Use of ePump to update PDFs for precision measurement of the weak mixing angle

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*on behalf of the ResBos+CTEQ+ePump working group**
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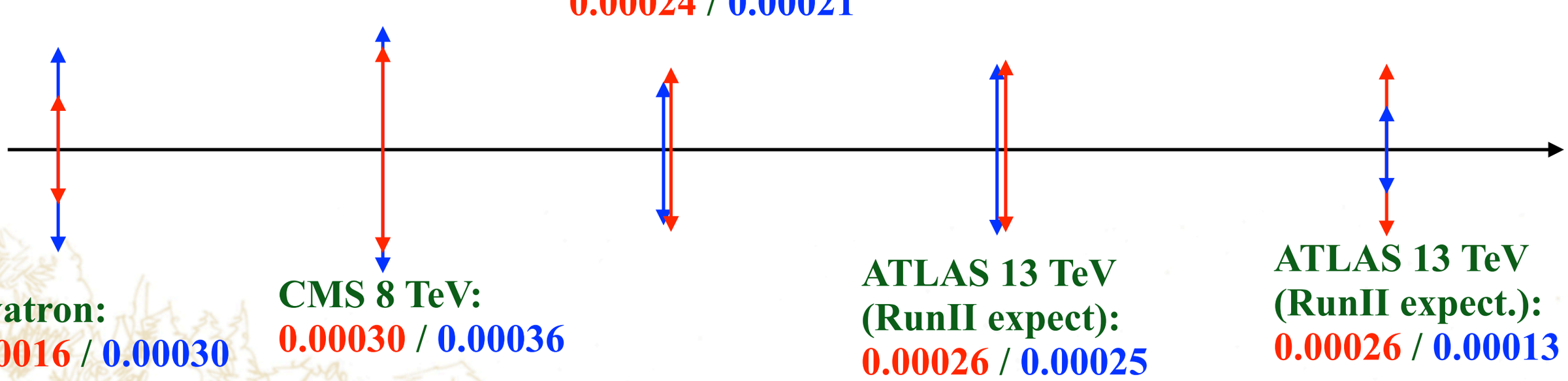
PDF unc. in the weak mixing angle measurement

The leading unc. in the future hadron collider experiments

- **Blue: statistical uncertainty**
- **Red: PDF uncertainty**

ATLAS 8 TeV (preliminary):
0.00024 / 0.00021



Tevatron:
0.00016 / 0.00030

CMS 8 TeV:
0.00030 / 0.00036

ATLAS 13 TeV (RunII expect):
0.00026 / 0.00025

ATLAS 13 TeV (RunII expect.):
0.00026 / 0.00013

ePump
(Error PDF Updating Method Package)

Quick update on the PDF with new data input

Ref: arXiv:1806.07950

- for eigenvector-type PDFs (Hessian updating)
- minimize total $\chi 2$ and diagonalize hessian matrix within seconds
- output an updated central and hessian eigenvector PDF
- good approximation to the global fitting

$$\Delta\chi^2(z)_{\rm new} = T^2 \sum_{i=1}^{N} z_i^2 + \sum_{\alpha,\beta=1}^{N_X} \left(X_\alpha(z) - X_\alpha^E\right) C^{-1}_{\alpha\beta} \left(X_\beta(z) - X_\beta^E\right)$$

Use ePump in the $\sin^2\theta_W$ measurement

Motivation

- use ePump to update PDF
- how much improvement on the PDF uncertainty for ATLAS RunII weak mixing angle measurement
- how large correlation will be between PDF updating and weak mixing angle extraction
- looking into updated PDF separately for quarks and gluons

Use ePump in the $\sin^2\theta_W$ measurement

Basic settings

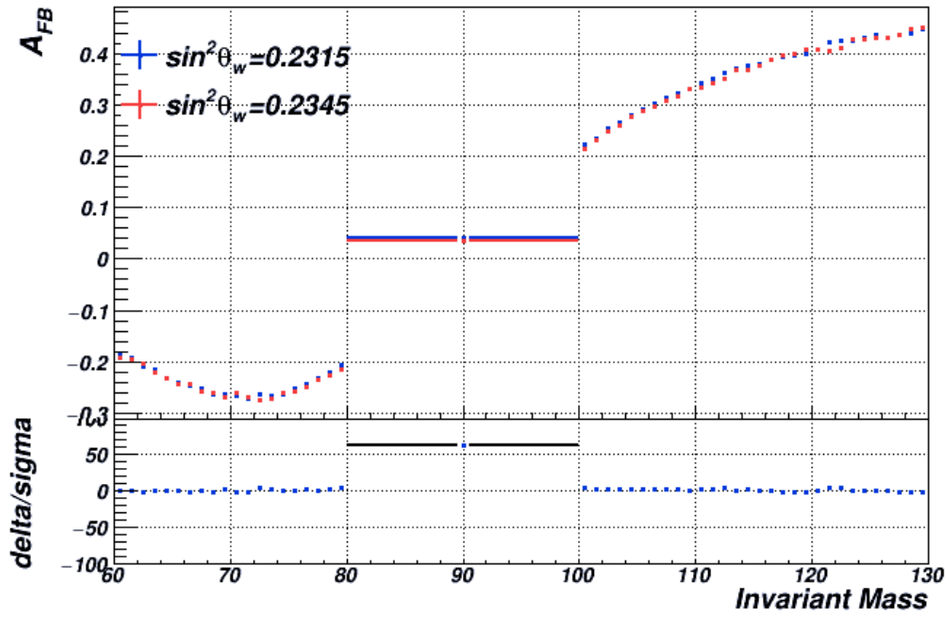
- ResBos pseudo-data and theory templates (normalized to 130 fb^{-1})
- ATLAS kinematic cuts:
  - lepton pT>25 GeV, M = [60, 130] GeV
  - eeCC & dimuon: lepton $|\eta|<2.5$
  - eeCF: one lepton $|\eta|<2.5$, one lepton $2.5<|\eta|<5.0$
- pseudo-data: CT14HERA2NNLO, $\sin^2\theta_W = 0.2345$
- theory template: CT14HERA2NNLO, $\sin^2\theta_W = 0.2315$

Observables

- A_{FB} vs mass spectrum (side band: [60, 80] - [100, 130] / full spectrum)
- Z boson pT spectrum
- Z boson rapidity

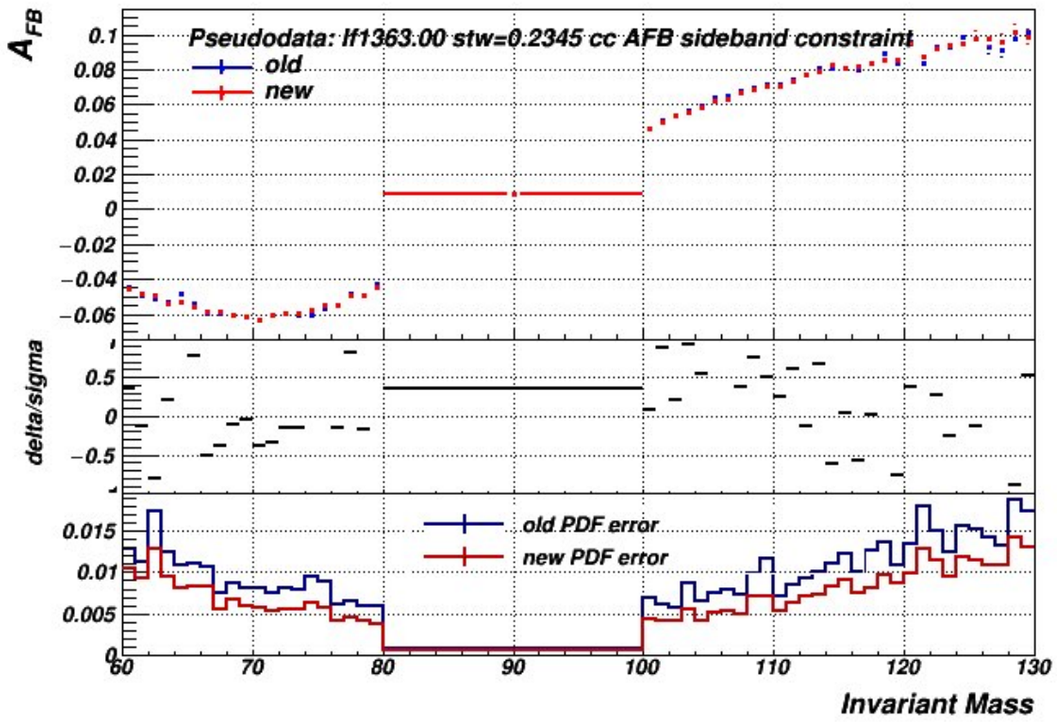
A_{FB} sideband update

Using sideband AFB spectrum to update PDF, observe the AFB value at Z-pole reagion

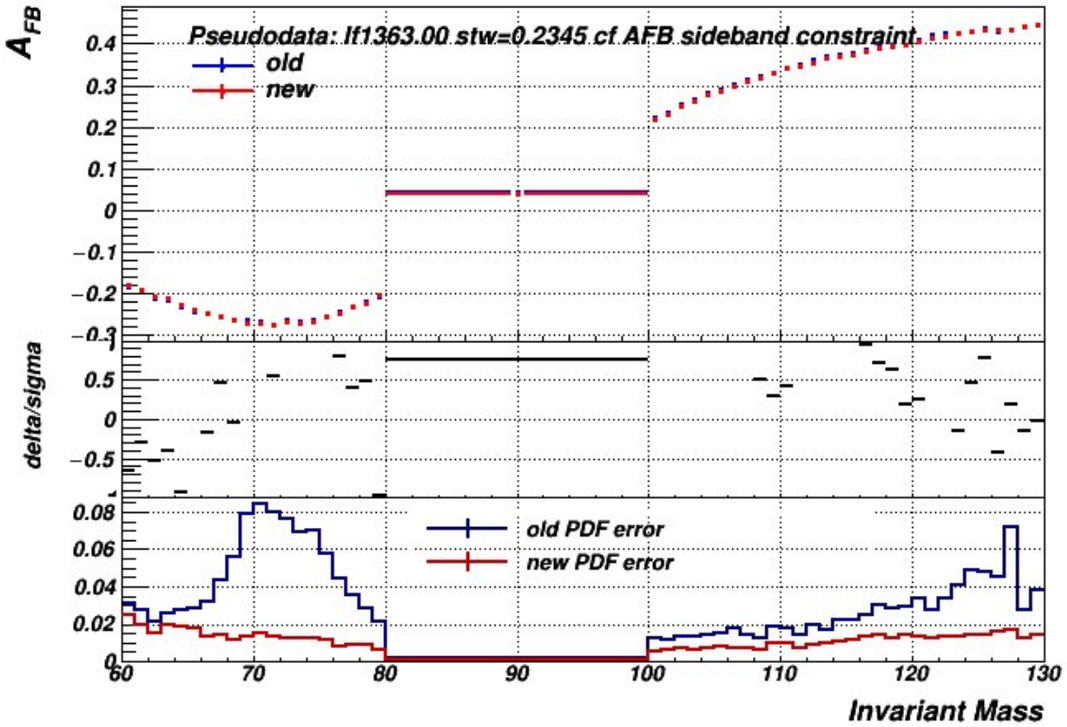


	pseudo-data AFB at Zpole (CT14HERA2 stw=0.2345)	theory template AFB at Zpole (CT14HERA2 stw=0.2315)		PDF unc.	
		before update.	after update	before update.	after update
CC	0.00698	0.00876 ±0.00008	0.00873	0.00083	0.00068
CF	0.03415	0.04170 ±0.00012	0.04161	0.00192	0.00128
full phase space	0.01825	0.02273 ±0.00005	0.02271	0.00111	0.00071

A_{FB} sideband update

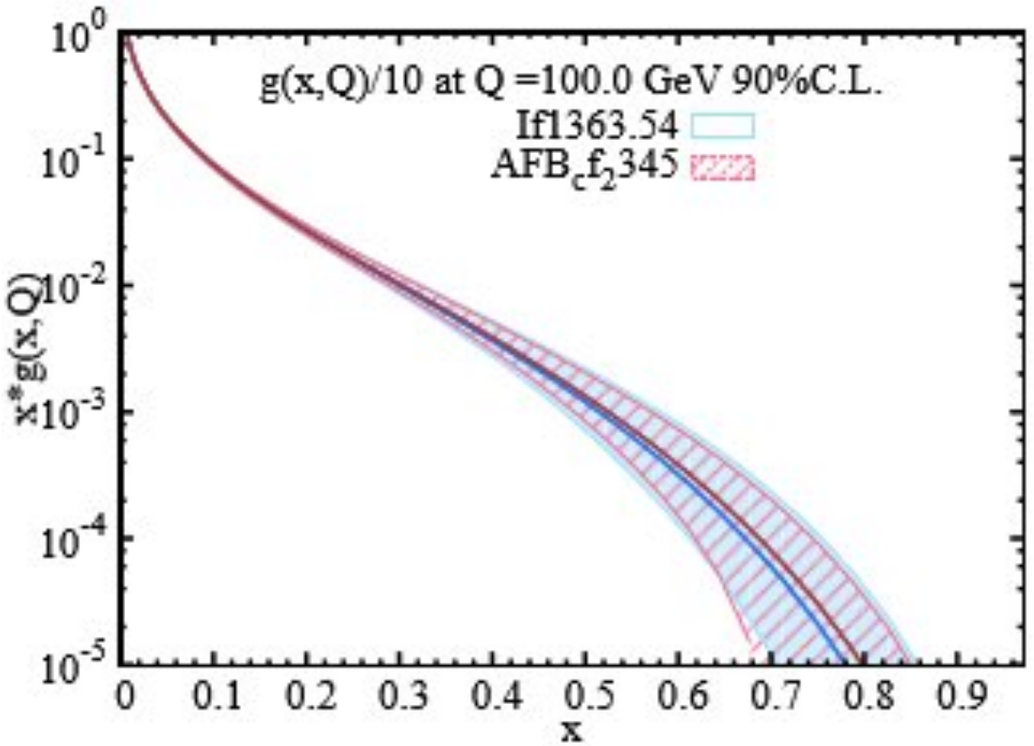


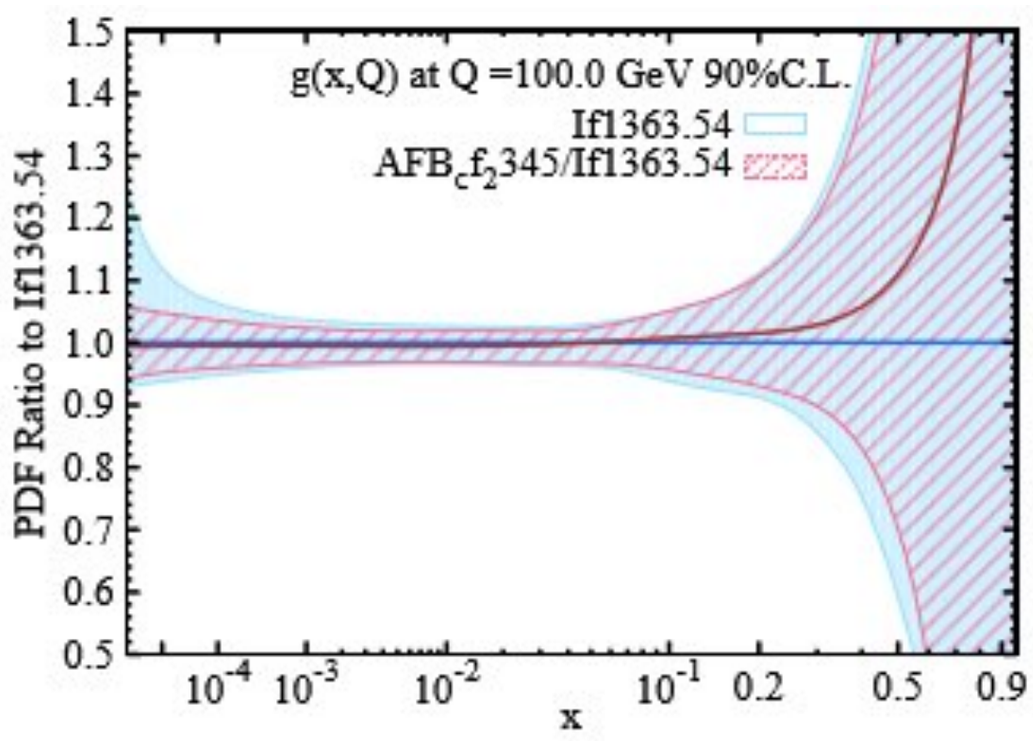
AFB vs. mass spectrum before/ after PDF update for CC events

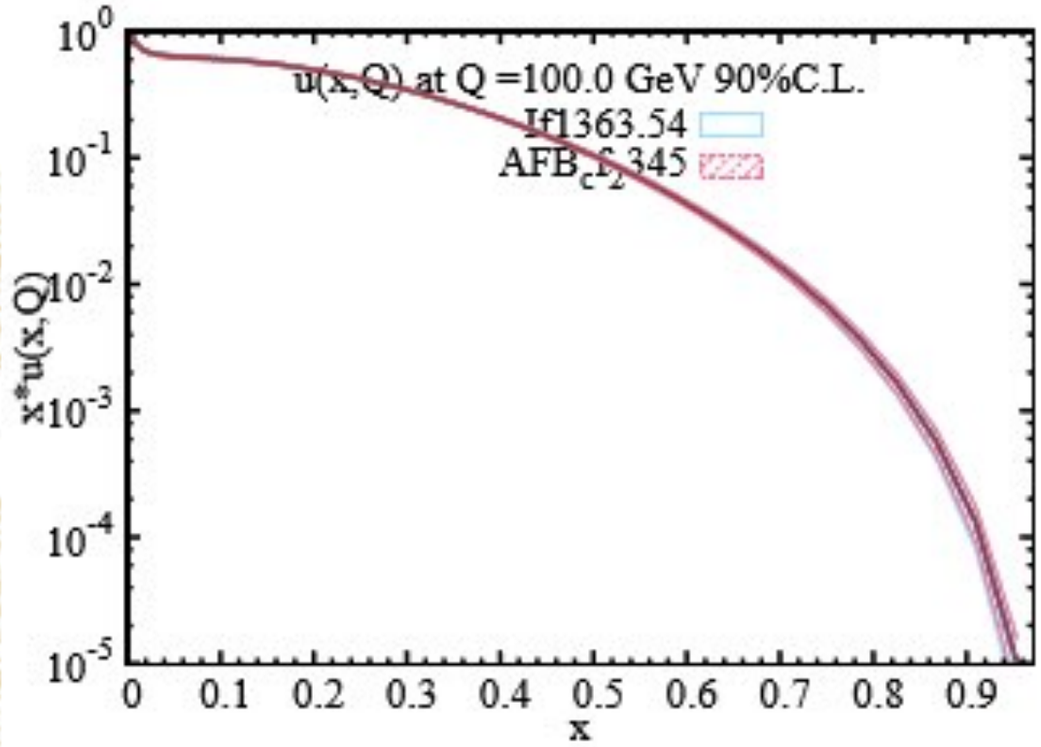


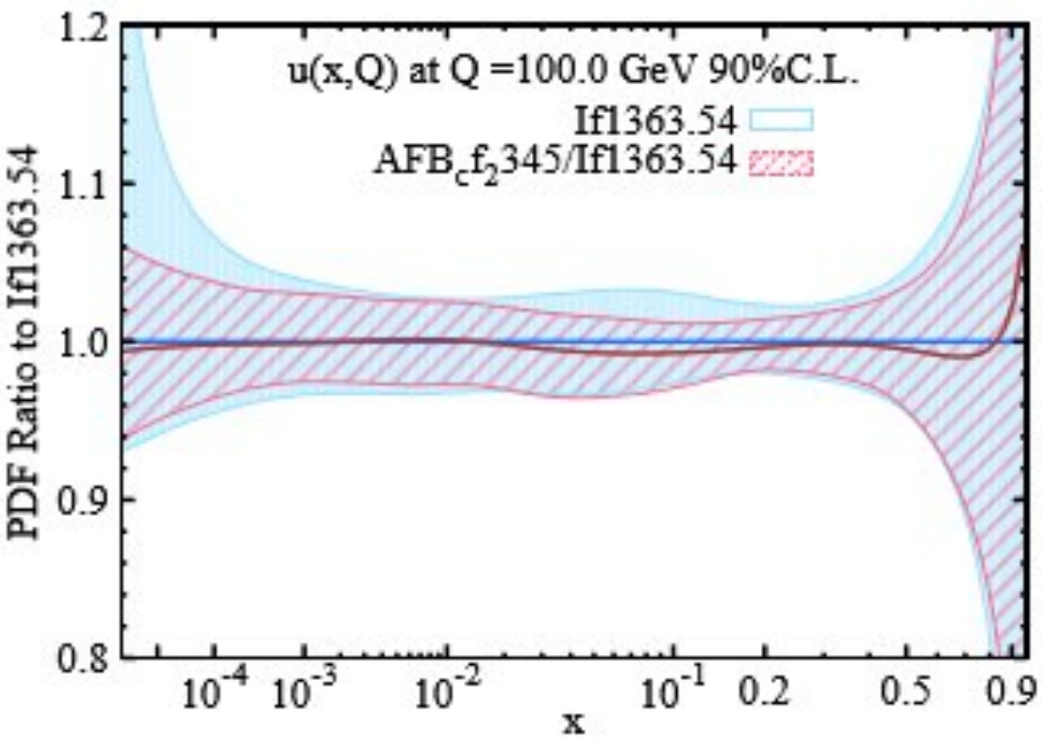
AFB vs. mass spectrum before/ after PDF update for CF events

A_{FB} sideband update







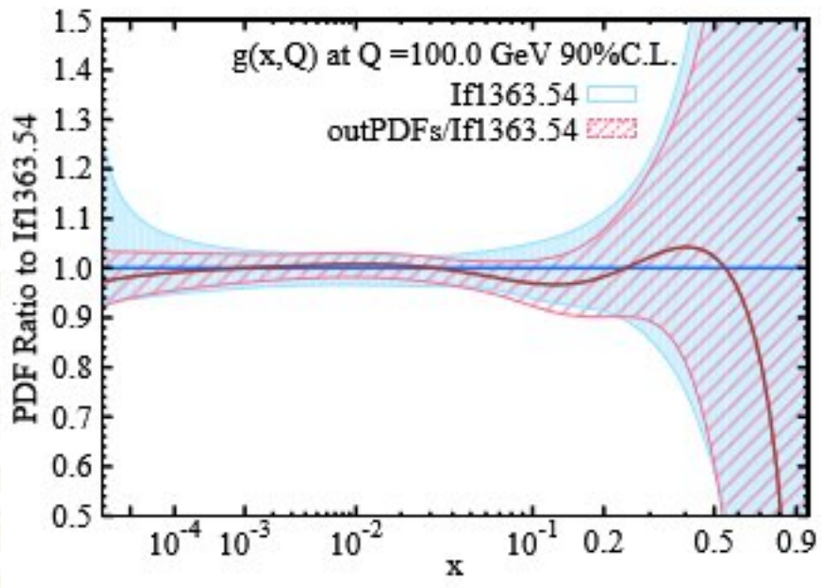


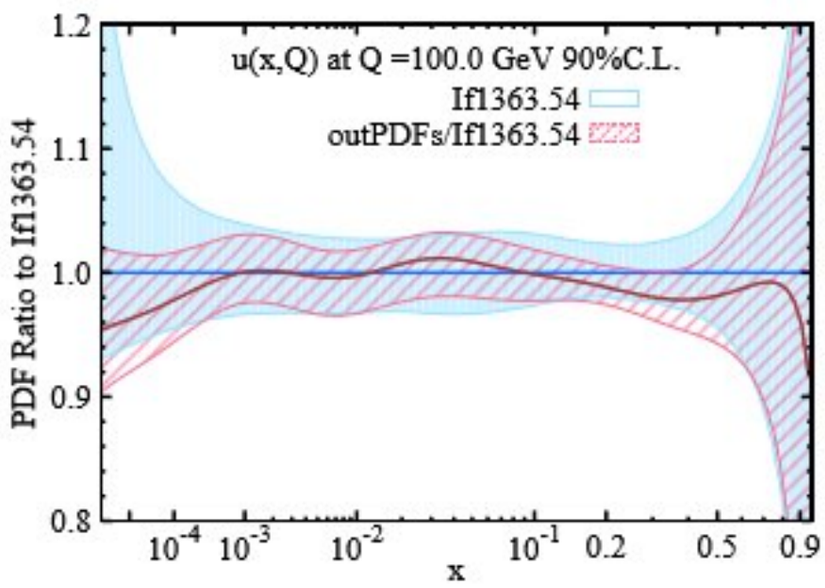
A_{FB} full spectrum update

	pseudo-data AFB at Zpole (CT14HERA2 stw=0.2345)	theory template AFB at Zpole (CT14HERA2 stw=0.2315)		PDF unc.	
		before update.	after update	before update.	after update
CF	0.03415	0.04170 ±0.00012	0.03710	0.00192	0.00085

Use full AFB vs. mass spectrum to update PDF, observe the AFB value at Z-pole reagion

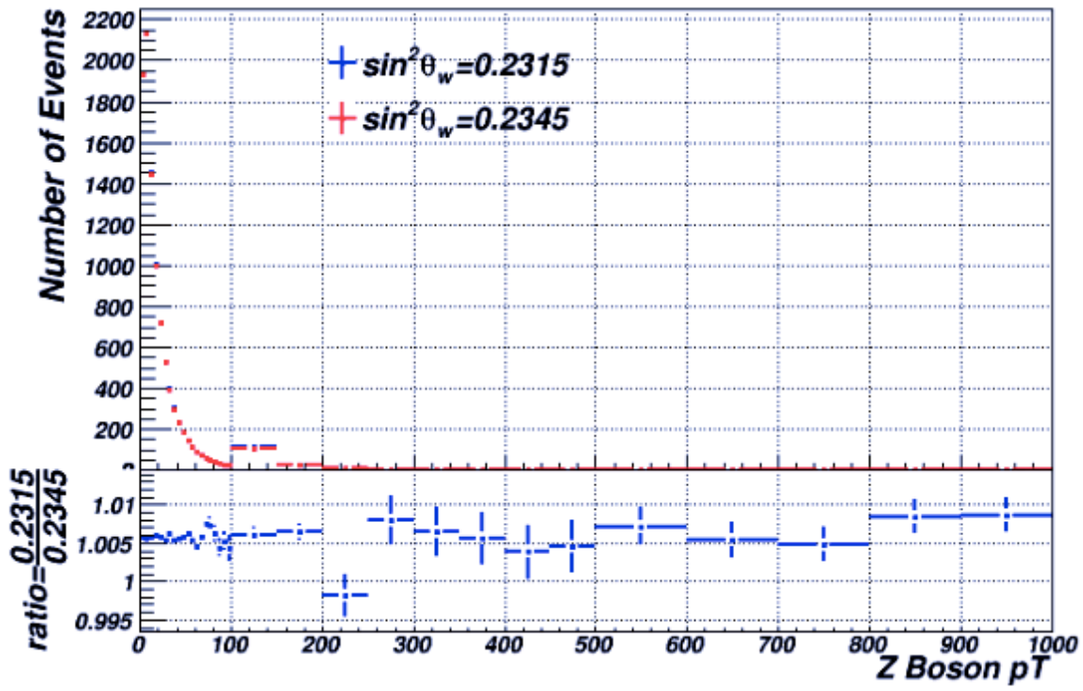
Due to correlation, the fit forces the input of weak mixing angle into PDF update, giving bad output, showing strong tension with the CMS 7 TeV and D0 W-lepton asymmetry data included in CT14





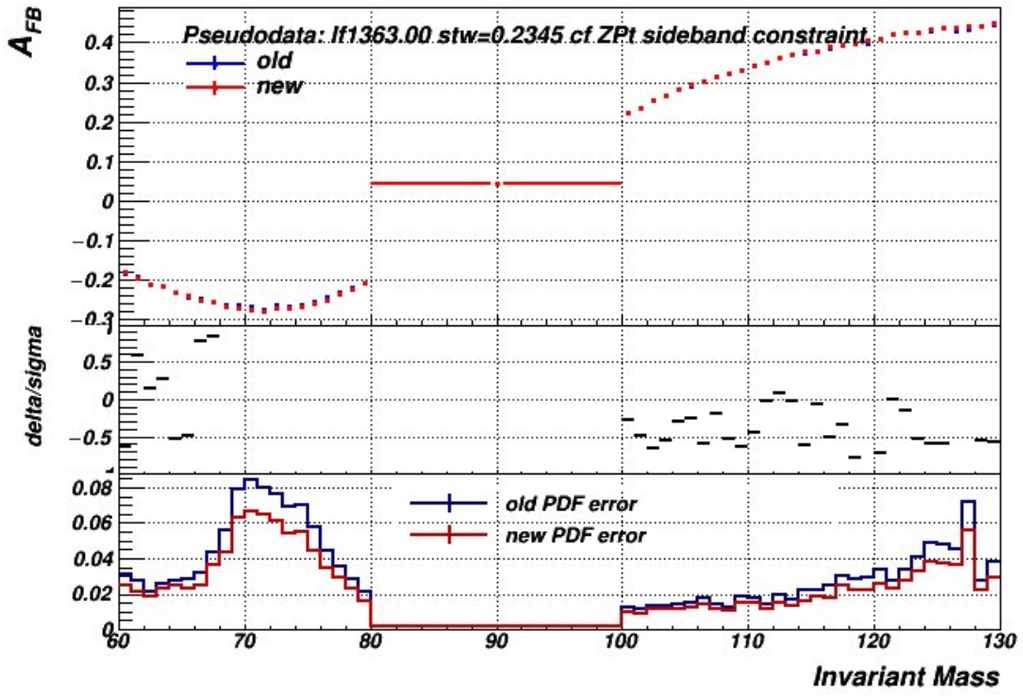
Z-pT update

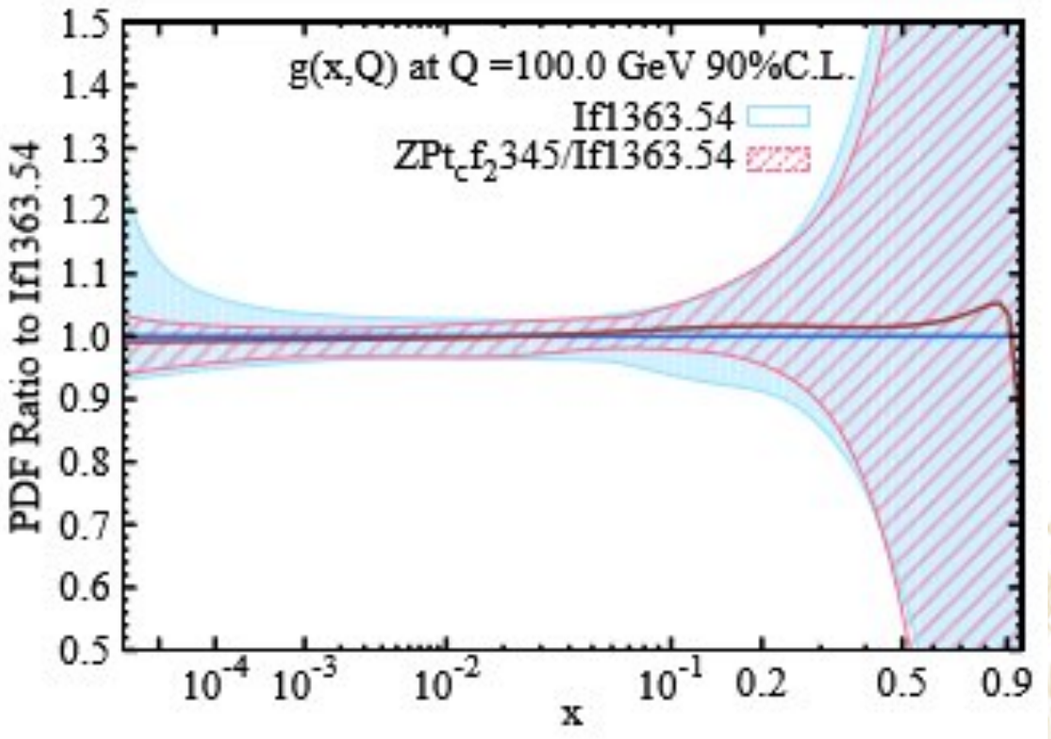
Use Z-pT spectrum to update PDF, observe the AFB value at Z-pole reagion

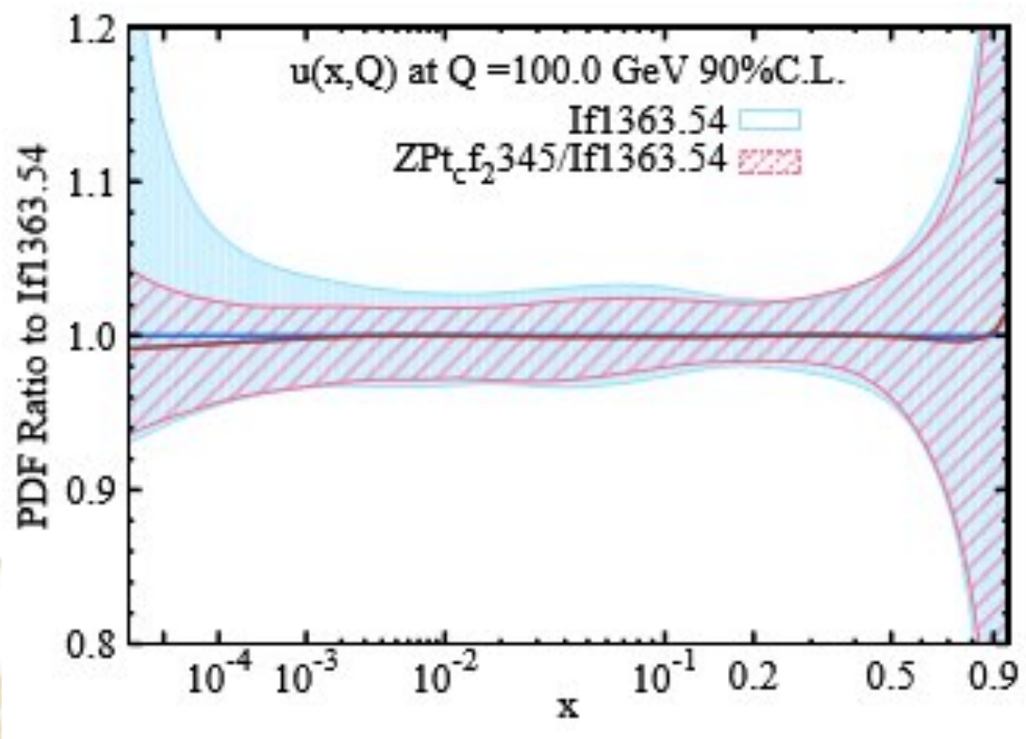


	pseudo-data AFB at Zpole (CT14HERA2 stw=0.2345)	theory template AFB at Zpole (CT14HERA2 stw=0.2315)		PDF unc.	
		before update.	after update	before update.	after update
CC	0.00698	0.00876 ±0.00008	0.00872	0.00083	0.00076
CF	0.03145	0.04170 ±0.00012	0.04194	0.00192	0.00163
full phase space	0.01825	0.02273 ±0.00005	0.02295	0.00111	0.00086

Z-pT update

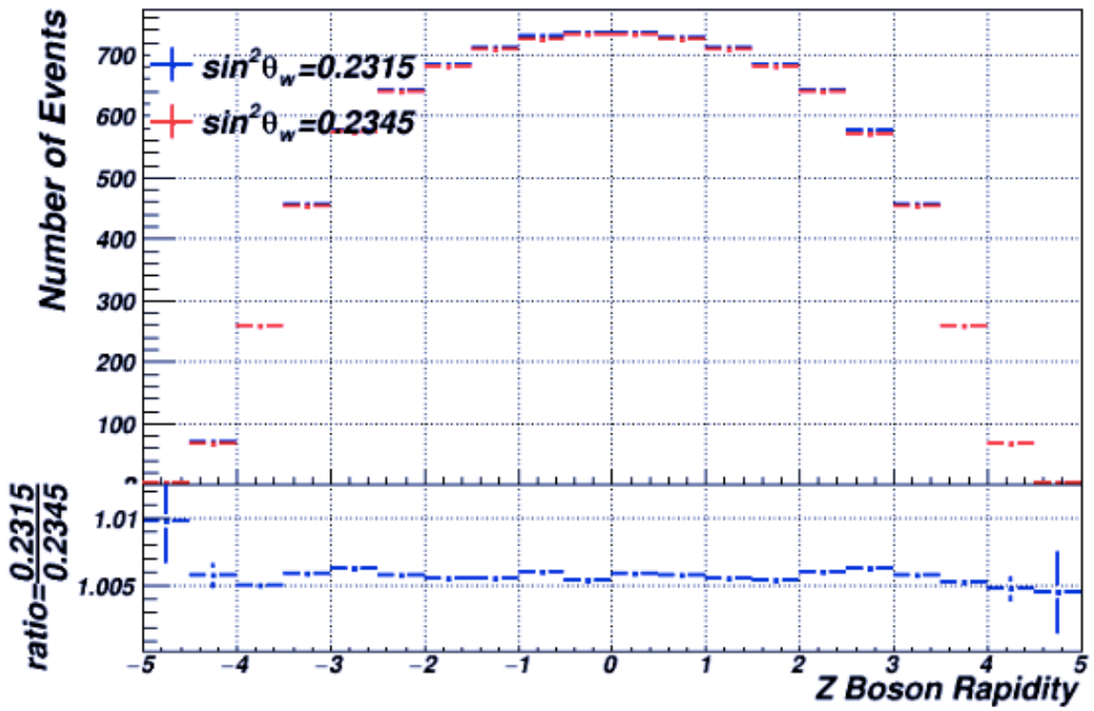

Pseudodata: lf1363.00 stw=0.2345 cf ZPt sideband constraint
old
new
A_{FB}
delta/sigma
old PDF error
new PDF error
Invariant Mass


g(x,Q) at Q =100.0 GeV 90%C.L.
If1363.54
ZPt_c_f2345/If1363.54
PDF Ratio to If1363.54
x


u(x,Q) at Q =100.0 GeV 90%C.L.
If1363.54
ZPt_c_f2345/If1363.54
PDF Ratio to If1363.54
x

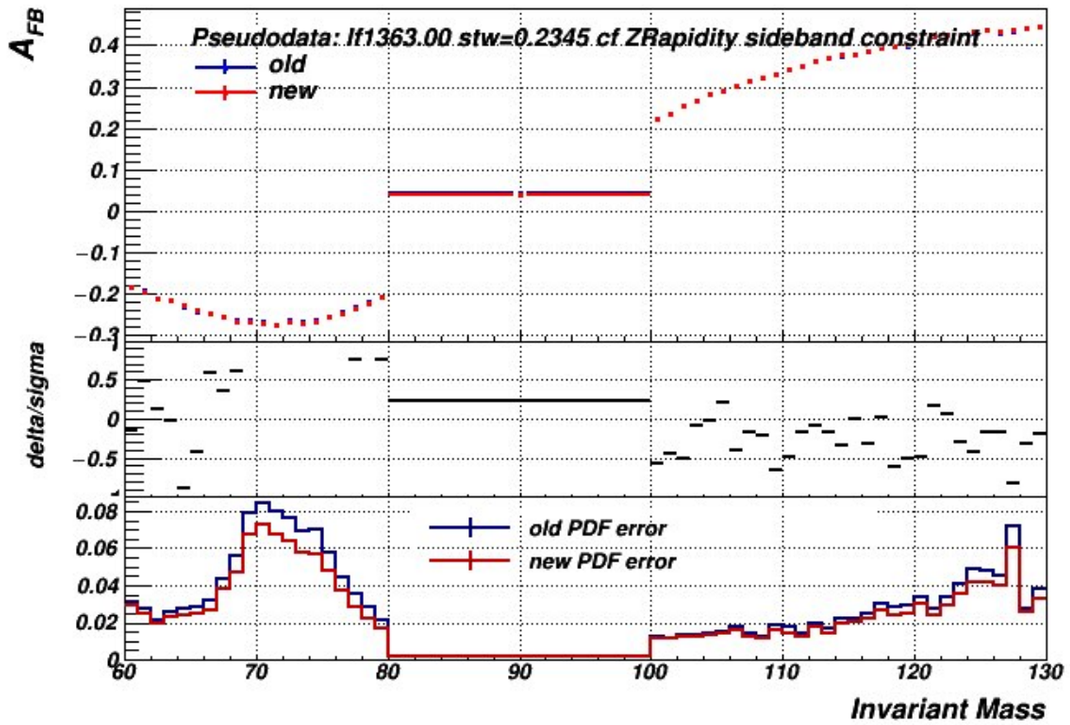
Z-rapidity update

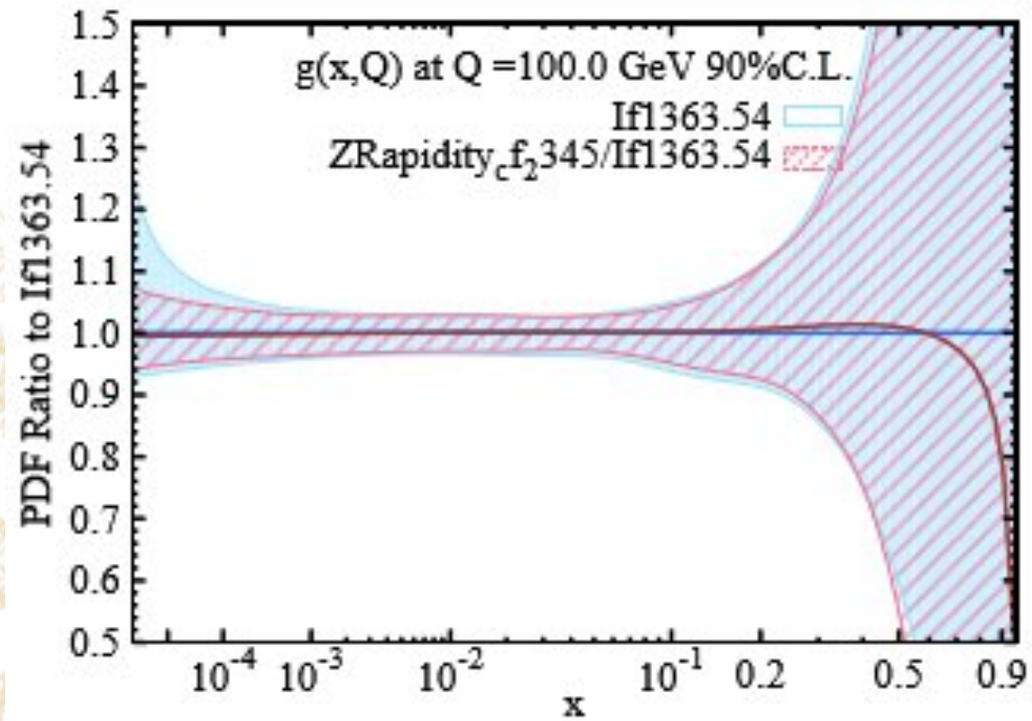
Use Z-rapidity spectrum to update PDF, observe the AFB value at Z-pole reagion

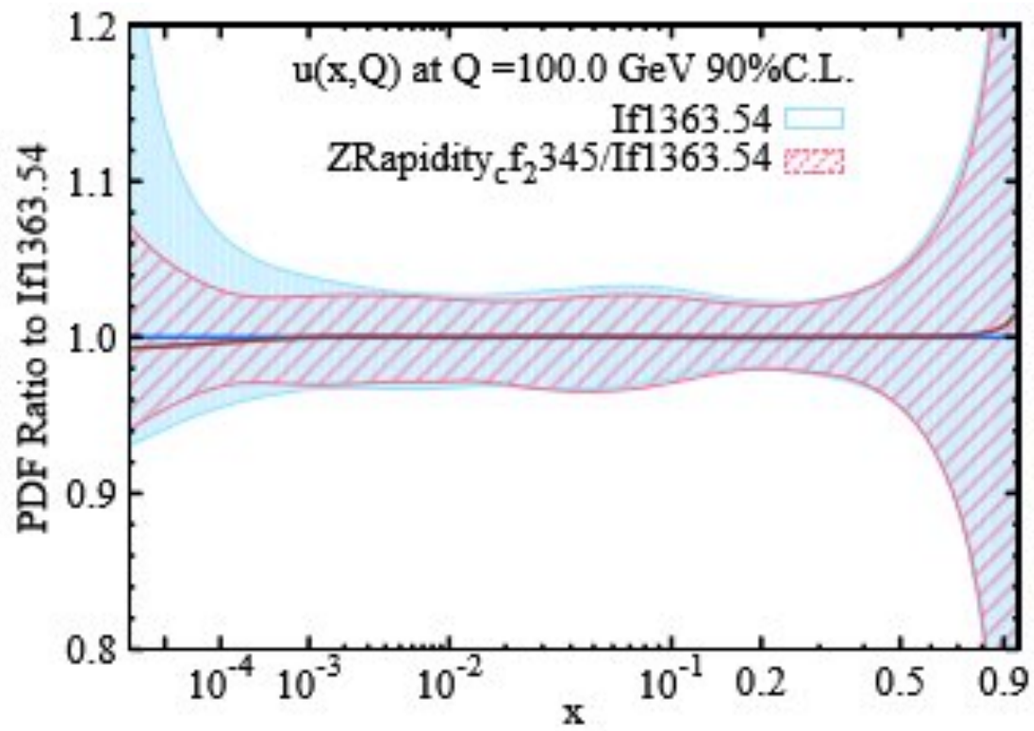


	pseudo-data AFB at Zpole (CT14HERA2 stw=0.2345)	theory template AFB at Zpole (CT14HERA2 stw=0.2315)		PDF unc.	
		before update.	after update	before update.	after update
CC	0.00698	0.00876 ±0.00008	0.00874	0.00083	0.00080
CF	0.03145	0.04170 ±0.00012	0.04168	0.00192	0.00162
full phase space	0.01825	0.02273 ±0.00005	0.02274	0.00111	0.00079

Z-rapidity update







Summary and conclusion

Reduce PDF uncertainty @ weak mixing angle (CT14HERA2)

- AFB sideband spectrum is most sensitive (PDF unc. reduced by ~30%)
- uncertainties at low x range ($<10^{-3}$) is more significantly reduced, while the PDF uncertainties on AFB is reduced due to improvement at x ~ [10^{-3},0.3]
- a “new” PDF is given for all flavours

Correlation between A_{FB} and CT14HERA2

- A_{FB} sideband and Z-rapidity updating has negligible correlation
  - the A_{FB} @ Z-pole is not changed after updating
  - the PDF after updating is consistent with the original CT14 PDF
- Z-pT and A_{FB} full spectrum updating affect the weak mixing angle measurement