QGP physics – from fixed target to LHC (SS 2015): Homework asssignments

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problem sheet
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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: Center-of-mass energy for heavy-ions at the LHC

Show that the center-of-mass energy $\sqrt{s_{NN}}$ for collisions of two nuclei with charges Z_1, Z_2 and mass numbers A_1, A_2 in a magnetic field set for protons of momentum p_p is given by

$$\sqrt{s_{NN}} = 2cp_p\sqrt{\frac{Z_1 Z_2}{A_1 A_2}}$$

and that the rapidity shift of the center-of-mass frame in th lab frame is given by

$$y_{NN} = \frac{1}{2}\log\left(\frac{Z_1 A_2}{Z_2 A_1}\right) .$$

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 number of $c\bar{c}$ and $b\bar{b}$ pairs in central Pb-Pb collisions

Use the Mathematica notebook from the lecture website to calculate the average number of $c\bar{c}$ and $b\bar{b}$ pairs per unit rapidity at midrapidity for the 10% most central Pb-Pb collisions assuming

$$\frac{d\sigma_{c\bar{c}}}{dy} = 200\,\mu\mathrm{b} \quad \text{and} \quad \frac{d\sigma_{b\bar{b}}}{dy} = 20\,\mu\mathrm{b}.$$

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:

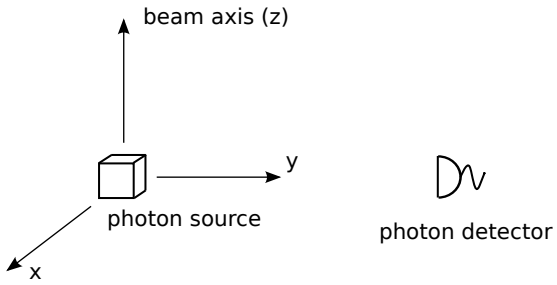
a) What is the average number of nucleon-nucleon collisions in inelastic p-Pb collisions?

b) What is the average number of nucleon-nucleon collisions in p-Pb collisions with impact parameter $b = 0$?

c) What is the average number of nucleon-nucleon collisions in Pb-Pb collisions with impact parameter $b = 0$?

Use an inelastic nucleon-nucleon cross-section of $\sigma_{NN}^{\mathrm{inel}} = 64\,\mathrm{mb}$.

Problem 6: Boosted photon source



The energy spectrum of a static photon source may be given by

$$E\frac{d^3n_\gamma}{d^3p} = A\exp\left(-E/T\right).$$

Show that the inverse slope parameter of the measured photon spectrum is given by $T\sqrt{\frac{1+\beta}{1-\beta}}$ if the source moves with velocity β towards the photon detector. At which source velocity does the measured inverse slope parameter increase by a factor 2?

Problem 7: Anti-proton-to-proton ratio

In the statistical model the density of particles of species i is given by

$$n_i = N_i/V = \frac{g_i}{2\pi^2}\int_0^\infty \frac{p^2\,dp}{\exp\left(\frac{\sqrt{p^2+m^2}-\mu_i}{T}\right)}$$

a) Show that the $\bar{p}/p$ ratio (before feeddown from decays of particles with higher mass) is given by $\exp(-2\mu_B/T)$ if quantum statistical effects are neglected.

b) Particle production at RHIC can be described with $T_{\mathrm{ch}} = 156\,\mathrm{MeV}$ and $\mu_B = 21\,\mathrm{MeV}$. What is the corresponding $\bar{p}/p$ ratio?