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What we know about  
**HBT at RHIC**

# What do we know about HBT?

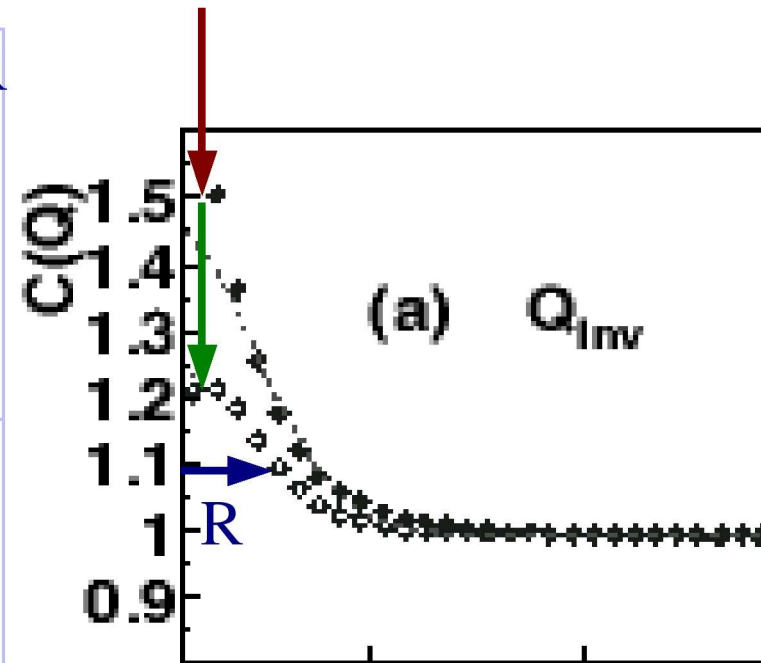
- Statistical interference measures  $R$

$$C_2 = 1 + |\tilde{\rho}(q)|^2$$

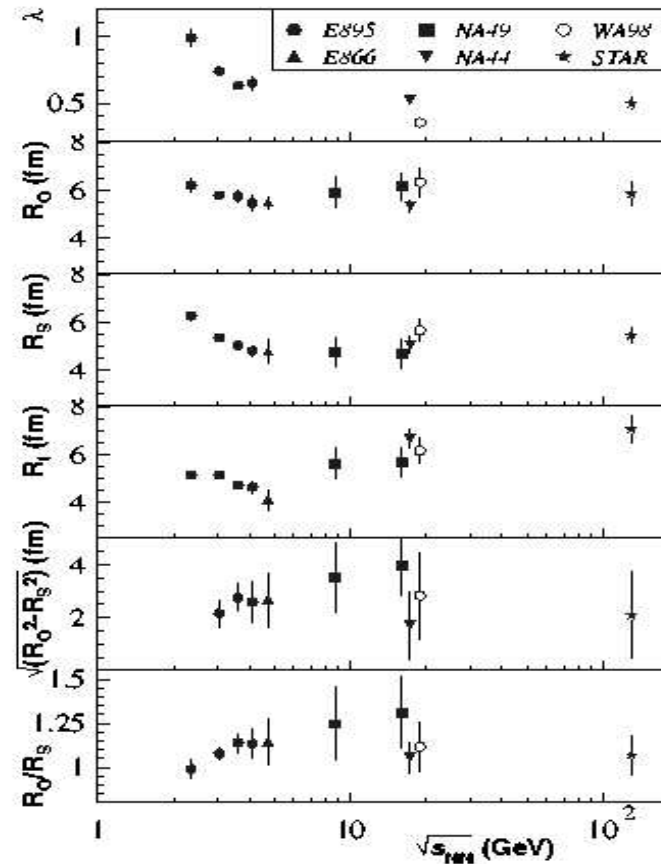
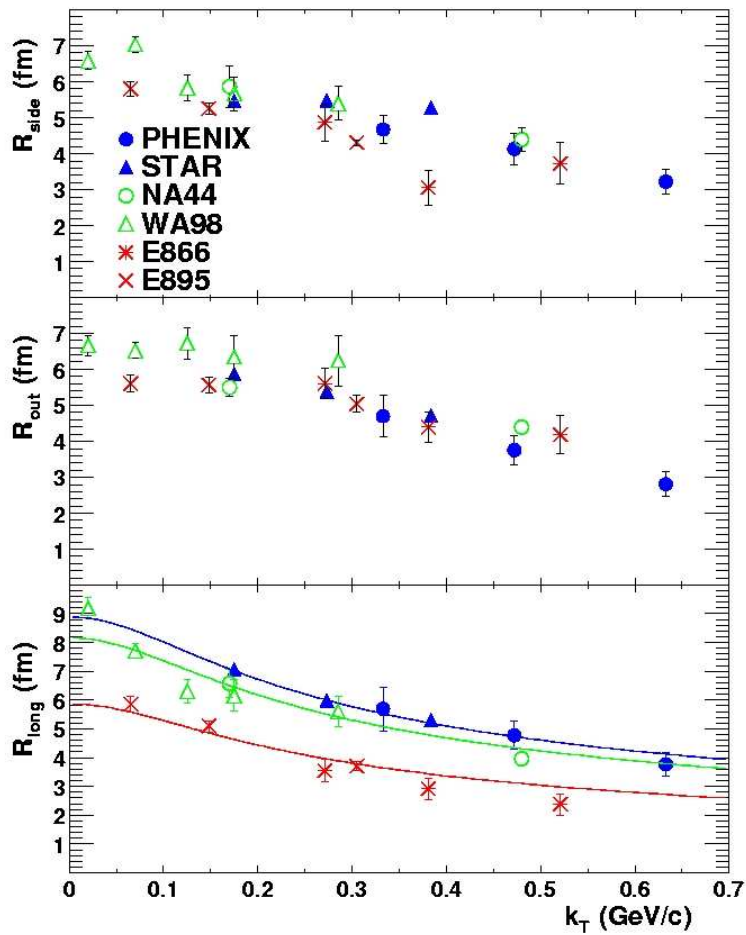
- Resonance decays reduce  $C_2(q=0)$

- Final State Coulomb modifies  $C_2$

- Expansion/dynamics make  $C_2(k_T)$

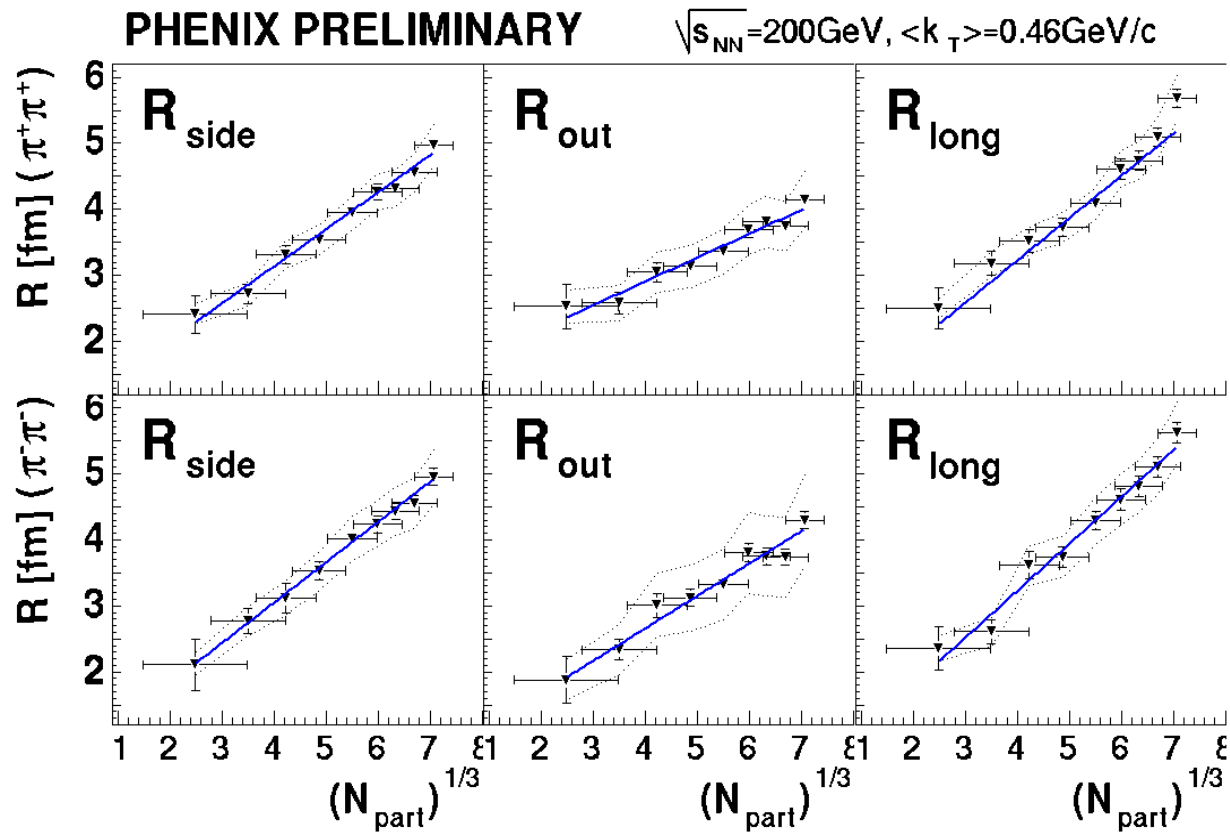


# RHIC Run1 Results



- ◆  $R_{\text{side}}, R_{\text{out}}$  stable from 5-130 GeV
- ◆  $R_{\text{long}}$  increases with energy
- ◆  $k_T$  dependences similar

# RHIC Run2 Preliminary Results



- ◆ Linear in  $A^{1/3}$  dependence, strongest for  $R_{\text{long}}$

# PHOBOS Run2 Results

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Phobos preliminary  
200 GeV Au-Au  
 $0.2 < y < 1.5$   
 $0.15 < k_T < 0.35$   
15% most central events

	$\lambda$	$R_{\text{out}}$	$R_{\text{side}}$	$R_{\text{long}}$	$R^2_{\text{out-long}}$
$\pi^- \pi^-$	$0.54 \pm 0.02$	$5.8 \pm 0.2$	$5.1 \pm 0.4$	$6.8 \pm 0.3$	$4.9 \pm 1.7$
$\pi^+ \pi^+$	$0.57 \pm 0.03$	$5.8 \pm 0.2$	$4.9 \pm 0.4$	$7.3 \pm 0.3$	$4.5 \pm 1.9$

Systematic error on radii of 1 fm, on  $\lambda$  of 0.06

- ◆ Phobos (non-cross term) radii are consistent

# Partial Coulomb Correction

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M.G. Bowler, Phys. Lett. B270:69 (1991) *Coulomb corrections to Bose-Einstein correlations have been greatly exaggerated*

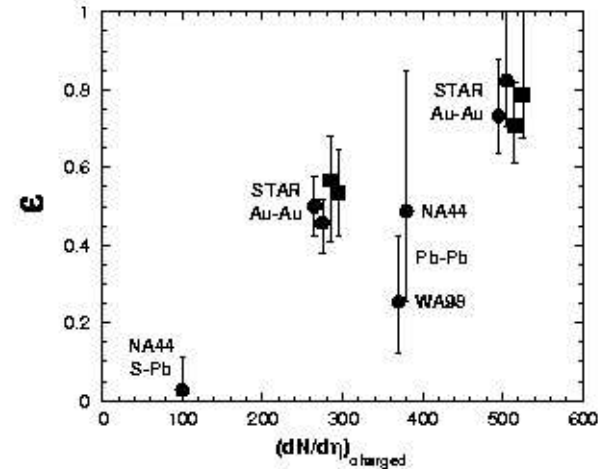
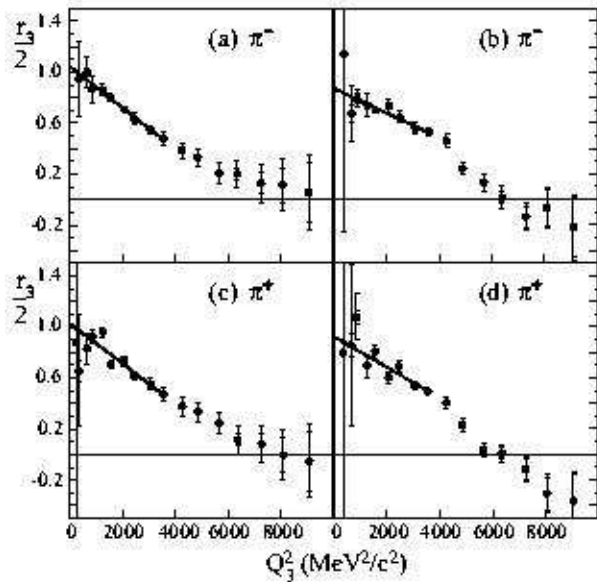
Commenting on the advent of high statistics data sets - “**Very soon our understanding of the phenomenon will become limited by systematic uncertainty in the correction of raw data.**”

$$C_2 = C_{core} + C_{halo}$$
$$C_2 = \lambda F (1 + G) + (1 - \lambda)$$

- ♦ If we apply it, how do we know it's right?
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# 3π Correlations

nucl-ex/0306028, R. Wilson, OSU



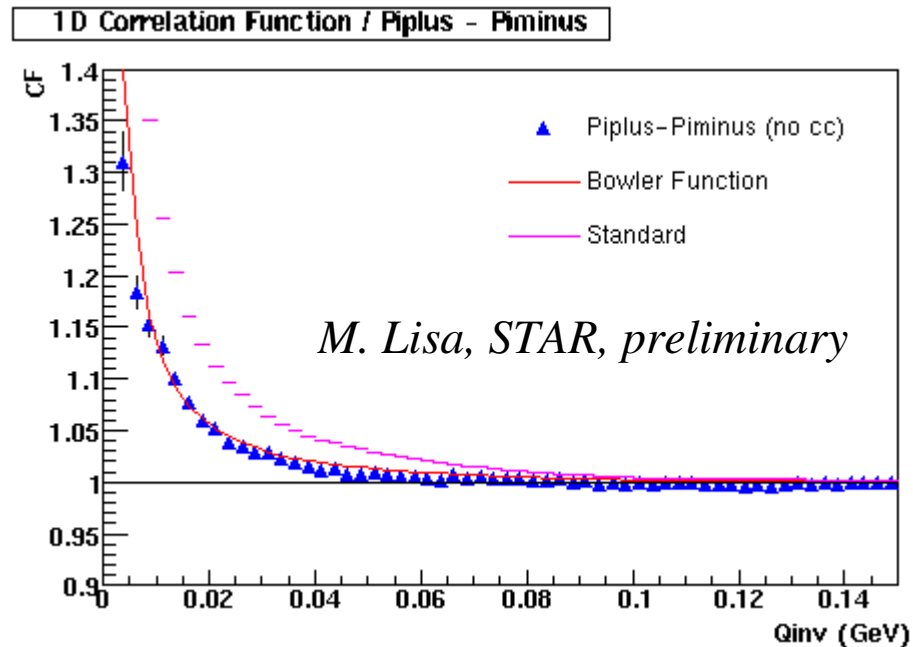
- ♦ 3π source assymetry analysis *hard*  
Heinz & Zhang, Phys Rev. C56:426 (1997)
- ♦ Q=0 extrapolation gives chaoticity

$$r_3(Q_3 = 0) = \frac{R_3(Q_3 = 0)}{R_2(Q_2 = 0)^{3/2}} = 2 \sqrt{\epsilon} \frac{3 - 2\epsilon}{(2 - \epsilon)^{3/2}}$$

- ♦ STAR Au-Au central consistent with  $\epsilon=1$

# $\pi^+\pi^-$ Coulomb Interaction

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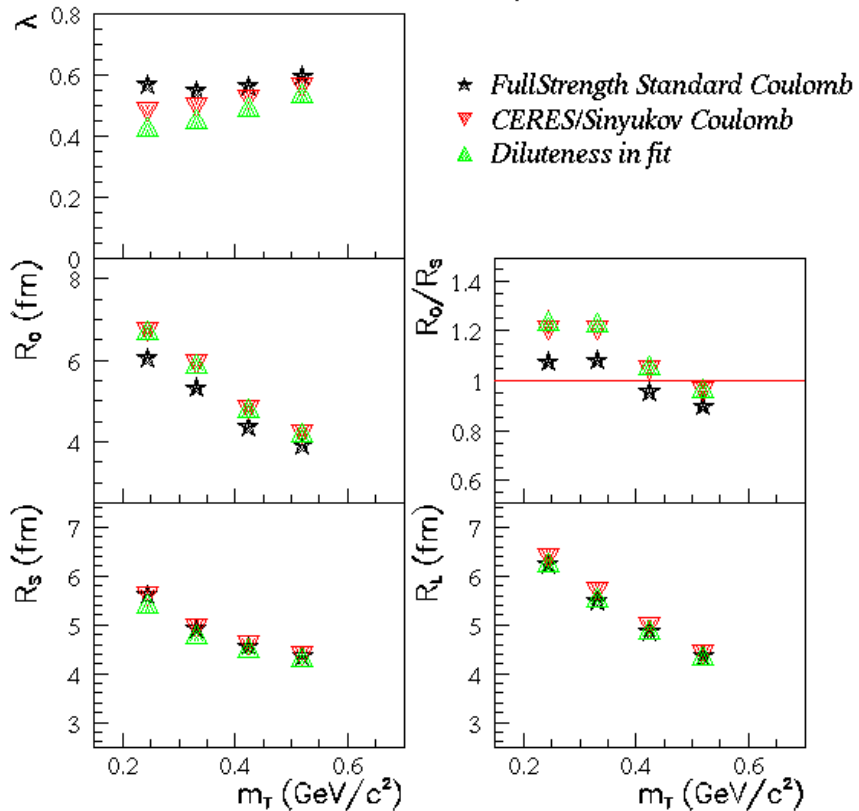


- ♦ STAR  $\pi^+\pi^-$  clearly inconsistent with full Coulomb
- ♦ PHENIX obtains reasonable agreement for 50% Coulomb

# Partial Coulomb (2)

M. Noriega, OSU

STAR Au+Au 200 GeV data - Test of Coulomb Methods



- ◆ ~10% increase in  $R_{out}/R_{side}$
- ◆ PHENIX results ready soon

◆  $R_{out}/R_{side}$  driven up ~10%

# STAR $\pi K$ correlation

nucl-ex/0307025, *Fabrice Retiere, LBL*

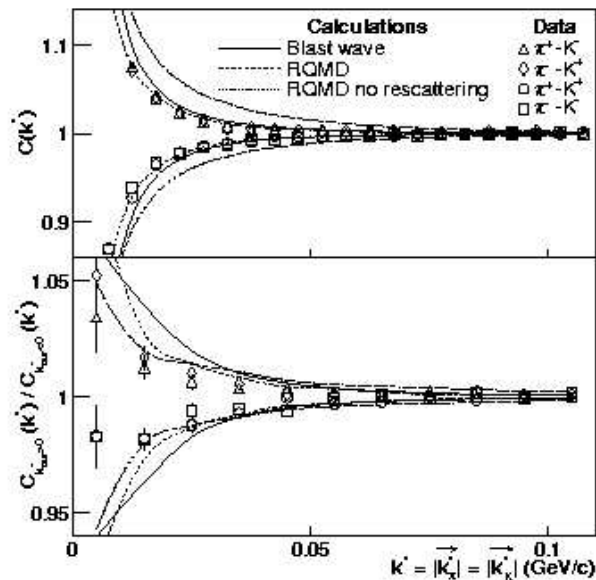


FIG. 2: Comparison of the correlation functions between data and model. Upper panel,  $C(k^*)$  correlation function. Lower panel, ratio  $C_+/C_-$  with respect to the sign of  $k_{out}^*$ .

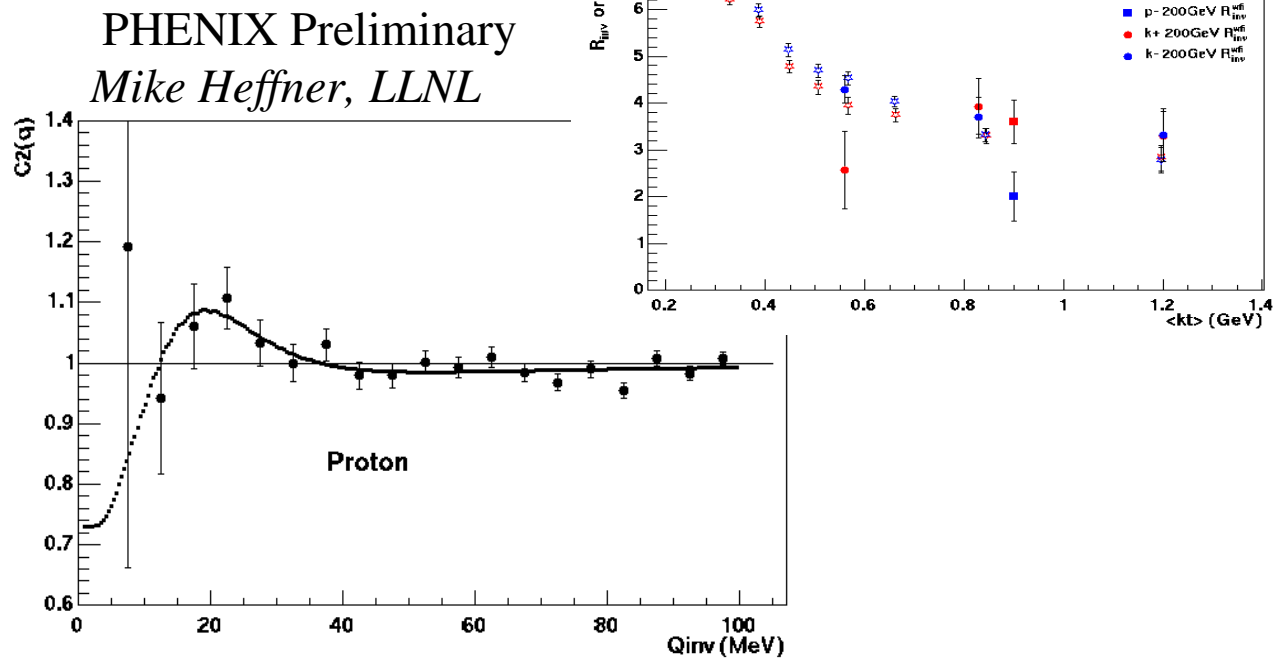
pair	$\sigma$ (fm)	$\langle \Delta r_{out}^* \rangle$ (fm)	$\chi^2 / \text{dof}$
$\pi^+ - K^+$	$12.2 \pm 0.6$	$-6.3 \pm 1.2$	25.8/26
$\pi^- - K^-$	$12.2 \pm 0.7$	$-5.7 \pm 1.2$	23.6/26
$\pi^+ - K^-$	$13.5 \pm 0.8$	$-5.3 \pm 1.2$	41.9/26
$\pi^- - K^+$	$12.7 \pm 0.6$	$-4.6 \pm 1.0$	43.1/26

- ◆ Ratio  $C_{\pi K}(k^+)/C_{\pi K}(k^-)$  measures displacement  $\pi$  source relative to  $K$
- ◆ Fits include FSI

- ◆ Combined 1D Gaussian fits in pair frame data give space-time displacement of  $-5.6 \pm 0.6$  fm
- ◆ Models give qualitative description

# PHENIX 2proton correlation

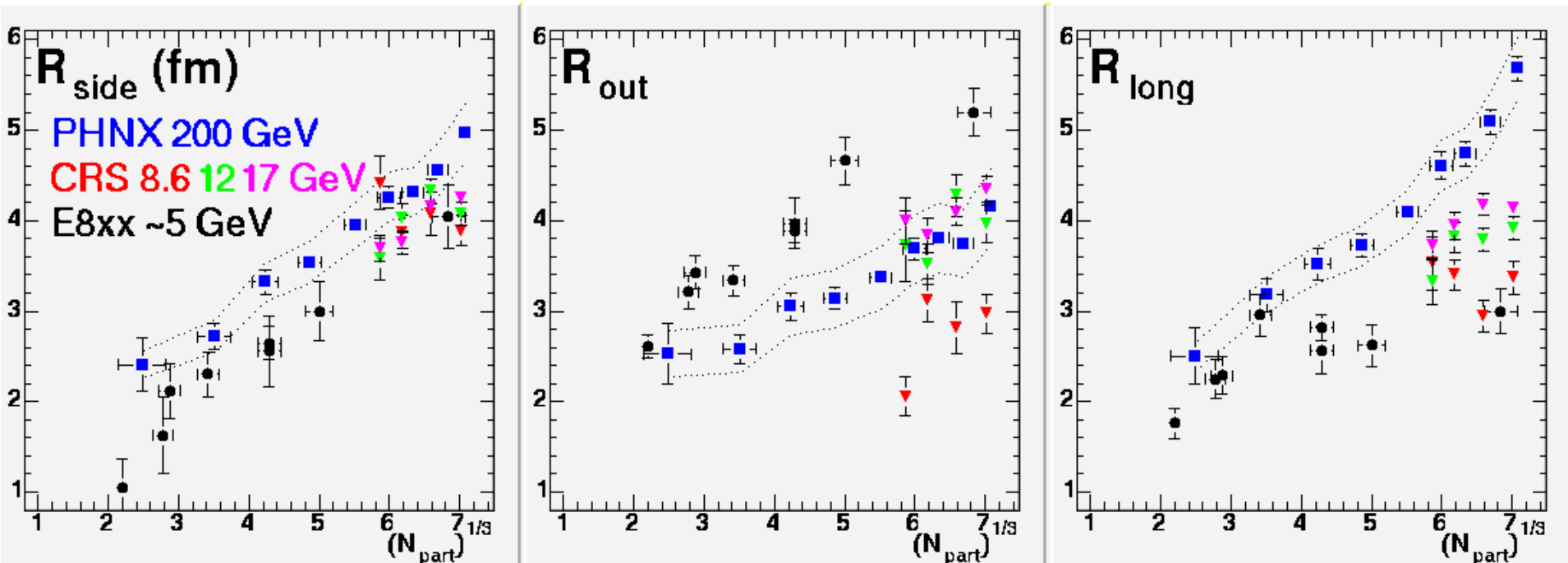
- ◆ Fit symmetrized wave functions



- ◆ Proton/Kaon sources consistent with  $m_T$  scaling

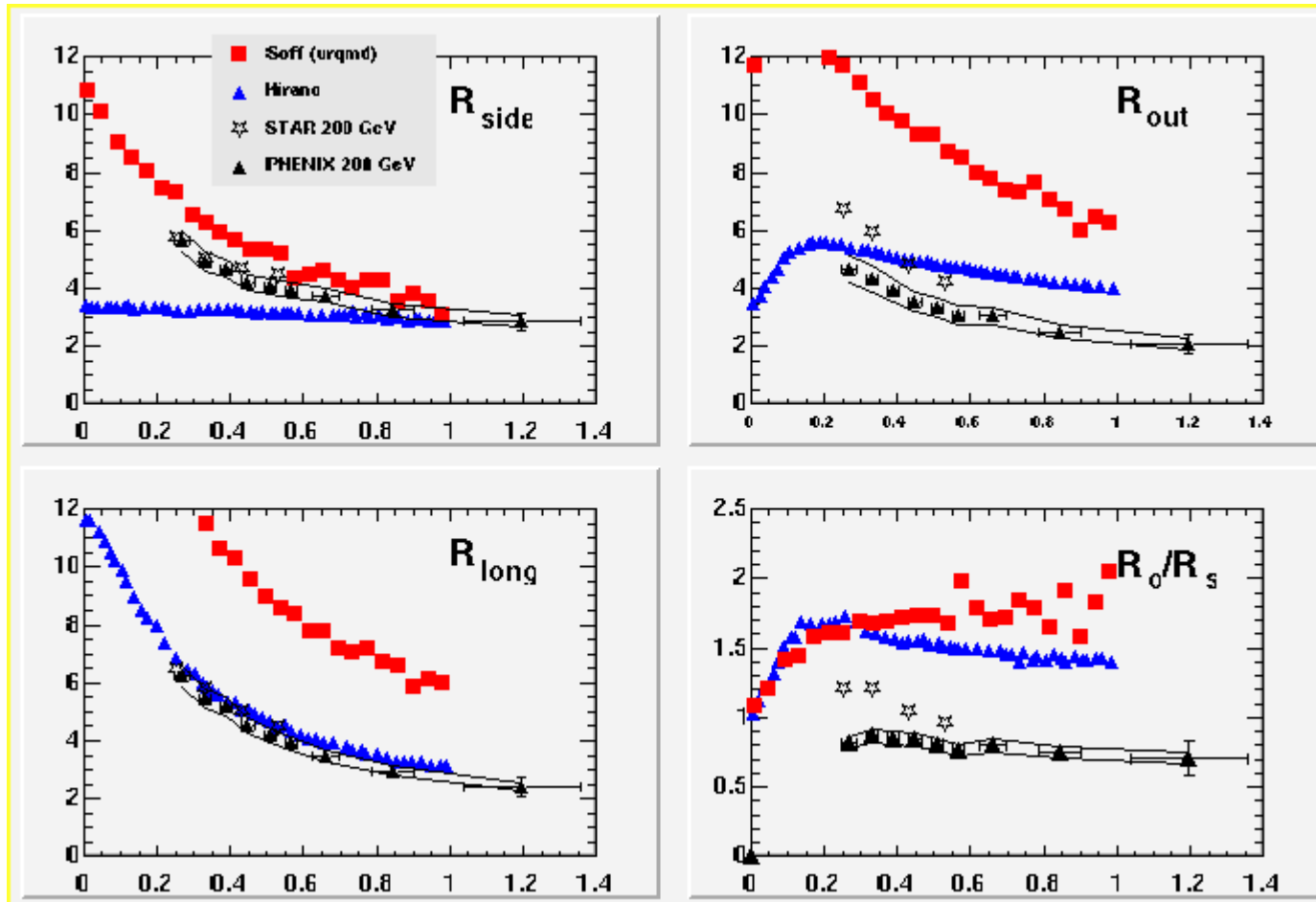
# Centrality Dependence

- ◆ 5 Energies, 3 experiments,  $k_T$  from 0.32-0.46 GeV/c



- ◆ Rapid increase in  $R_{long}$  at high energy
- ◆ Systematics fairly well constrained

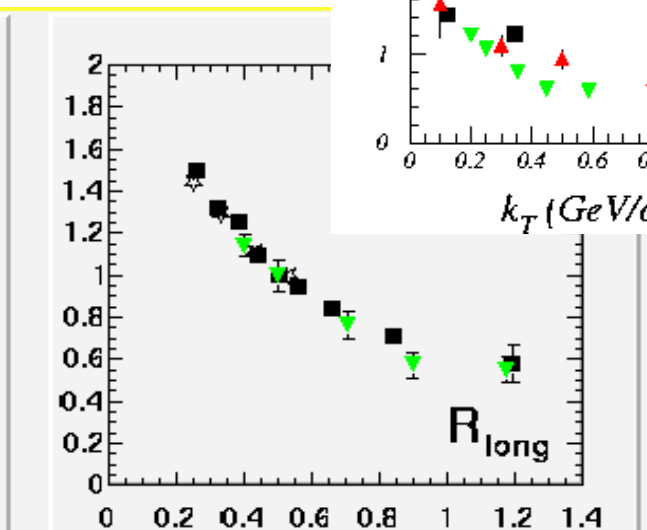
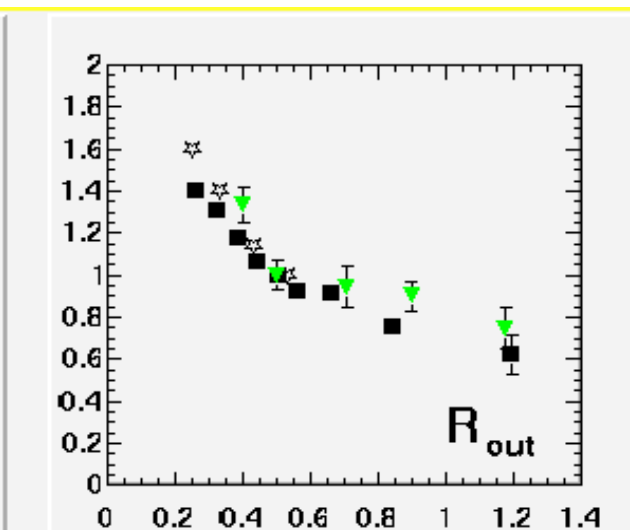
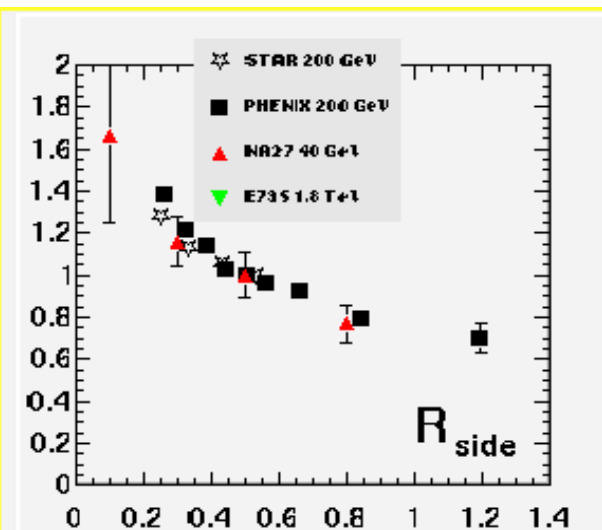
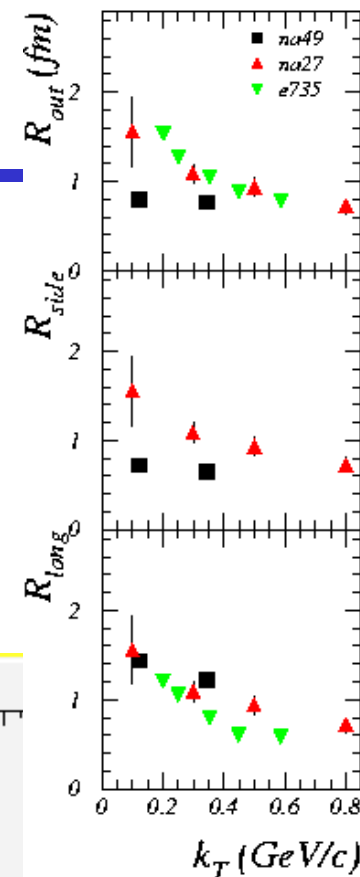
# Model Comparisons ... the HBT Puzzle



# Comparison to p-p collisions

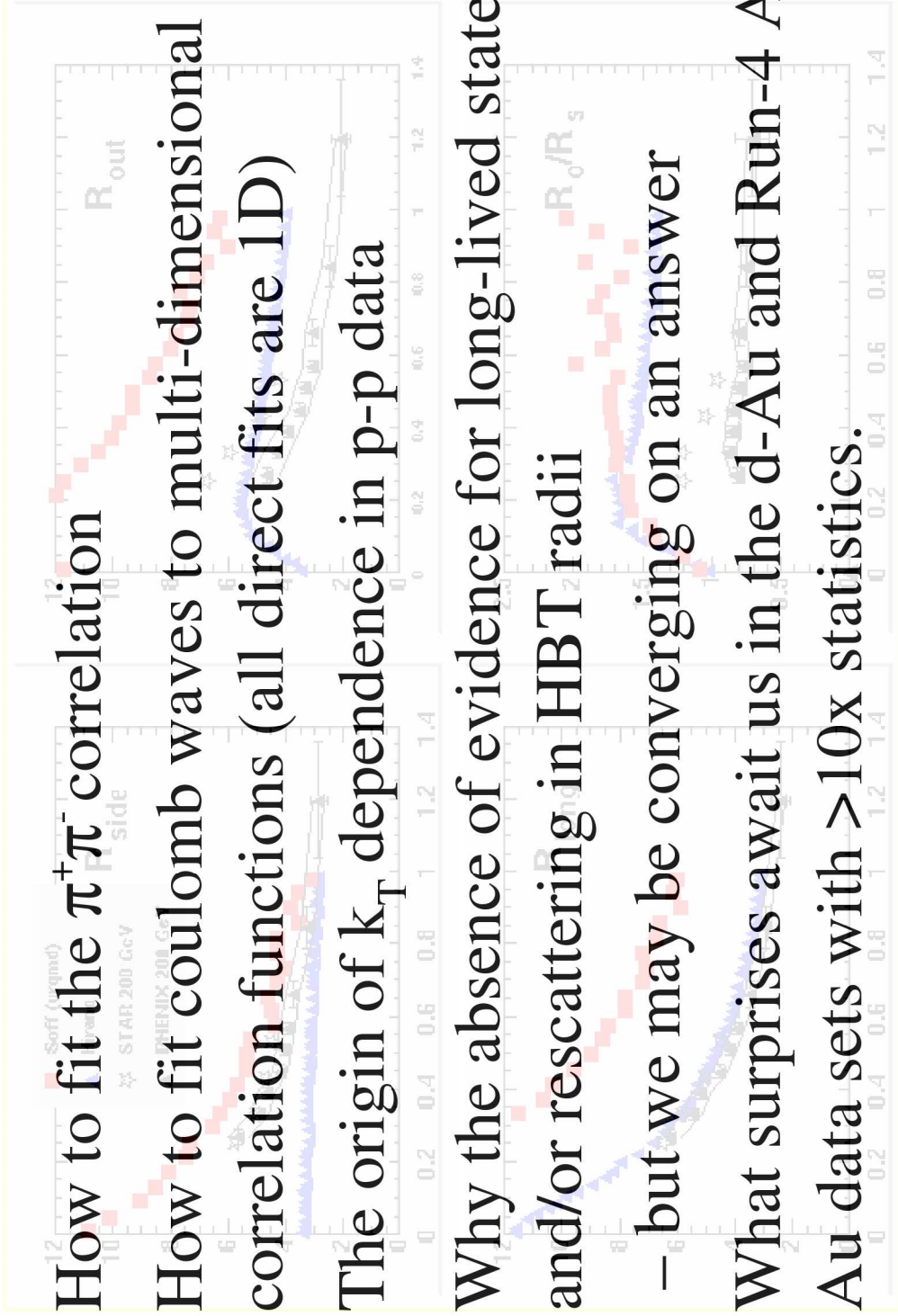
- ◆ PHENIX, STAR, E735 (2D), NA27 (1D)
- all radii normalized to unity at  $k_T=0.5$

- ◆ What is the origin of  $k_T$  dependence in p-p?
- ◆ Need a modern, high statistics analysis.



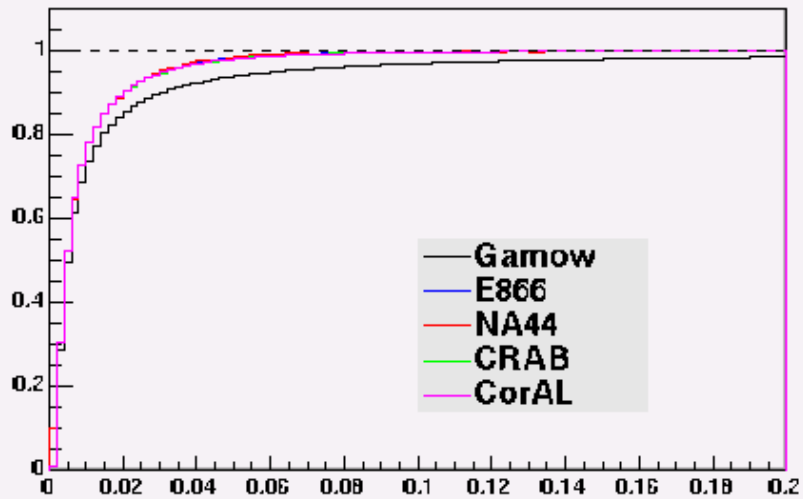
# What don't we know...

- How to fit the  $\pi^+\pi^-$  correlation
- How to fit coulomb waves to multi-dimensional correlation functions (all direct fits are 1D)
- The origin of  $k_T$  dependence in p-p data
- Why the absence of evidence for long-lived states and/or rescattering in HBT radii
  - but we may be converging on an answer
- What surprises await us in the d-Au and Run-4 Au-Au data sets with  $>10x$  statistics.



# Backup

5fm Qinv Coulomb Corrections (and Gamow)



Ratios to CorAL Coulomb

