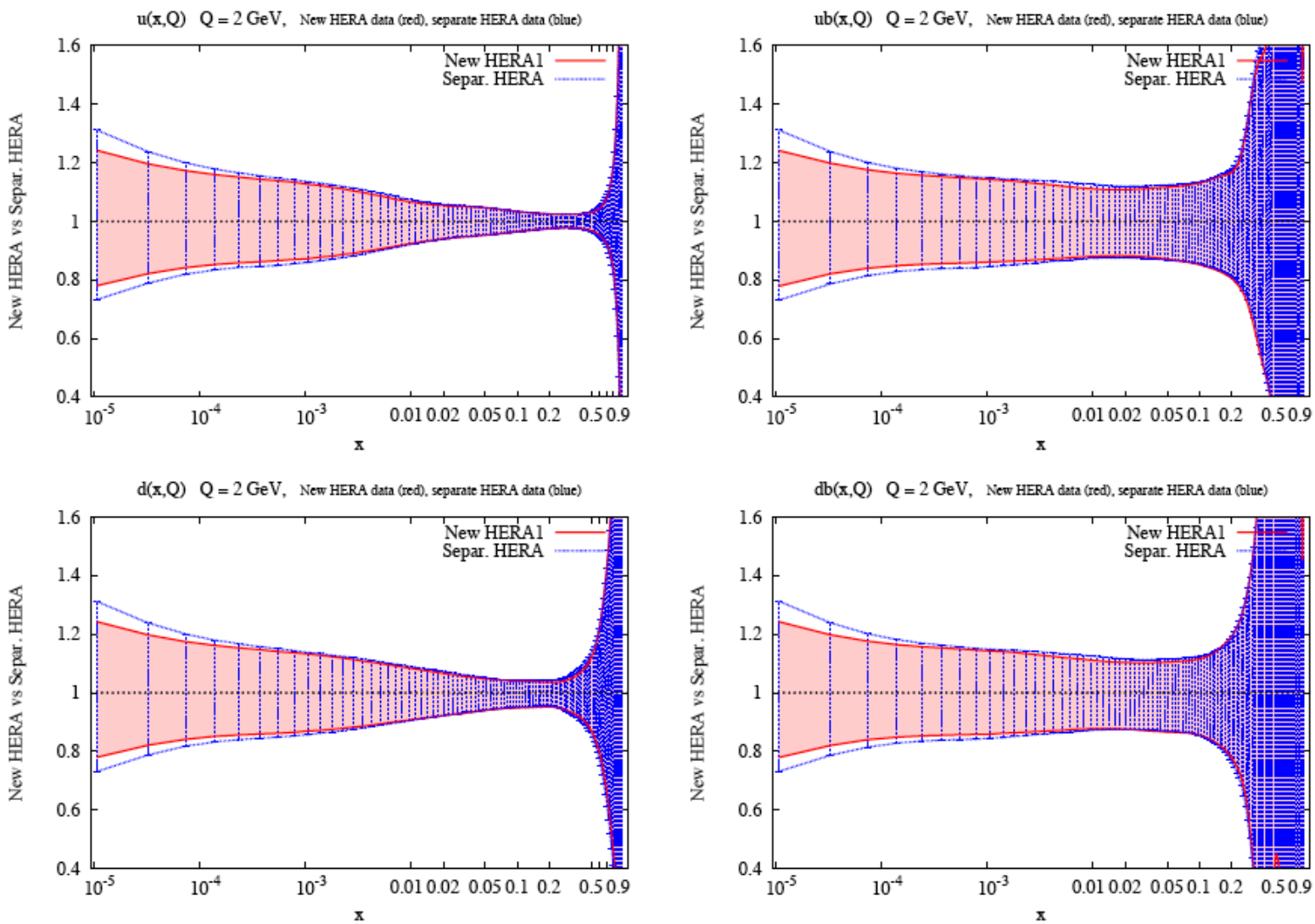


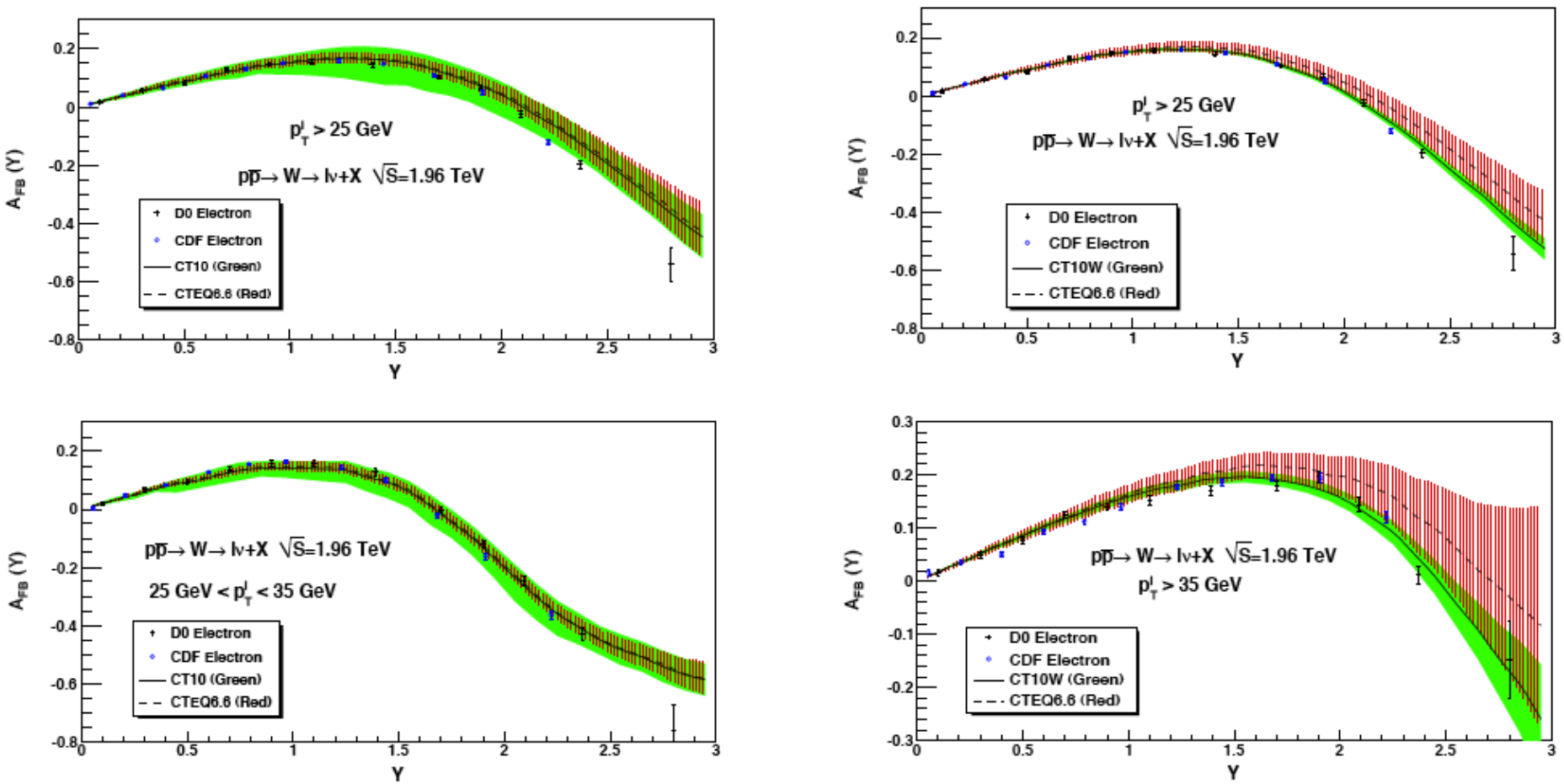
Figure: Error bands: (red) CT10 new HERA Run I data, (blue) CT10 with the separate HERA data. $g(x)$, $Q = 2$ GeV.

Impact of new HERA data on light quark uncertainties

$u, \bar{u}, d, \bar{d}$



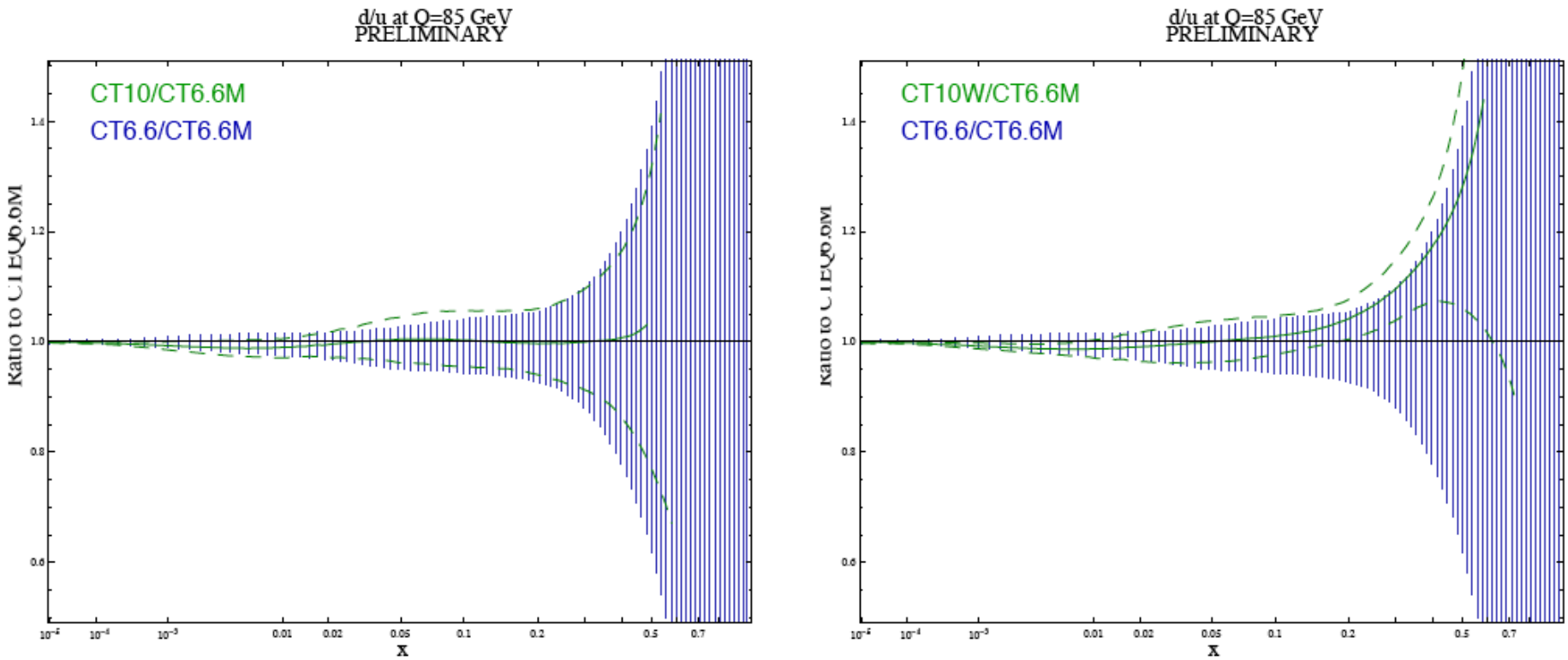
CT10 and CT10W fits with Tevatron Run-2 data



CT10W agrees better with W asy data; has smaller uncertainty than CTEQ6.6/CT10

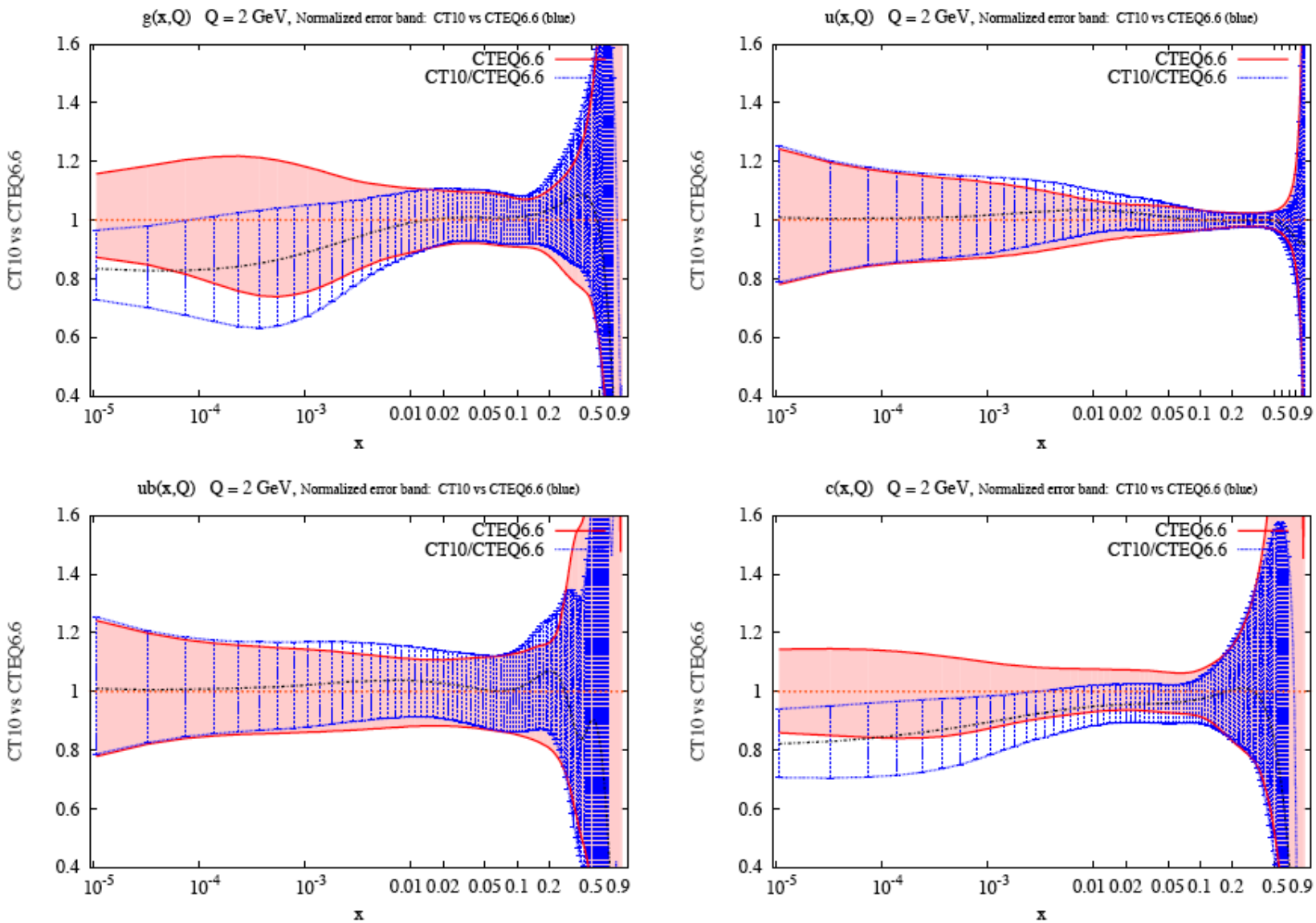
CT1OW vs CTEQ6.6

$d(x,Q)/u(x,Q)$ **at** $Q = 85$ **GeV**



CT10W prefers larger d/u, has smaller uncertainty

CT10 vs CTEQ6.6

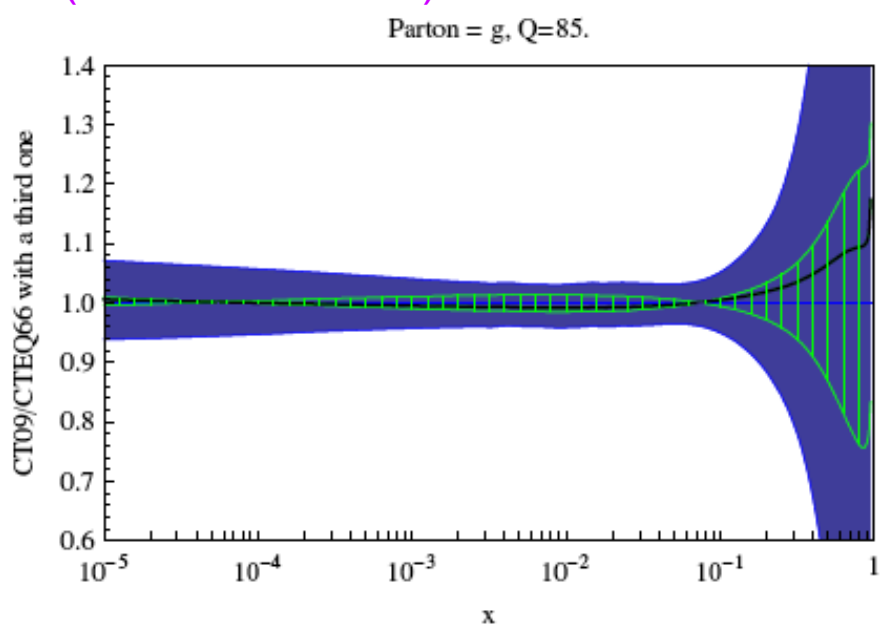


For CTEQ: α_s series

- Take CTEQ6.6 as base, and vary α_s (m_Z) +/-0.002 (in 0.001 steps) around central value of 0.118
- Blue is the PDF uncertainty from eigenvectors; green is the uncertainty in the gluon from varying α_s
- We have found that change in gluon due to α_s error (+/-0.002 range) is typically smaller than PDF uncertainty with a small correlation with PDF uncertainty over this range
  - as shown for gluon distribution on right
- **PDF error and α_s error can be added in quadrature**
  - expected because of small correlation
  - in recent CTEQ paper, it has been proven this is correct regardless of correlation, within quadratic approximation to χ^2 distribution

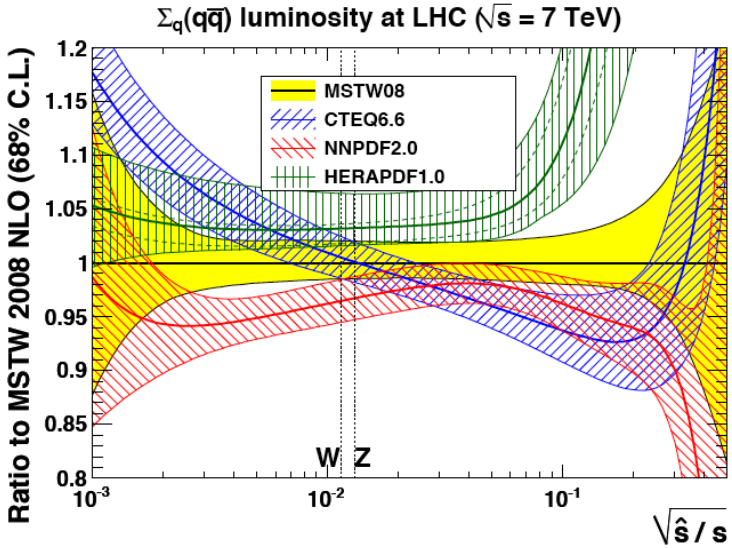
arXiv:1004.4624; PDFs available from LHAPDF

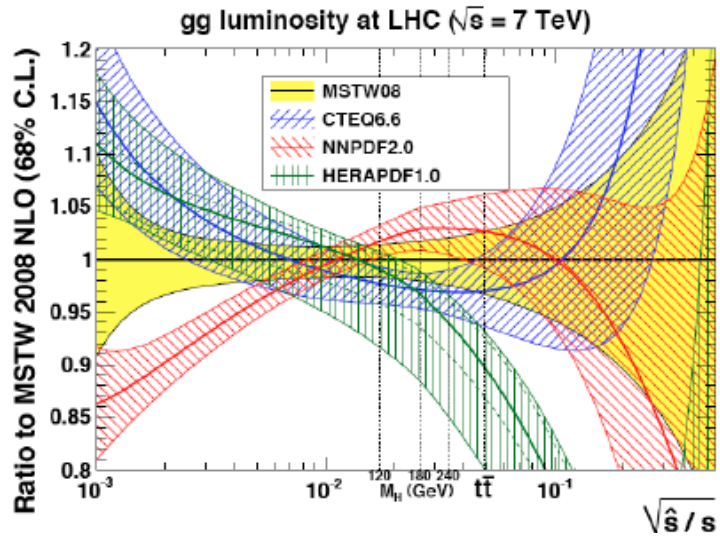
So the CTEQ prescription for calculating the total uncertainty (PDF+α_s) involves the use of the 45 CTEQ6.6 PDFs and the two extreme α_s error PDF's (0.116 and 0.120)

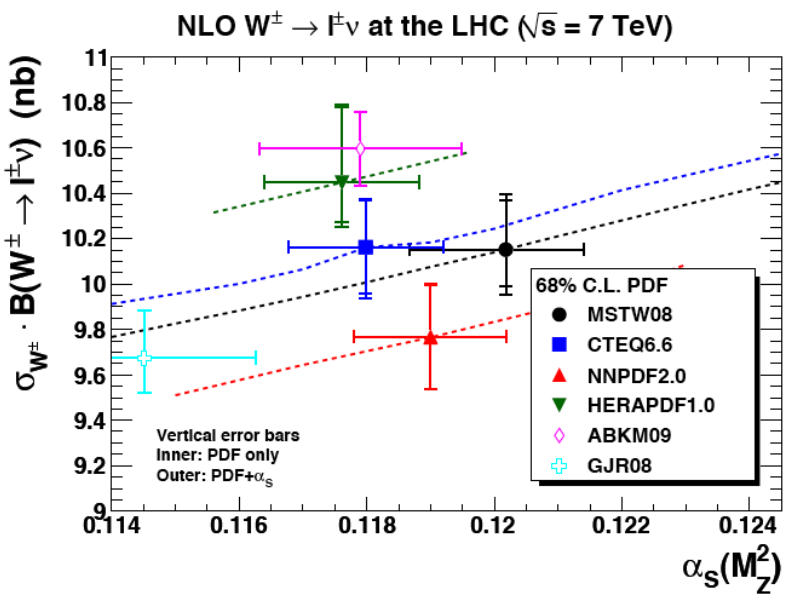


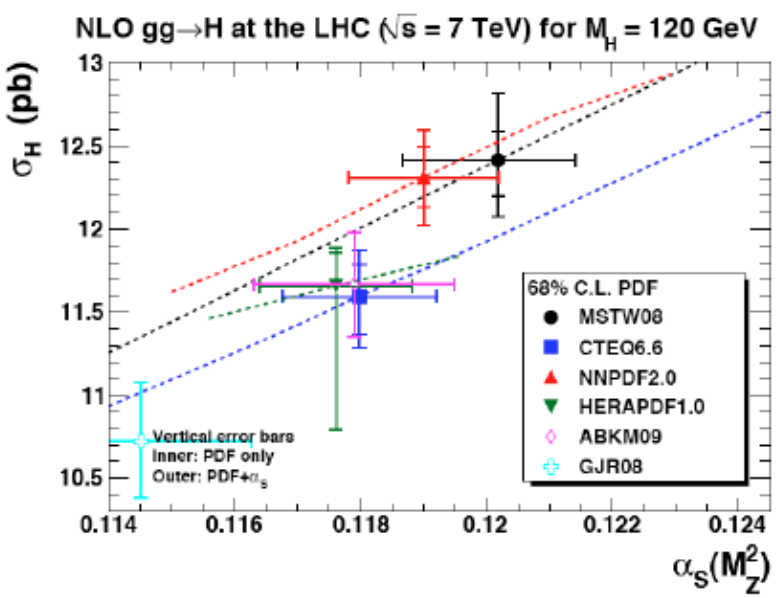
This also means that one can naively scale between 68% and 90% CL.

Some results from the benchmarking









Tables from note

$\alpha_s(m_Z)$	$\sigma_{W^+} * BR(W^+ \to l^+\nu)$[nb]	$\sigma_{W^-} * BR(W^- \to l^-\nu)[nb]$	$\sigma_{Z^o} * BR(Z^o \to l^+l^-)[nb]$
0.116	5.957	4.044	0.9331
0.117	5.993	4.068	0.9384
0.118	**6.057**	**4.106**	**0.9469**
0.119	6.064	4.114	0.9485
0.120	6.105	4.139	0.9539

Table 1: Benchmark cross section predictions for CTEQ6.6 for $W^\pm, Z, t\bar{t}$ production at 7 TeV, as a function of $\alpha_s(m_Z)$. The results for the central value of $\alpha_s(m_Z)$ for CTEQ6.6 (0.118) are shown in bold.

Process	Cross section	PDF errors (asym)	PDF errors (sym)	$\alpha_s(m_Z)$ error	combined	correlation
$\sigma_{W^+} * BR(W^+ \to l^+\nu)[nb]$	6.057	+0.123/-0.119	0.116	0.045	0.132	0.87
$\sigma_{W^-} * BR(W^- \to l^-\nu)[nb]$	4.106	+0.088/-0.091	0.088	0.029	0.092	0.92
$\sigma_{Z^o} * BR(Z^o \to l^+l^-)[nb]$	0.9469	+0.018/-0.018	0.018	0.006	0.0187	1.00
$\sigma_{t\bar{t}}[pb]$	156.2	+7.0/-6.7	6.63	4.59	8.06	-0.74
$\sigma_{gg\to Higgs}(120GeV)[pb]$	11.59	+0.19/-0.23	0.21	0.20	0.29	0.01
$\sigma_{gg\to Higgs}(180GeV)[pb]$	4.840	+0.077/-0.091	0.084	0.091	0.124	-0.47
$\sigma_{gg\to Higgs}(240GeV)[pb]$	2.610	+0.054/-0.058	0.056	0.055	0.078	-0.73

Table 3: Benchmark cross section predictions and uncertainties for CTEQ6.6 for $W^\pm, Z, t\bar{t}$ and Higgs production (120, 180, 240 GeV) at 7 TeV. The central prediction is given in column 2. Errors are quoted at the 68% c.l.. (For CTEQ6.6, this involves dividing the normal 90%c.l. errors by a factor of 1.645. Both the symmetric and asymmetric forms for the PDF errors are given. In the next-to-last column, the (symmetric) form of the PDF and $\alpha_s(m_Z)$ errors are added in quadrature. In the last column, the correlation cosine with respect to Z production is given.

see corr.C

Table from note

y_W	$\frac{d\sigma_{W+}}{dy} * BR$	PDF Error	$\frac{d\sigma_{W-}}{dy} * BR$	PDF Error	$\frac{d\sigma_{Z^o}}{dy} * BR$	PDF Error
-4.4	0.002	0.0005	0.000	0.0003	0.000	0
-4.0	0.094	0.006	0.019	0.0063	0.005	0.00032
-3.6	0.367	0.013	0.122	0.0126	0.031	0.00109
-3.2	0.634	0.016	0.274	0.013	0.071	0.00184
-2.8	0.806	0.0187	0.414	0.0128	0.106	0.00235
-2.4	0.878	0.019	0.517	0.0131	0.127	0.00255
-2.0	0.886	0.018	0.597	0.0134	0.141	0.00255
-1.6	0.883	0.018	0.653	0.0144	0.148	0.00286
-1.2	0.867	0.020	0.697	0.017	0.155	0.00347
-0.8	0.862	0.023	0.723	0.02	0.166	0.00408
-0.4	0.855	0.025	0.739	0.023	0.161	0.00469
0.0	0.864	0.026	0.750	0.0236	0.162	0.0049
0.4	0.854	0.025	0.740	0.0226	0.161	0.00479
0.8	0.865	0.023	0.728	0.020	0.158	0.00418
1.2	0.870	0.020	0.690	0.0167	0.155	0.00347
1.6	0.882	0.018	0.654	0.0144	0.148	0.00286
2.0	0.890	0.018	0.606	0.0134	0.141	0.00265
2.4	0.872	0.019	0.508	0.0128	0.114	0.0025
2.8	0.806	0.019	0.416	0.0128	0.106	0.00235
3.2	0.640	0.016	0.274	0.0128	0.071	0.00184
3.6	0.364	0.013	0.120	0.0127	0.031	0.00109
4.0	0.095	0.006	0.023	0.0064	0.005	0.00031
4.4	0.003	0.0005	0.000	0.00029 0	0.000	0

Table 4: Benchmark cross section predictions ($d\sigma/dy * BR$ in nb) for CTEQ6.6 for $W^{\pm}, Z^o$ production at 7 TeV, as a function of boson rapidity.

W/Z rapidities and uncertainties

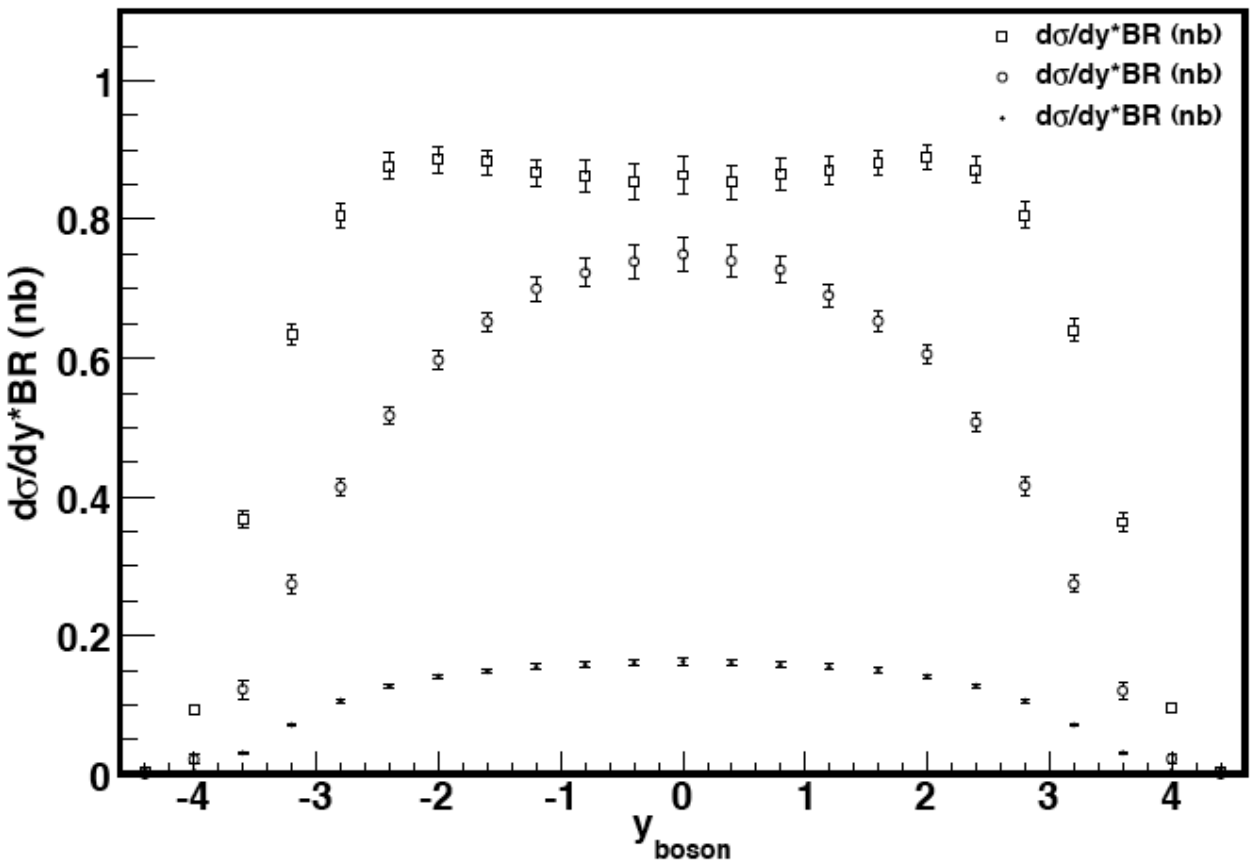
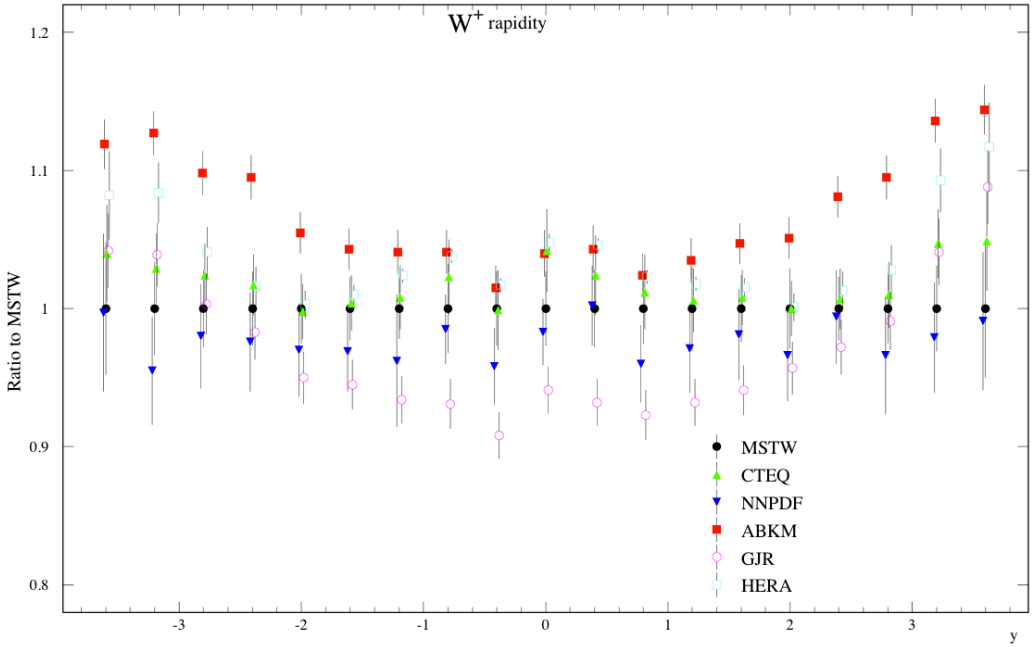
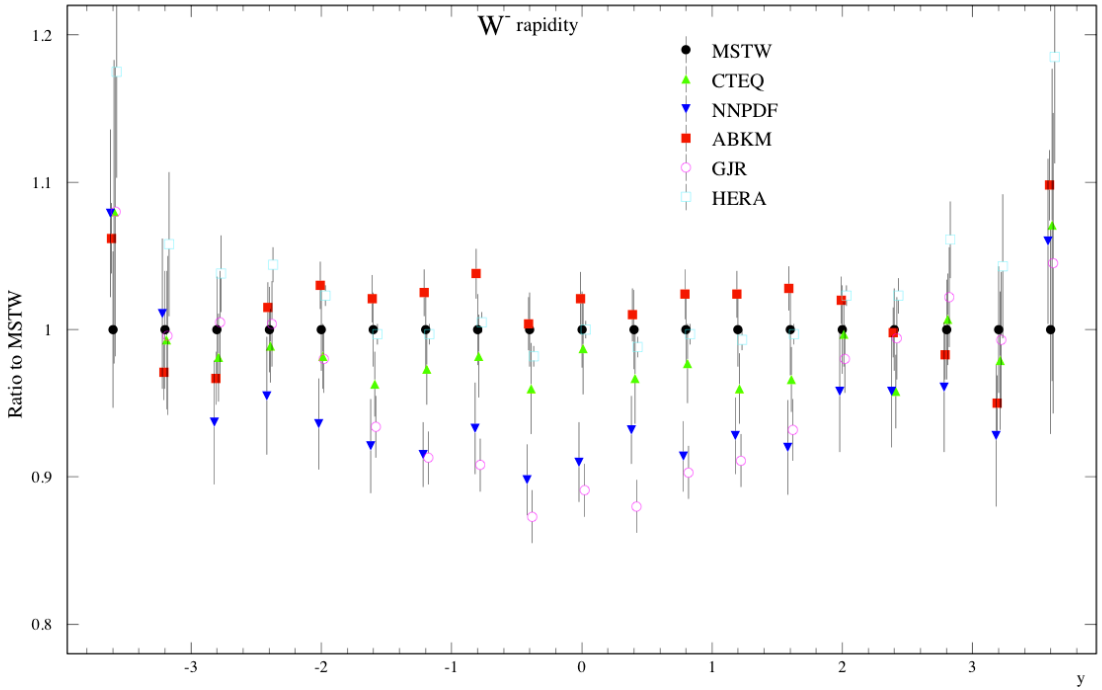


Fig. 10: The W^+, W^- and Z cross sections at 7 TeV (along with the PDF uncertainties) as a function of rapidity for the CTEQ6.6 PDFs. The error bars indicate the PDF uncertainties.


W+ rapidity
Ratio to MSTW
y
MSTW
CTEQ
NNPDF
ABKM
GJR
HERA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Ratio to MSTW
y
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HERA

Summary

- CTEQ6.6 PDFs are most commonly used
- CT10 is most recent update (LO,NLO)
- CT09MC1,CT09MC2, CT09MCS are modified LO PDFs
- All of above are available from CTEQ webpage or from LHAPDF
- NNLO in progress
- Combined (q_T+x) PDFs in progress

Correlations

- Consider a cross section X(a)
- i^{th} component of gradient of X is

$$\frac{\partial X}{\partial a_i} \equiv \partial_i X = \frac{1}{2}(X_i^{(+)} - X_i^{(-)})$$

- Now take 2 cross sections X and Y
  - or one or both can be pdf's
- Consider the projection of gradients of X and Y onto a circle of radius 1 in the plane of the gradients in the parton parameter space
- The circle maps onto an ellipse in the XY plane
- The angle ϕ between the gradients of X and Y is given by

$$\cos\varphi = \frac{\vec{\nabla}X \cdot \vec{\nabla}Y}{\Delta X \Delta Y} = \frac{1}{4\Delta X\,\Delta Y}\sum_{i=1}^{N}\left(X_i^{(+)} - X_i^{(-)}\right)\left(Y_i^{(+)} - Y_i^{(-)}\right)$$

- The ellipse itself is given by

$$\left(\frac{\delta X}{\Delta X}\right)^2 + \left(\frac{\delta Y}{\Delta Y}\right)^2 - 2\left(\frac{\delta X}{\Delta X}\right)\left(\frac{\delta Y}{\Delta Y}\right)\cos\varphi = \sin^2\varphi$$

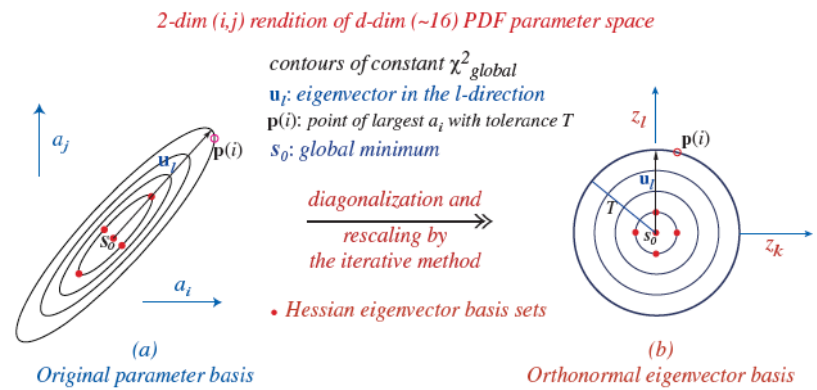


Figure 28. A schematic representation of the transformation from the pdf parameter basis to the orthonormal eigenvector basis.

- If two cross sections/pdf's are very correlated, then cosϕ~1
- …uncorrelated, then cosϕ~0
- …anti-correlated, then cosϕ~-1

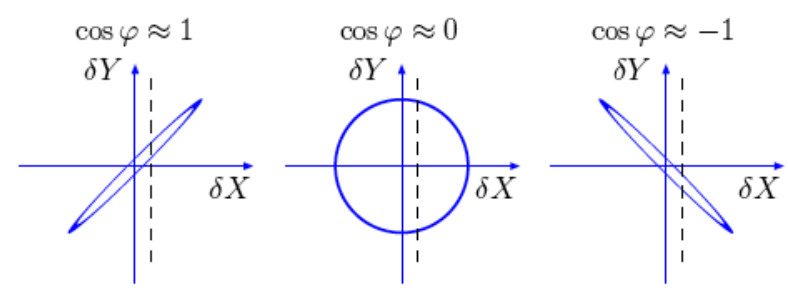
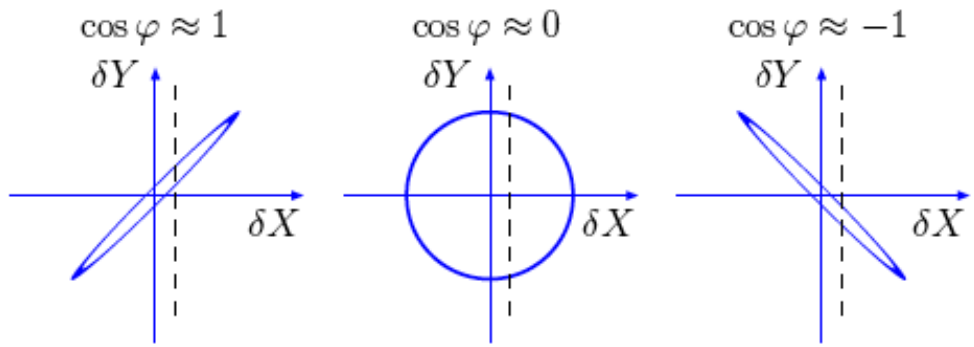


Figure 1: Dependence on the correlation ellipse formed in the $\Delta X - \Delta Y$ plane on the value of the correlation cosine $\cos\varphi$.

Correlations

Define a correlation cosine between two quan



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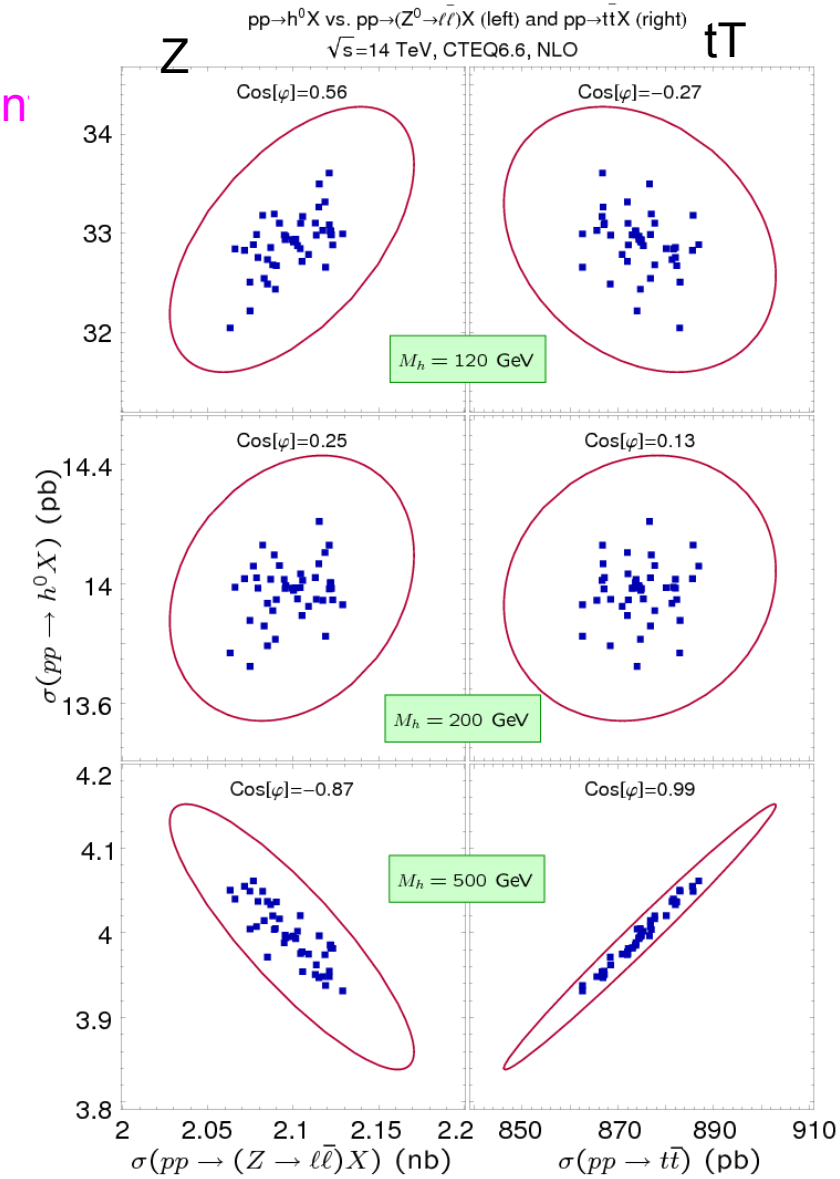
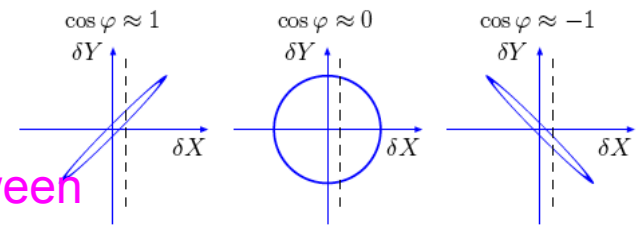


Correlations with Z, tT

Define a correlation cosine between two quantities



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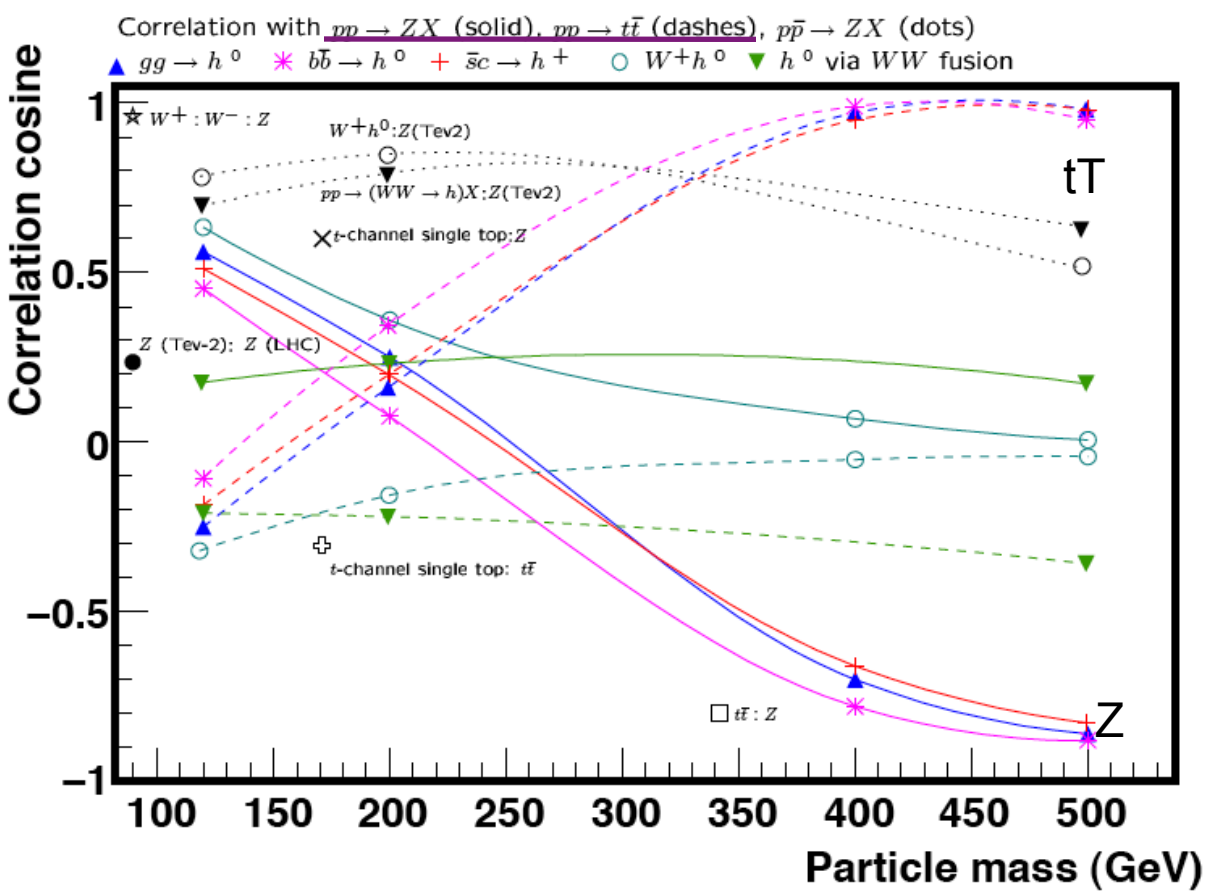

- If two cross sections are very correlated, then cosϕ~1
- …uncorrelated, then cosϕ~0
- …anti-correlated, then cosϕ~-1

- Note that correlation curves to Z and to tT are mirror images of each other

- By knowing the pdf correlations, can reduce the uncertainty for a given cross section in ratio to a benchmark cross section **iff** cos ϕ > 0;e.g. $\Delta(\sigma_{W^+}/\sigma_Z)$~1%

- If cos ϕ < 0, pdf uncertainty for one cross section normalized to a benchmark cross section is larger

- So, for gg->H(500 GeV); pdf uncertainty is 4%; $\Delta(\sigma_H/\sigma_Z)$~8%