Particle Physics FYS4560

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Project 1

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1 – SM and beyond: Allowed, forbidden and discovery processes

1. State whether the following processes are allowed or not.
   1. Classify them according to the underlying interaction and draw the corresponding Feynman graphs.
   2. For each particle decay, indicate the lifetime and the branching ratio.
   3. What conservation laws, invariance principles, or other mechanisms account for the suppressing or forbidding of some processes.
   4. Why are processes 3, 4, 8, 10, 11, 14 and 18 of particular importance? Justify and tell more.

1. $e^+e^- \to q\bar{q}gg$	2. $gg \to e^+e^-$	3. $e^+e^- \to \tilde{l}^+\tilde{l}^-$
4. $p\bar{p} \to l^+l^-X$	5. $\tau^+ \to \mu^+\nu_e\bar{\nu}_\tau$	6. $K^-p \to \Omega^-K^+K^0$
7. $\nu_e e^- \to \nu_e e^-\gamma$	8. $pp \to l^+l^-l^+l^-X$	9. $e^+e^- \to HH\gamma$
10. $q\bar{q} \to W^+W^-Z$	11. $e^+e^- \to ZZZ$	12. $e^+e^- \to H \to gg$
13. $e^+e^- \to \nu\bar{\nu}\gamma\gamma$	14. $gg \to t\bar{t}HH$	15. $e^+e^- \to \Upsilon(3s) \to B^0\bar{B}^0$
16. $q\bar{q} \to gge^+e^-$	17. $gg \to H \to Z\gamma$	18. $ep \to J/\psi + X$
19. $D^0 \leftrightarrow \bar{D}^0$	20. $e^+e^- \to Z^0t\bar{t}$	

2 – Top quark and W-boson

1. Start by introducing the CKM matrix and the role of the W boson
    1. Which of the matrix elements are related to B-Bbar mixings
    2. How are these measured experimentally.
2. Discuss top-quark production in electron-positron, proton-proton and proton-antiproton collisions
    1. Consider single top and top-anti-top
    2. Corresponding Feynman graphs?
3. How does the top decay –
    1. Feynman diagram(s)
    2. How is top identified experimentally?
        1. Consider all possible categories of final states
        2. Find an ATLAS display of a top candidate and describe/comment it.
4. Top production is often considered as an important SM background to various searches for new physics.
    1. Discuss the supersymmetric process: $pp \rightarrow chi^{+}_{1}\ chi^{0}2$ leading to $WZ + 2chi^{0}_{1}$ where chi^{0}_{1} is the latest supersymmetric particle not interacting in the detector
    2. Which kinnematical requirements allow to reduce the top background?

3 – Gauge theories

1. Discuss the classification of particles in the SM
    1. How are the SM symmetries behind related to conservation laws.
    2. Discuss the classification of particles in Grand Unified Theories
1. Define the gauge principle and apply it to Quantum Chromo-Dynamics, QCD
    1. Go through all steps in detail – as you have done for QED
    2. Derive the QCD Lagrangian
2. Make a detailed comparison of QCD and QED
    1. Conceptually
    2. Experimentally
3. Deduce the Electroweak Lagrangian based on QED and QCD formulation
    1. Ignore the gauge boson masses
    2. Where are the complications?