Assignment 3: MadEvent & Feynman Diagrams
Due: February 6, 2008

PHYX442-0 Winter 2008 : Collider Physics

Homework Assignment 3 :
MadEvent and Feynman Diagrams

1. Let's take MadEvent for a test drive.

Go to the MadEvent Web site:

http://madgraph.hep.uiuc.edu/

Click the "Generate Process" link at the top left.

There are two different ways to generate a new process in MadEvent. We're going to use (I) which is an online form you fill out.

Choose: **Model: SM** (which stands for the "Standard Model" of particle physics. Below that, type into the **Input Process** box: $pp > e + e-$. This generates the process in which two protons collide, resulting in an electron and a positron. Leave everything else the same (the "MAX" boxes let you select up to which order in perturbation theory you will consider, the defaults are fine for us). The definitions allow us to define which fundamental particles make up the proton; again the default is fine for us. Finally, we can sum over different kinds of leptons in the last line, but we picked the electron specifically in our process, so there is nothing to sum over.

Click the **Submit** button and wait a few seconds for the server to think. It should quickly redirect you to the "MadEvent Card for $pp > e + e-$". If you can't wait, or don't want to do this whole problem in one sitting, you can get back to the results later by clicking **My Database** from the MadEvent main page.

From the "Card" page we can look at what it computed, download a code to run on our own computer, or generate events online. First, take a look at **Process Information**. There should be four subprocesses listed, one initiated by up quarks, and one by down quarks. There are four listed because MadEvent considers the cases with the two initial particles swapped distinctly. Open the **html** under **Feynman Diagrams** for one of the processes (doesn't matter which one). You should see two quarks (u or d, depending on the process) coming in, fusing into either a photon (A) or a Z boson, which then splits into the e^+e^- pair.

A. Copy down the Feynman diagrams. We haven't learned how to treat fermions, or vector particles (yet), but for the purposes of this assignment, treat the A and Z as real scalar fields (A has mass zero and Z mass M_Z), and the quarks and electrons as complex scalar fields (treat them all as having zero mass). Using the Feynman rules for scalar fields, write down the expression for the amplitudes in those Feynman diagrams in terms of the momenta of the incoming quarks, and outgoing electron and positron. (We should worry about the coupling constants at each vertex, but don't for now).

Go back to the “MadEvent Card for $pp > e + e-$” web page. Click the “On-line Event Generation” link. (You may have to put your password in again when you do that). We’ll learn how to use the options on this page in later assignments, but for now lets stick with the defaults. Click the“ **send** the form to generate the cards” button. Click “**send**” again to start the job on the server. It may take a few minutes to run the job on the UIUC cluster. If you need to log out before it finishes, you can get to the results later from the **My Database** link on the main page.

When the run finishes, it will report the results in a table (along with any runs you generated in the past - please be responsible and delete the runs when you’re sure you are finished with them). When the run finishes, click the **plots** link on the table entry for that run. You should see a page with some histograms that were automatically generated when the cluster calculated the cross section. Scroll down to the m(e+1e-1) plot. That code means the invariant mass of the first electron and the first positron, or $E = \sqrt{(p_{e^-} + p_{e^+})^2}$.

B. Look at the plot and compare with the expression you wrote down in part **A**. The histogram shows a behavior that is large at small E and falls as E increases. That can be understood from the Feynman diagram in which the massless A is exchanged. The graph should also show a peak at some value of E. Explain how this is expected from the Feynman diagram with the Z in it, and what that tells you about the value of M_Z.