Particle (Anti-Baryon to Baryon) Ratios at RHIC from STAR

Au + Au $\sqrt{s_{NN}} = 130$ GeV

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Intriguing Questions for Baryon Production at Mid-rapidity in Au+Au Collisions at RHIC

1) **Mechanisms for Anti-Baryon and Baryon Pair Production:**

    Hadronic Production Picture --- String Fragmentations
        diquark and anti-diquark fragmentation produces
            baryon and anti-baryon pairs

    Baryons in QGP --- Strings (T=200 MeV) too soft to
        fragment into baryon and anti-baryon pairs. Then how
        to produce baryons in QGP? ?
        (topological defects…..?)

2) **Mechanisms for Baryon Number Transport (Stopping):**

    Initial Baryon Numbers at Beam-Target Rapidity ---
        +- 5 units of rapidity (0.9999c speed)

    Final (net) Baryon Number at Mid-Rapidity ---
        0 rapidity (0c longitudinal speed)

    What dynamics will transport baryon number over such
        large rapidity gap??

We study features in baryon production via particle ratios

Pbar to P Ratio at Mid-Rapidity

1) **Pbar Yield from Pair Production Only:**

$$Y_{pbar} = Y_{pair}$$

2) **P Yield from Both Pair Production and Baryon Transport:**

$$Y_P = Y_{pair} + Y_{tr}$$

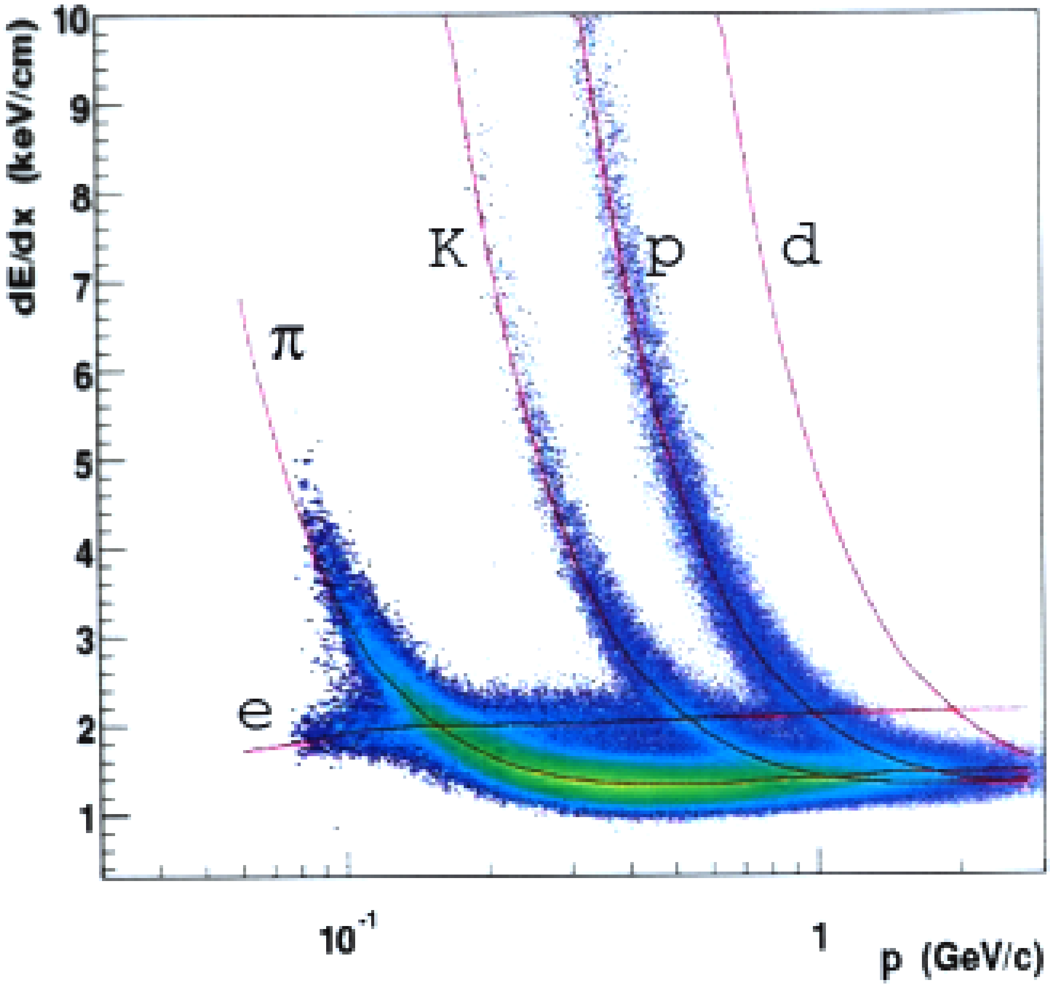
(not meant to give a precise description of physical pictures involved, just to broadly denote two contributions: 1) conserves baryon number; and 2) with a net baryon number related to initial baryon number by whatever mechanisms.)

Pbar to P Ratio:

$$Y_{pair} / (Y_{pair} + Y_{tr})$$

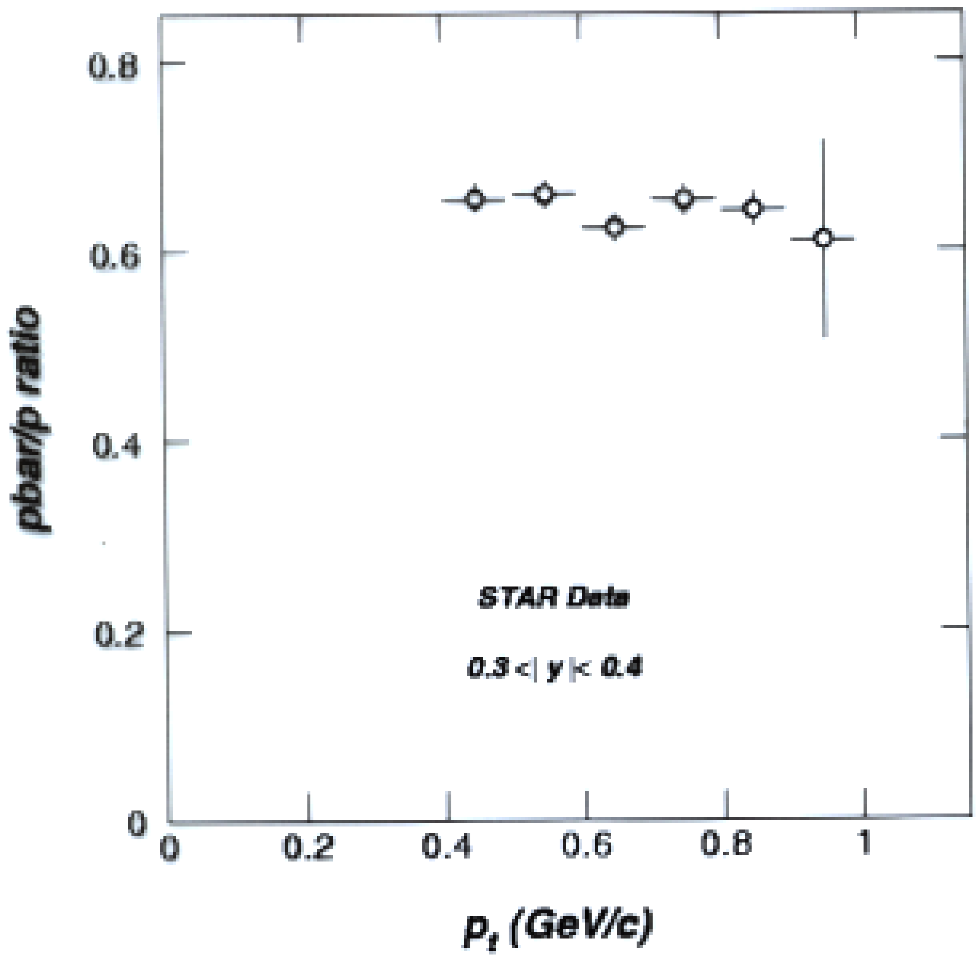
- Relative Strength of Pair Production and Baryon Transport
- P_T, Rapidity and Centrality Dependence of the Relative Strength

Pbar and P are Identified Using TPC dE/dx



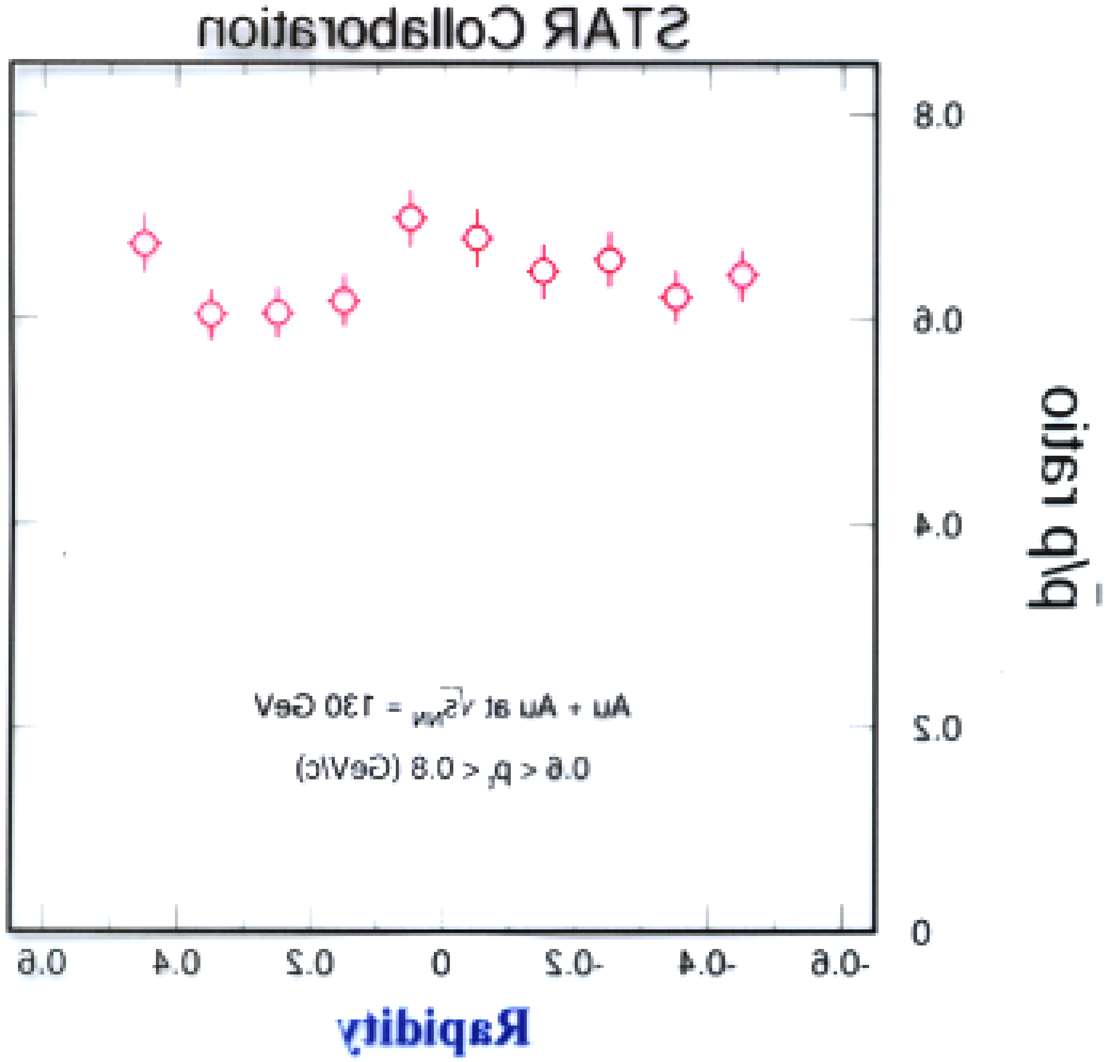
K-p separation up to 1.0 GeV/c using TPC dE/dx !

Pbar to P Ratio as a Function of P_T



1) Minimum bias Au + Au events
2) Systematic errors < 10%
3) Pbar/P ~ 0.65
4) No strong P_T dependence within the acceptance

Pbar to P Ratio as a Function of Rapidity



1) Minimum bias Au + Au events
2) Systematic errors < 10%
3) No or Weak rapidity dependence within acceptance

Relative Strength of Y_{pair} and Y_{tr} for Pbar and P Production

Within the TPC dE/dx Acceptance:

p_T 0.4 to 1.0 GeV/c

y -0.5 to 0.5

$$\frac{Y_{pbar}}{Y_p} = \frac{Y_{pair}}{Y_{pair} + Y_{Tr}} \approx 0.65$$

Pair Production is larger than Baryon Transport !

$$\frac{Y_{pair}}{Y_{Tr}} \approx 2$$

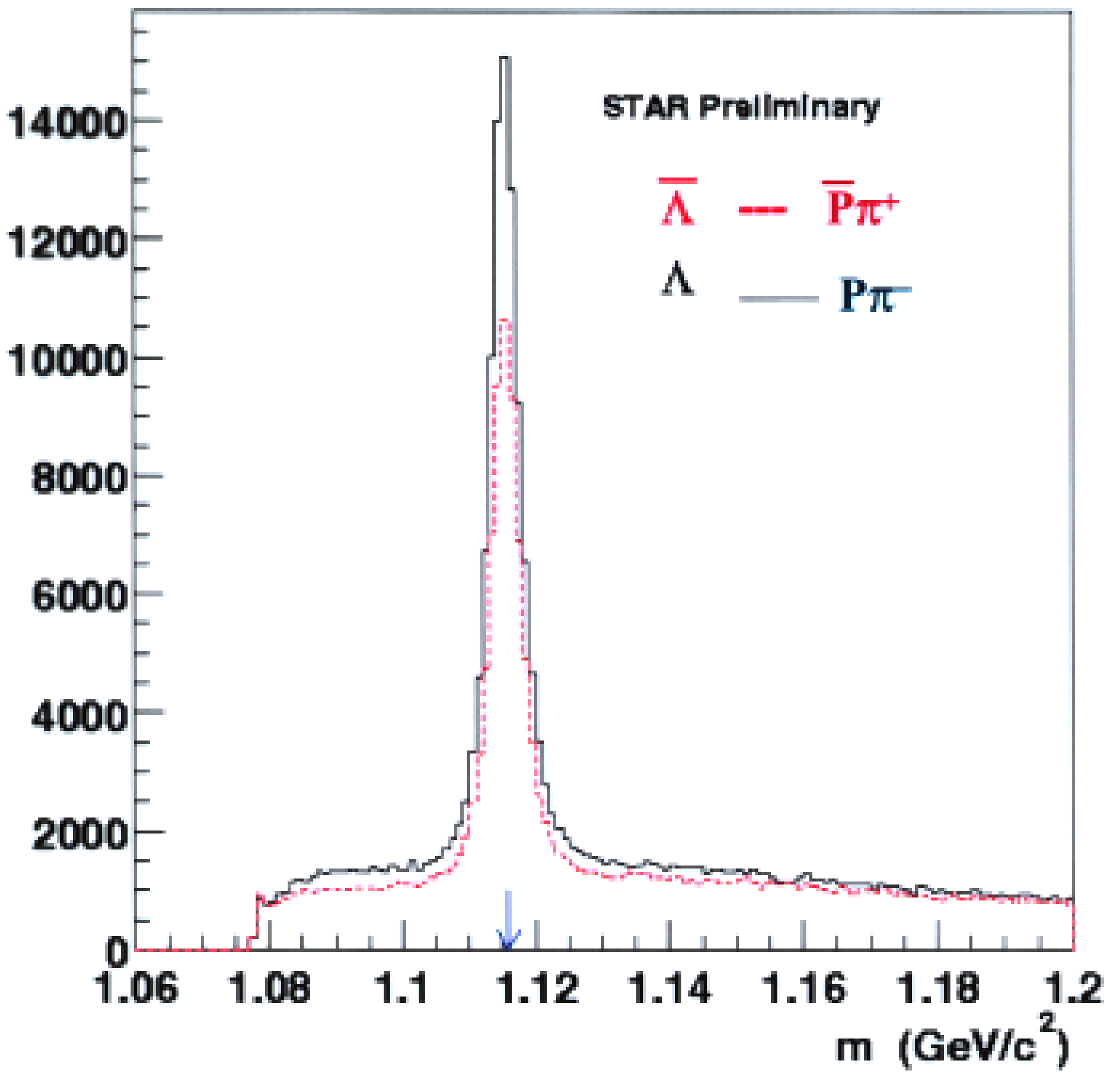
protons at mid-rapidity in Au+Au collisions

a) ~2/3 of protons from pair productions.

b) ~1/3 of protons from initial baryon number transported over 5 units of rapidity.

(for the acceptance covered by the STAR TPC dE/dx)

Lambda and Anti-Lambda Are Reconstructed From Decay Daughters in the STAR TPC

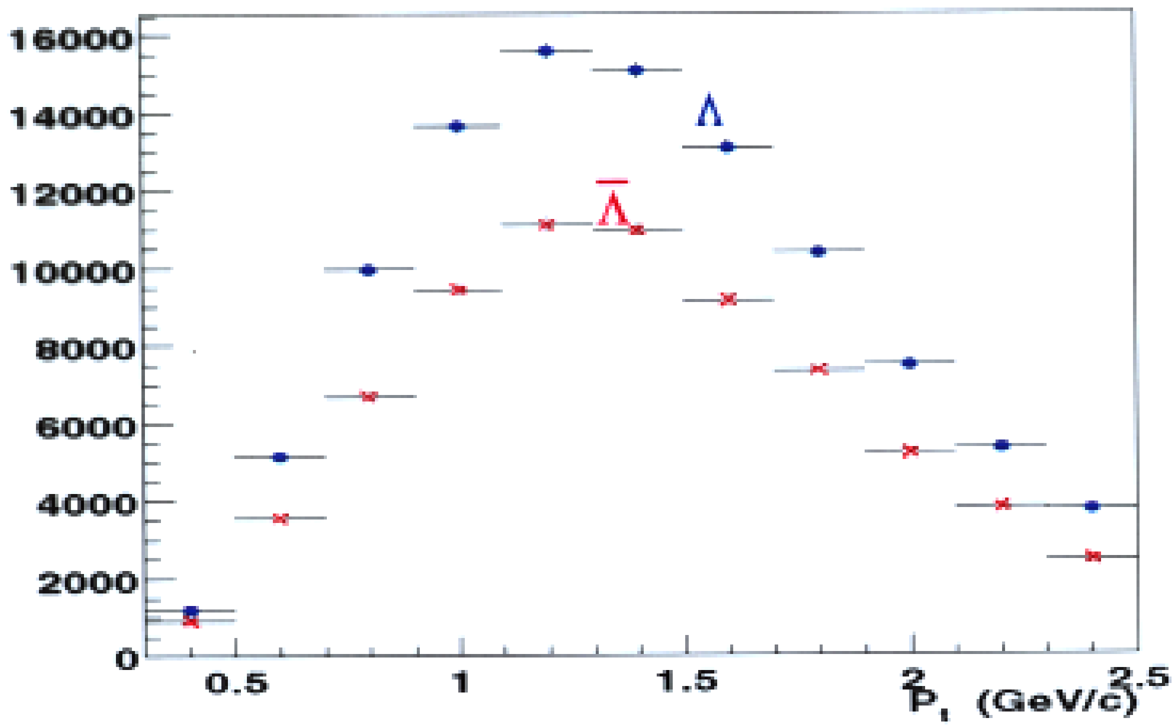


Mass Resolution ~ 2-3 MeV/c^2

~ 0.84 Λ/ Central Events Reconstructed

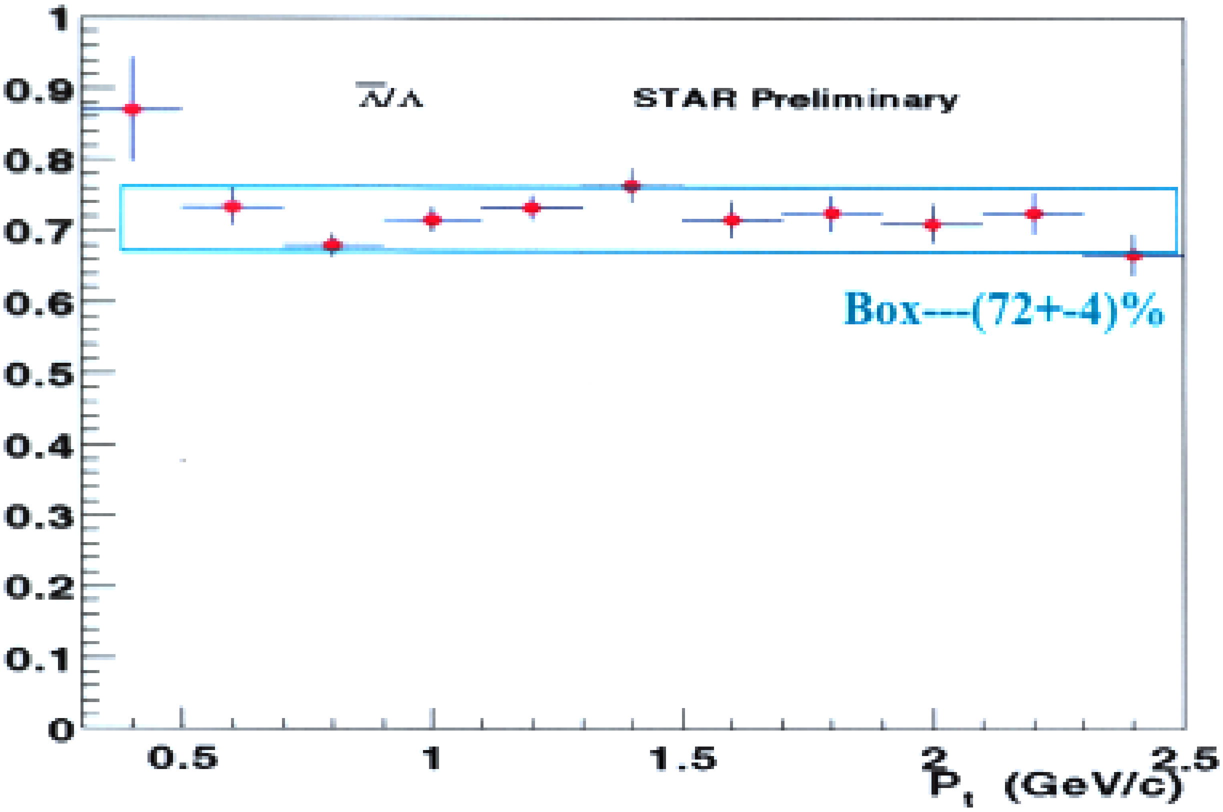
Measured Lb and L Yield Strong P_T Dependence

STAR Preliminary



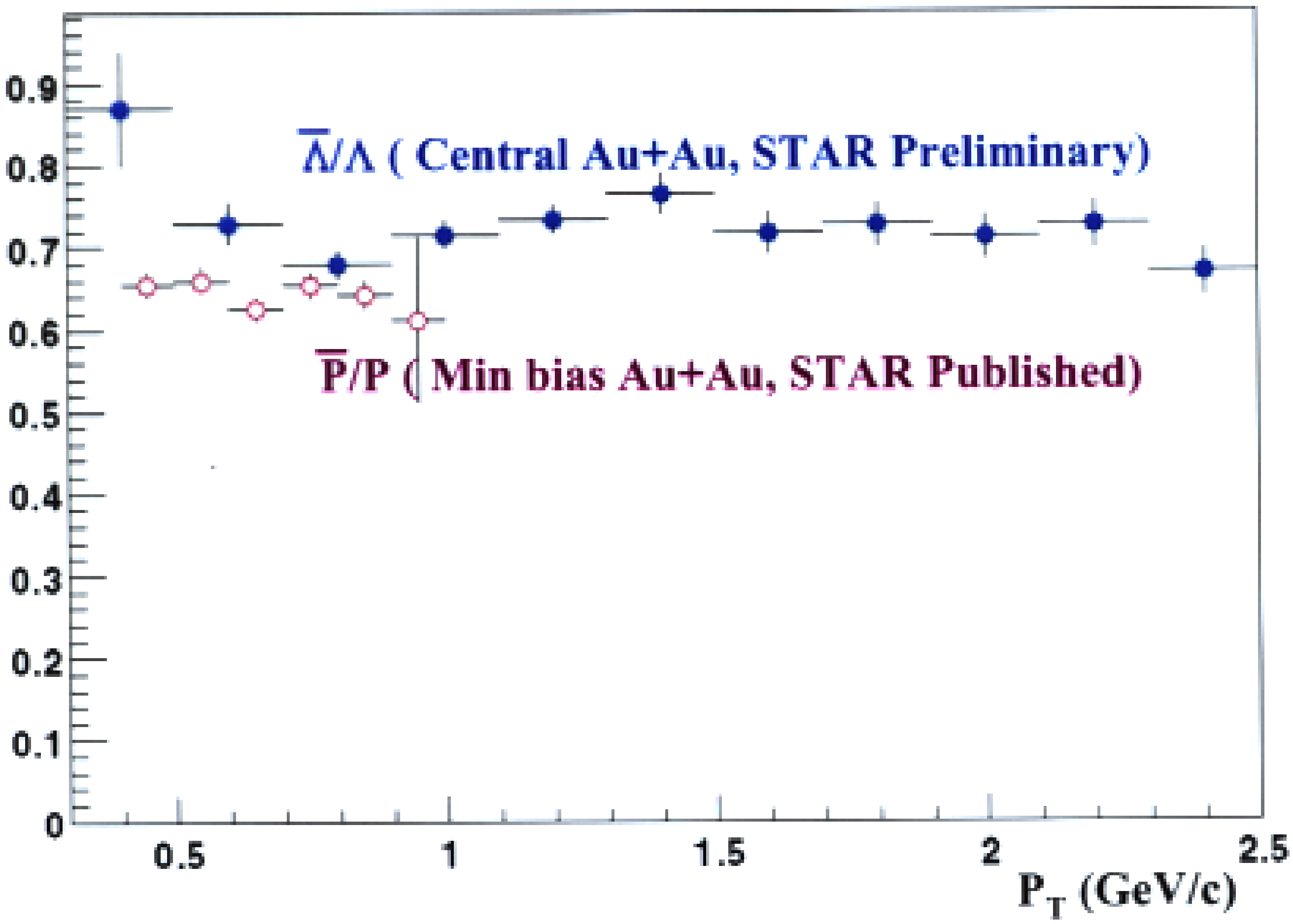
Strong p_T Dependence --- Sensitive to Absolute p_T Scale
--- Major source of systematic uncertainty

Anti-Lambda to Lambda Ratio vs P_T



1) From 200 K Central Au + Au Events ~ top 15% multiplicity.
2) Systematic errors at the low and high p_T ends are larger than that at middle p_T region. no significant p_T dependence in the ratio.
3) The mean ratio ~ 0.72
4) Using event mixing, a ratio of 0.77+-0.07 was obtained (Zhangbu Xu)
5) Errors include those from statistical and due to absorption.

Comparison of Pbar/P and Lbar/L Ratios



The pbar/p ratio for central Au+Au is slightly lower than that for min bias Au+Au collisions.

An Interesting Observation

Anti-protons:

100% from pair production!

Protons:

~2/3 from pair production

~1/3 from baryon number transport over 5 units of rapidity!

Pair production and baryon number transport are very different dynamical processes !

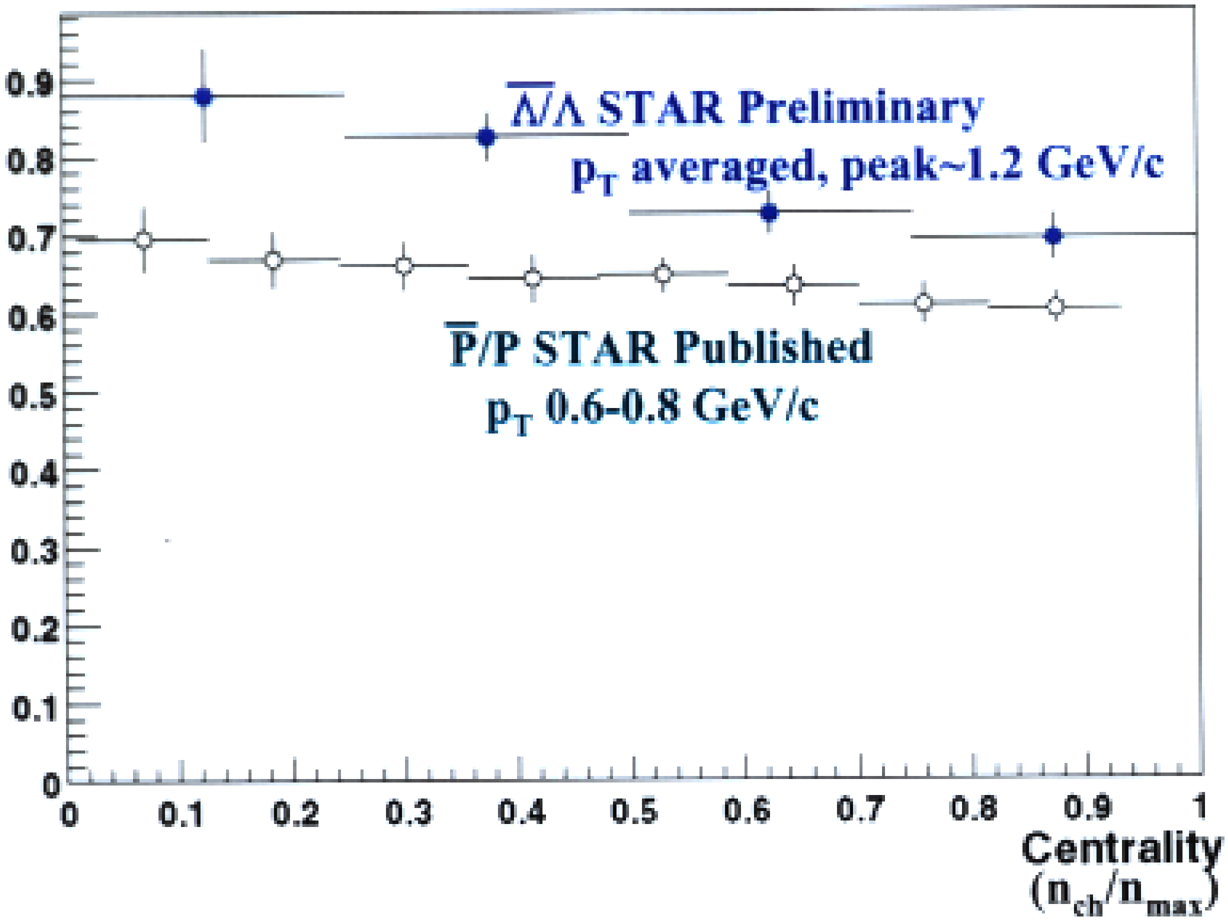
Experimentally we observed no significant p_T dependence in the ratio over p_T region from 0.5-2.5 GeV/c at mid-rapidity!

→ Pair production and baryon number transport yielded similar p_T distribution.

What is the physical explanation for this?

Is the physical origin pre-hadronization or post-hadronization?

Centrality Dependence of the Ratios



1) Slight decrease of ratios in central collisions
2) Anti-Lambda to Lambda ratio is somewhat higher than anti-proton to proton ratio
3) Statistical errors only in the figure
4) Systematic errors
   - anti-p to p ratio ~ 5%
   - anti-L to L ratio – under evaluation

Connecting pbar/p, Lbar/L and K$^+$/K$^-$ Ratios

Particle Ratios:

$$\frac{\bar{\Lambda}}{\Lambda} = \frac{Y_{Pair}(\Lambda\bar{\Lambda})}{Y_{Pair}(\Lambda\bar{\Lambda}) + Y_{Tr}(\Lambda K^+, X)}$$

$$\frac{\bar{P}}{P} = \frac{Y_{pair}(P\bar{P})}{Y_{pair}(P\bar{P}) + Y_{Tr}(P \to P, N \to P, XX)}$$

Quark Counting →

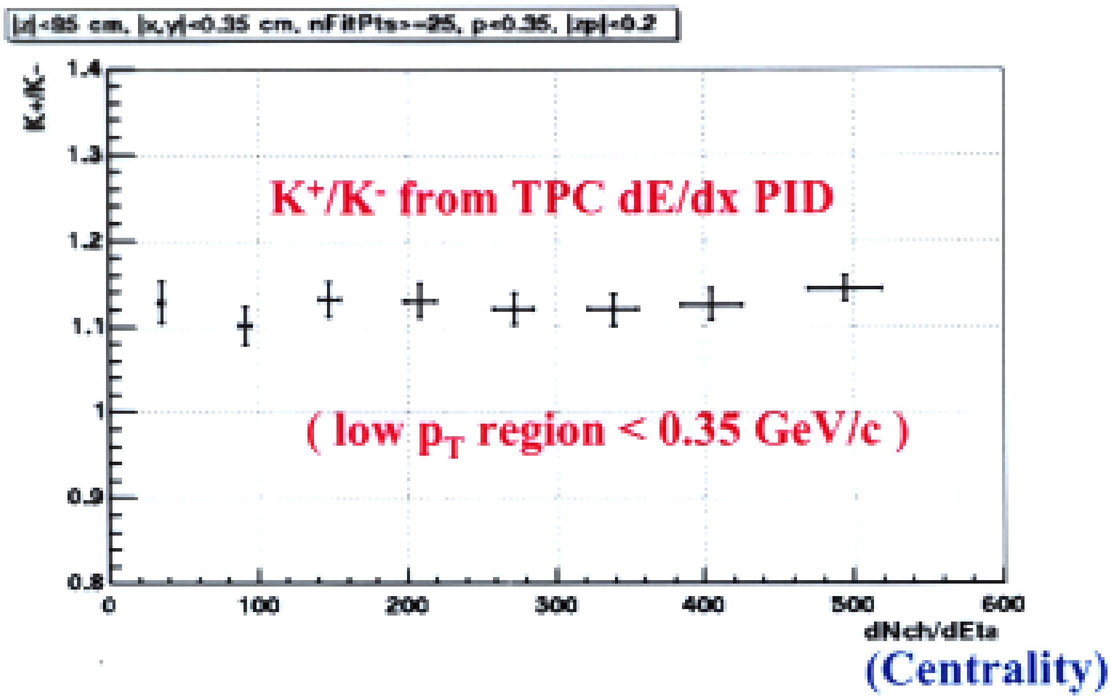
$$\frac{\bar{\Lambda}(\bar{u}\bar{d}\bar{s})}{\Lambda(uds)} = \frac{\bar{P}(\bar{u}\bar{u}\bar{d})}{P(uud)} \times \frac{K^+(u\bar{s})}{K^-(\bar{u}s)}$$

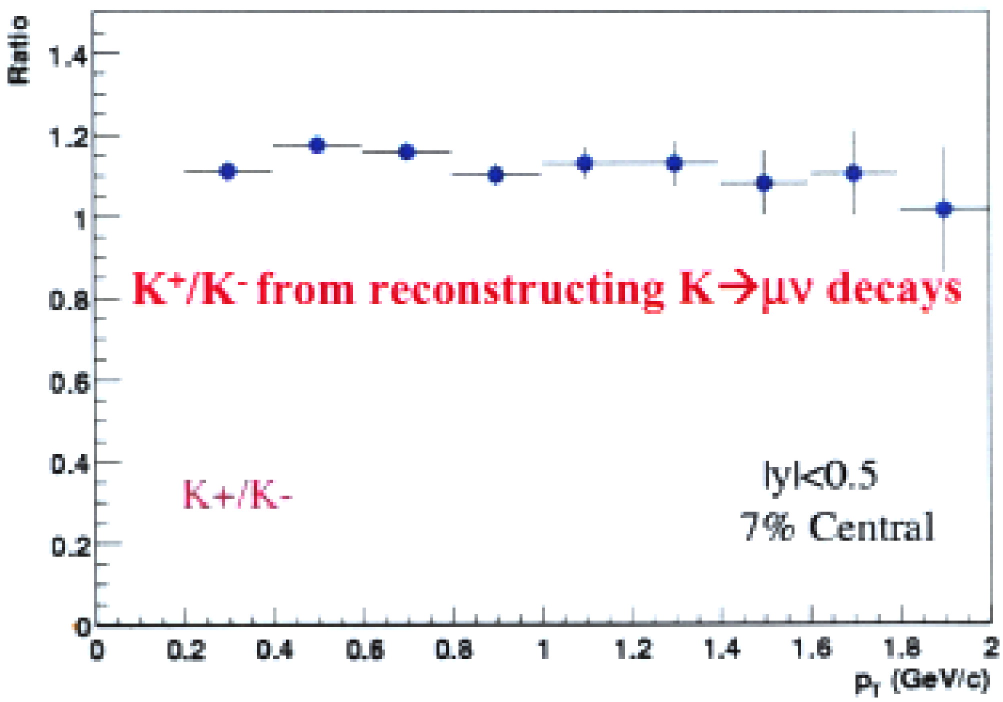
Baryon Ratios indicated K$^+$/K$^-$ > 1.0

Similarily:

$$\frac{\bar{\Xi}(\bar{d}\bar{s}\bar{s})}{\Xi(dss)} = \frac{\bar{\Lambda}(\bar{u}\bar{d}\bar{s})}{\Lambda(uds)} \times \frac{K^+(u\bar{s})}{K^-(\bar{u}s)}$$

K^+/K^- Ratios



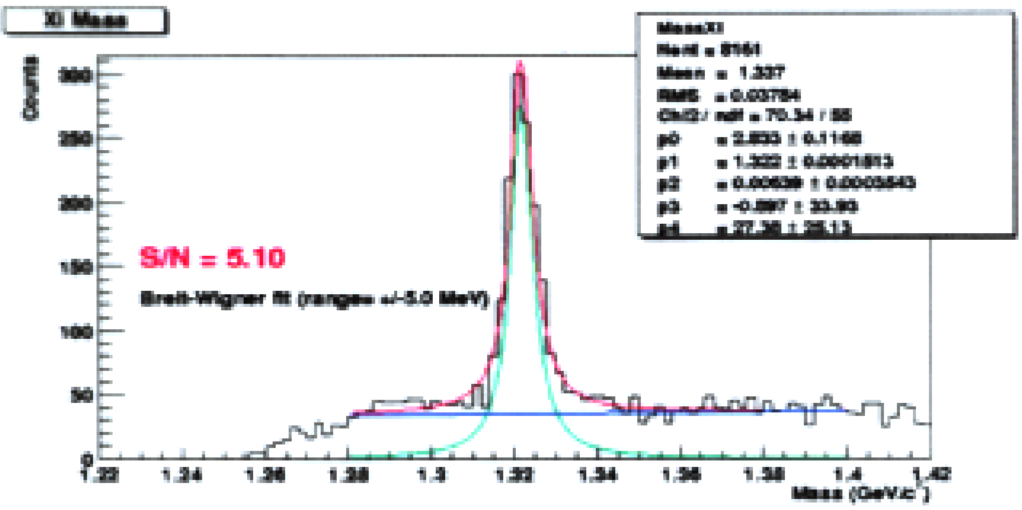


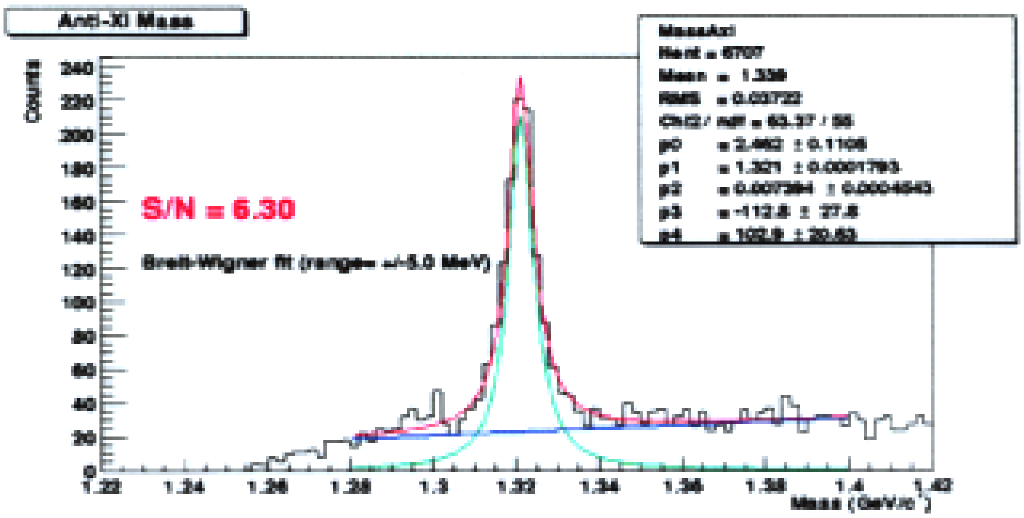
Indeed $K^+/K^- > 1$!!

Globally True → Baryon number and strangeness Consevation

Why should it be locally true?

$\overline{\Xi}^+/\Xi^-$ Ratios from STAR





1) From ~0.5 M central Au+Au collisions
2) Preliminary $\overline{\Xi}^+/\Xi^-$ Ratio ~ 0.82+-0.08(sta.)
3) $\overline{\Xi}^+/\Xi^-$ ratio consistent with $(\overline{\Lambda}/\Lambda)(K^+/K^-)$
4) Ω ratio very interesting ! If not one, baryon number transported to Ω with no up and down quarks! → Next QM

Comments on Thermal Calculations

1) It was emphasized by many that in thermal calculations:

a) ratios of 4π yields should be used

b) a single set of μ and T describes hadronization of all

2) At RHIC:

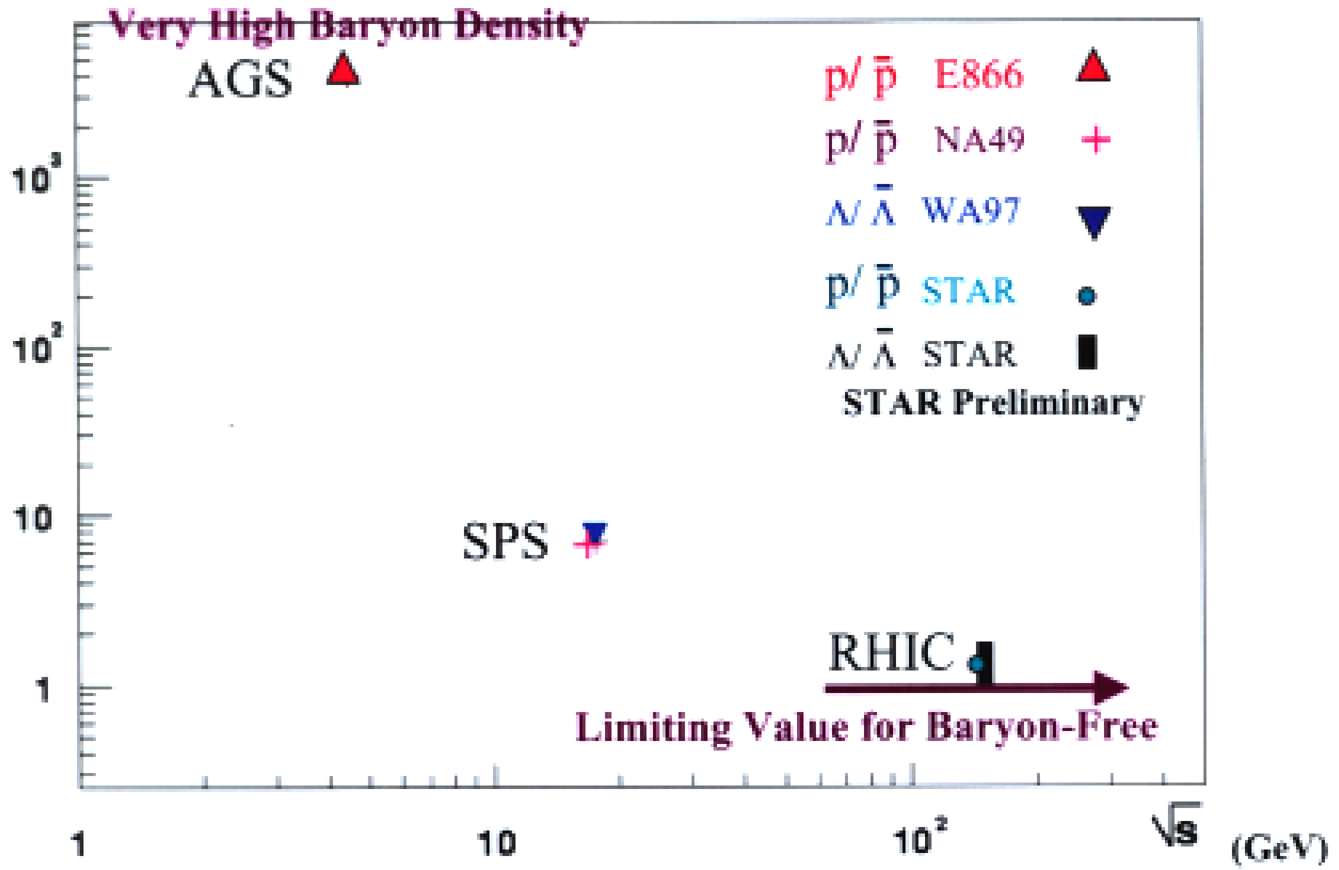
a) unlikely to have 4π yields soon

b) likely separation of phase space → gluon-dominated central rapidity region vs. baryon fragmentation regions at forward and backward rapidity.

c) is a single set of μ and T justified to describe hadronizations in different rapidity regions at RHIC?

d) with limited acceptance, measured yield in momentum phase space (p_T-y); thermal equilibrium in position phase space (x-y-z). How are they related?

Baryon Ratios at Mid-Rapidity



1) Approaching relative low net baryon density region at mid-rapidity at RHIC.
2) Particle production at mid-rapidity at RHIC likely originating from gluon-dominated processes.

Summary

1) We have measured pbar/p and Lbar/L ratios at mid-rapidity from Au+Au collisions at RHIC.

2) The ratios show no strong p_T and rapidity dependence within the STAR acceptance.

3) There may be slight decrease in the ratio from peripheral to central Au+Au collisions.

4) Both pair production and baryon number transport are important for baryon yields at mid-rapidity. Approximately 2/3 protons from pair production and 1/3 from baryon number transport.

5) Baryons from pair production and from baryon number transport have similar p_T distribution in the final state within the STAR TPC acceptance!

6) We are approaching a low net baryon density region at mid-rapidity at RHIC where particle production mechanisms may be dominated by gluon induced processes.