// for permil

Rheinische Friedrich-Wilhelms-Universität Bonn Sommer Semester 2010

Hadron Collider Physics

Prof. N. Wermes, Dr. E. von Törne

Exercises 6

Goetz Gaycken and Vadim Kostyukhin
(Tel. CERN: 0041-22-767 8052 or 3831)

Classwork

6.1 Kinematics of the W decay

The tranverse mass for the $W \to l\nu$ decay is defined as

$$m_\top = \sqrt{2 \cdot |p_{\top l}| \cdot |p_{\top \mathrm{mis}}| \cdot (1 - \cos(\triangle\phi_{p_{\top l} - p_{\top \mathrm{mis}}}))}$$

Show that the distribution of $m_\top$ in the $W \to l\nu$ events has a Jacobian peak. What is the position of this peak? To simplify the calculations assume that the W has $p_\top^w = 0$.

6.2 Vector boson production at LHC

(a) What processes contribute to the $pp \to e^-\mu^+ + 2$ jets final state? Find at least three processes and draw the feynman diagrams for them.

(b) Draw the feynman diagrams for the following processes (at least one diagram for each process):

(a) $pp \to \gamma\gamma$

(b) $pp \to WZ$

(c) $pp \to \gamma +$ jet

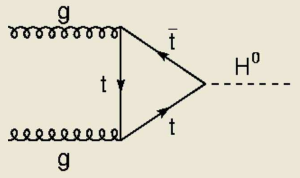
Bonus Homework

6.3 Some production processes at LHC

(a) Draw the leading order Feynman diagrams for three single top-quark production processes via weak interaction. Why can the magnitude of the CKM-matrix element Vtb be extracted directly by a measurement of the single top-quark production but not of the tt-bar pair production?

(b) Draw the leading order Feynman diagrams for the WZ vector boson pair production. Why at the LHC the production cross section of the W^+Z is bigger than the cross section of the W^-Z ?

(c) Draw at least 3 Feynman diagrams for $t\bar{t}H$ production at LHC.
It's well known that the so called "gluon fusion" process going via top quark loop (see diagram)



is dominant in the Higgs boson production at LHC. Why the $t\bar{t}H$ production cross section is much smaller than the "gluon fusion" one in the most probable Higgs boson mass range 120-200 GeV?

6.4 Collinear Approximation

Consider the reaction pp $\rightarrow$ Z^0 $\rightarrow \tau^+\tau^- \rightarrow \mu^+\nu_\mu\bar{\nu}_\tau$, $\mu^-\bar{\nu}_\mu\nu_\tau$

(a) Draw the Feynman diagram of the tau decay.

(b) In the collinear approximation for this case the two neutrino momenta are assumed to point in the same direction as the tau-lepton. Argue why this approximation is justified.

(c) The quantities x_1 and x_2 are defined as $x_1 = E(\mu^+)/E(\tau^+)$ and $x_2 = E(\mu^-)/E(\tau^-)$. Use the conservation of transverse momentum to show that one can calculate x_1 and x_2 from the two muons and from the $E_\top^{\text{miss}}$ vector.

(d) Show that the mass of the Z boson can be reconstructed using x_1, and x_2. For simplification, neglect the lepton masses.