Elliptic Flow of Multi-strange Baryons at RHIC – Evidence of Partonic Collectivity

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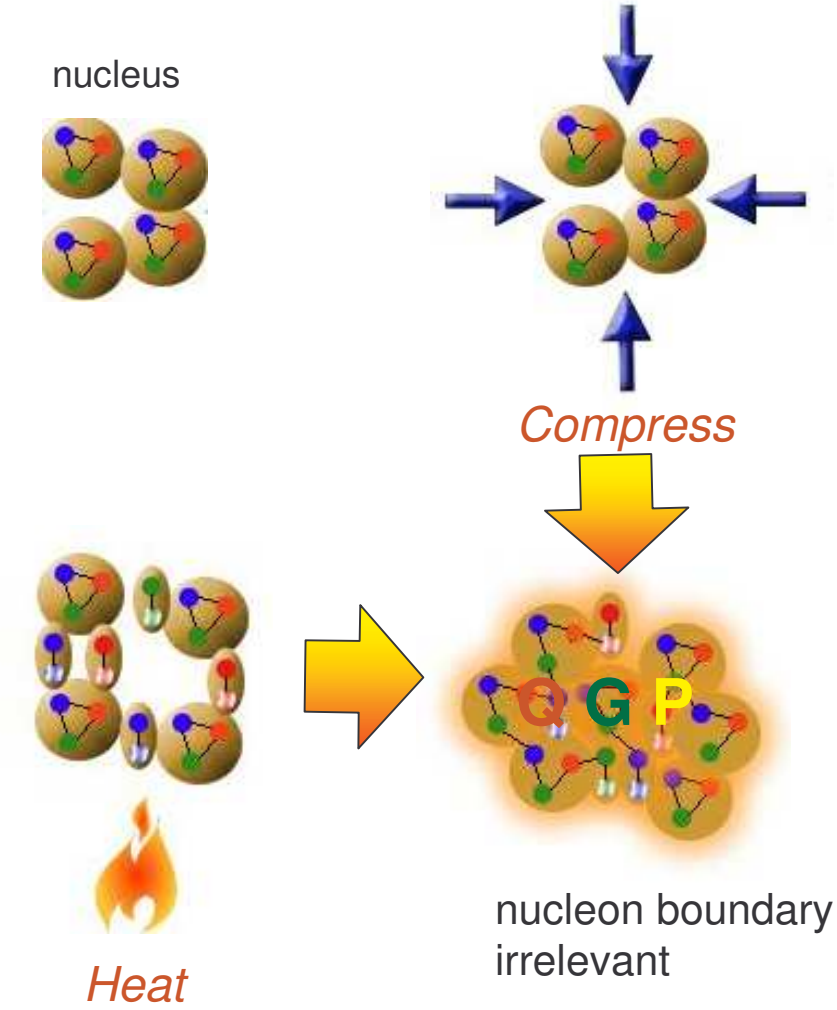
Outline

- Introduction
- Spectra – Transverse Radial Flow
- Multi-strange hadron spectra and partonic collectivity
- Summary

Motivation



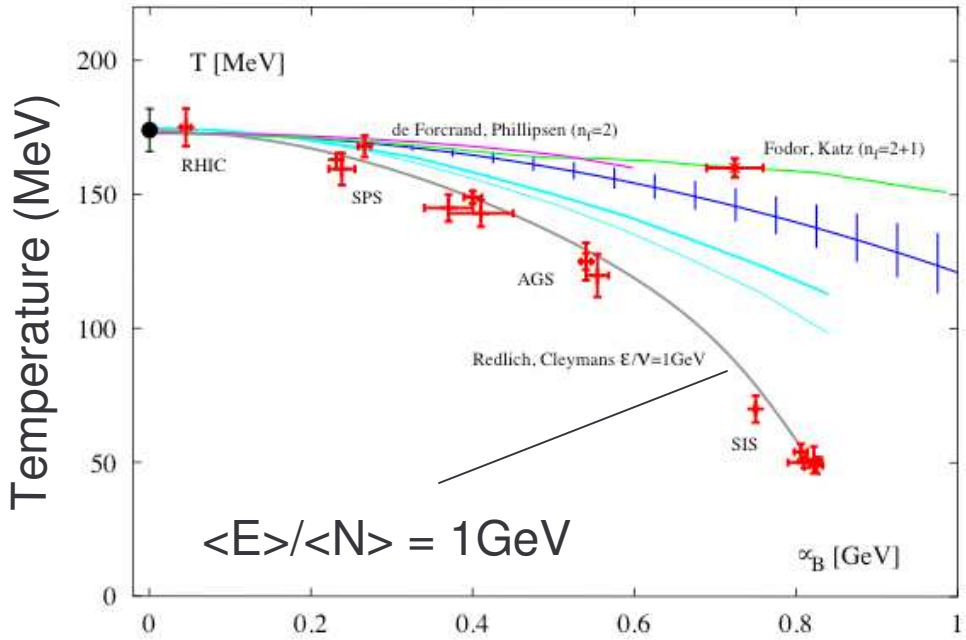
Quark Gluon Plasma:

Deconfined and thermalized state of quarks and gluons

- Equilibration:
  - hadron yields
- ***Partonic Collectivity:***
  - ***Spectra of multi-strange baryons***
- Thermalization:
  - heavy charm quark
  - (thermal photons, di-pletons)

J.C. Collins and M.J. Perry, Phys. Rev. Lett. 34 (1975) 1353.

Chemical Freeze-out



Temperature (MeV)

Baryon-Chemical potential μ_B(GeV)

- Inelastic interactions cease at <E>/<N> = 1GeV*
- At RHIC, chemical and critical conditions coincide

⇒ ***Inelastic hadronic interactions reduced at RHIC !***

⇒ ***Partonic Collectivity?***

Lattice QCD: Fodor, Katz, hep-lat/0106002.

*<E>/<N>=1GeV: J. Cleymans and K. Redlich, Phys. Rev. Lett. 81, 5284 (1998).

Transverse Flow Observables

$$\frac{dN}{p_t dp_t dy d\varphi} = \frac{1}{2\pi} \frac{dN}{p_t dp_t dy} \left[1 + \sum_{i=1} 2 v_i \cos(i(\varphi - \psi_R)) \right]$$

As a function of particle mass:

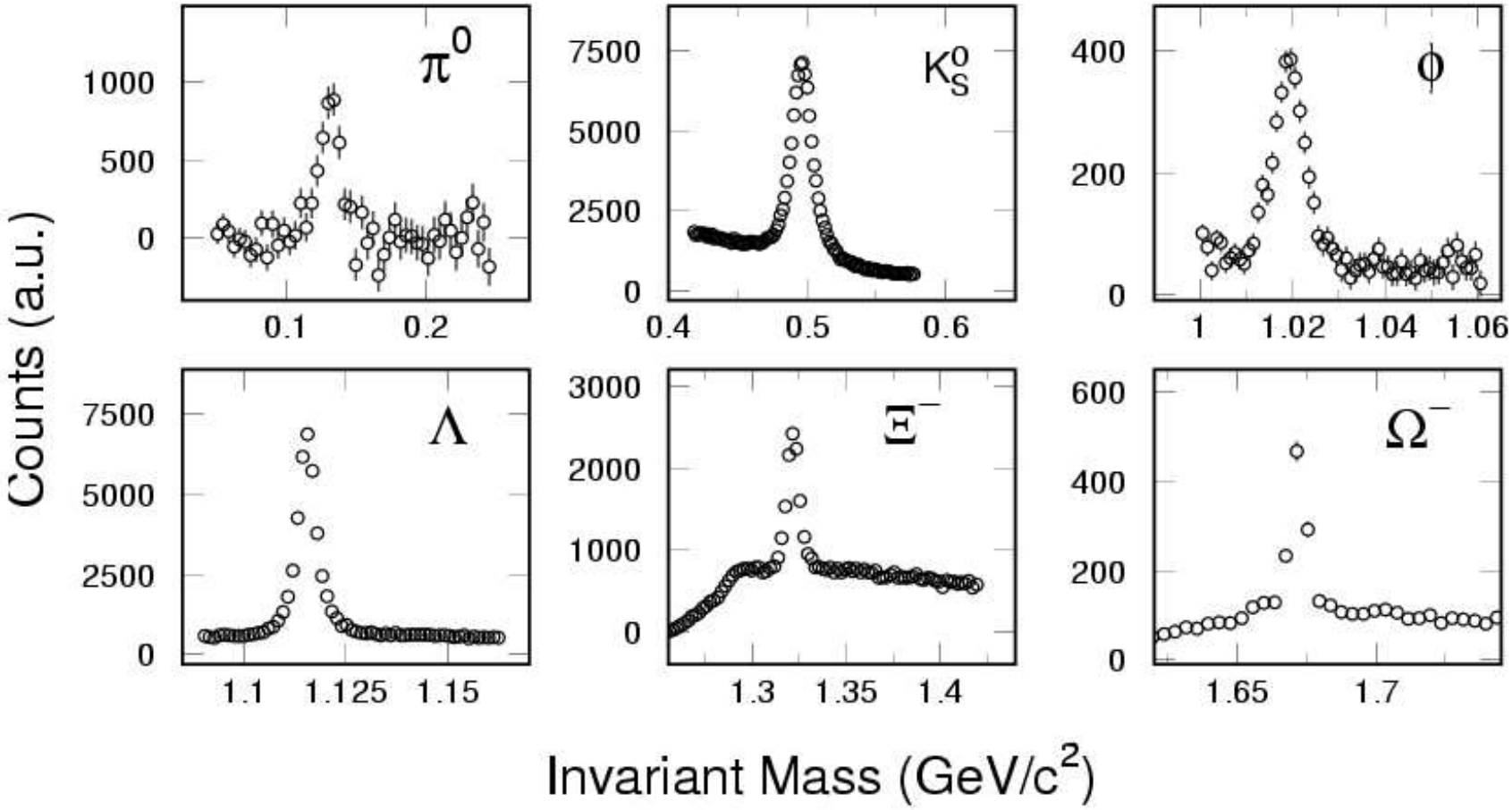
- Directed flow (v_1) – early
- Elliptic flow (v_2) – early
- Radial flow – integrated over whole evolution

Note:

1) Collectivity is cumulative – partonic + hadronic

2) No thermalization needed – pressure gradient only depends on the ***density gradient and interactions***.

Particle Identification

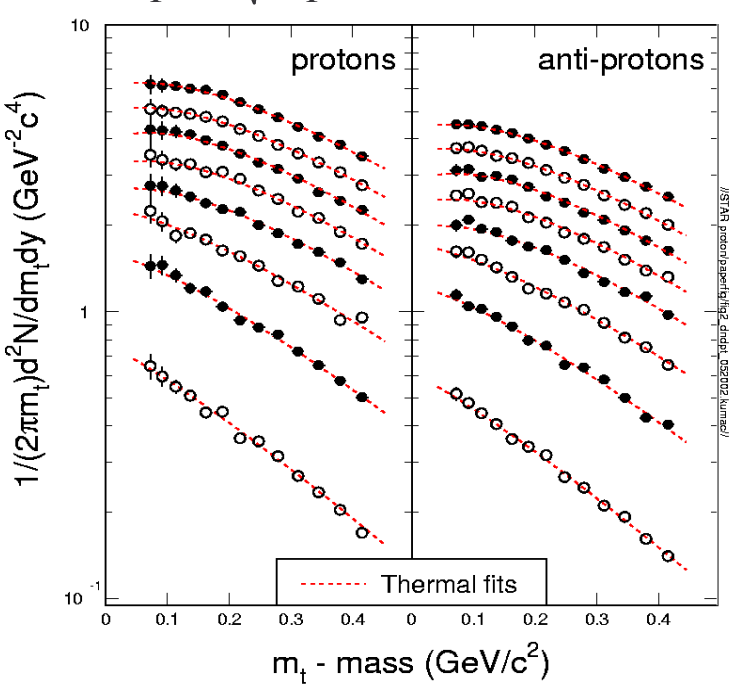


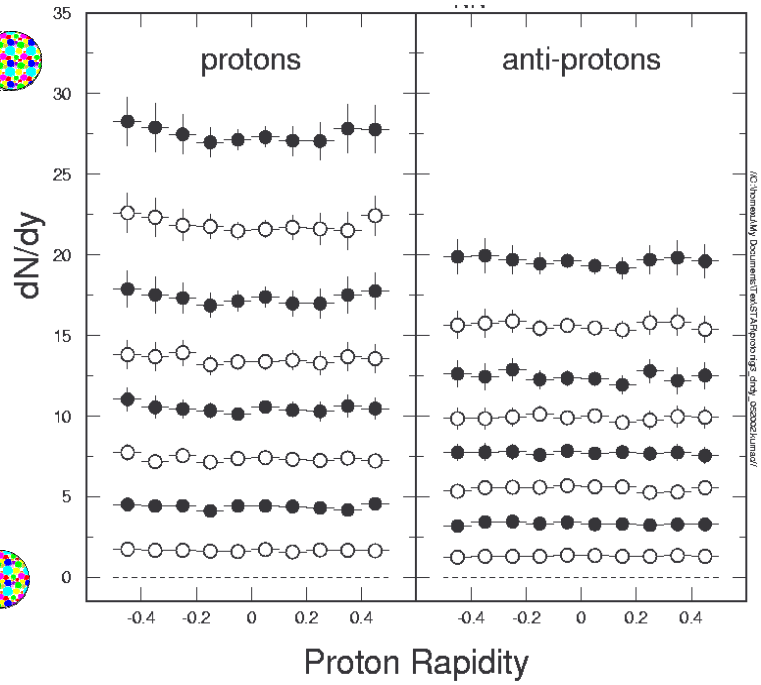
Reconstruct resonances in full azimuthal acceptance of STAR!

(Anti-)Protons from RHIC

$$m_T = \sqrt{p_T^2 + mass^2}$$

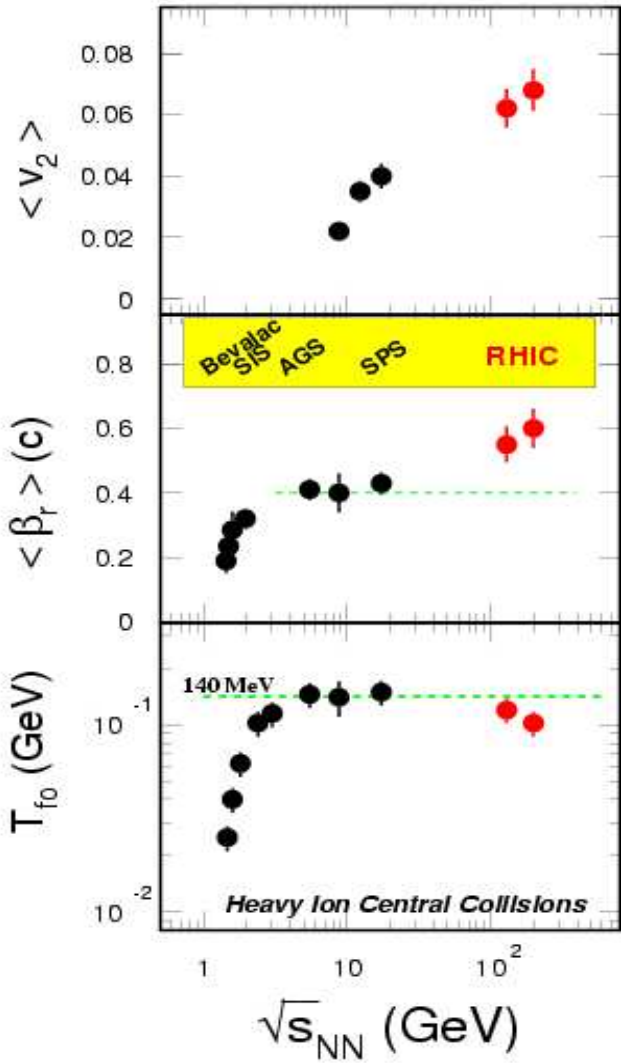
130 GeV Au + Au Collisions, STAR Preliminary





1) In central collisions, m_t distributions become more convex
   $\Rightarrow$ collective flow !
2) Within |y|<0.5, dN/dy and $\langle p_T \rangle$ are flat $\Rightarrow$ boost invariant !

Freeze-out Systematics (π,K,p)

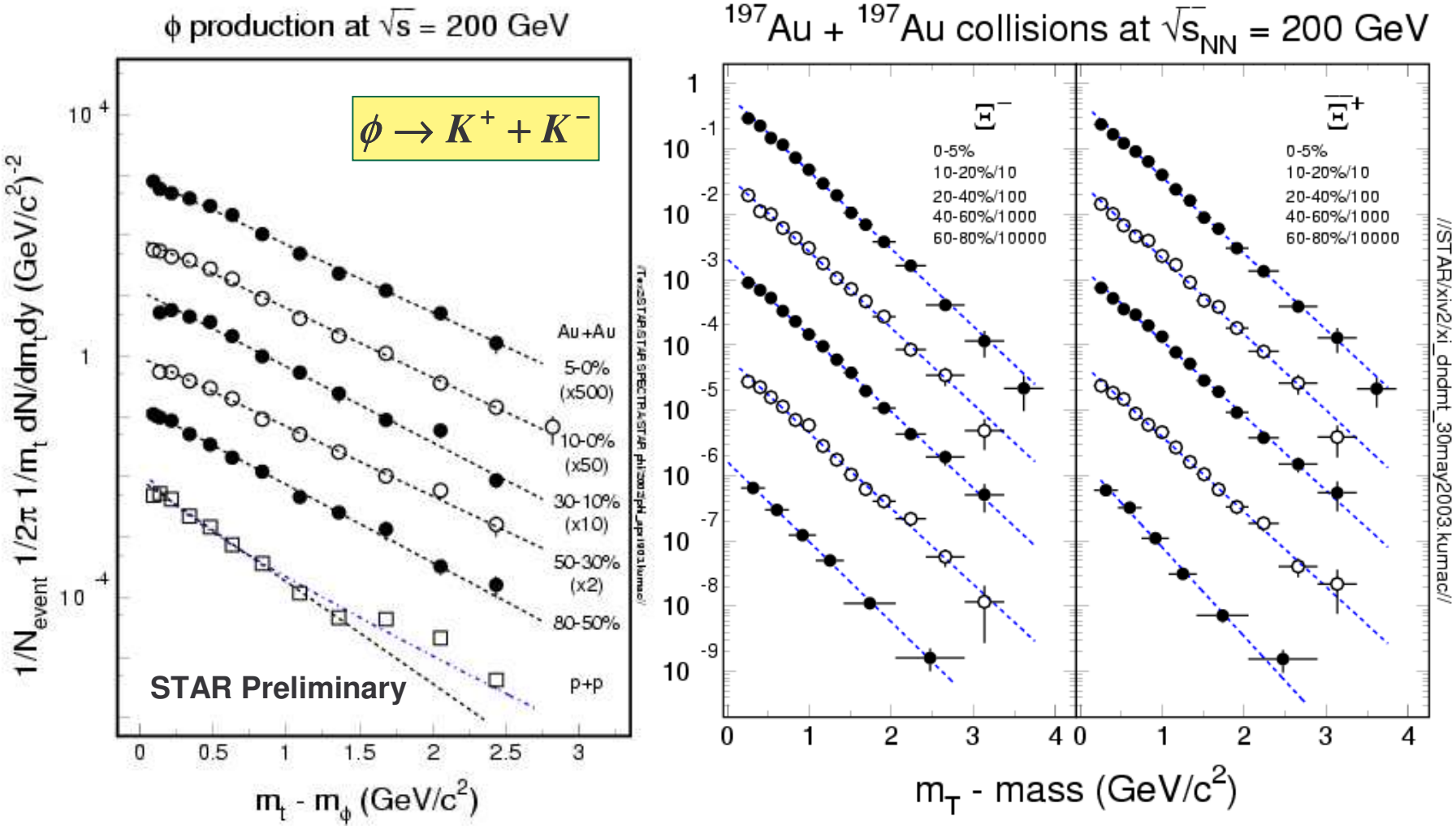


At RHIC, $\beta_T = 0.60 \pm 0.05(c)$

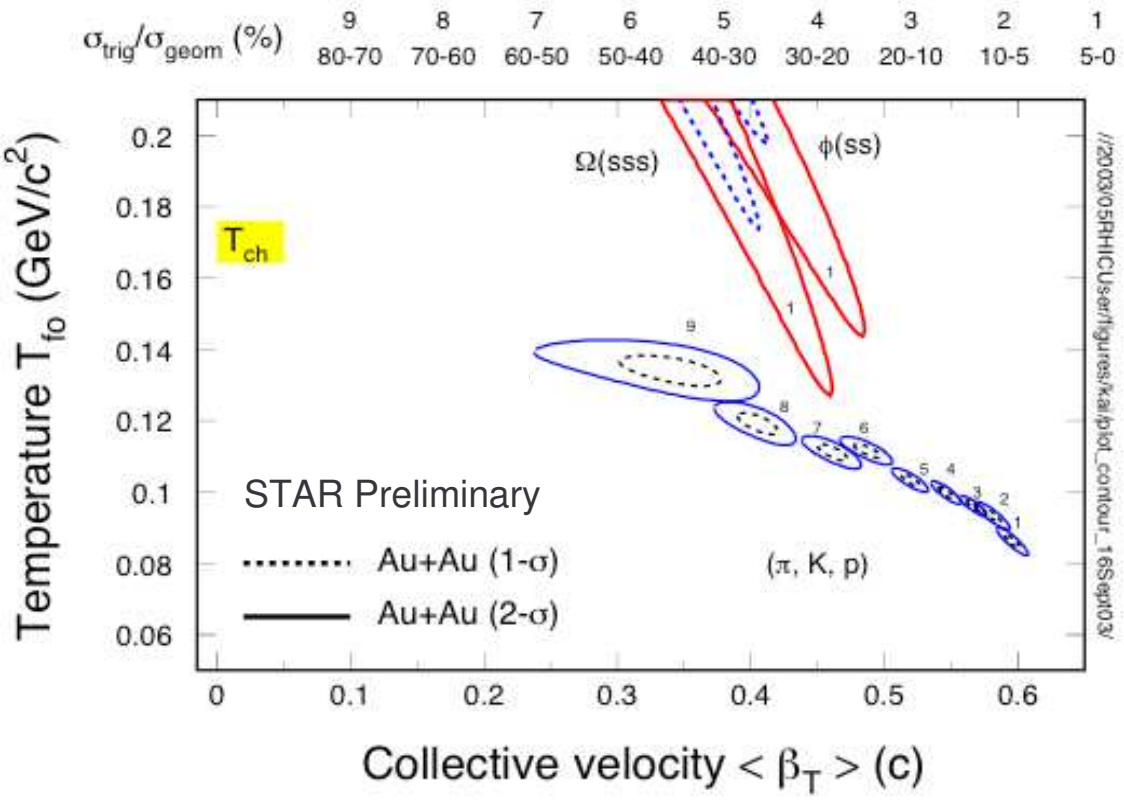
$\Rightarrow$ Explosive expansion!

$\Rightarrow$ Hadronic or partonic ?

Transverse Momentum Spectra



Kinetic Freeze-out at RHIC



1) Compare to π, K, and p, multi-strange particles ϕ, Ω are found at higher T and lower $<\beta_T>$

ð ð Collectivity prior to hadronization

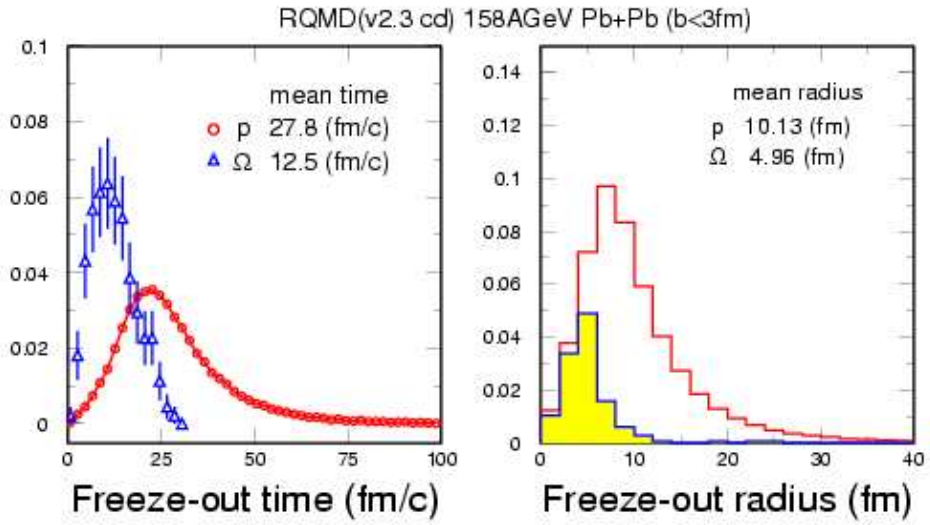
2) Sudden single freeze-out* Resonance decay lower T_{fo} for (π, K, p)

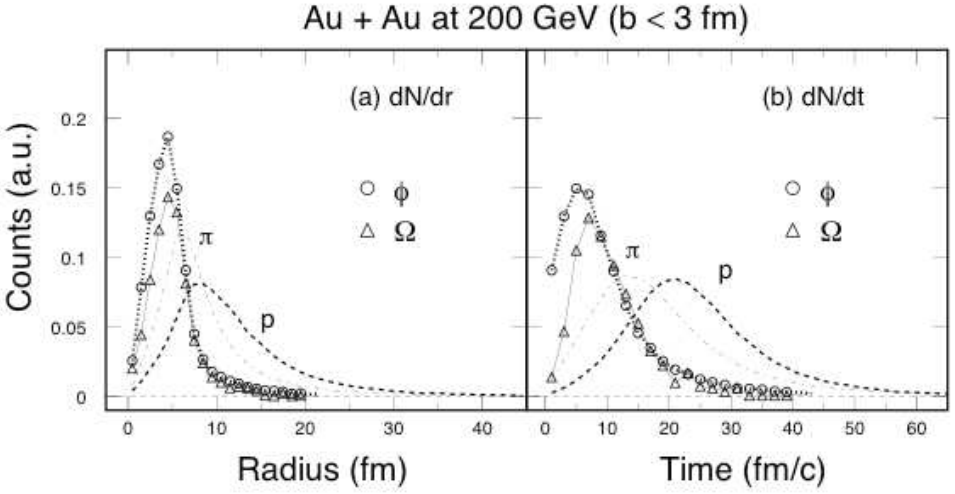
ð ð Collectivity prior to hadronization

Partonic Collectivity !

Data: STAR preliminary Au+Au@200GeV: Nucl. Phys. A715, 129c(2003).
*A. Baran, W. Broniowski and W. Florkowski; nucl-th/0305075

Hadronic-Model Test





- SPS energy:

H. van Hecke, H. Sorge, NX,
Phys. Rev. Lett., **81**, 5764(1998).

- RHIC energy:

Y. Cheng, F. Liu, Z. Liu, K.S., N. Xu,
Phys. Rev. **C68**, 034901(2003)

Multi-strange hadrons freeze-out early!

Summary(i)

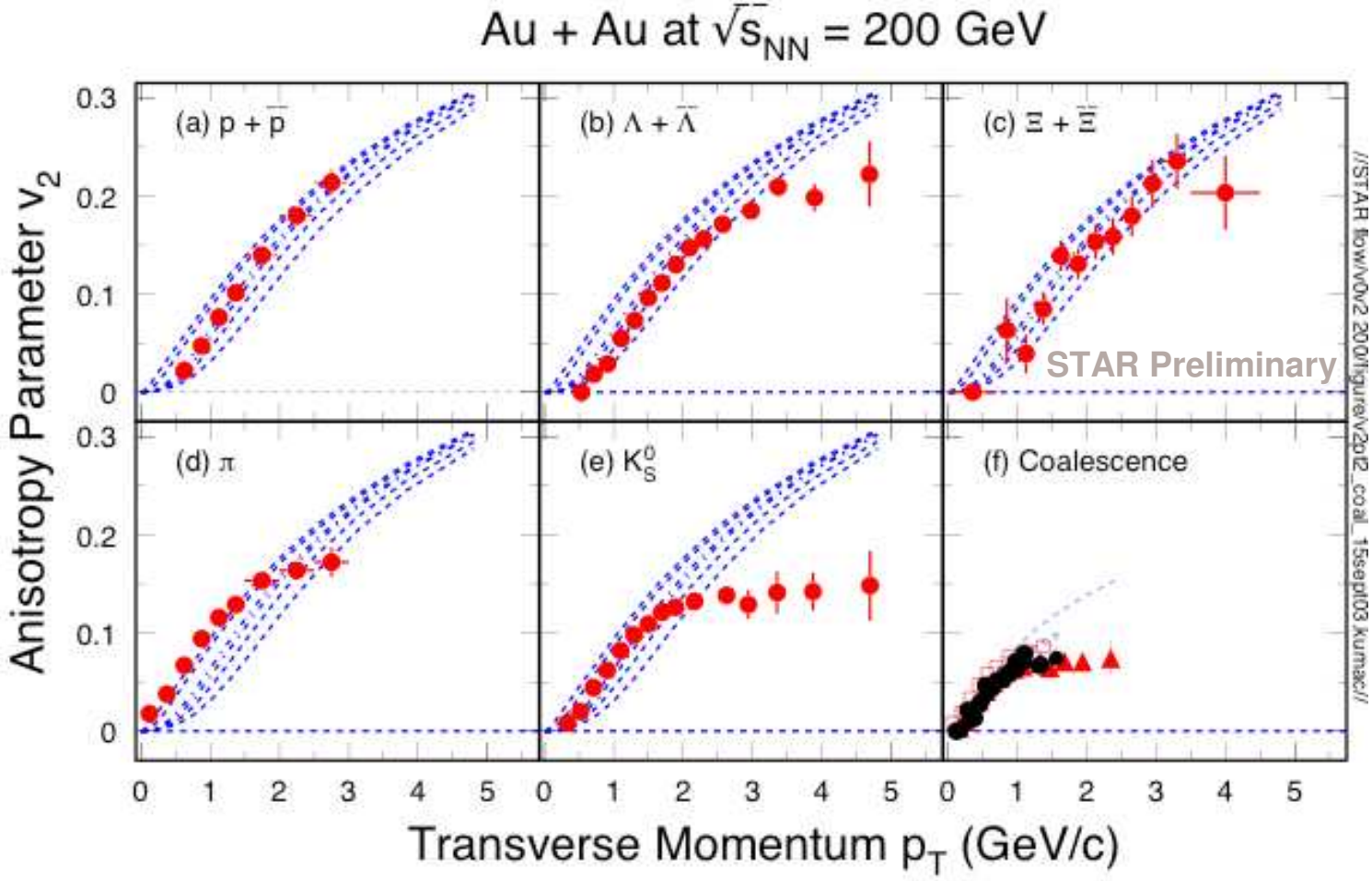
- Large transverse radial flow,

$\beta_T = 0.60 \pm 0.05(c)$

- Multi-strange hadrons freeze out early

- Partonic collectivity ?

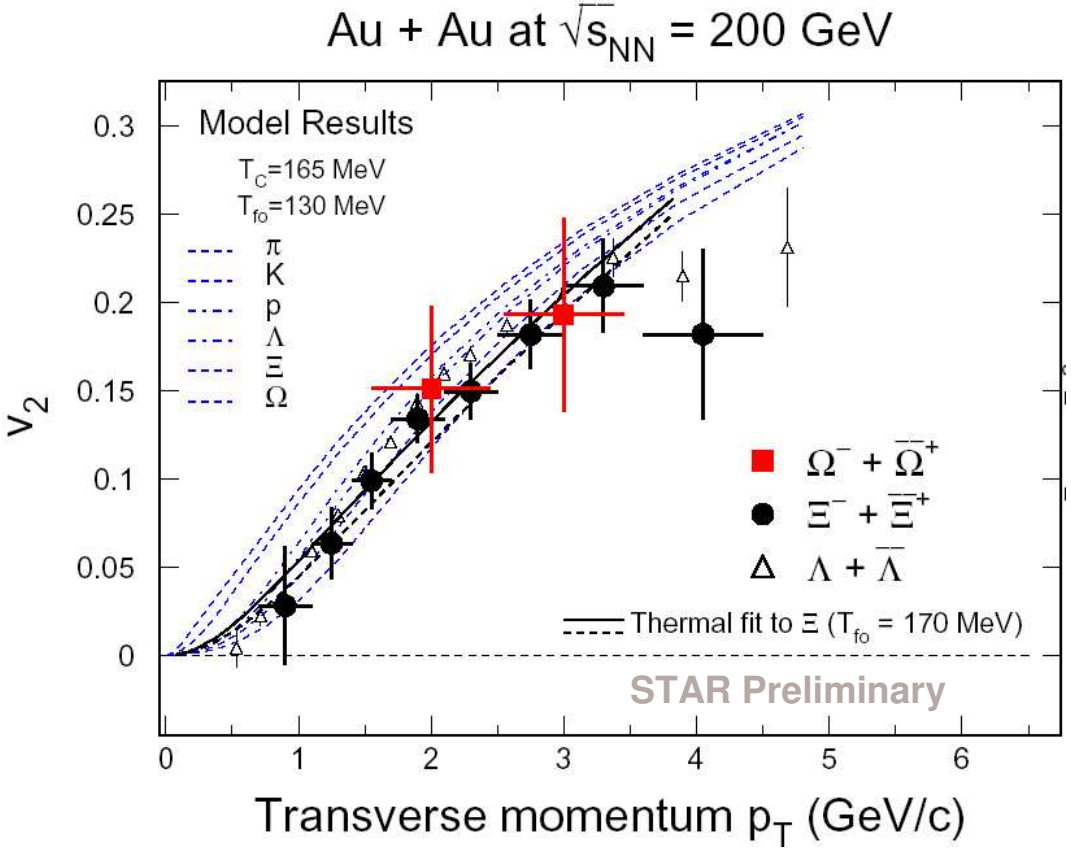
Elliptic Flow at RHIC



Proton and pion data: PHENIX, nucl-ex/0305013.

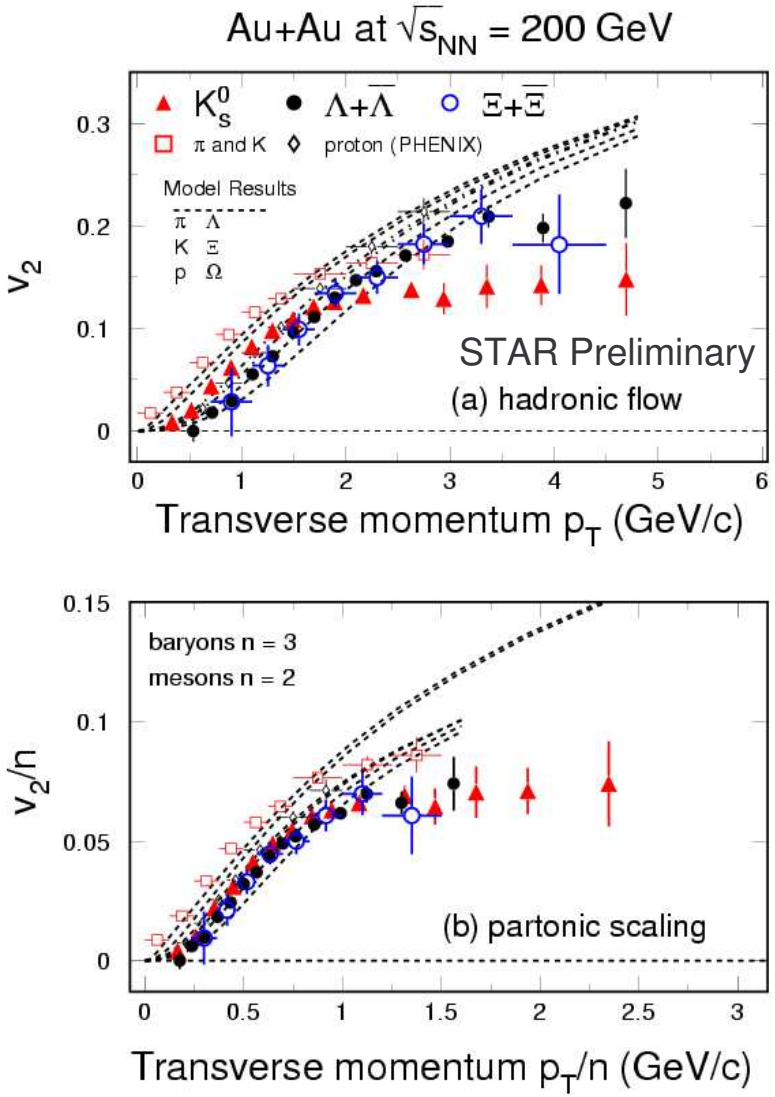
Hydro- calculations: P.Huovinen, et al., Phys. Lett. **B503**, 58 (2001).

Multi-Strange Baryons v_2



- Multi-strange baryons show collectivity !
- ***Partonic collectivity at RHIC!***

Quark Coalescence



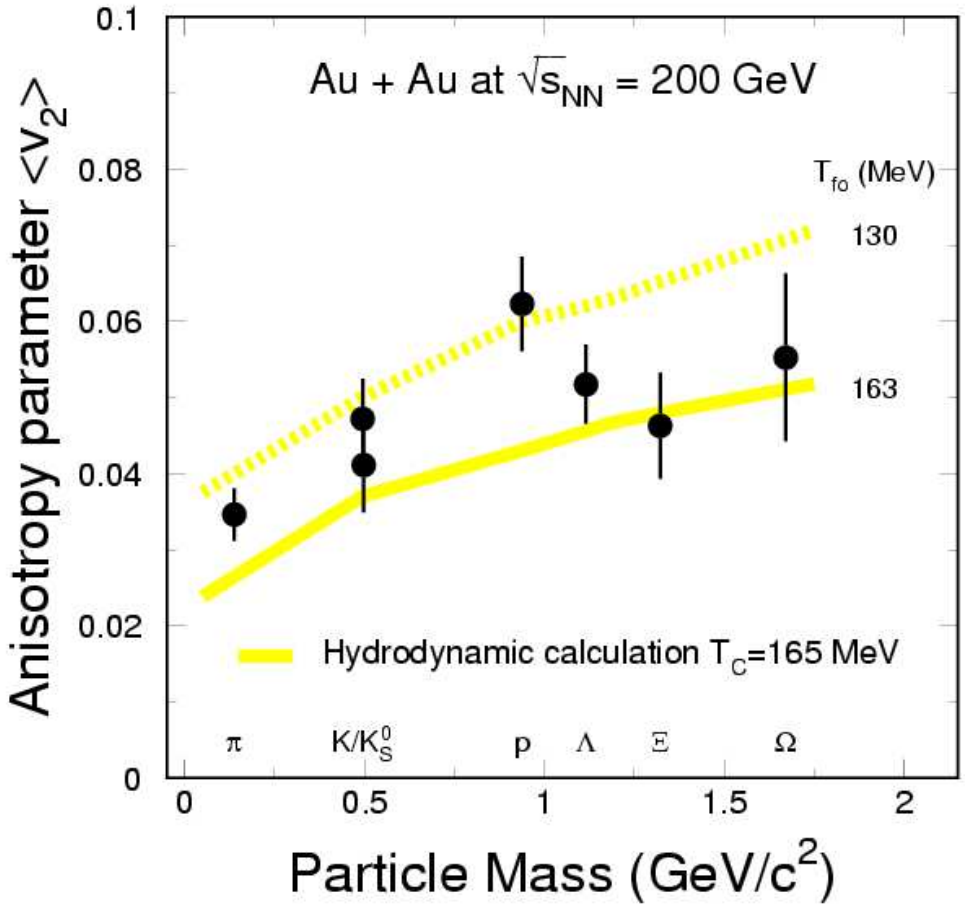
- Exp. data consistent with quark coalescence scenario
- ***Partonic collectivity at RHIC!***
- Pentaquark*

$\theta^+(uudd\bar{s})$, n=5 ?

Z. Lin et al., Phys. Rev. Lett., 89, 202302 (2002)
R. Fries et al., nucl-th/0306027
D. Molnar and S.A. Voloshin, PRL 91, 092301 (2003)

*DIANA: hep-ex/0304040
CLAS: hep-ex/0307018
LEPS: Phys. Rev. Lett. 91, 012002-1 (2003)
SAPHIR: hep-ex/0307083

v_2 vs Particle Mass



Two lines:

(a) T_{fo} = 130MeV fits π, K, p

(b) T_{fo} = 163 MeV fits (multi-)strange baryons

⇒ multi-strange baryons freeze out earlier

Y. Kondo, O. Morimatsu, nucl-th/0308023

T. Doi, Y. Kondo and M. Oka, hep-ph/0311117

Summary(ii)

- Spectra and v_2 of multi-strange hadrons

→ Partonic Collectivity at RHIC !

- Measure centrality dependence of spectra and v_2 of

ϕ, Ξ, Ω, …, D^0, D_s, Λ_c, J/ψ, (θ^+)

– quantify partonic collectivity

– probe thermalization

→ ***Discover QGP !***

- thermal photons + di-leptons → plasma temperature