

# IDPASC School of Flavour Physics

2-7 May 2013

## BULLETIN 1: STRONG INTERACTIONS

### Problem 1

Draw the tree-level Feynman diagrams and calculate, in terms of the Mandelstam variables  $s$ ,  $t$  and  $u$ , the differential cross section of some of the following partonic collisions (take  $m_q = 0$ ):

- a)  $q + q \rightarrow q + q$
- b)  $q + \bar{q} \rightarrow q + \bar{q}$
- c)  $q + g \rightarrow q + g$
- d)  $q + \bar{q} \rightarrow g + g$
- e)  $g + g \rightarrow q + \bar{q}$
- f)  $g + g \rightarrow g + g$

Note that some of the amplitudes can be related by crossing symmetry.

### Problem 2

Consider the processes  $q + \bar{q} \rightarrow g + g$  and  $q + \bar{q} \rightarrow G + \bar{G}$ , where  $G$  ( $\bar{G}$ ) is the ghost (antighost).

- a) Draw the Feynman diagrams contributing at tree level and calculate the corresponding invariant matrix elements  $M_{q\bar{q} \rightarrow gg}^{\mu\nu}$  and  $M_{\text{Ghost}}$ .
- b) Show that the so-called QCD Ward identity is fulfilled

$$p_\mu M_{q\bar{q} \rightarrow gg}^{\mu\nu} = p'^\nu M_{\text{Ghost}}$$

where  $p$  and  $p'$  are the momenta of the outgoing gluons in the first process and of the antighost and ghost, respectively, in the second one.

- c) Consider now the QED process  $e^+ + e^- \rightarrow \gamma + \gamma$ . Show that the QED Ward Identity

$$p_\mu M_{e^+e^- \rightarrow \gamma\gamma}^{\mu\nu} = 0 = p'_\nu M_{e^+e^- \rightarrow \gamma\gamma}^{\mu\nu}$$

is fulfilled.

### Problem 3

Compute the cross section at order  $\alpha_s$  for the three jet process

$$e^+ + e^- \rightarrow q + \bar{q} + g$$

Hint: see the Final Project: Radiation of Gluon Jets on page 259 of Peskin's book and follow the indications.