2018-3-12

PPP10 Exercises: QGP and heavy-ion physics

1.1 Glauber

Write a simple Glauber Monte Carlo and calculate the distribution in number of wounded nucleons, using the description in the lecture slides ("The standard (naive) Glauber implementation"). You can e.g. use the parameters of the Pb–Pb run at LHC in `arXiv:1012.1657 [nucl-ex]`. For the pp cross sections you need to put in, you can e.g. use the default parameterisation in Pythia8 (do a short run with `SoftQCD::all = on` at the relevant collision energy and study the output).

1.2 Azimuthal anisotropic flow

We assume in the following that the particles in an event is distributed according to:

$$f(\varphi) = \frac{1}{2\pi}\left(1 + \sum_{i=1}^{\infty} 2v_i \cos[i(\varphi - \Psi_i)]\right), \tag{1}$$

where φ is in the range from 0–2π, v_i is the i-th order flow coefficient and Ψ_i is called the i-th order symmetry plane (really an angle in general). We only consider measurements of the elliptic flow, v_2, in the following, so that:

$$f(\varphi) = \frac{1}{2\pi}\left(1 + 2v_2 \cos[2(\varphi - \Psi_2)]\right). \tag{2}$$

a) Make a drawing that illustrates the initial elliptic overlap region, indicating Ψ_2.

b) The event plane method. Show by explicit calculation that Ψ_2 can be estimated as:

$$\Psi_2 = \frac{1}{2}\tan^{-1}\left(\frac{\langle\sin(2\varphi)\rangle}{\langle\cos(2\varphi)\rangle}\right), \tag{3}$$

where the brackets indicate averages.
Hint: calculate the means using trigonometric identities.

c) Two particle correlations. The Event Plane method is criticized for the need to first determine the event plane and then measure v_2 since the statistical precision with which we can determine the event plane event-by-event will affect the result (even one typically corrects for this using a resolution function). One can avoid this by studying 2-particle correlations [1]. Show that

$$\langle\cos[2(\varphi_1 - \varphi_2)]\rangle = v_2^2, \tag{4}$$

where the brackets indicate an average over all pairs, and the assumption is that there are no direct correlations between particle 1 and 2, but only indirect correlations through the common event plane Ψ_2.

[1] The biggest gain is when we go to higher order correlations, but that is beyond the scope here, see e.g. Phys. Rev. C 83 (2011) 044913.

1.3 The medium temperature

a) The charged particle multiplicity increases by a factor ≈2 from RHIC to LHC. Assuming this is true also for the energy density what is the estimated temperature increase of the medium from RHIC to LHC?
Hint: what is the expected relation between energy density and temperature.

b) Try to give an argument for why the increase is so small and reflect on what the gain would be for heavy-ion physics by increasing the beam energy by another factor 10. *Hint: if the question is hard to understand, one can run PYTHIA to get an idea of the increase.*