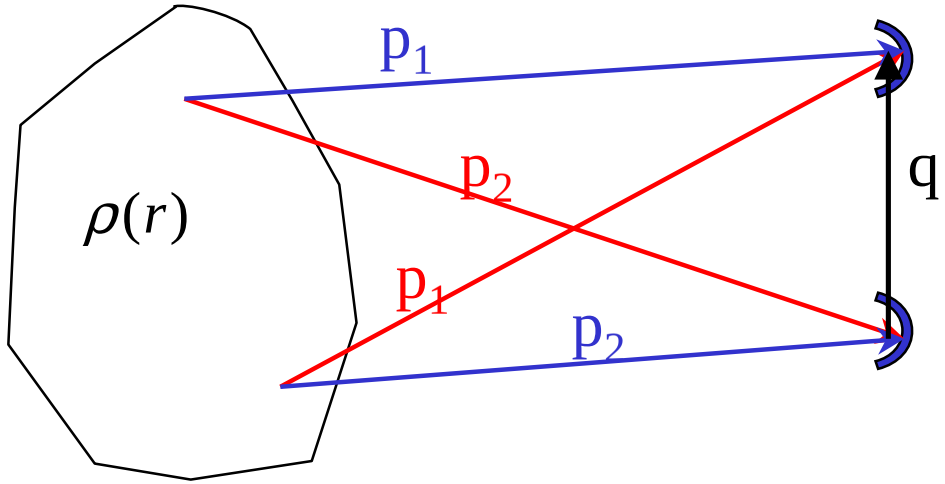
First Results on Two-Particle Correlations Determined by PHENIX

Stephen C. Johnson
Lawrence Livermore National Lab
for the PHENIX Collaboration

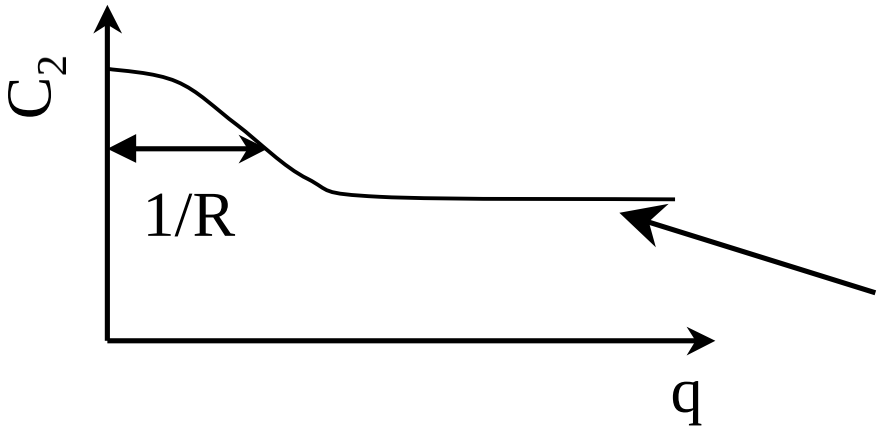
Why study particle correlations?

(Preaching to the choir)

- Measures the relative spatial-temporal separation at the point of last interaction
  - Sensitive to relative separation in phase space of pairs at freeze-out



$$C_2 = \frac{A(q)}{B(q)} = 1 + \left|\tilde{\rho}(q)\right|^2$$

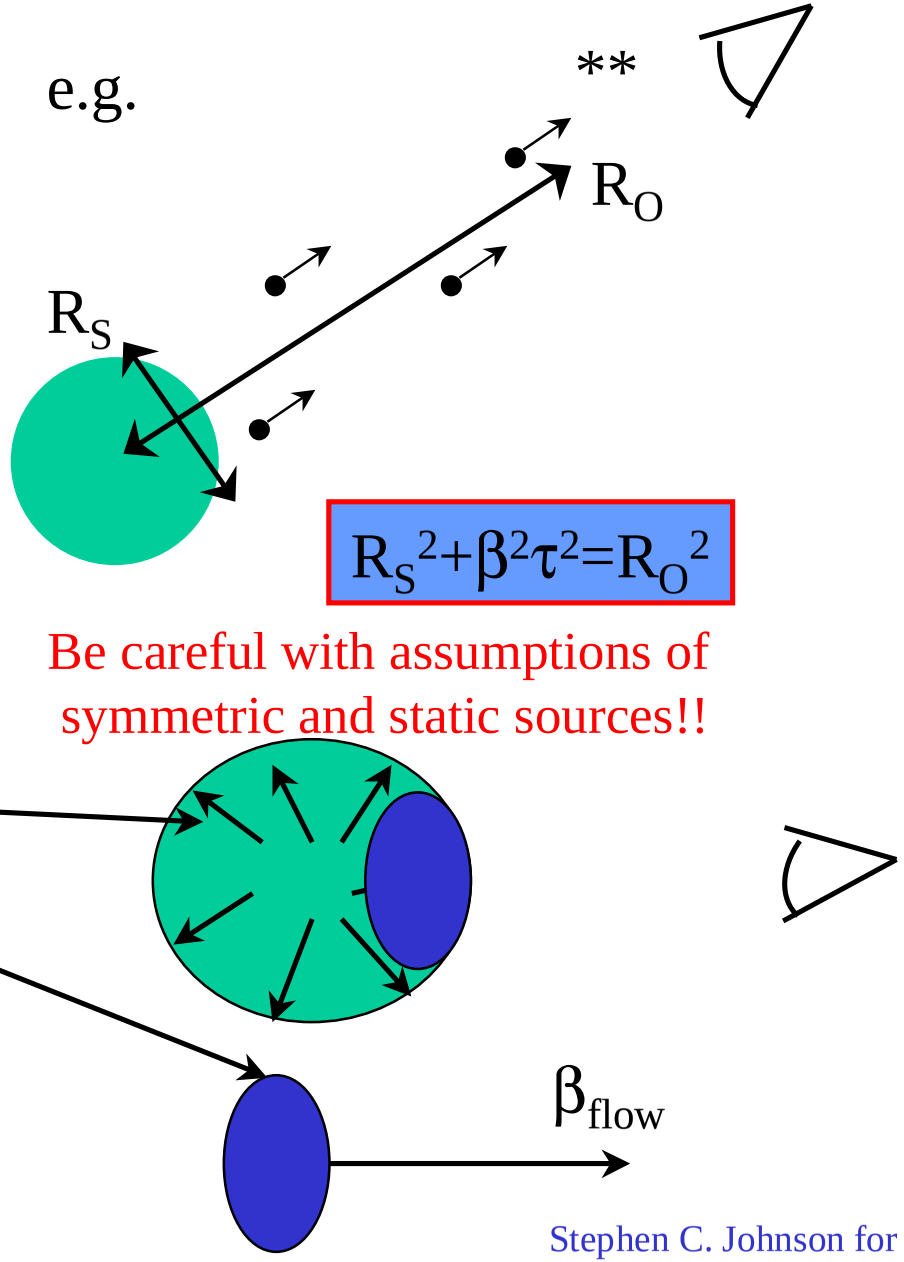


Assuming a chaotic source with no dynamical correlations and no final state interactions the resulting correlation function is rather straight-forward:

But Beware!!

- "C_2 depends on more variables than you can think of."
  - Anonymous HBT expert

- In particular
  - Dynamical correlations
  - Lorentz kinematics



**This first figure unabashedly stolen from M. Lisa

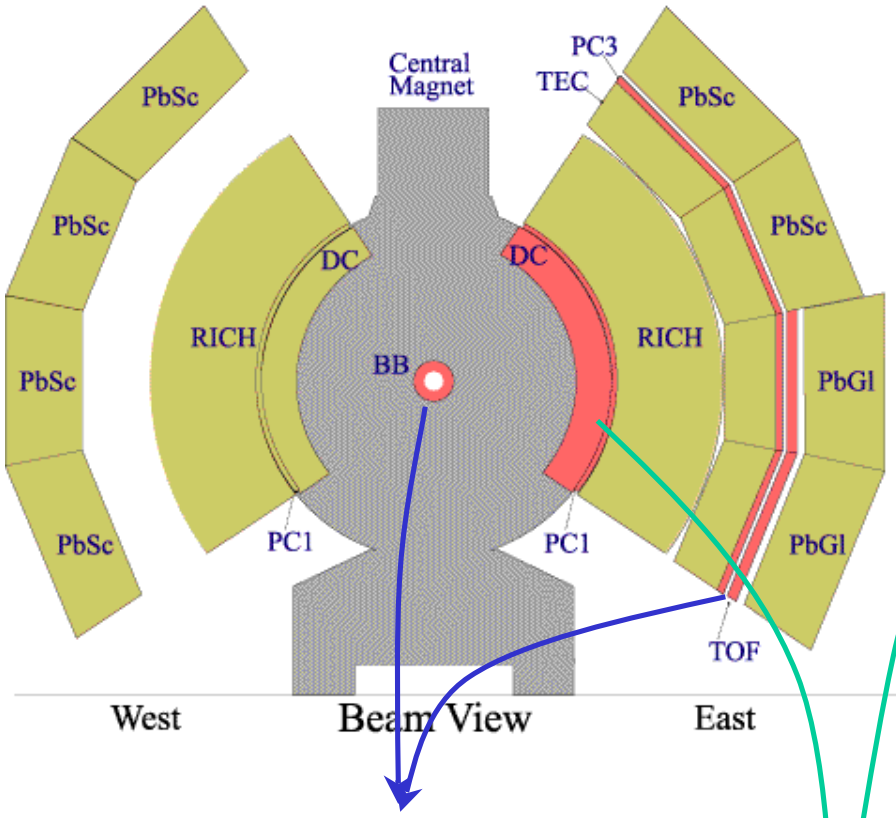
Agenda

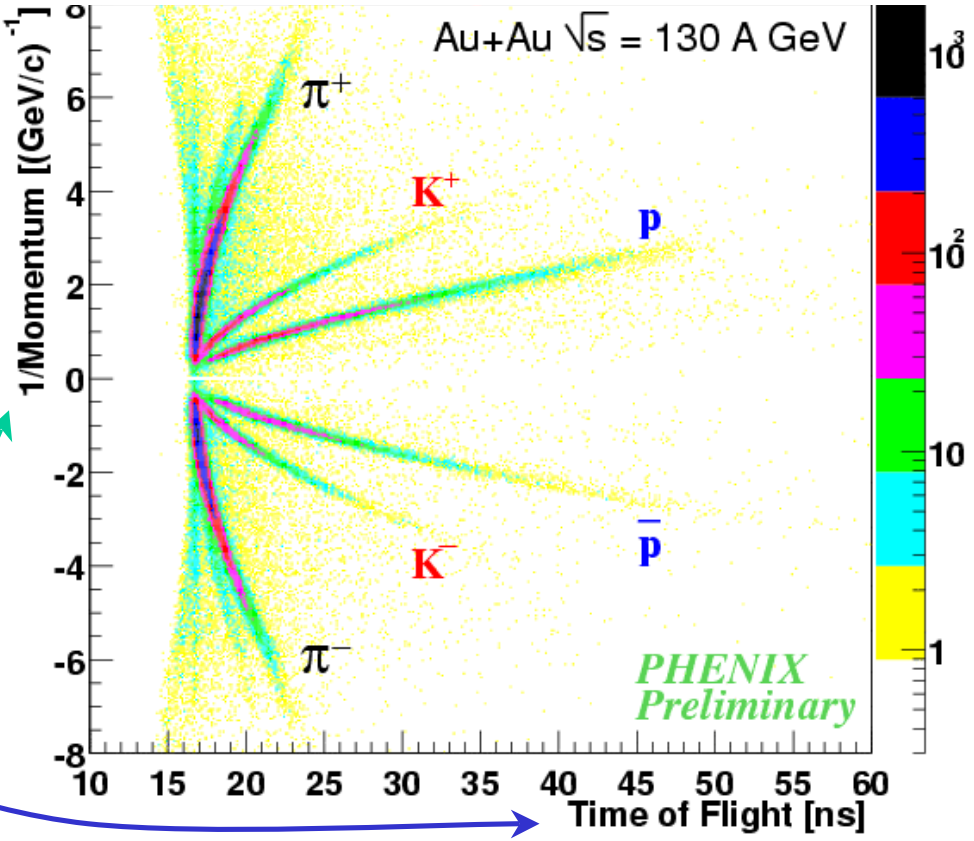
- First PHENIX HBT results from Run 1.
- Proof of principle – capability of PHENIX to perform these measurements
  - PID capabilities and analysis
  - 1D correlations
  - Bertsch-Pratt 3D fit to R_{OSL}
  - Confirm dependencies of R on k_t
- Comparisons and Conclusions
- A glance at future capabilities.

Stephen C. Johnson for
the PHENIX Collaboration

Particle identification

- For this analysis: π =
  - 2 σ within π peak
  - 3 σ away from K peak
  - 180<p< 2000 MeV/c

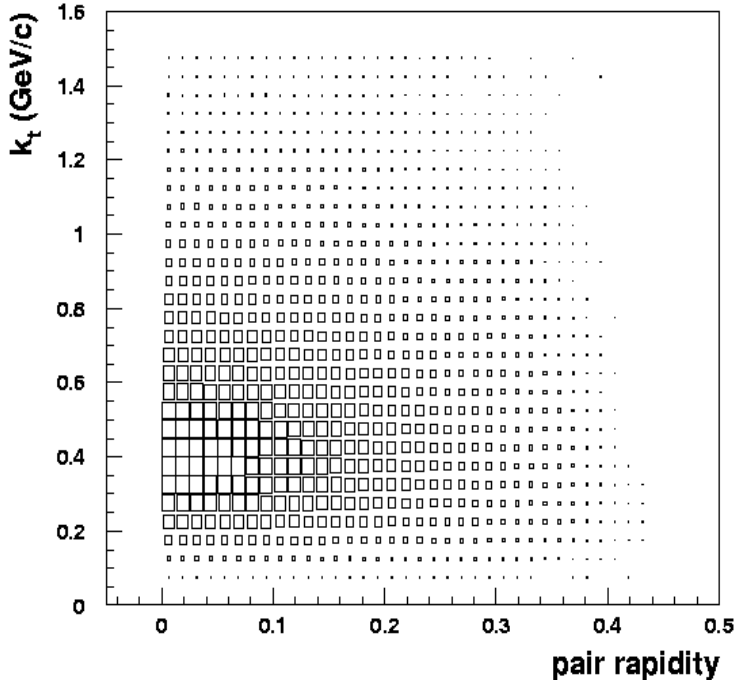


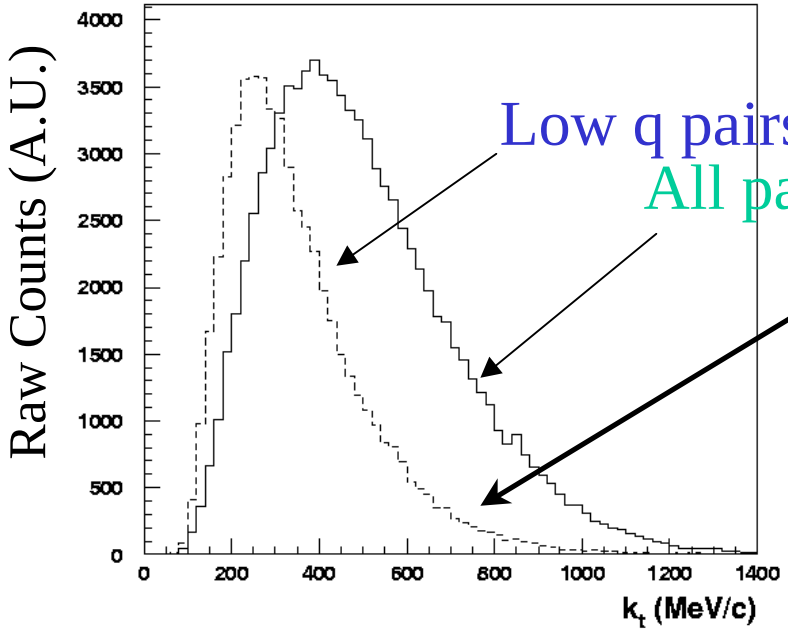


Time of flight with TOF & Beam-Beam Counter

Tracking with Drift Chamber/Pad Chambers

"Particle identification capability of the PHENIX experiment"
H. Hamagaki





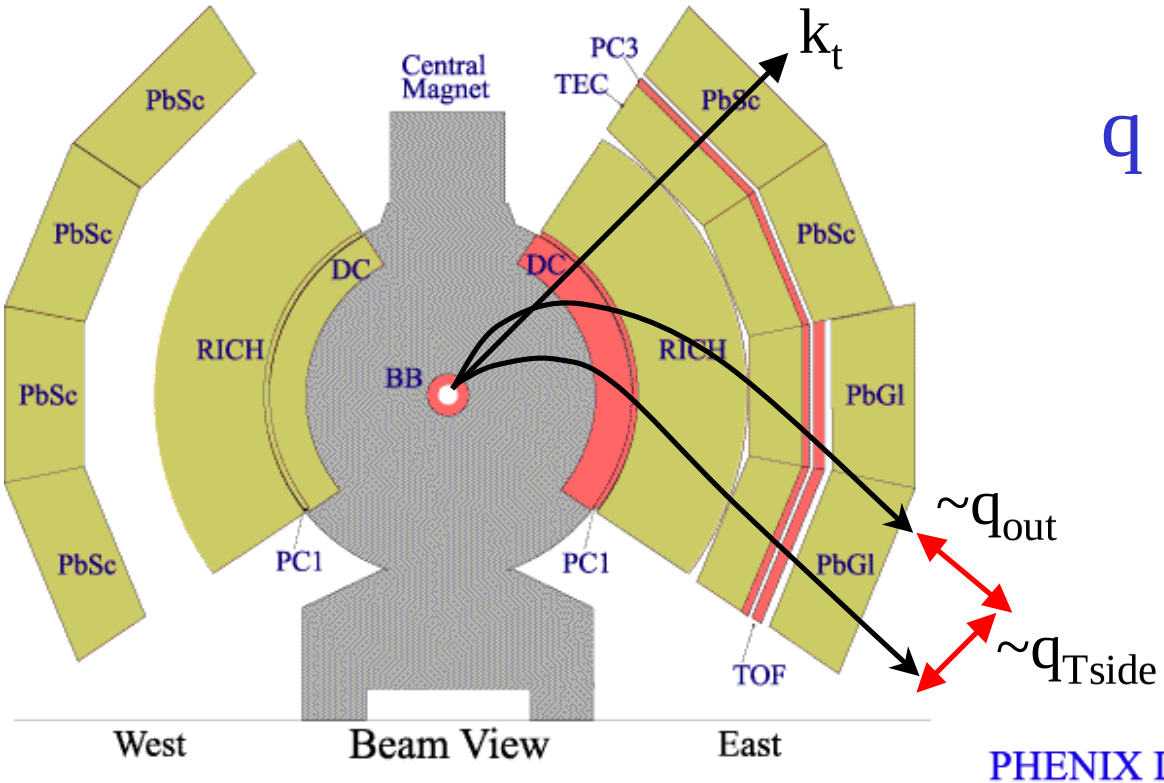
Pair Acceptance

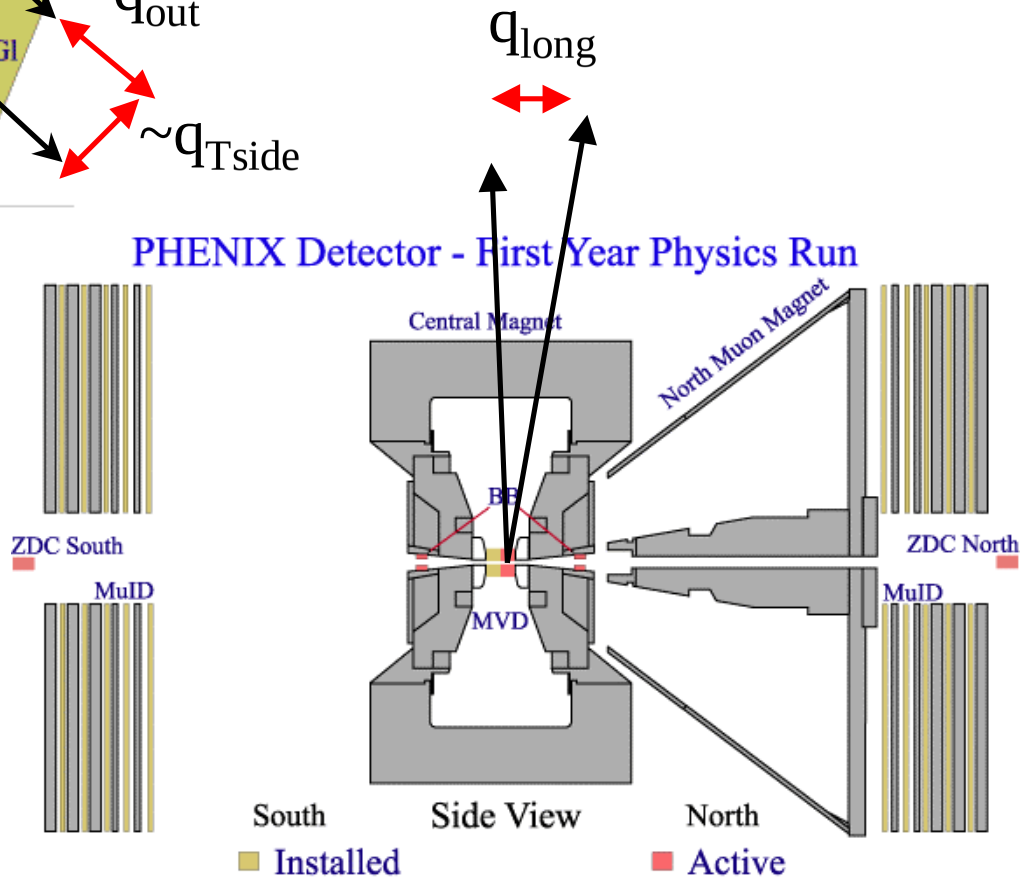
- Acceptance about time-of-flight wall restricts correlation measurement to $y_{pair}<.3$
- PHENIX excellent PID allows pair reconstruction to very high kt
  - => larger statistics of year-2 will allow high k_t 3D measurements

$$\langle k_t \rangle \equiv \frac{1}{2}\sqrt{(p_{x1}+p_{x2})^2+(p_{y1}+p_{y2})^2}$$
$$= 350 MeV$$

Stephen C. Johnson for
the PHENIX Collaboration

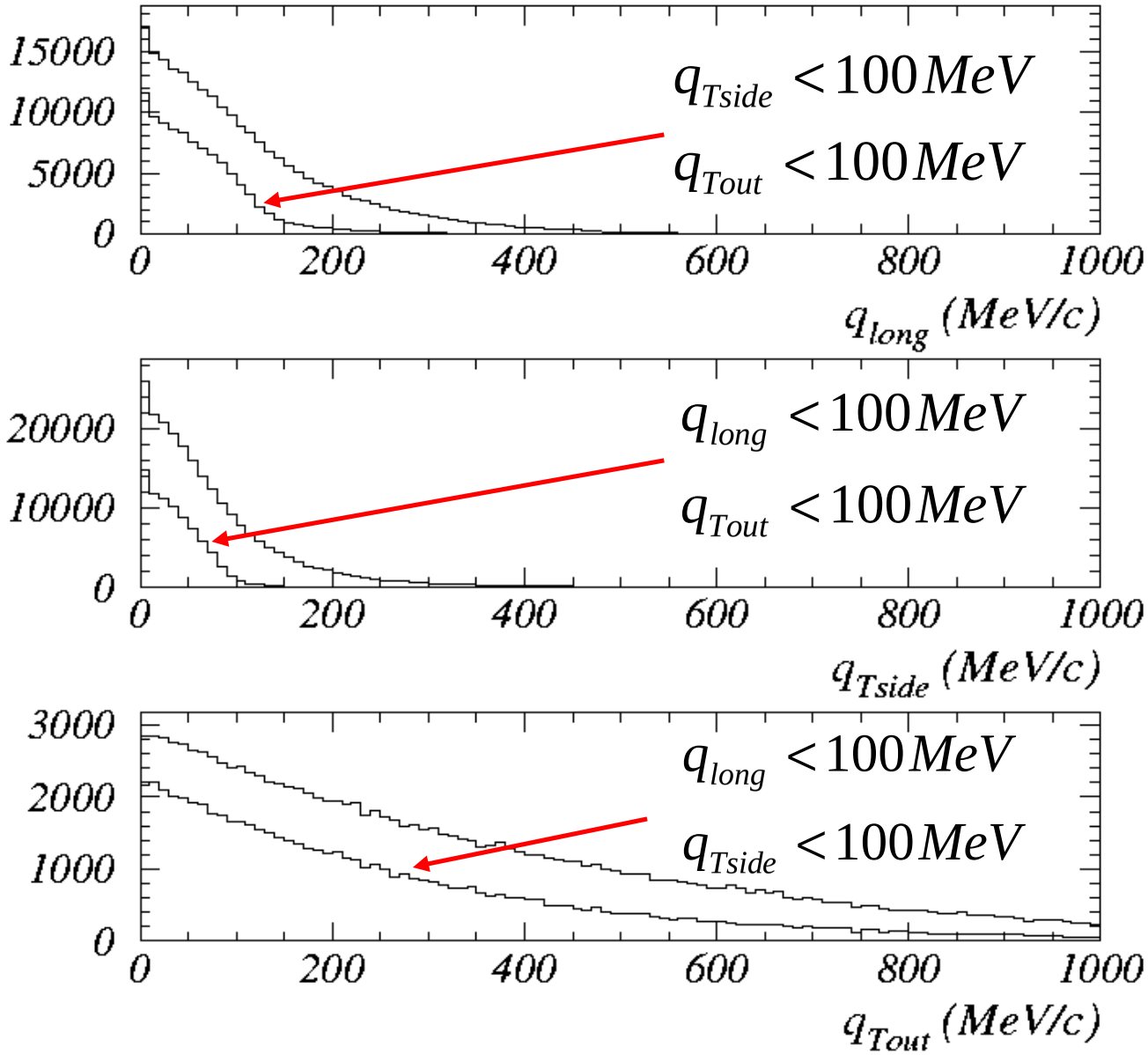
q Acceptance





- Finite acceptance in δy and $\delta\phi$ => finite q_{Tside} and q_{long} reach.
- Excellent particle identification to large p => large q_{Tout} bite.

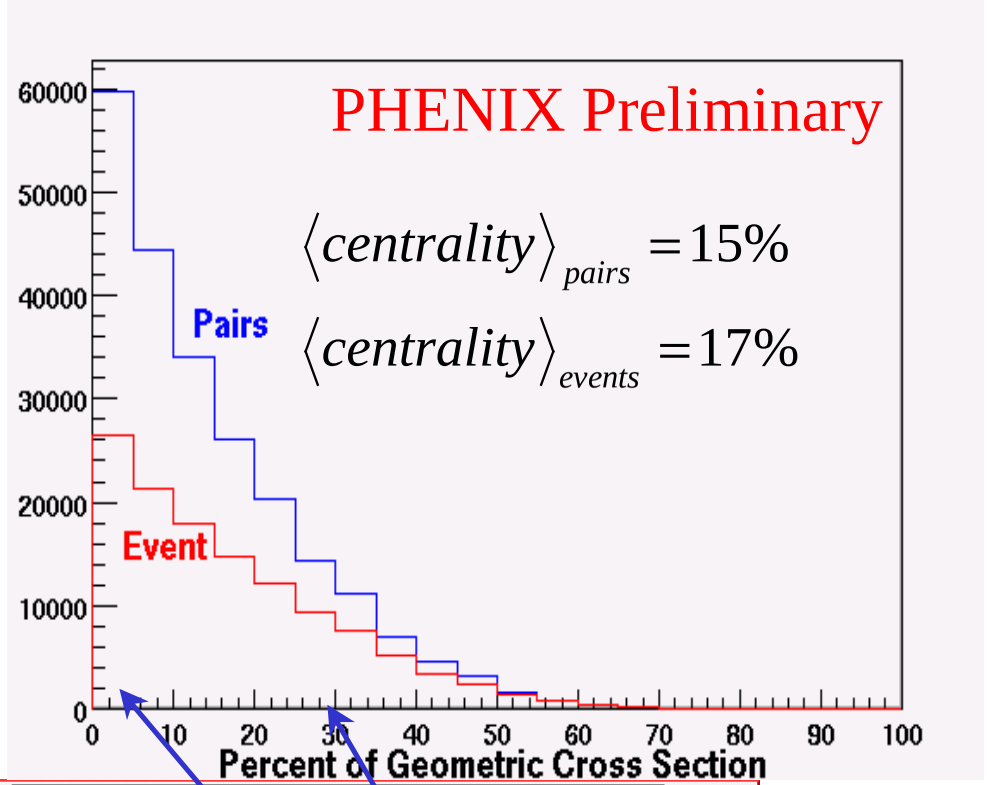
q acceptance

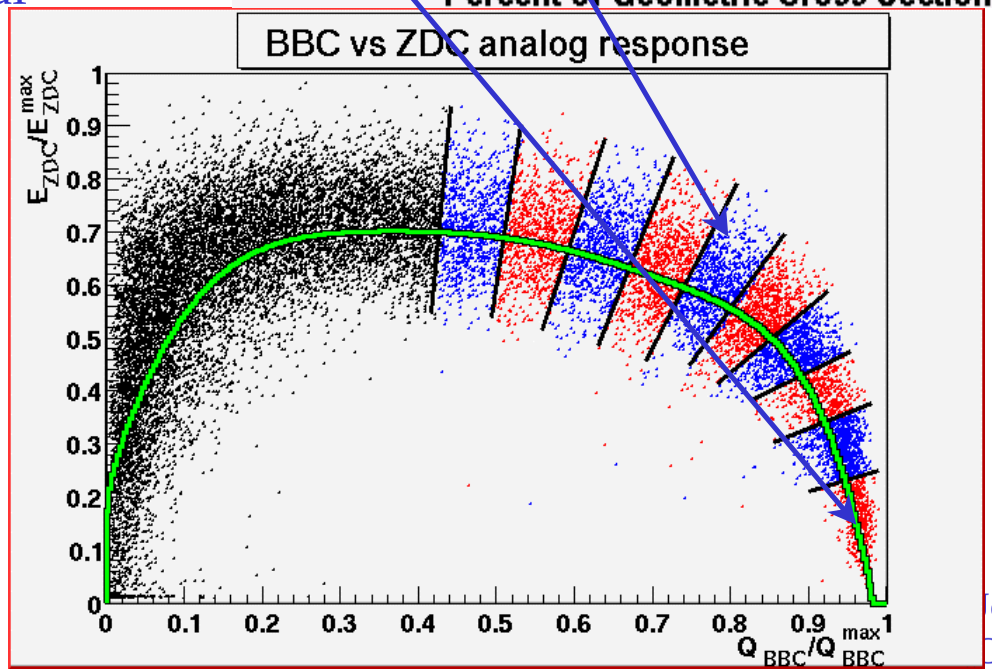


Stephen C. Johnson for
the PHENIX Collaboration

Centrality

- All data presented today are for ‘minimum bias collisions’ (i.e. only with trigger on z_{vtx})
- However: finite detector + minimum bias sample + pairs requirement
  - => bias towards central collisions in min bias sample
- Truly a central event sample



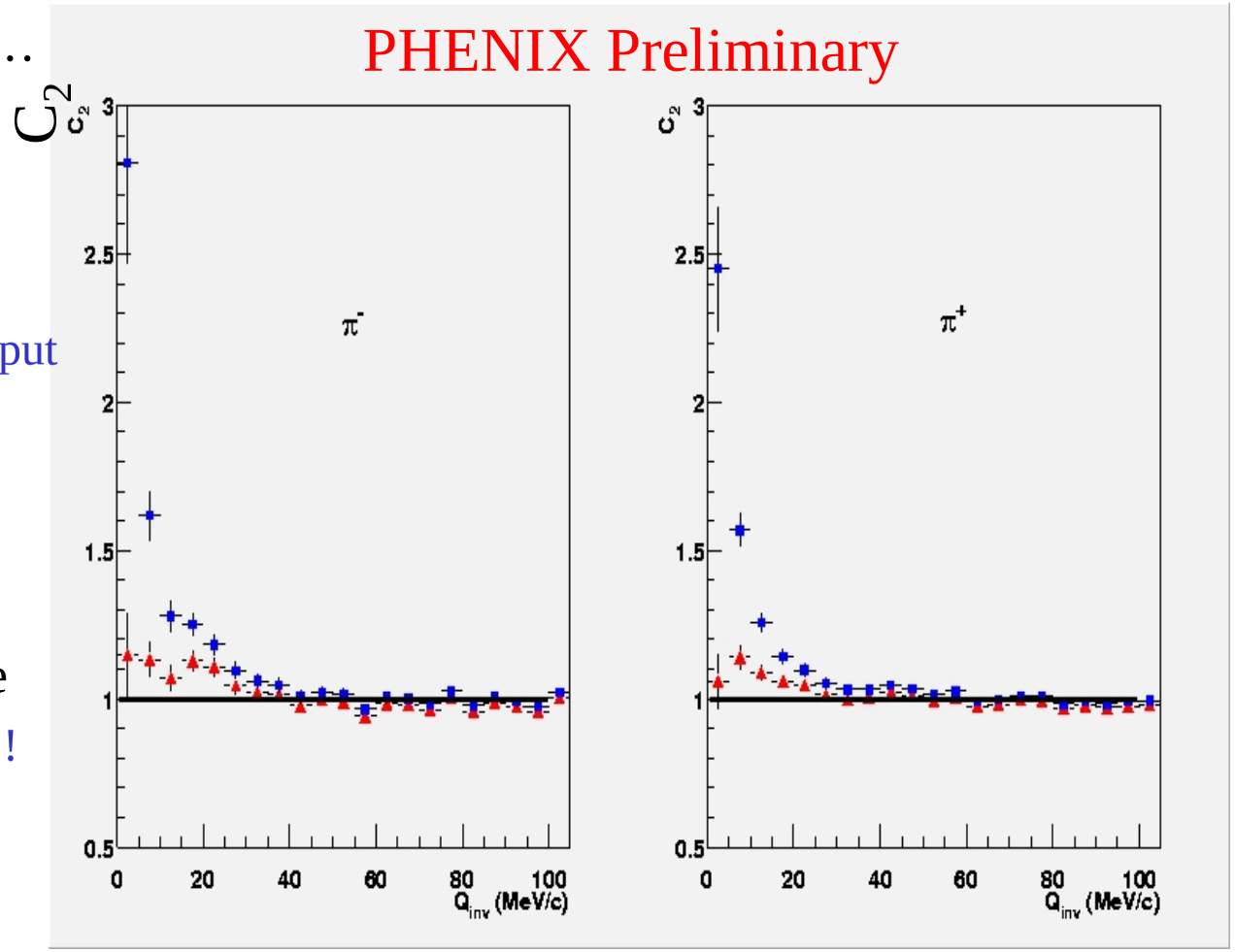


Johnson for Collaboration

Q_{inv} distributions

- Full coulomb correction…
  - Analytic coulomb correction assumes $R(Q_{inv})$ source
  - Resulting radii independent of R_{Qinv} input within ~10%

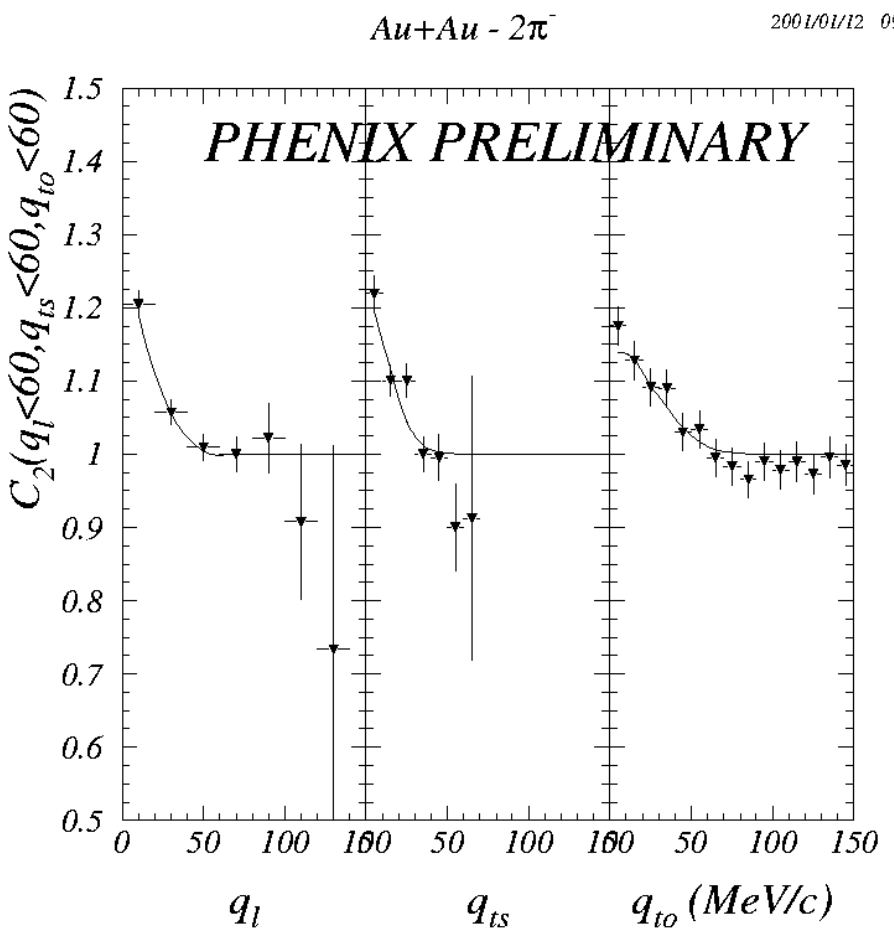
- Q_{inv} => measurement of relative separation of the pair in the pair rest frame
  - Acceptance dependent!!

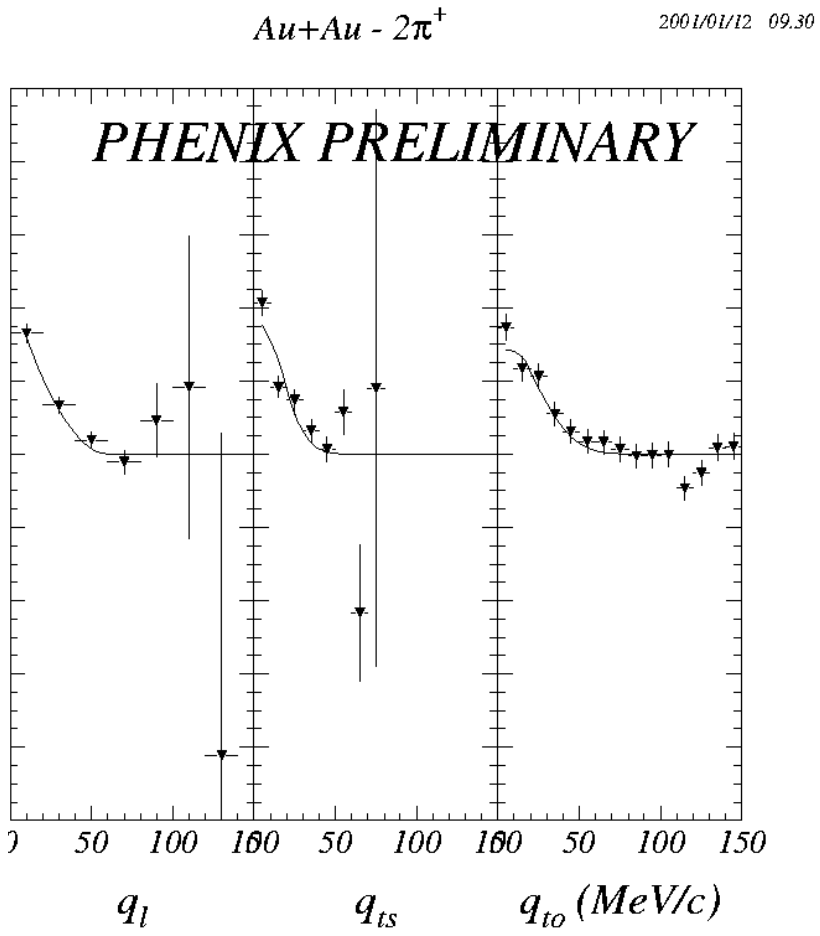


Q_{inv} (MeV/c)

Stephen C. Johnson for
the PHENIX Collaboration

Bertsch-Pratt Fit Results

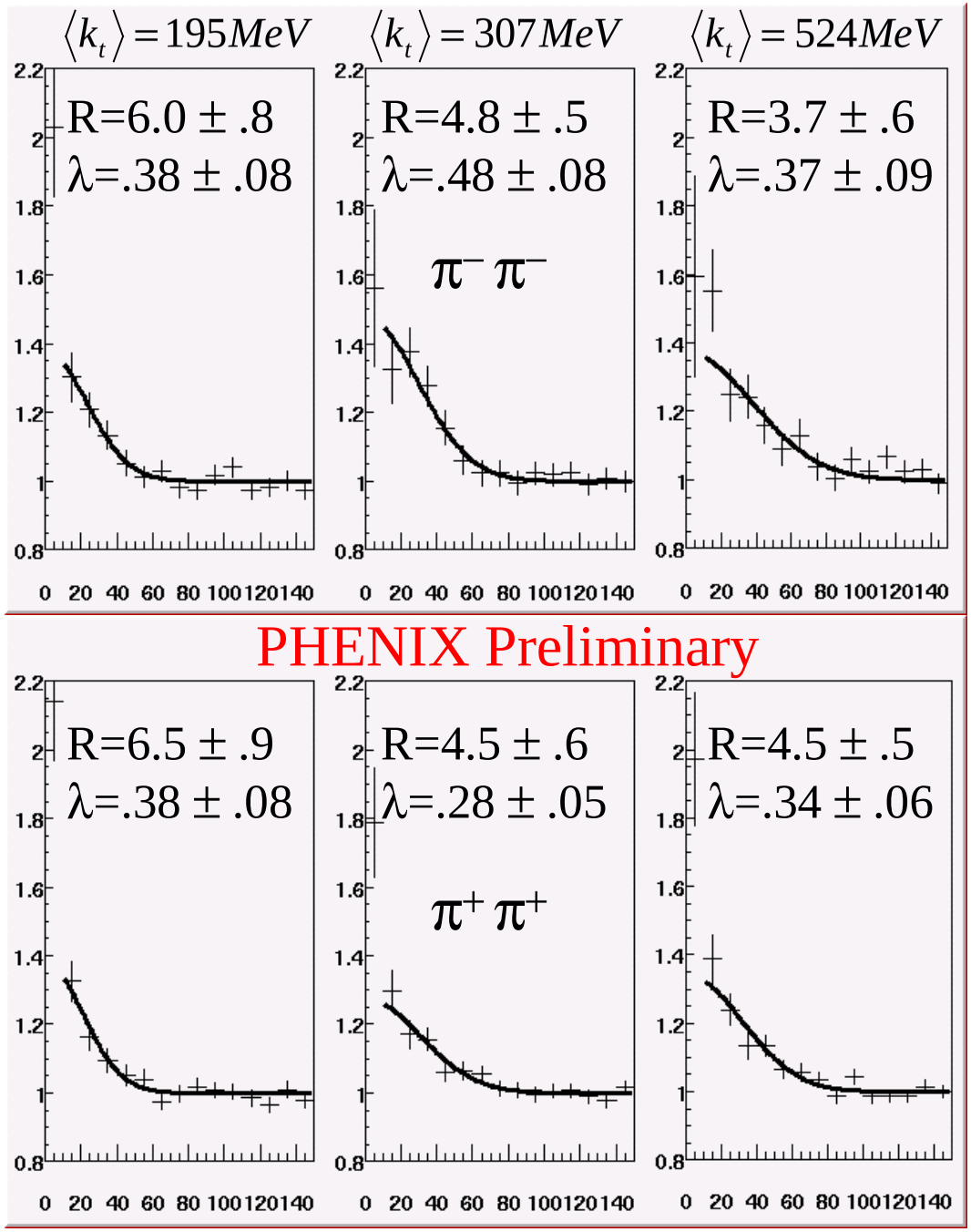




$R_l = 6.7 \pm .9$
$R_{Tside} = 5.8 \pm 1.5$
$R_{Tout} = 5.49 \pm .54$
$\Lambda = .493 \pm .061$

$R_l = 4.0 \pm 1.2$
$R_{Tside} = 7.9 \pm 1.1$
$R_{Tout} = 6.23 \pm .54$
$\Lambda = .493 \pm .050$

Stephen C. Johnson for
the PHENIX Collaboration



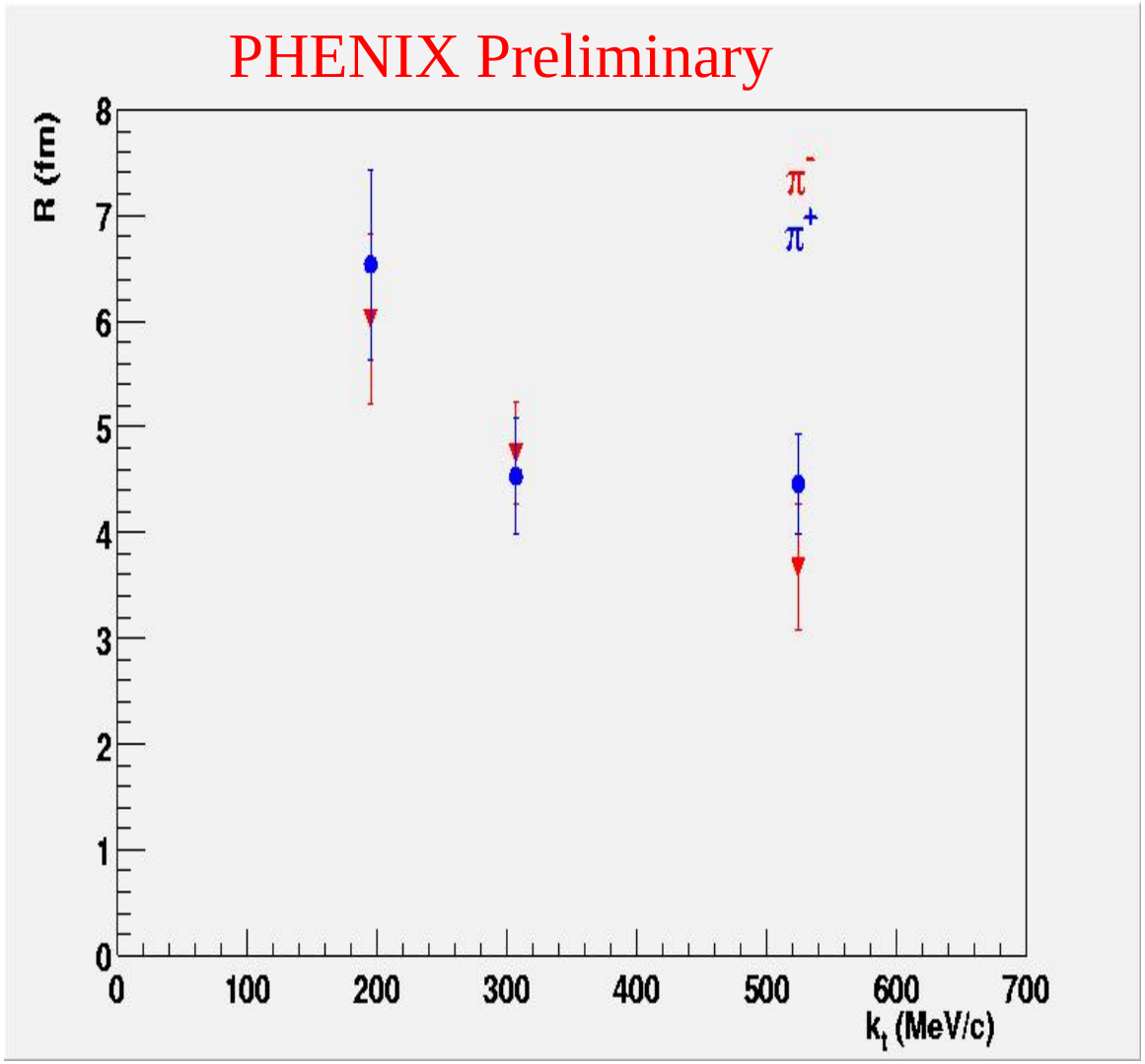
1D correlations

- Full coulomb correction
- q =>Measure of relative separation of pair in the rest frame of the collision.

Stephen C. Johnson for
the PHENIX Collaboration

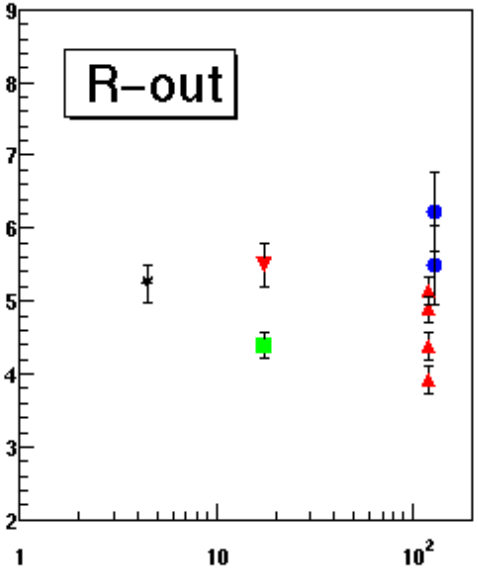
As a function of k_t

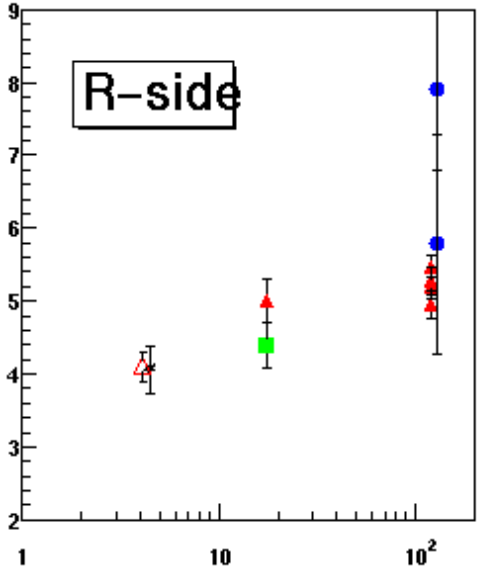
- k_t dependence is well behaved
- Measured relative separation of pions from source expected to decrease versus k_t possibly due to collective behavior of source or resonance contributions.

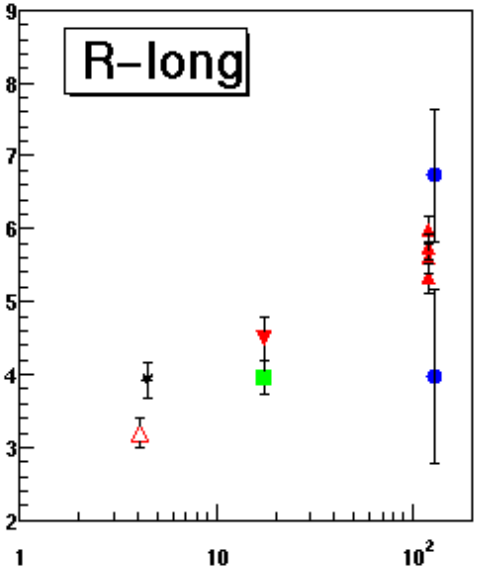


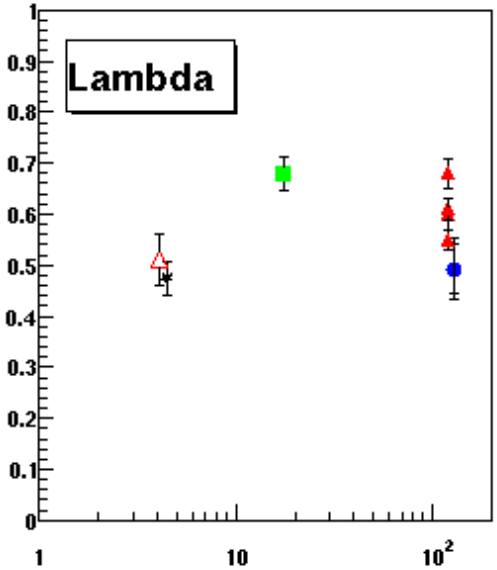
Stephen C. Johnson for
the PHENIX Collaboration

Comparisons









root-s

- No indication of large volumes
- Comparable results to SPS and preliminary STAR with similar <k_t>/centrality
  - Not exactly the same, so be careful…
- Perhaps indicative of same effective freeze-out due to convolution of
  - larger source and
  - stronger dynamical correlations / high flow velocities / resonances(?)

▲ Star Preliminary (M. Lisa)
■ NA44
▼ NA49
★ E866
△ E895
● PHENIX Preliminary

Conclusions*

- First measured $\pi^{+/-}$ correlation function from PHENIX at RHIC including most Run 1 dataset:
  - 1D correlation looks well behaved => used to determine coulomb correction.
  - 3D correlation comparable to SPS published and STAR preliminary results when comparing similar k_t bins
  - Dependencies of Rl and Rs on beam energy are gradual and well behaved.
  - No indication of long lived source in correlation function
    - But be careful what you conclude from that…
- First proof-of-principle methodology -- looking forward to increased statistics and systematic studies…

* Don't leave yet, I still have 3 more slides…

Stephen C. Johnson for
the PHENIX Collaboration

For the future...

- This year
  - Complete systematic studies of π^+/π^- correlations
  - h^-h^- π-p, π-K (1D)
  - with EMCAL:
    - $\pi\pi$, KK, pp (1D)

Coherent interpretation of source size

- Next year
  - 100x statistics =>
    - π vs centrality and k_t
    - pp, KK
  - with EMCAL
    - anti-neutron, π^0 (?)
- In general
  - Are there other methods we can use to extract info from correlations? ==>

Stephen C. Johnson for
the PHENIX Collaboration

Other methods

- Explicit inversion of correlation function to deduce relative separation of pairs at freeze-out.
- How sensitive is this method to the source?
  - Can we learn more than just the RMS?
  - Extract multi-D source parameters?
  - Systematic studies underway.

See poster by D. Brown

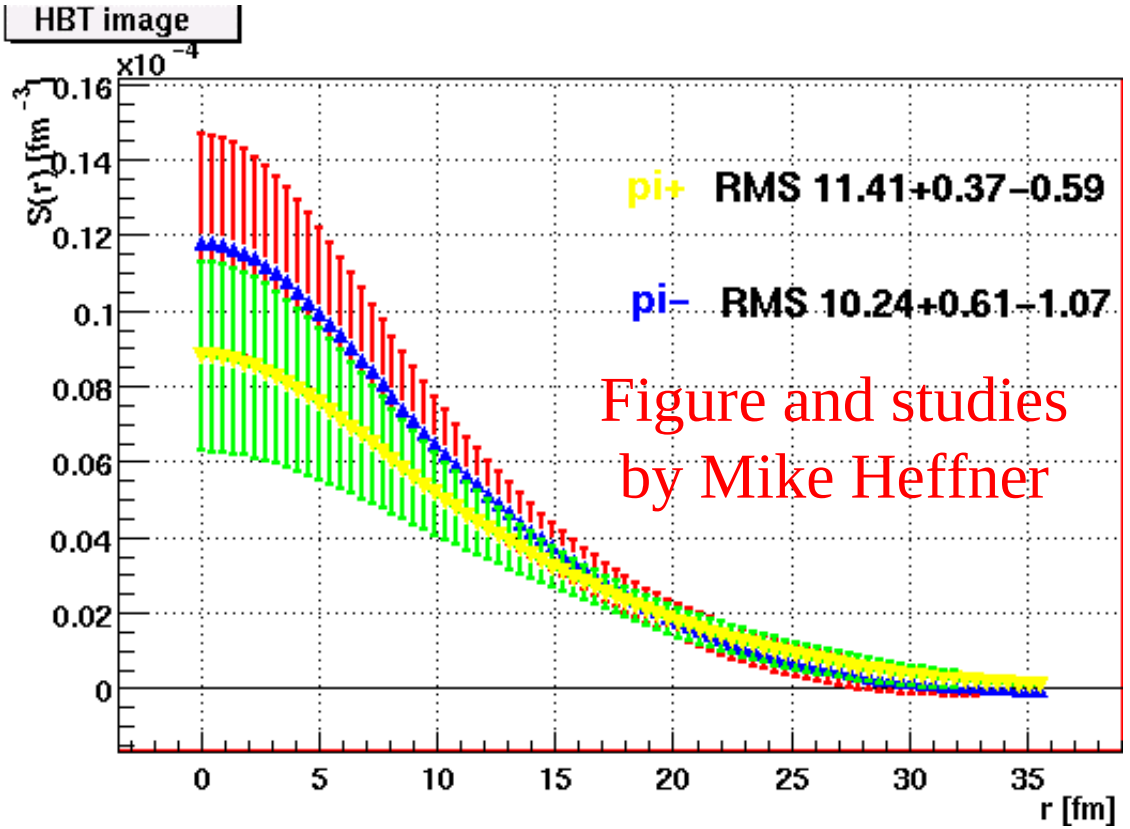


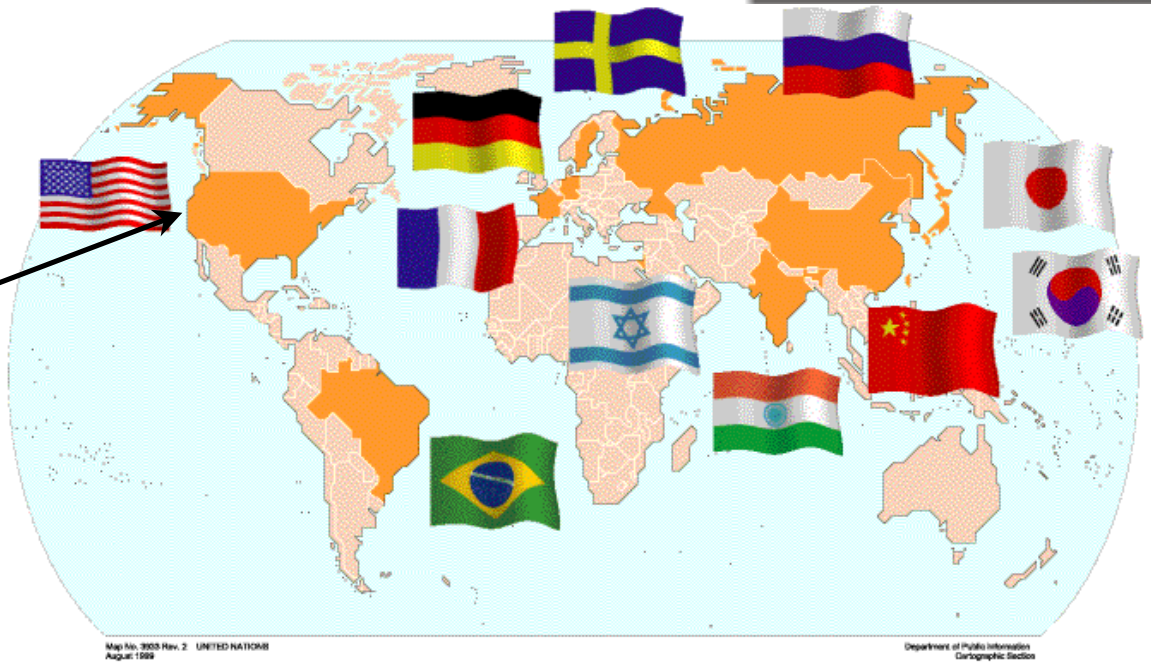
Figure and studies by Mike Heffner

Brown and Danielewicz nucl-th/0010108

Special Thanks

PHENIX

R. Soltz
M. Heffner



University of São Paulo, São Paulo, Brazil
Academia Sinica, Taipei 11529, China
China Institute of Atomic Energy (CIAE), Beijing, P. R. China
Laboratoire de Physique Corpusculaire (LPC), Universite de Clermont-Ferrand, 63170 Aubiere, Clermont-Ferrand, France
Dapnia, CEA Saclay, Bat. 703, F-91191, Gif-sur-Yvette, France
IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, BP1, F-91406, Orsay, France
LPNHE-Palaiseau, Ecole Polytechnique, CNRS-IN2P3, Route de Saclay, F-91128, Palaiseau, France
SUBATECH, Ecole des Mines at Nantes, F-44307 Nantes, France
University of Muenster, Muenster, Germany
Banaras Hindu University,Banaras, India
Bhabha Atomic Research Centre (BARC),Bombay, India
Weizmann Institute, Rehovot, Israel
Center for Nuclear Study (CNS-Tokyo), University of Tokyo, Tanashi, Tokyo 188, Japan
Hiroshima University, Higashi-Hiroshima 739, Japan
KEK, Institute for High Energy Physics,Tsukuba, Japan
Kyoto University, Kyoto, Japan
Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki, Japan
RIKEN, Institute for Physical and Chemical Research, Hirosawa, Wako, Japan
University of Tokyo, Bunkyo-ku, Tokyo 113, Japan
Tokyo Institute of Technology, Ohokayama, Meguro, Tokyo, Japan
University of Tsukuba, Tsukuba, Japan
Waseda University, Tokyo, Japan
Cyclotron Application Laboratory, KAERI, Seoul, South Korea
Kangnung National University, Kangnung 210-702, South Korea
Korea University, Seoul, 136-701, Korea
Myong Ji University, Yongin City 449-728, Korea
System Electronics Laboratory, Seoul National University, Seoul, South Korea
Yonsei University, Seoul 120-749, KOREA
Institute of High Energy Physics (IHEP-Protvino or Serpukhov), Protovino, Russia
Joint Institute for Nuclear Research (JINR-Dubna), Dubna, Russia
Kurchatov Institute, Moscow, Russia
PNPI: St. Petersburg Nuclear Physics Institute, Gatchina, Leningrad, Russia
Lund University, Lund, Sweden
Abilene Christian University, Abilene, Texas, USA
Brookhaven National Laboratory (BNL), Upton, NY 11973
University of California - Riverside (UCR), Riverside, CA 92521, USA
Columbia University, Nevis Laboratories, Irvington, NY 10533, USA
Florida State University (FSU), Tallahassee, FL 32306, USA
Georgia State University (GSU), Atlanta, GA, 30303, USA
Iowa State University (ISU) and Ames Laboratory, Ames, IA 50011, USA
LANL: Los Alamos National Laboratory, Los Alamos, NM 87545, USA
LLNL: Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
University of New Mexico, Albuquerque, New Mexico, USA
New Mexico State University, Las Cruces, New Mexico, USA
Department of Chemistry, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA
Department of Physics and Astronomy, State University of New York at Stony Brook (USB), Stony Brook, NY 11794-, USA
Oak Ridge National Laboratory (ORNL), Oak Ridge, TN 37831, USA
University of Tennessee (UT), Knoxville, TN 37996, USA
Vanderbilt University, Nashville, TN 37235, USA