Identifying the Particles Produced by Au+Au Collisions

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What is Quark Gluon Plasma?

• Quark Gluon Plasma (QGP) consists of quarks and gluons which are no longer confined to hadrons (e.g., protons and neutrons).
• In the state of QGP, the temperature is about $10^{11}$ K.
• 10^{-10} s after the Big Bang, the universe was filled with QGP.
• The phase transition from QGP to hadrons is the last phase transition in the evolution of the universe.

Fig.2 The phase diagram of nuclear matter

Fig.3 Inner structure of hadron and meson

The STAR Experiment

• Au+Au collisions in the Relativistic Heavy-Ion Collider at BNL create mini Big Bangs in the lab.
• Baryon and mesons are created when the QGP quickly cools down.
• Here, a QGP only lasts for 30-50 yottoseconds (1 yottosec = $10^{24}$ sec!!)
• STAR detects and identifies many types of particles.

To identify particles, we have to determine their mass and charge.

Example: If a particle is accelerated and its energy becomes 100 GeV, then the velocity of the particle is 99.996% of the speed of light.

$m = \frac{p}{\beta}$

$\frac{1}{\beta} = \sqrt{1 - \frac{v^2}{c^2}}$

Considering the special relativity...

Results

• Fig.5-1,2 made with ROOT, a modular scientific software toolkit data is 7,500 out of $10^{10}$ Au+Au collisions taken in 2014.
• Figures shows the distribution of measured particles (positive and negative charge) with each 1/β and momentum p (GeV/c).
• more than 1.5 million tracks (particles!) in these figures.
• The red line is the theoretical line by using equation (*).
• Each theoretical line was drawn by substituting the value of the rest mass (see table 7).
• The color shows how many particles were detected with that momentum and that 1/β. Considering the color bar with log scale, pion was detected the most.

Discussion

• We can identify 8 particles: proton, antiproton, electron, positron, K^+, K^- and π^+, π^-.
• pion is a meson (a particle made of 2 quarks) and the lightest of all the 3 hadrons. It is the easiest to produce pion.
• The rest mass of the electron is so light that the graph is almost straight.
• Measurements agree with theoretical expectation.
• N(pos) vs N(neg)

Future Research

The STAR experiment and this analyzing data leads to the solution of the following questions:

• What are the properties of a strongly interacting nuclear many-body system in very high temperatures?
• What does the phase diagram of QCD matter look like?
• What are the properties of the phase transition?
• Is there also a QGP in neutron star collision?

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References