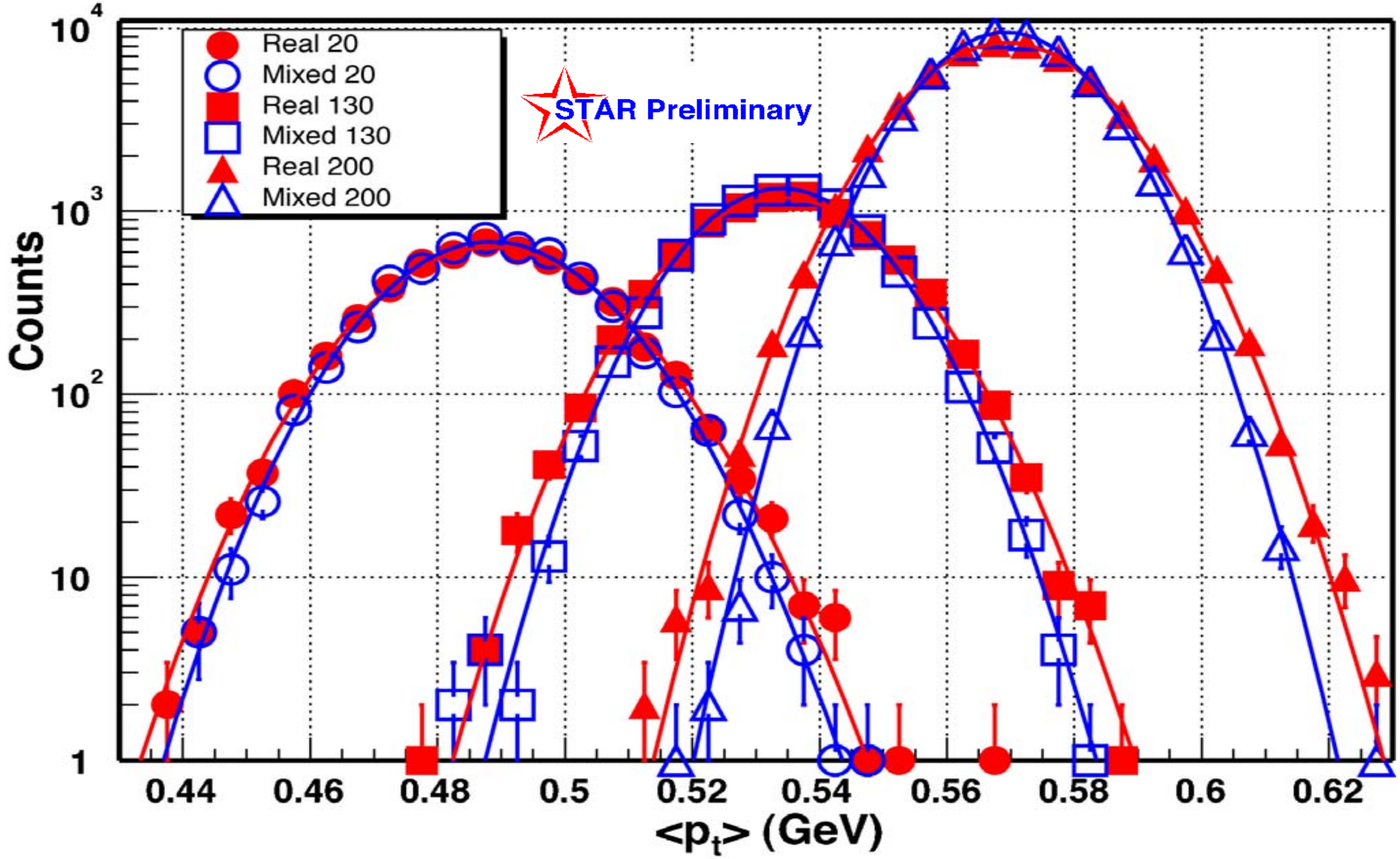
Fluctuations and correlations Summary QM2004

Harald Appelshäuser, GSI Darmstadt

Mean p_t fluctuations

G. Westfall (STAR)



Now we need a measure….

H. Appelshäuser, QM2004 Oakland

What we want to have

A good measure should be:

Independent of particular experiment

Comparable to theory

Corrected for detector effects
(e.g. 2-track resolution)

Not corrected for ``known physics effects´´
(e.g. HBT, flow, superposition of
independent sources etc.)

What we have:

F_{pT} PHENIX

J. Mitchell (Plenary)

$\sigma^2_{pT,dyn}$ STAR

$<\Delta p_{t,i}\Delta p_{t,j}>$

$\Delta\sigma_{pT,n}$ STAR

$$F_{p_T} \approx \frac{\Phi_{p_T}}{\sigma_{p_T,incl.}}$$

$$\sigma^2_{p_T,dyn} \cong \frac{2\Phi_{p_T}\sqrt{\overline{\Delta p_T^2}}}{\langle N\rangle}$$

$$\Delta\sigma_{p_T,n} \cong \sqrt{\left(\Phi_{p_T} + \sigma_{p_T,incl}\right)^2 - \sigma^2_{p_T,incl}}$$

$$\sigma_{p_T,incl.} = \sqrt{\langle p_T^2\rangle - \langle p_T\rangle^2}$$

$$\overline{\Delta p_T^2} \equiv \overline{p_T^2} - \overline{p_T}^2$$

$$\Sigma_{p_T} = \frac{\sigma_{p_T}}{\overline{p_T}}\sqrt{\frac{2F_{p_T}}{< N >}}$$

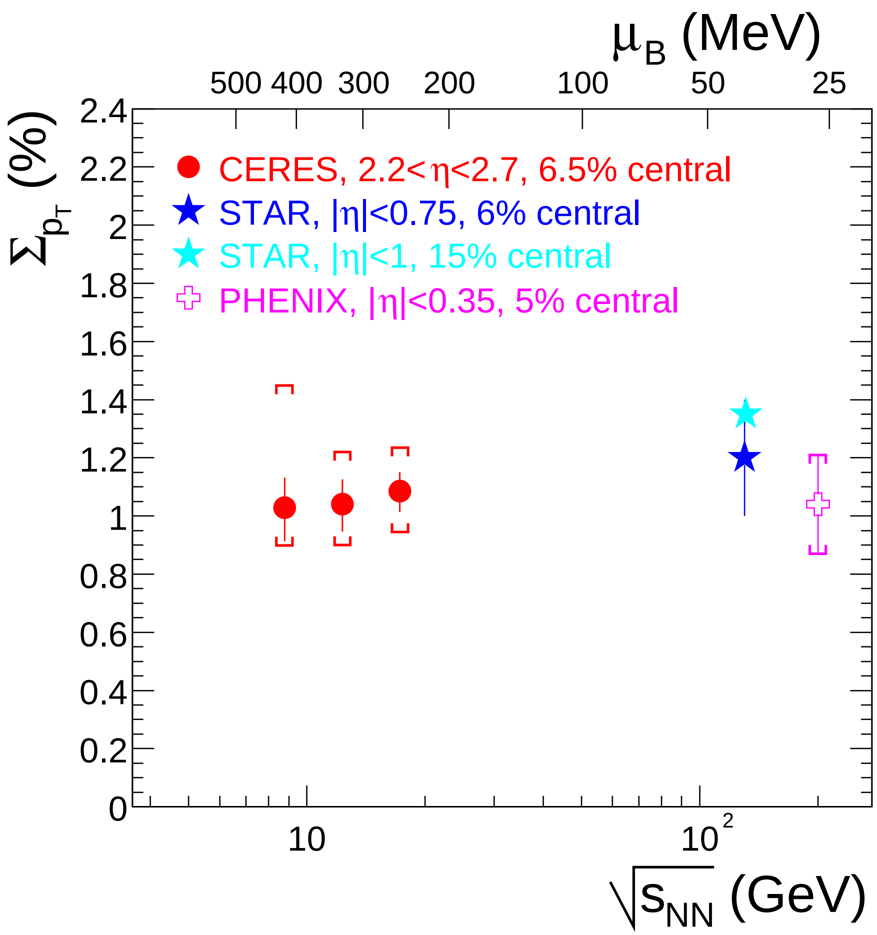
$$\Sigma_{p_T} \equiv \mathrm{sgn}\left(\sigma^2_{p_T,dyn}\right)\frac{\sqrt{|\sigma^2_{p_T,dyn}|}}{\overline{p}_T}$$

NA49 Φ_{pT}

Σ_{pT} CERES

The critical point of QCD

...should show up as a peak in the excitation function (Stephanov, Rajagopal, Shuryak)

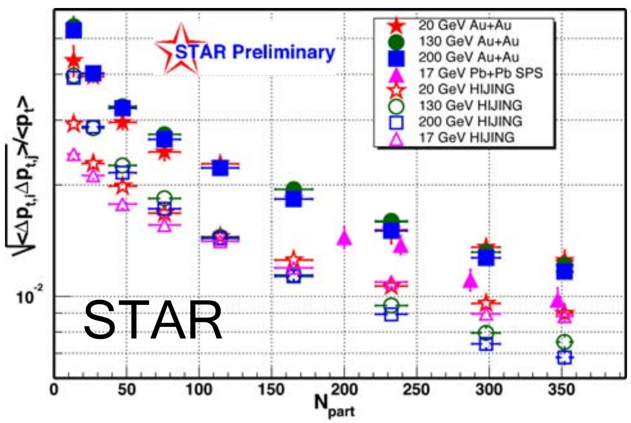


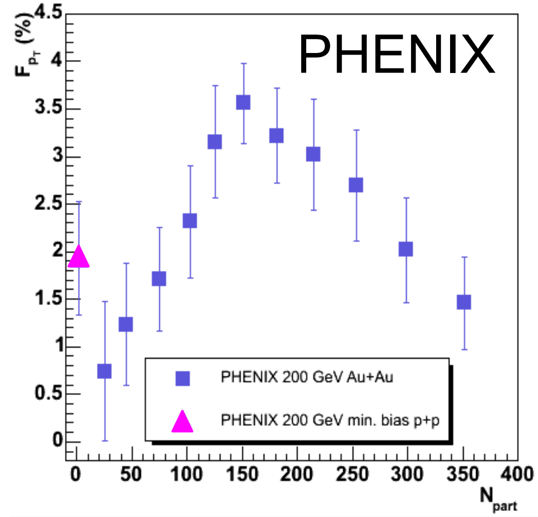
H. Sako (CERES)

- No indication for the critical point so far
- Scan between SPS and RHIC
- 20 and 30 GeV/c from NA49
- GSI SIS 300

Centrality dependence

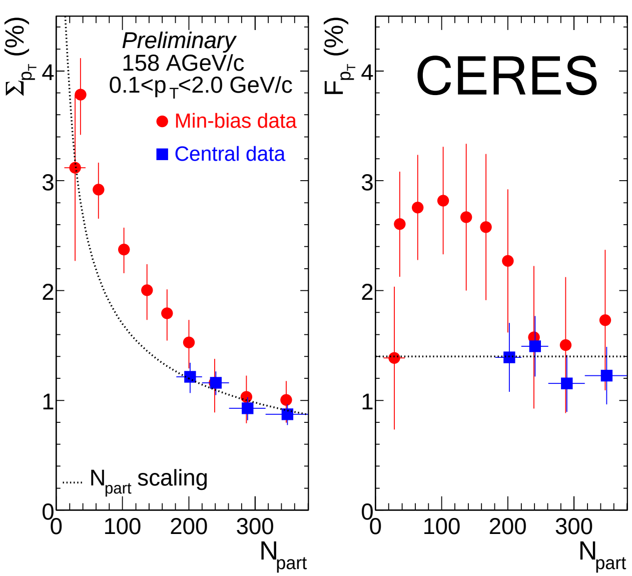
G. Westfall & Poster by C. Pruneau

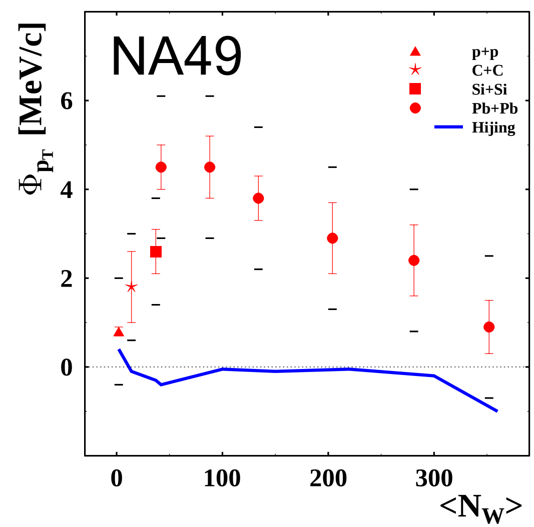




M. Tannenbaum
J. Mitchell

H. Sako



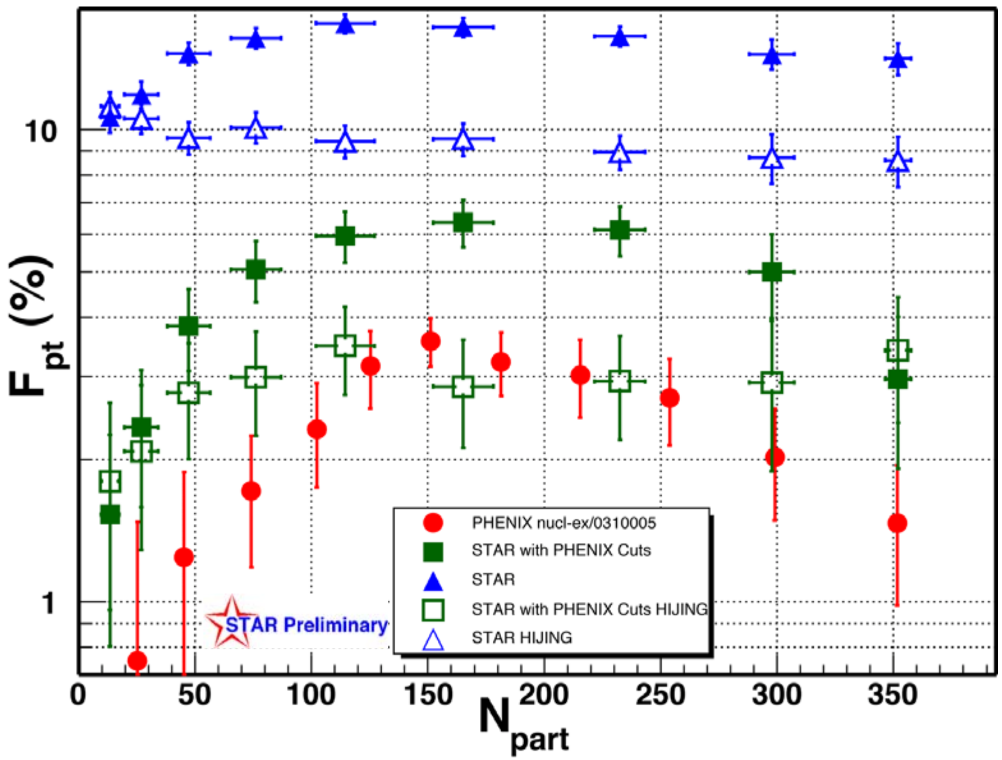


Poster by
K. Perl, M. Rybczynski

H. Appelshäuser, QM2004 Oakland

Centrality dependence

G. Westfall (STAR)

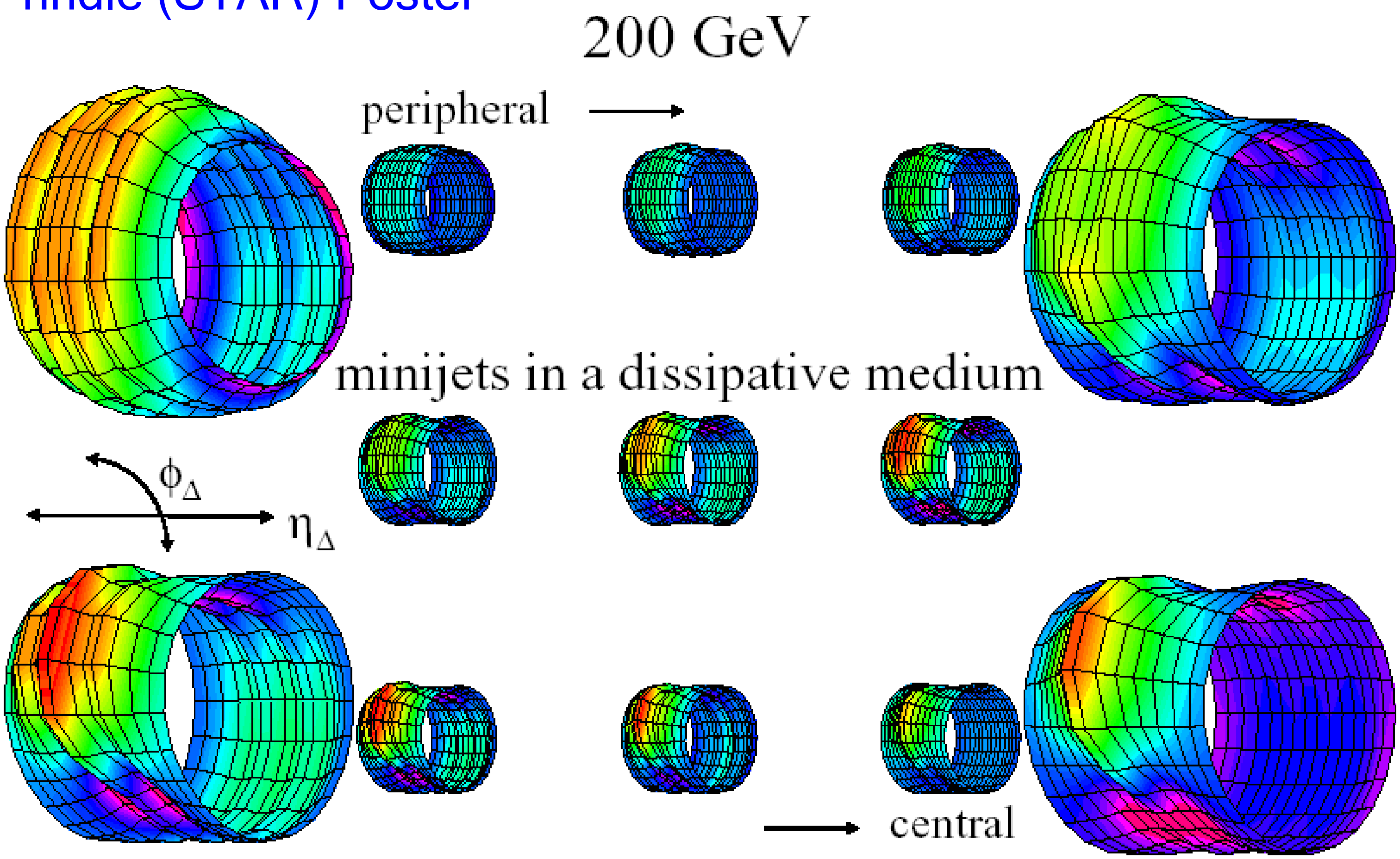


Acceptance matters!

Fluctuation signal is scale dependent

Scale dependence of p_t correlations

D. Prindle (STAR) Poster

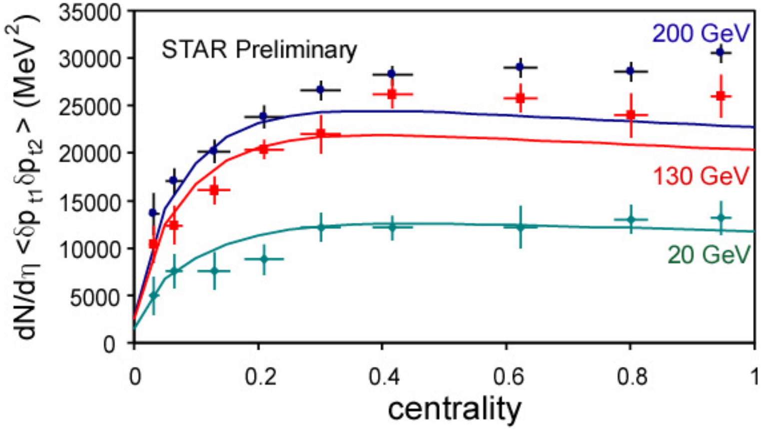


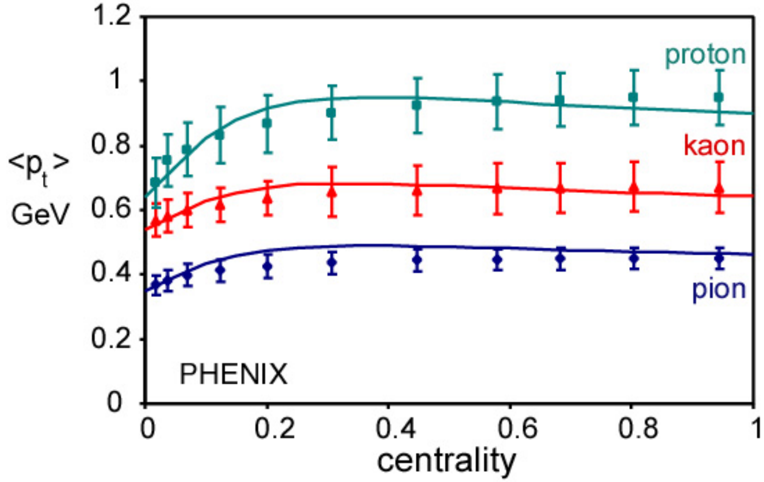
Medium response to minijets?

Centrality dependence

Traces of thermalization?

S. Gavin





Larger centrality =
Longer lifetime =
Smaller survival probability S

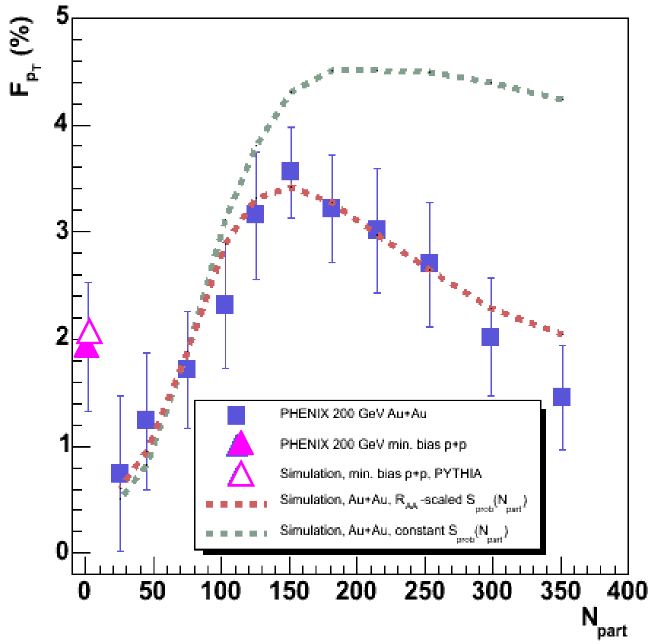
$\langle p_t \rangle = \langle p_t \rangle_o S + \langle p_t \rangle_e (1-S)$

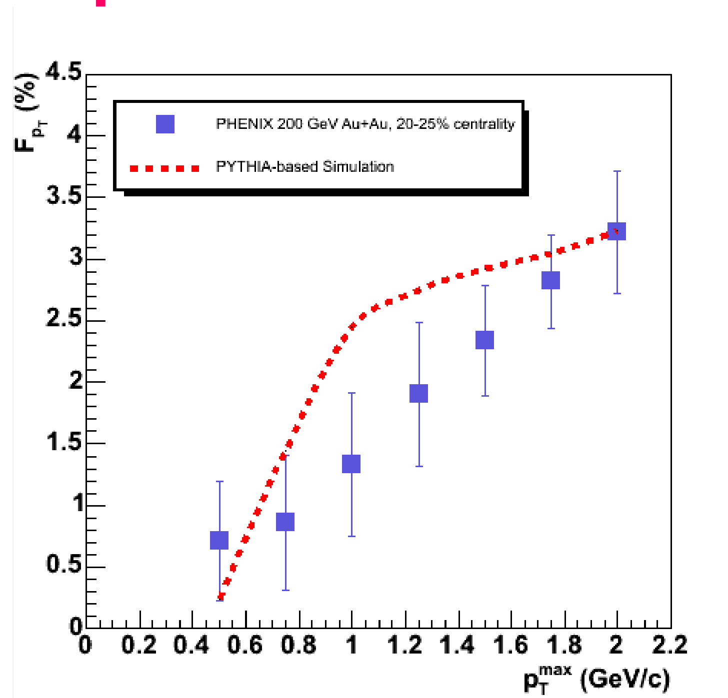
$\langle \delta p_{t1} \delta p_{t2} \rangle = \langle \delta p_{t1} \delta p_{t2} \rangle_o S^2 + \langle \delta p_{t1} \delta p_{t2} \rangle_e (1-S^2)$

Deviation in central events
due to jets?

Thermalized partons or hadrons?

Centrality dependence





M. Tannenbaum, J.Mitchell (PHENIX):

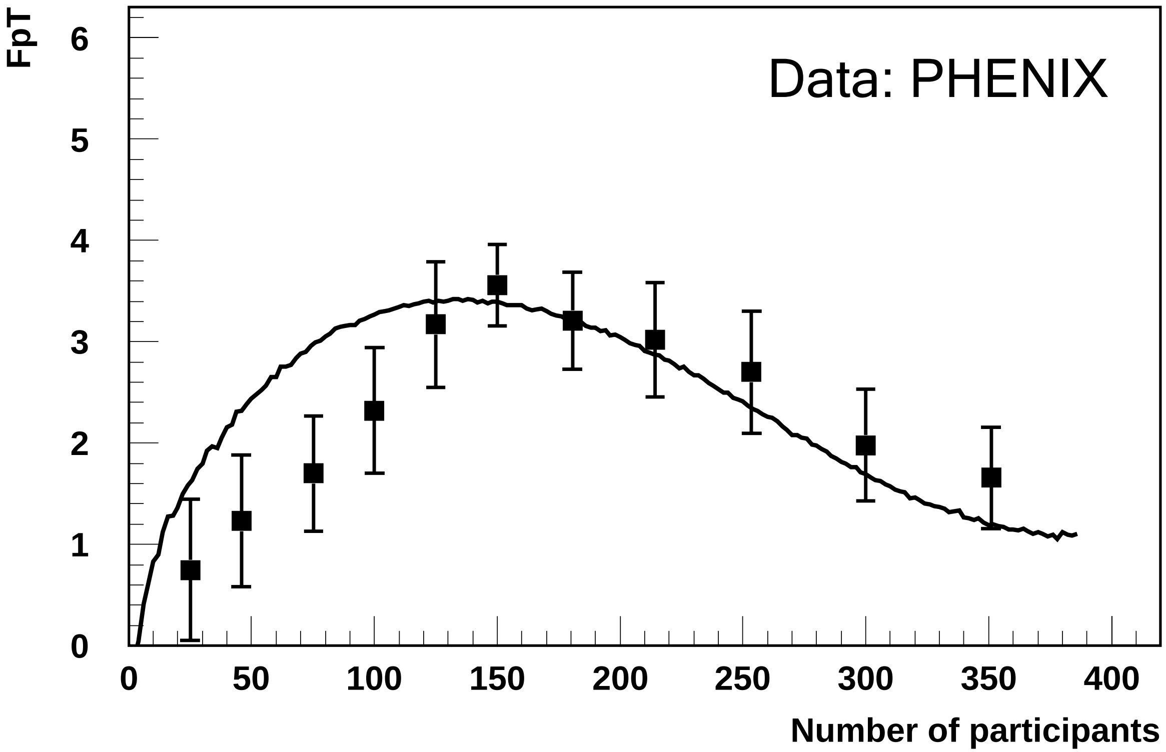
This is not flow, these are jets!

Phenomenological, PYTHIA-based model gives good description

What happens to the quenched jets?

Other explanations

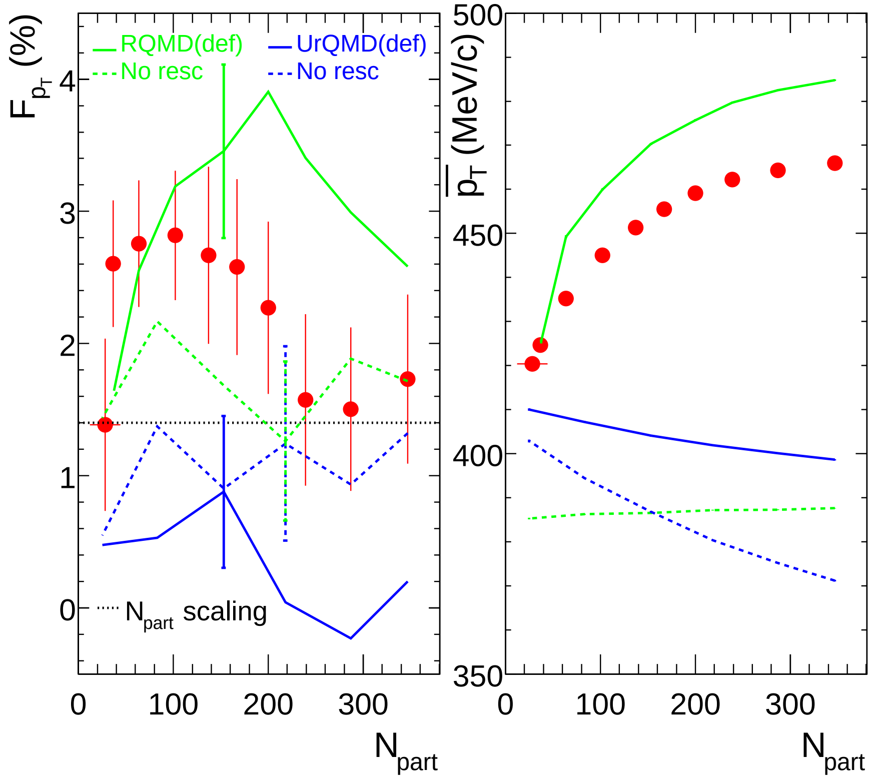
E. Ferreira, Poster



$\langle p_t \rangle$ fluctuations by string percolation

Other explanations

H. Sako (CERES):
Comparison to cascade models



Charge fluctuations

Charges are more evenly distributed in a QGP

Strongly reduced net charge fluctuations in a small region of phase space

This has not been observed!

Charge (and multiplicity) fluctuations may give insight to the particle production mechanism, thermalization etc.

Charge fluctuations (NA49, CERES, STAR)

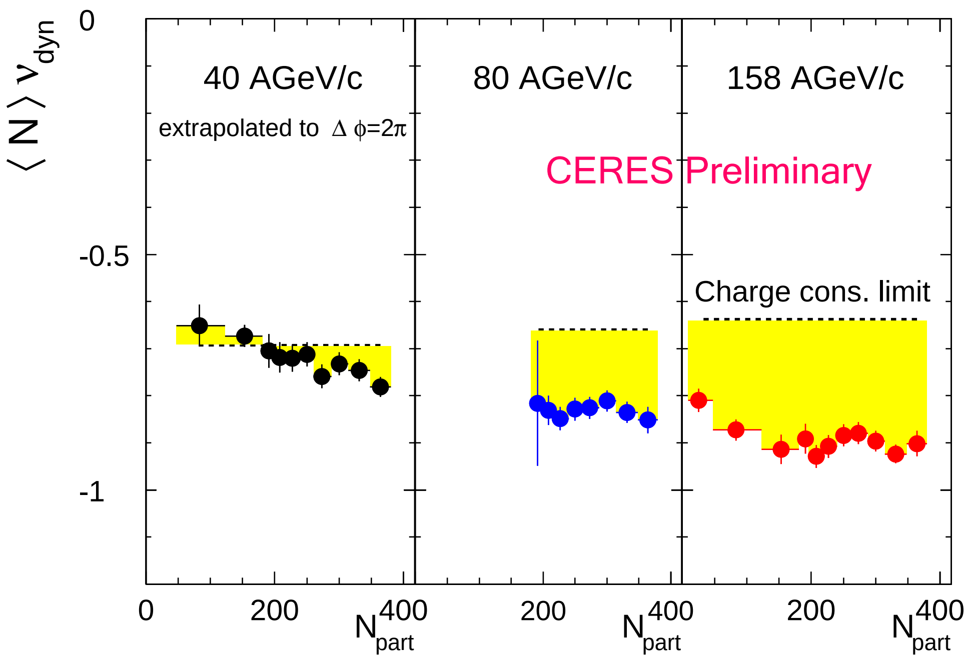
Balance functions (NA49, STAR)

Multiplicity fluctuations (NA49, Phobos)

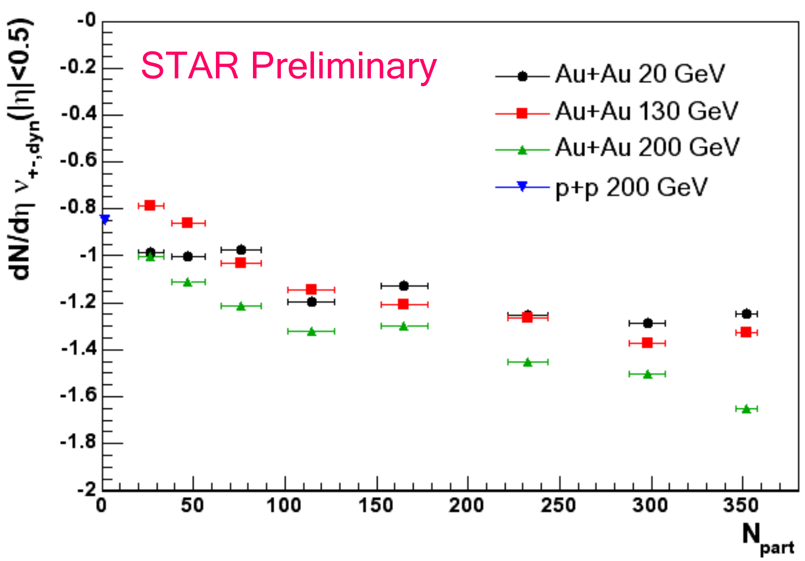
Charge fluctuations

$$\nu_{dyn} \equiv \left\langle \left(\frac{N_+}{\langle N_+ \rangle} - \frac{N_-}{\langle N_- \rangle} \right)^2 \right\rangle - \left(\frac{1}{\langle N_+ \rangle} + \frac{1}{\langle N_- \rangle} \right)$$

H. Sako (CERES)



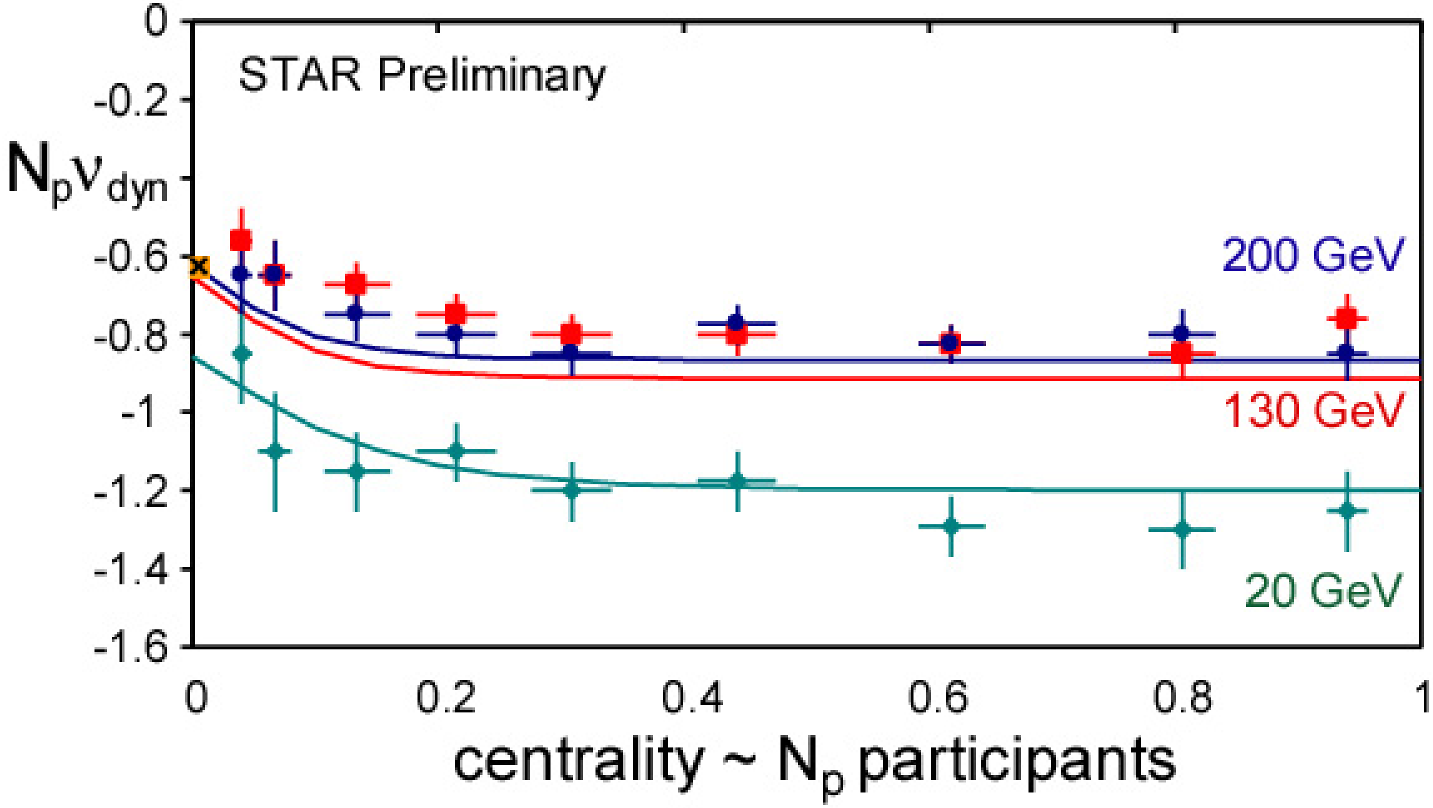
G. Westfall (STAR)



Multiplicity scaling violated at small N_{part}

Charge fluctuations

S. Gavin



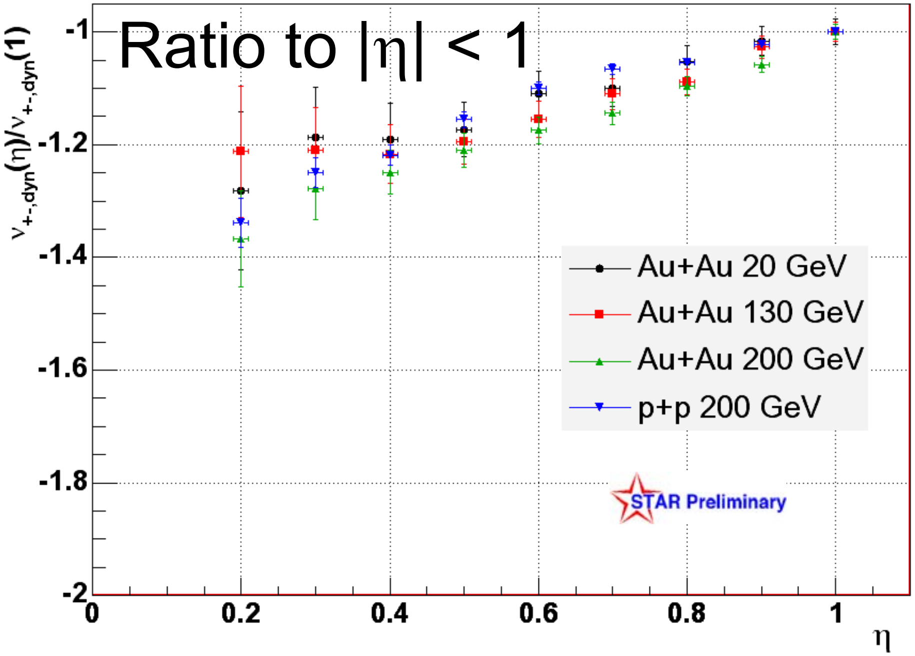
Common thermal explanation for p_t and charge fluctuations

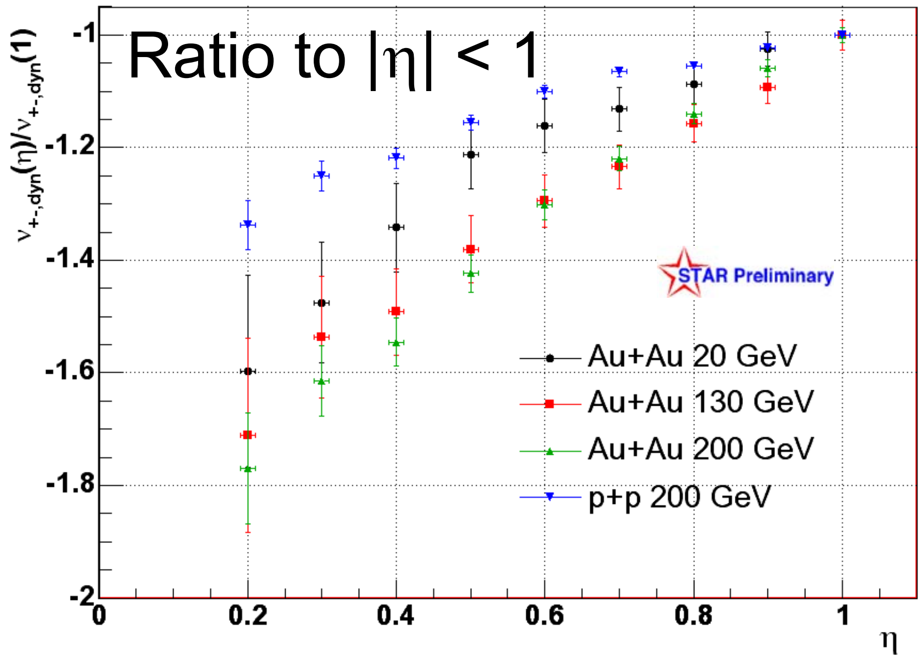
Charge fluctuations

50-70% centrality

S. Westfall (STAR)

0-10% centrality





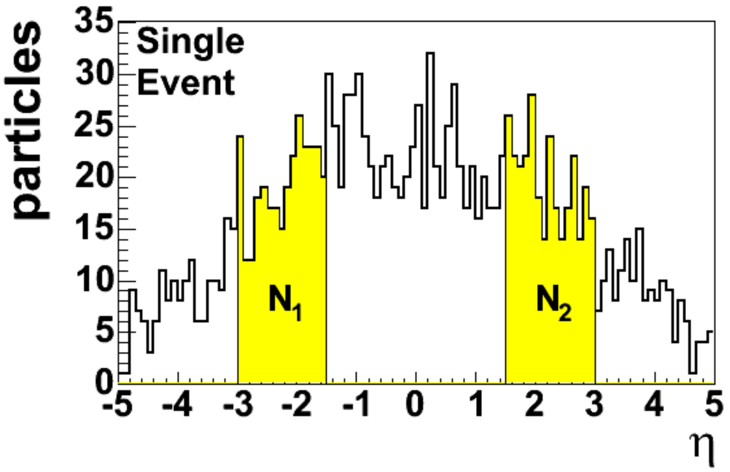
Consistent with narrowing of balance function: $B(Y|Y) = -\langle N \rangle \nu_{dyn}/4$

Pruneau, Gavin, Voloshin

Consistent with late hadronization plus flow

Multiplicity fluctuations

K. Wozniak (PHOBOS)

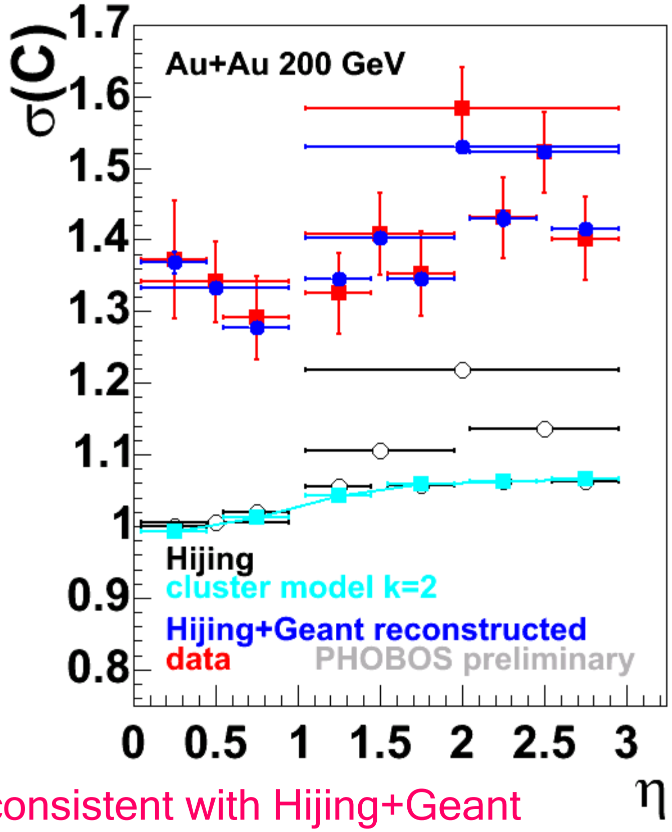


$$C = \frac{N_1 - N_2}{\sqrt{N_1 + N_2}}$$

For statistical fluctuations

$\sigma^2(C) = 1$

Independent of multiplicity



Data consistent with Hijing+Geant

Hijing consistent with cluster model k=2 and correlation width $\Delta\eta$=1

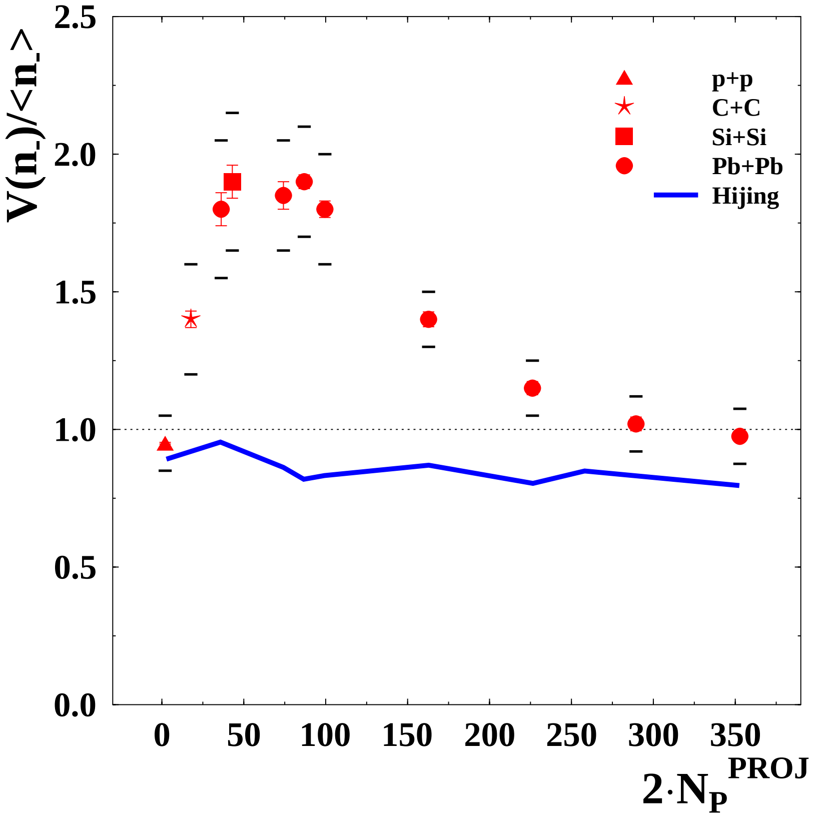
Consistent with STAR nucl-ex/0307007

H. Appelshäuser, QM2004 Oakland

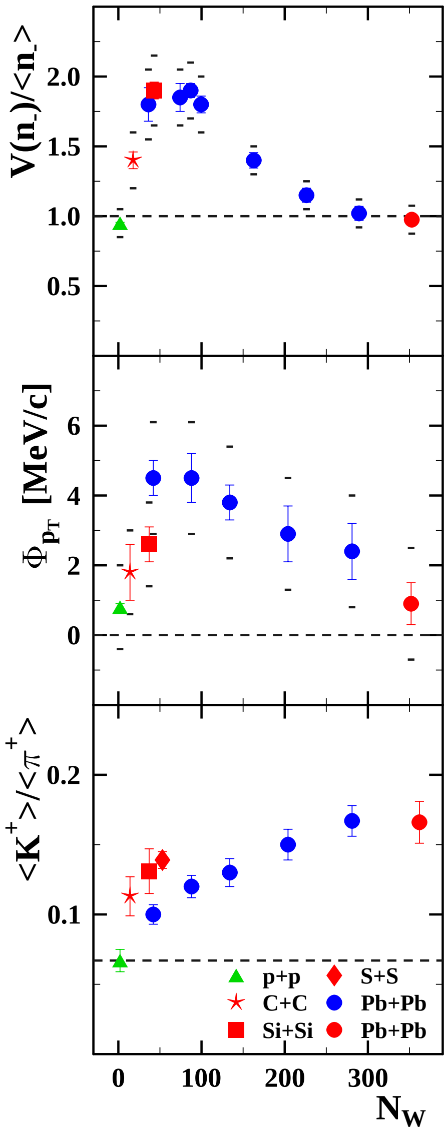
Multiplicity fluctuations

158 AGeV/c Pb-Pb

NA49, Poster K. Perl, M. Rybczynski



$V(n_-) = \langle n_-^2\rangle - \langle n_-\rangle^2$



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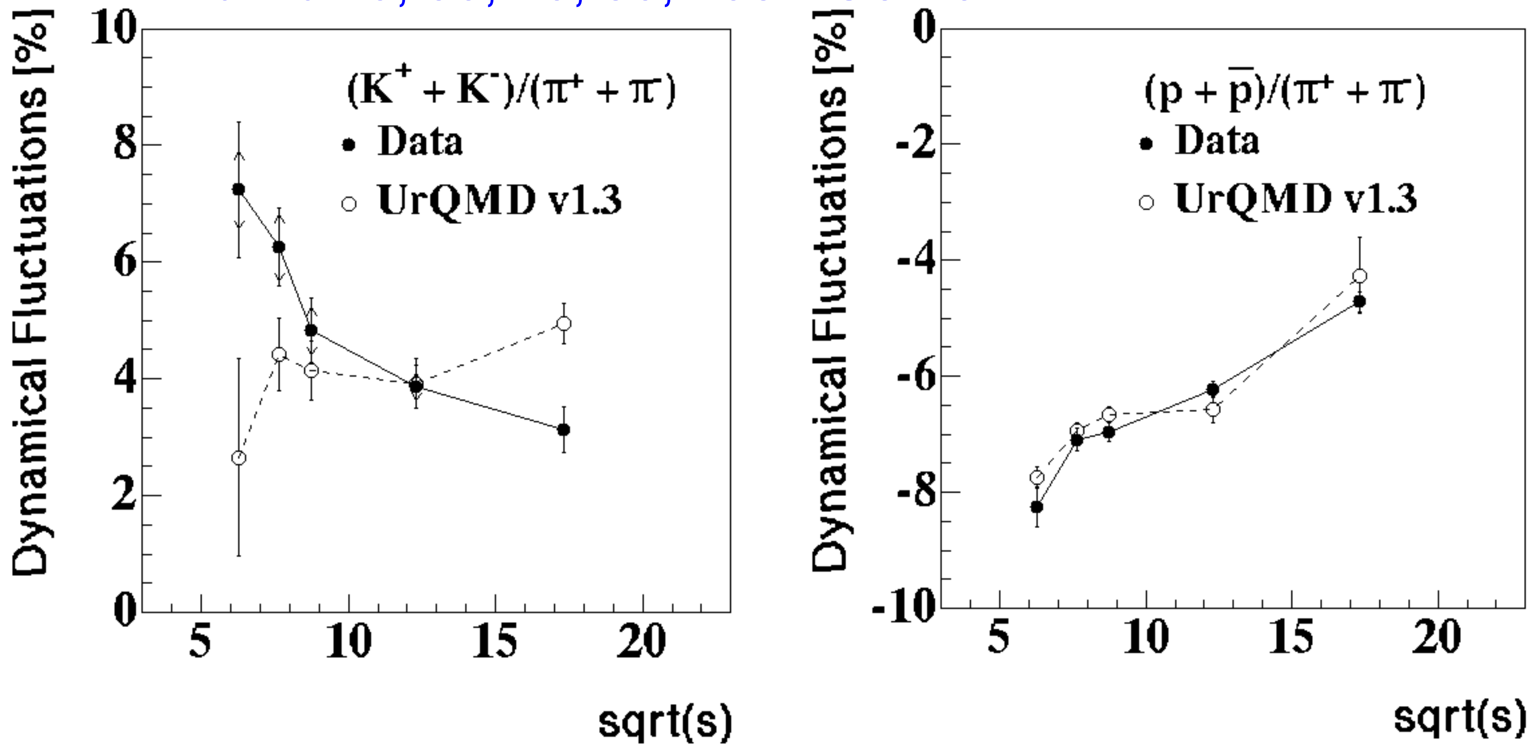
Particle ratio fluctuations

Christof Roland (NA49)
Pb-Pb 20, 30, 40, 80, 158 AGeV/c



K/π fluctuations increase towards lower beam energy (new horn?)

p/π fluctuations explained by resonance decays

We want more!

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Non-identical particle correlations

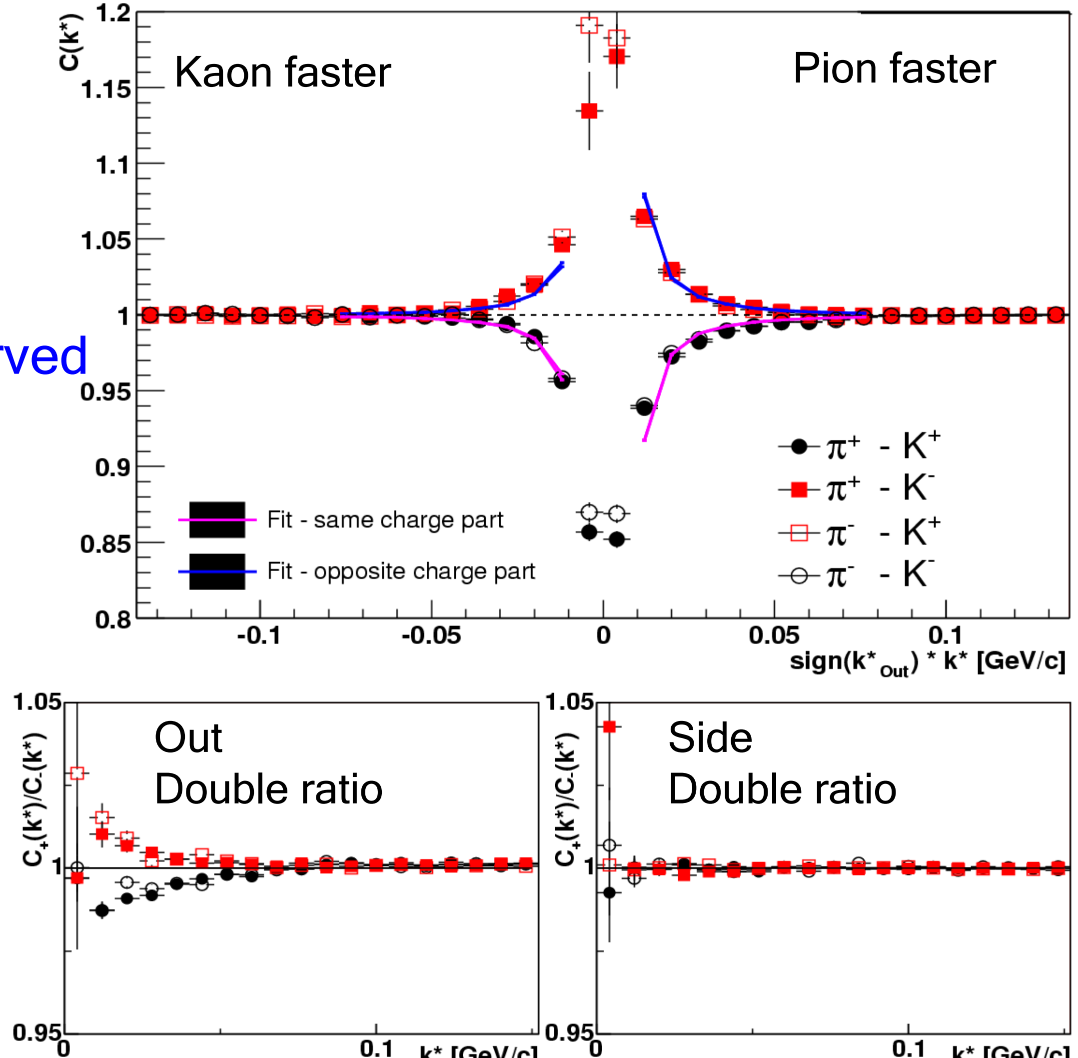
A. Kisiel (STAR):

πp in 130 GeV Au-Au
πp, πK, pK in 200 GeV Au-Au

Significant asymmetry observed

Particles are not emitted from the same space-time region

Consistent with strong x-p-correlations



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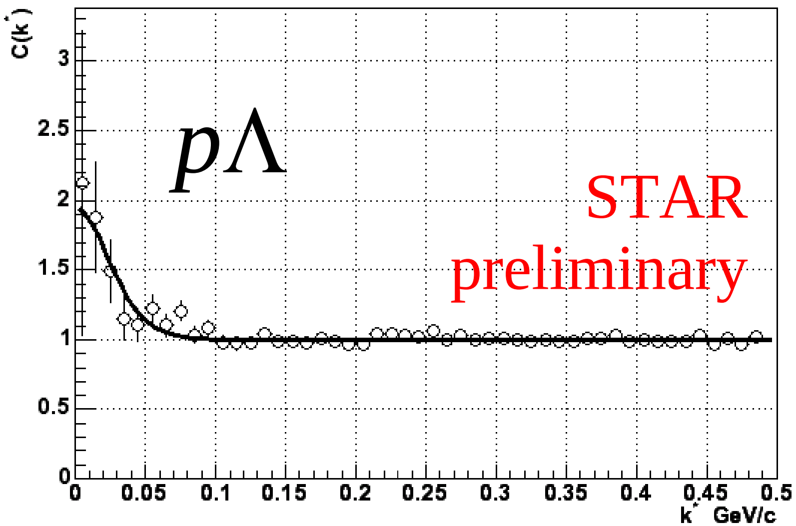
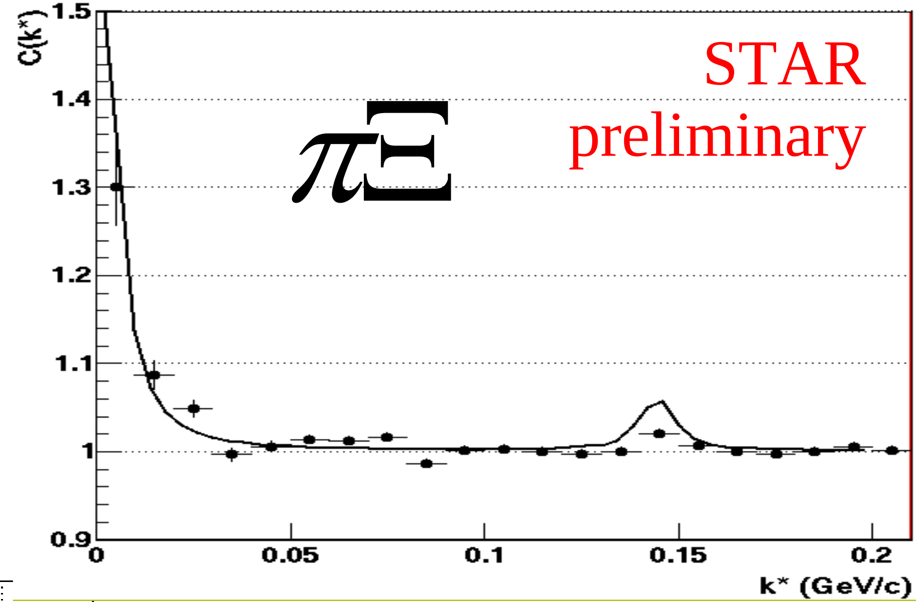
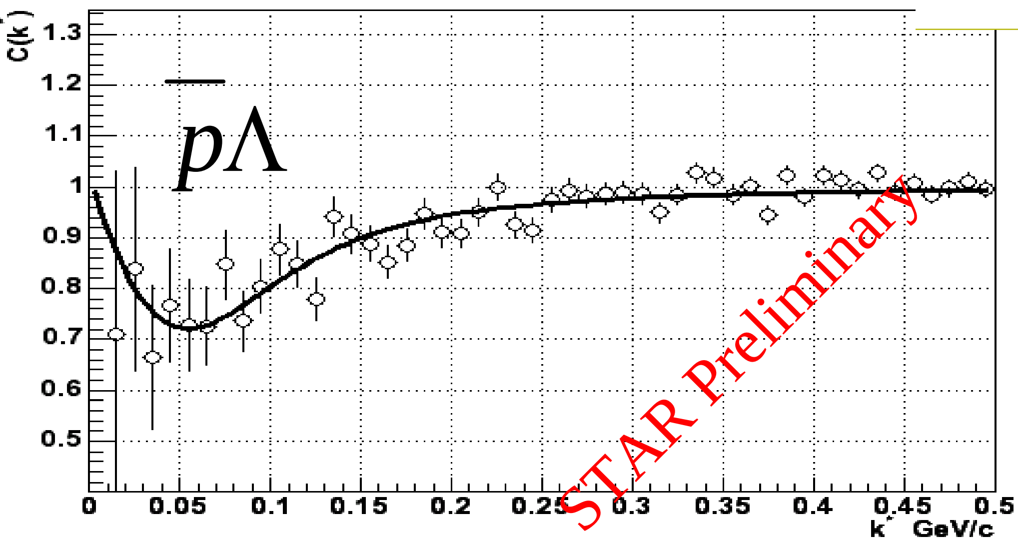
More to come…



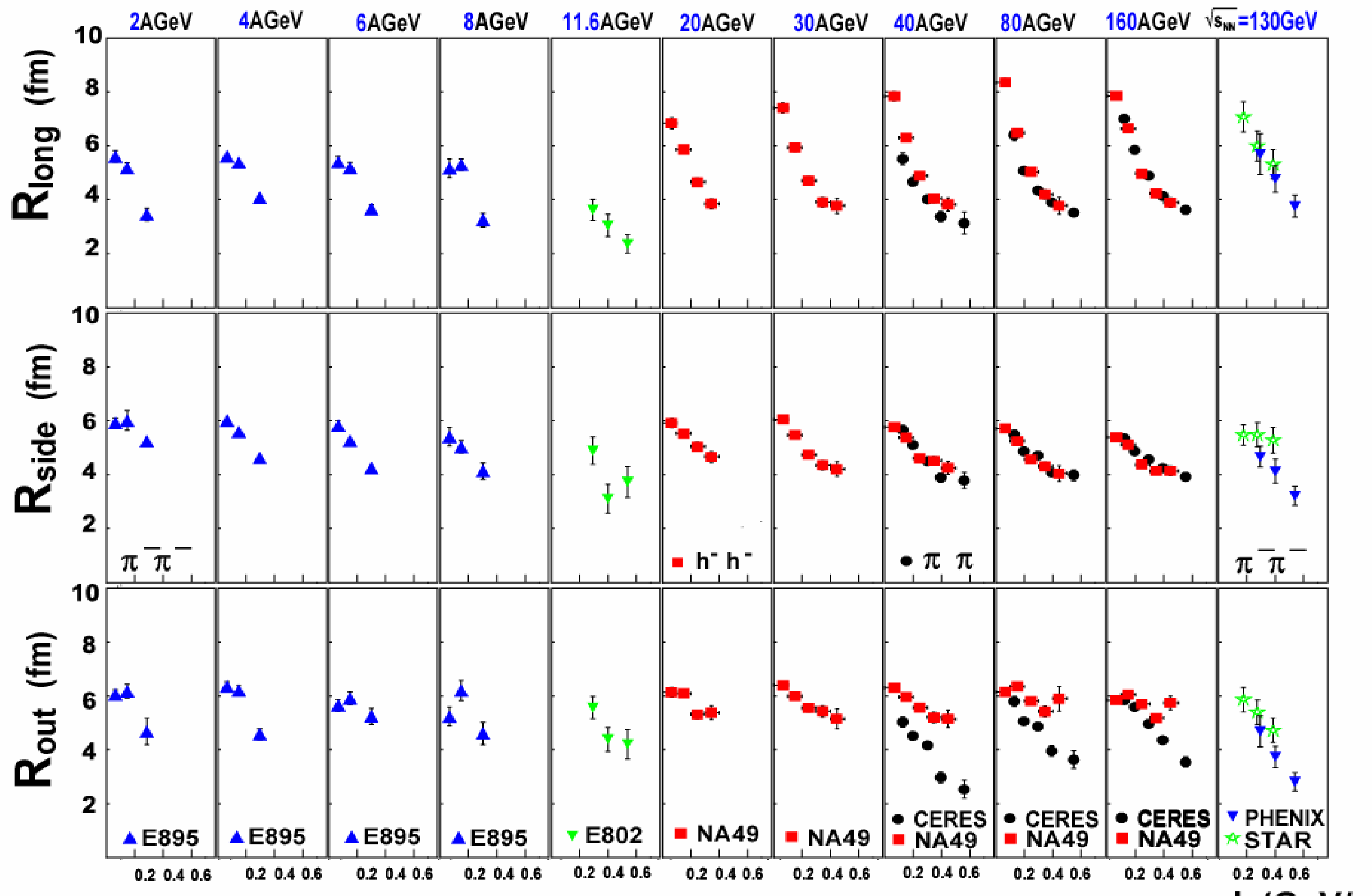




A. Kisiel (STAR)

π HBT: Energy scan at SPS

Pb-Pb central (S. Kniege, NA49)



...from midrapidity to (near) beam rapidity

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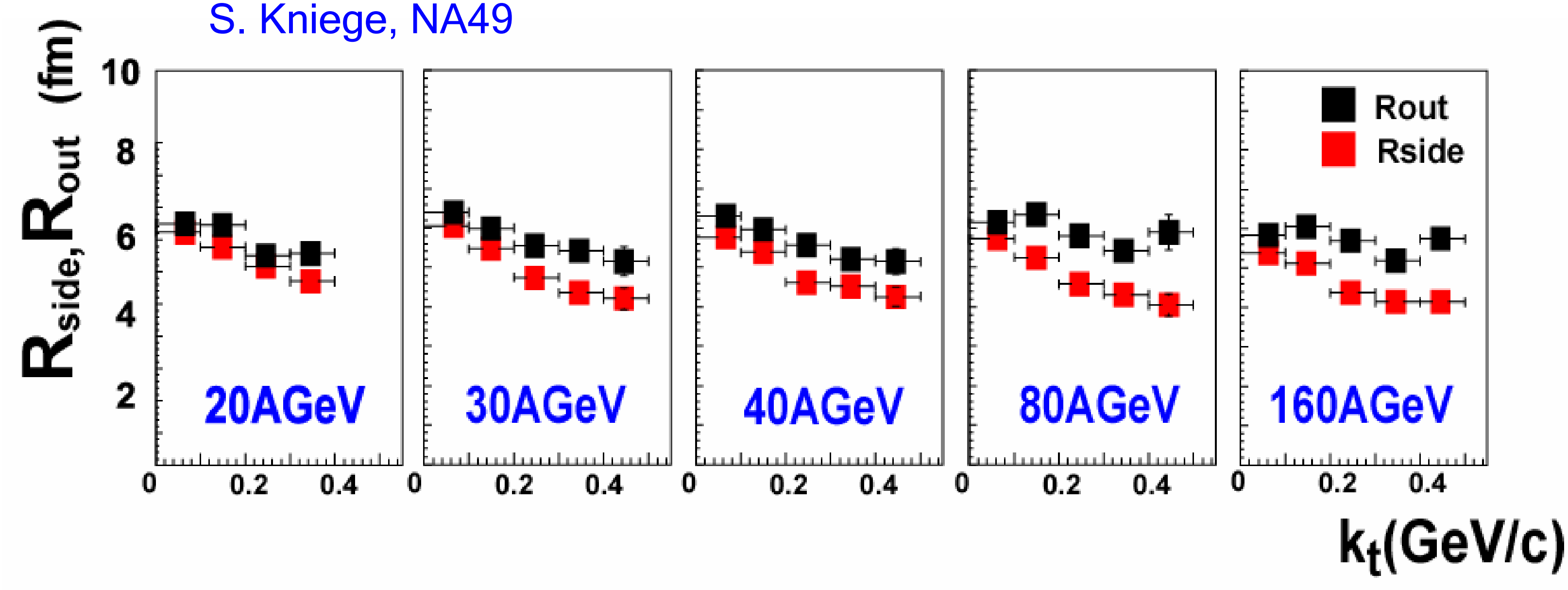
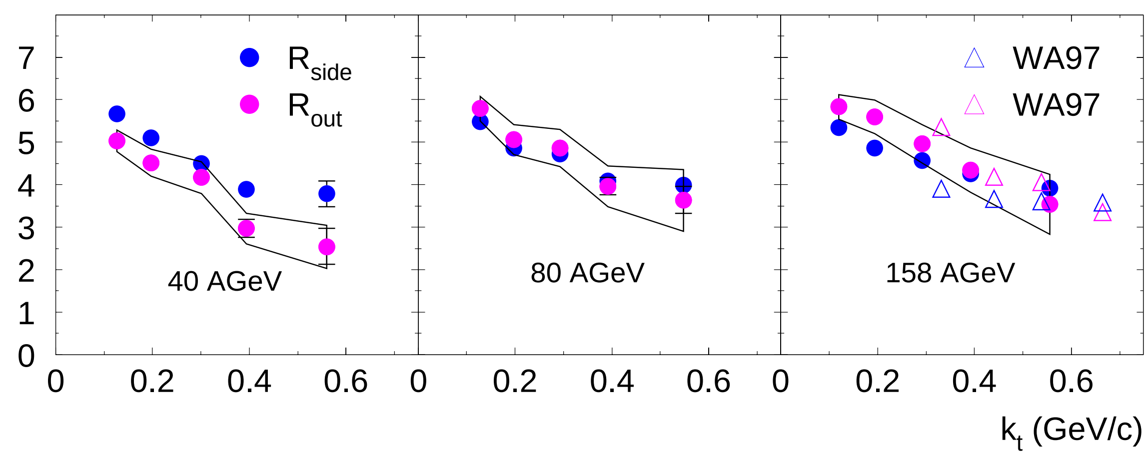
R_{out}/R_{side} at SPS

S. Kniege, NA49





CERES, NPA714 (2003)

WA97, J.Phys.G27 (2001)

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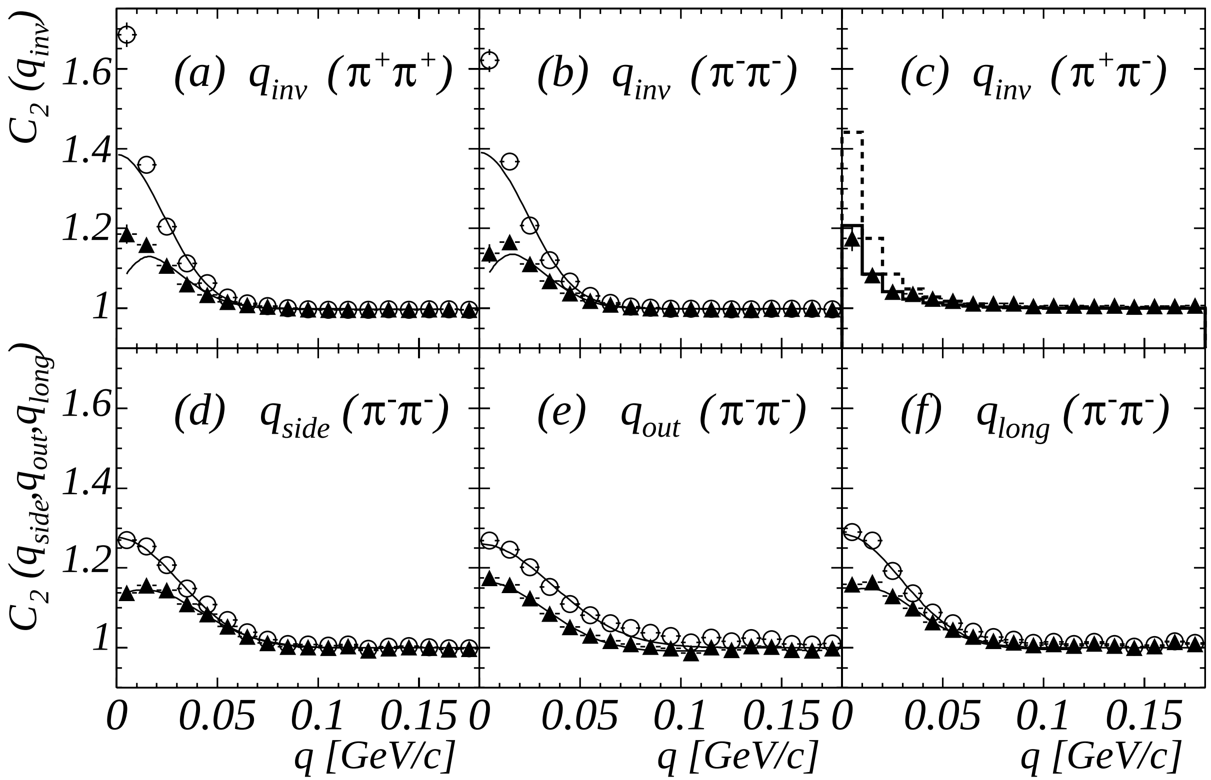
Coulomb

Purity…

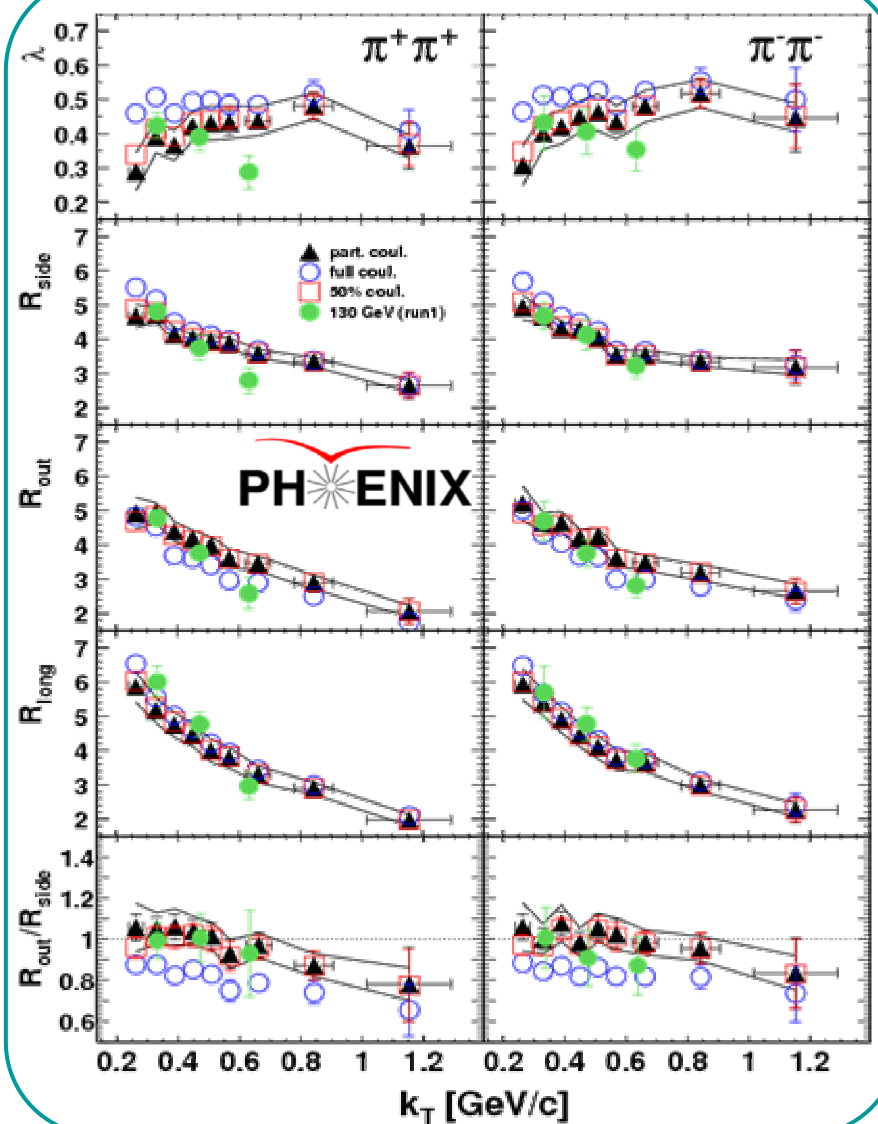
Coulomb



200 GeV Au-Au central
(M. Heffner, PHENIX)

- Purity of pion sample has to be taken into account!
- Partial Coulomb correction adapted by all experiments

Coulomb

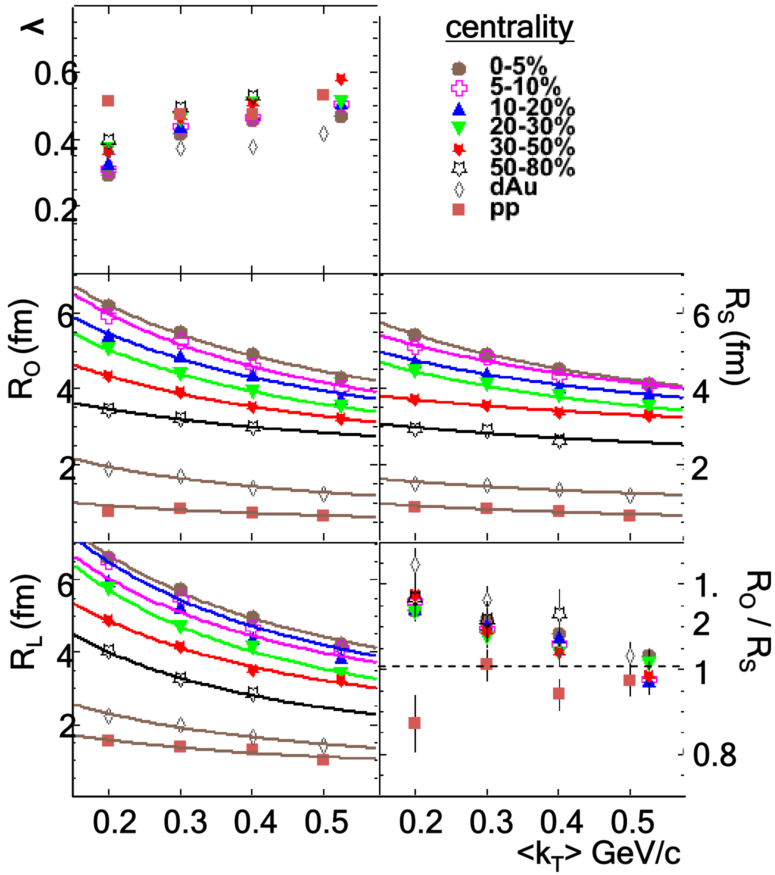


‚New' Coulomb treatment affects mainly R_{out} (and R_{out}/R_{side})

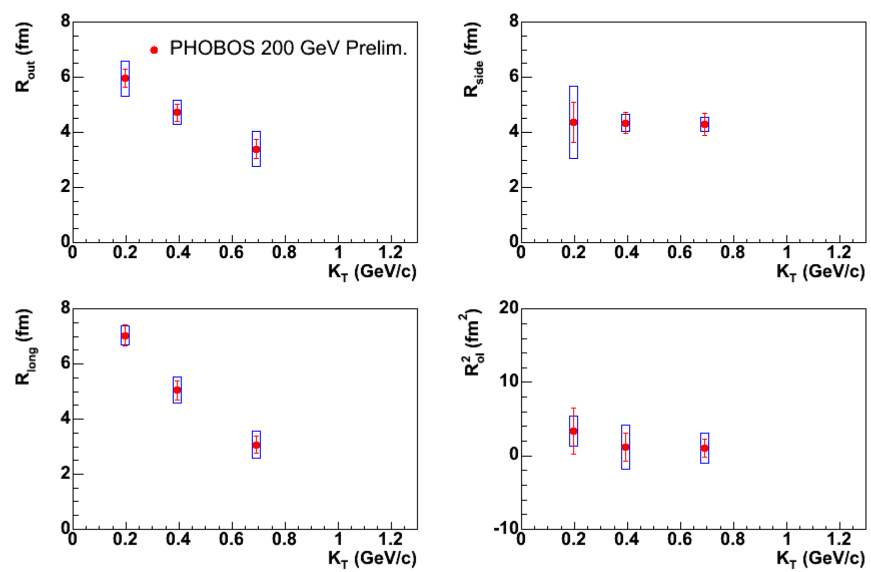
200 GeV Au-Au central (M. Heffner, PHENIX)

π HBT at 200 GeV

STAR 200 GeV, S. Bekele, T. Gutierrez



PHOBOS 200 GeV Au-Au 0-15% central
B. Holzman



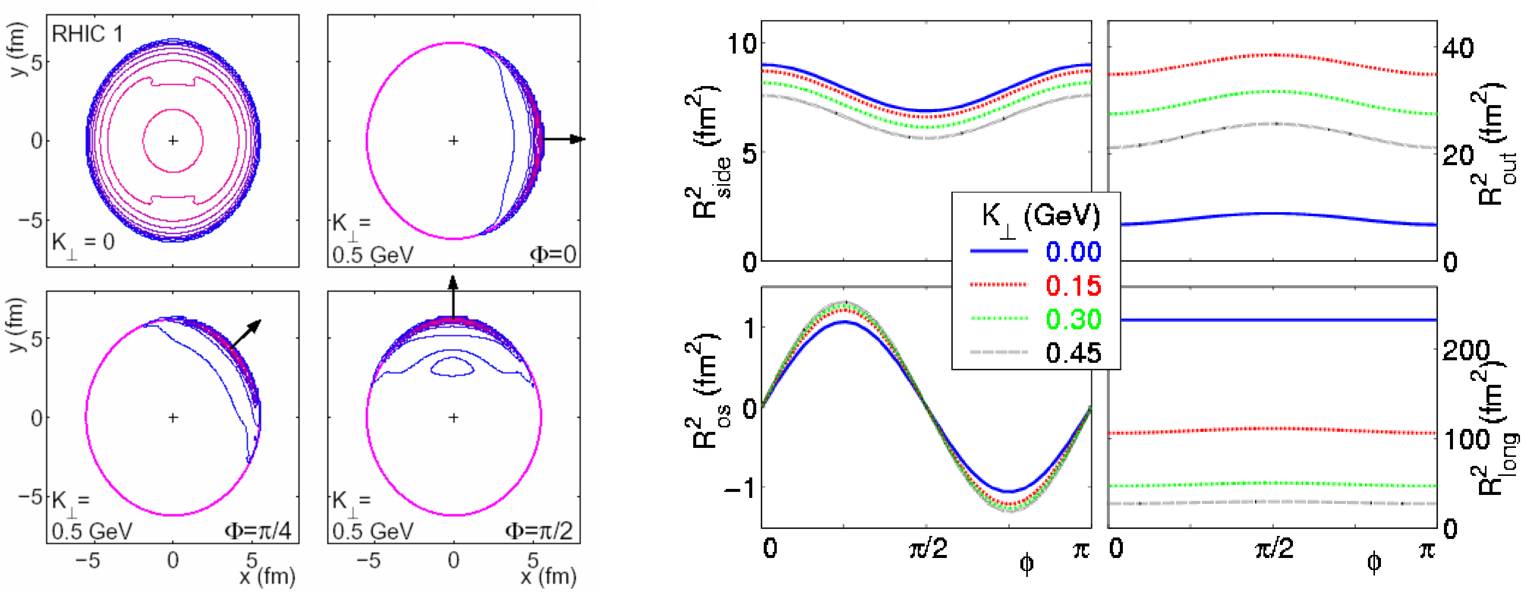
Results consistent so far, needs detailed checks…

Azimuthal HBT

Measure HBT-Radii relative to the reaction plane in non-central collisions:

U. Wiedemann a.m.m.

- out-side crossterm
- characteristic oscillations

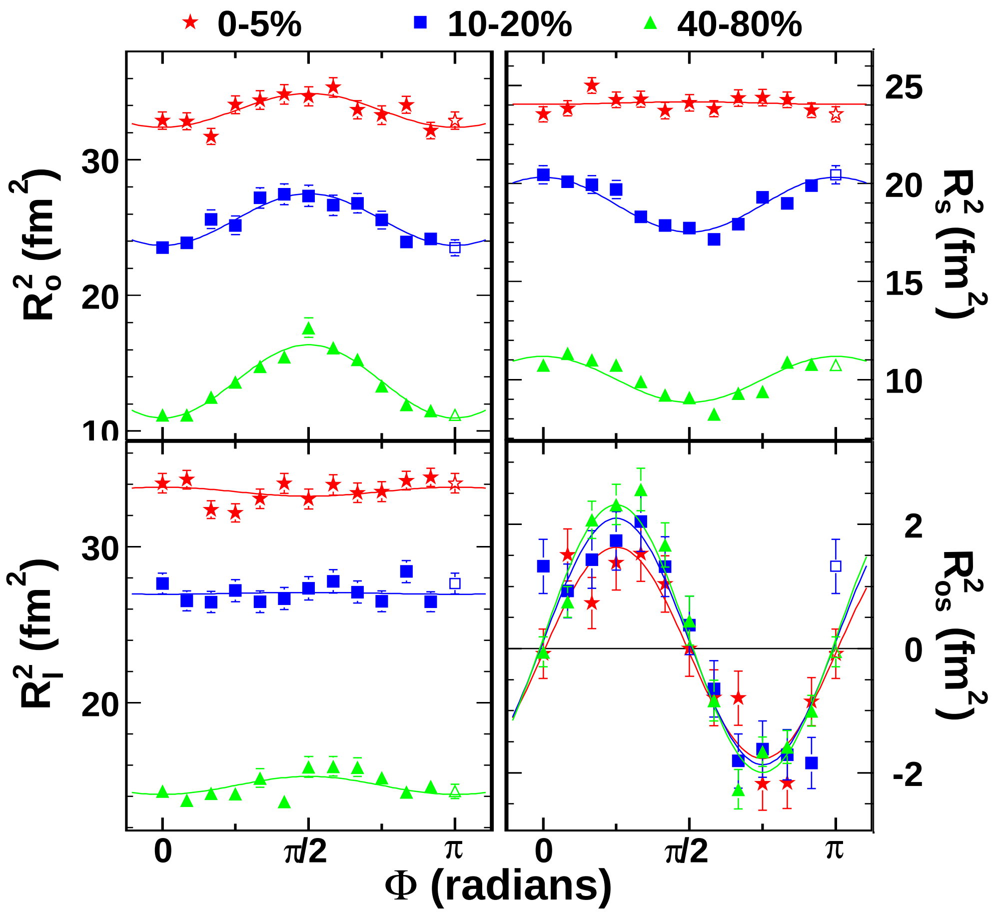


Heinz, Kolb PLB 542 (2002)

➡ *spatial* anisotropy of the pion source at freeze-out!

Azimuthal HBT

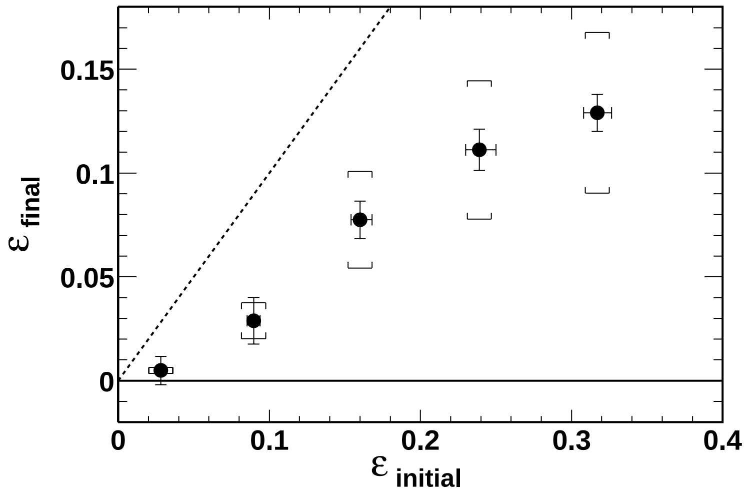
D. Magestro (STAR)



Source eccentricity:

$$\varepsilon_{initial} \equiv \left(R_y^2 - R_x^2\right)/\left(R_y^2 + R_x^2\right)$$

$$\varepsilon_{final} \approx 2R_{s,2}^2 / R_{s,0}^2$$



...source retains initial orientation!

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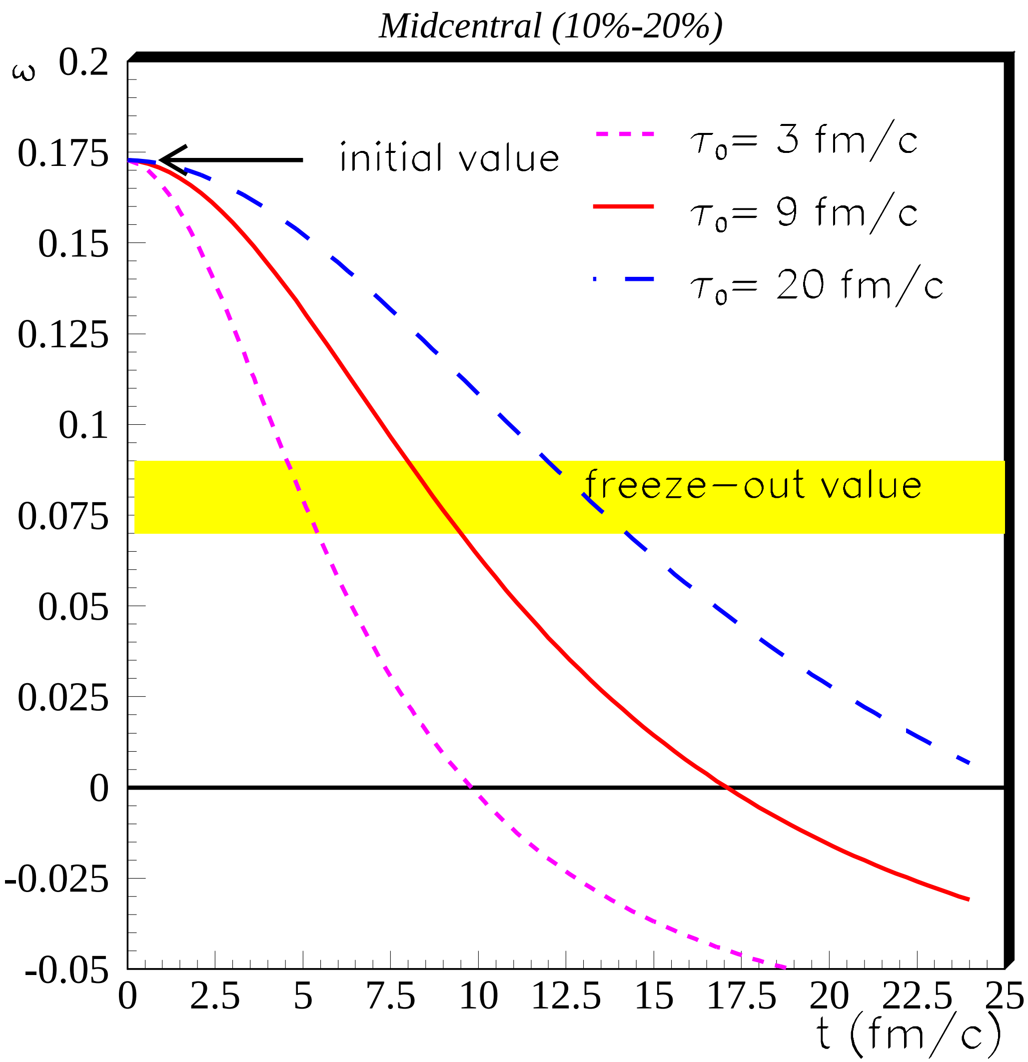
Consistency check of lifetime



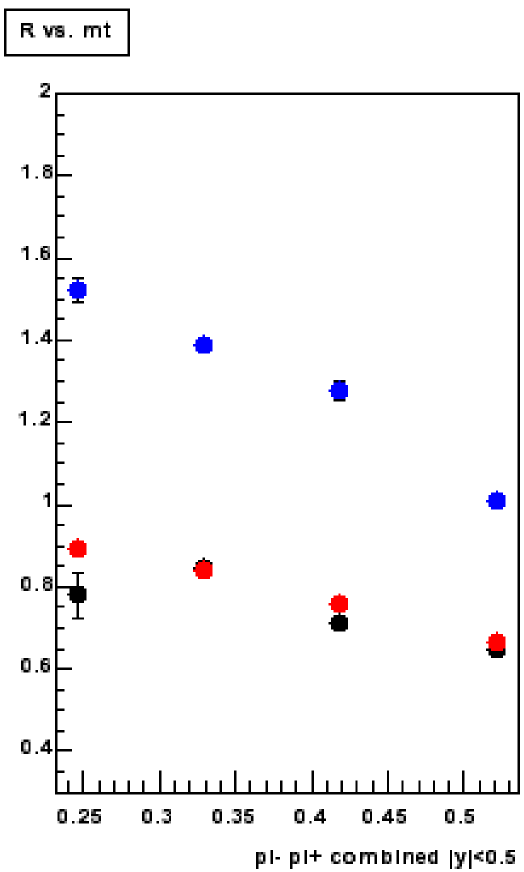
M. Lisa (ISMD2003)

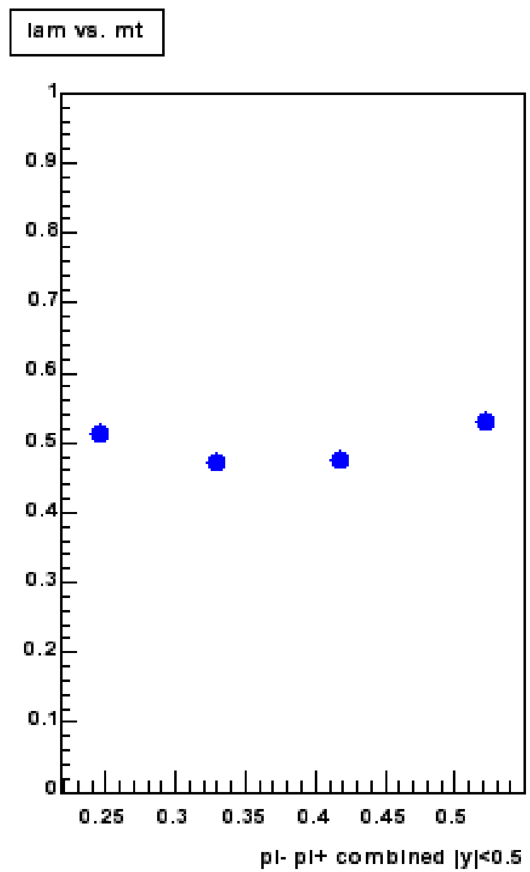
Freeze-out eccentricity confirms short lifetime (e.g. from R_{long})

HBT parameters are internally consistent

HBT in pp

Poster M. Gutierrez (STAR)



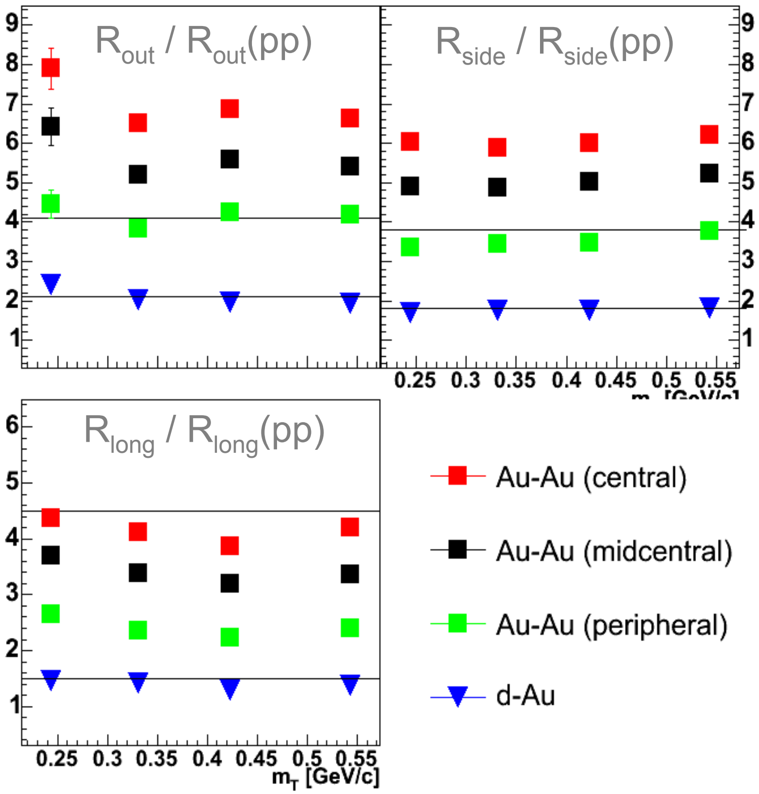


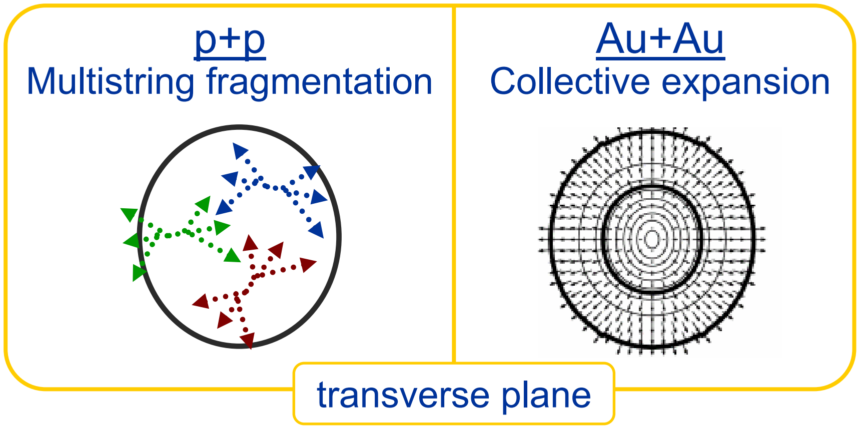
Results are much smaller than in Au-Au

K_t dependence is very similar!

System size dependence

STAR preliminary



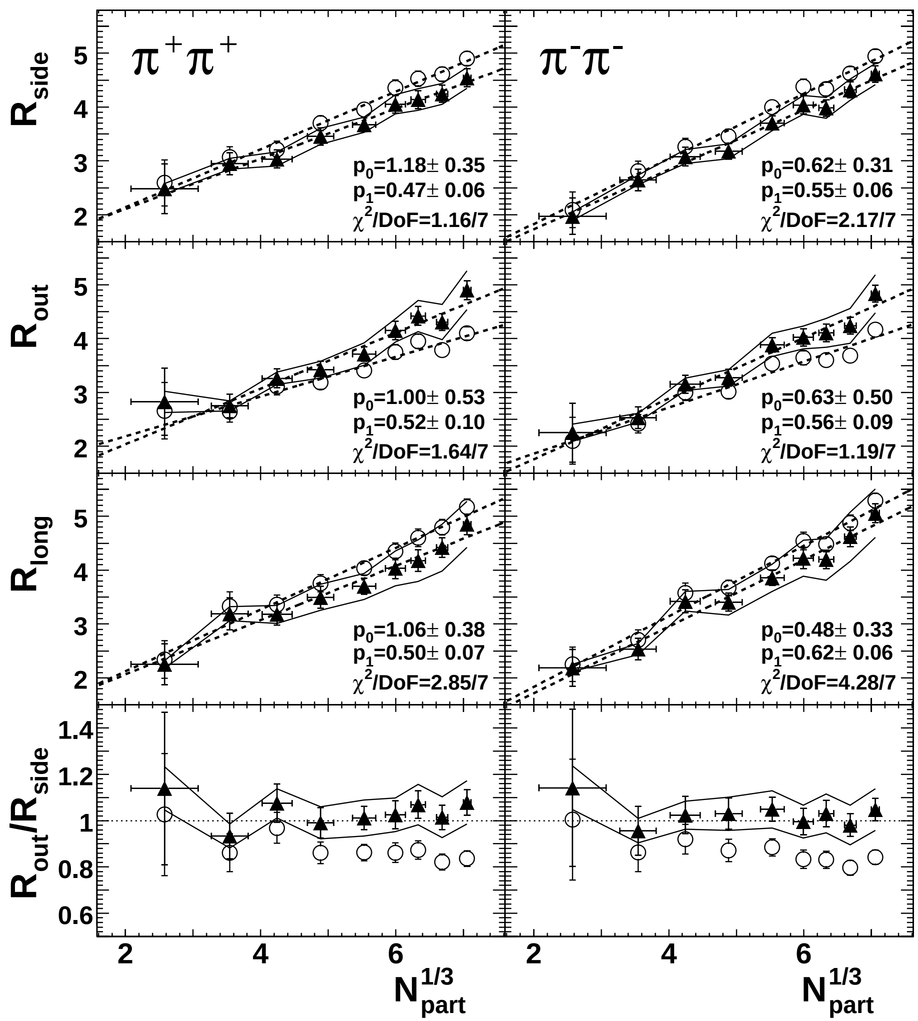


- Presumably very different dynamics in p-p and Au-Au
- But the HBT radii look qualitatively the same

Do we believe in coincidences?

System size dependence

M. Heffner (PHENIX) Au-Au 200 GeV



All radii scale with $N_{part}^{1/3}$

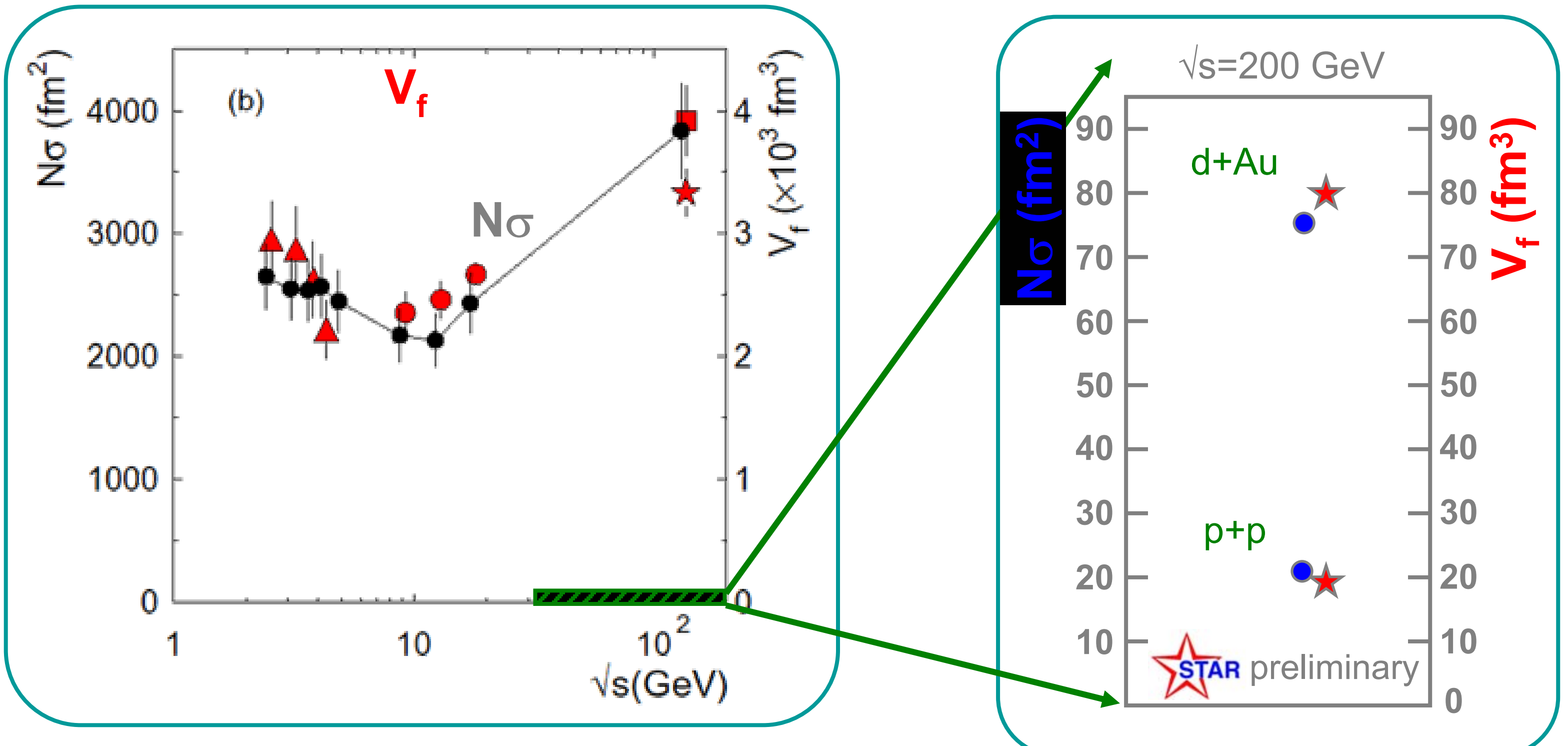
Consistent with freeze-out at constant density

Not new, but centrality (system size) dependence was never really challenged!

Universal Pion freeze-out

Mean free path at freeze-out: $\lambda_f = \frac{1}{\rho \cdot \sigma} = \frac{V_f}{\sum_i N_i \cdot \sigma_{\pi,i}} \approx 1\,fm$

D. Magestro (STAR)



CERES, PRL 90 (2003) 022301

→ also in small systems!

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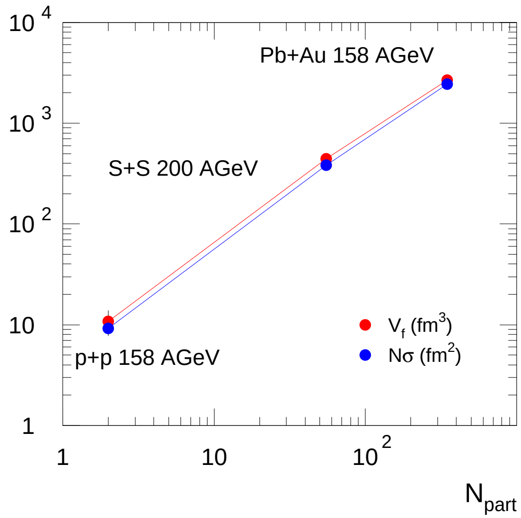
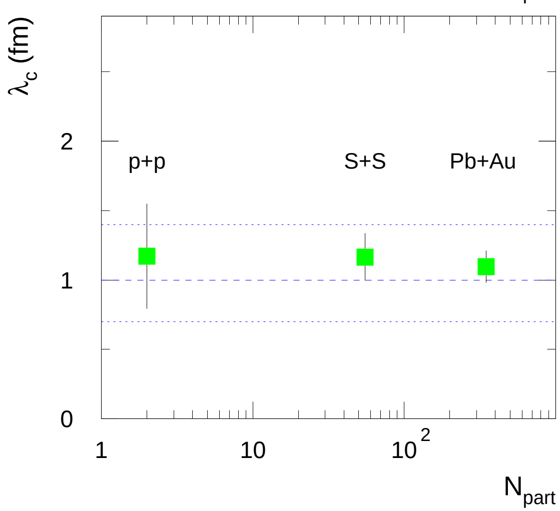
Universal Pion freeze-out

Same at SPS:





CERES (Pb+Au)
NA35 (S+S)
NA49 (p+p)

Freeze-out at constant mean free path is counter-intuitive if late stage is dominated by hadronic rescattering:
size dependence expected!

In p-p: $$\lambda_f \approx R_{geo}$$

In Au-Au: $$\lambda_f << R_{HBT} < R_{geo}$$

Flow in Au-Au may lead to local freeze-out

But why does it *exactly* compensate?

Do we believe in coincidences (II)?

H. Appelshäuser, QM2004 Oakland

New old HBT puzzle

pp and Au-Au data look qualitatively and quantitatively the same (needs confirmation)

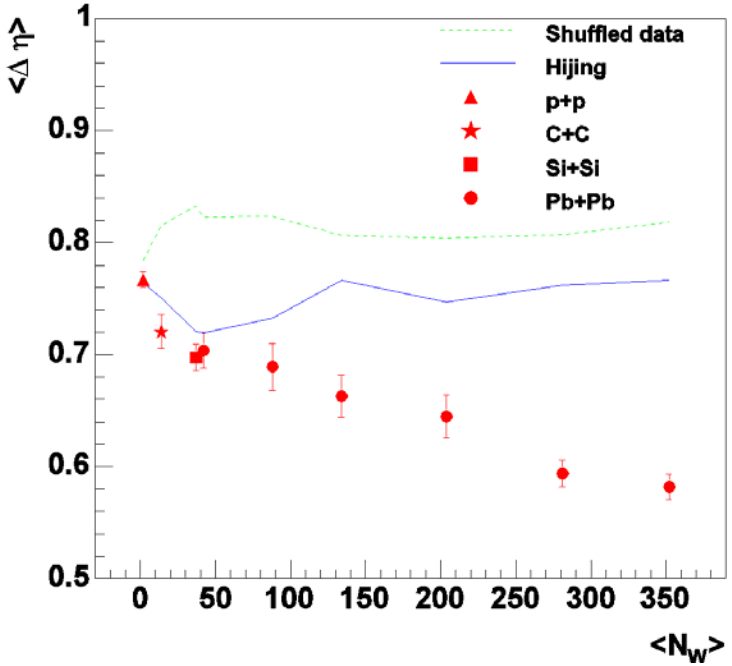
Models: Non-trivial dynamics must lead to trivial freeze-out

Study system size dependence

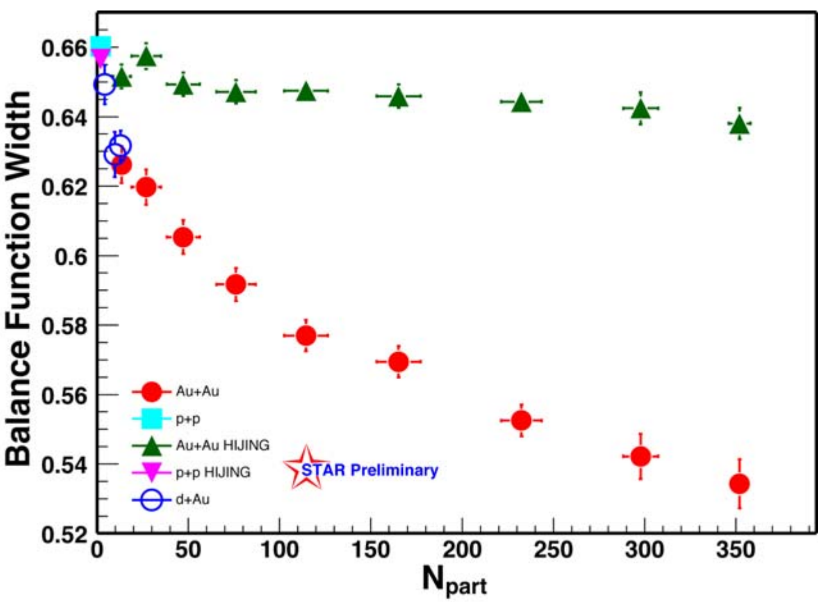
Balance function width

158 AGeV/c

P. Christakoglou (Poster) NA49



G. Westfall (STAR) 200 GeV Au-Au



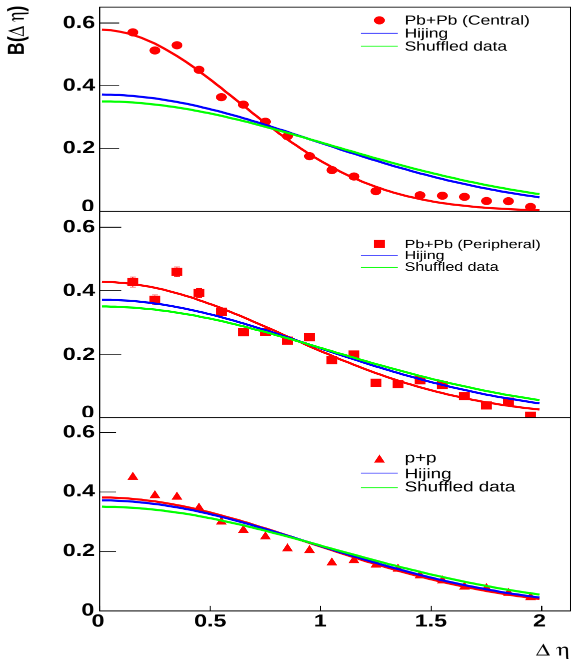
H. Appelshäuser, QM2004 Oakland

Balance functions

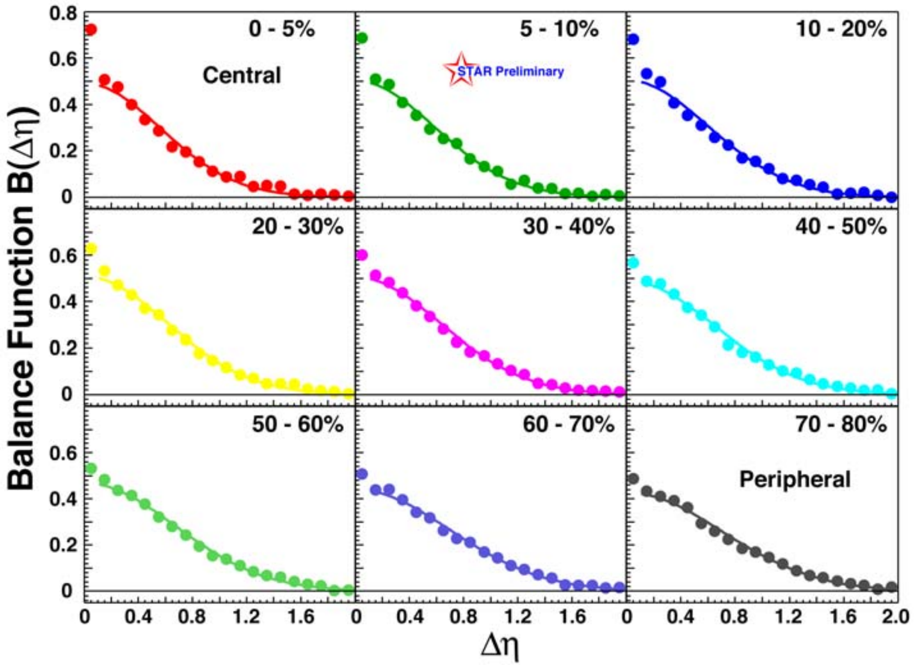
$$B(\Delta y) = \frac{1}{2}\left\{\frac{N_{+-}(\Delta y) - N_{++}(\Delta y)}{N_{+}} + \frac{N_{-+}(\Delta y) - N_{--}(\Delta y)}{N_{-}}\right\}$$

158 AGeV/c

P. Christakoglou (Poster) NA49



G. Westfall (STAR) 200 GeV Au-Au



H. Appelshäuser, QM2004 Oakland