Measurement of direct photon azimuthal anisotropy in $\sqrt{s_{NN}}=200\text{GeV}$ Au+Au collisions in RHIC-PHENIX experiment

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High-energy heavy-ion collision experiments have been carried out since 2000 at the Relativistic Heavy Ion Collider (RHIC), to study the properties of quark-gluon plasma (QGP). Direct photons are defined as all photons except for those coming from hadron decays. Photons do not strongly interact with the medium. Furthermore, they are emitted from various sources, such as initial hard scattering, jet fragmentation, and thermal radiation, during all stages of collisions. Thus, direct photon is a powerful tool to study QGP.

Direct photon $p_T$ spectra have been measured via a calorimeter method$^{1}$, virtual photon method$^{2}$, and conversion photon method$^{3}$. It is found that the $p_T$ spectra of Au+Au collisions include an additional exponential $p_T$ spectra compared to those of $p+p$ collisions scaled by the number of binary collisions. The effective temperature is obtained from the inverse slope of the exponential $p_T$ spectra, it is approximately 240 MeV. It is found that photons mainly originate from a very hot medium in the early stage of collisions, since the kinetic freeze-out temperature obtained is approximately 100 MeV.

Azimuthal anisotropy is defined as the relative amplitude of anisotropic azimuthal distribution with respect to the event plane. To quantify the anisotropy, Fourier series is used for the azimuthal distribution of the number of emitted particles.

$$dN/d\phi = N_0[1 + \sum_{n} 2v_n \cos \{n(\phi - \Psi_n)\}], \quad (1)$$

$$v_n = \langle \cos \{n(\phi - \Psi_n)\} \rangle, \quad (2)$$

where $\phi$ is the azimuthal angle of photons, and $v_n$ and $\Psi_n$ are the strength and event plane of the $n^{th}$-order harmonic azimuthal anisotropy, respectively.

The mechanism of azimuthal anisotropy has been studied, and it is understood that it strongly depends on the initial geometry shape. The photon emission angle is expected to depend on the photon sources and initial geometry of the participant shape: thermal photons have $v_2 > 0$, photons fragmented from a jet have $v_2 > 0$, and prompt photons have zero $v_2$. Direct photon $v_2$ is measured$^{4}$ to identify the photon sources. It is found that the strength of direct photon $v_3$ at around 2 GeV/c is comparable to that of hadron $v_2$. There is a discrepancy called “photon puzzle”. There are no models to explain both the results simultaneously. In order to constrain the photon production mechanism, the third-order azimuthal anisotropy $v_3$ is measured. Figure 2 shows direct photon $v_3$ for $p_T < 4$ GeV/c. It is found that the strength of direct photon $v_3$ is comparable to that of hadron $v_3$. It shows a similar trend to direct photon $v_2$. It can be interpreted that photons emitted in the late stage of collisions are dominant in the low $p_T$ region. These results would be helpful for understanding the photon puzzle.

Fig. 1. (Left) $v_2$ as a function of $p_T$ of a neutral pion (black) and inclusive photon (red). (Right) $v_2$ as a function of $p_T$ of a direct photon$^2$.

Fig. 2. $v_3$ as a function of $p_T$ of a neutral pion (red) and direct photon (black) by 20% centrality steps from 0 to 60%.

References
4) A. Adare et al.: P.R.L. 109, 122302 (2012)