Collision energy dependent Levy analysis of HBT correlation functions in Au+Au collisions at PHENIX

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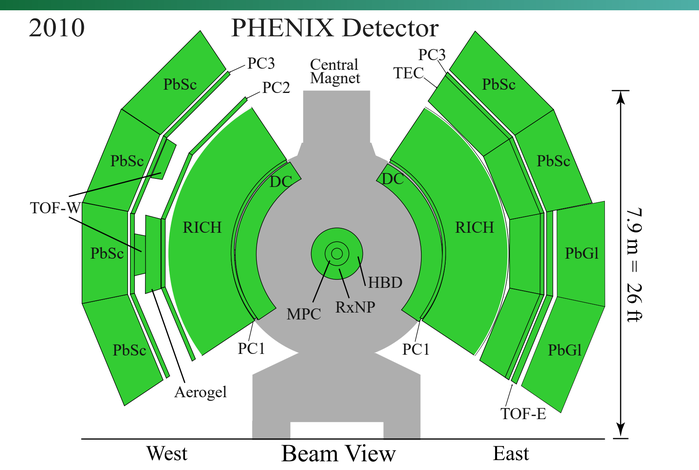
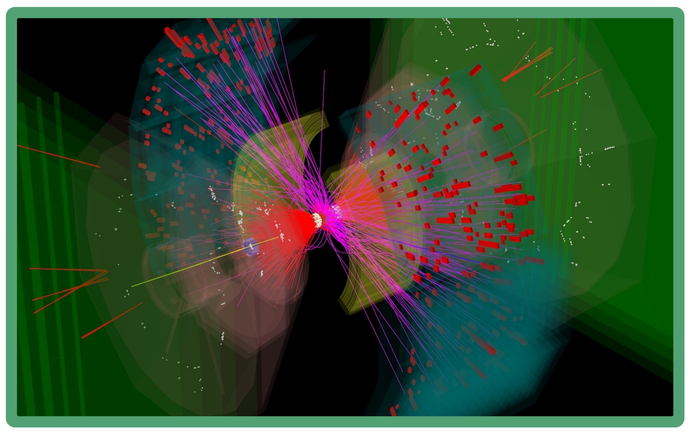
The PHENIX experiment at RHIC





- Au+Au BES: 200, 62, 39, 27, 19, 15 GeV

Introduction to Bose-Einstein correlations

- $N_1(p), N_2(p)$ - invariant momentum distributions, the definition of the correlation function:

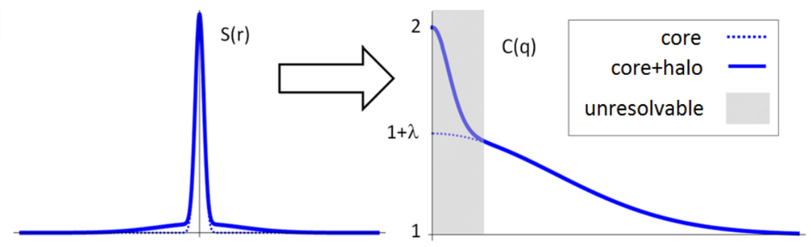
$$C_2(p_1,p_2) = \frac{N_2(p_1,p_2)}{N_1(p_1)N_1(p_2)}, \text{ where } N_2(p_1,p_2) = \int S(x_1,p_1)S(x_2,p_2)|\Psi_2(x_1,x_2)|^2 d^4x_2 d^4x_1 \quad (1)$$

- $S(x,p)$ source function (usually assumed to be Gaussian - Levy is more general)
- Ψ_2 two-particle wave function - interaction free case: $|\Psi_2|^2 = 1+\cos(qx)$
- If $k_1 \simeq k_2$: $C_2 \rightarrow$ inverse Fourier-trf. $\rightarrow S$

$$C_2(q,K) \simeq 1 + \left|\frac{\widetilde{S}(q,K)}{\widetilde{S}(0,K)}\right|^2, \ \widetilde{S}(q,k) = \int S(x,k)e^{iqx}d^4x \qquad K=(k_1+k_2)/2, \quad x = x_1 - x_2, \ q = k_1 - k_2$$

Final state interactions, resonances

- Identical charged pions - Coulomb interaction distort the simple picture
  - different methods of handling, e.g. Coulomb-correction: $C_{B\text{-}E}(q) = K(q)\cdot C_{\text{meas.}}(q)$
- Resonance pions reduce the corr. strength [1, 2]
- Core-Halo model: $S = S_C + S_H$
- Primordial pions - Core $\lesssim 10$ fm
- Resonance pions - from very far regions - Halo
- Corr. strength→C-H ratio: $\lambda = \left(\frac{N_C}{N_C+N_H}\right)^2$



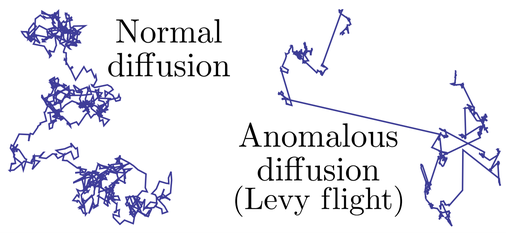
The Levy distribution as source function

- In expanding hadron resonance gas, mean free path increases with time → Levy flight
- Anomalous diffusion, generalized centr. limit th. → Levy-distribution

$$\mathcal{L}(\alpha,R,r) = \frac{1}{(2\pi)^3}\int d^3q e^{iqr} e^{-\frac{1}{2}|qR|^\alpha} \quad \begin{cases} \alpha = 2 : \text{Gaussian} \\ \alpha = 1 : \text{Cauchy} \end{cases}$$

- Shape of the correlation func. with Levy source [3]:

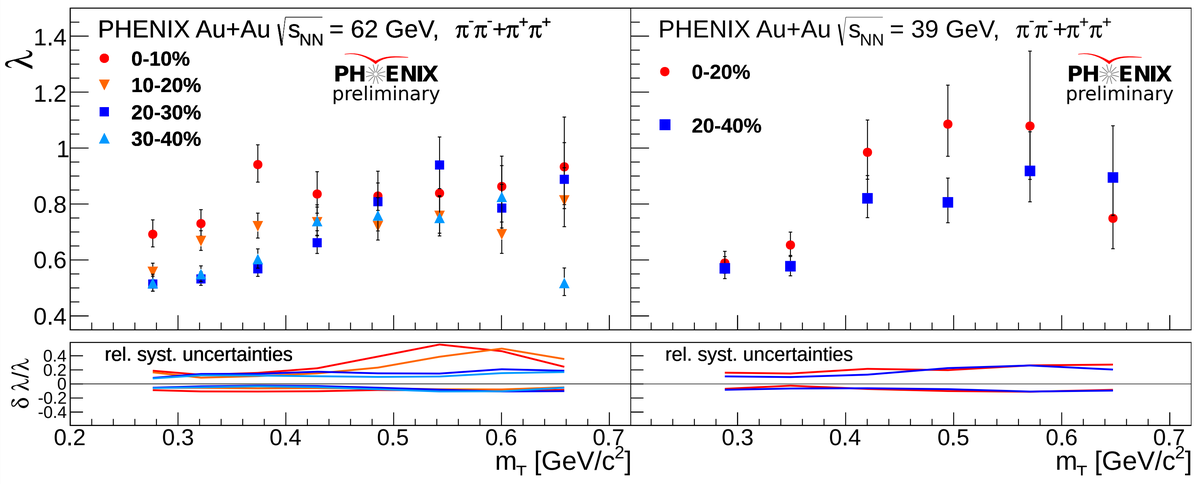
$$C_2(|k|) = 1 + \lambda \cdot e^{-(2R|k|)^\alpha}$$



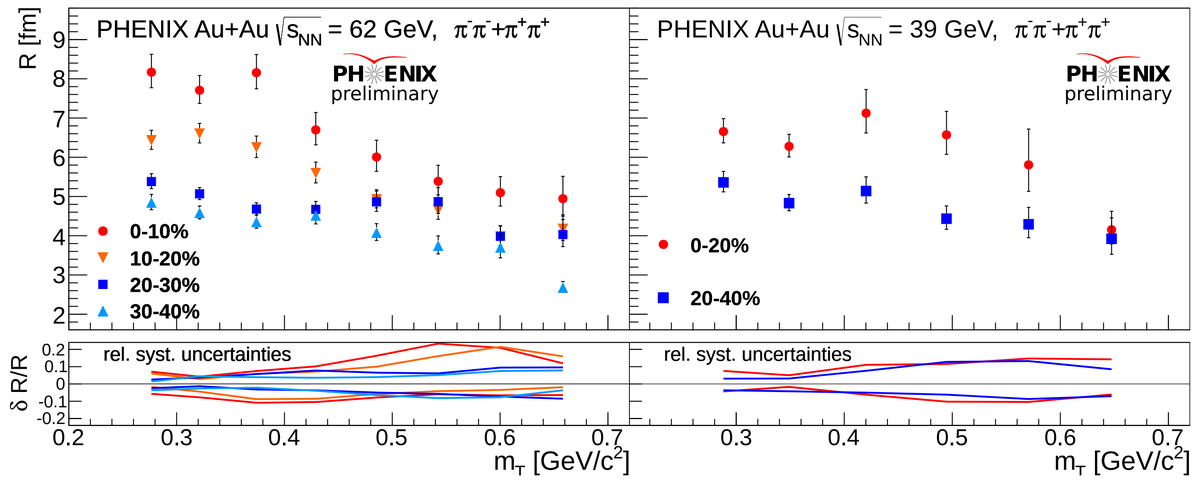
Critical behavior

- Crit. behavior→ described by crit. exponents
- At CEP in 3 dim.$\langle\Psi(0)\Psi(r)\rangle \propto r^{-1-\eta}$
- Levy distr. $\rightarrow$ spatial corr. $\propto r^{-1-\alpha}$ $\Big\}\alpha \equiv \eta$
- QCD universality class ↔ 3D Ising [4]
- $\eta(\text{CEP}) = 0.03631(3)$ from 3D Ising [5]
- $\eta(\text{CEP}) = 0.5 \pm 0.05$ from rfd.3D Ising [6]

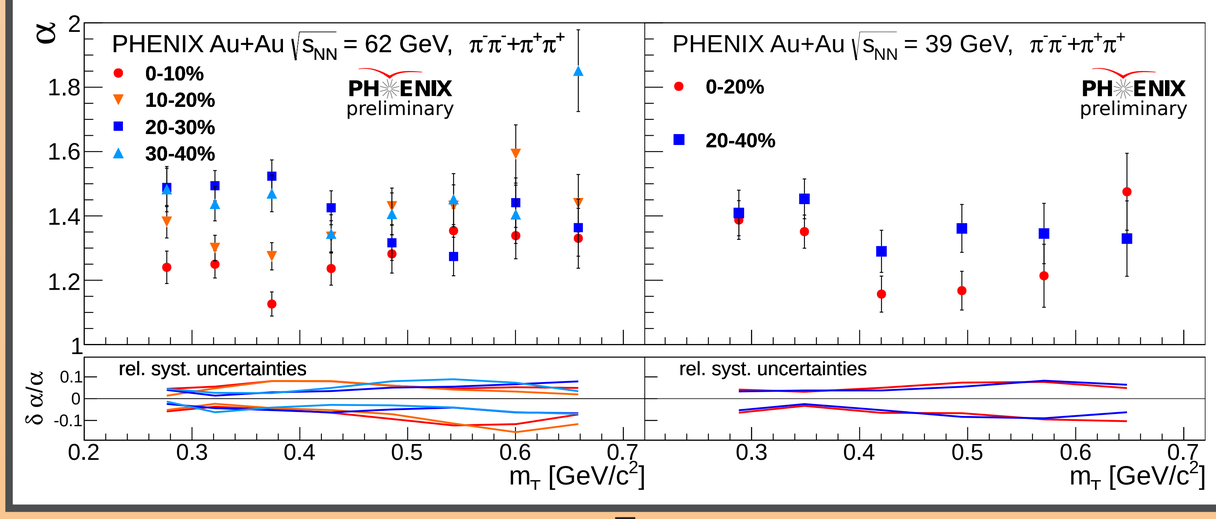
Low m_T supression in correlation strength λ



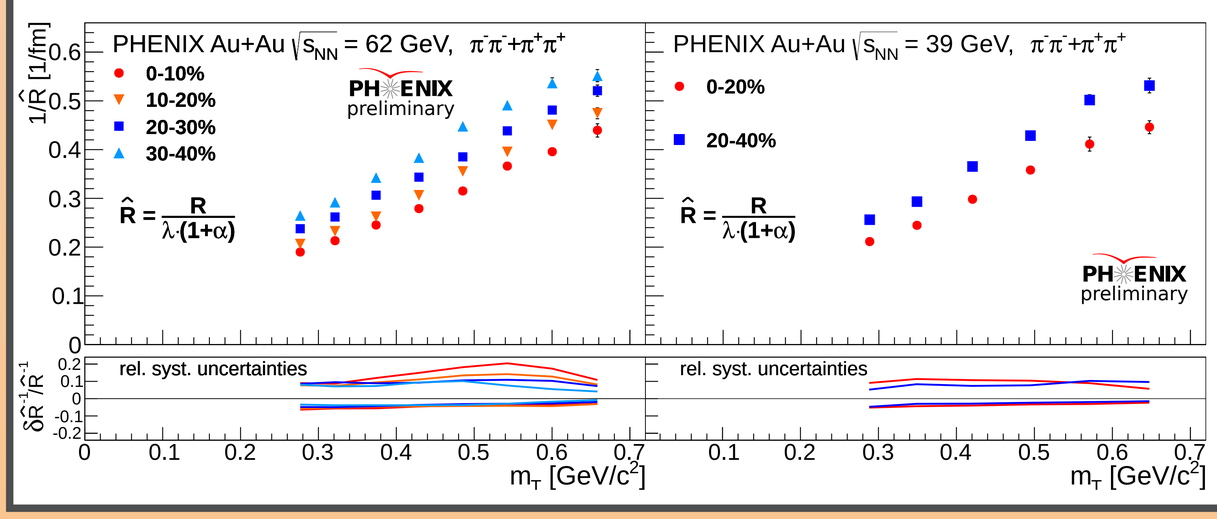
Decreasing trend, geom. cent. dep. of Levy scale R



Levy exponent $\alpha > 0.5$(CEP limit) and < 2(hydro limit)



Newly found scaling parameter $1/\widehat{R}$ linear in m_T



Summary

- Bose-Einstein corr. with Levy source
  - Good agreement with data
  - Levy exponent $\alpha \equiv$ crit. exp. η
  - α vs. $\sqrt{s_{\text{NN}}}$ ↔ proximity of CEP
  - Motivation for coll. energy dep. meas.
- Preliminary Levy HBT results
  - Magnitude of Levy scale is similar at 62 & 39 GeV
  - Levy exponent α is far from hydro limit (2)
  - Levy exponent α is far from CEP limit (0.5)
  - Increase of halo fraction is present at small m_T
  - Scaling of $\widehat{R}$ as $1/m_T$ is valid at 62 & 39 GeV

This research was supported by the funding agencies listed in ref. [7].
In addition, D. K. was supported by the ÚNKP-16-2 New National Excellence program of the Hungarian Ministry of Human Capacities.

References

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