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The λ energy dependence deduced from BEC of $\pi\pi$ pairs produced in *pp* collisions

G. Alexander[1] and V.A. Okorokov[2]

[1]Tel-Aviv University, Israel,

[2]NRNU MEPhI, Moscow, Russia

Outline

1. Bose–Einstein correlations (BEC) – brief reminder
2. BEC function and its 1D parameterizations
3. The energy dependence of the BEC quantities
4. Results and comparison with data
5. Summary

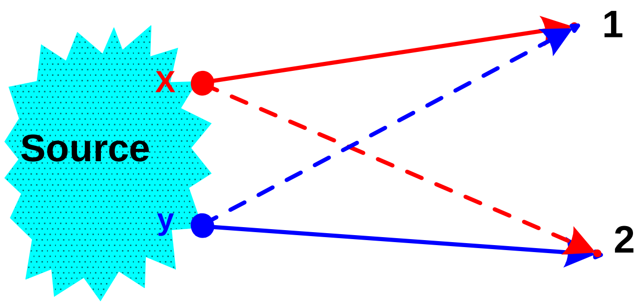
Why study BEC

- Bose – Einstein correlations (BEC) – correlations between two identical bosons (consequence of the symmetry of identical bosons wave function) – BEC effect corresponds to an enhancement in two identical boson correlation function (CF) when the two particles are near in momentum space.

- BEC – excellent tool for the study and sensitive probe of the space–time geometry of the hadronization region – allows the determination of both the size and the shape of the emission region of secondary particles.

- Dependence of BEC on collision energy helps to understand the features of multiparticle production mechanism at non-perturbative (soft) regime.

Two-particle correlation function



Two identical particles are emitted from the points X and Y of the source with 4-momenta p_1 and p_2.

Definition: the correlation function of two identical particles is the ratio of the probability to observe two particles with momenta p_1 and p_2 to the product of single-particle probabilities.

$$C(p_1, p_2) = P(p_1, p_2) / [P(p_1)P(p_2)].$$

CF is studied in terms of the relative momentum of particles in pair (q):

$$q = p_1 - p_2.$$

Usually in one-dimensional (1D) analysis the Lorentz invariant 4-momentum difference squared is used:

$$Q^2 = - q^2.$$

1D parameterizations of BEC effect

1D BEC effect is described by a function with two parameters, R, the dimension of the emission region and its strength λ also referred to as the chaoticity parameter.

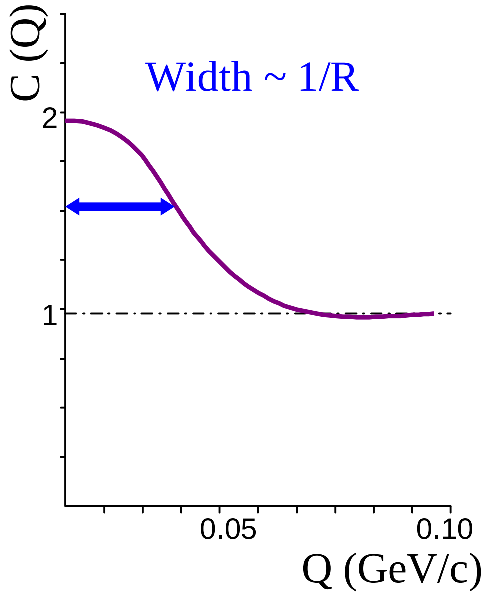
$$C(Q) \propto 1 + \lambda\Omega(QR).$$

1. The Goldhaber spherical source model of a static Gaussian source in the plane-wave approach (Gauss parameterization)

$$\Omega(QR) = \exp(-Q^2R^2).$$

2. The static source model assumed a radial Lorentz distribution of the emission points (exponential parameterization)

$$\Omega(QR) = \exp(-QR).$$



Schematic view of the 1D CF and the relation between the width of CF and source radius.

Experimental CF is the ratio of the signal distribution (like-sign pairs distribution) to the reference distribution (unlike-sign pairs distribution)

$$C(Q) = D_{sig}(Q) / D_{ref}(Q).$$

Physics motivation

- The R parameter has been measured in pion pars at different *pp* collisions energies.

- To the λ behavior on energy so far very little attention has been given. At the same time the chaoticity parameter λ plays an important and crucial role in the understanding of the main features of the out going particle source.

This study is focused on the energy dependence of chaoticity parameter λ.

The R dependence on number of sources

In the 1D BEC there exists a relation between $R_{n=1}$ and R_n where n is the number of the independent similar emitting pion group sources, namely [*see e.g. G. Alexander, Rep. Prog. Phys. 66, 481 (2003)*]

$$R_n = n(\lambda_n / \lambda_{n=1})\, R_{n=1}$$

which relates the one group sources dimension R_1 at low energies with its value R_n for n identical group sources. The $\lambda_{n=1}$ and λ_n parameters are the chaoticity values respectively for $n = 1$ and n group sources. The main interest is the energy behavior of chaoticity parameter rather than on its absolute value. Thus it is sufficient to study the ratio $\lambda \equiv \lambda_n / \lambda_{n=1}$.

The set of available experimental results deduced from 1D BEC analyzes results in an approximate energy dependence of BEC dimension [*G. Alexander, J. Phys. G 39, 085007 (2012)*]

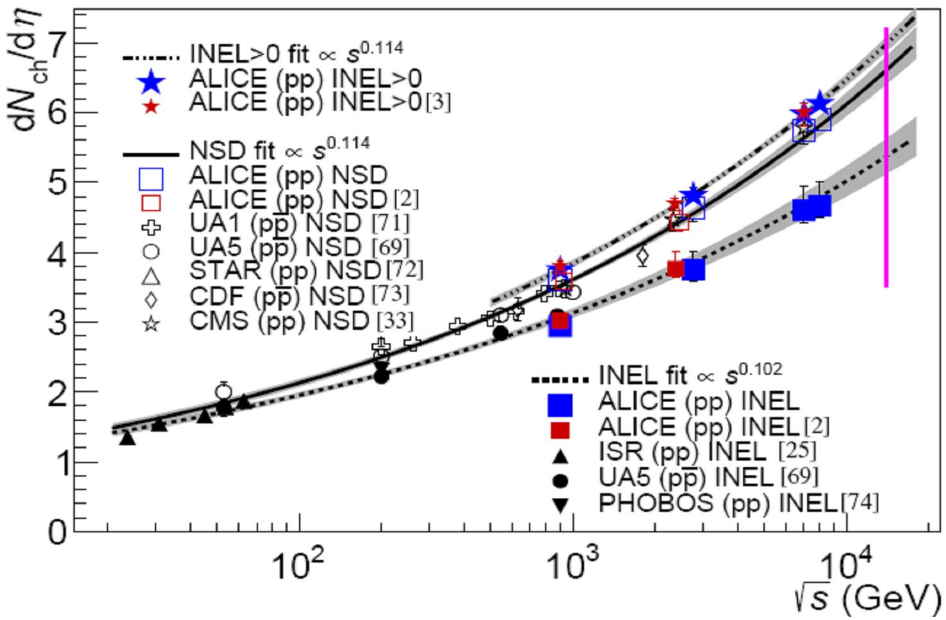
$$R_n(s_{pp}) = [\alpha + \beta \ln(s_{pp} / s_0)]\, R_{n=1},$$

$\alpha = 1.64 \pm 0.11$, $\beta = 0.07 \pm 0.01$, $[s_{pp}] = \text{TeV}^2$, $s_0 = 1\ \text{TeV}^2$.

Energy dependence of λ

Within the framework of eikonal approach to hadron production [*D. Kharzeev, M. Nardi, Phys. Lett. B507, 121 (2001)*] one can get for *pp* collisions (N_{part} = 2 and N_{coll} = 1)

$$n(s_{pp}) \propto \mathrm{d}N_{ch} / \mathrm{d}\eta = 3.43(s_{pp} / s_0)^{0.11}.$$



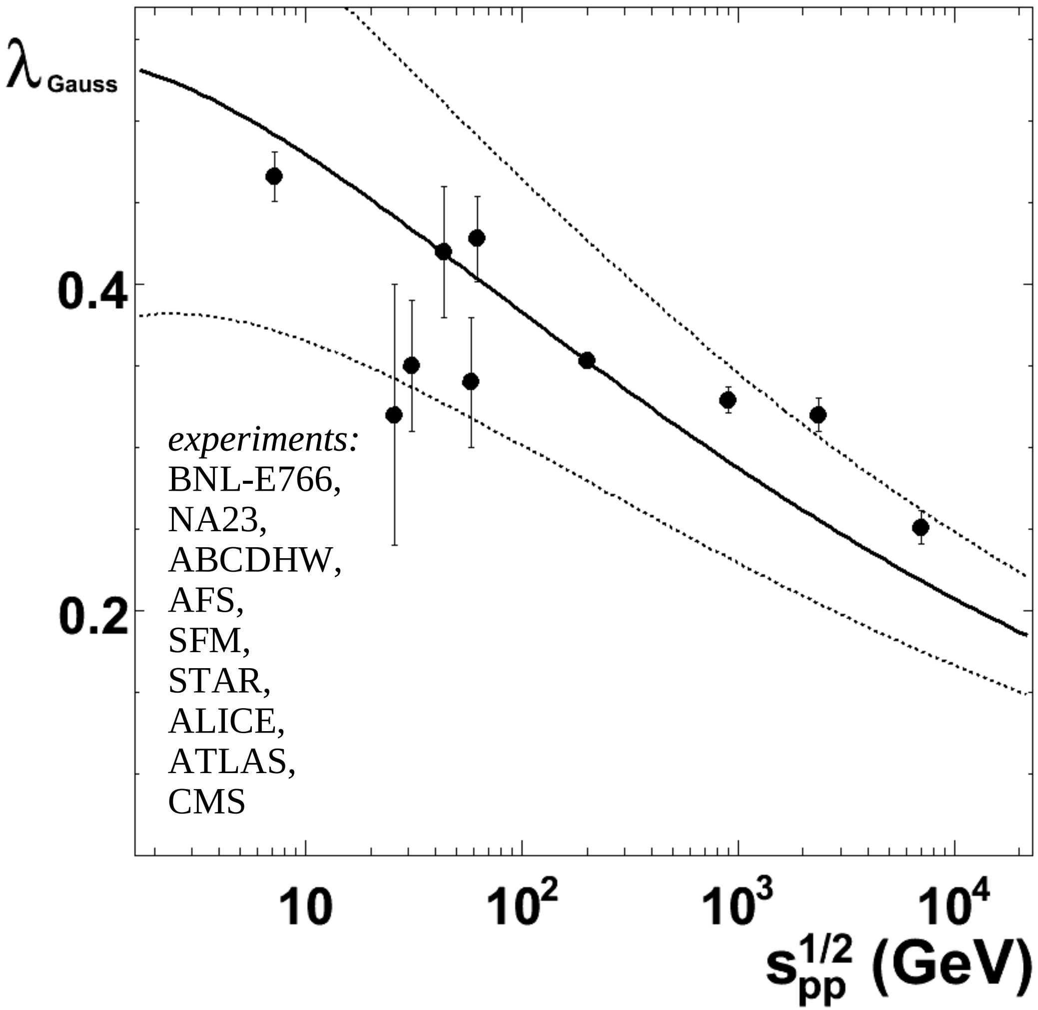
This function agrees rather well over a wide energy region with the experimental data of charged particle multiplicity measured in *pp* collisions per unit of pseudo-rapidity.

ALICE energy dependence of $dN_{ch} / d\eta$ in the pseudo-rapidity region $|\eta| < 0.5$ for various types of collisions. Lines indicate fits with a power-law dependence on s. Grey bands represent the ± 1 s.d. range. The LHC nominal centre-of-mass energy is indicated by a vertical line.
ALICE Collaboration, arXiv: 1509.07541.

Therefore one can derive

$$\lambda(s_{pp}) \propto [0.48 + 0.02\ln(s_{pp} / s_0)]\,(s_{pp} / s_0)^{-0.11}.$$

Comparison with experiments



The 1D BEC chaoticity λ_{Gauss} as a function of $\sqrt{s_{pp}}$ as deduced from the measured $\pi\pi$ pairs produced in pp collisions using the Gaussian parametrization. The expected energy dependence of λ_{Gauss} derived in this work is shown by the continuous line, normalized to the measured λ_{Gauss} at 200 GeV where the dotted lines represent its ±1 s.d. limits.

The data are seen to scatter somewhat in the energy region of 20 to 60 GeV which may well be attributed to problems concerning the reference samples and different analysis criteria.

In spite of the scattered data in the 20 to 60 GeV region a general decrease with energy of the λ_{Gauss} values is apparent.

Our expectation for the λ_{Gauss} energy dependence describes rather well the experimental measured values.

Summary

1. The 1D BEC measured values of λ are seen to decrease with energy.

2. The approach of relating the R and multiplicity increase with *pp* collisions energy with the number of sources results in a decrease of the 1D λ similar to the one obtained experimentally.

3. Prediction for the λ dependence on energy is obtained over a multi-TeV energy range, for instance, $\lambda = 0.20 \pm 0.04$ at the LHC full energy $\sqrt{s_{pp}} = 14$ TeV.

Thanks for you attention