Homework Set 8 Instructor: Ralf W. Gothe **3/26/24**

8.1) **Callan-Gross Relation**

8.1.1) [4] Derive the Callan-Gross relation that connects the structure functions F_1 and F_2!

8.2) **Deep Inelastic Scattering**

Deep inelastic electron-proton scattering is studied at the HERA collider. Electrons with $30\,GeV$ are collided head on with $820\,GeV$ protons.

8.2.1) [3] Calculate the center of mass energy of this reaction. What energy does an electron beam, that hits a stationary proton target, have to have to reproduce this center of mass energy?

8.2.2) [4] The relevant kinematic quantities in deep inelastic scattering are the square of the four momentum transfer Q^2 and the Bjorken scaling variable x. You already have derived Q^2 in dependence of the electron's kinematic variables E_e, the beam energy, E'_e, the energy of the scattered electron and ϑ_e, the electron scattering angle. In certain kinematic regions it is better to extract Q^2 from other variables since their experimental values give Q^2 with smaller errors. Find a formula for Q^2 that depends only on the scattering angles of the electron ϑ_e and of the scattered quark γ_q as well as E_e. How may γ_q be determined experimentally from the measured hadron energies and momenta of the final state?

8.2.3) [2] Show that the four momentum transfer Q^2 at HERA equals in good approximation s, if you consider an electron scattering angle ϑ_e of 180^o! Use s^2 and Q^4.

8.2.4) [2] What is the largest possible four momentum transfer Q^2 at HERA? What Q^2 values are attainable in experiments with stationary targets and $30\,GeV$ electron beam energies? Estimate and compare the spatial resolutions within the proton in both cases!

8.2.5) **[GS]** [2] Find the kinematic region in Q^2 and x that can be reached with the ZEUS calorimeter, which covers the angular region 7^o to 178^o. The scattered electron needs to have at least $5\,GeV$ to be resolved.