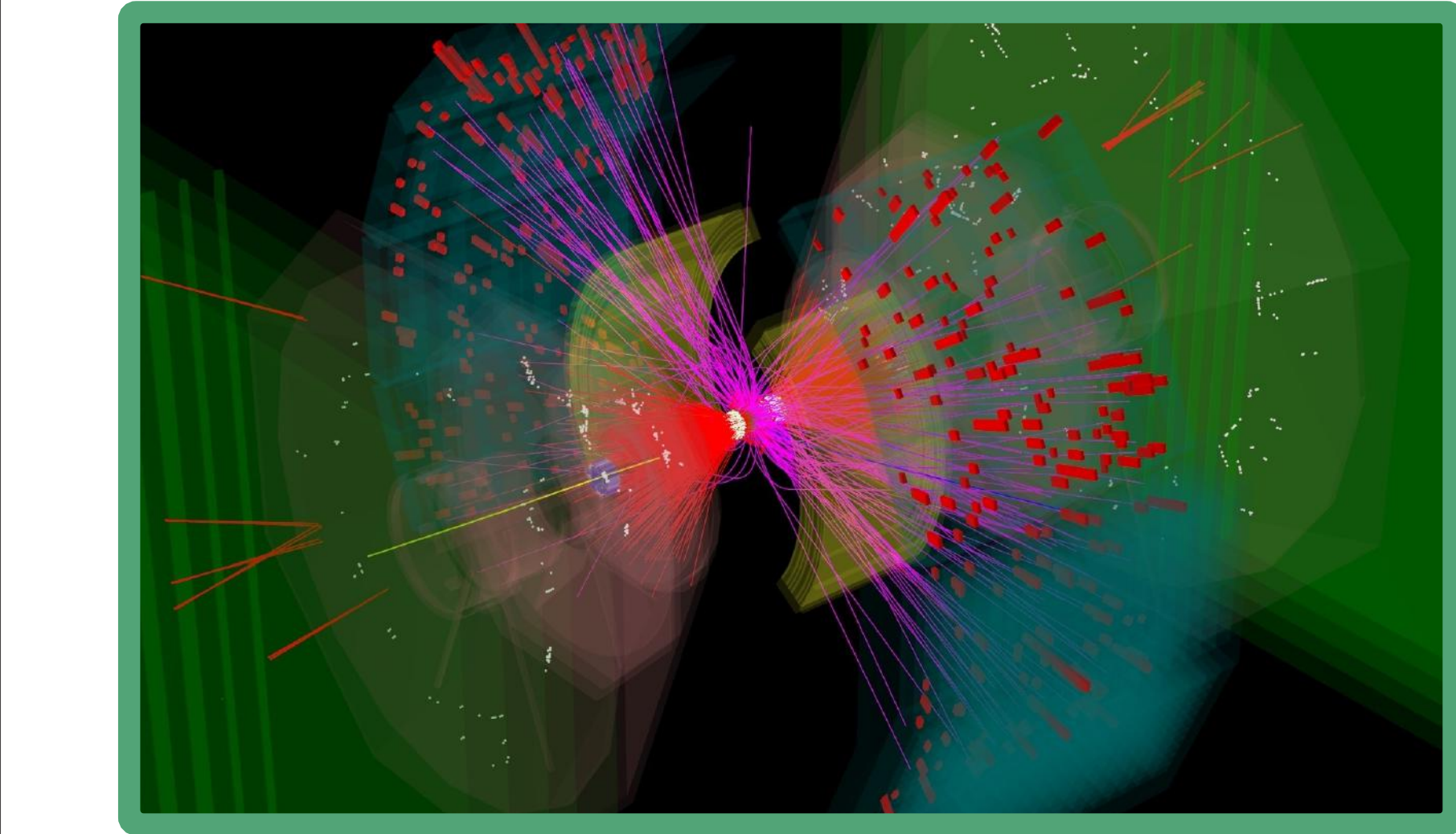
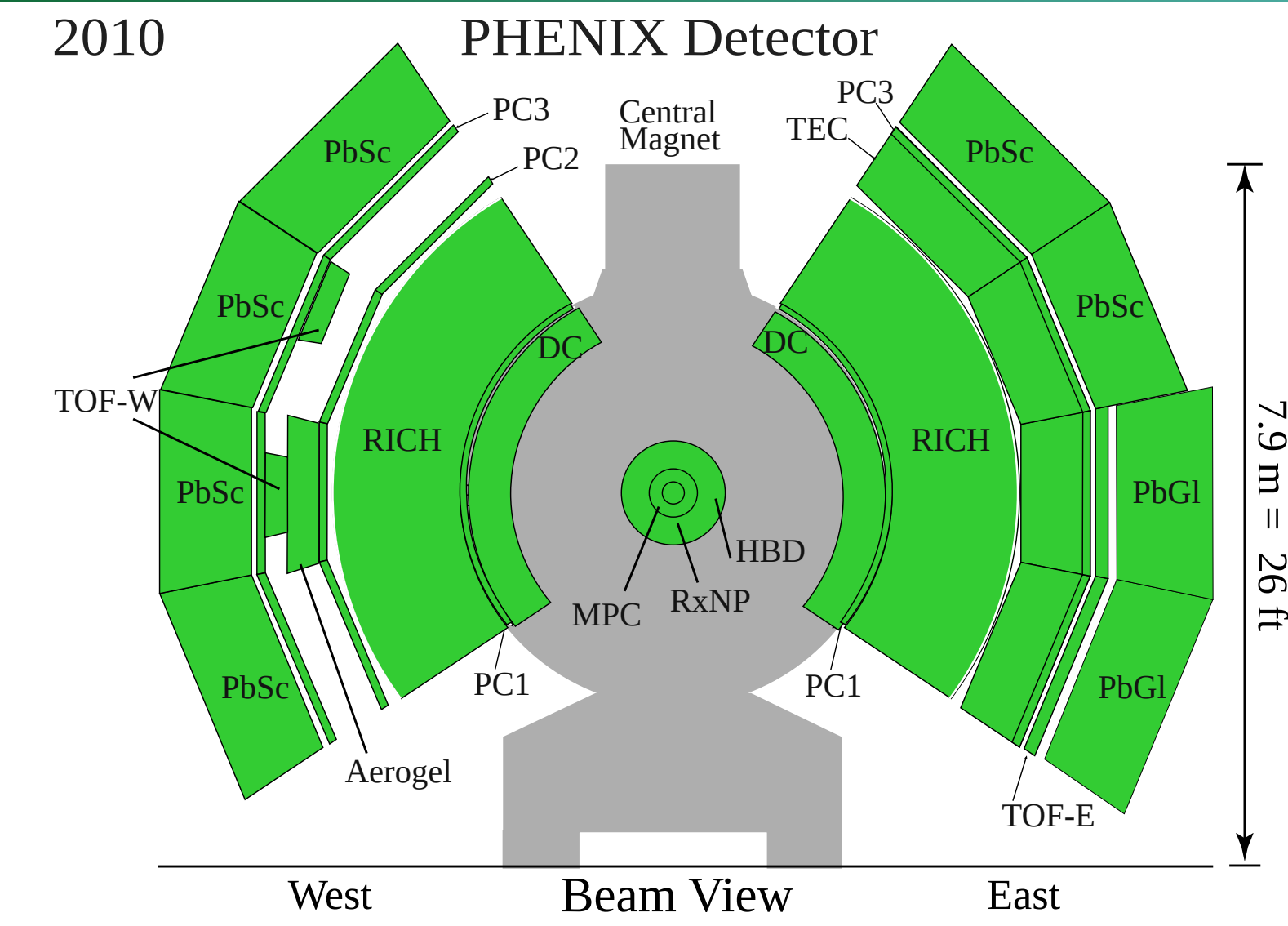


The PHENIX experiment at RHIC



- 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. $\rightarrow S$

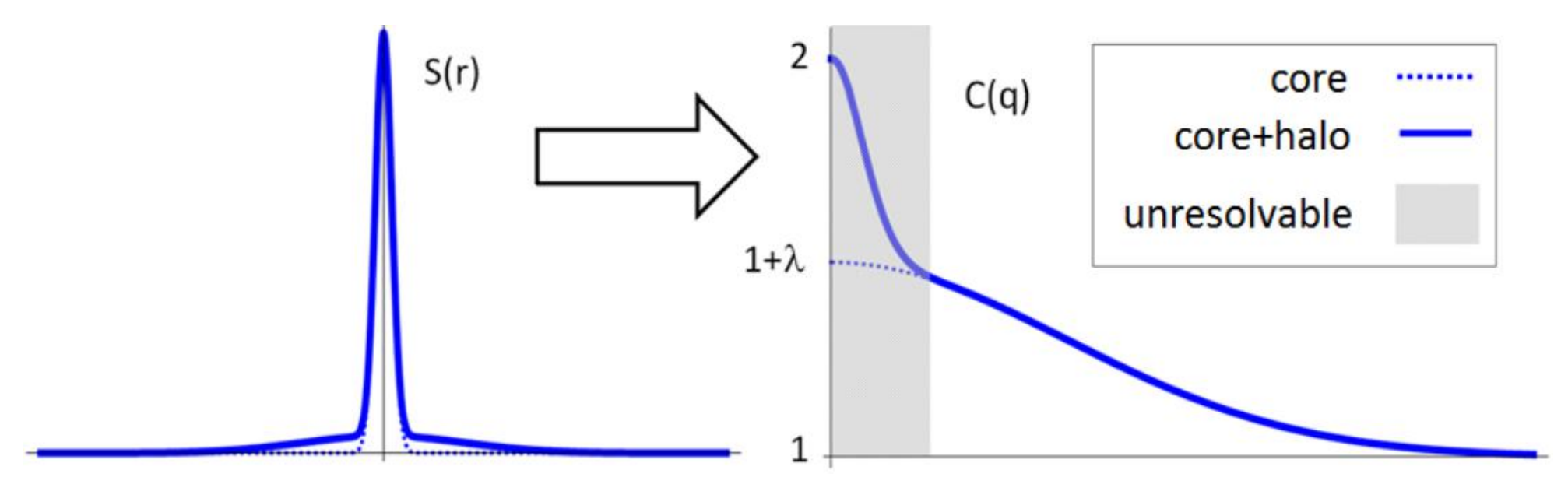
$$C_2(q, K) \simeq 1 + \left| \frac{\tilde{S}(q, K)}{\tilde{S}(0, K)} \right|^2, \quad \tilde{S}(q, k) = \int S(x, k) e^{iqx} d^4x$$

$$K = (k_1 + k_2)/2$$

$$x = x_1 - x_2, \quad q = k_1 - k_2$$

Final state interactions, resonances

- Identical charged pions - Coulomb interaction distort the simple picture
 - different methods of handling, e.g. Coulomb-correction: $C_{B-E}(q) = K(q) \cdot C_{\text{meas.}}(q)$
- 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 $\rightarrow$ C-H ratio: $\lambda = \left(\frac{N_C}{N_C + N_H} \right)^2$



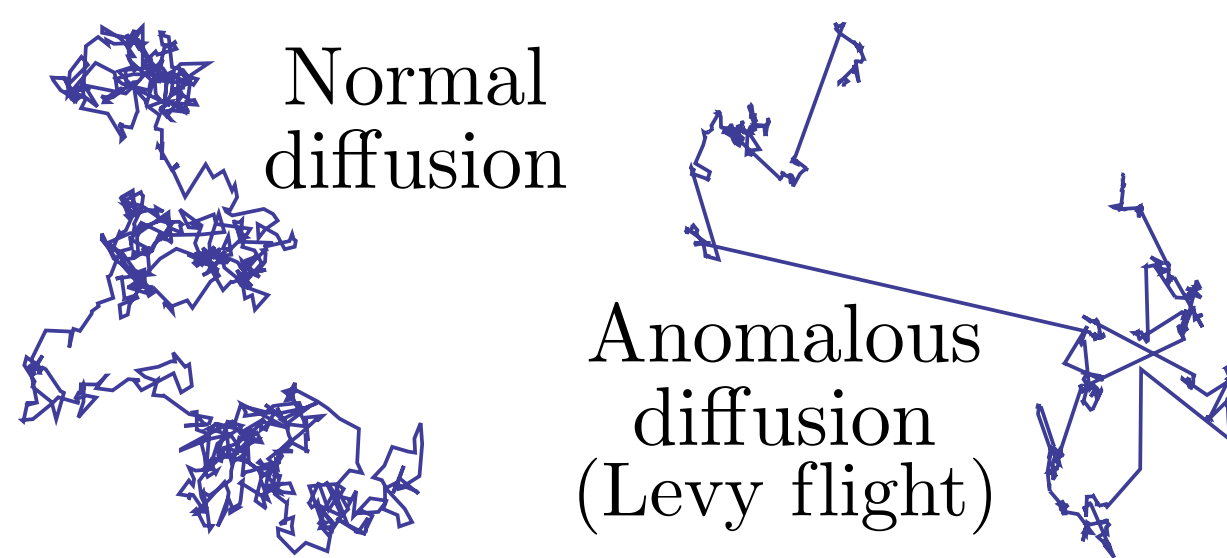
The Levy distribution as source function

- In expanding hadron resonance gas, mean free path increases with time $\rightarrow$ Levy flight
- Anomalous diffusion, generalized centr. limit th. $\rightarrow$ 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]:

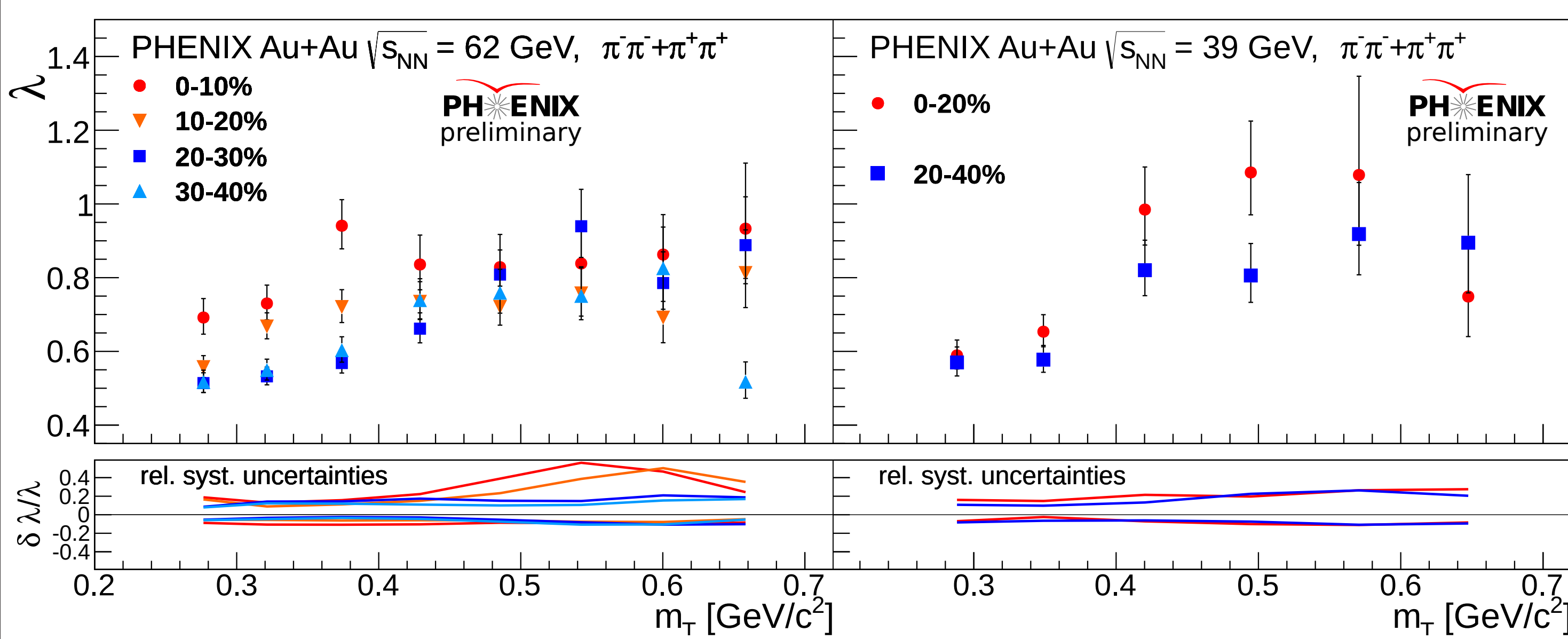
$$C_2(|k|) = 1 + \lambda \cdot e^{-(2R|k|)^\alpha}$$



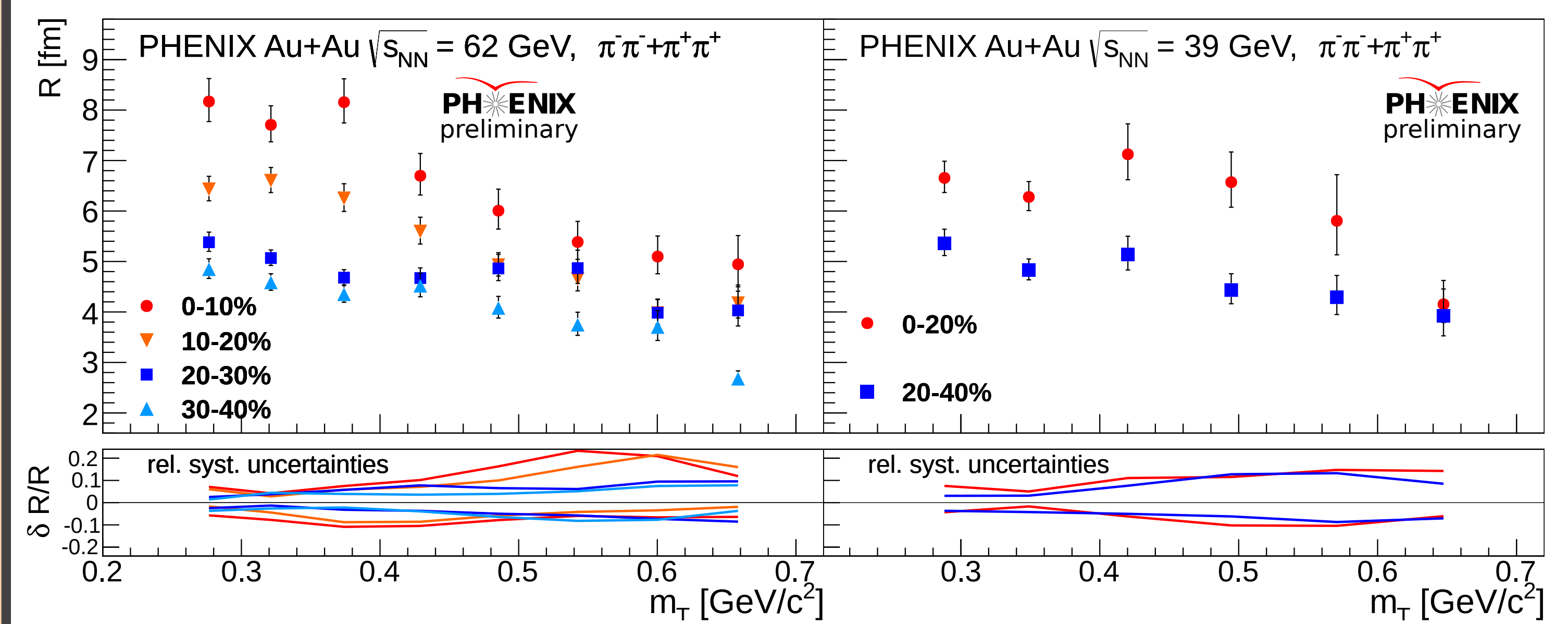
Critical behavior

- Crit. behavior $\rightarrow$ described by crit. exponents
- At CEP in 3 dim. $\langle \Psi(0)\Psi(r) \rangle \propto r^{-1-\eta}$
- Levy distr. $\rightarrow$ spatial corr. $\propto r^{-1-\alpha}$ } $\alpha \equiv \eta$
- QCD universality class $\leftrightarrow$ 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]

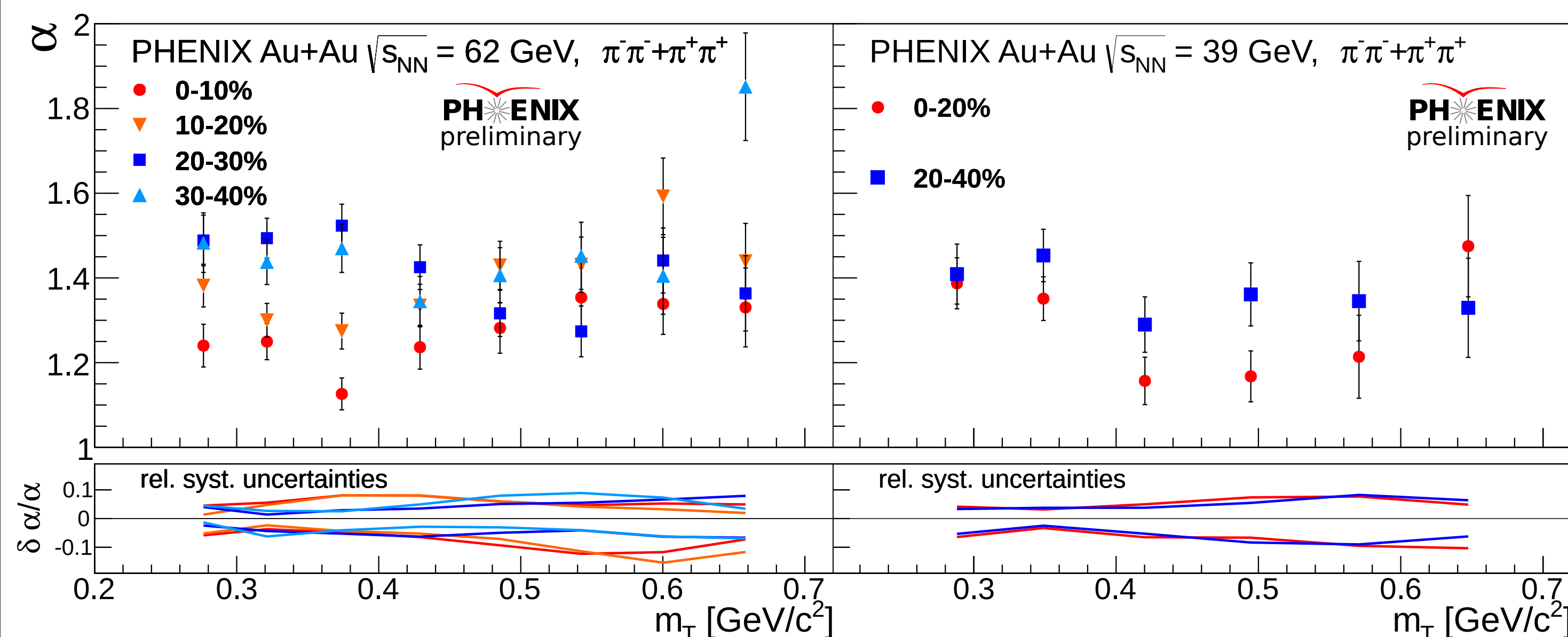
Low m_T suppression in correlation strength λ



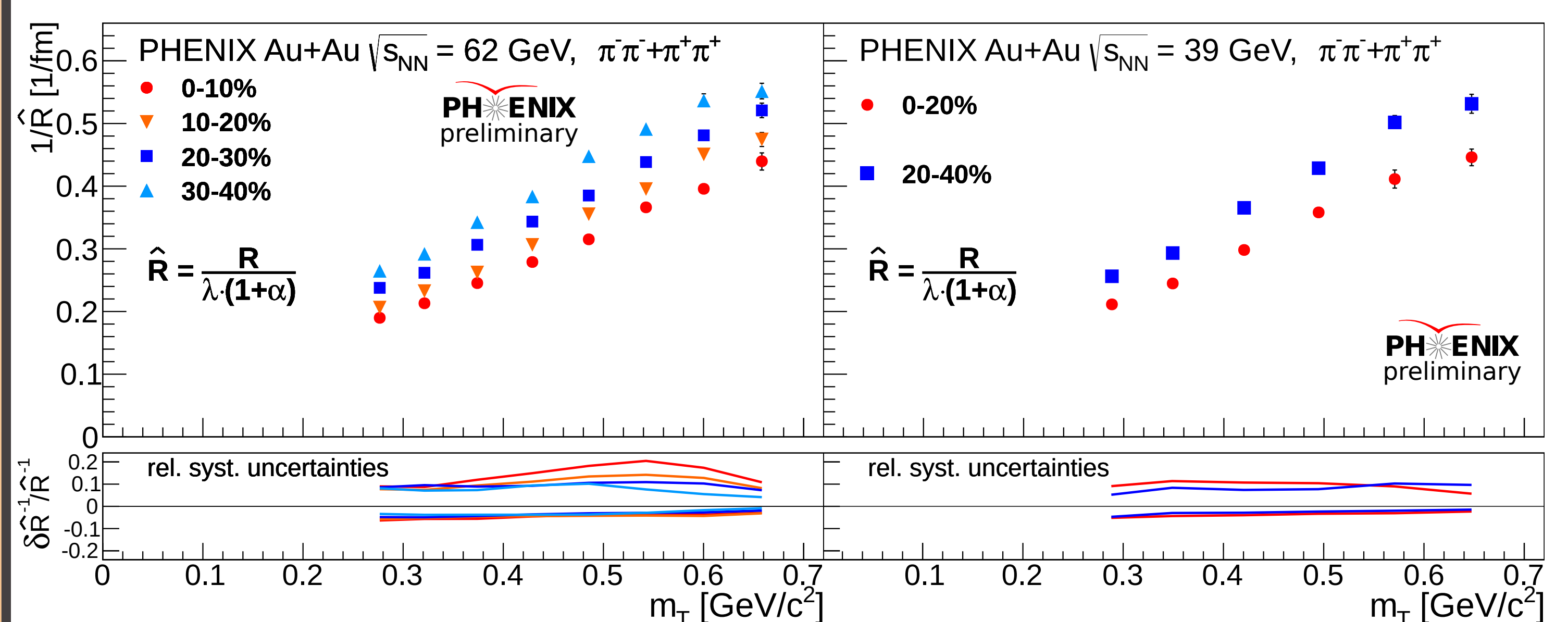
Decreasing trend, geom. cent. dep. of Levy scale R



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



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



Summary

- Bose-Einstein corr. with Levy source
 - Good agreement with data
 - Levy exponent $\alpha \equiv$ crit. exp. η
 - α vs. $\sqrt{s_{NN}} \leftrightarrow$ 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 $\hat{R}$ as $1/m_T$ is valid at 62 & 39 GeV

References

- [1] J. Bolz et al., Phys.Rev. D47 (1993) 3860
- [2] T. Csörgő et al., Z.Phys. C71 (1996) 491
- [3] T. Csörgő et al., Eur.Phys.J. C36 (2004) 67
- [4] Stephanov et al., Phys.Rev.Lett.81 (1998) 4816
- [5] El-Showk et al., J.Stat.Phys.157 (2014) 869
- [6] Rieger, Phys.Rev.B52 (1995) 6659
- [7] <http://www.bnl.gov/rhic/PHENIX.asp>