Probing formation time in p+p at LHC via HBT[1]

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Motivation

- Hanbury-Brown Twiss (HBT) correlations provide a unique tool to extract the freeze-out configuration in high energetic collisions
- Bulk behaviour like radial flow can be tested by identical particle HBT correlations
- The correlations provide insight into the timescales of the string breakup

Femptoscopic Correlations

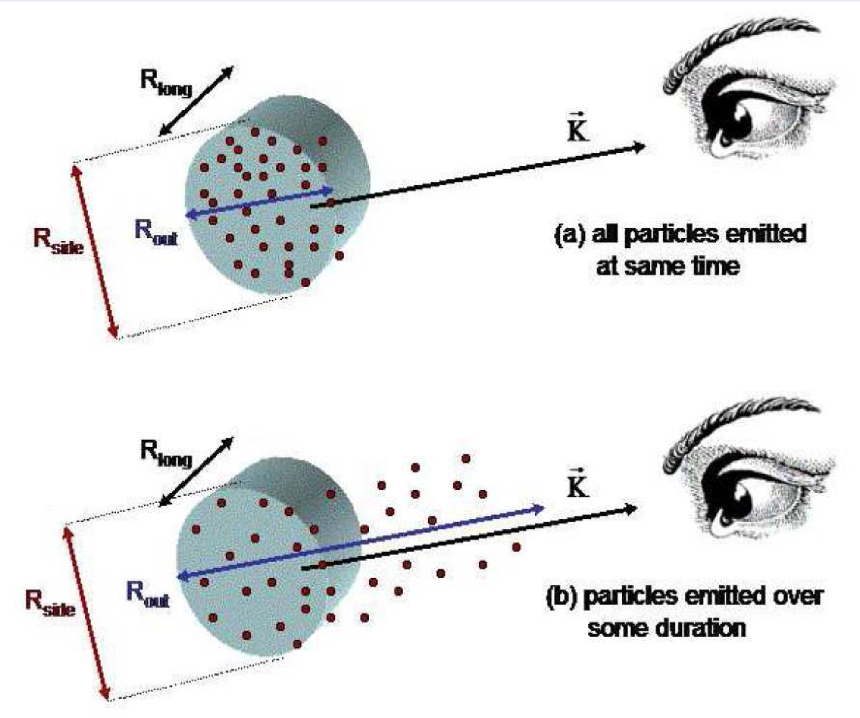

Figure: Demonstrative picture [2] for HBT results in the Out-Side-Long System.

- Symmetrization of wavefunction for identical boson pairs leads to an enhanced particle yield at low relative momentum q
- Pairs analyzed in the Out-Side-Long system

$$C = 1 + \frac{\left|\int S(x,K) e^{i \cdot q \cdot x} d^4x\right|^2}{\left|\int S(x,K) d^4x\right|} = 1 + \lambda \cdot exp(-\sum_{i,j} R_{ij}^2 q_i q_j)$$

Region of Homogeneity

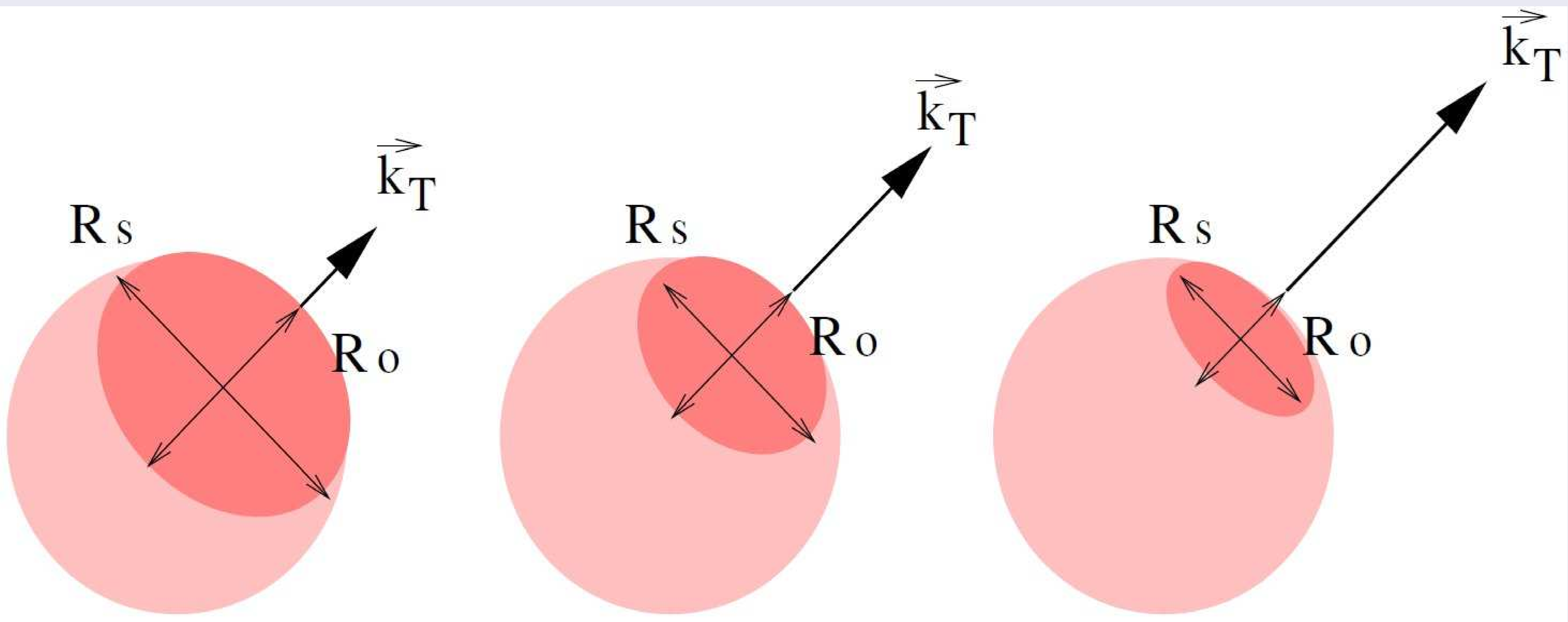

Figure: Probed regions for different $K_\perp$ intervals [3].

- HBT correlation analysis is only sensitive to close momentum pairs
- Radial flow leads to close momentum pairs being close in space (regions of homogeneity)
- Regions of homogeneity lead to pair momentum ($K_\perp$) dependence in the HBT radii

Model

We use the UrQMD = Ultra-relativistic quantum molecular dynamics model [4] to generate particle freezeout distributions.
UrQMD features:

- Nonequilibrium transport model
- All hadrons and resonances up to 2.2 GeV included
- Full space-time dynamics of hadrons from beginning to end
- String excitation and fragmentation

String fragmentation

- Particle creation via string breakup takes time
- This time is often referred to as formation time
- So far, there is no measurement of the formation time
- The UrQMD model uses formation time as a parameter

Correlation Function

We use the formula

$$C(\vec{q},\vec{K}) = 1 + \int d^4x \cos(q \cdot x) d(x,K)$$

to generate the 3D correlation function, where q and x are momentum and spacial distance of pions in a pair, $\vec{x}$ and $\vec{q}$ are the corresponding 3 vectors and d(x,K) is the separation distribution of the pairs.

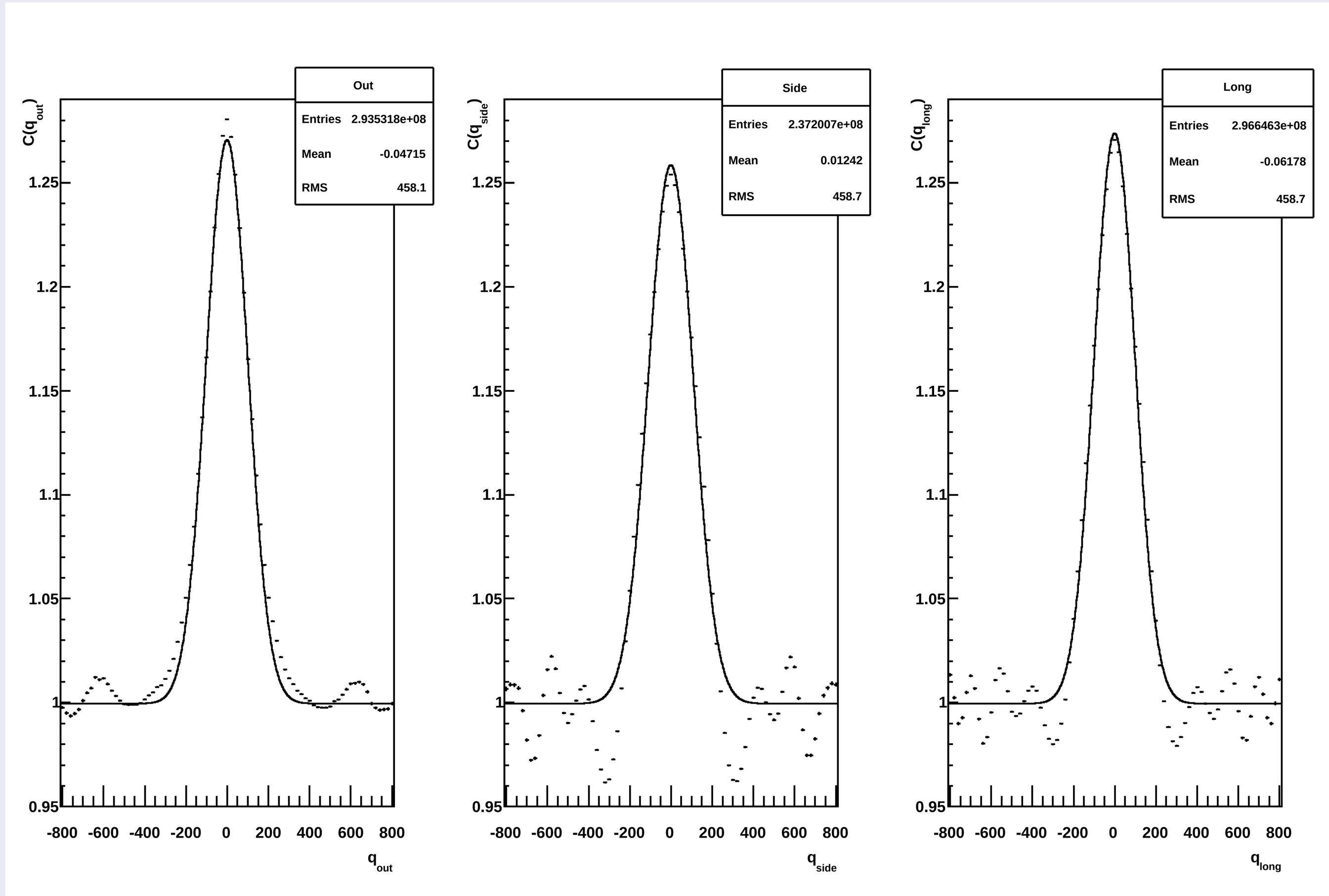

Figure: Projections of an example correlation function for $dN_{ch}/d\eta$ = 23-29 for $K_\perp$=0.3-0.4 GeV and the corresponding fit.

HBT for p+p at $\sqrt{s} = 7$ TeV

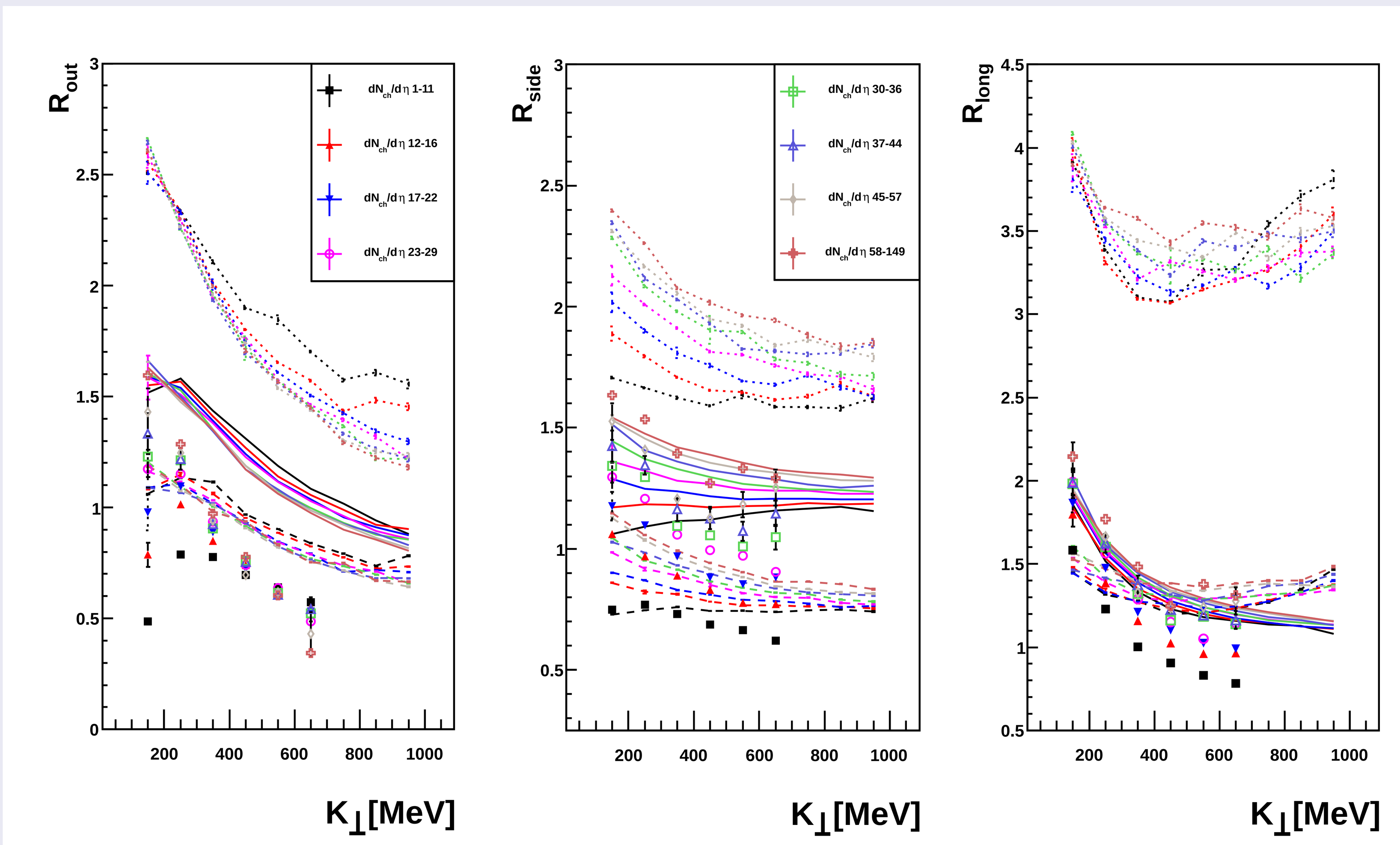

Figure: UrQMD results [1] are the lines with formation eigentimes of 0.3 fm/c (dashed), 0.8 fm/c (full - default) and 2 fm/c (dotted). The Symbols represent ALICE data [5] for different multiplicity classes.

Results & Outlook

- HBT measurements in p+p collisions allow to probe formation times
- UrQMD shows next to no multiplicity scaling in R_{out} and R_{long} and weak multiplicity scaling in R_{side}
- Constraints for a more refined treatment of formation times can be extracted from p+p HBT

References

[1] G. Graef, Q. Li and M. Bleicher, J. Phys. G G39, 065101 (2012) [arXiv:1203.4421 [nucl-th]].
[2] M. A. Lisa, Size Matters: Spacetime geometry in subatomic collisions, http://www.physics.ohio-state.edu/~lisa/SizeMattersSambamurti2004.pdf
[3] Mercedes Lopez Noriega, PhD Thesis, Pion Interferometry in Au+Au Collisions at a Center of Mass Energy per Nucleon of 200 GeV
[4] H. Petersen, J. Steinheimer, G. Burau, M. Bleicher, H. Stocker, Phys. Rev. C78, 044901 (2008). [arXiv:0806.1695 [nucl-th]].
[5] K. Aamodt et al. [ALICE Collaboration], [arXiv:1101.3665 [hep-ex]].