Jet physics at the LHC

Frédéric Dreyer

Laboratoire de Physique Théorique et Hautes Énergies

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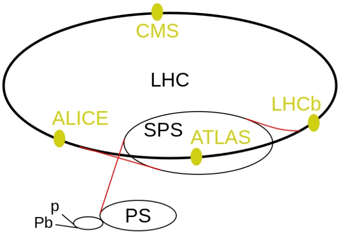
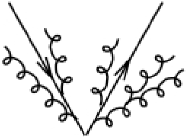
Large Hadron Collider at CERN

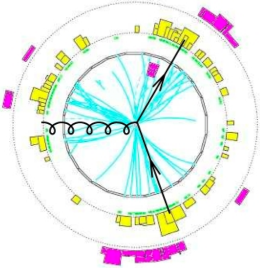
- Largest and highest-energy particle accelerator in the world.
- Collides protons with center of mass energy of 8 (14 in 2015) TeV.
- Some of the most important analyses rely on jet measurements.
- Essential to have a precise understanding of QCD processes : groundwork to understand backgrounds and constrain BSM physics.



Jets

- Parton processes are at the heart of hadron colliders, however we do not see quark and gluons directly.
- We can observe jets, cones of particles produced by hadronization of a quark or gluon
- Jet algorithms are procedures to combine particles in order to retrieve information on what happened in the event
- No unique definition of a jet, but good jet definitions are the closest we get to observing single partons

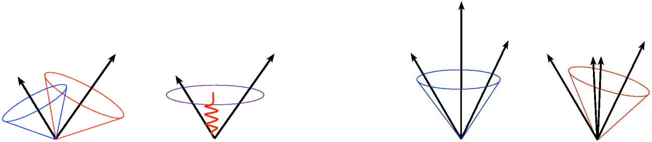




Jet algorithms

The requirements for a good jet definition are

- Infrared and collinear safety : Adding a soft parton or replacing a parton with a collinear pair should not change the number of jets



(a) Infrared problem (b) Collinear problem

- Insensitive to hadronization
- Simple to implement in theoretical calculations and experimental analyses

k_t algorithms

Define distance measures for all particles

$$d_{ij} = \min\left(p_{ti}^{2p}, p_{tj}^{2p}\right)\frac{\Delta_{ij}^2}{R^2}\,, \quad d_{iB} = p_{ti}^{2p}\,. \tag{1}$$

where R sets the angular scale on which particles can recombine into a single jet, p_{ti} is the transverse momentum of particle i, and

$$\Delta_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2\,, \tag{2}$$

where y_i and ϕ_i are the rapidity and azimuth of particle i.
$p = (-)1$ for the (anti-)k_t algorithm, $p = 0$ for the C/A algorithm,

- if $\min\{d_{ij}\} < \min\{d_{iB}\}$, merge i and j.
- if $\min\{d_{iB}\} < \min\{d_{ij}\}$, then particle i is a jet, remove it from the list
- iterate until all jets are complete

Microjets

- Modern jet tools resolve small subjets within a single jet, using small R values.
- In small-R jets, correspondence between jet momentum and parton momentum affected by radiation angles larger than R.
- Dominant terms in expansion of difference between parton and jet momenta is
$$\alpha_s^n \ln^n R^2 \tag{3}$$
- For microjets with large $\ln R^2$ the series may converge very slowly or not at all, and require all-order resummation.

Generating functional approach

Starting from a parton we consider emissions at successively smaller angular scales. Define evolution variable t

$$t = \int_{R^2}^{1} \frac{d\theta^2}{\theta^2} \frac{\alpha_s(p_t\theta)}{2\pi} \tag{4}$$

Taking a parton on an scale t_1, we define a generating functional $Q(x, t_1, t_2)$ encoding the parton content if the parton is resolved on an angular scale $t_2 > t_1$.
We can write an evolution equation for the generating functional

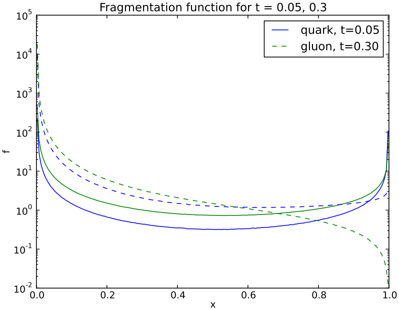
$$\frac{dQ(x,0,t)}{dt} = \int dz\, p_{qq}(z)\left[Q(zx,0,t)\, G((1-z)x,0,t) - Q(x,0,t)\right]. \tag{5}$$

(Similar for the gluon case)

Inclusive microjet observables

For a parton of flavour i, the inclusive distribution of microjets of flavour j carrying a momentum fraction z is $f^{\text{incl}}_{j/i}(z,t)$. The inclusive jet spectrum is given by

$$\frac{d\sigma_{\text{jet}}}{dp_t} = \sum_i \int_{p_t} \frac{dp'_t}{p'_t} dz \frac{d\sigma_i}{dp'_t} f^{\text{incl}}_{\text{jet}/i}(p_t/p'_t, t) \tag{6}$$



Hardest microjet observables

Define $f^{\text{hardest}}(z)$ the probability that the hardest microjet carries a momentum fraction z. The energy difference between the hardest microjet and the initial parton is given by

$$\frac{\langle \Delta p_t \rangle}{p_t}^{\text{hardest}} \equiv \int_0^1 dz\, f^{\text{hardest}}(z)(z-1)\,. \tag{7}$$

An interesting quantity is the logarithmic moment

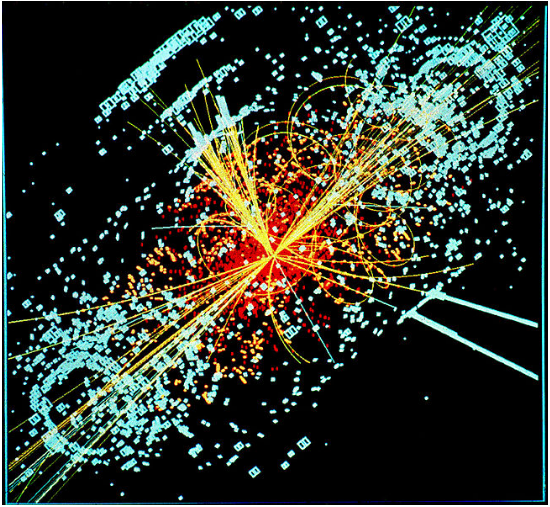
$$\langle \ln z \rangle^{\text{hardest}} \equiv \int_0^1 dz\, f^{\text{hardest}}(z) \ln z\,. \tag{8}$$

which appears in microjet vetoes, where the probability of not emitting any gluons above a scale p_t can be expressed

$$P(\text{microjet veto}) = \exp\left[-\bar{\alpha}_s Y \ln\frac{Q}{p_t} - \bar{\alpha}_s Y \int_0^1 dz\, f^{\text{hardest}}(z) \ln z\right], \tag{9}$$

Outlook

- Looking at a larger range of observables and cases, such as subjet flavour, multi-subjet observables, dijet asymmetries
- Applications to Higgs physics, searches for new heavy particles, heavy-ions, $\cdots$
- Extend calculations to subleading powers of log R, such as $\alpha_s^n \ln^{n-1} R$



Thank you for your attention.