

RESONANCE PRODUCTION IN Au+Au AND $p+p$ COLLISIONS AT $\sqrt{s_{NN}} = 200$ GeV*

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The $\rho^0(770)$, $K^{*0}(892)$, $f_0(980)$, $\phi(1020)$, and $\Lambda(1520)$ production in Au+Au and $p+p$ collisions at $\sqrt{s_{NN}} = 200$ GeV are presented. These resonances are used as a sensitive tool to examine the collision dynamics in the hadronic medium through their decay and regeneration. The modification of resonance mass, width, and shape due to phase space and dynamical effects are also discussed.

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1. Introduction

The measurement of resonances provides an important tool for studying the dynamics in relativistic heavy-ion collisions by probing the time evolution of the source from chemical to kinetic freeze-out and the hadronic interactions at later stages.

Physical effects such as thermal weighting of the states [1–8] and dynamical interactions with matter [3, 5, 7] may modify resonance masses, widths and shapes. Partial-waves analyses have successfully parameterized $\pi\pi$ scattering [9]. Introducing to the formalism the rescattering of pions, in which $\pi^+\pi^- \rightarrow \rho(770)^0$, the interference between different scattering channels can distort the line shape of resonances [10].

2. Data analysis and results

The $\rho^0(770)$ [11], $K^{*0}(892)$ [12], $f_0(980)$ [13], $\phi(1020)$ [14], and $\Lambda(1520)$ [15] production were measured via their hadronic decay channels at mid-rapidity ($|y| \leq 0.5$) in Au+Au and $p+p$ collisions at $\sqrt{s_{NN}} = 200$ GeV using the STAR detector at RHIC. The ϕ [16] meson was also measured via its hadronic decay channel in Au+Au collisions using the PHENIX detector.

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The ρ^0 mass is shown as a function of p_T in Fig. 1 for peripheral Au+Au (40–80% of the hadronic cross-section), high multiplicity $p+p$ (top 10% of the minimum bias $p+p$ multiplicity distribution for $|\eta| < 0.5$), and minimum bias $p+p$ interactions. The ρ^0 mass was obtained by fitting the data to a p -wave Breit–Wigner function times the phase space (BW \times PS) described in [11]. Fig. 1 also shows the K^{*0} mass as a function of p_T for central Au+Au (top 10% of the hadronic cross-section) and minimum bias $p+p$ interactions. The K^{*0} mass was obtained by fitting the data to the BW \times PS function [11] and a linear function representing the residual background described in [12].

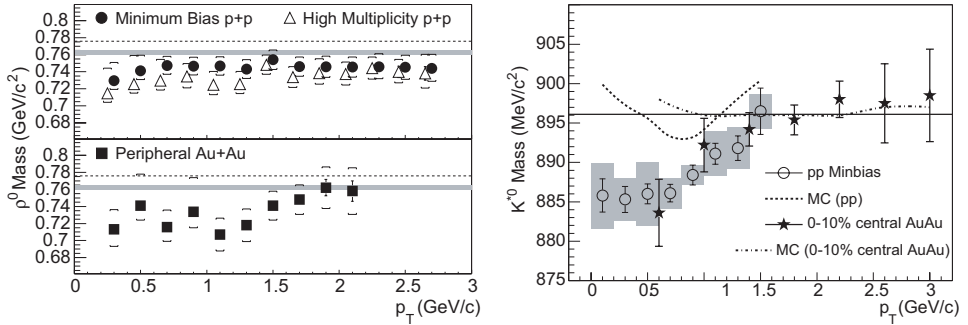


Fig. 1. Left panel: The ρ^0 mass as a function of p_T . The error bars indicate the systematic uncertainty. The dashed lines represent the average of the ρ^0 mass measured in e^+e^- [17]. The shaded areas indicate the ρ^0 mass measured in $p+p$ collisions [18]. The open triangles have been shifted downward on the abscissa for clarity. Right panel: K^{*0} mass as a function of p_T . The grey shaded boxes are the systematic uncertainties in minimum bias $p+p$. The solid line corresponds to the average of the K^{*0} mass reported in [17]. The dotted and dashed lines are the results from the Monte Carlo simulations, which accounts for detector effects and kinematic cuts, for central Au+Au and minimum bias $p+p$, respectively.

The ρ^0 and K^{*0} masses increase as a function of p_T and are systematically lower than the value reported in [17]. The ρ^0 mass measured in peripheral Au+Au collisions is lower than the minimum bias $p+p$ measurement. The ρ^0 mass for high multiplicity $p+p$ interactions is lower than for minimum bias $p+p$ interactions for all p_T bins, showing that the ρ^0 mass is also multiplicity dependent. Recent calculations are not able to reproduce the ρ^0 mass measured in peripheral Au+Au collisions without introducing in-medium modification of the ρ^0 meson [3–8].

Previous observations of the ρ meson in e^+e^- [19–21] and $p+p$ interactions [18] indicate that the ρ^0 line shape is considerably distorted from a p -wave Breit–Wigner function. A mass shift of -30 MeV/ c^2 or larger was observed in e^+e^- collisions at $\sqrt{s} = 90$ GeV [19–21]. In the $p+p$ mea-

surement at $\sqrt{s} = 27.5$ GeV [18], a ρ^0 mass of 0.7626 ± 0.0026 GeV/ c^2 was obtained from a fit to a relativistic p -wave Breit–Wigner function times the phase space [18]. This result is the only $p+p$ measurement used in the hadro-produced ρ^0 mass average reported in [17].

The ρ^0 [11] and f_0 [13] measurements do not have sufficient sensitivity to permit a systematic study of the ρ^0 and f_0 widths and the f_0 mass. The K^{*0} [12] width, the ϕ [14,16] mass and width, and the $\Lambda(1520)$ [15] mass and width are in agreement with the values reported in [17].

The ρ^0/π^- , K^{*0}/K^- , f_0/π^- , ϕ/K^- , and Λ^*/Λ ratios as a function of charged hadron multiplicity ($dN_{ch}/d\eta$) for Au+Au and $p+p$ interactions are depicted in Fig. 2. In the case of the ϕ , the effect of the daughter rescattering and regeneration should be negligible due to the ϕ longer lifetime (~ 44 fm) and the small KK cross section [22], respectively. In the case of short lived resonances such as the ρ^0 (~ 1.3 fm), the daughter rescattering and regeneration processes should be comparable because the $\pi^+\pi^-$ cross-section is dominated by the ρ^0 resonance. The $\pi^+\pi^-$ cross-section is larger than the $K\pi$ cross-section by a factor of ~ 5 [22]. Therefore, the daughter rescattering should be the dominant process in the case of the K^{*0} (~ 4 fm). In this picture, the ϕ/K^- and ρ^0/π^- ratios should be independent of $dN_{ch}/d\eta$, while the K^{*0}/K^- ratio should decrease as a function of $dN_{ch}/d\eta$, which is in agreement with the measurements presented in Fig. 2.

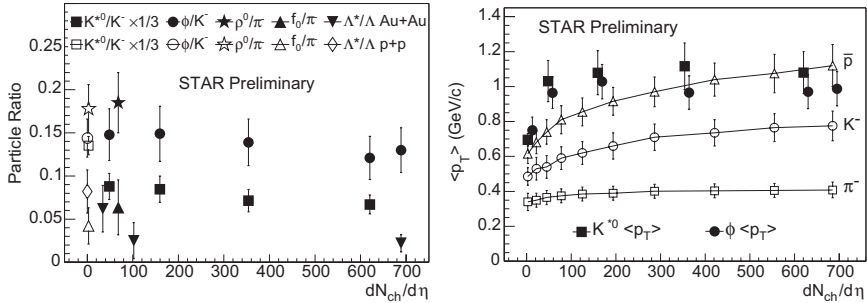


Fig. 2. Left panel: The ρ^0/π^- , K^{*0}/K^- , f_0/π^- , ϕ/K^- , and Λ^*/Λ ratios as a function of $dN_{ch}/d\eta$ for Au+Au and $p+p$ interactions. Right panel: The K^{*0} and ϕ $\langle p_T \rangle$ as a function of $dN_{ch}/d\eta$ compared to that of π^- , K^- , and \bar{p} .

The K^{*0} and ϕ $\langle p_T \rangle$ as a function of $dN_{ch}/d\eta$ are compared to that of π^- , K^- , and \bar{p} in Fig. 2. The K^{*0} $\langle p_T \rangle$ is higher than that of \bar{p} for peripheral collisions, even though $m_{K^{*0}} < m_{\bar{p}}$. One interpretation of this result is that the daughter rescattering is the dominant process compared to the K^{*0} regeneration, since only K^{*0} with higher p_T are more likely to decay outside the fireball. In the case of central Au+Au collisions, the K^{*0} $\langle p_T \rangle$ is comparable to that of \bar{p} possibly because the hadron production increases

and the regeneration process becomes significant. The ϕ $\langle p_T \rangle$ is independent of $dN_{\text{ch}}/d\eta$ in Au+Au collisions. This is expected if the ϕ has a smaller cross-section and therefore less sensitivity to hadronic rescattering.

3. Conclusions

We have presented results on resonance production at mid-rapidity in Au+Au and $p+p$ collisions at $\sqrt{s_{NN}} = 200$ GeV. The measured ρ^0 and K^{*0} masses are p_T dependent and lower than previous measurements reported in [15]. Dynamical interactions with the surrounding matter, interference between various scattering channels, phase space distortions, and Bose–Einstein correlations are possible explanations for the apparent modification of resonances properties. The resonances ratios as a function of $dN_{\text{ch}}/d\eta$ may be interpreted in the context of hadronic cross sections.

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