Exercises Physics VI (Nuclei and Particles)

Summer Semester 2009

Exercise sheet Nr. 8

Work out until 2.07.2009

Exercise 1: Intrinsic parity of Ξ (Points: 2)

Based on the reaction $\Xi^- p \to \Lambda\Lambda$ which proceeds through the strong interaction, determine the intrinsic parity of the Ξ^-. Assume, that the Ξ^- is captured in an S-wave and that spins of the Λ particles are antiparallel. Note that the parity of the proton is positive by definition and that the wave function of fermions must be asymmetric. What is the relative spin orientation of Ξ^- and p in the initial state?

Exercise 2: Isospin (Points: 2)

a) Proton and neutron form an isospin doublet. Identify the possible isospin states (I and I_3) of

$$p + p, \quad p + n, \quad n + n$$

Justify why the deutron has to be an isospin singlet.

b) Which isospin states are the combinations $d + \pi^+$, $d + \pi^0$, $d + \pi^-$? Based on the assumption of isospin invariance of the strong interaction, investigate the ratio

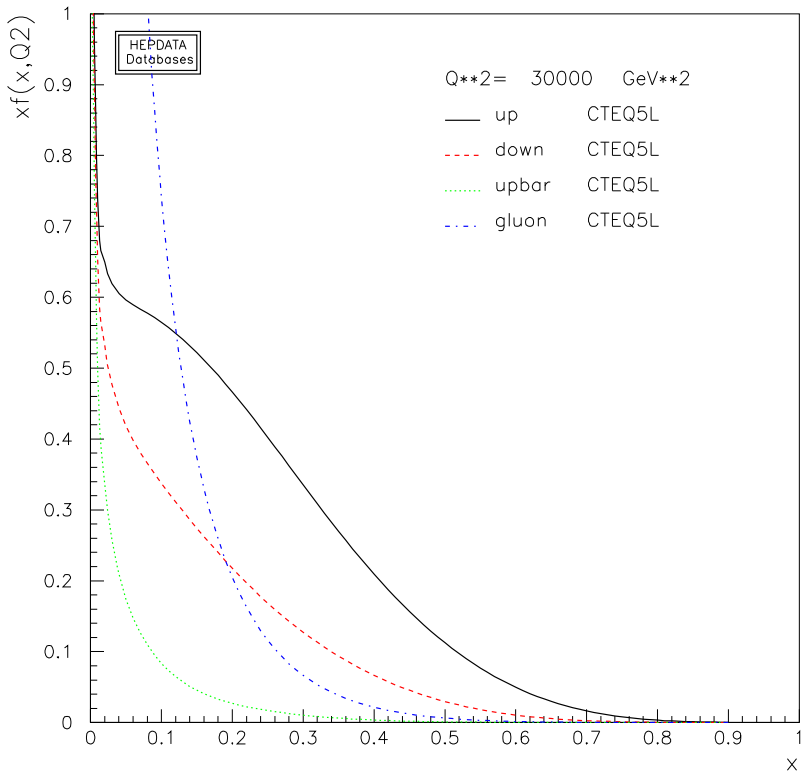
$$\sigma(pp \to d\pi^+) \,:\, \sigma(pn \to d\pi^0) \,:\, \sigma(nn \to d\pi^-)$$

Exercise 3: Top-quark production at Tevatron (Points: 5)

At the Tevatron accelerator, protons and antiprotons collide at a center-of-mass energy of $\sqrt{s} = 1.96$ TeV. There the top-quark ($m_t = 175$ GeV) was discovered in 1995.

a) At the Tevatron, top-quarks are mainly produced as $t\bar{t}$ pairs through the strong interaction. Draw the Feynman diagrams which contribute to $t\bar{t}$ production at lowest order.

b) The parton-parton centre-of-mass energy depends on the Bjorken scale variable of proton (x_p) and antiproton $x_{\bar{p}}$. What is the minimal value of x under the condition $x := x_p = x_{\bar{p}}$ to produce a $t\bar{t}$ pair?



The momentum probability distribution as a function of x for a parton in a proton can be seen in the above figure. Use it to decide which process from part a) is most important for production of $t\bar{t}$ pairs at Tevatron. Which process will be dominant at the LHC, where protons will collide at a centre-of-mass energy of 14 TeV?

c) The top-quark decays practically immediately ($\tau = 4.7 \cdot 10^{-25}$ s) and can therefore be regarded as the decay of a free quark. Through which interaction does the top-quark decay proceed? Draw the Feynman diagram of the top-quark decay and motivate its short lifetime. Why do the b-quarks (or rather hadrons with b-quarks) have longer lifetimes of the order $1.5 \cdot 10^{-12}$ s and why is the lifetime larger for c-quarks (or rather hadrons with c-quarks)?

d) Discuss how $t\bar{t}$ pairs can experimentally be detected. Which signature (decay channels) are possible and what are their advantages and disadvantages?

e) In a top-quark mass measurement in semileptonic decays, the neutrino momentum has to be reconstructed. Under the assumption that all momenta of all other particles are measured, one can estimate momentum of neutrino. Two solutions are possible so give the formula for both of them.