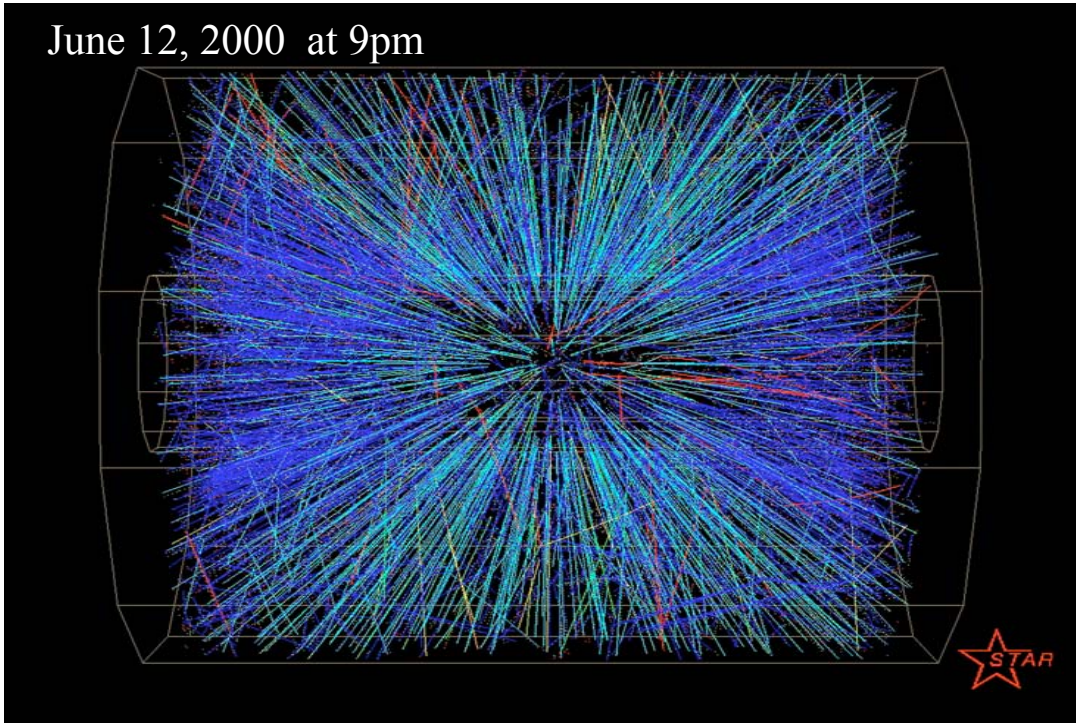
Soft Spectra from STAR

Zhangbu Xu

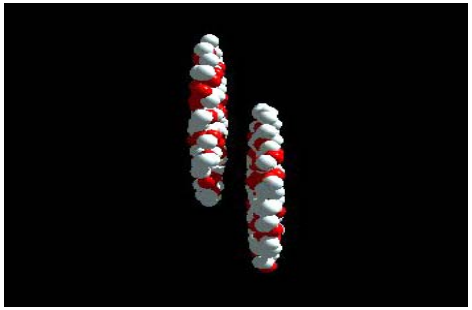
(BNL)

for the STAR Collaboration

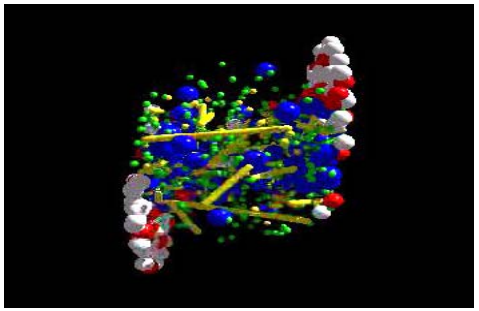


Outline

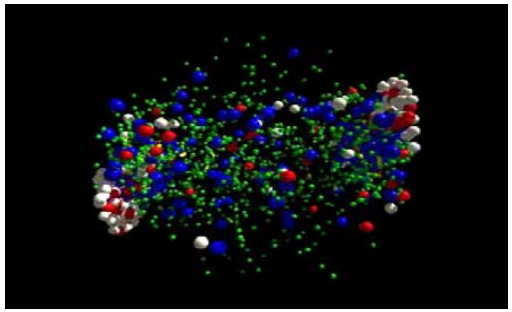
- Multiplicity
- <pt>
- High Pt
- Elliptic Flow (75)
- Stopping
- Particle Spectra, Ratios
  π, K, ϕ, p, Λ, Ξ
- Event-by-Event
- HBT (23)
- Radial Flow
- Resonances (K*)
- Antinuclei



Initial Condition

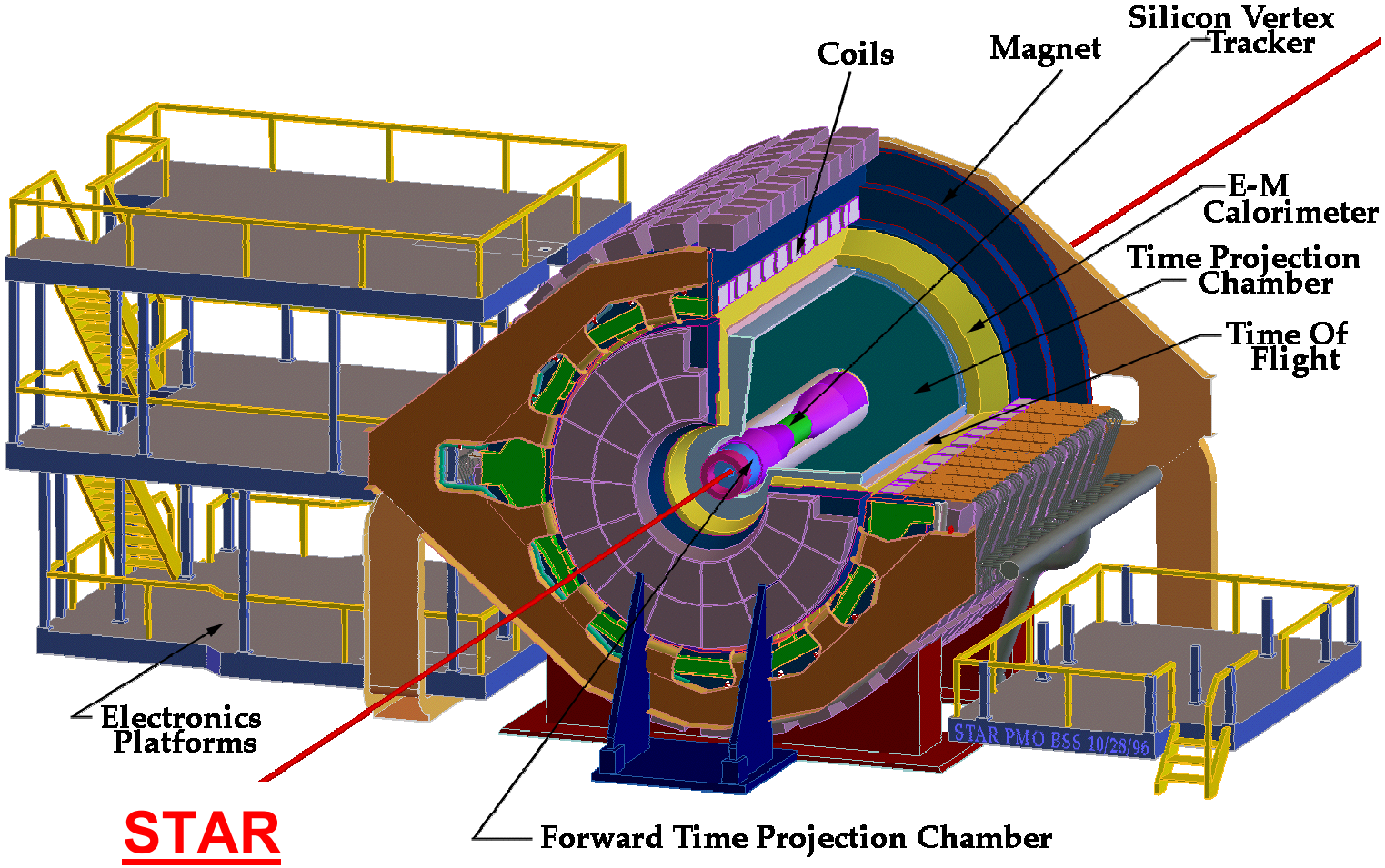


Strongly Interacting System?



Freeze-out

STAR Collaboration/Detector

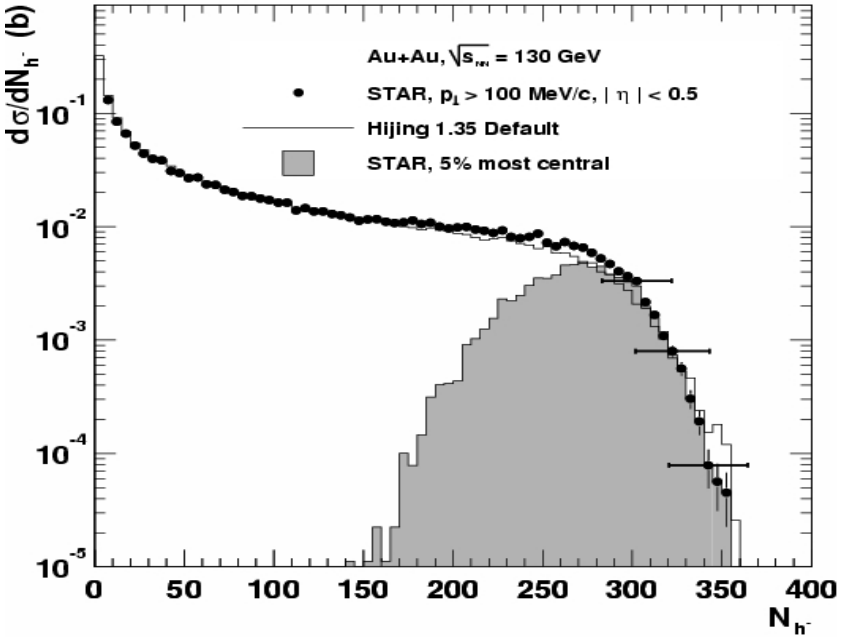


STAR

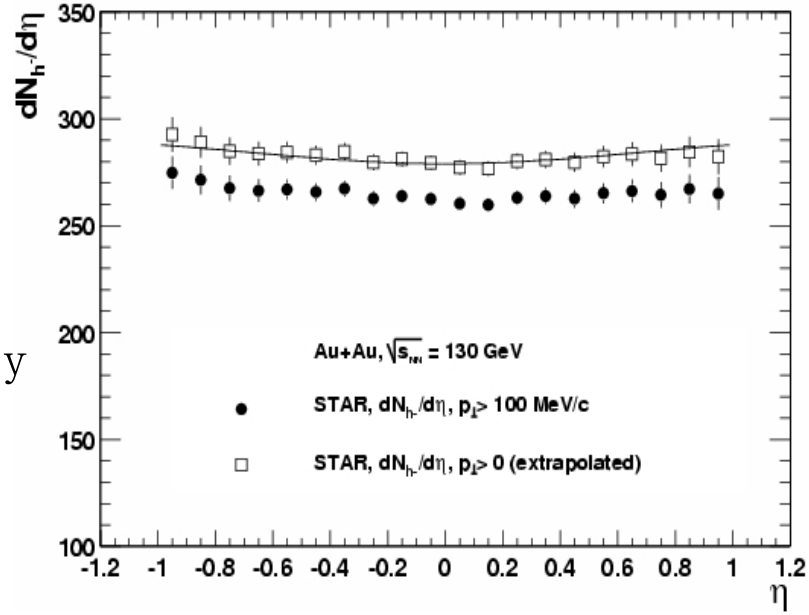
Solenoidal field
Large-Ω Tracking
TPC's, Si-Vertex Tracking
RICH, EM Cal, TOFp
~420 Participants

- Measurements of Hadronic Observables using a Large Acceptance
- Event-by-Event Analyses of Hadrons and Jets

Multiplicity

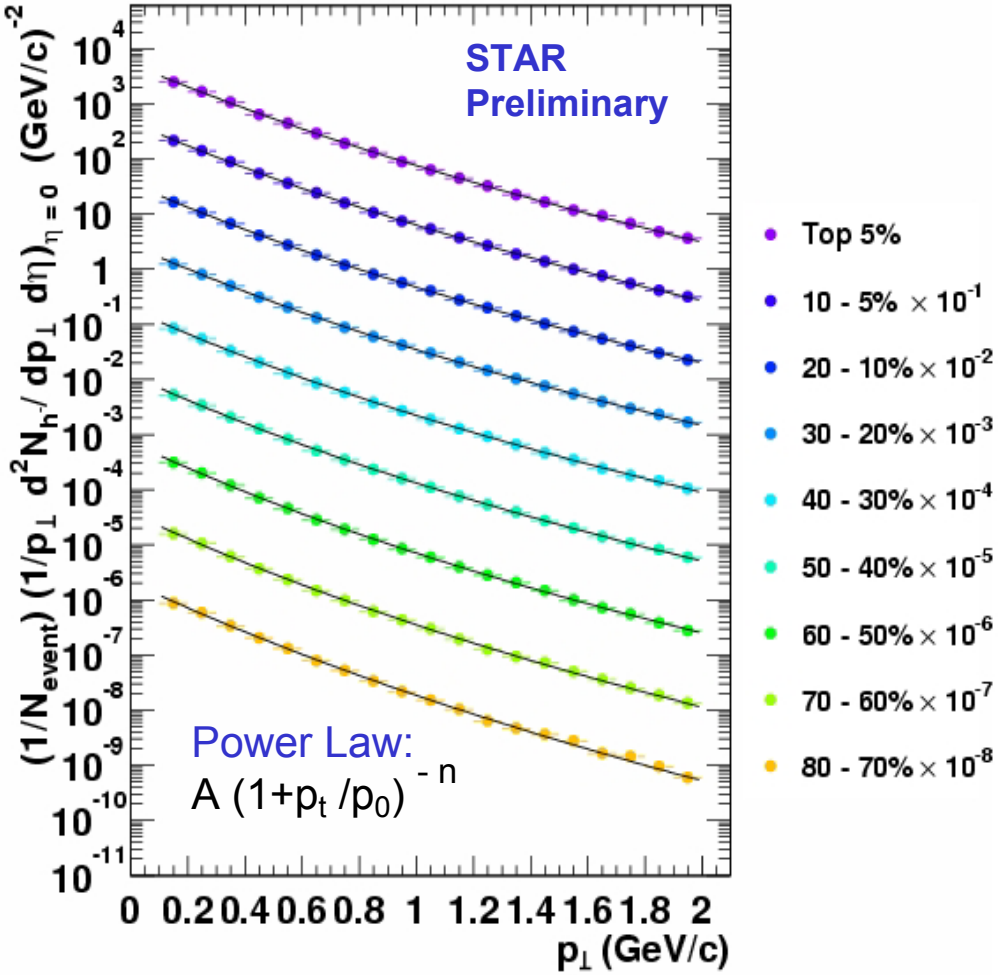


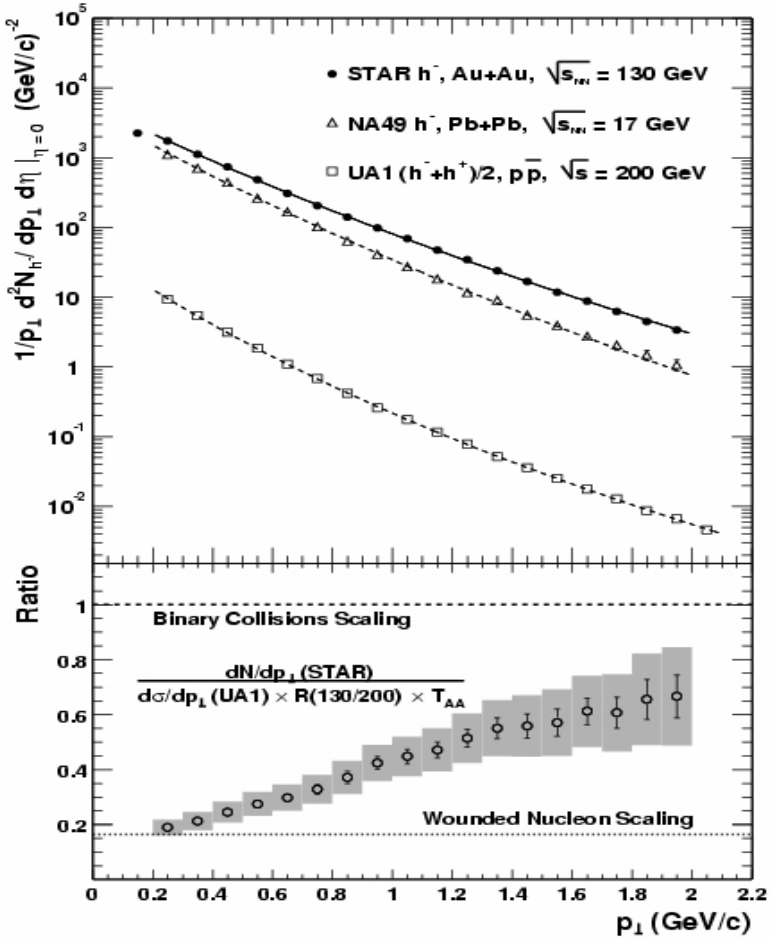
$dN_{h^-}/d\eta|_{\eta=0}$ = 280±1±20
$dN_{ch}/d\eta|_{\eta=0}$ = 567 ±1±38
38% ⇑ pp
52% ⇑ SPS



Multiplicity dominated by Geometry
Relatively flat in η (<1.)
Centrality Consistent with other experiments

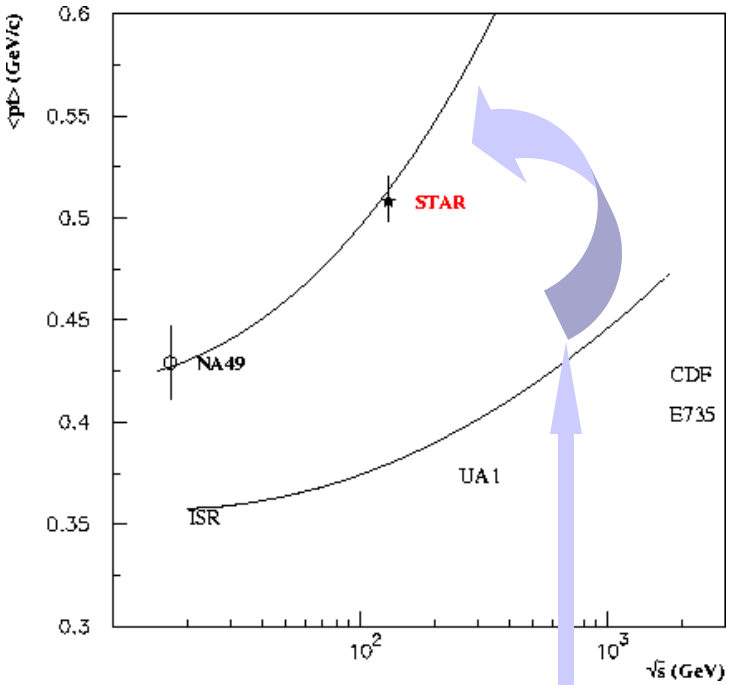
Transverse Spectra

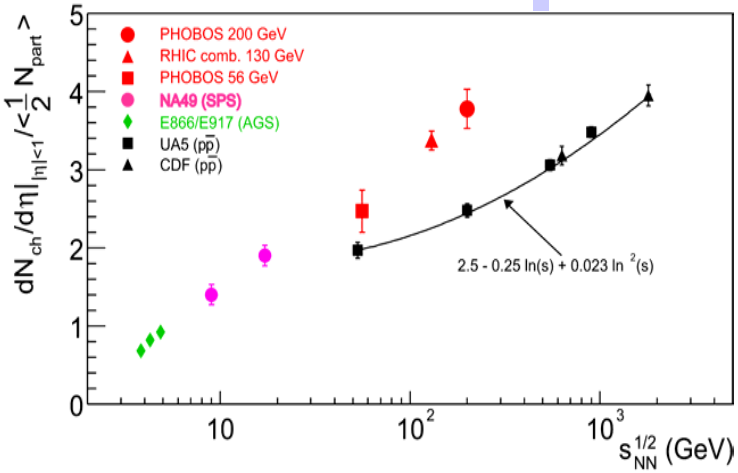


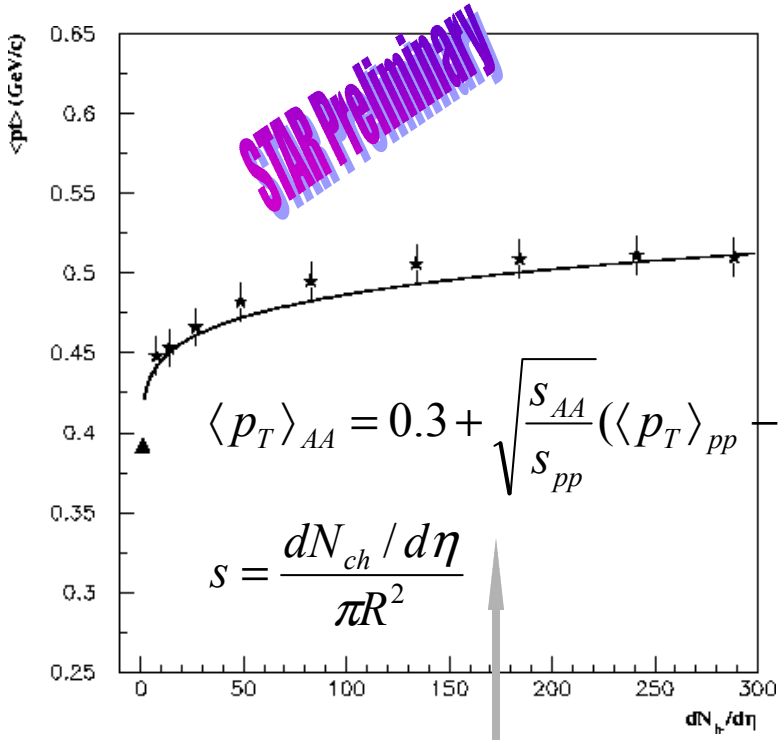


<pt>=0.508±0.012GeV/c (top 5%), increases from pp, SPS

<pt> Scaling





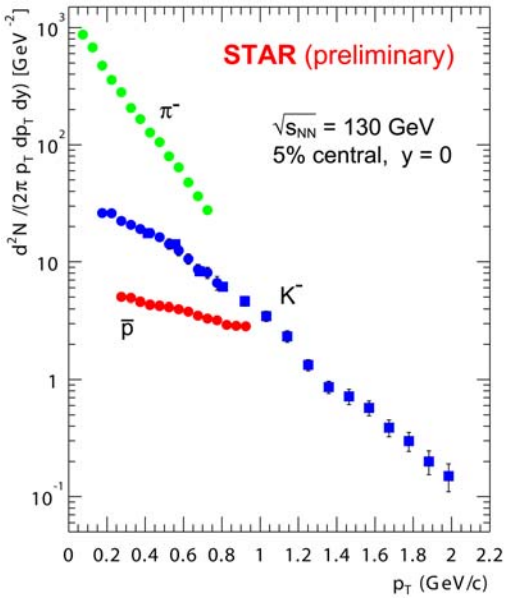


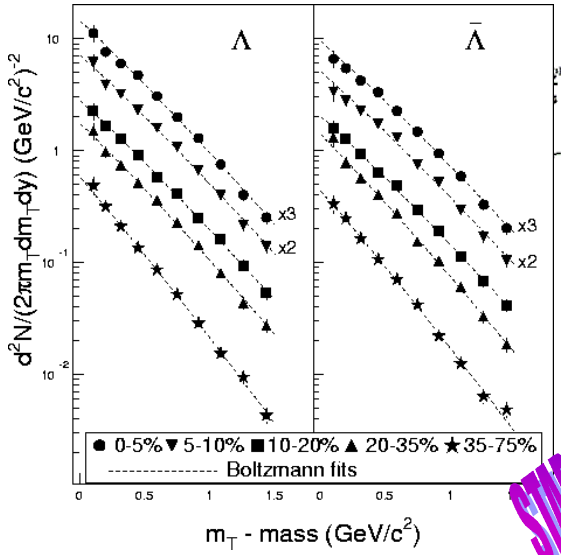
$$\langle p_T \rangle_{AA} = 0.3 + \sqrt{\frac{s_{AA}}{s_{pp}}}(\langle p_T \rangle_{pp} - 0.3)$$

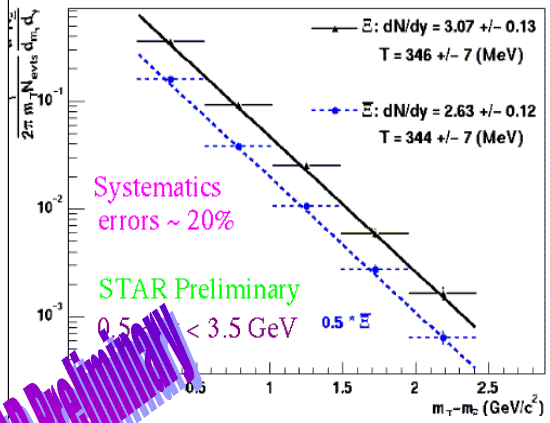
$$s = \frac{dN_{ch}/d\eta}{\pi R^2}$$

Saturation model:
J. Schaffner-Blielich, *et al.* nucl-th/0108048
D. Kharzeev, *et al*. hep-ph/0111315

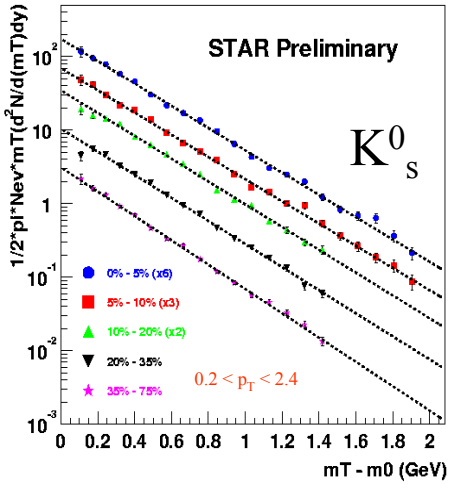
Some Particle Spectra

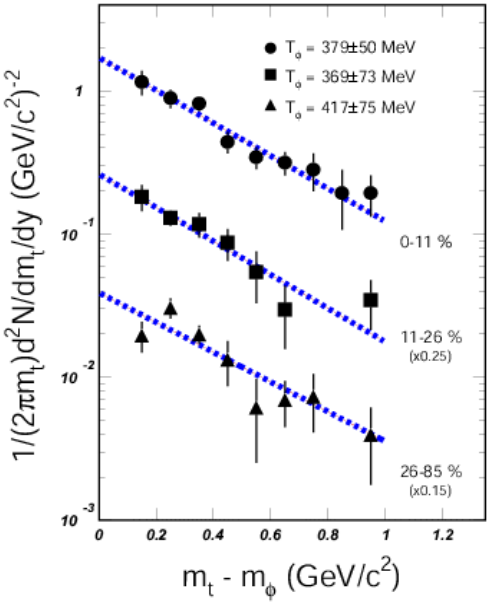


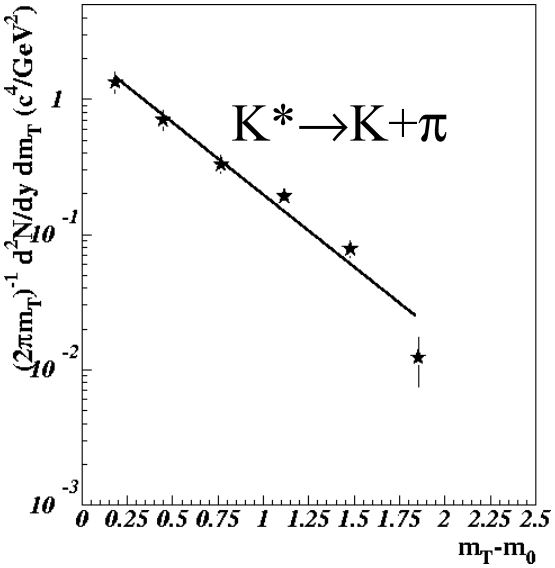




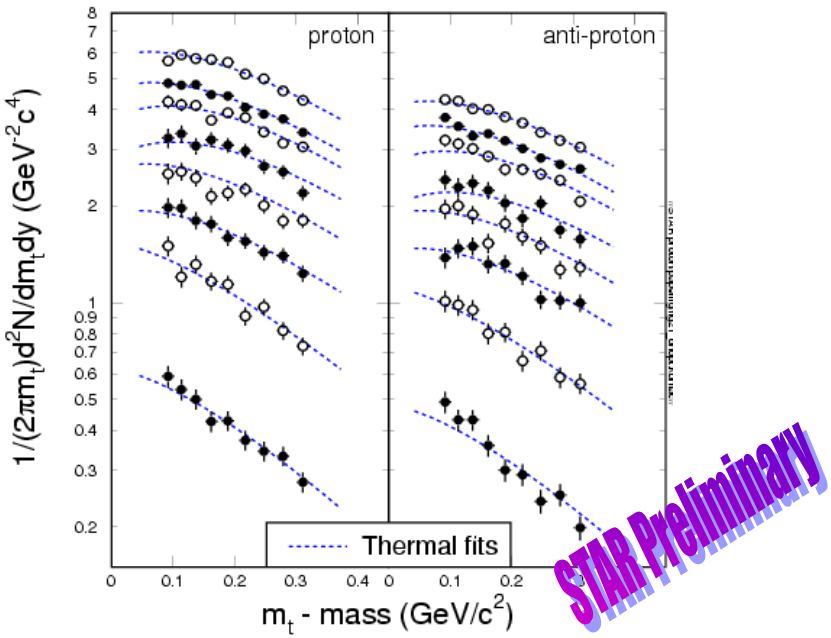
STAR Preliminary

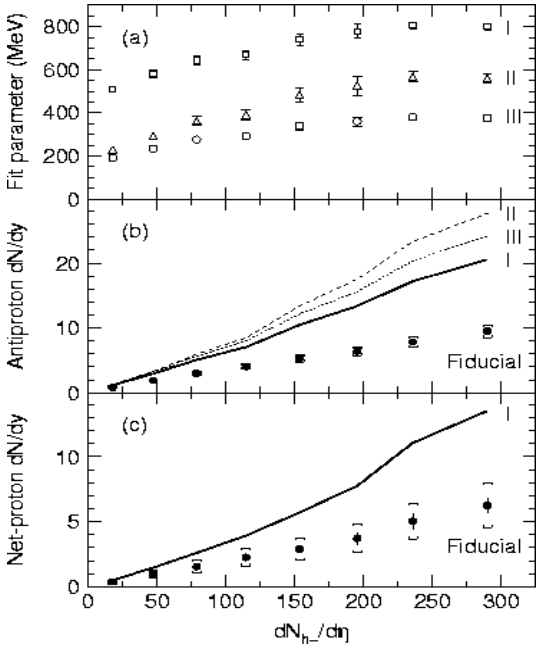


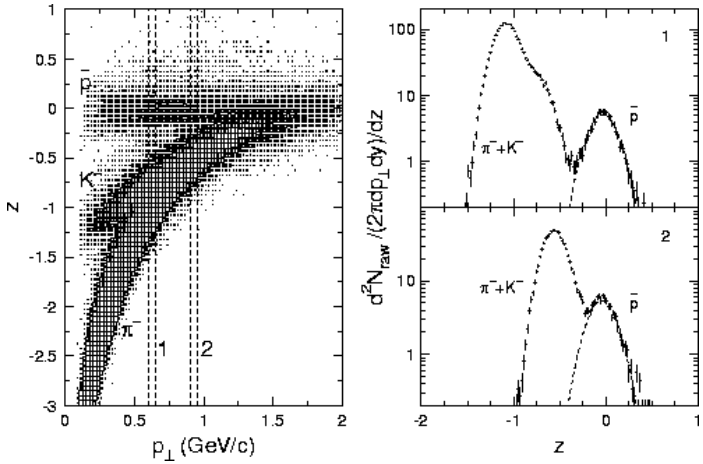




Proton, Anti-proton

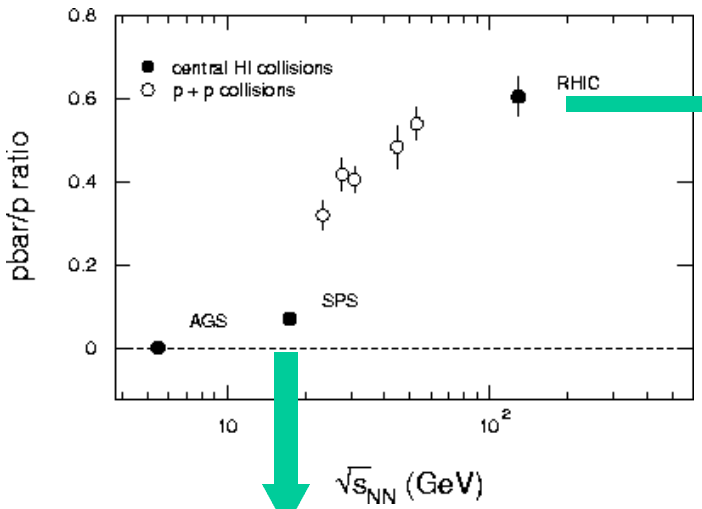


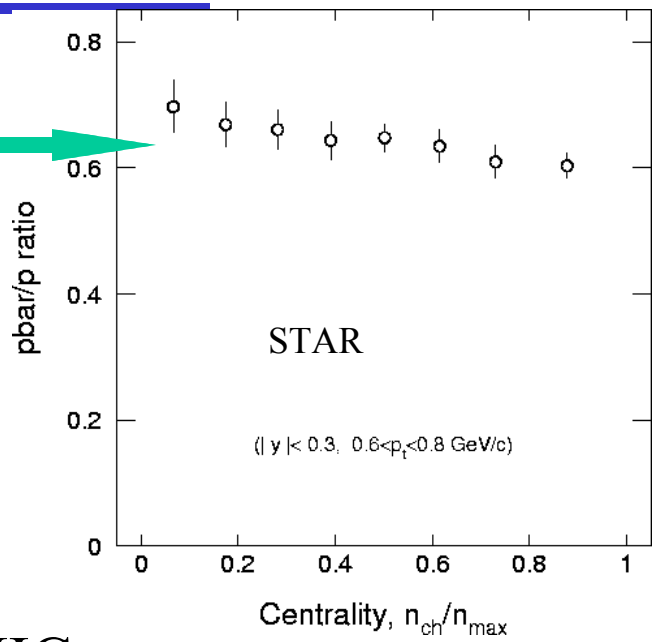


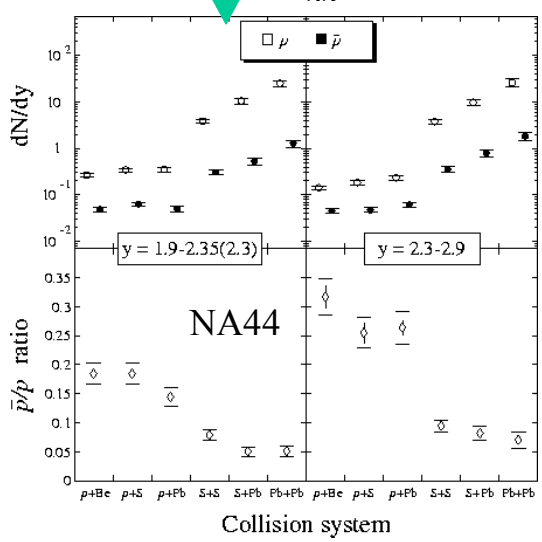


- Finite Baryon Stopping

$\bar{p}/p$ ratio







RHIC:

2/3 proton from production (how?)

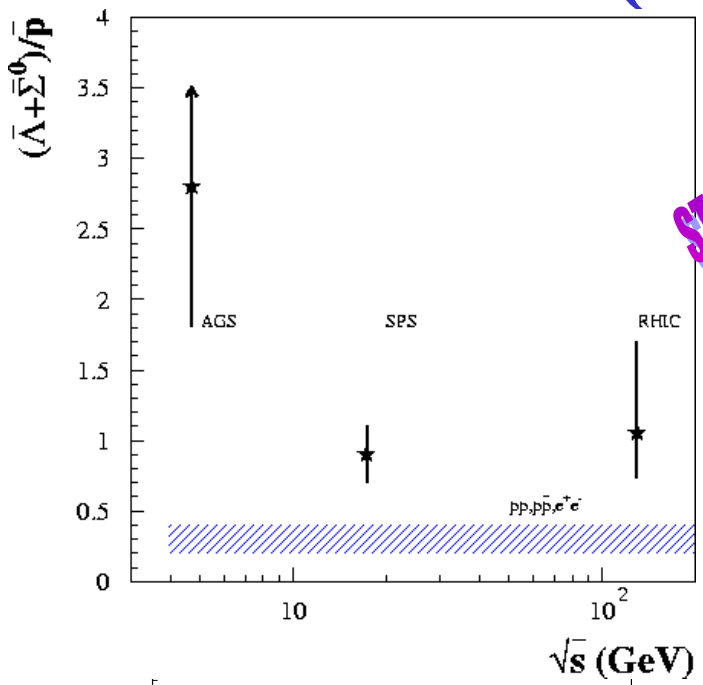
1/3 from transport

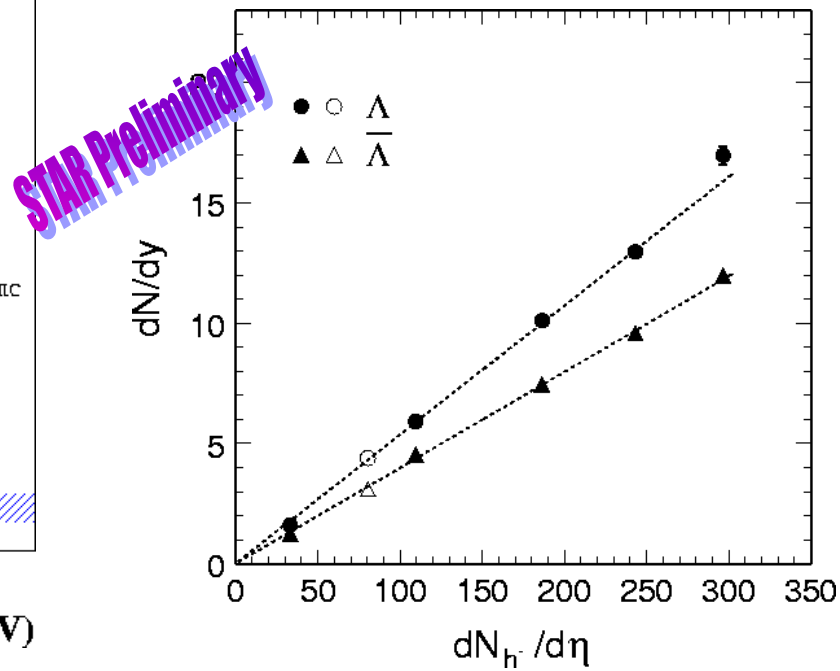
(AGS: 10^{-4}; SPS: 1/10)

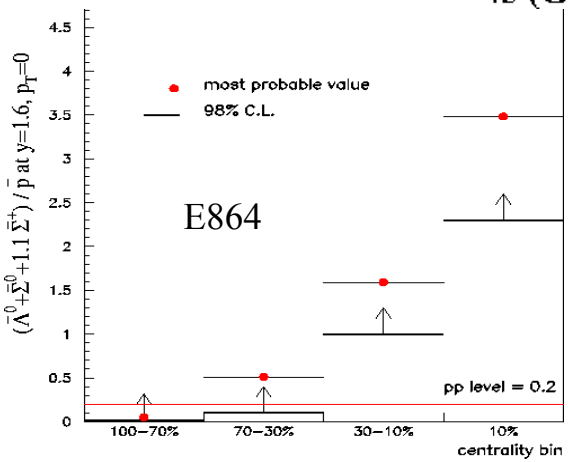
Small centrality dependence

$\Rightarrow$Small effect of $\bar{p}$ absorption?

$(\bar{\Lambda} + \bar{\Sigma}^0)/\bar{p}$

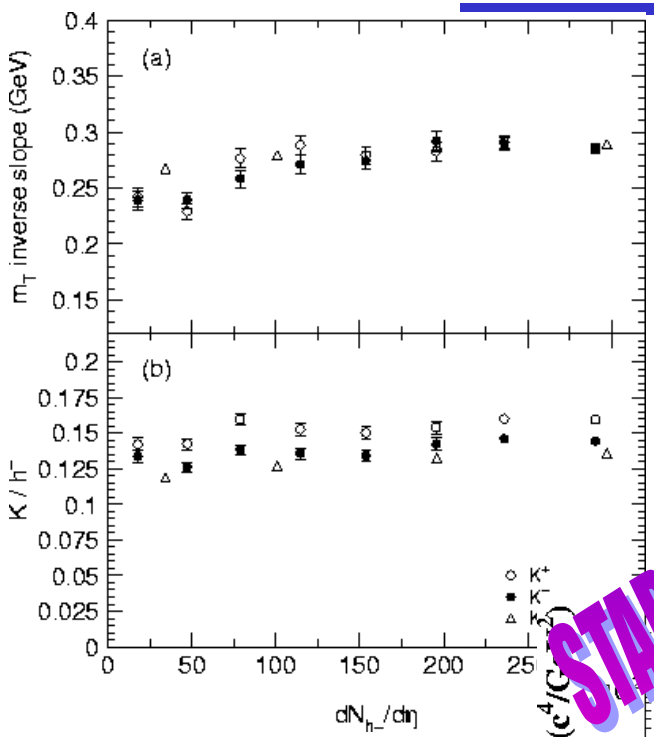


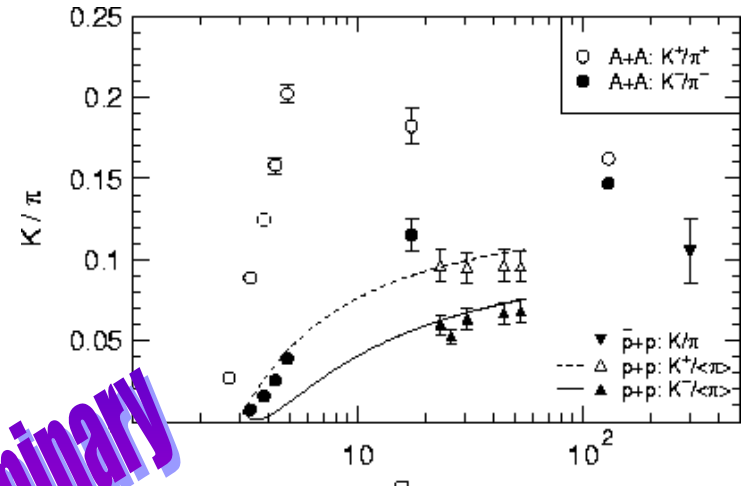




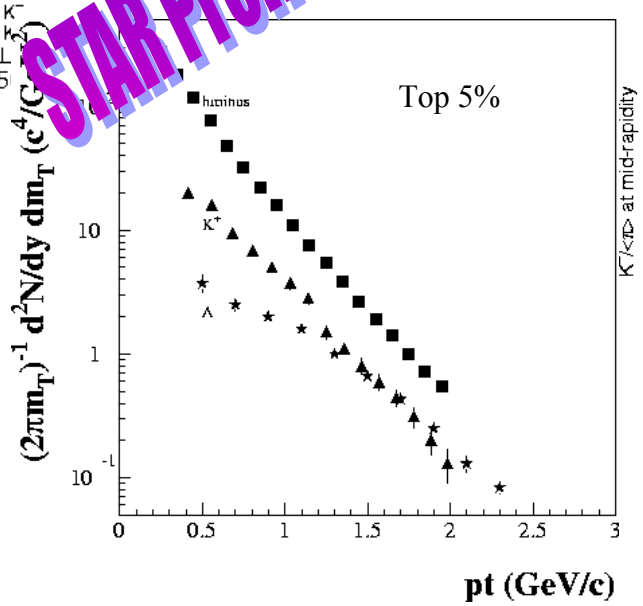
- Values in AA >> pp,e^+e^- strangeness enhancement?
- AGS: strong centrality dependence
- RHIC: little centrality dependence

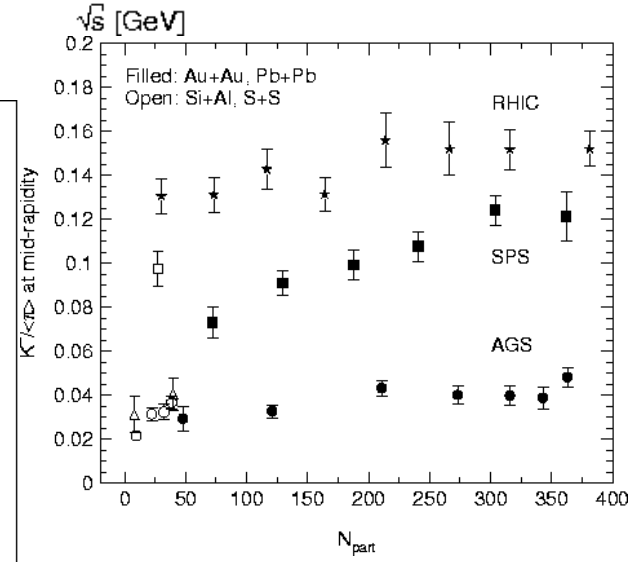
Kaon Systematics





STAR Preliminary





- K/π centrality
- Λ/K≥1 (pt>1.5GeV/c)

Chemical Freeze-out at RHIC

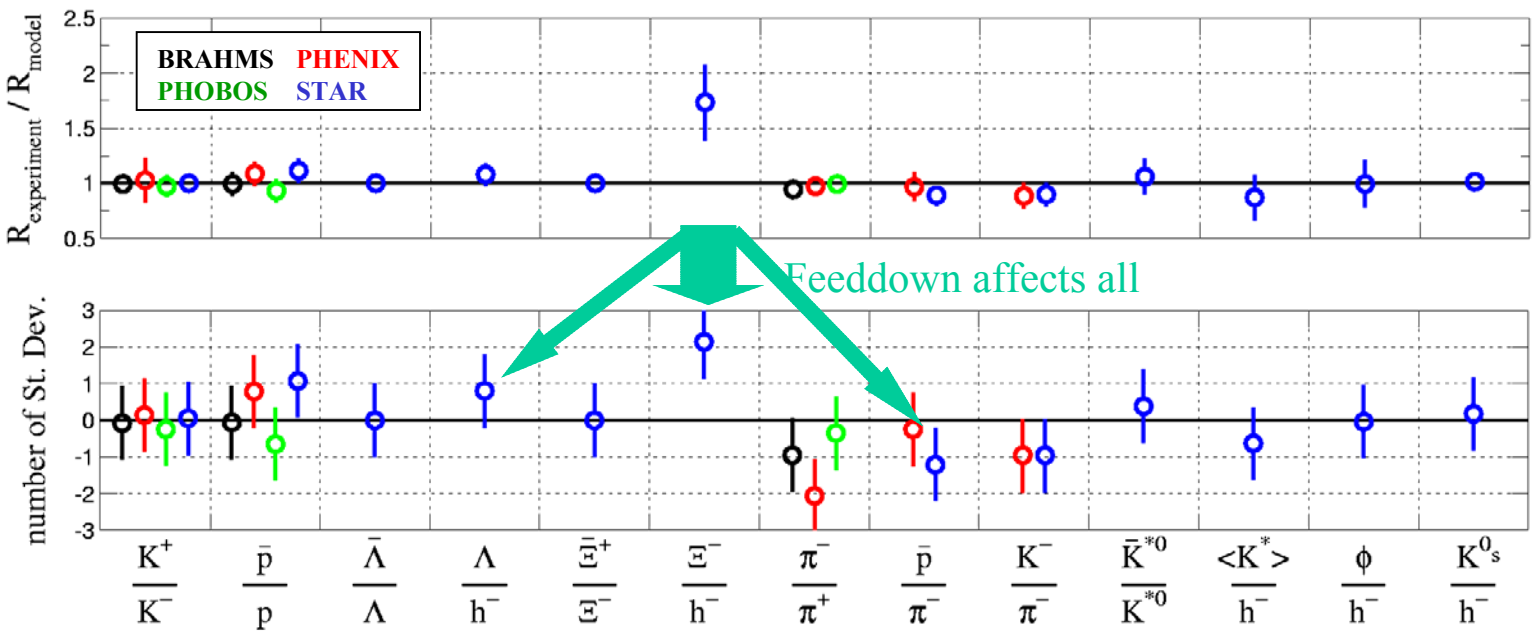
Hadron resonance ideal gas + decay effect

Chemical freeze-out parameters
T_{ch} = 170±4 MeV
μ_B = 40±4 MeV

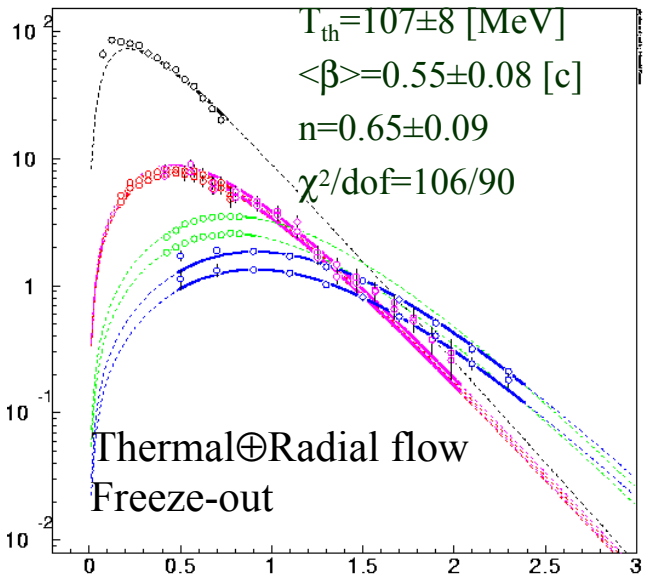
μ_s = 1.1±2.0 MeV
γ_s = 1.09 ±0.06

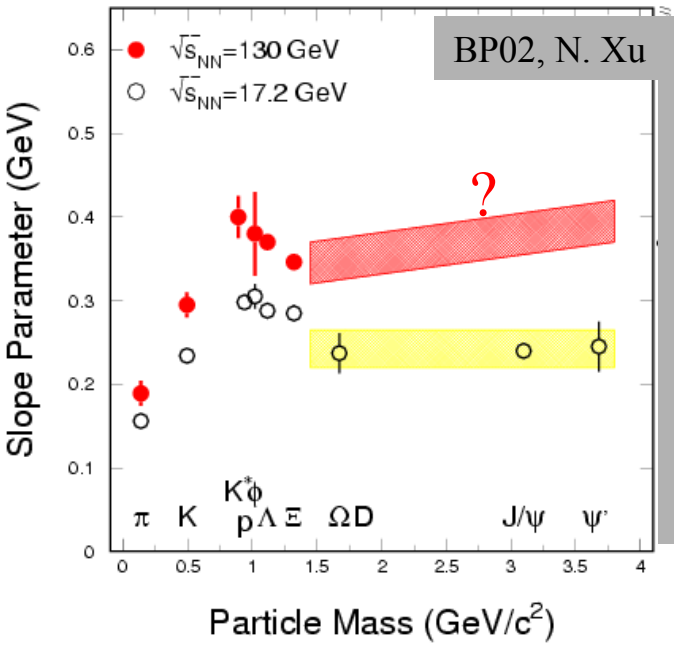
$\chi^2/\mathrm{dof} = 16.7/9$

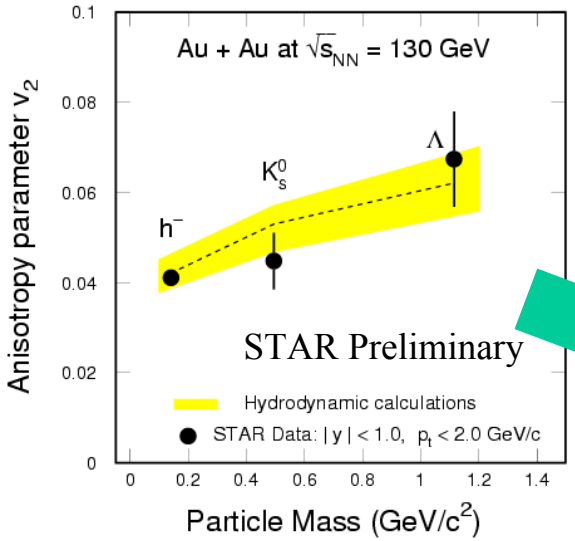
M. Kaneta



m_T Slope





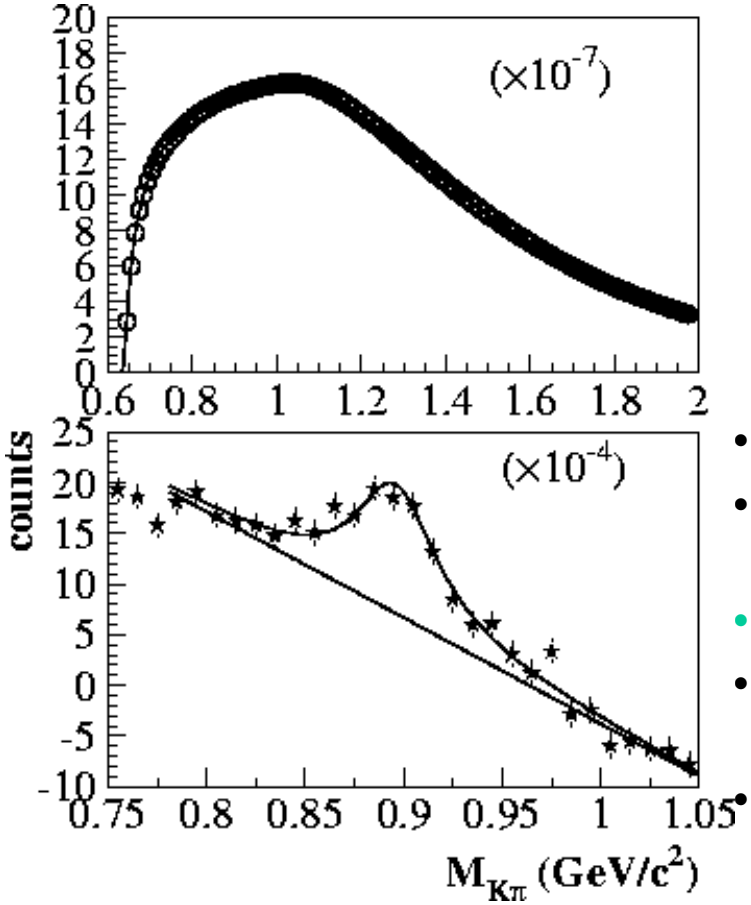


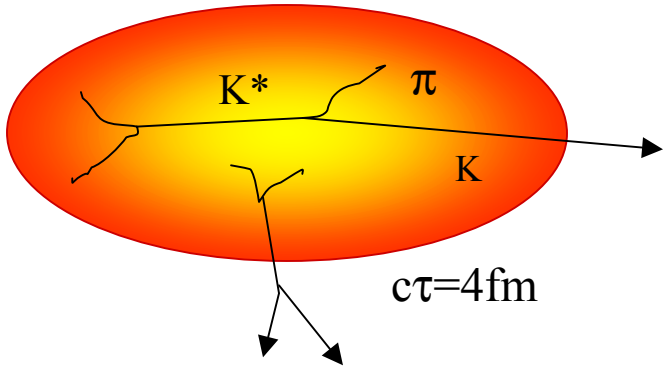
test?

- Spectra harder than SPS
- Large Radial Flow?
- Λ≥K (pt>1.5GeV/c)

Flow? or
high-pt meson suppression⊕junction?

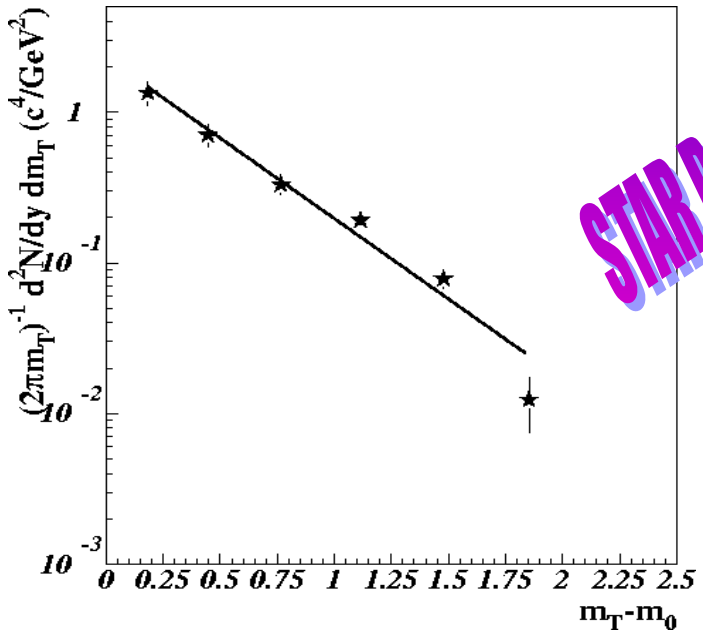
Resonances

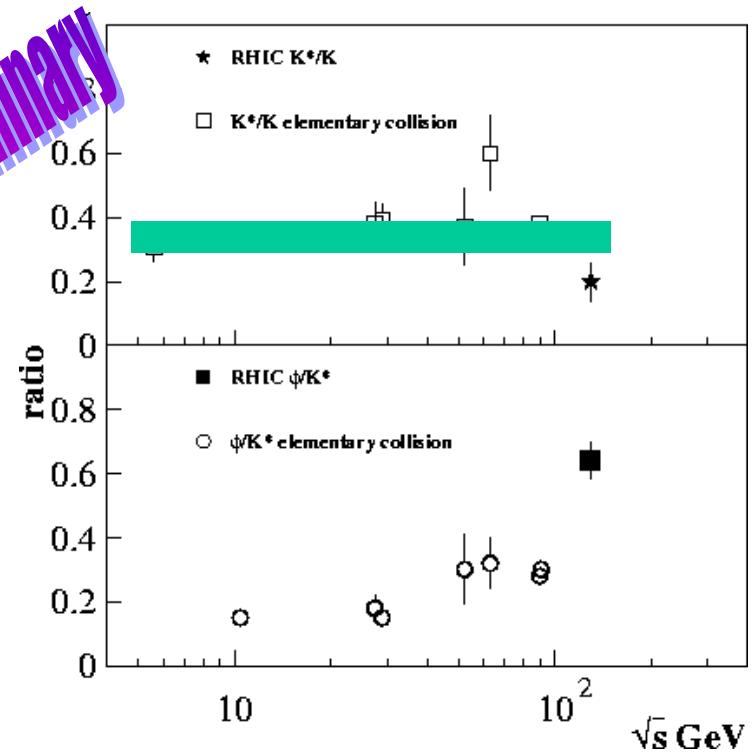




- Natural 2-particle correlation
- Resonances creation:
  Before Chemical Freeze-out
- Yield, pt Spectra, v2, mass, width, S/N
- Surviving possibility between Chemical and Kinetic Freeze-outs (Δt)
- Sensitive to
  Time Scale of the System
  Dynamics of the system

K* Spectrum

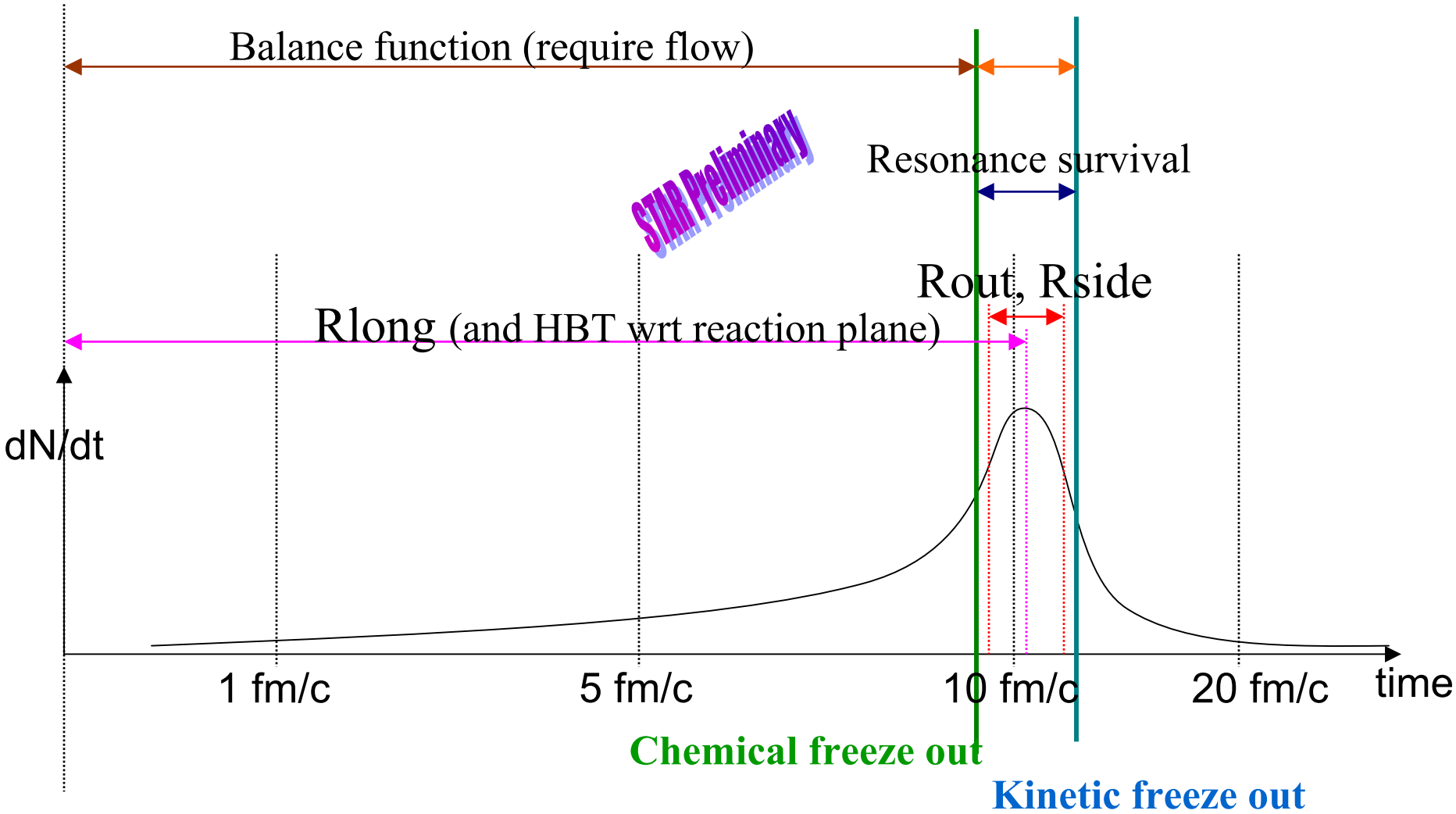




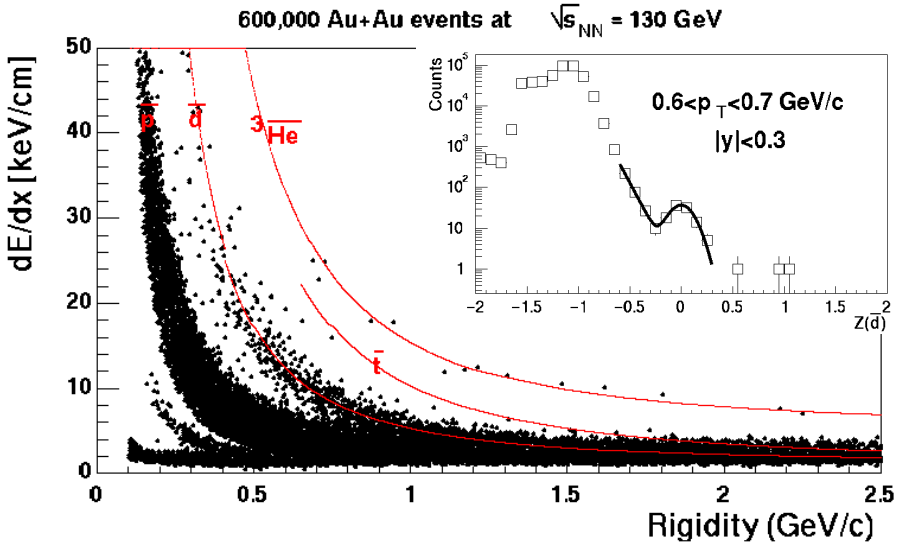
- Inverse Slope (T=0.41±.2±.4GeV) similar to φ,Λ
- K*/K, T consistent with sudden freeze-out scenario
- Alternative explanation: K+π→K*
  (regeneration after Chemical Freeze-out)

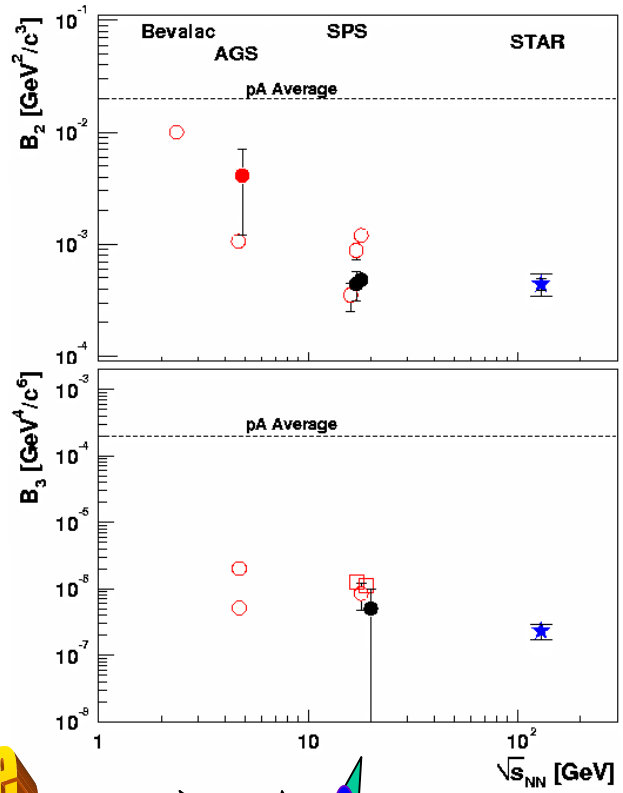
Collision Time Scale from STAR

In Blast Wave Scenario



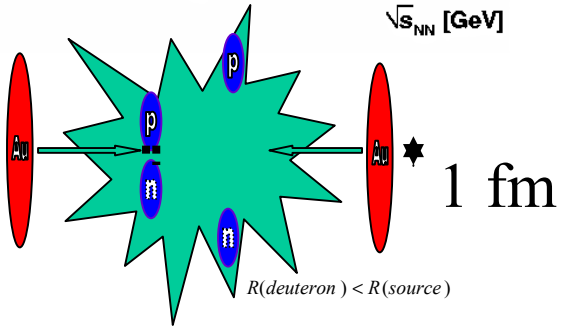
Antinuclei



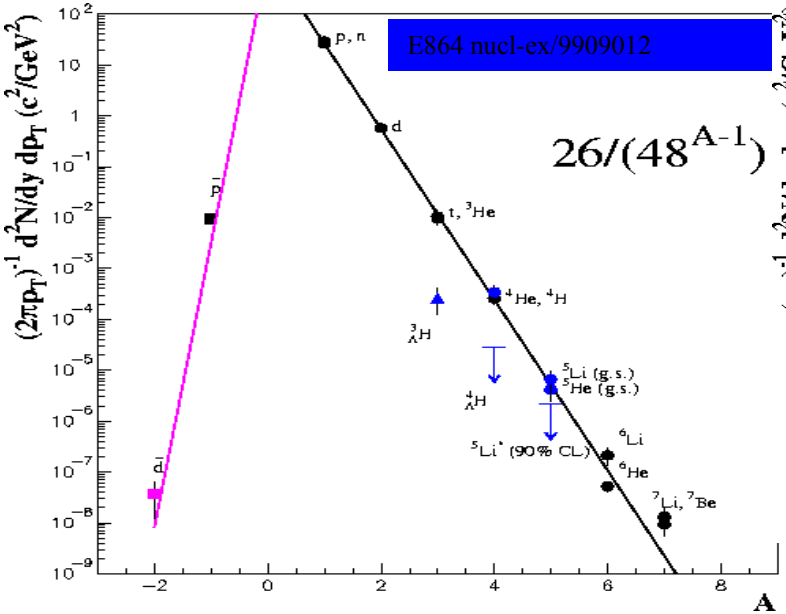


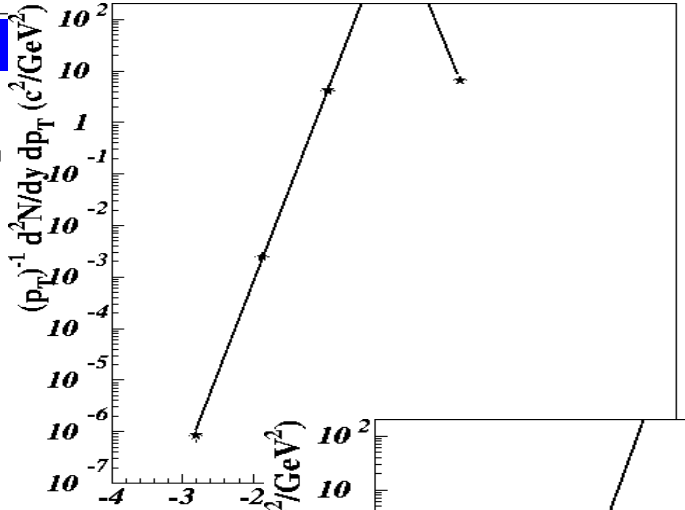
$$E\frac{d^3N_A}{d^3P} = B_A\left(E\frac{d^3N_N}{d^3p}\right)^A$$

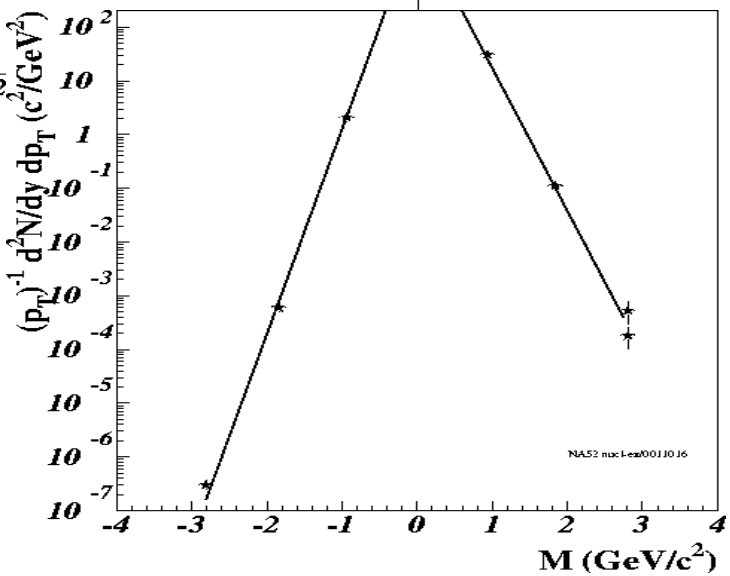
$$p = \frac{P}{A}, B_2 \propto \frac{1}{V}$$



Define Freeze-out







- *yield*∝exp(-(m_n±μ_b)n/T)

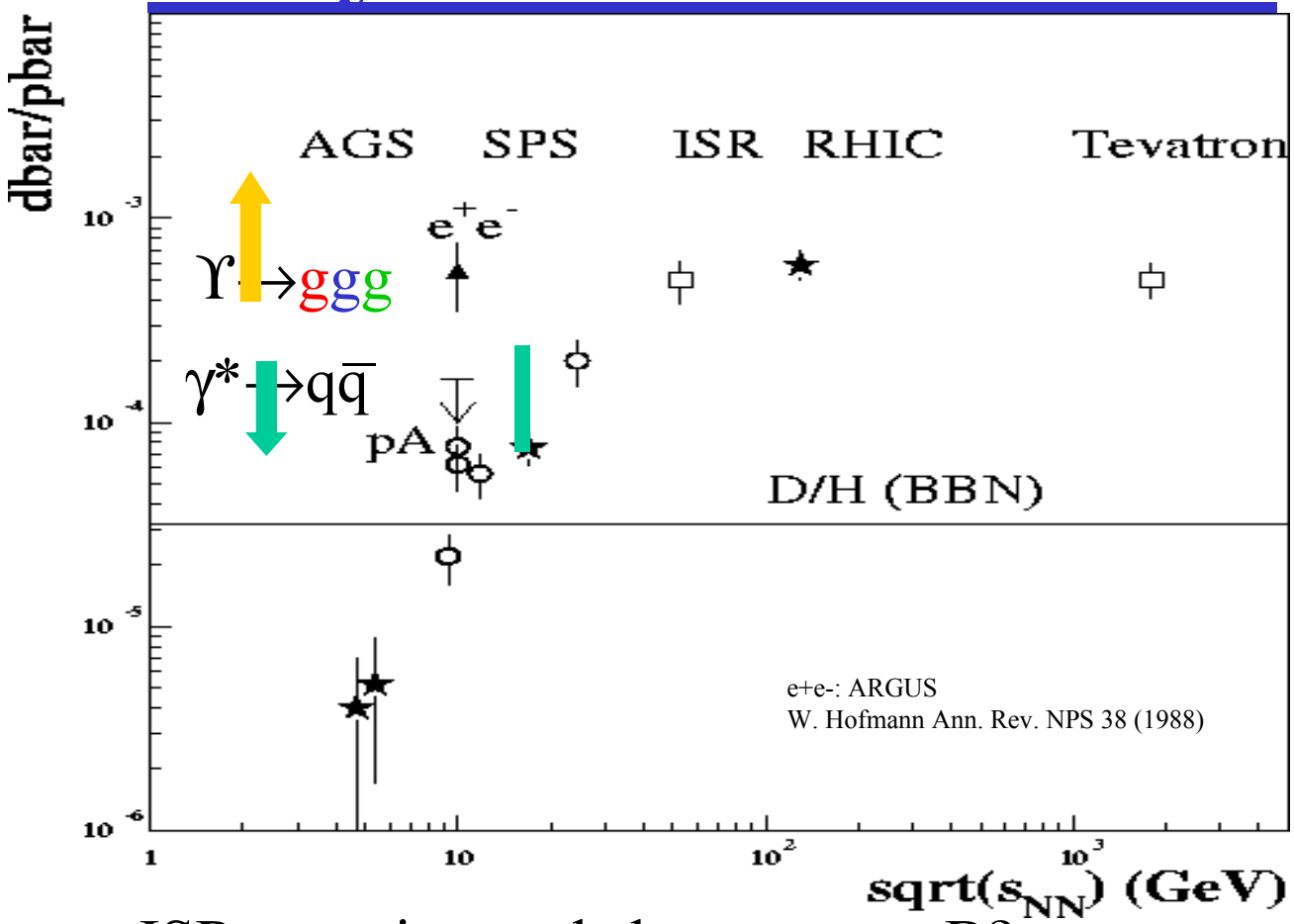
R. Scheibl, U. Heinz, PRC59(1999)1585
E864 nucl-ex/9909012

AGS central: μ_b=500MeV, T=110MeV

SPS minbias: μ_b=170MeV, T=130MeV

RHIC central: μ_b=28MeV, T=130MeV

Baryons from Gluons?



ISR energies and above: ggg→B?

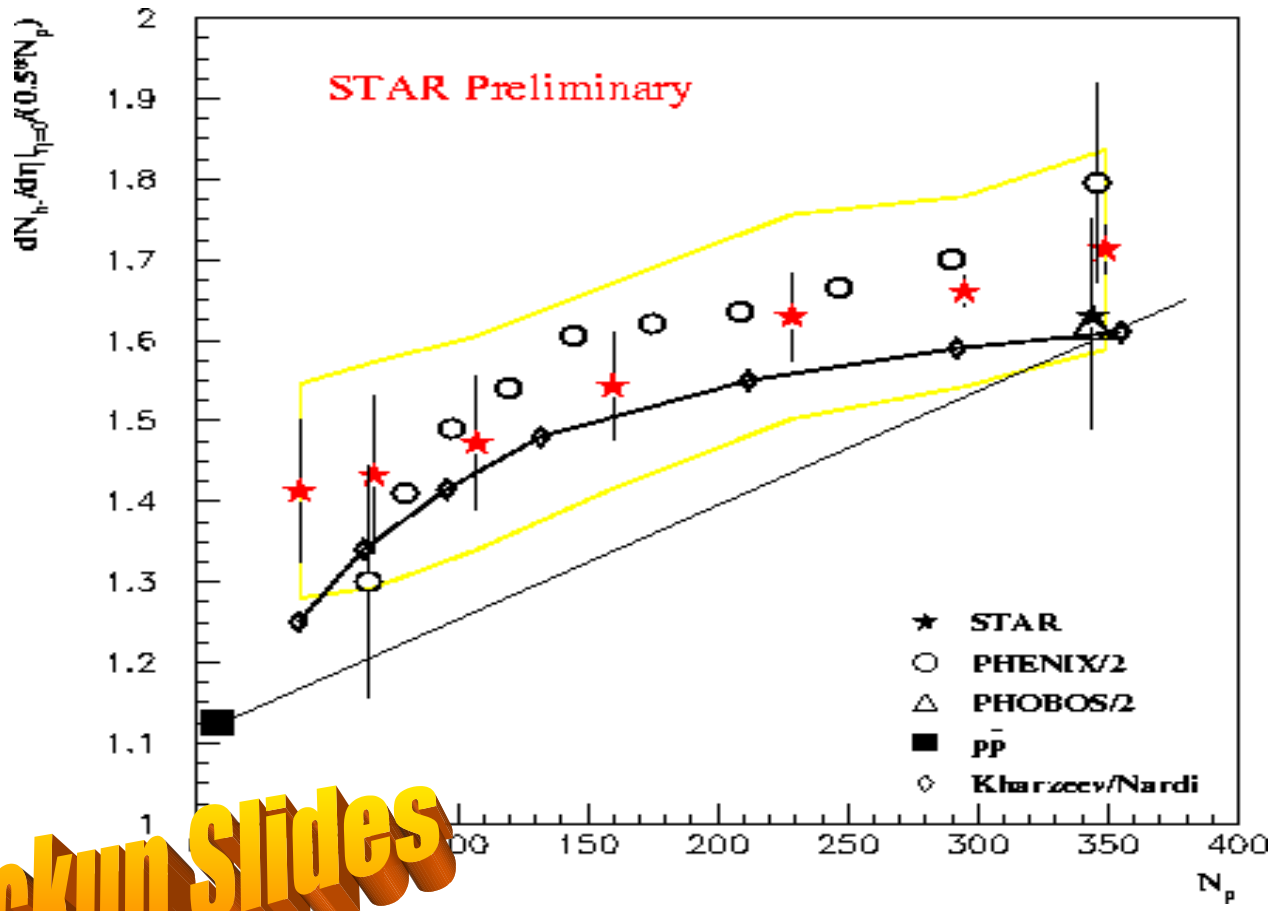
Below: $q\bar{q}$→B?

BBN: p(n, γ)D at T≈1 MeV

Conclusions

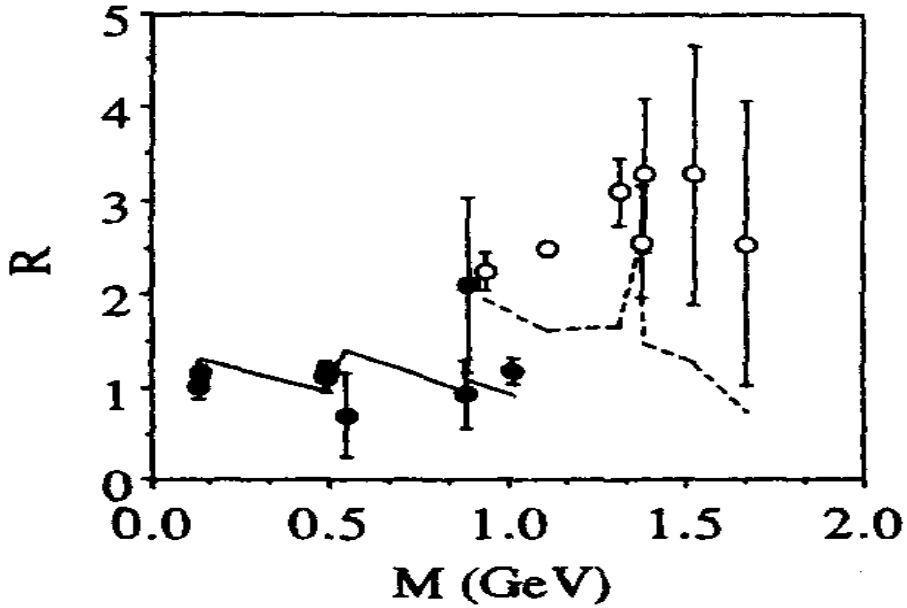
Future

Particle Production /Npart



Backup Slides

Baryon Enhanced in gluon jets



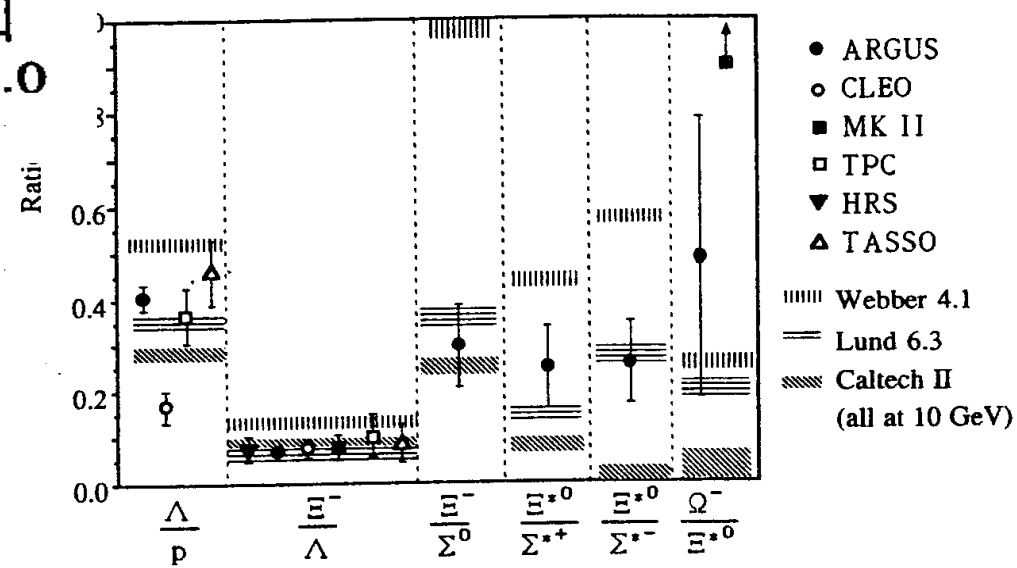


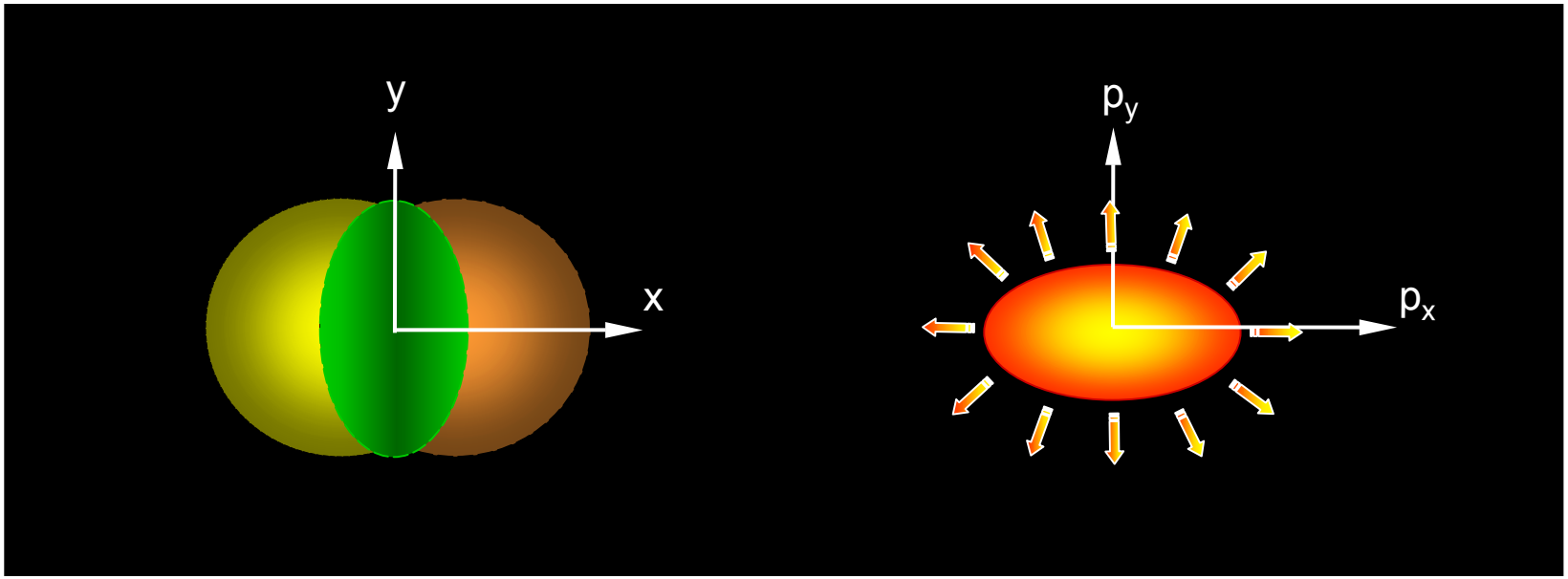
Figure 21 Strangeness suppression in baryon production. Shown are ratios of baryon cross sections for strangeness $s+1$ and s ($s = 0, 1, 2$), for baryons in the same spin multiplet. Data from e^+e^- annihilation at $\sqrt{s} \approx 10$ GeV from ARGUS (77) and CLEO (33), and at $\sqrt{s} \approx 30$ GeV from HRS (79, 82), MARK II (80, 83, 88), TASSO (35, 46, 84), and TPC (36, 81, 85). Shaded bands represent model predictions for $\sqrt{s} = 10$ GeV; the results for $\sqrt{s} \approx 30$ GeV are very similar.

Backup Slides

Event Anisotropy

Sensitive to initial/final conditions and equation of state (EOS) !

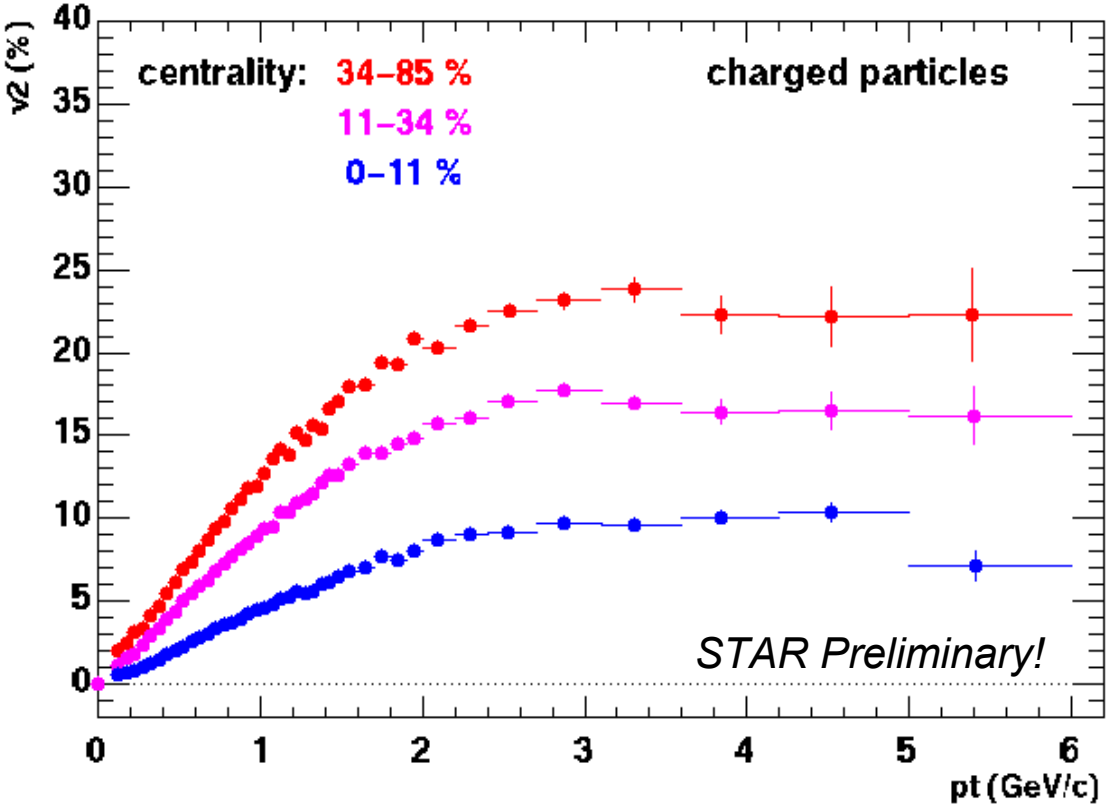
coordinate-space-anisotropy ⇔ momentum-space-anisotropy



$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle} \qquad v_2 = \langle \cos 2\varphi \rangle, \quad \varphi = \tan^{-1}\left(\frac{p_y}{p_x}\right)$$

Backup Slides

v_2 at higher p_t



Au+Au at 130 GeV

- At p_t >2 GeV/c, v_2 saturates;

2) The saturation values increases with impact parameters;

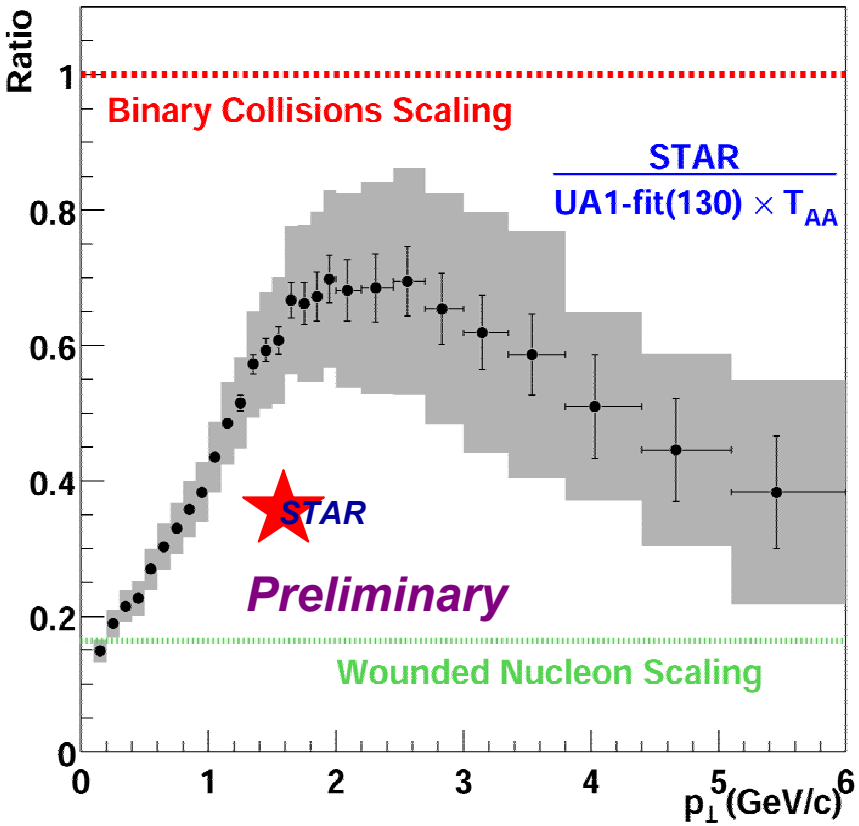
3) Clearly different from hydro model predictions.

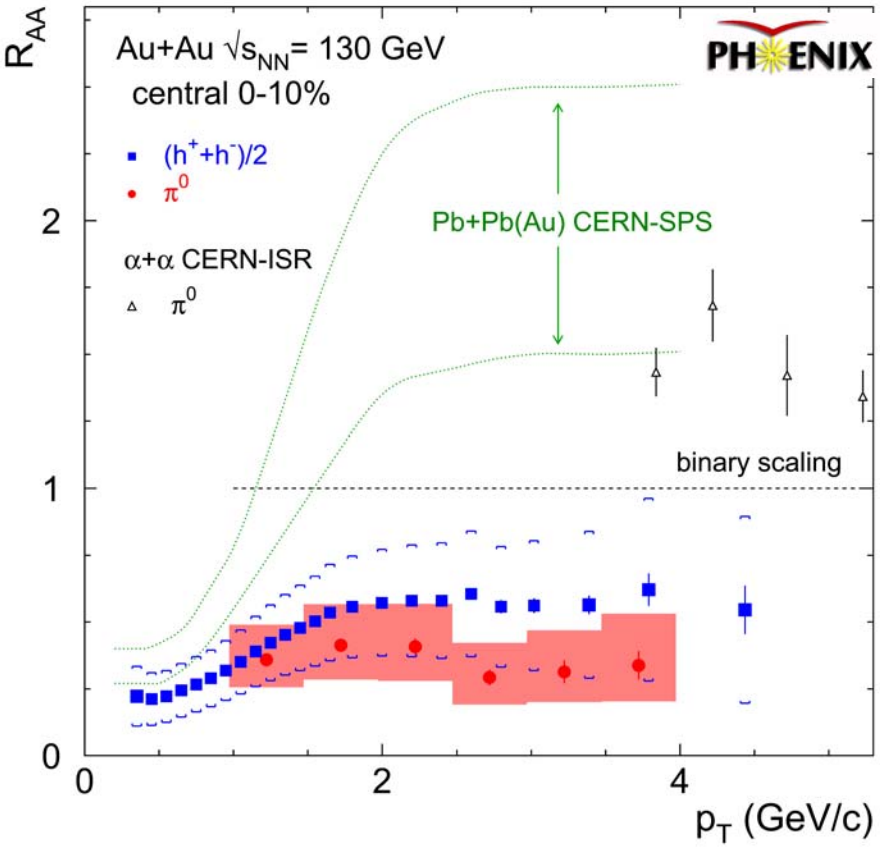
A new puzzle!

Backup Slides

Comparison of Central Au-Au to p-p

$$R_{AA} = \frac{Au + Au}{\langle N_{binary} \rangle pp}$$





Ratio exhibits characteristic features:

- increases up to ~ 2 GeV
- saturates at R < 1
- decrease at high p_T ?

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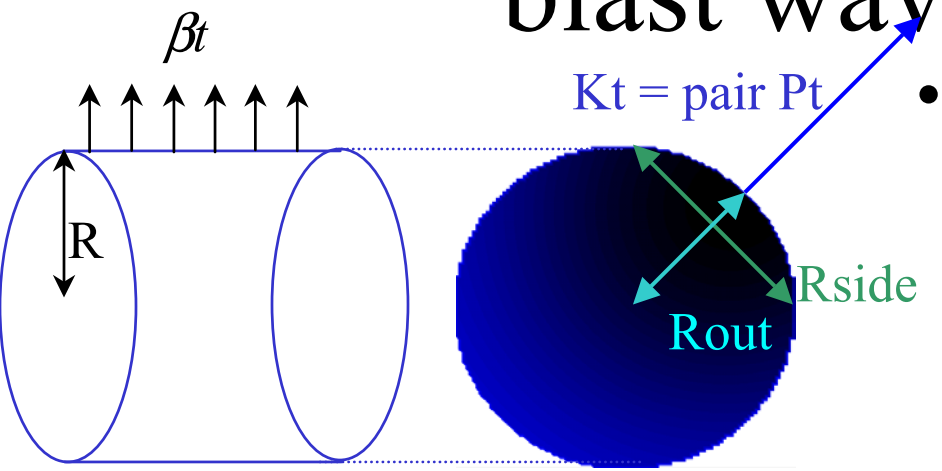
Handling space: blast wave scenario



$$f(\vec{x},\vec{p}) = K_1\left(\frac{m_T}{T}\cosh\rho\right)\cdot$$

$$e^{\frac{p_T}{T}\sinh\rho\cos(\phi_s-\phi_p)}\cdot$$

$$\theta\left(1-\sqrt{y^2+\eta^2x^2}/R_{\eta}\right)$$

$$e^{-t^2/\Delta\tau^2}$$

- "Hydro-like" parameterization
  - Flow
    - Space-momentum correlations
    - $\langle\rho\rangle = 0.6$ (average flow rapidity)
    - Assymetry (periph) : $\rho_a = 0.05$
  - Temperature
    - T = 110 MeV (T thermal)
  - System geometry
    - R = 13 fm (central events)
    - Assymetry periph) $s_2 = 0.05$
  - emission duration
    - $\Delta\tau = \tau_{Kinetic} - \tau_{chemical}$?

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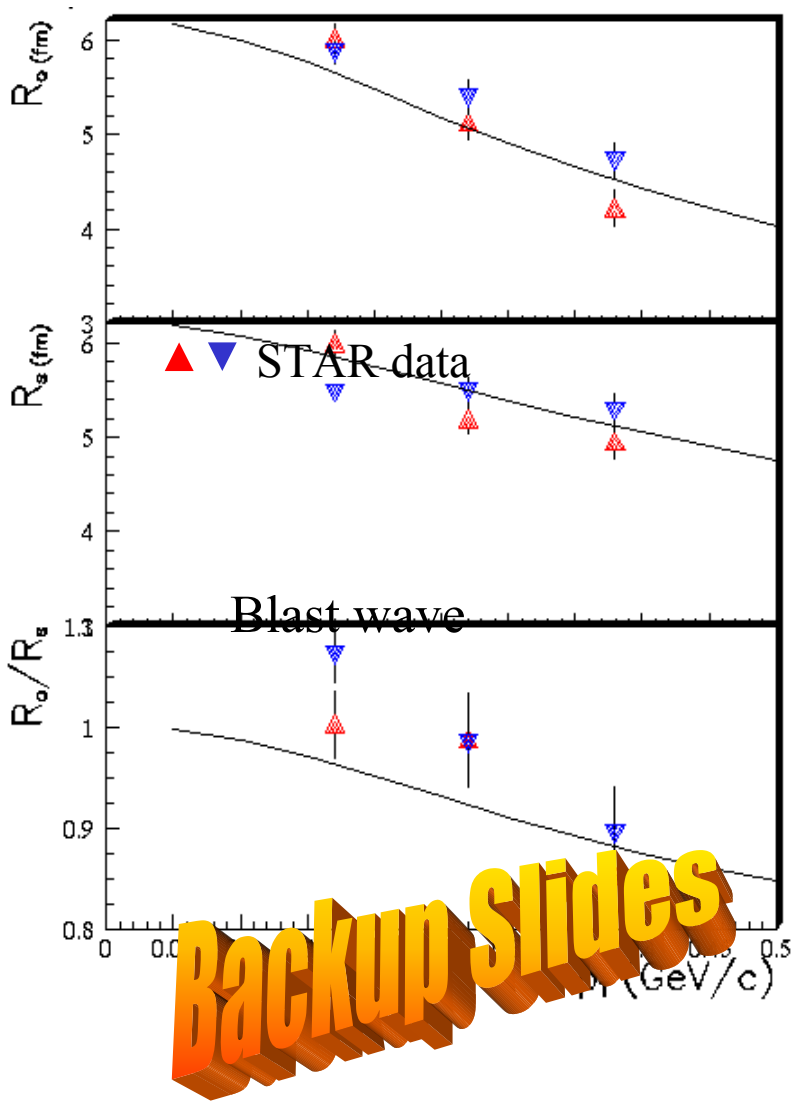
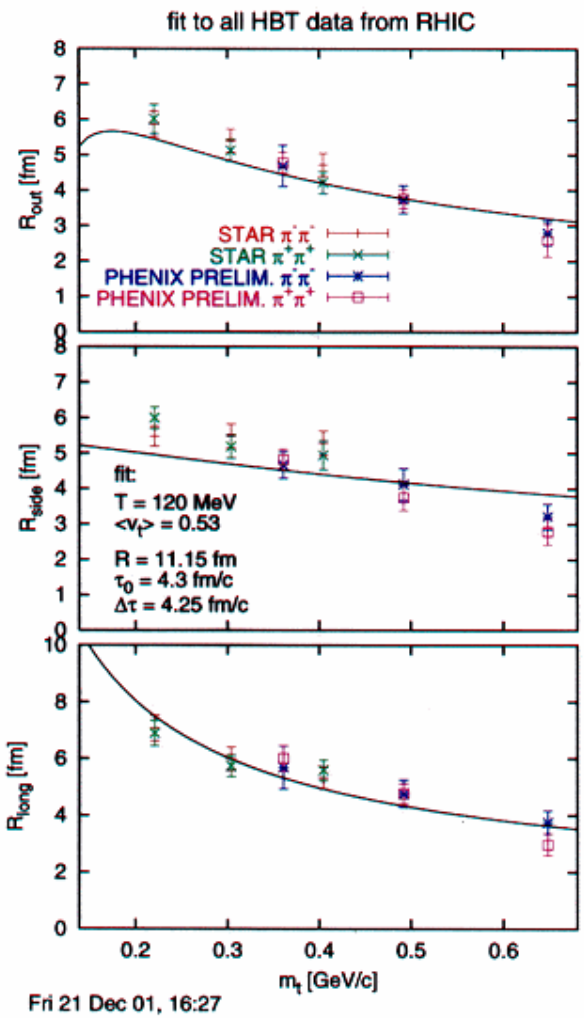
Very short emission duration



- Published STAR HBTdata
- Blast wave with "default" parameters
  - Pt dependance of radii well reproduced
    - Thanks to space-momentum correlations
- Striking feature: short emission duration

  $\Delta\tau = 1.5$ fm/c

- B. Tomasik fit to both STAR and PHENIX data
  - $\tau_{Kinetic}$ decreases
    - Becomes unreasonably short
  - $\Delta\tau$ increases
  - T and flow remain in the same ballpark



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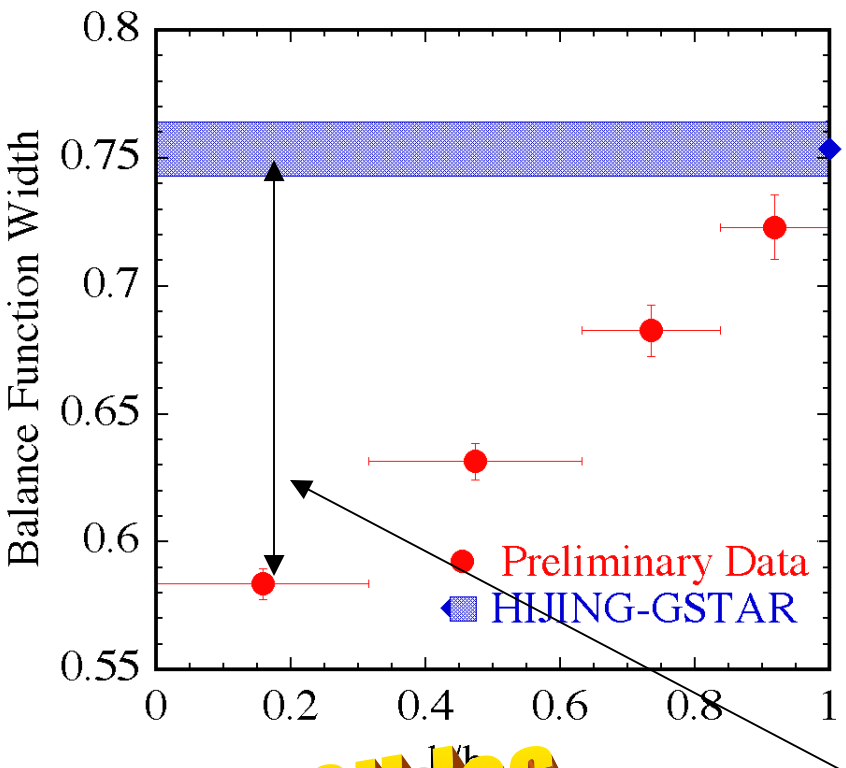
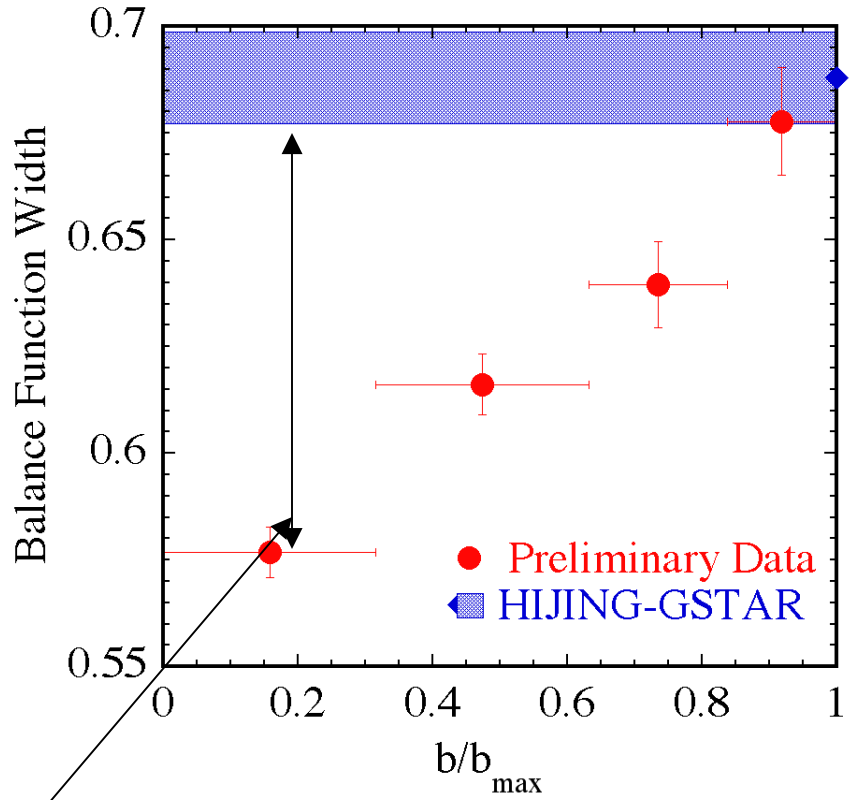
Balance functions:Summary plot

Charged Particles



Pions



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g fundamentally different from p-p is happening