Resonance Studies at STAR

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for the STAR Collaboration

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

Decay Mode

$$\rho \rightarrow \pi^{+}\pi^{-}$$

$$K^{*} \rightarrow K\pi$$

$$\omega \rightarrow \pi^{+}\pi^{-}(\pi^{0})$$

$$\eta' \rightarrow \pi^{+}\pi^{-}(\eta)$$

$$\eta \rightarrow \pi^{+}\pi^{-}(\pi^{0})$$

$$K_{S}^{0} \rightarrow \pi^{+}\pi^{-}$$

$$\Delta \rightarrow N\pi$$

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

$$\Lambda \rightarrow p\pi$$

$$\Lambda(1520) \rightarrow pK^{-}$$

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

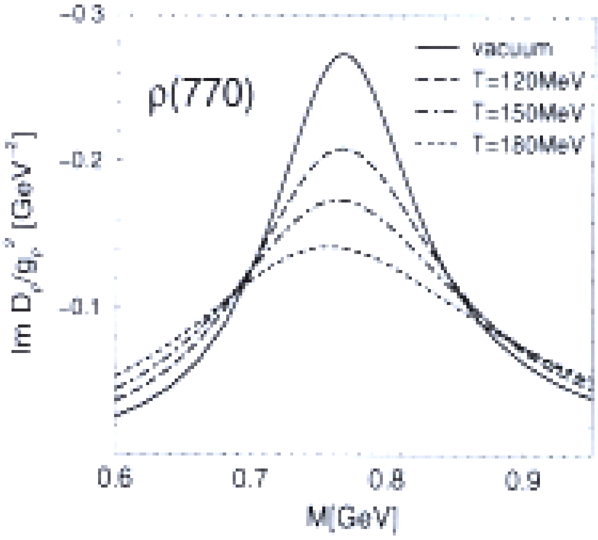
Motivation

- Overcome Combinatorics
  - Large Acceptance of STAR TPC for hadrons
- Production from hadronic mode
  - Absolute/Relative Yields→Equilibrium?
  - Compare with l^+l^- yields (ϕ)
  - (Y, Pt) →Flow, Temperature
  - Strangeness (K*)
- Mass Shift?
  - Mass, Width (ρ, K*, etc.)
  - High η' yield? (x3→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.)

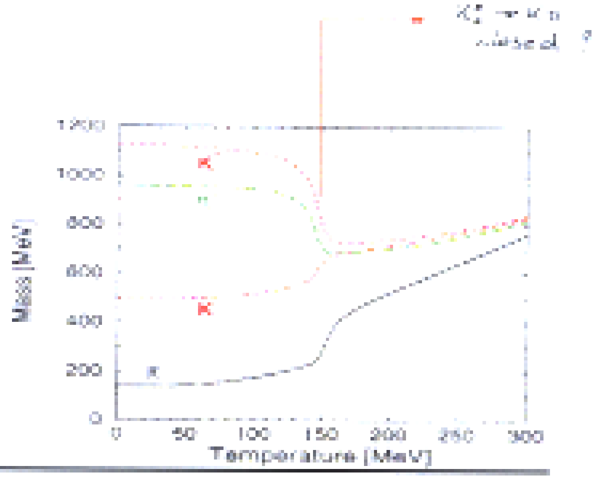
Last Call for RHIC Predictions
Nucl.Phys. A661 (1999) 205-260



- 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



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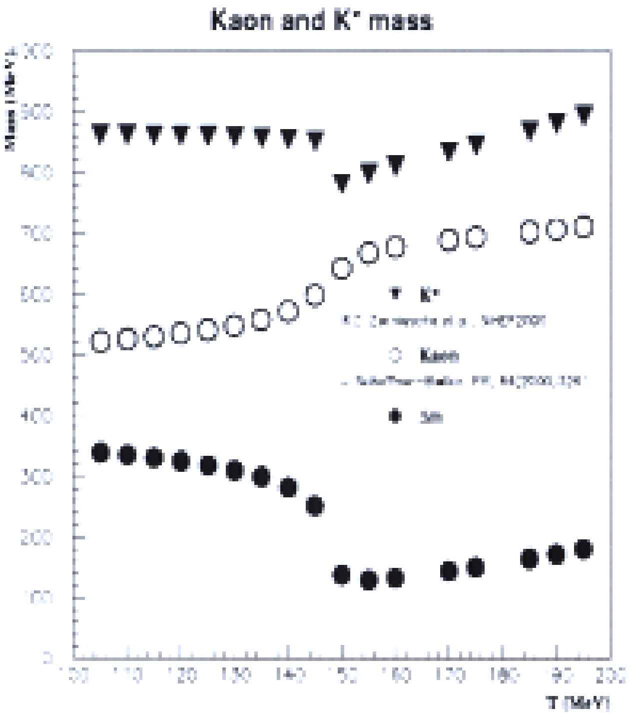
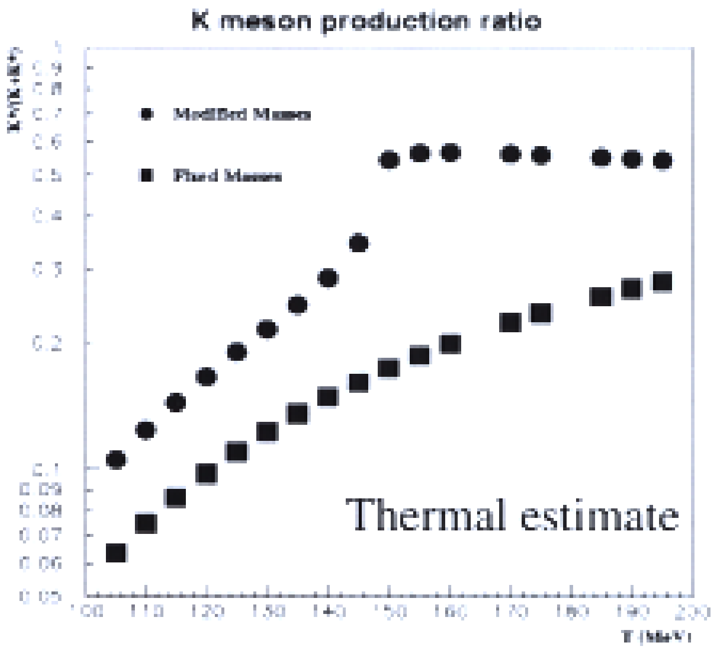
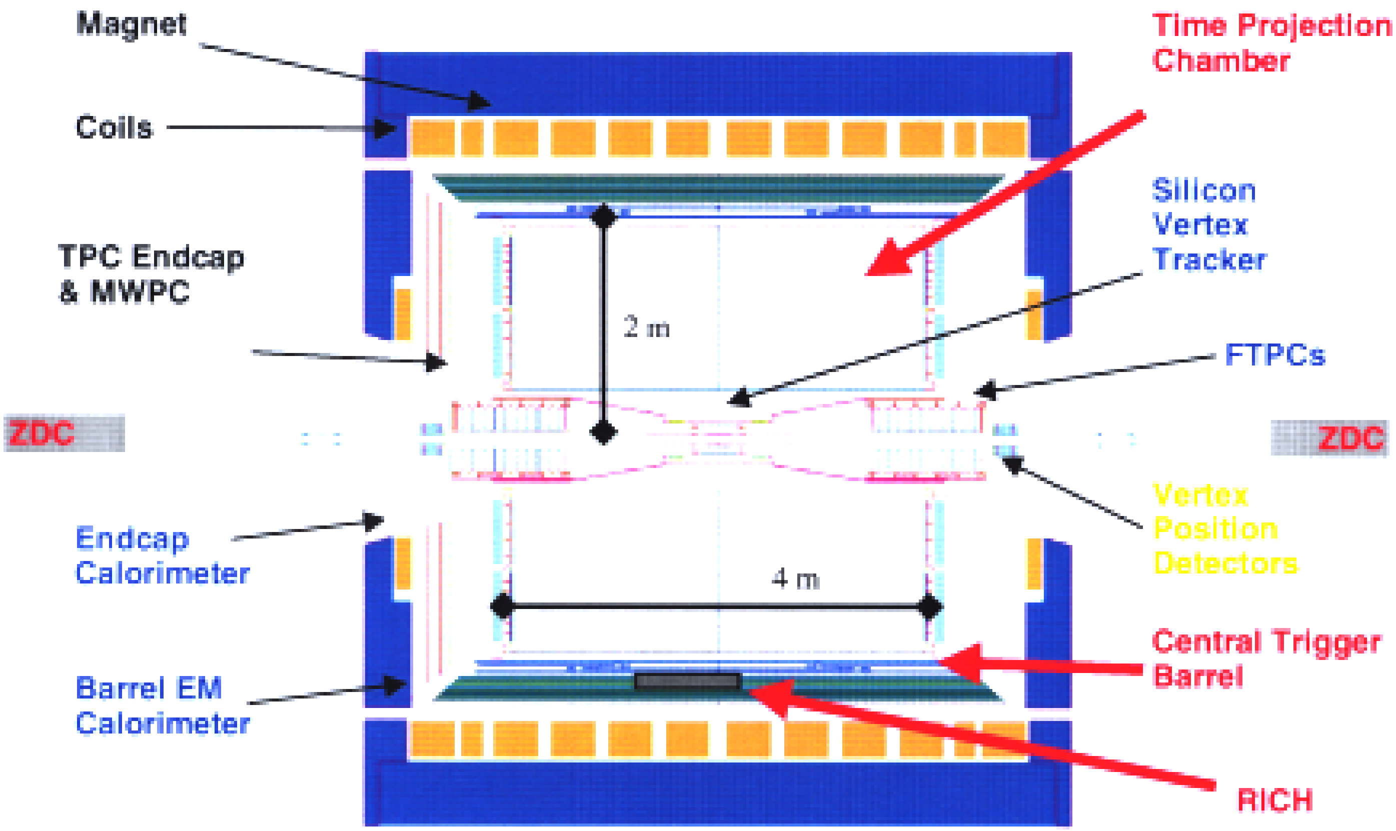
Measure yields





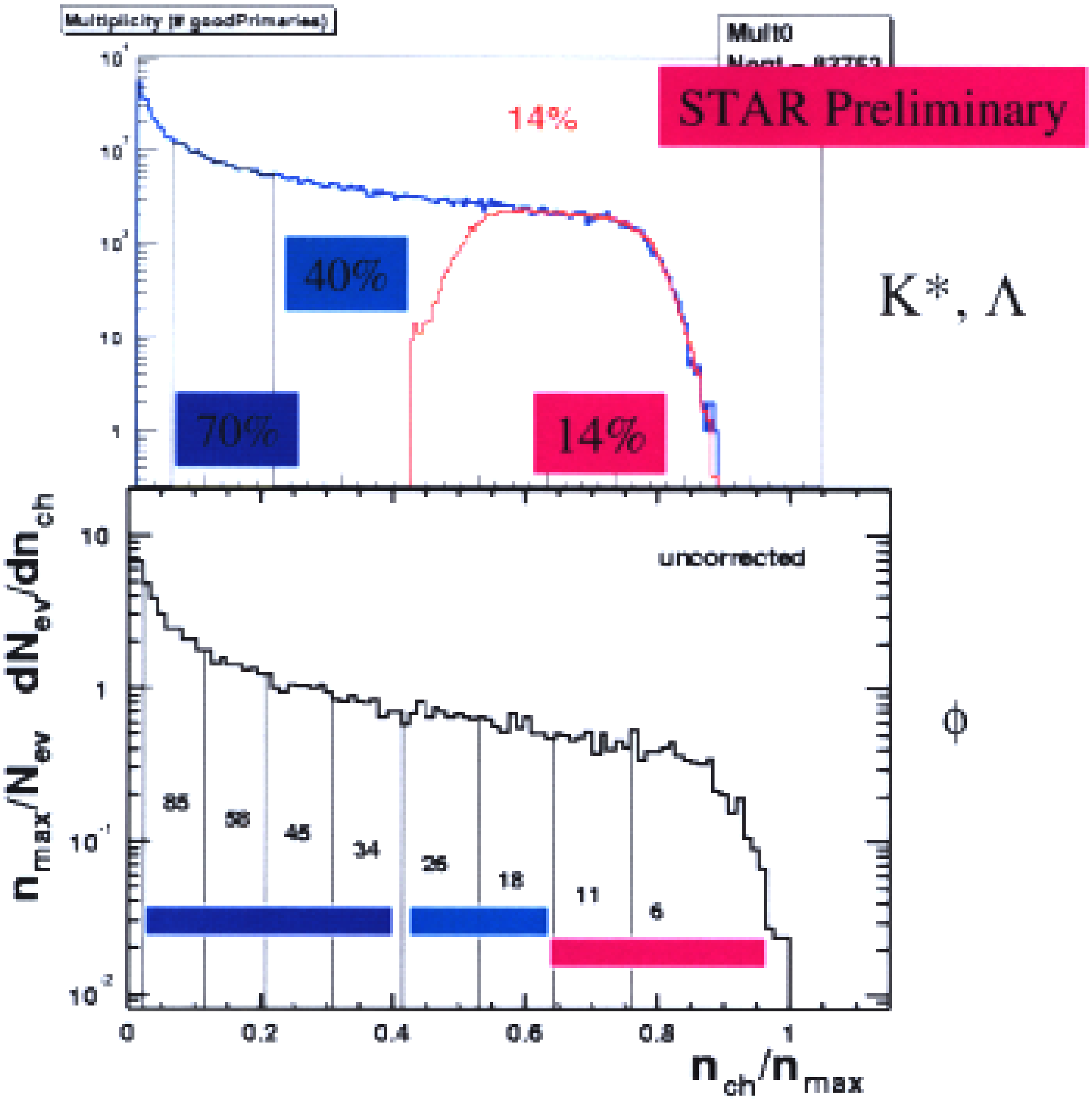
- Sensitive to medium effects
  - V/(V+P) spin counting: 0.75
  - V/(V+P) e+e-, pp: 0.4, 0.6
  - strangeness suppression:
    ϕ/K^* e+e- pp: 0.3
- Effects of $U_A(1)$ restoration on η,η' production
  (3--50 enhancement, related to parity-odd bubble)
  Poster (E. Finch, Yale, STAR)

STAR TPC



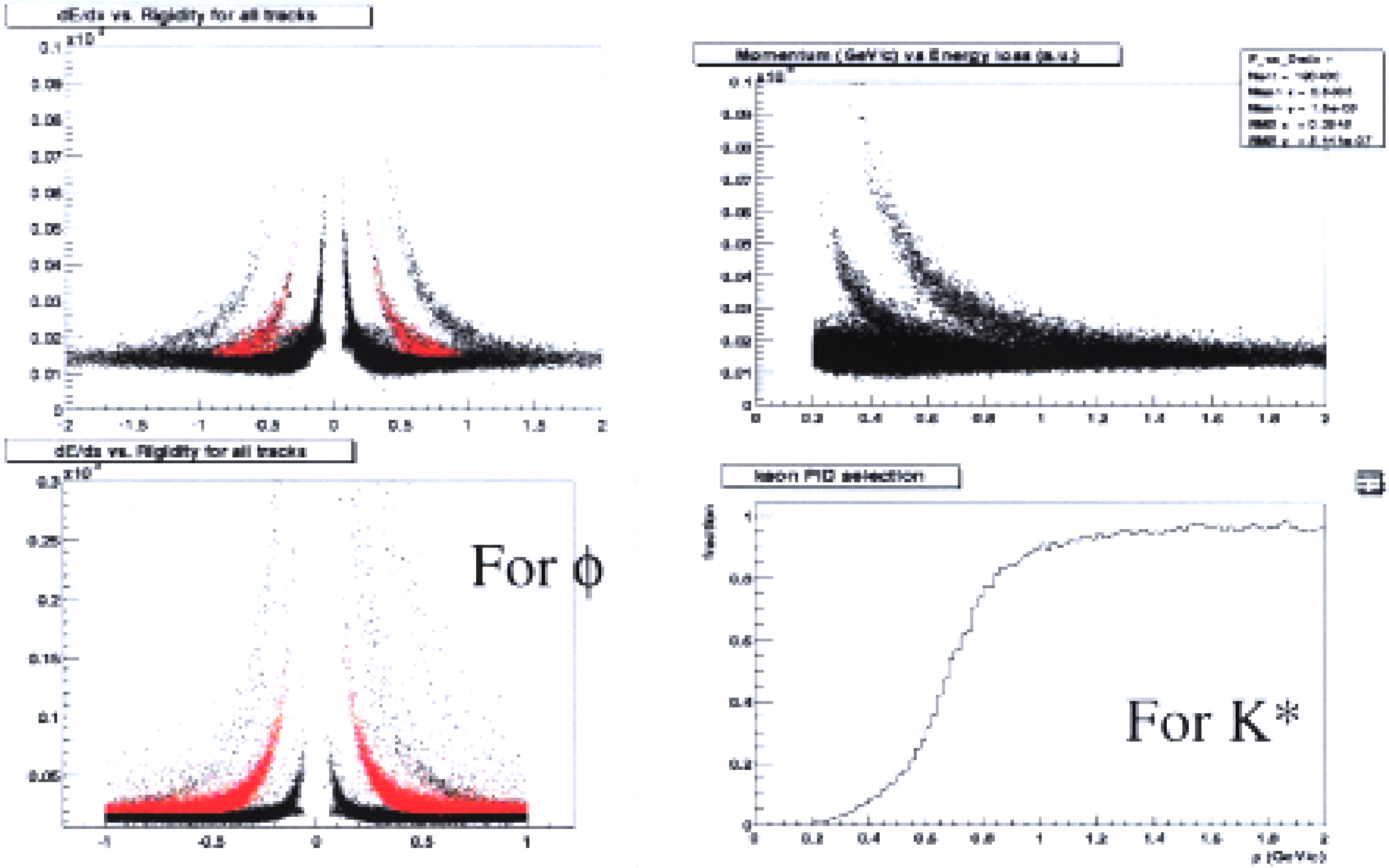
- Beam energy: $\sqrt{S_{NN}} = 130 GeV$
- Detectors:
  - TPC (tracking, p)
  - ZDC, CTB (trigger)

Event Selection



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

Particle Selection



- K π for K*:
  0.2<p<2GeV, nTpcHits>=10
  dE/dX: K $(-2.5\sigma_k,+3\sigma_k)$, π $(-3\sigma_\pi,+3\sigma_\pi)$,
  $|\eta|<0.8$, $\theta_{K\pi}>0.2$
- $K^+ K^-$ for φ:
  0<p<1GeV, nTpcHits>15
  dE/dX: $(-3\sigma_k,+4\sigma_k)$, $>3\sigma_\pi$
  $|\eta|<1.5$, $|y_\phi|<0.5$

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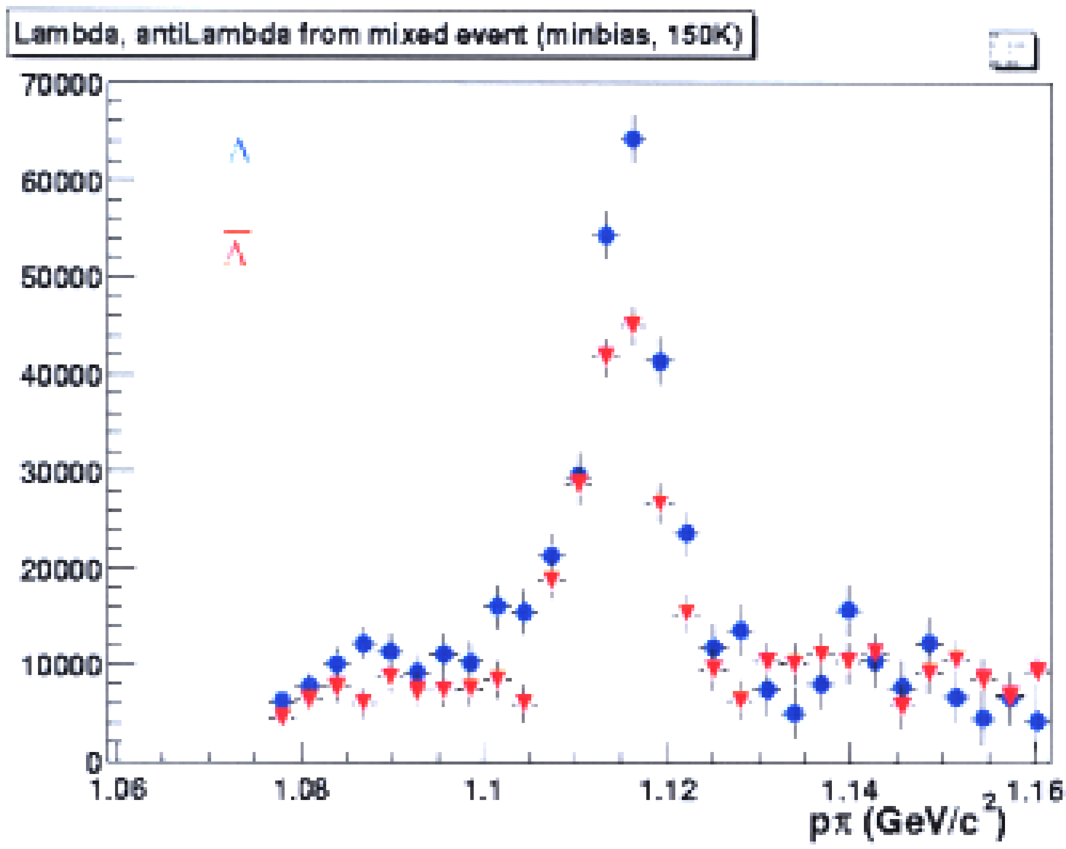
Lambdas from Mixed events



$0<p<2$GeV/c,

p $(-2.5\sigma_p,+3\sigma_p)$, π $(-3\sigma_\pi,+3\sigma_\pi)$

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

0.77±0.07(stat)

0.74±0.03(stat) (V0)

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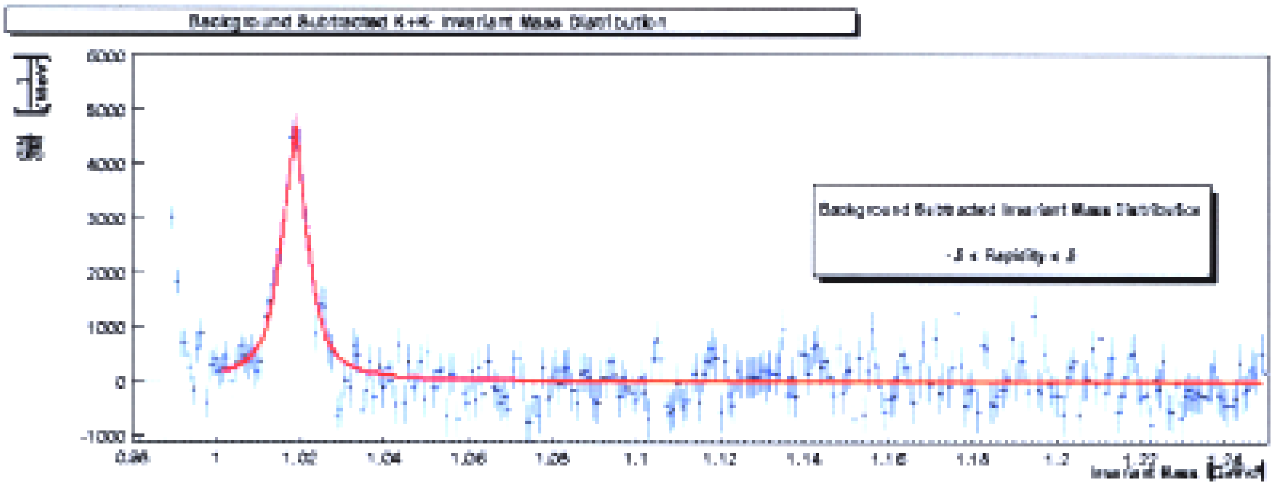
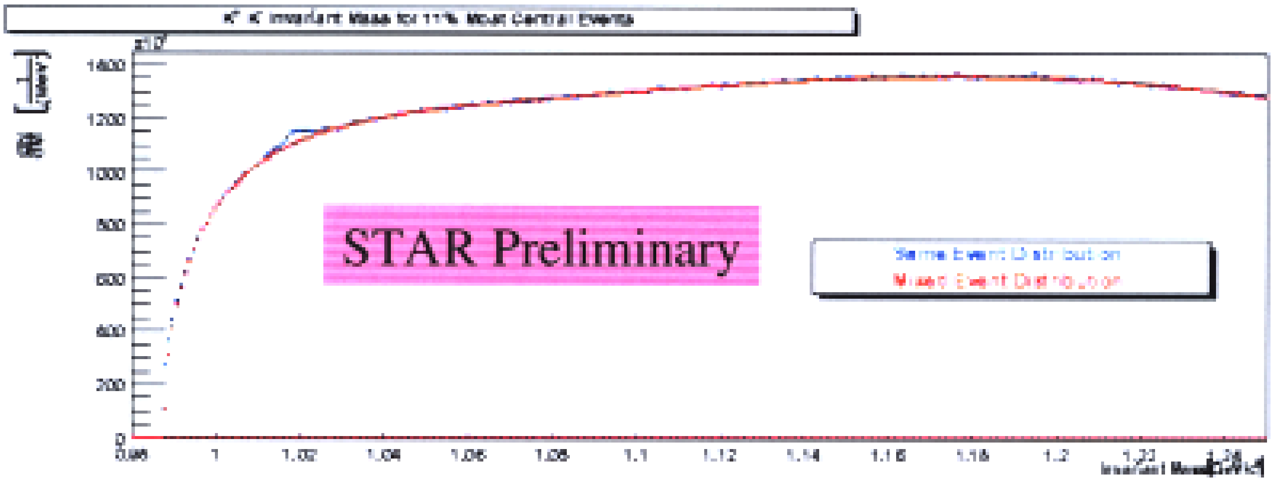
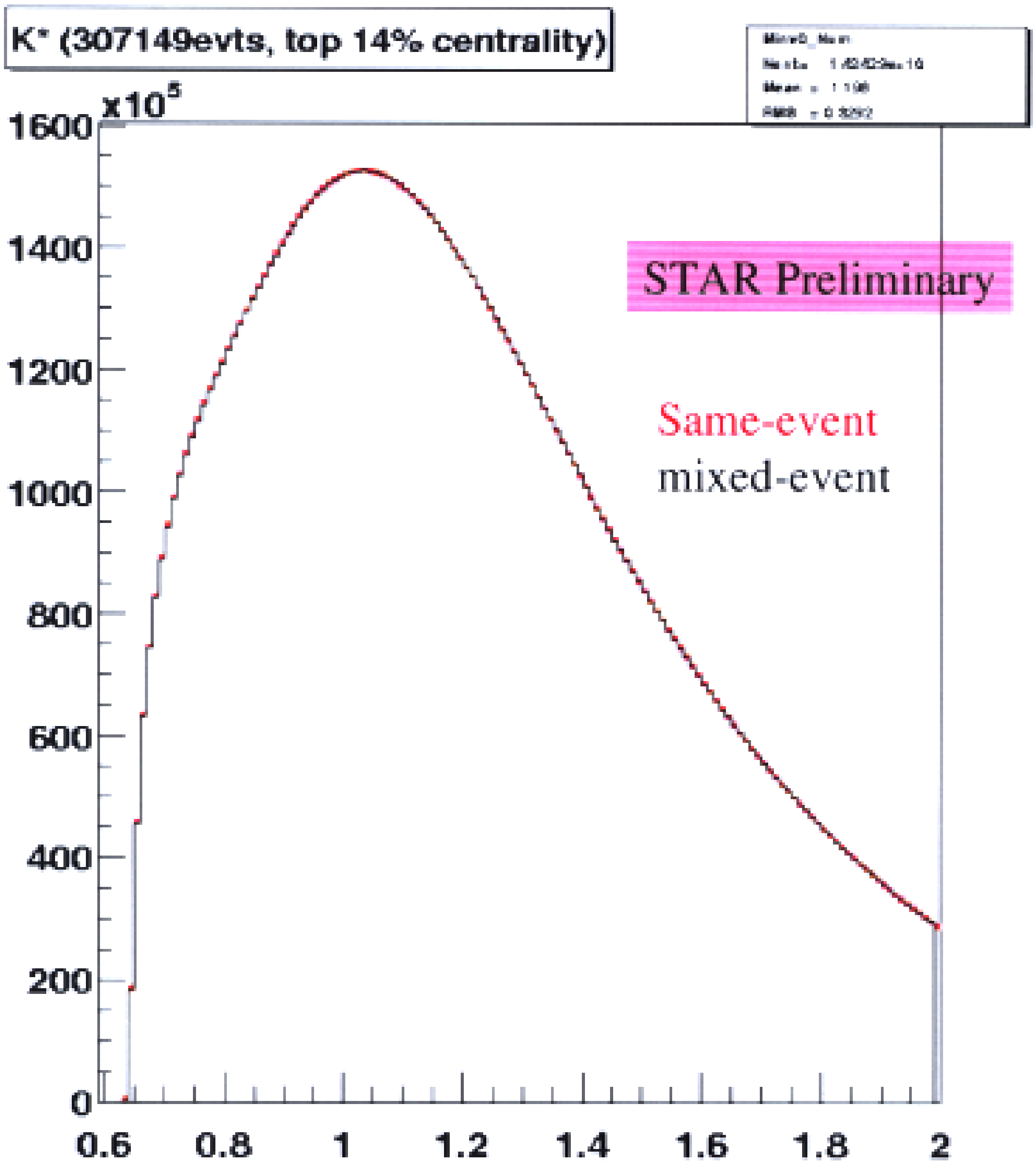
$\phi \rightarrow K^{+} + K^{-}$





- pT spectra, centrality dependency:
  almost ready

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

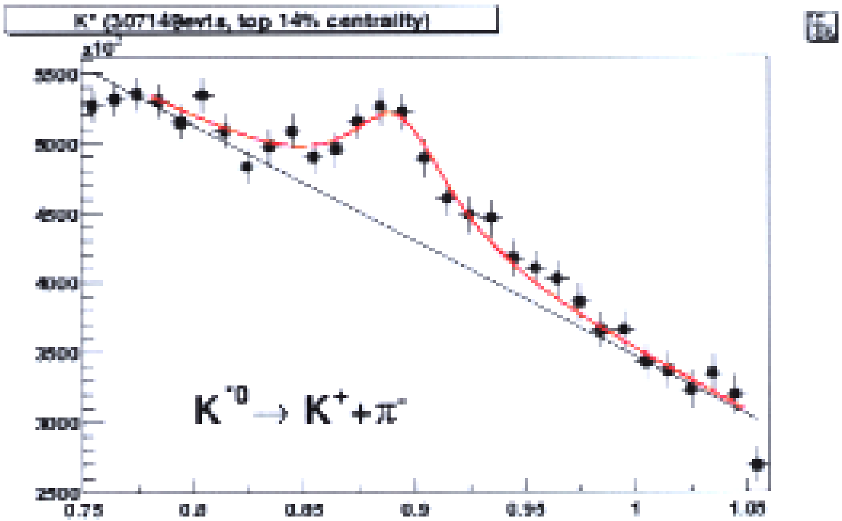


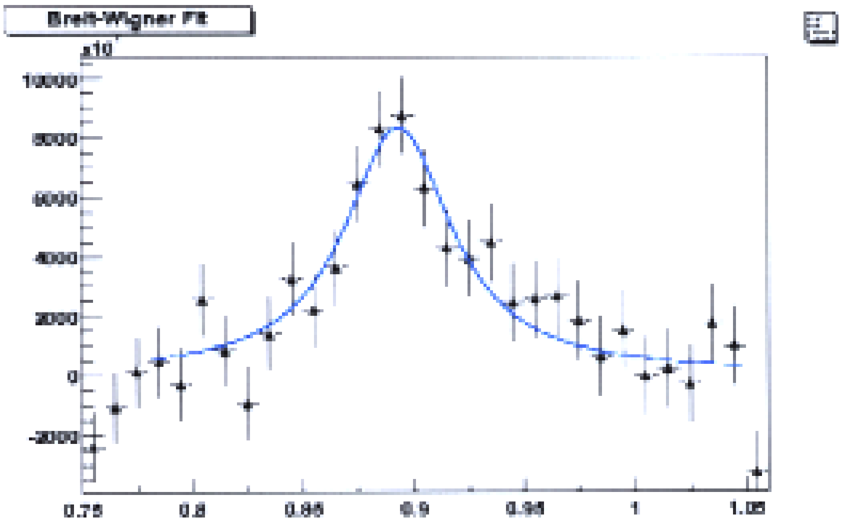
K*→K⁺+π⁻

- 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: ±20%
- Breit-Wigner

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

- P-wave RBW?





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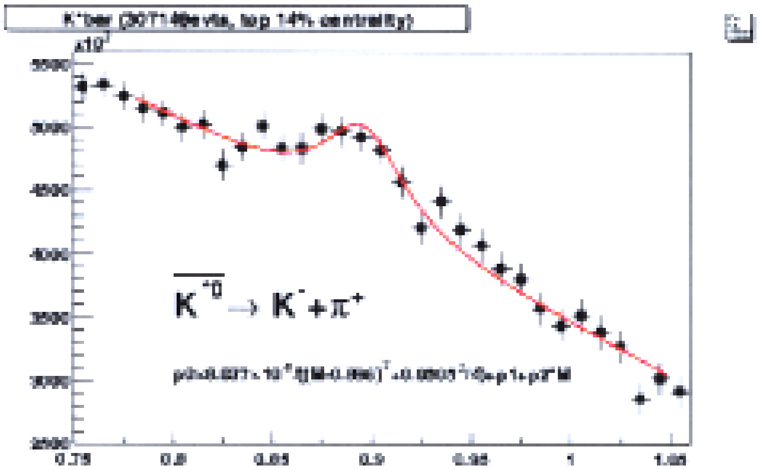
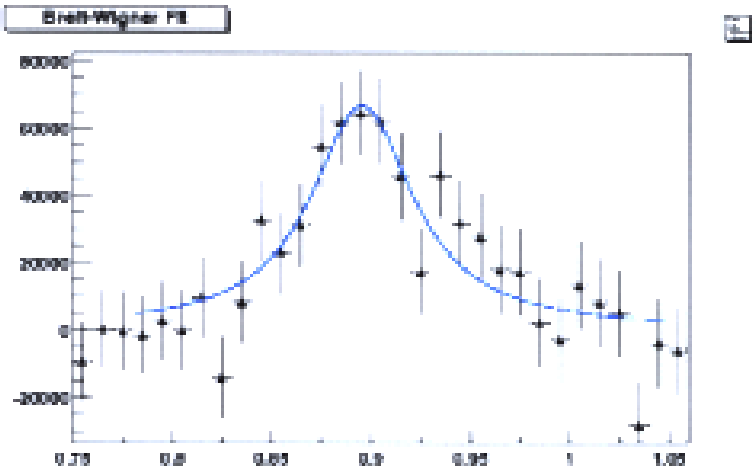
$K^* \rightarrow K^- + \pi^+$

- 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: ±18%
- Breit-Wigner

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





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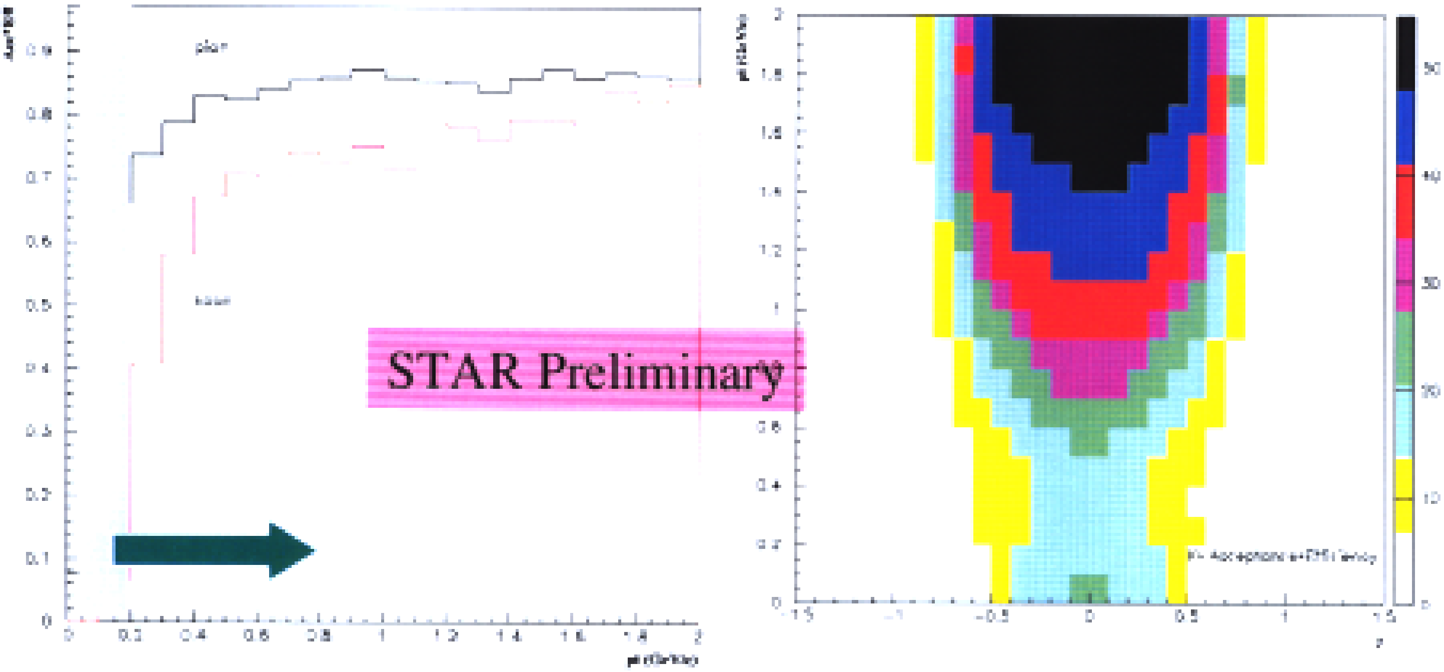
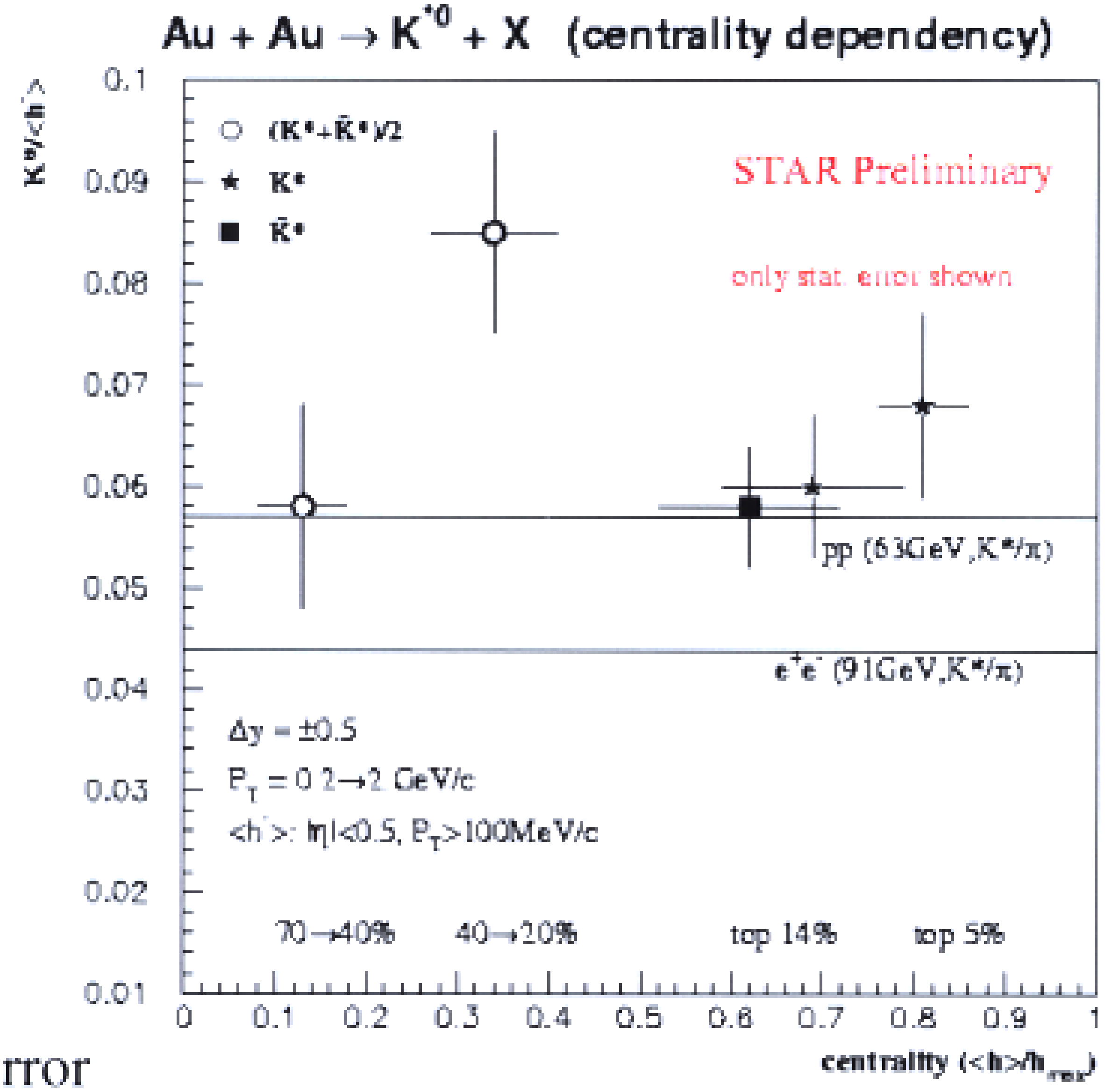
Acceptance*Efficiency



- High "Efficiency": ~80% for single track
- K*: large OpenAngle between Kπ,
  efficiency: K* = kaon*pion (binBybin)
  K, π from embedding MC to data
- K* reconstruction efficiency:
  20%→50% (|y|<~0.5, pt<2GeV)
  (input) T=300MeV, 31%

K* yield



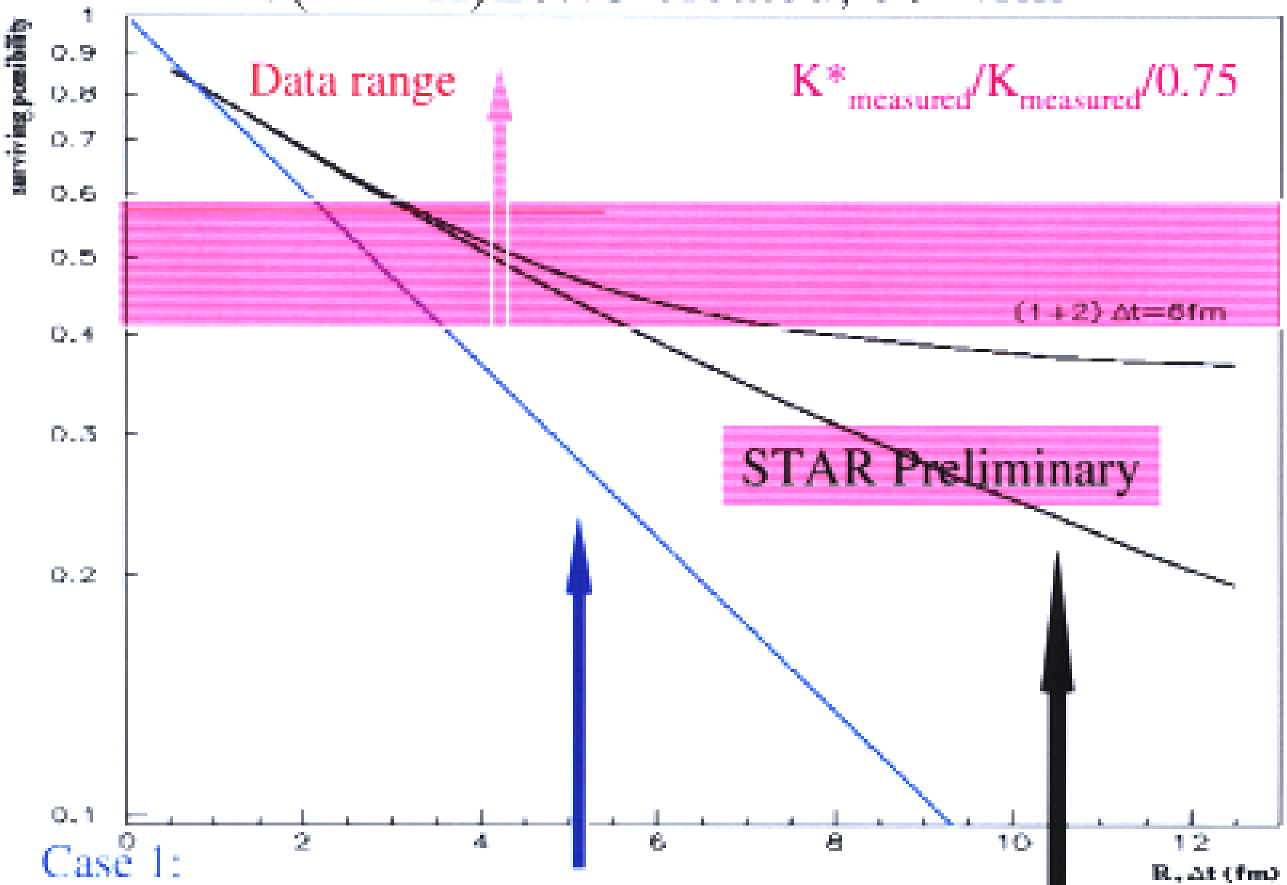
Error

pp: ~ ±20%(sys)

RHIC: ~±25%(sys)

K* surviving possibility

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



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)

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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 = 156MeV
  - K, pbar (RHIC) T$\geq$250MeV
- Volume:
  - $S/N \propto 1/(Vq\Gamma)$
- Centrality dependency:
  - T, K*/K
  - $\overline{K}^*/K^* \approx \overline{K}/K$?

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 ($\rho \rightarrow \pi+\pi-$)