# *Probing the hadronic phase via the measurement of resonances in Au+Au collisions at 19.6 GeV from STAR BES-II*

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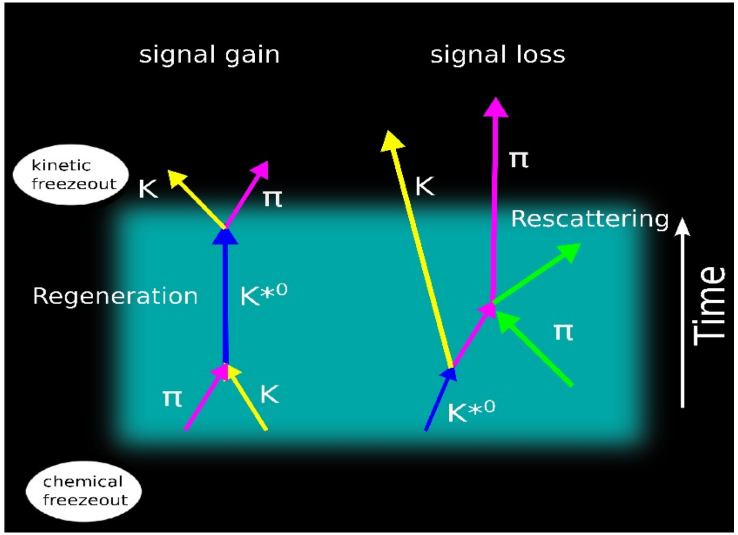
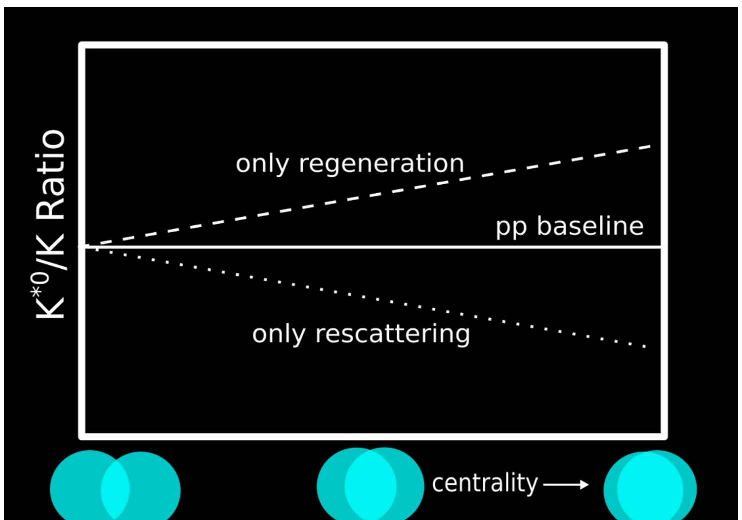
# Outline

- Motivation
- The STAR detector
- Signal reconstruction
- Results
  - Transverse momentum spectra
  - $p_T$ integrated yield (dN/dy)
  - $K^{*0}/K$ ratio
  - Hadronic phase lifetime
- Summary

# Why $K^{*0}$ Resonance



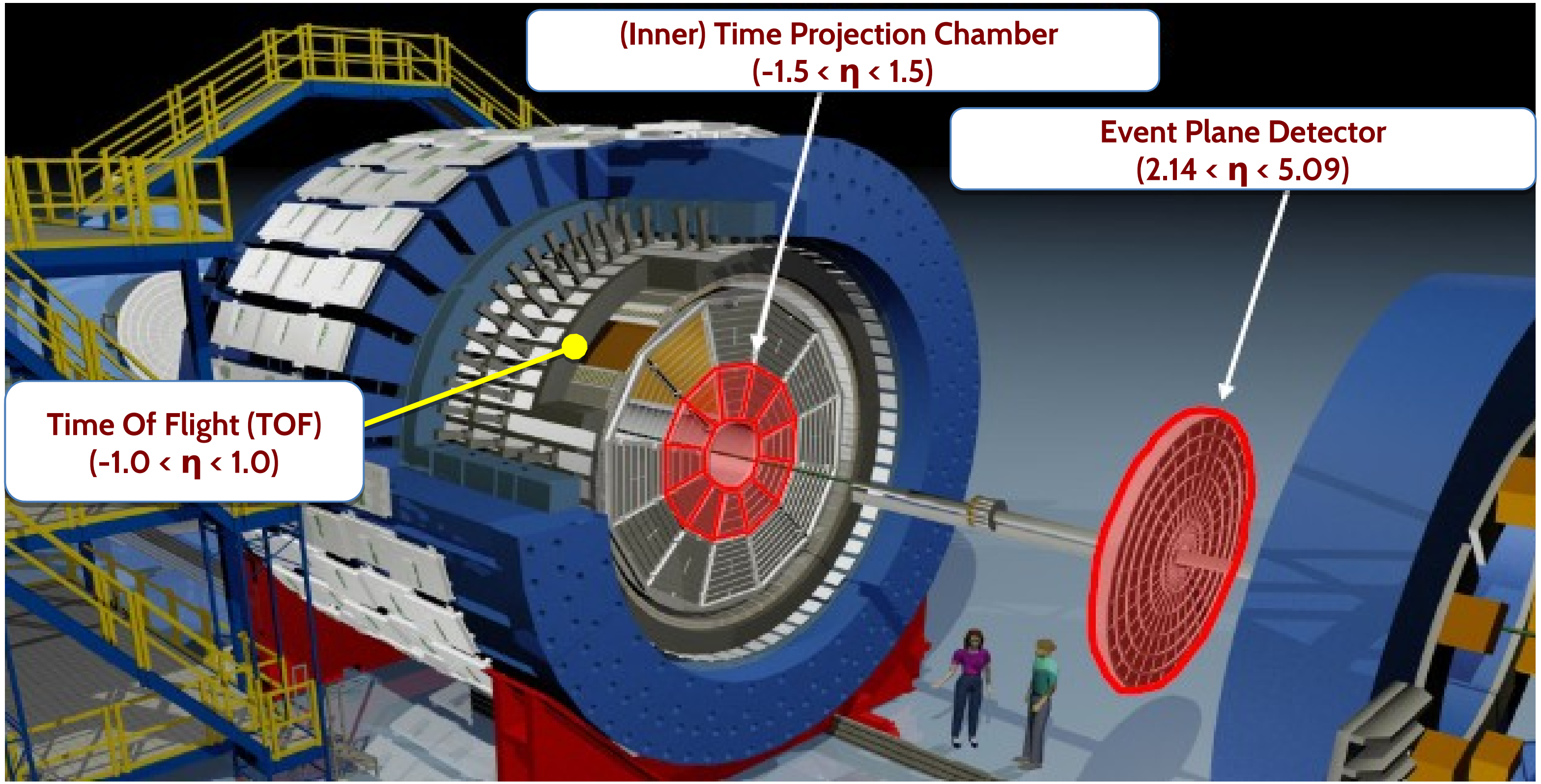

| Resonance | Quark content | Decay Channel | t (fm/c) |
|---|---|---|---|
| $K^{*0}$ (896) | $d\bar{s}$ | $\pi^- K^+$ (B.R= 0.66) | 4.16 |

- Lifetime comparable to that of the *hadron gas phase*.
- Modification of resonance yields due to interplay of rescattering and regeneration

$K^{*0}/K$ ratio can be used to probe these effects in heavy ion collisions

STAR. Phys. Rev. C 66 (2002) 61901

# The STAR Detector and Data Set



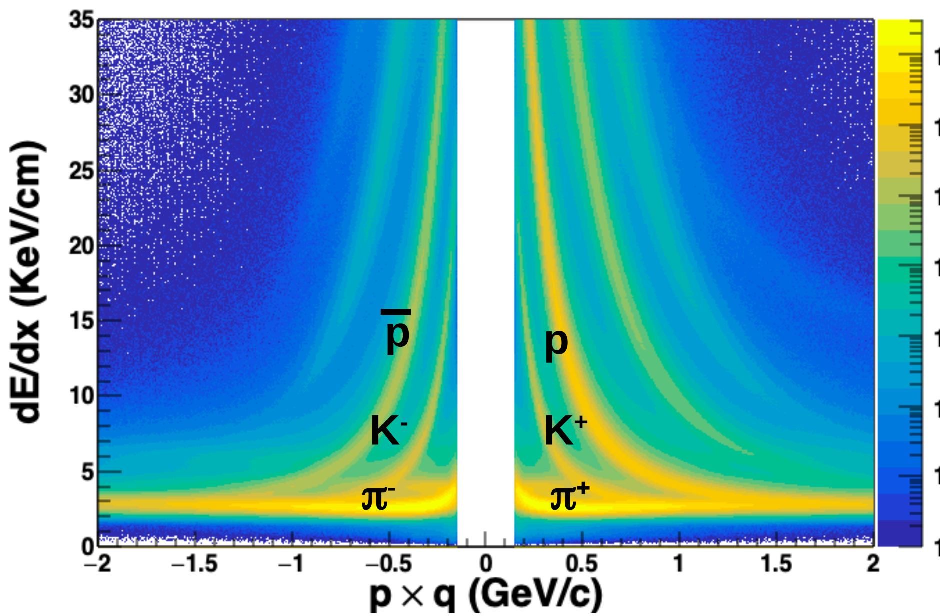

**Data Set :**
**System:** Au+Au 19.6 GeV (BES-II)
**# of events :** ~710 M

**Tracking:**
TPC

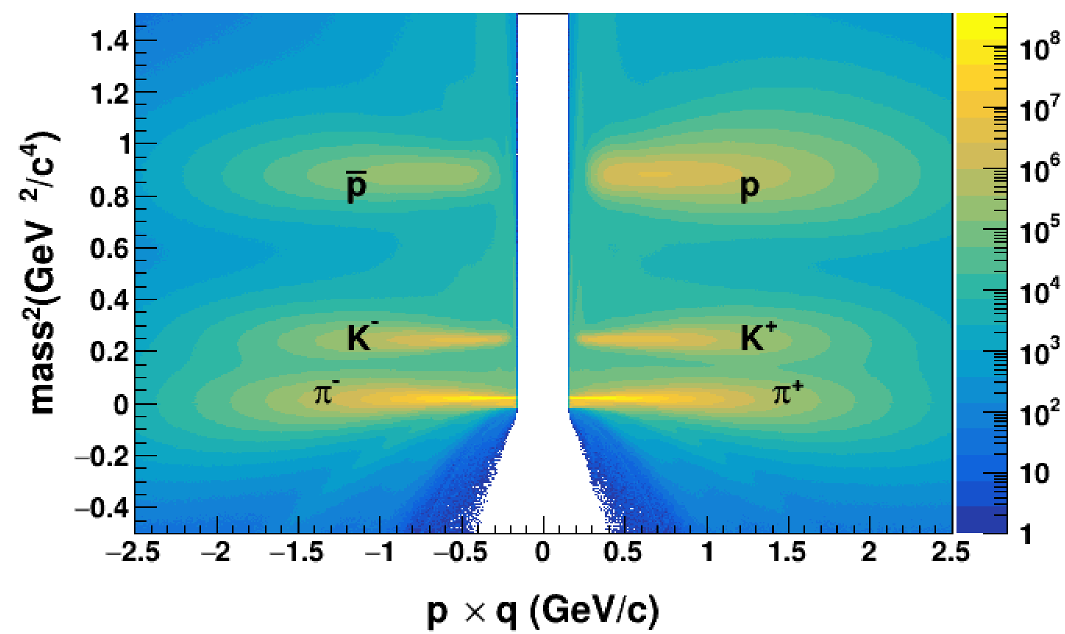
**Particle Identification:**
TPC & TOF

# Particle Identification

Au+Au 19.6 GeV

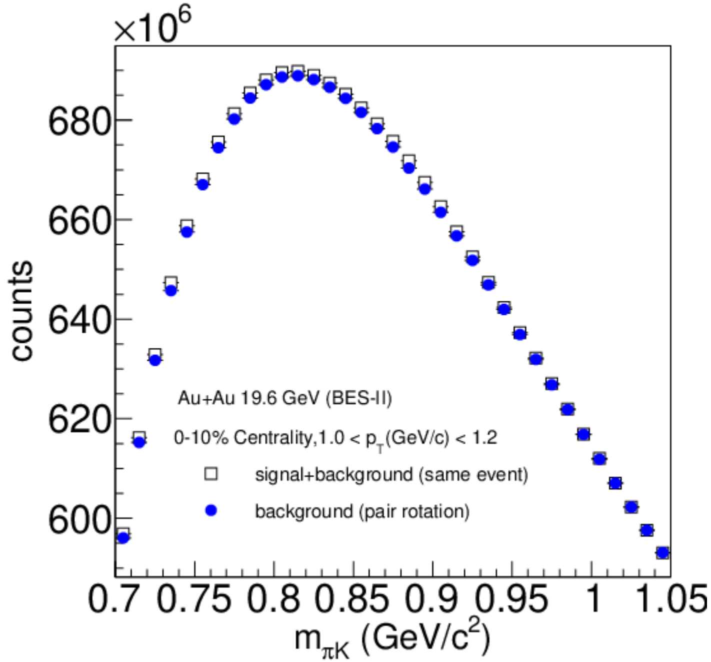


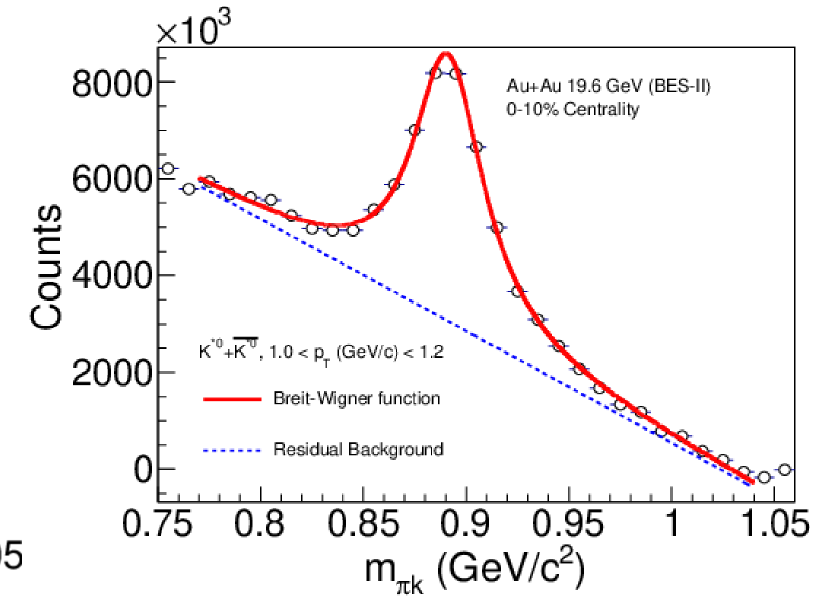

( Using TPC )




( Using TOF )

# Signal Reconstruction



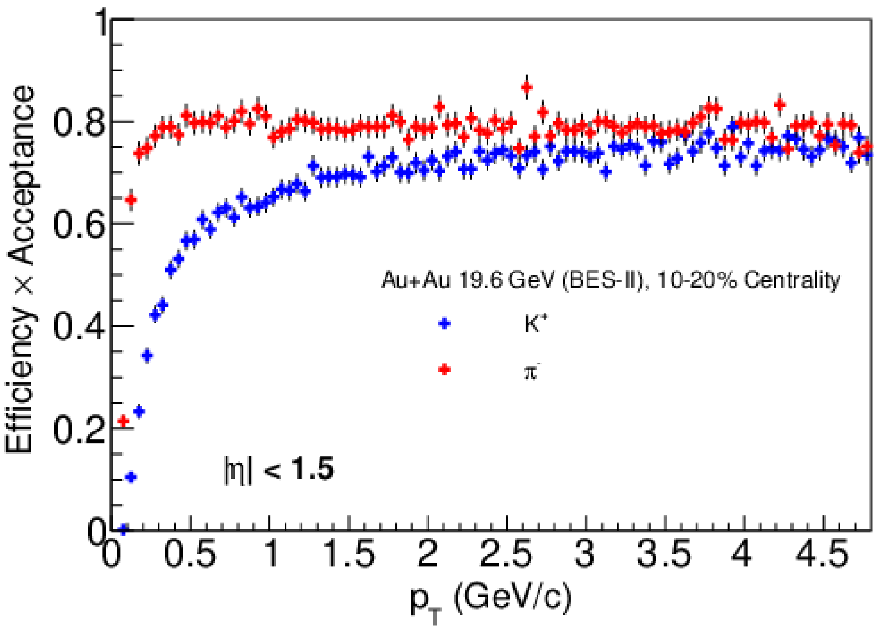



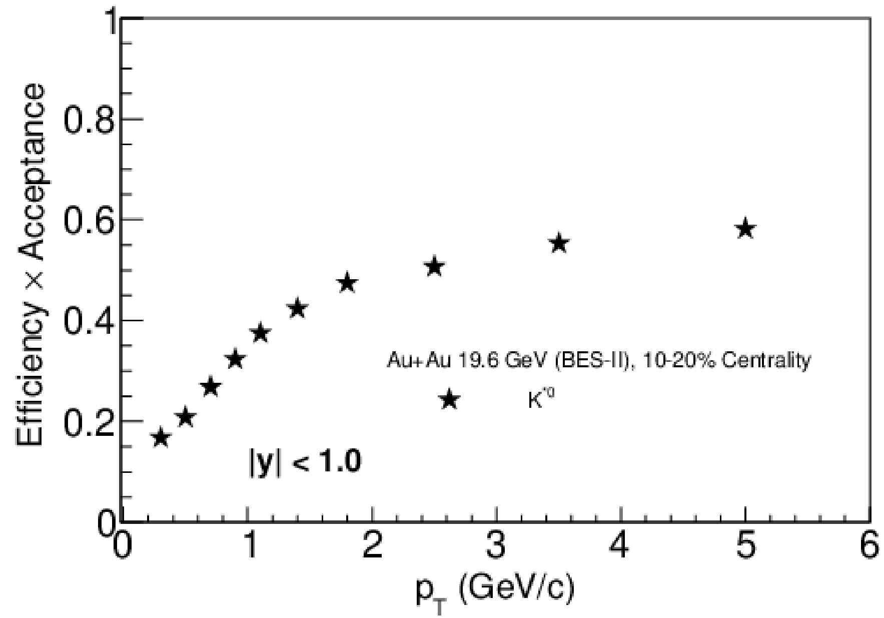

| 0-10% centrality , 1.0 < $p_T$ (GeV/c) < 1.2 | |
|---|---|
| 19.6 GeV | S/√(S+B) |
| BES-I | 20 |
| BES-II | 80 |

- Signals are extracted using invariant mass method.

  Invariant mass: $m^2_{inv} = E^2 - p^2$ where, $E^2=(E_\pi + E_K)^2$ and $p^2=(p_\pi + p_K)^2$
- Combinatorial background is estimated using pair rotation method.
- Fitting function: $\frac{Y}{2\pi}\times[\frac{\Gamma_0}{(M-M_0)^2+\frac{\Gamma_0}{4}}]$ + 1st order polynomial (residual background)

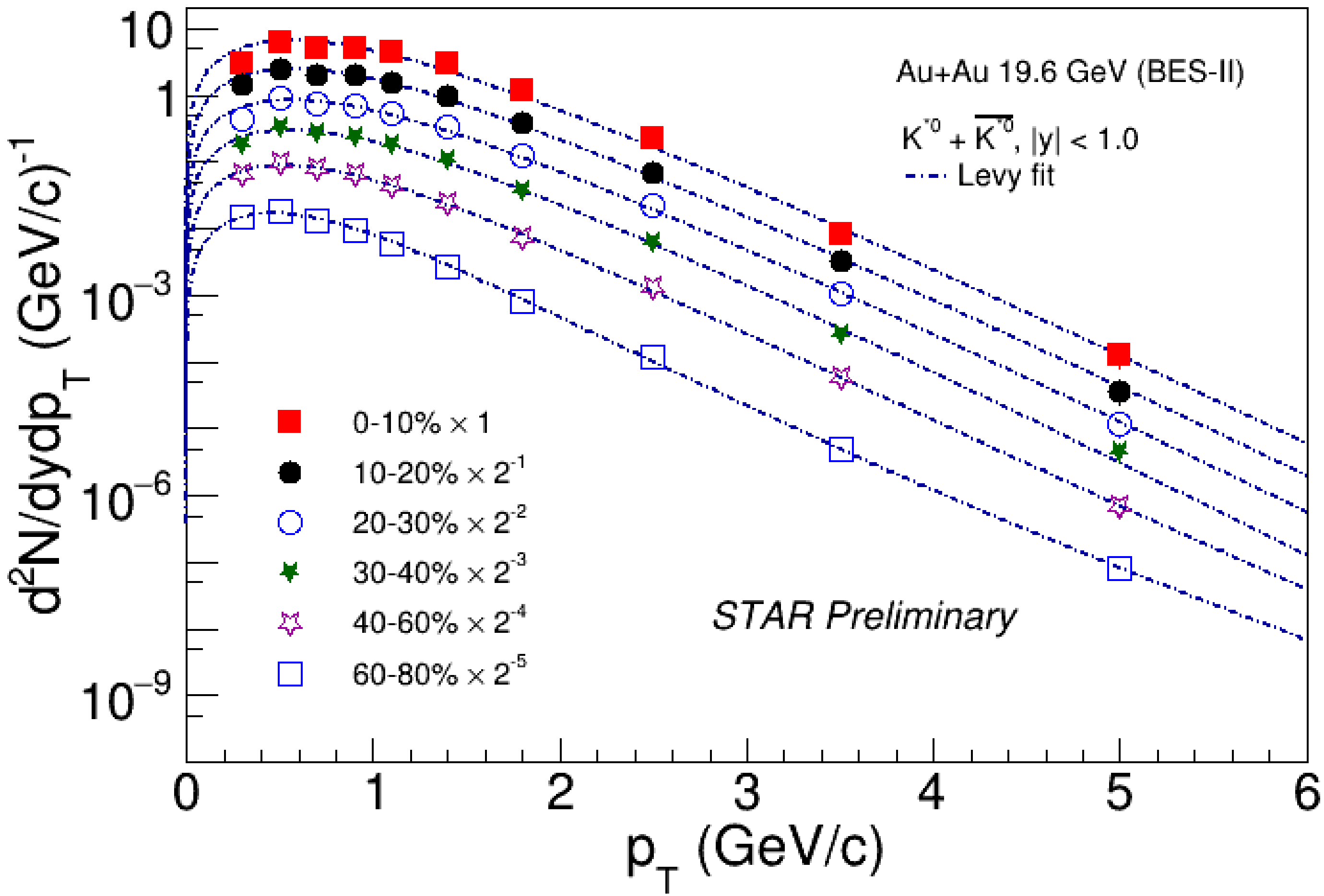
# Efficiency × Acceptance




- $K^{*0}$ reconstruction efficiency is estimated based on single particle efficiency

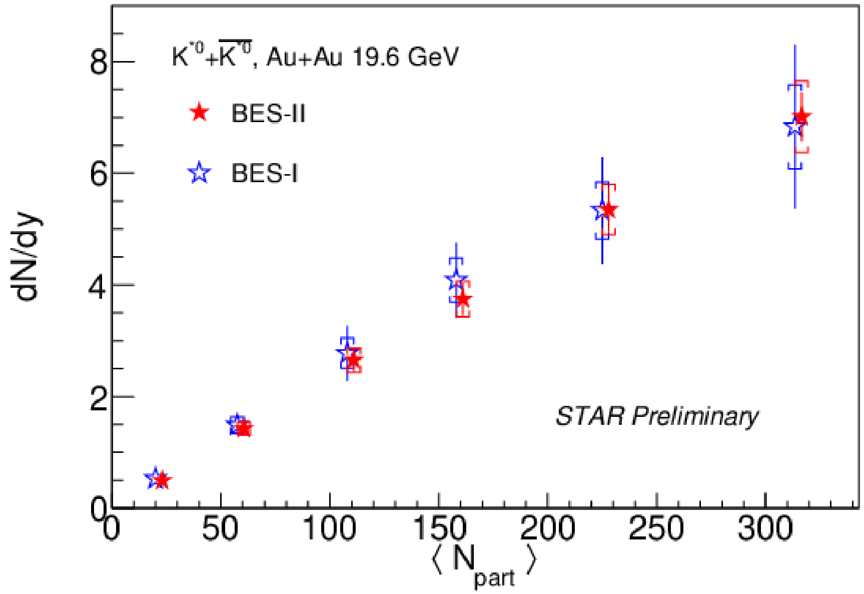
# Transverse Momentum Spectra



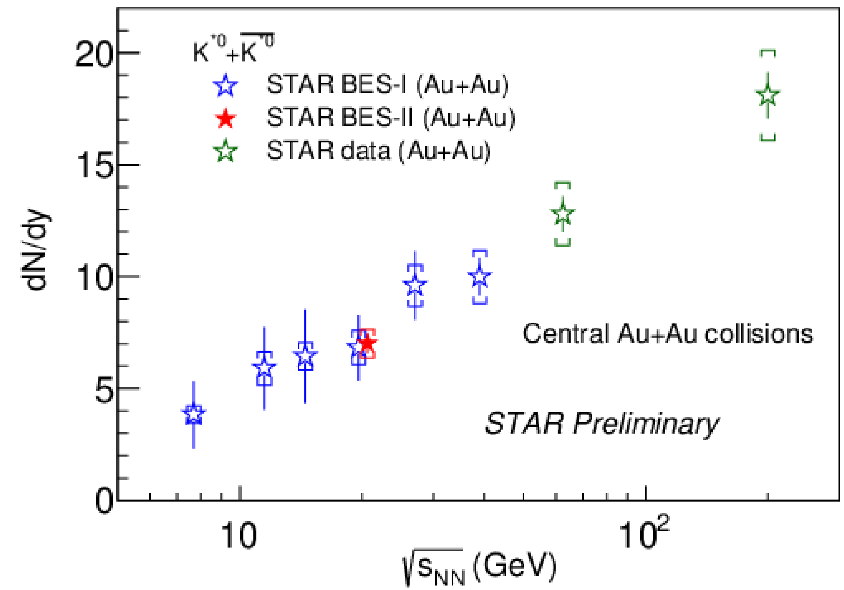

- Levy Tsallis function is used to extrapolate yield at low and high $p_T$ regions.

C. Tsallis, J. Statist. Phys., 52:479–487, 1988

# $p_T$ Integrated Yield




BES-I result : arXiv:2210.02909

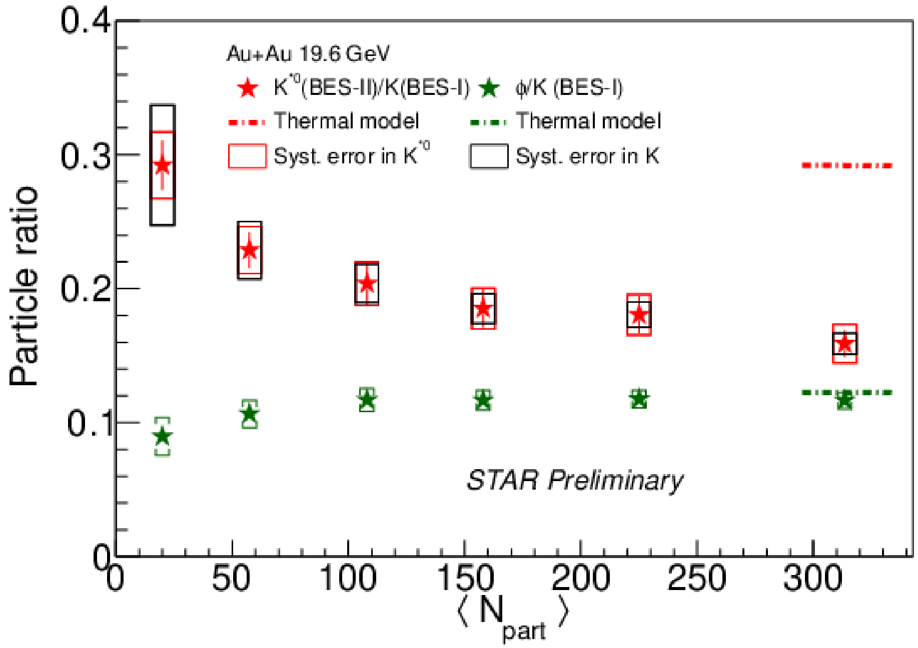


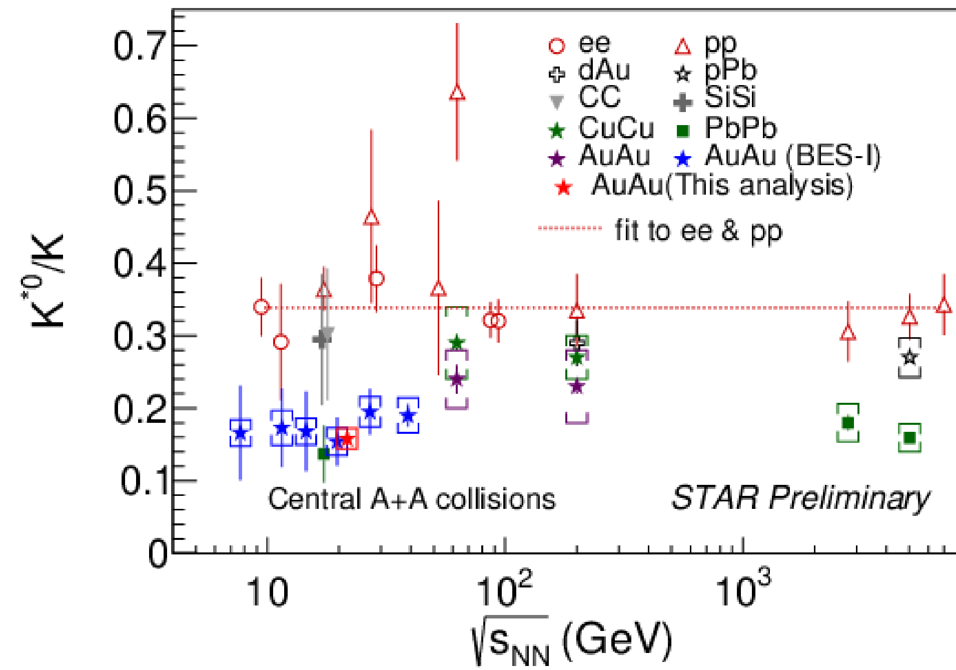

STAR. Phys.Rev.C 84 (2011) 034909 (62.4 and 200 GeV)

dN/dy increases with centrality and collision energy

The statistical errors are reduced by a factor of **3** in BES-II compared to BES-I

# $K^{*0}/K$ Ratio





H. Albrecht et al..Z. Phys. C, 61:1–18,1994 (e+e)
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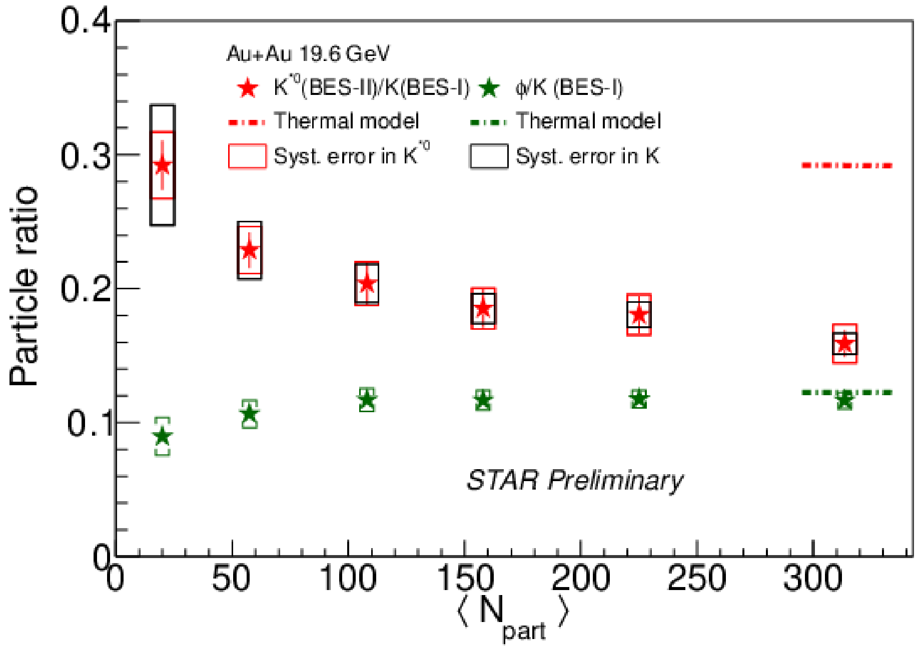
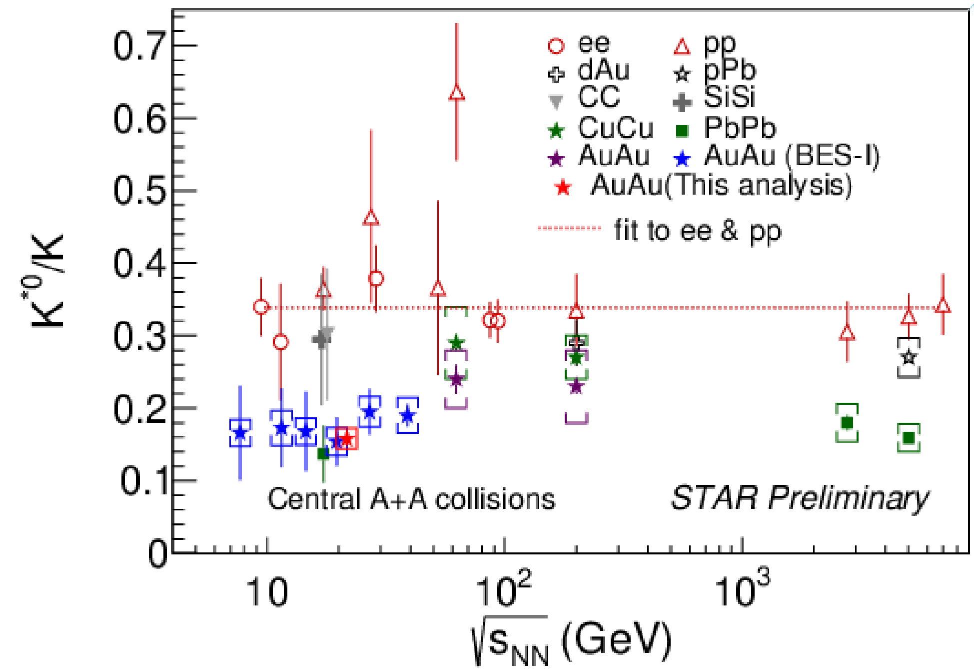
ALICE. Eur. Phys. J. C, 76(5):245,(2016) (p+Pb)

# $K^{*0}/K$ Ratio

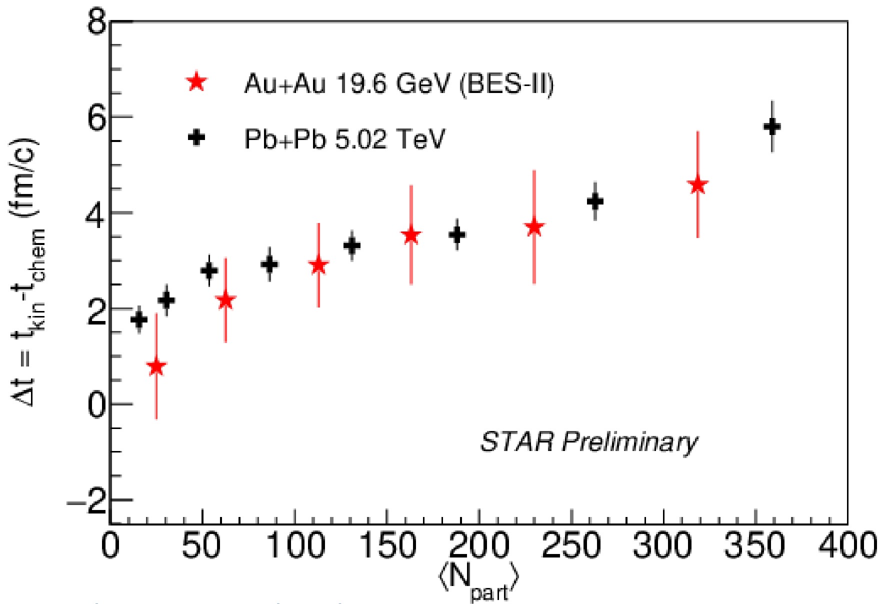


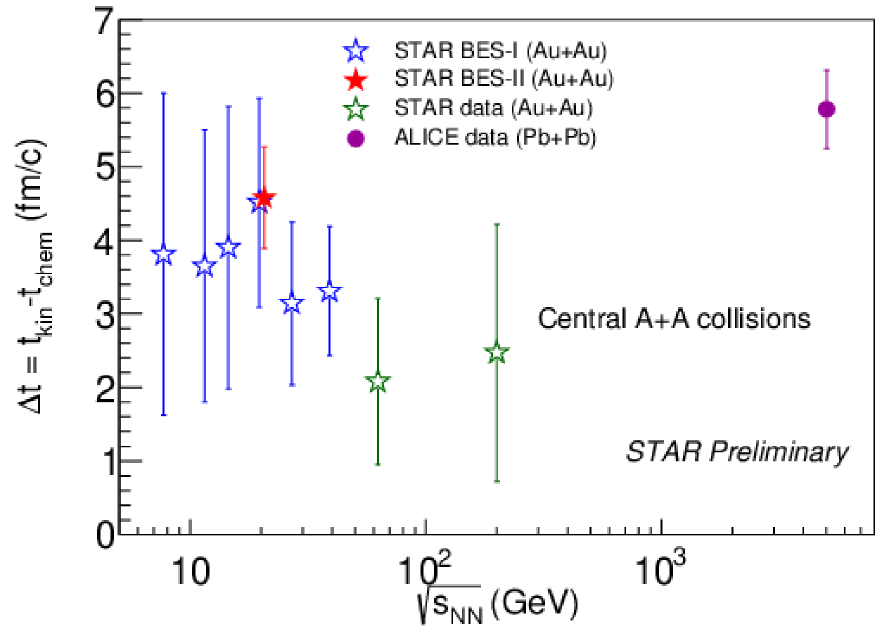

- $(K^{*0}/K)_{central} < (K^{*0}/K)_{peripheral}$
- $(K^{*0}/K)_{central} < (K^{*0}/K)_{pp/ee\text{-}reference}$
- $(\varphi/K)$: independent of centrality
- Themal model explains the $\varphi/K$, but overpredicts the $K^{*0}/K$ in central collision

***Favors dominant hadronic rescattering in central collisions***

# Lower Limit of Hadronic Phase Lifetime




ALICE: Phys.Lett.B 802 (2020) 135225
STAR: Phys. Rev. C, 84:034909, (2011)




- Errors are the quadratic sum of statistical and systematic errors

- $(K^{*0}/K)_{kin} = (K^{*0}/K)_{chem} \times e^{-\Delta t/\tau}$

  where, $\Delta t$ = lower limit of hadronic phase lifetime ( $t_{kin} - t_{chem}$ )

  $\tau$ = Lifetime of $K^{*0}$

- Here we can take

  $(K^{*0}/K)_{kin} \approx (K^{*0}/K)_{AA}$

  $(K^{*0}/K)_{chem} \approx (K^{*0}/K)_{pp}$

STAR. Phys. Rev. C 66 (2002) 61901
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S.Singha.etal.Int.J.Mod.Phys.E 24 (2015) 05, 1550041

- Here, $(K^{*0}/K)_{pp} = 0.34 \pm 0.01$

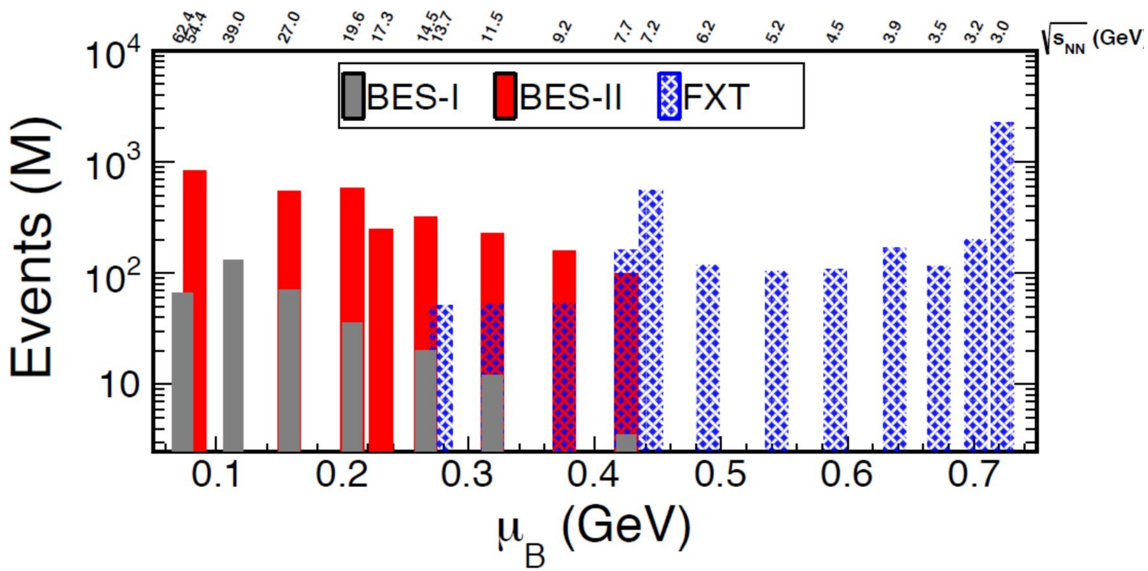
- *No clear energy dependence within the current uncertainties at RHIC*

# Summary

- $K^{*0}$ resonance production in BES-II Au+Au collisions at 19.6 GeV is presented
- $K^{*0}/K$ ratio indicates dominance of hadronic rescattering over regeneration in central Au+Au collisions
- The lower limit of hadronic phase lifetime increases with centrality, and no clear energy dependance is observed within current uncertainities for RHIC measurements.

# Outlook

- $K^{*0}$ resonance measurement using high statistics data collected in STAR BES-II program
- Constraints on the hadronic phase lifetime
- Explore more differential measurements (e.g. rapidity dependence)



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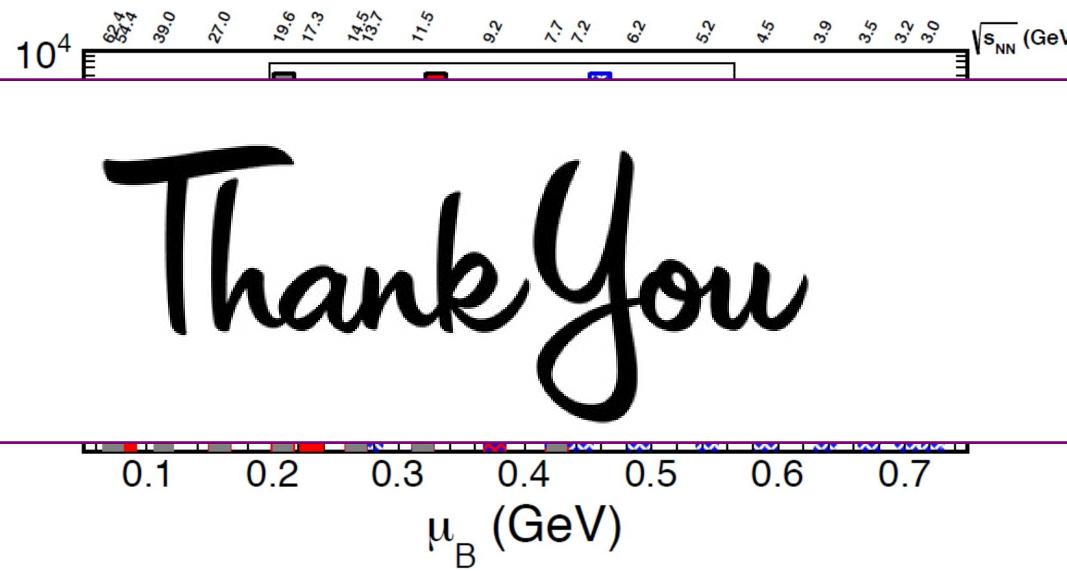


Thank You

# Backup

- Thermal model parameters : $T_{ch}$ = 153.9 MeV, $\mu_s$ = 43.2 MeV, $\mu_B$ = 187.9 MeV

Phys. Rev. C 96, 044904 (2017)