Sphericity dependent pion HBT analysis
- pp & pA -

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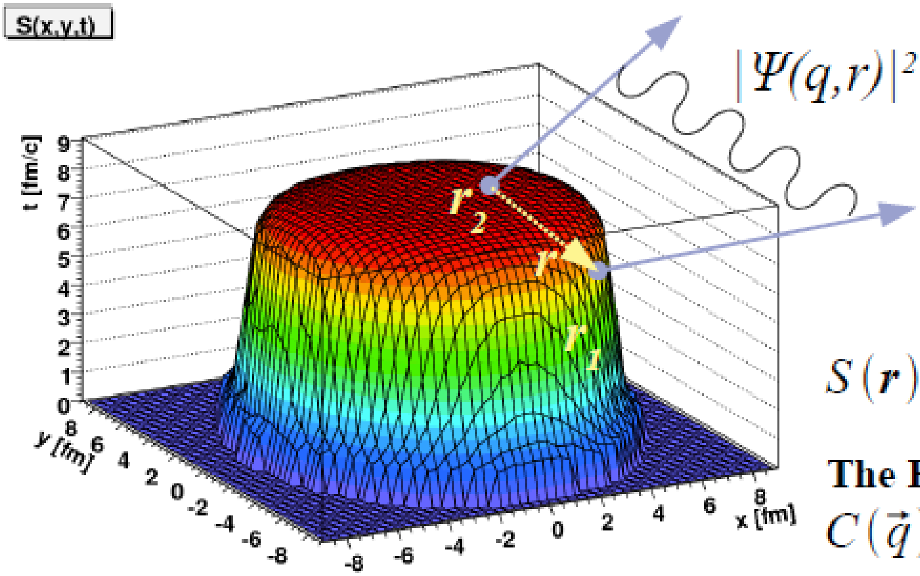
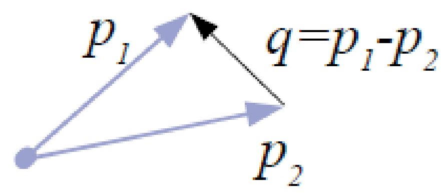
Measuring space-time extent: femtoscopy





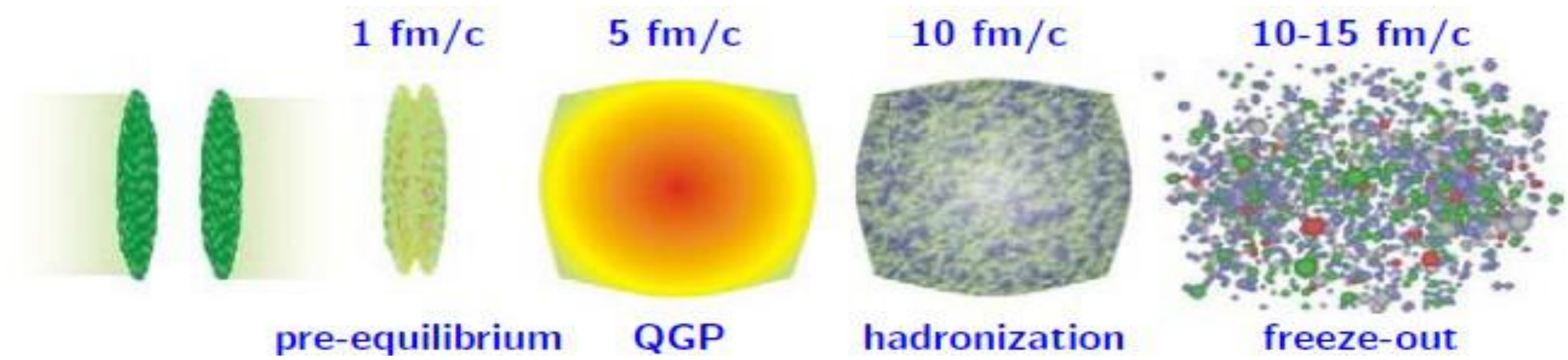
$$S(\boldsymbol{r}) = \int S_a(\boldsymbol{r_1}) S_b(\boldsymbol{r_2}) \delta(\boldsymbol{r} - (\boldsymbol{r_1} - \boldsymbol{r_2})) d^4 r_1 d^4 r_2$$

The Koonin-Pratt Equation:

$$C(\vec{q}) = \int S(\boldsymbol{r}) |\Psi(\vec{q}, \boldsymbol{r})|^2 d^4 r$$

Femtoscopy uses the correlation between two particles, reflected in the pair wave function Ψ. It comes from a combination of the quantum statistics (anti-)symmetrization, Coulomb and strong interactions. Using the Koonin-Pratt equation, one tries to learn as much as possible about the source (i.e. the source emission function S), from the measured correlation C.

Femtoscopy in practice (HBT)

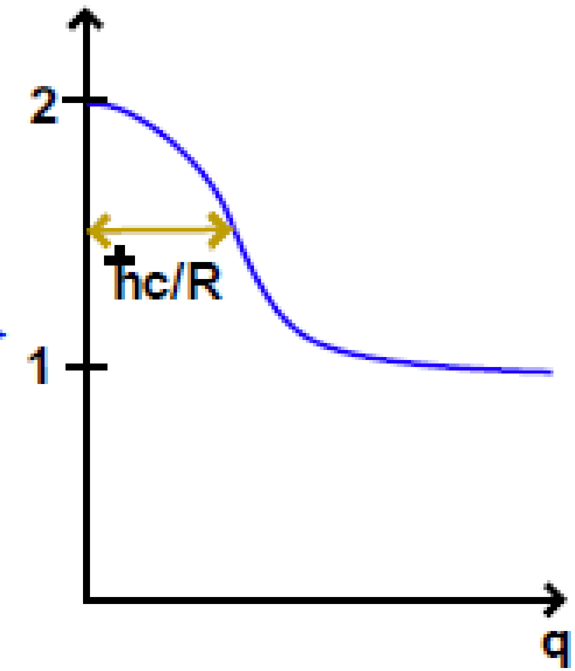


two-particle correlation function:

theory : $C(q) = \frac{N_2(p_1, p_2)}{N_1(p_1)N_2(p_2)}, \quad C(\infty) = 1$

experiment : $C(q) = \frac{S(q)}{B(q)}, \quad q = p_1 - p_2$

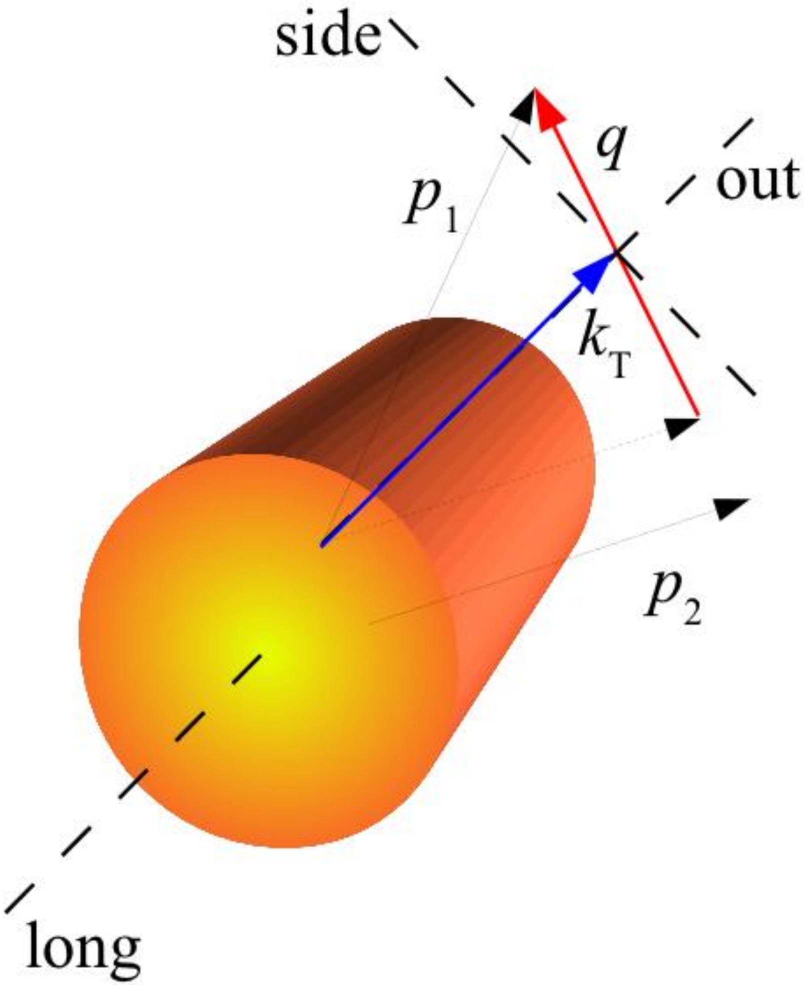
$\Rightarrow$



S - distribution of pair momentum difference of particles from the same events

B - reference distribution, built by mixing particles from different events

Refference systems and 3D representations

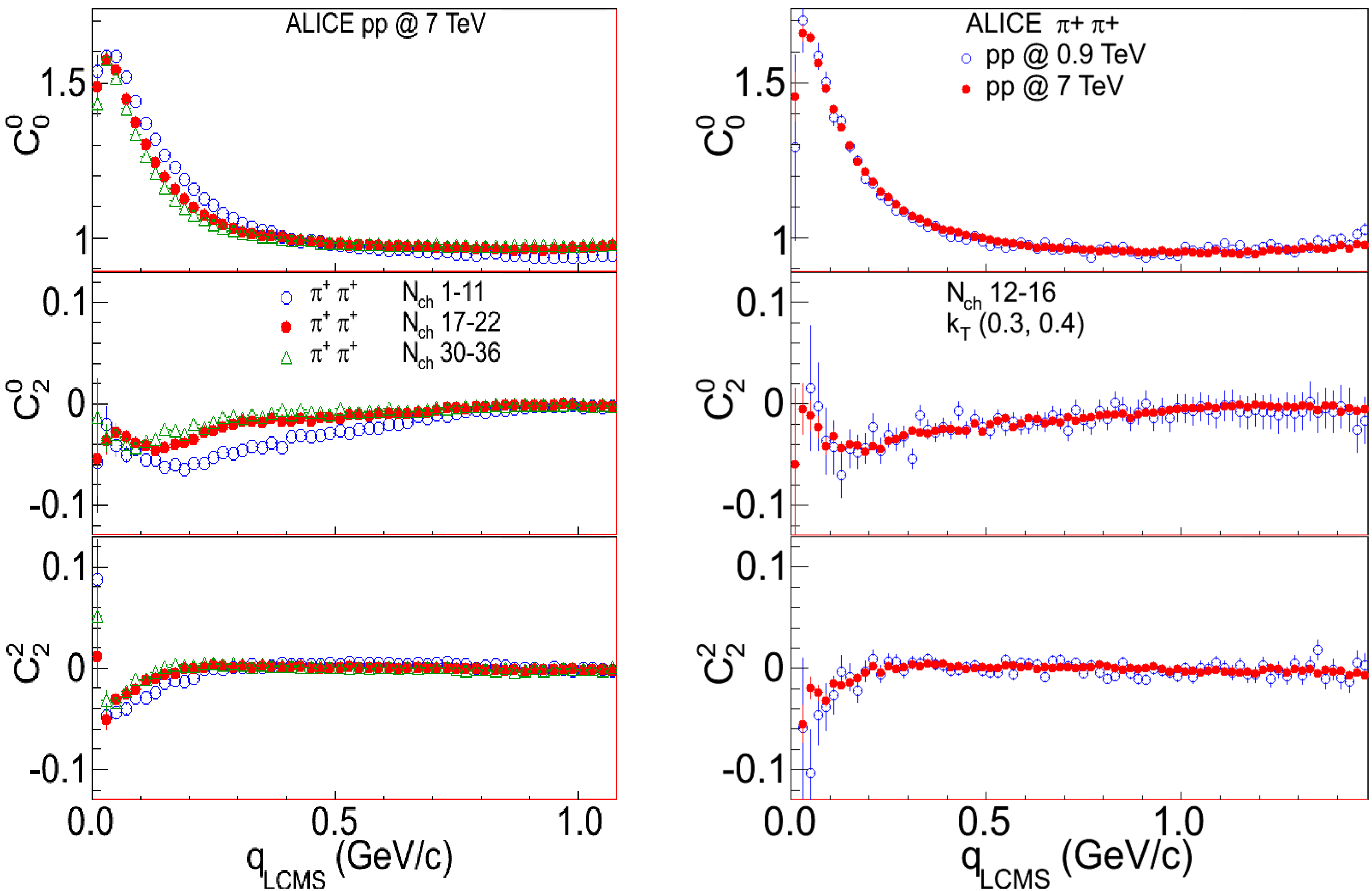


$$m_T = (k_T^{\,2} + m_\pi^{\,2})^{1/2}$$

1-dimensional analysis uses invariant relative momentum and can only extract *the mean system radius* in all directions
In the LCMS reference system
(Longitudinally Co-Moving System, LCMS) three new directions: ***long*** *– beam line,* ***out*** – pair momentum, ***side*** – normal to *long* and *out*.
In LCMS the long component disappears.
New three directions for analysis:
Separation of information for each dirrection.
– ***side*** *is interpreted as* ***"geometric size"***
– ***out*** *gives info on* ***"emission process"***
– ***long*** *is used for* ***emission time approx.***

$$k_T = \frac{1}{2}(k_1^T + k_2^T)$$

HBT spherical components



An innovation in the approach !

Apart from the knowledge gain by the removal of nonfemtoscopic contributions coming from jets there is a wealth of information integrated over within the minimum bias data. Just by differentiating soft and hard physics one is able to understand details of manybody-hot-dense QCD processes. This understanding is crucial for interpreting pA and AA.

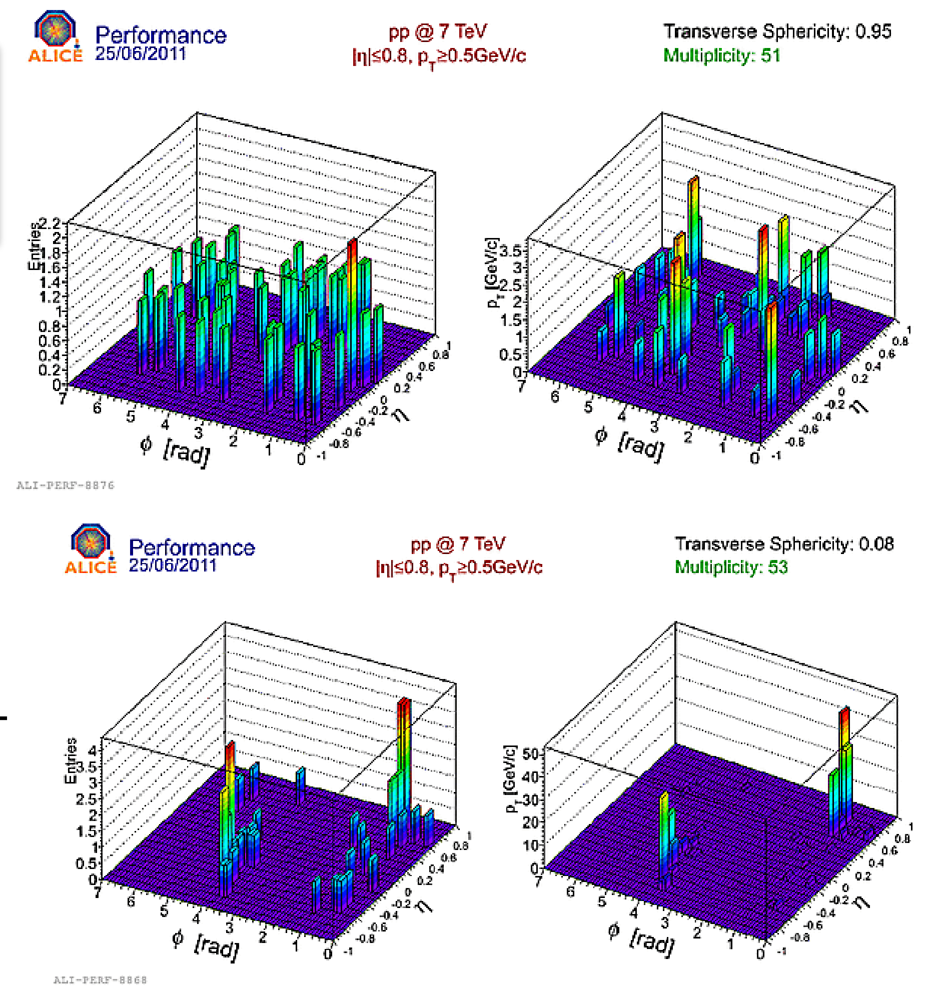
Transverse sphericity

- momentum space event shape variable
- defined with eigenvalues λ of the transverse momentum matrix

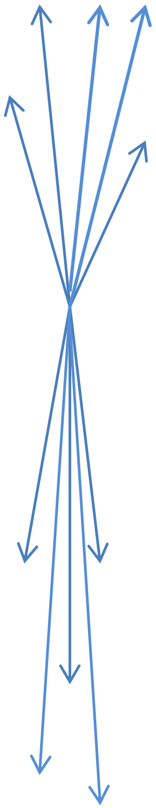
$$S^{L}_{xy} = \frac{1}{\sum_i p_{T\,i}} \sum_i \frac{1}{p_{T\,i}} \begin{pmatrix} p_{x\,i}^2 & p_{x\,i}\,p_{y_i} \\ p_{y_i}\,p_{x\,i} & p_{y_i}^2 \end{pmatrix}$$

$$S_T = \frac{2\lambda_2}{\lambda_1 + \lambda_2} \Rightarrow S_T = \begin{cases} \approx 0 & \text{JET-LIKE} \\ \approx 1 & \text{SPHERICAL} \end{cases}$$

- events with same multiplicity can have very different sphericities



What do we gain with this ?

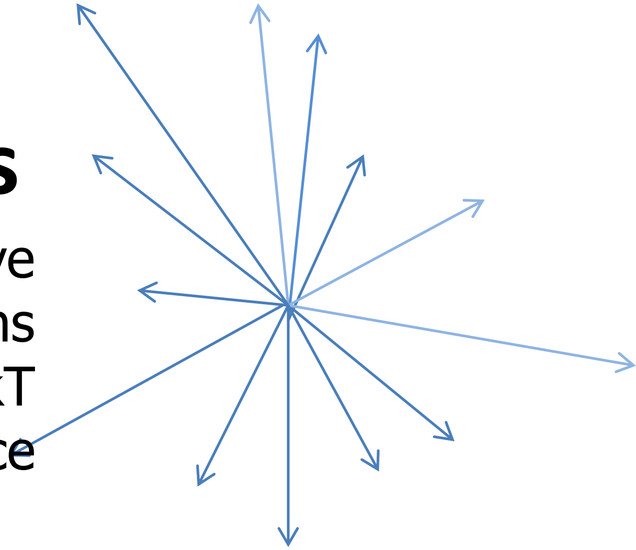


JETS

- Initially a hard process, particle poduction dominated by jet hadronization, large jet collimation contribution to particle correlations
- usually modelled and removed as background

Spherical events

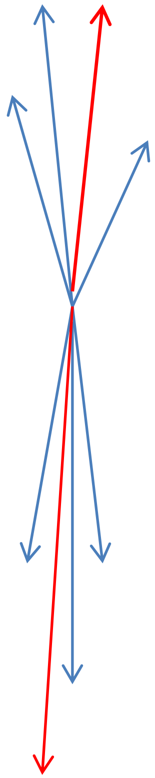
- multiple soft processes, non-perturbative QCD production, no collimation contributions to particle correlations and no pair kT dependence



kT bins and jets

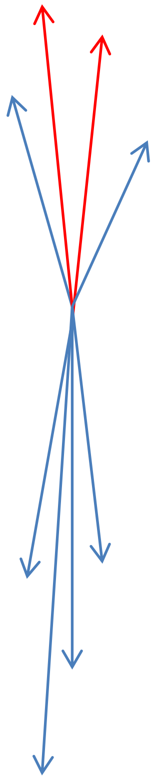
… they come with a bonus of a particle pair assosiation via a basic kT cut

$$k_T = \frac{1}{2}(k_1^T + k_2^T)$$



Opposite jet pion pairs

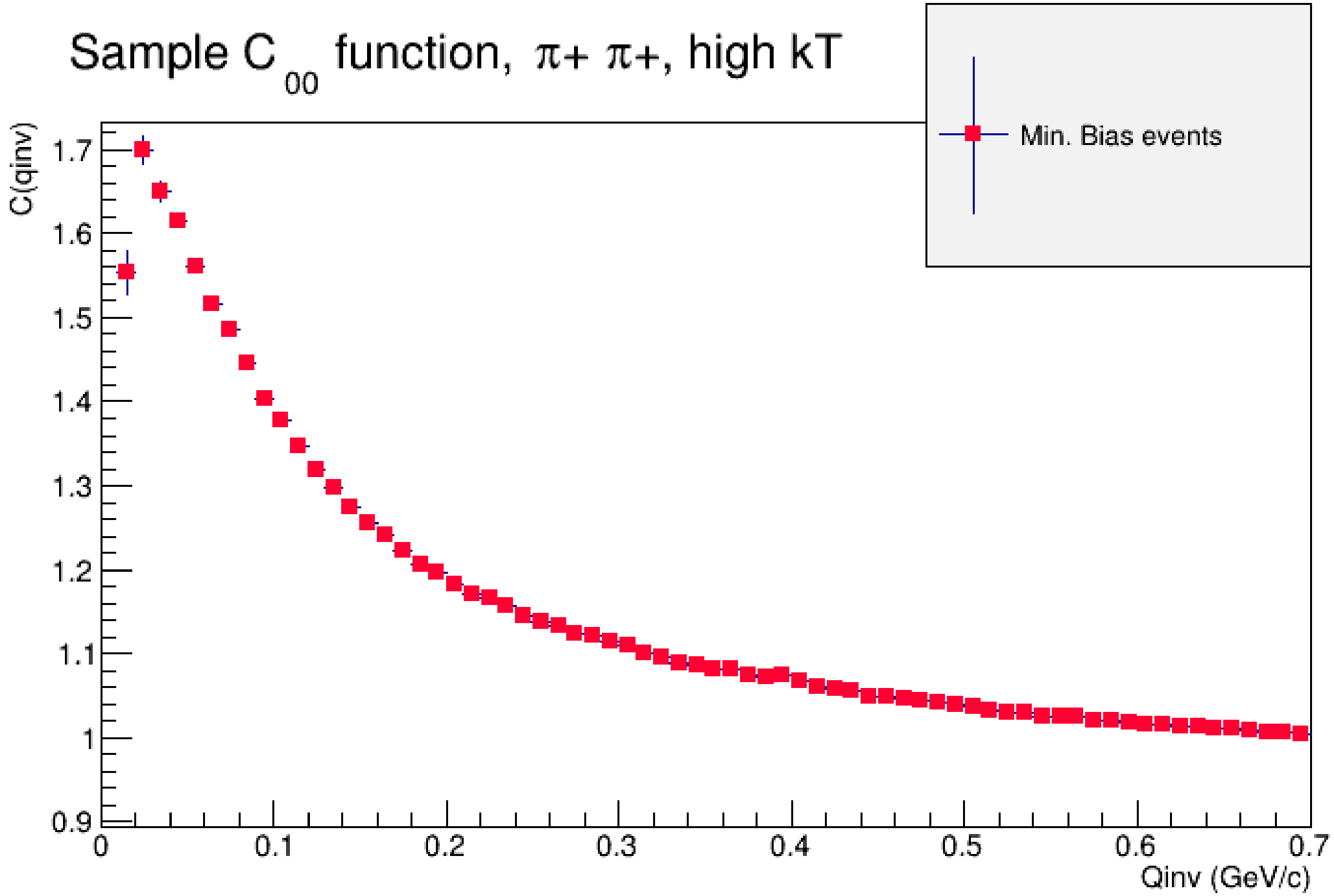
- low kT and high Qinv



Same jet pion pairs

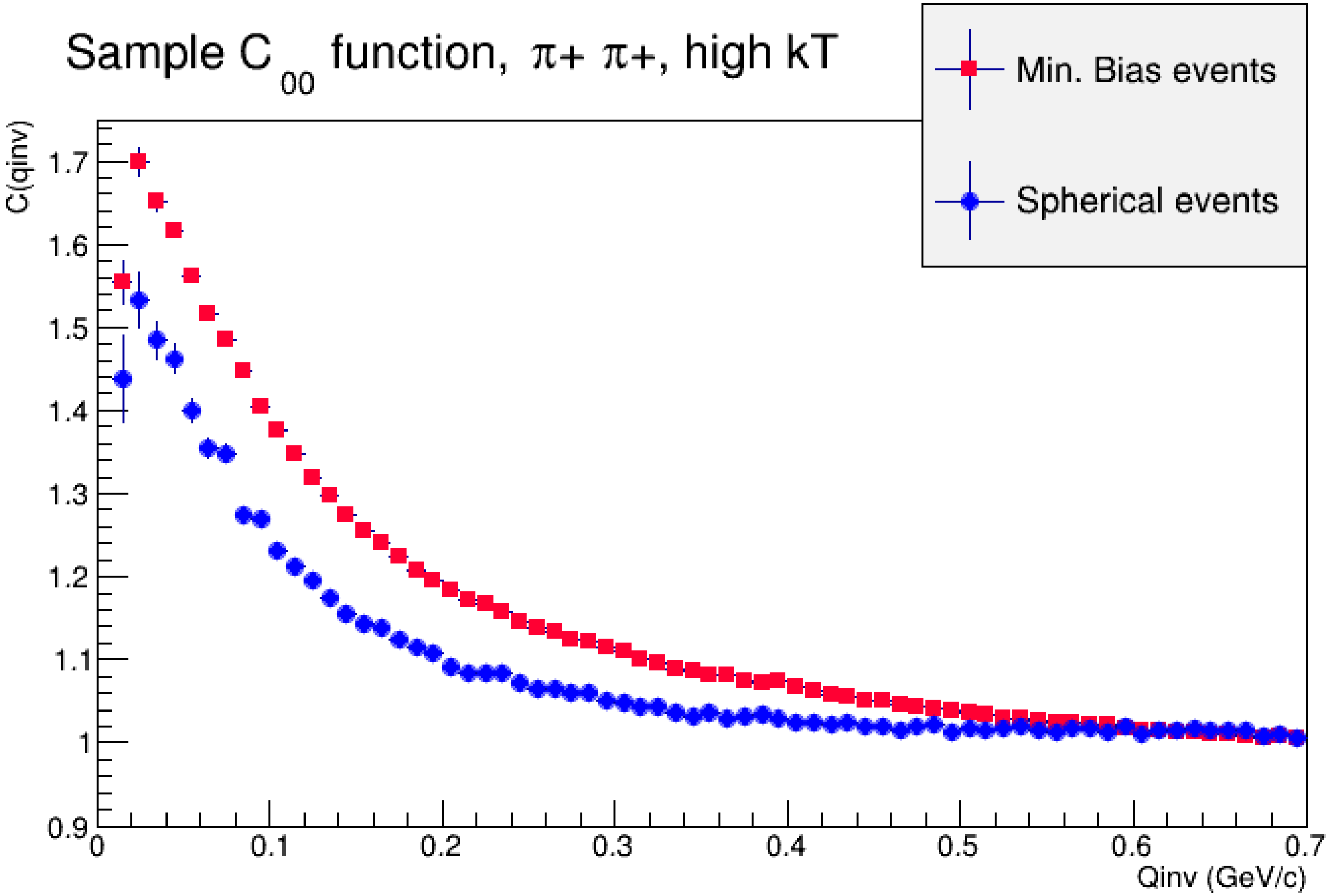
-high kT and low Qinv (jet HBT ?)

Example in pp data



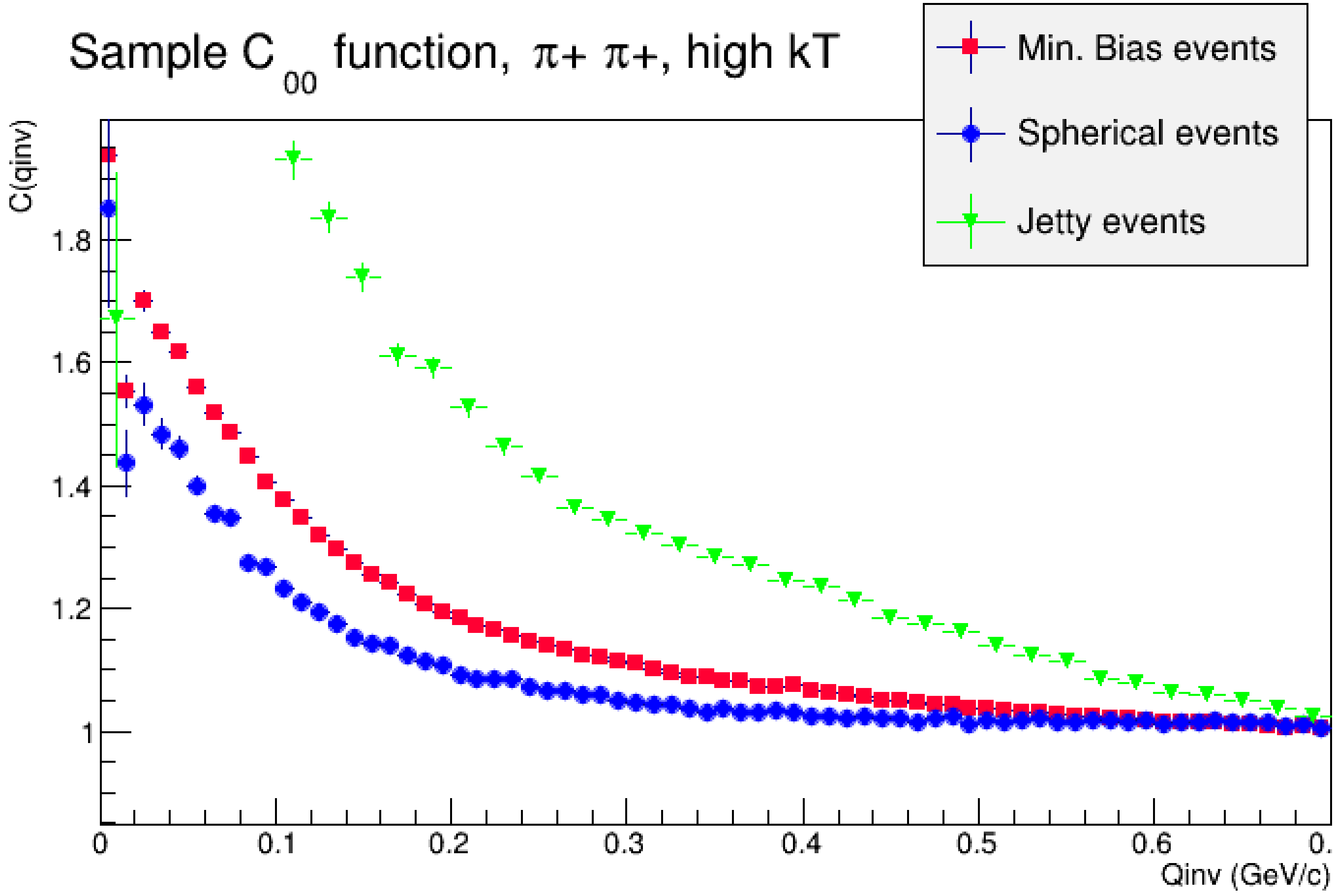
Standard correlation function contains a standard HBT signal but also non-femto correlations from Coulomb interaction at low Qinv and jet correlations which rises with high kT

Example in pp data



Sphericity cut lowers correlation and is a better fit for pure HBT fit function (EXP/Gauss)

Example in pp data

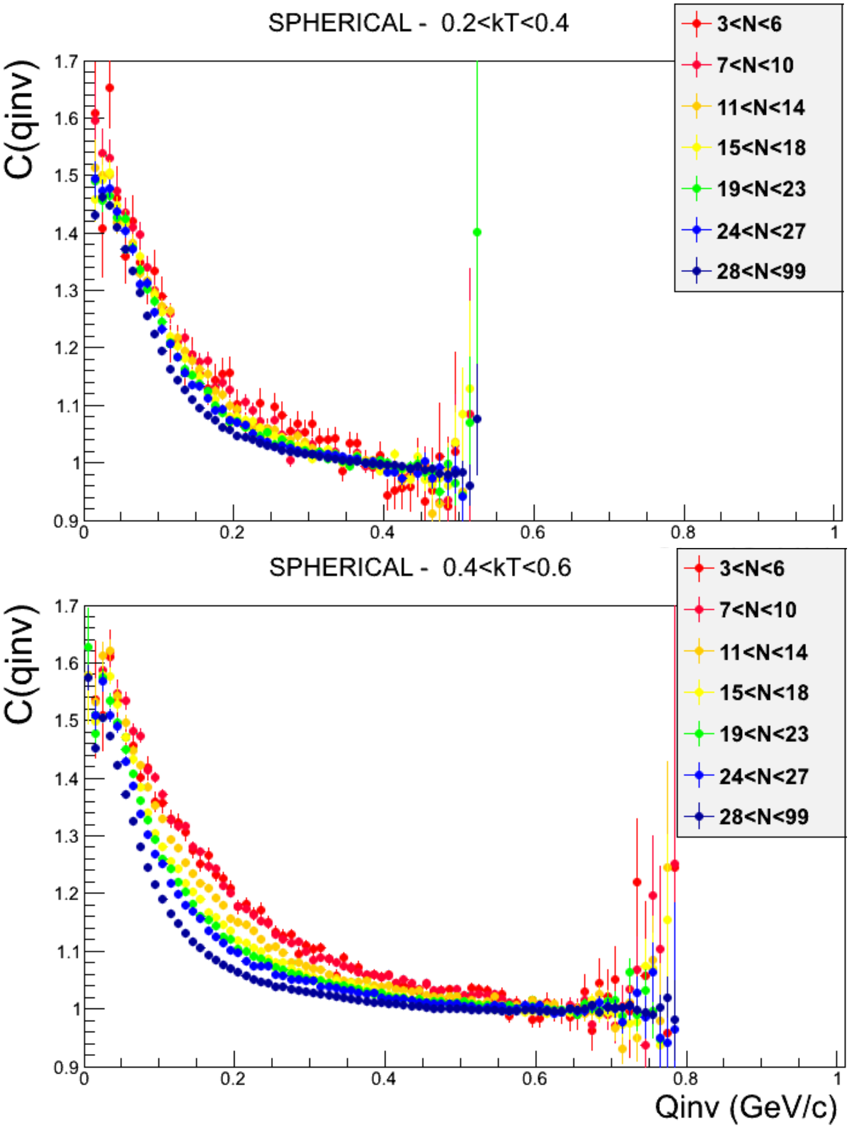


- big non-femtoscopic contribution brings the correlation over the theoretical maximum
- kink in the correlation around 0.25 GeV/c shows difference between HBT and jets

Spherical events in pp

The idea is to redo the published femtoscopic analysis without any nonfemtoscopic contributions and check for consistency

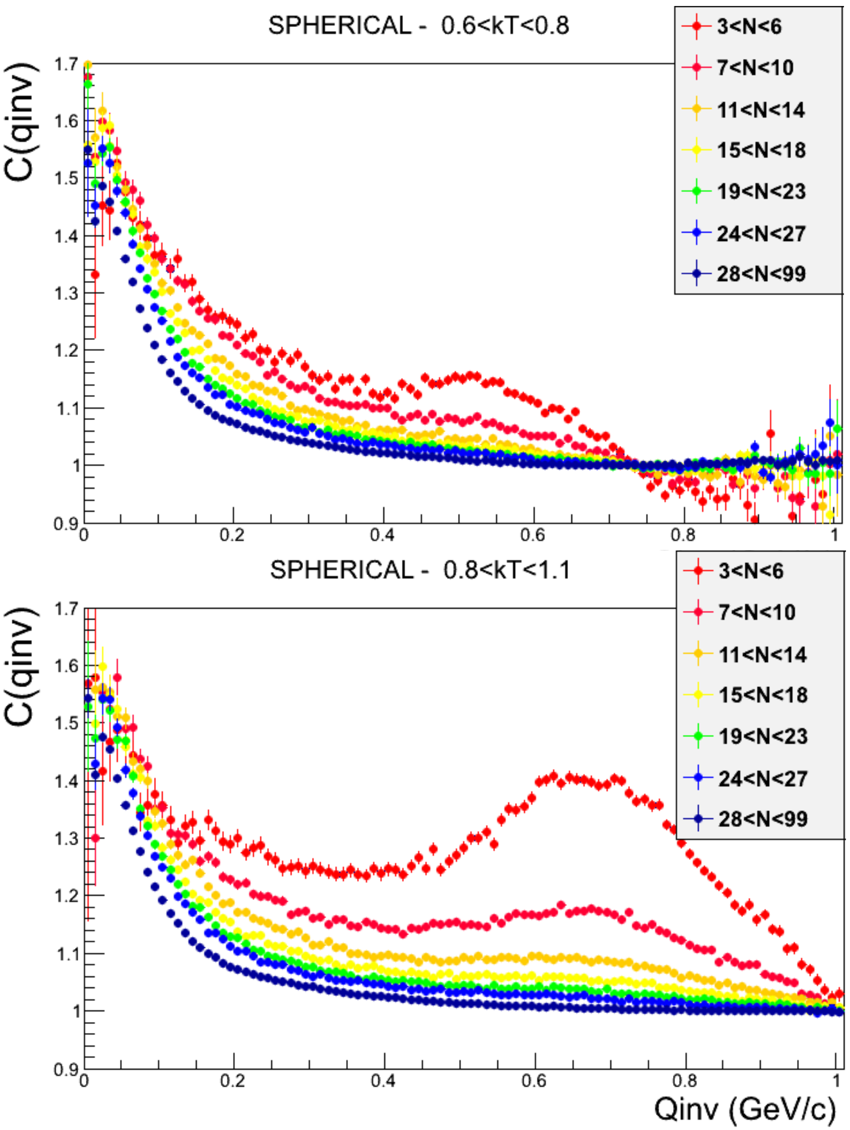
Spherical events, $\pi^+\pi^+$, pp @ 7 TeV



Familiar behaviour:

- HBT radii rise with multiplicity
- Coulomb contribution at low Qinv
- shape of correlation resembles NoCut

Spherical events, $\pi^+\pi^+$, pp @ 7 TeV



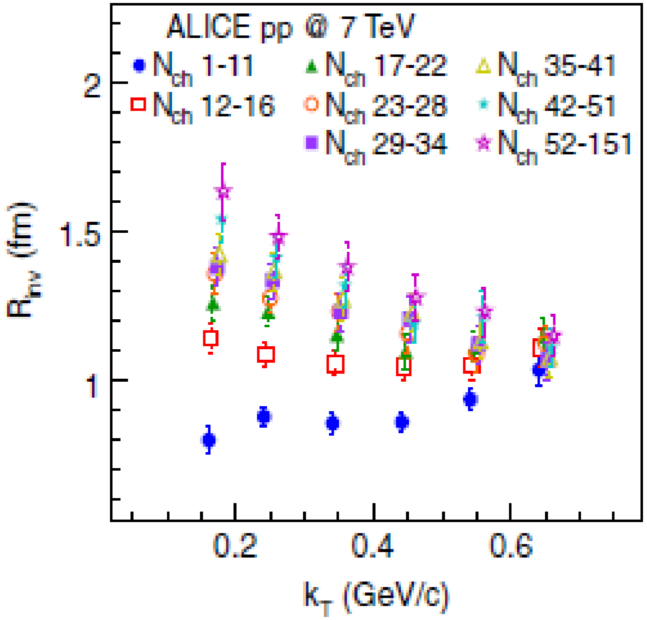
New behaviour:
- evolution of a "bump" with high kT and low multiplicity
- this behaviour is seen even without PID
- obviously it has to be a kinematic effect

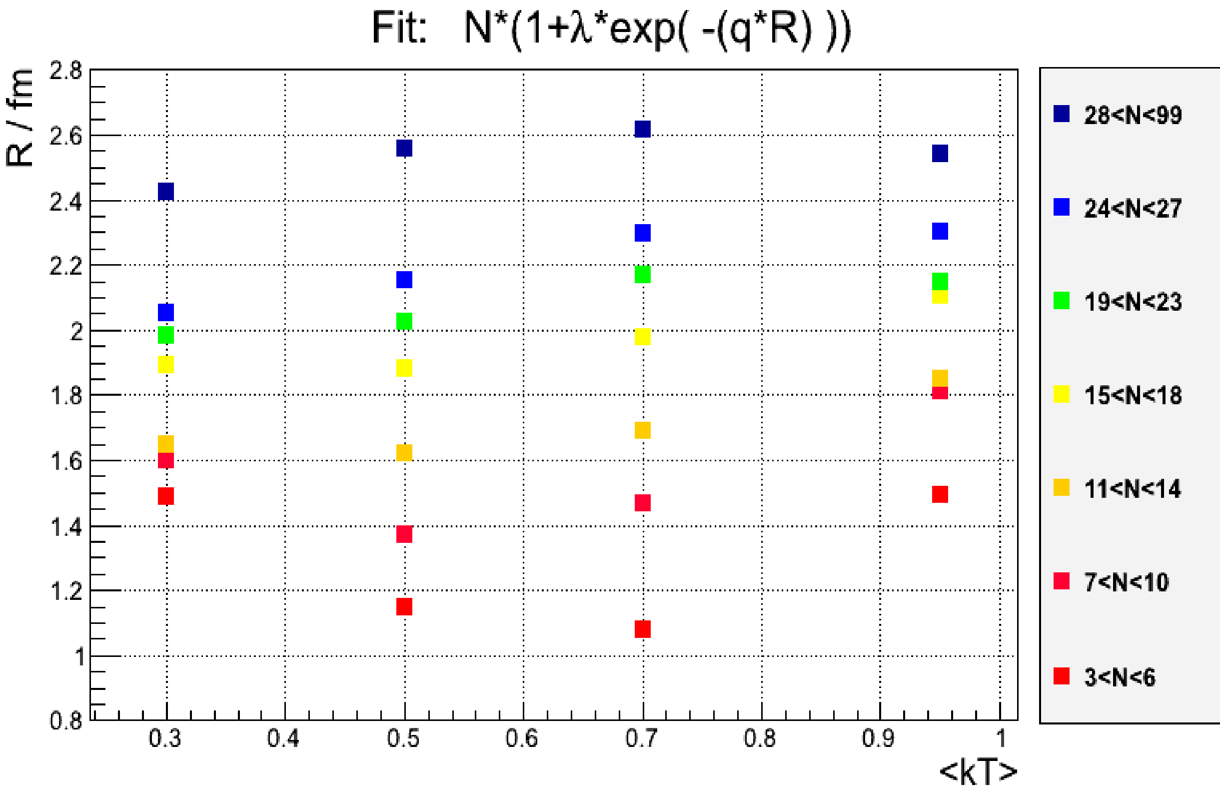
→Pythia check !

If this is just a kinematic effect in connection with the sphericity and kT cuts then Pythia should see it. No HBT signal is present in Pythia calculations so any correlations observed will not be of femtoscopic origin

Results from pp @ 7 TeV - R vs. <kT>

Phys. Rev. D 84, 112004 (2011)



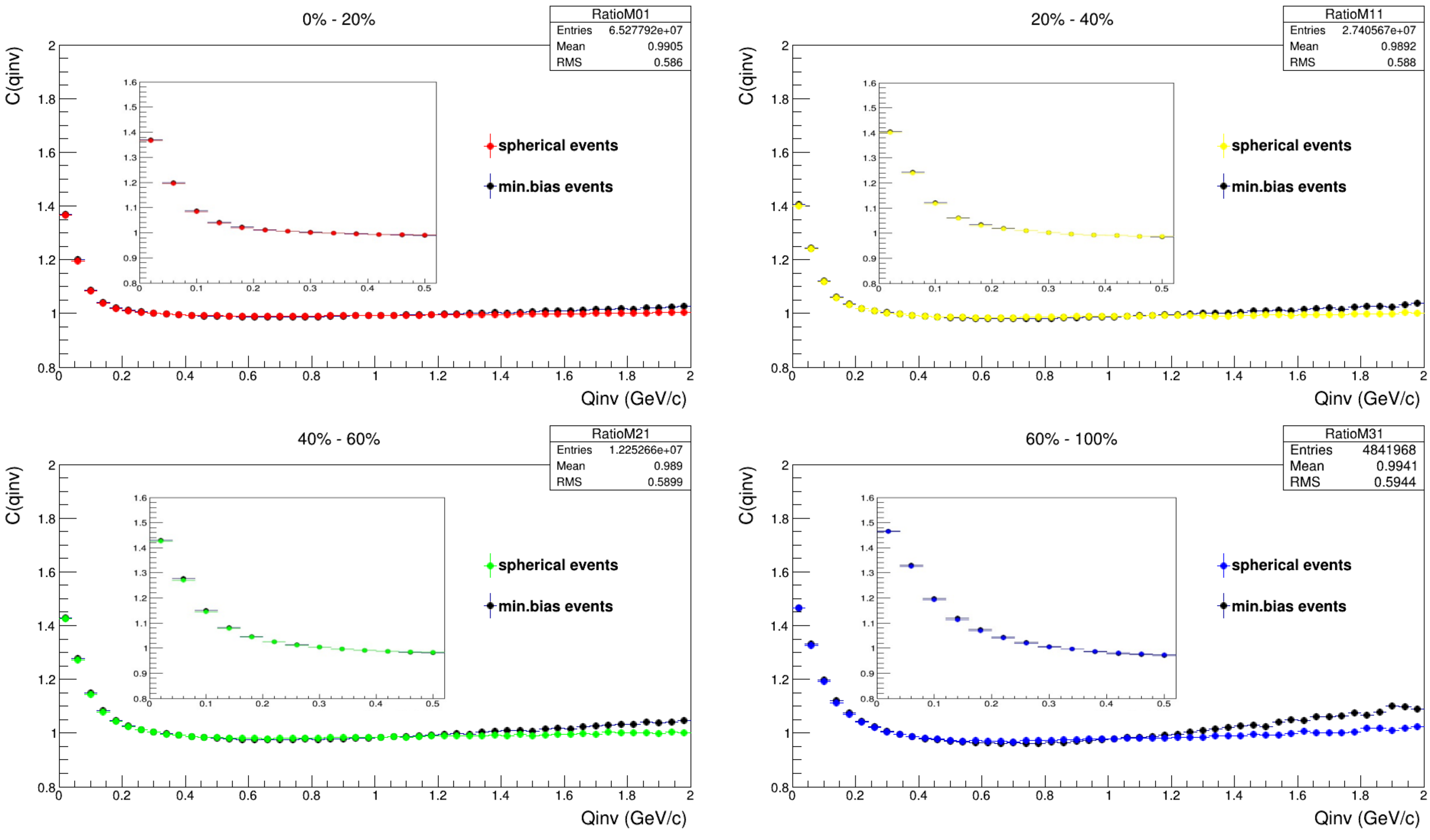


The analysis range in kT has been increased by ~50% and the familiar kT dependence from published results has dissapeared as would be expected from no collective flow scenarios.

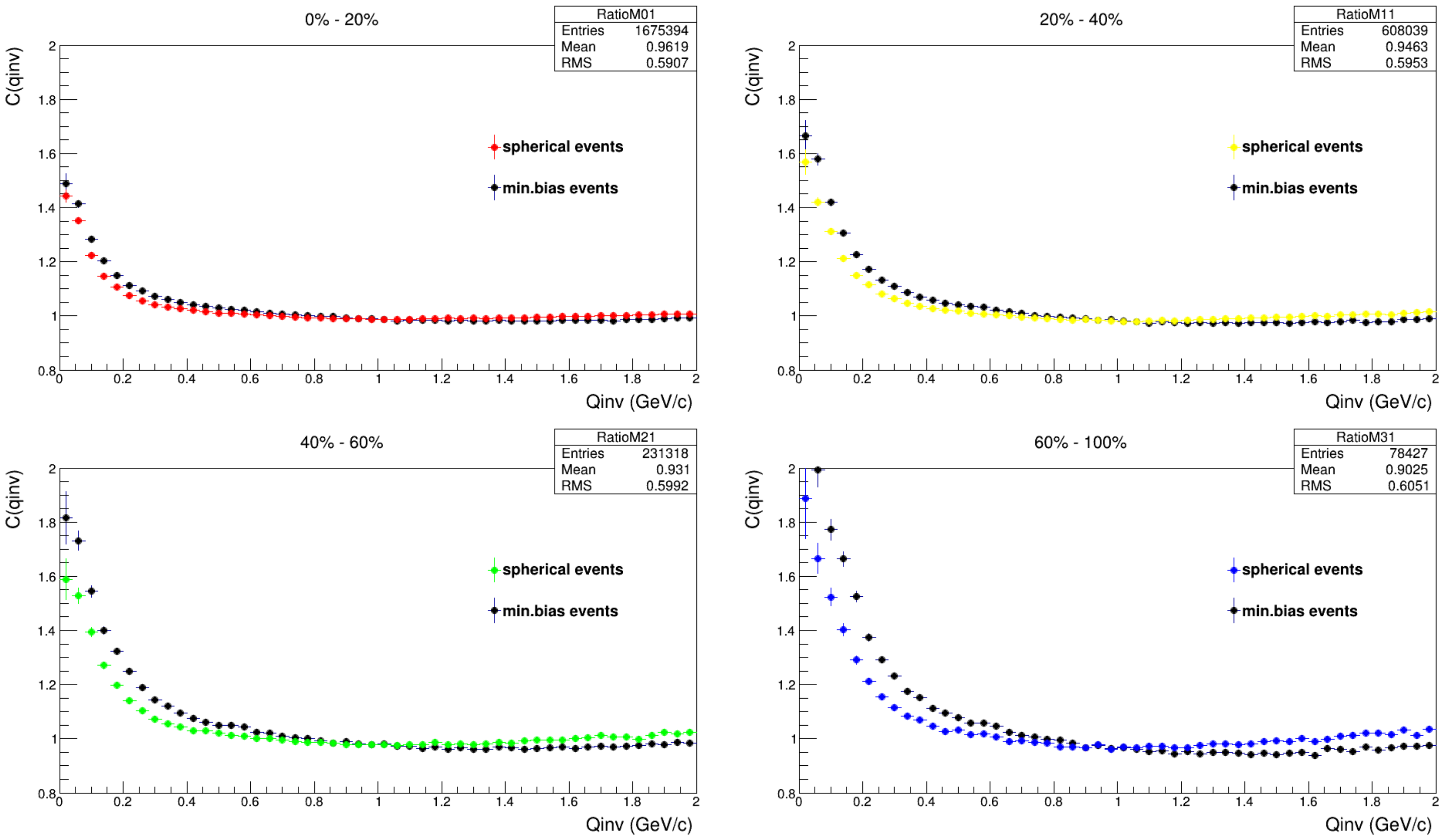
Spherical events in pA

Again we try to identify jet contributions in pA and remove them.

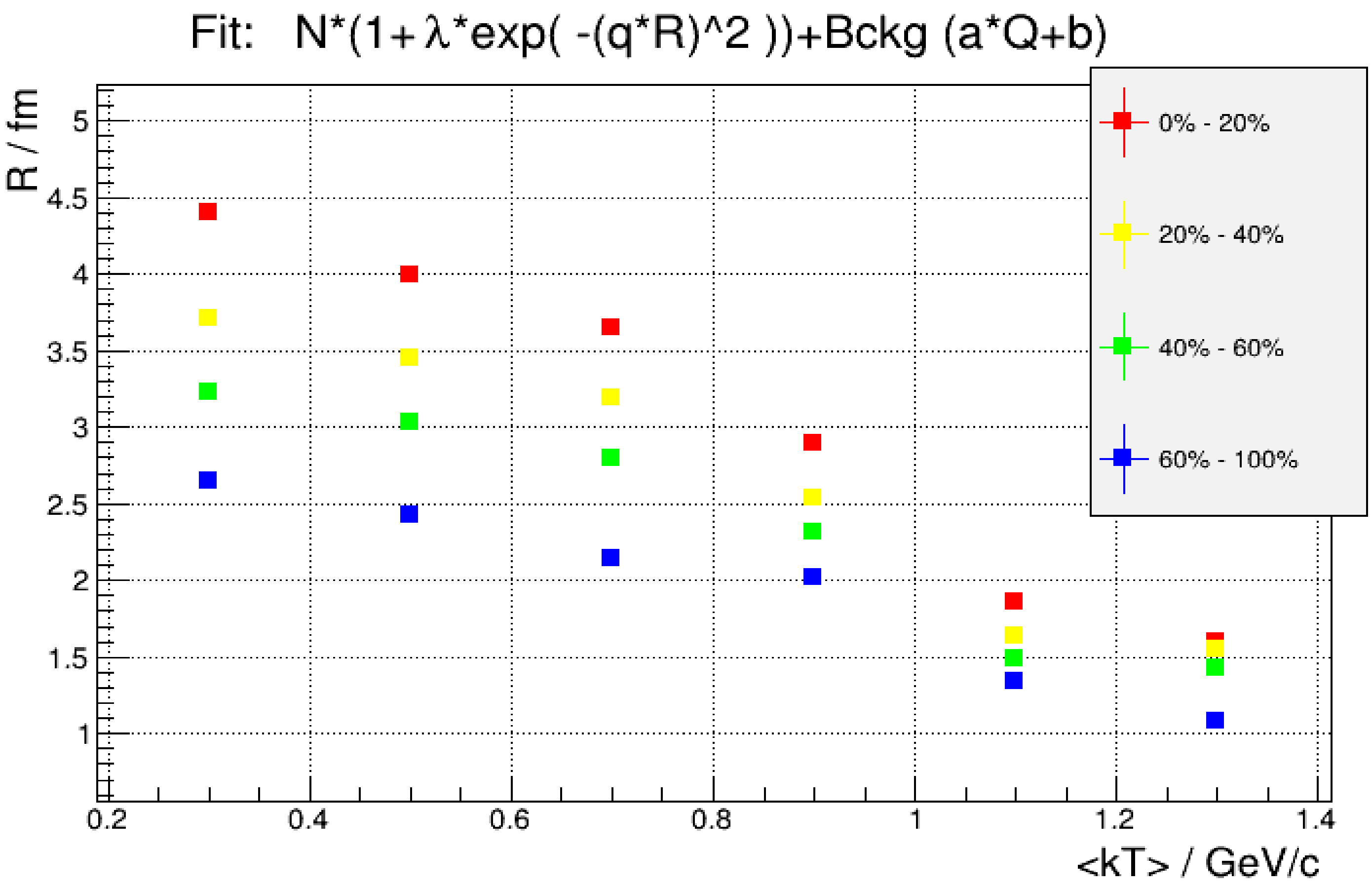
Measured events, $\pi^+\pi^+$ & $\pi^-\pi^-$, 0.2<kT<0.4



Measured events, $\pi^+\pi^+$ & $\pi^-\pi^-$, 1.0<kT<1.2



Results from pA - R vs. <kT>

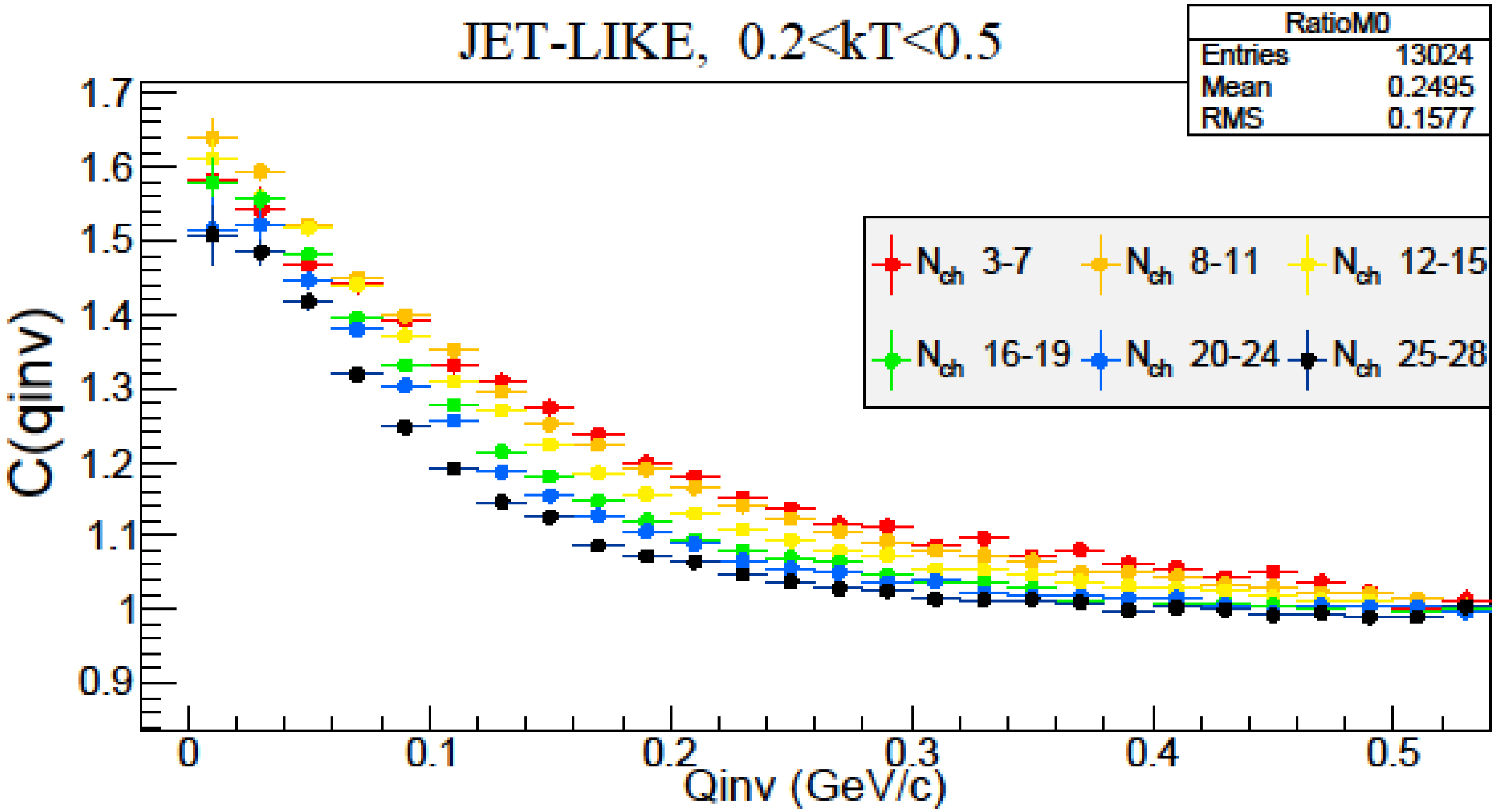


- min. bias R(kT) dependence is restored in spherical pA events

Jet-like events in pp

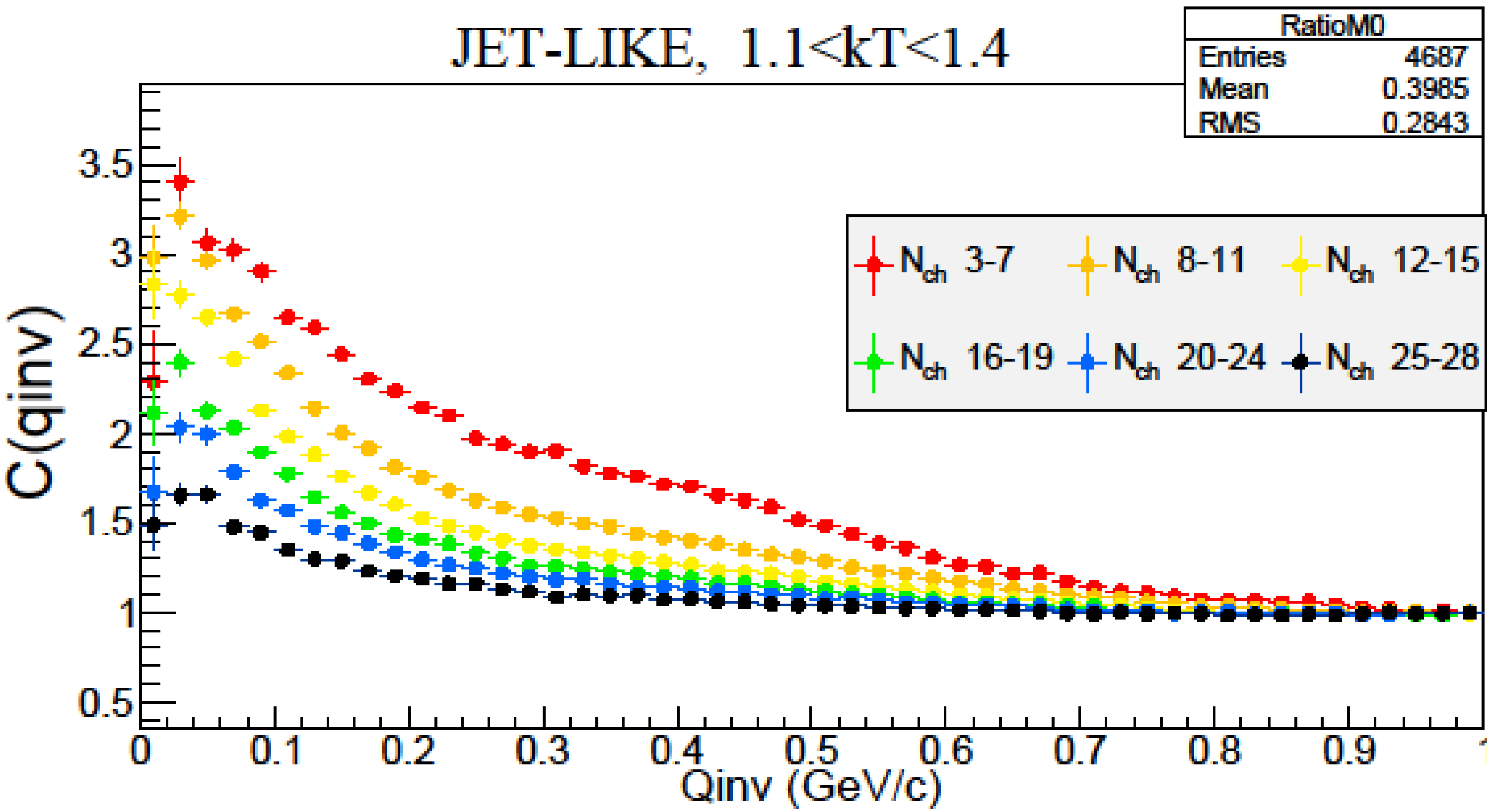
We are looking for the shape and evolution of the non-femtoscopic background correlations. This understanding can create an opportunity for developing a sound background removal technique.

Jet-like events, $\pi^+\pi^+$, pp @ 7 TeV



Low kT pairs show no obvious contribution from jet collimations, which is consistent with our understanding. In comparison with spherical events there is no visible difference.

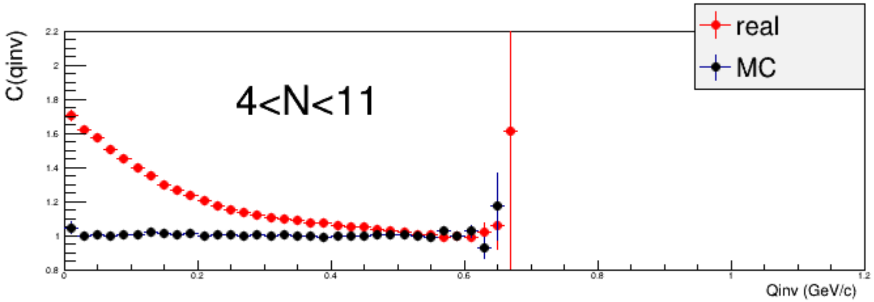
Jet-like events, $\pi^+\pi^+$, pp @ 7 TeV

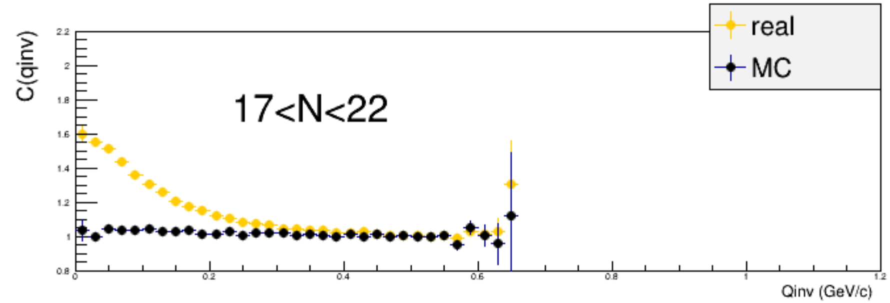


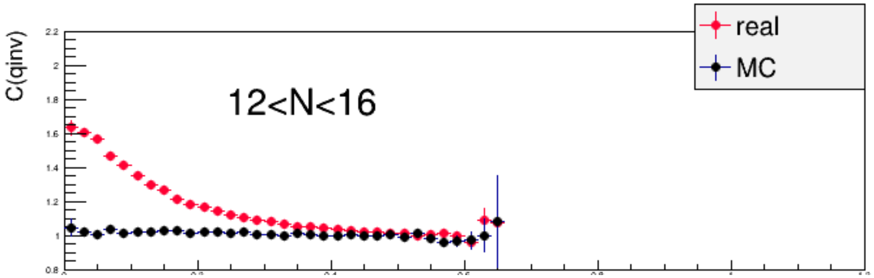
High kT pairs contain predominantly jet collimation signal and are basically non accesible to femtoscopy without background removal.

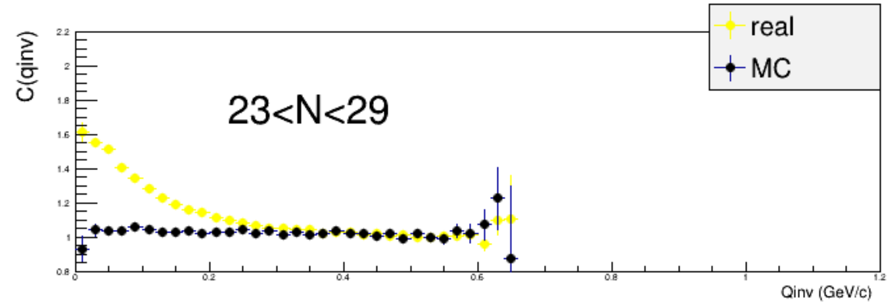
There are two obvious choices: background modeling or background removal via MC

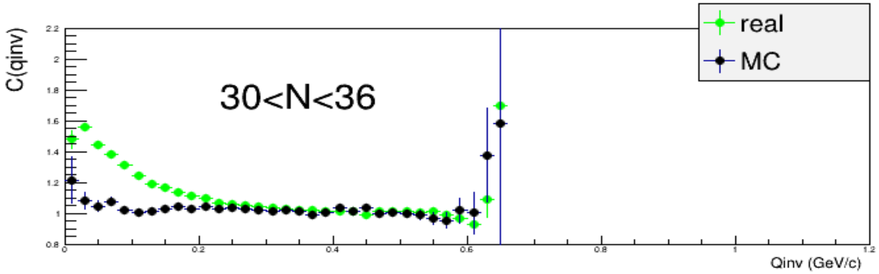
Data vs. MC, $\pi^+\pi^+$ & $\pi^-\pi^-$, 0.2<kT<0.5

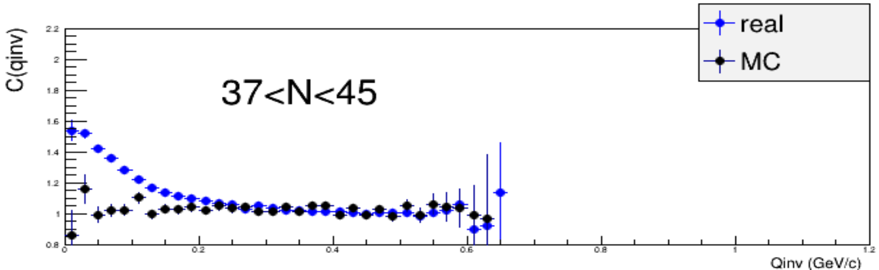






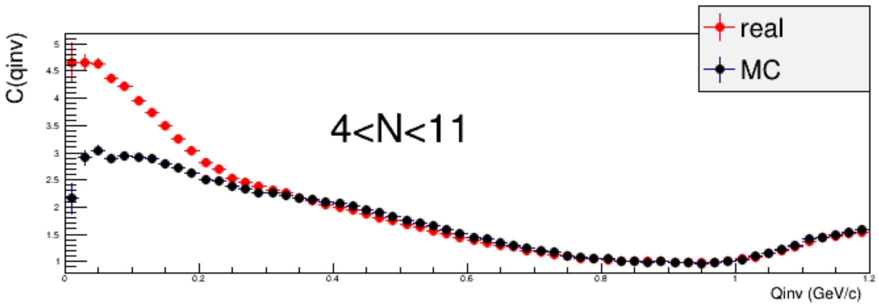


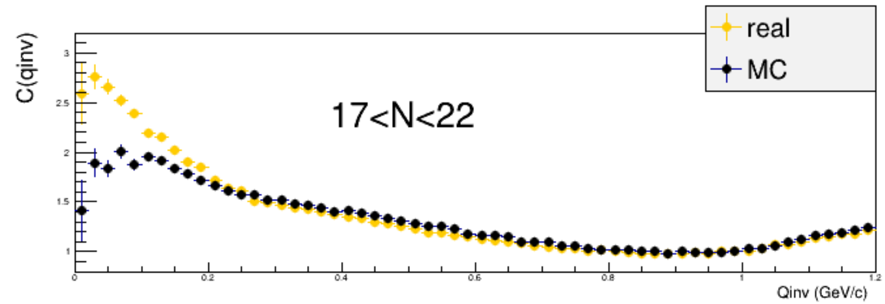


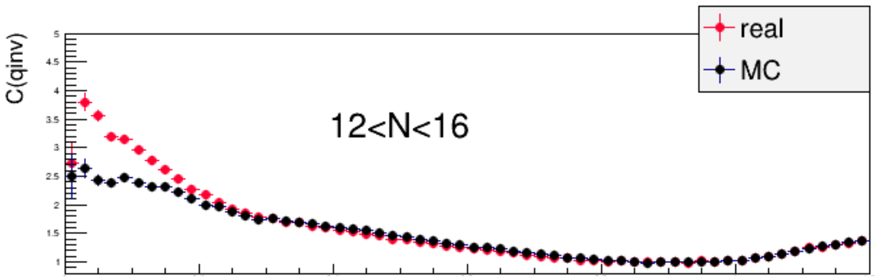


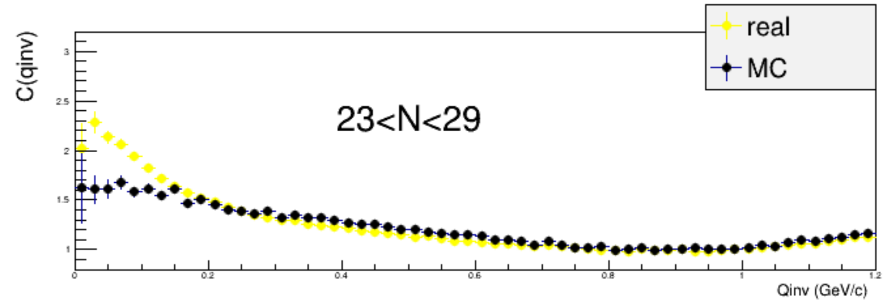
- MC seems to reproduce expected HBT shape for low kT's, no correlations from jets and no expected corrections to Rinv

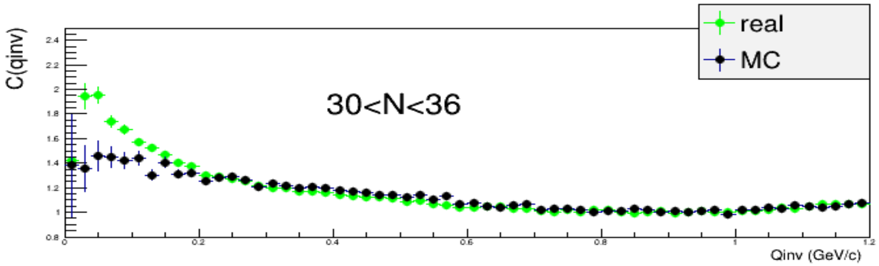
Data vs. MC, $\pi^+\pi^+$ & $\pi^-\pi^-$, $1.1<kT<1.4$

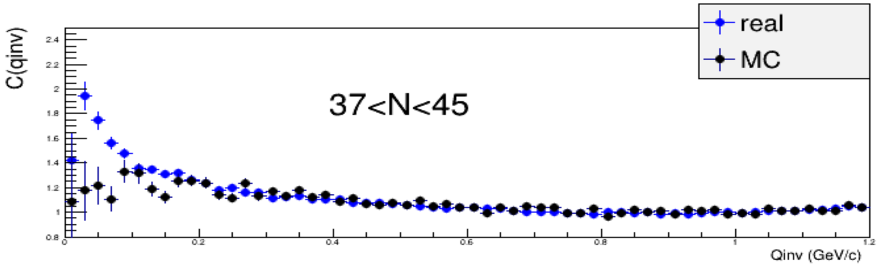






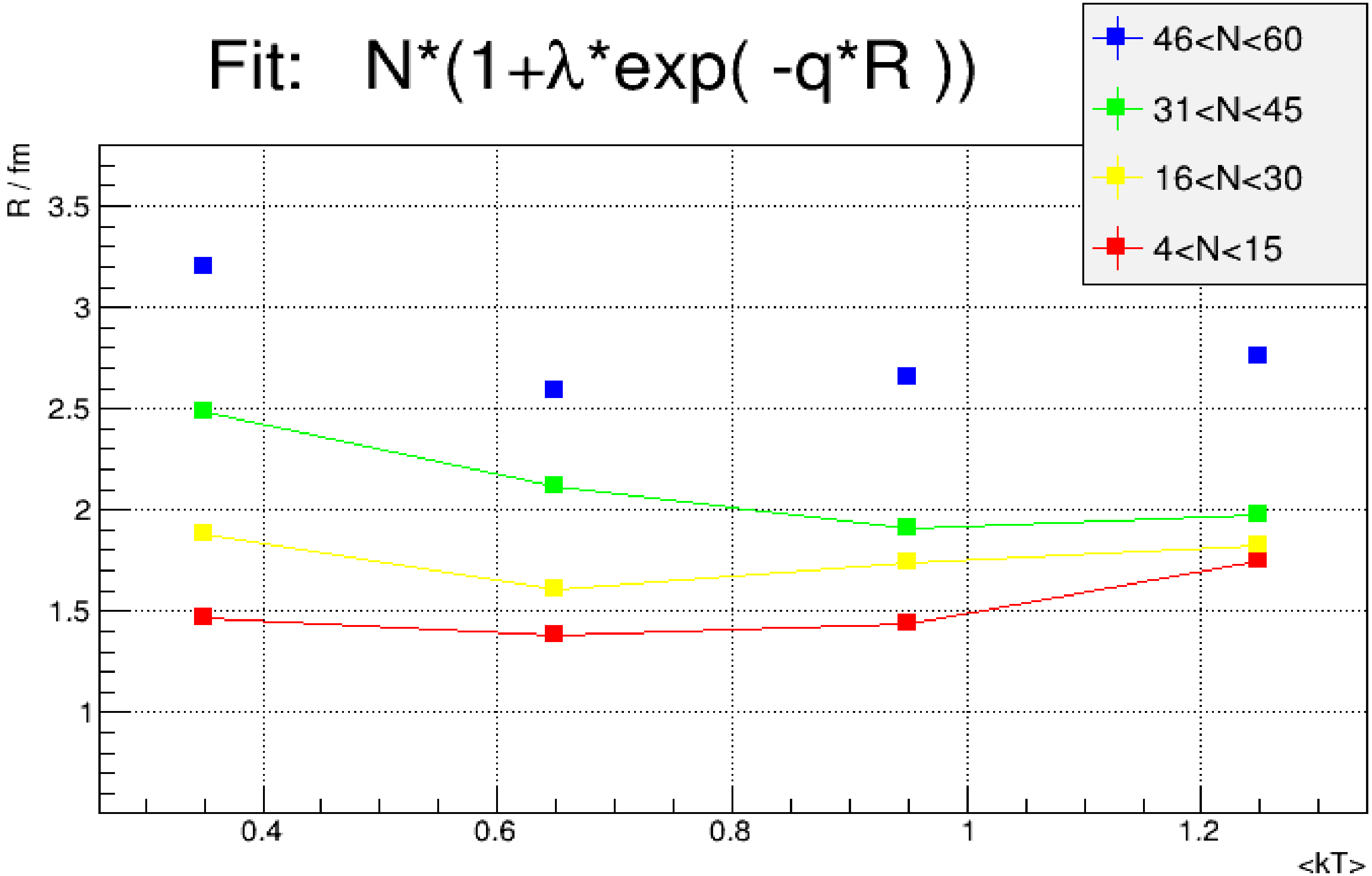






- Almost perfect situation, lack of MC statistics is the only error driving force !

MC corrected results, Exponential fit



Jet-like pp events have low (or no) R-kT dependence

Conclusions

- We have shown that a sphericity cut removes background signals coming from jet collimation and expands the kT fit range of the Femto analysis
- Jet contributions systematically lower fitted HBT radii influencing the min. bias fit results
- Spherical pp events do not have the reported R-kT dependence, in pA this characteristic is restored
- MonteCarlo data qualitatively agrees with our understanding of event topology