Two-particle correlations in pp-collisions at ultrarelativistic energies in QGSM.

Mads Stormo Nilsson, Ludmila Malinina, Larissa Bravina, Eugene Zabrodin

UNIVERSITAS OSLOENSIS
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- Model
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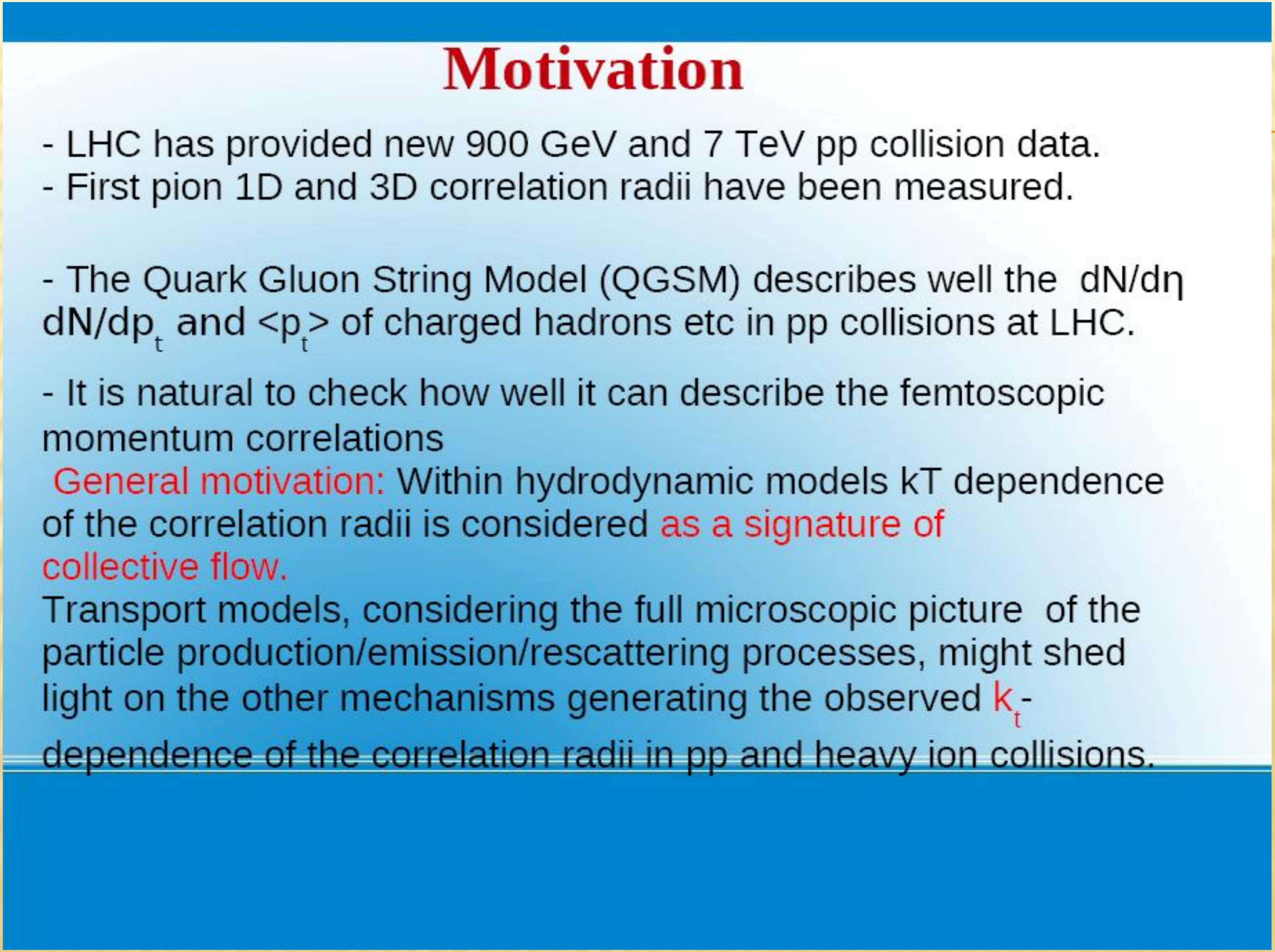
- 3D Correlations
- Conclusions

Outline



Motivation

- LHC has provided new 900 GeV and 7 TeV pp collision data.
- First pion 1D and 3D correlation radii have been measured.

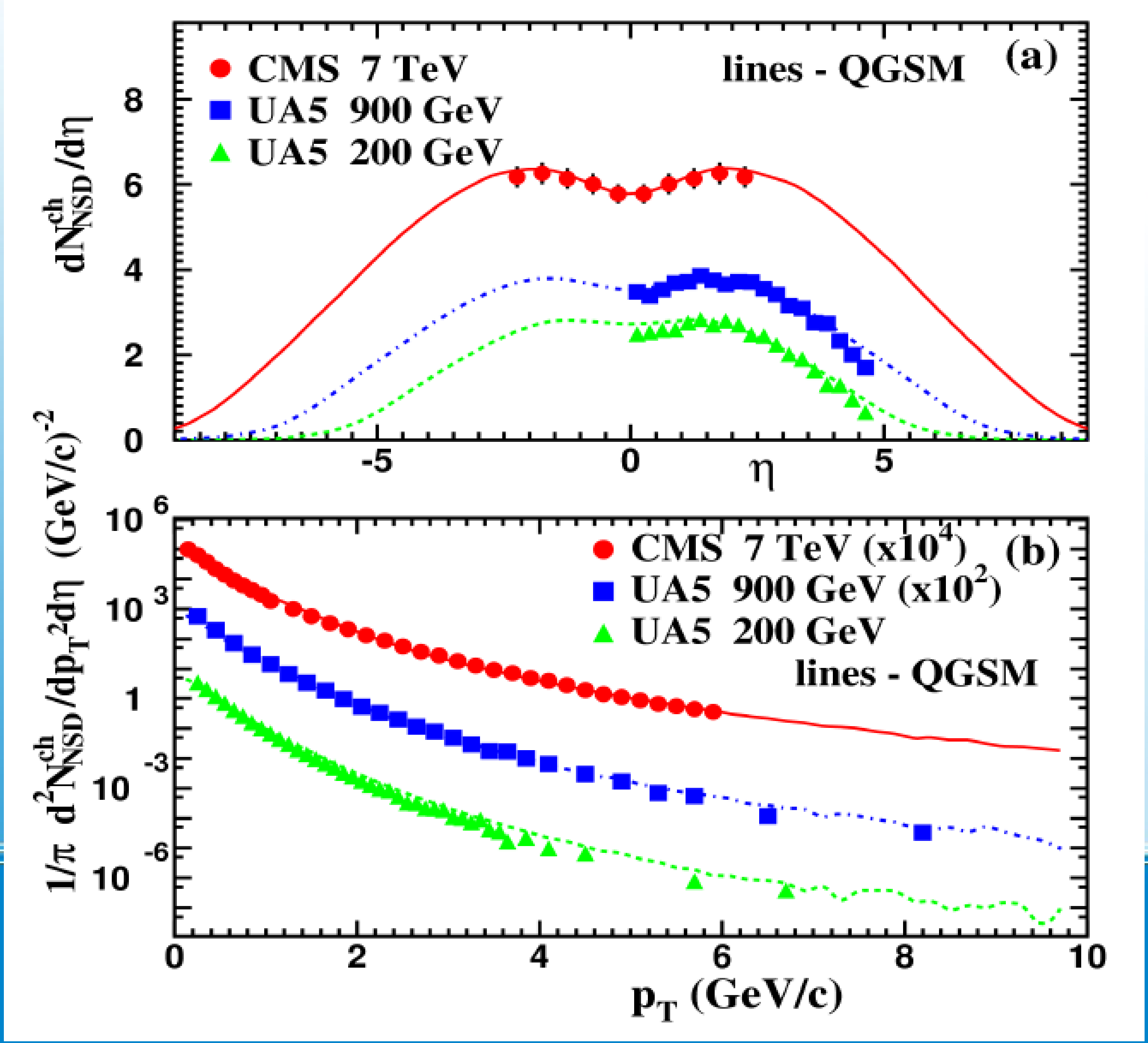
- The Quark Gluon String Model (QGSM) describes well the dN/dη dN/dp_t and $<p_t>$ of charged hadrons etc in pp collisions at LHC.

- 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.

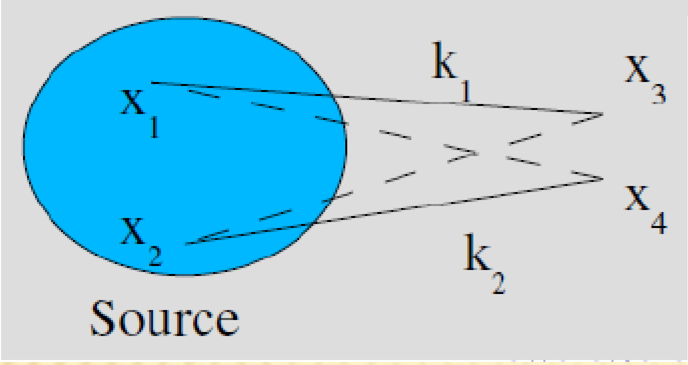
Transport models, considering the full microscopic picture of the particle production/emission/rescattering processes, might shed light on the other mechanisms generating the observed k_t-dependence of the correlation radii in pp and heavy ion collisions.

Motivation



CMS 7 TeV
UA5 900 GeV
UA5 200 GeV
lines - QGSM
(a)
$dN^{ch}_{NSD}/d\eta$
0
2
4
6
8
-5
0
5
η
CMS 7 TeV ($x10^4$)
UA5 900 GeV ($x10^2$)
UA5 200 GeV
lines - QGSM
(b)
$1/\pi\ d^2N^{ch}_{NSD}/dp_T^2d\eta\ (GeV/c)^{-2}$
10^6
10^3
1
10^{-3}
10^{-6}
0
2
4
6
8
10
p_T (GeV/c)

HANBURY-BROWN—TWISS CORRELATIONS

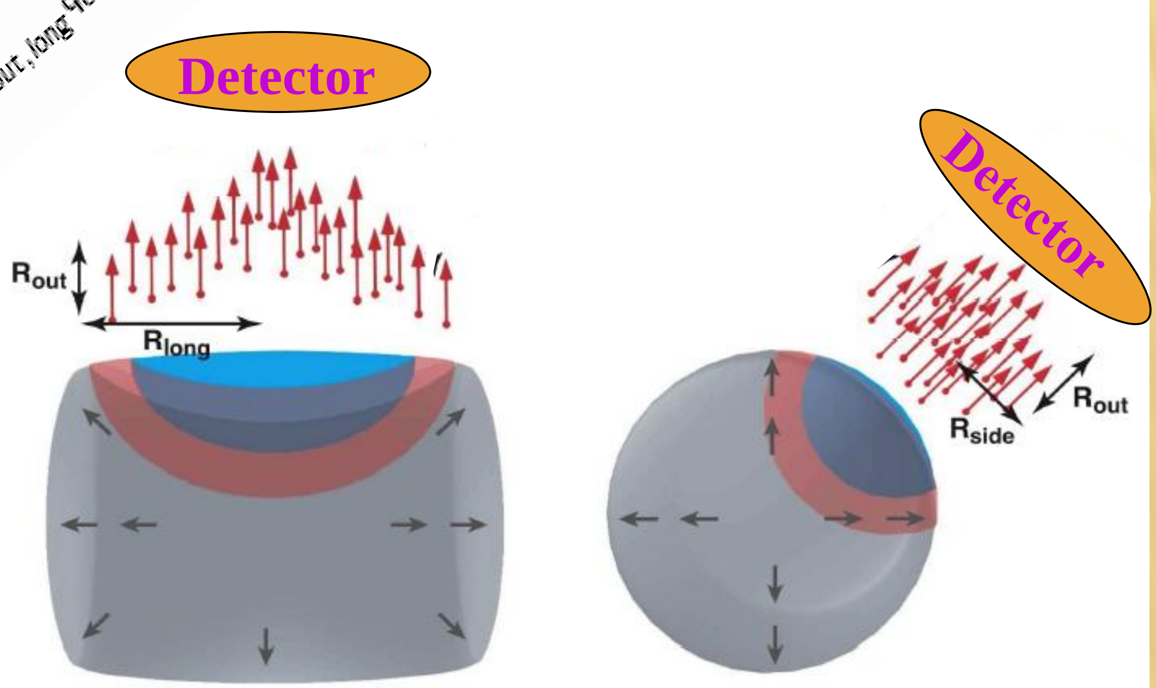


- We can consider two pions emitted from two spacetime points in the extended source.
- Correlations will then arise from exchange symmetry between identical particles.
- It is defined as the probability to measure both particles in coincidence, divided on the probability of measuring each separately.

$$C_2(k_1, k_2) = \frac{P(k_1, k_2)}{P(k_1)P(k_2)}$$

$$\mathbf{q} = \mathbf{p_1} - \mathbf{p_2}$$

$$C_2(q) = 1 + \lambda e^{-R_{out}^2 q_{out}^2 - R_{side}^2 q_{side}^2 - R_{long}^2 q_{long}^2 - R_{out,long}^2 q_{out,long}}$$



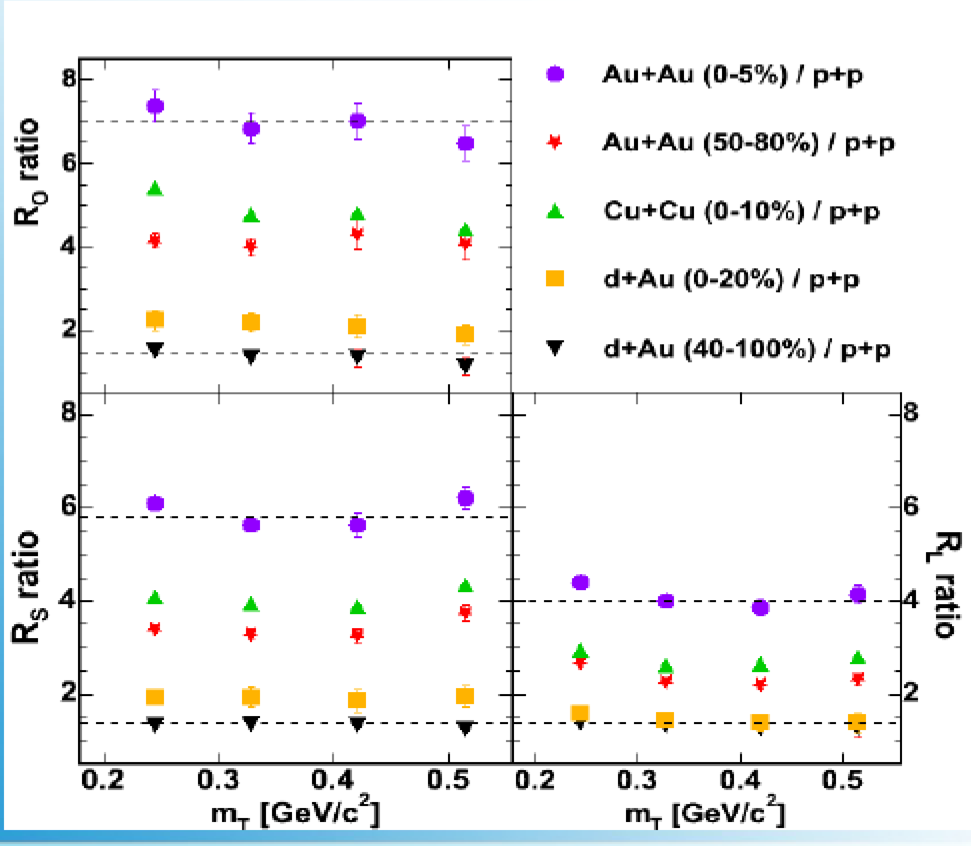
Femtoscopy in pp STAR data

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

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

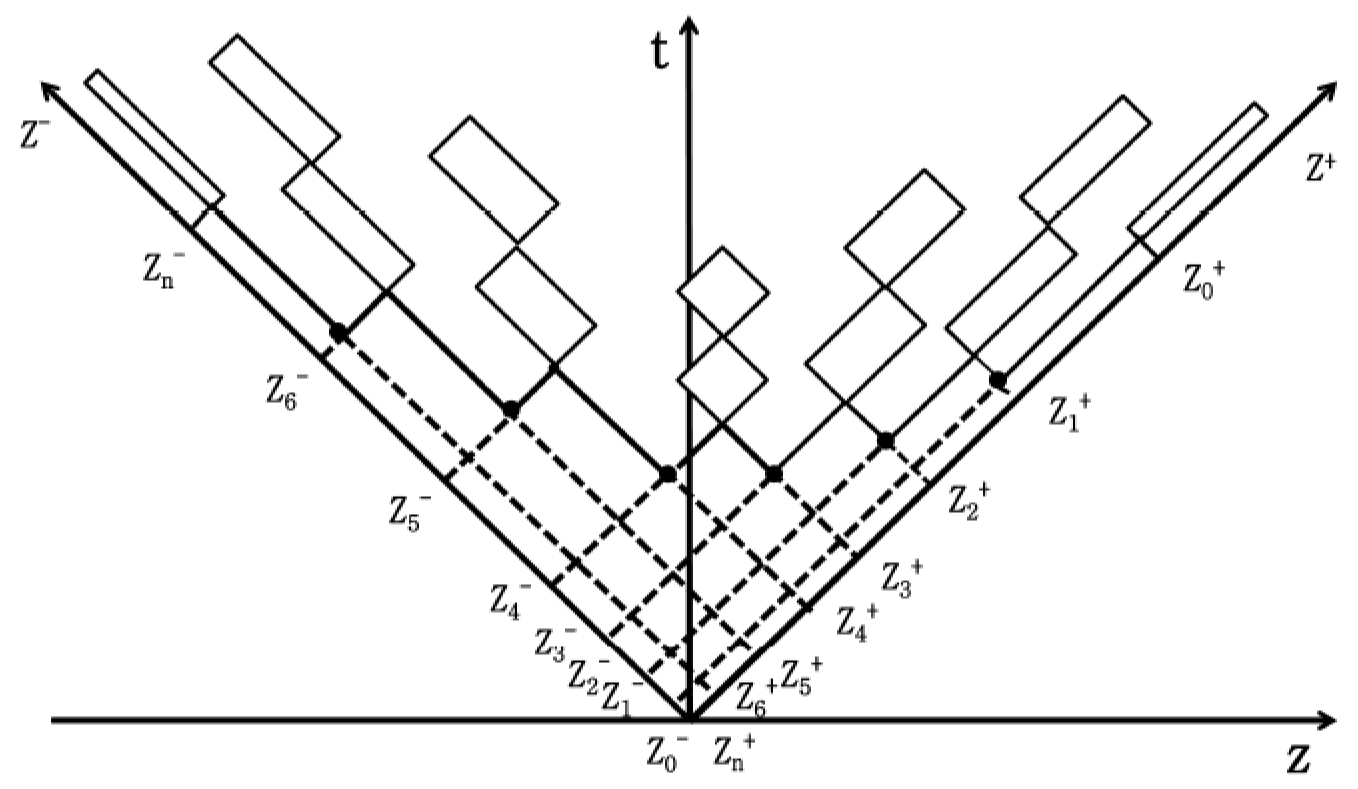
All Kt(mt) dependences of correlation radii observed by STAR scale with pp (!?) although the expected origins of these dependences are different.

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



String Phenomenology

- Field-Feynman mechanism of string fragmentation
- Particles are created from the breaking of quark-antiquark (quark-diquark) strings.
- The string length $L=M_s/K$ is dependent on the string mass M_s and the string tension K.
- The length of the string varies, the maximum determined by the momentum of the incident hadron and the minimum determined by the pion mass.



String Fragmentation

Formation time and coordinate

- In the Lund schema formation time and z-coordinate of the produced hadron are calculated in the string cms.

$$t_i^* = \frac{1}{2\kappa}\left(M_s - 2\sum_{j=1}^{i} p_{zj}^*\right)$$

$$z_i^* = \frac{1}{2\kappa}\left(M_s - 2\sum_{j=1}^{i} E_j^*\right)$$

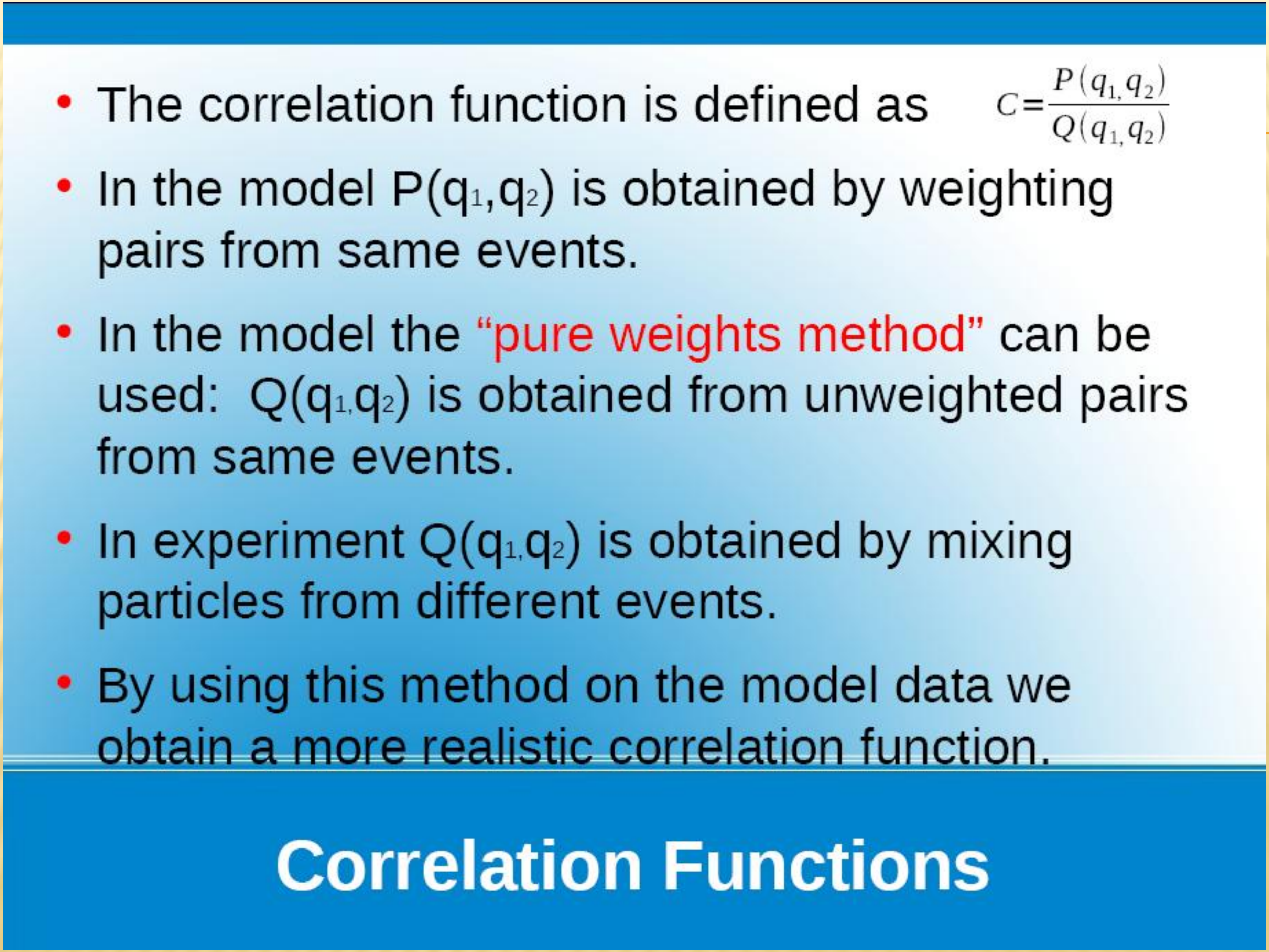
$$a_i = a_{0i} + t_i\, p_{ai} / E_i$$

$$a = x, y, z$$

Scaling Parameter

- An increase in string tension will cause a reduction in formation time.
- We introduce a scaling parameter α of the string tension K.
- $\alpha=1$ gives $K=K_0=0.88$GeV/c

$$\kappa = \alpha \kappa_0$$



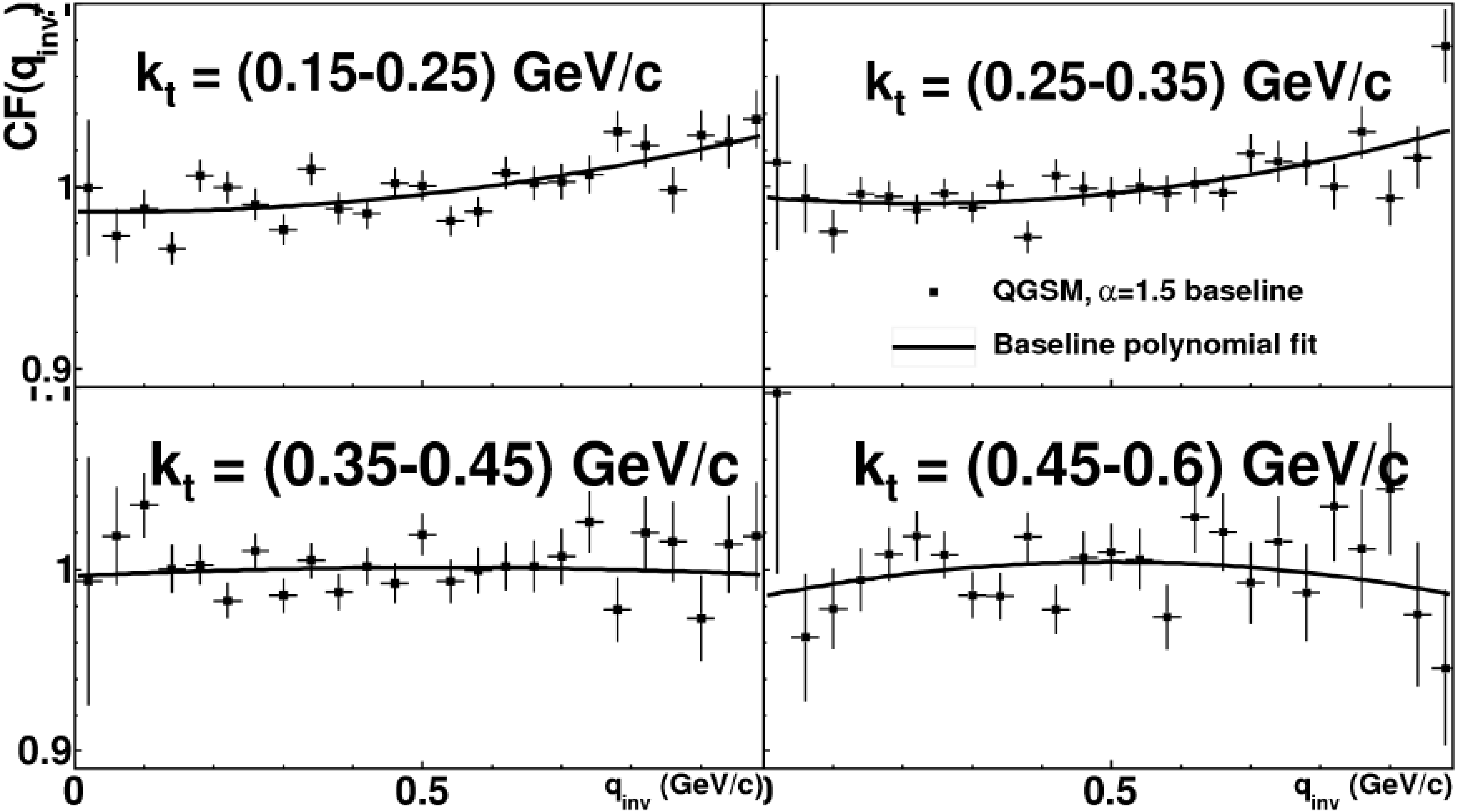
Correlation Functions

- 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 by 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.

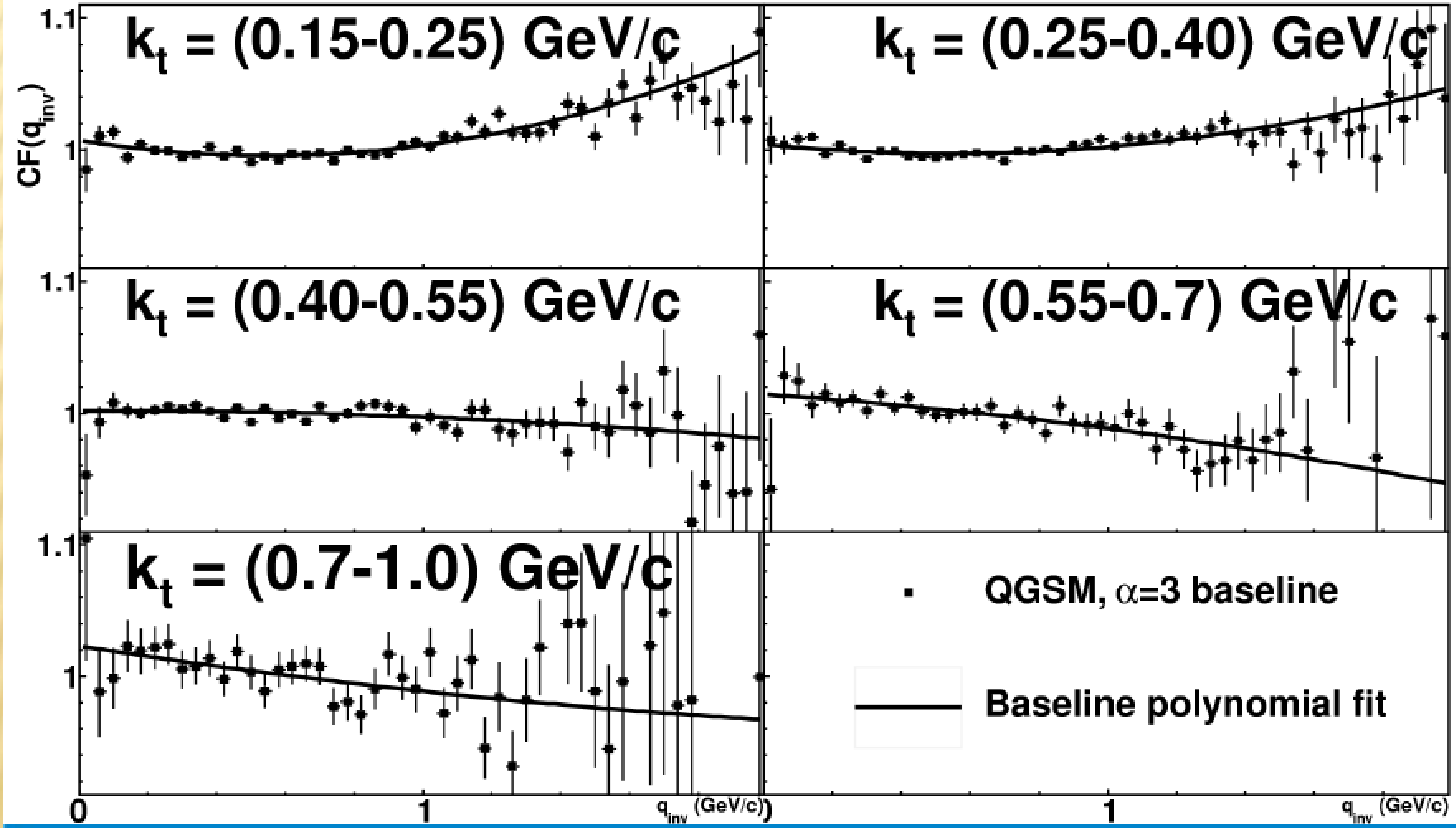
Fitting 1D correlation functions

- We use a gaussian fitting function for the correlation function. $C = N(1+\lambda e^{-q_{inv}^2 R_{inv}^2}) D(q_{inv})$
- 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.
- The parameters a and b were then fixed when fitting the correlation function.

$\pi^+\pi^+$ Baseline pp 200GeV



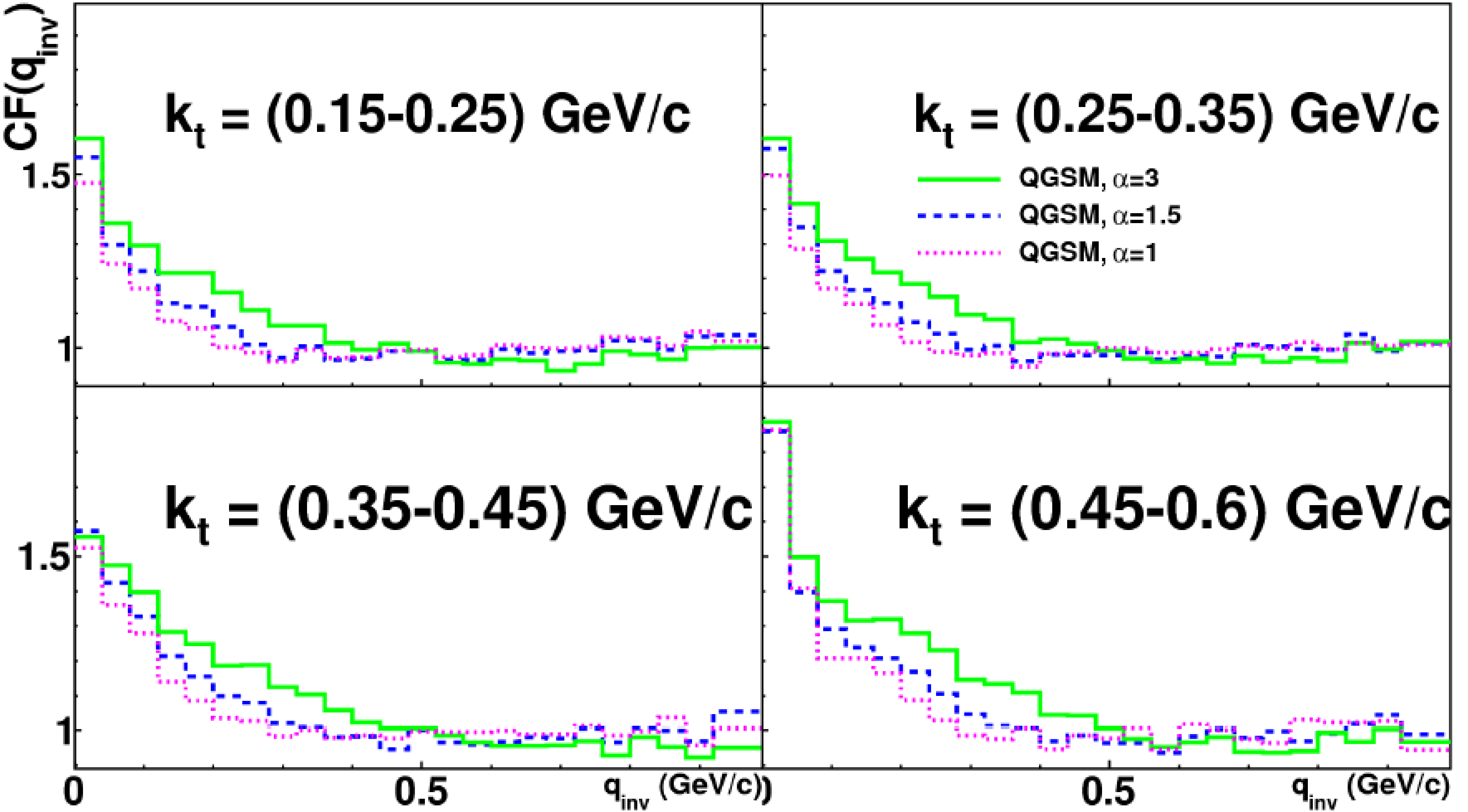
$\pi^+\pi^+$ Baseline pp 900GeV



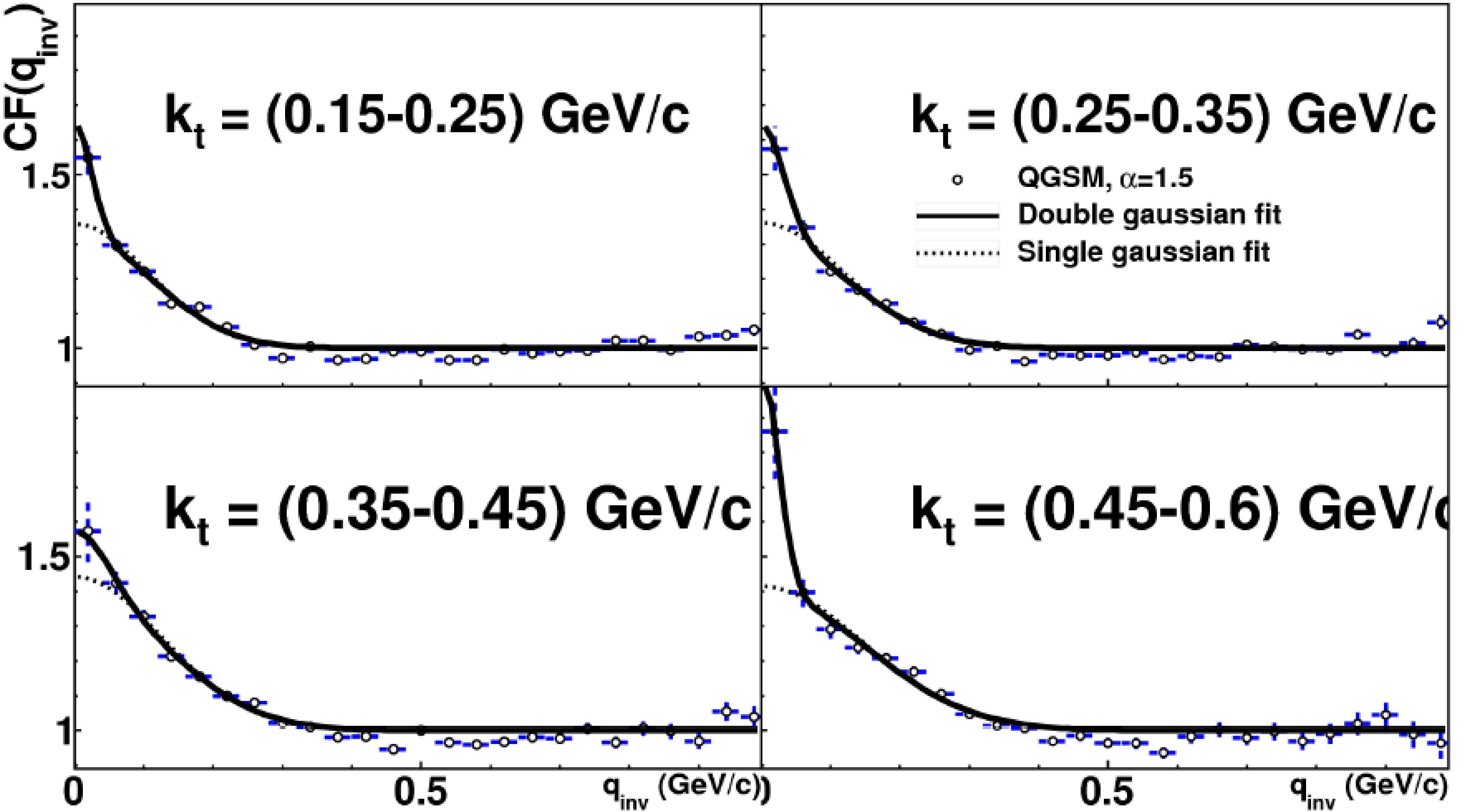
Baseline in experiment

- The STAR experiment have fitted their data using a flat baseline and other parametrisations e.g. EMCICS.
- The ALICE experiment have fitted their data using the polynomial baseline obtained from PYTHIA.
- ALICE have also published fitting results using flat baseline
- In order to easily compare results between 200GeV and 900GeV we will do our fitting using a flat baseline. This is also supported by the shape of the QGSM non-femtoscopic correlations

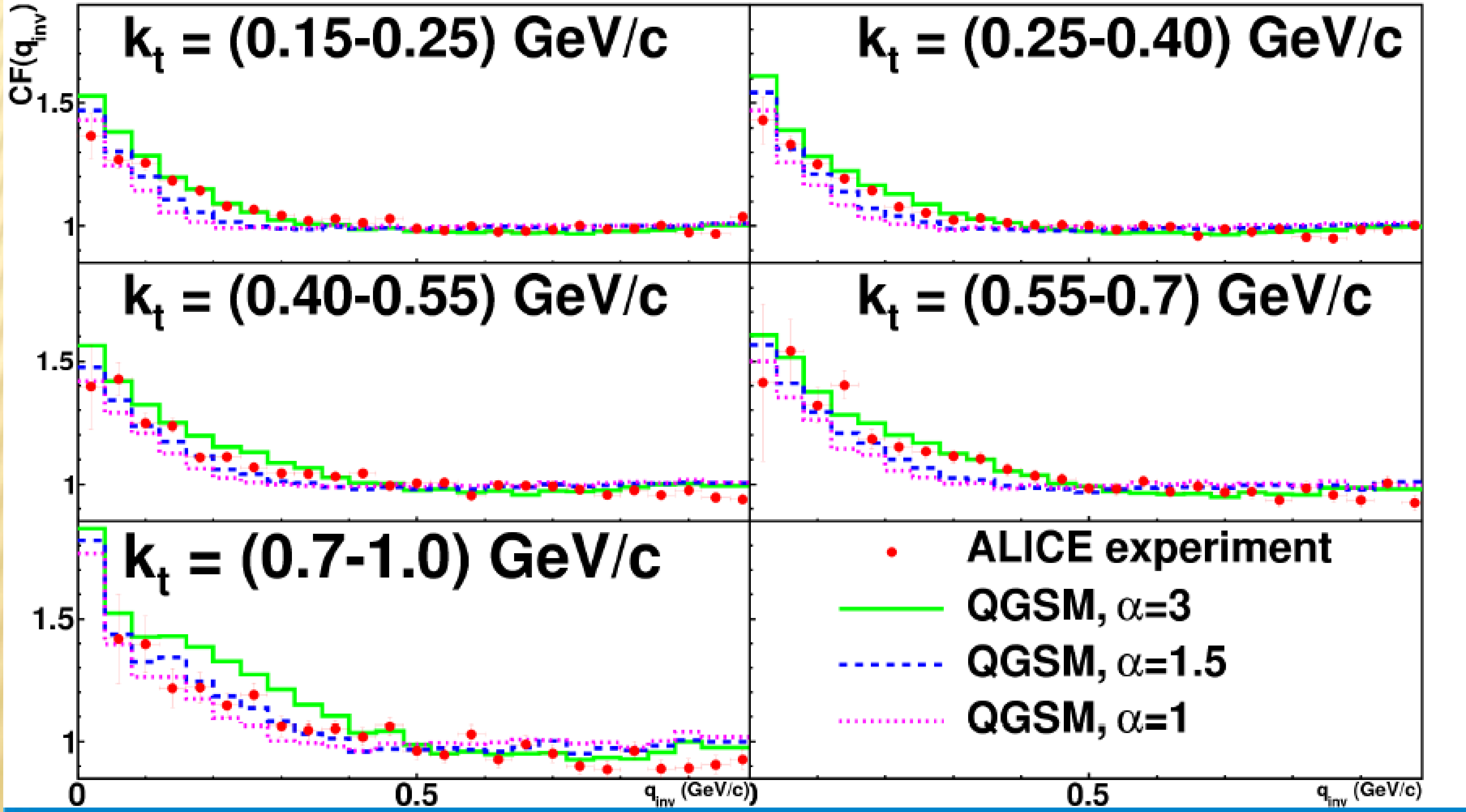
$\pi^+\pi^+$ Correlation function pp 200GeV



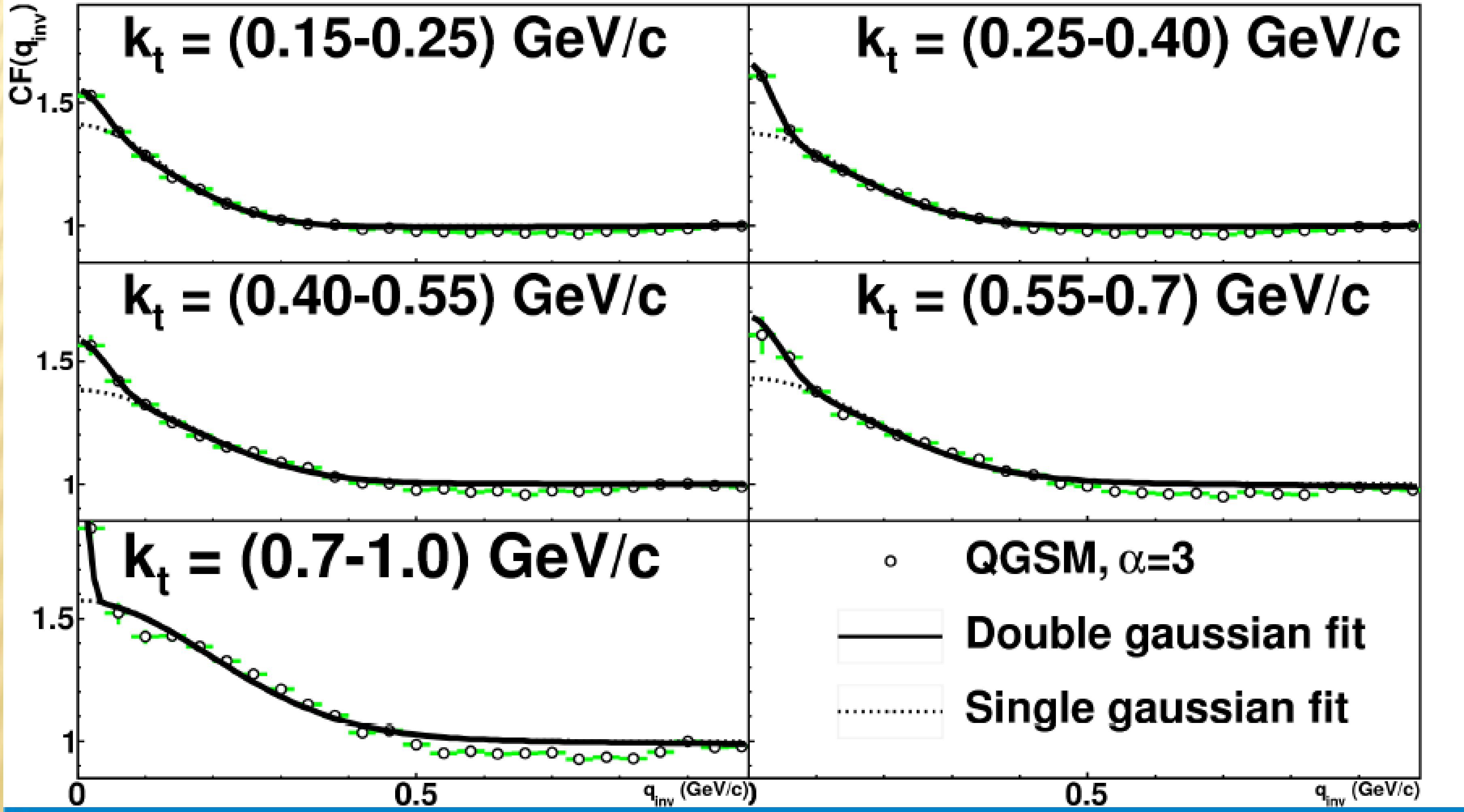
$\pi^+\pi^+$ Correlation function fit pp 200GeV, using α=1.5



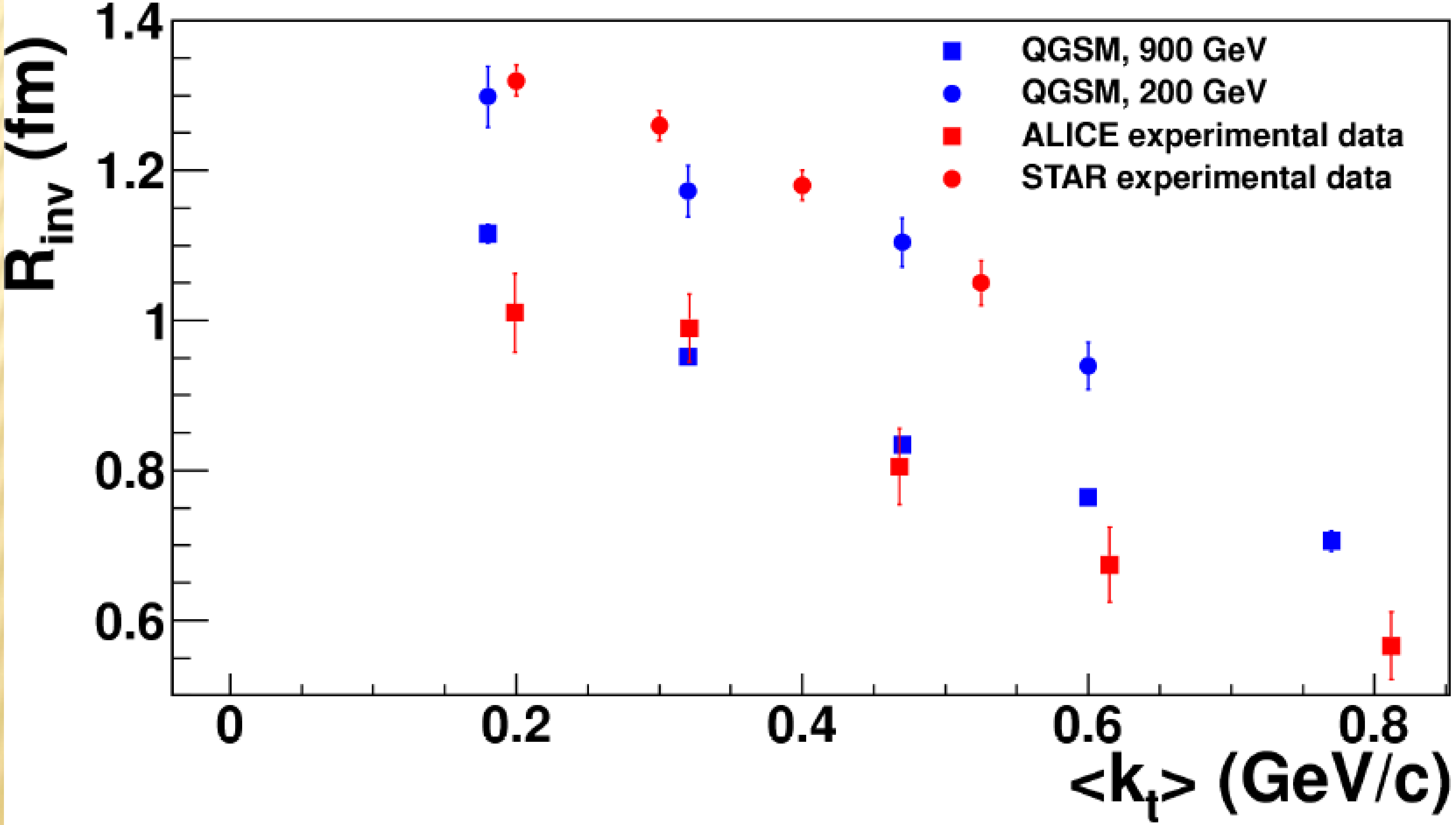
$\pi^+\pi^+$ Correlation function pp 900GeV



$\pi^+\pi^+$ Correlation function fit pp 900GeV, using $\alpha=3$



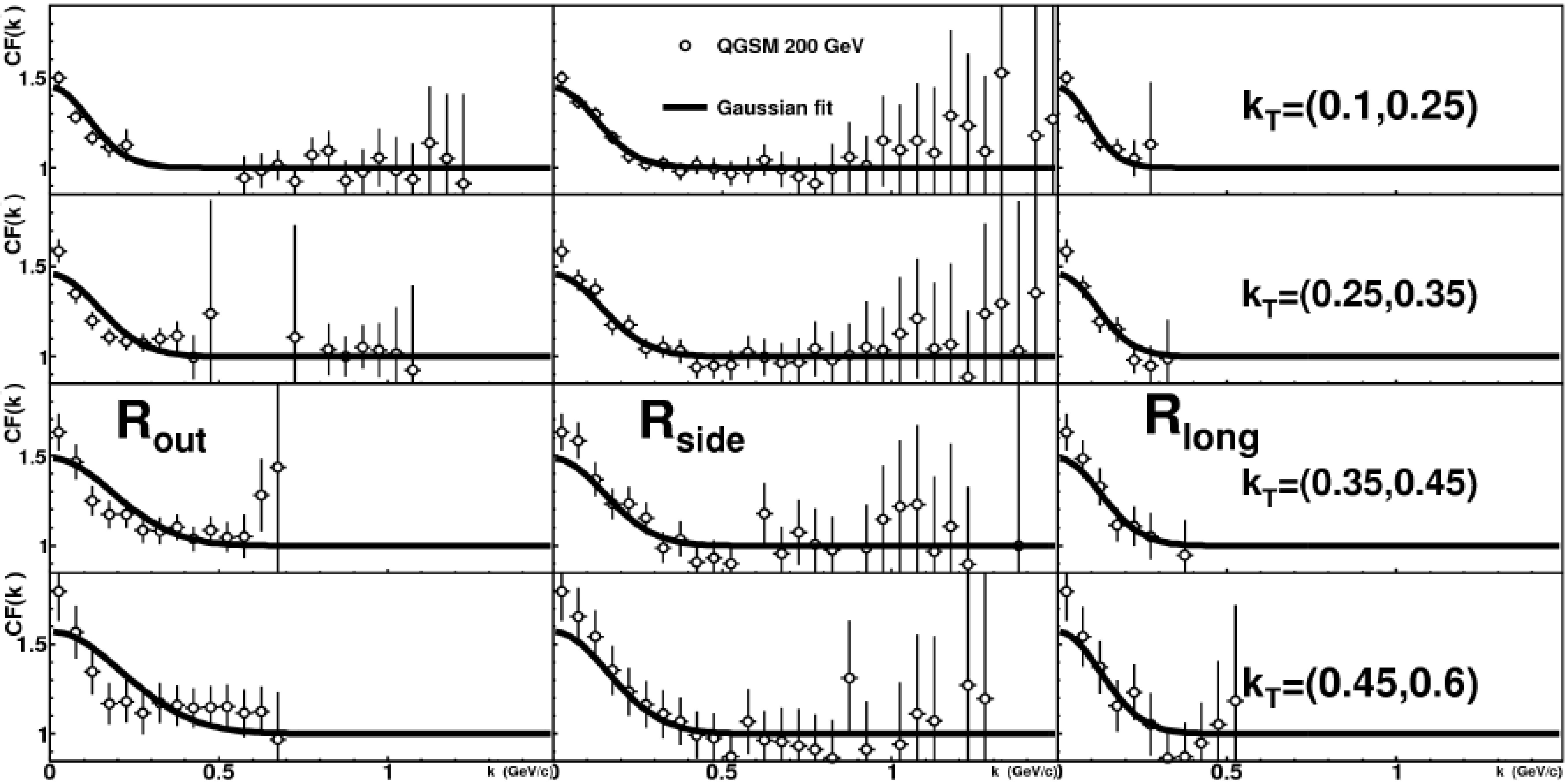
Comparison to experimental data



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

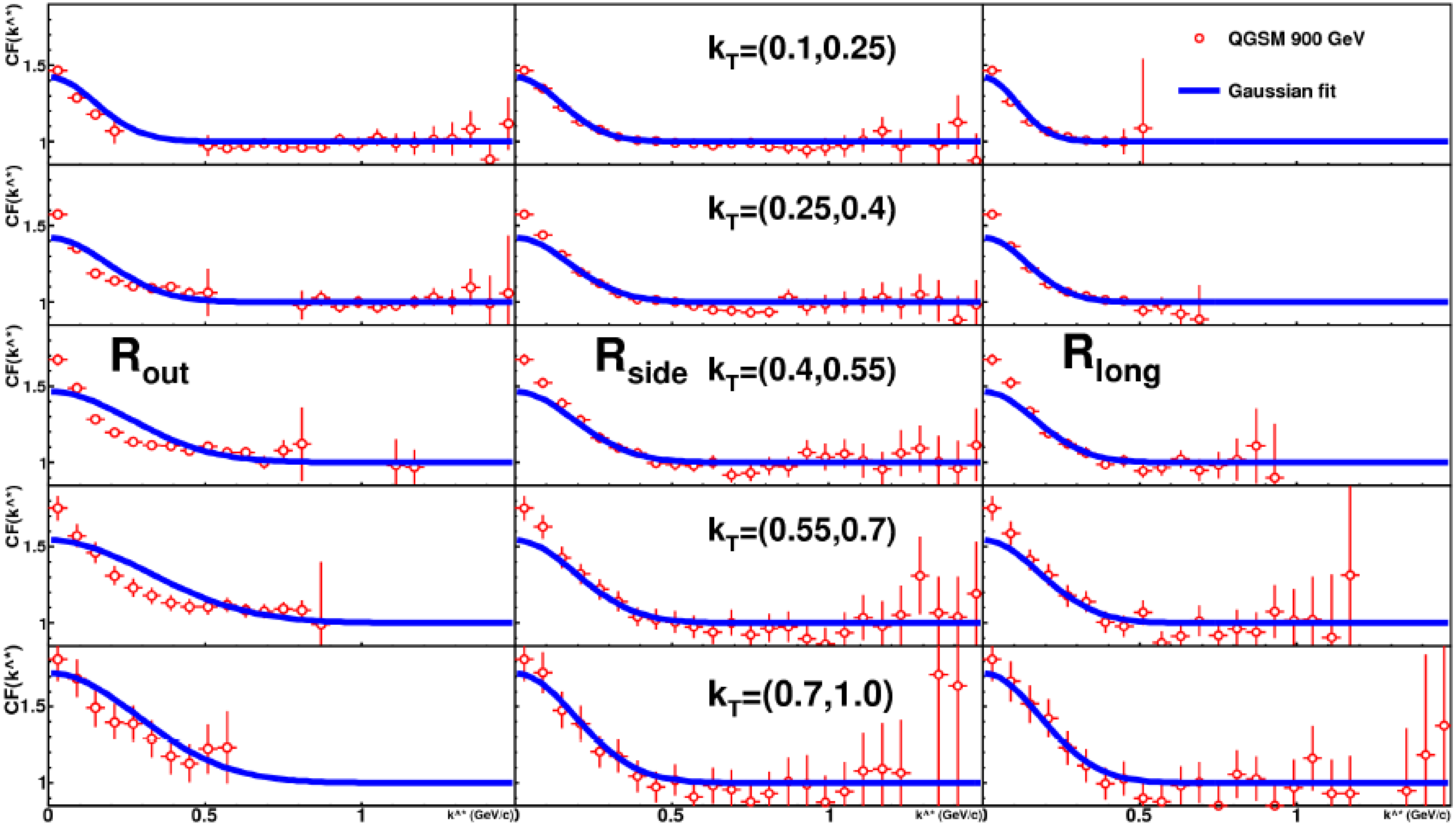
- We have extracted correlation radii in out-side-long directions from QGSM using a full 3d fit.

3D Correlation functions

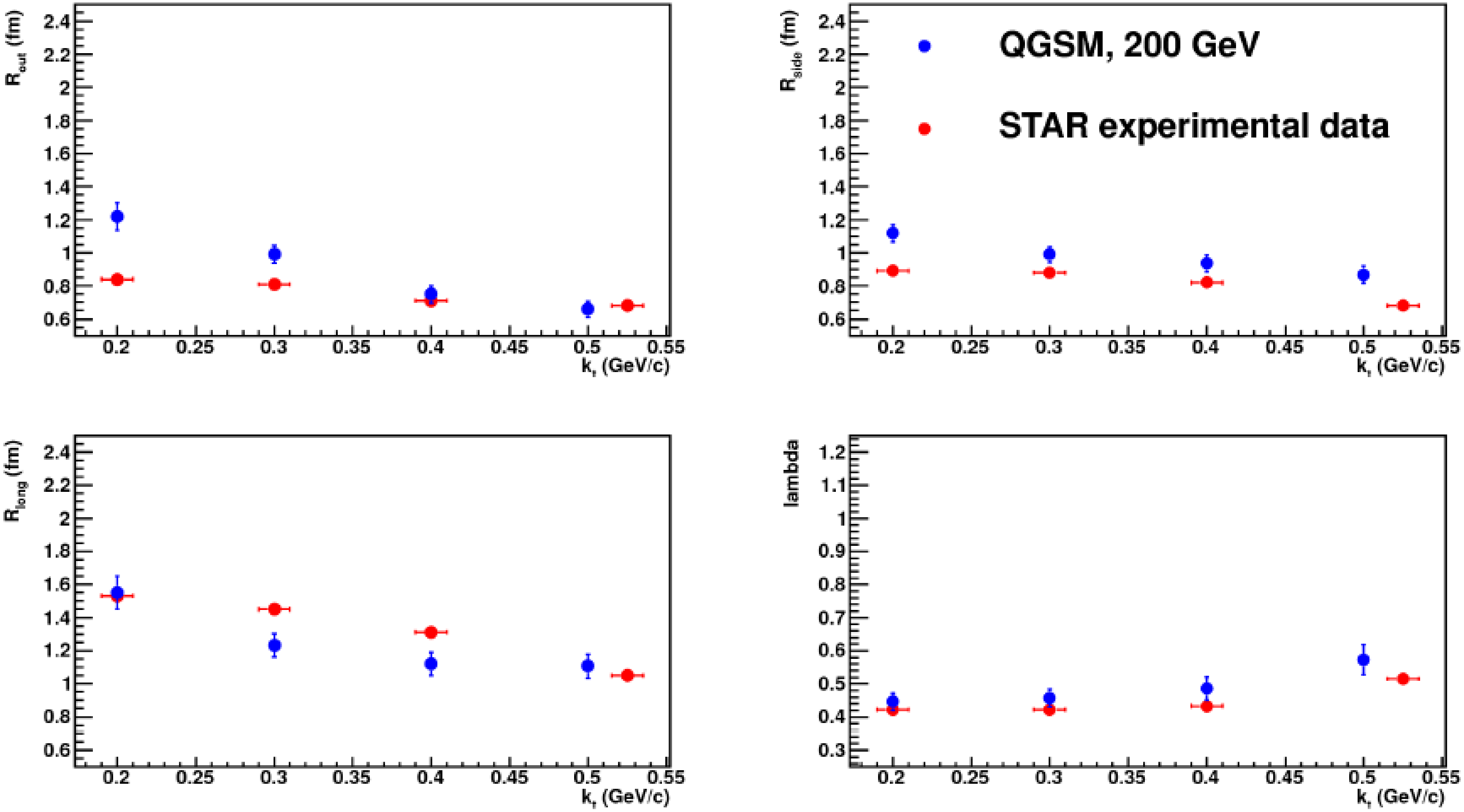


$\pi^+\pi^+$ 3D Correlation function pp 200GeV

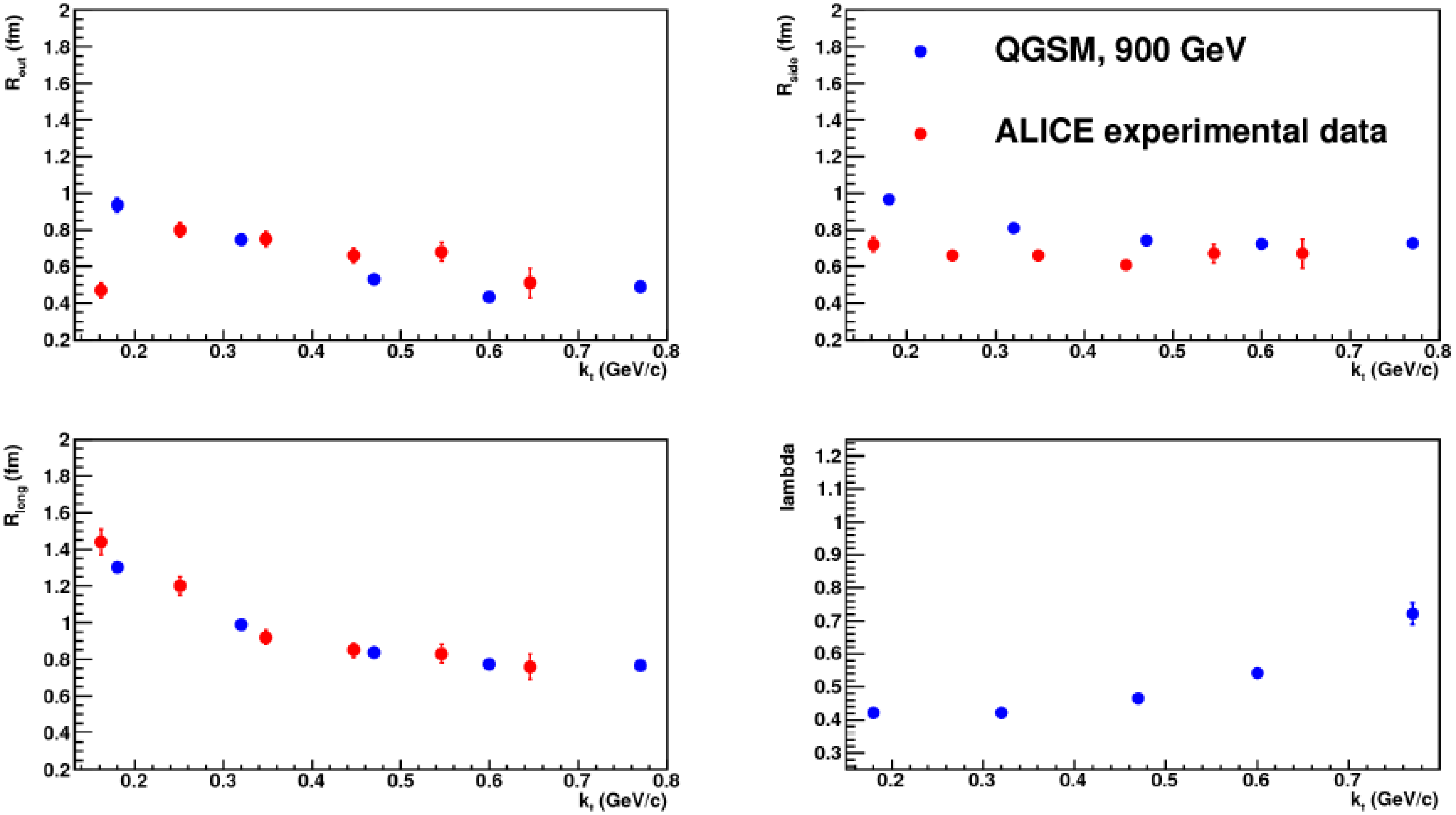
$\pi^+\pi^+$ 3D Correlation function pp 900GeV



Correlation radii 200GeV

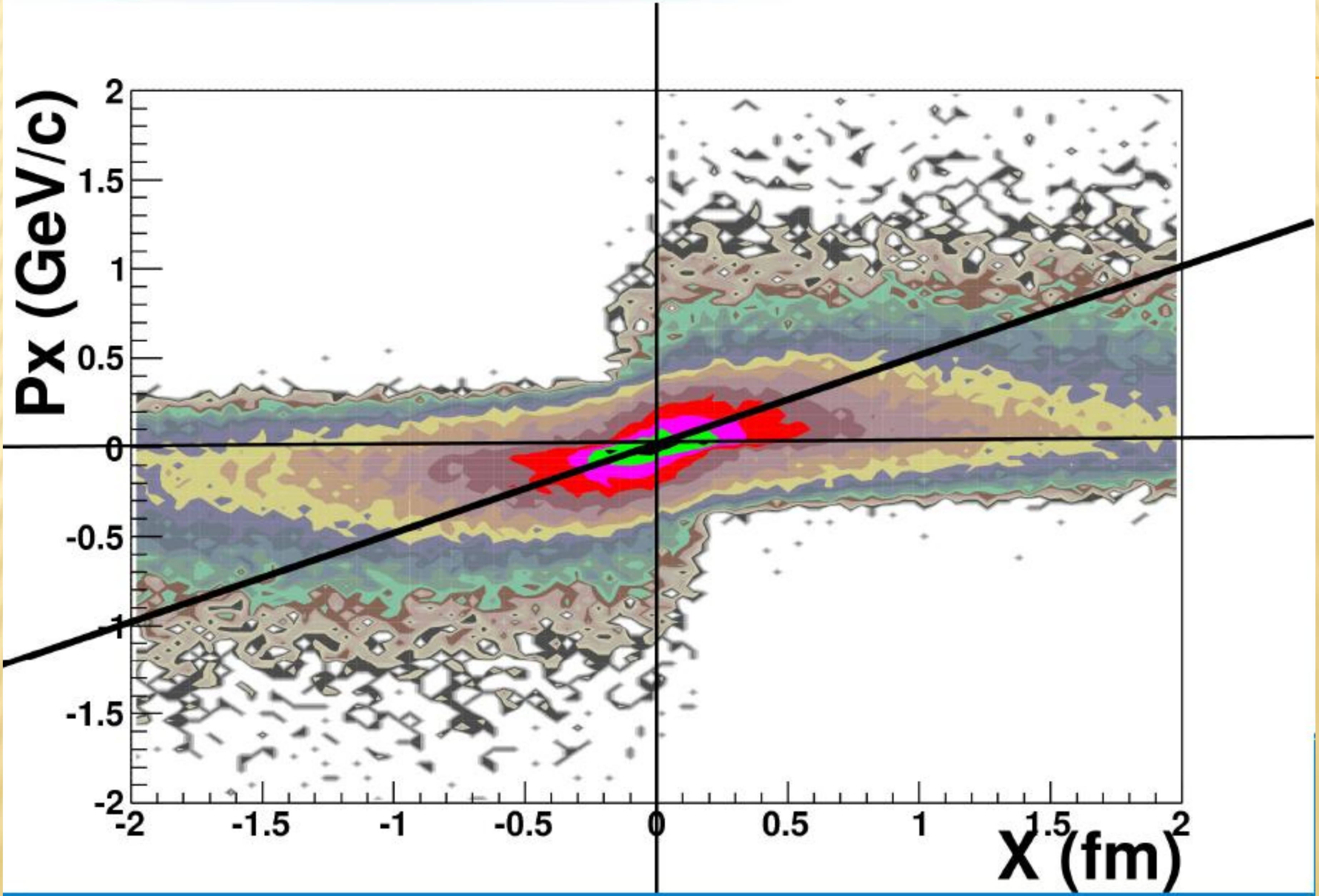


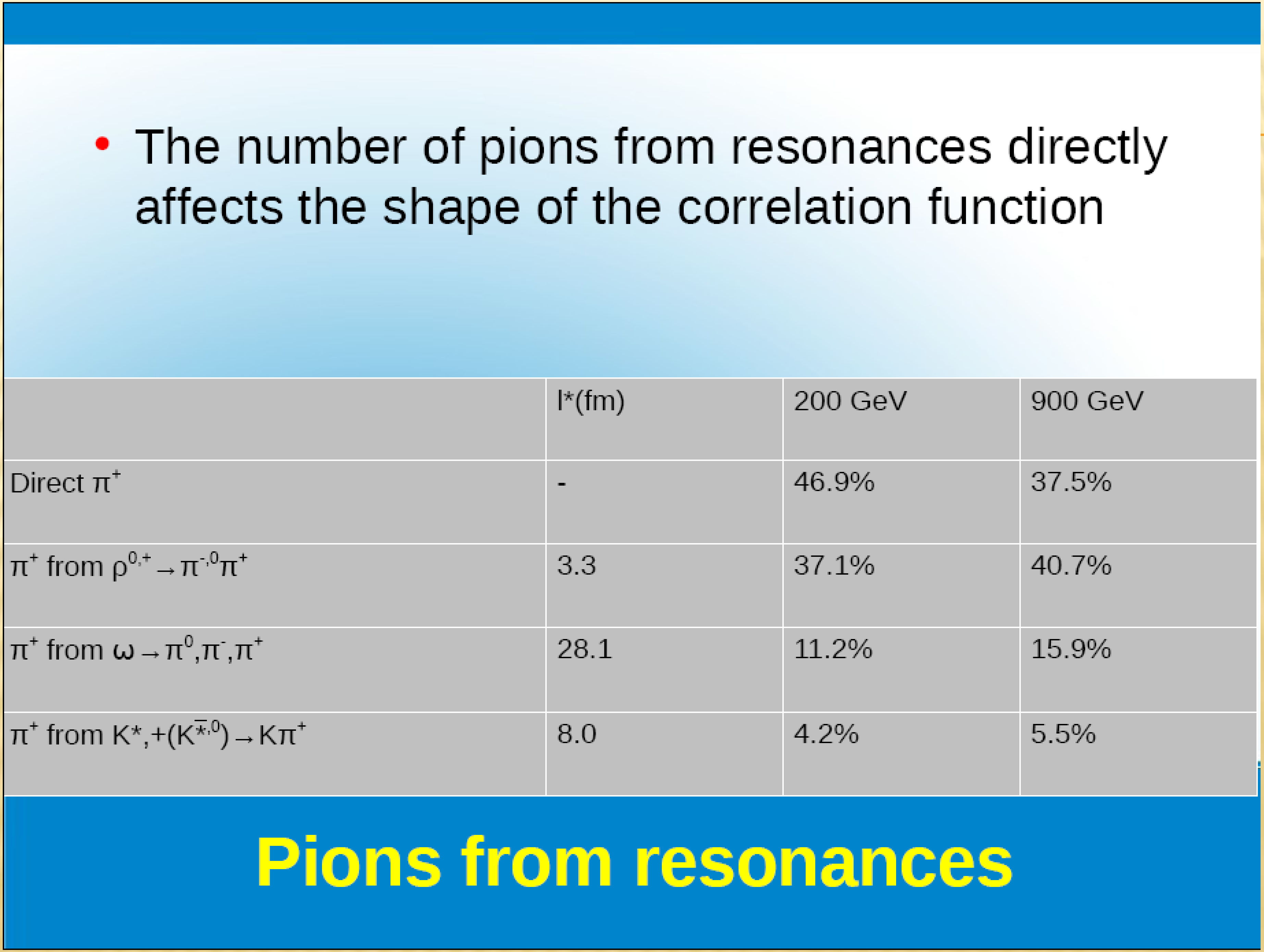
Correlation radii 900 GeV



- What is the origin of the kt-dependence in QGSM?
- We have studied the contribution from pion-decay from resonances.
- Px-x dependence for direct particles

Kt-dependence

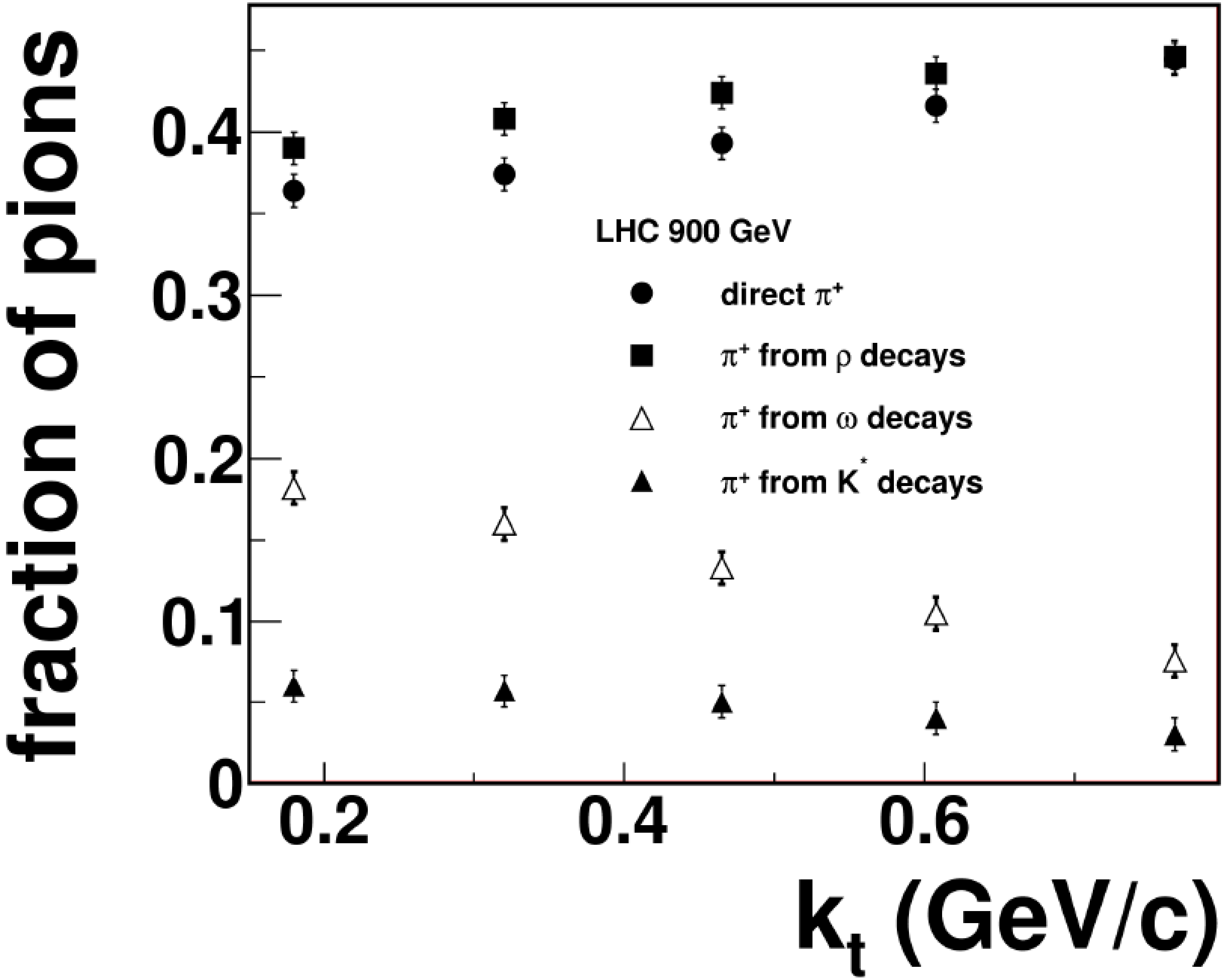

Px (GeV/c)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
X (fm)



- The number of pions from resonances directly affects the shape of the correlation function

	l*(fm)	200 GeV	900 GeV
Direct π^+	-	46.9%	37.5%
π^+ from $\rho^{0,+} \rightarrow \pi^{-,0}\pi^+$	3.3	37.1%	40.7%
π^+ from $\omega \rightarrow \pi^0,\pi^-,\pi^+$	28.1	11.2%	15.9%
π^+ from $K^{*,+}(\overline{K}^{*,0}) \rightarrow K\pi^+$	8.0	4.2%	5.5%

Pions from resonances


fraction of pions
0.4
0.3
0.2
0.1
0
0.2
0.4
0.6
k_t (GeV/c)
LHC 900 GeV
● direct π^+
■ π^+ from ρ decays
△ π^+ from ω decays
▲ π^+ from K^* decays

- Experimental results are reasonably well described in lower kt-bin using a simple string model
- Testing of different fitting strategies reveals a systematic error of about 20%
- Study of resonances helps to explain the kt-dependence of the HBT radii in QGSM
- Paper: arXiv:1106.1786v1 [hep-ph] (PRD84, in press)

Conclusions