Three particle Levy HBT from PHENIX

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The PHENIX experiment

- Different collision energies

  7.7-200 GeV in $\sqrt{s_{\mathrm{NN}}}$
  20-400 MeV in μ_{B}

- Different collision systems

  p+p, p+A, A+A

- This analysis: 200 GeV Au+Au

  0-30% Centrality
  pion triplets

$\sqrt{s_{NN}}$ [GeV]		Al	Au	Au	Au	Cu Cu	Cu Au	Au Au	U U
510	✓								
200	✓	✓	✓	✓	✓	✓	✓	✓	✓
130								✓	
62.4	✓			✓		✓		✓	
39				✓				✓	
27								✓	
20				✓		✓		✓	
14.5								✓	
7.7								✓	

Three particle correlation functions

- Correlation function:

$$C_3(\mathbf{k_1},\mathbf{k_2},\mathbf{k_3}) = \frac{N_3(\mathbf{k_1},\mathbf{k_2},\mathbf{k_3})}{N_1(\mathbf{k_1})N_1(\mathbf{k_2})N_1(\mathbf{k_3})}$$

- Single particle momentum distribution:

$$N_1(\mathbf{k}) = \int S(\mathbf{k},\mathbf{r})|\Psi_{\mathbf{k}}(r)|^2 \mathrm{d}^4 r$$

- Three particle momentum distribution:

$$N_3(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3) = \int |\Psi_{\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3}(\mathbf{r}_1,\mathbf{r}_2,\mathbf{r}_3)|^2 \prod_{i=0}^{3} S(\mathbf{k}_i,\mathbf{r}_i)\mathrm{d}^4\mathbf{r}_i$$

Levy-type source assumption

Assumption for source function → Levy-type source

$$S(\mathbf{r}) = \mathcal{L}(\alpha, R, \mathbf{r}) = \frac{1}{(2\pi)^3} \int \mathrm{d}^3 q e^{i\mathbf{q}\mathbf{r}} e^{-\frac{1}{2}|qR|^\alpha}$$

- Levy-exponent: α (Gaussian $\alpha = 2$, Cauchy $\alpha = 1$)
- Levy-scale parameter: R

The correlation function (without final Coulomb-interaction):

$$C_3^{(0)}(q_{12}, q_{13}, q_{23}) = 1 + \ell_3 e^{-0.5(|q_{12}R|^\alpha + |q_{13}R|^\alpha + |q_{23}R|^\alpha)} + \ell_2 \left(e^{|q_{12}R|^\alpha} + e^{|q_{13}R|^\alpha} + e^{|q_{23}R|^\alpha} \right)$$

Parameters:

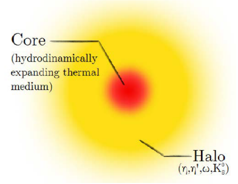
- Already known from two particle measurements: α, R
  A. Adare et al. Phys. Rev. C 97, 064911 (2018) arXiv:1709.05649
- Now measured: ℓ_2, ℓ_3

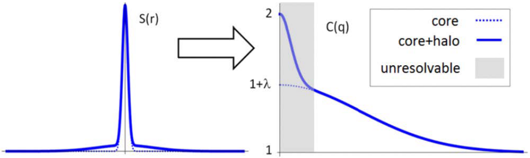
We are looking for three-particle correlation strength: λ_3

$$\lambda_3 = C_3(q_{12} = q_{13} = q_{23} \to 0) - 1 = \ell_3 + 3\ell_2$$

Core-Halo model

- Two component source: $S = S_c + S_h$
  T. Csörgő, B. Lörstad, J. Zimányi, Z. Phys. C71 , 491 (1996), arXiv:9411307
  - Core: thermalized medium, expanding source
  - Halo: long lived resonances ($\tau > 10$ fm$/c$)$\rightarrow$ experimentally unresolvable
- Fraction of core: $f_c = N_{core}/(N_{core} + N_{halo})$
- Two particle correlation strength: $\lambda_2 = f_c^2$
- Three particle correlation strength: $\lambda_3 = 2f_c^3 + 3f_c^2$
- Core-Halo independent parameter: $\kappa_3 = 0.5(\lambda_3 - 3\lambda_2)/\lambda_2^{3/2} = 1$





Partial coherence

- If there are pions emitted coherently:

$$S_c = S_c^{coherent} + S_c^{incoherent}$$

- Fraction of pions emitted coherently:

$$p_c = N_{coherent}/(N_{coherent} + N_{incoherent})$$

- Partial coherence + Core-Halo:

  T. Csörgő et al. Eur. Phys. J. C9 275-281 (1999) arXiv:9812422

$$\lambda_2 = f_c^2 \left[(1 - p_c)^2 + 2p_c(1 - p_c)\right]$$
$$\lambda_3 = 2f_c^3 \left[(1 - p_c)^3 + 3p_c(1 - p_c)^2\right] + 3f_c^2 \left[(1 - p_c)^2 + 2p_c(1 - p_c)\right]$$

Analysis details

- 200 GeV Au+Au collisions
- 29 m_T bins
- Correlation functions of identified, same charged pion triplets
- Cuts:
  - Event selection: z-vertex, 0-30% Centrality
  - Particle selection: 2σ cuts for PID
  - Single track cuts: 2σ matching
  - Pair cuts: customary shaped cuts for Δz - $\Delta\varphi$ distributions

Fit function

Fit function:

$$C_3^{(fit)} = N(1+\varepsilon q_{12})(1+\varepsilon q_{13})(1+\varepsilon q_{23})K_3 C_3^{(0)}$$

Background and normalisation: ε, N
Coulomb-correction:

- Generalized Riverside method:

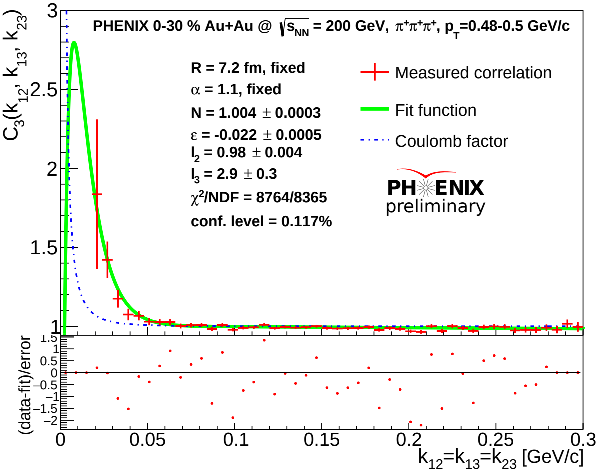
$$K_3(q_{12}, q_{13}, q_{23}) \approx K_1(q_{12})K_1(q_{13})K_1(q_{23})$$

- Detailed numerical table for $K_1(q, \alpha, R)$

Fit parameters: ℓ_2, ℓ_3, N, ε
Already known from 2-particle correlations: α, R

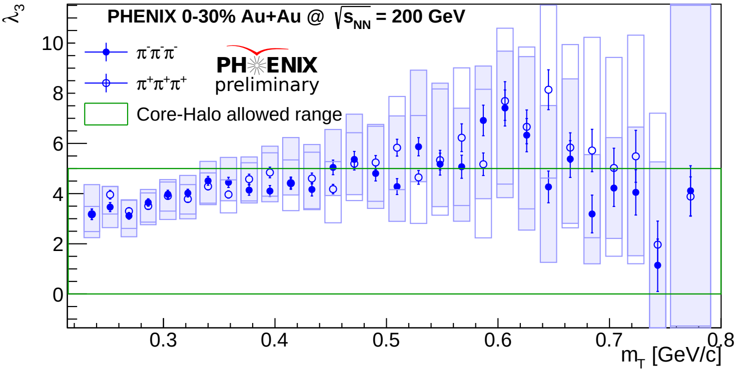
Example fit

- Diagonal visulaization of 3D correlation function



Three particle correlation strength

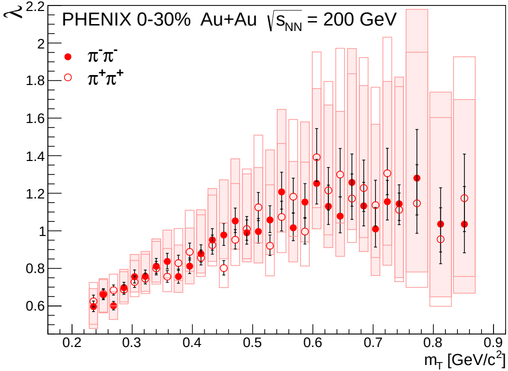
- From Core-Halo model: $0 < \lambda_3 < 5$



Two particle correlation strength from previous analysis

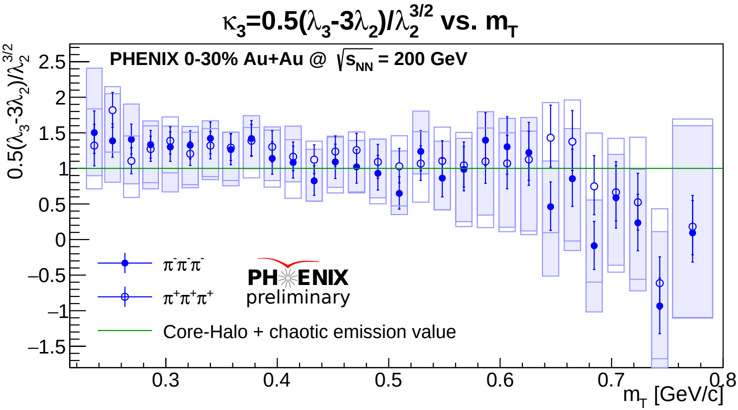
- λ_2 is from previous PHENIX measurement

  A. Adare et al. Phys. Rev. C 97, 064911 (2018) arXiv:1709.05649
- Let us compare 2- and 3-particle correlations

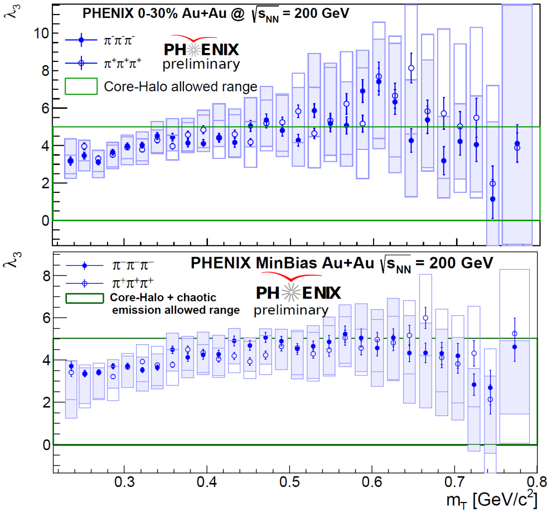


Core-Halo independent parameter

- Independent from f_c
- Expectation: $\kappa_3 = 1$

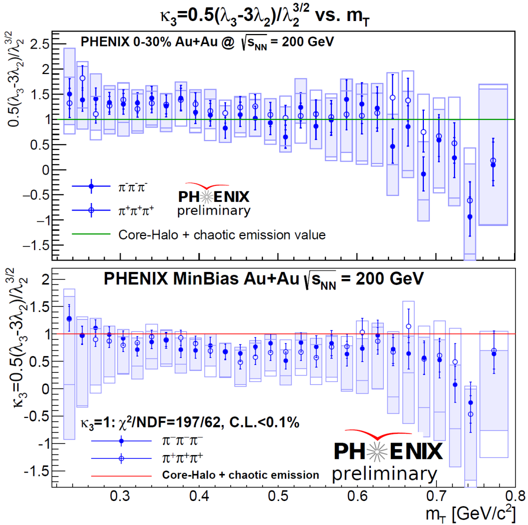


MinBias vs 0-30% Centrality: λ_3



- 0-30% Centrality
- Density & size dependence
- Similar to MinBias
- Within Core-Halo range

MinBias vs 0-30% Centrality: κ_3

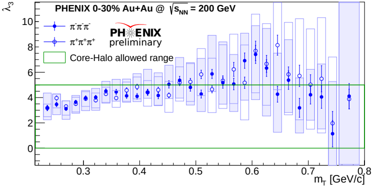


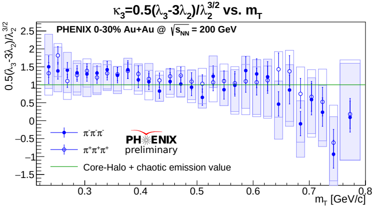
- 0-30% Centrality
- Density & size dependence
- Similar to MinBias
- 0-30% compatible with 1

Summary

The results of this work:

- Three particle B-E correlation function for 200 GeV Au+Au
- 0-30% Centrality
- Described by Levy fits (α and R from 2-particle correlations)
- κ_3 consistent with 1
- $0 < \lambda_3 < 5$ within errors





Thank you for your attention!

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