Bose-Einstein Correlations of Charged Hadrons in pp Collisions at 13 TeV

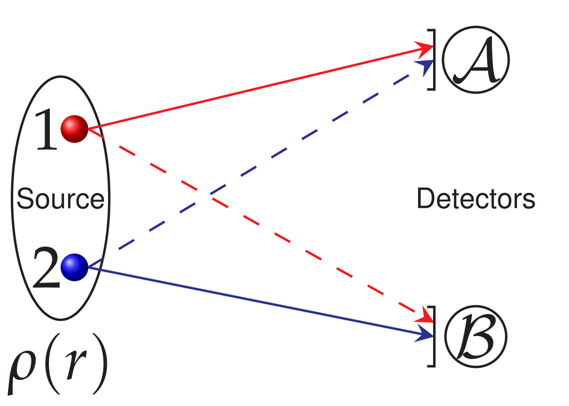
Cesar A. Bernardes — cesar.augusto.bernardes@cern.ch,
for the CMS Collaboration
São Paulo State University (UNESP)

Overview

Bose-Einstein correlations (BEC) are useful tools to probe the size and shape of the particle emitting region in high-energy collisions. Measurements of the one-dimensional correlation function using three different techniques are presented for minimum-bias (MB) and high-multiplicity (HM) events in proton-proton collisions at $\sqrt{s} = 13$ TeV, collected with the CMS detector. The MB range in this analysis covers track multiplicities up to 80, and HM above that. Comparisons with previous measurements at $\sqrt{s} = 7$ TeV and theoretical predictions are also discussed.

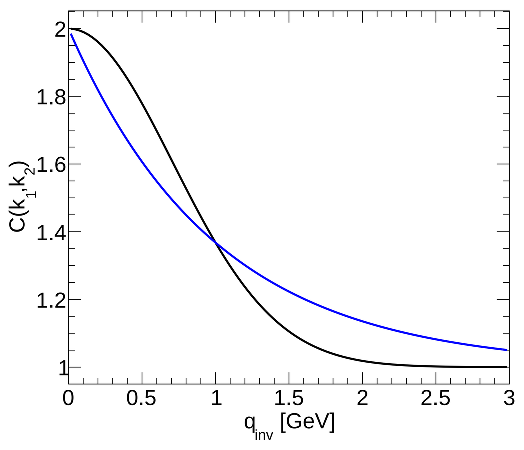
BEC Concept

Observed as an enhancement in the low relative momentum (q_{inv}) region, BEC are a quantum statistical effect involving identical bosons with similar kinematics, emitted from the system formed in the collision.



$$C(k_1,k_2) = \frac{P_2(k_1,k_2)}{P_1(k_1)P_1(k_2)} = 1 + \lambda\left|\mathcal{F}\left[\tilde{\rho}(q)\right]\right|^2$$

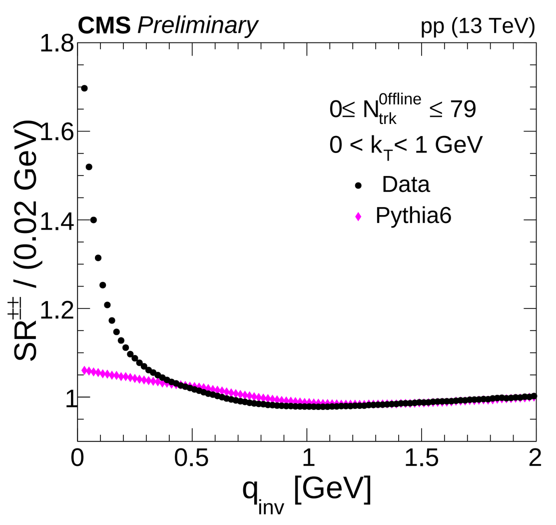
$$q^2 \equiv q^2_{\mathrm{inv}} = -(k_1 - k_2)^2$$



Experimental correlation function (single ratio, SR)

$$\mathrm{SR} \equiv \frac{\mathcal{S}(q_{\mathrm{inv}})}{\mathcal{B}(q_{\mathrm{inv}})}.$$

- $\mathcal{S}(q_{\mathrm{inv}})$: normalized q_{inv} distribution of same-sign charged particle pairs from the same event (contains BEC)
- $\mathcal{B}(q_{\mathrm{inv}})$: similar to $\mathcal{S}$, but with pairs from different events (mixing technique, no BEC)



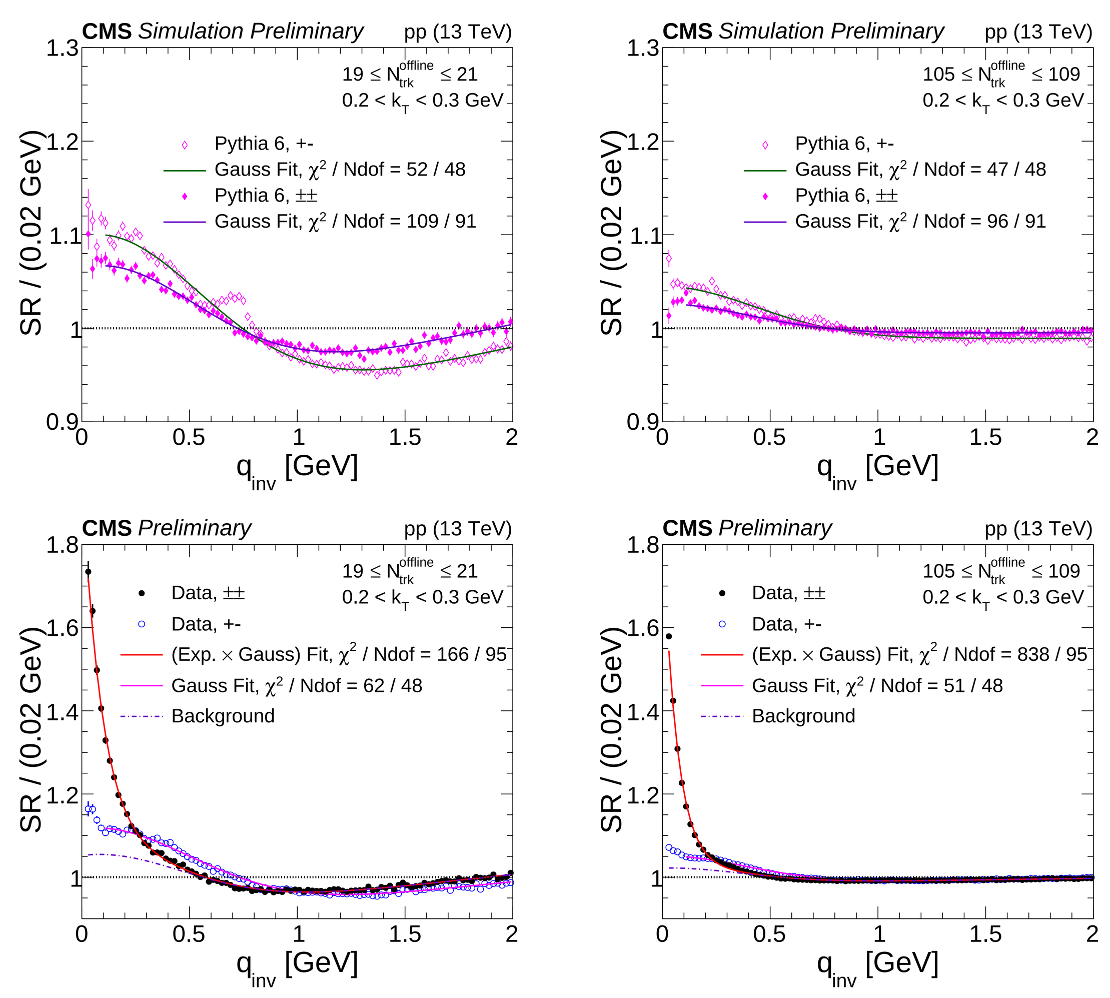
Correlation function parameterization for fits

$$C_{\mathrm{BE}}(q_{\mathrm{inv}}) = C\left[1 + \lambda e^{-q_{\mathrm{inv}}R_{\mathrm{inv}}}\right](1 + \epsilon q_{\mathrm{inv}})$$

- λ: intercept parameter
- R_{inv}: length of homogeneity
- ϵ: long-range term

Analysis Techniques

- Double ratios (DR): data SR divided by Monte Carlo (MC) simulation SR (MC using Pythia 6 Z2* tune, without BEC effects) [2]
- Cluster subtraction (CS): background contribution to SR estimated with data SR from same event opposite-sign pairs [2]
- Hybrid cluster subtraction (HCS): similar to CS, but background estimated using convertion factors (opposite-sign to same-sign) from MC simulations [3]

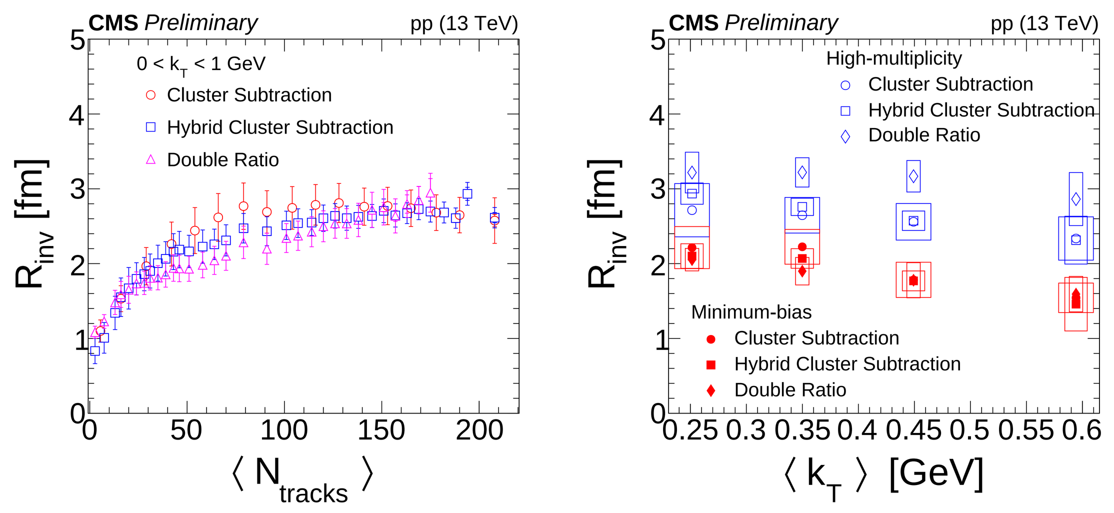


Larger non-BEC contribution (mainly resonances and jets) for lower track multiplicities.

Wider SR distribution for lower track multiplicity (BEC peak), implying lower R_{inv}.

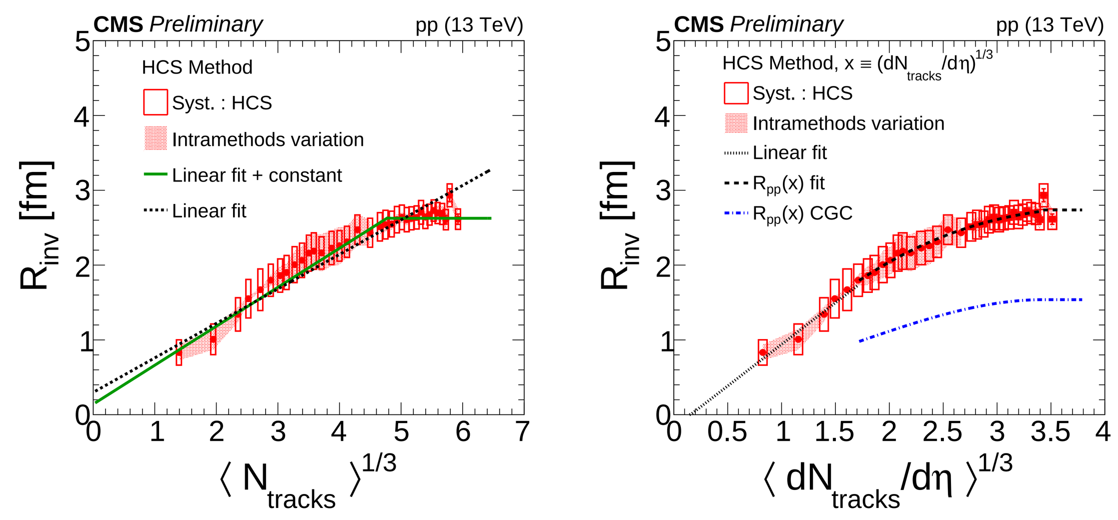
Figure 1: Single ratios with fits for same- and opposite-sign track pairs in MC (top row) and data (bottom row). The "background" corresponds to the non-BEC estimate from HCS method [4].

Results



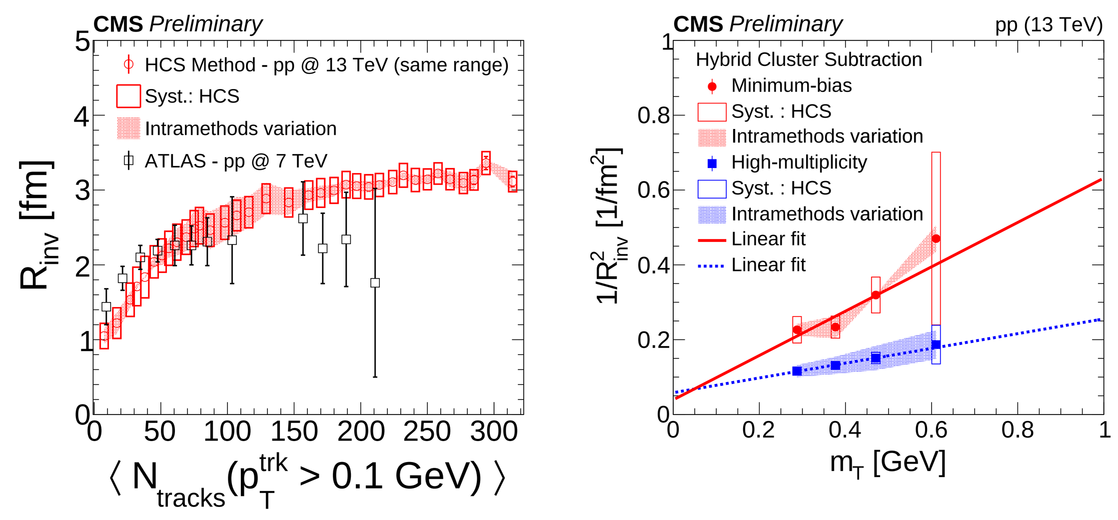
Results compatible among the three methods: R_{inv} increases with multiplicity (left) and decreases with k_{T} (right).

Figure 2: R_{inv} as a function of charged particle multiplicity (left) and $k_{\mathrm{T}} = \frac{1}{2}|\vec{k}_{T,1} + \vec{k}_{T,2}|$ (right) for the three methods [4].



(Left) Dependence of R_{inv} on $N^{1/3}_{\mathrm{tracks}}$: linear rise or linear+constant. (Right) Similar shape as from CGC predictions at 7 TeV [5].

Figure 3: R_{inv} as function of $N^{1/3}_{\mathrm{tracks}}$ (left) and $(dN_{\mathrm{tracks}}/d\eta)^{1/3}$ (right) [4].



(Left) Values of R_{inv} compatible with ATLAS results at $\sqrt{s} = 7$ TeV; (Right) $1/R^2_{\mathrm{inv}}$ vs m_{T} (hydro): larger slope in MB as compared to HM.

Figure 4: (Left) Comparison with ATLAS measurements [6] using proton-proton collisions at 7 TeV. (Right) $1/R^2_{\mathrm{inv}}$ dependence on $m_{\mathrm{T}} = \sqrt{m^2_\pi + k^2_{\mathrm{T}}}$ for MB and HM ranges [4].

References

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[2] CMS Collaboration, "Bose-Einstein correlations in pp, pPb, and PbPb collisions at $\sqrt{s_{NN}} = 0.9$ - 7 TeV", *To appear in Phys. Rev. C* (2017) arXiv:1712.07198.
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[4] CMS Collaboration, "Femtoscopic Bose-Einstein correlations of charged hadrons in pp collisions at 13 TeV", *CMS Physics Analysis Summary* **FSQ-15-009** (2018).
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[6] ATLAS Collaboration, "Two-Particle Bose-Einstein Correlations in pp collisions at $\sqrt{s}$ =0.9 and 7 TeV with the ATLAS detector", *Eur. Phys. J. C* **75** (2015) 466.

Acknowledgements

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