Scaling Properties of Identified Hadron Transverse Momentum Spectra in Au+Au and Cu+Cu Collisions at RHIC-PHENIX

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Hadron production in heavy ion collisions at RHIC

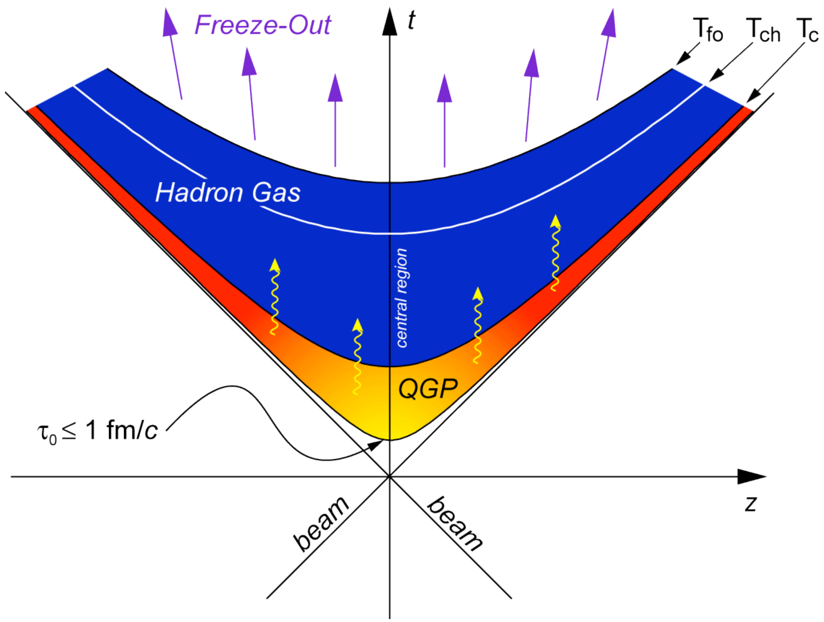
- Hadron production mechanisms:
  - Thermal emission
  - Quark recombination
  - Jet fragmentation

- Bulk properties of the system:
  - Thermalization
  - Collective flow
  - Freeze-out (Chemical, Kinetic)

Soft

- High-p_T phenomena in the medium:
  - Jet quenching(Energy loss)
  - Particle correlation of jets

Hard



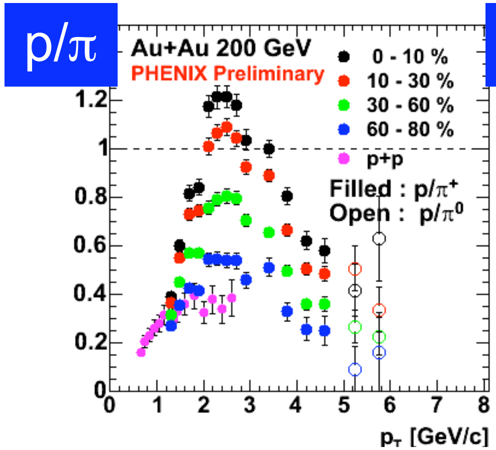
Space-time evolution of a heavy ion collision

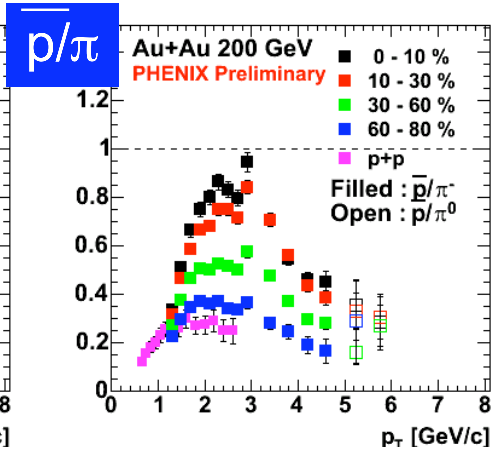
- Single particle spectra and particle ratios provide the most basic observables to investigate the mechanisms of hadron production.

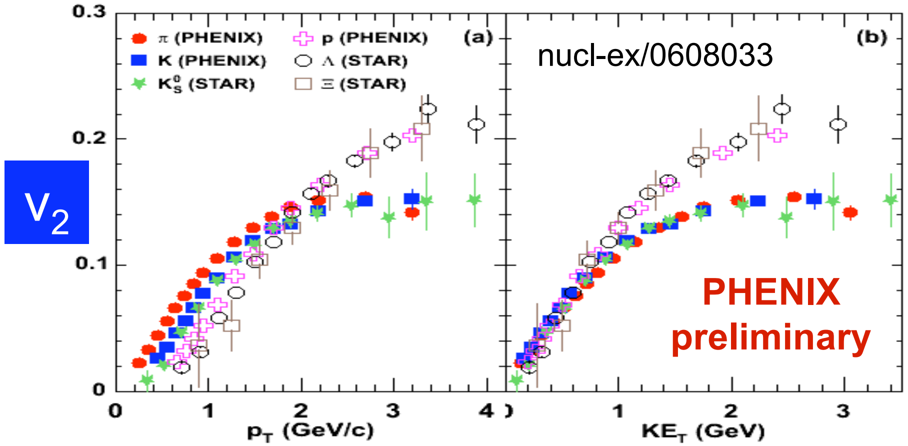
- Particle Identification (PID) over wide p_T range is also crucial.

Hadron production at intermediate p_T

- Baryon/meson difference at intermediate p_T (2~5 GeV/c)
  - Baryon enhancement in particle ratios
  - Splitting of v_2 strength into baryon/meson groups
- Now explained in quark recombination picture
- A transition from soft to hard production at intermediate p_T







(=m_T-m)

What is the next?

Purposes:

- Relative contributions of hadron production mechanisms (soft/hard)
- Scaling properties of identified hadron p_T spectra in different collision systems.

↓

- Systematic scan over different collision systems (colliding species, beam energies) with available data obtained at PHENIX.

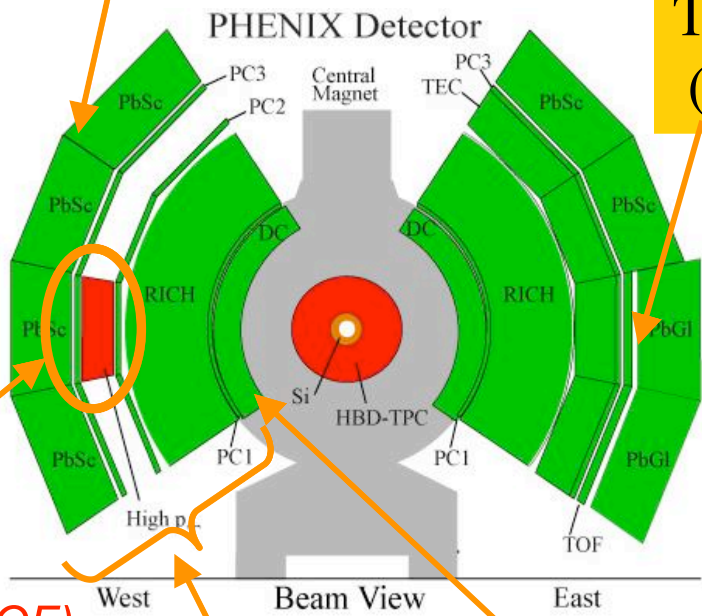
(Au+Au, Cu+Cu at $\sqrt{s_{NN}}$ = 62.4, 200 GeV)

PHENIX Detector

- Central Arm Detectors
- Centrality and Reaction Plane
-determined on an E-by-E basis.
- PID (particle identification) is
  a powerful tool to study hadron
  production.

EM Calorimeter (PID)

TOF
(PID)



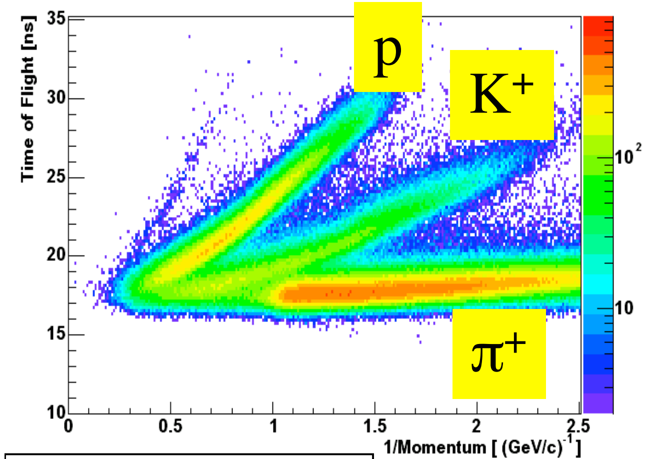
Aerogel Cherenkov (PID)

Drift Chamber
(momentum meas.)

Tracking detectors
(PC1,PC2,PC3)

Aerogel Cherenkov (ACC)

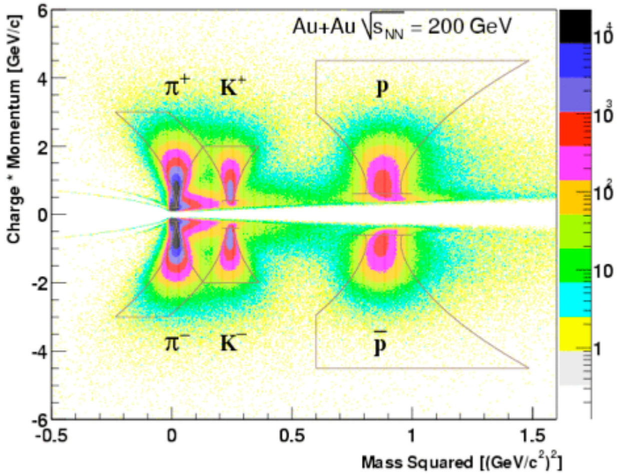
p ($\bar{p}$) ID up to 7 GeV/c



Veto for proton ID

Time of Flight (TOF)

p ($\bar{p}$) ID up to 4 GeV/c



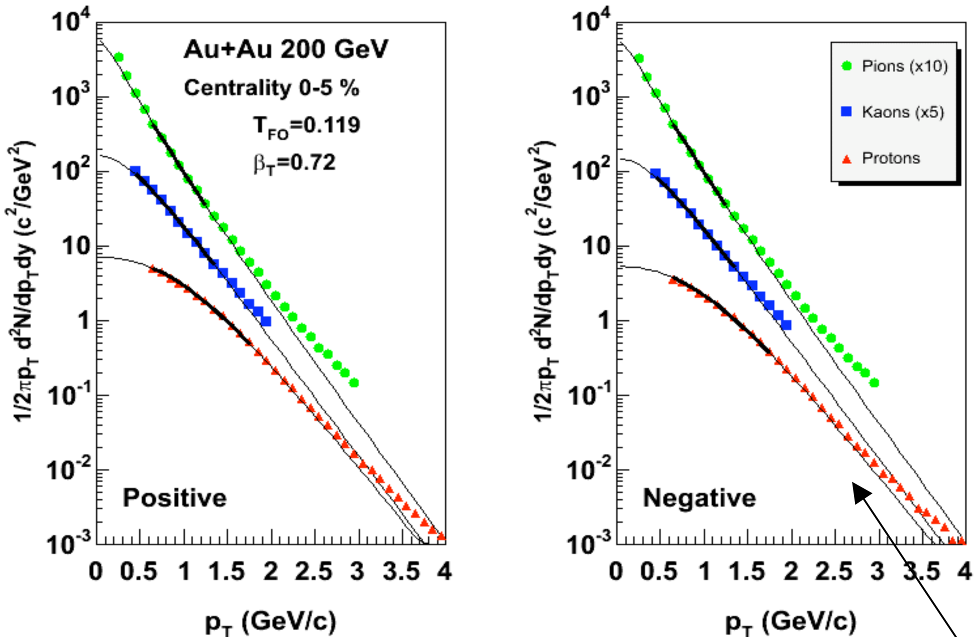
Blast-wave Model Fit

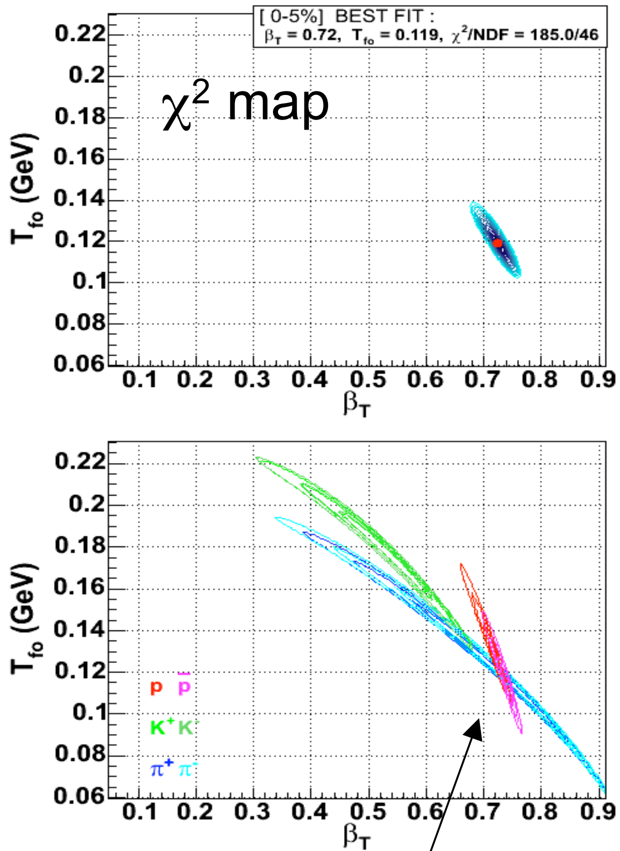
* Ref: PRC48(1993)2462

- Blast-wave model is a hydrodynamic-inspired model.
- Extracting kinetic freeze-out properties with BW model.
- Simultaneous fit to p_T spectra (π/K/p) for each centrality class.

$$\frac{dn}{m_T\, dm_T} \propto \int_0^R r\, dr\, m_T\, K_1\!\left(\frac{m_T \cosh\rho}{T}\right) I_0\!\left(\frac{p_T \sinh\rho}{T}\right)$$

$$\rho = \tanh^{-1}\beta_r \qquad \beta_r(r) = \beta_s f(r)$$

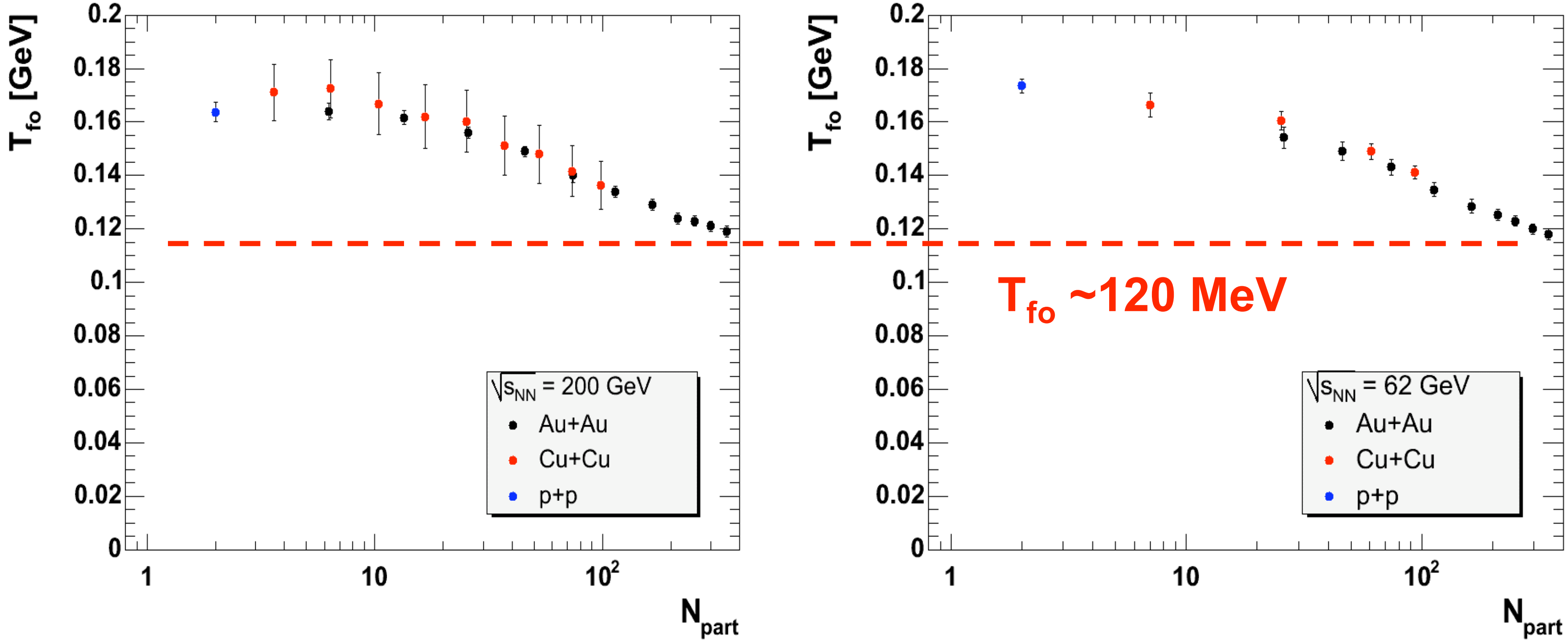




(* Resonance decay feed-down correction not applied.
Instead, tighter p_T fitting range used.
π; 0.6-1.2 GeV/c K; 0.4-1.4 GeV/c, p/pbar; 0.6-1.7 GeV/c)

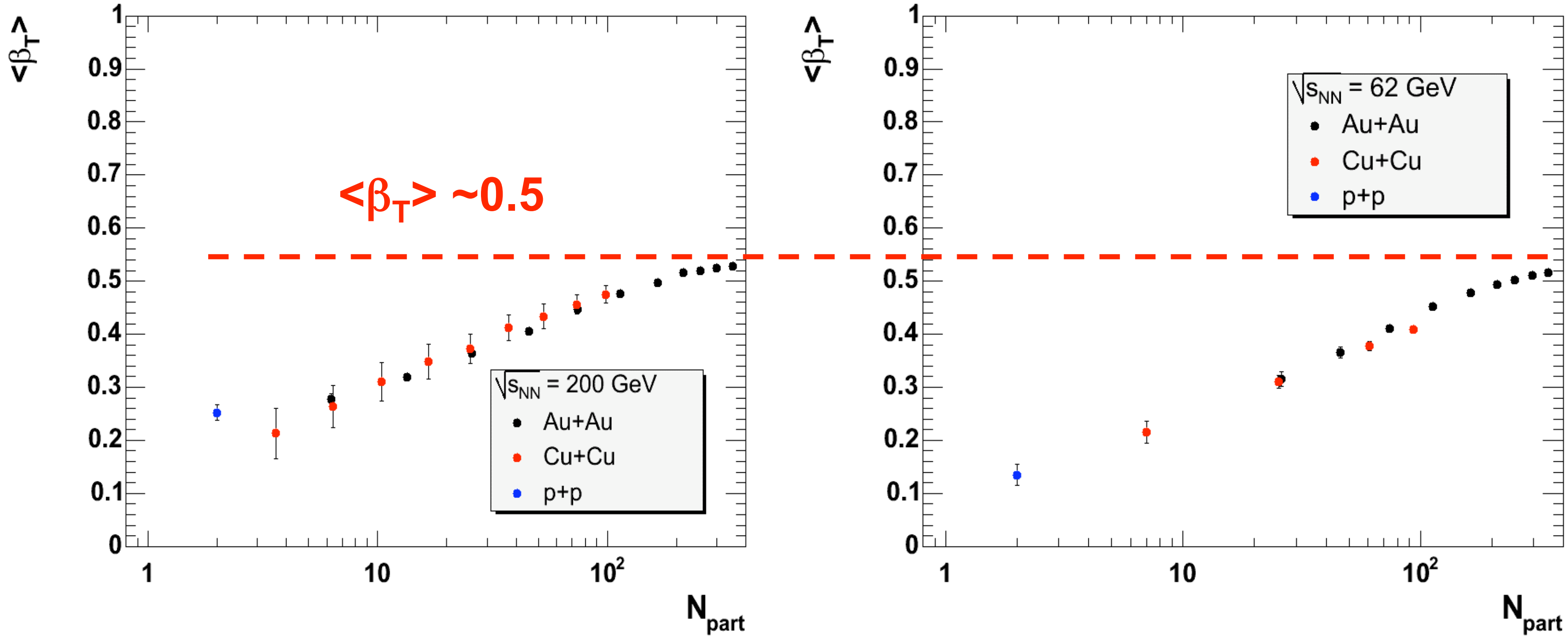
Spectra for heavier particles has a convex shape due to **radial flow**.

Blast-wave Model Fit - T_{fo} vs. N_{part}



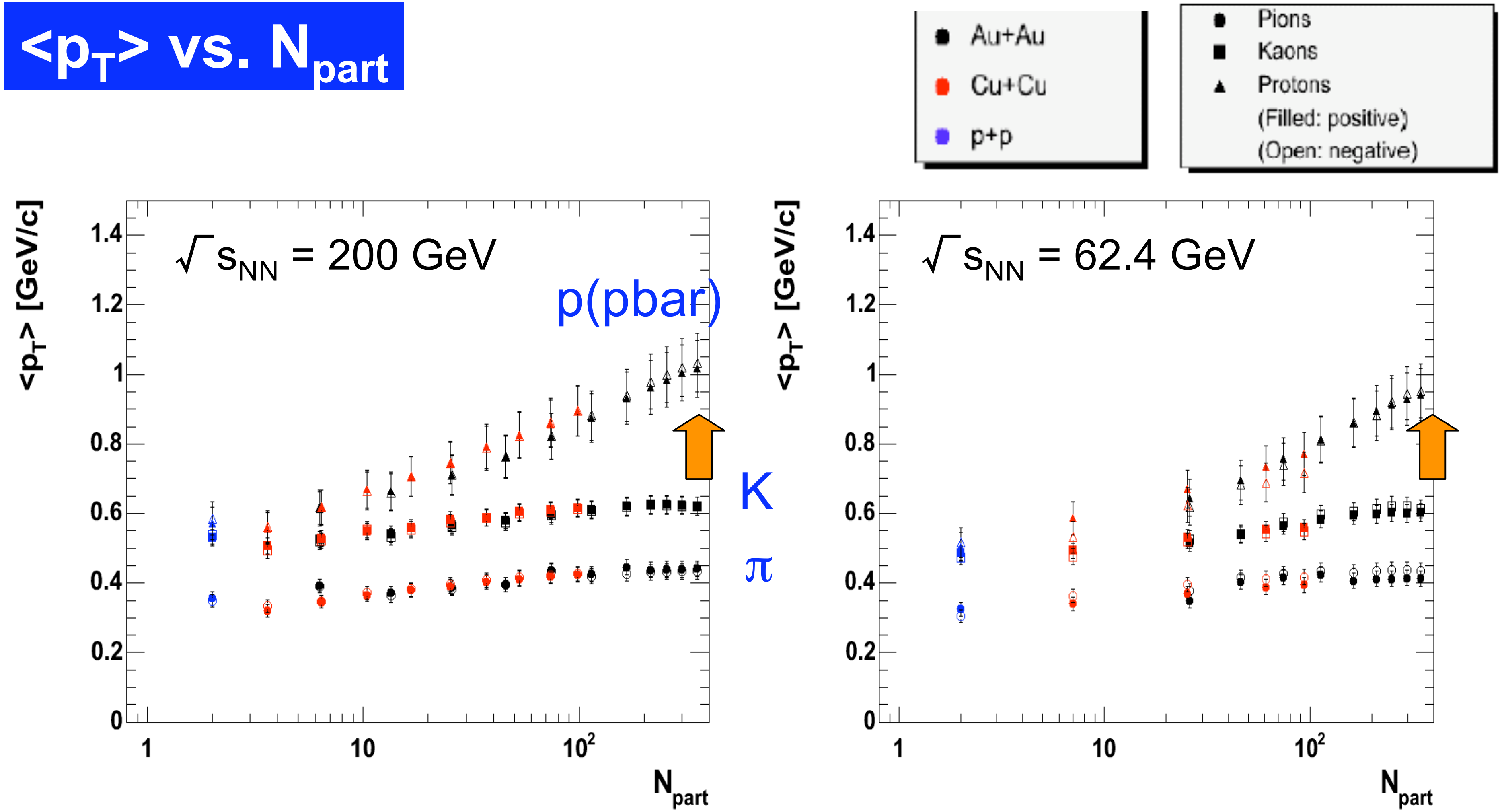
- N_{part} scaling of T_{fo} between Au+Au and Cu+Cu
- Almost same T_{fo} at $\sqrt{s_{NN}}$ = 62.4, 200 GeV

Blast-wave Model Fit - $<\beta_T>$ vs. N_{part}



- N_{part} scaling of $<\beta_T>$ between Au+Au and Cu+Cu
- Almost same $<\beta_T>$ at $\sqrt{s_{NN}}$ = 62.4, 200 GeV

$\langle p_T \rangle$ vs. N_{part}



- $\langle p_T \rangle$: π<K<p (mass dependence)
- Consistent with radial flow picture

- N_{part} scaling of $\langle p_T \rangle$ between Au+Au and Cu+Cu
- Almost same $\langle p_T \rangle$ at $\sqrt{s_{NN}}$ = 62.4, 200 GeV

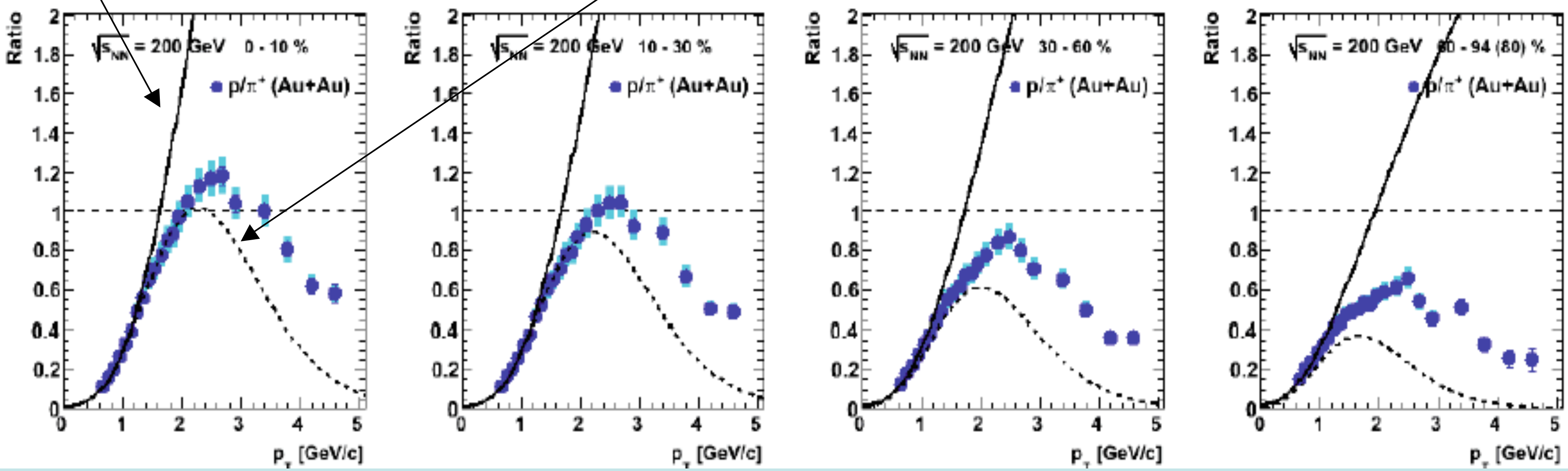
Estimation of p/π at intermediate p_T

- Extrapolate low-p_T Blast-wave fit results to intermediate p_T in order to estimate p/π ratio.

* No weak decay feed-down correction applied.

(hydro p)/(hydro π)

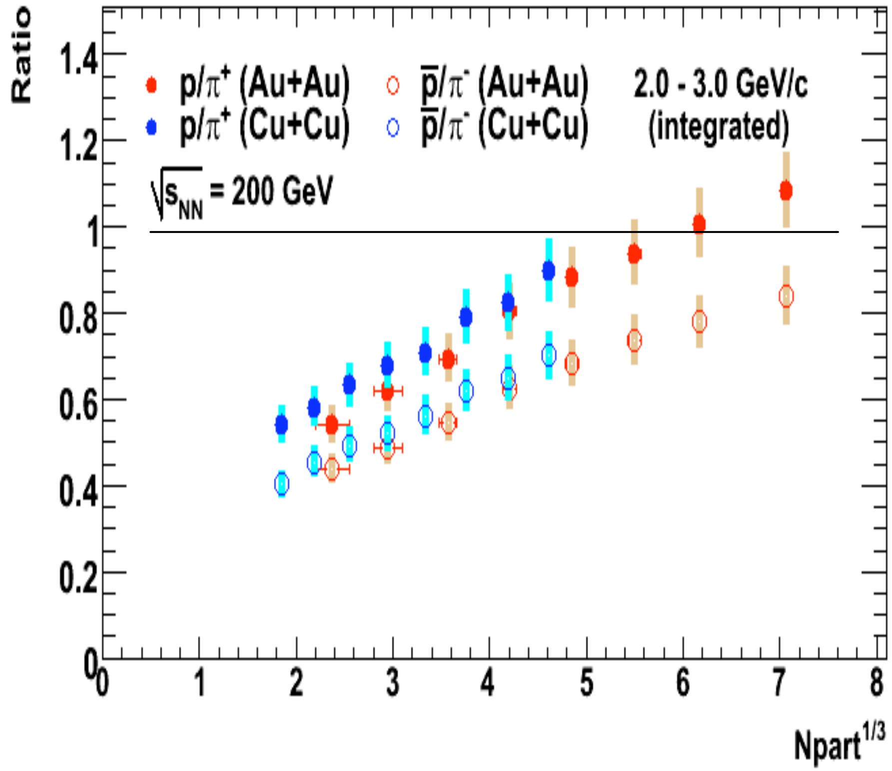
(hydro p)/(real π)



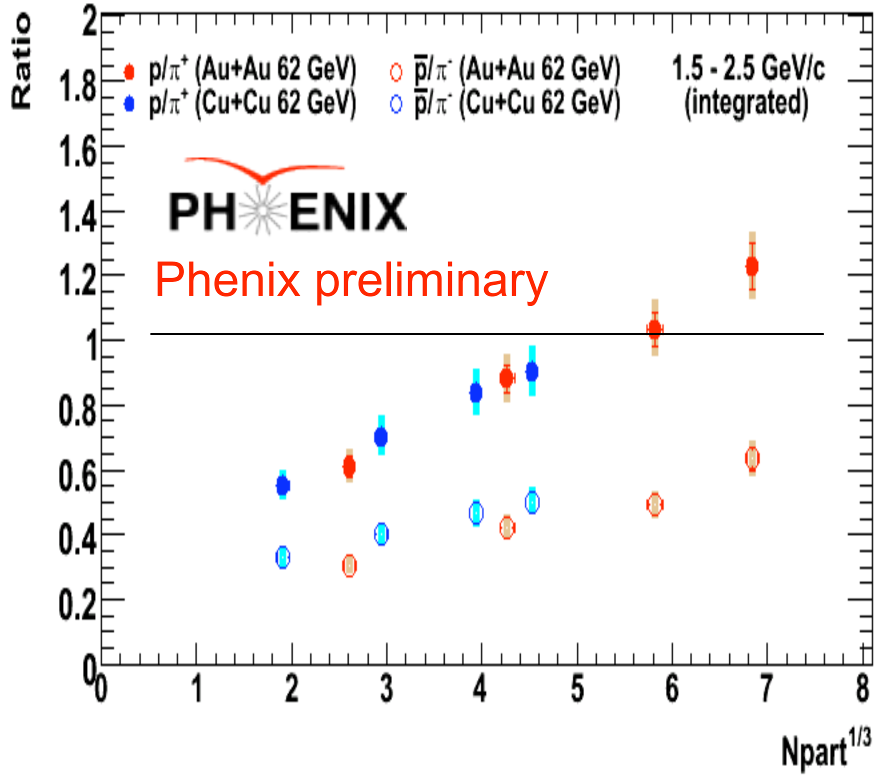
Central ← Peripheral

- Hydrodynamic contribution for protons is one of the explanations of baryon enhancement.
- Other contribution is also needed: Recombination, Jet fragmentation

Baryon enhancement - p/π vs. N_{part}



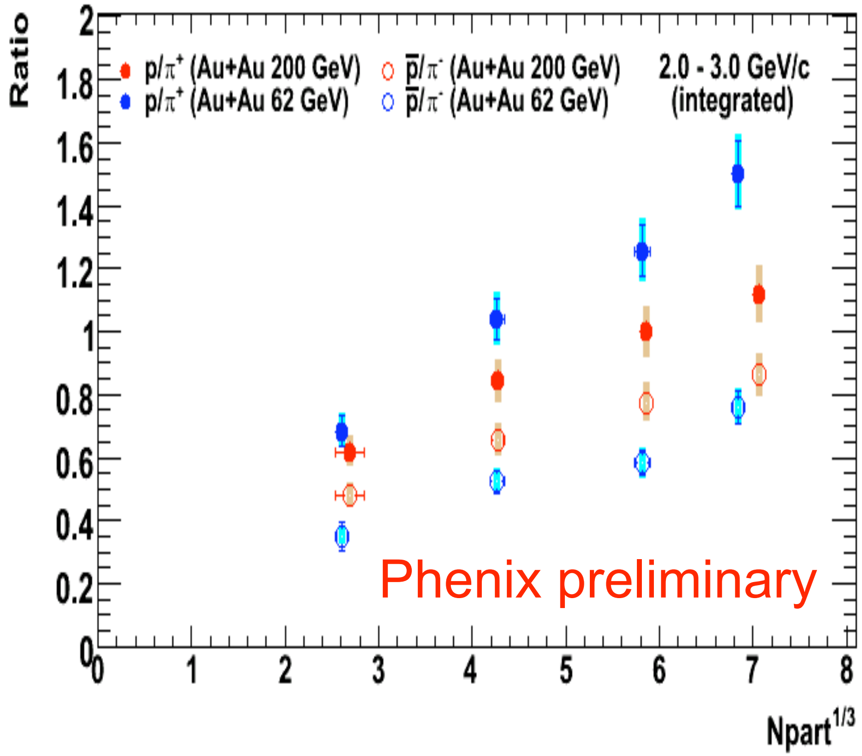
Au+Au vs. Cu+Cu at 200 GeV

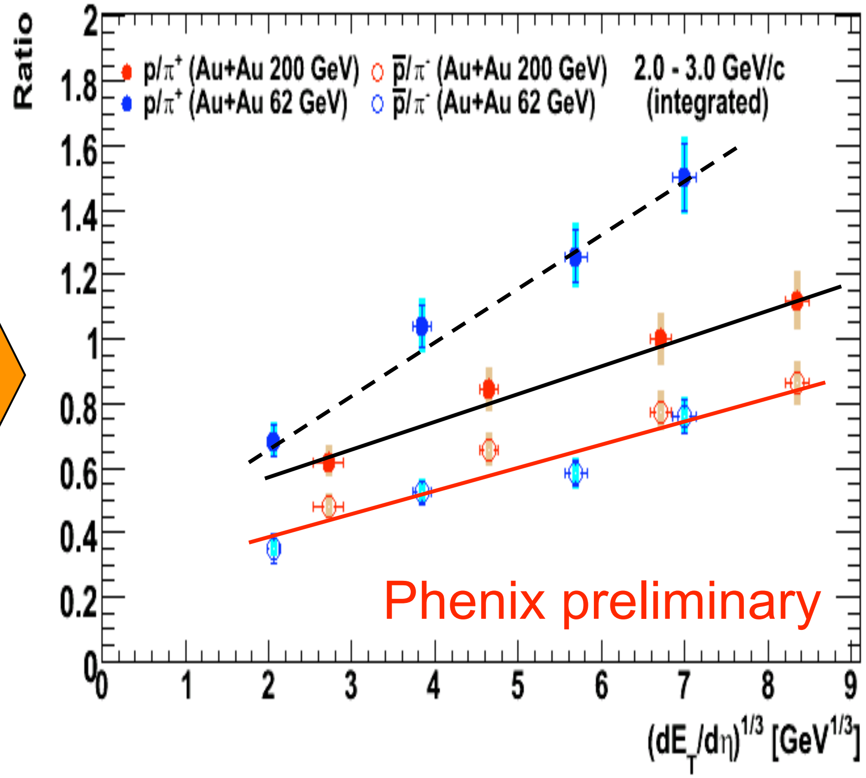


Au+Au vs. Cu+Cu at 62.4 GeV

- N_{part} scaling of p/π between Au+Au and Cu+Cu at same $\sqrt{s_{NN}}$

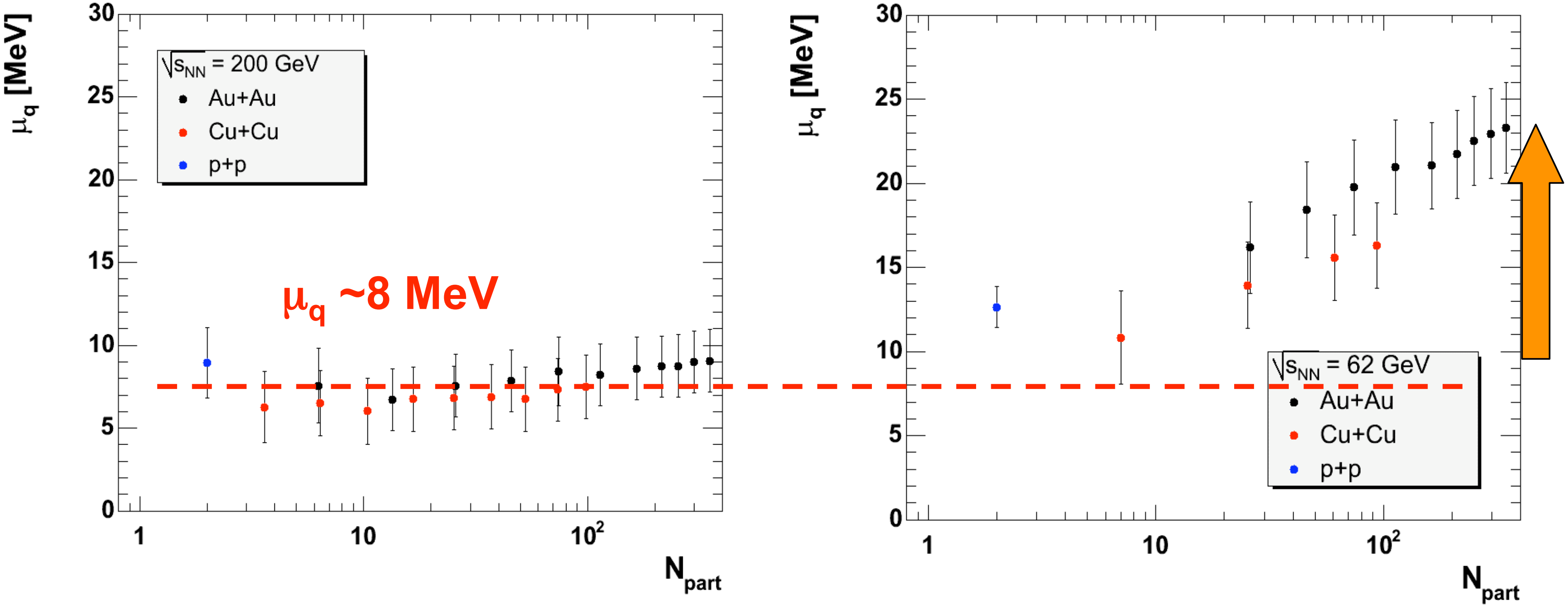
Baryon enhancement - p/π vs. dE_T/dy





- No N_{part} scaling of p/π (pbar/π) in Au+Au between 62.4 and 200 GeV.
- dE_T/dy scaling of pbar/π seen. => Proton production (at this p_T range) at 62.4 GeV is partly from baryon transport, not only pair production. Nuclear stopping is still large at 62.4 GeV.

Statistical Model Fit - μ_q vs. N_{part}



- N_{part} scaling of μ_q between Au+Au and Cu+Cu
- Larger μ_q at $\sqrt{s_{NN}}$ = 62.4 GeV than that at 200 GeV

Summary

- Scaling properties of PID p_T spectra tested with Au+Au and Cu+Cu data at $\sqrt{s_{NN}}$ = 62.4/200 GeV.

- Bulk properties (dN/dy, $\langle p_T \rangle$, kinetic and chemical freeze-out properties) are scaled with N_{part} (~volume) at same $\sqrt{s_{NN}}$.

- p(pbar)/π ratios:
  (1) N_{part} scaling between Au+Au and Cu+Cu at same sqrt(s_{NN})
  (2) dE_T/dy scaling between 62.4 and 200 GeV in Au+Au
  (3) pbar/π is a good indicator of baryon enhancement

On-going

- MRPC-type TOF counter (σ_{TOF}~100ps) was installed behind the Aerogel for high-p_T PID upgrade. Run-7 has just started for 200 GeV Au+Au. Higher-p_T physics can be reached.

Backup

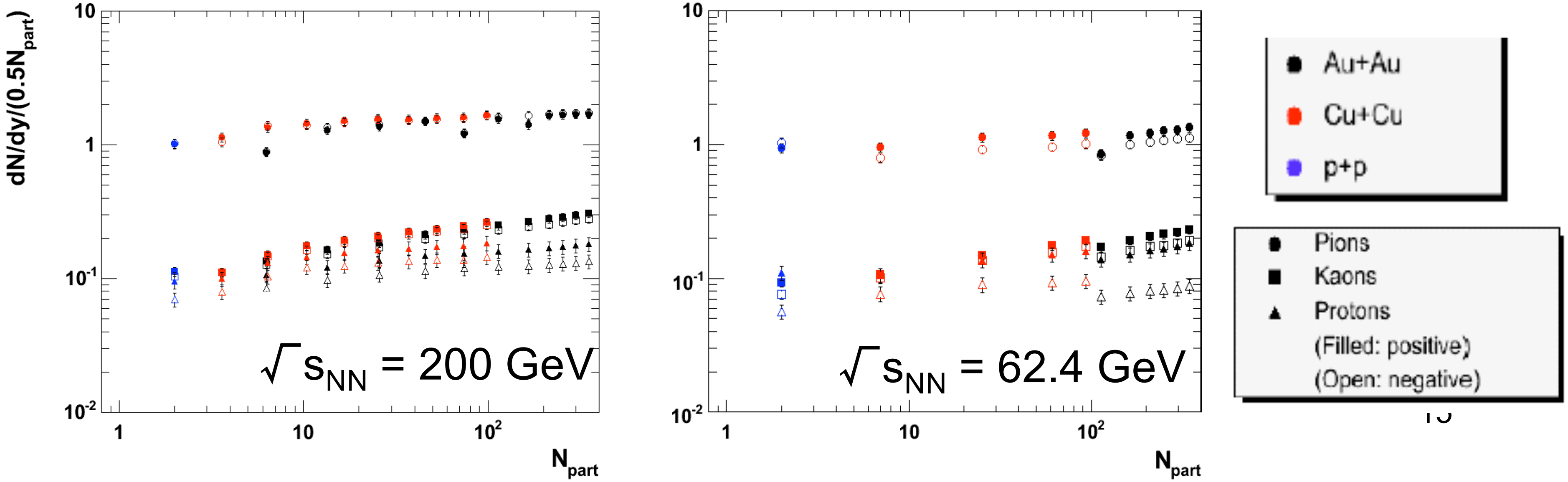
Statistical Model Fit

- Extracting chemical freeze-out properties with statistical model fit.
- Fitting particle ratios of dN/dy (π/K/p) at y~0.
- Assuming chemical equilibrium of light quarks (u,d,s), γ_s=1.
- Partial feed-down correction taken into account.

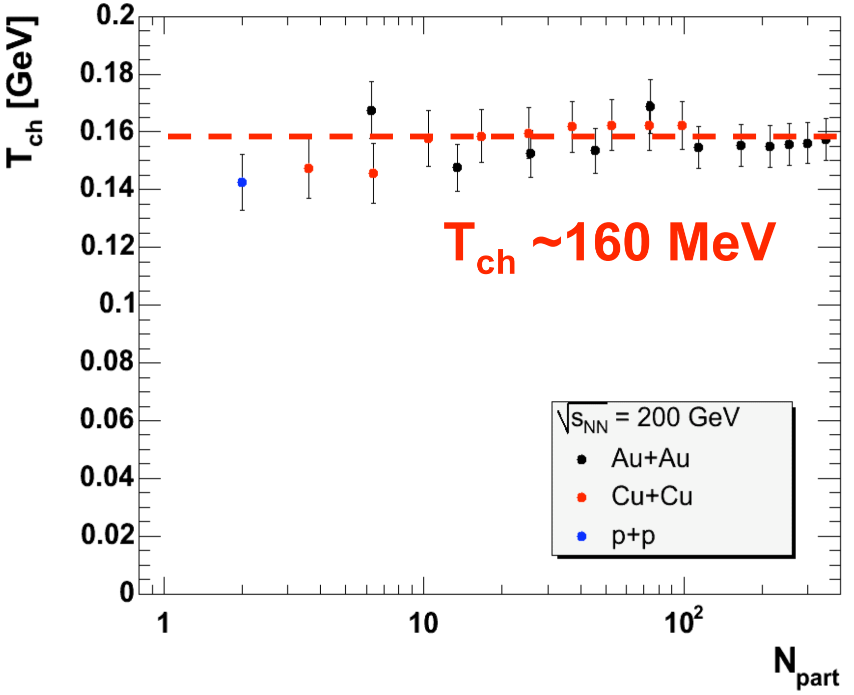
$$\frac{N_i(T,\mu)}{V} = \frac{g_i}{2\pi^2}\gamma_s^{|S_i|}\int_0^\infty \frac{p^2 dp}{e^{(E_i-\mu_B B_i-\mu_s S_i)/T} \pm 1}$$

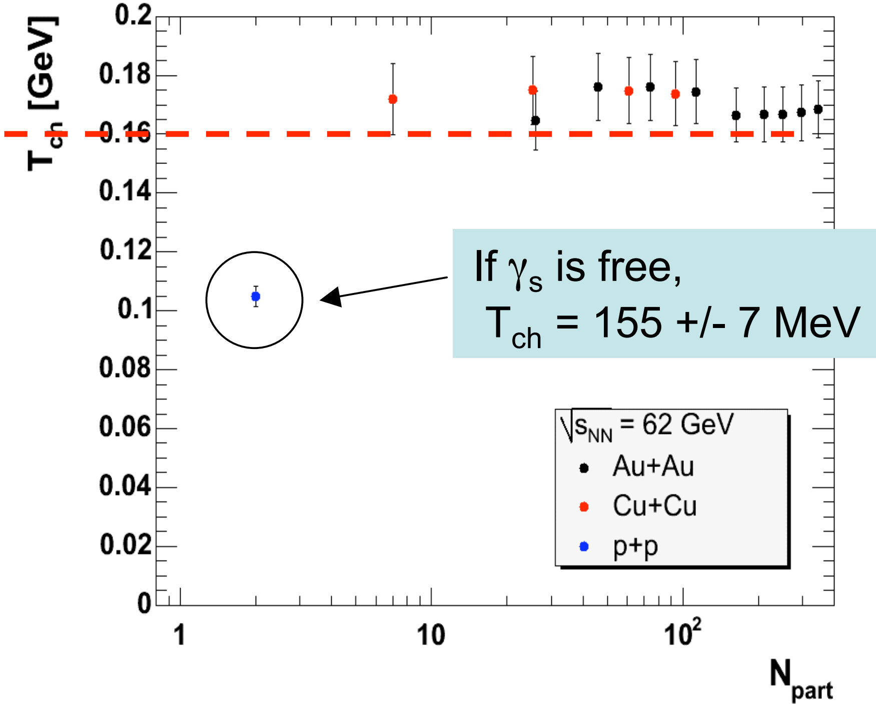
Refs:
Phys. Rev. C71 054901, 2005
nucl-th/0405068
NPA698(2002)306C

- T_{ch}, μ_q : relatively stable
- μ_s, γ_s : not determined with this set of ratios (π/K/p). Strangeness info is short.



Statistical Model Fit - T_{ch} vs. N_{part}





- N_{part} scaling of T_{ch} between Au+Au and Cu+Cu
- Almost same T_{ch} at $\sqrt{s_{NN}}$ = 62.4, 200 GeV