ρ^0 – vector meson production (and v_2) in Cu+Cu Collisions at $\sqrt{s_{NN}}$ = 200 and 62.4 GeV at RHIC in STAR

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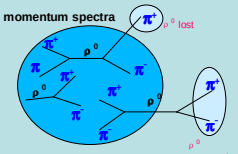
Abstract: The study of the ρ^0 vector meson in relativistic heavy-ion collisions provides information on the properties of the hot and dense medium created in such collisions. The ρ^0 measured via its hadronic decay channel can be used as a sensitive tool to examine the collision dynamics in the hadronic medium through the rescattering and regeneration. The analysis method used to obtain the ρ^0 mass , transverse momentum spectra, and invariant yield at mid-rapidity measured in Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 and 62.4 GeV using the STAR detector are presented in this poster. We also discuss the method for analyzing the ρ^0 v_2 and preliminary results in Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV.

Motivation: Importance of ρ^0 study

- **Important probe to study the properties of hot and dense medium**
  - ρ^0 life time ~ 1.3 fm/c ⟶ Expected to decay, rescatter and regenerate inside medium
- **Modification in ρ^0 mass, width and transverse momentum spectra**
  - Re-scattering and Regeneration effects.
- **production mechanism of ρ^0**
  - Elliptic Flow, v_2 ⟶ $\pi^+\pi^-$ → ρ^0
  - $q\,\bar{q}$ → ρ^0
- **study of ρ^0 meson in p+p and Heavy ions (Au+Au, Cu+Cu etc.) at the same c.m. energy** ⟶ Understanding of the dynamics of these systems.

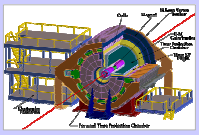


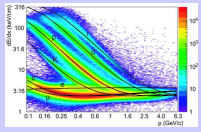
Data Set

Cu+Cu 200 GeV ~ 27 Million events
Cu+Cu 62.4 GeV ~ 14 Million events

Analysis

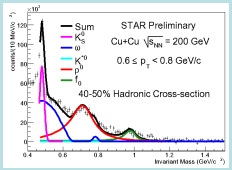
Vertex cut in Z direction:	-30cm < Z < 30cm
NsigmaPion:	±3
Track No. of fit pts. :	> 15
Track NFit / NMax :	> 0.55
Dist. of closest approach:	< 3 cm
Transverse momentum :	> 0.2 GeV/c
Pseudorapidity range :	±0.8
Pair rapidity :	±0.5
Number of centrality bins :	6





STAR TPC is used for pion selection

ρ^0 Mass Extraction



Signal : $\pi^+\pi^-$

Like-sign background distribution

Background : $\sqrt{\pi^+\pi^+ \times \pi^-\pi^-}$

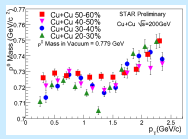
Hadronic cocktail fitting

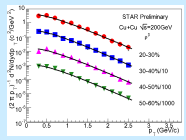
K_S is fit to a Gaussian function

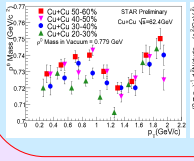
ω and K* shapes obtained from HIJING event generator

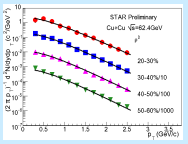
ρ^0, f_0 and f_2 fit with relativistic Breit-Wigner times the Phase Space

ρ^0 mass and p_T spectra

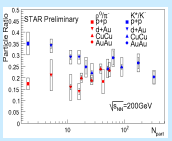


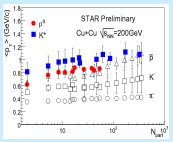


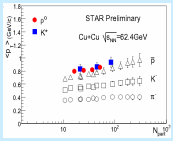


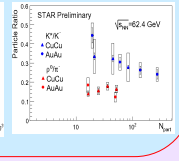


ρ^0 <p_T> and Particle ratio









Elliptic Anisotropy v_2

The azimuthal distribution of particles in the momentum space is defined by the triple differential equation -

$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left\{1+\sum_{n=1}^{\infty} 2v_n \cos\left(n(\phi-\Psi_r)\right)\right\}$$

Expansion of the above bracketed quantity is given by :

$$1 + 2v_1\cos(\phi-\Psi_r) + 2v_2\cos[2(\phi-\Psi_r)] + \ldots$$

elliptic flow ↑ reaction plane ↑

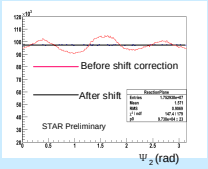
elliptic flow, $v_2 = \langle\cos(2(\phi-\Psi_2))\rangle$

Anisotropic flow is the azimuthal correlation of the particles with the Reaction plane.

Estimated reaction plane from FTPC

- **Method to remove the detector bias**

1. By applying phi weights to the flow tracks.
2. Applying shift on west and east reaction planes
3. Shift on full event plane.



$$\Psi_1' = \Psi_1 + \sum_n \frac{2}{n}\left(-\langle\sin(n\Psi_1)\rangle\cos(n\Psi_1) + \langle\cos(n\Psi_1)\rangle\sin(n\Psi_1)\right)$$

v_2 analysis method

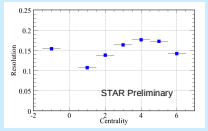
- The normalization of the cocktail between the same event and the background is done for each p_T and $\phi - \Psi_2$ bin. The subtracted invariant mass distribution is zero in the normalization region.
- ρ^0 counts are obtained for each p_T and $\phi - \Psi_2$ bin.
- The ρ^0 counts as a function $\phi - \Psi_2$ are plotted.
- The ρ^0 counts as a function $\phi - \Psi_2$ are fitted to $A\,[1+2v_2^{obs}\cos2(\phi - \Psi_2)]$
- Final $v_2 = v_2^{obs}$ / reaction plane resolution.

reaction plane resolution determination

- Due to finite number of particles detected there is a limited resolution in the event plane angle.
- Randomly divide one event into two sub-events a and b and calculate the event planes Ψ^a and Ψ^b from these two sub-events.

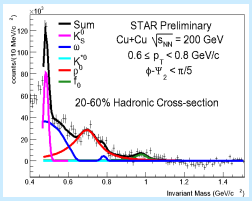
$$\langle\cos(n(\Psi_n - \Psi_r))\rangle = C\sqrt{\langle\cos(n(\Psi_n^a - \Psi_n^b))\rangle}$$

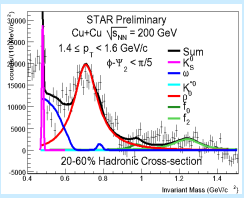
$$v_n = \frac{v_n^{obs}}{\langle\cos(n(\Psi_n - \Psi_r))\rangle}$$

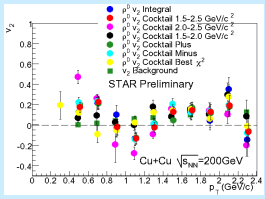


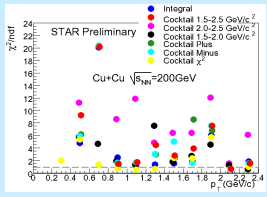
The ρ^0 v_2 was obtained for the following cases:

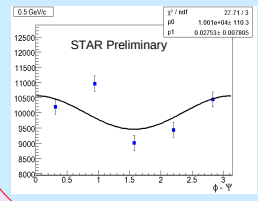
- Cocktail with normalization between same event and background between 1.5 and 2.5 GeV/c². This was used to obtain the spectra.
- Cocktail using the error on the normalization for the case above. It will give two values Plus and Minus.
- Cocktail with normalization between 1.5 and 2.0 GeV/c².
- Cocktail with normalization between 2.0 and 2.5 GeV/c².
- Cocktail with best χ^2 from 0.46 to 2.5 GeV/c².
- The v_2 is obtained by using the integral in the region of the ρ mass plus and minus 3 sigmas.

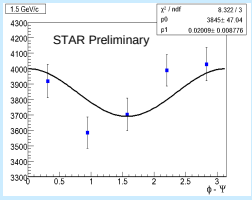


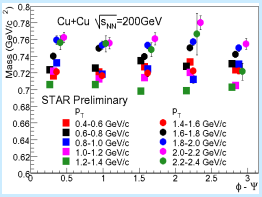


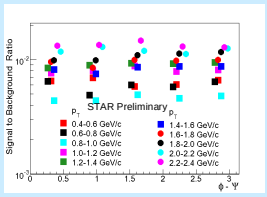




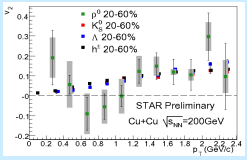


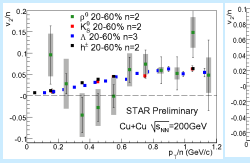


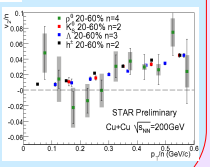




Results:







Summary:

- Significant ρ^0 production measured in Cu+Cu collisions at $\sqrt{s_{NN}}$=200 and 62.4 GeV in 20-60% of hadronic cross-section.
- ρ^0 mass shift from the PDG value is observed for both 200 and 62.4 GeV Cu+Cu collisions.
- An exponential function is used to fit the transverse momentum spectra
  ⇒ The contributions from hard process in this p_T region is small.
- The ρ^0/π^- yield ratio slightly increases in Cu+Cu collisions in comparison to p+p collisions
  ⇒ Regeneration compensating for the rescattering of the daughter particles.
- First measurement of the ρ^0 v_2 in Cu+Cu 200 GeV collisions using the reaction plane method
  ⇒ significant ρ^0 v_2 measured.
- p_T range covered not sufficient for conclusive statement on the ρ^0 production mechanism.