Fall Quarter 2009
UCSD Physics 214 & UCSB Physics 225
Final Exam

Exam is due on Friday, December 4th, 2009, at 10am in my office.

This is an open book exam in the sense that you are welcome to use any of the references listed or linked in on the course web site, including Halzen & Martin. You will need a computer to do some of the work. You will need to look some things up in the particle data book, and may do so either online or on paper.

You are not allowed to use solution sets from a previous year’s class, as many of the problems are similar to problems from previous years.

1. 26 Points: As mentioned in class, I want you to do a crude evaluation of an analysis. The analysis we’ll do is to search for two processes: W+W+W- (and charge conjugate) as well as t bar W+ (as well as charge conjugate). We will pretend to search for these processes at the LHC with 14TeV proton-proton center of mass in the final state of two same sign dileptons (electron or muon), i.e. the final states ee, mumu, emu. What I want you to calculate is the amount of integrated luminosity needed to find a signal of 10 events. I want you to calculate this separately for each of the two processes. Let me walk you through this one step at a time.

a. Let’s start with an efficiency estimate. Take a look at the WW production PAS Note EWK-09-002 that our group produced. This is linked in at the course website for your convenience. What is the probability to observe two leptons (e or mu) in a WW event?

b. In both processes of interest, you have three Ws in the final state. Is there a factor from combinatorics that you should worry about when estimating the expected yield of same sign dileptons from the 3 W final state?

c. Verify that you can reproduce the cross section calculation for W+W- using comphep. (Hint: Make sure you calculate each of the relevant processes, and add them up properly. I got 74pb at 14TeV. The PAS note claims 74pb at 10TeV. The numerical agreement is accidental because the PAS note is NLO, whereas comphep is LO. If you have trouble installing comphep, ask me for help.) A gzipped tar archive is linked in at the course web site. Here’s what you do to install it:
(a) wget 
http://physics.ucsd.edu/students/courses/fall2009/physics214/fina
lExamComphep.tgz
(b) tar –xvzf finalExamComphep.tgz
(c) cd comphep-4.4.3
(d) ./configure
(e) make
(f) make setup WDIR=/data/tmp/fkw/wkdir (you of course need to
pick a working directory of your own here.)
(g) cd /data/tmp/fkw/wkdir
(h) ./comphep &
(i) At this point, follow the instructions given in class on Monday
Nov.30th. You’ll want to use the structure function 12 (cteq6l1)
d. Now calculate the cross sections for WWW and tbarW using comphep.
(Hint: Remember to add charge conjugates, as well as parton-parton
subprocesses).
(a) As an aside. Explain the difference in W+W+W- and W+W-W-
cross sections.
e. At this point you have all the pieces together to estimate the integrated
luminosity required to observe 10 events in the same sign dilepton final
state. Go ahead and estimate it for each of the two processes.
f. As an afterthought, read the PAS note again. There is one requirement that
is made there (in addition to the opposite sign leptons requirement) which
does not make any sense for a WWW or tbarW analysis because it would
kill the signal. What is it? How might one use something like it to
distinguish WWW from tbarW?
2. 10 points: Consider J^p = 1^- mesons with zero strangeness that can be built from
u,d, and s quarks and anti-quarks.
a. What are the flavor wave functions of rho+,-0, omega, and phi ?
b. What is the color wave function ?
c. What is the spin wave function for Jz=0 ?
3. 8 points: Consider the process e+e- -> Upsilon(4S) -> B+B- .The Upsilon(4S) is
a bbar bound state with quantum numbers J^{PC} = 1^- . What is the angular
distribution of the B-mesons in the center of mass? Explain your reasoning.
4. 10 points: Let A, B, C be pseudoscalar mesons. Let D be a vector meson (NOT
an axial vector meson). Which of the following decays if any is allowed if parity
is conserved? Explain your reasoning.
a. A -> BC
b. D -> BC
c. D -> BC if B and C are identical particles.
5. 10 points: Consider the Omega (S=-3, I=0) hyperon. First write down the
obvious strong interaction decays that you might expect, given its quantum
numbers. Then check its lifetime and decay modes in the particle data book. Did
you find the strong interaction decays you expected? If not, why not? What’s the
interaction responsible for its decay? Why?
6. **8 points:** Let’s assume you observed the reaction e-proton → electronneutrino + l⁺ + l⁻ + X++, where X++ refers to the double charged remnants of the inelastic collision with the proton, and l refers to some lepton flavor. (Hint: Draw the appropriate second order weak interaction diagram and explain it.)
   a. What’s the significance of this observation if l=electron?
   b. Does your conclusion change when l=muon?

7. **8 points:** W⁻ bosons can be produced in pp or ppbar collisions via the parton process $\overline{u} + d \rightarrow W^-$. This is a charged weak interaction process, and only left-handed fermions and right-handed anti-fermions contribute.
   a. Sketch the expected polarization of the $W^-$ with respect to the direction of motion of the $\overline{u}$ and $d$ quarks.
   b. Make qualitative comments about the difference, if any, in the $W$-polarization at the CERN SppbarS (ppbar at 630GeV center of mass), Tevatron (ppbar at 2TeV), and LHC (pp at 14TeV).
   c. How does your conclusion change if the LHC was colliding p pbar instead of pp?

8. **20 points:** Isospin arguments can in some cases be used to relate amplitudes from weak processes, despite the fact that weak interactions violate isospin. In these cases, the flavor symmetry arguments relate the hadronization of final state quarks into hadrons, which conserves isospin. A very important example is the weak decay of B mesons into two pions.
   a. Write down the Isospin decomposition of the two pion final state. Why is $I=1$ forbidden in this case? You are thus left with only two transition amplitudes $\Delta I=1/2$ and 3/2.
   b. The figure below shows the two kinds of Feynman diagrams. The ones on the left are called “tree diagram” the ones on the right are called “penguin diagram”.
      (a) Explain why tree diagrams are an admixture of $\Delta I=1/2$ and 3/2 while the penguin diagram is pure $\Delta I=1/2$.
      (b) Why is there no penguin diagram for $B^+ \rightarrow \pi^+ \pi^0$?
   c. Armed with all of this information, show the amplitude relationship:
      $$(1/\sqrt{2}) A^+ + A^{00} = A^{+0}$$
      Where the charge superscript refers to the charges of the final state pions.
$B^0 \rightarrow \pi^+ \pi^-$

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