Supplementary material for LHCb-PAPER-2015-039

Covariance matrix

In order to account for the correlation between bins of $m_{\mu\mu}$ in the NNPDF uncertainty, the covariance matrix needs to be calculated and inverted. It is given in Table 5.

Table 5: Covariance matrix for the NNPDF uncertainty. As the same uncertainty is used for both years only 13 invariant mass bins are given, but the full matrix is 26 by 26. The elements have been multiplied by a factor of 10^6.

$m_{\mu\mu}$ [GeV]	60 -72	72 -81	81 -86	86 -88	88 -89	89 -90	90 -91	91 -92	92 -93	93 -94	94 -98	98 -120	120 -160
60 -72	94.83	48.27	9.64	0.16	1.79	-11.27	-16.48	-23.09	-34.35	-48.71	-51.67	-81.26	-121.66
72 -81	48.27	46.52	7.52	4.37	0.15	-4.92	-6.08	-13.76	-19.71	-23.62	-29.85	-49.45	-54.30
81 -86	9.64	7.52	11.53	2.11	-0.23	-1.11	-1.64	-2.49	-3.01	-6.56	-8.06	-13.88	-14.03
86 -88	0.16	4.37	2.11	14.42	-2.04	2.19	3.18	-1.13	1.59	9.23	2.36	5.84	25.35
88 -89	1.79	0.15	-0.23	-2.04	10.96	-0.75	-0.42	-0.23	-0.70	-3.58	0.10	-2.59	-5.92
89 -90	-11.27	-4.92	-1.11	2.19	-0.75	12.30	5.16	3.42	7.19	12.95	8.78	22.84	47.00
90 -91	-16.48	-6.08	-1.64	3.18	-0.42	5.16	12.94	7.30	11.08	20.62	16.39	32.45	61.07
91 -92	-23.09	-13.76	-2.49	-1.13	-0.23	3.42	7.30	13.53	12.99	21.28	22.30	36.99	53.66
92 -93	-34.35	-19.71	-3.01	1.59	-0.70	7.19	11.08	12.99	23.50	30.96	29.71	50.55	83.26
93 -94	-48.71	-23.62	-6.56	9.23	-3.58	12.95	20.62	21.28	30.96	76.25	50.87	94.64	172.16
94 -98	-51.67	-29.85	-8.06	2.36	0.10	8.78	16.39	22.30	29.71	50.87	60.28	88.13	144.97
98 -120	-81.26	-49.45	-13.88	5.84	-2.59	22.84	32.45	36.99	50.55	94.64	88.13	186.94	297.44
120 -160	-121.66	-54.30	-14.03	25.35	-5.92	47.00	61.07	53.66	83.26	172.16	144.97	297.44	685.86

Unfolding matrices

The data are unfolded to correct for detector effects, and the unfolding matrix is obtained using simulation. The unfolding matrices used for the training are given for $\sqrt{s} = 7$ TeV and $\sqrt{s} = 8$ TeV in Table 6 and Table 7.

Table 6: Elements of the unfolding matrix obtained from the Pythia $Z \to \mu^+\mu^-$ sample at $\sqrt{s} = 7$ TeV, used to correct the data for the detector resolution. The generated invariant mass is given in the columns and the reconstructed in the rows. Note that no unfolding for FSR is applied in this analysis.

$m_{\mu\mu}$ [GeV]	60 -72	72 -81	81 -86	86 -88	88 -89	89 -90	90 -91	91 -92	92 -93	93 -94	94 -98	98 -120	120 -160
60 -72	0.959	0.027	–	–	–	–	–	–	–	–	–	–	–
72 -81	0.038	0.886	0.044	–	–	–	–	–	–	–	–	–	0.001
81 -86	0.001	0.077	0.744	0.100	0.010	0.002	–	–	–	–	–	0.001	0.001
86 -88	–	0.003	0.150	0.483	0.150	0.030	0.008	0.003	0.001	0.001	0.001	0.001	0.001
88 -89	–	0.001	0.024	0.202	0.302	0.123	0.031	0.010	0.005	0.004	0.002	0.001	–
89 -90	0.001	0.001	0.015	0.113	0.291	0.337	0.160	0.054	0.023	0.015	0.008	0.003	0.005
90 -91	0.001	0.002	0.012	0.065	0.170	0.347	0.443	0.285	0.130	0.073	0.034	0.008	0.001
91 -92	–	0.002	0.007	0.029	0.063	0.130	0.290	0.464	0.384	0.221	0.092	0.013	0.009
92 -93	–	0.001	0.002	0.006	0.011	0.024	0.057	0.152	0.326	0.313	0.128	0.011	0.002
93 -94	–	–	0.001	0.001	0.003	0.004	0.009	0.025	0.103	0.257	0.177	0.011	0.001
94 -98	–	–	0.001	0.001	0.001	0.002	0.002	0.006	0.026	0.115	0.525	0.133	0.003
98 -120	–	–	–	–	–	–	–	–	–	0.001	0.033	0.811	0.067
120 -160	–	–	–	–	–	–	–	–	–	–	–	0.007	0.908

Table 7: Elements of the unfolding matrix obtained from the PYTHIA $Z \rightarrow \mu^+\mu^-$sample at $\sqrt{s} = 8$ TeV, used to correct the data for the detector resolution. The generated invariant mass is given in the columns and the reconstructed in the rows. Note that no unfolding for FSR is applied in this analysis.

$m_{\mu\mu}$ [GeV]	60 -72	72 -81	81 -86	86 -88	88 -89	89 -90	90 -91	91 -92	92 -93	93 -94	94 -98	98 -120	120 -160
60 -72	0.954	0.029	–	–	–	–	–	–	–	–	–	–	–
72 -81	0.041	0.871	0.048	0.001	–	–	–	–	–	–	–	–	–
81 -86	0.001	0.087	0.720	0.104	0.010	0.002	0.001	–	–	–	–	0.001	0.001
86 -88	–	0.003	0.157	0.452	0.146	0.035	0.010	0.004	0.002	0.002	0.002	0.002	0.001
88 -89	–	0.001	0.027	0.198	0.271	0.120	0.034	0.012	0.006	0.004	0.002	0.002	0.001
89 -90	0.001	0.002	0.019	0.119	0.287	0.314	0.160	0.061	0.029	0.017	0.010	0.005	0.002
90 -91	0.001	0.003	0.015	0.080	0.189	0.343	0.424	0.286	0.145	0.085	0.041	0.010	0.004
91 -92	0.001	0.003	0.010	0.035	0.077	0.149	0.297	0.446	0.381	0.232	0.105	0.016	0.003
92 -93	–	0.001	0.002	0.009	0.016	0.029	0.061	0.156	0.308	0.309	0.144	0.014	0.003
93 -94	–	0.001	0.001	0.002	0.003	0.005	0.010	0.029	0.100	0.233	0.175	0.013	0.001
94 -98	–	–	0.001	0.001	0.001	0.002	0.003	0.008	0.028	0.116	0.486	0.146	0.002
98 -120	–	–	–	–	–	–	–	–	–	0.001	0.035	0.784	0.061
120 -160	–	–	–	–	–	–	–	–	–	–	–	0.007	0.919

Calculating the χ^2

In order to calculate the χ^2 for a prediction of A_{FB} one must first combine the covariance matrices corresponding to the statistical, systematic and theoretical uncertainties. To simplify the calculation, one can neglect all off diagonal terms except those from the PDF uncertainties, as they are either zero or negligible. The covariance matrix for the PDF uncertainty is given in Table 5. The remaining diagonal terms to be added to this matrix can be obtained from the numbers corresponding to the statistical and systematic uncertainties from Tables 2 and 3 and the remaining theoretical uncertainties. These are

$$33.26, 28.2, 16.78, 29.12, 28.17, 15.83, 7.51, 6.89, 21.81, 56.6, 38.2, 28.84, 182.07$$

for $\sqrt{s} = 7$ TeV and

$$25.59, 22.83, 10.27, 15.0, 18.02, 7.78, 4.52, 4.7, 10.84, 16.22, 15.38, 14.53, 91.84$$

for $\sqrt{s} = 8$ TeV. Note that the numbers have been multiplied by a factor of 10^6 and the asymmetries have been averaged. Using C to denote the total covariance and letting V be the vector of the differences between the measured and predicted A_{FB}, the χ^2 is given by

$$\chi^2 = V^T C^{-1} V.$$