Recent HBT results in Au+Au and p+p collisions from PHENIX at RHIC

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LLNL-PRES-411825

HBT nomenclature

$$C_2(\mathbf{q}) = A(\mathbf{q})/B(\mathbf{q}) = \frac{\text{Actual q distribution}}{\text{Background q distribution}} \qquad \mathbf{q} = \mathbf{p_1} - \mathbf{p_2}$$

$$= 1 + \int d\mathbf{r} K(\mathbf{q},\mathbf{r}) S(\mathbf{r})$$

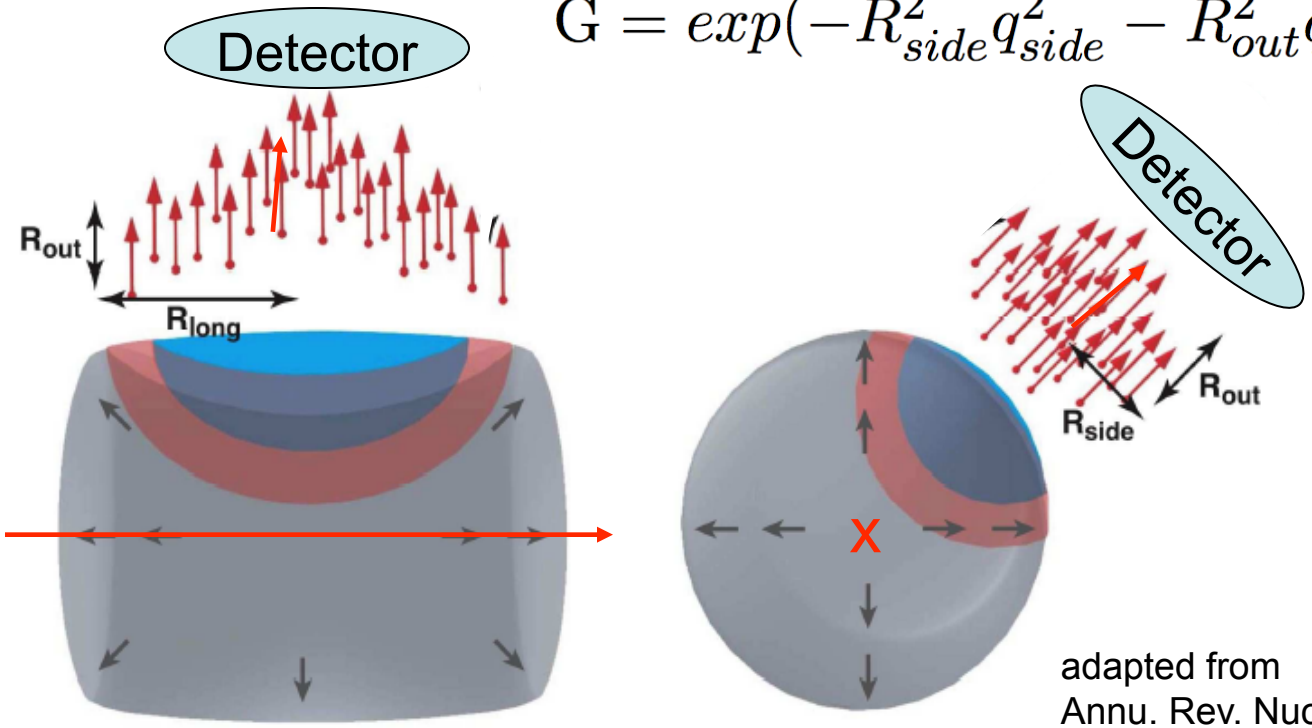
The source *S* can be directly recovered with imaging

or

$$= \lambda(1 + \mathrm{G})\mathrm{F_C} + 1 - \lambda$$

Make assumptions about the source

$$\mathrm{G} = exp(-R^2_{side}q^2_{side} - R^2_{out}q^2_{out} - R^2_{long}q^2_{long})$$



Simplified for identical particles

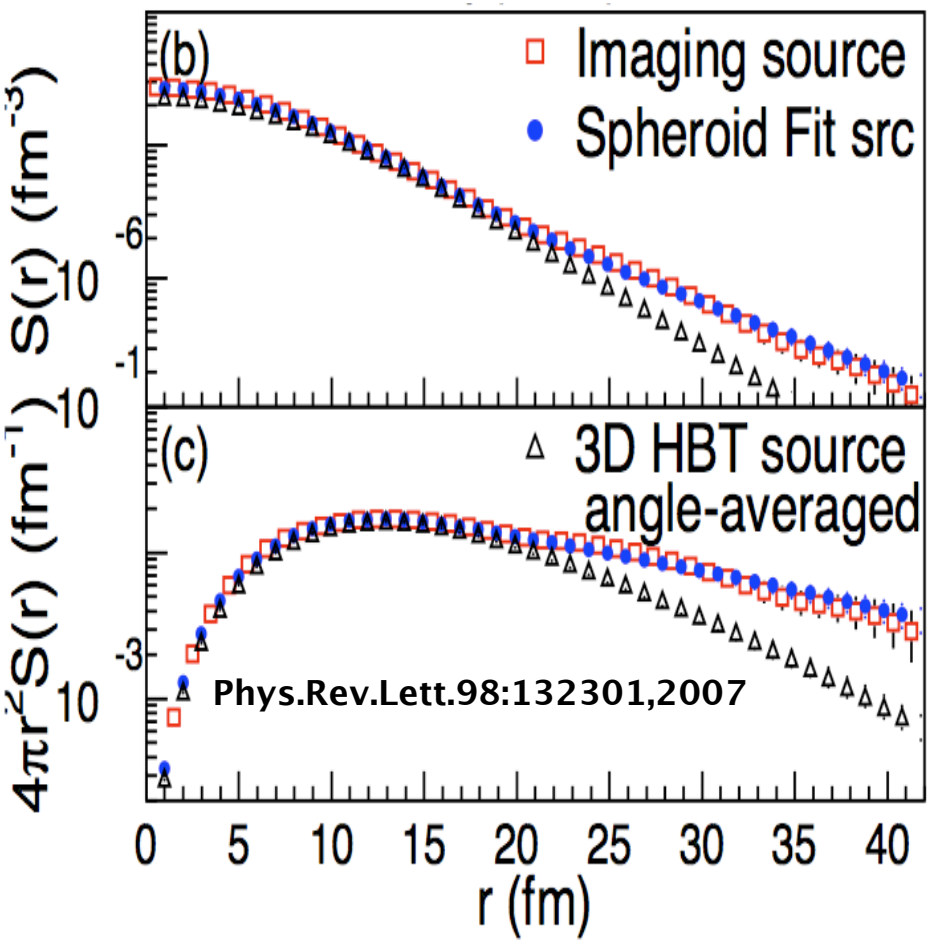
Bose-Einstein Enhancement at Low q

adapted from
Annu. Rev. Nucl. Part. Sci. 2005. 55:357–402

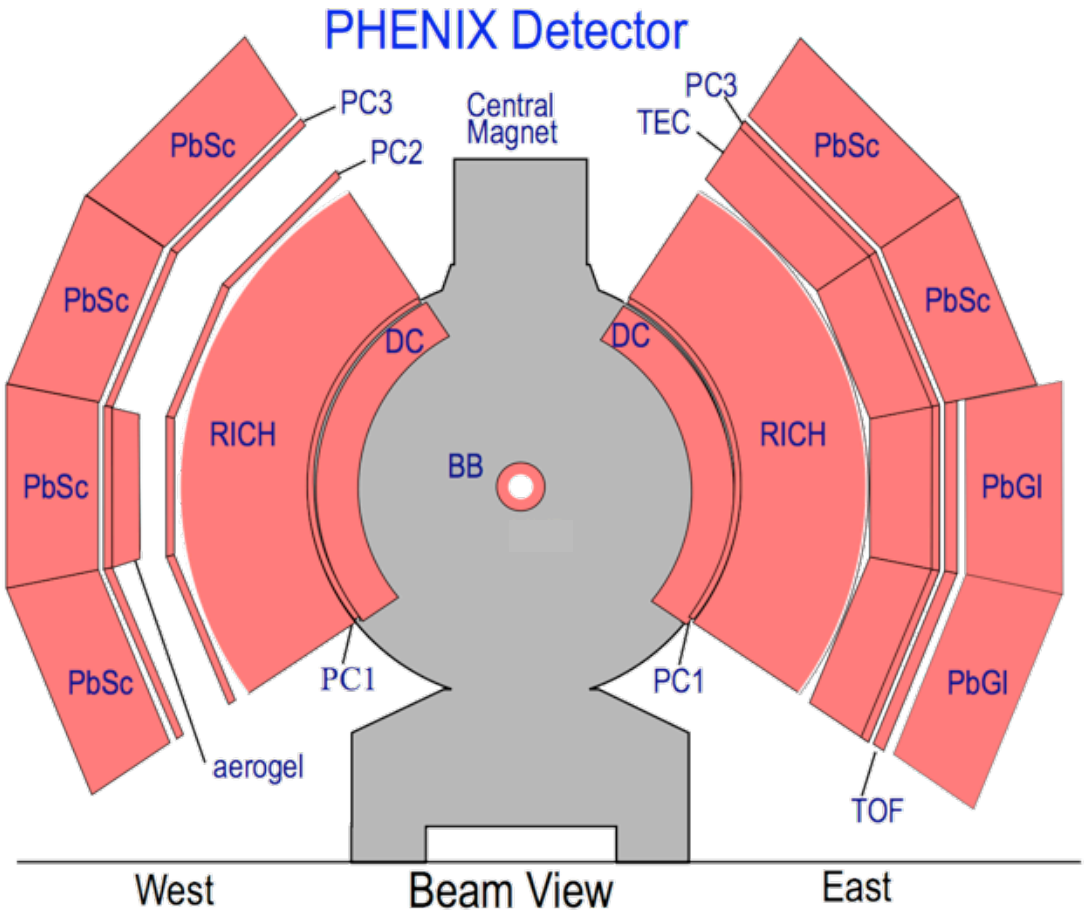
Why Kaons in Au+Au

- More constraints for theory
  - Help address the HBT puzzle
- Recall pion imaging (what is the tail?)
  - Long lived resonance?
  - Hadronic rescattering?
  - Both different for Kaons

Phys. Rev. Lett. 100, 232301 (2008)

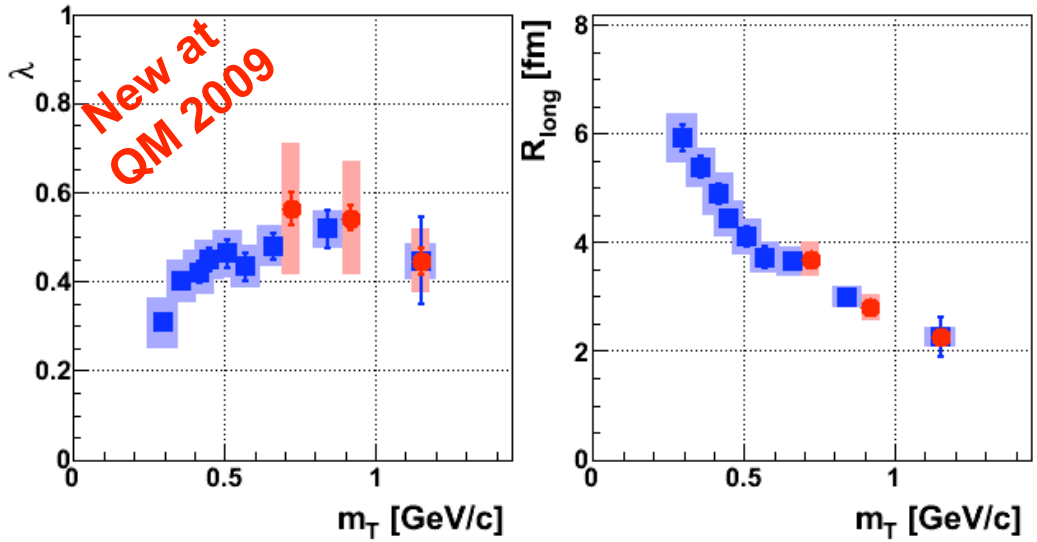


A few analysis details



- 600M events from Run4 Au+Au 200 GeV minimum biased dataset (~30M like sign Kaon pairs)
- Charged Kaons identified by time of flight from PbSc
- Matching cuts reduce backgrounds
- Pair selection cuts to remove merging and splitting
- Monte Carlo based corrections to extend into regions with reduced pair efficiency

Transverse mass scaling



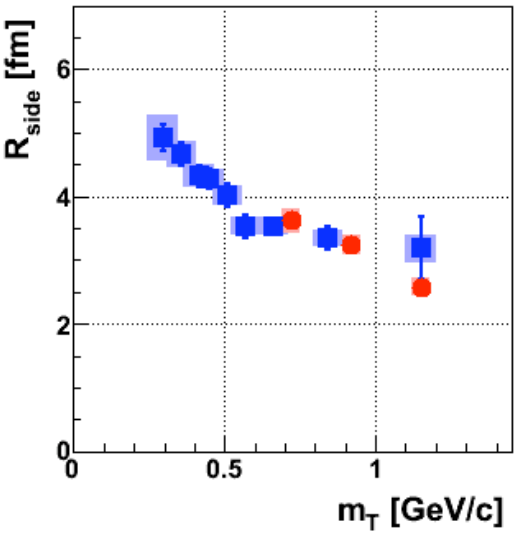
T. Csorgo and B.Lotstad
Phys.Rev.C54:1390-1403,1996

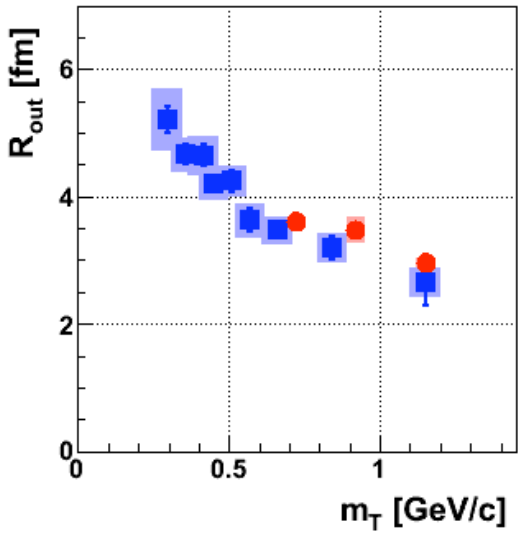
Au+Au $\sqrt{s_{NN}}$=200 GeV
0-30% Central
$K^+K^+ + K^-K^-$
$\pi^-\pi^-$ PRL 92 152302 (2004)

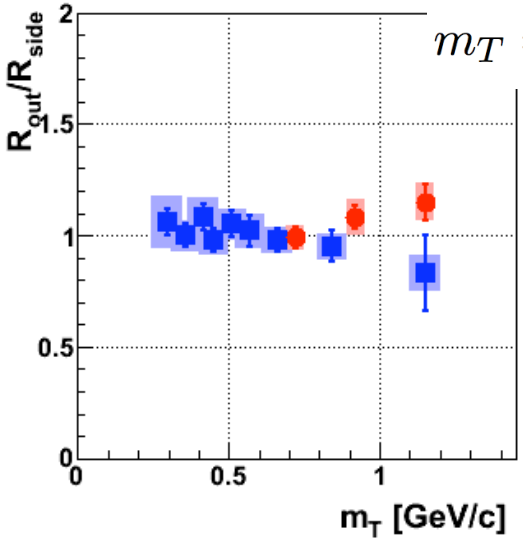
arXiv:0903.4863

$$k_T = (p_{1T} + p_{2T})/2$$

$$m_T = \sqrt{k_T^2 + m^2}$$

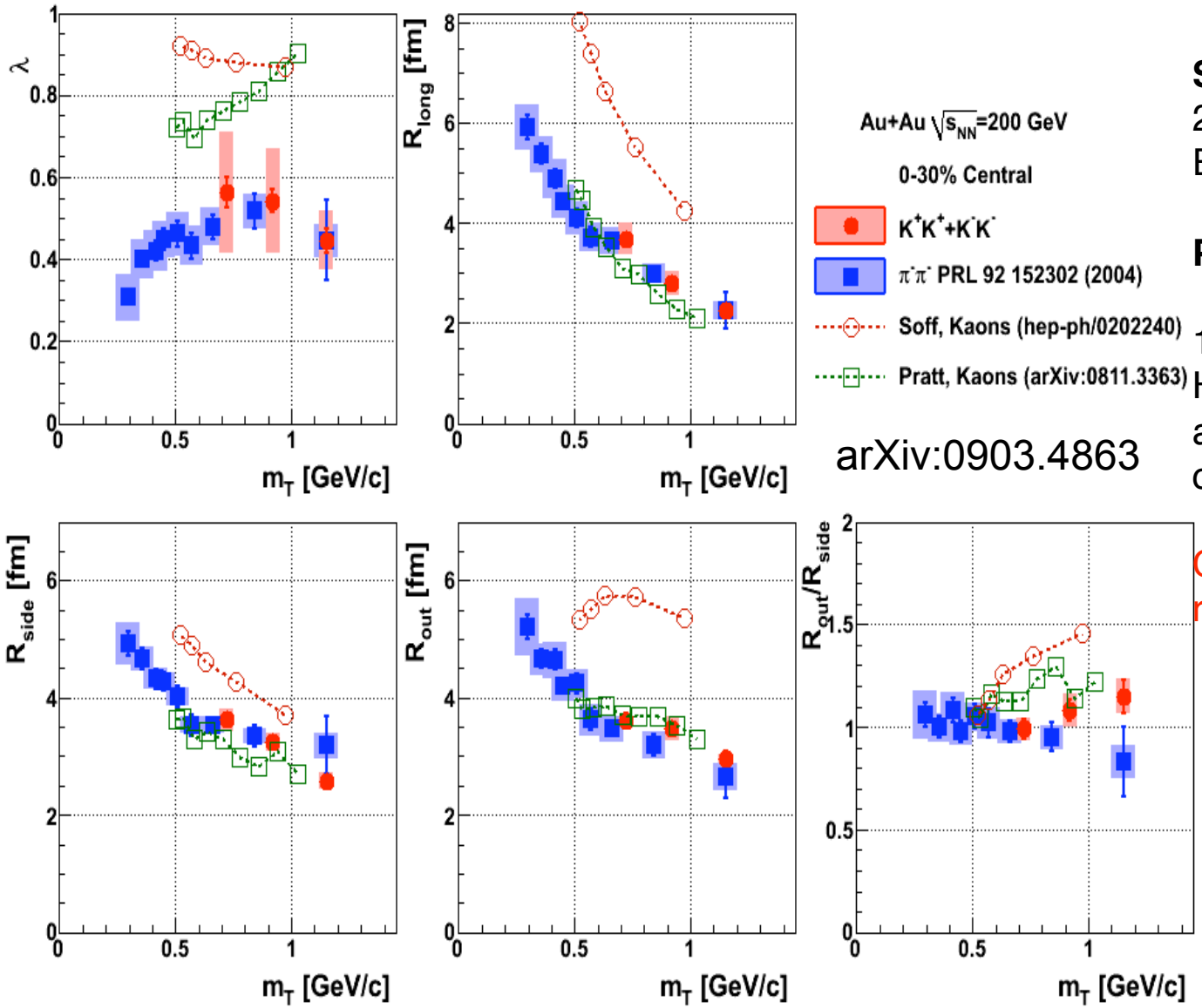






Follows same scaling curve as previous pion measurement

Some theory comparison



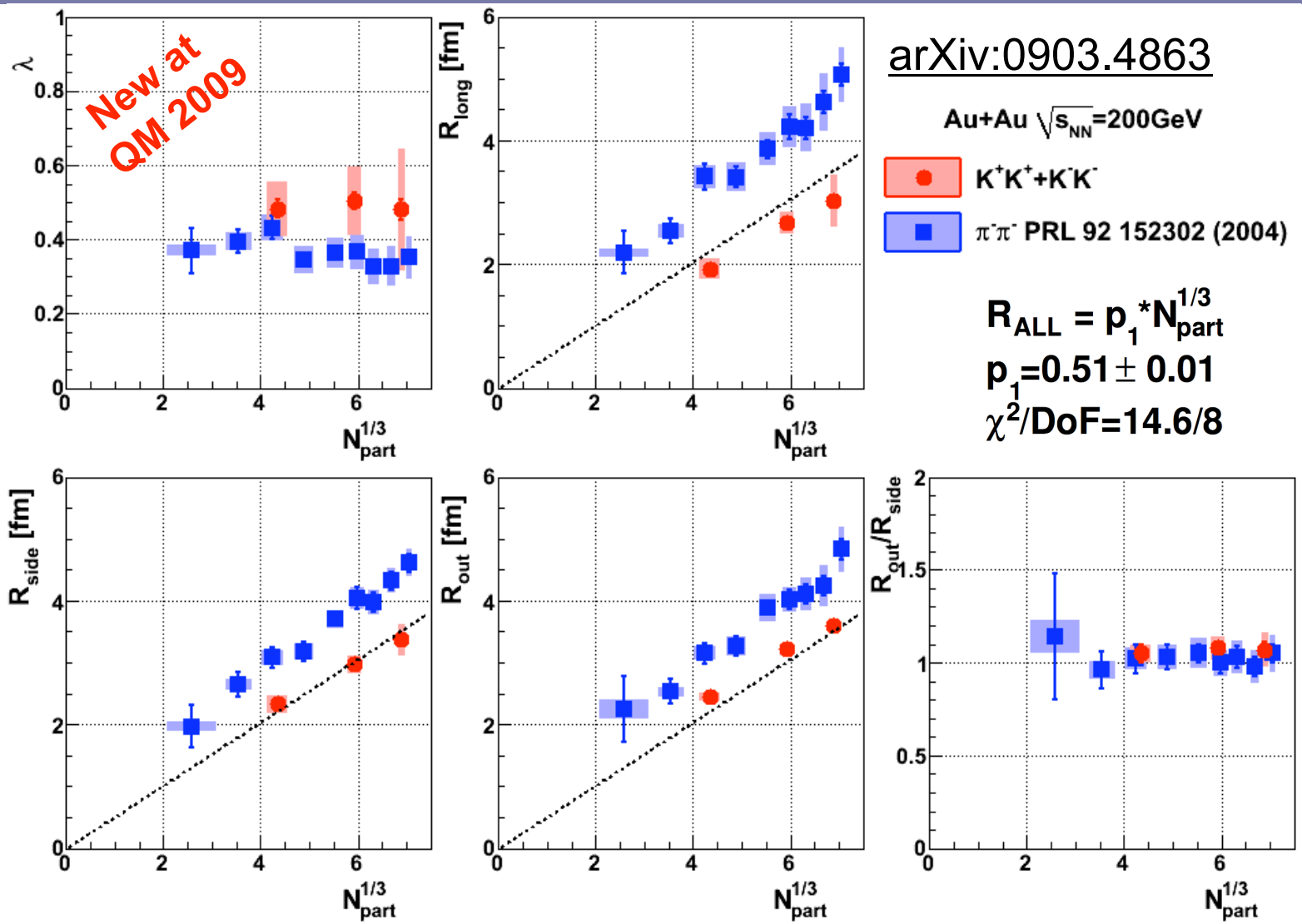
arXiv:0903.4863

Soff hep-ph/0202240:
2D+1 hydrodynamic+UrQMD
Example of "HBT puzzle"

Pratt nucl-th/0811.3363 +private communication:
1D+1 hydro+cascade.
Has pre-equilibrium flow and lattice inspired equation of state. Not tuned to Kaons.

Can 3D+1 implementation reproduce elliptic flow?

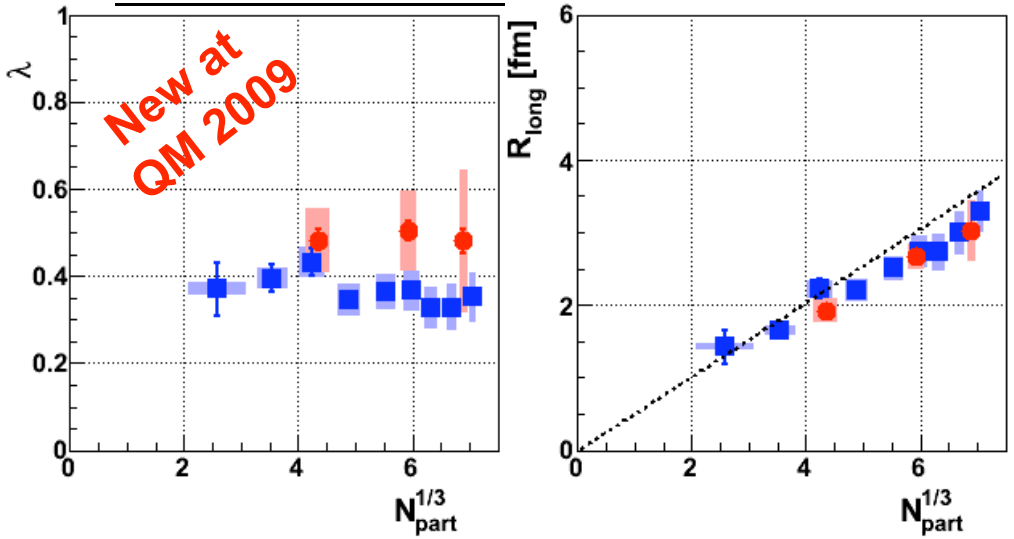
Centrality Dependence



Similar slope as pions, agrees well with linear extrapolation R=0 for N_{part}=0

Compared to rescaled pions

arXiv:0903.4863



$F_\pi(m_T=\langle m_T\rangle_K)/F_\pi(m_T=\langle m_T\rangle_\pi)$

$\langle m_T\rangle_\pi \sim 0.47$ GeV/c^2

$\langle m_T\rangle_K \sim 0.89$ GeV/c^2

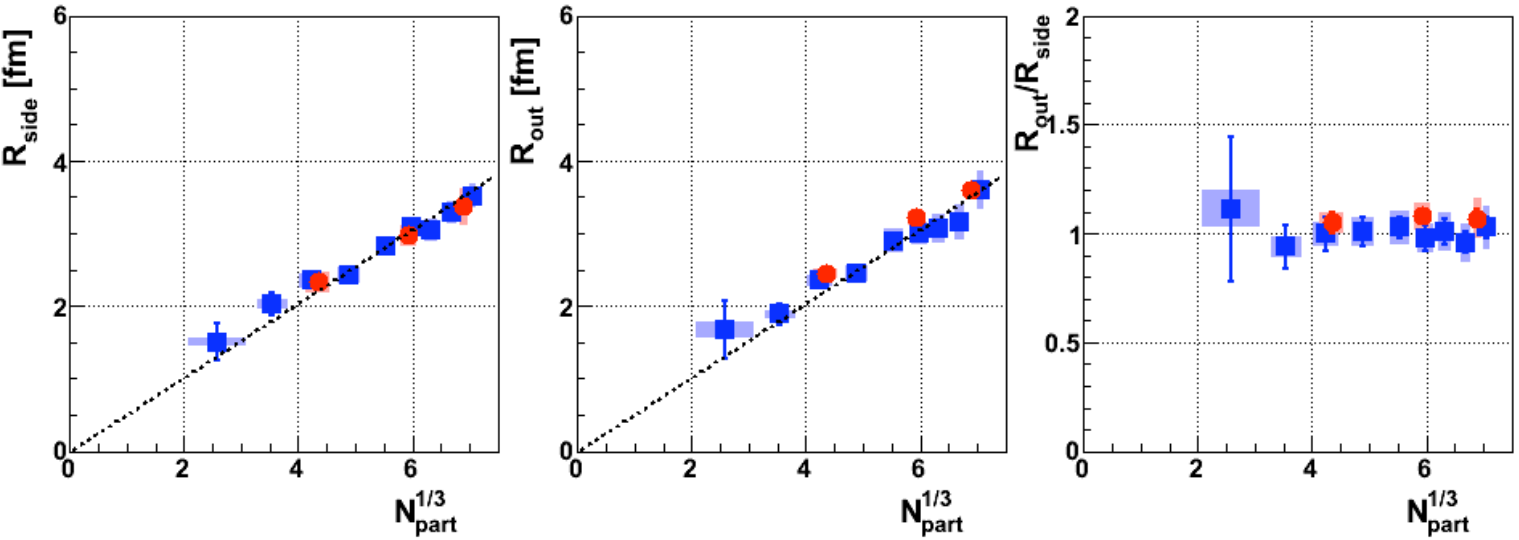
Au+Au $\sqrt{s_{NN}}$=200GeV

$K^+K^+ + K^-K^-$

$\pi^-\pi^-$ PRL 92 152302 (2004)

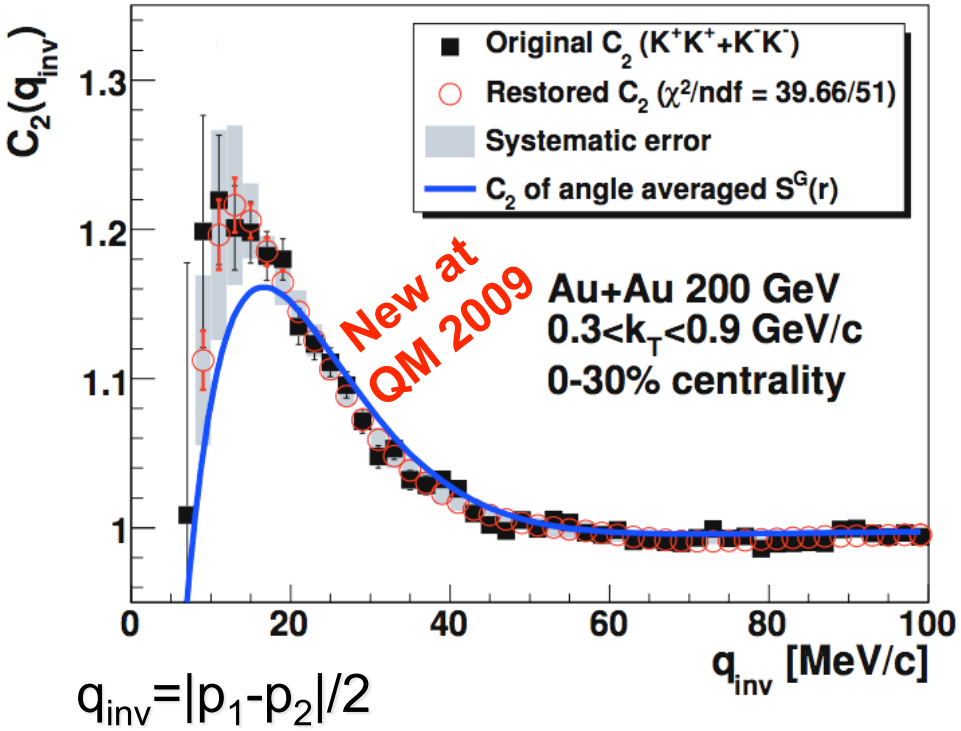
(Rescaled to $\langle m_T\rangle$ of KK)

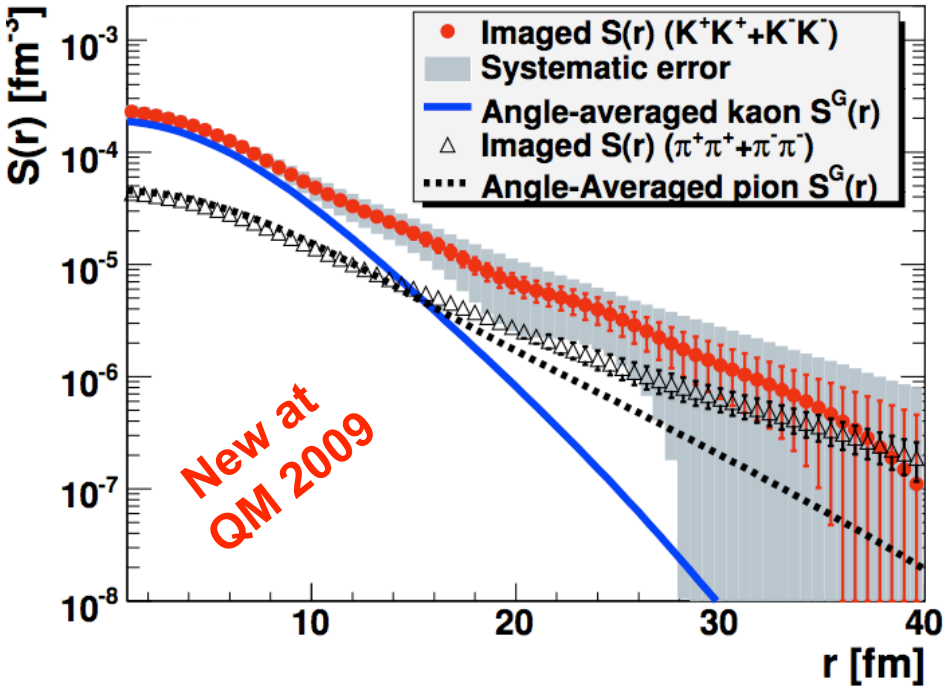
Consistent with previous pion measurement



Source Imaging

arXiv:0903.4863





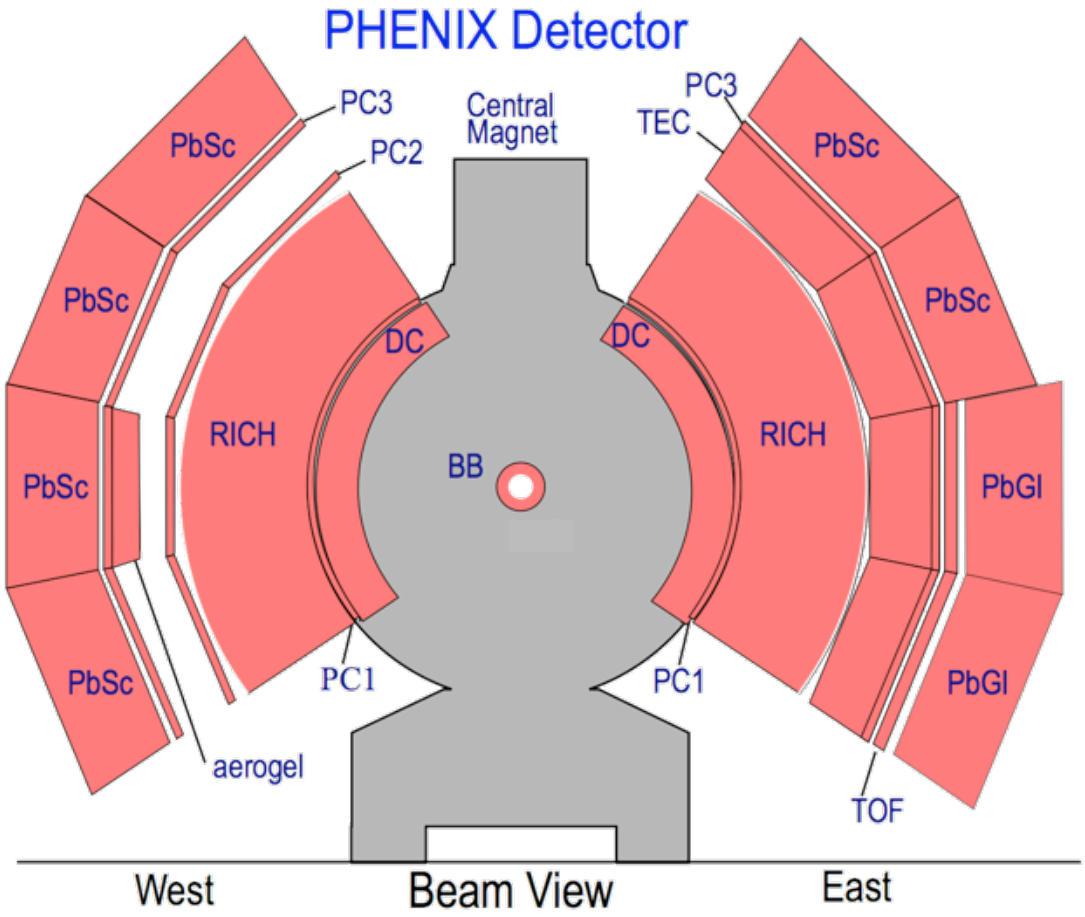
- Significant tail for r>10 fm for Kaon source
- Pion source is not only from long lived resonance (ω) decays
- Larger kaon tail consistent with hadronic resonance cascade models

M. Csanad, hep-ph/0702032, T. Csorgo, nucl-th/0512060298

Pions in p+p

- Baseline measurement
- Proving ground for understanding and dealing with non-HBT contamination
  - Event selection Phys.Rev.C78:064903,2008
  - Relative to jet
  - Multiplicity
  - …
- Capability likely needed for future heavy ion analyses relative to jet axis…

A few analysis details



- Run5 p+p minimum biased (~2.5M like sign pion pairs)

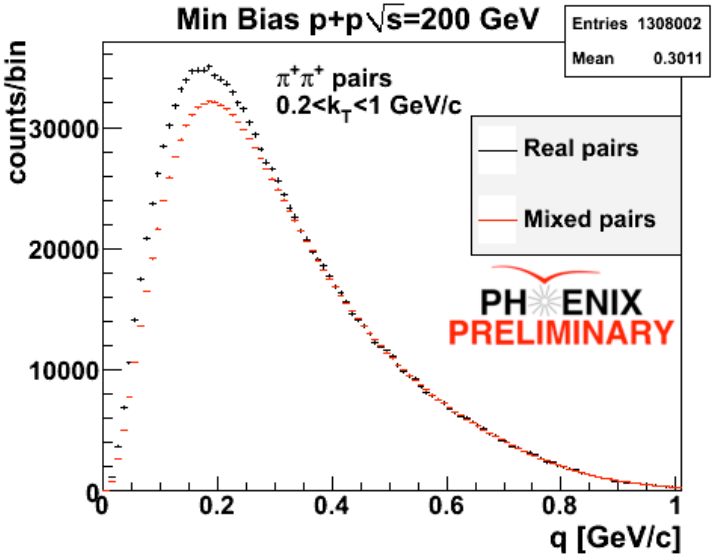
- Charged pions identified by time of flight from West PbSc

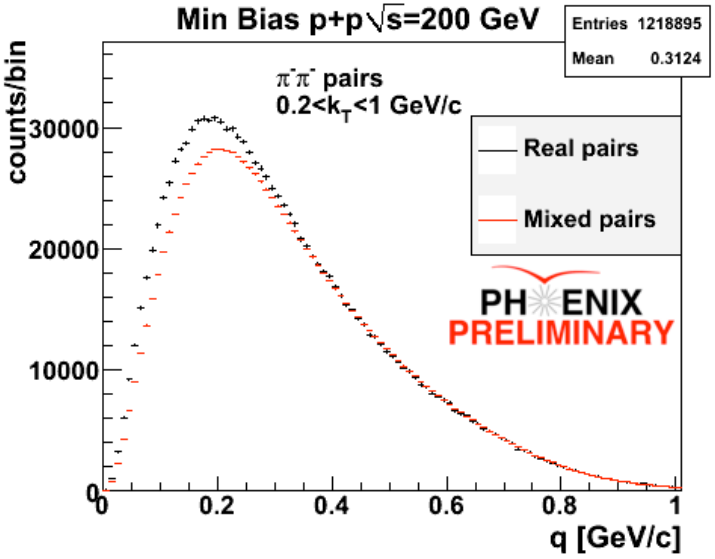
- Matching cuts reduce backgrounds

- Pair selection cuts to remove merging and splitting

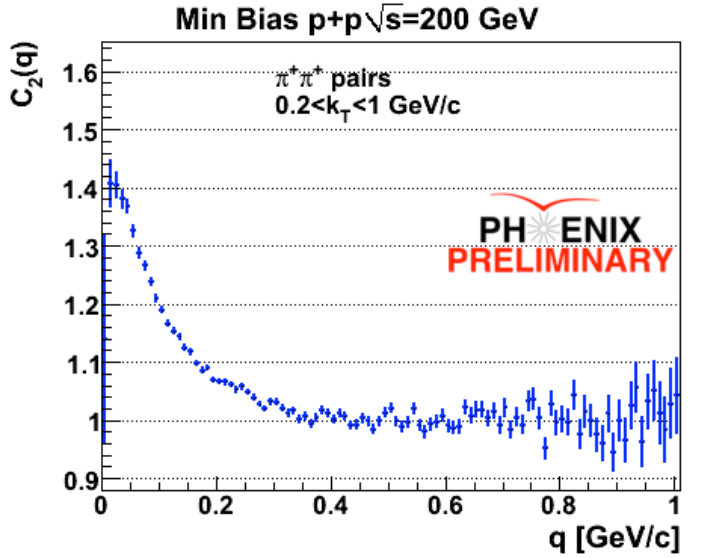
- No Monte Carlo based corrections so more selective pair cuts

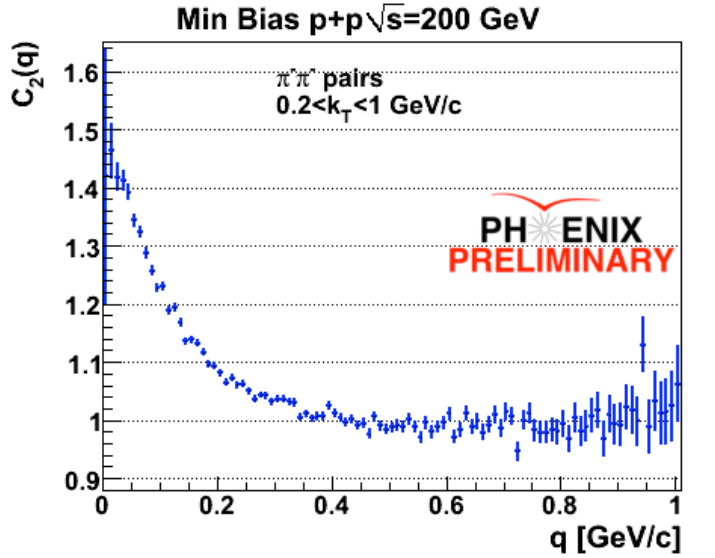
1-D Correlations





New at QM 2009





Imaging analysis in near future

Slices of 3-D Correlation

Bowler-Sinyukov: $C_2 = [\lambda(1+G)]F_c(q_{inv}) + [1+\lambda]$

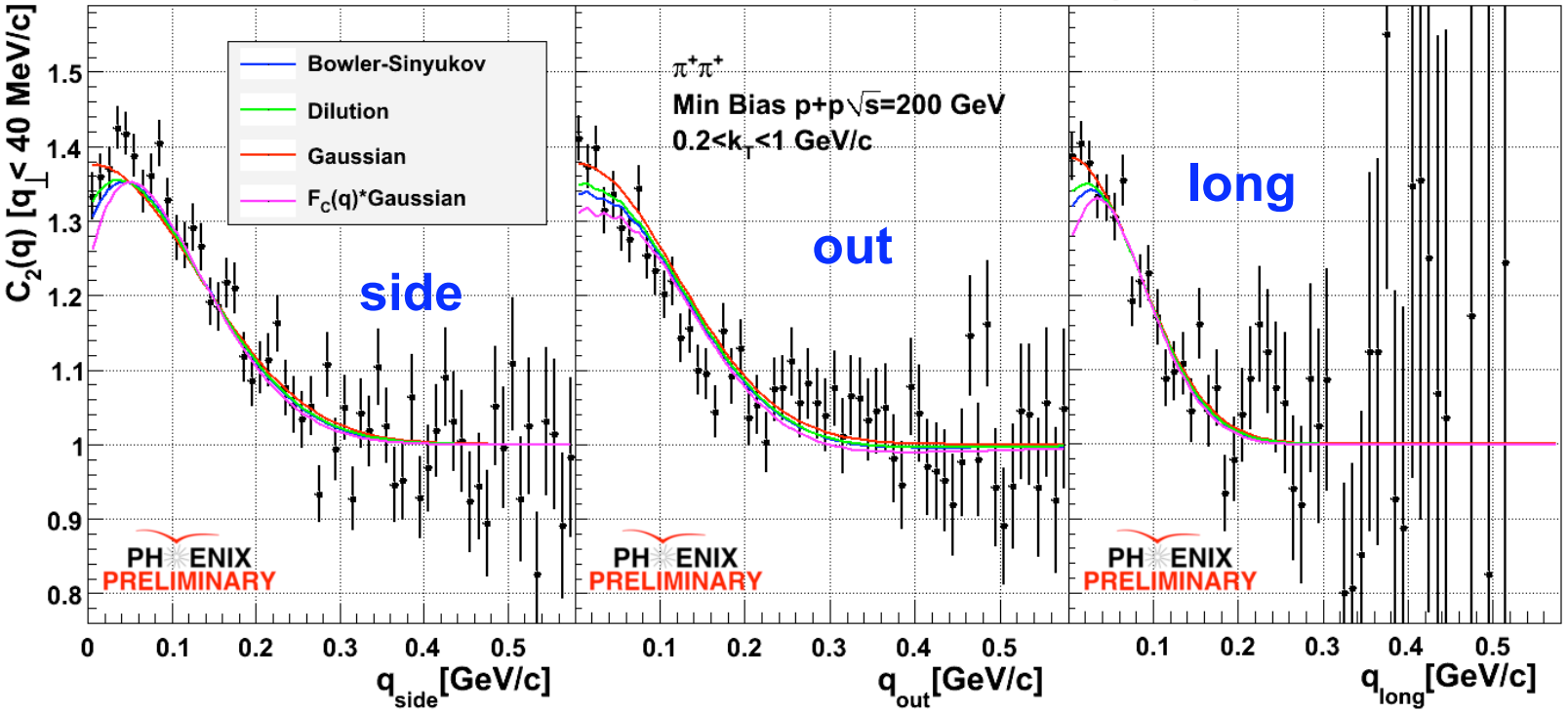
Dilution: $C_2 = [\lambda(1+\lambda G)]F_c(q_{inv}) + [1+\lambda]$

Coulomb corrected Gaussian: $C_2 = (1+\lambda G)F_c(q_{inv})$

Gaussian: $C_2 = 1+\lambda G$

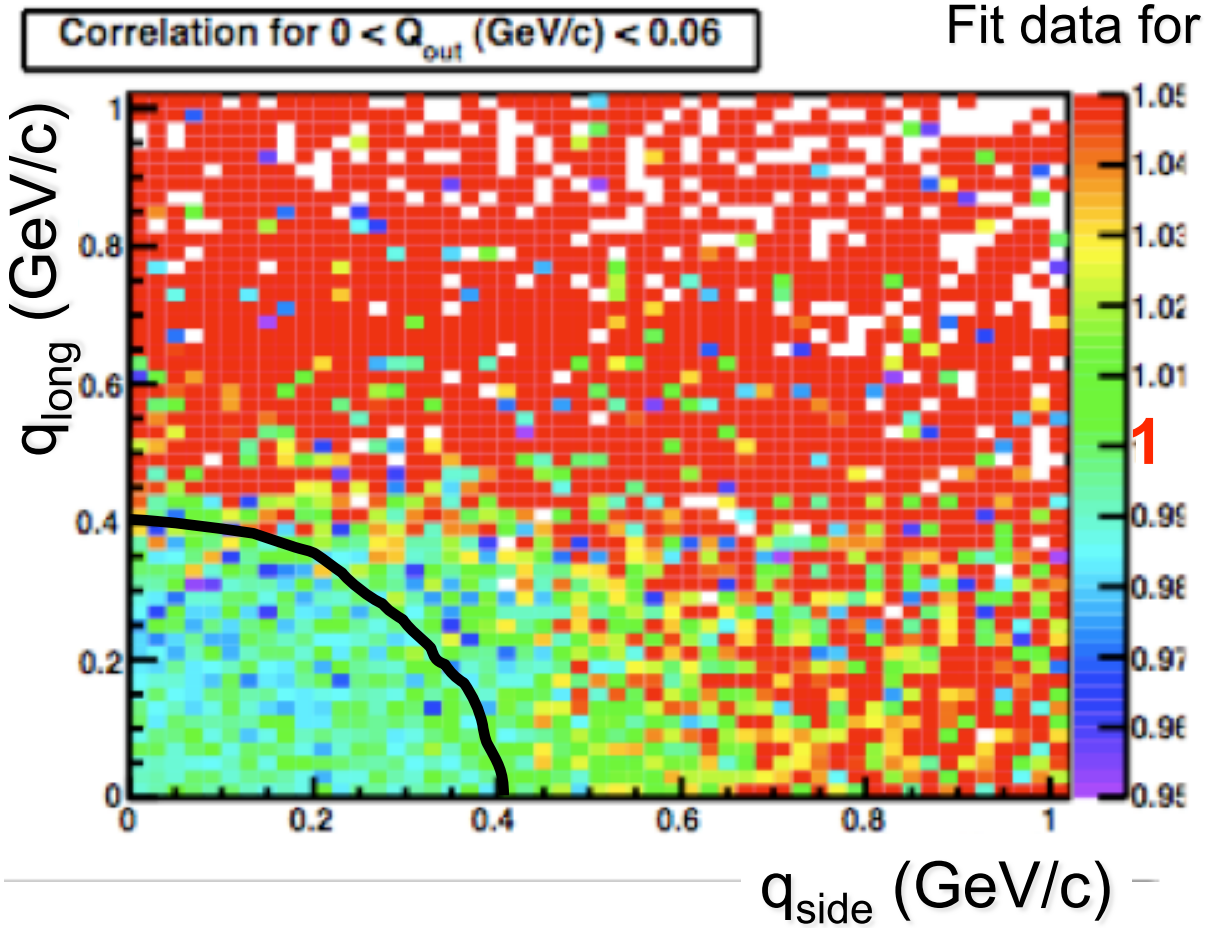
where $G = \exp(R_{side}^2 q_{side}^2 + R_{out}^2 q_{out}^2 + R_{long}^2 q_{long}^2)$

New at QM 2009



A few words on fitting

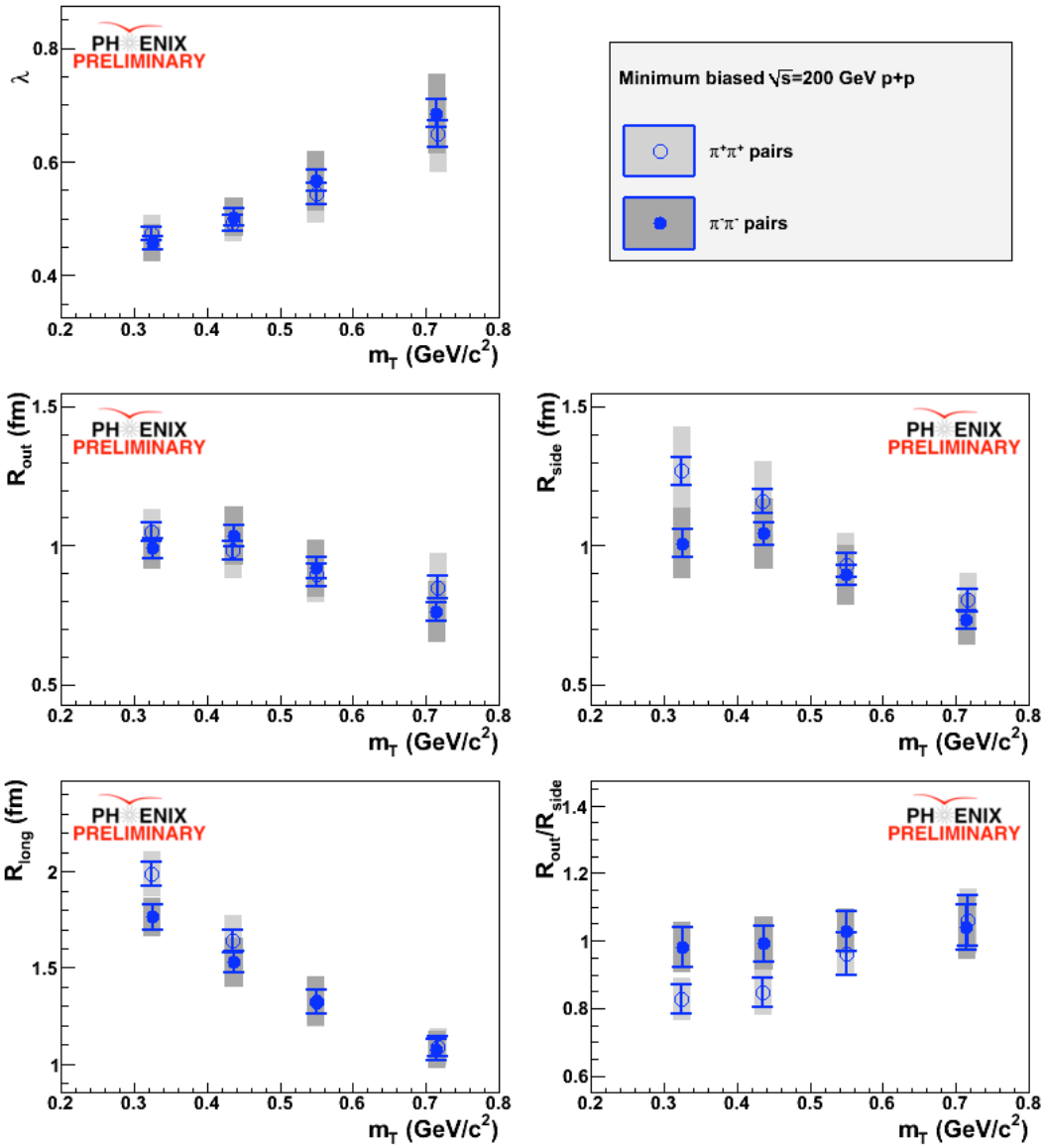
PYTHIA used as sanity check to limit fit range
and help minimize impact of non-HBT correlations



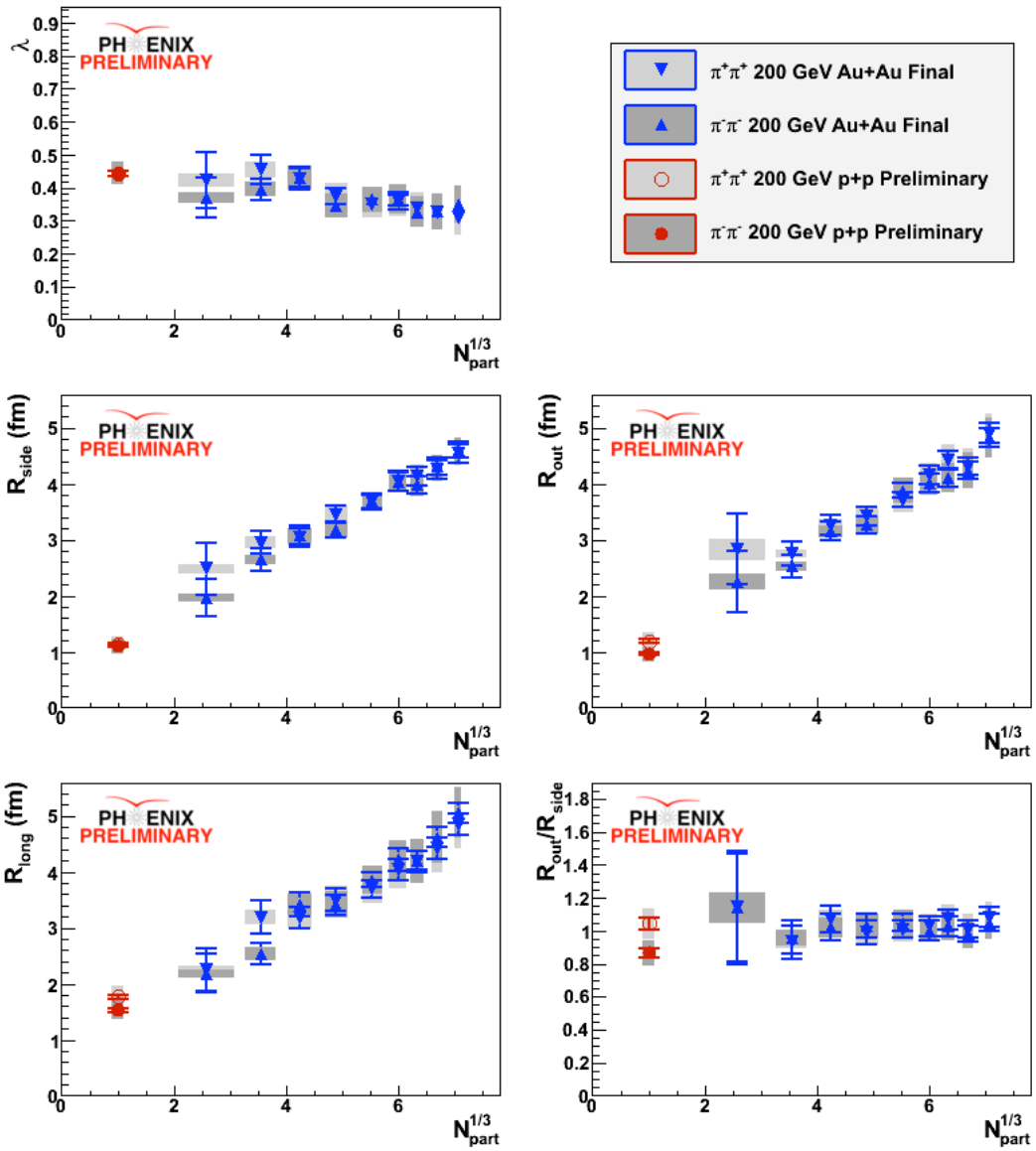
Fit data for $q_o^2+q_l^2+q_s^2<(0.4\text{GeV/c})^2$

one example of many slices

Transverse Mass Dependence



Au+Au Comparison

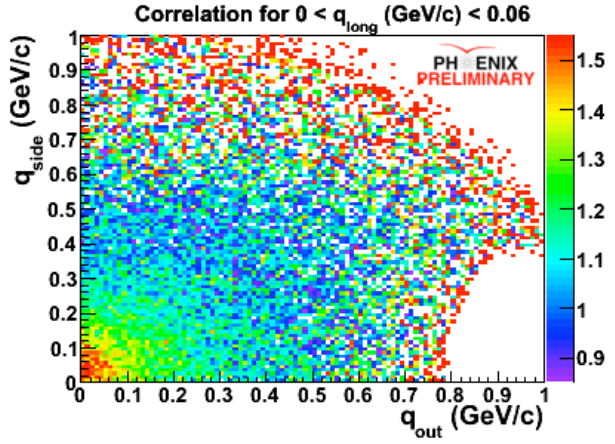


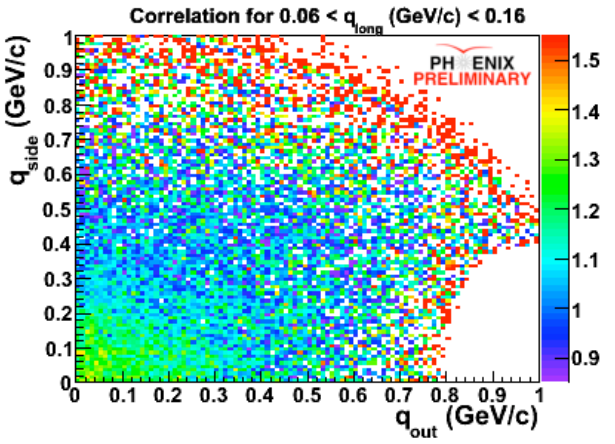
Summary for KK in Au+Au

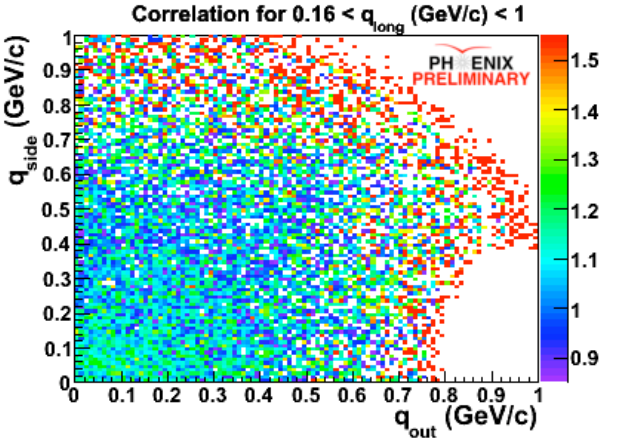
- Kaon m_T and m_T scaled centrality dependence looks same as pion.
- Kaon m_T dependence has linear trend consistent with R=0 at N_{part} =0
- Radii are in agreement with promising 1+1D+hydro+cascade with initial flow (not tuned to Kaons)
- Tail in imaged source for r>10fm
  - Tail in pions not just from resonances

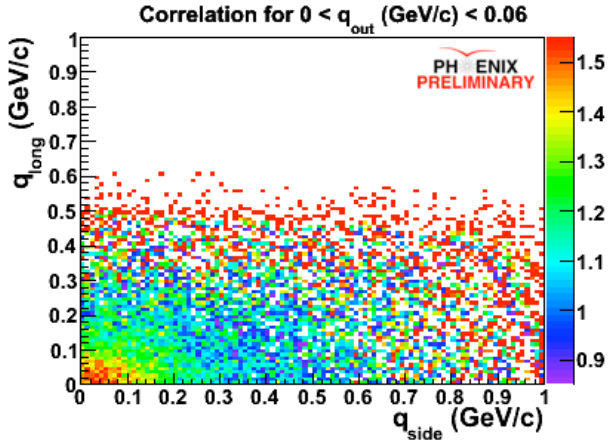
Summary for $\pi\pi$ in p+p

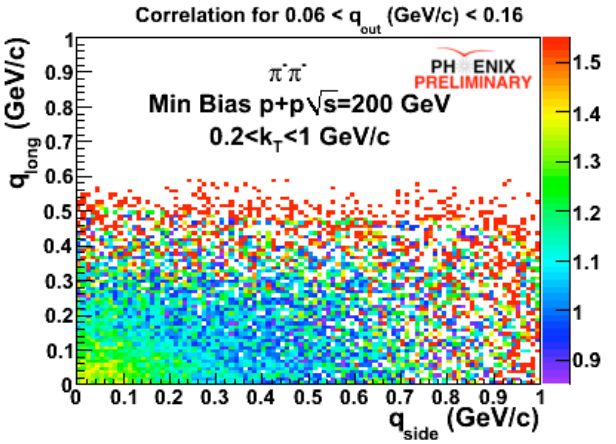
- Pion correlations in minimum biased collisions for PHENIX west arm acceptance do not appear to show energy momentum contamination within statistics.
- Measured radii consistent with centrality extrapolation from Au+Au
- Plenty still to look at (multiplicity dependence…)
- Jet selected events on the horizon (will need tools to deal with energy-momentum contamination)

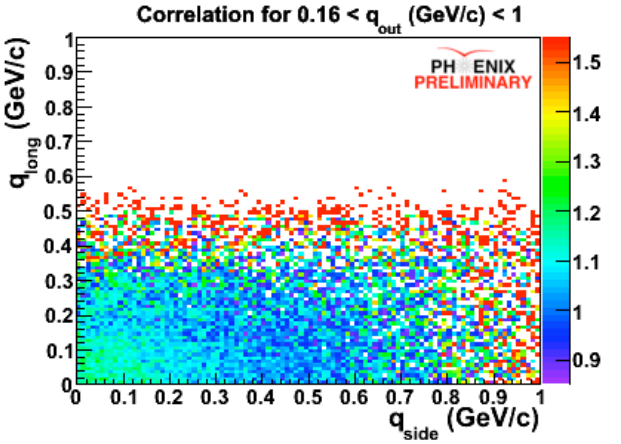

Correlation for 0 < q_long (GeV/c) < 0.06
PH ENIX
PRELIMINARY
q_side (GeV/c)
q_out (GeV/c)

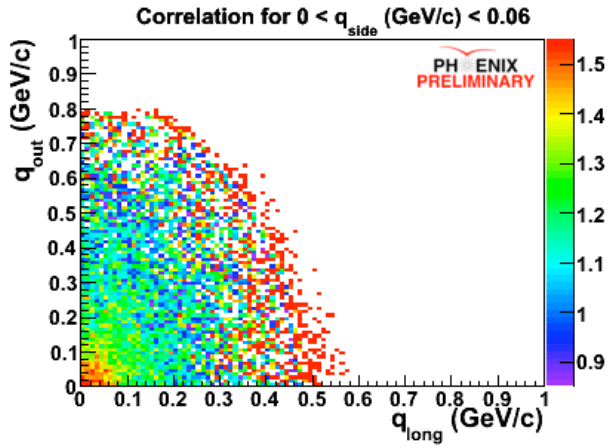

Correlation for 0.06 < q_long (GeV/c) < 0.16
PH ENIX
PRELIMINARY
q_side (GeV/c)
q_out (GeV/c)

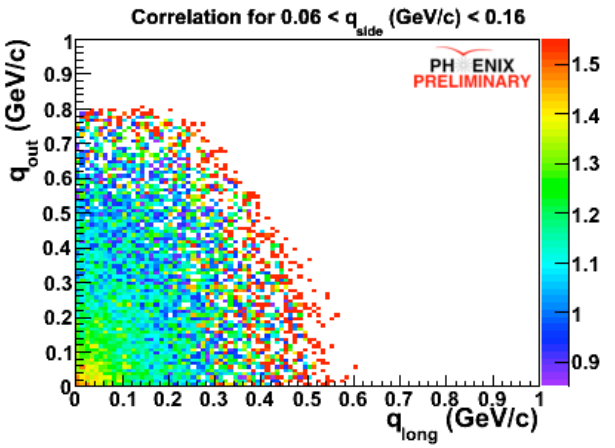

Correlation for 0.16 < q_long (GeV/c) < 1
PH ENIX
PRELIMINARY
q_side (GeV/c)
q_out (GeV/c)

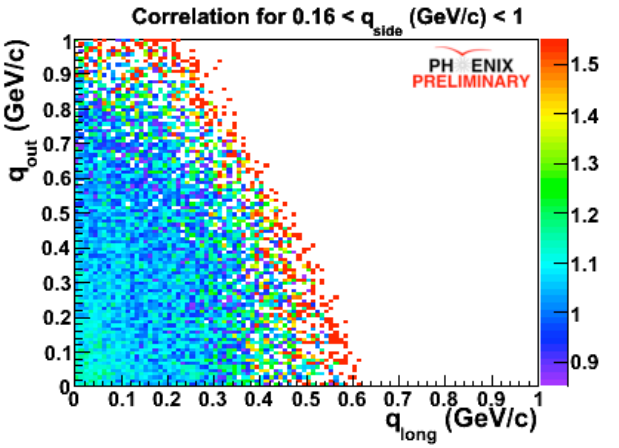

Correlation for 0 < q_out (GeV/c) < 0.06
PH ENIX
PRELIMINARY
q_long (GeV/c)
q_side (GeV/c)

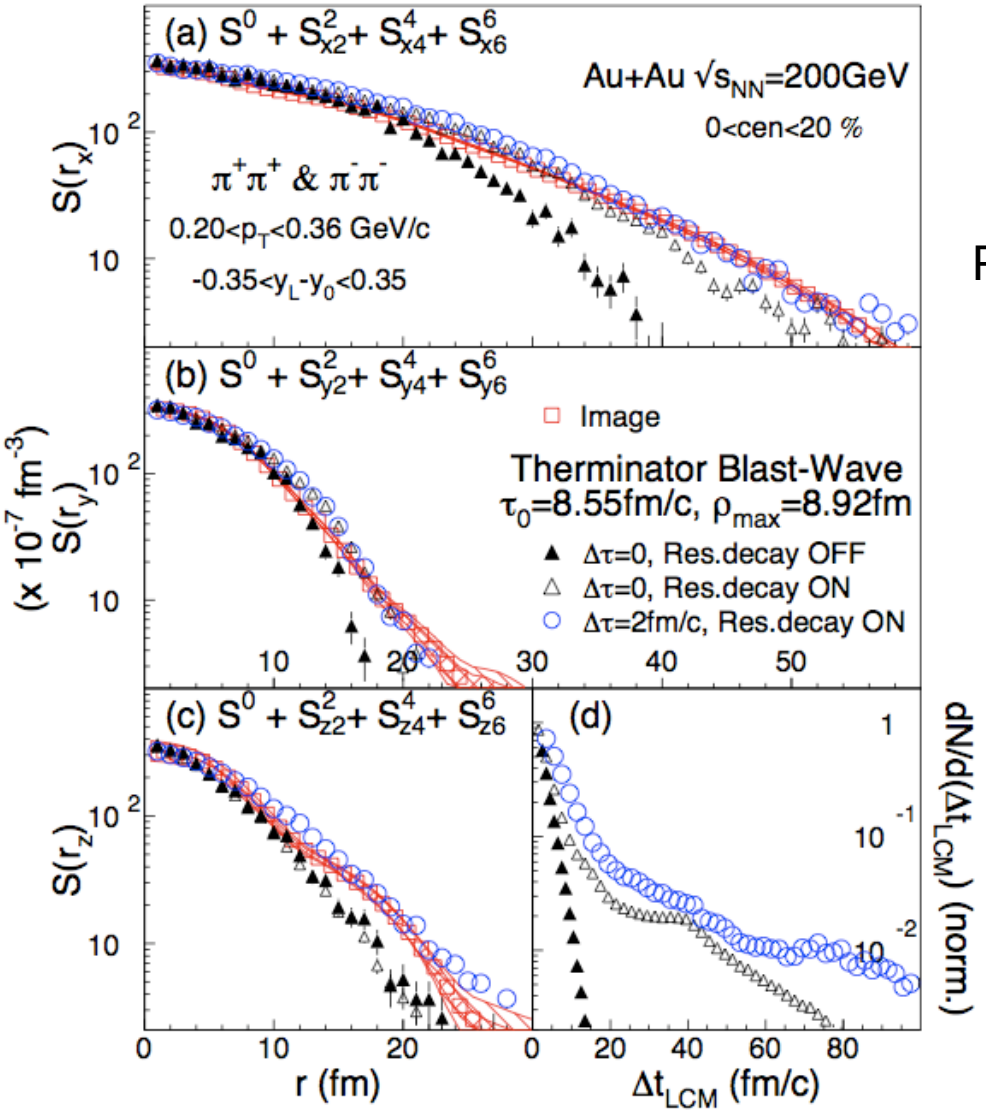

Correlation for 0.06 < q_out (GeV/c) < 0.16
π⁻π⁻
Min Bias p+p√s=200 GeV
0.2<k_T<1 GeV/c
PH ENIX
PRELIMINARY
q_long (GeV/c)
q_side (GeV/c)


Correlation for 0.16 < q_out (GeV/c) < 1
PH ENIX
PRELIMINARY
q_long (GeV/c)
q_side (GeV/c)


Correlation for 0 < q_side (GeV/c) < 0.06
PH ENIX
PRELIMINARY
q_out (GeV/c)
q_long (GeV/c)


Correlation for 0.06 < q_side (GeV/c) < 0.16
PH ENIX
PRELIMINARY
q_out (GeV/c)
q_long (GeV/c)

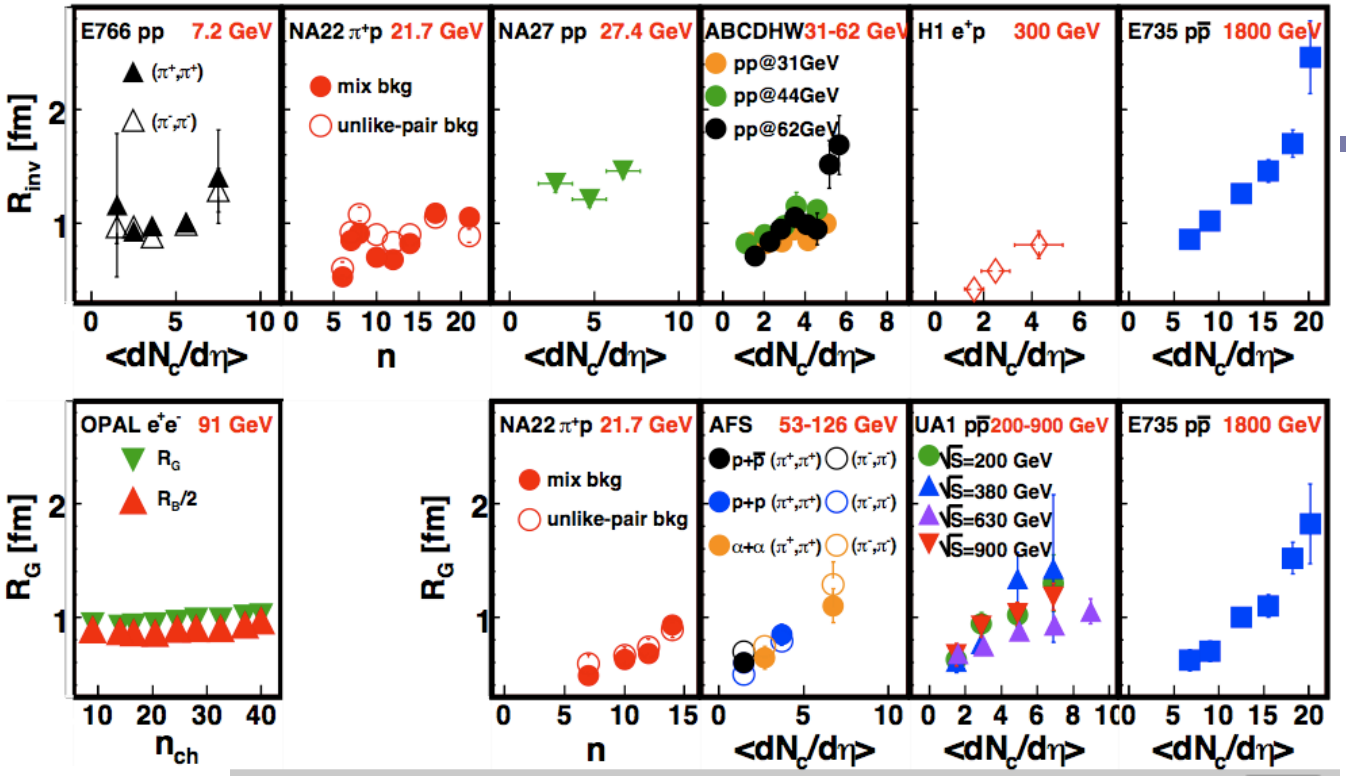

Correlation for 0.16 < q_side (GeV/c) < 1
PH ENIX
PRELIMINARY
q_out (GeV/c)
q_long (GeV/c)

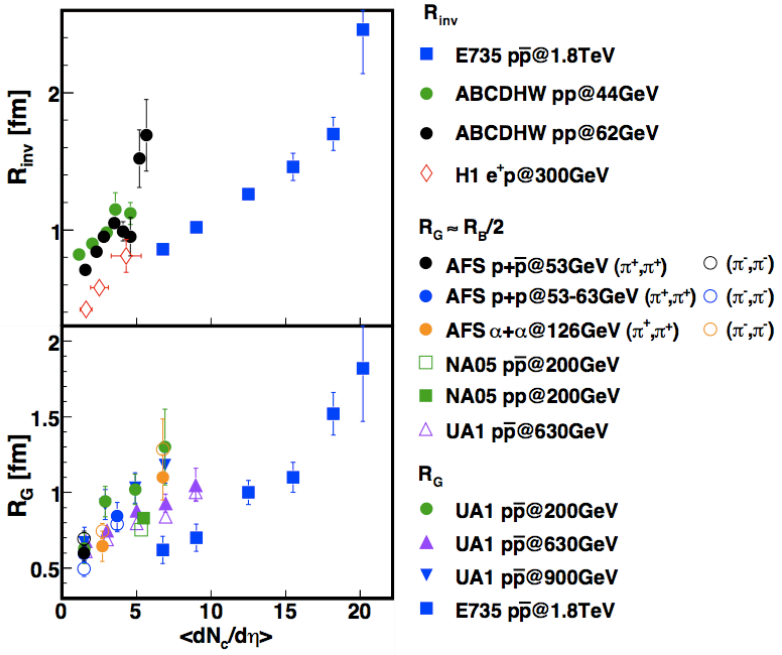


Phys. Rev. Lett. 100, 232301 (2008)

p+p Teaser

- Minimum biased data shows no serious energy-momentum correlation contamination
- An early look at events with a reconstructed jet show this should be interesting.





arXiv:0901.4078