PHENIX results on Levy analysis of three particle Bose-Einstein correlation functions

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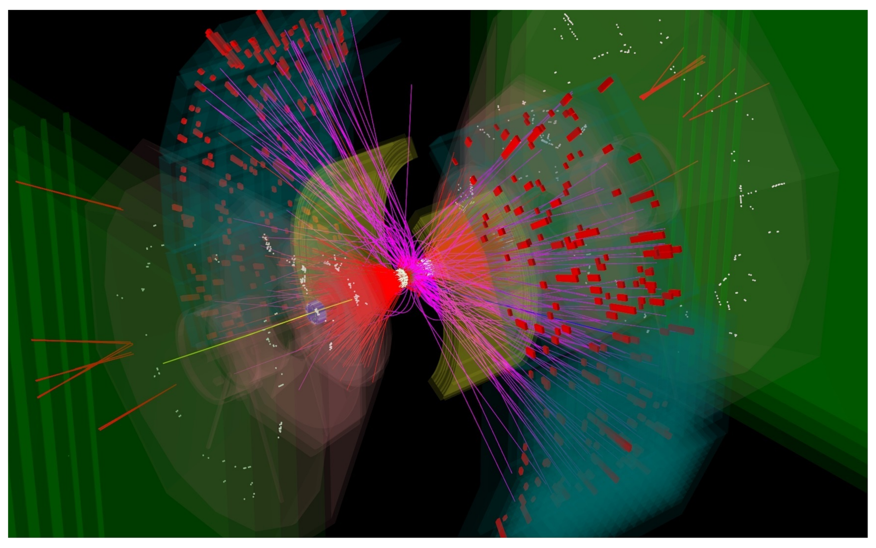
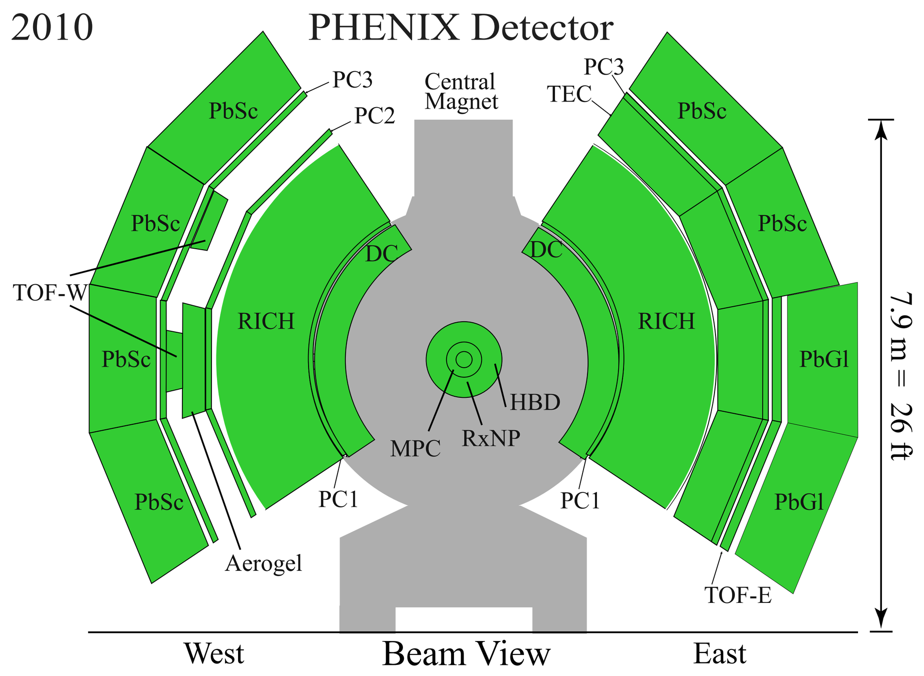
The PHENIX experiment at RHIC





- Charged pion ID from ~ 0.2 to 2 GeV/c

Introduction to three particle Bose-Einstein correlations

- Invariant momentum distributions: $N_1(p_i), N_2(p_1,p_2), N_3(p_1,p_2,p_3)$
- The definition of the correlation function:

$$C_n(p_1,\ldots,p_n)=\frac{N_n(p_1,\ldots,p_n)}{N_1(p_1)\cdots N_1(p_n)},\ \text{for chaotic emission: } N_n(x_1,\ldots,x_n)=\int\prod_{i=1}^{n}S(x_i,p_i)|\Psi_n(\{x_i\})|^2d^4x_1\ldots d^4x_n$$

- $S(x,p)$ source function (usually assumed to be Gaussian - Levy is more general)
- Ψ_n n-particle wave function - interaction free case: symmetrized combination of plane waves $\to C_n^{(0)}$
- Coordinate transformation: $q_{ij}=p_i-p_j \Longrightarrow C_3(q_{12},q_{13},q_{23})$ for various $p_T=|p_{T1}+p_{T2}+p_{T3}|/3$
- Longitudinal co-moving system of triplet: $k_{ij}=|q_{ij}^{\text{LCMS3}}|$
- Three dimensional correlation function: $C_3(k_{12},k_{13},k_{23})$

Final state interactions, pion production mechanisms

- Identical charged pions - Coulomb interaction distort the simple picture
- Coulomb-corrected correlation: $C_3(k_{12},k_{13},k_{23})=K_3(k_{12},k_{13},k_{23})\cdot C_3^{(0)}(k_{12},k_{13},k_{23})$
- Coulomb-correction from Generalized Riverside [1, 2]: $K_3(k_{12},k_{13},k_{23})\approx K_1(k_{12})K_1(k_{13})K_1(k_{23})$
- Resonance pions contribute to the full source: $S=S_{\text{core}}+S_{\text{halo}}$
- Reduce the measurable correlation function to $C_2(0)=1+\lambda_2$ with $\lambda_2=f_c^2=\left(\frac{\text{core}}{\text{core+halo}}\right)^2$ [3, 4]
- Non-chaotic emission also possible; coherent fraction: $p_c=\frac{\text{coherent}}{\text{coherent+incoherent}}$

The Levy-distribution and the three particle correlation strength

- Generalized Gaussian from anomalous diffusion: Levy-distribution, $\alpha=2$: Gauss, $\alpha=1$: Cauchy

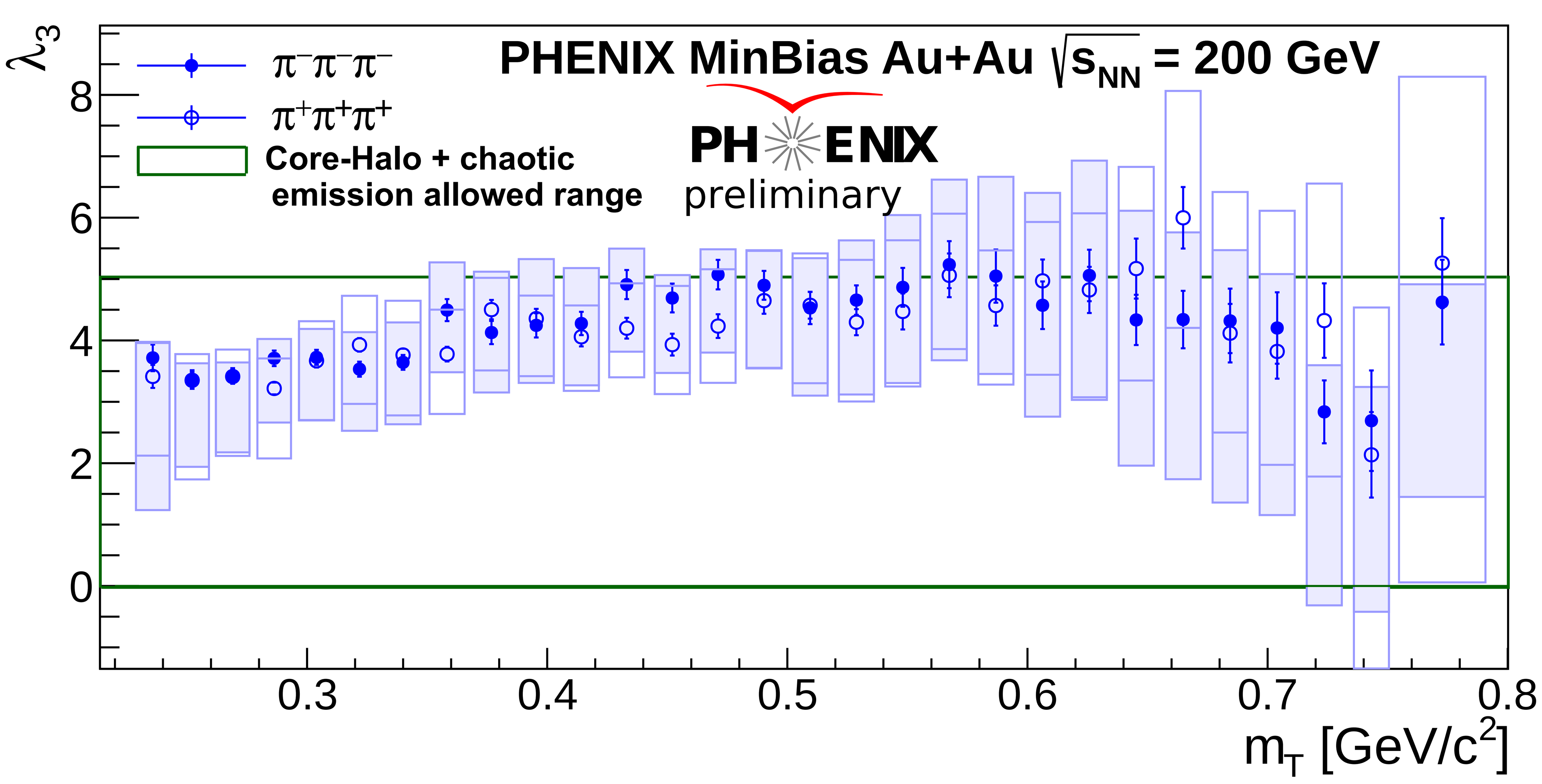
$$\mathcal{L}(\alpha,R,r)=(2\pi)^{-3}\int d^3q e^{iqr}e^{-\frac{1}{2}|qR|^{\alpha}}$$

- Interaction free correlation function with Levy source:

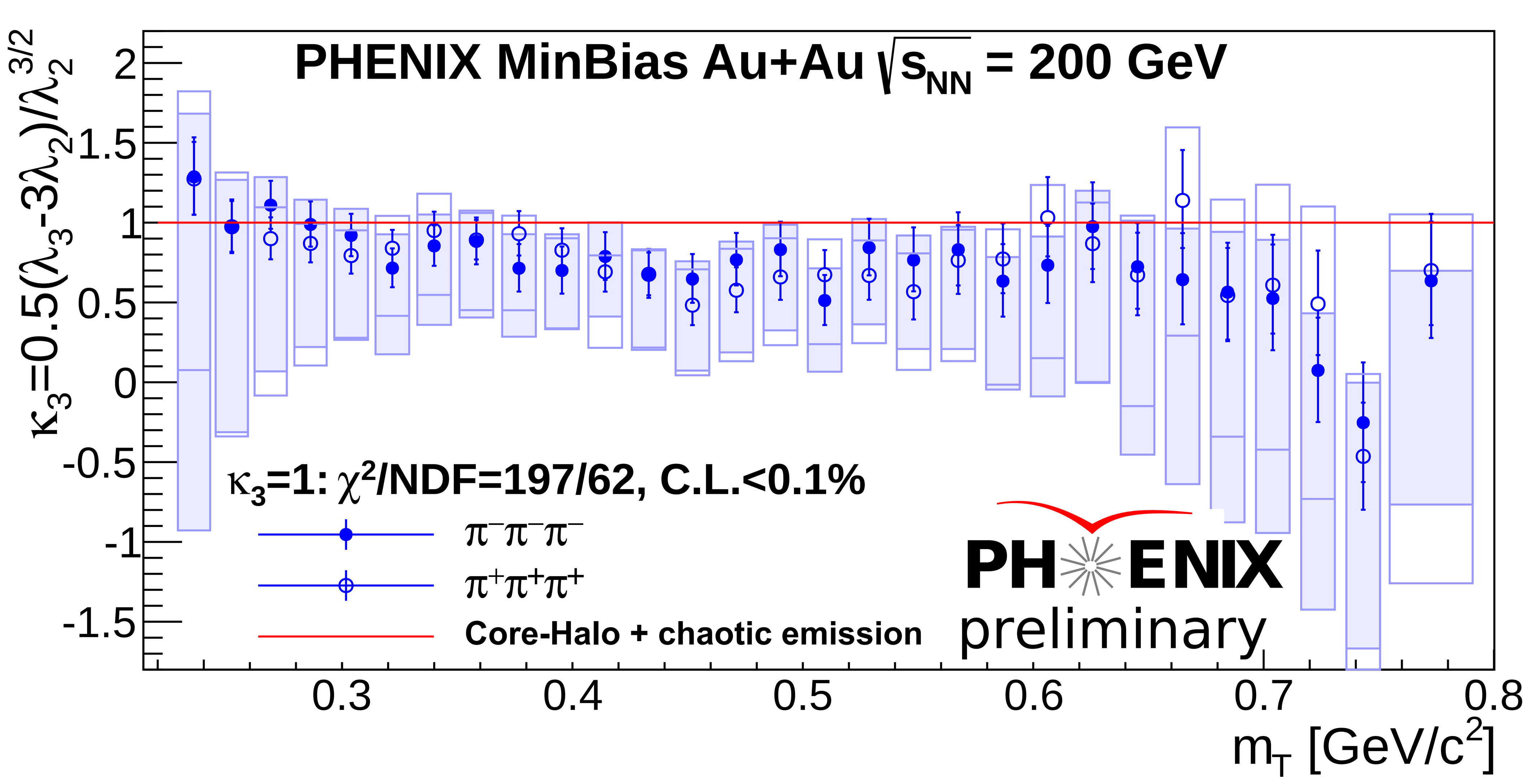
$$C_3^{(0)}(k_{12},k_{13},k_{23})=1+\ell_3 e^{-0.5\left(|2k_{12}R|^{\alpha}+|2k_{13}R|^{\alpha}+|2k_{23}R|^{\alpha}\right)}+\ell_2\left(e^{|2k_{12}R|^{\alpha}}+e^{|2k_{13}R|^{\alpha}}+e^{|2k_{23}R|^{\alpha}}\right)$$

- Three particle correlation strength: $\lambda_3\equiv C_3(k_{12}=k_{13}=k_{23}=0)-1=\ell_3+3\ell_2$
- Core-Halo independent parameter: $\kappa_3=(\lambda_3-3\lambda_2)/(2\lambda_2^{3/2})$, where $\lambda_2\equiv C_2(k=0)-1$ (two particle corr. strength)

Correlation strength λ_3 is within core-halo + chaotic emission range of $[0,5]$ for all m_T

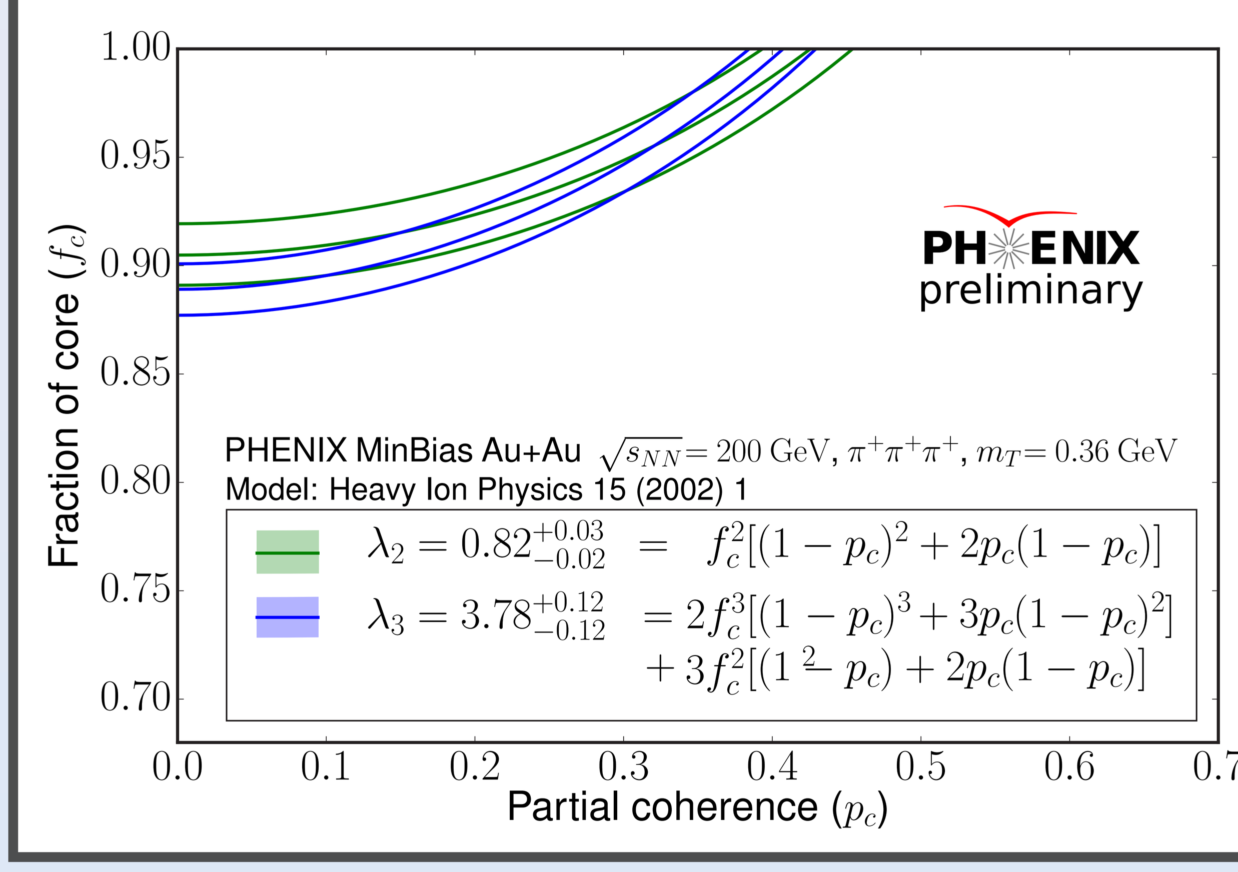


Core-halo independent parameter κ_3 vs m_T: $\kappa_3\neq 1$ is statistically significant



Partial coherence (p_c) vs fractional core (f_c)

- Simple theoretical model [5]: $\lambda_2(f_c,p_c)$, $\lambda_3(f_c,p_c)$
- Measured $\lambda_2^{\text{meas.}}\to$
  $\lambda_2^{\text{meas.}}=\lambda_2(f_c,p_c)\Longrightarrow f_c(p_c)$ (green lines)
- Measured $\lambda_3^{\text{meas.}}\to$
  $\lambda_3^{\text{meas.}}=\lambda_3(f_c,p_c)\Longrightarrow f_c(p_c)$ (blue lines)
- Example 2D plot at $m_T=0.36$ GeV/c^2:



Summary

- 3 pion B-E correlations with Levy-source are shown
- Good agreement with data
- λ_3 within Core-Halo + chaotic emission limits (0-5)
- λ_2, λ_3 are consistent within 1σ region on (f_c,p_c) plots
- Core-Halo + chaotic emission $\kappa_3=1$
- Statistically significant deviation from $\kappa_3=1$
- Statistically significant exclusion region: analyzed at $m_T=0.36$ GeV/c^2
  - $f_c<0.82$ can be excluded
  - $p_c>0.5$ can be excluded
  - Small ($p_c<0.5$) partial coherence cannot be excluded
- Further m_T regions will be investigated
- m_T dependent exclusion limits on f_c,p_c to be analyzed

References

[1] M. M. Aggarwal et al. (WA98 Collaboration) Phys. Rev. Lett. 85 2895 (2000)

[2] J. Adams et al. (STAR Collaboration) Phys. Rev. Lett. 91 262301 (2003)

[3] J. Bolz et al., Phys.Rev. D47 (1993) 3860

[4] T. Csörgő et al., Z.Phys. C71 (1996) 491

[5] T. Csörgő, Heavy Ion Physics 15 (2002) 1

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