PHZ 6358: Standard Model I  
Fall Term 2013  
Homework Set 7  

Due Wednesday, November 1, 2013

Reading: PYTHIA manual: the first chapter (Introduction), sections “The complexity of high-energy processes”, “Event generators” and “Disclaimer”, the rest of the introduction is optional. For information on PYTHIA’s histogramming capabilities, see Sec. 15.6 Histograms. The physics processes in PYTHIA are listed in Tables 17-24 (note that not all have been implemented so far).

**Problem 1. Top cross-sections.** Calculate the total $t\bar{t}$ cross-section

(a) at the Tevatron, using PYTHIA;
(b) at the LHC, using PYTHIA;
(c) at the Tevatron, using CalcHEP (compare to the answer from (a));
(d) at ILC500, using PYTHIA.

**Problem 2. Fourth generation.** In this exercise we will figure out how PYTHIA treats fourth generation fermions (see section 8.6.1 of the PYTHIA manual).

(a) Use $MSEL=7$ or $MSEL=8$ to select $b'b'$ and $t't'$ pair production, respectively.
(b) From the summary decay table, figure out:

1. the default masses for $t'$, $b'$, $\tau'$ and $\nu_{\tau'}$;
2. their possible decay modes which are known to the program.
3. discuss the default values for the branching fractions of the allowed decay modes.

(c) Compare the cross-sections (at the Tevatron) for $t\bar{t}$ pair production and $t'\bar{t}'$ pair production for the same quark mass ($m_{t'} = 175$ GeV).

**Problem 3. $p_T$ spectra.** Investigate the shape of the $p_T$ spectrum of the $Z$-boson in the Drell-Yan process at the LHC (see section 8.4.2).

(a) Use process number 1 ($f\bar{f} \to Z$) in PYTHIA with ISR and FSR turned on and plot $p_T^Z$.
(b) Repeat (a), but use processes 15 ($f\bar{f} \to gZ$) and 30 ($fg \to fZ$). Compare to the result from (a).
(c) Finally, make a cross-check with CalcHEP.