FUTURE MEASUREMENT OF F_L WITH H1

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The plan is briefly discussed of the H1 Collaboration to measure the longitudinal structure function $F_L(x, Q^2)$ in a dedicated run period of reduced proton beam energy at HERA.

The deep inelastic inclusive *ep* scattering (DIS) cross section is characterised by two independent structure functions, $F_2(x, Q^2)$ and $F_L(x, Q^2)$. For decades one has disentangled their contributions to lepton-hadron scattering, first, at SLAC, to access the quark spin, because for spin 1/2 quarks the longitudinal structure function F_L is zero [1], and later, in fixed target experiments, to ensure the extraction of the dominating structure function F_2 to be reliable. At each energy, F_L is measured at lowest Bjorken x corresponding to large inelasticities y, both being related by $Q^2 = sxy$. Here s is the cms energy squared in the process and Q^2 the negative four-momentum squared transferred from the electron to the proton in *ep* DIS. The reduced cross section at low Q^2 is given by

$$\sigma_r = \frac{Q^4 x}{2\pi\alpha^2 Y_+} \cdot \frac{d^2\sigma}{dxdQ^2} = F_2(x, Q^2) - f(y) \cdot F_L(x, Q^2) \qquad (1)$$

with $Y_+ = 1 + (1-y)^2$ and $f(y) = y^2/Y_+$. For low Q^2 the contribution of F_L to the cross section at HERA is only sizeable at x smaller than approximately 10^{-3}. In this domain the gluon density dominates over the sea quark distribution. Therefore, and only roughly, F_L determines rather directly the gluon distribution: following an approximate solution of the Altarelli-Martinelli relation [2], which links $F_L(x, Q^2)$ to the convolution of the gluon and sea quark distributions with respective splitting functions, one obtains [3]

$$xg(x) = 1.8[\frac{3\pi}{2\alpha_s} F_L(0.4x) - F_2(0.8x)] \simeq \frac{8.3}{\alpha_s} F_L(0.4x). \qquad (2)$$

Presently the gluon distribution at low x is constrained indirectly by the Q^2 evolution of $F_2(x,Q^2)$. As Eq.2 illustrates, low x data on $F_L(x,Q^2)$ represent a direct measure of xg and thus provide an important cross check on the understanding of low x physics.

Phenomenologically, at low Q^2 and x the evolution of $F_2(x,Q^2)$ is not uniquely governed by xg, recent fits from MRST and CTEQ deviate much in the relative contributions from quarks and gluons to this evolution. The additional constraint from F_L closes the circle: data on F_2 , $\partial F_2/\partial \ln Q^2$ and F_L constrain the theory such that the sea quark and the gluon distribution can be disentangled at low x. It is thus not only, as Frank Sciulli put it 10 years ago, that "F_L has to be measured because it is there", though this is a most convincing reason, yet, moreover one hopes to constrain as strong as possible the low x theory. This requires to measure F_L at HERA.

The extraction of F_L requires to measure the DIS cross section at fixed x and Q^2 at at least two beam energy settings leading to a Rosenbluth separation of the different photon polarisation contributions to the cross section. It is advantageous at HERA to keep the electron beam energy E_e fixed and to lower the proton beam energy E_p. In a recent HERA note [4] estimates were given for the expected performance of a low proton beam energy run. Including an initial setup and luminosity tuning time, within 96 days a luminosity of L=15 pb^{-1} is expected to be delivered at 460 GeV which for the simulations is taken to correspond to about 10 pb^{-1} of data collected by H1. There are arguments to run at more than one reduced energy to cover a somewhat extended range of x with F_L data and to provide valuable systematic cross checks on this difficult measurement. Practically one needs to keep in mind that HERA now has to provide high statistics data in polarised positron-proton scattering at 920 GeV, in order to allow the high energy e^+p programme to be pursued with $L \geq$ 100 pb^{-1} and exotic features of the data, as the isolated lepton events, to be studied further. Thus there are 3 months left for a low energy run, and this requires HERA to function with high efficiency over its last year of running. The low energy run remains to be a challenge and its preparation requires further studies.

The uncertainty δ on F_L can be represented as $\delta F_L = \delta(\Delta\sigma_r)/\Delta f$, see Eq. 1, where Δ denotes the difference of the cross sections and kinematic factors, respectively, for the two energy settings considered. A rough estimate illustrates the difficulty of this measurement: approximating Δf by y^2_{max}, which is the larger y from the lower energy setting, and using $\sigma_r \sim 1$, one finds $\delta F_L \simeq 1/y^2_{max} \cdot \delta(\Delta\sigma_r)/\sigma_r$. Thus, for $y_{max} \simeq 0.8$, δF_L is roughly two times the relative cross section error. One therefore needs to measure the cross sections at high and low y at the per cent level of relative accuracy in order to obtain an absolute uncertainty on $F_L(x,Q^2)$ of about 0.05. In some models this is a $10-20\,\%$ accuracy of F_L. The measurement has three main challenges: i) it requires enough statistics, estimated to be of the order of $10\,\mathrm{pb}^{-1}$, while reducing the proton beam energy diminishes the luminosity approximately $\propto E_p^{-2}$; ii) it requires a maximum cancellation of systematic errors obtained from a high efficiency of the backward detectors and a uniform acceptance region for the scattered electron which desirably is independent of s. This is approximately ensured with the proton beam energy E_p reduced and E_e fixed, it is better ensured if for the high energy data the z vertex was shifted by about $+20\,\mathrm{cm}$ in the positive z direction; iii) the identification of the scattered electron at large y, i.e. of an electron of down to 3 GeV energy which only statistically may be distinguished from a large background of low energy particles in the backward scattered final state in DIS and photoproduction.

Based on the so far obtained experience in low Q^2 DIS and the three key detector components, the central jet drift chamber, the newly installed backward silicon tracker and the backward calorimeter, which is used both for triggering and for measuring the scattered electron energy down to 3 GeV, the H1 Collaboration has obtained a simulated measurement result [5] as presented in Fig. 1. Such a result would certainly resolve the existing discrepancy of the MRST and CTEQ fit results and, more important and principally, would represent a serious cross check on low x theory, i.e. test QCD at higher orders [6] and constrain low x phenomenology.

The dominant role of gluons in the diffractive parton densities [7] implies that the longitudinal structure function F_L^D must also be relatively large. Assuming the validity of hard scattering collinear factorisation for diffraction, this gluon dominance results in a leading twist F_L^D which is approximately proportional to the diffractive gluon density, as in Eq. 2. A measurement of F_L^D would thus provide a very powerful independent tool to verify the understanding of the underlying dynamics and to test the gluon density extracted indirectly in QCD fits from the scaling violations of F_2^D. A simulation shows [5] that H1 may expect F_L^D to be measured in such a low energy run with a significance of about three standard deviations providing first ever access to the longitudinal cross section part in diffraction.

Summarising, the H1 Collaboration is interested in measuring F_L and F_L^D in a low energy run as is explained in detail in [5]. Previously H1 has determined F_L with different assumptions on F_2. Precision low and high energy data are expected to measure F_L at low x and Q^2 accurately and

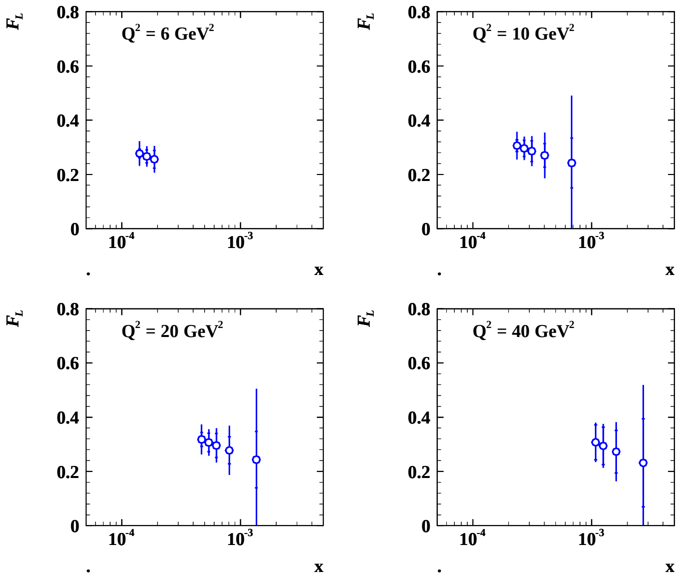

Figure 1. Simulation of a measurement of $F_L(x, Q^2)$ based on data at proton beam energies of 920 GeV (30 pb^{-1}) and 460 GeV (10 pb^{-1}). The inner error bars show the statistical accuracy and the total error bars represent the total uncertainty taking into account correlations of systematic effects and adding both uncertainties in quadrature.

independently of F_2. This measurement, together with precise cross section data at high y, will allow theory to be constrained in the high gluon density regime much better than hitherto.

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