Phenomenology of Particle Physics II

Exercise Sheet 10

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Exercise 18 [*Rapidity and pseudorapidity*]

Consider a particle of mass m produced in a hadron collision. Its *rapidity* y is definded through,

$$y = \frac{1}{2} \ln \frac{E + p_L}{E - p_L},$$

where E is its energy and p_L its momentum along the beam axis, both in the laboratory frame (where the measurement is performed).

Another commonly used observable is the *pseudorapidity* η,

$$\eta = - \ln \tan \vartheta / 2,$$

with ϑ being the angle of the particle with the beam axis.

(i) Show that in the limit $m \to 0$, $\eta \equiv y$.

(ii) Show that the rapidity of a particle of mass m and energy E is contained in the range,

$$\left[- \ln \frac{2E}{m}, \ln \frac{2E}{m} \right].$$

Explain why heavy particles are kinematically expected to be produced centrally, i.e. with small $|y|$, and hence why most detectors focus on this region.

(iii) Show that the difference of two rapidities is invariant under longitudinal boosts.

– please turn over –

Exercise 19 [*Transverse mass*]

Hadron colliders rely on the definition of observables invariants under longitudinal boosts, for example for the search for W'-bosons [1, 2]. Their cleanest potential decay channel is the leptonic one $W' \to l\nu_l$ which involves a neutrino which invariably escapes the detector undetected (apart from the unbalance of transverse momentum in the event, which however does not allow to reconstruct the full kinematics). It is also not possible to reconstruct directly the invariant mass of the W'-boson to measure it's mass.

Let's say that you have measured the differential cross section, $\frac{1}{\sigma}\frac{d\sigma}{d(\cos\vartheta)}$, where ϑ is the angle that the charged lepton is doing with the beam axis.

Look at the *transverse mass* M_T, which experimental collaborations define (in the special case of massless decay products) through,

$$M_T^2 = 2p_{T,1}p_{T,2}(1-\cos\phi_{12}),$$

with ϕ being the angle between particles 1 and 2 in the transverse plane. At leading order, there is no other particle produced and the above formula gets simplified. Express $\frac{1}{\sigma}\frac{d\sigma}{d(M_T^2)}$ from the differential cross section you have, discuss the feature you see and how it can be used to measure $m_{W'}$.

Hint: Take a look at Ref. [3].

References

[1] ATLAS collaboration, *Search for a heavy gauge boson decaying to a charged lepton and a neutrino in 1 fb-1 of pp collisions at* $\sqrt{s} = 7$ *TeV using the ATLAS detector* http://arxiv.org/abs/1108.1316

[2] CMS collaboration, *Search for leptonic decays of W' bosons in pp collisions at* $\sqrt{s} = 7$ *TeV* http://arxiv.org/abs/1204.4764

[3] http://tid.uio.no/~farido/FYS4560-Magnar-W%27.pdf