Problems on Event Generator Physics

Use the event generator of your choice for the following exercises.

1. Generate hadronic Z^0 decays via $e^+e^- \to Z^0 \to q\bar{q}$ ($q = d, u, s, c, b$). Compare the charged multiplicity distribution and the distribution of $\ln(1/x_p)$ ($x_p = 2|\mathbf{p}|/\sqrt{s}$) with LEP1 data.

2. Generate $e^+e^- \to q\bar{q}$ ($q = d, u, s, c, b$) at higher energies, $\sqrt{s} = 200, 500, 1000$ GeV. (Turn off QED radiation, otherwise you will be dominated by $e^+e^- \to Z^0\gamma$.)

   (a) Compare the mean charged multiplicity with the QCD prediction

   $$\langle n_{\rm ch} \rangle \sim a \frac{\exp\sqrt{cL}}{\sqrt{L}}$$

   where a is a non-perturbative constant, $c = 72/23$ and $L = \ln(s/\Lambda^2)$. At each energy, compute the variance and hence the error in your MC result.

   (b) Compare the position ξ_p of the peak in the distribution of $\ln(1/x_p)$ with the QCD prediction

   $$\xi_p \sim \text{const} + \frac{1}{4}\ln s \ .$$

3. Generate $e^+e^- \to t\bar{t}$ at threshold and force the tops to decay leptonically (to e or μ).

   (a) Compare the charged and neutral lepton p_T distributions with those shown in the lectures.

   (b) Explain why the neutrinos tend to have higher p_T than the charged leptons. How would things change if the decay went via $t \to bH^+$ with $m_{H^+} = m_W$?

4. Same as qu.3, but for $pp \to t\bar{t}X$ at LHC energy ($\sqrt{s} = 14$ TeV). Here p_T should be defined relative to the direction of motion of the parent t or $\bar{t}$.