Jet Conversion in a Hadronic Gas

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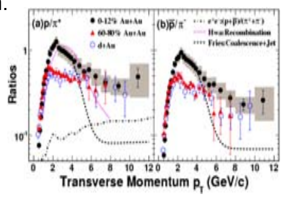
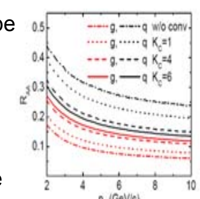
Introduction

It is believed that the temperatures reached during heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC) are sufficient to create a state of matter called the Quark-Gluon Plasma (QGP), where quarks and gluons can exist in an unbound state with color degrees of freedom.



from STAR [1]

The quark and gluon jets that are produced are quenched by the dense medium. Energy loss can be explained by theoretical models but there are open questions. The predicted relative suppression of gluons to quarks of color factor 9/4 is not seen in the data.



from [2]

The jet flavor is not conserved in the medium because it can be changed through elastic or inelastic scattering [3].

$$q+\bar{q}\leftrightarrow g+g \qquad q+g\to\gamma+g \qquad g+Q\leftrightarrow Q+g$$
$$q+g\leftrightarrow g+q \qquad q+g\to\gamma+q \qquad g+g\leftrightarrow Q+\bar{Q}$$

Elastic Channels

The conversion width, Γ_c gives the probability of the leading parton of the jet changing its flavor.

$$\Gamma_C=\frac{1}{2E_1}\int\frac{g_2 d^3p_2}{(2\pi)^3 2E_2}\frac{d^3p_3}{(2\pi)^3 2E_3}\frac{d^3p_4}{(2\pi)^3 2E_4}f(p_2)[1\pm f(p_4)] \times\overline{|M_{12\to34}|^2}(2\pi)^4\delta^{(4)}(p_1+p_2-p_3-p_4)=\left\langle\overline{|M_{12\to34}|^2}\right\rangle \tag{1}$$

Hadronic Gas

To see whether results are unique for jets in a QGP, we need to compare to the case of a jet fragmented into hadrons propagating in a hadronic medium. The main degrees of freedom in this case would be pions (π) and kaons (K).

The equations of motion for the particles propagating through this medium can be expressed by the interaction Lagrangian [4].

$$\mathcal{L}=\mathcal{L}_0+ig\mathrm{Tr}\left(\partial^\mu P\left[P,V_\mu\right]\right)-\frac{g^2}{4}\mathrm{Tr}\left(\left[P,V_\mu\right]^2\right) + ig\mathrm{Tr}\left(\partial^\mu V^\nu\left[V_\mu,V_\nu\right]\right)+\frac{g^2}{8}\mathrm{Tr}\left(\left[V_\mu,V_\nu\right]^2\right)\ . \tag{2}$$

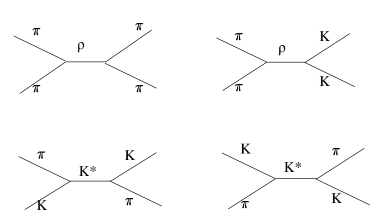
We use this Lagrangian to find the corresponding scattering amplitudes, $M_i = M_{12\to34}$, for each channel.

Drag Coefficient and Conversion Width

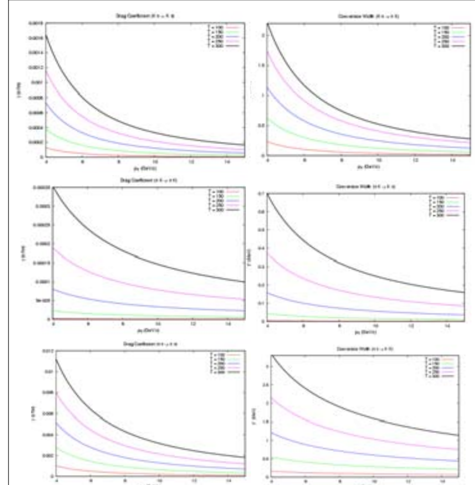
From there we calculate the drag coefficient, γ (eq. 3), and conversion width, Γ_c (eq. 1), as functions of the transverse momentum of the leading particle, p, and temperature, T.

$$\gamma(|\mathbf{p}|,T)=\sum_i\left\langle|M_i|^2\right\rangle-\frac{\sum_i\left\langle|M_i|^2\mathbf{p}\cdot\mathbf{p}'\right\rangle}{|\mathbf{p}|^2} \tag{3}$$

The four main channels we are concerned with are $\pi\ \pi\to\pi\ \pi$, $\pi\ K\to K\ \pi$, $K\ \pi\to\pi\ K$, and $\pi\ \pi\to K\ K$.



Extrapolation Program



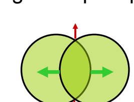
We use the explicitly calculated values to create a function that extrapolates γ and Γ_c for any value of T and momentum, p_T.

Nuclear Modification Factor and Elliptical Flow

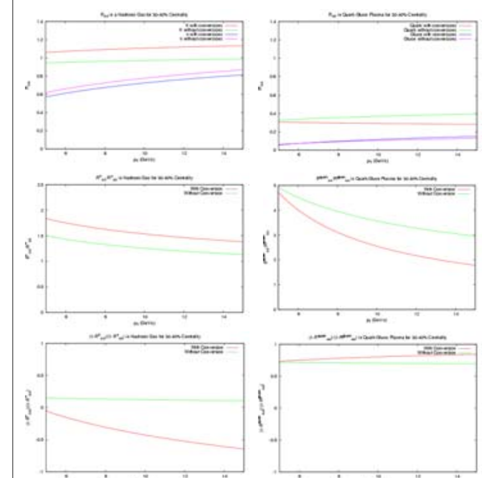
The nuclear modification factor, R_{AA}, is a useful tool to probe the suppression of jets in a medium. It is a measure of the ratio of number of particles produced in Au+Au collisions to the number of particle produced in p+p collisions scaled by the average number of collisions.

$$R_{AA}=\frac{\dfrac{dN^{AA}}{dp_T}}{\left\langle N_{coll}\right\rangle\dfrac{dN^{pp}}{dp_T}} \tag{4}$$

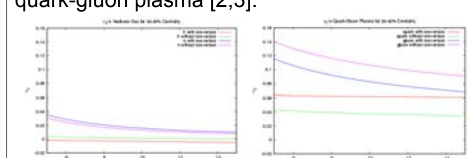
We also compute elliptical flow, v_2, which is an azimuthal anisotropy in the particle momentum caused by having an impact parameter, b, greater than 0.



Results



These plots compare the R_{AA} results for collisions at 30-40% centrality in the hadronic gas and the quark-gluon plasma [2,3].



These plots compare the v_2 results for both media.

Conclusions

- ❑ Much less suppression in hadronic gas than quark-gluon plasma
- ❑ K yield in hadronic gas is greater than one due to net conversions overcoming small energy loss from drag.
- ❑ Significant difference between the QGP and hadronic gas scenarios, which will help distinguish between the two cases.
- ❑ v_2 is essentially zero in hadronic gas.

References

[1] B.I. Abelev et al. (STAR Collaboration), Phys. Rev. Lett. 97:152301 (2006).
[2] W. Liu, C.M. Ko, and B.W. Zhang, Phys.Rev.C75:051901 (2007).
[3] W. Liu and R.J. Fries, Phys. Rev. C77:054902 (2008).
[4] Ziwei Lin and C.M. Ko, Phys. Rev. C62:034903 (2000)