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SYSTEMATIC ERRORS OF α_s AND POINT-TO-POINT CORRELATIONS OF DEEP INELASTIC SCATTERING DATA

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Abstract

Alekhin S.I. Systematic errors of α_s and point-to-point correlations of deep inelastic scattering data.: IHEP Preprint 95-65. – Protvino, 1995. – p. 5, figs. 1, tables 2, refs.: 13.

We have analysed the BCDMS data on muon proton/deuterium scattering on the basis of the Bayesian statistical model with full treatment of point-to-point correlations due to systematic errors. Systematic errors of strong coupling constant α_s and gluon distribution obtained in this approach turned out significantly less than in the standard one.

Аннотация

Алехин С.И. Систематические ошибки α_s и корреляции данных по глубоконеупругому рассеянию.: Препринт ИФВЭ 95-65. – Протвино, 1995. – 5 с., 1 рис., 2 табл., библиогр.: 13.

Мы проанализировали данные BCDMS коллаборации по рассеянию мюонов на протоне и дейтерии на основе бейесовской статистической модели с полным учетом корреляций данных из-за систематических ошибок. Систематические ошибки α_s и глюонного распределения,получаемые в этом подходе,оказались существенно меньше, чем в стандартном.

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It is well known that errors in the recent and most precise data on deep inelastic scattering have significant systematic component. Extraction of strong coupling constant α_s from deep inelastic scattering data give a good example when systematic error of the parameter is dominant. Standard statistical approaches based on the simple χ^2 minimization can be inadequate for phenomenological analysis of these data. In [1] we have shown that systematic errors of phenomenological parameters extracted from the data with large systematic errors can be reduced if a full treatment of point-to-point correlation of data is provided. This paper is devoted to the examination of how efficient is this reduction in the analysis of real data.

For our analysis we use data of the BCDMS collaboration on deep inelastic scattering of muons off protons [2] and deuterium [3]. Differential cross sections for proton and deuterium were fitted simultaneously to obtain the parameters of parton distributions and strong coupling constant α_s. The value of $R = \sigma_L/\sigma_T$ was taken from [4]. Deuterium data were corrected for Fermi motion using procedure [5] with the Paris wave function for deuterium [6]. An important feature of our analysis is that this correction was made interactively in the fit and as a result we obtain fully consistent set of structure functions describing the data. The data were cut to reduce effects of high twists

$$W > 4\ GeV, \qquad Q^2 > 9\ GeV^2.$$

After this cut we have 315 points in proton and 242 points in deuterium data sets. The F_2 for nucleon was approximated by combination of parton distributions for 4 flavours implying isotopic symmetry for valence and sea distributions (recent NMC data [7] reveal that $\bar{u} \neq \bar{d}$ but the BCDMS data are compatible with the symmetric quark sea) Light quarks and gluon distributions at $Q_0^2 = 9\ GeV^2$ were chosen as follows

$$xu_V(x) = A_u x^{a_u}(1-x)^{b_u}, \qquad xd_V(x) = A_d x^{a_d}(1-x)^{b_d},$$
$$xS(x) = A_s(1+b_s)(1-x)^{b_s}, \qquad xG(x) = A_G(1-x)^{b_G},$$
$$u_S(x) = d_S(x) = \frac{S(x)}{4+2\kappa}, \qquad s(x) = \kappa \cdot u_S(x).$$

We did not consider A_G, A_u, A_d as a free parameters, they were calculated from other parameters using momentum and fermion number conservation. The value of κ was fixed

at 0.4 which is compatible with recent CCFR findings [8] . We assumed that $c-$quark sea is zero at $Q^2 = 9\ GeV^2 = 4m_c^2$, at higher Q^2 it was generated radiatively using prescription [9]. Other parton distributions were evolved using GLAP equations [10] in the leading order on α_s.

At the first stage of the analysis we used more or less standard approach (see, e.g. [12]) when the data are fitted using statistical errors only. The results of this fit are presented in the first column of Tab.1. Then, in accordance with this approach we evaluated systematic

Table 1. The parameters values, their statistical and total experimental errors including systematics (in parenthesis) obtained using various approaches.

	I	II
a_u	0.732 ± 0.003 (0.017)	0.737 ± 0.003 (0.005)
b_u	3.31 ± 0.01 (0.10)	3.31 ± 0.01 (0.03)
a_d	0.99 ± 0.02 (0.03)	0.99 ± 0.02 (0.02)
b_d	5.40 ± 0.09 (0.15)	5.37 ± 0.09 (0.10)
b_G	7.7 ± 0.9 (3.9)	8.6 ± 1.2 (1.9)
A_s	0.111 ± 0.002 (0.006)	0.117 ± 0.002 (0.005)
b_s	14.4 ± 0.4 (1.3)	14.8 ± 0.5 (0.8)
$\alpha_s(50GeV^2)$	0.200 ± 0.005 (0.015)	0.208 ± 0.005 (0.007)
χ^2/NDF	573/549	563/549

errors of the parameters shifting data by the value of systematic errors and repeating the fit. The shifts of the parameters obtained in the last fits are treated as the systematic errors of the parameters. These systematic errors were combined in quadrature with the statistical ones to give the total experimental error of the parameters, which is also presented in Tab. 1. One can see that for most of parameters systematic errors are dominant. During this last step we assumed that most of systematic errors of proton and deuterium data are totally correlated [11], meanwhile general normalization error and relative normalization of proton and deuterium data were not accounted. One technical note is that really we did not perform the fits with systematical shifts but evaluated systematic errors using analytical formula from [1].

On Fig.1a we present the bounds of gluon distribution at Q_0^2 obtained in this analysis with account of correlations between parameters of parton distributions. One can note that in the region of $x \sim 0.1$ these bounds are significantly less than elsewhere, this is a direct consequence of momentum conservation.

Alternatively one can use in the analysis χ^2 functional which fully accounts for correlations due to systematic shifts (formula (3) of [1]). The values of the parameters obtained with the minimization of this functional are presented in column II of Tab.1, the bounds of gluon distribution are shown on Fig. 1b. One can see that systematic errors of parton distributions and α_s obtained in the second approach are significantly less than in the standard one. The reasons of this suppression were discussed in [1], here we can only

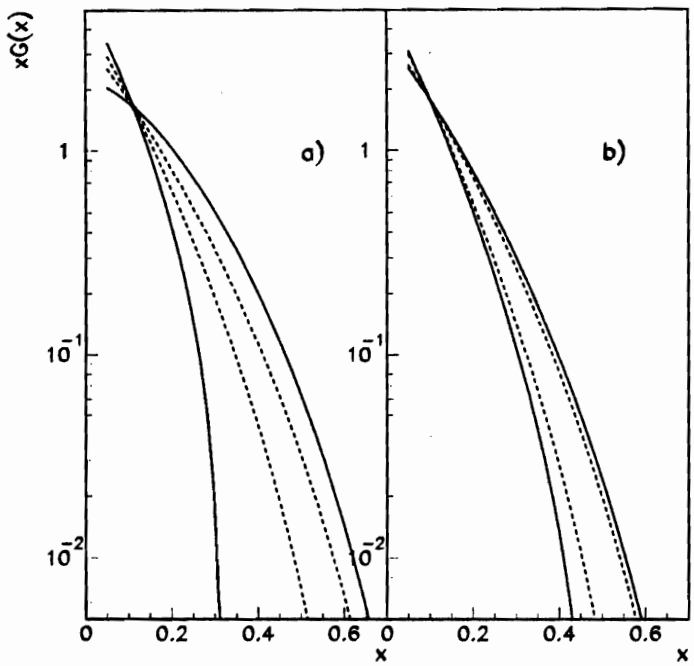

Fig. 1. Bounds of gluon distribution at Q_0^2 obtained in the various approaches: a) - standard approach, b) - with the full treatment of correlations. Full lines correspond to the total experimental errors, dashed - to the statistical only.

add that for the considered task this difference is especially pronounced since global correlation coefficients for the parameters are about unity (see Tab.2) which corresponds to significant increase of statistical errors of the parameters due to their correlations [13]. It is worth to note that in some similar analysis the number of free parameters is much

Table 2. Correlation matrix and global correlation coefficients (GCC) for parton distribution parameters obtained using standard approach.

	a_u	b_u	a_d	b_d	b_G	A_s	b_s	a_s	GCC
a_u	1.	0.50	-0.11	-0.01	0.17	0.16	0.29	0.19	0.97
b_u	0.50	1.	-0.21	-0.09	0.44	0.02	-0.08	-0.68	0.97
a_d	-0.11	-0.21	1.	0.91	0.24	0.18	0.36	-0.02	0.97
b_d	-0.01	-0.09	0.91	1.	0.24	0.13	0.33	-0.18	0.97
b_G	0.17	0.44	0.24	0.24	1.	-0.19	-0.50	-0.46	0.93
A_s	0.16	0.02	0.18	0.13	-0.19	1.	0.71	0.09	0.83
b_s	0.29	-0.08	0.36	0.33	-0.50	0.71	1.	0.27	0.95
α_s	0.19	-0.68	-0.02	-0.18	-0.46	0.09	0.27	1.	0.97

larger and probably correlations of parameters are also larger which can lead to the further increase of systematic errors in the standard approach.

We emphasize that effect of systematics reduction does not depend on the specific shape for the probability functions of systematic shifts, we only imply that it has zero average. Meanwhile it seems that these probability functions can be well approximated by Gaussian due to the central limit theorem of statistics since the total systematics is combined from 9 sources of comparable scale. The validity of the last approximation is supported by the reasonable value of χ^2/NDF.

The differences of fitted parameters obtained in various approaches are within their experimental errors. The most significant shift is obtained for the values of total sea momentum and strong coupling constant. The shift of the last value is especially interesting as far as the data discussed here are among of the most precise ones for fixed target experiments and this shift can lead to the change of world average for α_s determined from low energy data.

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References

[1] Alekhin S.I. - IHEP 95-48, Protvino, 1995.

[2] BCDMS collaboration, Benvenuti A.C. et al., // Phys. Lett. 1989, V.223B, P.485.

[3] BCDMS collaboration, Benvenuti A.C. et al., // Phys. Lett. 1990, V.237B, P.592.

[4] Whitlow L.W. et al., // Phys. Lett. 1990, V.250B, P.193.

[5] West Geoffrey B., // Ann. Phys. 1972, V.74, P.464.

[6] Lacombe M. et al., // Phys. Rev. 1980, V.C21, 861; Lacombe M. et al., // Phys. Lett. 1981, V.101B, 139.

[7] NMC collaboration, Arneodo et al., // Phys. Rev. 1994, V.D50, P.R1.

[8] CCFR collaboration, Bazarko et al., // Z. Phys. 1995, V.C65, P.189.

[9] Gluck M., Hoffmann E., Reya E., // Z. Phys. 1982, V.C13, P.119.

[10] Gribov V.N., Lipatov L.N., // Sov. Journ. Nucl. Phys. 1972, V.15, P.438; ibid. P.675; Altarelli G., Parisi G., // Nucl. Phys. 1977, V126B, P.298.

[11] BCDMS collaboration, Benvenuti A.C. et al., // Phys. Lett. 1990, V.237B, P.599.

[12] BCDMS collaboration, Benvenuti A.C. et al., // Phys. Lett. 1989, V.223B, P.490.

[13] James F., Roos M., – CERN Program Library D506. MINUIT – Function Minimization and Error Analysis, Version 92.1, 1992.

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