Event shape and multiplicity dependence of freeze-out radii in pp collisions at 7 TeV

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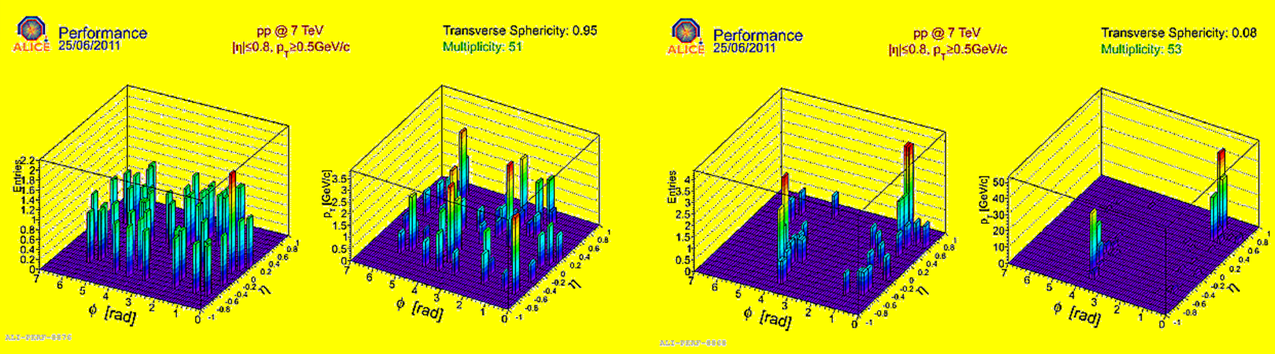
Particle interferometry in high-energy collisions is a powerful tool for investigating spatio-temporal characteristics of the created system. In femtoscopy, measuring homogeneity radii as a function of pair k_T is of fundamental importance. From numerous investigations it is known that the accessible range in k_T is highly limited in small collision systems due to a steady rise in background correlations, which are associated with the mini-jet collimation effect. In this analysis we propose a novel method of event shape dependent two-particle interferometry with the aim of removing a large portion of the jet induced background. By categorizing events by their transverse sphericity S_T, we identify two classes of events, which significantly differ in hardness. Spherical events ($S_T > 0.7$) show a strong reduction in background correlations while jet-like ($S_T < 0.3$) carry all the characteristics of previously observed backgrounds. Here we present extracted correlation functions for both categories of events and offer several interpretations for their difference.

Transverse sphericity - S_T

- momentum space event shape variable [1]
- defined with eigenvalues $\lambda_{1,2}$ of the transverse momentum matrix
- used to separate "soft" and "hard" events [2]
- events with same multiplicity can have very different sphericities



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

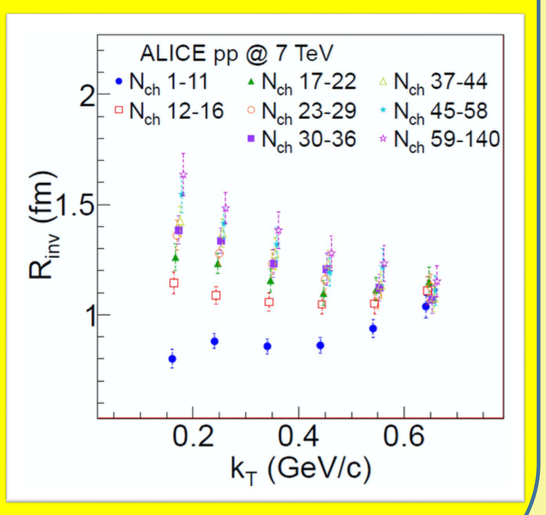
$$S_T = \frac{2\lambda_2}{\lambda_1 + \lambda_2} \Rightarrow S_T = \begin{cases} \approx 0 & \text{Jet-like} \\ \approx 1 & \text{Spherical} \end{cases}$$

Homogeneity radii (R_{inv}) for proton-proton collisions at $\sqrt{s} = 7$ TeV

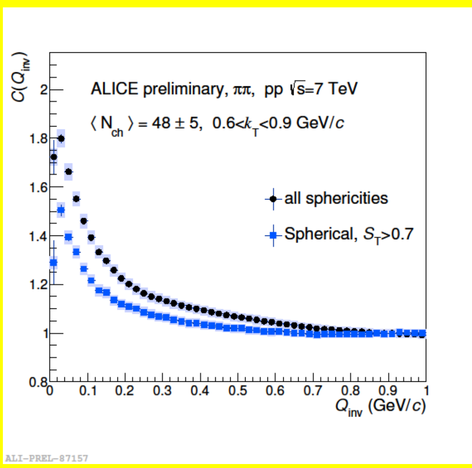
$$C(Q_{inv}) = (1-\lambda) + \lambda K_{coul}(Q_{inv})[1 + \exp(-R_{inv}^2 Q_{inv}^2)]$$

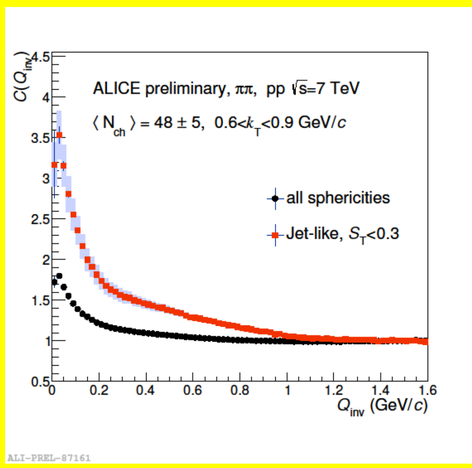
$$Q_{inv} = |p_1 - p_2| \qquad k_T = |\boldsymbol{p}_{T,1} - \boldsymbol{p}_{T,2}|/2$$

- decrease of extracted homogeneity radii R_{inv} with k_T is interpreted as a sign of hydrodynamic collectivity [3]
- non-femtoscopic background significantly limits the accessible range of k_T
- this behaviour indicates a mini-jet origin
- a transverse sphericity event shape cut will remove (as shown bellow) a large portion of the jet background and significantly extends the k_T reach of femtoscopic radii

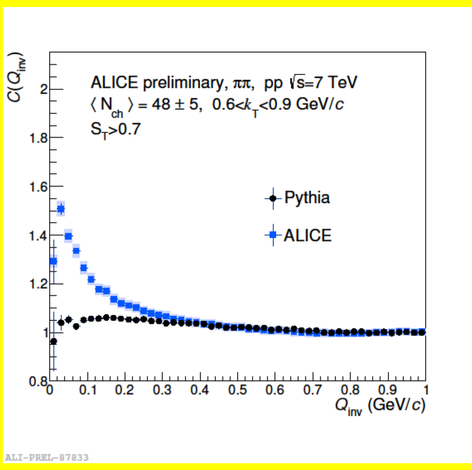


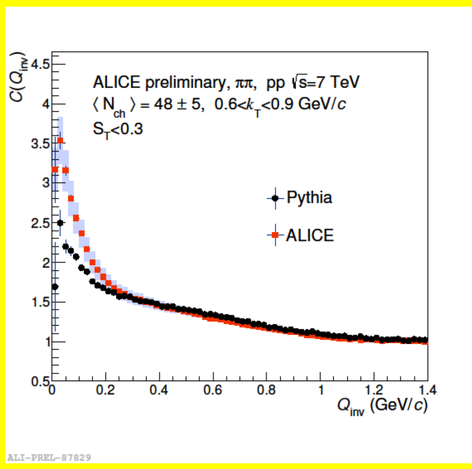
Proof of method





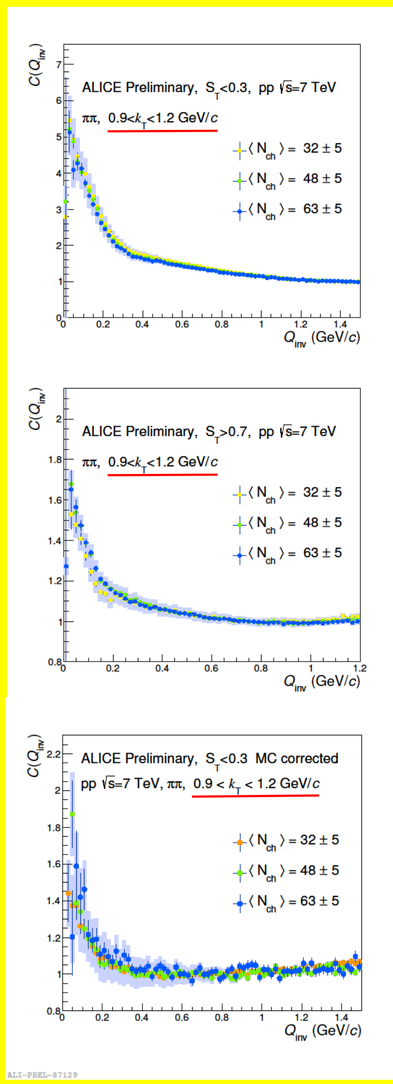
- spherical events show a clear reduction in non-femtoscopic background at high Q_{inv}
- jet-like event correlation functions are dominated by in-jet particle collimation





- MC generators without femtoscopic correlations agree on the background
- jet-like event background is well described with event generator data

First results and background removal



- **jet-like event correlation functions are much higher than expected theoretical maximum of $C(0) \leq 2.0$**
- **background correlation is not described by a simple Gaussian shape**
- **spherical event correlation functions contain low non-femtoscopic background for high values of pair k_T**
- **background can be described and removed using MC data**

$$C(Q_{inv})_{JETS}^{Corr.} = \frac{C(Q_{inv})_{JETS}^{DATA}}{C(Q_{inv})_{JETS}^{MC}}$$

Conclusions

- transverse sphericity is an extremely useful tool in high energy particle interferometry
- using cuts on sphericity significantly extends the accessible k_T range for femtoscopic study
- highly spherical events show little or no signs of non-femtoscopic contributions from the jet particle collimation previously observed in minimum bias data

Outlook

- extract homogeneity radii in bins of sphericity, charged particle multiplicity and pair k_T
- understand the evolution of non-femtoscopic background
- connect the event sphericity with the shape of the produced charged pion emission source
- investigate in more detail the observed homogeneity radii dependence on pair k_T

References

[1]-"*Resummed event shapes at hadron-hadron colliders*", Banfi, Salam, Zaderighi JHEP 0408 (2004) 062

[2]-"*Transverse sphericity of primary charged particles in minimum bias proton-proton collisions at $\sqrt{s}$ =0.9, 2.76 and 7 TeV*", ALICE coll., Eur.Phys.J. C72 (2012) 2124

[3]-"*Femtoscopy of pp collisions at $\sqrt{s}$ =0.9 and 7 TeV at the LHC with two-pion Bose-Einstein correlations*", ALICE coll., Phys.Rev.D 84.112004