User guide of a QCD fit programme : QCDFIT Version : 4.00

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Abstract

To answer the request of some of our H1 collegues, we provide a user guide for our structure functions fit programme. We also provide different data samples.

Introduction

We have written a programme to solve the DGLAP [1] integro-differential equations. The numerical methods used are described in ref. [2]. The aim of this programme is to fit deep inelastic data from various experiments.

The DGLAP equations are considered in the Leading Log(Q^2) Approximation (LLA) and in the Next to Leading Log(Q^2) Approximation (NLLA).

Let us stress that this program cannot be considered as a 'black box' and that any user should read carefully the references. At least, a good expertise of the MINUIT program of [3] and a good understanding of the Furmanski and Petronzio's paper [4] is required (an educational description of the DGLAP equation solution can be also found in the Martinelli et al. paper [39]).

In the first section of this note, a detailed description of the solution of the DGLAP equation is given. A particular effort is made to describe precisely the partonic content of the distributions evolved by these equations. The topics explained in section 1 are necessary to understand the following sections where the parameters and the different options of the programme are described. Section 2 to 4 give insight to extensions of the original simple evolution necessary to take care of the real cases. Section 5 and 6 give some computer oriented technical details.

1 Solution of the DGLAP equations

QCDFIT solves the DGLAP evolution equations in the x space. These equations consist on a set of three differential equations describing the non-singlets, a gluon and a singlet parton densities inside nucleons. The non-singlet DGLAP equation reads :

$$\frac{\partial q^{\pm}_{NS}}{\partial t} = P^{\pm}_{NS} \otimes q^{\pm}_{NS}$$

where $t = \log(Q^2)$, $\otimes$ stands for the convolution product in the x space and $P^{\pm}_{NS}$ are the + or − non-singlet splitting functions [5] :

$$P^{\pm}_{NS}(x) = P_{qq}(x) \pm P_{q\bar{q}}(x)$$

with

$$P_{qq}(x) = \frac{\alpha_s(t)}{2\pi} P^{[1]}_{qq}(x) + \frac{\alpha_s^2(t)}{2\pi} P^{[2]}_{qq}(x) + O(\alpha_s^3)$$
$$P_{q\bar{q}}(x) = \frac{\alpha_s^2(t)}{2\pi} P^{[2]}_{q\bar{q}}(x) + O(\alpha_s^3)$$

Notice that $P_{q\bar{q}}$ vanishes in LLA and that only one type of non-singlet distribution exists in this approximation.

The singlet and gluon densities evolutions are coupled and solved in the x space :

$$\frac{\partial}{\partial \log(Q^2)} \begin{pmatrix} \Sigma(x, Q^2) \\ g(x, Q^2) \end{pmatrix} = \int_x^1 \frac{dz}{z} \begin{pmatrix} P_{qq}(z) & n_f P_{qg}(z) \\ P_{gq}(z) & P_{gg}(z) \end{pmatrix} \begin{pmatrix} \Sigma(\frac{x}{z}, Q^2) \\ g(\frac{x}{z}, Q^2) \end{pmatrix} \tag{1}$$

where the splitting functions are expended up to α_s^2 order [6]. **For n_f active quark flavors, QCDFIT computes the following two dimensional distributions** :

1. the singlet density

$$x\Sigma(x, Q^2) = \sum_{i=1}^{i=n_f} x\{q_i(x, Q^2) + \bar{q}_i(x, Q^2)\} \tag{2}$$

2. a non-singlet density[1]

$$\begin{aligned} xU^+(x, Q^2) &= x[u^+(x, Q^2) + c^+(x, Q^2)] \\ &= x\left[u(x, Q^2) + \bar{u}(x, Q^2) - \frac{\Sigma(x, Q^2)}{n_f}\right] + x\left[c(x, Q^2) + \bar{c}(x, Q^2) - \frac{\Sigma(x, Q^2)}{n_f}\right] \end{aligned} \tag{3}$$

3. the gluon density, $xg(x, Q^2)$

4. if neutron or deuteron data are also fitted, a second non singlet density :

$$\begin{aligned} x\Delta^+(x, Q^2) &= x[u^+(x, Q^2) - d^+(x, Q^2)] \\ &= x\left[u(x, Q^2) + \bar{u}(x, Q^2) - \frac{\Sigma(x, Q^2)}{n_f}\right] - x\left[d(x, Q^2) + \bar{d}(x, Q^2) - \frac{\Sigma(x, Q^2)}{n_f}\right] \end{aligned} \tag{4}$$

[1] *Below the charm threshold $c^+(x, Q^2)$ is set to zero. When $n_f = 3$ $c^+(x, Q^2) \equiv 0$ $\forall Q^2$.*

5. if neutrino structure functions are fitted, two − non singlet density types are needed :

$$xV(x,Q^2) = xu^-(x,Q^2) + xd^-(x,Q^2)$$
$$= x[u(x,Q^2) - \bar{u}(x,Q^2)] + x[d(x,Q^2) - \bar{d}(x,Q^2)] = x[u^v(x,Q^2) + d^v(x,Q^2)] \quad (5)$$

$$x\Delta^-(x,Q^2) = xu^-(x,Q^2) - xd^-(x,Q^2)$$
$$= x[u(x,Q^2) - \bar{u}(x,Q^2)] - x[d(x,Q^2) - \bar{d}(x,Q^2)] = x[u^v(x,Q^2) - d^v(x,Q^2)] \quad (6)$$

Notice that our choice of the four non-singlet densities is purely arbitrary. Notice also that the evolutions of the + and − non-singlet densities are different in NLLA and identical in LLA. From the knowledge of xg, Σ, U^+ and Δ^+ we are able to compute the DIS observables. To show it, we first define

$$\bar{F}_2 = \sum_{i=1}^{n_f} e_i^2 \{q_i + \bar{q}_i\},$$

the light parton contribution to F_2 is then given by $F_2 = x\bar{F}_2$ in LLA. In NLLA, we use the $\overline{\textbf{MS}}$ **scheme** and the previous expression reads :

$$\frac{F_2}{x} = \left(1 + \frac{\alpha_s}{2\pi} C_q^2\right) \otimes \bar{F}_2 + \frac{\alpha_s}{2\pi} C_g^2 \otimes \left(\sum_f e_f^2\right) g$$

The symbol $\otimes$ stands for the convolution product in the x space. The kernels C_q^2 and C_g^2 are the Leading Order (LO) Wilson coefficients [4]. **In QCDFIT, the factorization scale and the renormalization scale are taken both to be equal to Q^2.**

$\bar{F}_2$ can easilly be explained in term of the evolved densities, Σ, U^+ and Δ^+ :

$$\bar{F}_2^p = A_u\left(U^+ + \frac{a}{n_f}\Sigma\right) + A_d\left(\frac{n_f - a}{n_f}\Sigma - U^+\right)$$
$$\Longleftrightarrow \quad \bar{F}_2^p = \Big(A_u - A_d\Big)U^+ + \frac{1}{n_f}\Big(a(A_u - A_d) + n_f A_d\Big)\Sigma \quad (7)$$

for protons and

$$\bar{F}_2^n = A_u\left(U^+ - \Delta^+ + \frac{a}{n_f}\Sigma\right) + A_d\left(\frac{n_f - a}{n_f}\Sigma - U^+ + \Delta^+\right)$$
$$\Longleftrightarrow \quad \bar{F}_2^n = \Big(A_u - A_d\Big)U^+ + \Big(A_d - A_u\Big)\Delta^+ + \frac{1}{n_f}\Big(a(A_u - A_d) + n_f A_d\Big)\Sigma \quad (8)$$

for neutrons. The parameter a is egal to 1 when $n_f = 3$ and 2 when $n_f > 3$. In the case of one γ exchange, $A_u = 4/9$ and $A_d = 1/9$. When the Z_0 exchange and the $\gamma - Z^0$

interferences are included, A_u and A_d are function of Q^2 :

$$A_q(Q^2) = e_q^2 - 2e_q v_e v_q P_Z + (v_q^2 + a_q^2)(v_e^2 + a_e^2)P_Z^2, \quad \begin{cases} P_Z(Q^2) = 1/4 \sin^2\theta_W \cos^2\theta_W \left(1 + \frac{M_Z^2}{Q^2}\right) \\ v_e = -\frac{1}{2} + 2\sin^2\theta_W \\ a_e = -\frac{1}{2} \\ v_u = \frac{1}{2} - \frac{4}{3}\sin^2\theta_W \\ a_u = \frac{1}{2} \\ v_d = -\frac{1}{2} + \frac{2}{3}\sin^2\theta_W \\ a_d = -\frac{1}{2} \end{cases} \tag{9}$$

However one should notice that structure function data are usually corrected for Z^0 effects and that one should just forgot them.

To solve the DGLAP equations, one must define some mathematical functions of x at a given input scale Q^2 (that we shall denote Q_0^2) for each of the six distributions to be evolved. The first and immediat way to do it is to parametrize Σ, U^+, Δ^+ and g. However, one may be interested to use some external parton distribution input (*i.e.* from the pdflib library [21]) or to directly parametrize the quark densities (valence, sea...) and then to build the linear combinations of eq. 2, 3, 4. Therefore, we consider up to 6 functions of x (the minimum being 0 when the pdflib is used) : $\zeta_i(x)$, $i = 1, ..., 6$. Let us denote by N the number of functions ζ. The user is free to choose the partonic content of each of these functions, *i.e* he must define a $[8+N] \times 6$ matrix M such that :

$$\overrightarrow{E} = M\overrightarrow{I} \quad , \tag{10}$$

where $\overrightarrow{E}$ contains the six densities to be evolved by QCDFIT[2] :

$$\overrightarrow{E} = \left(xg, x\Sigma, x\Delta^+, xU^+ + \frac{n_{2/3}}{n_f}x\Sigma, xV, x\Delta^-\right)$$

and $\overrightarrow{I}$ the input densities : $\overrightarrow{I} = \overrightarrow{I}_{pdf} \oplus \overrightarrow{I}_{param}$. For an educative purpose, we distinguish here the pdflib and parametrized contributions.
Thus :

$$\overrightarrow{I}_{pdf} = \left(\frac{x[b+\bar{b}]_{pdf}}{2}, \frac{x[c+\bar{c}]_{pdf}}{2}, \frac{x[s+\bar{s}]_{pdf}}{2}, x\bar{u}_{pdf}, x\bar{d}_{pdf}, xg_{pdf}, xd^v_{pdf}, xu^v_{pdf}\right)$$

and

$$\overrightarrow{I}_{param} = \left(\zeta_1(x), \zeta_2(x), \zeta_3(x), \zeta_4(x), \zeta_5(x), \zeta_6(x)\right)$$

In order to be more explicit, we give three examples. The first one is taken from the H1 fit of **??**. For this fit we only considered proton DIS data and $n_f = 3$. We did not use a

[2] *$n_{2/3}$ is the number of charge 2/3 quarks*

pdflib information (as ZEUS did in **??** indeed)

$$M = \begin{array}{cc} \underbrace{\begin{array}{cccccccc} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array}}_{PDF \quad coefficients} & \underbrace{\begin{array}{cccc} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1/3 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{array}}_{\zeta_i \quad coefficients} \end{array}$$

One can simply see that we had chosen $\zeta_1 = xg$, $\zeta_2 = x\Sigma$, $\zeta_4 = xU^+$ and $\zeta_{3,5,6} = 0$ in this case.

The second example is taken from the the H1 fit of **??**. Here Deuterium data have been introduced and we kept $n_f = 3$. In order to constraint the valence quarks we choose to parametrize $\zeta_1 = xg$, $\zeta_2 = x(\bar{u} + \bar{d})$, $\zeta_3 = xu^v$, $\zeta_4 = xd^v$. Then, assuming $\bar{u} = \bar{d} = 2s$ we have :

$$M = \begin{array}{cc} \underbrace{\begin{array}{cccccccc} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array}}_{PDF \quad coefficients} & \underbrace{\begin{array}{cccc} 1 & 0 & 0 & 0 \\ 0 & 5/2 & 1 & 1 \\ 0 & 0 & 1 & -1 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{array}}_{\zeta_i \quad coefficients} \end{array}$$

The last example given here describes how to use the pdflib without fitting (it is of course also possible to mix the pdflib and parametrization input functions). Let us consider 5 active flavours ($n_f = 5$) at Q_0^2. Using eq. (2,3, 4) one can write down the matrix M :

$$M = \begin{array}{cc} \underbrace{\begin{array}{cccccccc} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 2 & 2 & 2 & 2 & 2 & 0 & 1 & 1 \\ 0 & 0 & 0 & 2 & -2 & 0 & -1 & 1 \\ 0 & 2 & 0 & 2 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 \end{array}}_{PDF \quad coefficients} & \underbrace{\begin{array}{cccc} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{array}}_{\zeta_i \quad coefficients} \end{array} .$$

In that case, there is no fit and the programme act as an interface with the pdflib. All the lines being filled one can get any structure functions.

The mathematical form of the $\zeta_i(x)$ functions is not predicted by QCD (except the condition $\zeta_i(1) = 0 \; \forall Q^2$). The assymptotic behaviour of structure functions is such that :

$$\zeta_i(x) \xrightarrow[x \to 1]{} (1-x)^c, \quad c > 0 \text{ and } \zeta_i(x) \xrightarrow[x \to 0]{} x^{c'}$$

We then propose several different mathematical forms :

for **i_type** = 1 or 2

$$\zeta_i(x) = A_i x^{B_i}(1-x)^{C_i}\left[1+\sum_{k=1}^{6} a_i^k x^{k(\delta_i+1)}\right]^p \tag{11}$$

for **i_type** = 3 or 4

$$\zeta_i(x) = A_i x^{B_i}\log^{C_i}\left(\frac{1}{x}\right)\left[1+\sum_{k=1}^{6} a_i^k \left(\log\frac{1}{x}\right)^{k(\delta_i+1)}\right]^p \tag{12}$$

for **i_type** = 5 or 6

$$\zeta_i(x) = A_i x^{B_i}(1-x^{\delta_i+1})^{C_i}\left[1+\sum_{k=1}^{6} a_i^k (1-x^{\delta_i+1})^k\right]^p \tag{13}$$

for **i_type** = 7 or 8

$$\zeta_i(x) = A_i x^{B_i}(1-x^{\delta_i+1})^{C_i}\left[1+\sum_{k=1}^{6} a_i^k (x(1-x^{\delta_i+1}))^k\right]^p \tag{14}$$

for **i_type** = 9 or 10

$$\zeta_i(x) = A_i(1-u^{\delta_i+1})^{B_i}u^{C_i}\left[1+\sum_{k=1}^{6} a_i^k (u(1-u^{\delta_i+1}))^k\right]^p \tag{15}$$

where $u = 1-x$

for **i_type** = 11 or 12

$$\zeta_i(x) = A_i x^{B_i}((1+a)^{\delta_i+1} - x^{\delta_i+1})^{C_i} \tag{16}$$

for **i_type** = 13 or 14

$$\zeta_i(x) = A_i x^{B_i}(1-x)^{C_i}\left[1+\sum_{k=1}^{6} a_i^k v^{k(\delta_i+1)}\right]^p \tag{17}$$

where $v = 0.1 - x$ [**?**]

for **i_type** = 15 or 16

$$\zeta_i(x) = A_i x^{B_i}(1-x)^{C_i}\left[1+\sum_{k=1}^{6} a_i^k w^{k(\delta_i+1)}\right]^p \tag{18}$$

where $w = 0.1log(1+exp(10-100x))$ [**?**]

with $p = 1$ or $p = 2$(for even **i_type**). This latter case has been introduced to force the positivity of the distributions. All the parameters $A_i, B_i, C_i, \delta_i, a_i^k$, are free. To determine these parameters one must minimize a χ^2 which compare the measured value of F_2 to the evolved ones :

$$\chi^2 = \sum_{exp}\sum_{data} w_{data}\left(\frac{F_2^{THEORY}}{c_{exp}} - F_2^{data}\right)^2 + \sum_{experiments}\frac{(1-c_{exp})^2}{\sigma_{exp}^2} \tag{19}$$

where w_{data} are the wheights and can be the inverse statistical error squared or the inverse of the quadratic sum of the statistical and systematic errors. This is a choice of the user's steering. The parameters c_{exp} are introduced to renormalize the different data sets entering the fit. To avoid biases, the second sum of the r.h.s of eq. 19 is introduced : we assume that the renormalization parameter fluctuations are gaussian. This is a Baysian approach for taking into account the data normalizations. The errors σ_c occuring in this second sum are the published overall experimental normalization uncertainties (see table 1). However, instead of the parameter c_{exp} we define the parameter

$$n_{exp} = \frac{1-c_{exp}}{\sigma_{exp}}$$

i.e. we prefer to normalize to a standard deviation. Assuming $n_{exp} \ll 1$, we linearize the first term of eq. (19) in order to increase the efficiency of the minimization procedure (MINUIT). After all, this approximation is certainly not worse that the choice of a χ^2 minimization... The expression that we minimize is finally :

$$\chi^2 = \sum_{exp}\sum_{data} w_{data}\left(F_2^{THEORY}(1+n_{exp}) - F_2^{data}\right)^2 + \sum_{exp} n_{exp}^2 \tag{20}$$

The present version of QCDFIT may accomodate up to 40 experimental data sets (see as an example table 1).

An important feature of any QCD fit program is the sum-rules. Two kind of sum-rules can be applied, the momentum sum-rules :

$$\int_0^1 dx\{xp(x,Q_0^2)\} = I_M$$

and the counting-rules :

$$\int_0^1 dx\{p(x,Q_0^2)\} = I_C$$

where $p(x,Q_0^2)$ represents a parton density. For example, the total momentum sum rule, with $p = \Sigma + g$ and $I_M = 1$, is usually set and one can also impose a certain amount of total gluon momentum with $p = g$ and $I_M = 0.44$ at $Q_0^2 = 4GeV^2$ for example. In the case of the former sum-rule, due to the splitting function properties, the condition stays true at any value of Q^2. If one choose $\zeta_1 = u^v$ and $\zeta_2 = d^v$, it is also common to impose the counting rules : $p = \zeta_1$ and $I_C = 2$, $p = \zeta_2$ and $I_C = 1$. These two later conditions are also very important when the renormalization parameters are let free in the fit. When any sum-rules or counting rules are applied, the normalization parameters

Experiment name	'registration name' (known by the programme)	overall normalization uncertainty
H1-1994 shifted vertex [9]	H1_SVX	4%
H1-1994 radiative events [9]	H1_RAD	1.5%
H1-1994 low-Q^2 [9]	H1_NVX	1.5%
H1-1994 high-Q^2 [9]	H1_HQ2	1.5%
ZEUS-1994 shifted vertex [10]	ZEUS_SVX	2%
ZEUS-1994 radiative events [10]	ZEUS_RAD	1.5%
ZEUS-1994 nominal vertex [11]	ZEUS_NVX	2%
NMC-90GeV beam [12]	NMC90_P and NMC90_D	2%
NMC-120GeV beam [12]	NMC120_P and NMC120_D	2%
NMC-200GeV beam [12]	NMC200_P and NMC200_D	2%
NMC-280GeV beam [12]	NMC280_P and NMC280_D	2%
NMC combined [13]	NMCP_NEW and NMCD_NEW	2%
BCDMS combined beam energies [14]	BCDMS_P and BCDMS_D	2%
E665 [15]	E665_P and E665_D	2.8%
SLAC combined experiments [16]	SLAC_P and SLAC_D	2%

Table 1: List of the available data set. All these data are $F_2^{e,\mu-H}$ or $F_2^{e,\mu-D}$ or F_2^{e-p} structure functions.

A_i corresponding to the evolved densities are determined. These constraints reduce the number of free parameters in the fit.
Numerically, all integrals between 0 and 1 of the functions of eq. (11,12) are expressed in term of the special gamma functions. When some input parton densities from the pdflib are used, or for **i_type** > 9, a numerical integral is performed. For the region $x \in [0, x_{min,pdf}]$ we just use a linear interpolation in log(x).

1.1 Strong coupling constant

The strong coupling constant is computed in LO and NLO. We account for heavy quark production thresholds according to [22]. The 'input' parameter is $\Lambda^{[4]}_{\overline{MS}}$. $\Lambda^{[3]}_{\overline{MS}}$ and $\Lambda^{[5]}_{\overline{MS}}$ are obtained by requiring the continuity of $\alpha_s(\mu)$ at $\mu = m_c$ and $\mu = m_b$ respectively. This is done at LO and NLO. **Notice that we take $\mu = \sqrt{Q^2}$ in our program.** In LO, α_s reads :

$$\alpha_s(Q^2) = \frac{4\pi}{\beta_0(\log Q^2/\Lambda^2)} + O(1/\log^2(Q^2/\Lambda^2))$$

and in NLO,

$$\alpha_s(Q^2) = \frac{4\pi}{\beta_0 \log(Q^2/\Lambda^2)}\left\{1 - \frac{2\beta_1}{\beta_0^2}\frac{\log\log(Q^2/\Lambda^2)}{\log(Q^2/\Lambda^2)}\right\} + O(1/\log^3(Q^2/\Lambda^2)) \qquad (21)$$

$$\beta_0 = 11 - 2n_f/3$$
$$\beta_1 = 51 - 19n_f/3$$

We also propose an expression of α_s obtained form an exact solution of the renormalization group equation at NLO :

$$\frac{Q^2 d\alpha_s}{dQ^2} = -\frac{\beta_0}{2\pi}\alpha_s^2 - \frac{\beta_1}{(2\pi)^2}\alpha_s^3 \tag{22}$$

2 Heavy quark prescription

The heavy quark contributions to F_2 can be handled according to two prescriptions : the Photon-Gluon-Fusion (PGF) [17, 18] and the Massless Evolution (MP) [20]. The user is free to choose one of the two prescriptions. However, none of these prescriptions are 'valid' and we recommand the reading of [19] and [18] before making any choice.

We do not consider the recent calculations [?],[?] which take into account the heavy quark electroproduction near the production threshold and at Q^2 much higher than mass.

2.1 PGF prescription

In that prescription, only **3** light quark flavours are evolved according to the DGLAP equations. The c quark is produced outside the proton from the Photon-Gluon-Fusion process (PGF) when $W^2 > (2m_c)^2$. The c contribution to F_2 is :

$$\begin{aligned} F_2^c(x, Q^2, m_c^2, \mu) = \quad & \frac{Q^2\alpha_s(\mu^2)}{4\pi m_c^2}\int_x^{z_{max}} \frac{dz}{z}\left[e_c^2 g(\frac{x}{z}, \mu^2)c_g^{(0)}\right] \\ + \quad & \frac{Q^2\alpha_s^2(\mu^2)}{\pi m_c^2}\int_x^{z_{max}} \frac{dz}{z}\left[e_c^2 g(\frac{x}{z}, \mu^2)\left(c_g^{(1)}(z) + \bar{c}_g^{(1)}\log\frac{\mu^2}{m_c^2}\right)\right. \\ + \quad & \bar{F}_2(\frac{x}{z}, \mu^2)\left(c_{\bar{F}}^{(1)} + \bar{c}_{\bar{F}}^{(1)}\log\frac{\mu^2}{m_c^2}\right) \\ + \quad & \left.\Sigma(\frac{x}{z}, \mu^2)\left(c_\Sigma^{(1)} + \bar{c}_\Sigma^{(1)}\log\frac{\mu^2}{m_c^2}\right)\right] \end{aligned} \tag{23}$$

The first term of the r.h.s is the LO contribution, where only the gluon density is involved, and the α^2 contribution depends on both gluon and quark densities. The kernels $C_i^{(1)}$ are very complicated and interpolated in a two dimensional table (see**??**). The upper bound of the integrals correspond to the production threshold : $z_{max} = Q^2/(Q^2 + 4m_c^2)$. F_2^c depends also on an extra scale, μ. 4 choices are available in the programme :

1. $\mu = 2m_c$;

2. $\mu = 4m_c$;

3. $\mu = \sqrt{Q^2}$;

4. $\mu = \sqrt{Q^2 + m_c^2}$ (standard choice).

Note that the numbers above are used in the programme to define the scale. In principle, the NLO PGF must be used when the NLLA DGLAP are solved in the $\overline{MS}$ scheme. In the same way, the LO PGF is used with the LLA DGLAP equations. Using that prescription the b quark contribution to F_2 is neglected.

The final F_2 reads :

$$\frac{F_2}{x} = \left(1 + \frac{\alpha_s}{2\pi} C_q^2\right) \otimes \bar{F}_2(n_f = 3) + \frac{\alpha_s}{2\pi} C_g^2 \otimes \left(\sum_{f=1}^{3} e_f^2\right) g + \frac{F_2^c}{x}$$

Warning : this heavy quark prescription should not be used at very high Q^2. (Although one does not really know what very high Q^2 means here...)

2.2 MP prescription

In that prescription, c and b quarks are assumed massless above the mass threshold. The initial conditions are then :

$$c(x) = \bar{c}(x) = 0 \text{ for } Q^2 \leq m_c^2$$

and

$$b(x) = \bar{b}(x) = 0 \text{ for } Q^2 \leq m_b^2.$$

When $Q^2 < m_c^2$, the number of flavors in the DGLAP equations is set to $n_f = 3$, the singlet and non-singlet densities are given by

$$\begin{aligned} \Sigma &= u + \bar{u} + d + \bar{d} + s + \bar{s} \\ U^+ &= u + \bar{u} - \frac{\Sigma}{3} \\ \Delta^+ &= u^+ - d^+ \end{aligned} \tag{24}$$

When $m_c^2 \leq Q^2 < m_b^2$, $n_f = 4$ and

$$\begin{aligned} \Sigma &= u + \bar{u} + d + \bar{d} + s + \bar{s} + c + \bar{c} \\ U^+ &= u + \bar{u} + c + \bar{c} - 2\frac{\Sigma}{4} \\ \Delta^+ &= u^+ - d^+ \end{aligned} \tag{25}$$

When $Q^2 \geq m_b^2$, $n_f = 5$ and

$$\begin{aligned} \Sigma &= u + \bar{u} + d + \bar{d} + s + \bar{s} + c + \bar{c} + b + \bar{b} \\ U^+ &= u + \bar{u} + c + \bar{c} - 2\frac{\Sigma}{5} \\ \Delta^+ &= u^+ - d^+ \end{aligned} \tag{26}$$

The non-singlet density U^+ is not continuous at the heavy quark thresholds.

WARNING : this prescription leads to a very bad description of the low-x and low-Q^2 H1 data. It should be used at very high Q^2.

3 Higher twists target mass and nuclear corrections

If one wants to include the high-x low-Q^2 data in the fit, one must take into account three effects : higher twists, target mass and nuclear corrections.

3.1 Target mass correction

In the high-x low-Q^2 region, the kinematical variable x does not represent the hadron momentum fraction carried by the interacting parton. When comparing F_2 measured at x to theory, one must make the following substitution in the theoretical calculations :

$$x \xrightarrow[x\to 1]{Q^2 \lesssim M^2} \zeta = \frac{2x}{1+\sqrt{1+\frac{4M^2x^2}{Q^2}}}$$

where the parton masses have been neglected and where M is the target mass in GeV (it is always the proton mass in the case of the data of table 1). To compare the F_2 measurements performed at x and Q^2, to F_2 computed at ζ and Q^2 it was shown that the following transformation is required [**?**] :

$$\begin{aligned} F_2(x,Q^2) = & \frac{x^2}{\left(1+\frac{4M^2x^2}{Q^2}\right)^{3/2}}\frac{F_2(\zeta,Q^2)}{\zeta^2} + \\ & 6\frac{M^2}{Q^2}\frac{x^3}{\left(1+\frac{4M^2x^2}{Q^2}\right)^{2}}\int_\zeta^1 dz \frac{F_2(z,Q^2)}{z^2} + \\ & 12\frac{M^4}{Q^4}\frac{x^4}{\left(1+\frac{4M^2x^2}{Q^2}\right)^{5/2}}\int_\zeta^1 dz \int_z^1 du \frac{F_2(u,Q^2)}{u^2} \end{aligned} \quad (27)$$

Numerically we use our method (based on Band matrice algebra [2]) to compute all the integrals of the r.h.s of eq. (27). That is we transform the integrals into convolution products by changing the variable $z \to y = \zeta/z$:

$$S(\zeta) = \int_\zeta^1 dz \frac{F_2(z,Q^2)}{z^2} = \frac{1}{\zeta}\int_\zeta^1 dy F_2(\frac{\zeta}{y},Q^2)$$

and

$$\int_\zeta^1 dz \int_u^1 dt \frac{F_2(u,Q^2)}{u^2} = \int_\zeta^1 \frac{dy}{y} S(\frac{\zeta}{y}) \quad .$$

In this form, we are allowed to use our fast integration method [2] and the full expression of eq. (27) is computed with no other approximation. Let us make some comments and statements concerning the target mass correction :

- it is only a kinematical correction and it does not modify significantly F_2 in the HERA domain;
- it should be applied when high-x, low-W^2 data are included in the fit ;
- **usually these corrections are not fully calculated**. For example, or the first integrale is computed [**?**], or a Taylor expension is performed [40] or it is not at all computed.

3.2 Higher twists correction

higher twist corrections should occur at small, but not too small, Q^2. Their mathematical form are usually purely empirical except for the recent calculations of [**?**]. They consist of $(1/Q^2)$ corrections to F_2 and may be writen as follows :

$$F_2(x,Q^2) = F_2^{QCD}(x,Q^2)\left(1 + \frac{\mathcal{H}(x)}{Q^2} + \mathcal{O}(1/Q^4)\right)$$

We propose different mathematical forms for the higher twist term $\mathcal{H}(x)$.

- A simple polynomial :

$$\mathcal{H}(x) = \sum_{i=0}^{6} h_i x^i \quad , \tag{28}$$

- A form recently proposed (and theoretically motivated) [**?**] .

3.3 Nuclear corrections

When deuterium data are included the fit, usually one does not apply nuclear corrections, *i.e.* :

$$F_2^D = \frac{F_2^p + F_2^n}{2}$$

We propose two methods of correction. The fist comes from refrerence ([36]).

Motivated by recent progresses of the covariant formalism describing the Deuteron nuclear effects [37],we have also applied these corrections on the calculated structure functions.

4 Beyond F_2

4.1 Longitudinal structure function F_L and reduced cross-section

So far we have only considered the F_2 structure function. But, if one wants to study the structure functions at high-y ($0.5 \lesssim y = Q^2/xs$), one must take into account the contribution of longitudinal photon exchange. The easiest way is to consider the reduced cross-section :

$$\sigma_r = F_2(x,Q^2) - \frac{y^2}{Y_M^+} F_L(x,Q^2) \equiv \frac{xQ^4}{2\pi\alpha_{em}^2 Y_M^+} \frac{d^2\sigma}{dxdQ^2}$$

With

$$Y_M^+ = 1 + (1-y)^2 - 2\frac{(xyM)^2}{Q^2}$$

Where we still consider only the one photon exchange process. The longitudinal structure function F_L is also 'predicted' by perturbative QCD. In the LO of the theory, one has

$$F_L(x,Q^2) = F_2(x,Q^2) - 2xF_1(x,Q^2) = 0$$

And in the NLO of the theory (but the first non vanishing order for F_L),

$$\frac{F_L}{x} = \frac{\alpha_s}{2\pi} C_q^L \otimes \bar{F}_2 + \frac{\alpha_s}{2\pi} C_g^L \otimes \left(\sum_f e_f^2\right) g \tag{29}$$

where the Wilson coefficients can be found in [4].
However, α_s^2 corrections to eq. (**??**) are sizable in the low-x and low-Q^2 region. The NLO Wilson coefficients have been calculated for F_L [**?**] and should be used. At this order we have :

$$\begin{aligned}\frac{F_L}{x} = &\left(\frac{\alpha_s}{2\pi} C_q^L + \frac{\alpha_s^2}{(2\pi)^2} C_{2,NS}^L\right) \otimes \bar{F}_2^{NS} \\ &+ \left(\frac{\alpha_s}{2\pi} C_q^L + \frac{\alpha_s^2}{(2\pi)^2} C_{2,S}^L\right) \otimes \bar{F}_2^{S} \\ &+ \left(\frac{\alpha_s}{2\pi} C_g^L + \frac{\alpha_s^2}{(2\pi)^2} C_{2,g}^L\right) \otimes \left(\sum_f e_f^2\right) g\end{aligned} \tag{30}$$

with

$$\begin{aligned}\bar{F}_2^{NS,p} &= \Big(A_u - A_d\Big) U^+ \\ \bar{F}_2^{S,p} &= \frac{1}{n_f}\Big(a(A_u - A_d) + n_f A_d\Big)\Sigma \\ \bar{F}_2^{NS,n} &= \Big(A_u - A_d\Big)(U^+ - \Delta^+) \\ \bar{F}_2^{S,n} &= \frac{1}{n_f}\Big(a(A_u - A_d) + n_f A_d\Big)\Sigma\end{aligned}$$

The heavy quark contributions to F_L are computed in the same way as for F_2. Namly according to the PGF or massless prescrition. In the case of the former prescription, the formula (23)is still available but with different coefficients (the longitudinal ones). Finally, the target mass and higher twist corrections are also computed in the case of F_L if required.

4.2 Electroweak fits

For neutrino cross-sections and in the high Q^2 regime of Hera one needs to include in the cross-sections the third structure function $xF_3(x,Q^2)$. This has been done in a consistent way, using the first order Wilson coefficients for the lights parton.
target mass and higher twist corrections are properly handled.
The reduced cross-section is now

$$\sigma_r = F_2(x,Q^2) - \frac{y^2}{Y_M^+} F_L(x,Q^2) \pm \frac{y-\frac{y^2}{2}}{Y_M^+} xF_3(x,Q^2) \equiv \frac{xQ^4}{2\pi\alpha_{em}^2 Y_M^+} \frac{d^2\sigma}{dxdQ^2}$$

For charged current processes the process $s \to c$ has been calculated using the Q^2 dependent coefficients of [38]. Finally for charged current cross-section we use the following definition of the reduced cross-section:

$$\sigma_r = \frac{(1+\frac{q^2}{m_w^2})^2}{(1+\frac{q^2}{M_w^2})^2} \left(F_2(x,Q^2) - \frac{y^2}{Y_M^+} F_L(x,Q^2) \pm \frac{y-\frac{y^2}{2}}{Y_M^+} xF_3(x,Q^2) \right) \equiv \frac{4\pi x}{G_F^2 Y_M^+} (1+\frac{q^2}{m_w^2})^2 \frac{d^2\sigma}{dxdQ^2} \tag{31}$$

$m_w = 80.33$ is the W Mass used to define the reduced cross-section while M_w is the true W Mass.

and the double differential cross-section reads:

$$\frac{d^2\sigma}{dxdQ^2} = \frac{G_F}{4\pi x(1+\frac{q^2}{m_w^2})^2} Y_M^+ \sigma_r$$

5 Code and computer

The code is written in FORTRAN within CMZ. No special H1 software is needed. Only the CERNLIB and PDFLIB libraries must be linked with this programme. This software is on group server in pascaud/public/nlo together with this notice.
Concerning the numerical algorithm used to solve the DGLAP set of equations we refer to [2]. We just mention here some programming extra details. All our numerical convolution integrals are performed in double precision using the *GADAP* algorithm [**?**] requiring the maximum allowed precision. We also use the N-point Gauss-Legendre quadrature formula (routine DGSET of [3]) to compute all integrals involved in the PGF calculations. All those integrals are performed only once at the initialization step.
At each MINUIT iteration, once the DGLAP evolution is performed, and various extra contributions computed, F_2 values are stored at the knots of a 'theoretical two dimentional net' in $\log x$ and $\log Q^2$: $\{x_i, Q_j^2\}$. Then the χ^2 is computed by making the difference between the experimental value F_2^{exp} and the 'theoretical' one interpolated in the net $\{x_i, Q_j^2\}$. We use a linear interpolation in log scale.

The figure 1 shows schematically what files and packages are required to run the programme :

- the CERNLIB, for MINUIT and other mathematical routines;
- the minuit steering command file : QCDFIT.DATA (see next section);
- the QCDFIT programme steering command file : QCDFIT.STEER (see next section);
- the experimental data file : EXPERIMENT.DAT;

On output, apart the minuit printout file, we provide :

- a ZEBRA file containing the required one dimensional plots : QCDFIT.RZ (see next section);
- a second ZEBRA file containing the experimental data and their related renormalization factor and χ^2 contribution : QCDFIT_T.RZ (see table 3). All informations are included in the PAW NTUPLE number 1. Each entry of this NTUPLE correspond to a datum. With such informations, one is able to construct its own PAW KUMAC command file to compare the data and the fit results.
- a FORTRAN function (included in PARAM.FOR), together with a data file(included in PARAM.DATA), containing a required two dimensional parametrization. The user must give a symbolic name exctracted from table 2 or defined in the **REACTIONS** field (se below). The programme performs a two dimentional interpolation : linear in $\log(F_2) - \log(Q^2)$ and using Chebyshev Polynomial in x (routine CHECF of [3]). For each value of Q_i^2 of the 'theoretical' net, we approximate $\mathcal{F}$ by :

$$\mathcal{F}(x, Q_i^2) \approx \sum_{j=1}^{n_c} \mathcal{A}_j^i \mathcal{T}_j(t) \text{ and } \begin{cases} n_c \leq 64 \\ t = \frac{2x - x_{min} - x_{max}}{x_{max} - x_{min}} \\ x \in [x_{min}, x_{max}] \end{cases}$$

  where $\mathcal{T}_j$ is the order j Chebyshev Polynomial and $\mathcal{A}_j^i$ the coefficients determined by the CERNLIB routine. n_c is the polynomial order of the interpolation and it depends on the required precision. All the parameters $\mathcal{A}_j^i$ are stored in a data file as described above. This parametrization tool has been motivated by the necessary reweighting procedure of H1 F_2 analysis. **When using PARAM.FOR, it is necessary to link the dchsum FORTRAN function of the CERNLIB** [3].

The details on the steering and output of QCDFIT are given in the next section. However, not all the fit parameters are set within the QCDFIT.STEER file:
There is a first level of selection made at the cmz level by the use of the '+SELF,name.' command [**?**]. The user is then obliged to compile the code with the required options. We give here all the compilation options :

- **unix** : for unix or ultrix machine ;

- **vax** : for VMS systems ;
- **ht_poly** : use higher twist correction of eq. (28) ;
- **ht_dmw** : use higher twist correction of eq. (**??**);
- **pdflib** : perform the link to the pdflib library ;
- **alfn** : use α_s from an exact solution of eq. (22) ;
- **heavy** : necessary for quark-gluon fusion prescription ;
- **tuple** to have a ntuple output ;
- **debug** to have debug printout (may be used for one or several decks) ;
- **tokarev** Deuterium correction from [36] is used ;
- **iron** For Deuterium to iron correction ;
- **neutrino** Necessary for neutrino reactions handling ;
- **nnlo** NLO Wilson coefficiants are used ;
- **symsyst** Only symmetric part of the systemmatic errors are considered ;
- **mnband** To make error bands with Minuit and not lsqfit ;
- **asband** Assymetric error bands with minuit (needs mnband) ;
- **drell** Include Drell Yang cross-section.
- **do_all** There is a built-in supression of unneeded calculations; as an example non singlets will not be evoluted if their parameters have not changed or if they are not needed to compute observables: this is the case for valences if no neutrino data is used. option do_all will remove this feature. It could be necessary for histograms because they are not looked upon to decide what calculations are needed.
- **refit_input** to make a parameter fit of partons distribution at some Q^2 ;
- **bfkl pw jet verif kernel pw_test fitpr rapgap user emc prevision work_shop vfns try_vfns norescaling** : should not be used.

For those who are interested in the extraction of the DGLAP kernels to write their own code, we mention that some terms (the singular ones) have been computed analyticaly. It is then only possible to use our code with the numerical method of [2].

6 Steering and output

6.1 MINUIT command file

All the unknow fit parameters are stored in the minuit command file (*i.e.* QCDFIT.DATA in schema 1) where a name and a number are assign to each one of them : see fig. 11. In this section we give correspondance between the fit parameters and the parameter number defined in the MINUIT command file [3] .

- **MINUIT number 1 to 10** : coefficients of $\zeta_1(x)$ according to eq. (11-18).
- **MINUIT number 11 to 20** : coefficients of $\zeta_2(x)$.
- **MINUIT number 21 to 30** : coefficients of $\zeta_3(x)$.
- **MINUIT number 31 to 40** : coefficients of $\zeta_4(x)$.
- **MINUIT number 41 to 50** : coefficients of $\zeta_5(x)$.
- **MINUIT number 51 to 60** : coefficients of $\zeta_6(x)$.
- **MINUIT number 71** : $\Lambda_{n=4}$.
- **MINUIT number 75** : this parameter is defined either as $\frac{M_W^2}{M_{Z_0}^2 \cos^2\theta_W}$ if it is close to one or as $M_{Z_0}^2 \cos^2\theta_W \sin^2\theta_W$ if it is over hundred.
- **MINUIT number 76** : M_W^2
- **MINUIT number 77** : $M_{Z_0}^2$
- **MINUIT number 78** : Lepton beam polarisation
- **MINUIT number 80** : target mass squared (to be set to zero when no target mass correction are required). **This is not a fit parameter** and it must be fixed during the MINUIT minimization procedure.
- **MINUIT number 81 to 109** : may be used depending on the +SELF options of cmz (it contains the higher twist coefficients for example).
- **MINUIT number 110 to 149** : experiment normalization parameters. The name of these parameters should be those of table 1 and **must be in the same order of appearence as in QCDFIT.STEER**.
- **MINUIT number 150 to 209** : experiment systematic parameters.

[3] *In fact we are refering here to the QCDFIT numbering. As Minuit accept only 100 parameters in its current version, QCDFIT translate its own numbering into a minuit numbering by keeping only parameters referenced as variable in the minuit input file; this is almost transparant to the user as QCDFIT output makes the reverse transform (however minuit output is in its own numbering)*

6.2 QCDFIT steering file

The steering file is made of fields begining by a certain name. Each line starting by a * is understood as a comment line. There is two classes of fields :

1. the necessary ones : **PAR1**, **EXPERIMENTS** , **PAR3** , **SCHEME** , **MEASURE** , **MINUIT** , **REACTIONS** and of course an ending card **END**.
2. the optional ones, *i.e.* the programme can run without them : **P_SUM**, **S_SUM**, **U_SUM**, **D_SUM** ,**EQUATI**, **KEEP**, **KILL**, **PLOT**.

In the following we describe the content of each field. First the necessary fields.

- $\boxed{\textbf{PAR1}}$
  BINX is the number of bins in the x net. Equidistant in $\log(x)$ from X_{MIN} (defined below) to 1 ;
  NBIS is the number which define the second net for a more accurate descrition of the parton densities at high-x. This second net starts at $X'_{MIN} = (X_{MIN})^{1/NBIS}$ up to $X'_{MIN} = 1$, the two nets have same number of bins;
  X_BIN_MIN= X_{MIN}. If X_{MIN} is greater than the one observed in the data, then the one observed in the data is taken ;
  Q2_BIN_MIN=Q^2_{min} in the net. If Q^2_{min} is greater than the one observed in the data, then the one observed in the data is taken ;
  Q2_BIN_MAX=Q^2_{max} in the net. If Q^2_{max} is lower than the one observed in the data, then the one observed in the data is taken ;
  Q2_INPUT = Q^2_0 : DGLAP evolution scale of departure ;
  XMC = charm effective mass in GeV;
  XMB = beauty effective mass in GeV (it is necessecary for α_s calculation);
  CHARM_OPEN = sqrt(Q^2) where the charm is fully active;
  BEAUTY_OPEN = sqrt(Q^2) where the beauty is fully active;
  If **CHARM_OPEN** = **XMC** then the massless quark prescripton is activated;
  ORD =1 for LLA and 2 for NLLA, 3 for NNLLA on F_L and 4 for NNLLA on F_L and F_2;
  X_CHARM_SCALE = flag defining the scale of the PGF calculation (see section ??);
  XPGF_NLO is the PGF order : 0 = no PGF, 1 = LO PGF, 2 = NLO PGF;
  XG_QUAD = number of points to be used in the numerical calculations of the integrals related to the PGF contribution. **It must only be chosen amongst** XG_QUAD=2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 20, 24, 32, 40, 48, 64, 80, 96;
  XCS_SCALE =flag defining the scale of the strange $\rightarrow$ charm NLO process.

- $\boxed{\textbf{EXPERIMENTS}}$
  Each experiment has its own line, format(a8,2x,4f10.4), with the following items:
  Experiment names (see table 1), 8 characters (in capital letters)

Overall experimental normalization uncertainties (see table 1).
Central normalization of the data : 1 = data in , 0 = data out, $\neq 0$ means the correponding data sample is globaly renormalized according to this factor.
The last two items give the renormalization factors of the χ^2 wheights for each experiment.

$$w = (p_4^2\sigma_{stat}^2 + (p_4^2 - p_5^2)\sigma_{syst}^2)^{-1}$$

- $\boxed{\textbf{PAR3}}$ is for experts (!)

- $\boxed{\textbf{SCHEME N}}$
  Where **N** is the number of functions to parametrize[4] .
  The first line contain **N** flag (of INTEGER type) defining the mathematical form of **N** parametrized functions, that is the parameter **i_type** describing the various choice of eq. (11-18).
  The second line contain four numbers necessary to use the pdflib : NTYPE, NGROUP, NSET, EVOL. The three first items are described in the pdflib documentation. EVOL = 1 means that the evolution is performed by the programme *i.e.* the pdflib information is only used at Q_0^2. EVOL = 0 means that no evolution is performed, the pdflib information is only used at any Q^2. Only the convolution products with Wilson coefficients are performed in the case **ORD=2**[5]
  Then follow **N** lines, each giving the 8 PDF coefficients and the **N** coefficients as described in eq. (10). If the last number m is not zero the m first terms and the $8 + \mathbf{N} - m$ last terms are summed separtly and both results are multipled together.

- $\boxed{\textbf{MEASURE}}$
  logical name for the file EXPERIMENT.DAT giving the measurements of the various experiments.[6]
  Several $\boxed{\textbf{MEASURE}}$ **may be given.**

- $\boxed{\textbf{MINUIT}}$
  logical name for the file QCDFIT.DATA

And now come the description of the optionnal fields ;

- $\boxed{\textbf{P\_SUMi or S\_SUMi}}$
  Constraint equation on the integral of the first moment distributions (*i.e.* momentum sum-rule or gluon momentum fraction).
  One must specify 8+**N**+2 coefficients (depending on the **SCHEME** choice)

$$g_1 \quad g_2 \quad g_3 \quad g_4 \quad g_5 \quad g_6 \quad g_7 \quad g_8 \quad g_{8+1} \quad \ldots g_{8+\mathbf{N}} \quad I_S$$

[4] *If* **N** < 6 *the unused parameters are then free and may be used for other purposes (in* $\boxed{\textbf{EQUATI}}$ *see below).*
[5] *One may still use a NLO pdflib with EVOL = 0 but then one as to define* **ORD** > 1.
[6] *Drell Yang data have their own special files and formats One may still use a NLO pdflib with EVOL = 0 but then.*

and the constraint reads :

$$I_S = \int_0^1 dx \Big\{ \sum_{i=1}^{8} g_i \times xp_i(x, Q_0^2) + \sum_{i=1}^{\mathbf{N}} g_{i+8} \times x\zeta_i(x, Q_0^2) \Big\}.$$

Where $xp(x, Q_0^2)$ are the parton momentum densities taken from the pdflib. When this constraint is applied, one must fix (in MINUIT.DATA) the parameter A_i corresponding to the ζ_i function. If **i** is not defined in the $*$_SUM card then it is defined by the one which has the highest coefficient g_i.

- $\boxed{\textbf{D\_SUMi or U\_SUMi}}$
  Same as P_SUM but for the distribution themselves (*i.e.* counting rule).
  in that case :

$$I_S = \int_0^1 dx \Big\{ \sum_{i=1}^{8} g_i \times p_i(x, Q_0^2) + \sum_{i=1}^{\mathbf{N}} g_{i+8} \times \zeta_i(x, Q_0^2) \Big\}.$$

- $\boxed{\textbf{EQUATI}}$
  This card provides a method to define some parameters as functions of others. One must give 10 numbers

$$n_1 \quad c_1 \quad n_2 \quad c_2 \quad n_3 \quad c_3 \quad n_4 \quad c_4 \quad n_5 \quad c_5$$

  and the constraint equation reads :

$$parameter(n_1) = c_1 + \sum_{i=2}^{5} c_i \times parameter(n_i)$$

  where n_i is the parameter number defined in the MINUIT command file. Note that if parameter n_1 appears in QCDFIT.DATA, it has to be kept fixed.
  This feature may be used to constraint already defined parameters or to define new parameters. One may also use this feature to change (fit) the coefficiants defined by SCHEME or $*$_SUM (as an example I_P is parameter 320).
  Equations are applied in reverse order: from last to first.

- $\boxed{\textbf{KEEP}}$
  Data selection card : keep experimental data in the fit within a given range of Q^2, x, or W^2. For example :

  $KEEP \quad XB \quad 0. \quad 0.75 \quad Q2 \quad 4. \quad 100000. \quad W2 \quad 15 \quad 100000. \quad MD99 \quad SLACP$

  means that only SLAC Hydrogene data in the range $x \in [0., 0.75] Q^2 \in [4, 10^5], W^2 \in [15, 10^5]$ are kept in the fit. **When no experiment name is specified** then the cuts are applied to all experiment data. The symbol MD99 must always be there and one is free to set any combination of cuts on the x, y, Q^2,W^2 and $P_\mu = (1-y)\frac{Q^2}{xyM}$. the corresponding symbols recognized are XB,YB,Q2,W2,PM.

- $\boxed{\textbf{KILL}}$
  Data selection card : same as the previous card but for rejection cuts.

- $\boxed{\textbf{REACTIONS}}$
  This section discribes the various functions dealt by the program:
  On each line, items are read with the format(a6,i4,i2,2f8.6,2f8.2,2f8.6,2f8.2)

  – name of reaction or distribution to plot: examples are F2-ep GLUON

  – reaction code : it is coded in the following way
    RC= 1000*C + 100*B + 10*T + M where the symbols may take the following values

    * C(urrent) 0: Dominent (Neutral for charged lepton,Charged for neutrinos)
      1: Non dominent

    * B(eam) 1: Neutrino 2: Antineutrino 3: 1/2(Neutrino+Anti) 4 unused
      5: $\mu-$ 6: $\mu+$ 7: Electron 8: Positron

    * T(arget) 0: n 1: p 2: (n+p)/2 3: d 4: Iron 5: d/p

    * M(easurement) 1: 2xF1 2: F2 3: xF3 4: Fl=F2-2xF1 5: sigma
      +5: for only charm.

  – correction code: it is a bited word only used for ploting;
    bit 0 set: Heavy quarks included
    bit 1 set: Higher twist included
    bit 2 set: Target mass correction included
    bit 3 set: distribution code is meaningless and an extra line is read with the format 8(i3,f7.5) where integers are
    1: gluon, 2: singlet, 3: u^+, 4: $u^+ - d^+$, 5: $u_v + d_v$, 6: $u_v - d_v$, 7: $s - s$,0: or blank end of data and the reals give the corresponding coefficiants used to form the desired distribution.

  – Eventually (for integrals) x_{min} x_{max} Q^2_{min} Q^2_{max} y_{min} y_{max} S_{min} S_{max}

  This section will end with a reaction with null reaction and correction codes. Note that table 2 gives a set of predefined functions.

- $\boxed{\textbf{PLOT N}}$
  This (optional) section describes the plots to be drawn by QCDFIT (HBFUN1 function from HBOOK is used) or function to be parametrized. **All axis are in** $\log_{10}$ **scale**. **N** is the number of bins as requested by HBFUN1.
  Each command line starts by a key word which is one of the following:

- **KERNEL** to plot all the Q^2 independent convolutions vectors (kernel for DGLAP,coefficient functions,higher twist ...).
- **FOR** list of names blank separated and eventually ended by a *
  It is followed by a second line with : ϵ '$name$'
  Those names have to be defined in the REACTIONS section.
  Two dimentional functions are created. ϵ is the **absolute** precision required for the Chebyshev polynomial interpolation. and '$name$' is a word of at most ten characters which identify the created functions.
- %**IJM** list of names blank separated and eventually ended by a *
  I,J and two other symbols K,L stand for the symbols X (for x_b) Q (for Q^2) Y (for y) and S (for CDM Energy). K is the first .not.I .not.J in the ordered list XQYS and L is the last one.
  I will be the argument of the plotted function.
  K and L will be held fixed.
  J is function of I,K,L according to $Q^2 = Sxy$.
  M is a suffix which may be absent. If present it can take the values:
  *D : The derivative with respect to I is plotted.
  *I : It is the integral with respect to limits defined in the reaction description.
  *B : One sigma error bands are drawn. B may follow D or I.
  This line is followed by a second line with:
  minimum of I, maximum of I,value of K, value of L, step for I (only for error band drawn with lsqfit)
  As an example the following two lines will draw gluon error band for
  $0.0002 < x < 1$, Q^2=5. , $y = 0.9$,$S = 5/0.9/x$ (note that the gluon distribution depends in fact only on x and Q^2).
  %XSB GLUON *
  0.0002 1. 5. .9 0.

Sumrules
If $x = 1.5$ then the plots contain $\int_0^1 dx[x \times function(x, Q^2)]$ (*i.e.* sum-rule as function of Q^2). If $x = 2.5$ then the plots contain $\int_0^1 dx[function(x, Q^2)]$ (*i.e.* counting-rule as function of Q^2).
special_user function
There is a possibity (see in Annexe flow shart) to define in a user dependent way a function which name is "SPE" and may be adressed by the plotting package.

This section and the whole steering is terminated by an END line.

6.3 QCDFIT data input text files

As explained the name of the files are given in QCDFIT.STEER with $\boxed{\textbf{MEASURE}}$ The files are organized in any number of sections. Each section gives the necessary information for one experiment or subexperiment. There is first one line, format(i5,a8,2i3,i5,f10.3,1x,a1,10i2) with the following items:

- Number of Measurements.
- Experiment names.
- Number of systematic errors.
- Number of symmetrical systematic errors.
- Reaction code.
- CDM energy.
- Systematic parameters flag. If its value is "N" then the systematics for this experiment are "new" and thus have to be added to the list. Otherwise they are "old": they have already be defined in a previous experiment or subexperiment.
- list of zero to ten parameters number. The numbering refer to the last "new" set of parameters and points to the systematics errors of the data points.

Then for each data point comes a line, format(8e14.7), giving x,y,q^2,statistical error,uncorrelated error,total error.
and, for those experimens which have systematic error sources, comes the list of systematic errors in % ,format(20f6.1).

6.4 QCDFIT output text files

- **out** : Standard output file, it gives a summary of the input command and the minuit output file.
- **last** : This file is written each time the χ^2 has decreased. It gives a list of the actual parameters, the total χ^2 and for each experiment the numer of data points, the coresponding χ^2 and the χ^2 of the coresponding systematics .
- **deb or fort.18** debug file for experts.

Conclusion & what 'could' be done

We provide a programme which solves the DGLAP equation in the NLLA approximation. This leads to the computation of cross-sections or structure function in NLO (and NNLO for F_L) approximation. The charm contribution to these structure functions is taken into account *via* two prescriptions : The massless and photon-gluon processes.
The main task of the programme is to perform a fit to DIS data. However, it can also serves to parametrize different structure functions (or cross-sections) according to a parton distribution taken from the pdflib or any fit results.

A pure α_s^2 order set of evolution equations, as it is defined in [35], could also be considered in order to study the sensitivity of the fit results to the α_s^3 terms of the perturbative expension.
We hope to have provided a 'clear' user guide for our code. In any case, it takes time to define the fit parameters and to understand the fit result. **A fast fit** means in general **a wrong fit**. So please take time to define your hypothesis and understand your futur fit results !

Some tricks

Phantom and prefited parameters

When file QCDFIT.DATA is read the parameters are classified into three categories:

- parameters with a null step or appearing after a line with "NOFIT" column 1 to 5 (which may be overcome by a line with "DOFIT" column 1 to 5) will be considered as constant and not passed to MINUIT.
- parameters appearing after a line with "DOLSQ" column 1 to 5 (which may be overcome by a line with "NOLSQ" column 1 to 5) will not be passed to MINUIT but will be instead fitted independently by routine LSQFIT.
  Routine LSQFIT will minimize the χ^2 over those parameters assuming it is the square of a vector. Vector derivatives of the parameters of this category are in general computed by finite differences. However if the parameters of this category are all sytematics (identifier bigger than 109) the derivatives are computed analytically. This way of fitting inside the Minuit minization procedure has important advantages:
  - This is a way to keep the number for minuit parameters not too high.
  - LSQFIT tends to make a better use of the CPU because most often only one parameter is changed at a time and only the necessary computations (partial or no evolution, application of coefficients functions ...) are done.
  - If all the parameters given to LSQFIT are sytematics then it is very fast and if furthermore the systematics are all linear functions of the parameters, LSQFIT will converge in 1 step with a 10^{-10} accuracy and MINUIT may work with its full own accuracy.

Changing Q_0^2

This obliges usually to refit everything with the possiblity that one does not get back to the same solution (minimum) of the evolution equations. [7]

[7] *This operation may be facilitated by the use of compilation option* **refit_input**.

Annexe Flow chart

In the following routines have a generation number starting by 1 for the main program QCDFIT and are increased by 1 at each downward call. Routines from program library TCLIB and packages MINUIT or HBOOK are not recorded. Each routine calling other routines is discribed as an item with its generation number given between $<>$ and with eventually some explanations.

- QCDFIT$< 1 >$ ERRORS,LSQFIT,MINUIT_FOR,PRINTOUT,SHOW_SEL,STEER
  main program
- ERRORS$< 2 >$ LIM_PARAM
- LSQFIT$< 2 >$ FITLINE,FIT_PR,MYEIGEN,MYEQLU,MYEQUL,MYPROJ,MYSYMUL, MYTRCHLU,PRTR,SET_DERIV
  Fitting package (see text).
- MINUIT_FOR$< 2 >$ FN_S,SET_NEW_PAR
  send commands to minuit in fortran-callable mode
- PRINTOUT$< 2 >$ AP_BACK,DESSIN,PARAMOUT,PLOT_BAND,SET_NET, TABLOUT
- STEER$< 2 >$ DRELL_INIT,SET_SCHEME,STEER_PLOT,SUMRULE
  Initialization Phase steering.
- LIM_PARAM$< 3 >$ EQUZERB,EVOL,LSQFIT
- FITLINE$< 3 >$ EVOL,GET_PLOT_PAW,SET_DERIV
- FIT_PR$< 3 >$ GET_LAMBDA
  Write file "last".
- SET_DERIV$< 3 >$ EVOL,GET_PLOT_PAW
- FN_S$< 3 >$ AP_BINNING,AP_EVOL_INPUT,AP_KERNEL,EVOL, GET_MEASURE,GET_PLOT_PAW,LSQFIT,PRINTOUT
  This the Function which is called by Minuit command. The first 3 routines it call are initialization routines.
- SET_NEW_PAR$< 3 >$ AP_BACK,EVOL,SET_NET
- PARAMOUT$< 3 >$ PARAM_FUNC,SET_NET
  Compute and output Chebyshev Polynomials.

- PLOT_BAND$< 3 >$ EVOL
  Error band treatement (sel mnband).

- SET_NET$< 3 >$ F2_NET

- TABLOUT$< 3 >$ PLOT_PAW,SET_NET

- EVOL$< 4 >$ AP_EVOL,CALCUL_CHI2,DRELL_CHI2,EVOL_INPUT, F2_NET,FIT_PR
  Steering for evolution and χ^2 calculations.

- GET_PLOT_PAW$< 4 >$ AP_BACK,EQUZERA,EVOL

- AP_EVOL_INPUT$< 4 >$ MULBND
  Computes parton distributions at Q_0^2.

- AP_KERNEL$< 4 >$ AP_DIS,KERN_F_PREP,SUM_KERNEL,XIKERN,XKERN
  Computes all the kernels needed.

- GET_MEASURE$< 4 >$ GET_SYST,RESEAU_THEORIQUE,SET_SYST
  Enter DIS Data and define nets.

- PARAM_FUNC$< 4 >$ PLOT_PAW

- F2_NET$< 4 >$ APPLY_TMC,MULBND,RENORMALON
  Apply Wilson coeffecents functions,Target mass correction and Higher twist to parton distributions. The result can be called quasi_DIS parton distributio

- PLOT_PAW$< 4 >$ALPHAS_MS,DEFINE_CHARGES,GETVAL,NP_DEUTERON, SPECIAL_USER,THEORY

- AP_EVOL$< 5 >$ AP_EVOL_NS,AP_EVOL_S
  Do DGLAP Evolution.

- CALCUL_CHI2$< 5 >$ CCFRCHI2,COR_SYST,DEUTIRON,NP_DEUTERON, THEORY,THEORY_INT,USER_CHI2
  For DIS χ^2.

- DRELL_CHI2$< 5 >$ BINS,DRELL_INT
  For Drell Yan χ^2.

- EVOL_INPUT$< 5 >$ AP_EVOL_INPUT,AP_SOLVE,SUMRULE

- AP_DIS$< 5 >$ BNDMUL

- SUM_KERNEL$< 5 >$ MULBND

- XIKERN$< 5 >$ GADAP_8,ZKERN
  Prepare Kernel convolution.

- XKERN$< 5 >$ FL_F2_NNLO
  For x dependent part of Kernels.

- APPLY_TMC$< 5 >$ HIGHER_TWIST,MULBND

- RENORMALON$< 5 >$ MULBND

- DEFINE_CHARGES$< 5 >$ BINS,CHARGES_WEAK,FAC_IN,KINEFAC
  DIS observables may be written as $\sum_i f(i)p(i)$ where $p(i)$ are quasi_DIS parton distributions and f(i) are coefficients dependent on the reaction code and on x, y, q^2 of the measurements.DEFINE_CHARGES computes those coefficients.
  CHARGES_WEAK deals with the CMK matrix and the various electroweak parameters.

- NP_DEUTERON$< 5 >$ BINS
  Computes when needed Deuterium correction.

- SPECIAL_USER$< 5 >$ DEFINE_CHARGES
  This routine is intended to be user dependent. It is called by routines of PRINTOUT to gives results (Plots Functions ...) under the name SPE (see table 2).
  In the present Veersion it is setup to make estimates of F_l by the extrapolation method.

- THEORY$< 5 >$ FCC_HEAVY,FCS_HEAVY,FLIGHT
  Computes DIS observable for light (FLIGHT) or Heavy (FCC_HEAVY FCS_HEAVY) quarks.

- AP_EVOL_NS$< 6 >$ MULBND,REPUT
  Non singlet DGLAP evolution.

- AP_EVOL_S$< 6 >$ REPUT
  Singlet DGLAP evolution.

- THEORY_INT$< 6 >$ INT_PAW,SET_NET
  Single differential DIS observable.

- DRELL_INT$< 6 >$ MAKE_DRELL

- AP_SOLVE$< 6 >$ AP_GET_NS,AP_GET_S,GET_LAMBDA
  Prepare DGLAP evolution (calculates α_s and evolution matrices).

- ZKERN$< 6 >$ FL_F2_NNLO
  For x/z dependent part of Kernels.

- FCC_HEAVY$< 6 >$ FF2_GET,FF2_PUT
  Computes Gluon fusion process for charm. FF2_PUT is called only once per Measurement.

- FCS_HEAVY$< 6 >$ FFN_PREP,KINEFAC,K_INTER,Q_INTER
  Computes strange $-->$ charm for charged currents. FFN_PREP is called only once per Measurement.

- INT_PAW$< 7 >$ KGAUSS,K_INTER,PLOT_PAW

- AP_GET_NS$< 7 >$ BNDEXP
  Non singlet Kernels exponentiation.

- AP_GET_S$< 7 >$ BNDEXP,BNDINV,BNDMUL,BNDSQR
  Singlet Kernels exponentiation.

- FF2_GET$< 7 >$ Q_INTER

- FF2_PUT$< 7 >$ FF2_PREP

- FFN_PREP$< 7 >$ K_INTER

- FF2_PREP$< 8 >$ BORN_L,BORN_T,GCORR_L,GCORR_T,K_INTER,
  QCORR_L,QCORR_T
  Call to **??** code.

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functions	symbolic name
ζ_1 to ζ_2	IN1 to IN6
pdflib components	IP1 to IP6
α_s	ALS
special_user	SPE

Table 2: Table of the symbolic name known by the programme.

Variable	Name	Meaning
1	x	x Bjorken
2	q2	Q^2
3	f2dat	Measure
4	d2sta	σ_{stat}(f2dat)
5	d2sys	σ_{syst}(f2dat)
6	ecart	(f2dat−f2_th*csyst)/d2sta
7	manip	experiment identifier
8	csyst	n_{exp} (see eq. (20))
9	f2_th	Theory
10	y	
11	code	reaction code

Table 3: Content of the NTUPLE QCDFIT_T.RZ (see text).

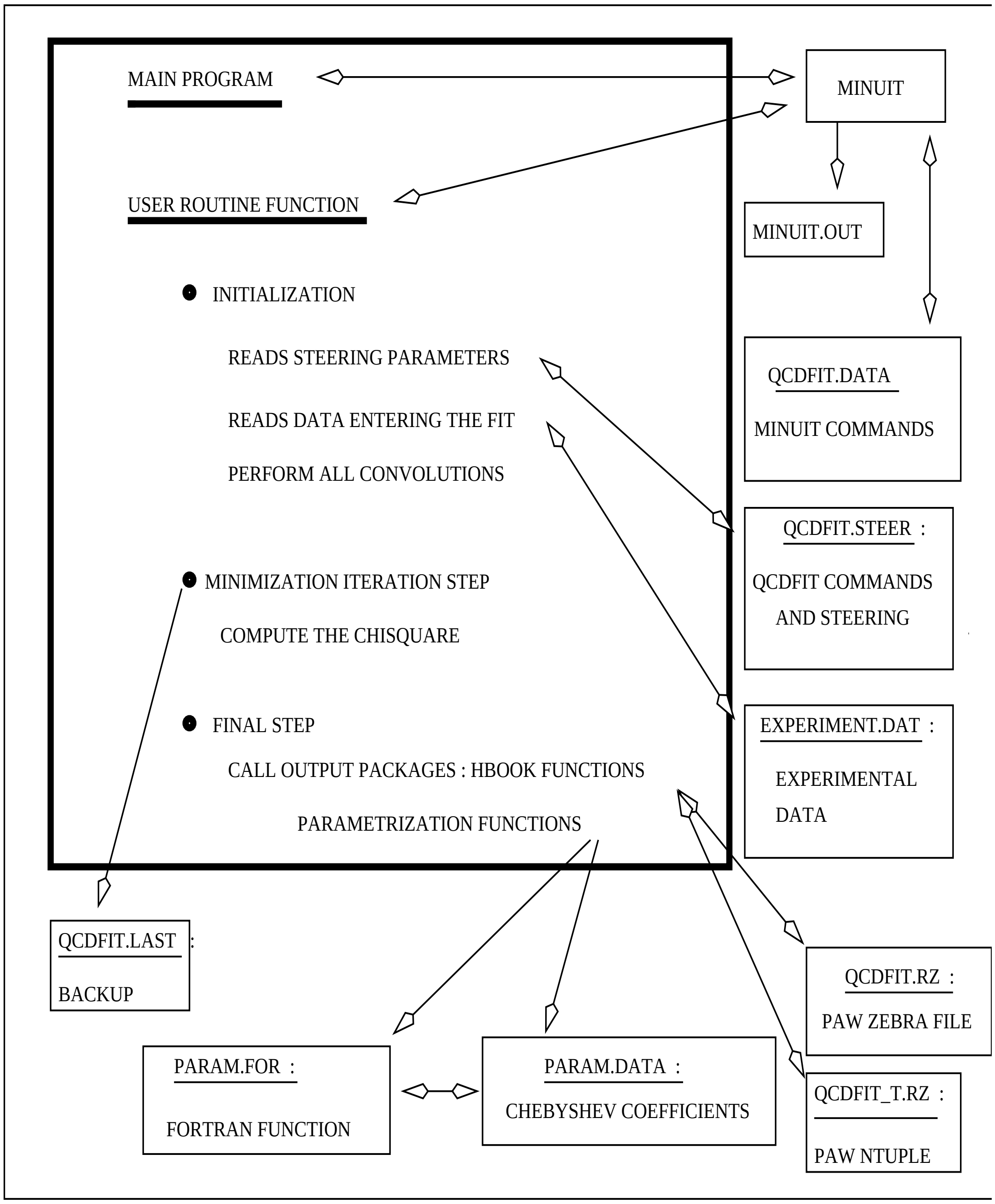
MAIN PROGRAM
MINUIT
USER ROUTINE FUNCTION
MINUIT.OUT
INITIALIZATION
READS STEERING PARAMETERS
READS DATA ENTERING THE FIT
PERFORM ALL CONVOLUTIONS
QCDFIT.DATA
MINUIT COMMANDS
QCDFIT.STEER :
QCDFIT COMMANDS
AND STEERING
MINIMIZATION ITERATION STEP
COMPUTE THE CHISQUARE
FINAL STEP
CALL OUTPUT PACKAGES : HBOOK FUNCTIONS
PARAMETRIZATION FUNCTIONS
EXPERIMENT.DAT :
EXPERIMENTAL
DATA
QCDFIT.LAST :
BACKUP
QCDFIT.RZ :
PAW ZEBRA FILE
PARAM.FOR :
FORTRAN FUNCTION
PARAM.DATA :
CHEBYSHEV COEFFICIENTS
QCDFIT_T.RZ :
PAW NTUPLE

Figure 1:

```
*  STEERING PARAMETERS FOR QCD  FIT PROGRAM *
*******************************************
PAR1
56. 5. 0.0001 0.5 6000. 2.56 1.499 5. 1.499 5. 3.1 4. 0. 24. 2. 0.224
EXPERIMENTS
NMCD_90       0.0200    1.0000    1.0000    1.0000
NMCD_120      0.0200    1.0000    1.0000    1.0000
NMCD_200      0.0200    1.0000    1.0000    1.0000
NMCD_280      0.0200    1.0000    1.0000    1.0000
BCDMS_D       0.0300    1.0000    1.0000    1.0000
E665_D        0.0190    0.0000    1.0000    0.0000
BEBCNUD   10000.0000    1.0000    1.0000    1.0000
BEBCANUD  10000.0000    1.0000    1.0000    1.0000
CDHWNFE       0.0300    1.0000    1.0000    1.0000
CDHWANFE      0.0300    1.0000    1.0000    1.0000
NMCP_90       0.0200    1.0000    1.0000    1.0000
NMCP_120      0.0200    1.0000    1.0000    1.0000
NMCP_200      0.0200    1.0000    1.0000    1.0000
NMCP_280      0.0200    1.0000    1.0000    1.0000
BCDMS_P       0.0300    1.0000    1.0000    1.0000
E665_P        0.0180    0.0000    1.0000    0.0000
H1_HQ2        0.0150    0.0000    1.0000    1.0000
H1_SVX        0.0400    1.0000    1.0000    1.0000
H1_NVX        0.0150    1.0000    1.0000    1.0000
H1_RAD        0.0150    0.0000    1.0000    1.0000
BEBCNUP   10000.0000    1.0000    1.0000    1.0000
BEBCANUP  10000.0000    1.0000    1.0000    1.0000
CDHS_NP       0.0330    1.0000    1.0000    1.0000
CDHSANP       0.0530    1.0000    1.0000    1.0000
SLAC_D        0.0300    1.0000    1.0000    0.0000
SLAC_P        0.0300    1.0000    1.0000    0.0000
CCFR_F2       0.0230    1.0000    1.0000    0.0000
CCFR_XF3      0.0430    1.0000    1.0000    0.0000
NA51          0.1000    1.0000    1.0000    0.0000
E866          0.0100    1.0000    1.0000    0.0000
E605          0.1500    1.0000    1.0000    0.0000
0.0000    0.0000    0.0000    0.0000
PAR3
1.d-3 12.d30 1.d-08 10000.01 1.d-04
```

Table 4: The table continue on the next page

```
SCHEME 6
1. 1. 1. 1. 1. 1.
0. 3. 35. 1.
0. 0. 0. 0. 0. 0. 0. 0. 1. 0.  0. 0.  0. 0.  0.
0. 0. 0. 0. 0. 0. 0. 0. 0. 1.  1. 0.  2. 2.  0.
0. 0. 0. 0. 0. 0. 0. 0. 0. 1. -1. -2.  0. 0. 0.
0. 0. 0. 0. 0. 0. 0. 0. 0. 1.  0. -1.  1. 0. 0.
0. 0. 0. 0. 0. 0. 0. 0. 0. 1.  1. 0.  0. 0.  0.
0. 0. 0. 0. 0. 0. 0. 0. 0. 1. -1. 0.  0. 0.  0.
P_SUM1
0. 0. 0. 0. 0. 0. 0. 0. 1. 1. 1. 0. 2. 2. 1.
D_SUM
0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 1.
U_SUM
0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 2.
EQUATI
52 0. 42 1. 0 0. 0 0. 0 0.
EQUATI
43 0. 33 1. 0 0. 0 0. 0 0.
EQUATI
53 0. 33 1. 0 0. 0 0. 0 0.
EQUATI
54 0. 44 1. 0 0. 0 0. 0 0.
EQUATI
55 0. 45 1. 0 0. 0 0. 0 0.
EQUATI
32 0. 12 1. 0 0. 0 0. 0 0.
EQUATI
51 0. 41 0.25 0 0. 0 0. 0 0.
EQUATI
61 0. 41 0.25 0 0. 0 0. 0 0.
EQUATI
62 0. 42 1. 0 0. 0 0. 0 0.
EQUATI
63 0. 33 1. 0 0. 0 0. 0 0.
EQUATI
64 0. 44 1. 0 0. 0 0. 0 0.
EQUATI
65 0. 45 1. 0 0. 0 0. 0 0.
EQUATI
22 0. 12 1. 0 0. 0 0. 0 0.
EQUATI
```

Table 5: The table continue on the next page

```
119 0. 110 1. 0 0. 0 0. 0 0.
EQUATI
120 0. 111 1. 0 0. 0 0. 0 0.
EQUATI
121 0. 112 1. 0 0. 0 0. 0 0.
EQUATI
122 0. 113 1. 0 0. 0 0. 0 0.
EQUATI
175 0. 172 1. 0 0. 0 0. 0 0.
KILL XB 0. .1 MD99 CCFR_F2
KILL XB 0. .1 MD99 CCFR_XF3
KILL XB 0. 1. MD99 CDHWANFE
KILL XB 0. 1. MD99 CDHWNFE
KILL XB 0. 1. MD99 BEBCNUP
KILL XB 0. 1. MD99 BEBCANUP
KILL XB 0. 1. MD99 BEBCNUD
KILL XB 0. 1. MD99 BEBCANUD
KILL XB 0. 1. MD99 CDHSANP
KILL XB 0. 1. MD99 CDHS_NP
KILL Q2 0. 3.49999 MD99
KILL W2 0. 14.9999 MD99
KILL XB 0.76 1. MD99
MEASURE ex_it10.dat
MINUIT light.data
DRELL  zomer/drell/ADY_na51
DRELL  zomer/drell/ADY_e866
DRELL  zomer/drell/e605
*
REACTION
f2-nf  142 7
f1-nf  141 7
f2-af  242 7
f1-af  241 7
f2-ep  612 7
f1-ep  611 7
f2-ed  632 7
f2-en  602 7
F2-ep  612 7
F2-ed  632 7
F2-en  602 7
F2-eD  622 7
```

Table 6: The table continue on the next page

```
FW2-ep1612 2
FW2-ed1632 2
ccfr2 2342 7
ccfr3 2343 7
ccfd2 2322 7
ccfd3 2323 7
S-nup  115 7
S-anup 215 7
S-nud  135 7
S-anud 235 7
S-nuI  145 7
S-anuI 245 7
GLUON  999 8
1  1.
SING  999 8
2  1.
PARTS  999 8
1  1.     2  1.
UVAL   999 8
5 0.5     6  0.5
DVAL   999 8
5 0.5     6 -0.5
UBAR   999 8
2.166667  4  0.5    5 -.25    6 -.25
DBAR   999 8
2.166667  3 -0.5    4  0.5    5 -0.25   6 0.25
SVAL   999 8
7 1.
SBAR   999 8
2.166667  3 0.5     4 -1.
endend   0 0
```

Table 7: The table continue on the next page

```
*******************************************************************
*  STEERING for reactions aprintout  : Use capital letters
*******************************************************************
PLOT 100 ! this card is mandatory
0.03 1. 1. .9 0.
0.03 1. 4. .9 0.
0.0002 1. 5. .9 0.
0.0002 1. 20. .9 0.
0.03 1. 100. .9 0.
1. 1000. 1.5 .9 0.
END
```

Table 8: QCDFIT steering file : QCDFIT.STEER.

```
SET TITLE
FIT OF F2(x,Q^2)
PARAMETERS
1 'A_glu     '  1.96639631290       0.00000E+00  -1000.0       1000.0
2 'B_glu     ' -0.603387653147E-01  0.71152E-03  -1.0000       30.000
3 'C_glu     '  4.87411698634       0.63418E-01  0.10000E-01   30.000
4 'delta_glu '  2.99950130194       0.27744E-01 -0.50000       5.0000
5 'a_glu     '  16.8791902707       0.35222      -1.0000       1000.0
11 'A_uval    '  0.403791493794      0.00000E+00  -1000.0       1000.0
12 'B_uval    '  0.287034505414      0.93808E-02  -1.0000       30.000
13 'C_uval    '  3.74885251565       0.24531E-01  0.10000E-01   30.000
14 'delta_uval' -0.357760958807E-01  0.21550E-01 -0.50000       5.0000
15 'a_uval    '  23.2367199069       0.33651      -1.0000       1000.0
21 'A_dval    '  0.835405806938E-02  0.98081E-01  -1000.0       1000.0
22 'B_dval    '  0.287034505414      0.00000E+00  -1000.0       1000.0
23 'C_dval    '  4.23672463259       0.31139E-01  0.10000E-01   30.000
24 'delta_dval' -0.499999850505      0.44979E-01 -0.50000       5.0000
25 'a_dval    '  361.728390055       0.21436      -1.0000       1000.0
31 'A_db_ub   '  0.113410976030E-02  0.20895E-01  -1000.0       1000.0
32 'B_db_ub   '  0.287034505414      0.45217E-01  -1.0000       30.000
33 'C_db_ub   '  9.79099879373       0.82964E-01  0.10000E-01   30.000
34 'delta_db_u'  0.000000000000E+00  0.00000E+00 -0.50000       5.0000
35 'a_db_ub   '  988.528975901       7.4773       -1.0000       1000.0
```

Table 9: The table continue on the next page

41	'A_db+ub '	0.174236267178	0.51866E-02	-1000.0	1000.0
42	'B_db_ub '	-0.205849211619	0.13182E-02	-1.0000	30.000
43	'C_db+ub '	9.79099879373	0.47409E-01	0.10000E-01	30.000
44	'delta_db_u'	0.000000000000E+00	0.00000E+00	-0.50000	5.0000
45	'a_db+ub '	15.4685520876	0.18722	-1.0000	1000.0
71	'lambda '	0.296000000000	0.00000E+00	0.10000	0.60000
75	'weak1 '	1.00000000000	0.00000E+00	-1000.0	1000.0
76	'xmw2 '	6451.30000000	0.00000E+00	-1000.0	1000.0
77	'xmz02 '	8315.40000000	0.00000E+00	-1000.0	1000.0
80	'tmc '	0.879844000000	0.00000E+00	0.00000E+00	0.00000E+00
DOLSQ					
110	'NMCD_90 '	-0.445226969067	0.10000	-0.10000E+06	0.10000E+06
111	'NMCD_120 '	-0.812206609332	0.10000	-0.10000E+06	0.10000E+06
112	'NMCD_200 '	0.441159889597	0.10000	-0.10000E+06	0.10000E+06
113	'NMCD_280 '	-0.212439164406E-01	0.10000	-0.10000E+06	0.10000E+06
114	'BCDMS_D '	-0.623150467753	0.10000	-0.10000E+06	0.10000E+06
115	'BEBCNUD '	0.320317071141E-04	0.00000E+00	-0.10000E+06	0.10000E+06
116	'BEBCANUD '	-0.173154838294E-04	0.00000E+00	-0.10000E+06	0.10000E+06
117	'CDHWNFE '	0.000000000000E+00	0.00000E+00	0.00000E+00	0.00000E+00
118	'CDHWANFE '	0.000000000000E+00	0.00000E+00	0.00000E+00	0.00000E+00
119	'NMCP_90 '	-0.445226969067	0.00000E+00	0.00000E+00	0.00000E+00
120	'NMCP_120 '	-0.812206609332	0.00000E+00	0.00000E+00	0.00000E+00
121	'NMCP_200 '	0.441159889597	0.00000E+00	0.00000E+00	0.00000E+00
122	'NMCP_280 '	-0.212439164406E-01	0.00000E+00	0.00000E+00	0.00000E+00
123	'BCDMS_P '	-1.04995721579	0.10000	-0.10000E+06	0.10000E+06
124	'H1_SVX '	-1.30358848536	0.10000	-0.10000E+06	0.10000E+06
125	'H1_NVX '	-2.78936316642	0.10000	-0.10000E+06	0.10000E+06
126	'BEBCNUP '	0.173200703293E-04	0.00000E+00	-0.10000E+06	0.10000E+06
127	'BEBCANUP '	0.258352587201E-04	0.00000E+00	-0.10000E+06	0.10000E+06
128	'CDHS_NP '	0.471238904533	0.00000E+00	-0.10000E+06	0.10000E+06
129	'CDHSANP '	0.241193075315	0.00000E+00	-0.10000E+06	0.10000E+06
130	'SLAC_D '	-0.160953266142	0.10000	-0.10000E+06	0.10000E+06
131	'SLAC_P '	0.583523968187	0.10000	-0.10000E+06	0.10000E+06
132	'CCFR_F2 '	-0.548518133949	0.10000	-0.10000E+06	0.10000E+06
133	'CCFR_XF3 '	0.203711616919	0.10000	-0.10000E+06	0.10000E+06
134	'NA51 '	0.000000000000E+00	0.00000E+00	0.00000E+00	0.00000E+00
135	'E866 '	0.000000000000E+00	0.1000E+00	0.00000E+00	0.00000E+00
136	'E605 '	1.18388212150	0.10000	-0.10000E+06	0.10000E+06

Table 10: The table continue on the next page

```
NOLSQ
150 'H1 e BEMC ' -0.645154090459        1.0000       0.00000E+00  0.00000E+00
151 'H1 t BEMC ' -0.606483147138        1.0000       0.00000E+00  0.00000E+00
152 'H1 e LAR  '  0.000000000000E+00  0.00000E+00  0.00000E+00  0.00000E+00
153 'H1 t LAR  '  0.000000000000E+00  0.00000E+00  0.00000E+00  0.00000E+00
154 'H1 h      ' -0.207379081675E-01   1.0000       0.00000E+00  0.00000E+00
DOLSQ
155 'H1 VTX    ' -0.785520202394        1.0000      -0.10000E+06  0.10000E+06
156 'H1 rad    '  0.000000000000E+00  0.00000E+00  -1000.0       1000.0
157 'H1 bg     ' -0.331504079178        1.0000      -0.10000E+06  0.10000E+06
158 'NMCD_280 a' -0.213563236805E-01  0.38741      -0.10000E+06  0.10000E+06
159 'NMCD_280 r'  -1.08359624367       0.82011      -0.10000E+06  0.10000E+06
160 'NMCP_280 R'  -1.40870268637        1.2633      -0.10000E+06  0.10000E+06
161 'NMCD_280 R' -0.826530582968E-01  0.96033      -0.10000E+06  0.10000E+06
162 'NMCD_90 E '  0.258301547783       0.82776      -0.10000E+06  0.10000E+06
163 'NMCD_90 e ' -0.427893575752        1.1441      -0.10000E+06  0.10000E+06
164 'NMCD_120 E'   2.14054519270        1.0701      -0.10000E+06  0.10000E+06
165 'NMCD_120 e'  -2.36640290701        1.0234      -0.10000E+06  0.10000E+06
166 'NMCD_200 E'  0.575564713738       0.89298      -0.10000E+06  0.10000E+06
167 'NMCD_200 e' -0.657077911769E-01  0.34213      -0.10000E+06  0.10000E+06
168 'NMCD_280 E'  0.558640290537       0.67636      -0.10000E+06  0.10000E+06
169 'NMCD_280 e'  -1.05469088873       0.86897      -0.10000E+06  0.10000E+06
170 'bcdms_p   '  0.676836621236E-01  0.10000      -0.10000E+06  0.10000E+06
171 'bcdms_d   '  0.611088610489       0.10000      -0.10000E+06  0.10000E+06
0
DEUTERON 0.1
migrad 100000.
call 5.
stop
```

Table 11: MINUIT steering file : QCDFIT.DATA.