Introduction to Phenomenology and Experiment of Particle Physics (PEPP)

Cycle 2

QCD cascades

Parton showers and jets

In principle one can view any jet clustering algorithm as an inverse parton shower. Instead of successively splitting partons into two, particles are successively clustered into jets. The distance measure will be more or less the ordering variable in the Sudakov form factor of the parton cascade, and in some sense also corresponds to a leading-logarithmic splitting function.

Literature

Most of this course is covered by

> R.K. Ellis, W.J. Stirling and B.R. Webber, *QCD and Collider Physics*, Cambridge University Press (1996).

and for this cycle the most relevant chapters are 5 and 6. Additional input can be found in lecture notes from various summer schools, eg.

> T. Sjöstrand, *Monte Carlo Generators*, `hep-ph/0611247`.

Goals

- Splitting functions
- Final-state parton showers
- Sudakov form factors
- Analytical calculations vs. Monte Carlo simulations

Exercises

1. The splitting kernel $P_{g\to q\bar{q}}(z) \propto z^2 + (1-z)^2$ is related to the QED angular relation

   $$\frac{d\sigma}{d\cos\theta}(e^+e^- \to \gamma^\star \to q\bar{q}) \propto 1 + \cos^2\theta$$

   Show how one may go from one to the other.

2. Check that $P_{q\to qg}(z)$ preserves the number of quarks.
   (Hint: you need to consider the "+"-prescription.)

3. Study the number of $q \to qg$ branchings in a typical LEP event, using a simplified model without coherence effects and other technical complications. Use the parameters
   $E_{cm} = Q_{\max} = 91$ GeV
   $Q_0 = Q_{\min} = 1$ GeV

   - Do a simple analytical calculation for fixed $\alpha_S = 0.15$ and $z_{\max} = 0.99$.
   - Do a Monte Carlo simulation using the *veto* algorithm for the same task.
   - Modify the Monte Carlo simulation so that $z_{\max}$ becomes Q-dependent: $z_{\max}(Q^2) = (1 + \sqrt{1 - Q_0^2/Q^2})/2$.
   - Modify again with $z_{\max}(Q^2) = 1 - Q_0/2Q$.
   - Modify the Monte Carlo simulation by introducing a running coupling

   $$\alpha_s(Q^2) = \frac{12\pi}{23\log(Q^2/\Lambda^2)} \quad , \qquad \Lambda = 0.2 \text{ GeV}$$

4. Calculate the transverse momentum of a branching $a \to bc$. Assume that a has a mass m_a while b and c are massless, and that b takes a fraction z of the momentum of a. Study how this changes if also b and c are massive.
   (Hint: The definition of z is not unambiguous. The answer becomes especially simple if z is interpreted as a fraction of light-cone momentum $p_+ = E + p_z$, with a along the z-axis. Use conservation of $p_- = E - p_z$.