Physics 450 – Problem Set # 1

(due Tuesday, November 11)

The problem sets in Physics 450 will be computer exercises relevant to LHC physics. On the course Web site, you will find a simple package `collider.tar.gz` for integrating two-body parton cross sections over parton distributions. The exercises will be constructed so that you can do the exercises using this package. The package is documented in the file `collider.pdf`, also on the course Web page. Alternatively, you can do these exercises using any collider physics program that you are familiar with, eg., MadGraph, CompHEP. It might be interesting to use several approaches and see how the answers compare.

1. Create a plot of the evolution of the up quark parton distribution in the proton, similar to Peskin and Schroeder, Fig. 17.21. Produce similar plots for the down quark, anti-down quark, gluon, and bottom quark distributions. For the last few distributions, you might want to use a log scale in x. Make a plot that compares the anti-down and anti-up distributions at a few values of Q.

2. Make a plot of the differential cross section for the production of a jet as a function of the jet p_T at the Tevatron collider, a $p\overline{p}$ collider with center of mass energy 2 TeV. Assume that the jet can be detected only for $-0.7 < \eta < 0.7$. Make a plot of the cross section for producing a jet of *at least* p_T in this η range. Remake these same set of plots for the LHC, with proton-proton collisions at $E_{CM} = 14$ TeV. For that case, use the η range $-4.0 < \eta < 4.0$.

3. Using these plots, estimate the rate of parton-parton scattering events with $p_T > P_T$ for various values of P_T. For what value of P_T is the rate such that all events can be written to permanent storage (rate < 100/sec). For what value of P_T is the rate so high ($> 10^4$/sec) that the events could never be analyzed? For some low value of P_T, we expect a 2-parton collision in every proton-proton collision. What is this value, at the Tevatron and at the LHC?

4. Compute the total cross section for Drell-Yan production, with $\mu^+\mu^-$ in the final state, at the Tevatron and at the LHC as a function of the mass of the muon pair. For the Tevatron, compare the cross section to that shown in the figure, p. 2, of the Oct. 10 lecture. Compute the y distribution of the muon pairs (not the η distribution) and compare it to the figure, p. 4. Note that the figure assumes that the muon pair mass lies in the interval $66 < m(\mu^+\mu^-) < 116$ GeV. Compute the cross sections and y distributions for $\mu^+\nu$ and $\mu^-\overline{\nu}$ production at the Tevatron and at the LHC. For the y distributions, use an interval around the W mass, $60 < m(\mu\nu) < 100$ GeV. Compute the y or η distribution of the charged leptons in these reactions.