

Resonance Studies at STAR

Zhangbu Xu

(Yale University)

for the STAR Collaboration

- Physics Motivation
 - Resonance **properties** (width, mass, rate)
 - Chemical **equilibrium** with other particles?
 - symmetry restoration
- Data Analysis
 - **Large** combinatorics: Need high statistics
 - Particle Selection
 - Acceptance*Efficiency
- Results
 - $K^* \rightarrow K\pi$ (67%) (particle and antiparticle)
 - $\phi \rightarrow K^+K^-$ (49%)
 - $\Lambda/\bar{\Lambda}$ ratio
- Conclusions and Future Plans

Decay Mode

$$\rho \rightarrow \pi^+ \pi^- \quad \leftarrow$$



$$K^* \rightarrow K \pi$$

$$\omega \rightarrow \pi^+ \pi^- (\pi^0) \quad \leftarrow$$

$$\eta' \rightarrow \pi^+ \pi^- (\eta) \quad \leftarrow$$

$$\eta \rightarrow \pi^+ \pi^- (\pi^0) \quad \leftarrow$$

$$K_S^0 \rightarrow \pi^+ \pi^- \quad \leftarrow$$

$$\Delta \rightarrow N \pi$$



$$\phi \rightarrow K^+ K^-$$



$$\Lambda \rightarrow p \pi$$

$$\Lambda(1520) \rightarrow p K^- \quad \leftarrow$$

$$\Sigma(1385) \rightarrow \Lambda \pi$$

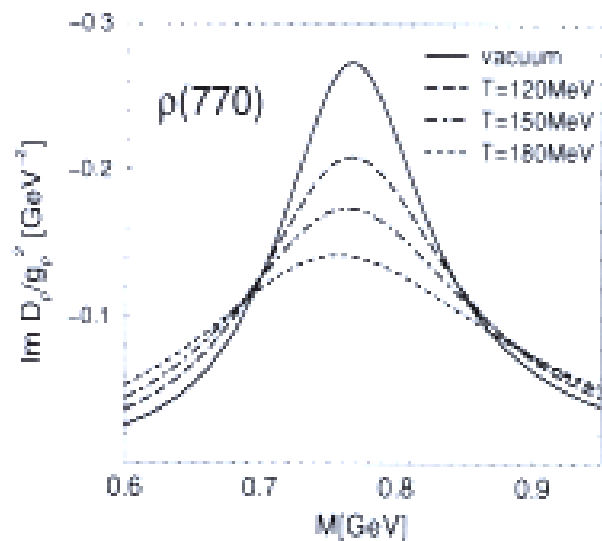
Motivation

- Overcome Combinatorics
 - Large Acceptance of STAR TPC for hadrons
- Production from hadronic mode
 - Absolute/Relative Yields → Equilibrium?
 - Compare with I^+I^- yields (ϕ)
 - (Y, Pt) → Flow, Temperature
 - Strangeness (K^*)
- Mass Shift?
 - Mass, Width ($\rho, K^*, \text{etc.}$)
 - High η' yield? ($\times 3 \rightarrow 50$)
- “Clock”?
 - 1.3fm (ρ) → 4fm (K^*) → 20fm(ω, ϕ) → ...(η)
- Surprises

Theoretical Predictions

- Low Mass Dilepton
(R. Rapp, et al.)
measuring ρ properties
- What about Hadronic decays?
- FSI: measure Volume?
 $S/N \propto 1/(Vq\Gamma)$
(S. Pratt, private comm.)

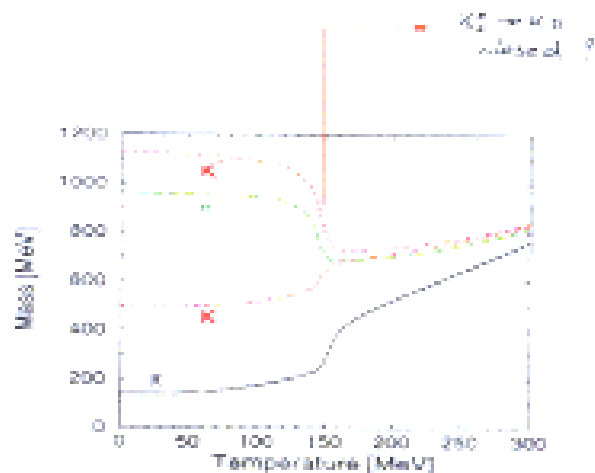
Last Call for RHIC Predictions
Nucl.Phys. A661 (1999) 205-260



- Chiral $U_A(1)$ symmetry restoration (J. Schaffner, D. Kharzeev, et al.)
- η' "obesity"

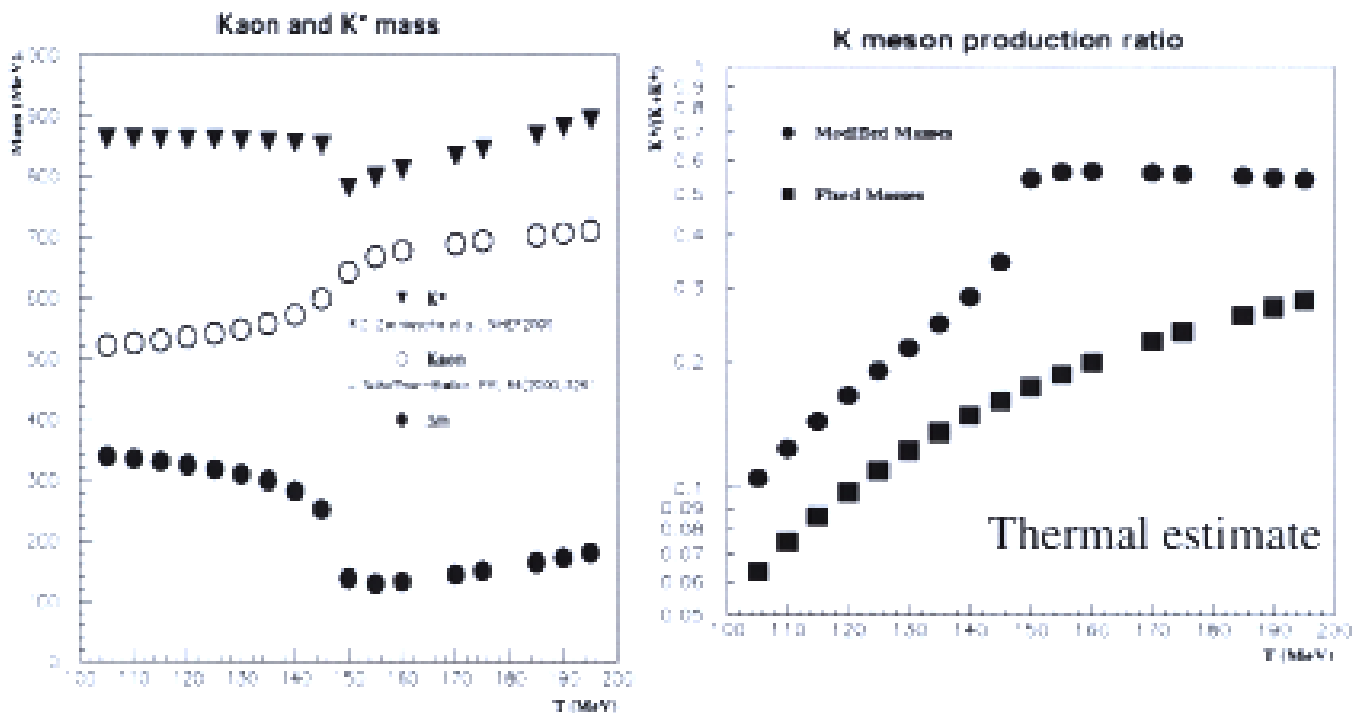
$$m_{\eta'}^2 = m_0^2 + (\Delta m)^2$$

related to CP violation



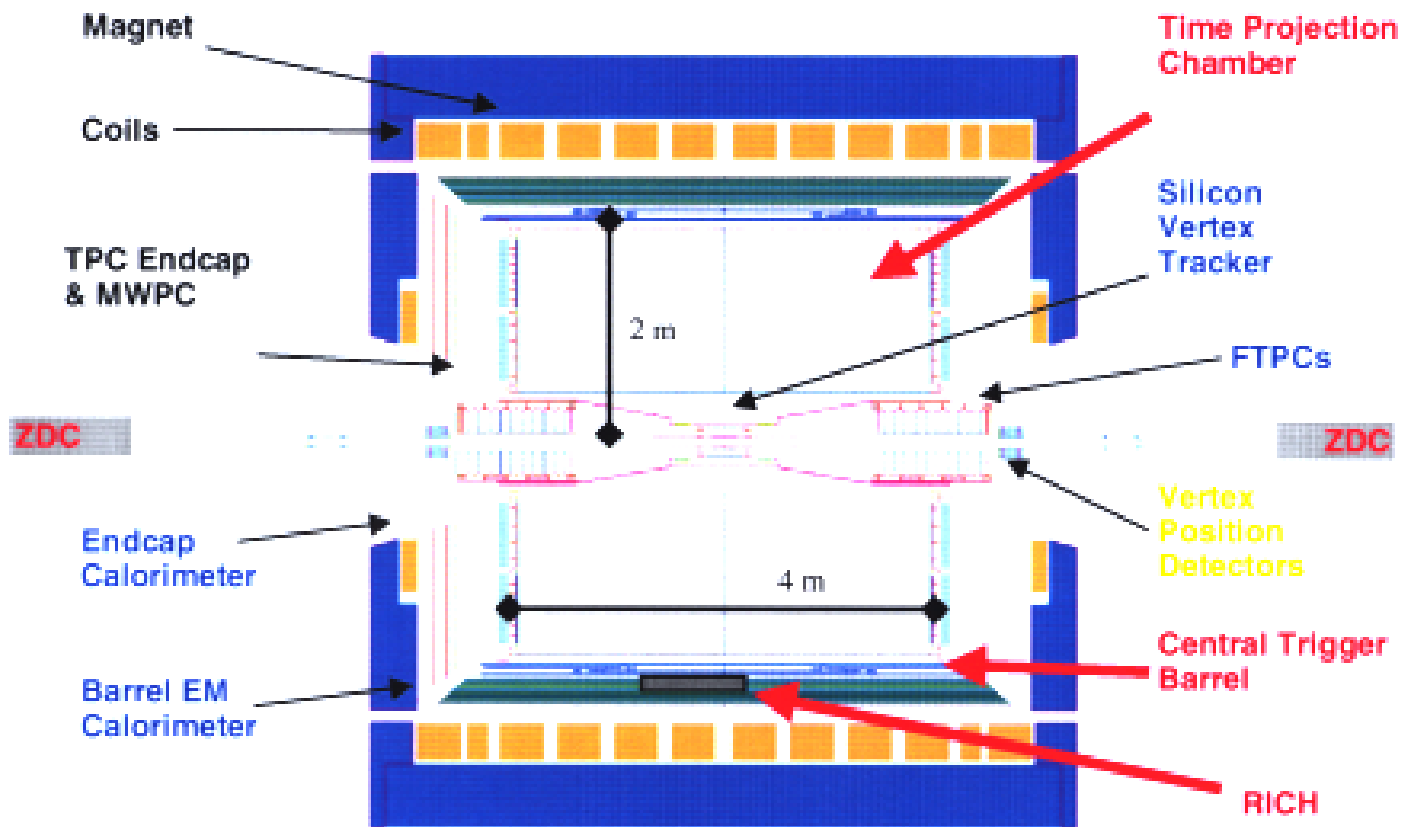
Z. Xu (Yale, STAR) QM01

Measure yields



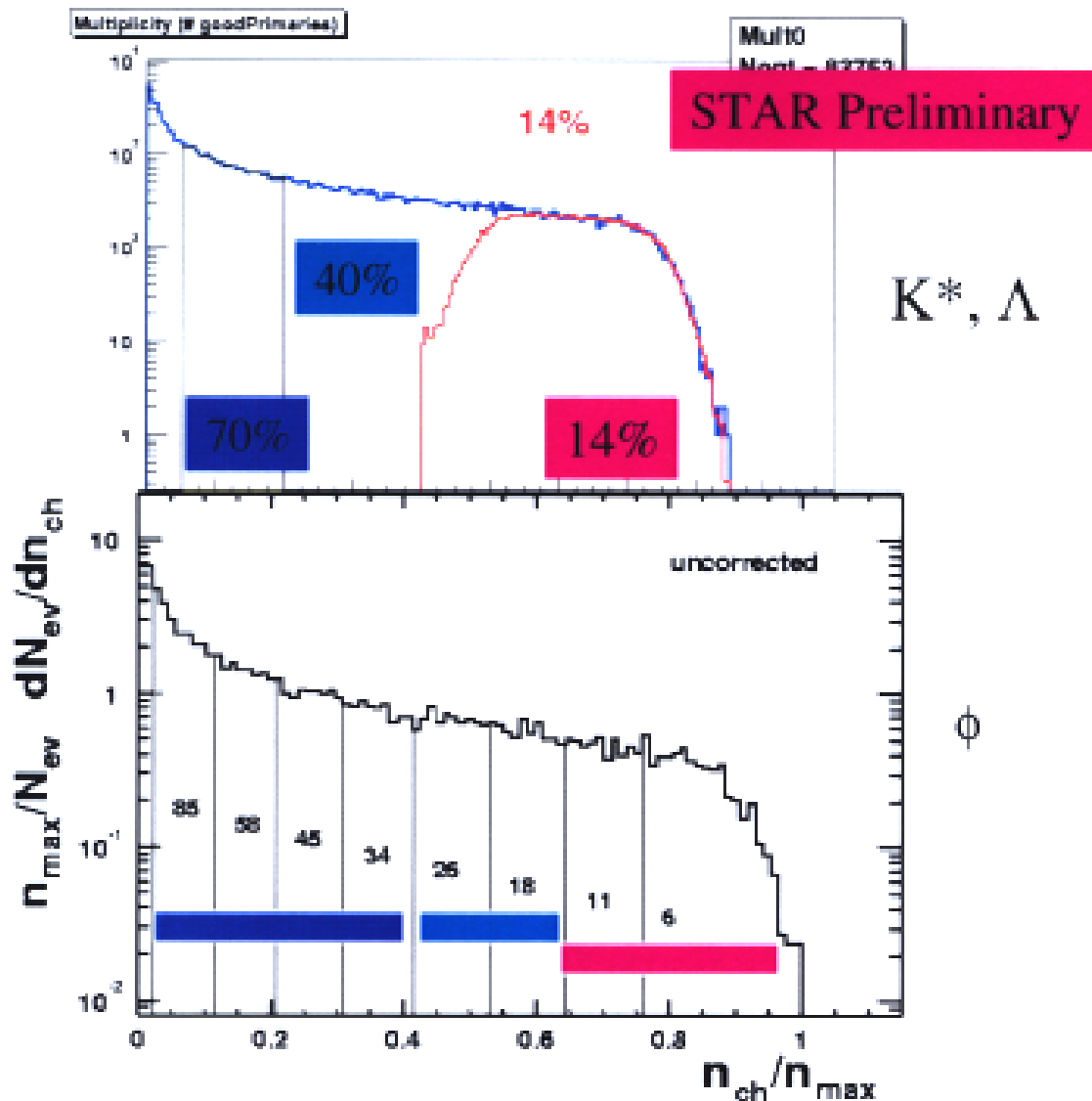
- Sensitive to medium effects
 - $V/(V+P)$ spin counting: 0.75
 - $V/(V+P)$ $e+e-$, pp: 0.4, 0.6
 - strangeness suppression:
 - ϕ/K^* $e+e-$ pp: 0.3
- Effects of $U_A(1)$ restoration on η, η' production
 - (3--50 enhancement, related to parity-odd bubble)
 - Poster (E. Finch, Yale, STAR)

STAR TPC



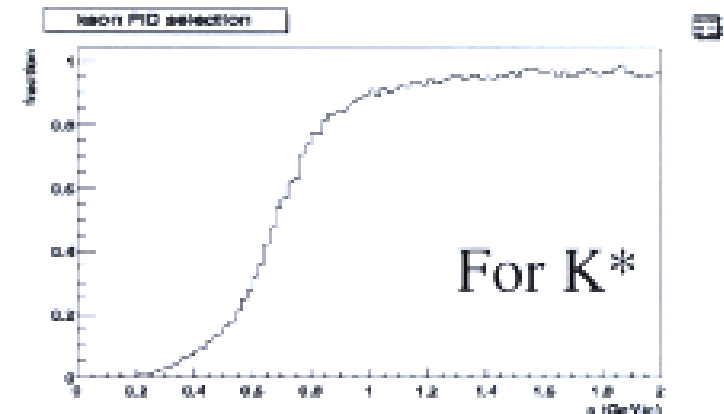
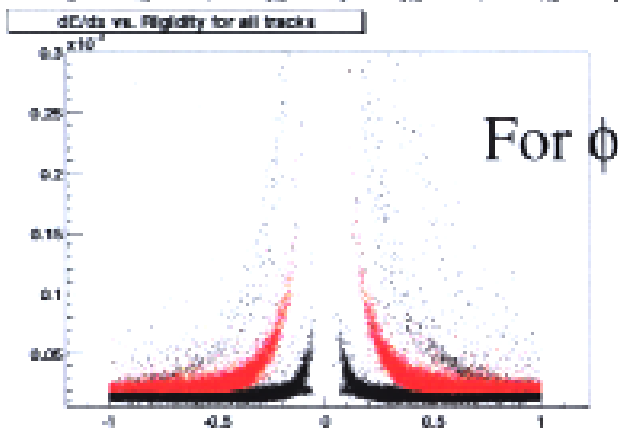
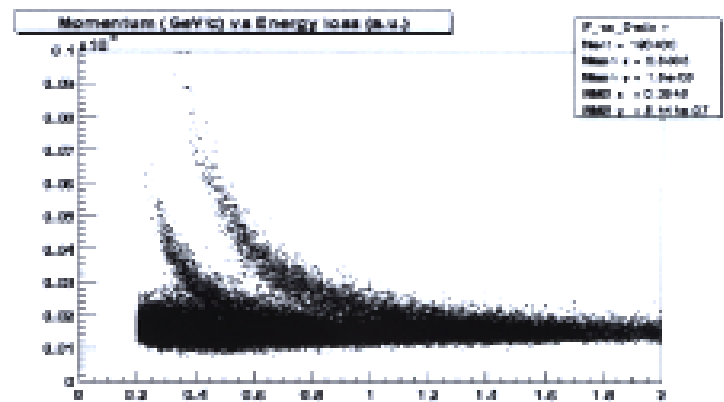
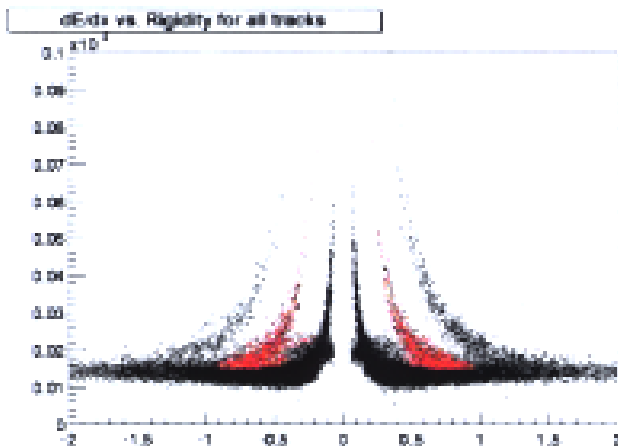
- Beam energy: $\sqrt{s_{NN}} = 130 GeV$
- Detectors:
 - TPC (tracking, p)
 - ZDC, CTB (trigger)

Event Selection



- Central events (14% central) 307K
- Minbias: 160K
- Centrality: NprimaryTracks
- vertex of interaction:
K* $|Z| < 95\text{cm}$, ϕ $|z| < 80\text{cm}$

Particle Selection



- $K \pi$ for K^* :

 $0.2 < p < 2 \text{ GeV}$, $nTpcHits = 10$

 dE/dX : $K (-2.5\sigma_K, +3\sigma_K)$, $\pi (-3\sigma_\pi, +3\sigma_\pi)$,

 $|\eta| < 0.8$, $\theta_{K\pi} > 0.2$
- $K^+ K^-$ for ϕ :

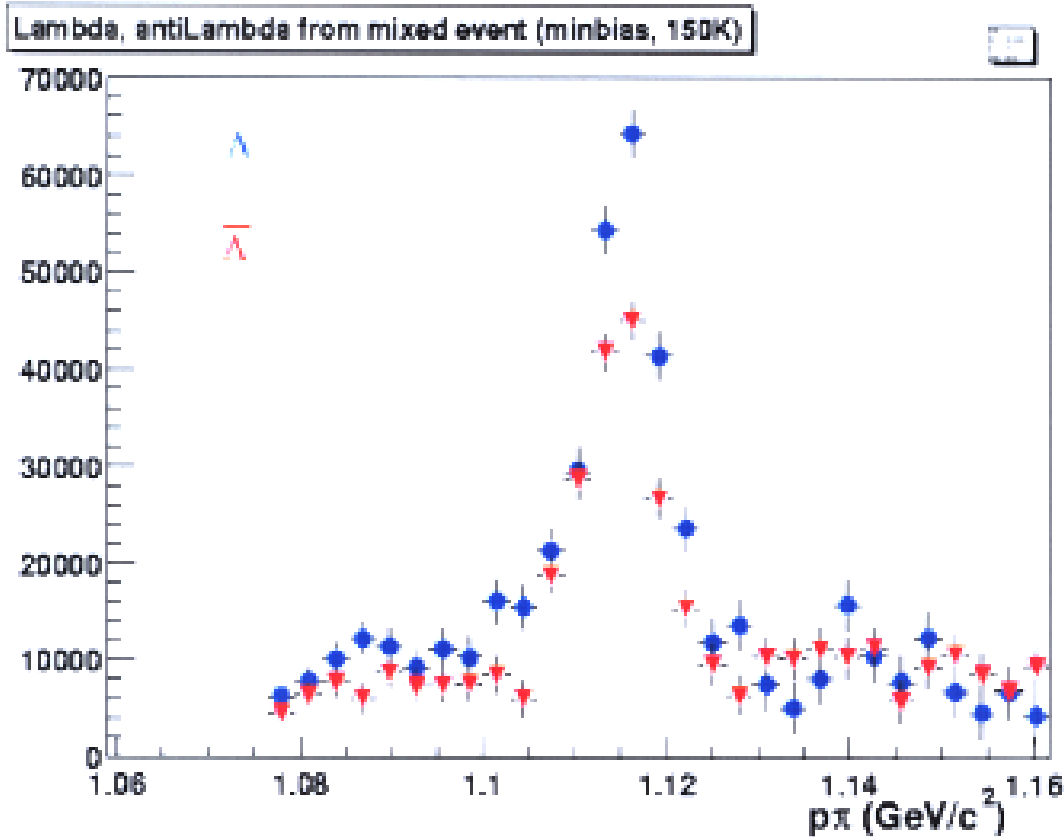
 $0 < p < 1 \text{ GeV}$, $nTpcHits > 15$

 dE/dX : $(-3\sigma_K, +4\sigma_K)$, $> 3\sigma_\pi$

 $|\eta| < 1.5$, $|y_\phi| < 0.5$

STAR Preliminary

Lambdas from Mixed events



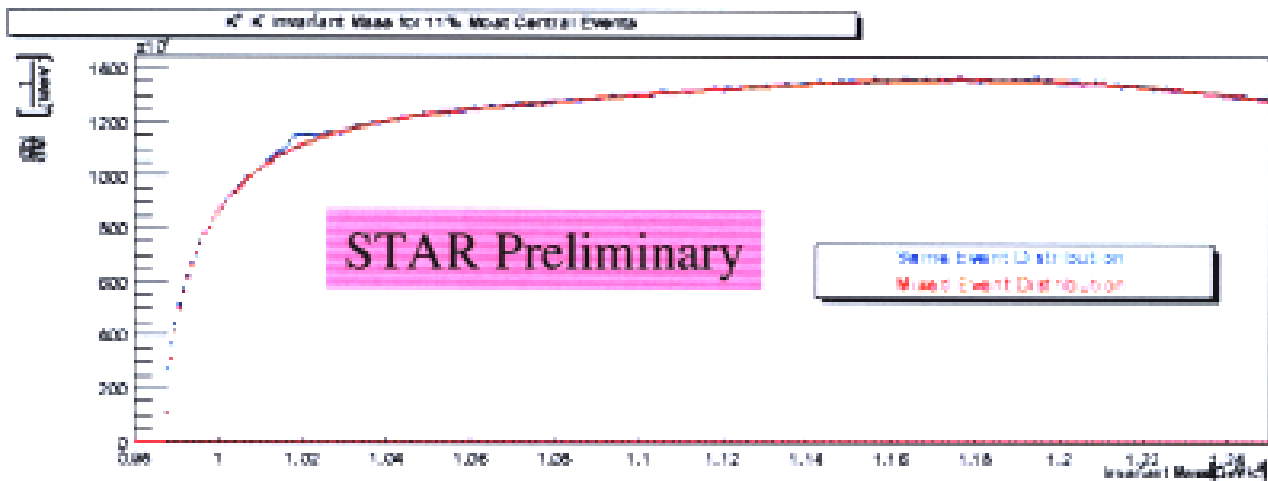
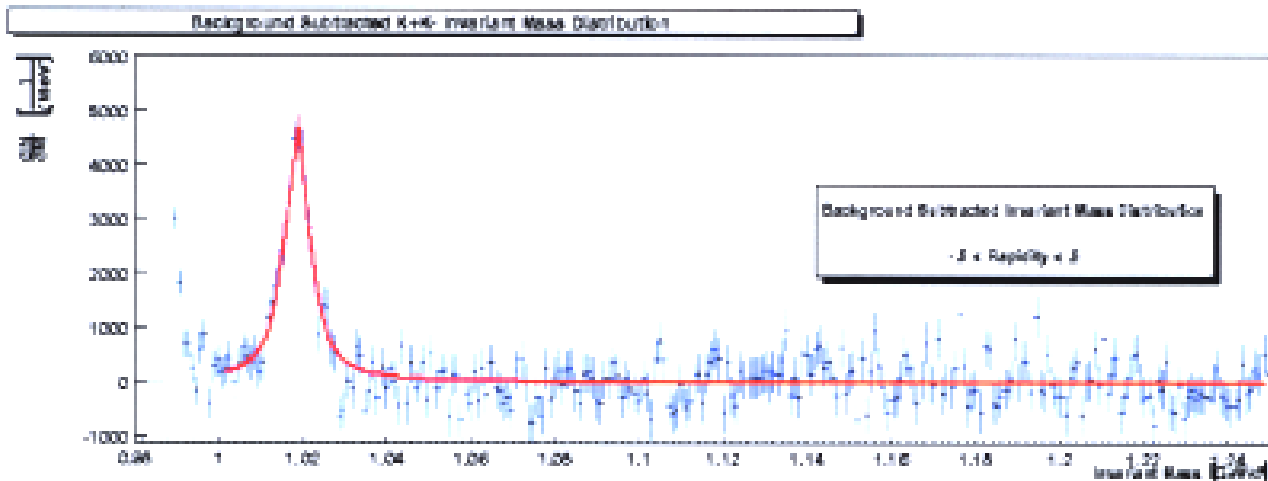
$0 < p < 2 \text{ GeV}/c$,
 $p (-2.5\sigma_p, +3\sigma_p)$, $\pi (-3\sigma_\pi, +3\sigma_\pi)$

- Large combinatoric background
- High efficiency (Λ , K_s)
- Integrated ratio:

0.77 ± 0.07 (stat)

0.74 ± 0.03 (stat) (V0)

STAR Preliminary

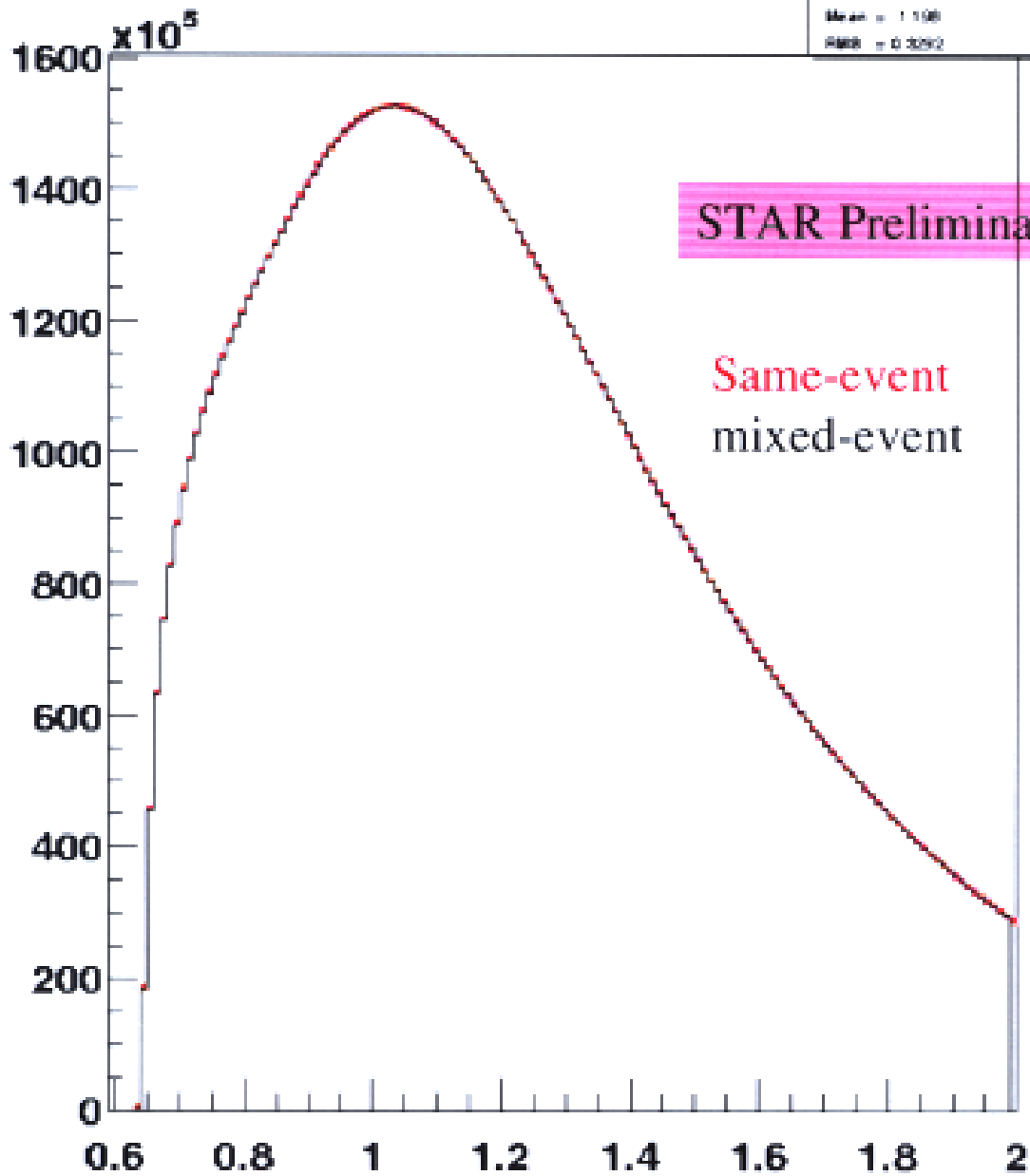


- pT spectra, centrality dependency:
almost ready



K* (307149evts, top 14% centrality)

Minv0_Mean
N entries = 1.42422e+10
Mean = 1.108
RMS = 0.3292

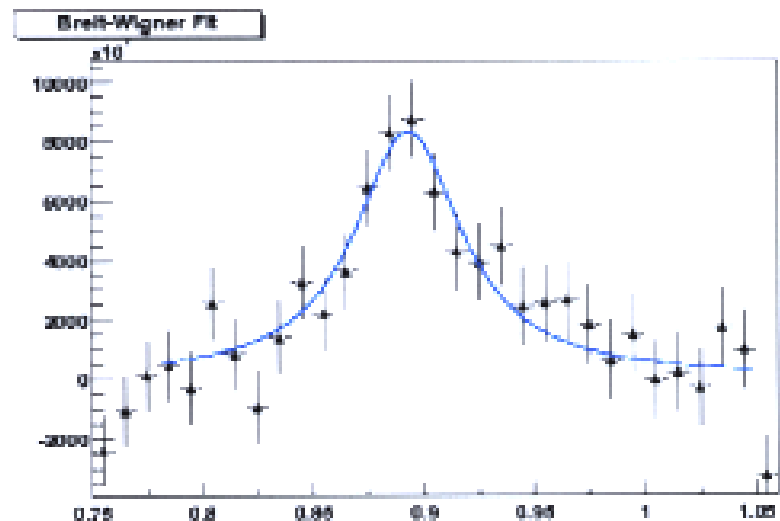
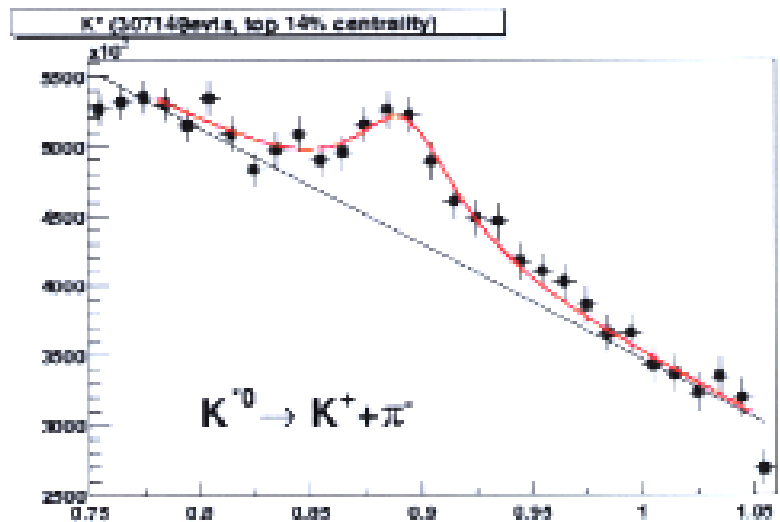


$K^* \rightarrow K^+ + \pi^-$

- Central events (top 14%)
- primary tracks: $K^+ \pi^-$
- K^* signal
 - $M_{K^*} = 0.893 \pm 0.003$
 - $\Gamma = 0.058 \pm 0.015$ (stats error only)
 - PDG
 - $M_{K^*} = 0.896$
 - $\Gamma = 0.0505$
- Background estimate: $\pm 20\%$
- Breit-Wigner

$$A \frac{\Gamma}{2\pi((m - M_0)^2 + \Gamma^2 / 4)}$$

- P-wave RBW?

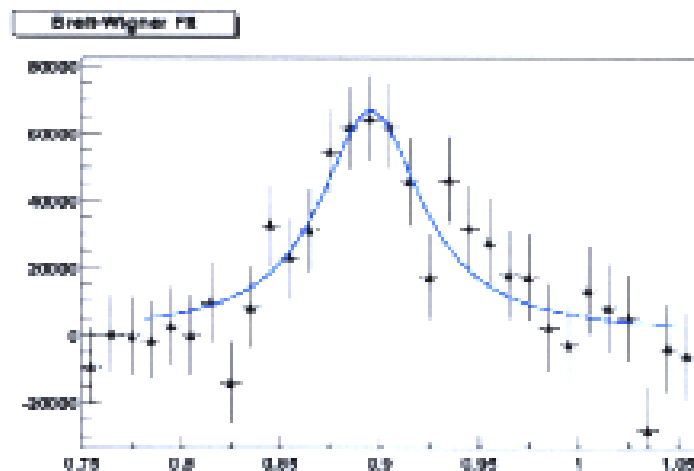
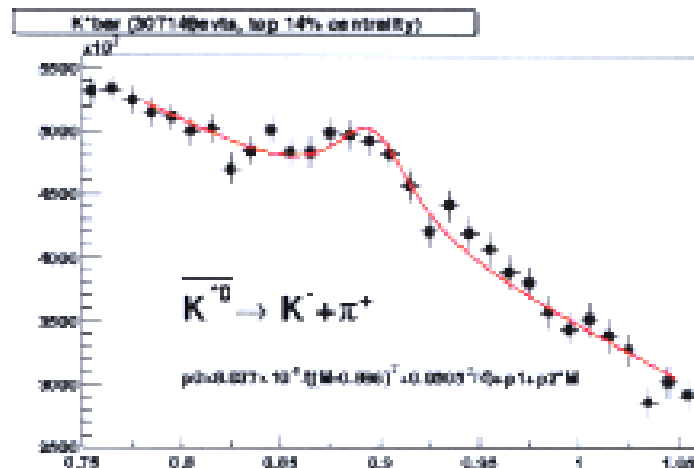


STAR Preliminary

$\bar{K}^* \rightarrow K^- + \pi^+$

- Central events (top 14%)
- primary tracks: K^-
 π^+
- K^* signal
 $M_{K^*} = 0.896 \pm 0.004$
 $\Gamma = 0.063 \pm 0.011$
 (stats error only)
- Background estimate:
 $\pm 18\%$
- Breit-Wigner

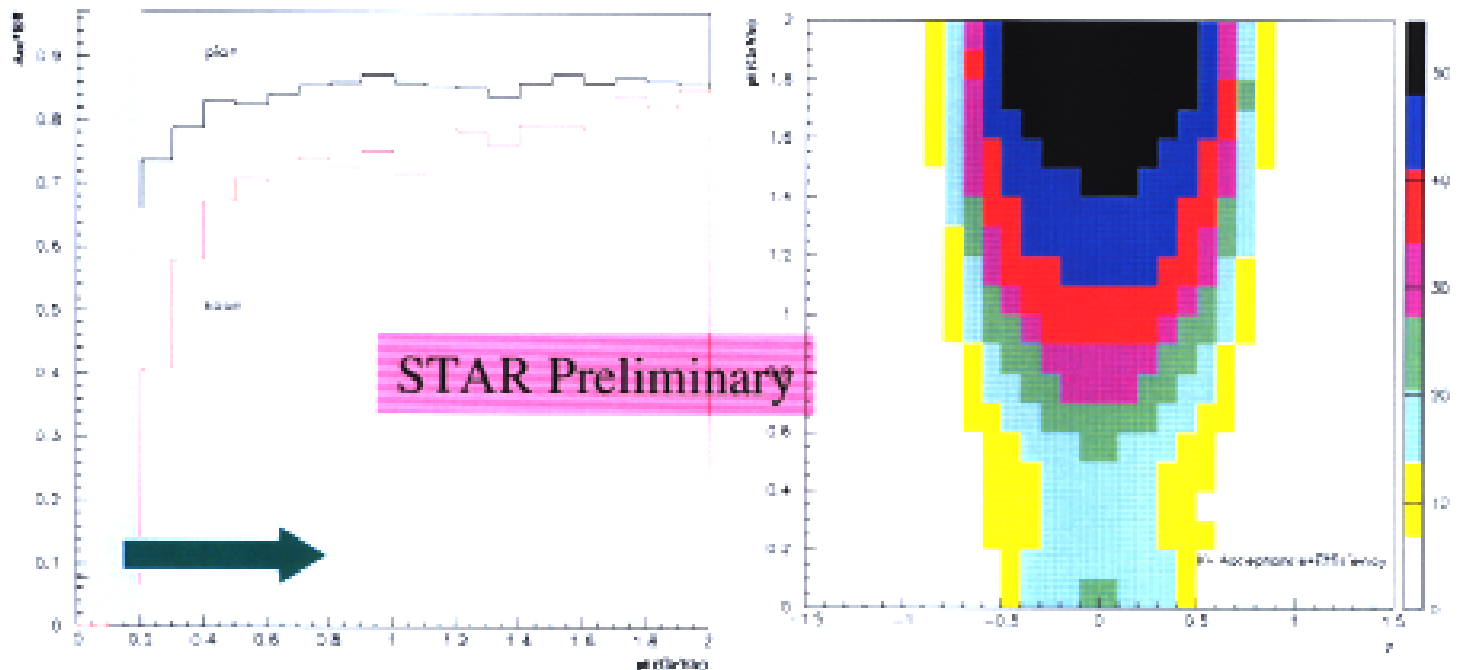
$$A \frac{\Gamma}{2\pi((m - M_0)^2 + \Gamma^2/4)}$$



STAR Preliminary

Z. Xu (Yale, STAR) QM01

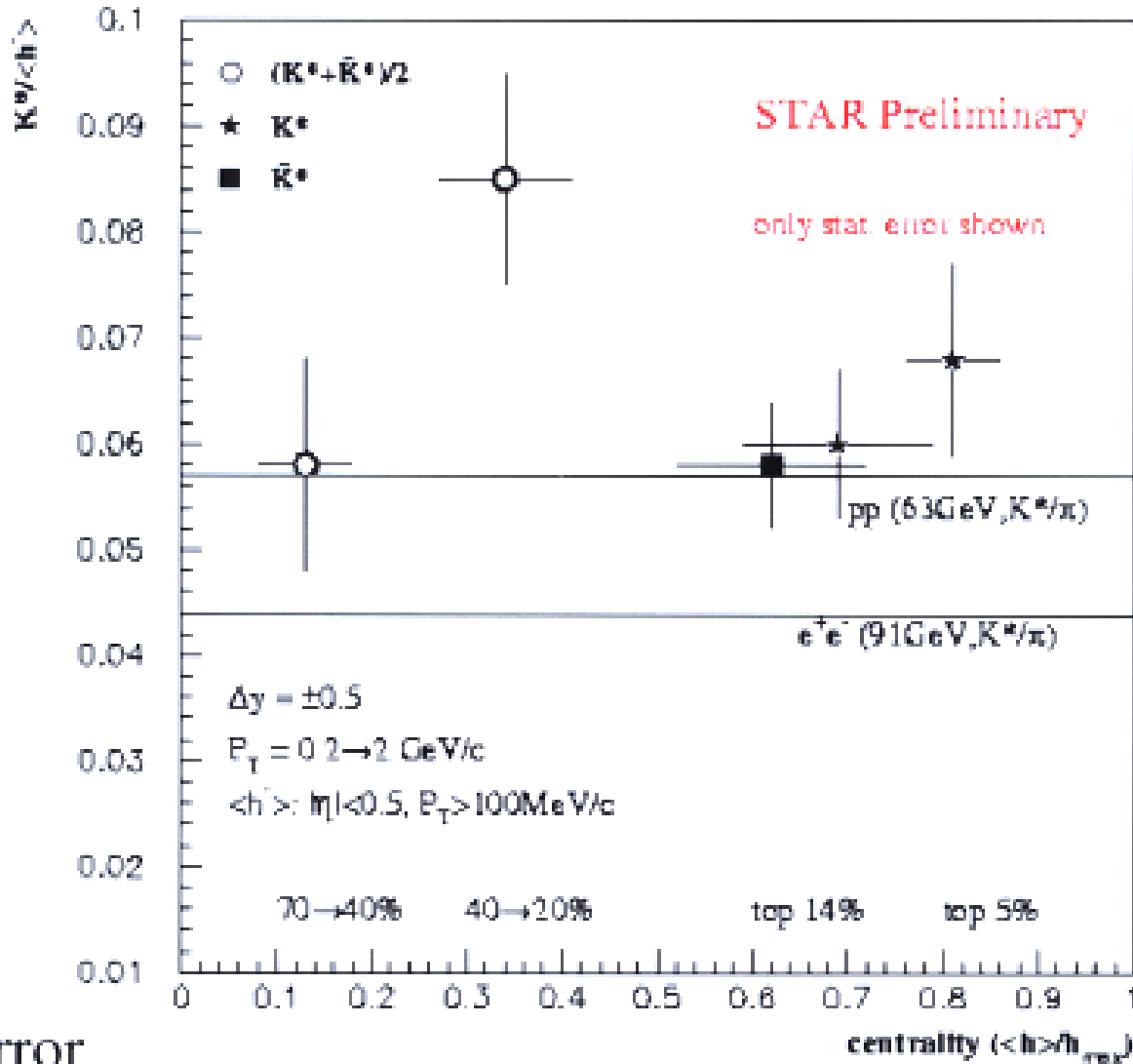
Acceptance*Efficiency



- High “Efficiency”: $\sim 80\%$ for single track
- K^* : large OpenAngle between $K\pi$,
efficiency: $K^* = \text{kaon} * \text{pion} (\text{binBybin})$
 K, π from embedding MC to data
- K^* reconstruction efficiency:
 $20\% \rightarrow 50\%$ ($|\eta| < \sim 0.5, p_t < 2 \text{ GeV}$)
(input) $T = 300 \text{ MeV}, 31\%$

K* yield

Au + Au → K*⁰ + X (centrality dependency)



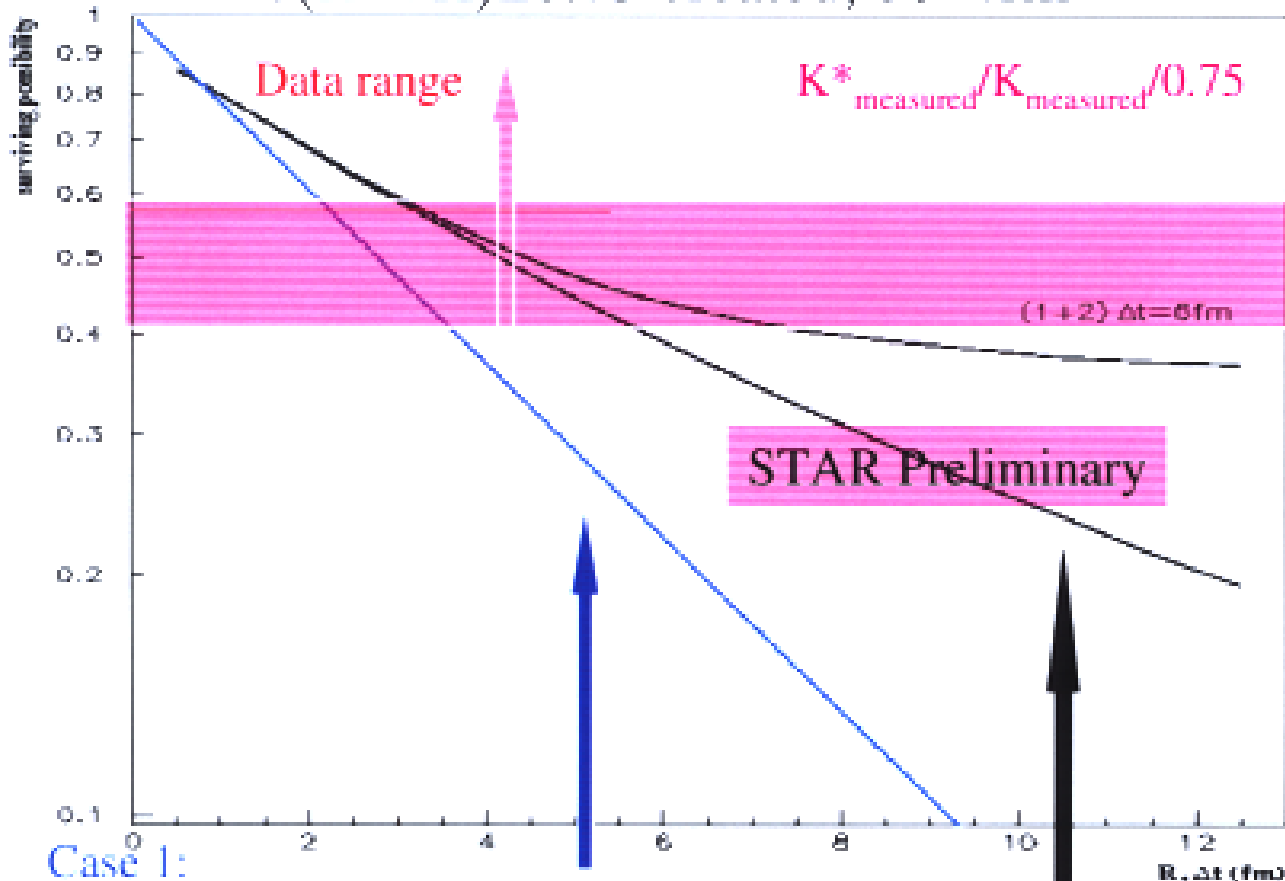
Error

pp: ~ ±20%(sys)

RHIC: ~±25%(sys)

K* surviving possibility

- $K^*/(K^*+K) \leq 0.75$ created, $c\tau=4\text{fm}$



Case 1:

Surviving possibility as function of Δt (fm)

Δt : time between chemical and kinetic freeze-out

Assume: K^* decays in Δt can not be reconstructed

Case 2:

Surviving possibility as function of static source size

R : the static source size (fm)

Assume

i) K^* decays inside the source can not be reconstructed

ii) Only K^* flying out the source can be reconstructed

iii) static source, (K^* "T"=300MeV)

Questions

- $K\pi \rightarrow K^* \rightarrow K\pi$?
 - Why K^*/h - consistent with pp(63GeV)?
 - Why mass, peak consistent with PDB?
 - $NN \rightarrow K^* \rightarrow K\pi$?
 - Cross section, resonance gas?
 - pT spectra: T. Akesson, NPB203(1982)27
 - K^*, ϕ, ρ (ISR) $T = 156\text{MeV}$
 - $K, pbar$ (RHIC) $T \geq 250\text{MeV}$
 - Volume:
 - $S/N \propto 1/(Vq\Gamma)$
 - Centrality dependency:
 - $T, K^*/K$
 - $\bar{K}^*/K^* \approx \bar{K}/K$?
-

Summary

- Several resonances observed
 K^* first in Heavy Ion Collisions
- Preliminary results:
 - production levels of K^*/h -
comparable to those at pp, e+e-
 - Centrality dependency
- $\bar{\Lambda}/\Lambda$ Consistent with V0
- The resonances:
 - p_T spectra (centrality dependency)
 - reaction plane,
 - more statistics,
 - improved systematic errors
- Other resonances ($\rho \rightarrow \pi^+\pi^-$)