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PHENIX results on three-particle Bose-Einstein correlations in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions

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WINTER SCHOOL ON HEAVY ION PHYSICS

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József Zimányi (1931 - 2006)

Outline

- Definition of three-particle Bose-Einstein correlation function
- The PHENIX Experiment
- Fit results
- Physical Interpretations
- Summary

Three-particle Bose-Einstein Correlation Function

- Correlation function:

$$C_3(\boldsymbol{k}_1, \boldsymbol{k}_2, \boldsymbol{k}_3) = \frac{N_3(\boldsymbol{k}_1, \boldsymbol{k}_2, \boldsymbol{k}_3)}{N_1(\boldsymbol{k}_1) N_1(\boldsymbol{k}_2) N_1(\boldsymbol{k}_3)}$$

- Three-particle momentum distribution:

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

- Assumption for source: Levy-distribution

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

Without Coulomb Interaction

- Correlation function without Coulomb interaction:

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

- Fit function:

$$C_{3,\mathrm{fit}}^{(0)}(k_{12}, k_{13}, k_{23}) = N(1+\epsilon k_{12})(1+\epsilon k_{13})(1+\epsilon k_{23})C_3^{(0)}(k_{12}, k_{13}, k_{23})$$

- Fitted parametrs: l_2, l_3, ϵ, N
- We already know: R, α

Correlation Function

- The full Bose-Einstein correlation function:

$$C_3(k_1, k_2, k_3) = C_3^{(0)}(k_1, k_2, k_3) K(k_1, k_2, k_3)$$

- „Generalized Riverside” method:

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

- Three-particle correlation strength is defined:

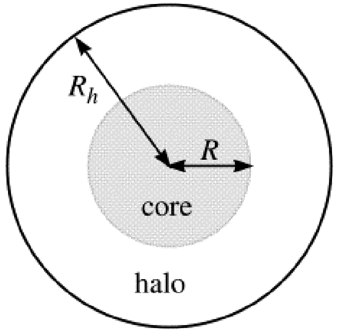
$$\lambda_3 \equiv C_3(k_{12} = k_{13} = k_{23} \to 0) - 1$$

- We are looking for: $\lambda_3 = l_3 + 3l_2$

Core-Halo model

- Two components of the source: $S = S_{\mathrm{core}} + S_{\mathrm{halo}}$

  Primordial Pions (Core); *Resonance Pions (Halo)*



- If no other effect $\lambda(K) = \left(\frac{N_{\mathrm{core}}(K)}{(N_{\mathrm{core}}(K) + N_{\mathrm{halo}}(K))} \right)^2$ equivalent to the intercept param.

- Then $\lambda_2 = f_C^2$ $\lambda_3 = 2f_C^3 + 3f_C^2$

- The core-halo independent new parameter $\kappa_3 = \frac{\lambda_3 - 3\lambda_2}{2\sqrt{\lambda_2^3}}$ =1

Partial Coherence

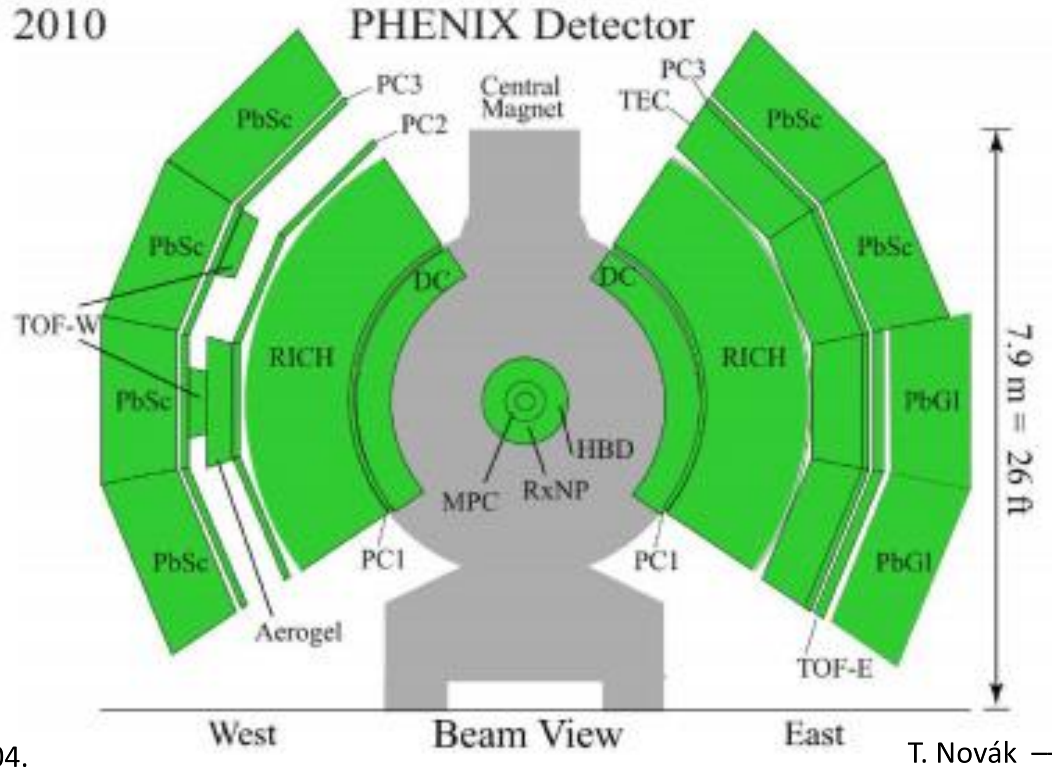
- If the core partially emits particles in coherent manner $\lambda \neq f_C^2$
- Fraction of coherently produced pions $p_c = \dfrac{N_{\text{coherent}}}{N_{\text{coherent}} + N_{\text{incoherent}}}$
- Core-Halo + Partial Coherence: $\lambda_2 = f_c^2\left[(1-p_c)^2 + 2p_c(1-p_c)\right]$

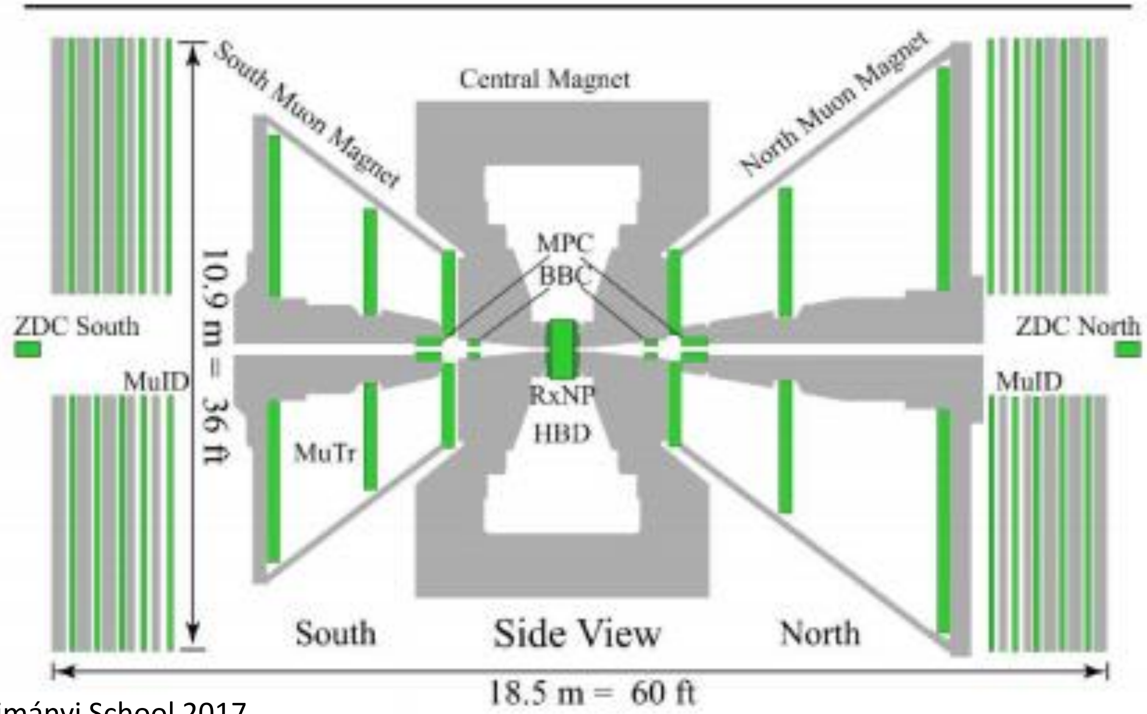
$$\lambda_3 = 2f_c^3\left[(1-p_c)^3 + 3p_c(1-p_c)^2\right] + 3f_c^2\left[(1-p_c)^2 + 2p_c(1-p_c)\right]$$

- Additional effects (e.g., not fully thermal): $\kappa_3 \neq 1$

The PHENIX Experiment at RHIC

- Observing collision of p, d, Cu, Au, U
- Charged pion ID from ~ 0.2 to 2 GeV
- Au+Au: $\sqrt{s_{NN}} = 200$ GeV
- This analysis: PID also with EMCal



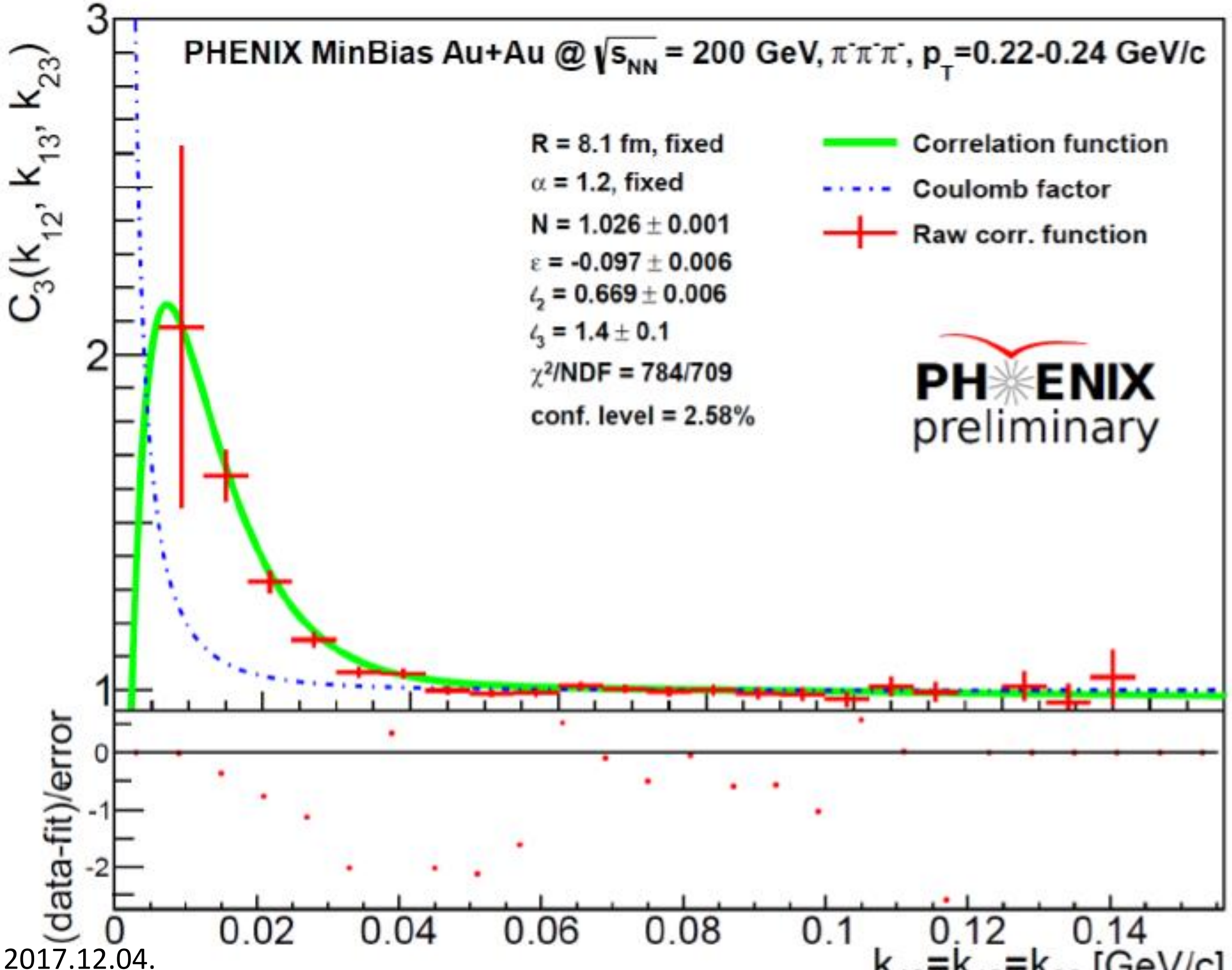


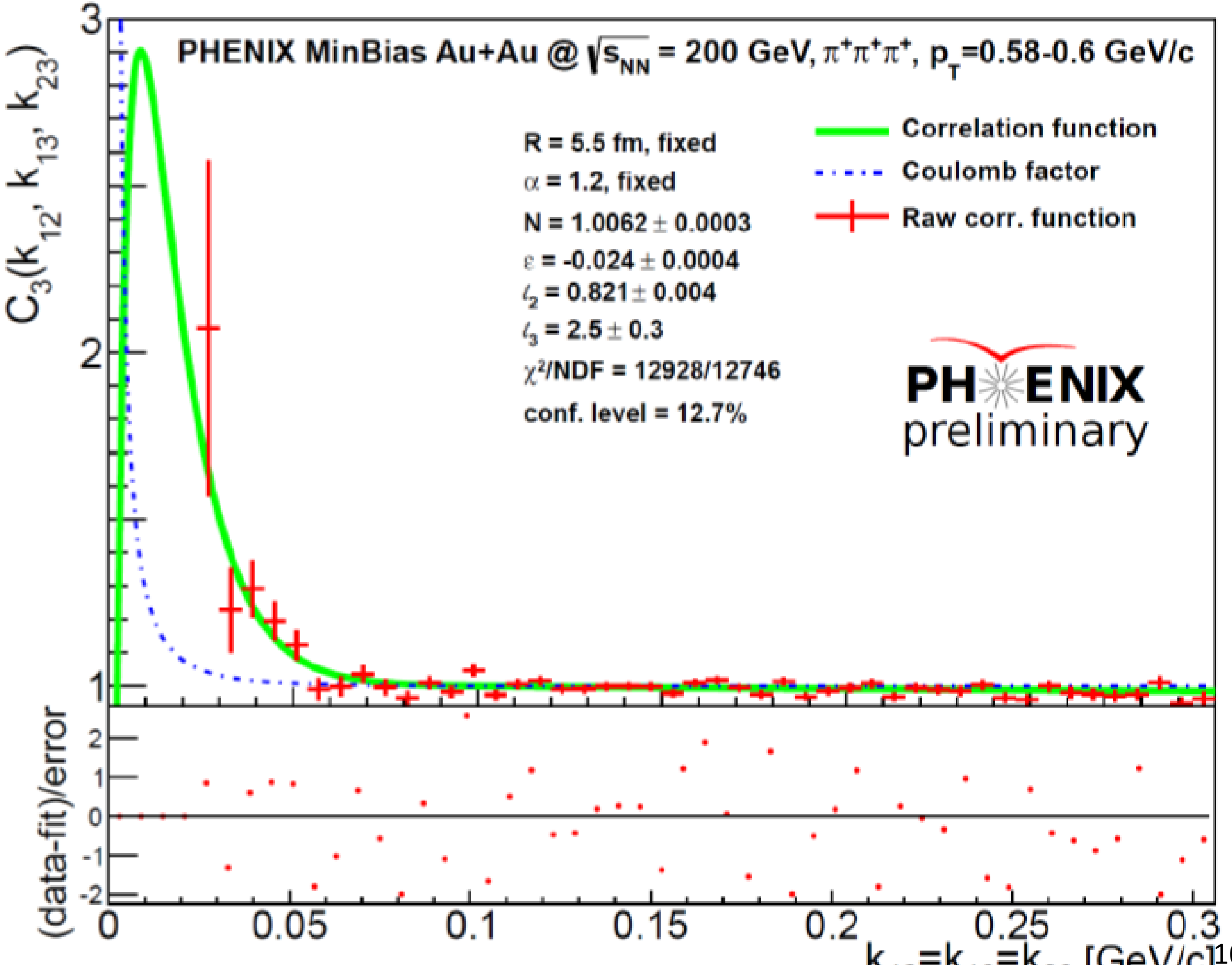
Dataset used for the Analysis

- Run-10, Au+Au, $\sqrt{S_{NN}} = 200$ GeV, $7.3 \cdot 10^9$ events
- Min. bias trigger
- Additional offline requirements:
  - Collision vertex position less than ± 30 cm
- Single track cuts:
  - 2σ matching cuts in TOF & PbSc for pions
- Particle identification:
  - Time-of-flight data from PbSc e/w, TOF e/w, momentum, flight length
  - 2σ cuts on m^2 distribution
- Pair-cuts:
  - A random member of pair assoc. with hits on same tower were removed
  - Customary shaped cuts on $\Delta\varphi - \Delta z$ plane for PbSc e/w, TOF e/w
- Triplet-cuts: pair-cuts on each pair of the triplet

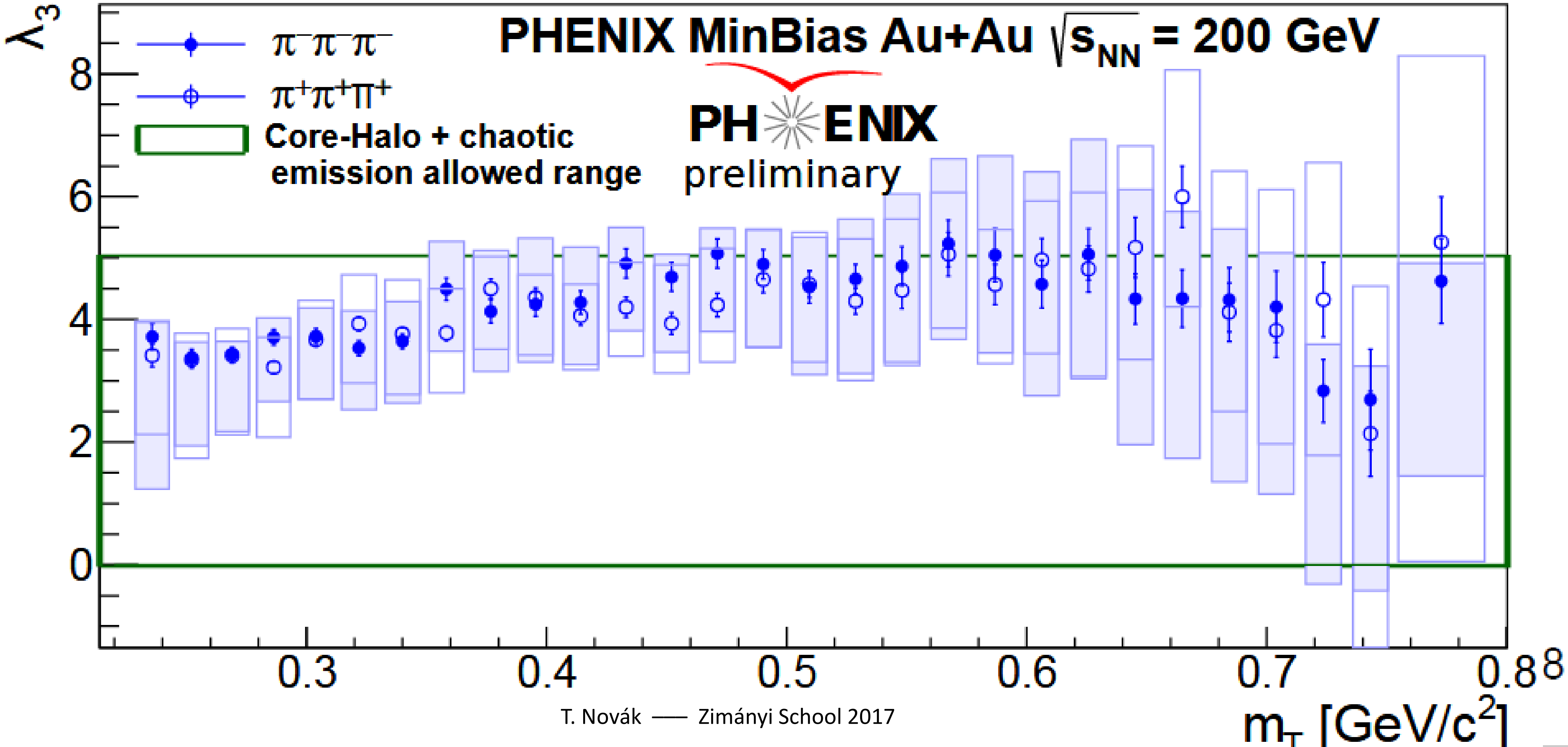
Diagonal visualization of fits

Visualization in $k_{12} = k_{13} = k_{23}$ subspace (3D not possible): shows good fits





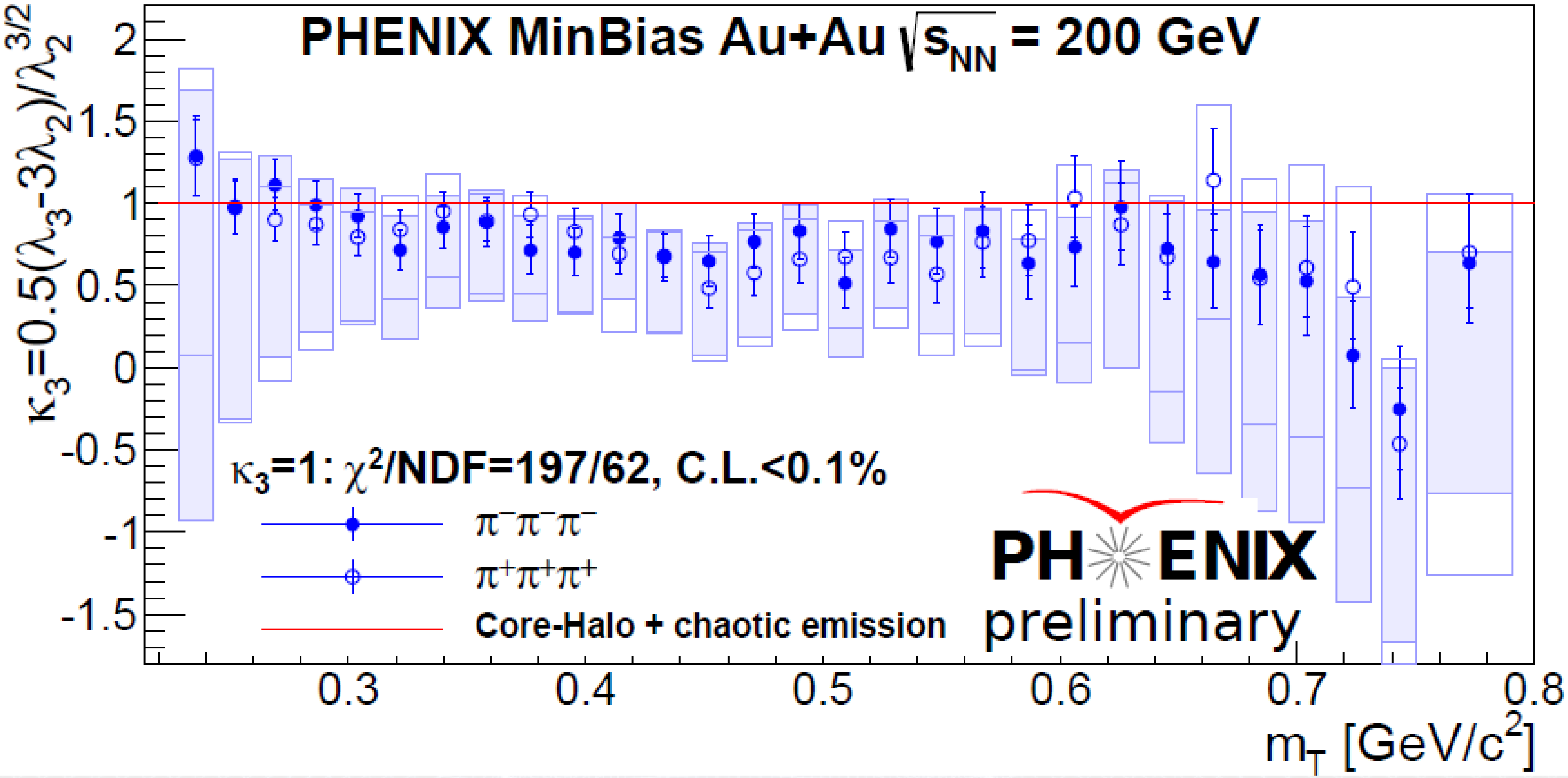
Three-particle correlation strenght: λ_3



Core-Halo independent parameter: κ_3

- Recall: $\kappa_3 = \frac{\lambda_3 - 3\lambda_2}{2\sqrt{\lambda_2^3}}$
- This parameter does not depend on $f_c = \text{core}/(\text{core} + \text{halo})$
- Core-Halo + thermal emission: $\kappa_3 = 1$
- Additional effects (e.g., not fully thermal): $\kappa_3 \neq 1$

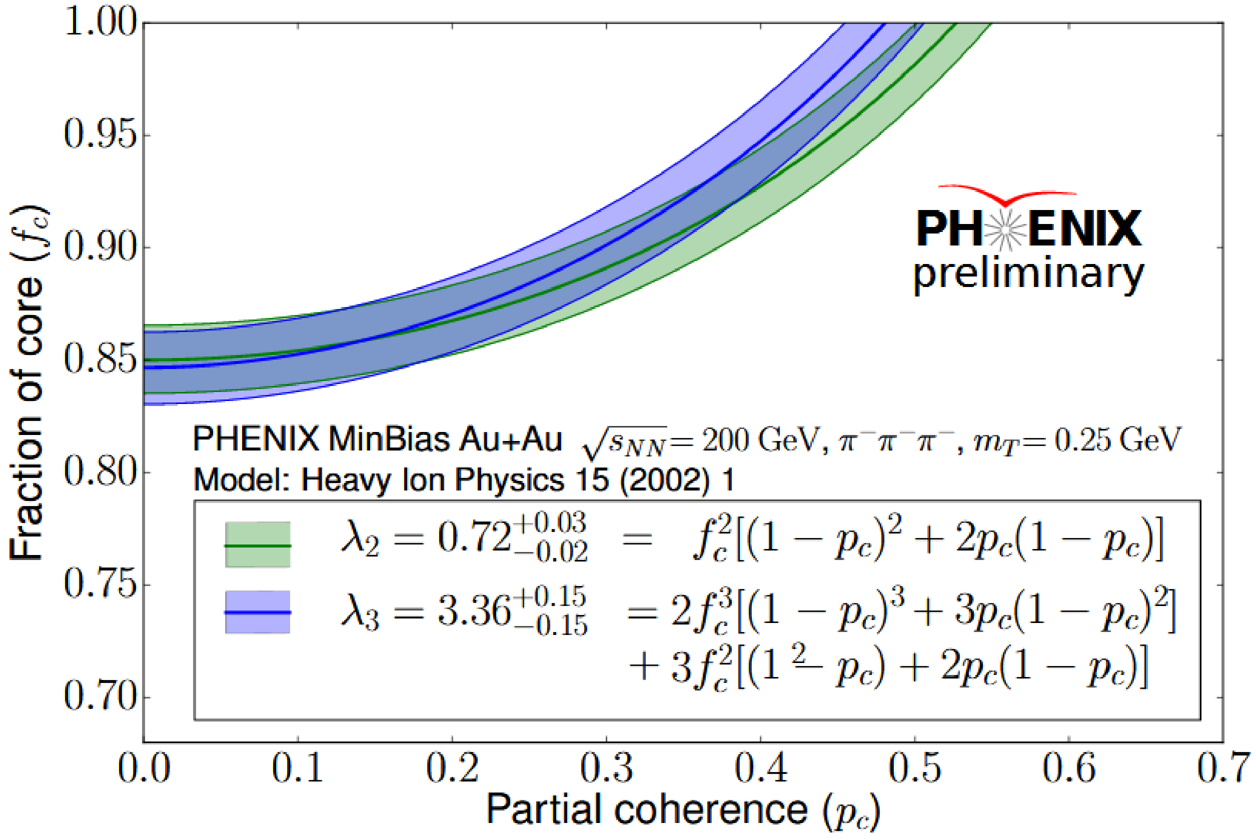
Core-Halo independent parameter: κ_3

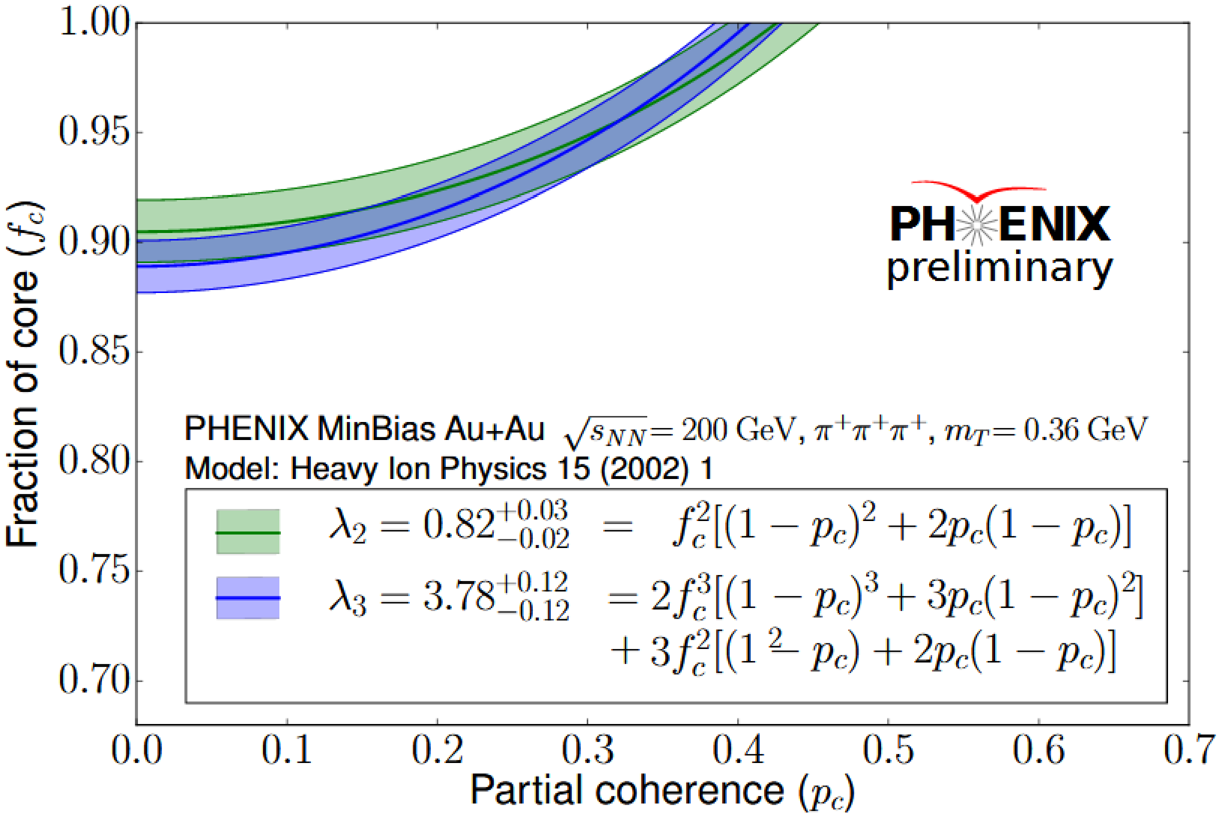


Fraction of core (f_c) *vs.* partial coherence (p_c)

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

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





Summary

- Three-pion BE correlation functions run-10 200 GeV Au+Au data
- Described with Levy fits
- λ_3 measures the strenght of correlation,
  within Core-Halo + chaotic emission limits (0-5)
- λ_2, λ_3 are consistent within 1σ region on (f_c, p_c) plots
- PHENIX preliminary κ_3 data indicate a significant effect
- We need to
  - finalize this analysis for 0 – 30%
  - study detailed centrality and $\sqrt{S_{NN}}$ etc dependence

Thank you for your attention!