Übungen zu Physik an Hadron-Collidern SS 2013
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Übungsblatt Nr. 3

Die Lösungen müssen bis 11 Uhr am Donnerstag, 8.5.2013 in die Briefkästen im Erdgeschoss des Gustav-Mie-Hauses eingeworfen werden!

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1. **Kinematic variables - 1**

   At a hadron collider, if a massive particle decays into a lepton and a neutrino, its invariant mass cannot be reconstructed, as the longitudinal component of the neutrino momentum cannot be measured.

   - How is the transverse momentum of the neutrino measured? [**1 point**]

   A useful variable to consider is the transverse mass M_T, defined as:

   $$M_T{}^2 = (E_T(1) + E_T(2))^2 - (\mathbf{p}_T(1) + \mathbf{p}_T(2))^2 \tag{1}$$

   - Derive a simplified formula for the transverse mass in the approximation $m_1 = m_2 = 0$ [**1 point**]

   We now consider a W boson with mass $M_W = 80$ GeV and its decay $W \to e\nu$ (there is no need here to distinguish the $W^+ \to e^+\nu$ and the $W^- \to e^-\bar{\nu}$). Assume that the W is produced at rest.

   - Determine the differential distribution dN/dM_T and its dependency on M_T. Show that the distribution has an end point at $M_T = M_W$ [**3 points**] [HINT: the following identity

   $$\frac{dN}{dM_T} = \frac{dN}{d\Omega}\frac{d\Omega}{dM_T} \tag{2}$$

   can be useful.]

2. **Kinematic variables - 2**

   - Show that the pseudorapidity $\eta = -\ln\tan(\theta/2)$ is a good approximation for the rapidity $y = \tanh^{-1}(p_z/E)$ if the particle mass is much smaller than its momentum (θ is the polar angle with respect to the beam line). [**2 points**]
   - Write down explicitly the equations to transform from a (x, y, z) coordinate system to a (r_T, η, ϕ) one (r_T being the projection on the transverse xy plane of the spherical coordinate r). [**2 point**]

3. **Two particle kinematics**

   Consider a proton-proton collision. The reference frame we consider (lab frame) is the proton-proton centre-of-mass (CM), in which each proton has momentum $|\mathbf{p}| \gg m_p$ (m_p being the mass of the proton). The two colliding partons carry a fraction x_1, x_2 of the initial proton momentum. Assume that the two partons are massless.

   - Compute the invariant mass M of the parton-parton system in terms of P, x_1, x_2 [**1 point**]

Assume that an object with mass M is indeed produced, and it decays into massless particles.

- Compute the differential angular distribution $dN/(d\phi\, d\eta)$ in the centre-of-mass frame of the produced particle (η being the pseudorapity computed with respect to the beam axis). **[3 points]**
- What is the distribution in the lab frame? **[1 point]**