Measurement of $K_s^0 - K_s^0$ correlation function in Au+Au collisions at the high baryon density region

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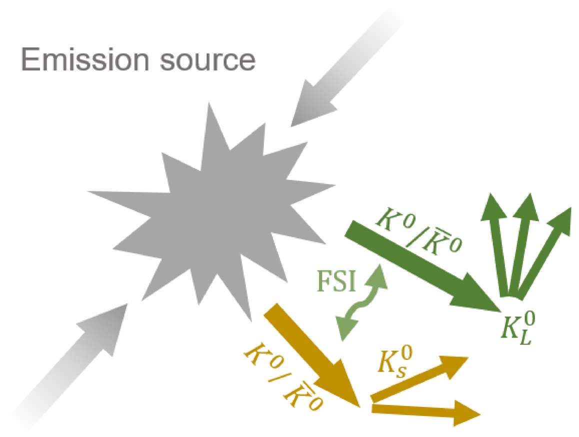
QM 2023

Abstract: Two-particle correlation analyses are often used to study the spatial and temporal extension of particle-emitting source in high-energy nuclear collisions. Precise information on the final state interactions amongst the particles under study can also be extracted from the measurement. It is particularly interesting to study the energy dependence of the extracted source size at the moment of freeze-out. Two-kaon correlations are an important supplement to those of pions, as they are less affected by resonance decays and they have smaller hadronic cross-section.

Motivation

The correlation function of $K_s^0 - K_s^0$ pair can provide information about particle emission source and final state interaction (FSI) between K^0K^0, $\bar{K}^0\bar{K}^0$ and $K^0\bar{K}^0$. Neglecting the effects of CP violation, the observed weak interaction eigenstates are given by[1]

$$|K^0_{s/l}\rangle = \frac{1}{\sqrt{2}}(|K^0\rangle \pm |\bar{K}^0\rangle).$$



Correlation function

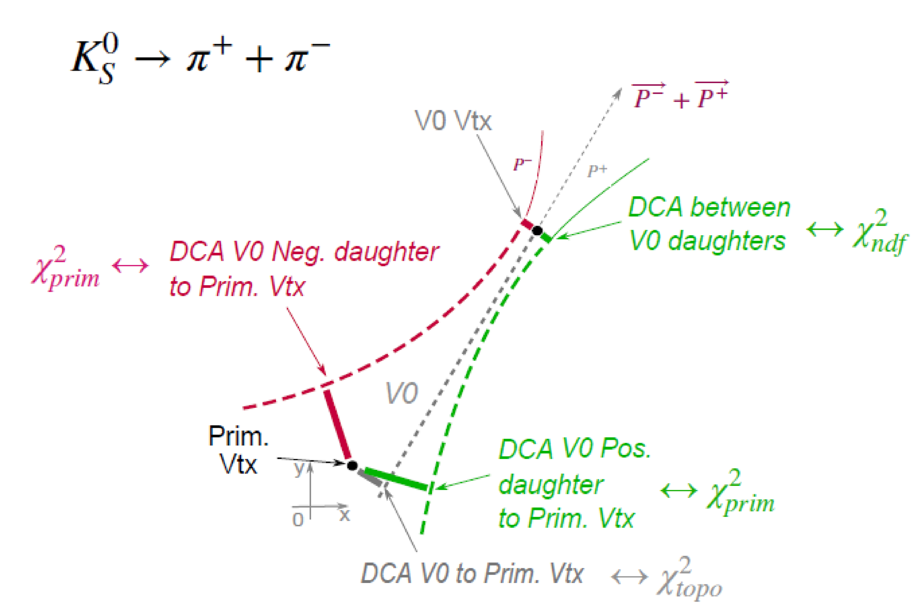
The correlation function is defined as below[2]

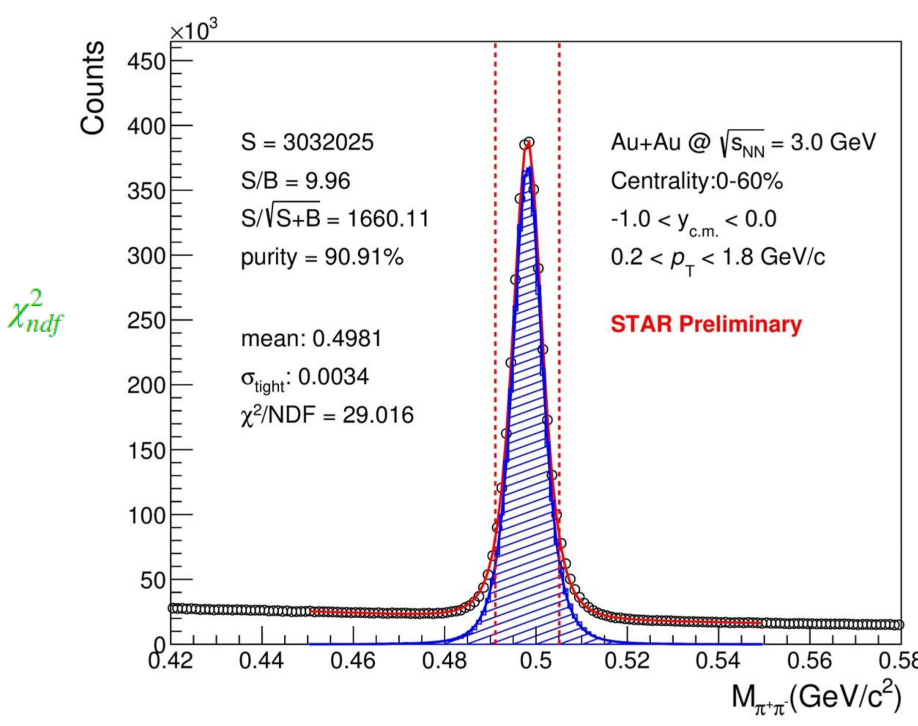
$$C(q_{inv}) = \int S(\vec{r}^*)\left|\Psi(\vec{k}^*,\vec{r}^*)\right|^2 d^3\vec{r}^* = \mathcal{N}\frac{N_{same}(q_{inv})}{N_{mixed}(q_{inv})}$$

Where relative momentum $q_{inv} = \sqrt{-q^\mu q_\mu}$, $q^\mu = p_1^\mu - p_2^\mu$. $\vec{k}^*$ represents momentum of the pair in pair reset frame. $N_{same}(q_{inv})$ is the distribution of q_{inv}, and $N_{mixed}(q_{inv})$ is distribution of q_{inv} at mixed events experimentally. $\mathcal{N}$ is the normalization factor. $S(\vec{r}^*)$ is the source function and $\Psi(\vec{k}^*,\vec{r}^*)$ is pair wave function.

Particle reconstruction

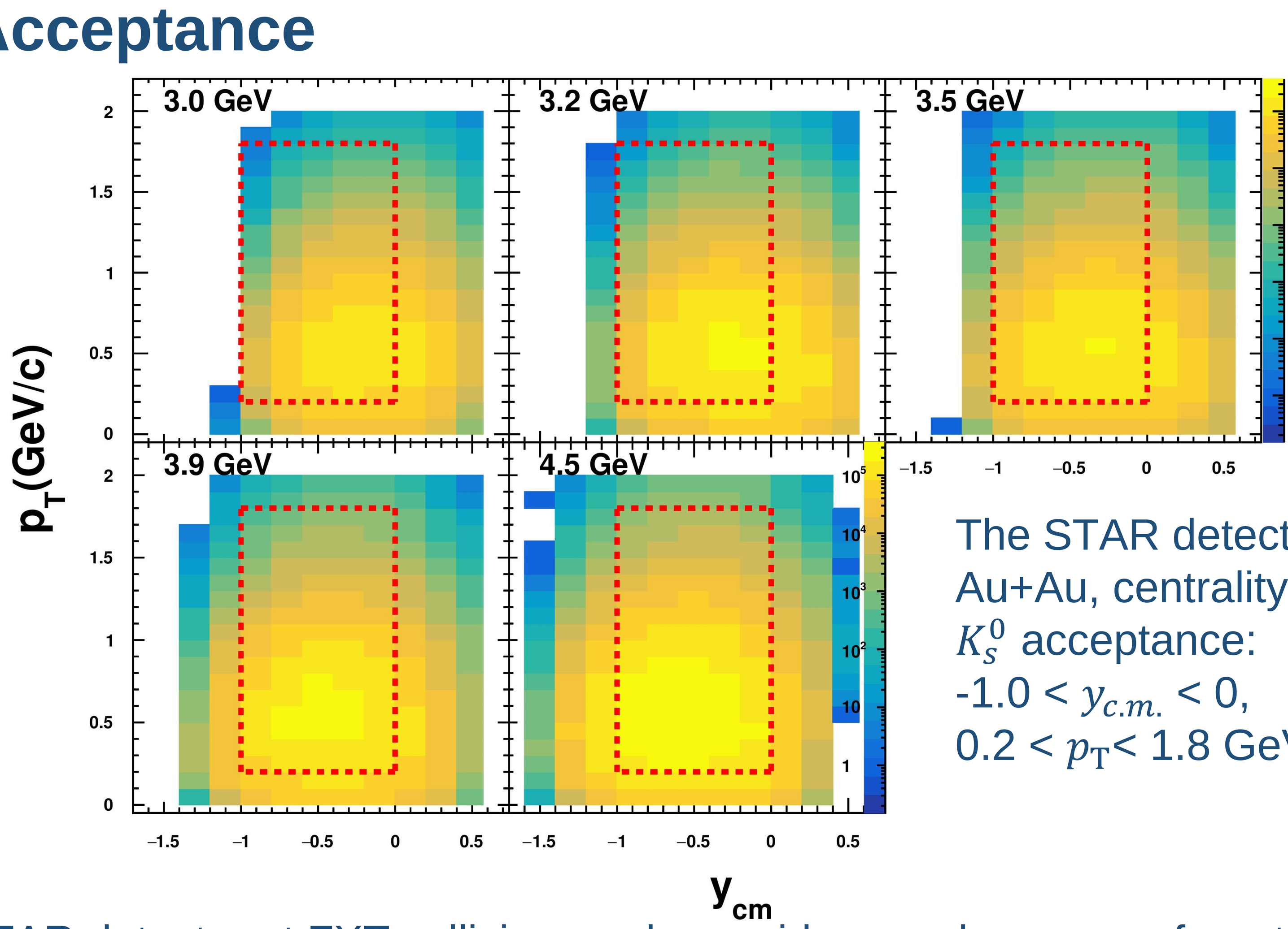
$K_s^0 \to \pi^+ + \pi^-$





- TPC (dE/dx) and TOF (β) are used for charged pion identification
- K_s^0 hadrons are reconstructed using invariant mass method
- KF Particle package [3] is used for the strange hadron reconstruction to improve the signal significance

K_s^0 Acceptance



The STAR detector
Au+Au, centrality 0-60%
K_s^0 acceptance:
$-1.0 < y_{c.m.} < 0$,
$0.2 < p_T < 1.8$ GeV/c

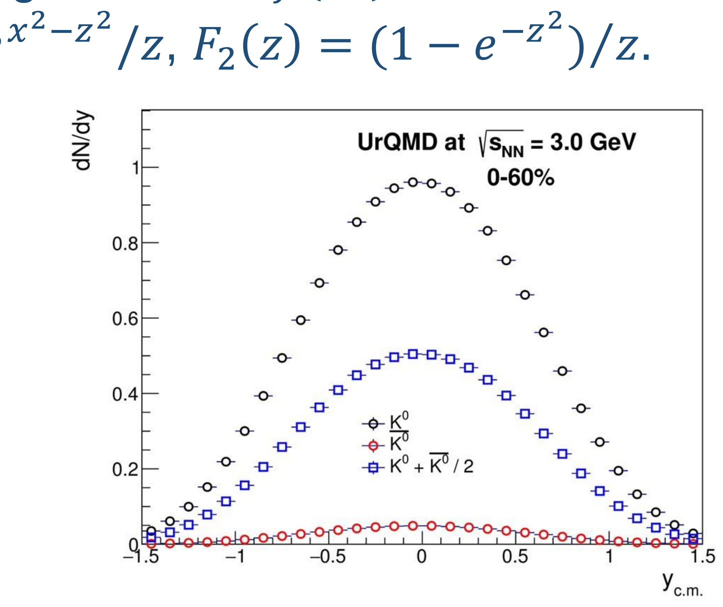
- STAR detector at FXT collision mode provides good coverage from target rapidity to mid-rapidity

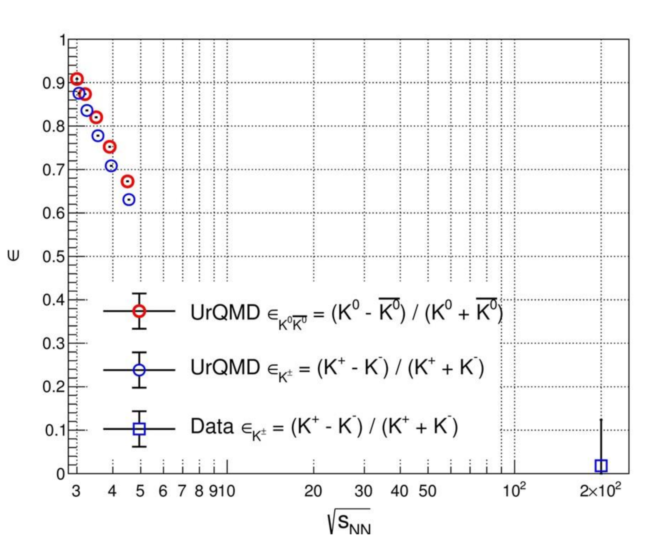
$K_s^0 - K_s^0$ correlation function

Correlation function can be described by Lednický-Lyuboshitz parameterization[1,4]

$$C_L(q_{inv}) = 1 + \lambda e^{-4q_{inv}^2R^2} + \lambda\alpha\left[\left|\frac{f(k^*)}{R}\right| + \frac{4Ref(k^*)}{\sqrt{\pi}R}F_1(q_{inv}R) - \frac{2Imf(k^*)}{R}F_2(q_{inv}R)\right]$$

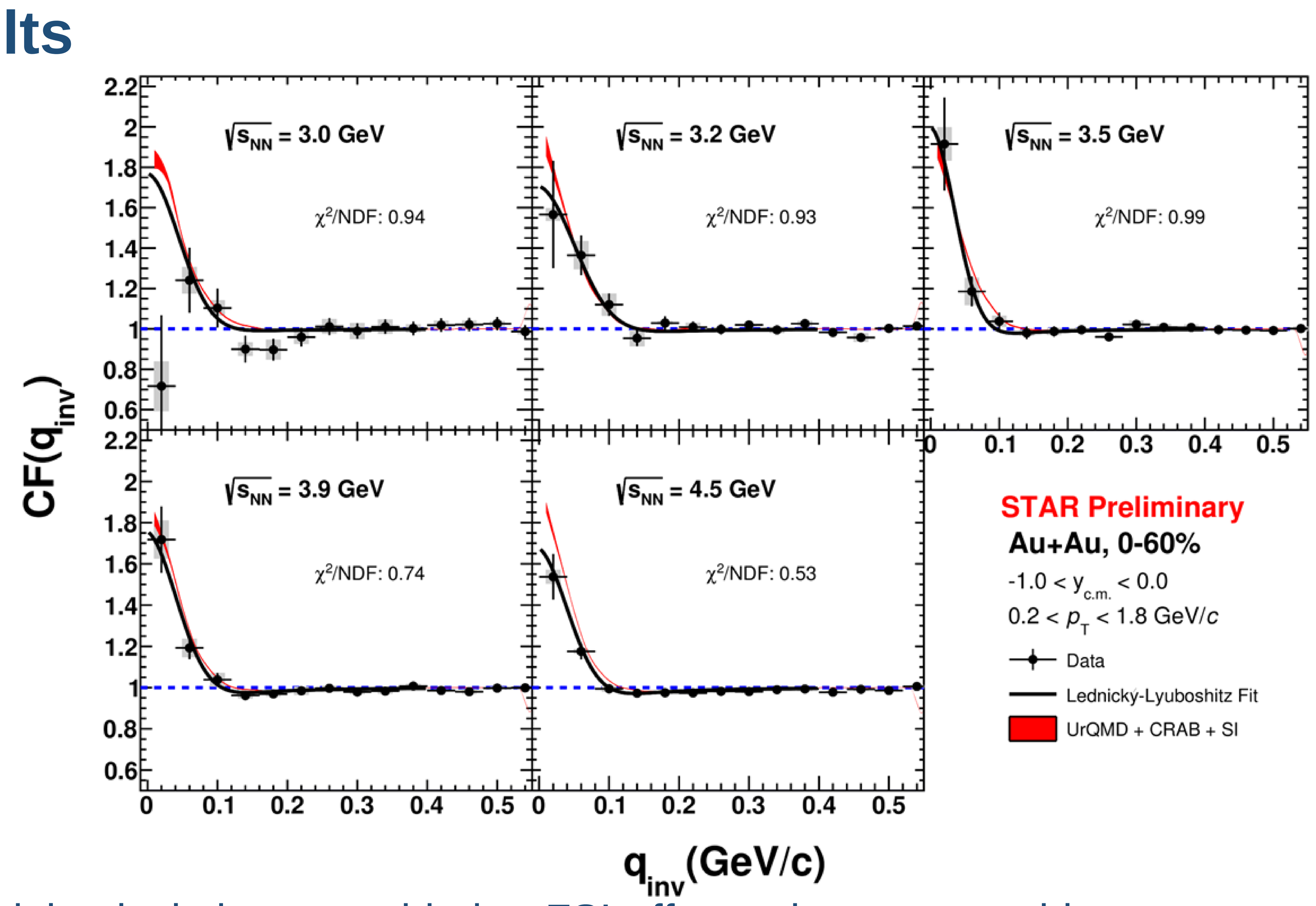
Where $\alpha = (1-\epsilon^2)/2$, and $\epsilon = (K^0 - \bar{K}^0)/(K^0 + \bar{K}^0)$ is the abundance asymmetry[1]. The asymmetry is 0.018±0.106 at $\sqrt{s_{NN}} = 200$ GeV[5], but higher at lower energies. The λ is the correlation strength, R is the size of the particle-emitting source. $f(k^*)$ is the s-wave $K^0\bar{K}^0$ scattering amplitude. $F_1(z) = \int_0^z dx e^{x^2-z^2}/z$, $F_2(z) = (1-e^{-z^2})/z$.





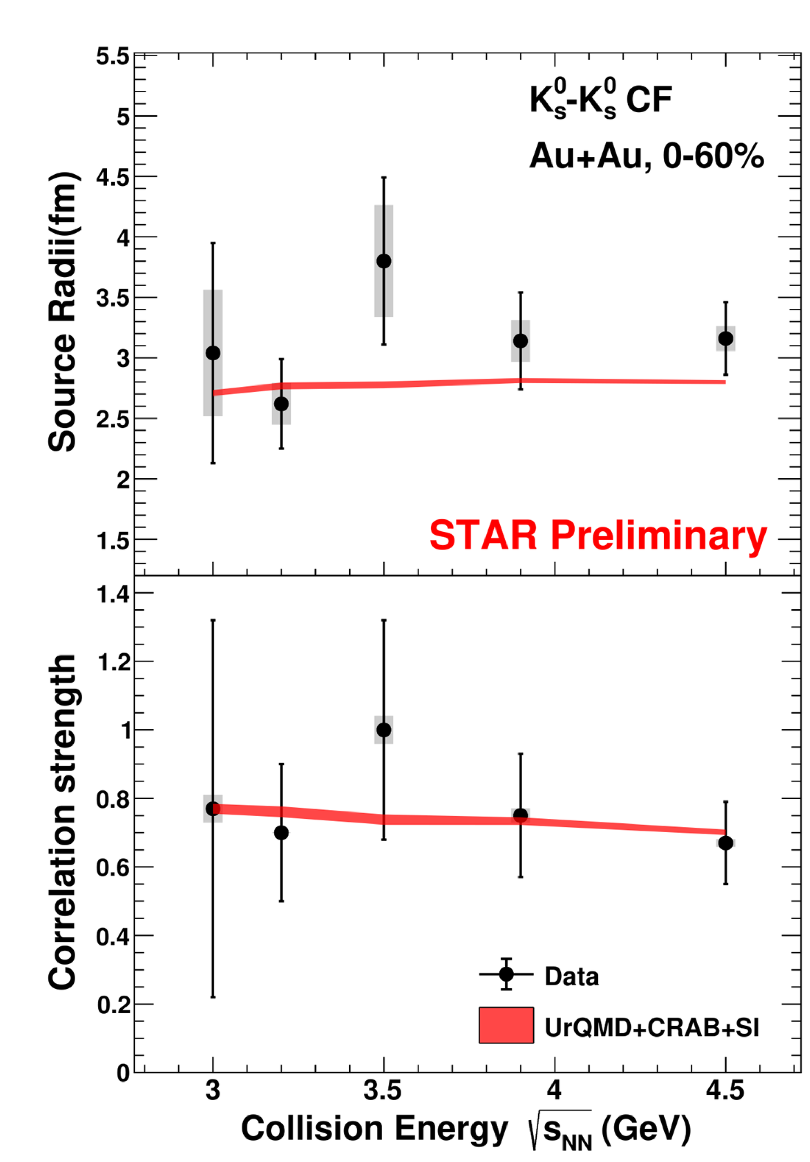
J. Adams et al. (STAR Collaboration), Phys. Rev. Lett. 92, 112301 (2004).

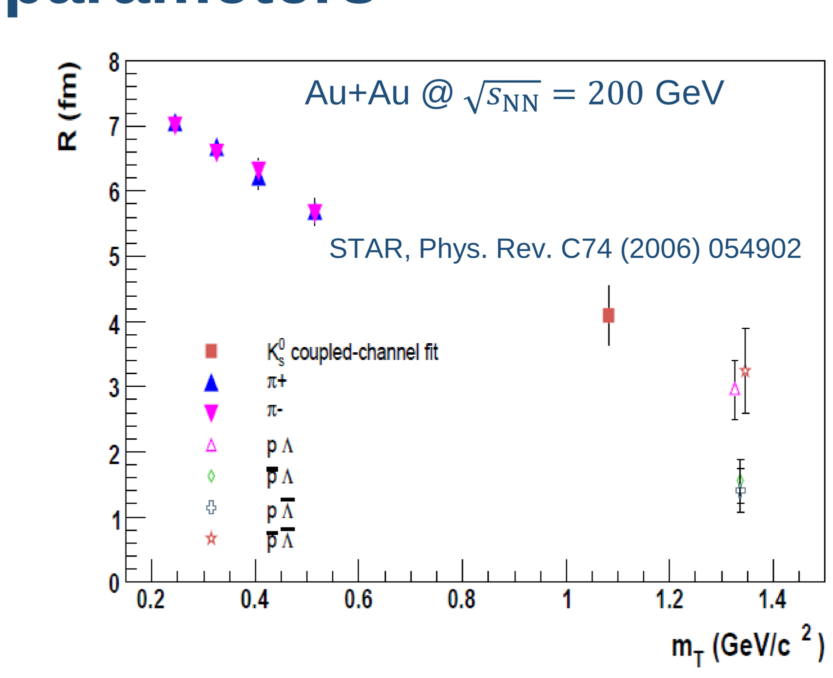
Results



- Model calculations considering FSI effects show reasonable agreement with the data
- Parameters of particle emission source are extracted by Lednický-Lyuboshitz model with $f_0(980)$ and $a_0(980)$ parameters from Antonelli[6].

Particle emission source parameters





- Extracted source size is close to the value in Au+Au at $\sqrt{s_{NN}} = 200$ GeV.
- No clear energy dependence was observed for both source radii and correlation strength.
- Particle emission source parameters can be described by UrQMD+CRAB[7] model calculations.

References:

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Supported in part by the
U.S. DEPARTMENT OF ENERGY Office of Science
NSFC
National Natural Science Foundation of China, and Fundamental Research Funds for the Central Universities

The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations