Problem Set for Hadron Collider Physics 2015

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Problem Set 4

Your solutions have to be handed in by 10:10 am on Tuesday, June 2nd 2015. Please drop them into the mailbox number 1 on the ground floor of the Gustav-Mie building!

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1. **Jet calibration**

   In this exercise we will learn how $pp \to \gamma\,$jet events can be used to determine the jet energy scale. We will make use of the fact that the transverse momenta of the outgoing parton and the photon are balanced in the partonic $2 \to 2$ process. The reconstructed jets can therefore be calibrated using the photons as a reference object. Remember that photons are reconstructed in the electromagnetic calorimeters with a considerably better energy resolution compared to hadrons measured in the hadronic calorimeters.

   You will find the necessary files for this exercise on the web page of this course (`http://portal.uni-freiburg.de/jakobs/Lehre/ss-15/hadron-collider`): `PythiaGammaJet.root` contains the events for the analysis. Take a look at `GammaJetAnalysis.h` to find out which branches are in the ROOT file or use a TBrowser for this. The branches `photon_pt,photon_eta,...` and `jet_pt,...` contain the information about all reconstructed photons and jets of the event (above a certain p_T threshold). Note that all of them are vectors which are ordered by p_T. The selection should be implemented in the `Loop()` method that can be found in the `GammaJetAnalysis.C`. The program can be run as learned in the last problem set.

   (a) Plot the distributions of: the p_T of the leading photon, the p_T of the leading jet, the p_T of the sub-leading jet. Here, "leading" simply means the jet/photon with the highest transverse momentum in the event and "sub-leading" jet being the one with the second-highest p_T.

   Also make a plot of the difference of the azimuthal angle between the leading photon and jet: $\Delta\phi(\gamma,\, jet)$. Make sure the result takes on values in the interval $[0,\, \pi]$. **[2 points]**

   (b) Implement the following selection cuts: $p_T(\gamma) > 20\,\text{GeV}, p_T(\text{leading jet}) > 20\,\text{GeV}$. Add a jet veto to the selection: discard events with $p_T(\text{sub-leading jet}) > 20\,\text{GeV}$ or $\Delta\phi(\gamma,\, jet) < 2.8$. Why is such a veto cut necessary? **[2 points]**

   (c) Plot the transverse momentum balance

   $$\rho := \frac{p_T(\text{leading jet}) - p_T(\gamma)}{p_T(\gamma)}.$$

   [2 points]

   (d) Correct the p_T(leading jet) with a constant scale C to result in a calibrated jet with

   $$p_T^{calib}(\text{leading jet}) = C \cdot p_T(\text{leading jet}).$$

   Derive C from the mean of the ρ distribution. Make plots of p_T^{calib}(leading jet) and ρ^{calib}. **[3 points]**

   (e) Redo (d) with C derived by fitting a Gaussian distribution to the ρ distribution. **[3 points]**

(f) Redo (e) with $C = C(p_T)$ depending on the transverse momentum of the photon: C_1 for $20\,\text{GeV} < p_T(\gamma) < 30\,\text{GeV}$, C_2 for $30\,\text{GeV} < p_T(\gamma) < 40\,\text{GeV}$ and C_1 for $p_T(\gamma) > 40\,\text{GeV}$. **[3 points]**