Two-particle correlations at ultrarelativistic energies in UrQMD and QGSM.

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Outline

- Motivation
- Models UrQMD, QGSM
- 1D Correlation functions
- 3D Correlation functions
- Study of the origins of kt dependence in QGSM in pp collisions.
- First attempts to describe 900 GeV data
- Possibilities to improve the description
- Conclusions

Motivation

- LHC has provided new 900 GeV and 7 TeV pp collision data.
- First pion 1D and 3D correlation radii have been measured.
- LHC Pb + Pb collisions at sqrt(sNN) = 2.76 TeV is planned in November, 2010.

- The Quark Gluon String Model (QGSM) describes well the $dN/d\eta$ dN/dp_t and $\langle p_t \rangle$ of charged hadrons etc in pp collisions at LHC.

- It is natural to check how well it can describe the femtoscopic momentum correlations

General motivation: Within hydrodynamic models kT dependence of the correlation radii is considered as a signature of collective flow.

Transport models, considering the full microscopic picture of the particle production/emission/rescattering processes, might throw light on the other mechanisms generating the observed k_t-dependence of the correlation radii in pp and heavy ion collisions.

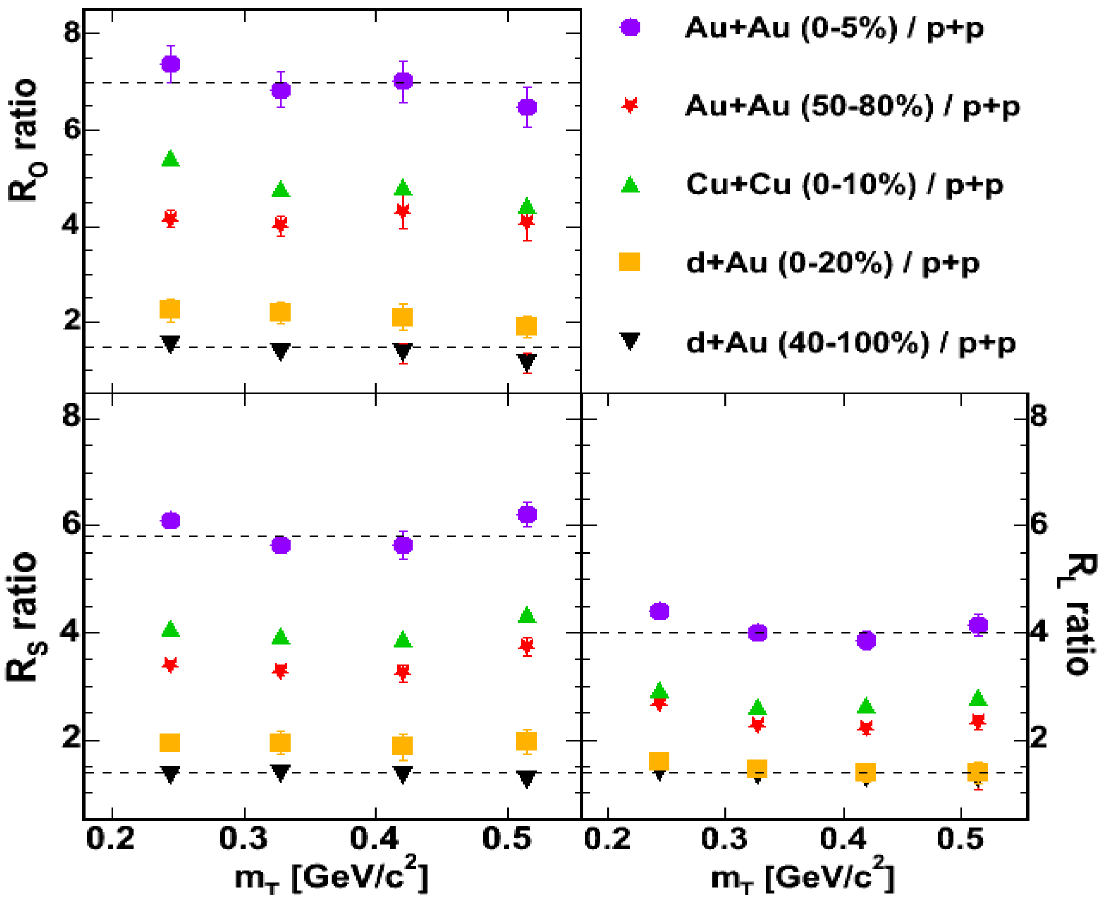
Femtoscopy in pp STAR data

Mt dependence (“x-p” correlations) in very small systems (pp, e+e-) is usually attributed to:

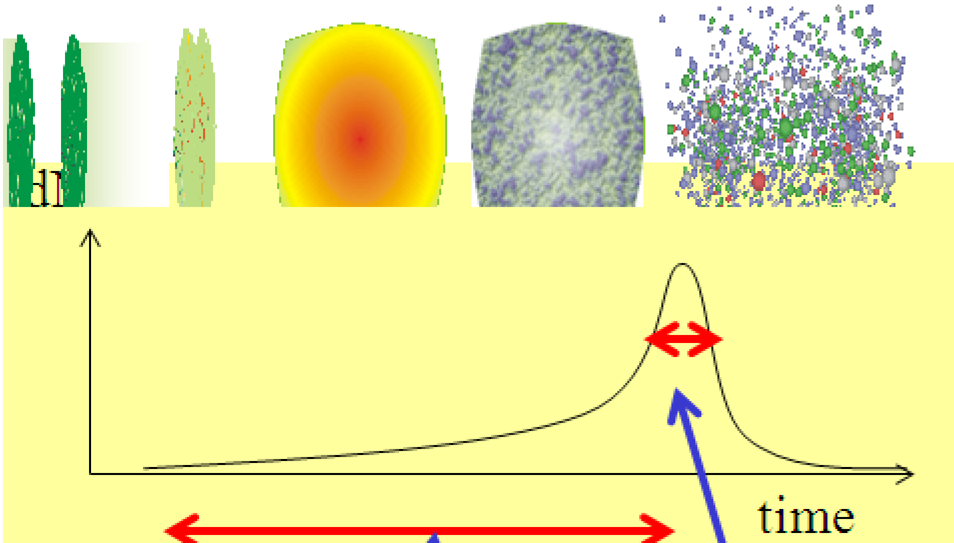
- -string fragmentation
- -resonance contribution
- -Heisenberg uncertainty
- -jets

All Kt(mt) dependences of correlation radii observed by STAR scale with pp (!?) although the expected origins of these dependences are different.

ALICE didn't observe a strong Kt dependence (!?)

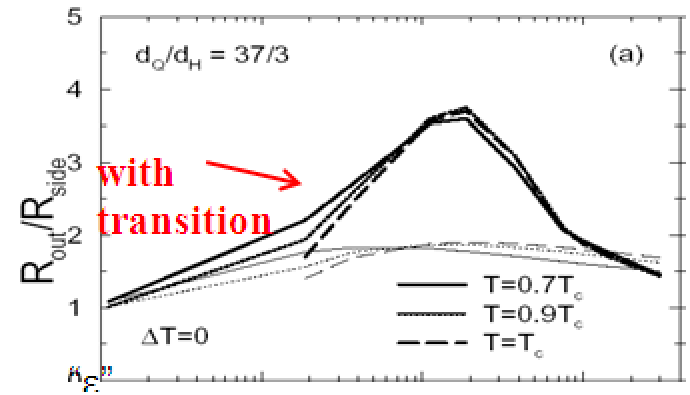


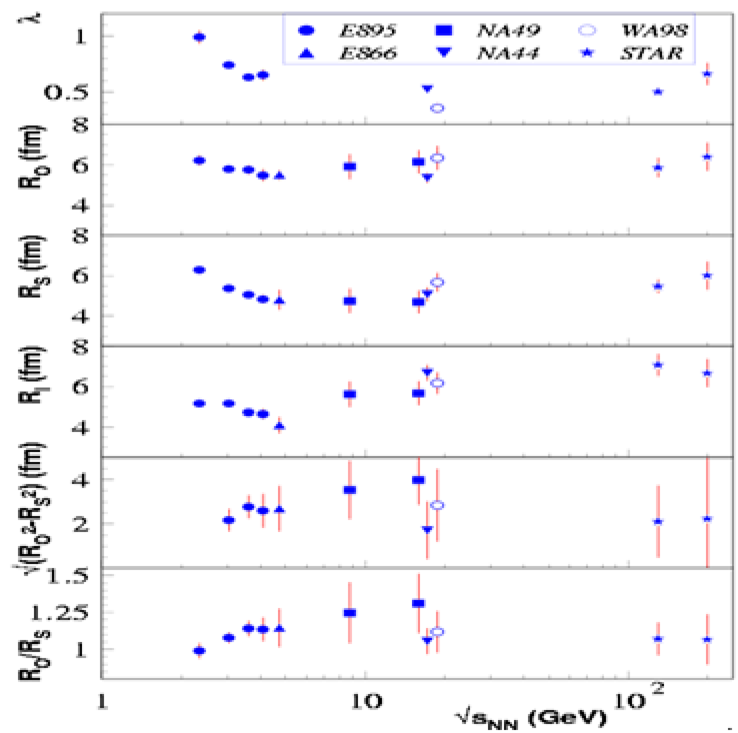
Expected QGP signature: increase of disintegration timescale



3D 1-fluid Hydrodynamics

Rischke & Gyulassy, NPA 608, 479 (1996)





Predictions:

Increase in $\tau \sim R_{long}$ and $\Delta\tau \sim R_{OUT}/R_{SIDE}$

due to deconfinement ↔ confinement transition

RHIC femtoscopy results:

- correlation radii decrease with k_T (strong flow)
- correlation radii increase with increasing centrality (geometrical radius also increases
- No significant changes in correlation radii AGS- SPS- RHIC (5 - 6 fm)

R_O / R_S ~ 1 (short emission duration)

p-space observables well-understood within hydrodynamic framework
→hope of understanding early stage
x-space observables not well-reproduced
→ ???

New theoretic approaches

The successful attempts to describe the correlation radii together with momentum observables (v2) stimulated the development of hydrodynamic models:

Yu. Sinyukov (pre-thermal flows) Act. Phys. Pol B37 3343 2006
Yu. Sinyukov, S. Akkelin, Yu.Karpenko, Y. Hama, PRC78 034906 2008,
Acta Phys.Polon.B40:1025-1036,2009
(Kinetics + hydrodynamics: pre-thermal flows, generalization of Landau/Cooper-Frye prescription for freeze-out.)

S. Pratt, arXiv:0811.3363 [nucl-th].
(pre-thermal acceleration, a stiffer equation of state, and adding viscous corrections)

W. Florkowski, W. Broniowski, M. Chojnacki and A. Kisiel, arXiv:0811.3761 [nucl-th].(the initial Gaussian density profile)

Microscopic Models

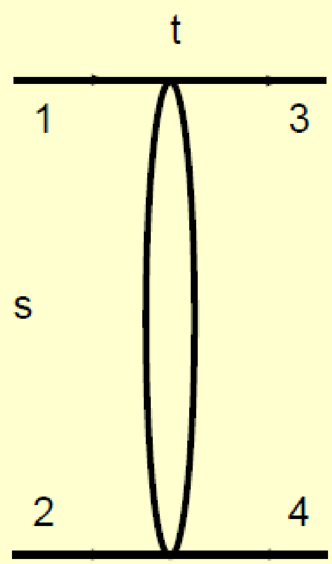
- The Ultra relativistic Quantum Dynamics Model (UrQMD) is a microscopic transport model designed for hadron-hadron, hadron-nucleus and nucleus-nucleus collisions, based on the Lund model.
- The energy range is from a few MeV to hundreds of GeV.
- At lower energies collisions are described as interactions between hadrons and their excited states, at higher energies particle production is described in terms of string fragmentation.
- http://th.physik.uni-frankfurt.de/~urqmd/

The Quark-Gluon String model

[1] A.B. Kaidalov and K.A. Ter-Martirosian, Phys. Lett. B **117** (1982) 247
[2] N.S. Amelin, L.V. Bravina, et al., Sov. J. Nucl. Phys. **50** (1989) 1058
[3] N.S. Amelin, E.F. Staubo, L.P. Csernai, Phys. Rev. D **46** (1992) 4873

Hadronic Collisions

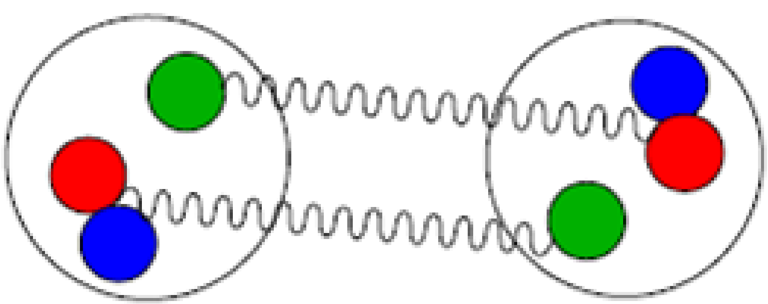
- The hadronic part of the model is based on the $1/N$ expansion of the amplitude for binary processes in QCD and on string type phenomenological model with colour exchange, which describe the transition of quarks into hadrons



- The model uses the structure and fragmentation functions for quarks, and the energy dependences of the subprocesses, obtained in the Gribov-Regge field theory
- For hadron-hadron interactions QGSM takes into account pre-asymptotical processes, multi-pomeron branchings, the processes of diffractive dissociation and annihilation, and hard processes
- For the description of string fragmentation the Field-Feynman model is employed

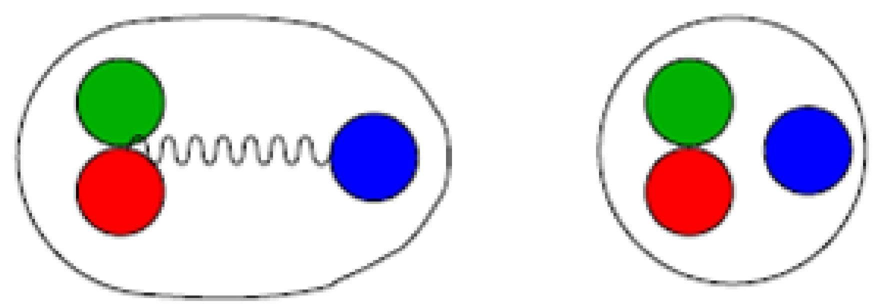
two different mechanisms:

- excitation due to exchange of pomerons (color exchange)
- transverse strings



- n cut pomerons give $2n$ strings

- excitation due to tranfer of momentum to a single parton
- longitudinal string



- purely phenomenological process

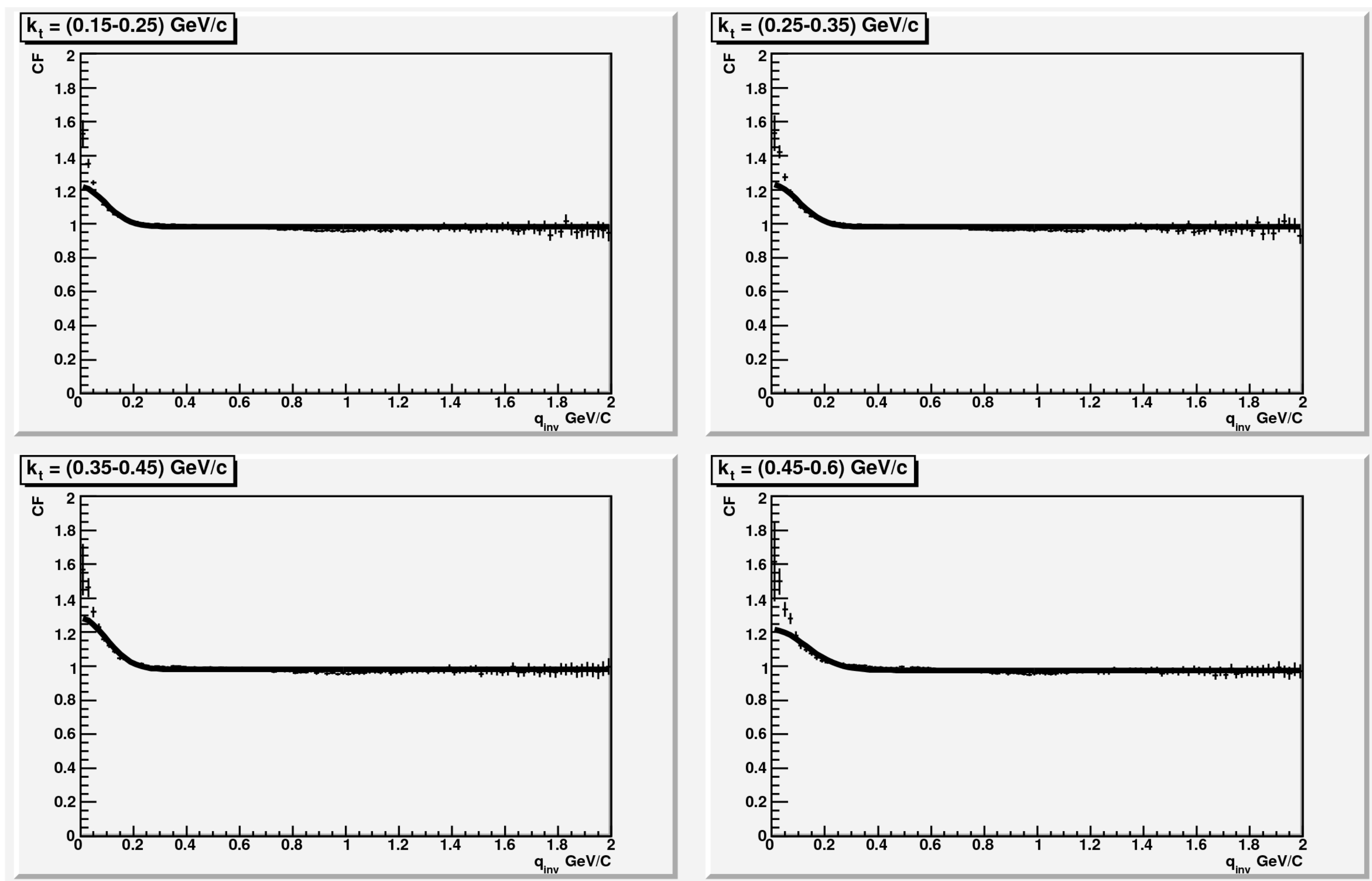
Correlation Functions

- The correlation function is defined as $C = \frac{P(q_1, q_2)}{Q(q_1, q_2)}$
- In the model $P(q_1,q_2)$ is obtained from weighting pairs from same events.
- In the model the "pure weights method" can be used: $Q(q_1,q_2)$ is obtained from unweighted pairs from same events.
- In experiment $Q(q_1,q_2)$ is obtained by mixing particles from different events.
- By using this method on the model data we obtain a more realistic correlation function.

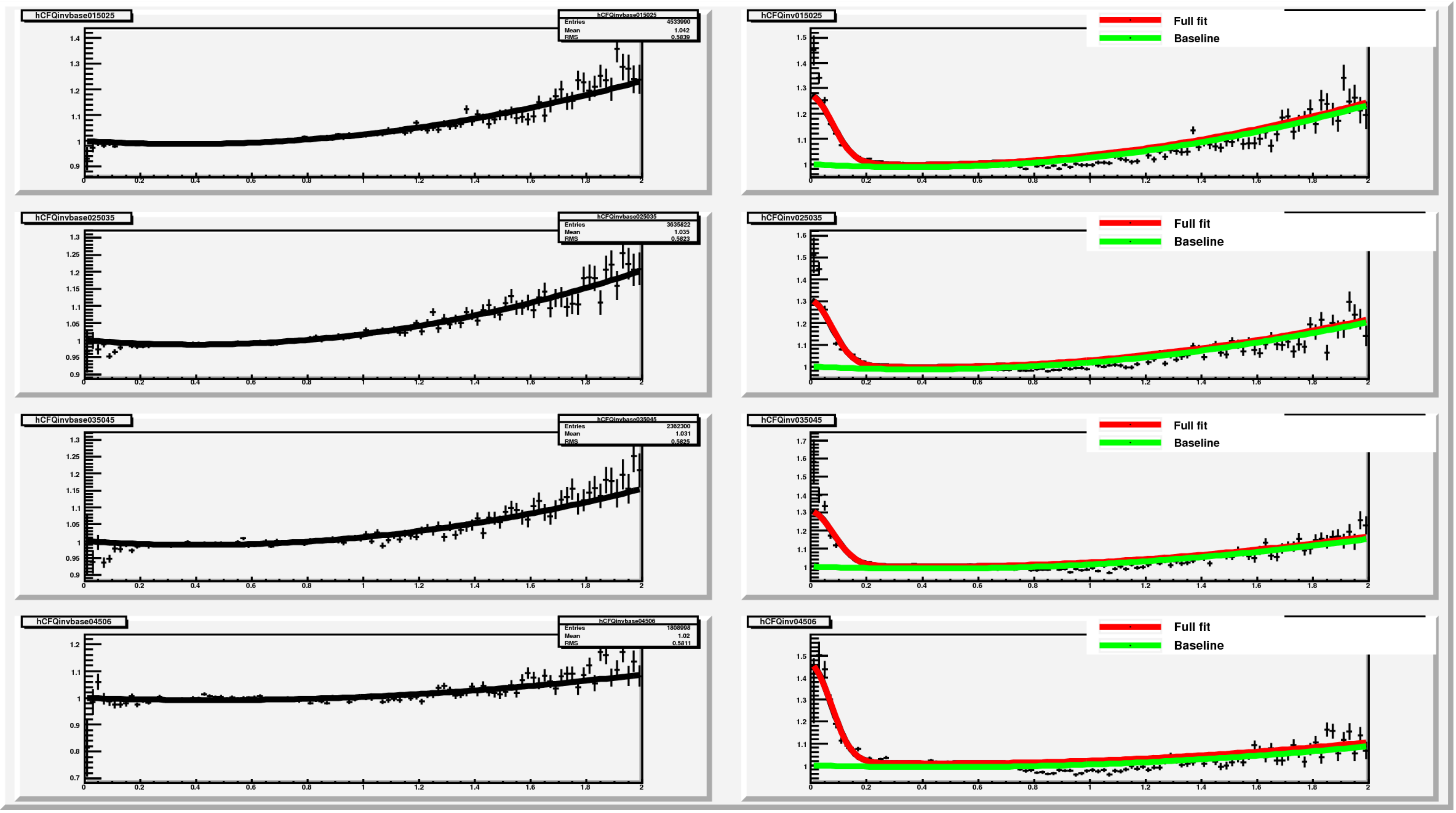
Fitting 1D correlation functions

- We use a gaussian fitting function for the correlation function. $C = N\left(1+\lambda e^{-q_{inv}{}^2 R_{inv}{}^2}\right) D(q_{inv})$
- The factor $D(q_{inv})$ accounts for long-range non-femtoscopic correlations
- We use $D(q_{inv})=1$ for “pure weights method” (no non-femtoscopic correlations)
- $D(q_{inv}) = aq_{inv}{}^2 + bq_{inv} + 1$ was used to fit the non-femtoscopic correlations first.
- The parameters a, b, and c were then fixed when fitting the correlation function.

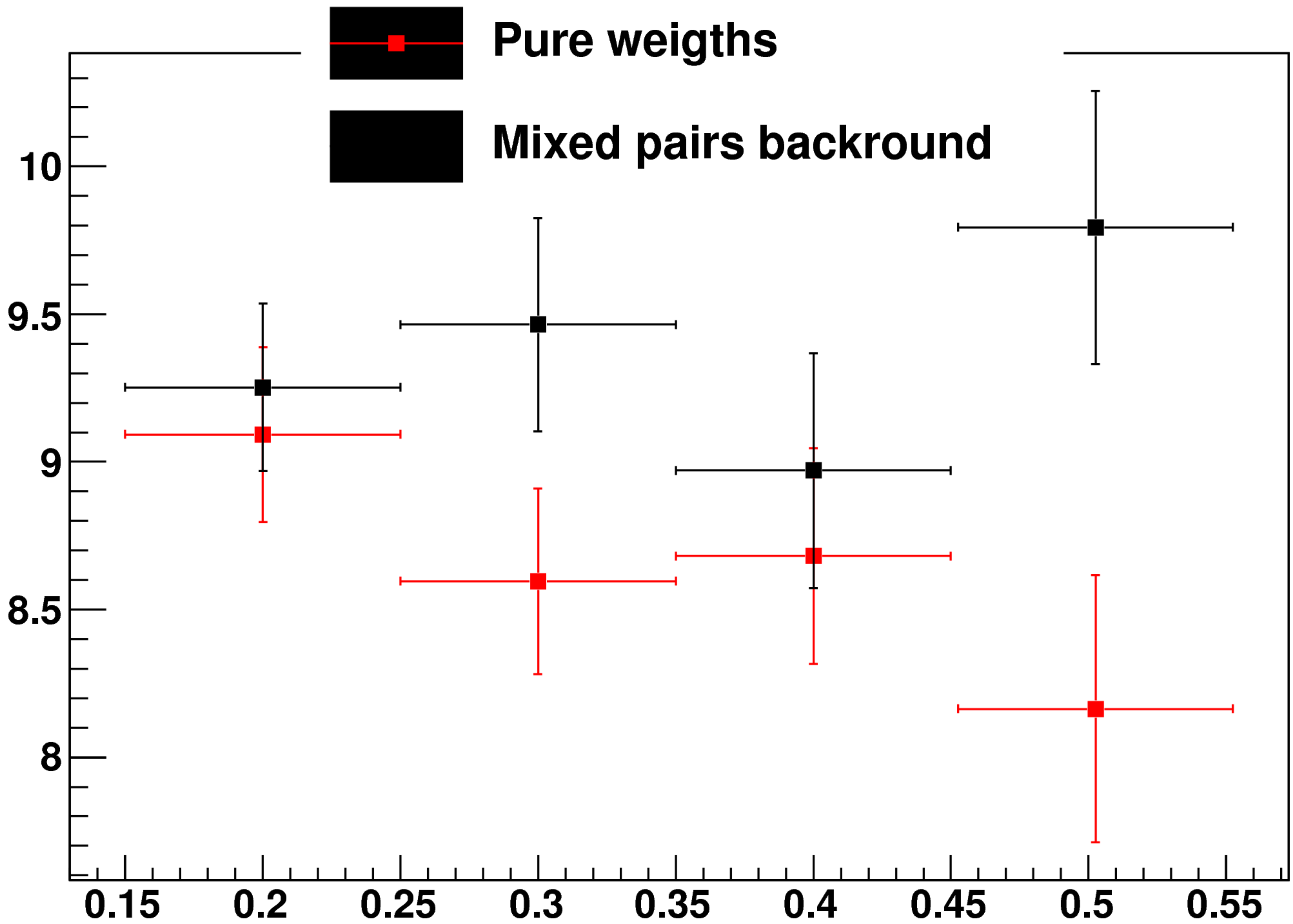
$\pi^+\pi^+$ Correlation function
UrQMD pp 200GeV "pure weights"



$\pi^+\pi^+$ Correlation function UrQMD 200GeV with mixed pair backround



R_{inv} for pp 200GeV UrQMD

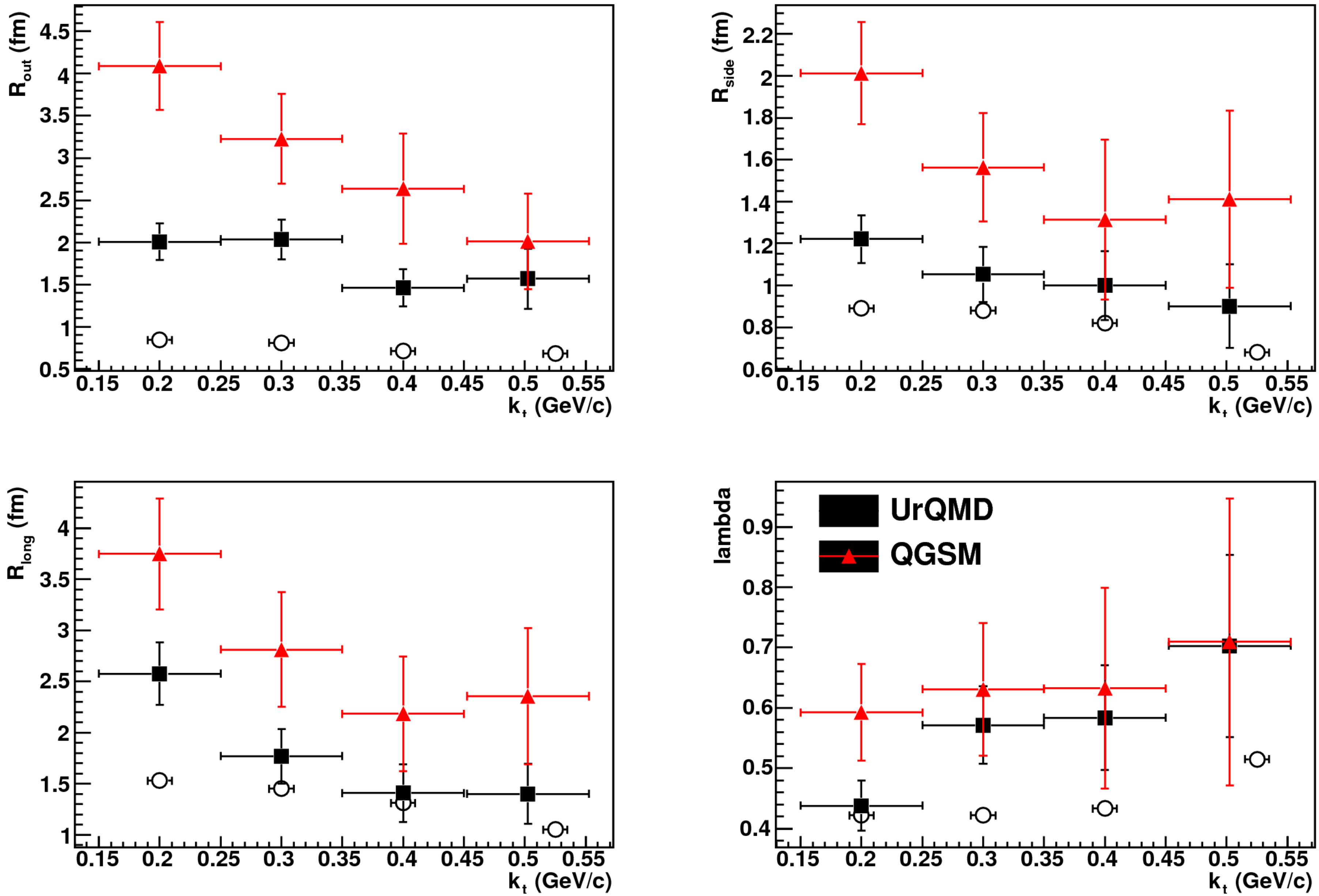


3D Correlation functions

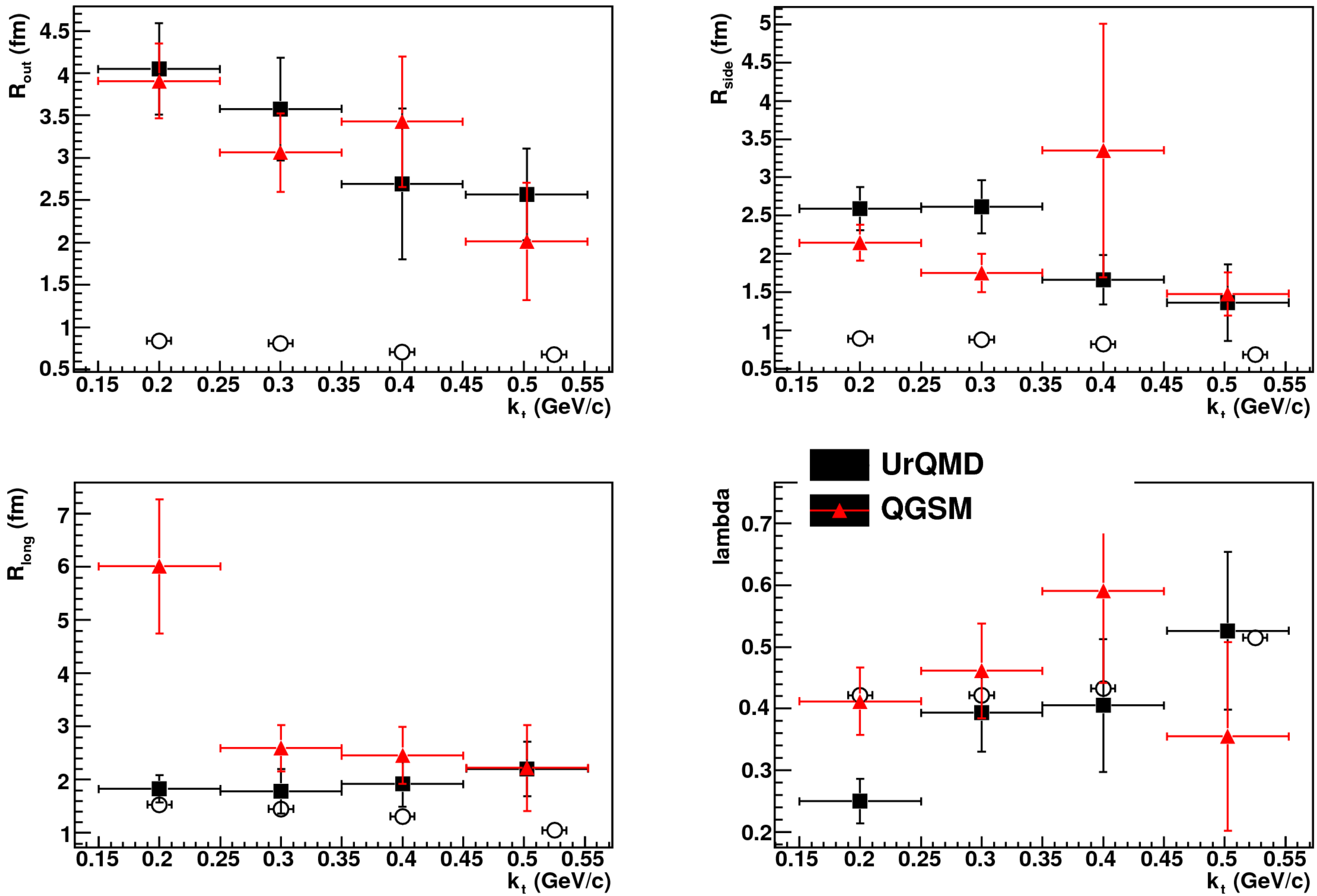
- 3D fit $CF = 1 + \lambda \exp(-R_{out}^2 Q_{out}^2 - R_{side}^2 Q_{side}^2 - R_{long}^2 Q_{long}^2)$

- We have extracted correlation radii in out-side-long directions from both UrQMD and QGSM models.
- We have calculated with both pure and mixed backround.

Correlation radii, UrQMD and QGSM 200GeV



Correlation radii, UrQMD and QGSM 200 GeV with mixed pair backround



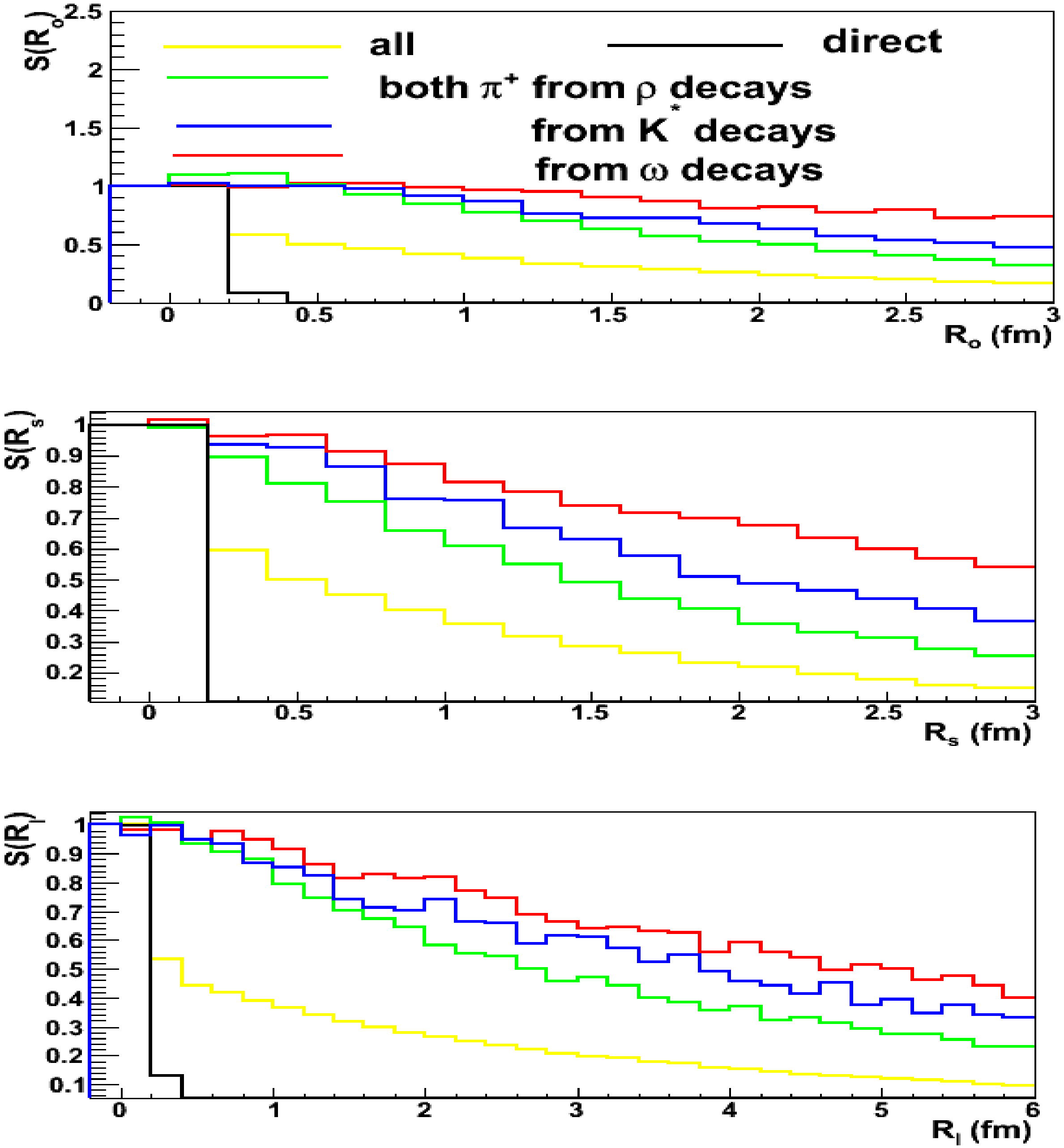
- The more realistic mixing method gives larger radii and steeper K_t dependence than the "pure weights" method.
- A strong K_t dependence is observed in pp collisions in both UrQMD and QGSM models
- Radii are too large in UrQMD and QGSM models
- What is the origin of the Kt dependence ?

  Resonances ? String fragmentation ?
- Is it possible to decrease the radii ?

  1) play with resonances/direct ratio

  2) decrease the fragmentation time

Source functions of direct pions and pions from different resonances in QGSM pp 200 GeV



Kt ~(0.15-0.25) GeV/c

Direct pions source size < 0.5 fm

$\rho^0 \rightarrow \pi^-\pi^\pm$, $\rho^\pm \rightarrow \pi^0\pi^\pm$

$K^{*\pm} \rightarrow K\pi^\pm$

$\omega \rightarrow \pi^-\pi^\pm\pi^0$ – maximal source size

Interplay between contributions of different resonances and direct pions determines the source size.

Relative contributions of direct pions and pions from different resonances QGSM (1:3)

Kt (GeV/c)	**(0.15-0.25)**	**(0.25-0.35)**	**(0.35-0.45)**	**(0.45-0.6)**
direct pion	26 .0 %	26 %	26 %	28 %
$\rho^0 \to \pi^- \pi^+$, $\rho^+ \to \pi^0 \pi^+$	41.3 %	45.5 %	48.7 %	50.6 %
$K^{*+} \to K\pi^+$	12.8%	12,0 %	10.9 %	9.6 %
$\omega \to \pi^- \pi^+ \pi^0$	12.3 %	10.5%	8.9 %	7.5 %
$\eta \to \pi^- \pi^+ \pi^0$, $\eta' \to \eta \pi^- \pi^+$, $\Delta^{++} \to p\pi^+$	7.6 %	6.0%	5.5 %	4.3 %

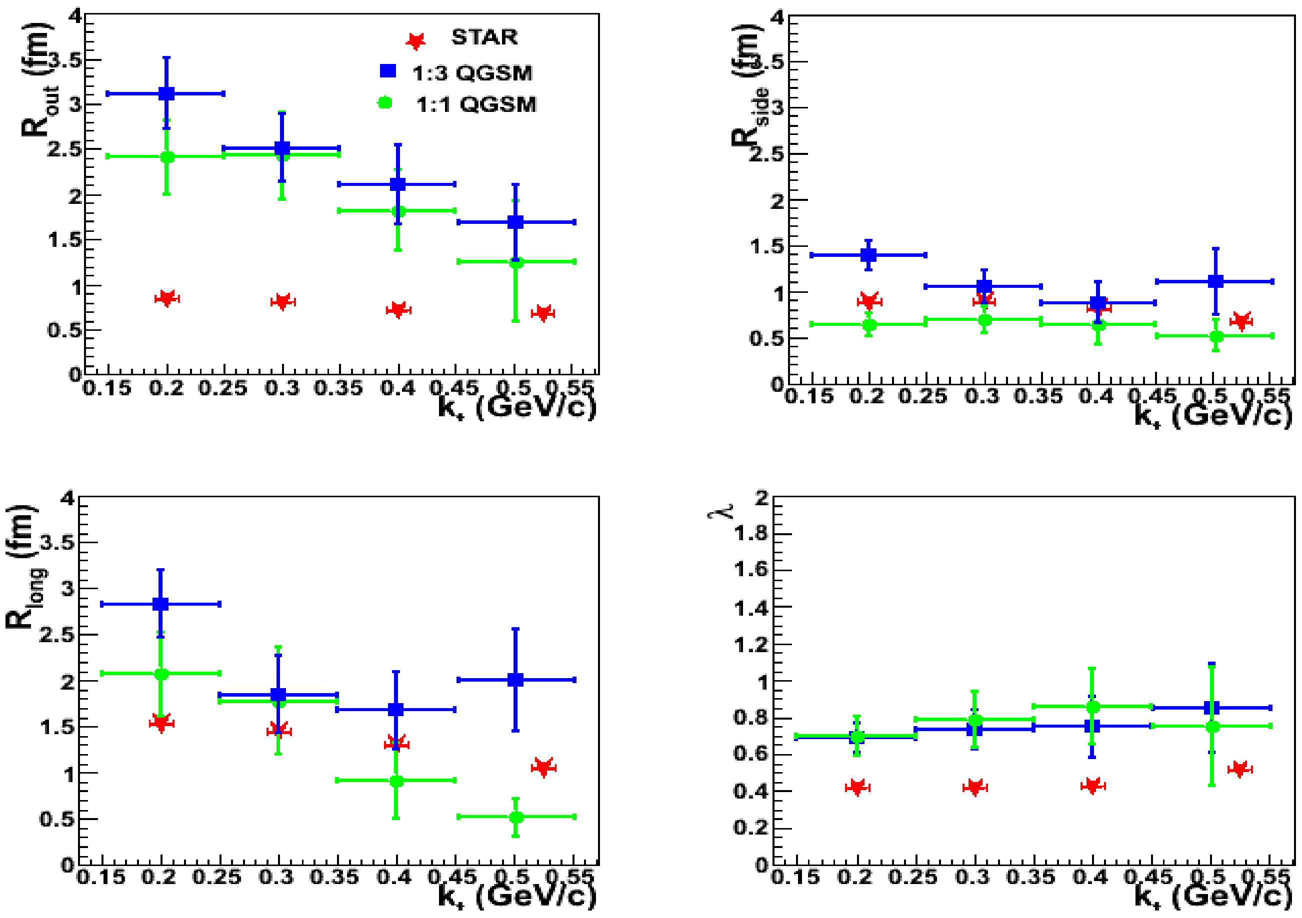
Relative contribution of pions from ρ increases with kt, when the relative contribution of ω, K* falls. It leads to decrease of correlation radii with kt. But the source size is too large (blue squares on slide 22) !

Relative contributions of direct pions and pions from different resonances QGSM (1:1)

Kt (GeV/c)	**(0.15-0.25)**	**(0.25-0.35)**	**(0.35-0.45)**	**(0.45-0.6)**
direct pion	39 .2 %	40.7 %	43.1 %	46.7 %
$\rho^0 \to \pi^- \pi^+$, $\rho^+ \to \pi^0 \pi^+$	33.7 %	36.0 %	37.3 %	37.1 %
$K^{*+} \to K\pi^+$	9.7%	8,9 %	7.9 %	6.8 %
$\omega \to \pi^- \pi^+ \pi^0$	10.3 %	8.7%	7.2 %	5.9 %
$\eta \to \pi^- \pi^+ \pi^0$, $\eta' \to \eta \pi^- \pi^+$, $\Delta^{++} \to p\pi^+$	7.1 %	5.7%	5.5 %	3.5 %

Relative contribution of direct and pions from ρ increases with kt, when the relative contribution of ω, K* falls. It leads to decrease of correlation radii with kt. Decrease of ratio “pions from ρ to direct pions” leads to requested decrease of the correlation radii (green circles on slide 22).

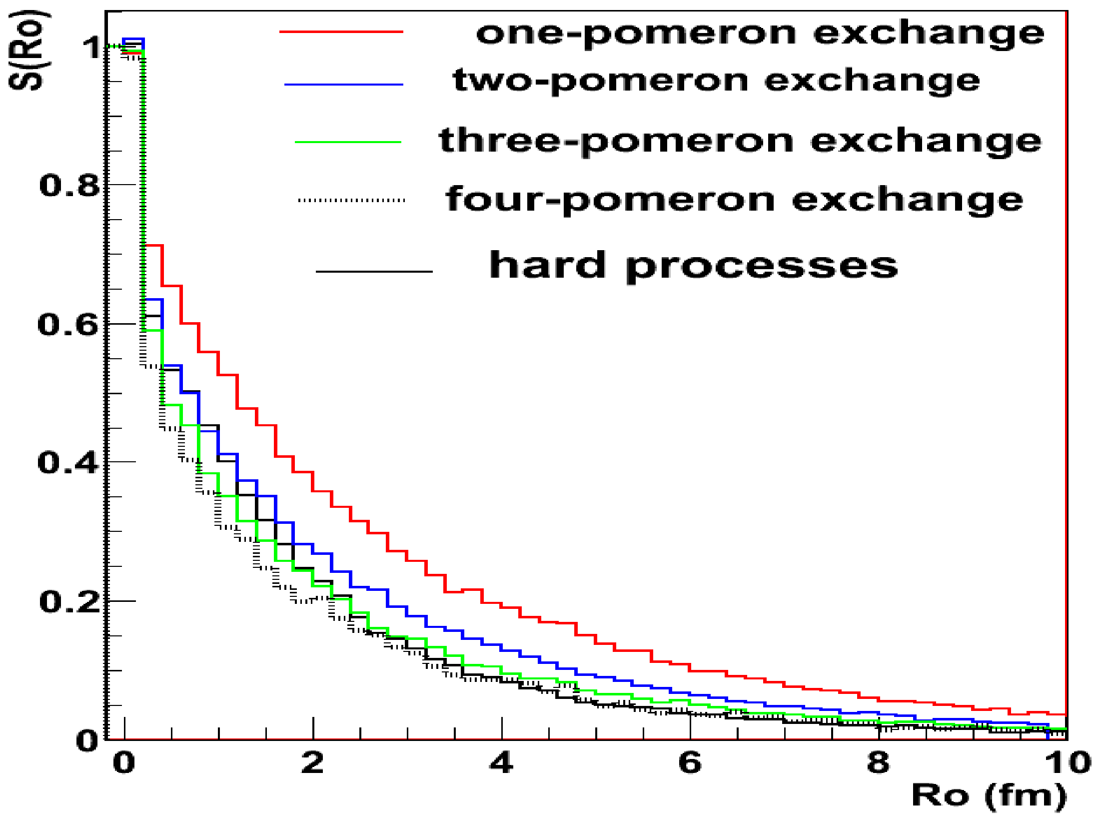
Kt-dependence of correlation radii pp at 200 GeV/c with QGSM ("pure weights")



There is strong Kt dependence in QGSM.

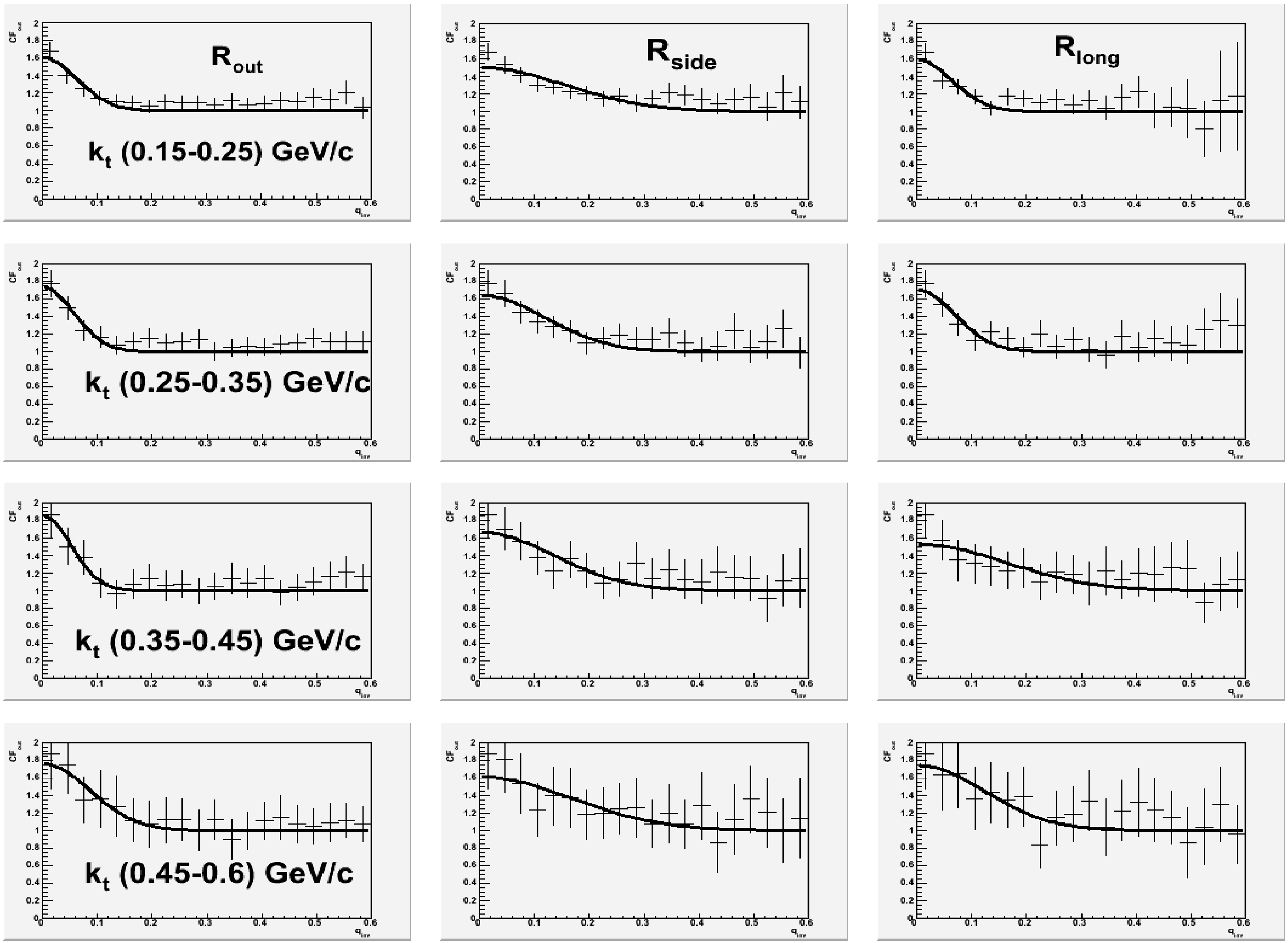
One of it's origins is the resonances. String fragmenation ?

Example of source function of pions from different processes QGSM pp 200 GeV

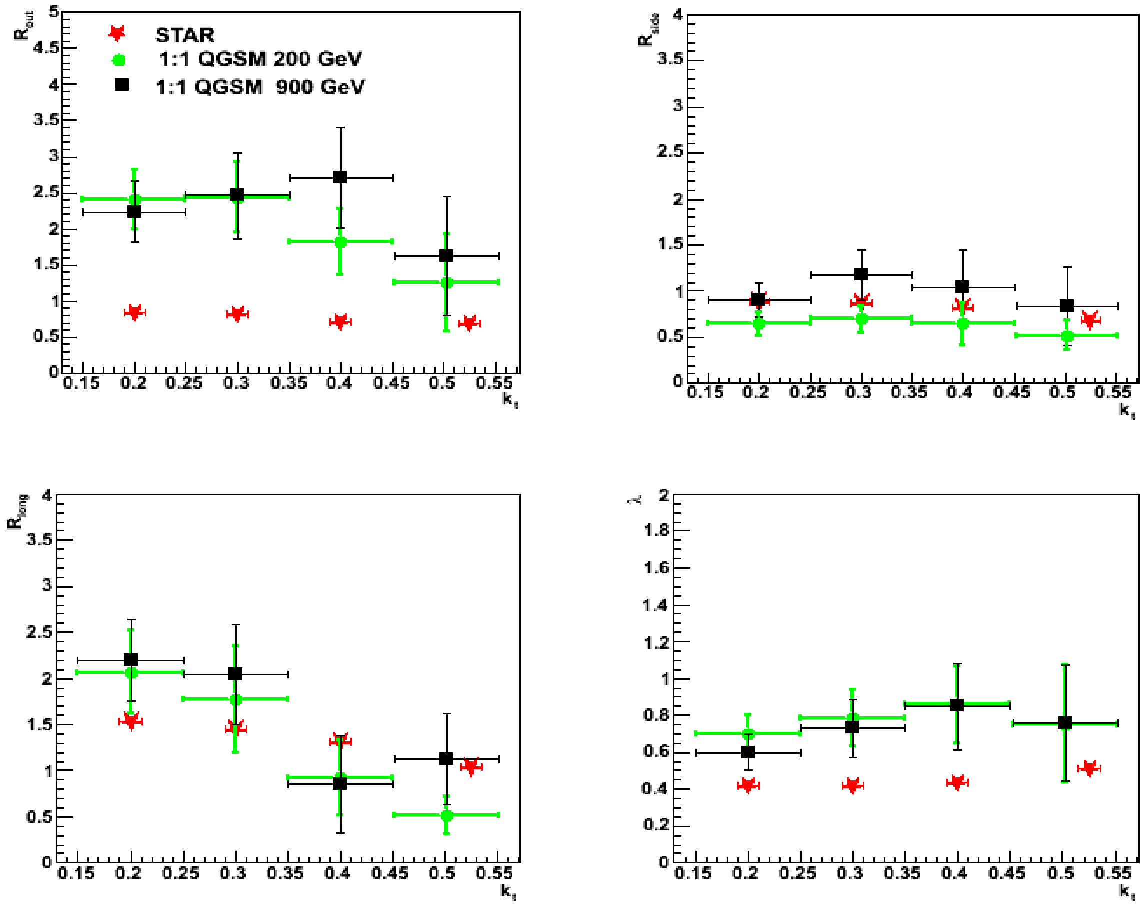


Relative contribution of pions from different processes determines the source size through the number of produced resonances. In one-pomeron exchange process more resonances are produced than in many-pomeron exchanges.

Correlation radii pp at 900 GeV/c with QGSM

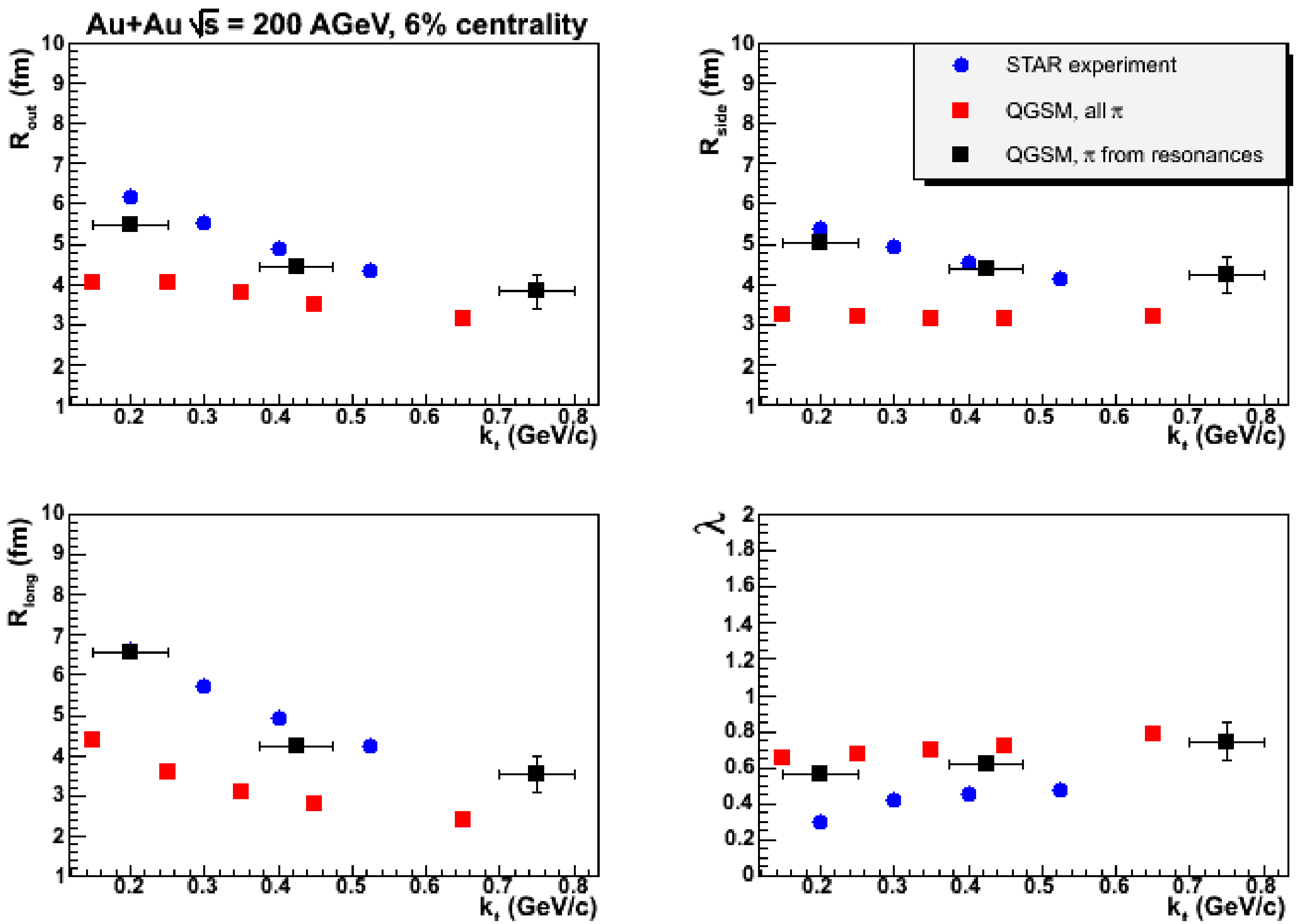


Kt-dependence of correlation radii pp at 900 GeV/c with QGSM



Radii are almost the same as at 200 GeV/c

Kt-dependence of correlation radii AuAu at 200 GeV/c with QGSM



QGSM shows smaller correlation radii then in experiment (red squares).

What if we play with number of direct/rho here ?

If we take only pions from the inelastic secondary interations and resonance decays (black points) the correlation radii drastically increase and become close to STAR experimental data

Conclusions

- Mixed pairs backround method increases both 1D and 3D radii.
- Increasing ratio of direct to resonance pion decreases the radii.
- We do not see any major difference between 200GeV and 900 GeV pp correlation radii.