Strange hadrons at intermediate and high transverse momentum in p+p, d+Au, Cu+Cu and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV measured with PHENIX detector

Prashant Shukla
Nuclear Physics Division
BARC, Mumbai India

PHENIX Collaboration

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Outline of the talk

- Why particles containing strange quarks are important ?

- PHENIX Detector Overview

- Measurements of particles containing strange quarks K^+/K^-, K_S, ϕ, K^* and Λ^0.
  These particles combined together cover a large p_T range

- Recent measurements on production and nuclear modification factor (RAA) of these particles in all systems at 200 GeV
  → d+Au
  → Au+Au
  → Cu+Cu

- Summary and outlook

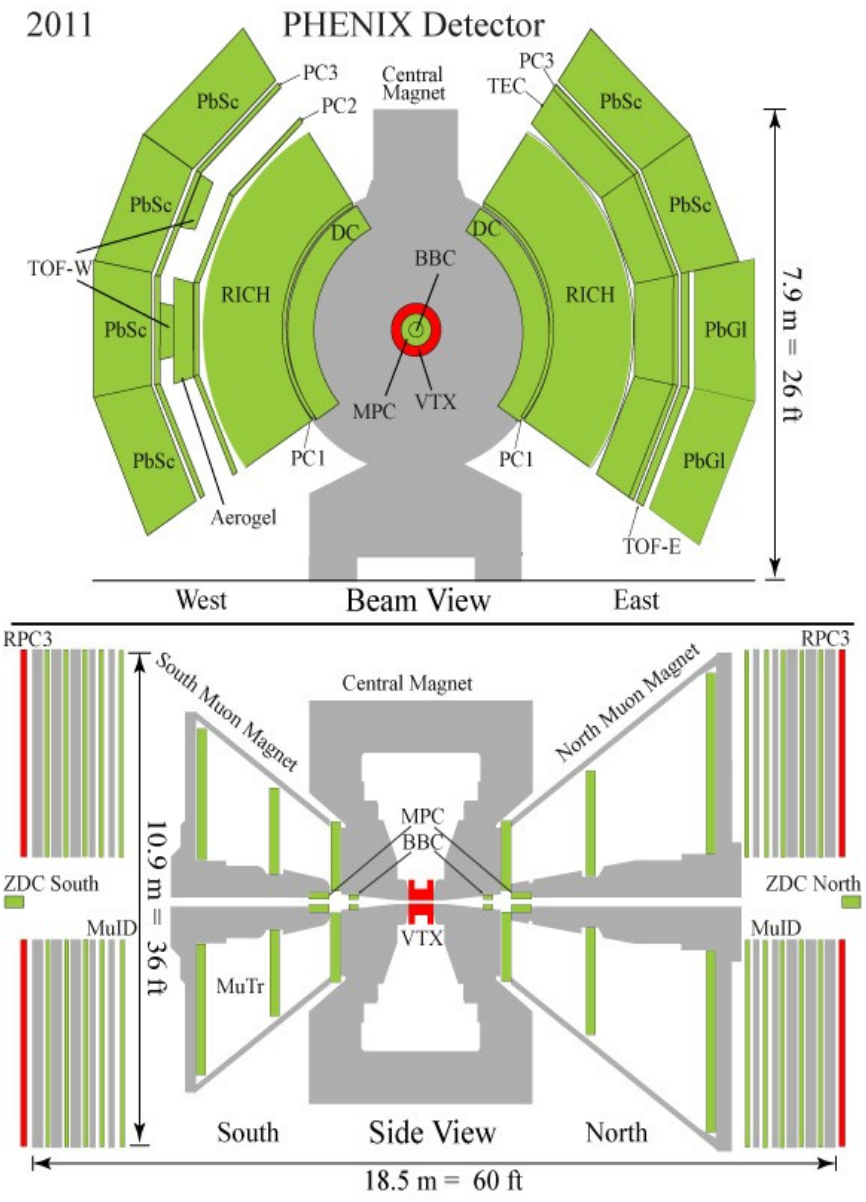
Why measure strange hadrons

- To study the properties of matter produced in heavy ion collisions we study the mass and flavour dependence of the nuclear modification factor of light hadrons containing u and d quarks and s quarks.

- In high p_T regions, the particles are observed to be suppressed due to jet quenching. Do strange hadrons have same suppression as light hadrons ?

- In intermediate p_T, the R_{AA} of hadrons has dependence on number of quarks and flavour composition of the hadron which can come from effects like quark coalescence. What is the dependence on strange quark content?

PHENIX Detector



GLOBAL DETECTORS

Beam-Beam Counter (BBC)

$3.0<|\eta|<3.9$, $\Delta\phi=2\pi$

Zero Degree Calorimeter (ZDC)

$|\eta| = \pm 2$, $\Delta\phi=2\pi$

CENTRAL DECTECTORS

(Tracking and PID)

Drift Chamber (DC) $|\eta|<0.35$, $\Delta\phi=90^0$ x 2

Pad Chambers (PC) $|\eta|<0.35$, $\Delta\phi=90^0$ x 2

Electro Magnetic Calorimeter (EMCAL)

Ring Imaging CHerenkov (RICH)

Time of Flight (TOF) $|\eta|<0.35$, $\Delta\phi=45^0$

FORWARD SPECTROMETERS

(Muon detection)

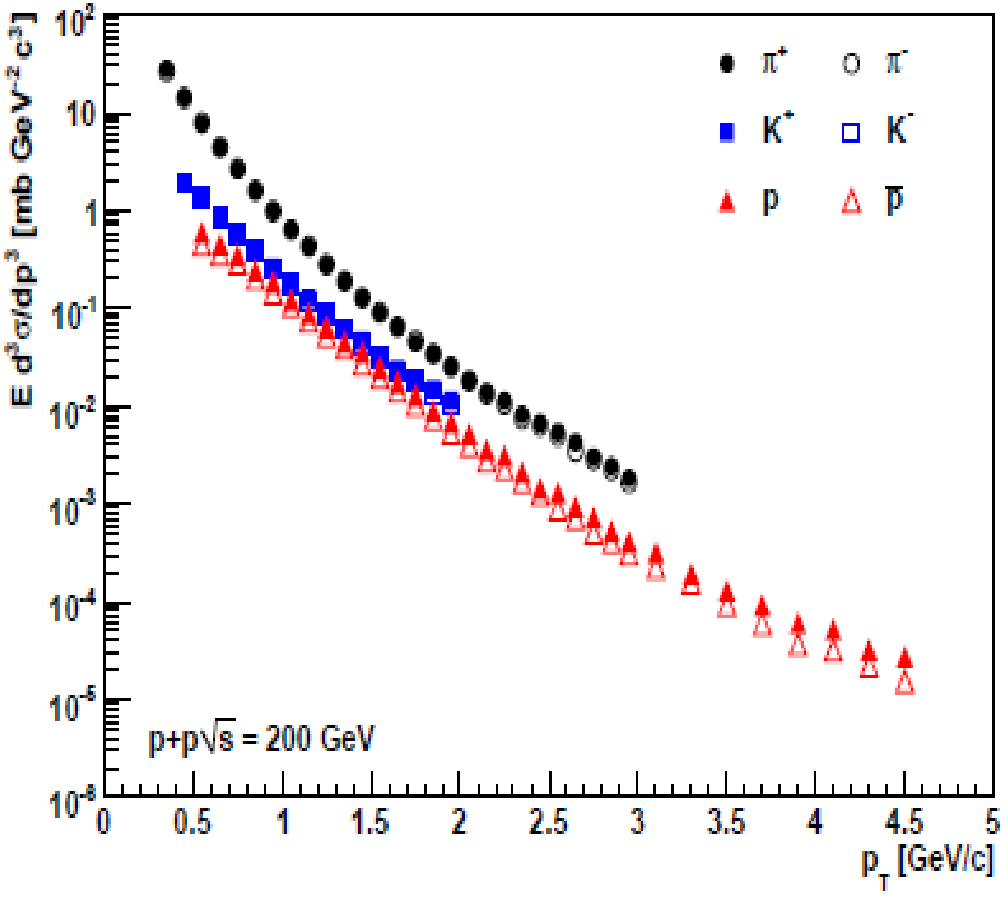
Charged Kaon measurement with TOF

The p_T range of measurement with TOF:

$\pi^{+/-}$ 0.3 – 3.0 GeV/c
$K^{+/-}$ 0.4 – 2.0 GeV/c
p 0.5 – 4.5 GeV/c

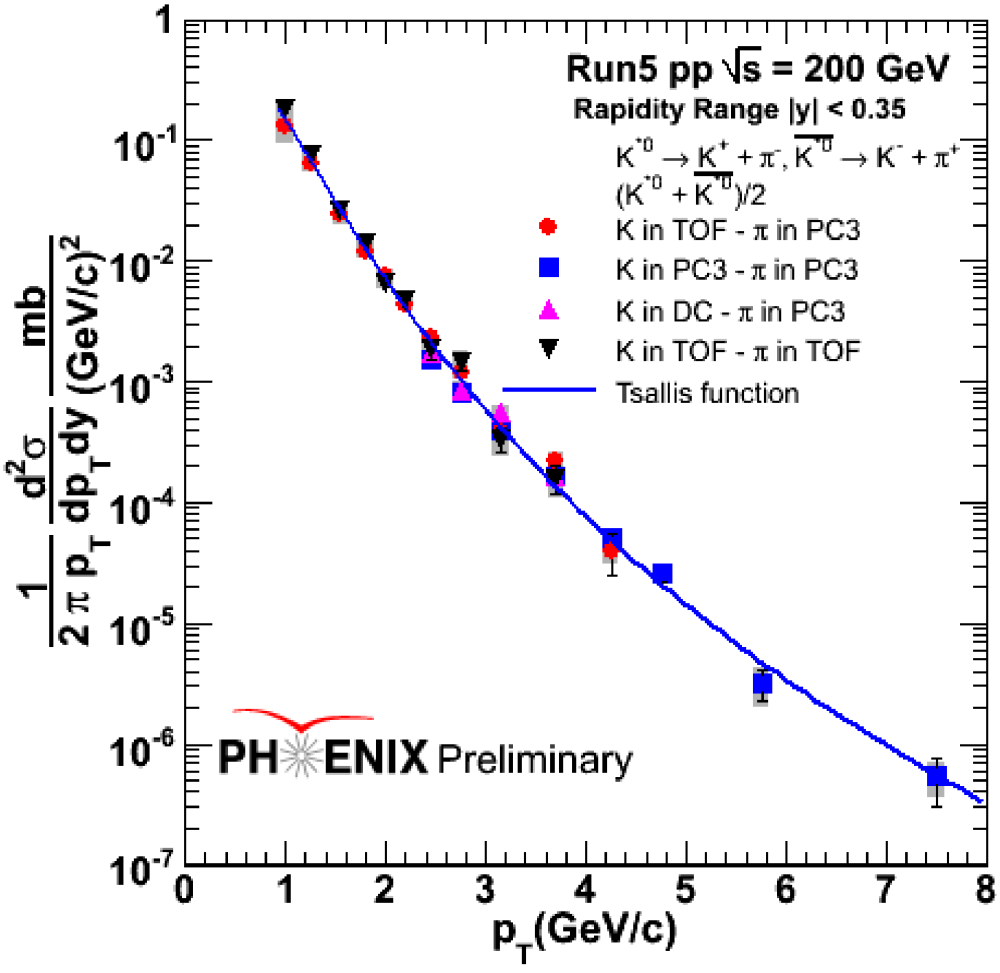
For high pT;

photonic decays of π^0 and K_s are measured in EMCAL



K* Meson in pp collisions at 200 GeV

$K^* \rightarrow K^+ + \pi^-$



K* Analysis Technique:

One leg PID:

K in TOF, π PC3 track.

Two leg PID:

Both K and π in TOF.

No PID:

Both K and π PC3 tracks.

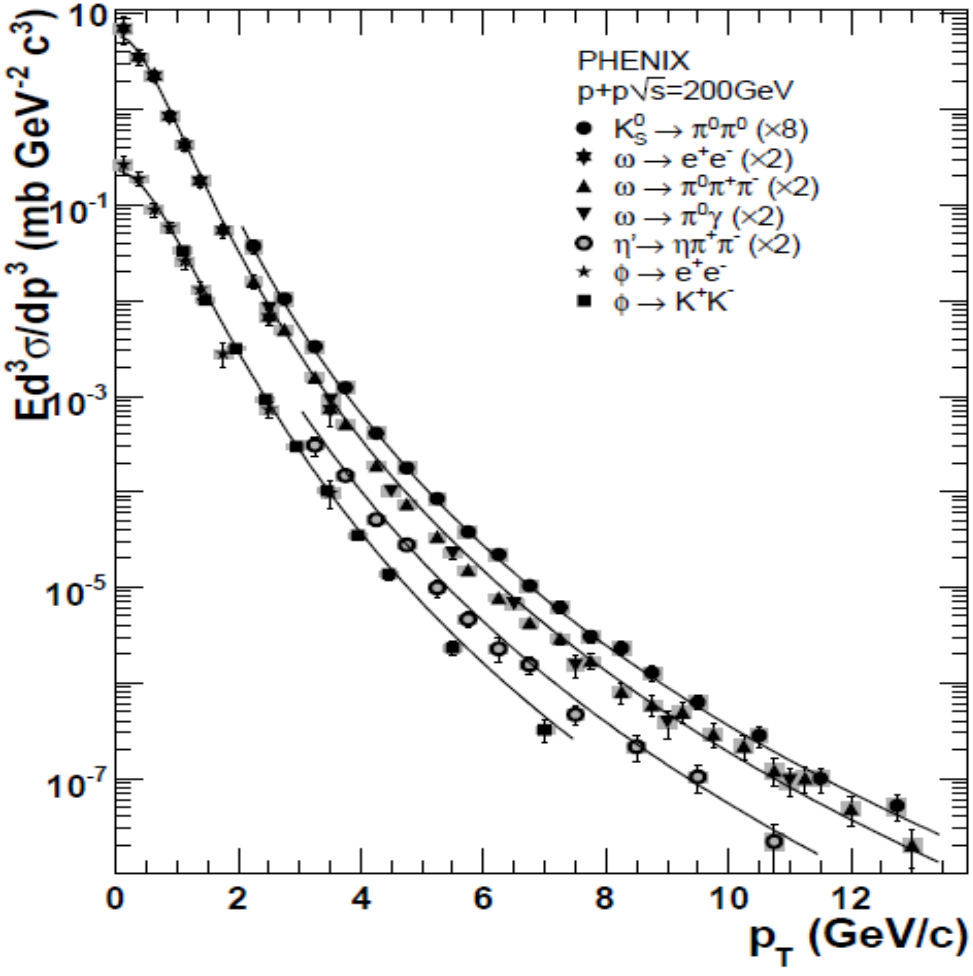
Kaon in Drift Chamber and π PC3 track.

The spectra is measured in the range p_T = 0.9 – 7.5 GeV/c.

K_S and ϕ meson in pp collisions at 200 GeV

$K_S \rightarrow 2\,\pi^0$ p_T range 2 – 13.5 GeV

$\pi^0 \rightarrow 2\,\gamma$ measured in EMCAL



$\phi \rightarrow K^+ K^-$

The ϕ spectra is measured in the range p_T = 1.0 – 8.0 GeV/c.

- The Tsallis distribution describes all mesons in p+p collisions which is a power law in high p_T region.

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Λ measurement

Λ → p + π-

One leg PID:

Proton identified in TOF–W and pions are PC3 tracks from the the west arm.

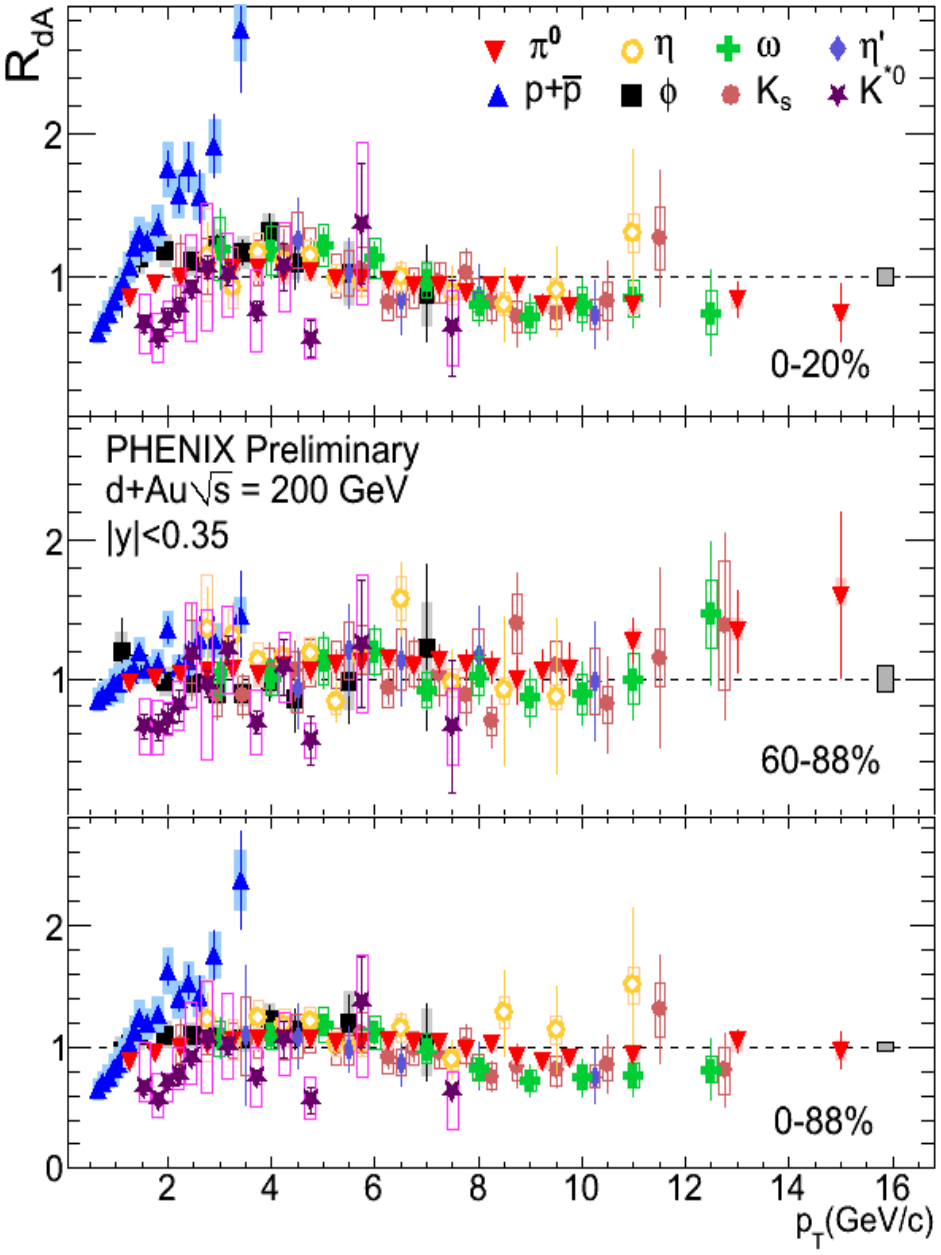
No PID:

Both the particles are PC3 tracks from same arm.

p_T range 2 - 6.5 GeV

d+Au at 200 GeV
Cold matter effects

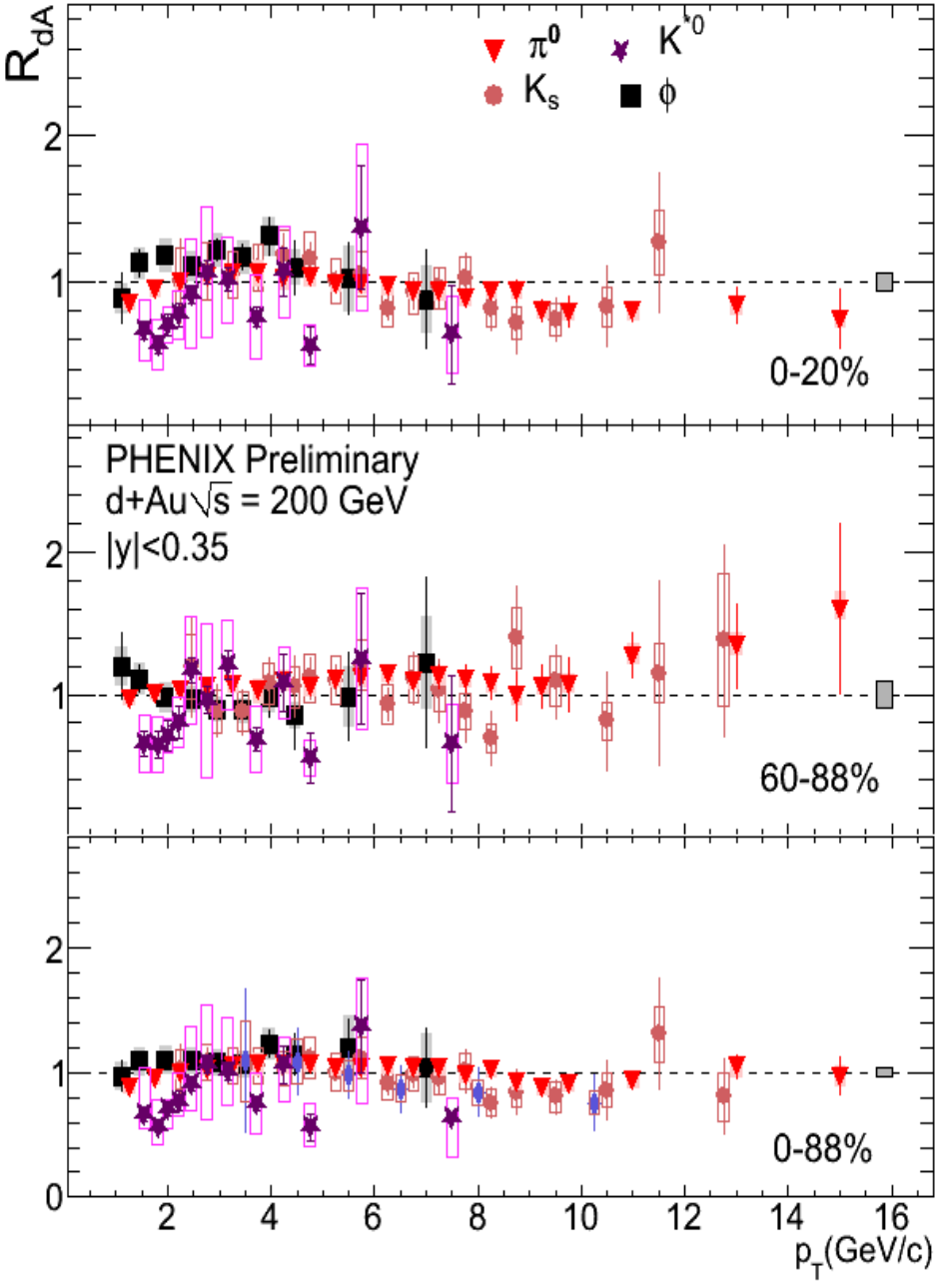
R_{AA} of K_S, ϕ and K* with other hadrons in d+Au at 200 GeV



K_S and ϕ R_{AA}

- Consistent with unity.
- Consistent with other light mesons in intermediate and low p_T
- proton enhancement in intermediate p_T

R_{AA} of K* in dAu collisions at 200 GeV



The lifetime of K* = 4 fm/c is of the order of size of the system. In heavy ion collision; re-scattering and regeneration.

The R_{AA} of K* for 4 centralities:

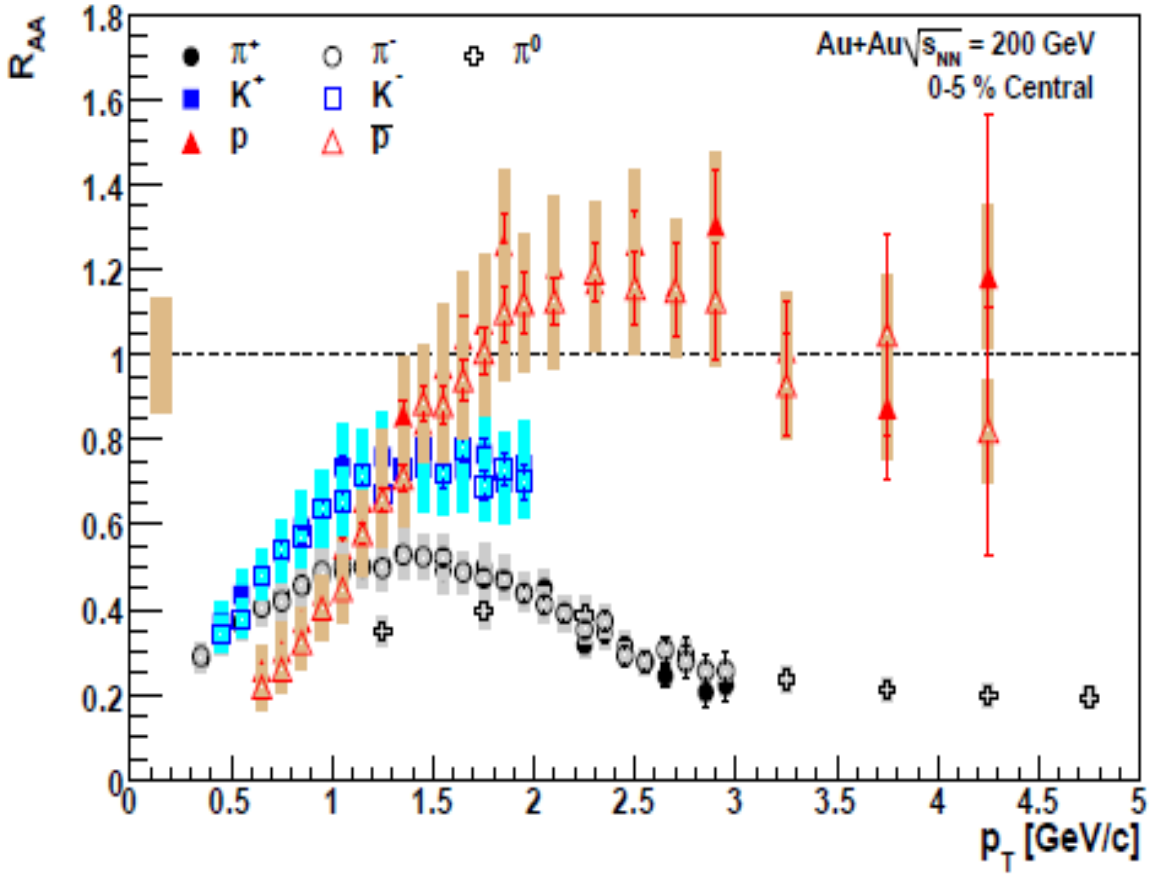
- **Same in all centralities.**
- **Consistent with unity accept at low p_T.**

Nuclear modification in heavy ion collisions
Au+Au at 200 GeV

R_{AA} of charged kaons in Au+Au

Charged Kaon RAA

Kaons are less suppressed in comparison to π in limited low p_T range measured.



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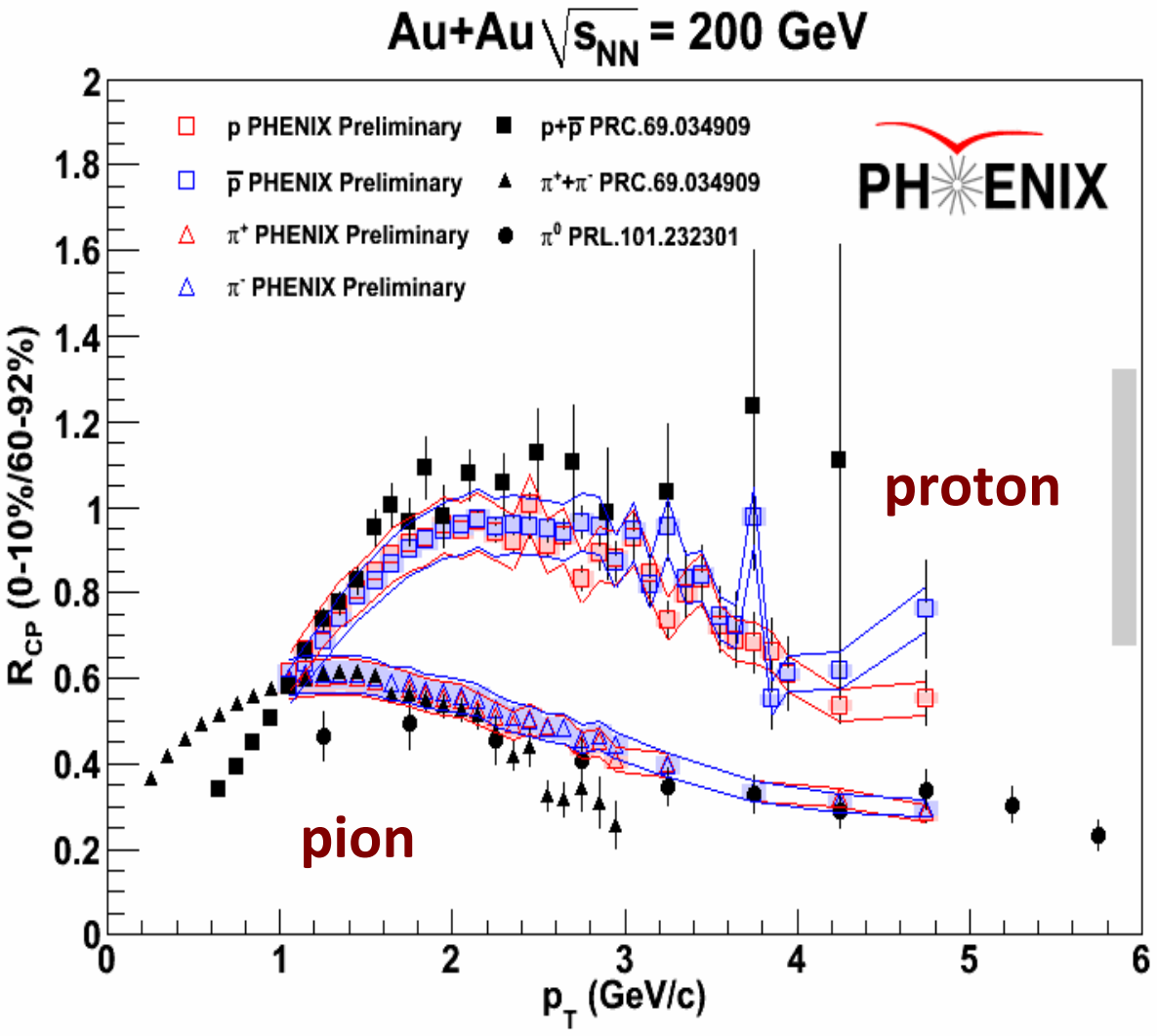
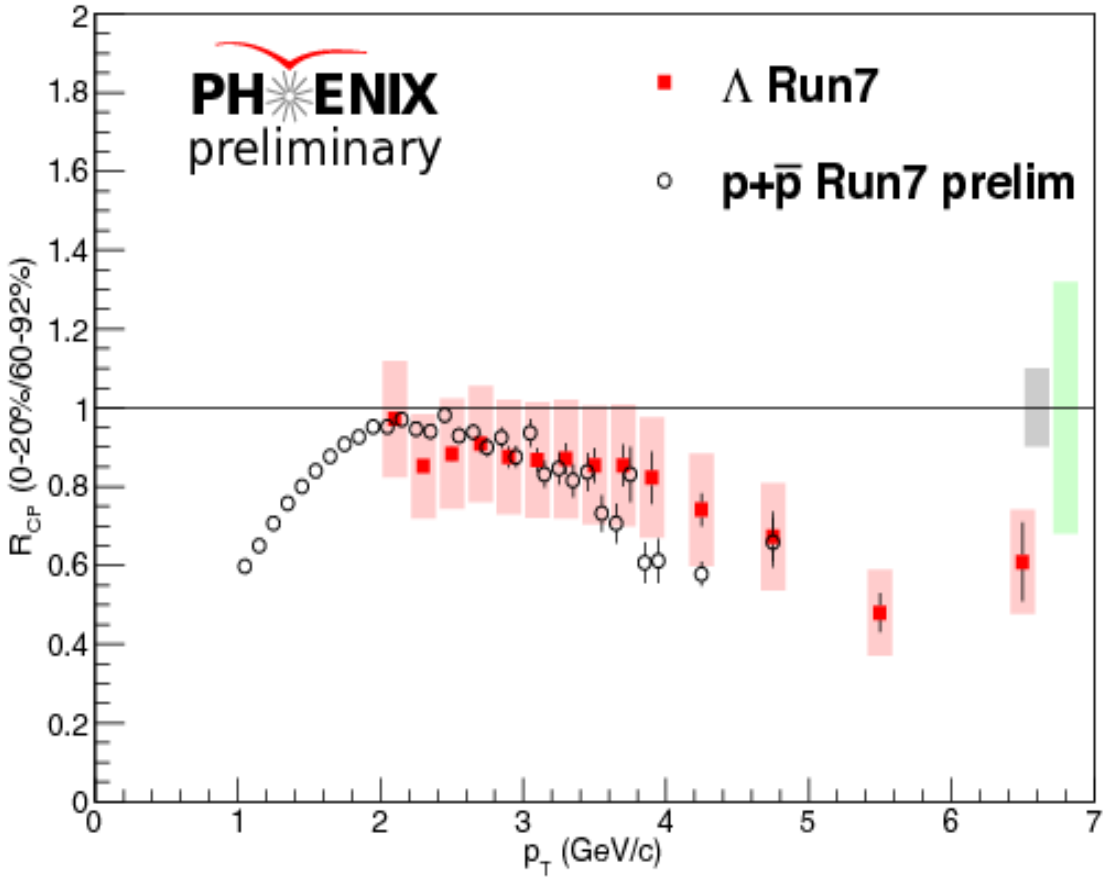
Identified charged particles in Au+Au at 200 GeV



R_{CP} with TOF-W

- Extended p_T range up to 5 GeV/c.
- Closed symbols old measurements.
- Open symbols new measurements.
- It will be possible to extend charged kaons R_{AA} to intermediate p_T.

R_{CP} of strange baryon in AuAu at 200 GeV



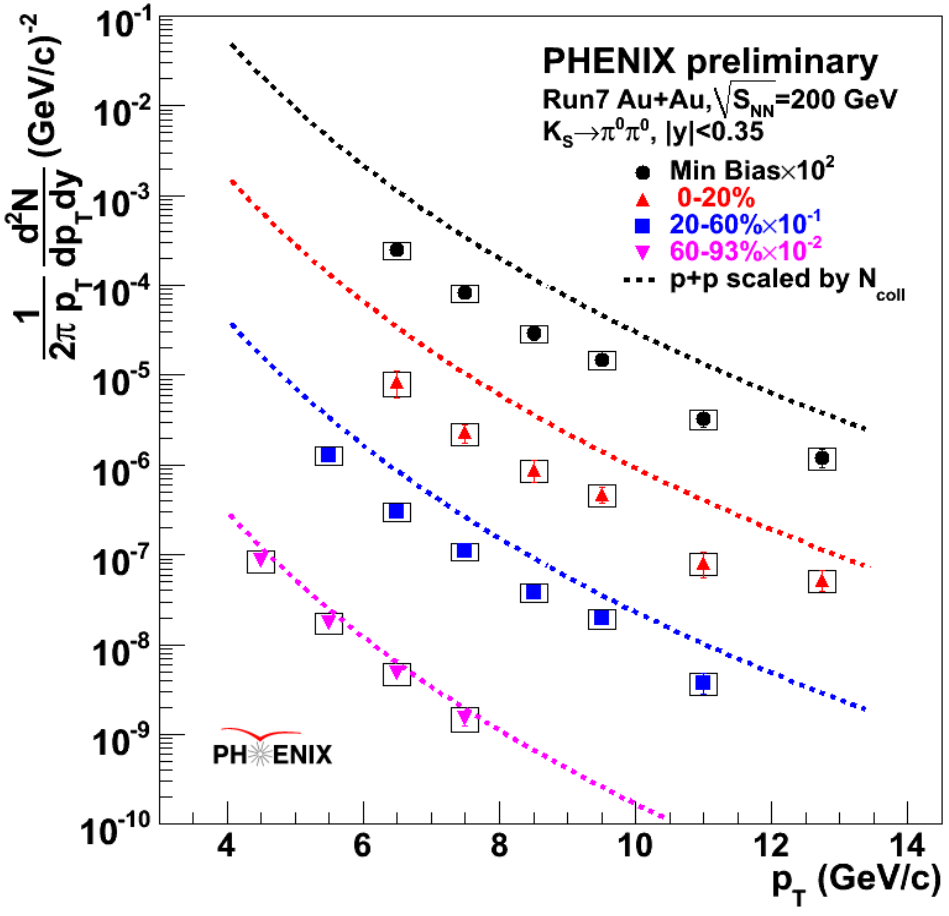
p_T range 2 - 6.5 GeV

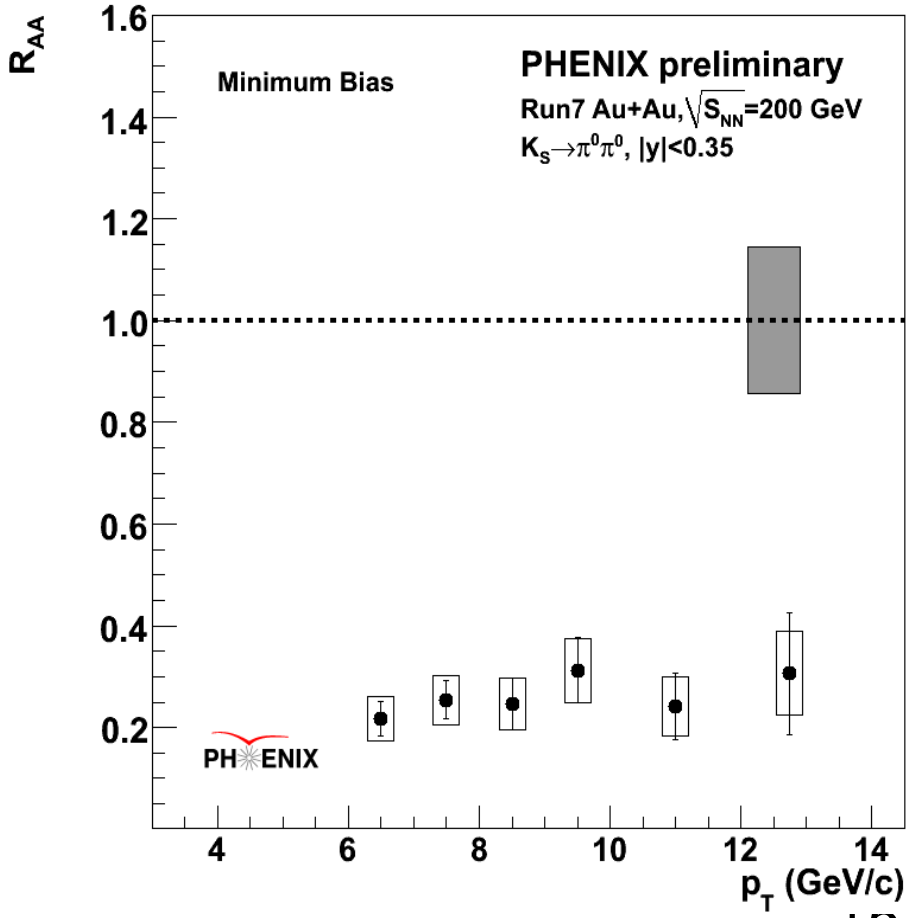
- Λ R_{CP} consistent with proton
- The enhancement at intermediate p_T is related to number of quarks content.

Spectra of K_S in Au+Au at 200 GeV

K_S R_{AA}

Extending Kaon measurements in high p_T range

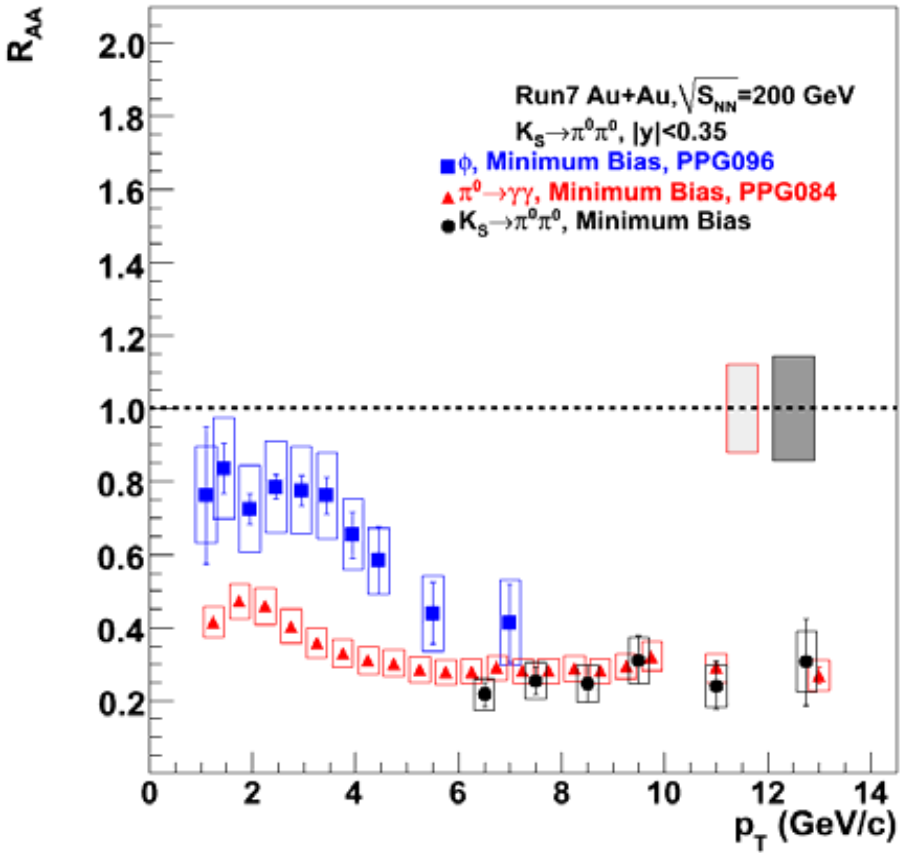


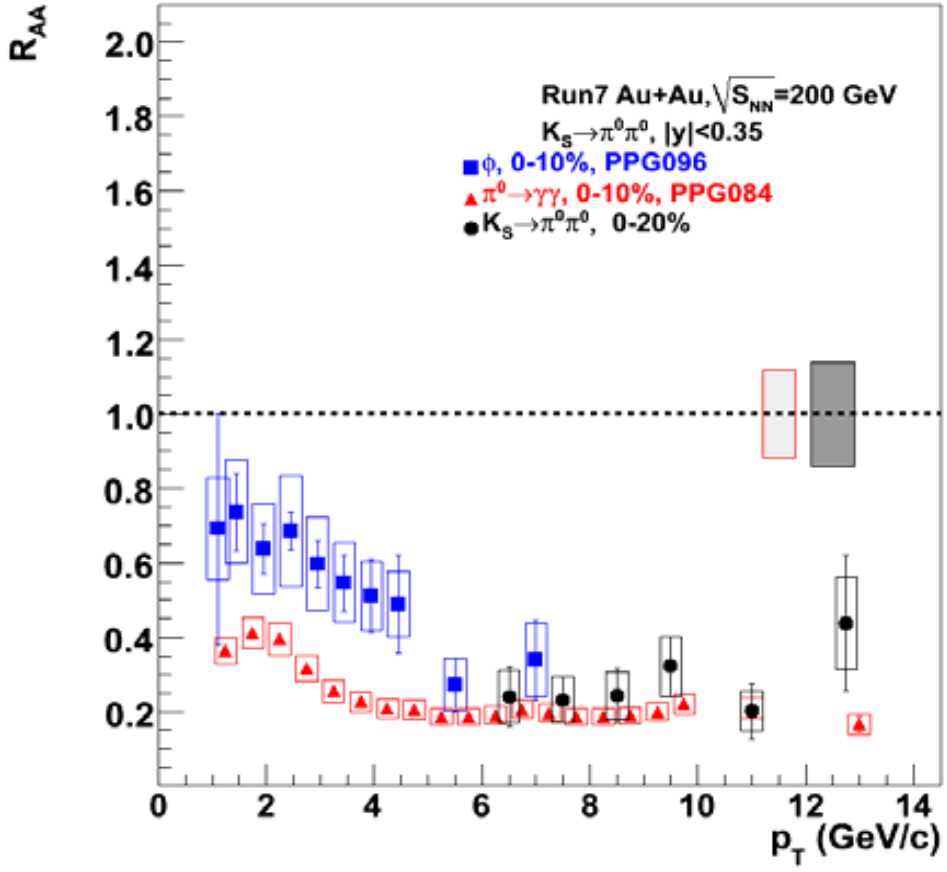


R_{AA} of K_S in Au+Au at 200 GeV

K_S R_{AA}

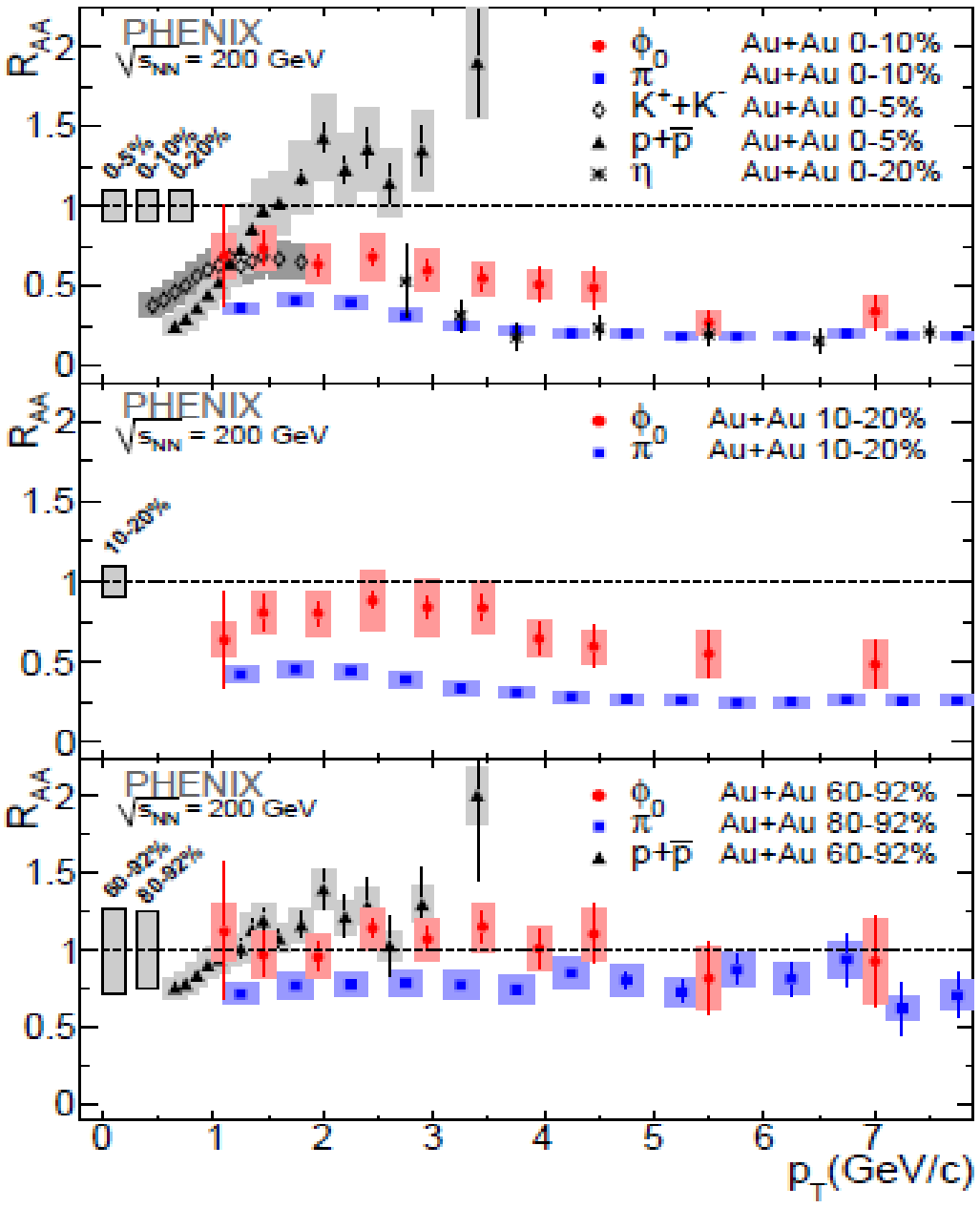
- Extending Kaon R_{AA} in high pT range
- At high p_T, K_S suppression is consistent with pions and with ϕ.





PPG096: PRC 83, 024909 (2011), PPG084: PRL101, 162301 (2008)

R_{AA} of ϕ in Au+Au system at 200 GeV



- At low and intermediate p_T, suppression of ϕ is different from pion and eta.
- At high p_T, suppression is consistent with pion and eta within error bars.
- Kaon follows the same trend as ϕ in low p_T

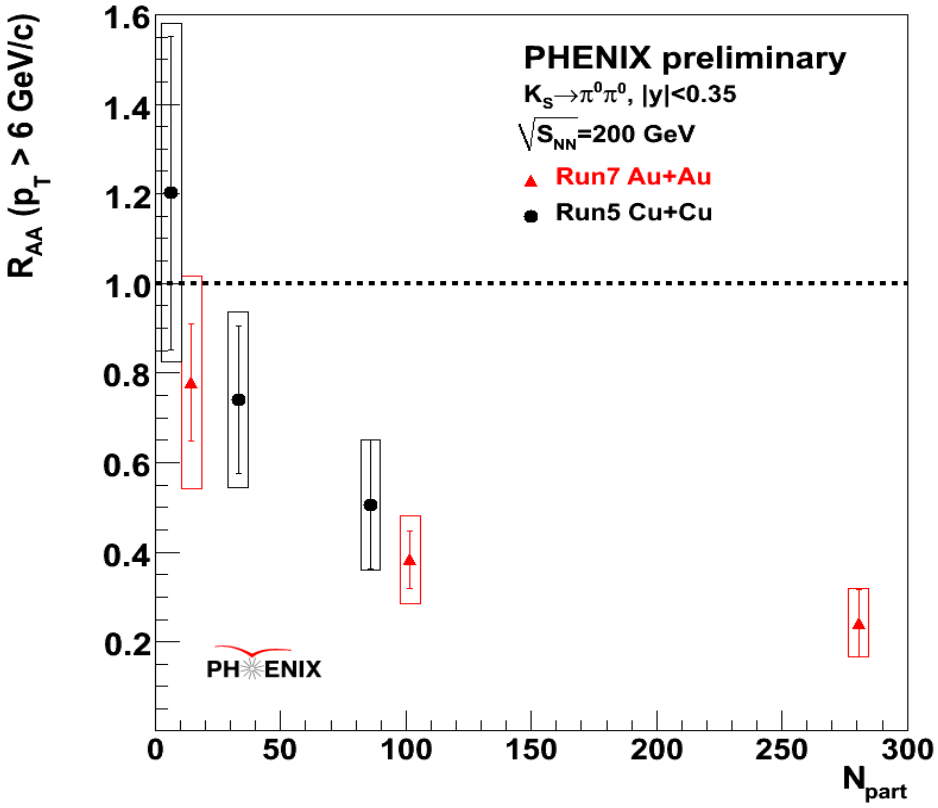
Phys.Rev.C 83, 024909 (2011)

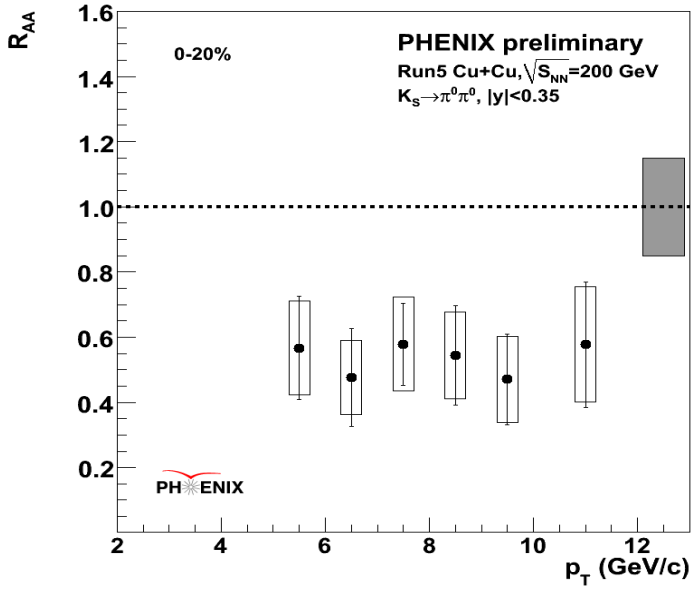
Cu+Cu at 200 GeV

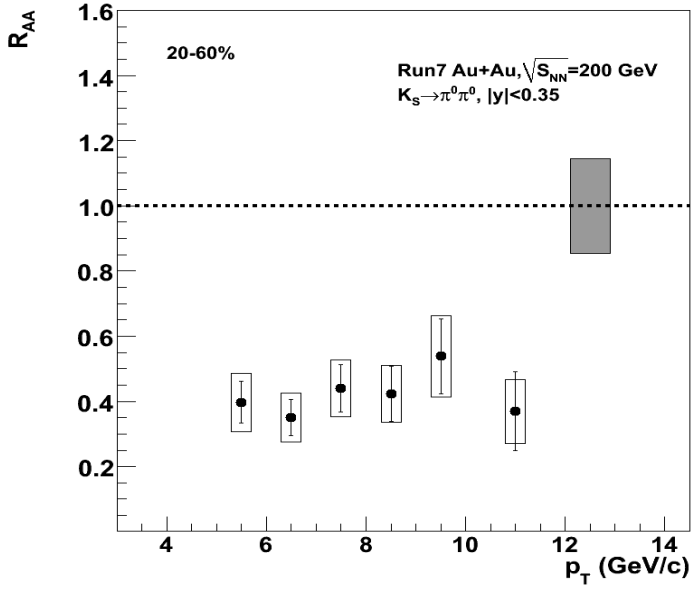
Spectra of K_S in Cu+Cu at 200 GeV

K_S R_{AA} in Cu+Cu:

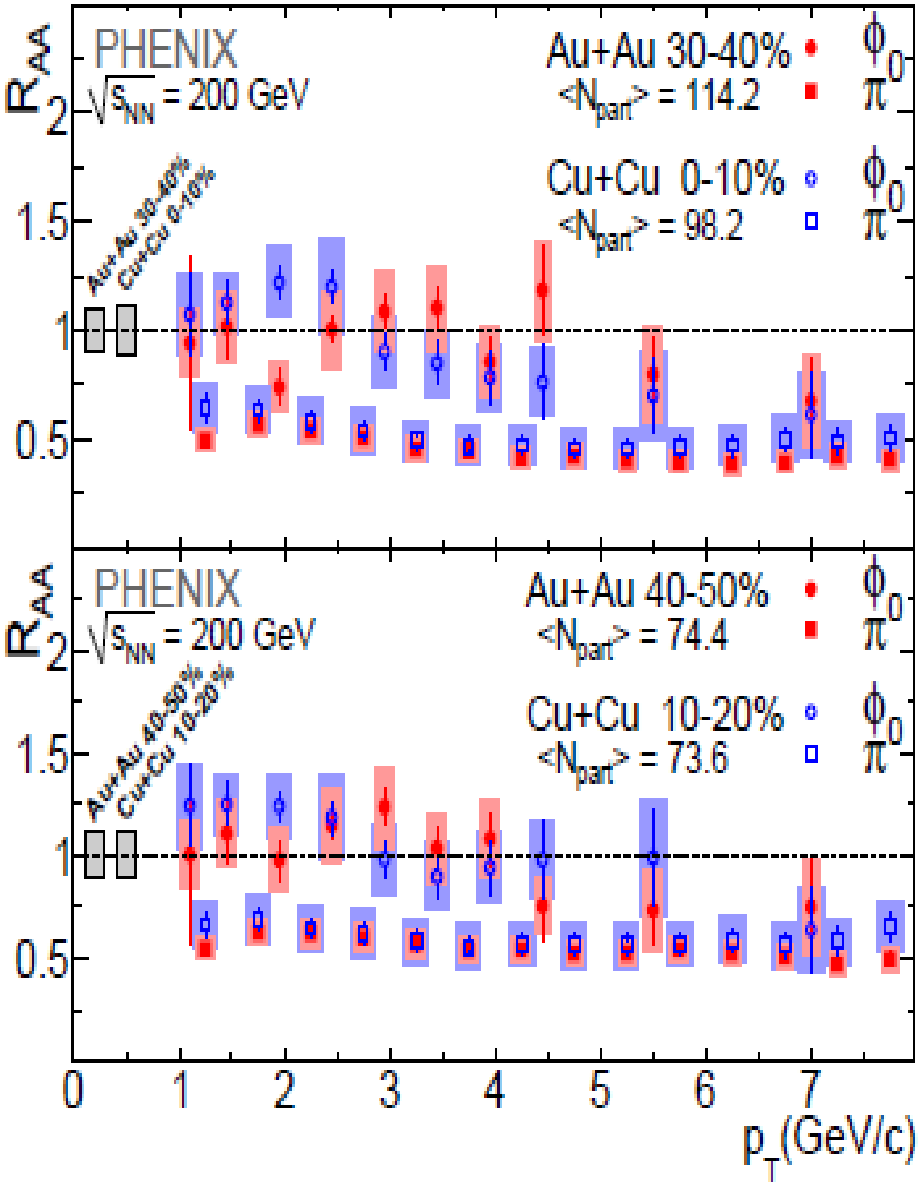
K_S suppression in CuCu similar to suppression in Au+Au as a function of npart.







R_{AA} of ϕ in Cu+Cu system at 200 GeV



- **Suppression is same in Cu+Cu as in Au+Au collisions with equivalent number of participants.**

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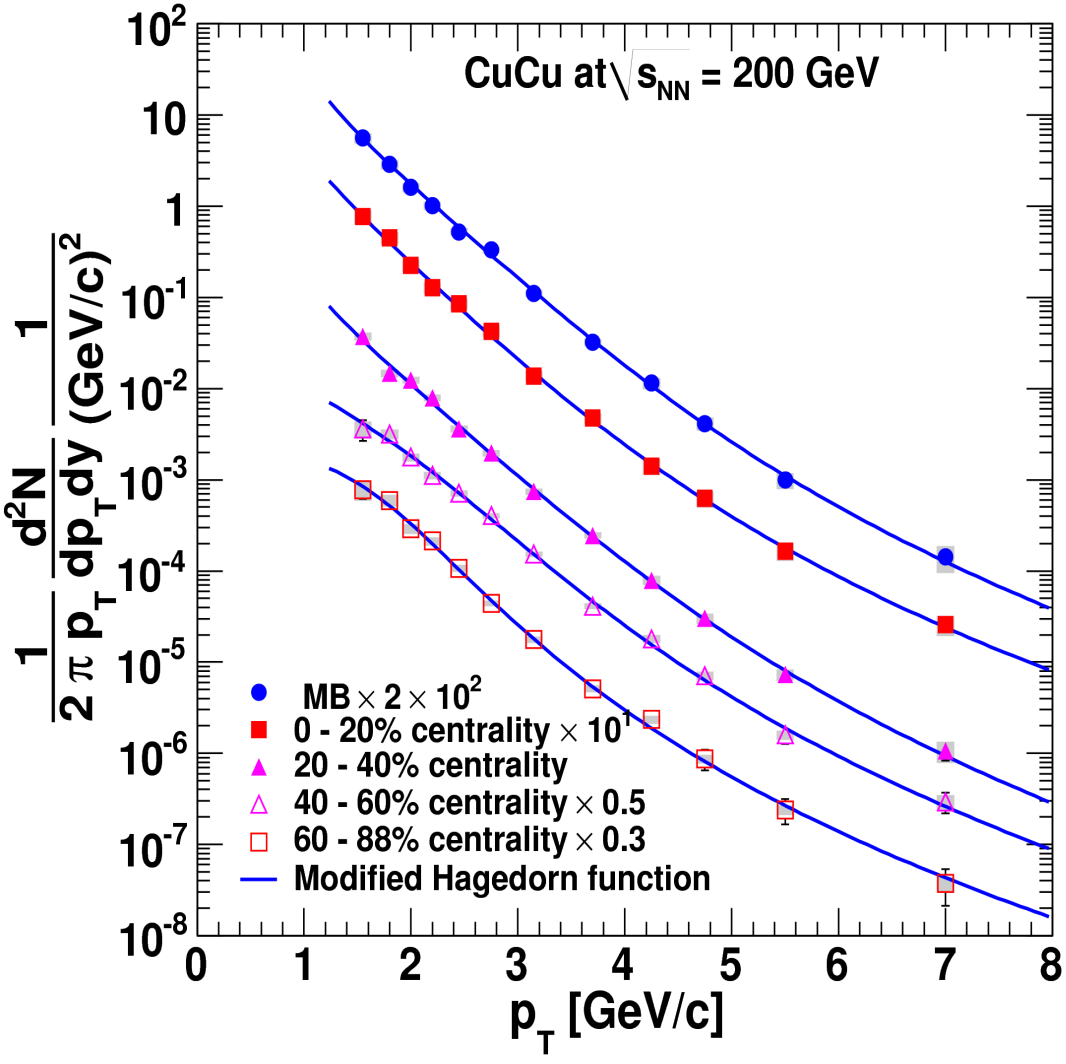
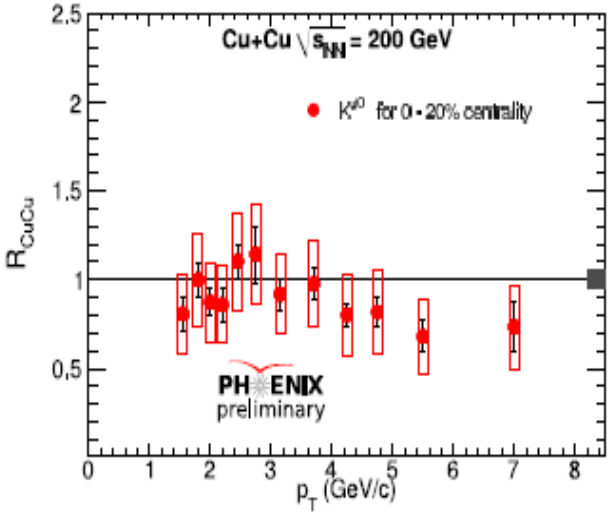
K* meson in CuCu collisions at 200 GeV

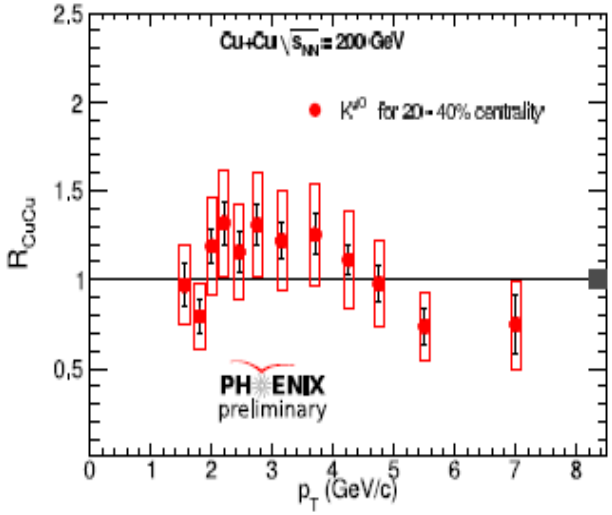


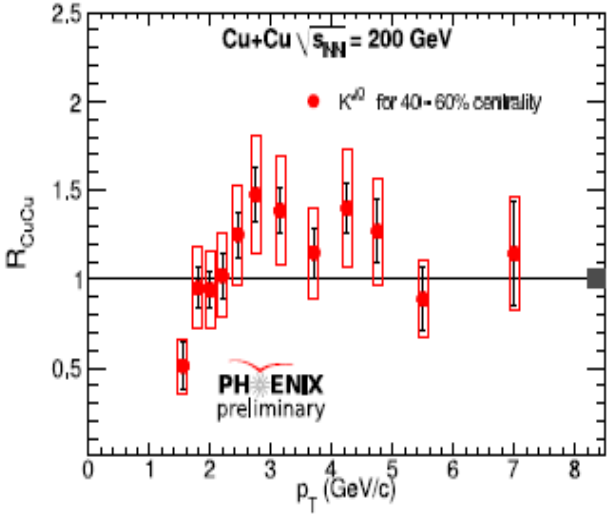
The spectra is measured in the range p_T = 1.4 – 7.0 GeV/c.

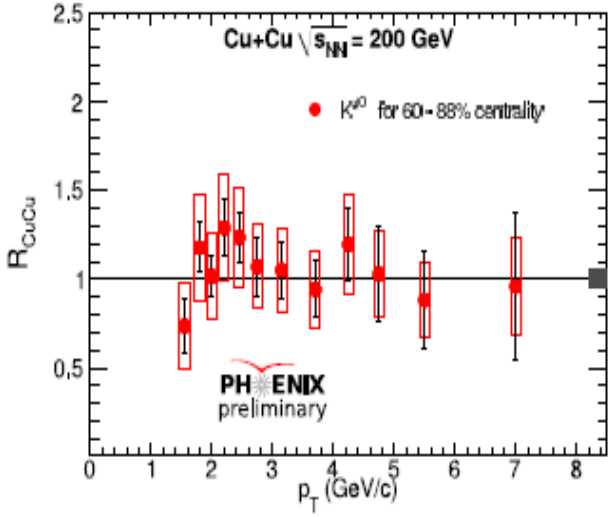
Hagedorn fit to guide eye

R_{AA} of K* in CuCu collisions at 200 GeV





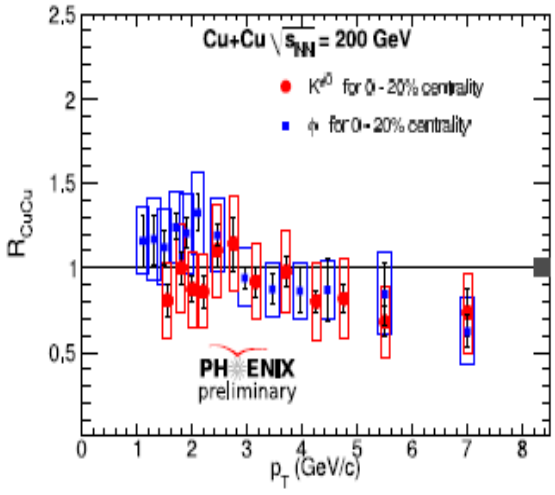


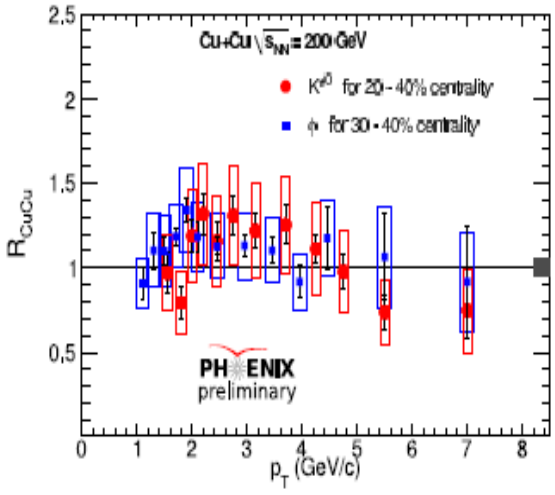


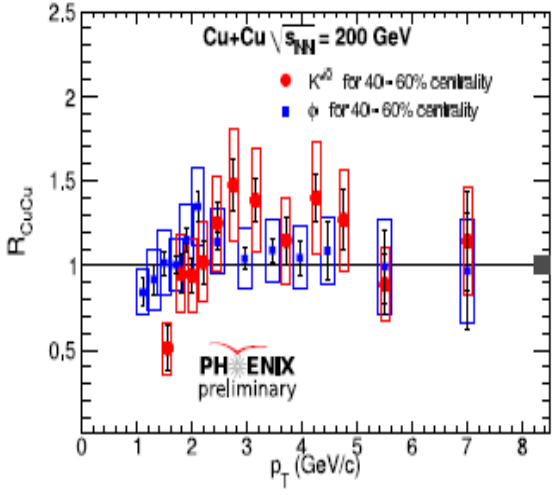
The R_{AA} for CuCu for 4 centralities:

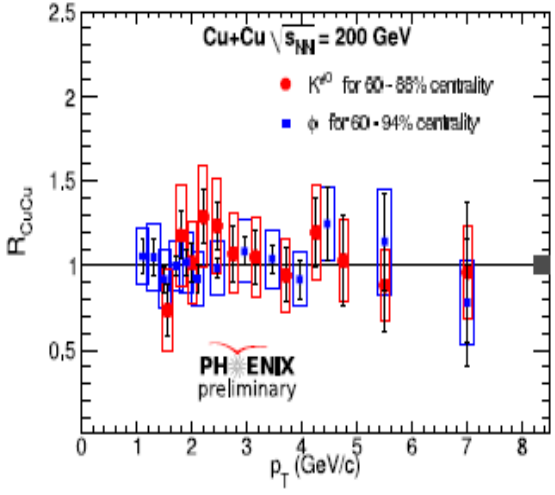
- **Central collisions show suppression at higher p_T.**
- **Peripheral collisions Consistent with unity.**

R_{AA} of K* and ϕ in CuCu collisions at 200 GeV









The RAA for CuCu for 4 centralities:

K* and ϕ consistent within error bars.

Summary

- Measurements in dAu at 200 GeV: K_S, ϕ, K *
  - RdA consistent with unity and consistent with light mesons in intermediate and high p_T range up to 8 GeV/c.
  - RdA for K* is smaller then unity in low p_T range < 2 GeV.

- Measurements in AuAu at 200 GeV: K+/K-, K_S, ϕ, and Λ
  - High p_T, ϕ and KS suppression consistent with light mesons.
  - Intermediate p_T, ϕ less suppressed as compared to light mesons.
  - RCP for Λ in intermediate p_T consistent with proton.

- Measurements in CuCu at 200 GeV: K_S, ϕ, and K*
  - Same suppression in Cu+Cu as compared to Au+Au.
  - K* suppression consistent with ϕ.

In heavy ion collisions:

- At high p_T (> 5 GeV), the particles containing strange quarks are suppressed like π/η.
- At intermediate p_T (2-5 GeV), ϕ and K* suppression same but smaller than π/η.
- At low p_T (< 2 GeV) charged kaons have lower suppression as compared to pions.
- Λ consistent with proton.

BACK UP

Particle ID in PHENIX
TOF east

Time of Flight Detector:

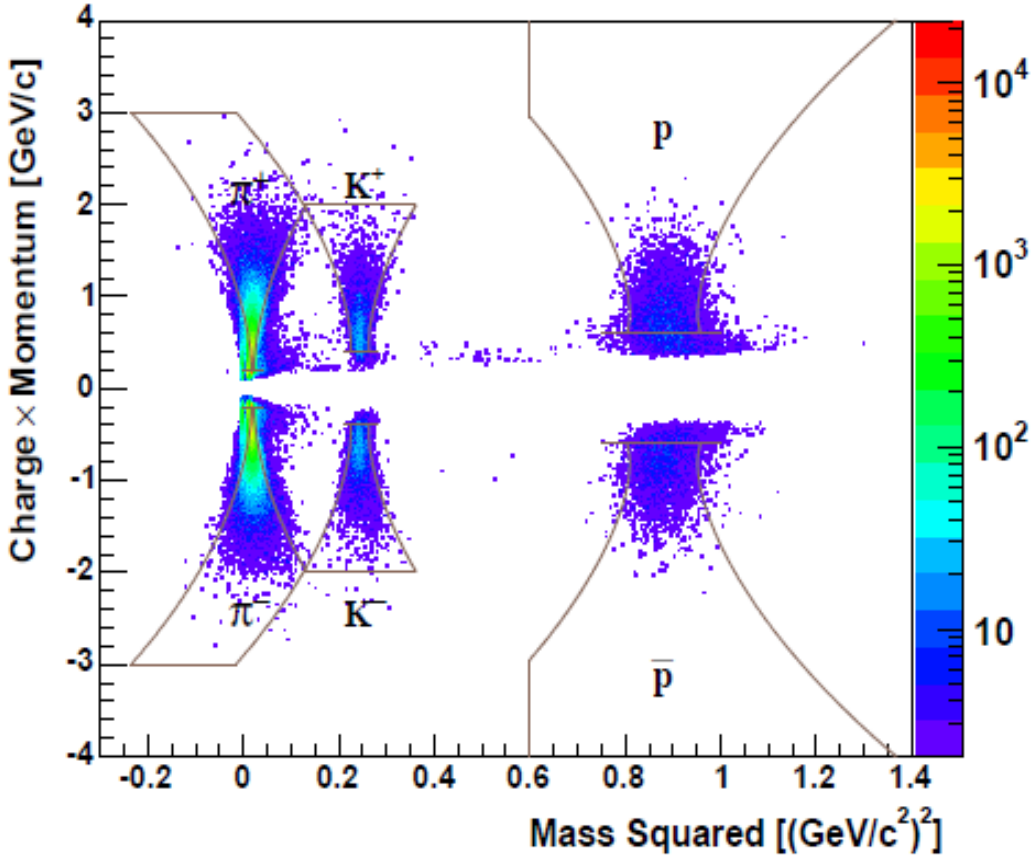
The PID is done by putting appropiate cuts in m^2 and momentum space.

Mom range for particle ID:

Π 0.3 – 3.0 GeV/c

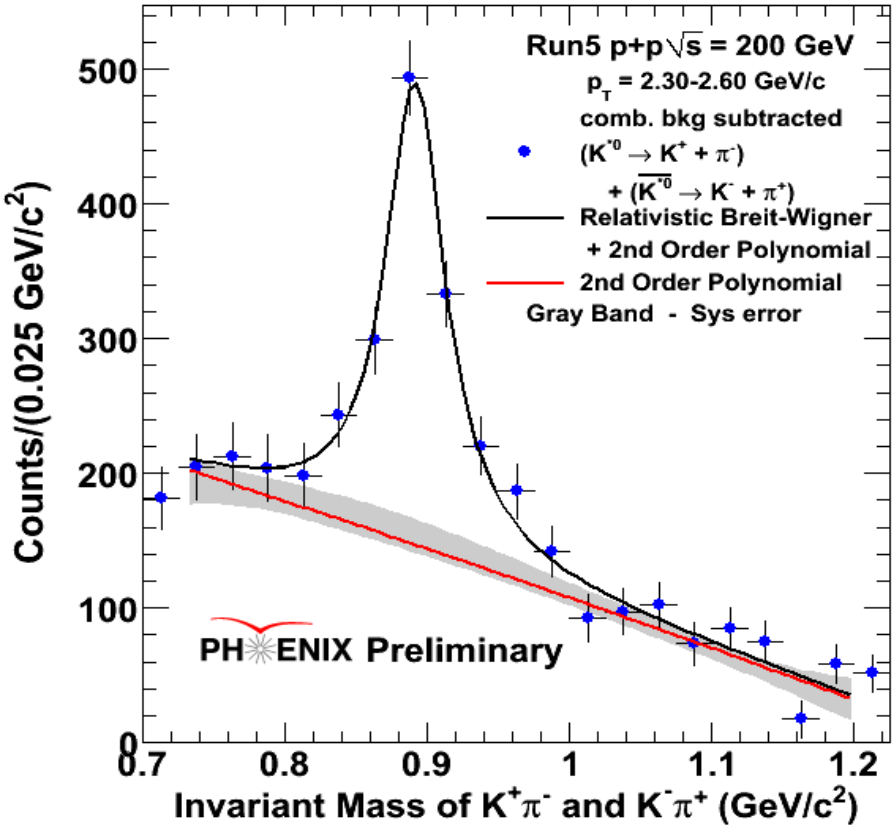
P 0.4 – 2.0 GeV/c

K 0.5 -- 4.5 GeV/c

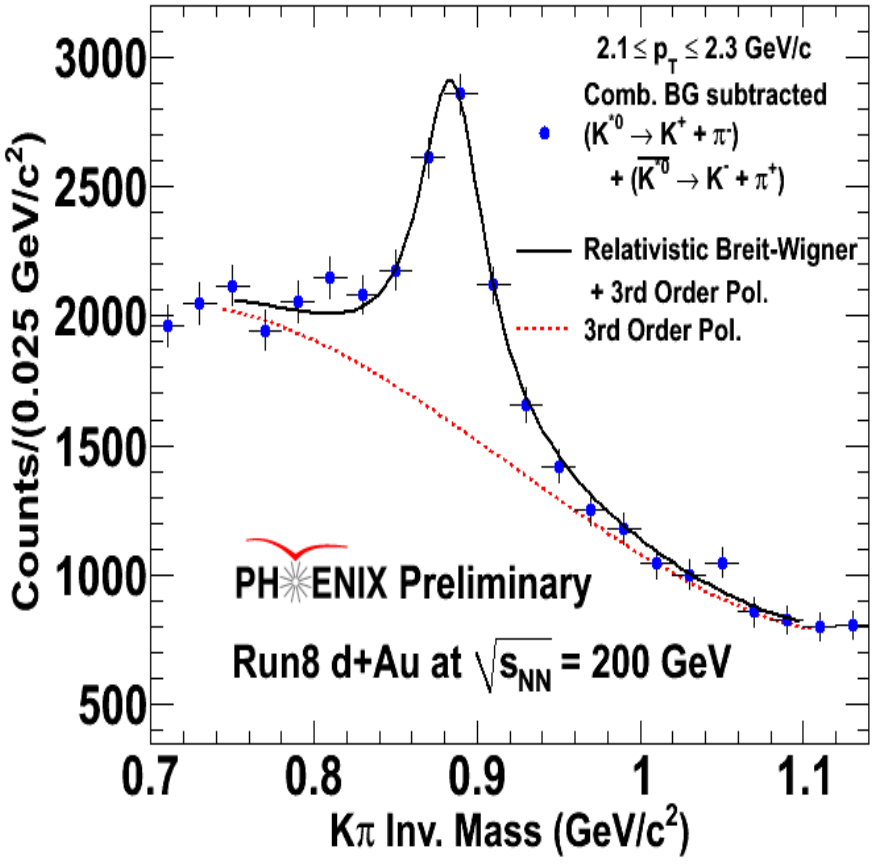


$$m^2 = \frac{p^2}{c^2}\left[\left(\frac{t_{\mathrm{tof}}}{L/c}\right)^2 - 1\right]$$

K* invariant mass plots

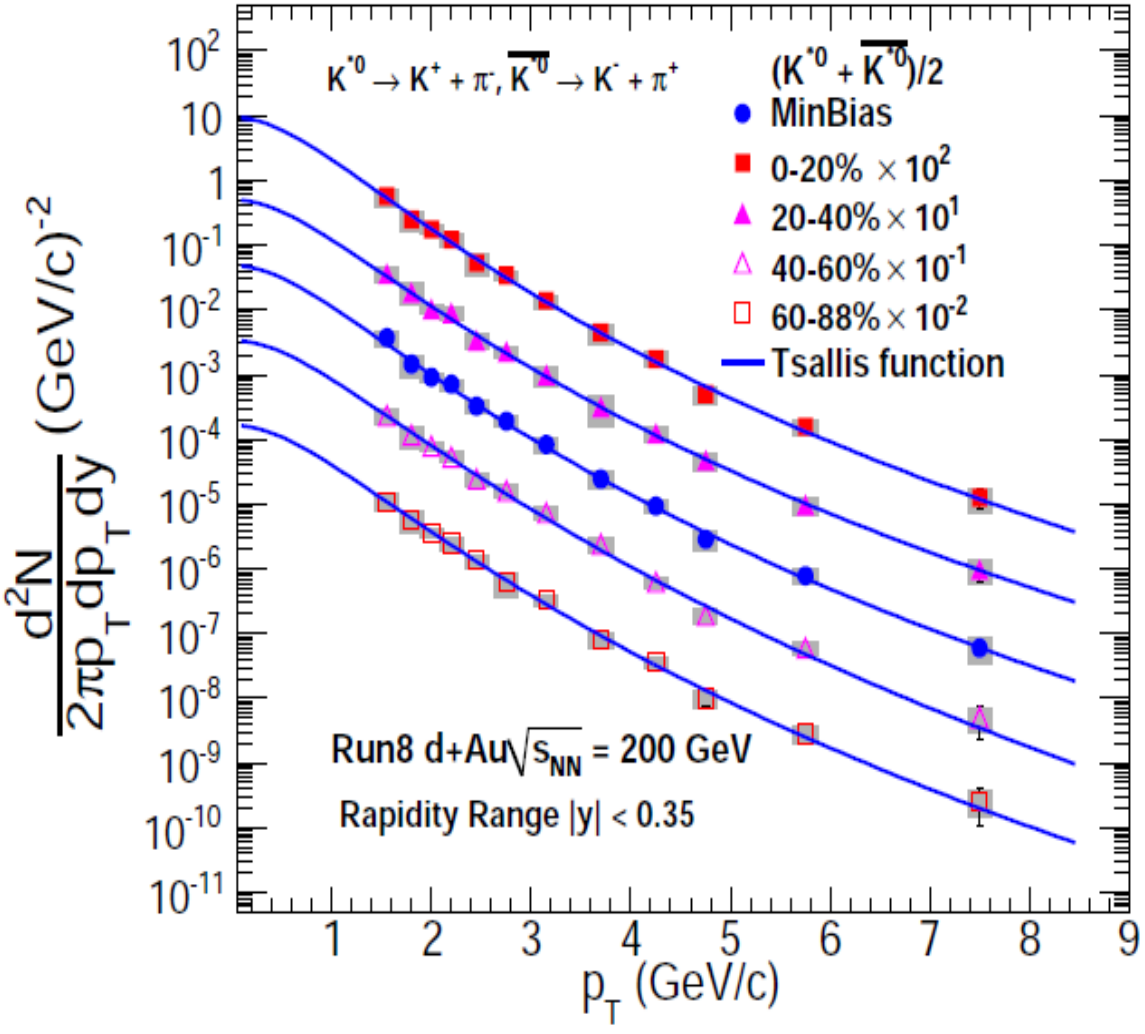


pp System



d-Au System

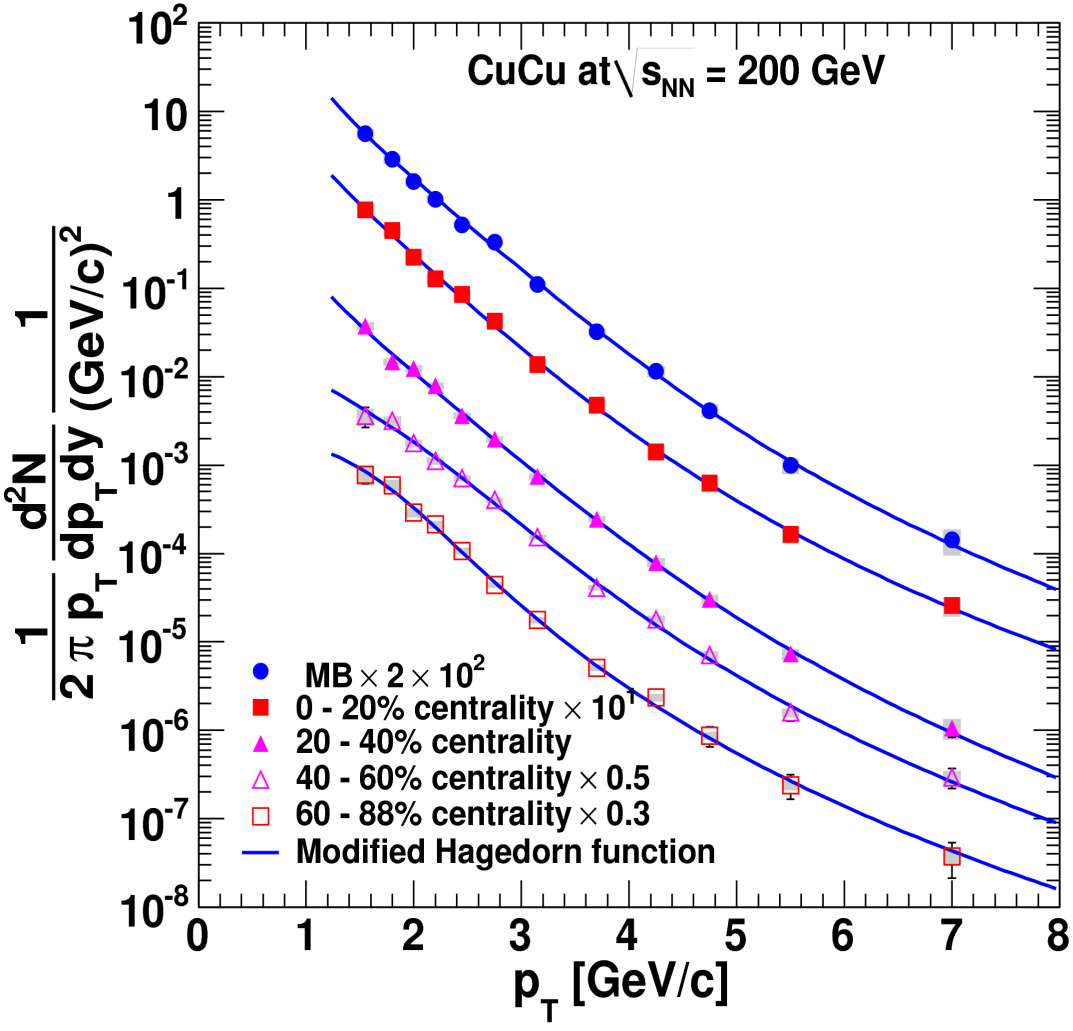
K* Meson in dAu collisions at 200 GeV



The spectra is measured in the range p_T = 1.2 – 7.5 GeV/c.

Well described by Tasllis distribution.

K* Meson in CuCu collisions at 200 GeV

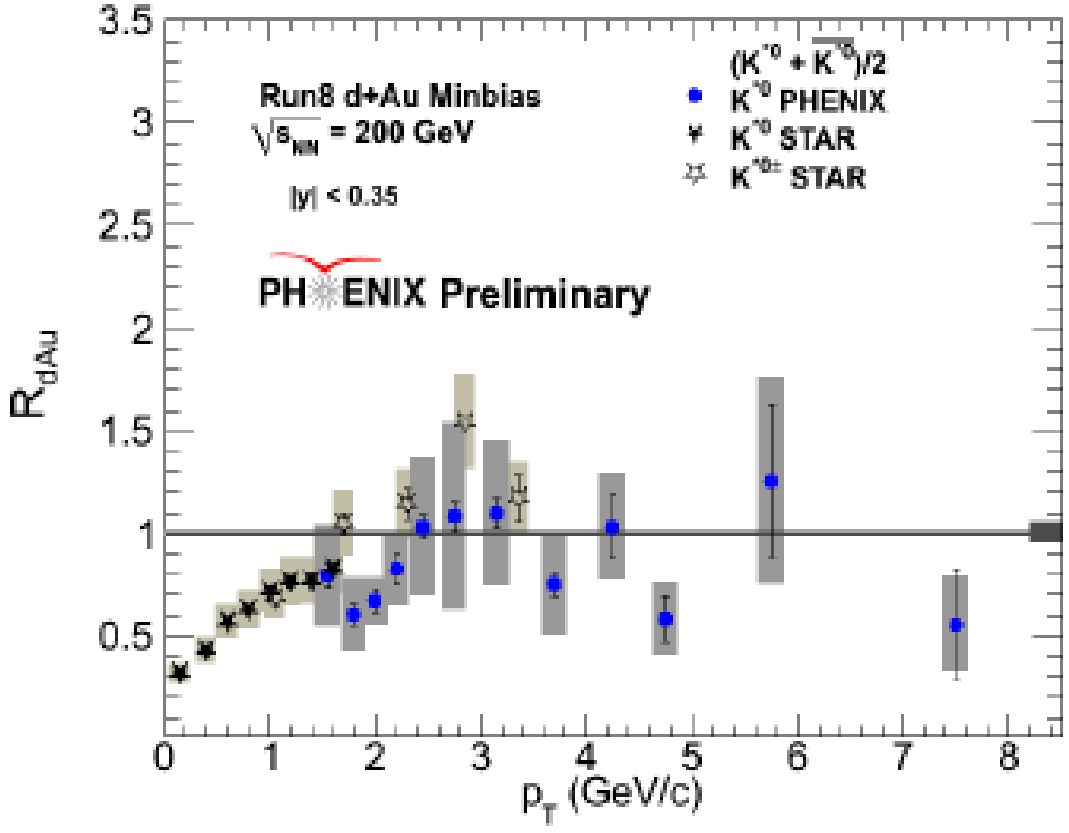


The spectra is measured in the range p_T = 1.4 – 7.0 GeV/c.

Well described by Modified Hagedorn distribution.

$$E\frac{d^3N}{dp^3} = \frac{A}{[exp(-ap_T - bp_T^2) + \frac{p_T}{p_0}]^n}$$

RAA of K* in dAu collisions at 200 GeV

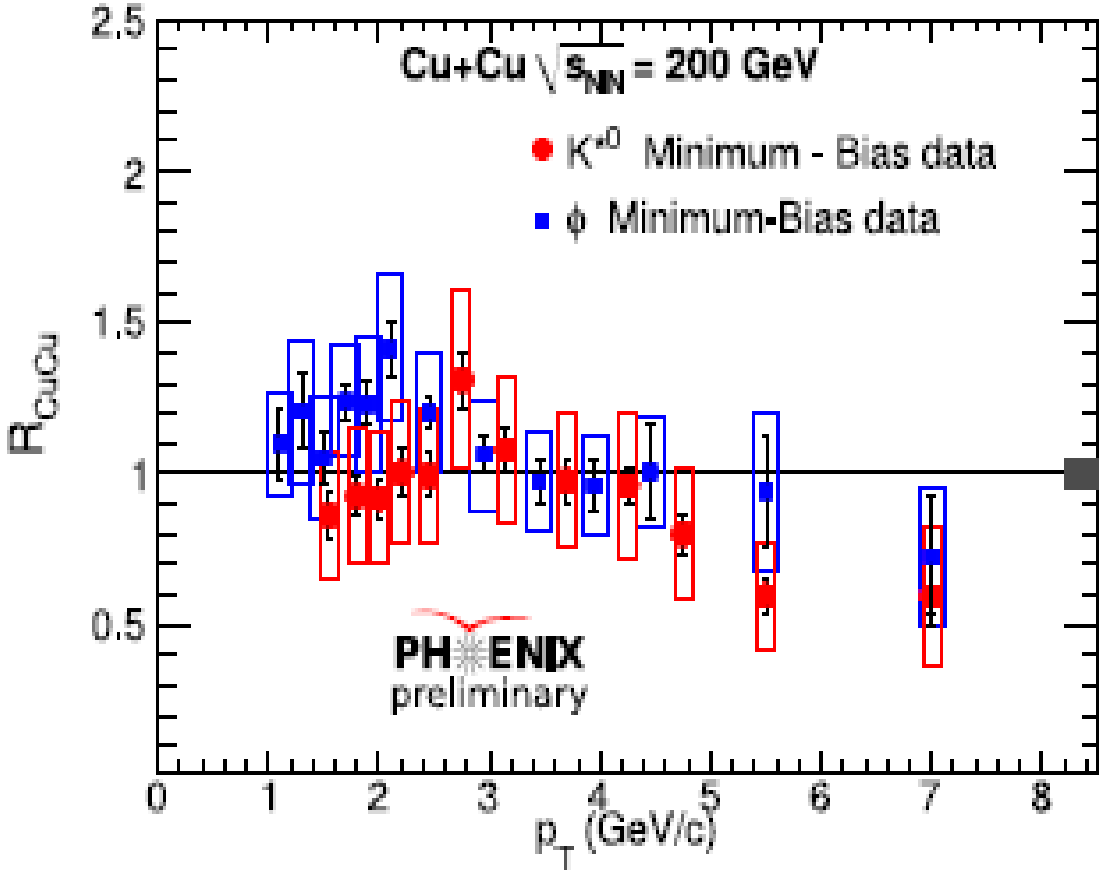


Minimum bias collisions:

The RAA is measured in the range p_T = 1.2 – 7.5 GeV/c.

Except low at p_T it is consistent with unity.

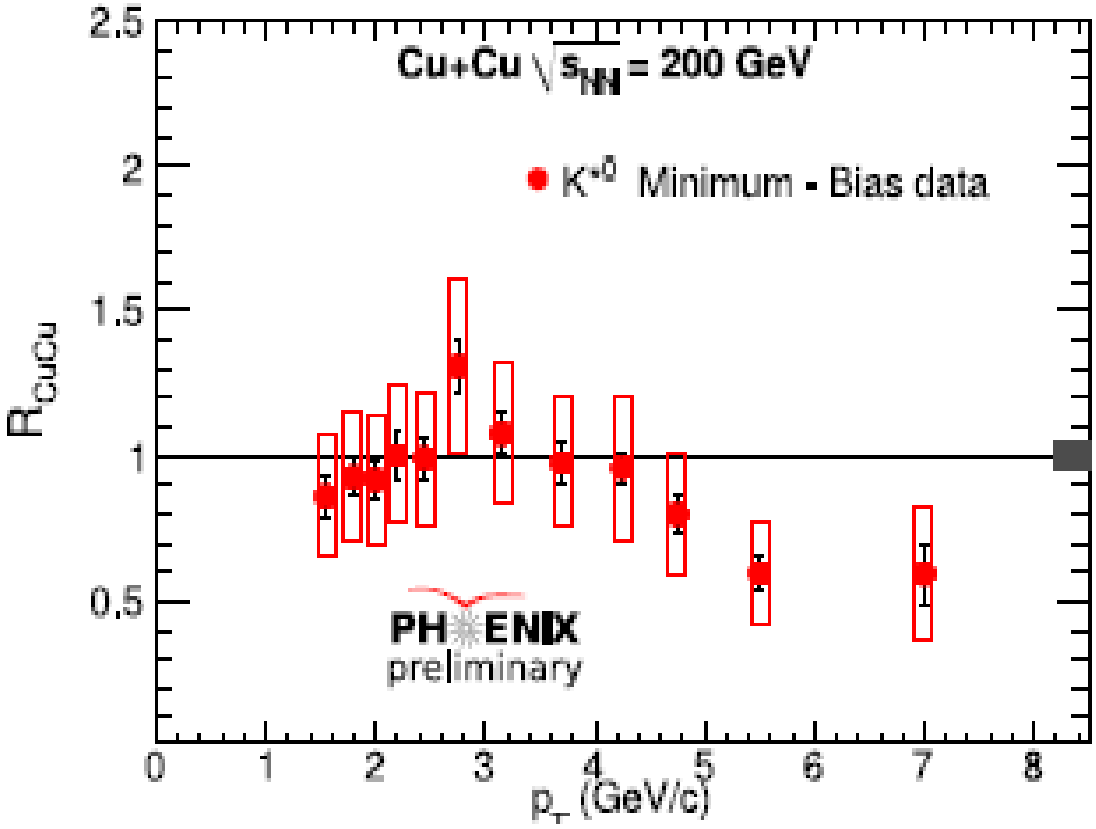
RAA of K* and ϕ in CuCu collisions at 200 GeV



Minimum bias collisions:

K* and ϕ similar except at low pT

RAA of K* in CuCu collisions at 200 GeV

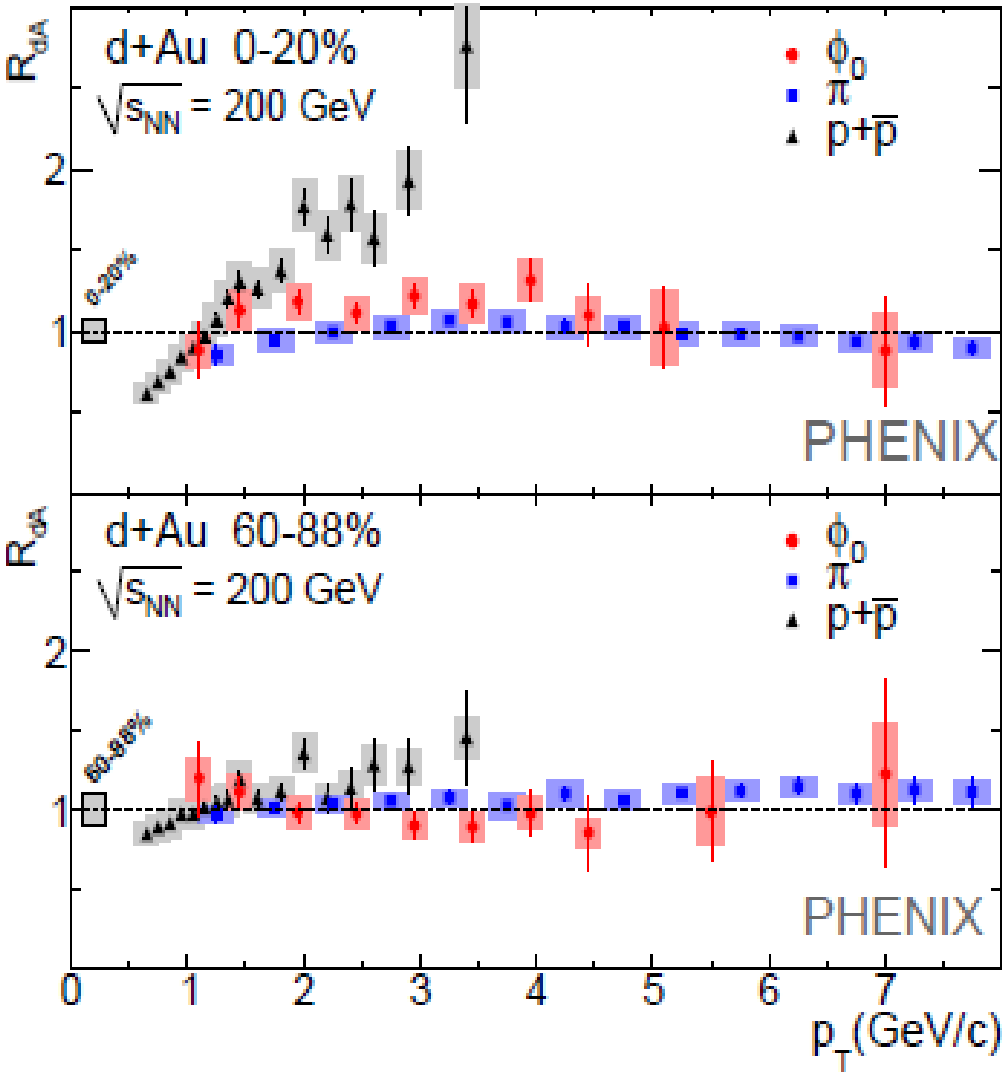


Minimum bias collisions:

The R_{AA} is measured in the range p_T = 1.4 – 7.0 GeV/c.

Suppression at high pT.

R_{AA} of ϕ in d+Au system at 200 GeV



* ϕ R_{AA} is consistent with unity in dAu collisions.

- Consistent with pions.

- The proton and ϕ are different; the proton enhancement is not due to mass and may be related to number of quarks.

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