Various Aspects of (anti)deuteron Spectra in Au+Au Collisions

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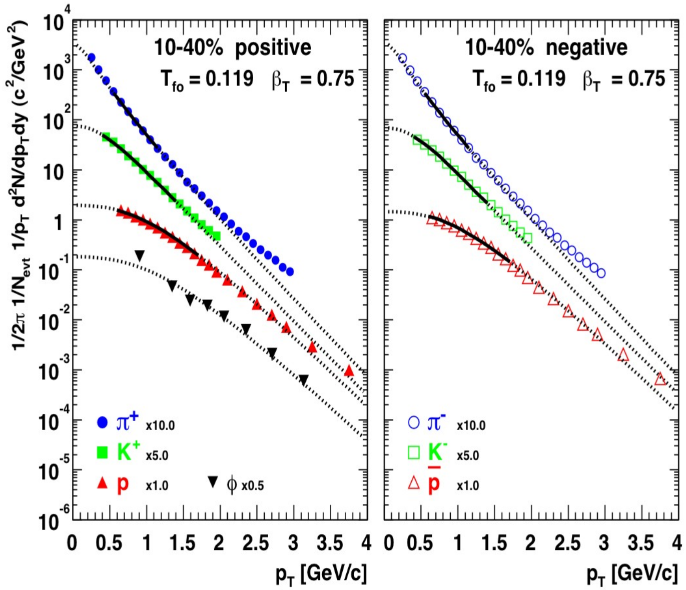
Outline

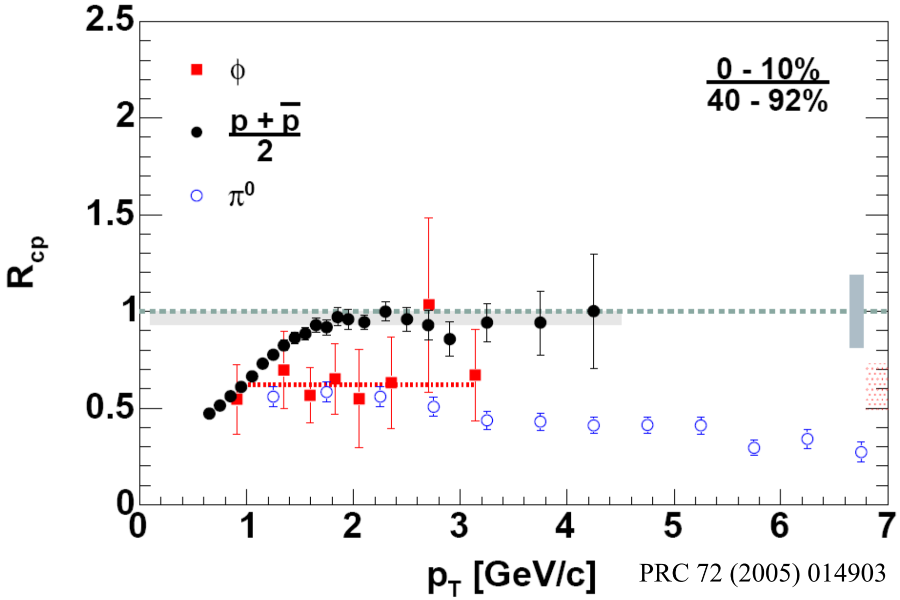
- Motivation
- Particle Identification
- Spectra
- Coalescence Parameter and Source Dynamics
- Particle Ratios and Constraints on Neutron Production
- Conclusion

Physics Motivation

- Source dynamics
  - Spectral shapes change with mass due to radial flow
  - Deuteron spectra can be used to infer source radius, complimentary to HBT measurements



PRC 72 (2005) 014903

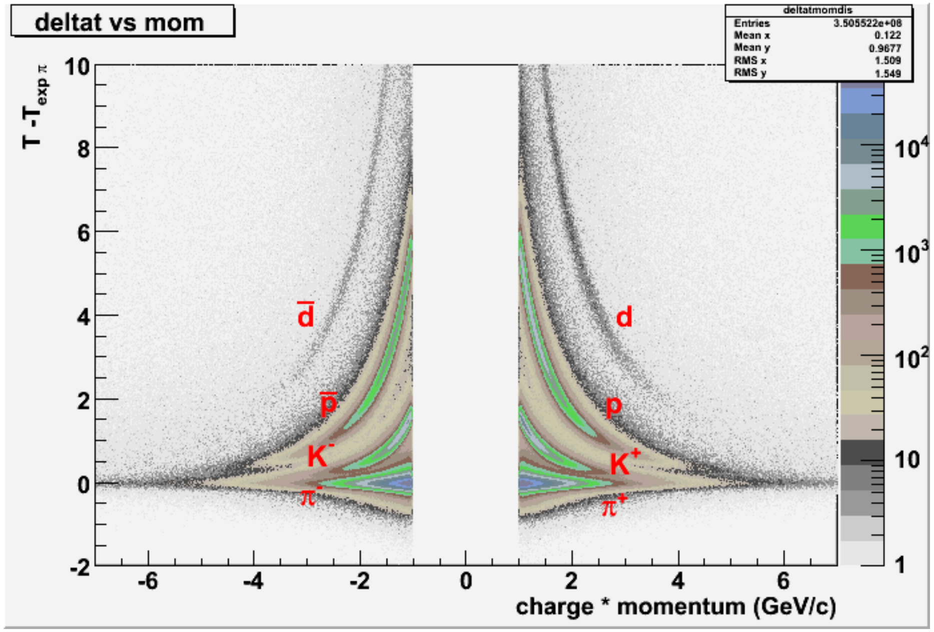


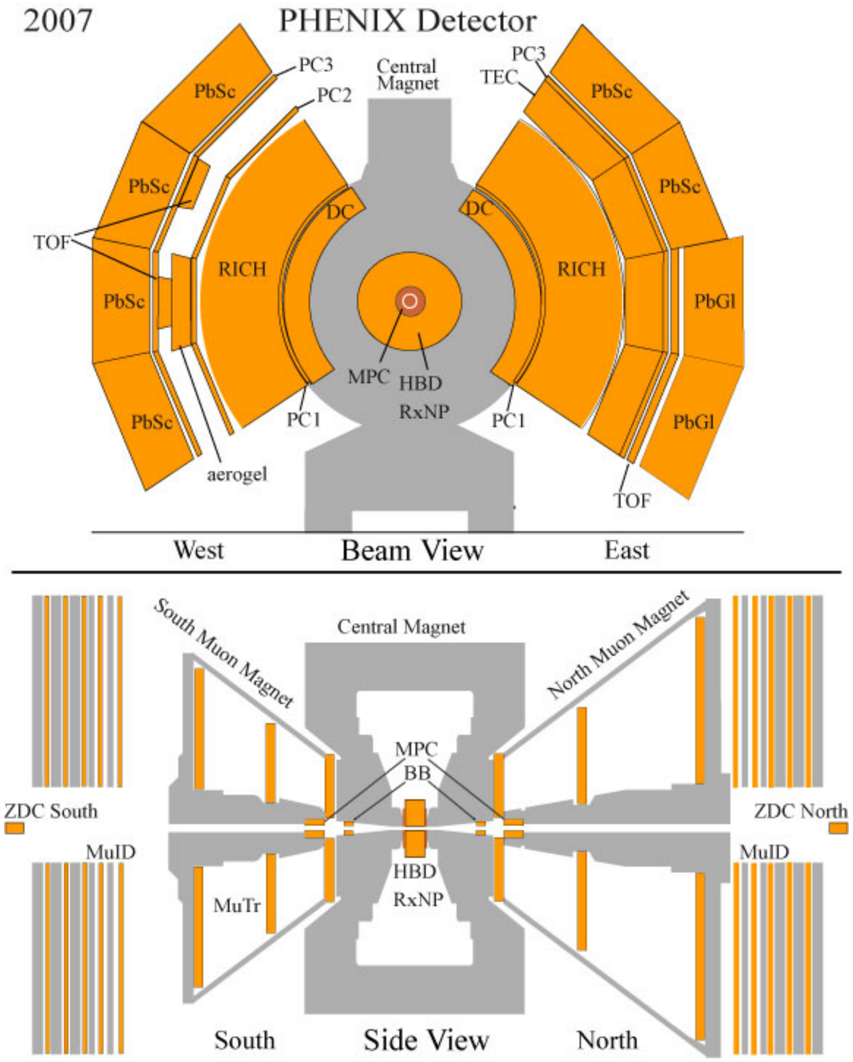
PRC 72 (2005) 014903

- Neutron production
  - Deuterons are produced by coalescence of neutrons and protons, and so can be used to place constraints on neutron production

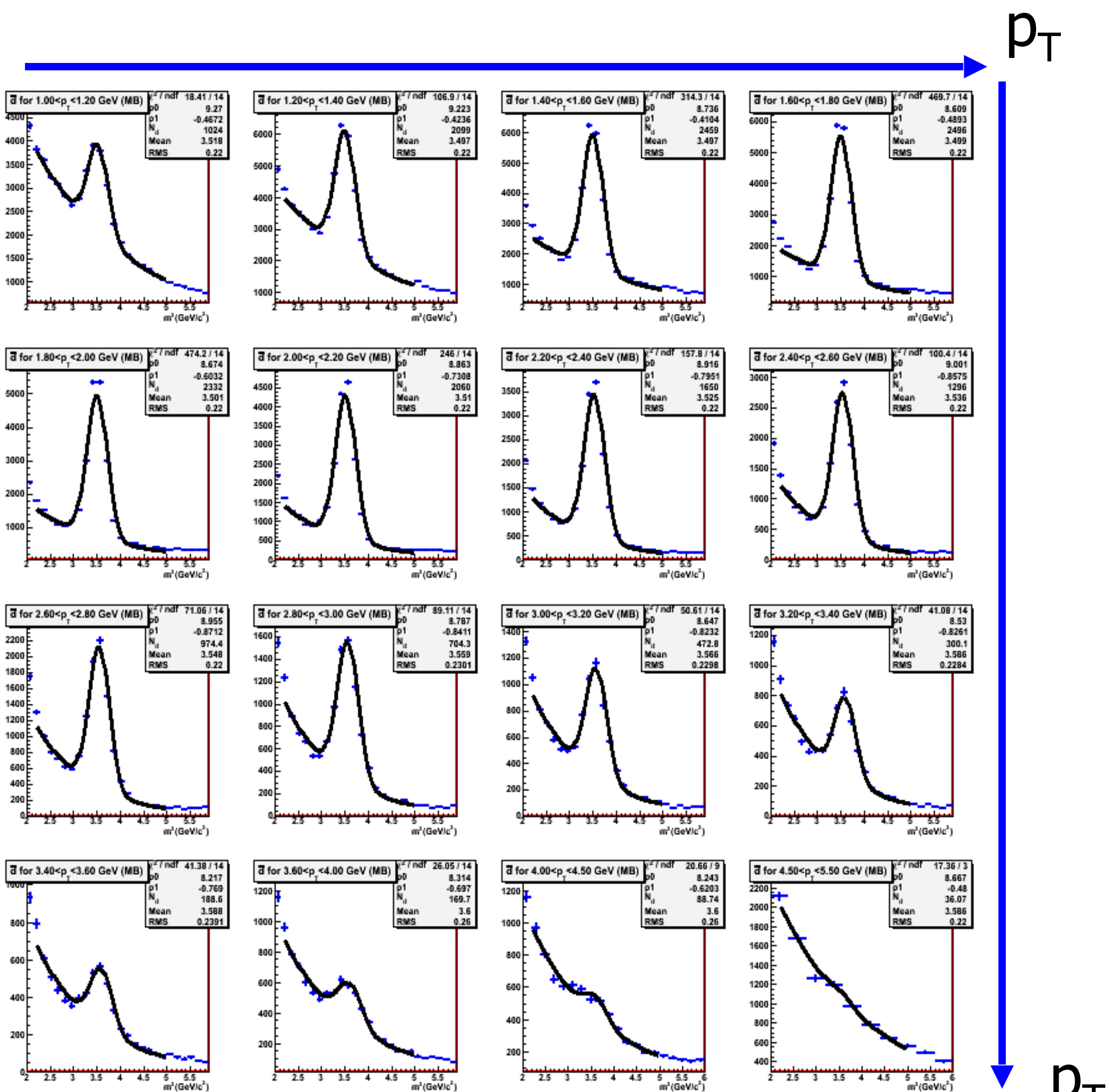
Particle Identification

- PHENIX Run 7
  - Au+Au 200 GeV
  - 1.9 out of 5.5 billion events total used for this study
- TOFW
  - 75 ps timing resolution
  - Excellent PID capabilities



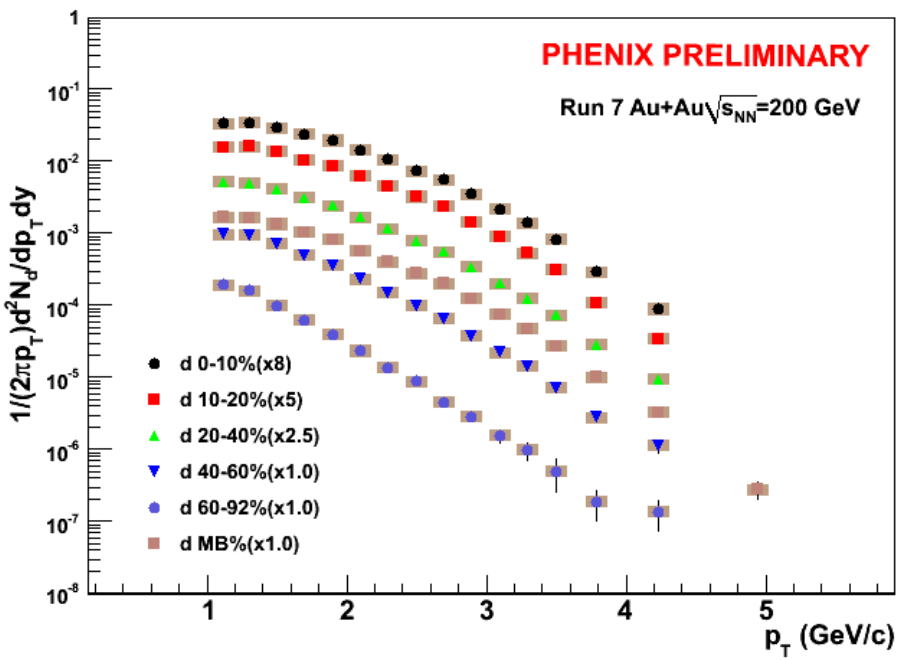


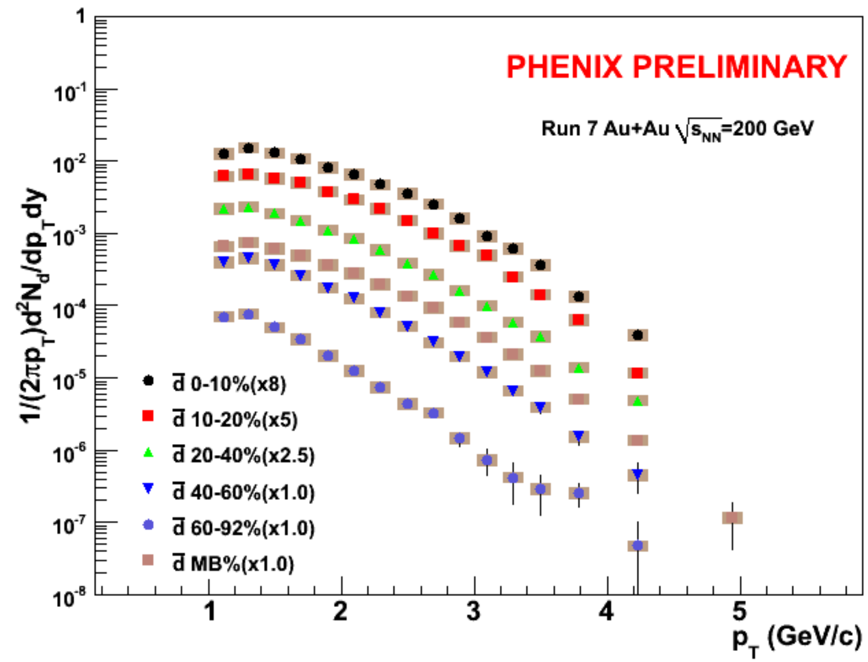
Particle Identification and Yield Extraction



- Fit the mass peak
  - Gaussian + exponential for background
- Extract the yield
  - Integrate under the gaussian

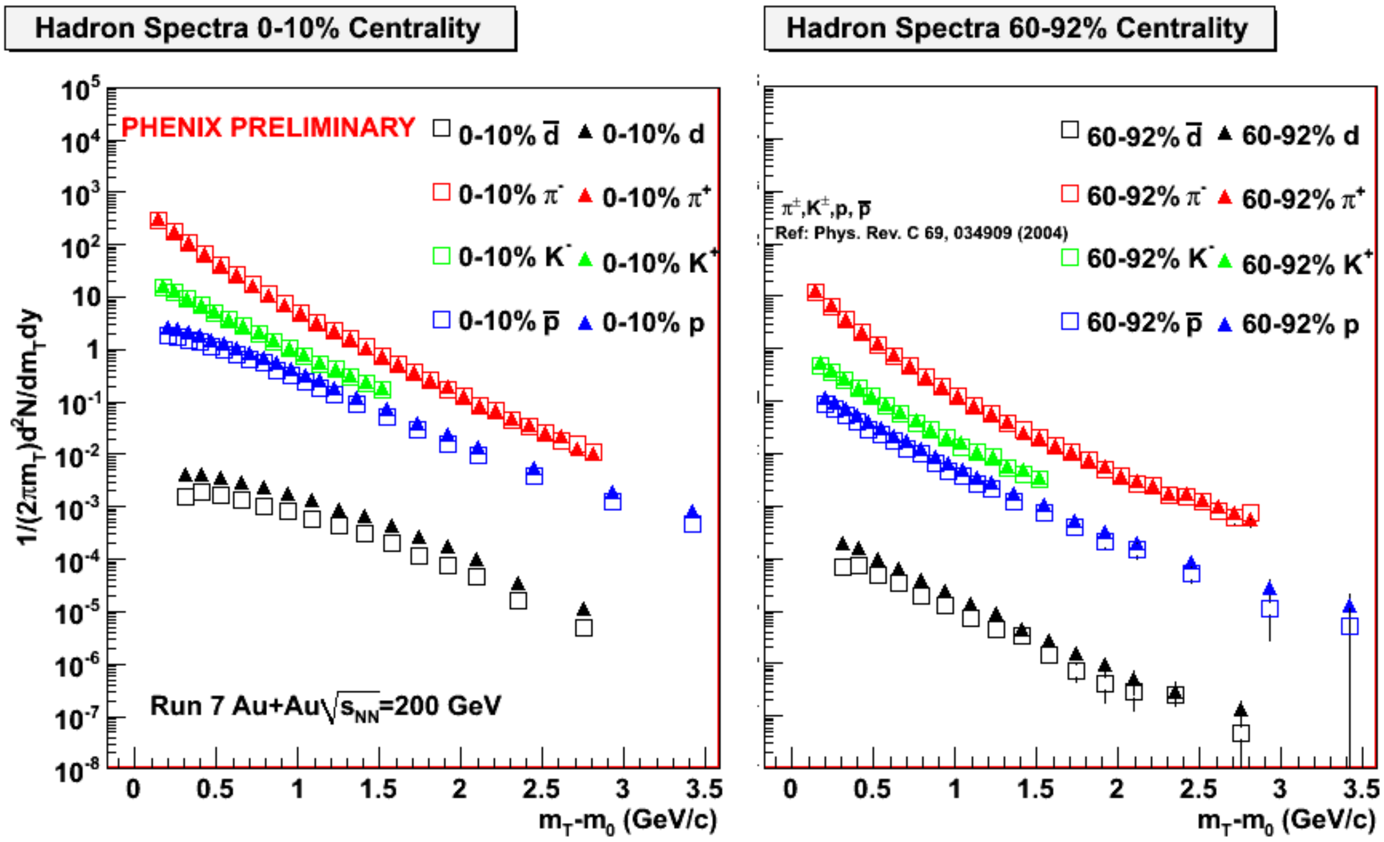
p_T Spectra





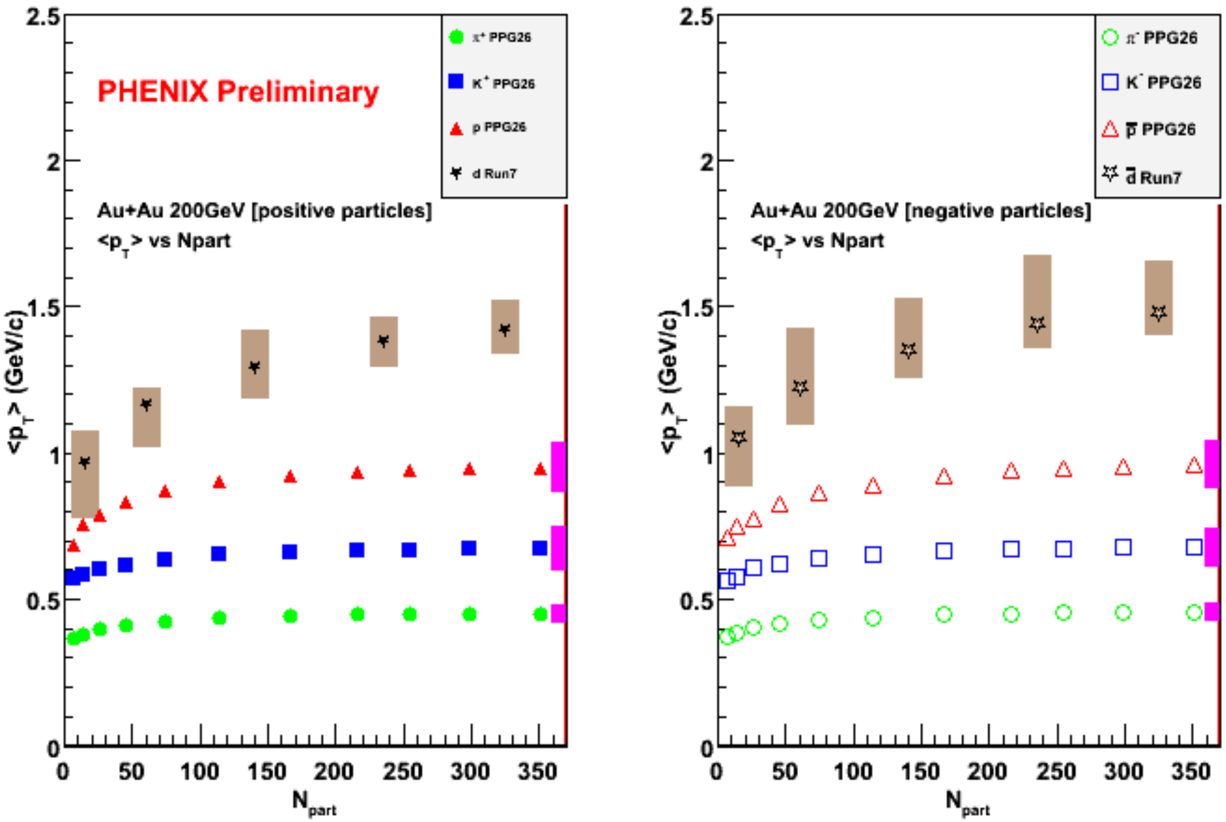
- 5 centrality classes + MinBias
- p_T from 1.1 GeV/c to 4.2 GeV/c (5 GeV/c for MinBias)
- Slope gets flatter with increasing centrality
  - Consistent with radial flow

m_T Spectra



- For central collisions deuteron is flatter than proton due to radial flow
- For peripheral collisions the d and p are have roughly the same slope

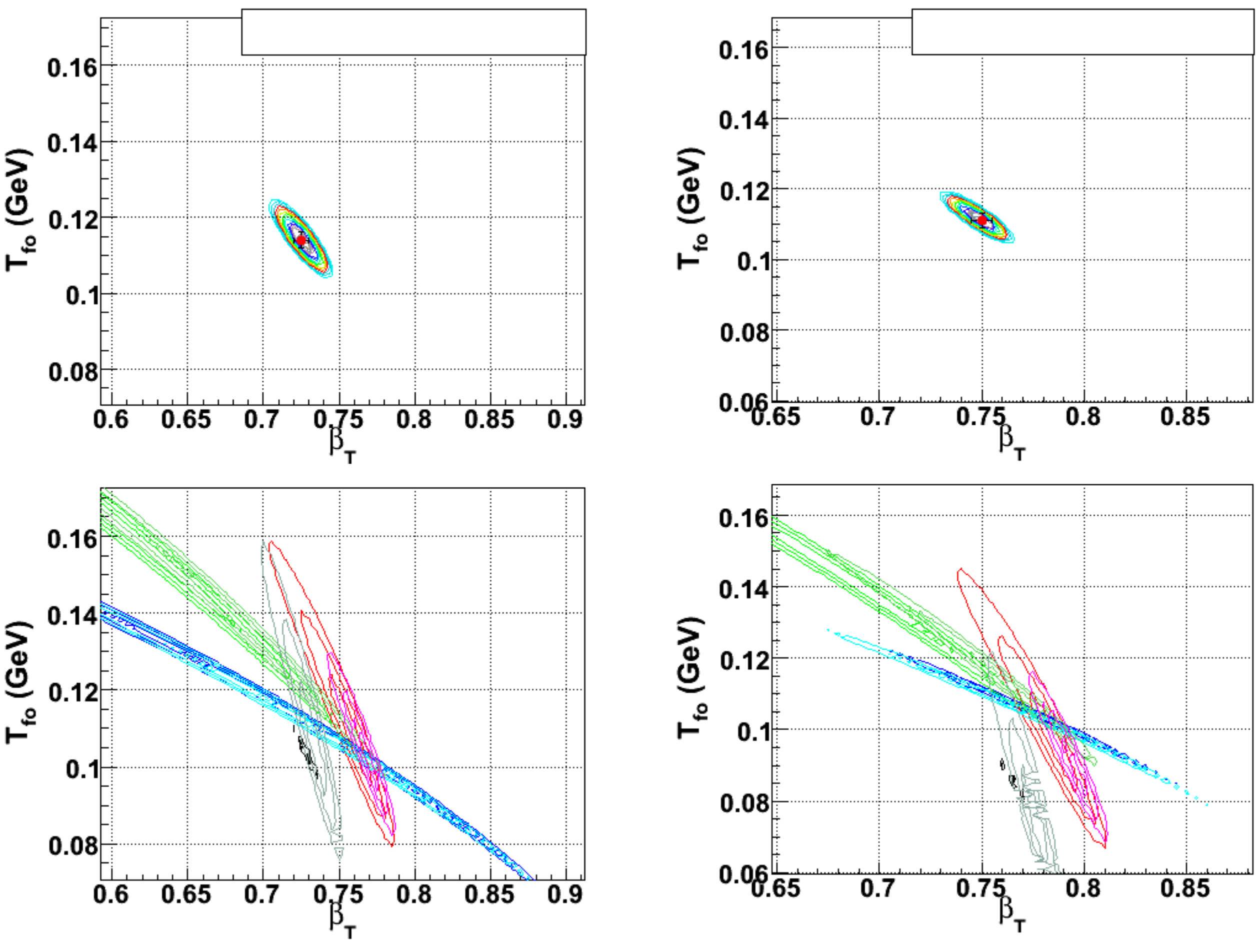
Mean p_T



- Mean p_T inceases with N_{part}
- Consistent with collective expansion
  – Radial flow velocity increases with centrality
  – Heavier particles get the largest increase of $<p_T>$

Blastwave Fits I

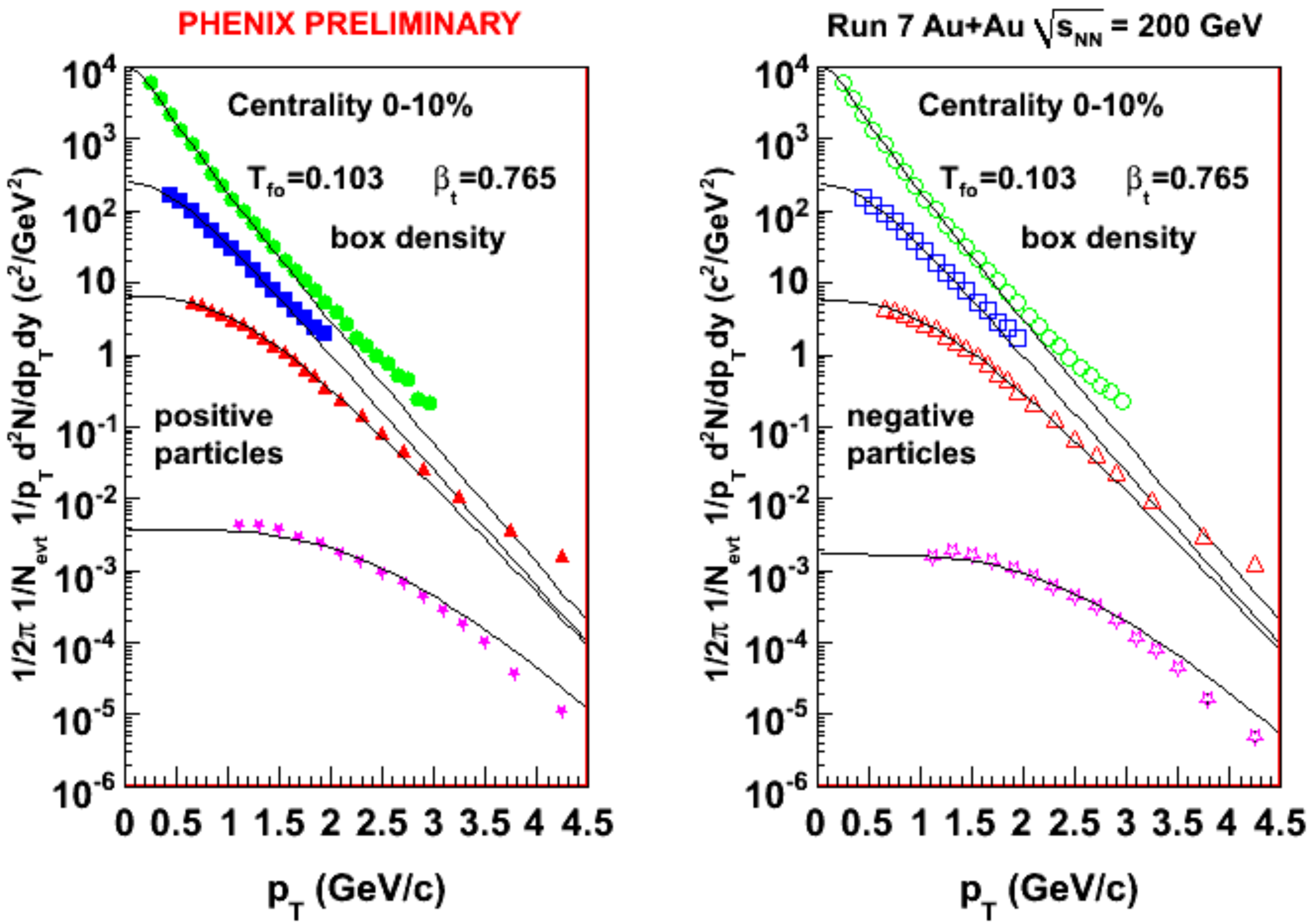
$$1/p_T\, dN/dp_T = A\int f(x)x\,dx\; m_T\, K_1(m_T \cosh \rho/T_{fo})\; I_0(p_T \sinh \rho/T_{fo})$$



- All particles are fit individually
- Consistent overlap for produced hadrons
- NO consistent overlap between deuterons and produced hadrons

Blastwave Fits II

- The fit from the produced particles poorly reproduces the deuteron spectra

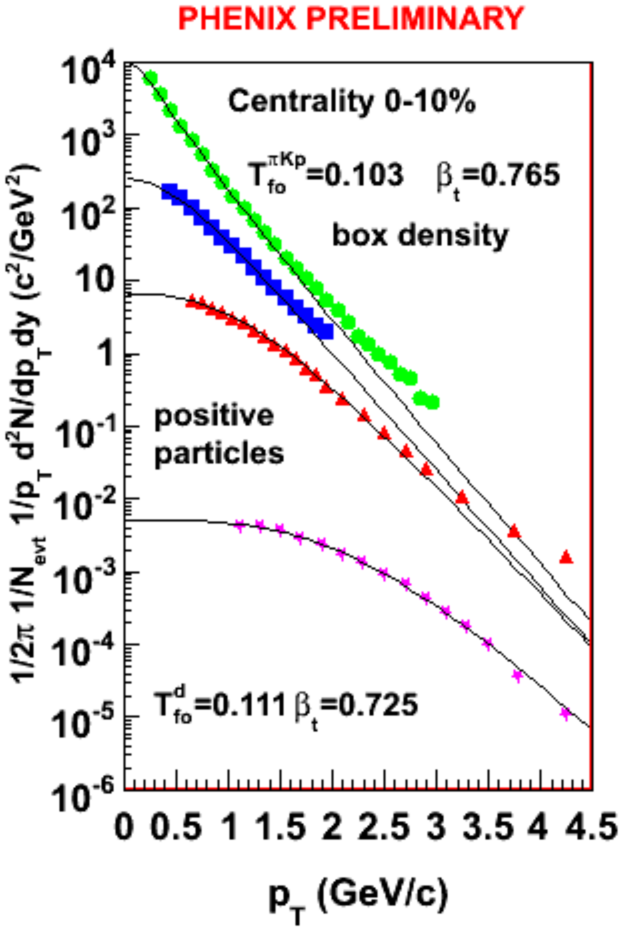


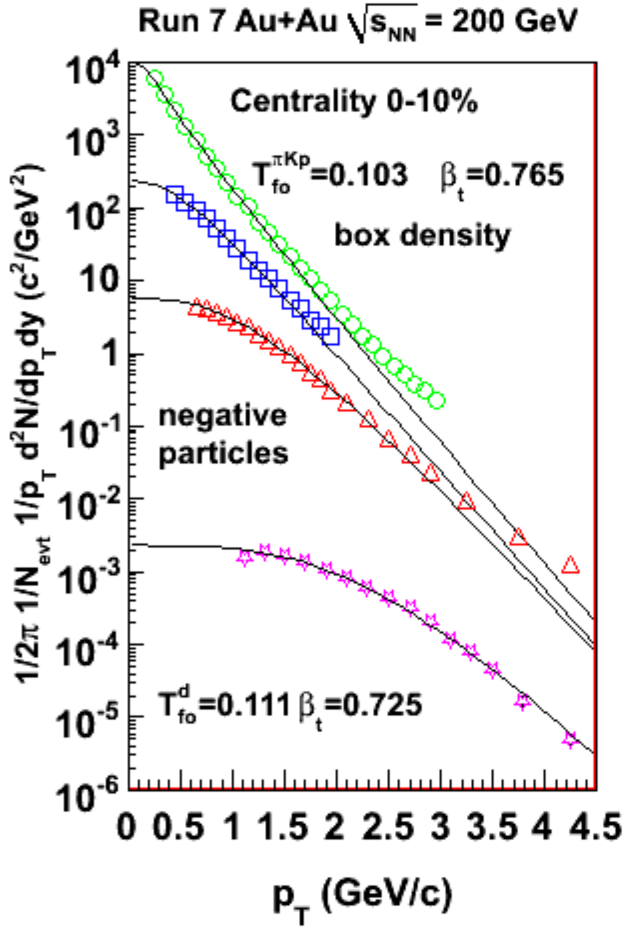
π K p -
PRC 69 (2004) 034909

d -
PHENIX PRELIMINARY
(this study)

Blastwave Fits III

- We use a simultaneous fit to produced hadrons and a separate fit for the deuterons
- These describe the data well, and either a gaussian or box density profile can be used





π K p -
PRC 69 (2004) 034909

d -
PHENIX PRELIMINARY
(this study)

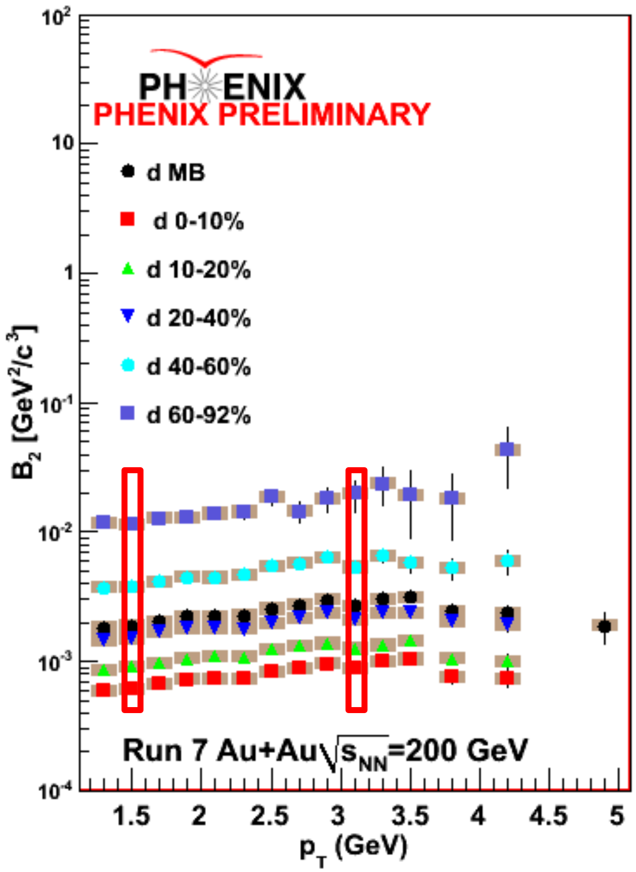
Coalescence Parameter I

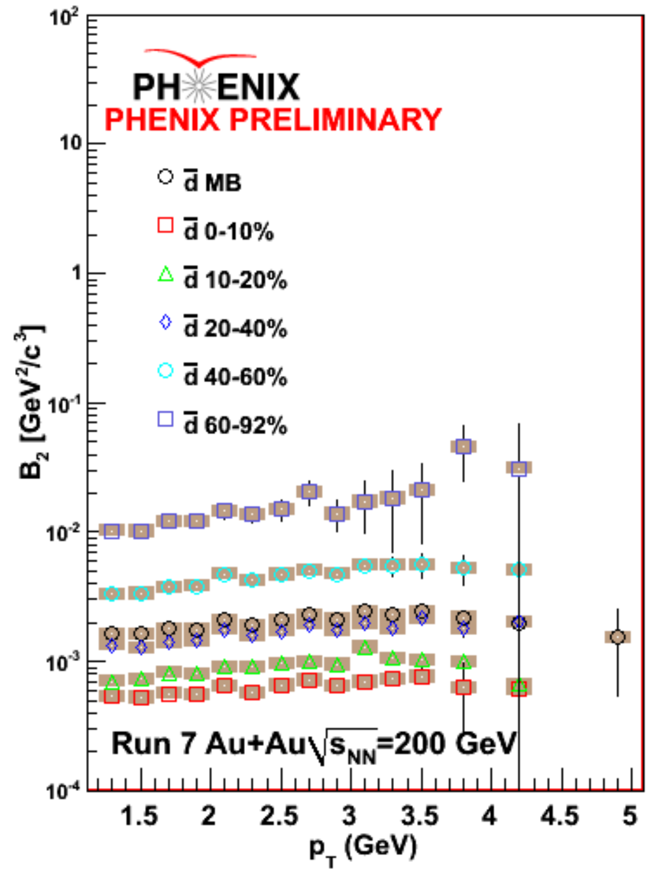
- Defined mathematically as:
  - $p_d = 2p_p$

$$E_d \frac{d^3N_d}{dp_d^3} = B_2\left(E_p \frac{d^3N_p}{dp_p^3}\right)^2$$

- Defined conceptually as probability of proton and neutron to coalesce into deuteron
- Depends on momentum and fireball size

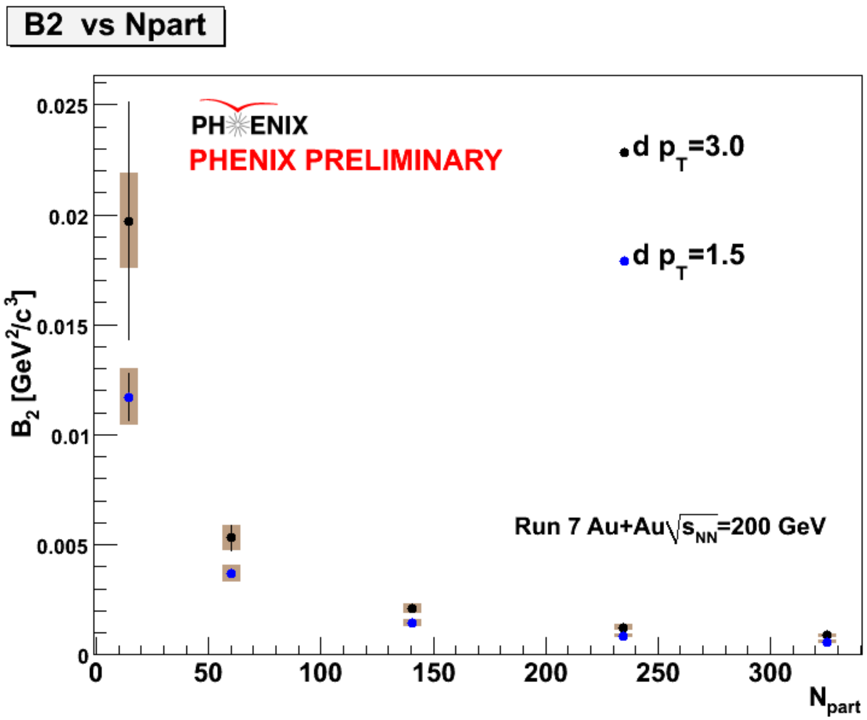
Coalescence Parameter II

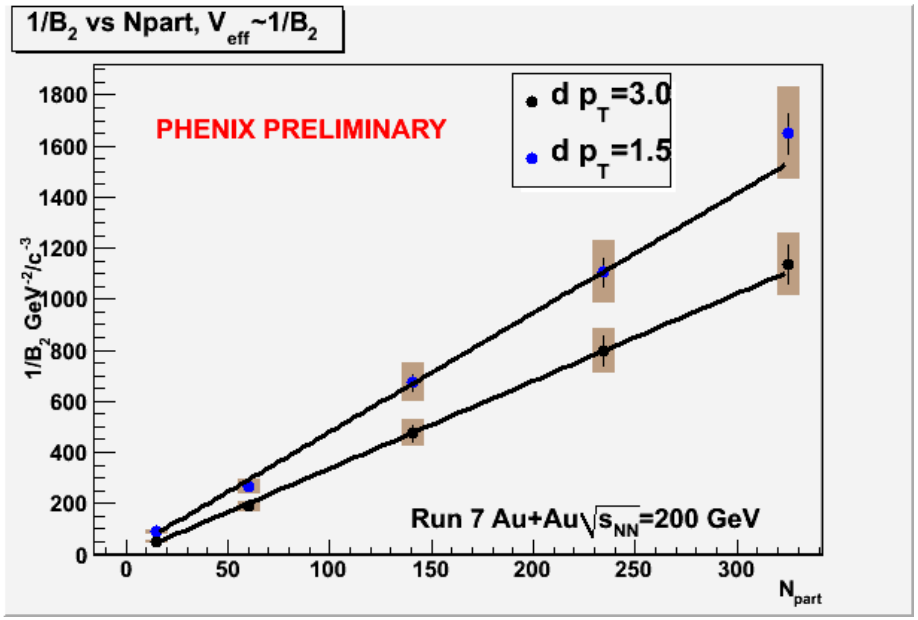




- B_2 increases with p_T
  - This is consistent with an expanding source
- B_2 decreases with centrality

Coalescence Parameter III



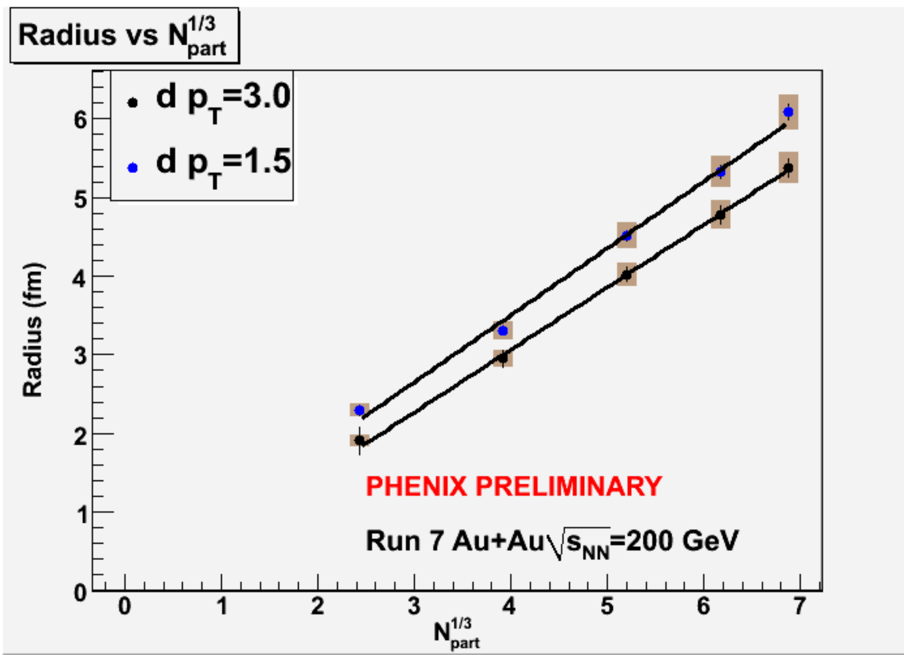


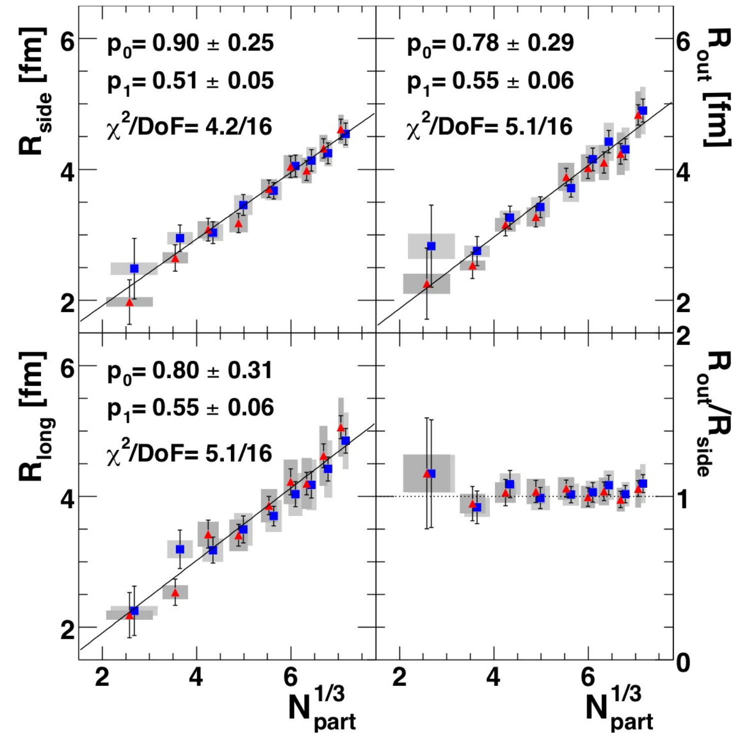
- B_2 decreases hyperbolically with N_{part}
- Effective volume (~$1/B_2$) increases linearly with N_{part}
  - Bulk particle production also goes as N_{part}
  - This implies that freezeout happens at constant particle density

Coalescence Parameter and Source Radius

$$R^3 = \alpha R_{np} (\hbar c)^3 \frac{m_d}{m_p^2} (B_2)^{-1}$$

PRC 17(3) 1051-1070 (1978)

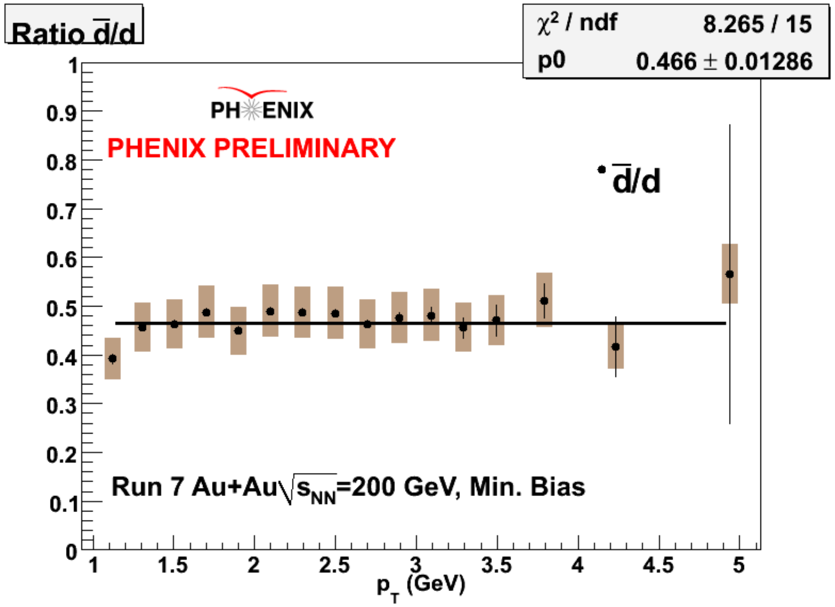


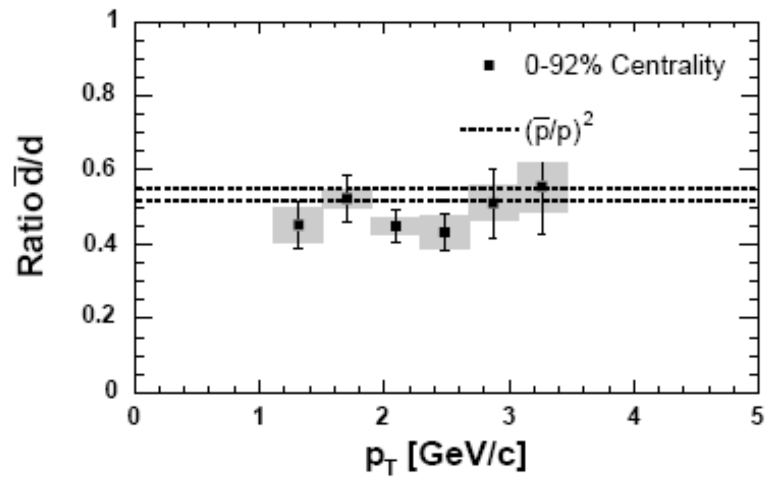


PRL 93 (2004) 152302

- Radius increases linearly vs $N_{part}^{1/3}$
- Good consistency with HBT results

Ratios I

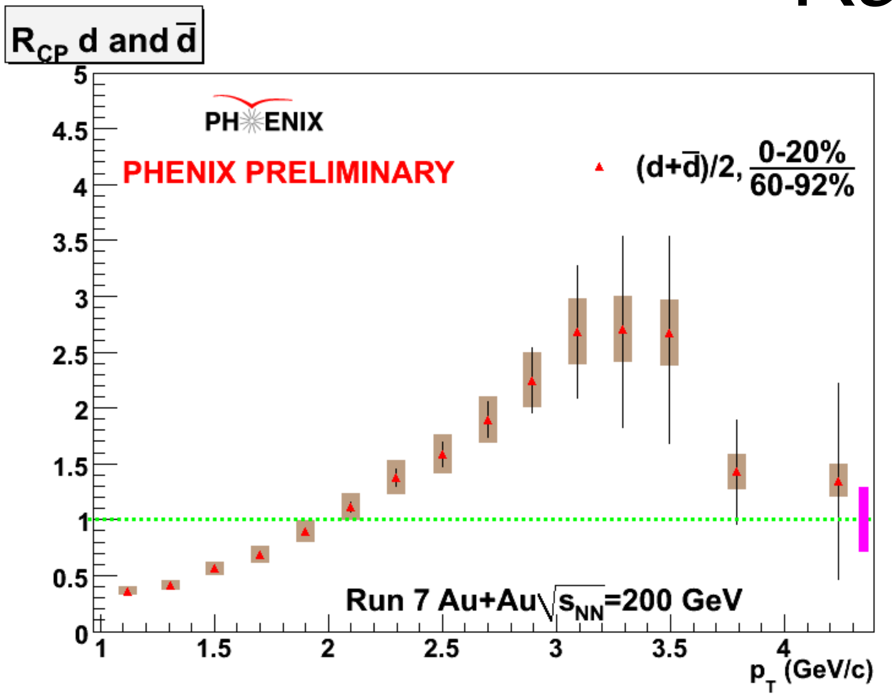


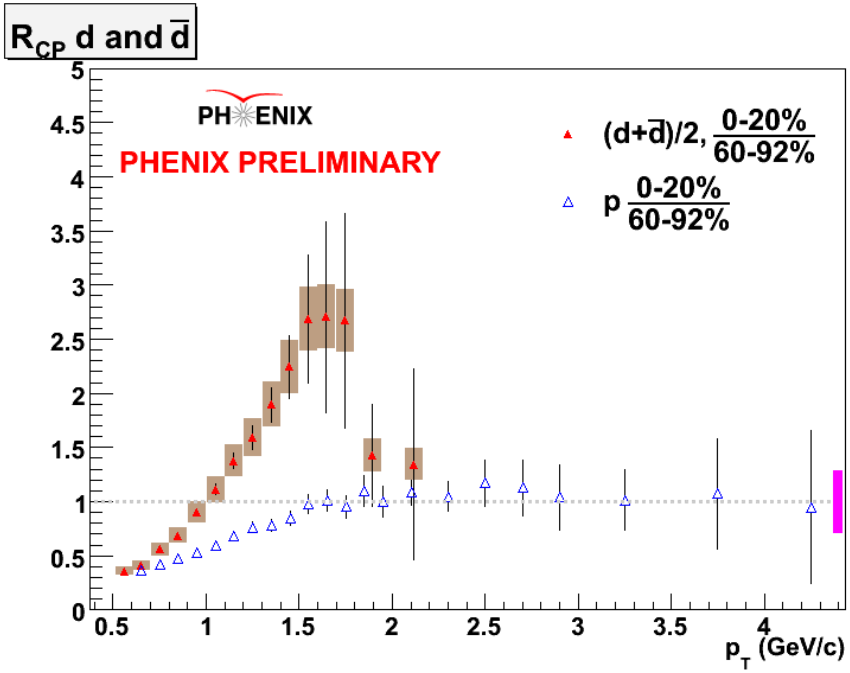


PRL 94 (2005) 122302

- dbar/d is consistent with (pbar/p)^2
- This suggests that nbar/n is similar to pbar/p
- dbar/d can be used to calculate deuteron fugacity -> deuteron chemical potential
- Since proton chemical potential is known, neutron chemical potential can be determined and therefore so can nbar/n
- nbar/n = 0.64 +/- 0.04

Ratios II





deuteron p_T divided by 2 to match the proton

- This measurement constrains the neutron R_{CP} to be similar to that of the proton

$$R_{CP} = \frac{Yield^{central} \bullet N_{coll}^{peripheral}}{N_{coll}^{central} \bullet Yield^{peripheral}}$$

Conclusion

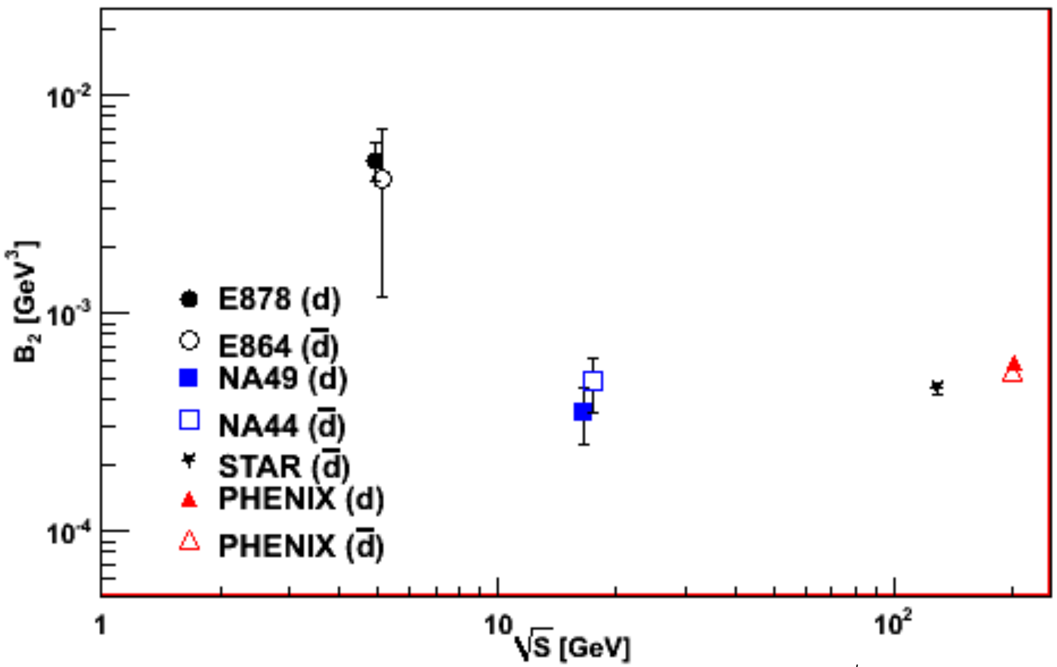
- Deuteron spectra
  - This new study has an expanded p_T reach and more centrality classes than previous studies at RHIC energies
  - The p_T and m_T spectra are consistent with radial flow
  - Mean p_T vs N_{part} also consistent with radial flow
- Blastwave fits
  - (Anti)deuterons do not freeze out contemporaneously with produced hadrons
- Coalescence parameter
  - Source radius decreases with p_T
  - Source radius increases with N_{part}
  - Coalescence probability increases with p_T (expanding source)
  - Effective volume goes as N_{part} (freezeout occurs at common particle density)
- Deuteron ratios
  - dbar/d shows that nbar/n is similar to pbar/p
  - R_{CP} of d+dbar shows that neutron and proton have similar R_{CP}

BACKUP SLIDES

B_2 vs Collision Energy

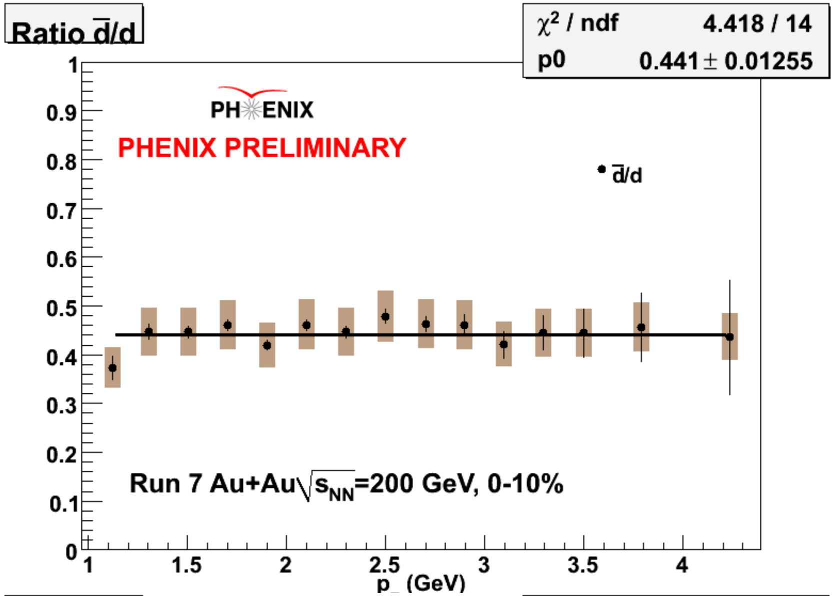
- Consistency between 17 GeV, 130 GeV, and 200 GeV
- Similar freezeout conditions at RHIC and SPS

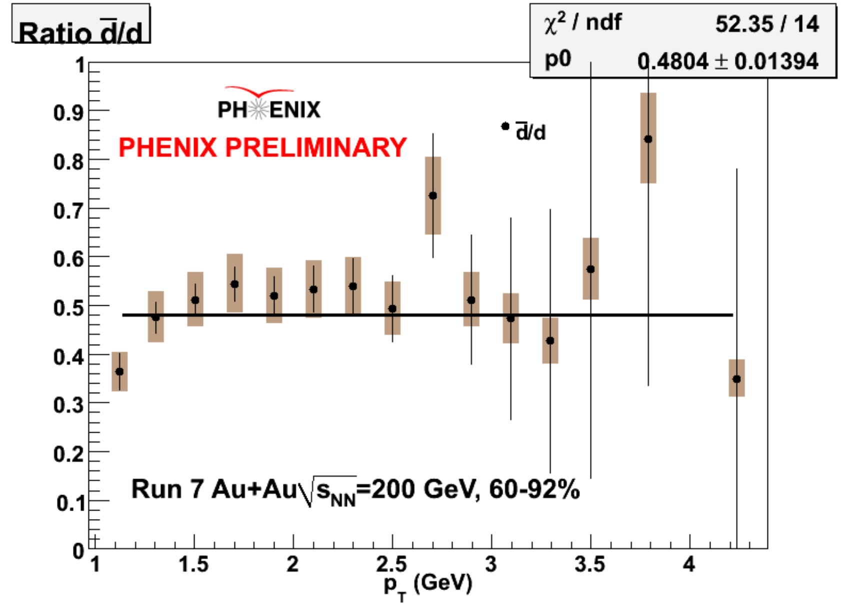
AGS SPS RHIC

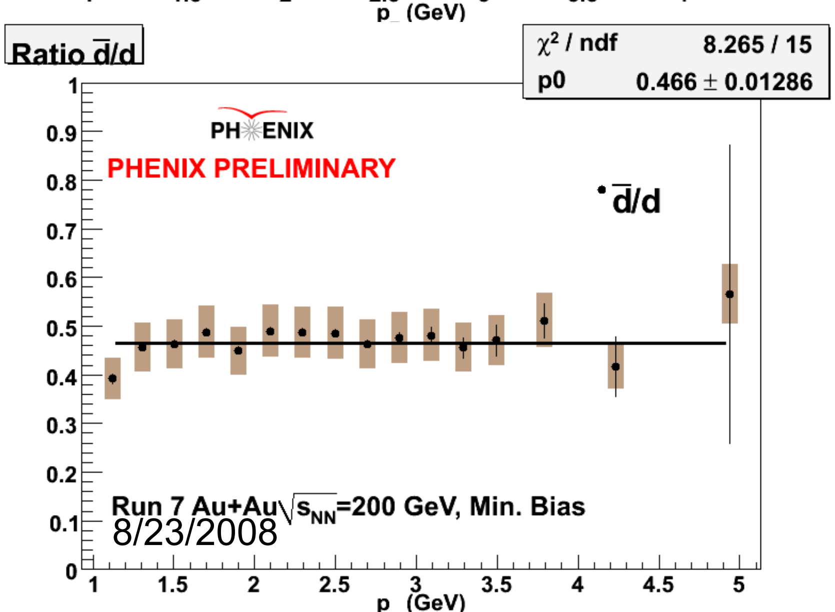


B_2 for central collisions at various $\sqrt{s}$

Ratios I



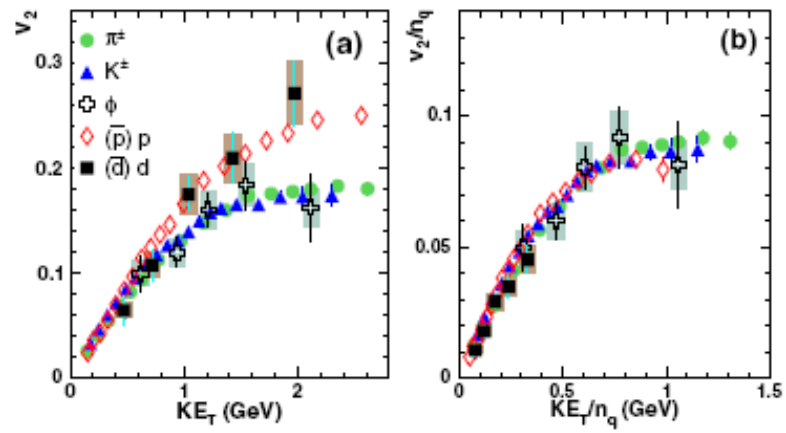




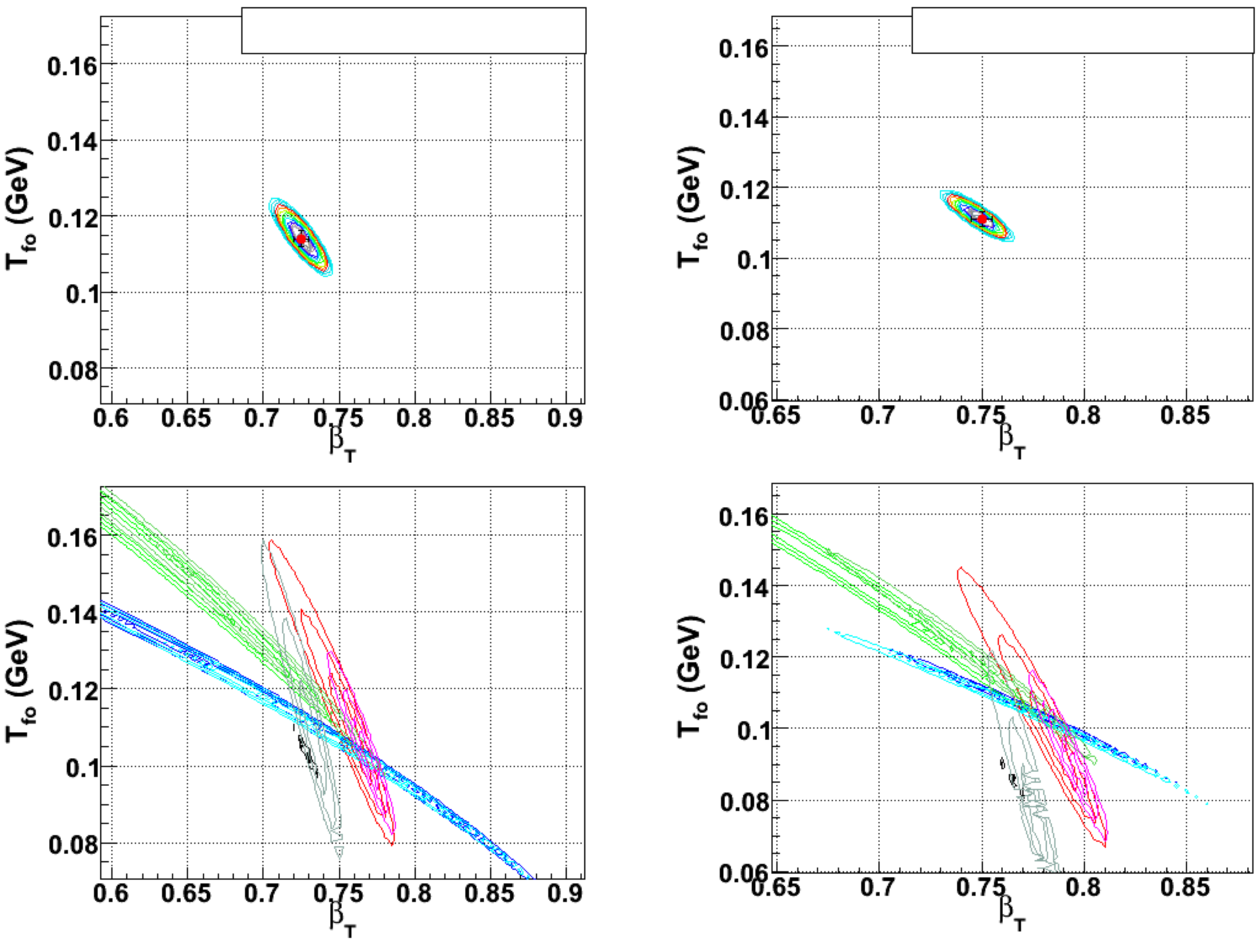
- dbar/d is consistent with (pbar/p)^2
- This measurement suggests that nbar/n is similar to pbar/p

Flow

- Deuteron flow follows NCQ scaling
- This suggests that neutron flow follows NCQ scaling



Blastwave Fits I



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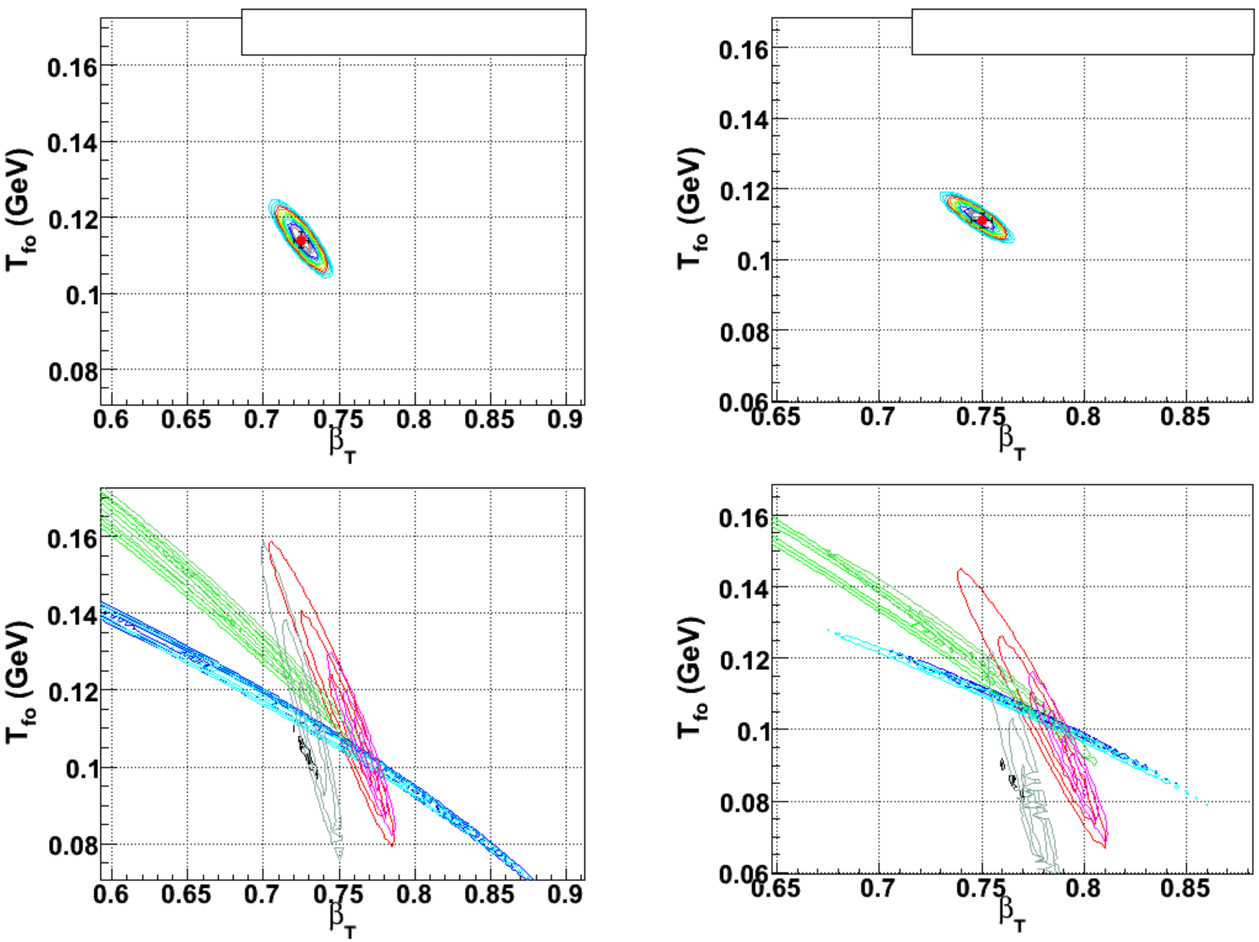

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