Paper - 5

Trasverse momentum and collision energy dependence of high pT hadron suppression in Au+Au collisions at ultrarelativistic energies

- **Motivation**
- **Measurement**
- **Results**
- **Summary**

Motivation

a) High energy partons propagating through matter are expected to lose energy via gluon radiation with energy loss proportional to the gluon density of the medium

b) Measurement of energy loss can probe the hot and dense matter created in the ultrarelativistic nuclear collisions.

c) The jets of correlated hadrons which are produced by the initial hard scattering are studied via measurement of high pT hadronic inclusive spectra.

d) Previous measurements are consistent with large partonic energy lose in matter created at RHIC nuclear collisions although other mechanisms have been proposed

e) Additional measurements were needed to discriminate among these models and isolate effects due to final state partonic energy loss.

Measurement of Inclusive charged hadron yield $(h^+ + h^-)/2$ at 200 GeV in Au + Au and p + p collision systems

(Summed yields of primary $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$)

system	Au + Au	p + p
Key differences with previous measurements	✧ higher statistics (1.7M MB + 1.5M Central) (after event cuts) ✧ pT range of measurement is extended ✧ Magnetic field was 0.5T resulting in a better momentum resolution at high pT	❖ First such measurement at this energy (5M Events)
Event Selection and Track Cuts	✧ Centrality selection was based on primary charged particle multiplicity N_{ch} ✧ |eta| < 0.5 ✧ |DCA| < 1cm	❖ Triggered on the coincidence of two BBCs. ❖ $\|Z_{vrtx}\|$ < 75 cm ❖ valid tracks required hit in CTB ❖ |DCA| < 1cm

R_{AA} and R_{CP}

For comparison of spectra and energy loss measurements from nuclear collisions to NN reference the nuclear-modification factor is used:

$$R_{AA}(pT) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA} d^2\sigma^{NN}/dp_T d\eta} \quad \text{Where, } T_{AA} = \frac{\langle N_{bin} \rangle}{\sigma_{inel}^{NN}}$$

, accounts for collision geometry

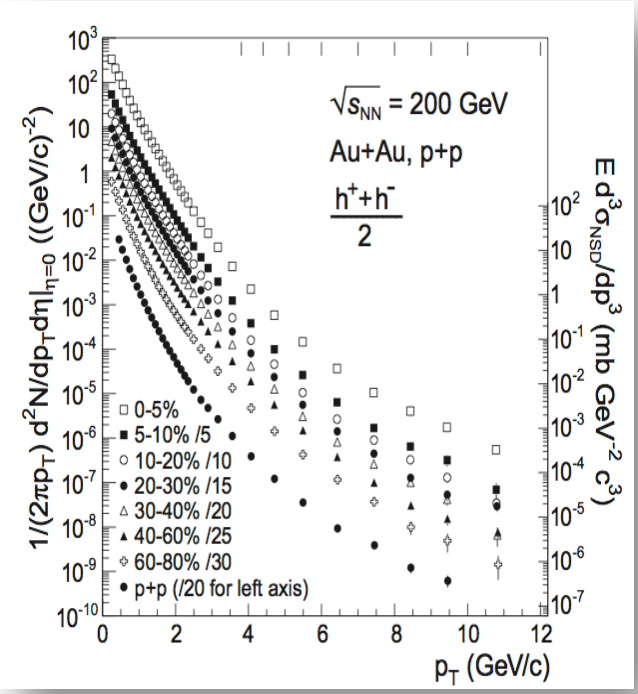
"R_{CP}" – The Nbin scaled centrality ratio

$$R_{CP}(p_T) = \frac{[(dN/dp_T)/\mathrm{N_{bin}}]^{Central}}{[(dN/dp_T)/\mathrm{N_{bin}}]^{Peripheral}}$$

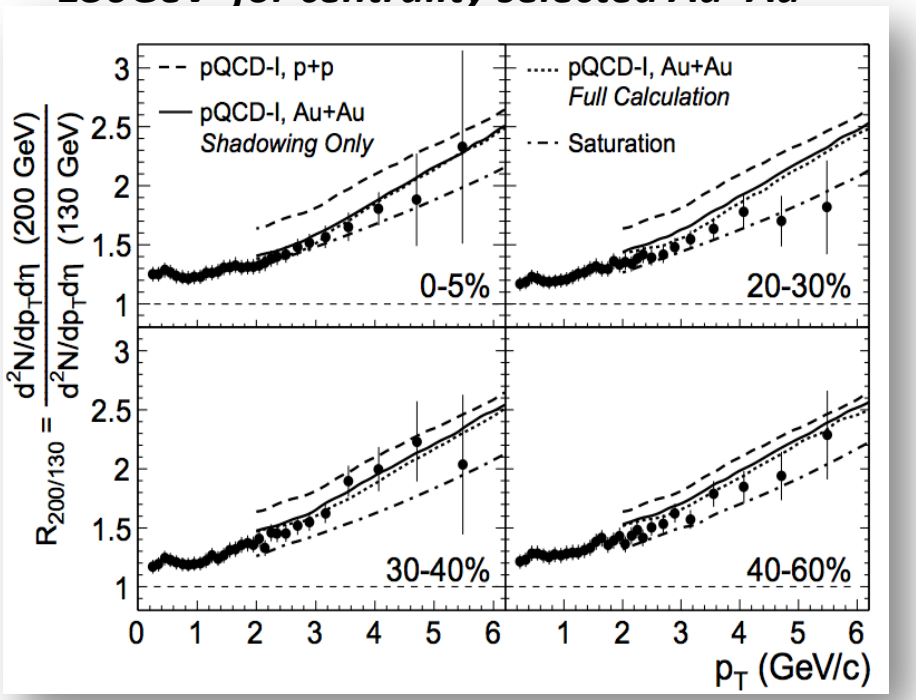
"R_{AA} and R_{CP} should be 1 if particle production in central Au+Au is equivalent to a superposition of independent NN collisions."

RESULTS

Inclusive Invariant pT distributions (Au+Au, p+p)



Ratio of hadron yields at $\sqrt{S_{NN}}$ = 200 and 130GeV for centrality selected Au+Au



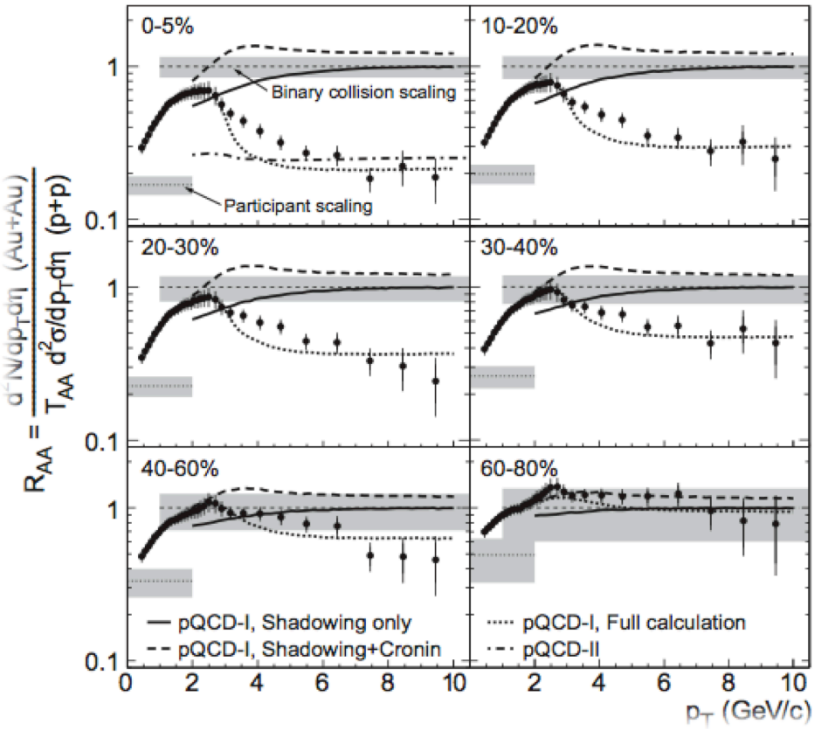
$R_{200/130}$(pT) is compared to
(1) pQCD – I
(2) Saturation model

◆pQCD model show that the reduction in ***$R_{200/130}$(pT)*** for Au+Au relative to p+p is due to nuclear shadowing.

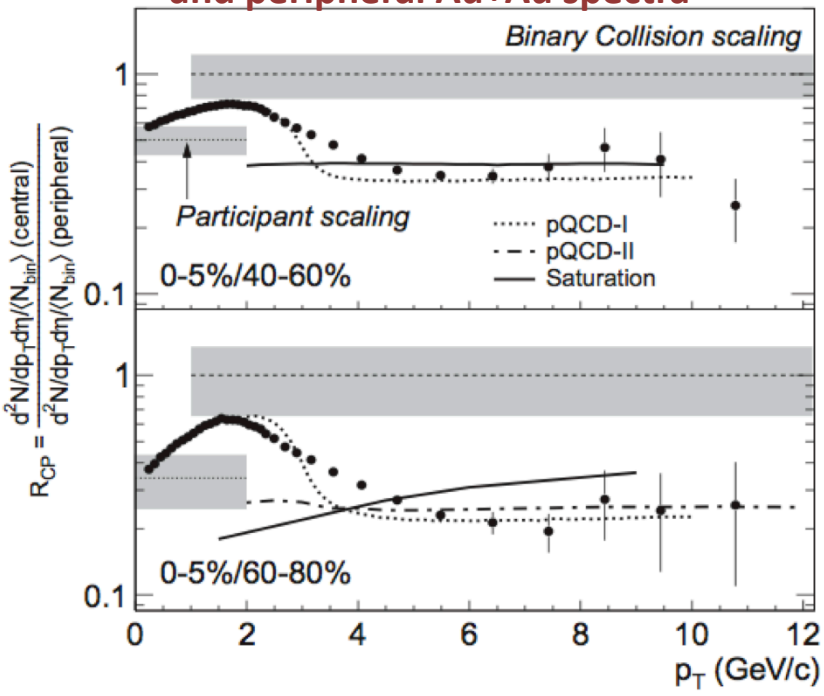
◆ Both models reproduce the pT dependence of the ratio for Au+Au for pT > 2 GeV/c

Results - R_{AA} and R_{CP} for $(h^+ + h^-)/2$

Au+Au spectra relative to p+p spectra



$\langle N_{bin} \rangle$ normalized ratio of central and peripheral Au+Au spectra



- For pT < 2GeV/c, hadron production increases monotonically for all centralities
- For pT> 2GeV/c, R_{AA} saturates near unity for peripheral bins ➔ "No Suppression"
  R_{AA} shows strong decrease for central bins ➔ "Suppression"
  R_{CP} shows similar pattern with hadronic suppression for central bins
- For 6 < pT < 10, R_{AA} shows 4-5 factor suppression for central bins

The Cronin enhancement and shadowing alone cannot account for the suppression, which is reproduced only if the partonic energy loss in dense matter is included.

Summary

✓ STAR has measured inclusive charged hadron yields from Au+Au and p+p at $\sqrt{S_{NN}}$ = 200GeV, at higher precision and extended pT range.

✓ Large constant hadron suppression is observed in central nuclear collisions at high pT

✓ The systematic behavior of suppression at high pT is well described both by

(1) pQCD calculations, incorporating final state partonic energy loss in dense matter

(2) saturation model of initial state gluon saturation in the central collision data

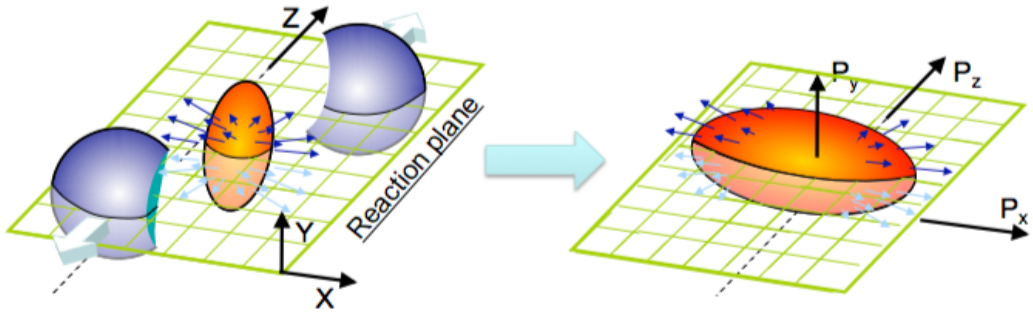
✓ Isolation of the initial state effect on high pT hadron production may be achieved through the study of d+Au collisions at RHIC.

Paper - 6

Particle-type dependence of azimuthal anisotropy and nuclear modification of particle production in Au+Au collisions at $\sqrt{S_{NN}}$ = 200 GeV

- **v2 and R_{CP}**
- **Measurement**
- **Results**
- **Summary**

Azimuthal anisotropy parameter(v_2) and R_{cp}



The distribution of particles in the azimuthal angle ϕ is analyzed in terms of Fourier expansion.

$$dN/d\phi \propto 1 + \sum_n 2v_n \cos n(\phi - \Psi_{RP})$$, Where Ψ_{RP} is the reaction plane.

And the coefficients v_n are calculated to be:

$$v_n(p_T, y) = \langle \cos[n(\phi - \psi_{RP})] \rangle$$

The second harmonic v2 is the dominant flow pattern and is called elliptic flow, v2

This analysis extends the pT range of v2 and Rcp measurement for identified particles and establishes particle type dependence of v2 and Rcp at intermediate(1.5-4.0 GeV/c) and high pT (pT>5GeV/c)

Measurement

➔ V_2, R_{CP} of:
- ✧ K_s^0 for (|y| < 1 and 0.2 < pT < 6.5 GeV/c)
- ✧ $\lambda + \bar{\lambda}$ for (|y| < 1 and 0.4 < pT < 6.0 GeV/c)

➔ R_{CP} of: ✧ $K^{\pm}$ for 0.2 < pT < 3.0 GeV/c

} @ 200GeV

Reconstruction decay channels:

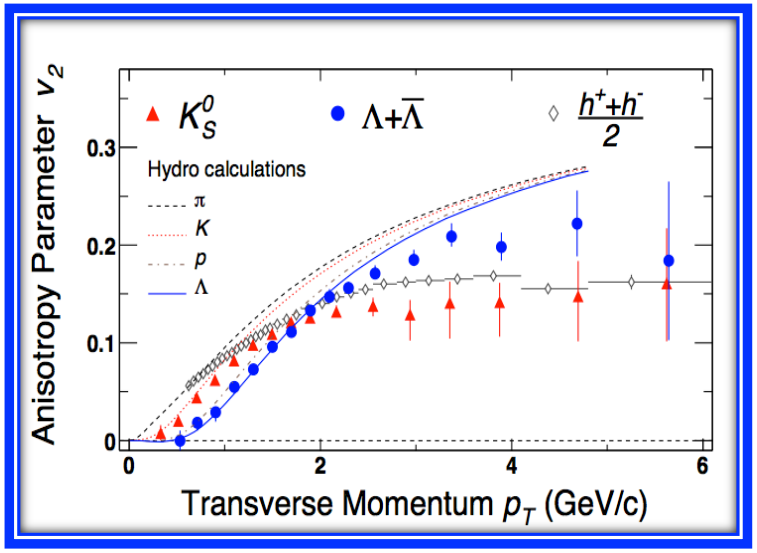
$$K_s^0 \rightarrow \pi^+ + \pi^-$$

$$\lambda(\bar{\lambda}) \rightarrow p + \pi^-(\bar{p} + \pi^+)$$

Reaction plane angle is estimated from azimuthal distribution of primary tracks within 0.1 < pT < 2.0 GeV/c and |η|<1.

RESULTS

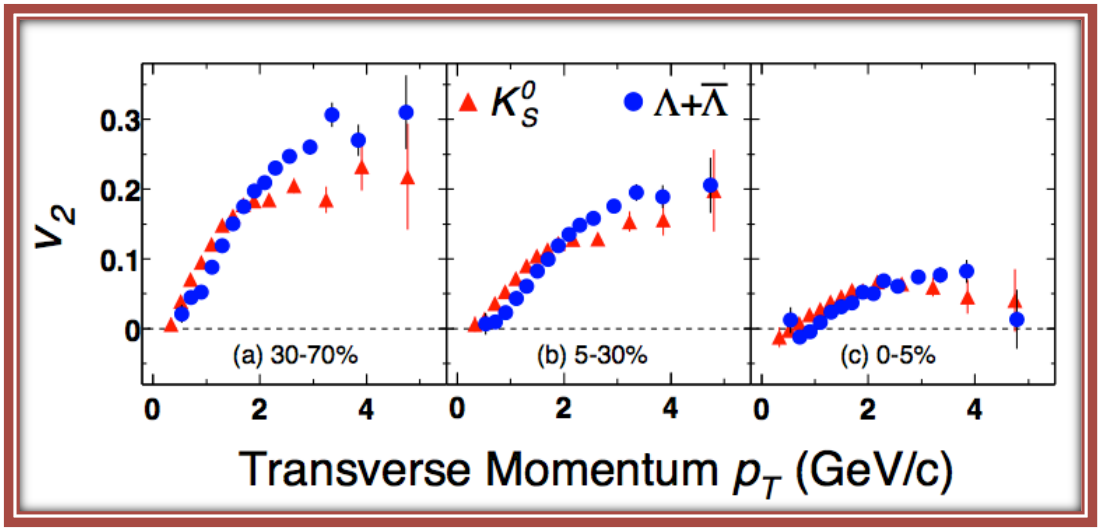
(V2 of identified particles)



- At low pT, v2 is consistent with hydrodynamic calc.
- At intermediate pT, there is particle type dependence.
- Hydro predicts smaller v2 for heavier particles, but observed $v_2^{\lambda} > v_2^{K}$

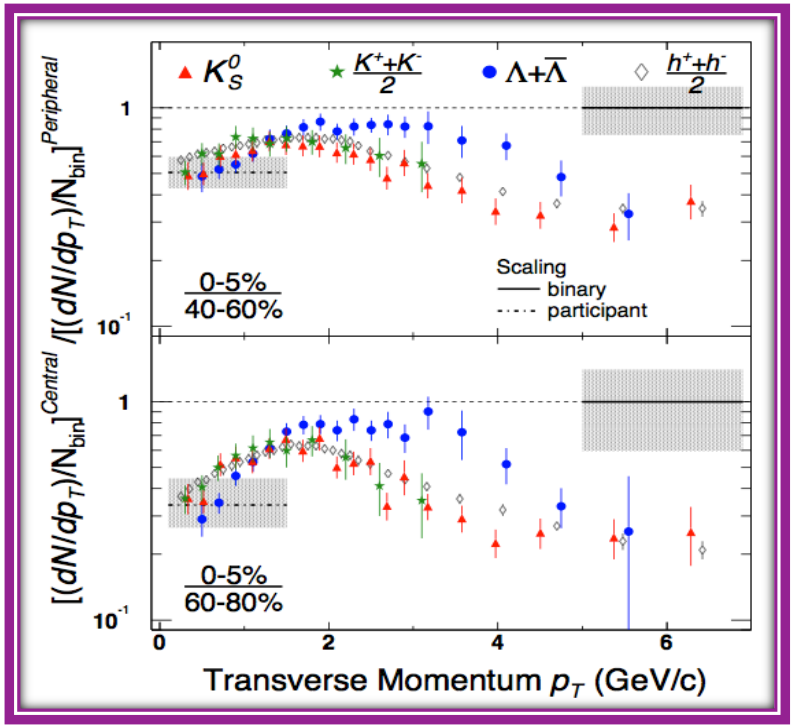
Could this be due to the fact that partons that fragment into λ (λbar) lose more energy than those that fragment into K_s^0?

➔ **Look at R_{CP} of identified particles**



- v_2 of K_s^0 and (λ+λ-bar) for various centralities
- In all 3 cases, v_2 rises at low pt and saturates at intermediate pt

R_{CP}
(most central events, normalized by peripheral)



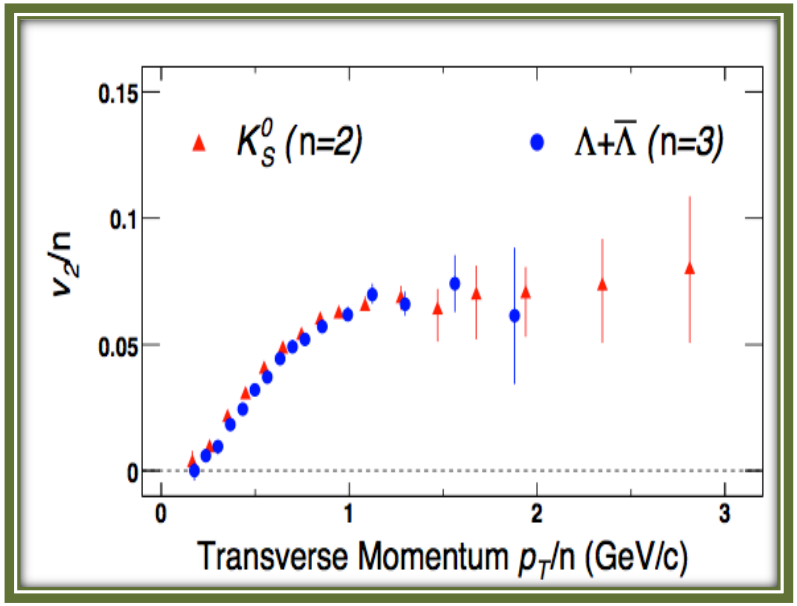
- At intermediate pT, the production of (λ+λbar) is enhanced compared to Kaons and it matches with Nbin scaling. Observed $R_{CP}^{\lambda} > R_{CP}^{K}$
- The particle type dependence of v_2 and R_{CP} at intermediate pT are in contradiction to expectations from energy loss followed by fragmentation in vacuum.
- A possible explanation is that Cronin effect giving enhancement of baryon production than mesons, although it is expected to decrease with increasing beam energy.
- The baryon enhancement observed at intermediate pT ends at pT ≈ 5GeV/c, revealing a cross-over.

- This is compatible with the picture in coalescence/recombination model of a pT region dominated by bulk partonic matter hadronization (coalescence) to one dominated by single parton fragmentation.

- Within the above model, the convergence of K_s0 and (λ+λbar) at pT~ 5GeV/c is expected, since at high pT, independent fragmentation is likely to dominate over multi-parton particle production mechanisms

V_2 scaled by the number of constituent quarks

Models using coalescence/recombination mechanisms in particle production predict that at intermediate pT, v_2 will follow scaling by the number of constituent quarks…



- ✓ Above pT/n ~ 0.7 GeV/c, the values match for both K^s_0 and (λ+λbar) within errors.
- ✓ The scaling of v_2/n reveals the azimuthal anisotropy at the partonic level.

Summary

V_2 Measurement

★ v_2 and R_{CP} measurement is extended to pT ~ 6.0GeV/c for Kaons and (Λ+Λbar) in Au+Au collisions at 200GeV

★ At low pT, hydrodynamic model calculation agree well with v_2 of K_s^0 and (Λ+Λbar). At intermediate pT, hydrodynamics fails.

★ The scaling of v2/n is compatible with the picture of anisotropy developing at the partonic level.

RCP Measurement

✦ R_{CP} shows that the yield of (λ+λbar) increases more rapidly with system size than Kaons

✦ At intermediate pT, the (λ+λbar) R_{CP} is close to binary scaling while Kaon R_{CP} is lower. At high pT (~ 5GeV/c), R_{CP} of K_s^0 and (λ+λbar) consistent with with the value of charged hadrons, indicating the end of centrality dependent baryon enhancement.

✦ The intermediate pT behavior of v_2 and R_{CP} indicates the presence of multi-parton particle formation mechanisms beyond the picture of parton energy loss followed by fragmentation.

end!