PHENIX results on centrality dependent Levy HBT analysis of Bose-Einstein correlations

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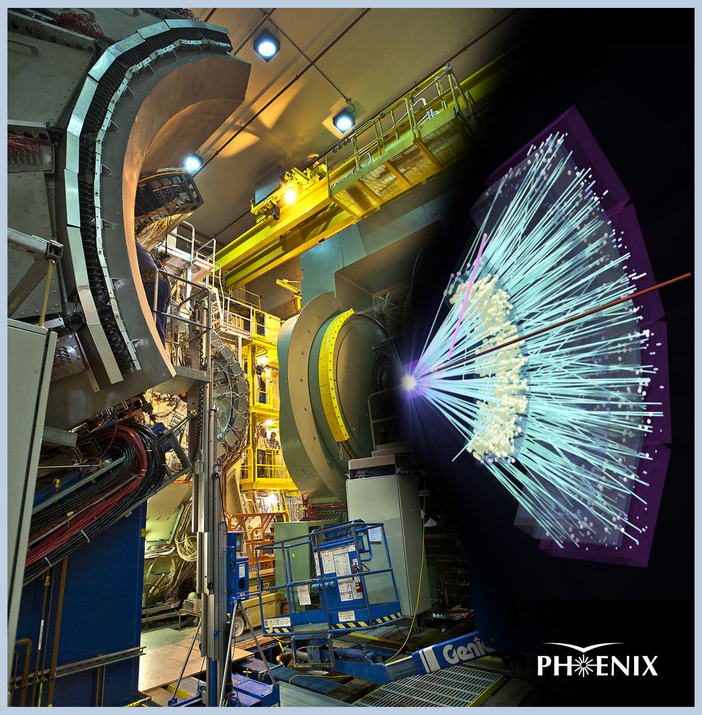
The PHENIX experiment



- Observing collision of p, d, Cu, Au, Al, He, U
- Detect pion from $p_t \sim 0.2$ to 2 GeV/c

Measurement details:

- Used dataset: Au+Au 200 GeV
- PID cuts: $2-\sigma$ for π, 2.5σ veto for K and p
- Double track rejection cut
- Detail QA of TOF detector applied

Bose-Einstein correlation function with Coulomb-effect

- Particle-emitting thermal source: $S(x,p)$, usually assumed to be Gaussian – Levy is more general
- Define the correlation function with invariant momentum distribution: $N_1(p)$:

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

- where Ψ_2 is the two particle wave function. Let $q = p_1 - p_2$, $K = (p_1+p_2)/2$. If $p_1 \approx p_2$

$$C_2(q,K) \approx 1 + \frac{|\tilde{S}(q,K)|^2}{|\tilde{S}(0,K)|^2} \text{ where } \tilde{S}(q,k) = \int S(x,k)e^{iqx}d^4x$$

- Identical charged pions $\rightarrow$ Coulomb repulsion in the final states
- Coulomb-correction needed: $C_{BE} = K(q)C_m(q)$.
- Resonance pions reduce the correlation strength [1, 2]
- Core-halo model: $S = S_{\text{core}} + S_{\text{halo}}$ primordial pions from core < 10 fm, resonance pions from halo

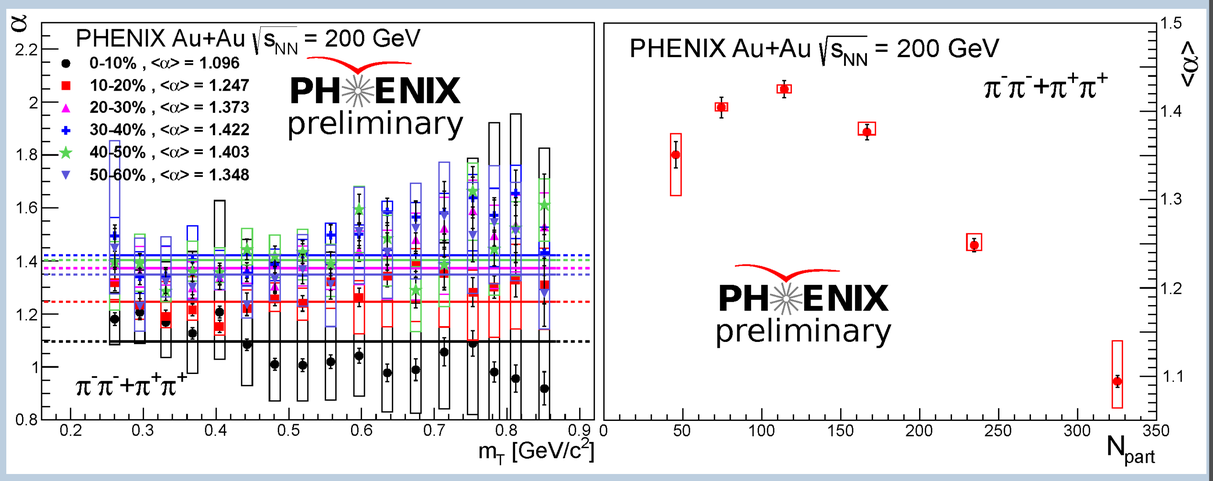
The Levy-distribution and the critical point

- Generalized Gaussian – Levy-distribution

$$\left.\begin{array}{l}\text{–Anomalous diffusion}\\ \text{–Generalized central limit th.}\end{array}\right\} \mathcal{L}(\alpha,R,\mathbf{r}) = \frac{1}{(2\pi)^3}\int d^3q e^{i\mathbf{qr}} e^{-\frac{1}{2}|\mathbf{q}R|^\alpha} \left\{\begin{array}{l}\alpha = 2: \text{ Gaussian}\\ \alpha = 1: \text{ Exponential}\end{array}\right.$$

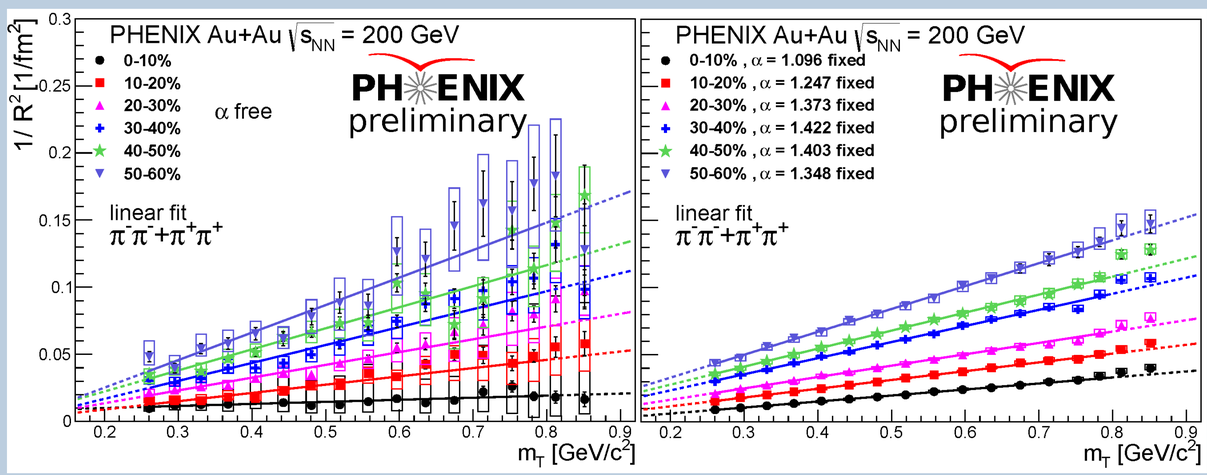
- The shape of the correlation function with Levy source[3]: $C_2(\mathbf{k}) = 1 + \lambda e^{-2|\mathbf{k}R|^\alpha}$
- η crit. exp. from spat. corr. $\sim r^{-1-\eta}$ in 3D & symm. stable Levy-distr. $\sim r^{-1-\alpha} \Rightarrow \alpha \equiv \eta$
- QCD universality class $\Leftrightarrow$ 3D Ising-model [4, 5]

$\langle\alpha\rangle(N_{part})$: non-monotonic behaviour



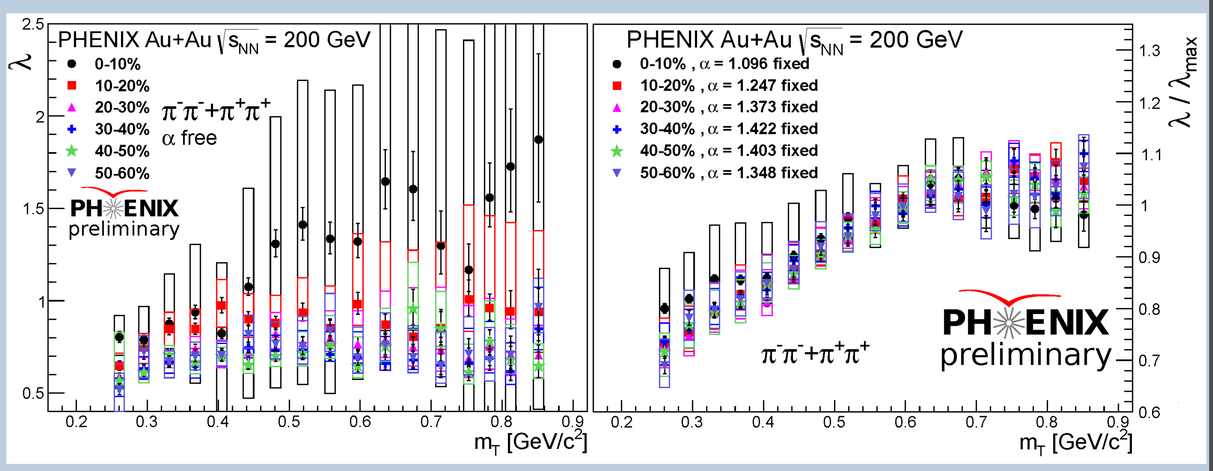
- $\langle\alpha\rangle(N_{part}) \neq const. \rightarrow$ the Levy shape depends on the centrality
- $\alpha(m_T)$ slightly non-monotonic: shown are const. fits over the m_T range

$1/R^2$: known hydro m_T scaling behaviour



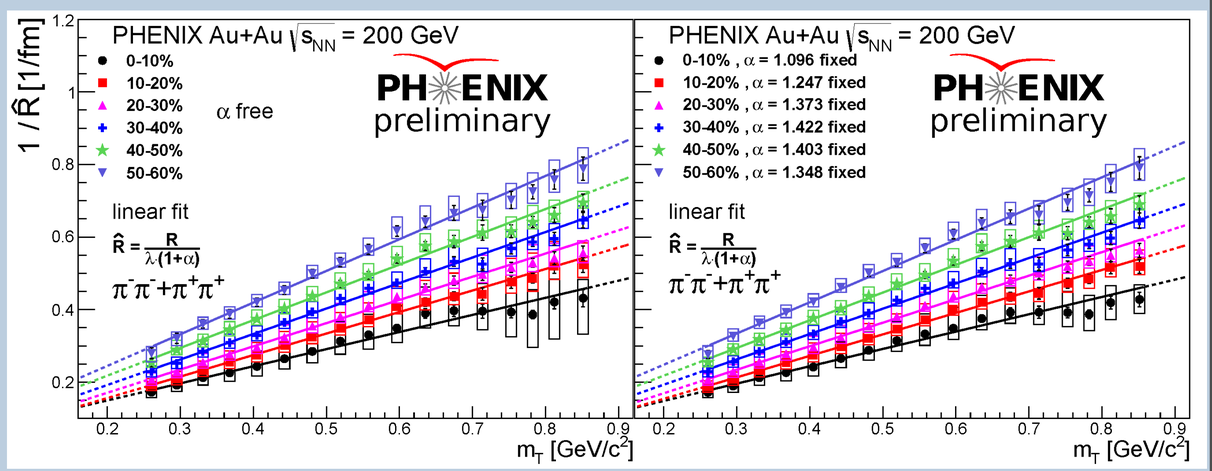
- Linear scaling not clear for high-m_T in free α case
- Linear scaling is better seen for fix α case

λ: low-m_T decrease in all centrality bins



- Corr-strength can be associated C-H ratio: $\lambda = [N_c/(N_c+N_h)]^2$
- Low-m_T suppression $\rightarrow$ larger halo $\rightarrow \eta'$ mass modification? [6]

$\hat{R}$: new scaling variable



- Empirically found, linear in m_T
- Physically not interpreted yet

Summary

- Levy-source fit of Bose-Einstein corr. works well in all centrality dependent case
- Levy-index $\alpha = \alpha(N_{\text{part}})$ depends on centrality
- α has weak dependence on $m_T \rightarrow \alpha = \langle\alpha\rangle$ fits
- Far from the Gaussian-case ($\alpha = 2$) and from the critical value ($\alpha = 0.5$): $0.9 < \alpha < 1.7$
- Low-m_T λ decrease is present in all centrality $\rightarrow$ possible η' mass-modification
- $1/\hat{R}$ new scaling variable, interpretation is not clear yet
- $1/\hat{R}$ is not sensitive to α fixation

References

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