Particle correlation in p+p collision $\sqrt{s_{NN}}=200$ GeV in PYTHIA *

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Abstract We calculated the relative abundances of charge hadron, K_S^0, Λ and $\bar{\Lambda}$ in the near-side and away-side cones correlated with triggered high p_T particles in minimum bias in p+p collisions at $\sqrt{s_{NN}}=200$ GeV in the PYTHIA model. From the quark and gluon jet events in the PYTHIA model, we have found that the particle yields' different splitting. So the di-hadron correlation in the quark jet events and gluon jet events are also presented. And the particle charge dependance of the di-hadron correlation is extracted from the PYTHIA model. The di-hadron plus and di-hadron minus correlations are similar in the near-side ($\Delta\phi\sim 0$), but in the away-side, the di-hadron minus correlation seems to be lower. The Hadron-K_S^0 and $-\Lambda+\bar{\Lambda}$ correlations seem to be differet. We have used a double-Gaussian function to fit those correlation functions and compared the fit parameters.

Key words particle correlation, PYTHIA, gluon jet, quark jet

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1 Introduction

The energetic partons through matter are predicted to lose energy. Energy loss results in jet quenching - suppressions of hadron yield and back-to-back angular correlation at high p_T. The observation of jet-quenching[1, 2] indicates that a dense medium is created at RHIC[3]. Studies of two particle azimuthal correlations have revealed detailed information about jet interactions with this medium[1, 4, 5].

An increase in the ratio of baryons to mesons has been observed in Au+Au collisions[6]. This increase may depend on the parton density of the system. By studying the correlation between the unidentified trigger hadrons with identified associated particles, we also can measure the baryon to mesons ratio as a function of $\Delta\phi$. The ratio seems increase at far from $\Delta\phi=\pi$. This measurement can provide a better understanding of the variation of local parton densities at the away side[7]. Also several scenarios have been proposed to account for the correlation's away-side splitting[8—13].

The production of particles in elementary parton-parton (p+p) collisions is thought to be two mechanisms, the soft, thermal-like process and the hard parton-parton interaction process. At the present time, the most ubiquitous model available for the description of hadron+hadron collisions is the PYTHIA event generator. PYTHIA was based on the Lund string fragmentation model[14, 15] but has been refined

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to include initial and final-state parton showers and many more hard processes. PYTHIA has been shown to be successful in the description of collisions of e+e., p+p, and fixed target p+p systems[16].

The results of separating PYTHIA events are based on their final state parton content. Events for which the final state is qq are labeled as containing quark jets, while events with gg are labeled as containing gluon jets. STAR's study[17] show that events with only quark jet final states seem to show a mass splitting in the high $m_{\rm T}$ region, while events whose final states contain jets from gluons show the shape difference between mesons and baryons with the meson spectra being harder than the baryon spectra. Another recent study found that the baryon density is largest in the collision processes involving gluons (i.e. qg, gg, q$\overline{\rm q}$g, or ggg)[18]. The energy loss for the gluon jet and quark jet will be different. Maybe this will also influence the particle production. So it is interesting to study the particles' azimuthal correlation in the p+p collision with quark jet or gluon jet.

We will present calculation of di-hadron correlations of unidentified trigger hadrons with identified $\rm K^0_S$, Λ, or $\overline{\Lambda}$ associated partners and the charge hadron associated partners in p+p collisions $\sqrt{s_{\rm NN}} = 200$ GeV in the PYTHIA model. For this analysis, a trigger hadron is any charged track with $3 < p_{\rm T} < 6$ GeV/c while associated partners are taken from $1 < p_{\rm T} < 4$ GeV/c. In the $|\Delta\eta| < 1 (\Delta\eta = \eta_{\rm asso} - \eta_{\rm trig})$ range, we get the yield $\mathrm{d}N/\mathrm{d}\Delta\phi$ for hadron plus, hadron minus, $\rm K^0_S$, Λ and $\bar{\Lambda}$ as a function of $\Delta\phi (\Delta\phi = \phi_{\rm asso} - \phi_{\rm trig})$.

2 Results

In Fig. 1[7], the STAR preliminary results are from the 10%—40% centrality interval of $\sqrt{s_{\rm NN}} = 200$ GeV Au+Au collisions. All data is from the η window $|\eta| < 1.0$. The upper panel shows the hadron-$\rm K^0_S$, and the hadron-$(\Lambda+\overline{\Lambda})$ $\mathrm{d}N/\mathrm{d}\Delta\phi$ distributions. The lower panel shows the hadron-Λ and hadron-$\overline{\Lambda}$ correlations separately. The yellow band around zero represents the systematic uncertainties. For all particle combinations a strong correlation is seen on the near-side of the charged hadron trigger ($\Delta\phi < 1.1$) as would be expected from fragmentation of a fast parton or jet. The correlation structure on the away-side of the trigger hadron is very broad and may even exhibit a minimum at $\Delta\phi = \pi$ where typically a maximum would exist. These features are similar to those already observed for unidentified di-hadron distributions which have much better statistics[19].

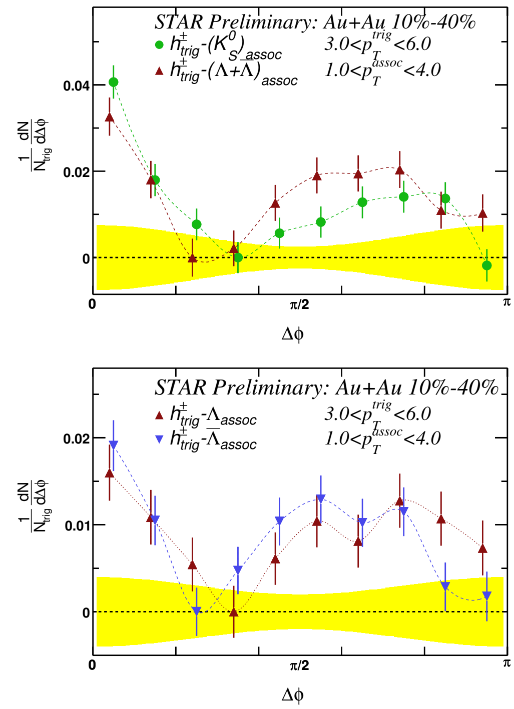

Fig. 1. Hadron-$\rm K^0_S$, -$\Lambda+\overline{\Lambda}$ (upper panel) and hadron-Λ, -$\overline{\Lambda}$ (lower panel) correlation function in the centrality bin 10%—40% in ^{197}Au+^{197}Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV. The trigger particles $p_{\rm T}$ range is $3.0 < p_{\rm T} < 6.0$ GeV/c; the associate $\rm K^0_S$, Λ, or $\overline{\Lambda}$ particles $p_{\rm T}$ range is $1.0 < p_{\rm T} < 4.0$ GeV/c. The yellow band around the zero is the systematic errors.

In Fig. 2, we show the di-hadron correlation in the minimum bias in p+p collisions $\sqrt{s_{\rm NN}} = 200$ GeV in the PYTHIA model. The black points is the PYTHIA events, the blue triangle points are from the quark jets events in the PYTHIA model. And the red star points are from the gluon jet events in the PYTHIA model. In the near-side and away-side, there are clearly correlation peak in the different PYTHIA model events. There is no suppression around $\Delta\phi \sim \pi$ in the away-side in the PYTHIA model, which is different from the di-hadron correlation results in Au+Au real data from STAR experiment. We also find that the conditional yields of charge hadron are different in the three kind of PYTHIA model events. In the gluon jet events, it is the highest, but in the quark jet events, it is the lowest.

The charge dependance in the di-hadron correlation in the p+p collision at $\sqrt{s_{\rm NN}} = 200$ GeV in the normal events in the PYTHIA model is shown in Fig. 3. The red points are the hadron plus, and the blue points are the hadron minus. The azimuthal distributions are characterized by a fit to the sum of the near-side (first term) and back-to-back(second term) Gaussian peaks and a constant[2]:

$$D(\Delta\phi)=A_{\rm N}\frac{{\rm e}^{-(\Delta\phi)^2/2\sigma_{\rm N}^2}}{\sqrt{2\pi}\sigma_{\rm N}}+A_{\rm B}\frac{{\rm e}^{-(|\Delta\phi|-\pi)^2/2\sigma_{\rm B}^2}}{\sqrt{2\pi}\sigma_{\rm B}}+P. \quad (1)$$

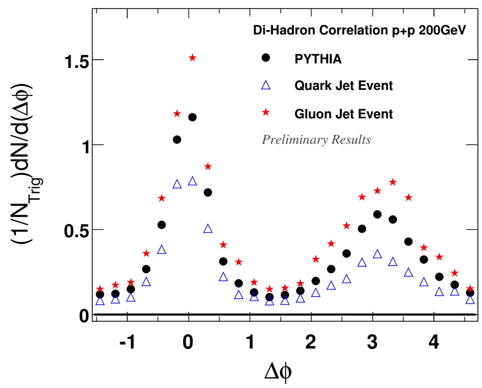

Fig. 2. Di-hadron correlation in the minimum bias in p+p collision $\sqrt{s_{\rm NN}}=200$ GeV in the PYTHIA Model. The black points are normal PYTHIA events. The blue triangle points are from quark jet events. The red star points are from gluon jet events in PYTHIA. The trigger particle $p_{\rm T}$ range is $3.0<p_{\rm T}<6.0$ GeV/c, and the associated particle $p_{\rm T}$ range is $1.0<p_{\rm T}<4.0$ GeV/c.

The fit parameters are compared with the $\rm K_S^0$ and Λ's fit parameters which are presented in the Table 1. In Fig. 3, we can see that the conditional yields of hadron minus is lower than those of hadron plus. And the azimuthal distributions's away-side($\Delta\phi\sim\pi$) peak in the di-hadron minus correlation seems to be narrow than that in the di-hadron plus correlation. But the near-side ($\Delta\phi\sim 0$) seems to be similar. This is also shown in the comparatione of fit parameter $\sigma_{\rm N}$ and $\sigma_{\rm B}$.

Figure 4 shows Hadron-$\rm K_S^0$, Hadron-$\Lambda+\overline{\Lambda}$ correlation function in the minimum bias in the p+p collisions at $\sqrt{s_{\rm NN}}=200$ GeV in normal events in the PYTHIA model. And the curves are fits using Eq. (1) with the parameters given in Table 1. From the plots, the azimuthal distribution seems different between the hadron-$\rm K_S^0$ and hadron-$\Lambda+\overline{\Lambda}$ correlations in the normal PYTHIA model. The hadron-$\Lambda+\overline{\Lambda}$ correlation distribution seems lower than the hadron-$\rm K_S^0$ correlation. But there are some fluctuate in those correlation distributions. In the away-side, a peak around $\Delta\phi\sim\pi$ is clearly observed which is different from the Au+Au results shown in Fig. 1.

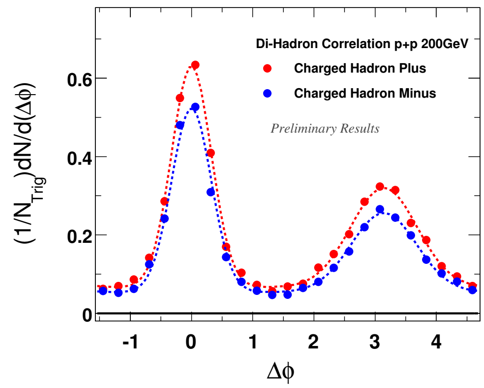

Fig. 3. The unidentified trigger hadrons with the hadron plus (red points) and the hadron minus (blue points) correlation in the minimum bias in p+p collisions at $\sqrt{s_{\rm NN}}=200$ GeV in normal PYTHIA events. The trigger hadron particle $p_{\rm T}$ range is $3.0<p_{\rm T}<6.0$ GeV/c, and the associated hadron particle $p_{\rm T}$ range is $1.0<p_{\rm T}<4.0$ GeV/c. The curves are fits using Eq. (1)[2], with the fit parameters given in Table 1.

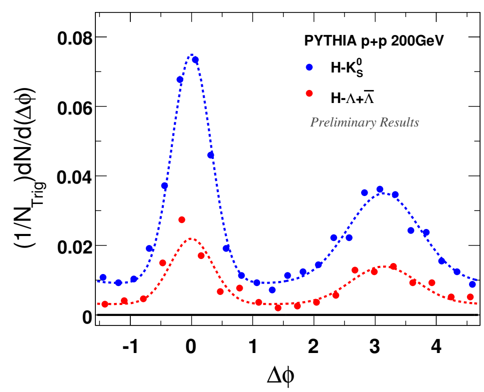

Fig. 4. Hadron-$\rm K_S^0$ (blue points), Hadron-$\Lambda+\overline{\Lambda}$ (red points) correlation function in the minimum bias in p+p collisions at $\sqrt{s_{\rm NN}}=200$ GeV in normal PYTHIA events. The trigger particles $p_{\rm T}$ range is $3.0<p_{\rm T}<6.0$ GeV/c; the associate $\rm K_S^0$, Λ, or $\overline{\Lambda}$ particles $p_{\rm T}$ range is $1.0<p_{\rm T}<4.0$ GeV/c. The curves are fits using Eq. (1) too, with the fit parameters given in Table 1.

Fit parameters are given in Table 1. The errors are statistical only. From the fit parameters, $A_{\rm N}$ and $A_{\rm B}$ seem to decrease from hadron plus to Λ. Maybe this is caused by the particle yields in the PYTHIA. And the $\sigma_{\rm N}$ which belongs to the near-side's peak seems similar for the hadron plus and hadron minus, but $\sigma_{\rm B}$ seems to decrease. From $\rm K_S^0$ to Λ, the $\sigma_{\rm N}$ seems to increase, but the $\sigma_{\rm B}$ is opposite.

Table 1. Fit parameter from Eq. (1). Errors are statistical only.

	h^+	h^-	K_S^0	$\Lambda+\overline{\Lambda}$
A_N	0.0577 ± 0.0002	0.04804 ± 0.0002	0.0066 ± 0.000078	0.002576 ± 0.000064
σ_N	0.3247 ± 0.0013	0.3244 ± 0.0014	0.3172 ± 0.0036	0.3465 ± 0.0107
A_B	0.0434 ± 0.0003	0.03401 ± 0.0002	0.00483 ± 0.0001	0.002296 ± 0.000075
σ_B	0.544 ± 0.003	0.5339 ± 0.0034	0.591 ± 0.011	0.5384 ± 0.0152
P	0.0083 ± 0.000056	0.00674 ± 0.00005	0.00114 ± 0.00002	0.0004867 ± 0.0000175

3 Summary

In summary, we calculate the correlation of charge hadron, K_S^0, Λ and $\bar{\Lambda}$ in the near-side and away-side cones correlated with triggered high p_T particles in minimum bias in the p+p collisions at $\sqrt{s_{NN}}=200$ GeV in the PYTHIA model. From the quark jets and gluon jet events in the PYTHIA model, we have found the difference of the particle yields between the different PYTHIA events. And the charge dependance of the di-hadron correlation is calculated in the PYTHIA model. The hadron-K_S^0 and -$\Lambda+\bar{\Lambda}$ correlations seem to be different in the PYTHIA model. We use the double-Gaussian function to fit the azimuthal distribution curve and compare the fit parameters. We used the PYTHIA 6.4 to do this analysis. There may be still some model dependance in the results. The further study about the particles ratio and other identified particle correlations in the PYTHIA model will be present soon in the next paper[20].

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