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HERAFitter for LHCb

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1. Getting started...

- Got to grips with the HERAFitter package
- Generated APPLGRID grids for LHCb W/Z inclusive production (after discussions with Mark Sutton)
- Performed PDF fits in HERAFitter with 2010/2011 LHCb W/Z production data [1], [2]

2. Initial PDF fitting objectives

(i) Fit with HERA NC and CC [3] + 2010/2011 LHCb *W/Z* production cross sections [1], [2] $W \to \mu\nu$ $\mathrm{Z} \to \mathrm{e}^+\mathrm{e}^-$

(ii) Fit with HERA NC and CC + LHCb lepton charge asymmetry [1] $A_\ell(\eta_\ell) = \frac{\mathrm{d}\sigma_{W^+}/\mathrm{d}\eta_\ell - \mathrm{d}\sigma_{W^-}/\mathrm{d}\eta_\ell}{\mathrm{d}\sigma_{W^+}/\mathrm{d}\eta_\ell + \mathrm{d}\sigma_{W^-}/\mathrm{d}\eta_\ell}$ (l=μ) & Z cross section [2]

(iii) Compare fits with {HERA + 2010/2011 LHCb *W/Z*} and {HERA + 2010 ATLAS *W/Z* [4]}

(iv) Compare fits with {HERA + LHCb lepton charge asymmetry & *Z*} and {HERA + 2010 CMS asymmetry & *Z* [5], [6]}

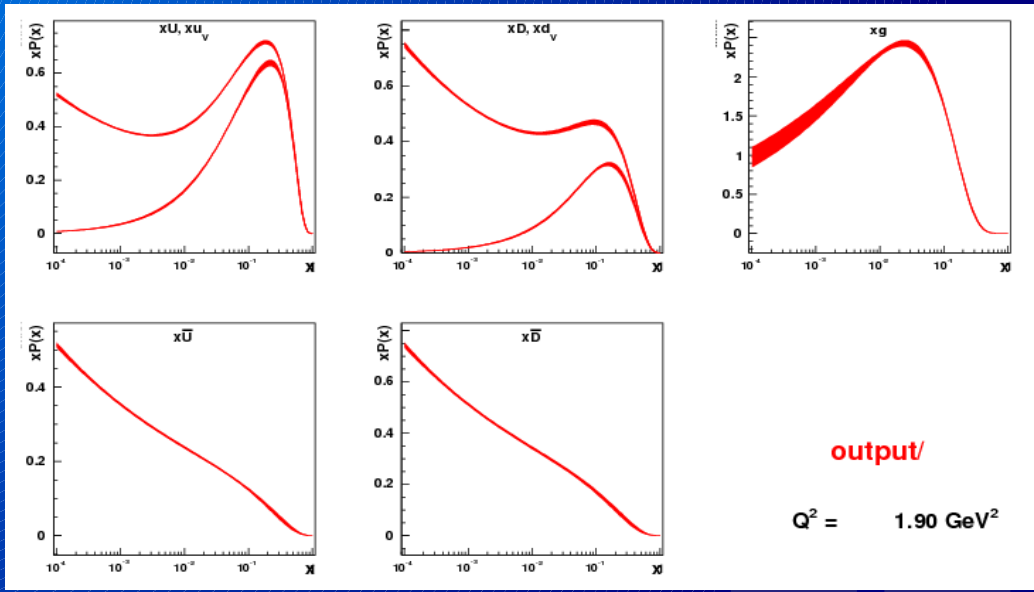
Fits used '10p HERAPDF' style with *fs* = 0.31 and $\alpha_S(M_Z)$ = 0.1176

(i) HERA + LHCb *W/Z*

	Partial χ^2	Ndofs, N
NC cross section HERA-I H1-ZEUS combined e-p	106.58	145
NC cross section HERA-I H1-ZEUS combined e+p	420.61	379
CC cross section HERA-I H1-ZEUS combined e-p	20.26	34
CC cross section HERA-I H1-ZEUS combined e+p	28.78	34
LHCb W+ muon pseudorapidity data (2010)	1.69	5
LHCb W- muon pseudorapidity data (2010)	4.51	5
LHCb Z to *ee* rapidity data (2011)	4.73	9

$\chi^2 / N = 587.50/601$

→ HERA only fit:
$\chi^2 / N = 575.08/582$



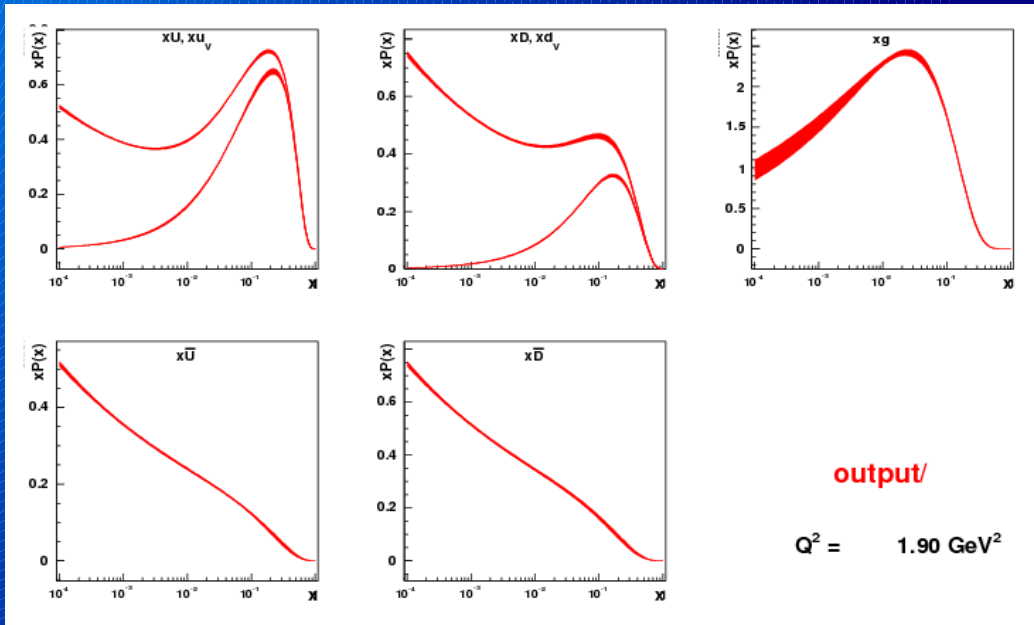
(ii) HERA + LHCb asymmetry & *Z*

	Partial χ^2	Ndofs, *N*
NC cross section HERA-I H1-ZEUS combined e-p	106.39	145
NC cross section HERA-I H1-ZEUS combined e+p	422.27	379
CC cross section HERA-I H1-ZEUS combined e-p	20.32	34
CC cross section HERA-I H1-ZEUS combined e+p	28.83	34
LHCb lepton charge asymmetry data (2010)	3.87	5
LHCb Z to *ee* rapidity data (2011)	4.88	9

$\chi^2/N = 586.59/596$

→ HERA only fit:

$\chi^2/N = 575.08/582$

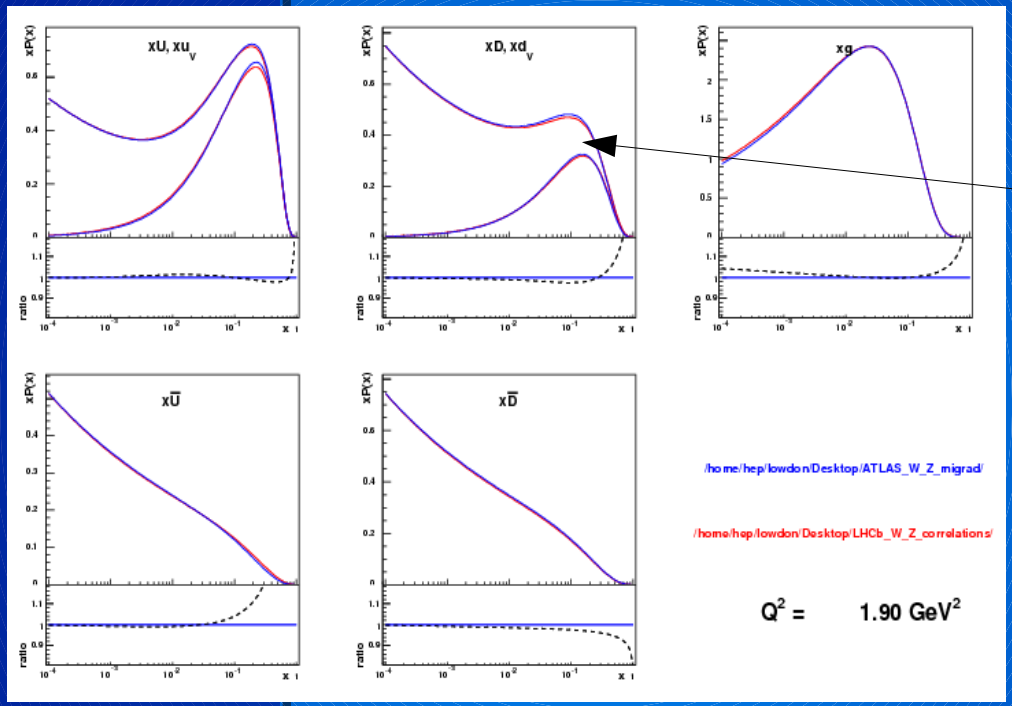


(iii) Comparison of LHCb and ATLAS W/Z fits

	Partial χ^2 LHCb	Ndofs, N LHCb	Partial χ^2 ATLAS	Ndofs, N ATLAS
NC cross section HERA-I H1-ZEUS combined e-p	106.58	145	106.34	145
NC cross section HERA-I H1-ZEUS combined e+p	420.61	379	422.65	379
CC cross section HERA-I H1-ZEUS combined e-p	20.26	34	19.42	34
CC cross section HERA-I H1-ZEUS combined e+p	28.78	34	30.53	34
W+ muon pseudorapidity data	1.69	5	24.11	11
W- muon pseudorapidity data	4.51	5	10.68	11
Z rapidity data	4.73	9	5.82	8

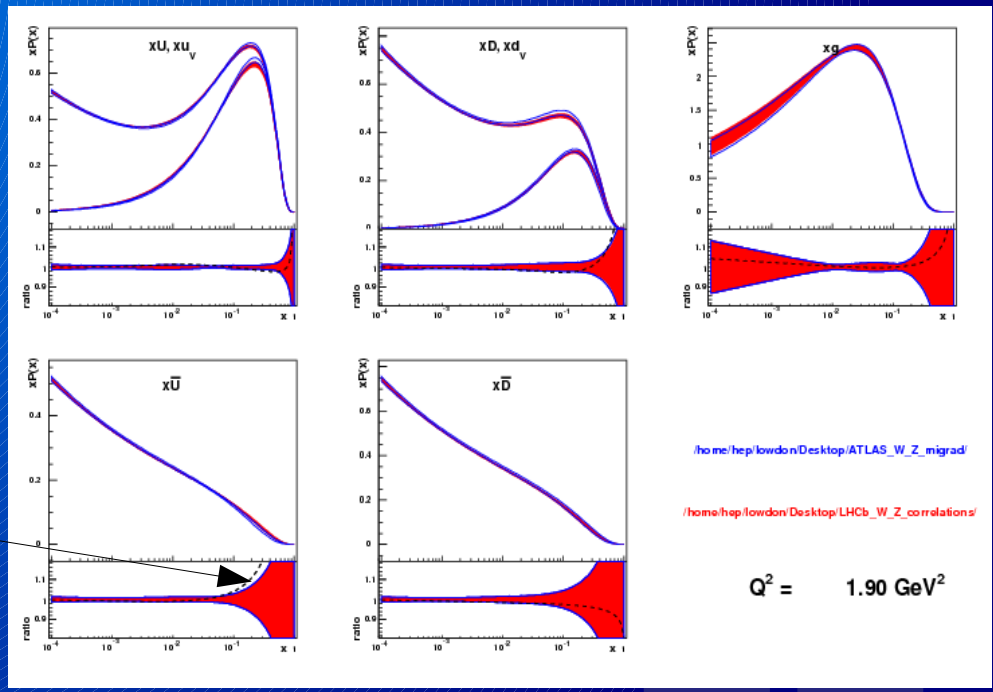
LHCb $\chi^2/N = 587.50/601$ ATLAS $\chi^2/N = 622.57/612$

(iii) Comparison of LHCb and ATLAS W/Z fits



LHC data fit suggests a slightly lower sea and valence quark density at high x, but PDFs largely coincide

PDF uncertainties are very similar for the gluon and for all quarks

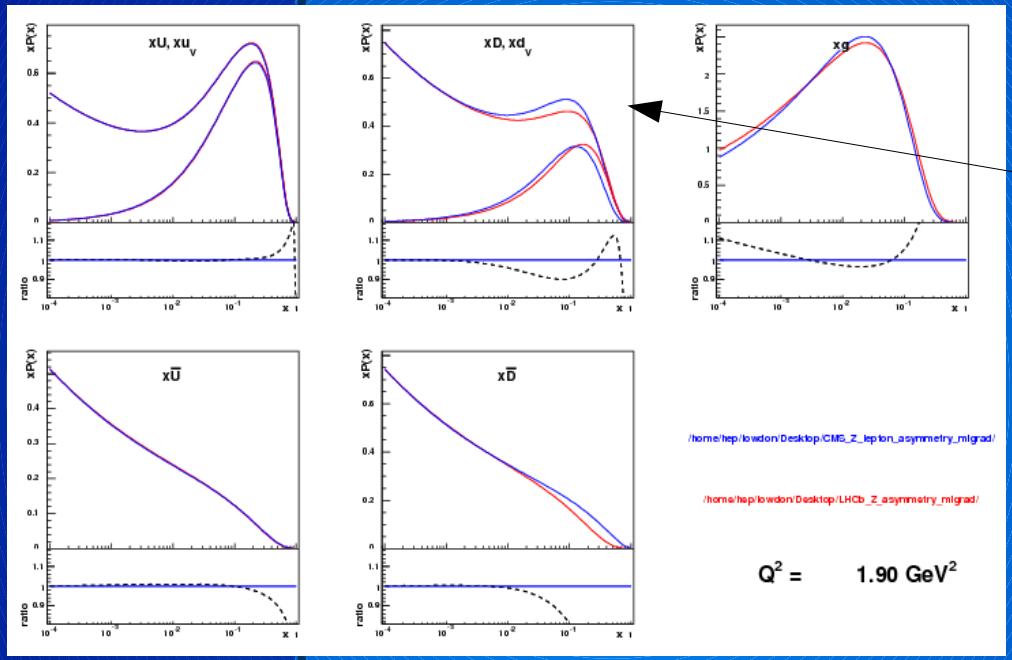


(iv) Comparison of LHCb and CMS asymmetry + *Z* fits

	Partial χ^2 LHCb	Ndofs, *N* LHCb	Partial χ^2 CMS	Ndofs, *N* CMS
NC cross section HERA-I H1-ZEUS combined e-p	106.39	145	107.92	145
NC cross section HERA-I H1-ZEUS combined e+p	422.27	379	423.24	379
CC cross section HERA-I H1-ZEUS combined e-p	20.32	34	19.17	34
CC cross section HERA-I H1-ZEUS combined e+p	28.83	34	29.97	34
Lepton charge asymmetry data	3.87	5	9.21	11
Z rapidity data	4.88	9	68.40	35

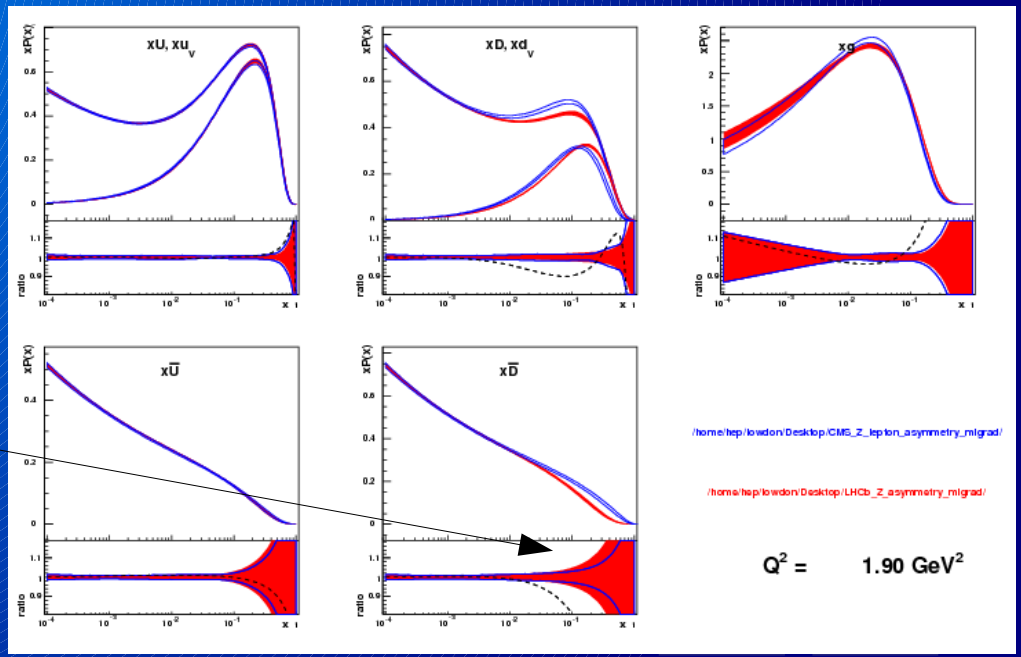
LHCb $\chi^2/N = 586.59/596$ CMS $\chi^2/N = 657.92/628$

(iv) Comparison of LHCb and CMS asymmetry + *Z* fits



LHCb data fit suggests a lower d valence and sea quark density at high x

CMS data fit constrains the sea quark PDFs better at high x



3. Summary

- Managed to successfully perform PDF fits with LHCb data
- Inclusion of LHCb W/Z data does not significantly change the PDF fit compared with fitting HERA data alone
- Compared fits with HERA + LHCb to equivalent ATLAS and CMS data fits, and found some parametrisation differences

4. Outlook

- Explore the effect of fitting LHCb data with a looser parametrisation (e.g. 13p HERAPDF with different fixed *fs* or free *fs* etc.)
- Determine the strange quark sea fraction *rs=sbar/dbar* using HERA + LHCb data and compare with the 2012 ATLAS result *rs*=1.00 [7] (currently work in progress...)
- Incorporate 2010/2011 LHCb data into global PDF fits

References

[1] *Inclusive W and Z production in the forward region at sqrt(s) = 7 TeV* [arXiv:1204.1620]

[2] *Measurement of the cross-section for Z->e+e- production in pp collisions at sqrt(s)=7TeV* [arXiv:1212.4620]

[3] *Combined Measurement and QCD Analysis of the Inclusive e±p Scattering Cross Sections at HERA* [arXiv:0911.0884]

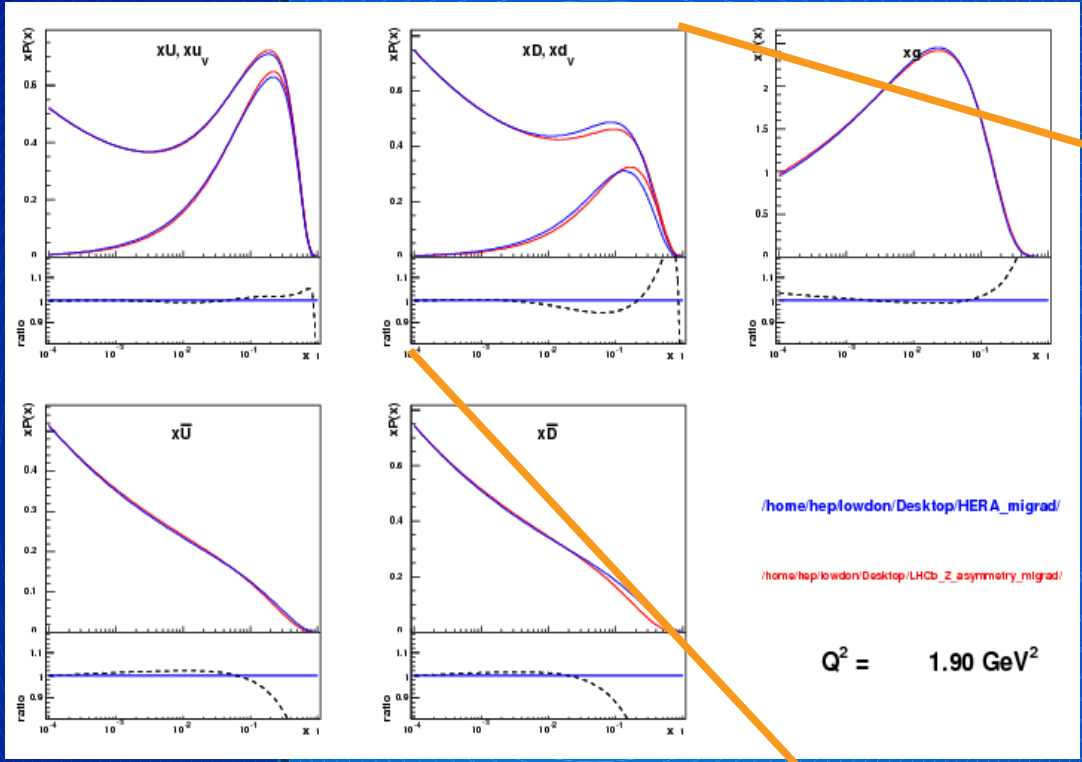
[4] *Measurement of the inclusive W± and Z/γ* cross sections in the electron and muon decay channels in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector* [arXiv:1109.5141]

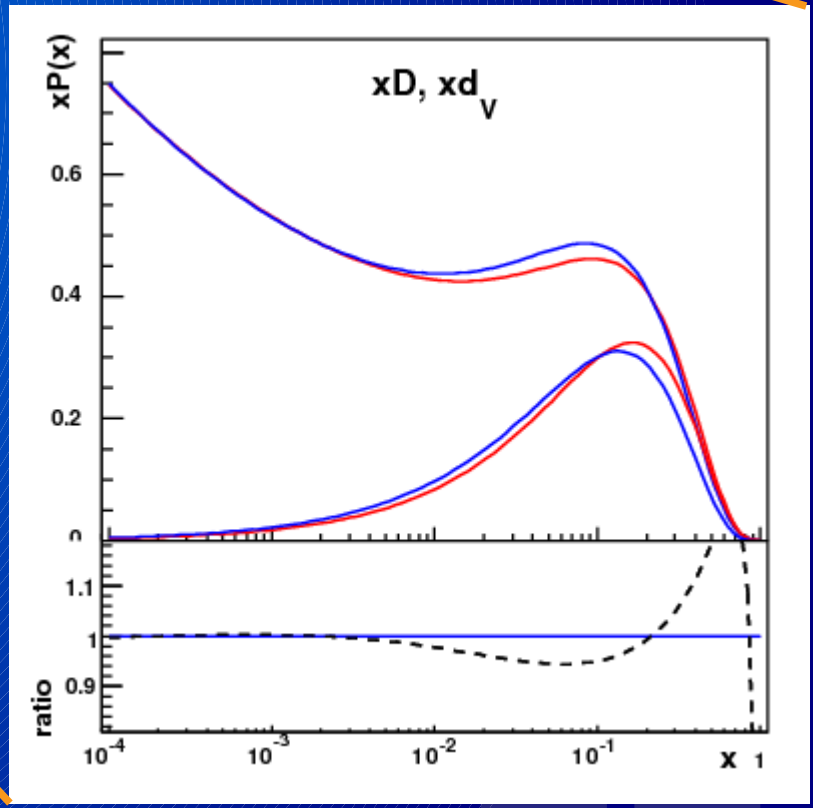
[5] *Measurement of the muon charge asymmetry in inclusive W production in pp collisions at sqrt(s) = 7 TeV* [CMS-PAS-EWK-11-005]

[6] *Measurement of the Rapidity and Transverse Momentum Distributions of Z Bosons in pp Collisions at sqrt(s)=7 TeV* [arXiv:1110.4973]

[7] *Determination of the strange quark density of the proton from ATLAS measurements of the W->l nu and Z->ll cross sections* [arXiv:1203.4051]

Back up slides





Back up slides

Results for:
/home/hep/lowdon/Desktop/LHCb_Z_asymmetry_migrad/

Fitted 10 parameters:
(most reliable available method: none
giving confidence in errors: none)

1:	'Bg'	=	0.204 ± 0.018
2:	'Cg'	=	8.483 ± 0.296
3:	'Buv'	=	0.700 ± 0.015
4:	'Cuv'	=	4.562 ± 0.106
5:	'Euv'	=	8.560 ± 0.798
6:	'Cdv'	=	3.575 ± 0.117
7:	'CUbar'	=	3.217 ± 0.417
8:	'ADbar'	=	0.172 ± 0.007
9:	'BDbar'	=	-0.159 ± 0.005
10:	'CDbar'	=	4.022 ± 0.499

Nuisance Parameters:

Results for:
/home/hep/lowdon/Desktop/CMS_Z_lepton_asymmetry_migrad/

Fitted 10 parameters:
(most reliable available method: none
giving confidence in errors: none)

1:	'Bg'	=	0.236 ± 0.031
2:	'Cg'	=	10.124 ± 0.793
3:	'Buv'	=	0.691 ± 0.016
4:	'Cuv'	=	4.693 ± 0.167
5:	'Euv'	=	9.267 ± 1.386
6:	'Cdv'	=	4.715 ± 0.531
7:	'CUbar'	=	3.032 ± 0.345
8:	'ADbar'	=	0.168 ± 0.007
9:	'BDbar'	=	-0.161 ± 0.005
10:	'CDbar'	=	1.847 ± 0.415

Nuisance Parameters:

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	Partial χ^2 LHCb + ATLAS	Ndofs, N
NC cross section HERA-I H1-ZEUS combined e-p	106.61	145
NC cross section HERA-I H1-ZEUS combined e+p	423.38	379
CC cross section HERA-I H1-ZEUS combined e-p	19.61	34
CC cross section HERA-I H1-ZEUS combined e+p	29.65	34
LHCb W+ muon pseudorapidity data	1.49	5
LHCb W- muon pseudorapidity data	4.37	5
LHCb Z rapidity data	4.95	9
ATLAS W+ muon pseudorapidity data	24.99	11
ATLAS muon pseudorapidity data	10.44	11
ATLAS Z rapidity data	5.76	8

$$\chi^2/N = 634.38/631$$

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	Partial χ^2 LHCb + CMS	Ndofs, *N*
NC cross section HERA-I H1-ZEUS combined e-p	107.18	145
NC cross section HERA-I H1-ZEUS combined e+p	423.62	379
CC cross section HERA-I H1-ZEUS combined e-p	19.88	34
CC cross section HERA-I H1-ZEUS combined e+p	29.04	34
LHCb Lepton charge asymmetry data	5.04	5
LHCb Z rapidity data	5.48	9
CMS Lepton charge asymmetry data	74.87	35
CMS Z rapidity data	10.48	11

$$\chi^2/N = 675.67/642$$