Study of the Bose-Einstein correlations of identical pions in proton-lead collisions

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Motivation

- Bose-Einstein Correlations (BEC)
  - enhanced production of identical bosons with similar four-momenta
  - emerges from symmetrization of two-particle wave funcion
  - provides insight into the characteristics of the emitter
  - proton-ion collisions probe early stages of its development
- LHCb detector
  - unique pseudorapidity coverage at the LHC
    - fully instrumented in the $2.0 < \eta < 5.0$ range [1]
    - results complementary to other experiments
  - proton-proton collisions explored by a previous study [2]

Datasets

- fully data-driven approach
- single-PV minimum-bias events at $\sqrt{s_{NN}} = 5$ TeV
  - 1.06 nb^{-1} pPb
  - 0.52 nb^{-1} Pbp
- datasets split into bins of reconstructed charged tracks multiplicity in the vertex detector (N_{VELO})

		sample fraction [%]	
bin#	N_{VELO}	pPb	Pbp
1	[5–10)	< 2	< 2
2	[10–15)	2	2
3	[15–20)	4	2
4	[20–25)	7	3
5	[25–30)	10	4
6	[30–35)	13	5
7	[35–40)	14	6
8	[40–45)	10	5
9	[45–50)	10	6
10	[50–55)	8	6
11	[55–60)	7	7
12	[60–65)	5	6
13	[65–80)	6	15
14	[80–90)	–	7
15	[90–100)	–	7
16	[100–115)	–	6
17	[115–140)	–	7
18	[140–180)	–	4

Correlation function

- the study is performed in a variable measuring the absolute difference of emitted particles' four-momenta

$$Q = \sqrt{-\left(q_1 - q_2\right)^2}$$

- pure BEC effect can be expressed as

$$C_{2,\mathrm{BEC}}\left(Q\right) = 1 + e^{-|RQ|^{\alpha_L}}$$

  with index of stability α_L fixed to unity for direct correspondence between the correlation radius R and the size of the emitter
- the full correlation function is

$$C_2(Q) = N\left[1 - \lambda + \lambda K(Q) \times \left(1 + e^{-|RQ|}\right)\right] \times \Omega(Q)$$

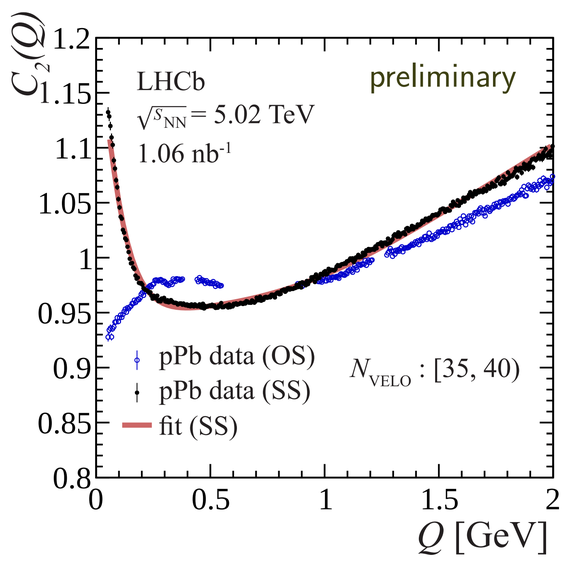
  with normalization constant N, the Gamov factor $K(Q)$ accounting for Coulomb interactions, $\Omega(Q)$ describing the non-femtoscopic contributions (long-range correlations, mini-jets etc.) and λ being the intercept of the correlation function extrapolated to $Q = 0$ GeV

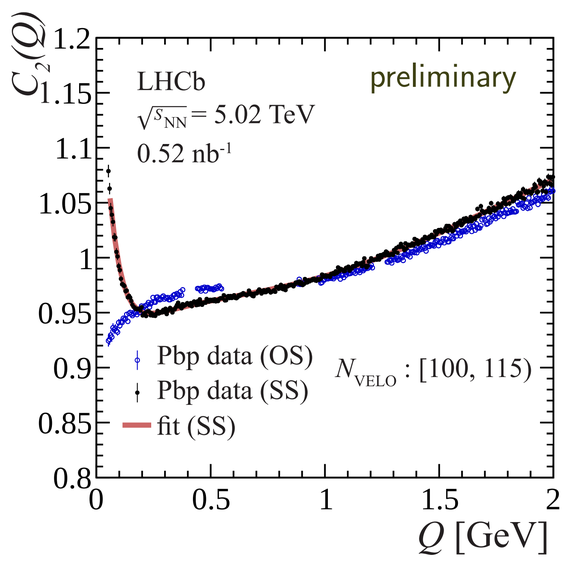
Acknowledgements

This study is supported by Narodowe Centrum Nauki (grant numbers 2013/11/B/ST2/03829 and 2018/29/N/ST2/01641)
and the PLGrid infrastructure.

Analysis

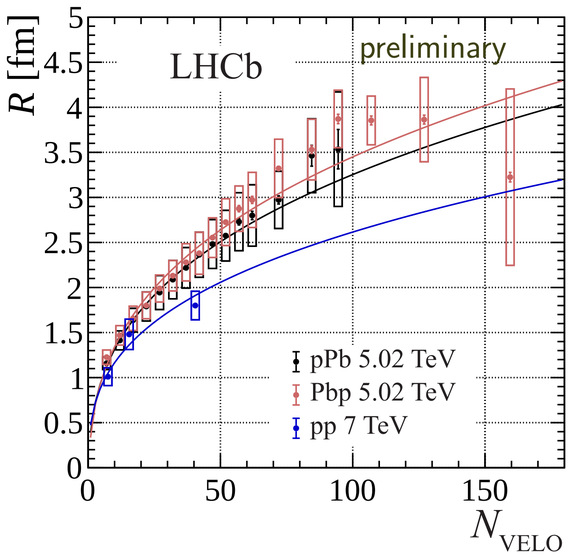
- two sub-samples constructed
  - same-sign pion sample (SS) – BEC effect present
  - opposite-sign pion sample (OS) – no BEC effect, similar background
  - several criteria applied to ensure similar kinematic characteristics
- shape of background determined by a fit of $C_2(Q)$ to the OS sample
  - Q ranges containing resonances excluded from the fit
  - additional scaling accounting for higher cluster contribution in the OS sample
- SS sample fitted using background parameters from previous step
- although a direct comparison is not meaningful, due to different effects at play, the figures below show the general shapes of the correlation function in both samples for a low and high N_{VELO} multiplicity bins

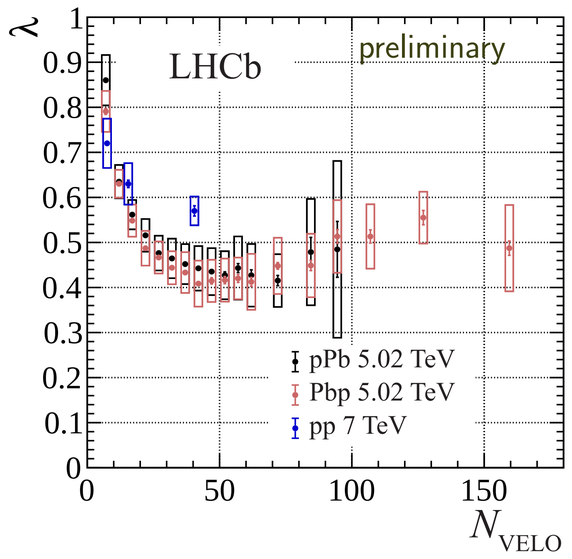




Results

- LHCb-PAPER-2023-002, CERN-THESIS-2021-302
- the correlation radius R and intercept parameter λ have been extracted from the SS fit and are shown below as functions of the N_{VELO} multiplicity
- their behaviour is consistent with observations of other experiments at LHC
- the linear dependence of R on the cube root of N_{VELO} is also compatible with the predictions based on the hydrodynamic models





- the dominant source of systematic error is the treatment of background, mainly the scaling procedure

Ongoing studies

- using bins of k_T and rapidity
- using Pb-Pb sample
- using D meson decays

References

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