Introduction to Phenomenology and Experiment
of Particle Physics (PEPP)

Cycle 3

Multi-particle production

Hadronization

The Lund string fragmentation model is based on the assumption that the colour field between a quark and an anti-quark can be described as a massless relativistic string. The production of mesons is then modeled by the production of additional quark–anti-quark pairs along the string. This can then be implemented as an iterative process where one hadron at the time is *chopped-off* from either end of the string. The observation that such a procedure must give causally disconnected vertices, that it must be Lorentz-invariant and must be symmetric w.r.t. going from one end of the string or the other, leads to a unique form of the fragmentation function.

Although the form is unique, the fragmentation function does contain a number of parameters, and the Lund model in general uses many parameters. This is in contrast to the cluster fragmentation model, where the number of parameters are kept to a minimum. Nevertheless, both models describe very well measured data at eg. LEP.

One important difference is related to the correlations between different particle species. In the Lund model it is eg. very difficult to produce two π^+ mesons close in phase space. When it comes to baryon correlations, both models typically produce eg. $\Lambda\bar{\Lambda}$ pairs very close in phase space. In fact the correlation is much stronger than what is found in data. In the Lund model this is solved by the so-called popcorn mechanism, at the expense of introducing even more parameters.

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 chapter is 5. Additional input can be found in lecture notes from various summer schools, eg.

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

A more thorough description of the Lund Model can be found in

> B. Andersson, *The Lund Model*, Cambridge University Press (1997).

Goals

- The massless relativistic string
- Fragmentation functions
- String vs. cluster fragmentation
- Particle correlations
- Mesons vs. baryons in hadronization

Exercises

1. Show that the relations

$$\begin{aligned} E &= \kappa(z_1 - z_2) \\ p_z &= \kappa(t_1 - t_2) \end{aligned}$$

   hold for a string piece at rest, i.e. with both ends at the same time. Then perform a boost along the z-axis to show that it holds generally.

2. The mass of the charm quark is in the range between 1.2 and 1.6 GeV. Estimate the range of tunneling suppression factors this would apply.

3. Assume that all string branchings produce particles with $m_\perp = 1$ GeV and has $z = 1/2$. Estimate the typical Γ value and deduce from that the typical proper time at which a string breaks.

4. A cluster with a mass of 1 GeV has the flavour content $u\bar{d}$. Enumerate the possibly two-body decay channels.

5. Compare the multiplicity of a "Mercedes" three jet event in e^+e^- ($E_q = E_{\bar{q}} = E_g = E_{CM}/3$) with a two jet event of the same energy. Assume that the multiplicity per string is proportional to its effective rapidity range.