QGP physics – from fixed target to LHC (SS 2013): Homework asssignments

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problem sheet 1
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Problem 1: Spectrometer Acceptance

The CERES/NA45 spectrometer covered an acceptance of $\theta = 8 - 14$ degrees. What pseudorapidity coverage does this correspond to? Indicate in a transverse momentrum p_T vs rapidity y diagram the acceptance for protons and pions.

Problem 2: p+Pb collisions at the LHC

In the 2013 p+Pb run at the LHC the beam energy per nucleon was $E_1 = 4\,\mathrm{TeV}$ for the proton beam and $E_2 = 1.58\,\mathrm{TeV}$ for the lead beam.

a) What is the rapidity of the nucleon-nucleon center-of-mass system in the laboratory frame?

b) What is the center-of-mass energy per nucleon-nucleon collisions $\sqrt{s_{NN}}$?

c) What is the angle w.r.t. the beam axis in the lab system of a photon that is emitted perpendicular to the beam axis in the center-of-mass system?

Problem 3: Energy density

The transverse energy at mid-rapidity in very central ($b \approx 0$) Cu+Cu collisions at $\sqrt{s_{NN}} \approx 200\,\mathrm{GeV}$ is $dE_T/dy|_{y=0} \approx 140\,\mathrm{GeV}$.

a) Estimate the initial energy density at a time $\tau = 1\,\mathrm{fm}/c$ using the Bjorken formula.

b) What is the temperature of an ideal gas of massless up quarks, down quarks, and gluons at the same energy density? How much larger is the temperature of this gas for an energy density of about $14\,\mathrm{GeV/fm^3}$ estimated for central Pb+Pb collisions at the LHC?

Problem 4: Average transverse momentum

The transverse mass dependence of the invariant cross section of a certain particle species is described by $E\frac{d^3\sigma}{d^3p} = A\exp(-m_T/T)$. Show that the mean transverse momentum is given by

$$\langle p_T \rangle = \frac{m^2 K_2(m/T)}{m+T} e^{m/T}.$$

Hint: Use the following representation of the modified Bessel function of second kind:

$$K_n(x) = \frac{2^{n-1}(n-1)!}{(2n-2)!} x^{-n} \int_x^\infty d\tau \, \left(\tau^2 - x^2\right)^{n-3/2} \tau e^{-\tau}.$$

Problem 5: Glauber Monte Carlo

Download the macro glauber_mc.C from the lecture website and run it under root. Modify it to answer the following questions:

a) What is the total inelastic Pb+Pb cross section for a nucleon-nucleon cross section of $\sigma_{\mathrm{NN}}^{\mathrm{inel}} = 64\,\mathrm{mb}$?

b) What is the total inelastic S+S cross section for $\sigma_{\mathrm{NN}}^{\mathrm{inel}} = 64\,\mathrm{mb}$?

c) What is the total inelastic cross section and the average number of nucleon-nucleon collisions in p+Pb collisions for $\sigma_{\mathrm{NN}}^{\mathrm{inel}} = 64\,\mathrm{mb}$?