Name(s) : Group:

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Particle Physics – Exercise Sheet 5 – WS 2011/12

5.1 Parton distribution functions (40P)

In the quark parton model the nucleons are composed of quarks and gluons. Their momentum distributions can be measured in deep inelastic scattering. The structure function $F_2(x)$ is given by

$$F_2(x) = \left(\frac{2}{3}\right)^2 x\left[u(x) + \bar{u}(x)\right] + \left(\frac{1}{3}\right)^2 x\left[d(x) + \bar{d}(x)\right] + \left(\frac{1}{3}\right)^2 x\left[s(x) + \bar{s}(x)\right]$$

where $u/d/s(x)$ are the probability to find a $u/d/s$-quark carrying a fraction x of the toal momentum of the nucleon. Contributions from heavier quarks (c, b, t) can be neglected.

a) Reorganize the above expression for $F_2(x)$ to group valence and sea quark contributions.

b) In deep inelastic scattering the structure function can be measured for protons and neutrons. Based on the form stated above, the assumption that u-type quarks and d-type quarks have the same distribution and isospin symmetry ($d_v^n(x) = u_v^p(x) = u_v(x)$) write down the structure function $F_2(x)$ for proton and neutron.

c) Fig. 1 (left) shows this ratio vs. x. What can one learn from the behaviour for $x \to 0$?

d) Which limiting value do you expect for $x \to 1$?
How can one reach the observed value of $\frac{F_2^n(x)}{F_2^p(x)} \approx 0.2 - 0.3$?

e) The right panel of Fig. 1 below shows the difference $F_2^p(x) - F_2^n(x)$. What does this difference represent? (Hint: You should use your result for (a)).

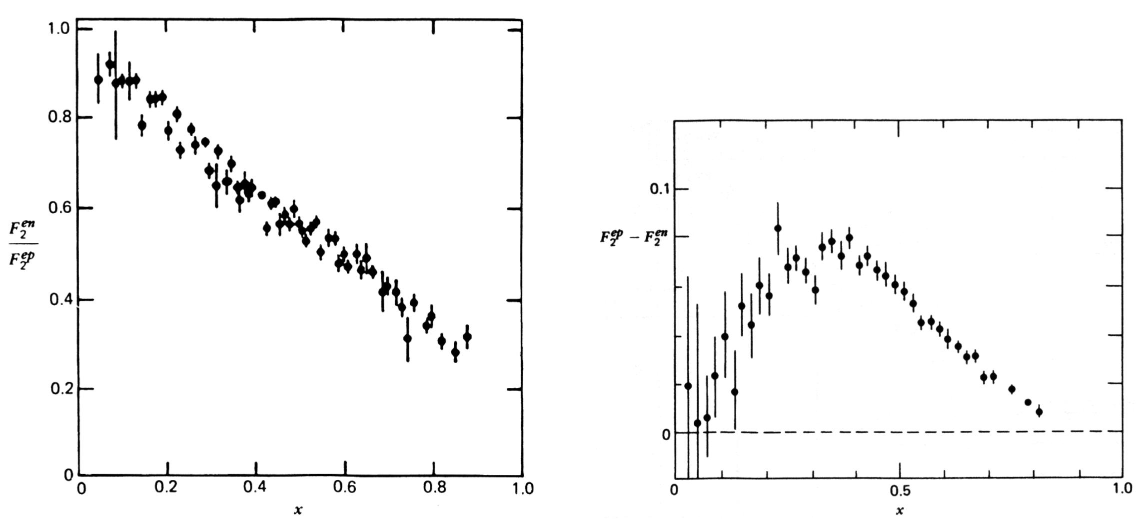

Abbildung 1: Structure function measurements from SLAC

5.2 Pseudorapidity and invariant mass reconstruction (30P)

In high-energy physics, the pseudorapidity η is frequently used to describe the direction of a particle:

$$\eta \equiv \frac{1}{2} \ln \frac{|\vec{p}| + p_z}{|\vec{p}| - p_z}$$

with $\vec{p}$ the particle momentum and p_z the momentum z-component.

a) Relate η to the polar scattering angle θ.

b) The following electron/positron pair has been measured in a proton - proton collision with the ATLAS detector at the LHC:

	E (GeV)	ϕ	η
e^+	44	2.51	1.01
e^-	48	5.74	-1.19

Calculate the invariant mass of the electron/positron pair. Use $m_e = 0$.

5.3 Isospin (30P)

The collision of a pion with a nucleon can lead to the formation of a nucleon resonance.

a) The resonances with isospin $I = 1/2$ are N^0 ($I_3 = -1/2$) and N^+ ($I_3 = 1/2$). Calculate the ratio $\frac{\Gamma(N^+ \to n\,\pi^+)}{\Gamma(N^+ \to p\,\pi^0)}$ from isospin invariance. Neglect phase space differences due to the different final state masses.

b) A resonance X decays via the strong interaction to $n\pi^0$ (branching ratio BR = 18%) and to $p\pi^-$ (BR = 36%). What is the isospin of X?