Final results of the centrality dependent Lévy HBT analysis

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Introduction

- PPG232 formed, i.e., final results are reached!
- Measuring 1D Bose-Einstein correlation function
- Data: PHENIX Run10 Au+Au @ 200 GeV
- Centrality bins: 0-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%
- Using 24 m_T bins (preliminary results used 18 m_T bins)
- Source parametrized via Lévy distribution
- Three physical parameter:
  - λ : intercept parameter
  - R : Lévy scale parameter
  - α : Lévy exponent
- Reached preliminary by the beginning of 2017
- Several major improvements since then
- Presented at several conferences, now writing the paper

Improvements

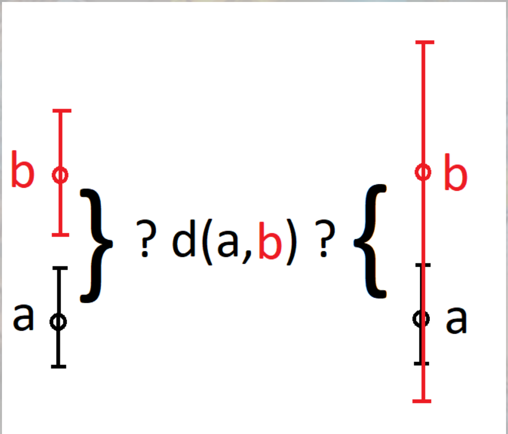
- Can resolve 24 m_T bins (preliminary: 18 m_T bins)
- More detailed analysis can be performed ($\lambda(m_T)$ could require that)
- Revised pair cuts, singletrack cuts, fit range dependencies
- Improved handling of the Coulomb correction
- Improved systematic uncertainties and their calculation
- More centrality dependence plots (previously, only have $\alpha(N_{\text{part}})$)

Improved Coulomb-correction – parametrization

- Using a parametrization of the Coulomb-correction
- (Thanks to Máté Csanád and Márton Nagy)
  - Based on the previously employed numerical table
  - No numerical fluctuation, do not need the iterative fitting method
  - Proven to be equivalent with the table but faster
- Method taken from following refs:
  - `https://arxiv.org/abs/1905.09714`
  - `https://arxiv.org/abs/1910.02231`

Improved calculation of the systematic uncertainties

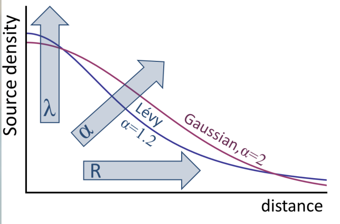
- Large statistical uncertainties with several cut settings
- PPG194 did not consider that
- Should not assign the same systematics for both case
- (Thanks to Wes Metzger, Máté Csanád and Márton Nagy)



Femtoscopy with Lévy source

- Three physical parameters: λ, R, α
- $\alpha = 1$ Cauchy, $\alpha = 2$ Gaussian

$$S(x,p) = \frac{1}{(2\pi)^3}\int d^3q e^{i\mathbf{qx}} e^{-\frac{1}{2}|\mathbf{x}R|^\alpha}$$



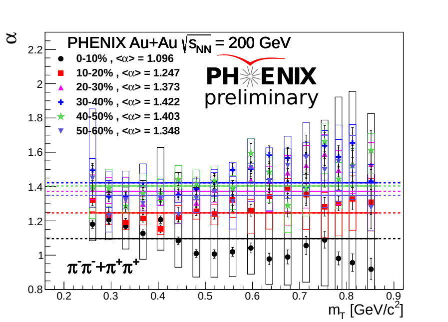
- C_2 with Lévy source:

$$C_2(Q) = 1 + \lambda \cdot e^{-(RQ)^\alpha}$$

- m_T dependence of the λ, R, α Lévy parameters and $\widehat{R} = \frac{R}{\lambda(1+\alpha)}$
- Also the cent. dep., i.e. N_{part} dependencies are interesting
- Cent. dep. of the fits of the $\alpha, \lambda/\lambda_{\text{max}}, 1/R^2, 1/\widehat{R}$

$\alpha(m_T)$ comparison

Preliminary

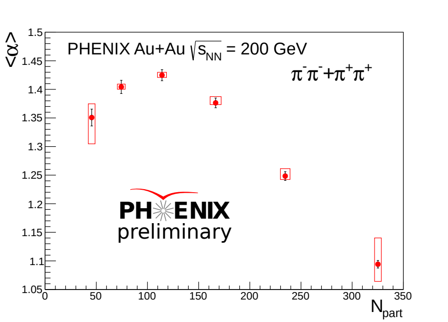


New

Confidential

$\langle\alpha\rangle(N_{\text{part}})$ comparison

Preliminary



New

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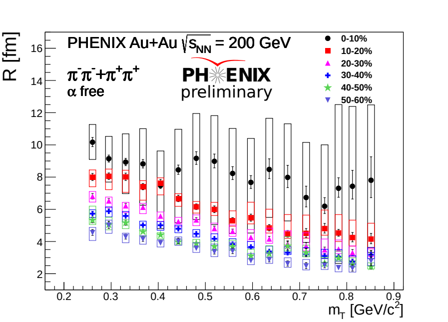
$R(m_T)$ comparison

Preliminary **New**



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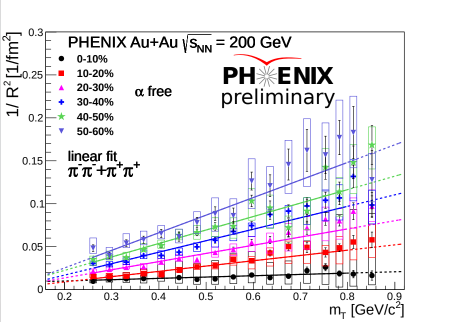
- Not the Gaussian size but very similar trends

$1/R^2(m_T)$ comparison

Preliminary

New



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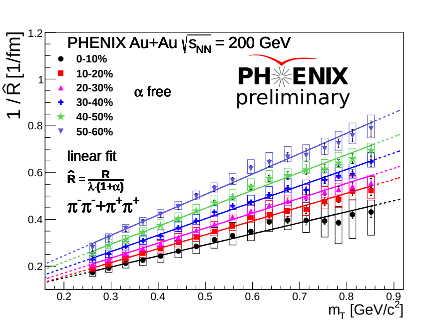
- Good linear behavior, similar to Gaussian

$1/\widehat{R}(m_T)$ comparison

Preliminary



New

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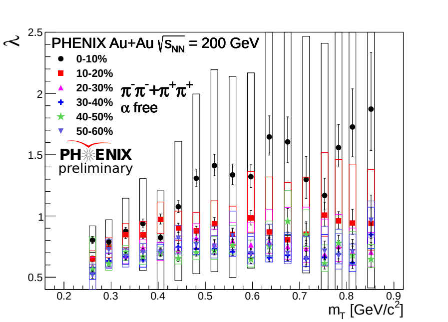
- Less linearity of $1/\widehat{R} = \lambda(1+\alpha)/R$ as before (restricted m_T range!)
- Probably because of the saturation of the $\lambda(m_T)$

$\lambda(m_T)$ comparison

Preliminary



New

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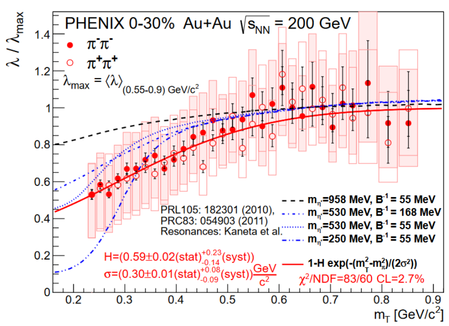
Comparison to resonance models

- Work of Gábor Kasza and Tamás Csörgő (considered models: Kaneta-Xu, THERMUS, SHARE)
- Fit resonance models to the λ/λ_{max} data
- Yield the best m_{η^*} modified η' meson mass and the B^{-1}
- Systematic checks of the CL maps to determine the significance



Summary

- Improved CC, systematics and revised cut settings
- Finalized version of the preliminary results
- New N_{part} plots of the parameters
- PPG232 formed!
- Comparison to simulation may be included

Thank you for your attention!

Backups

Improved calculation of the systematic uncertainties

- Assume two variable: a and b. The variance of the sum/difference:

$$\sigma^2(a \pm b) = \sigma^2(a) + \sigma^2(b) \pm 2\mathrm{cov}(a, b)$$

- Where $\mathrm{cov}(a, b) = \rho\sigma(a)\sigma(b)$ is the covariance matrix
- The total uncertainties has two source: statistical and systematical:

$$\sigma^2_{\mathrm{total}} = \sigma^2_{\mathrm{stat}} + \sigma^2_{\mathrm{syst}}$$

- The $\sigma^2_{\mathrm{total}}$ covers 1 standard deviation of difference in the results, i.e.:

$$(a - b)^2 = \sigma^2(a) + \sigma^2(b) - 2\rho \cdot \sigma(a)\sigma(b) + \sigma^2_{\mathrm{syst}}$$

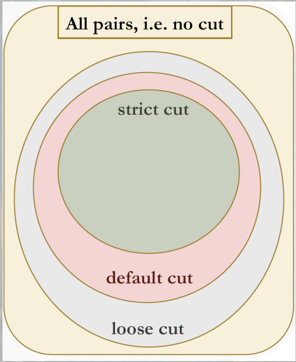
- So the systematic uncertainties can be expressed as

$$\sigma^2_{\mathrm{syst}} = (a - b)^2 - \boldsymbol{\sigma^2(a) - \sigma^2(b) + 2\rho \cdot \sigma(a)\sigma(b)}$$

- The highlighted part is the new in the estimation
- It is not a large effect, but reduce the systematics
- What about the ρ correlation coefficient?

Improved calculation of the systematic uncertainties

- Safe side: $\rho = 1$, but ρ can be estimated also
- Two different case can be identified:
  - When the default cut has **more** pairs, the cutted set: strict cut
  - When the default cut has **less** pairs, the cutted set: loose cut
- According to this difference, we have two definition for the ρ:
  - Strict cut: $\rho = \sqrt{\frac{N_{\text{strict cut}}}{N_{\text{default cut}}}}$
  - Loose cut: $\rho = \sqrt{\frac{N_{\text{default cut}}}{N_{\text{loose cut}}}}$
- $\rho > 0$ in every case!



The derivation of the ρ – example on arm choice

Statistically, there is no correlation between East and West arm at PHENIX, so

$$N_{def} = N_W + N_E \quad \text{so the std.dev. for East:} \quad \sigma(E) = \sqrt{N_E}$$

$$V(N_E + N_W) = V(N_E) + V(N_W) + 2cov(N_E, N_W) \text{ where}$$

$$2cov(N_E, N_W) = V(N_E, N_W) - V(N_E) - V(N_W) = N_E + N_W - N_E - N_W = 0$$

Because of the statistical independence.
Let's see the covariance of the $N_{\text{def}} = N_E + N_W$ and N_W:

$$V(N_E) = V(N_E + N_W - N_W) = V(N_E + N_W) + V(N_W) - 2cov(N_E + N_W, N_W) \text{ so}$$

$$2cov(N_E + N_W, N_W) = N_E + N_W + N_W - N_E = 2N_W$$

This goes for the N_E as well. So, from the definition of the ρ

$$\rho = \frac{V(E, W)}{\sqrt{N_E N_W}} = \sqrt{\frac{N_W}{N_E + N_W}}$$