lepton-hadron scattering. In the leading-logarithm approximation the measured structure functions $F_i(x, Q^2)$ are related to the quark distribution functions $q_i(x, Q^2)$ according to the naive parton model by the formulae in Sec. 24 of this *Review*. (In that section, q_i is denoted by the notation f_q).

A nonsinglet structure function offers in principle the most precise test of the theory, since the Q^2 evolution is independent of the unmeasured gluon distribution. The CCFRR collaboration fit to the Gross-Llewellyn Smith sum rule [17] is known to order α_s^3 [18]

$$\int_0^1 dx(F_3^{\overline{\nu}p}(x, Q^2) + F_3^{\nu p}(x, Q^2)) =$$
$$3\left[(1 - \frac{\alpha_s}{\pi}(1 + 3.58\frac{\alpha_s}{\pi} + 19.0(\frac{\alpha_s}{\pi})^2) - \varDelta HT\right] \quad . \qquad (25.14)$$

Where the higher-twist contribution $\varDelta HT = 0.032 \pm 0.016$ [18] Using the CCFRR data [19] this gives $\alpha_s(1.73\ \text{GeV}) = 0.320 \pm 0.043(\text{expt.}) \pm 0.029(\text{theory})$. Measurements involving singlet-dominated structure functions such as F_2 result in correlated measurements of $\Lambda^{(4)}_{\overline{\text{MS}}}$ and the gluon distribution. CCFRR gives $\Lambda^{(4)}_{\overline{\text{MS}}} = 210 \pm 28 \pm 41$ MeV [20] from $F_2(\nu N)$ and $F_3(\nu N)$. There is an additional uncertainty of ± 59 MeV from the choice of scale. The NMC collaboration [21] gives $\alpha_s(7\ \text{GeV}^2) = 0.264 \pm 0.018(\text{stat.}) \pm 0.070(\text{syst.}) \pm 0.013(\text{ higher-twist})$. A reanalysis [22] of EMC data [23] gives $\Lambda^{(4)}_{\overline{\text{MS}}} = 211 \pm 80 \pm 80$ MeV from $F_2(\nu N)$. Finally a combined analysis [24] of SLAC [25] and BCDMS [26] data gives $\Lambda^{(4)}_{\overline{\text{MS}}} = 263 \pm 42 \pm 55$ MeV.

The results from [20–22] and [24] can be combined to give $\alpha_s(M_Z) = 0.112 \pm 0.002 \pm 0.004$ or equivalently $\Lambda^{(4)}_{\overline{\text{MS}}} = 234 \pm 26 \pm 50$ MeV. (See the full *Review of Particle Properties* for a discussion of how this average was performed.)

Typically, Λ is extracted from the data by parametrizing the parton densities in a simple analytic way at some Q_0^2, evolving to higher Q^2 using the next-to-leading-order evolution equations, and fitting globally to the measured structure functions to obtain $\Lambda^{(4)}_{\overline{\text{MS}}}$. Thus an important by-product of such studies is the extraction of parton densities at a fixed-reference value of Q_0^2. These can then be evolved in Q^2 and used as input for phenomenological studies in hadron-hadron collisions (see below). A package is available in the from the CERN computer library that includes an exhaustive set of fits [27].

25.4. QCD in decays of the tau lepton

The semi-leptonic branching ratio of the tau (R_τ) is an inclusive quantity. It is related to the contribution of hadrons to the imaginary part of the W self energy $\big(\Pi(s)\big)$, just as R (see below, Sec. 25.7) is