PHENIX Measurement of Charged Kaon Interferometry in Au+Au Collisions at $\sqrt{s_{NN}}$=200 GeV

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Physics interests in kaon HBT (Outline)

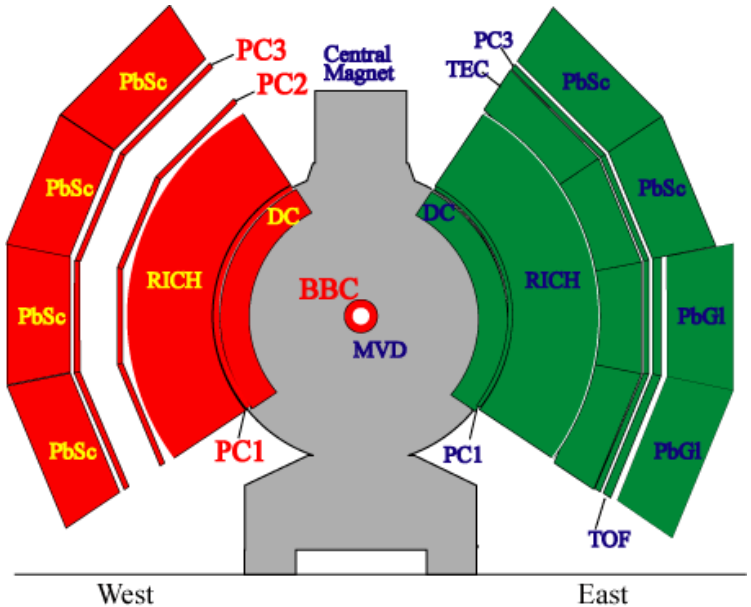
- Are there differences of HBT radii between pion and kaon?
  - Different x-p correlation, freezeout time? (different R_{side}, R_{long}?)
  - Different opacity to the outward direction? (larger R_{out} than that of pion?)
  - Measurements of kaon HBT radii and comparison with those of pion give us a detailed insight into a relation between source dynamics and HBT radii.

- How is it predicted by Hydrodynamics models?
  - An important step to get information to solve HBT-puzzle.

- Does kaon emission source function has "non-Gaussian" structure, which has been observed for pion 1-D HBT imaging?
  - We don't know where the non-Gaussian structure of pion source come from.

  (Core-halo structure due to long resonances? Just a kinetically oblong source?)
  - Kaon HBT-imaging analysis could clarify it.

Measurement of charged kaon pairs by PHENIX



- ✓ ~600M good events from PHENIX Run4 at Au+Au 200 GeV. ($|Z_{vertex}|<30$cm)
- ✓ Centrality is determined by BBC-ZDC correlation
- ✓ Charged hadrons tracks are reconstructed ed with DCH, EMCal, PC1,3. ($|\eta|<0.35$, $\Delta\phi=90°$)
- ✓ Charged hadrons within 2σ within kaon mass but 3σ away from pion and proton masses are identified as charged kaons. ($0.3<p<2.0$ GeV/c)

Total pair statistics : K^+K^+ ~15M, K^-K^- ~14M

(This talk shows results from K^+K^++K^-K^- of ~29M)

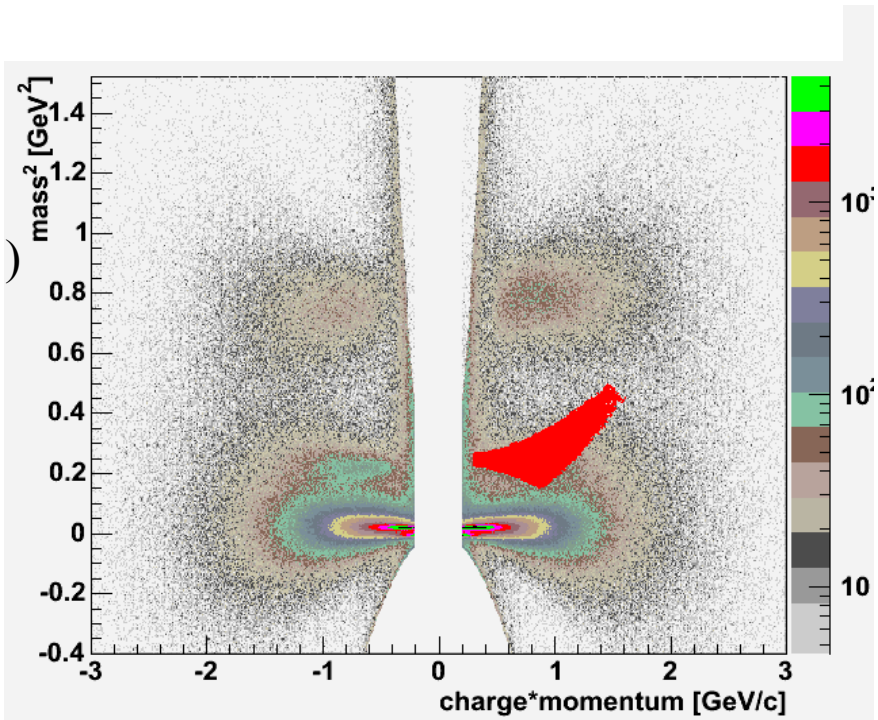
$$C_2(\vec{q}) = \frac{A_{signal}(\vec{q})}{B_{background}(\vec{q})}, \quad \vec{q} = \vec{p}_1 - \vec{p}_2$$

are measured for

k_T = 0.3-0.65, 0.65-0.9, 0.9-2.0 GeV/c

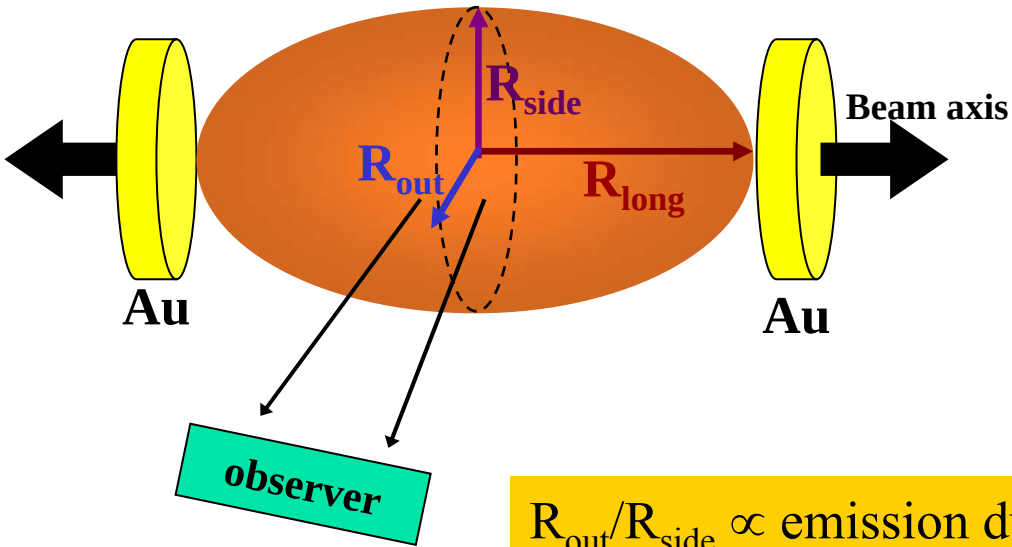
Centrality = 0-10, 10-20, 30-93%

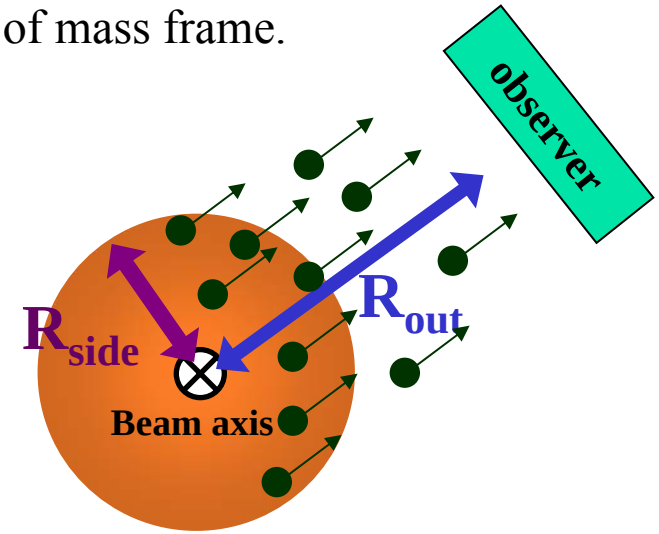
(Each has ~10M K^+K^++K^-K^- pairs.)



Reminder: Bertsch-Pratt parameterization

Assuming cylindrical source and longitudinally center of mass frame.



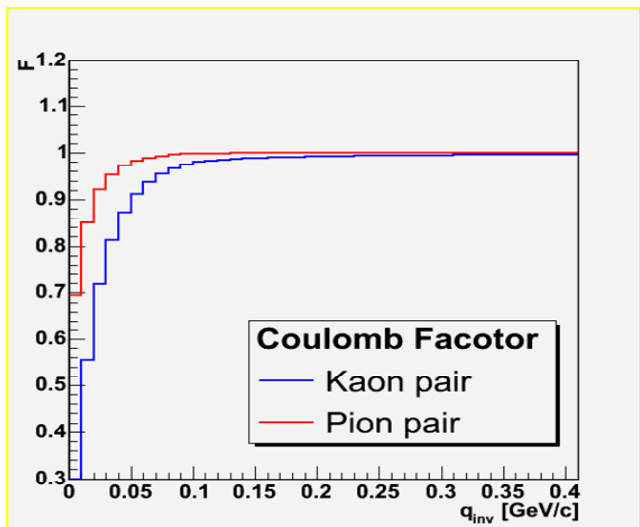


$R_{out}/R_{side} \propto$ emission duration, source opacity, kinetics…

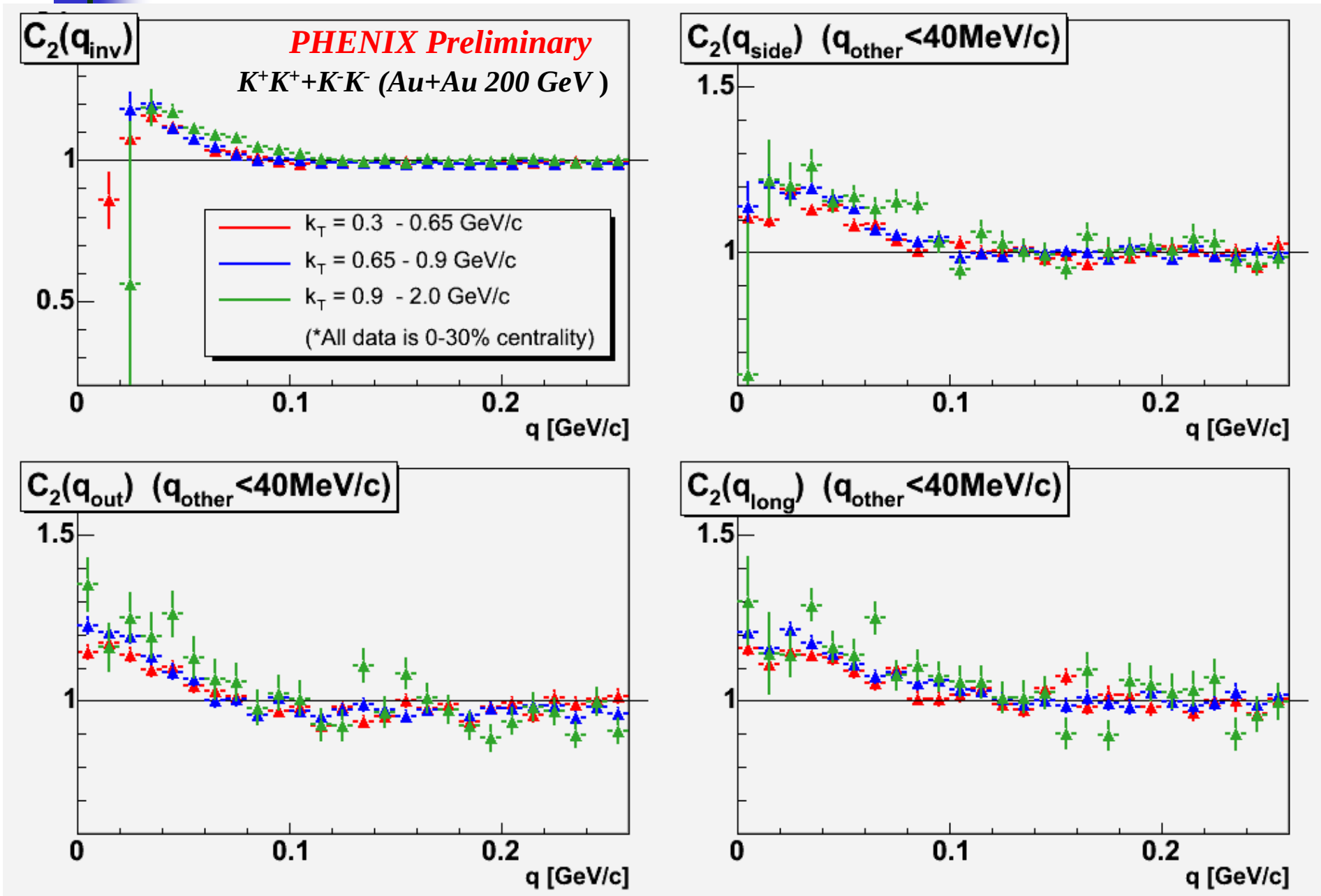
Sinyukov fit

$$C_2^{raw}(q) = C_2^{core}(q) + C_2^{halo}$$
$$= \left[(1+\lambda' G)F_C\right] + \left[1-\lambda'\right]$$

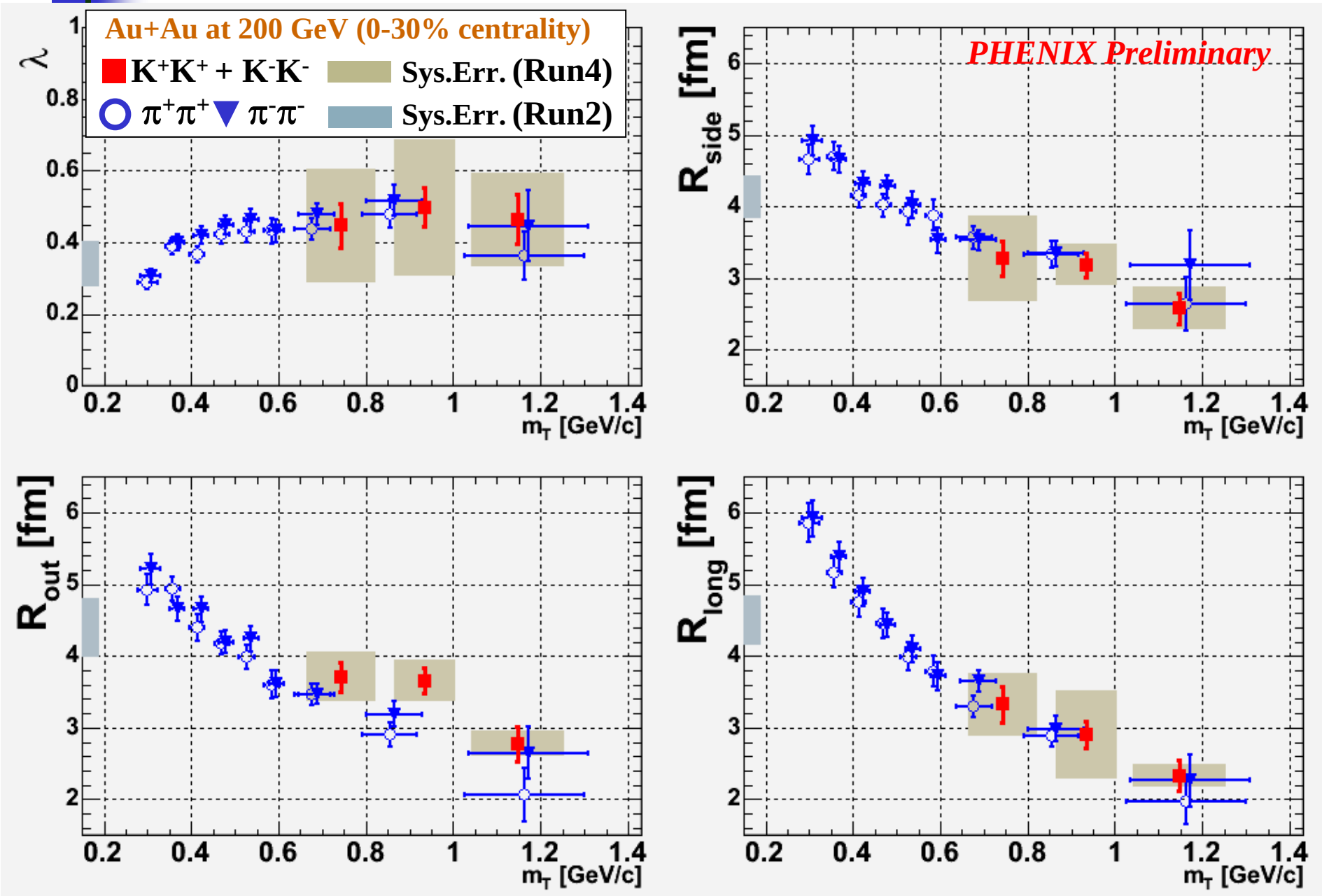
where $G = \exp(-q_{side}^2 R_{side}^2 - q_{out}^2 R_{out}^2 - q_{long}^2 R_{long}^2)$



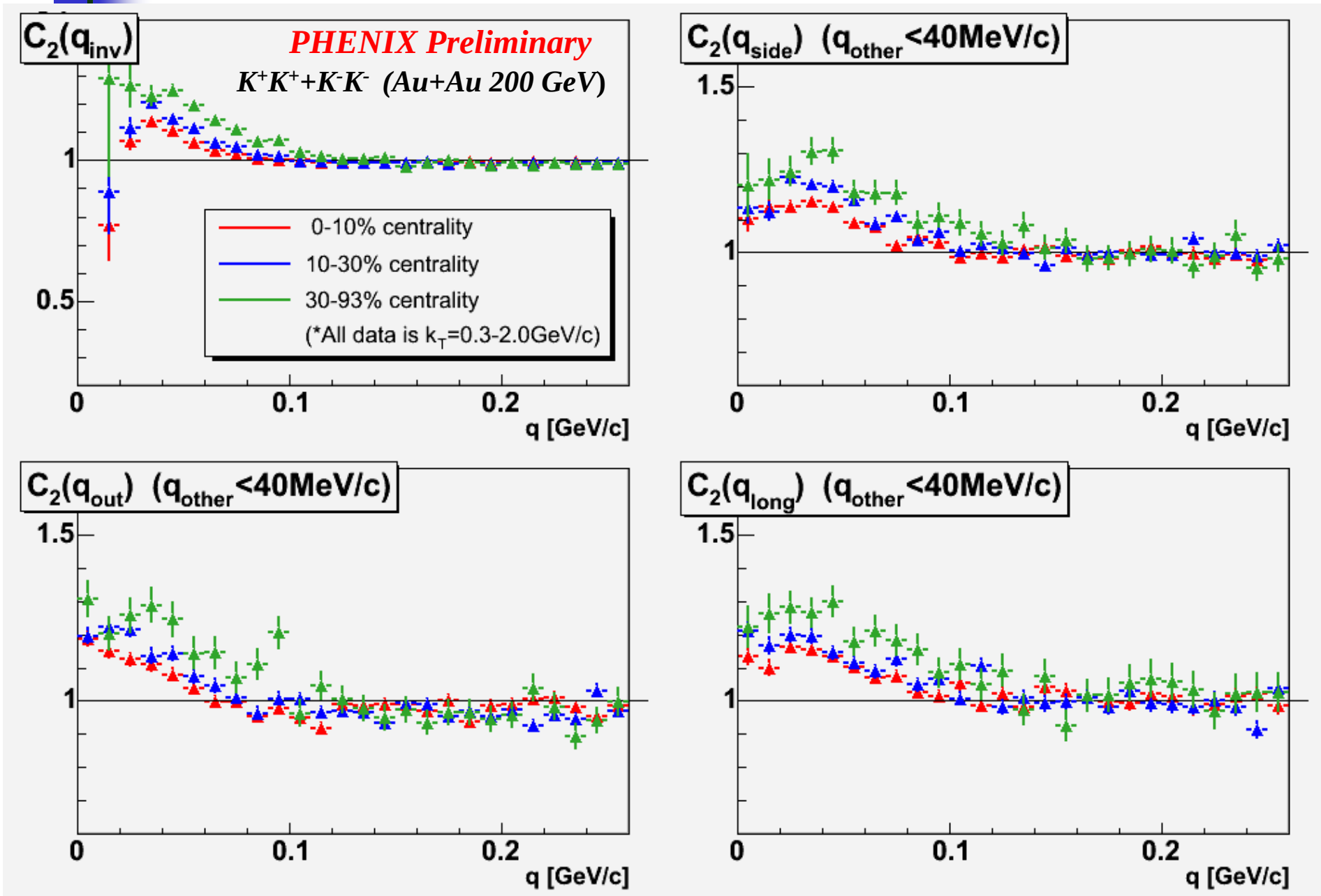
Pair momentum dependence of C_2 ($K^+K^+ + K^-K^-$)



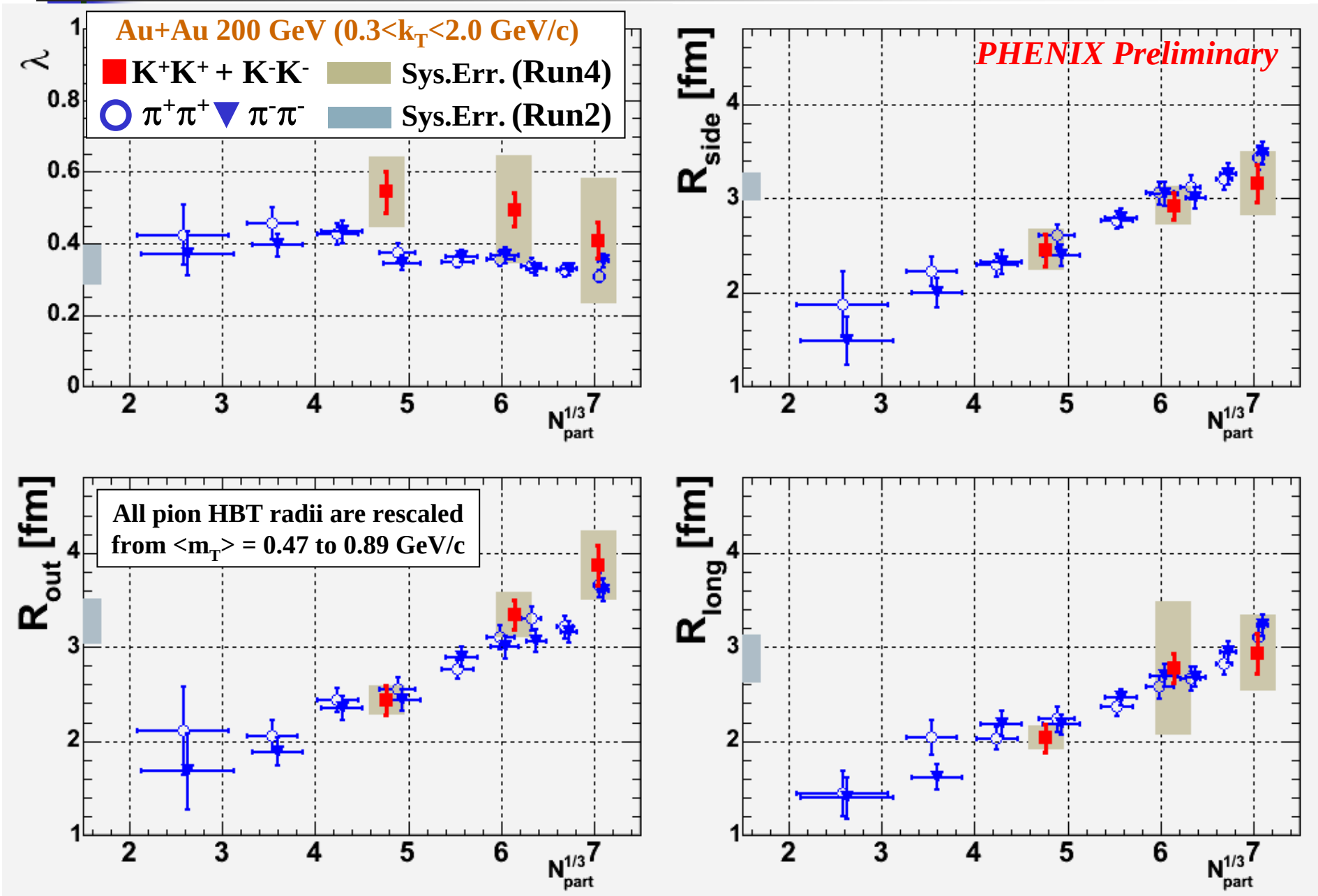
m_T dependence of HBT radii



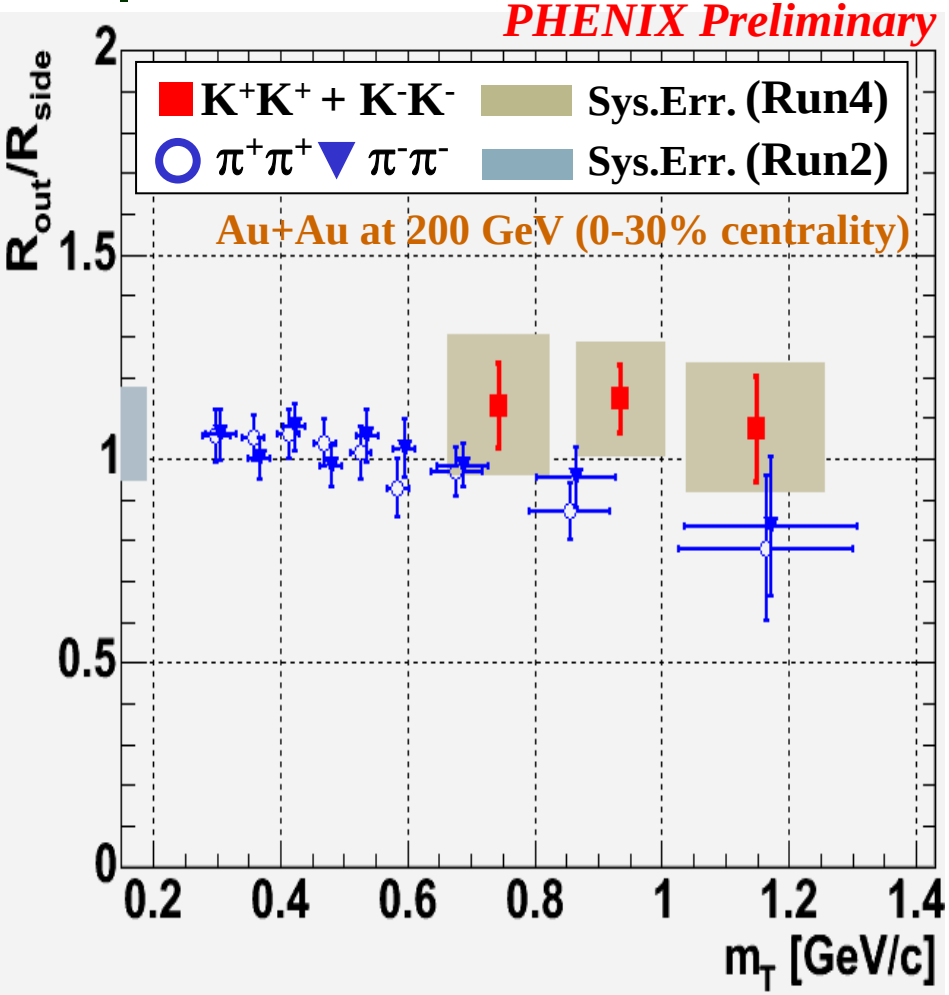
Centrality dependence C_2 ($K^+K^+ + K^-K^-$)

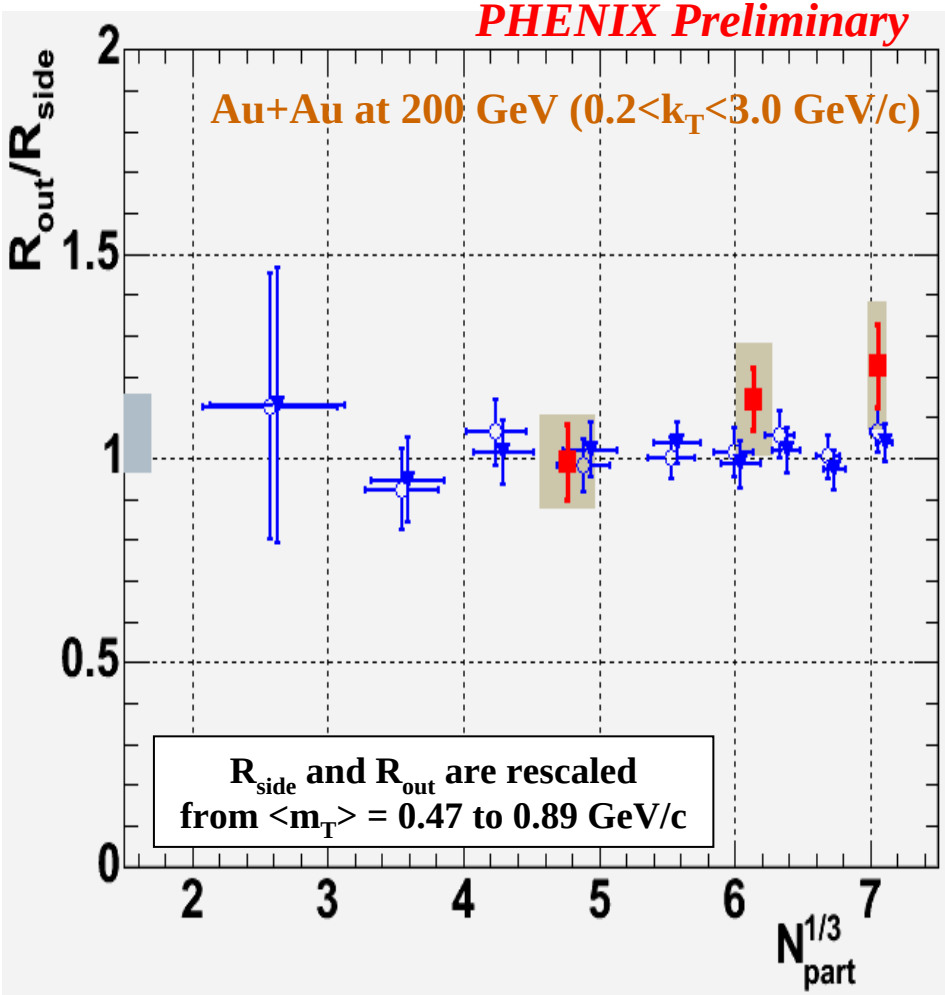


N_{part} dependence of HBT radii ($K^+K^+ + K^-K^-$)



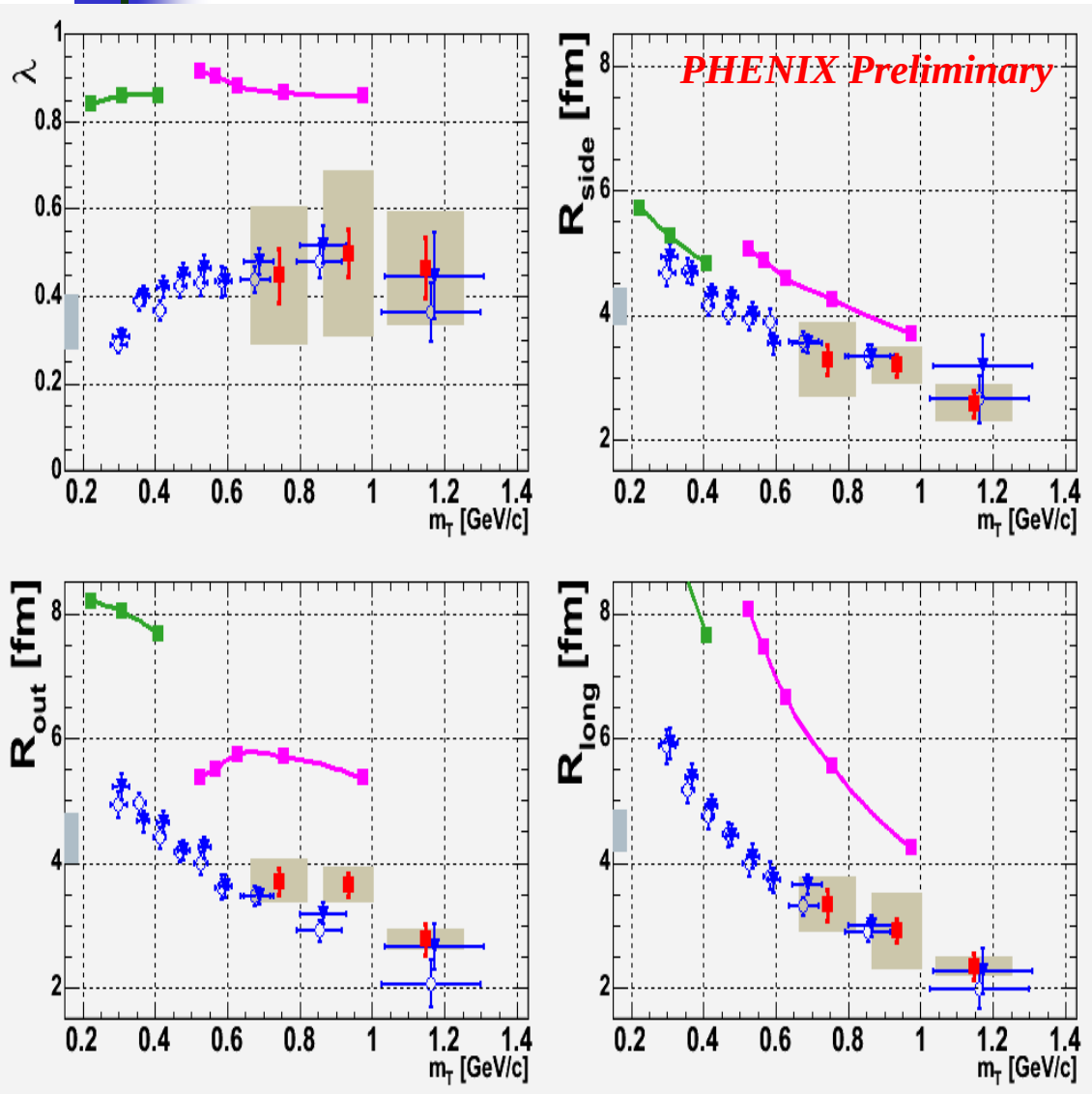
m_T and N_{part} dependence of R_{out}/R_{side}





R_{out}/R_{side} of kaon is systematically higher than that of pion at the central collision but consistent within errors.

Theoretical m_T dependence of kaon HBT radii



Au+Au at 200 GeV (0-30% centrality)

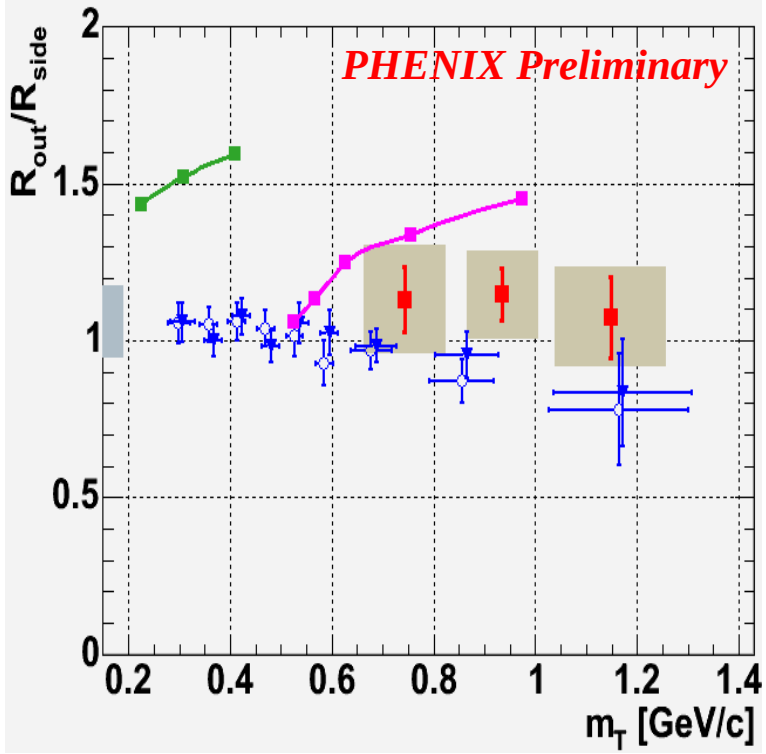
■ $K^+K^+ + K^-K^-$ Sys.Err. (Run4)

○ $\pi^+\pi^+$ ▼ $\pi^-\pi^-$ Sys.Err. (Run2)

Hydro+UrQMD – kaon

Hydro+UrQMD – pion

(S. Soff, nucl-th/0202240, T_c=160MeV)



Final rescattering effect should be negligible?

HBT-imaging analysis

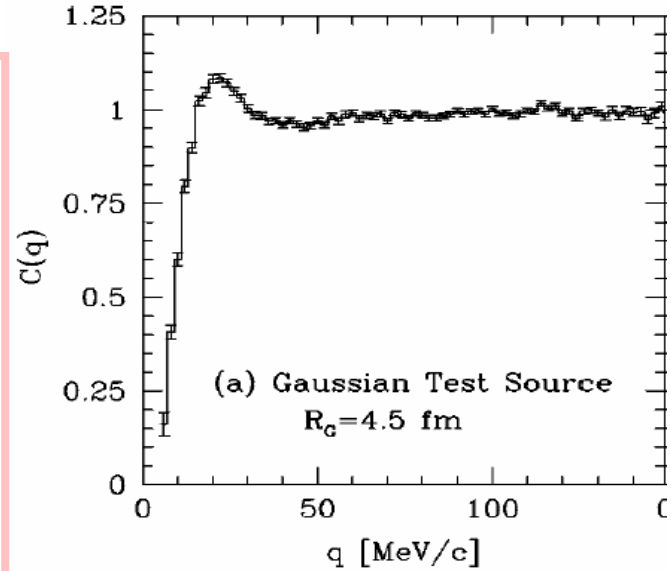
$$R_{\vec{P}}^{obs}(\vec{q}) \equiv C_{\vec{P}}^{obs}(\vec{q}) - 1 = \int d\vec{r} K(\vec{q},\vec{r}) S_{\vec{P}}(\vec{r})$$

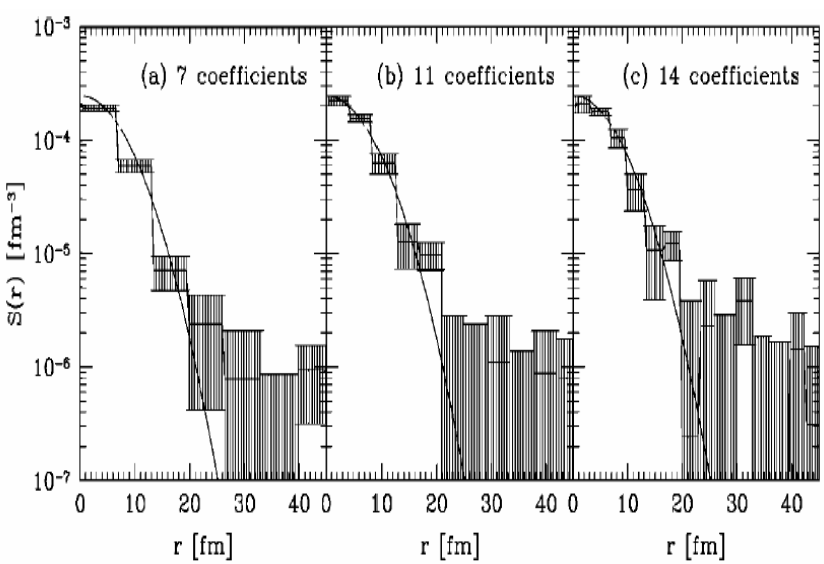
$$K(\vec{q},\vec{r}) = \left|\Phi_{\vec{q}}(\vec{r})\right|^2 - 1$$

is kernel which can be calculated from BEC and known final state interactions of pairs.

$$S_{\vec{P}}(\vec{r})$$

is source function which represents the emission probability of pairs at r in the pair CM frame.





D.A. Brown and P. Danielewicz
Phys. Rev. C. 64, 014902 (2001)

S(r) is expanded in a function basis.

$$S(r) = \sum_{i=1}^{N_M} S_i B_i(r) \qquad \Delta S(r) = \sqrt{\sum_{i,j=1}^{N_M} \Delta^2 S_{ij} B_i(r) B_j(r)}$$

Imaging by minimization of χ^2

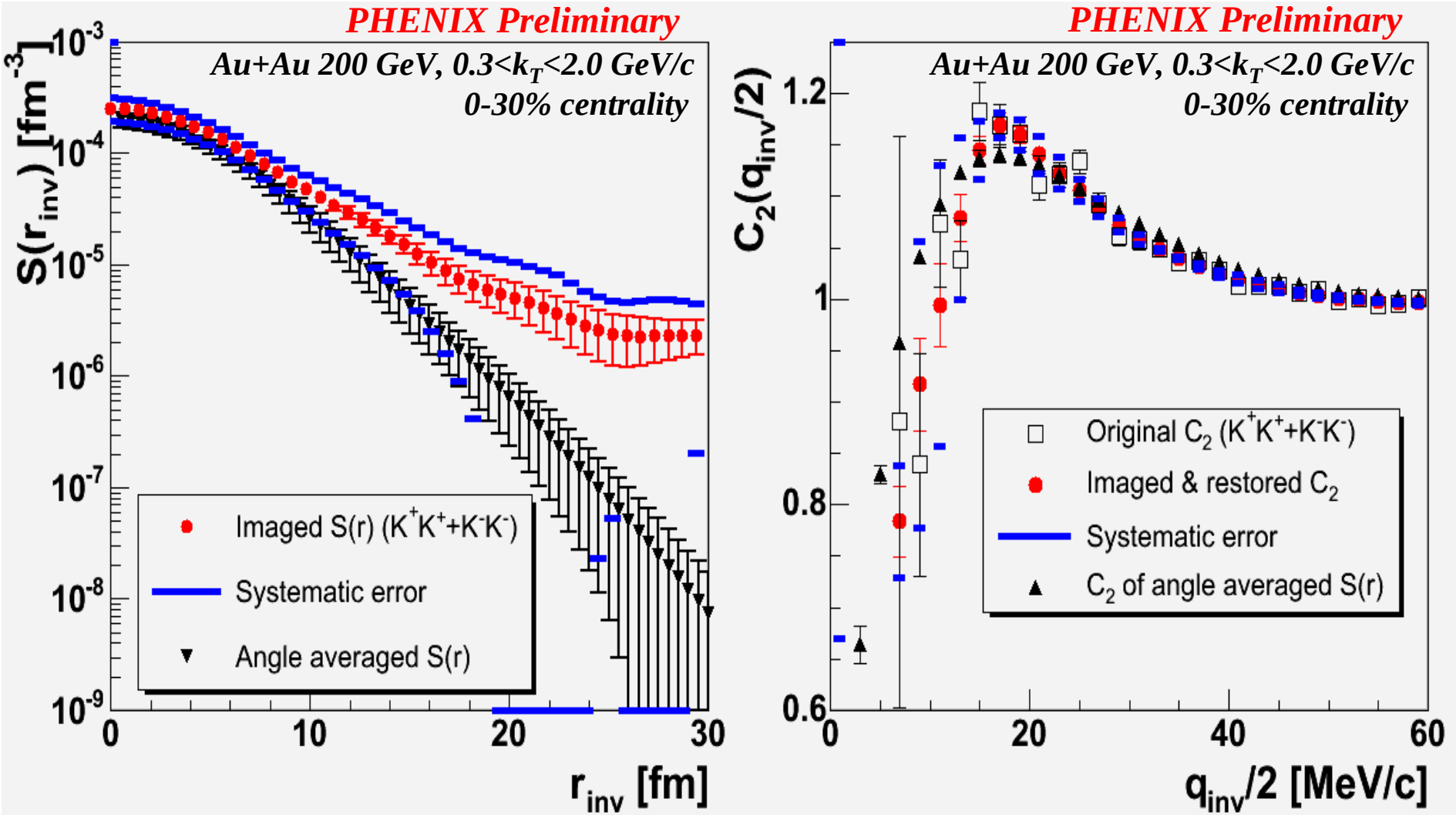
$$\chi^2 = \sum_i \left(R_i^{obs} - \sum_j K_{ij} S_j \right)^2 \Big/ \Delta^2 R_{ii}^{obs}$$

Most probable source function is

$$S = \Delta^2 S \cdot K^T \cdot (\Delta^2 R^{obs})^{-1} \cdot R^{obs}$$

$$\Delta^2 S = \left(K^T \cdot (\Delta^2 R^{obs})^{-1} \cdot K \right)^{-1}$$

1-D kaon ($K^+K^+ + K^-K^-$) imaging



Summary

3-D Bose-Einstein correlations for charged kaon pairs are analyzed using Run4 PHENIX data (~600M) at Au+Au 200 GeV.

- *Kaon HBT radii (R_{side}, R_{out}, R_{long}) well agree with those of pion as a function of transverse mass momentum (m_T).*
- *The number of participants dependence of R_{side}, R_{out}, R_{long} also agree with those of pion after rescaling them to the same $<m_T>$.*
  - *Probably there is no differences of x-p correlation and freezeout time between charged pions and kaons at the same m_T and N_{part} region.*
- *R_{out}/R_{side} at central collision shows systematically a bet larger value (~1.1-1.3), but still consistent with unity and pions within errors.*
  - *Comparison with hydrodynamics prediction maybe hint at small final rescattering effect.*
- *1-D source function by kaon imaging analysis shows a deviation from Gaussian shape, but consistent within large systematic errors.*

!Need a work to minimize systematic errors!

PHENIX

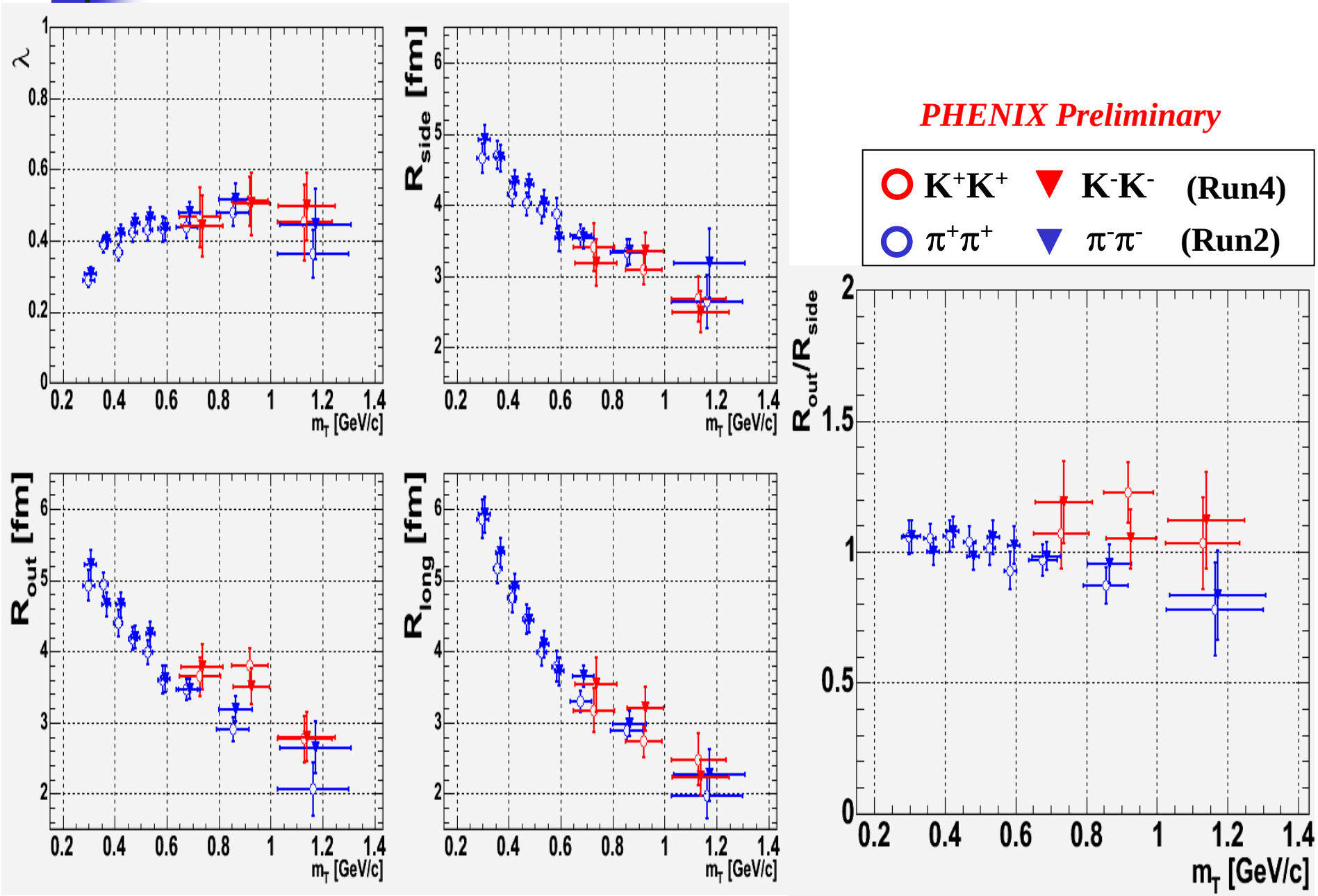
12 Countries; 58 Institutions; 480 Participants*

Brazil	University of São Paulo, São Paulo
China	Academia Sinica, Taipei, Taiwan
	China Institute of Atomic Energy, Beijing
	Peking University, Beijing
France	LPC, University de Clermont-Ferrand, Clermont-Ferrand
	Dapnia, CEA Saclay, Gif-sur-Yvette
	IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay
	LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau
	SUBATECH, Ecòle des Mines at Nantes, Nantes
Germany	University of Münster, Münster
Hungary	Central Research Institute for Physics (KFKI), Budapest
	Debrecen University, Debrecen
	Eötvös Loránd University (ELTE), Budapest
India	Banaras Hindu University, Banaras
	Bhabha Atomic Research Centre, Bombay
Israel	Weizmann Institute, Rehovot
Japan	Center for Nuclear Study, University of Tokyo, Tokyo
	Hiroshima University, Higashi-Hiroshima
	KEK, Institute for High Energy Physics, Tsukuba
	Kyoto University, Kyoto
	Nagasaki Institute of Applied Science, Nagasaki
	RIKEN, Institute for Physical and Chemical Research, Wako
	RIKEN-BNL Research Center, Upton, NY
	Rikkyo University, Tokyo, Japan
	Tokyo Institute of Technology, Tokyo
	University of Tsukuba, Tsukuba
	Waseda University, Tokyo
S. Korea	Cyclotron Application Laboratory, KAERI, Seoul
	Kangnung National University, Kangnung
	Korea University, Seoul
	Myong Ji University, Yongin City
	System Electronics Laboratory, Seoul Nat. University, Seoul
	Yonsei University, Seoul
Russia	Institute of High Energy Physics, Protovino
	Joint Institute for Nuclear Research, Dubna
	Kurchatov Institute, Moscow
	PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg
	St. Petersburg State Technical University, St. Petersburg
Sweden	Lund University, Lund
USA	Abilene Christian University, Abilene, TX
	Brookhaven National Laboratory, Upton, NY
	University of California - Riverside, Riverside, CA
	University of Colorado, Boulder, CO
	Columbia University, Nevis Laboratories, Irvington, NY
	Florida State University, Tallahassee, FL
	Florida Technical University, Melbourne, FL
	Georgia State University, Atlanta, GA
	University of Illinois Urbana Champaign, Urbana-Champaign, IL
	Iowa State University and Ames Laboratory, Ames, IA
	Los Alamos National Laboratory, Los Alamos, NM
	Lawrence Livermore National Laboratory, Livermore, CA
	University of New Mexico, Albuquerque, NM
	New Mexico State University, Las Cruces, NM
	Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
	Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
	Oak Ridge National Laboratory, Oak Ridge, TN
	University of Tennessee, Knoxville, TN
	Vanderbilt University, Nashville, TN

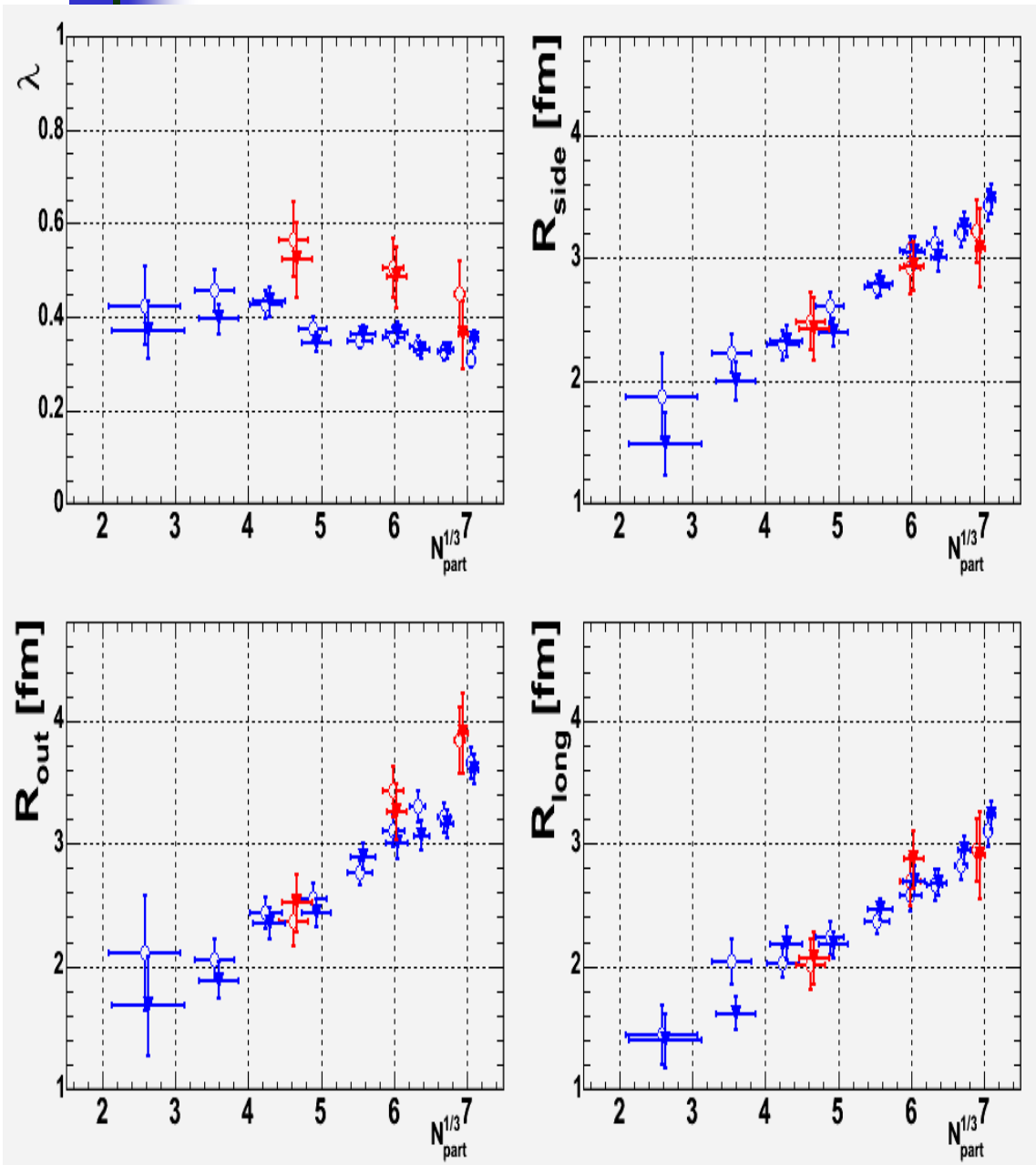
*as of January 2004

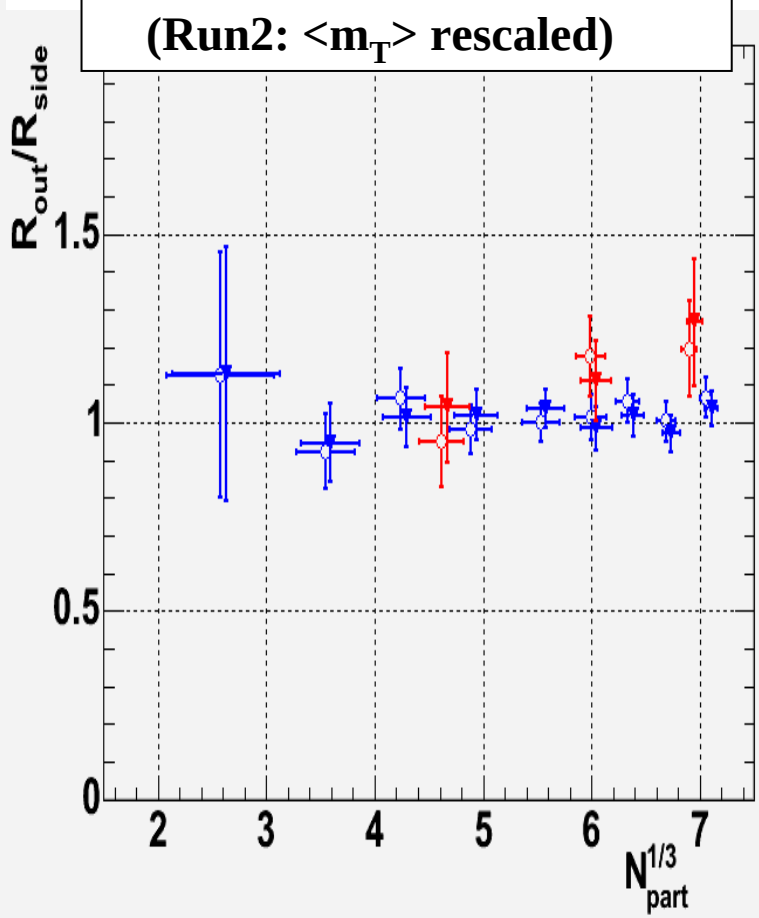
Backup slides

m_T dependence of HBT radii (K^+K^+ and K^-K^-)

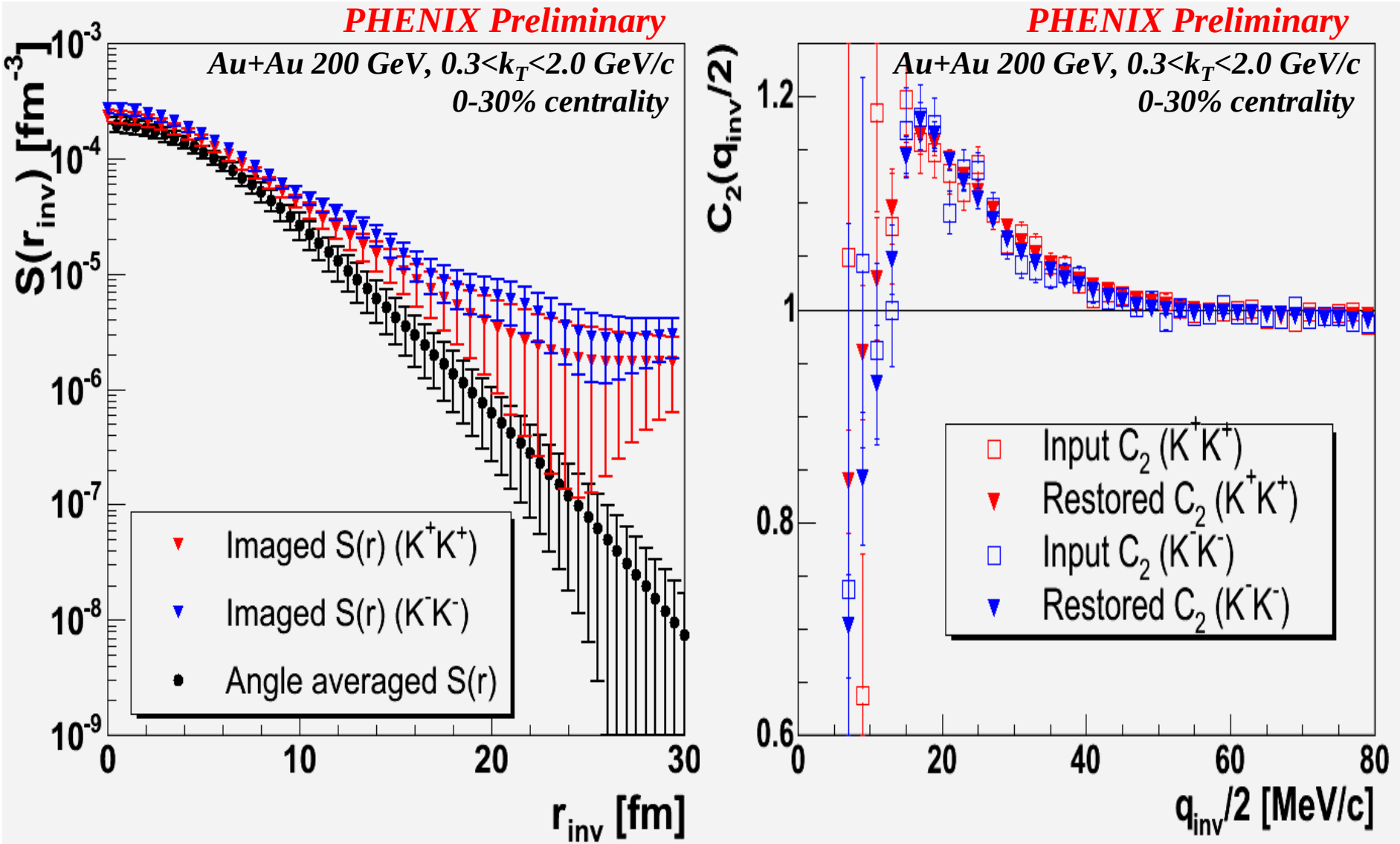


N_{part} dependence of HBT radii (K^+K^+ and K^-K^-)





1-D kaon (K^+K^+ and K^-K^-) imaging results



Systematic errors

	lambda	Rside	Rout	Rlong	Rout/Rside
Matching cut	8.03	5.03	5.44	5.44	10.47
Kaon PID cut	9.06	1.46	0.29	0.83	1.17
DCH pair cut*	3.13	1.72	2.6	0.48	0.88
EMCal pair cut*	10.42	0.75	2.18	0.01	2.93
Coulomb correction*	5.55	0.56	0.43	0.48	0.99
low-q uncertainty*	30.89	17.26	6.72	12.01	10.56
Total	35.35	18.14	9.31	13.23	15.26
Total (low-kT)	42.36	7.79	7.88	18.4	11.23
Total (mid-kT)	38.21	9.12	7.78	21.34	12.39
Total (high-kT)	28.07	11.65	6.4	6.87	14.81
Total (low-cent)	17.95	8.84	6.22	6.26	11.63
Total (mid-cent)	30.58	7.18	7.33	25.42	12.1
Total (high-cent)	42.86	10.89	9.42	13.81	12.67

***Unit is in percentage.**