Charge correlations and strongly intensive fluctuations in ultrarelativistic nuclear collisions in the string model

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Abstract and motivation

The fluctuations of the net electric charge of hadrons, produced in ultrarelativistic heavy ion collisions, were proposed as one of the indicators of the formation of a quark-gluon plasma [1,2].

Experimentally, they are studied in terms of dynamical fluctuation parameter vdyn and the balance functions. These observables showed to be robust against volume fluctuations and centrality class width, being therefore strongly intensive variables [3].

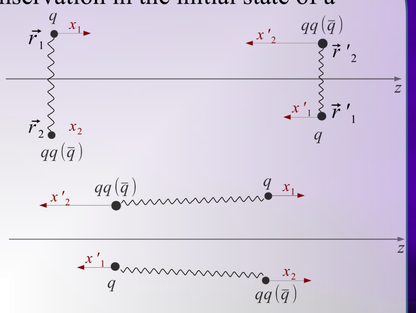
For the more detailed study, the method of net charge long-range correlations in the windows separated by rapidity has been proposed for the better exclusion the short-range correlation effects [4].

In this paper we calculate the strongly intensive correlations and fluctuations of charge of produced hadrons in a string-partonic Monte Carlo model [5, 6], taking into account fusion of quark-gluon strings [7,8], finite rapidity width of strings and explicit charge conservation in string decay. The model successfully describes the main features of forward-backward correlations between multiplicities and transverse momentum in pp and Pb-Pb collisions at LHC energy [9-12]. We demonstrate that the centrality dependence of the dynamical net charge fluctuation can be explained by formation in central AA collisions of the strings of higher string tension and provide the predictions for net charge correlations in Pb-Pb collisions at LHC energy.

Monte-Carlo model

- Partonic picture of nucleons interaction [5, 6].
- Energy and angular momentum conservation in the initial state of a nucleon.
- The probability of dipoles interaction depends on their transverse coordinates [13-14] with effective coupling (also accounting continement effects)

$$f = \frac{\alpha_s^2}{2} \ln^2 \frac{|\vec{r}_1 - \vec{r}'_1||\vec{r}_2 - \vec{r}'_2|}{|\vec{r}_1 - \vec{r}'_2||\vec{r}_2 - \vec{r}'_1|}$$



Multiplicity and transverse momentum are obtained in the approach of colour strings, stretched between projectile and target partons.

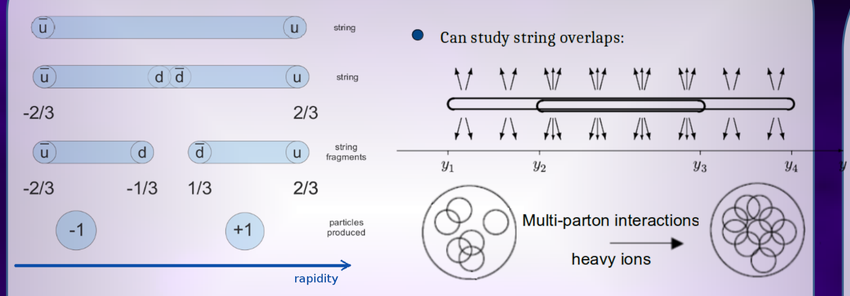
- The interaction of strings is realized in the accordance with the **string fusion** model prescriptions [7, 8]. Mean multiplicity and the mean transverse momentum of the particles produced from a cluster of strings are:

$$\langle \mu \rangle_k = \mu_1 \sqrt{k} \frac{S_k}{\sigma_1} \qquad \langle p_t^2 \rangle_k = p_1^2 \sqrt{k} \qquad \langle p_t \rangle_k = p_1 \sqrt[4]{k}$$

S_k – area, where k strings overlapping, $\sigma_1 = \pi r_{str}^2$ – single string transverse area, μ_1 and p_1 – mean multiplicity and transverse momentum from one string.

- Multiplicity from one string is distributed according to Poisson distribution, with Gaussian transverse momentum spectra.
- The **hardness** of the elementary collisions is defined by a transverse size of the interacting dipoles.
- Every parton can interact with other one only once (contrary to Glauber supposition of constant nucleon cross section).
- Parameters of the model are constrained from the data on inelastic cross-section and multiplicity [5, 15] (see also talk in the section H).

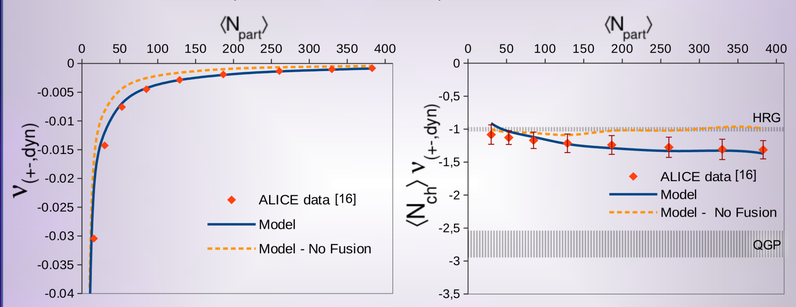
Charge in rapidity string decay



- Hadron charge discrimination with local charge conservation is implemented taking into account string fusion
- In case of different rapidity width of strings each overlap in rapidity is processed separately

Results: charge fluctuations

$$\nu_{dyn} = \left\langle \left(\frac{N_+}{\langle N_+ \rangle} - \frac{N_-}{\langle N_- \rangle} \right)^2 \right\rangle - \left(\frac{1}{\langle N_+ \rangle} + \frac{1}{\langle N_- \rangle} \right)$$



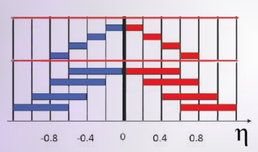
- MC model with string fusion successfully describes the centrality dependence of dynamical net-charge fluctuation.
- Scaling variable $\langle N_{ch} \rangle \nu_{(+-,dyn)}$ decreases with centrality towards the level of QGP estimation (which is in agreement with experiment)

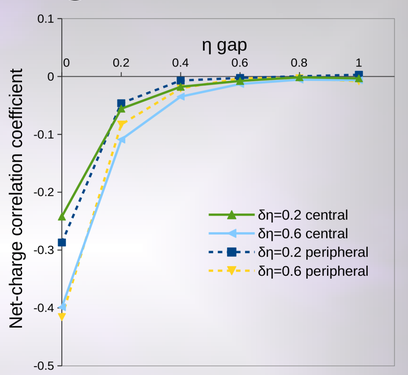
In case of no fusion, it remains constant at the level of HRG

Results: Net-charge correlations

Net charge forward-backward correlation coefficient

$$b = \frac{\langle Q_F Q_B \rangle - \langle Q_F \rangle \langle Q_B \rangle}{\langle Q_F^2 \rangle - \langle Q_F \rangle^2}$$





- Absolute value of net-charge forward-backward correlation coefficient decreases with the gap.
- Weak depedence on the cenrality
- A hint of a transition from negative to positive at large rapidity gap

Summary, conclusions and outlook

- The string decay model, which includes finite rapidity width of a string, string fusion, and local charge conservation, has been developed.
- The Monte Carlo model with string fusion reasonably describes the centrality dependence of the net-net charge fluctuation (without any parameter tuning).
- The version of the model without string fusion cannot agree with the experimental data.
- The predictions for net-charge forward-backward correlation coefficient have been obtained.
- Further studies should also include the following:
  - Taking into account experimental cuts on the transverse momentum of the produced particles
  - Implementation of the resonance production and decay
  - Application at different energies (SPS, RHIC, and NICA)
  - Study of mixed type correlations involving multiplicity, pt, charge, strangeness, baryon number etc.

Acknowledgement

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References

[1] S. Jeon and V. Koch, Phys. Rev. Lett. 85 (2000) 2076.

[2] M. Asakawa, U. Heinz, and B. Müller, Phys. Rev. Lett. 85 (2000) 2072.

[3] M. Gazdzicki, M. I. Gorenstein, M. Mackowiak-Pawlowska, Phys. Rev. C 88, 024907 (2013)

[4] A. Titov, V. Vechernin, PoS (Baldin ISHEPP XXI) 047, 2012.

[5] V. N. Kovalenko. Phys. Atom. Nucl. 76, 1189 (2013).

[6] V. Kovalenko, V. Vechernin, PoS (Baldin ISHEPP XXI) 072.

[7] M.A. Braun, C. Pajares, and V.V. Vechernin, Phys. Let. B 493, 54 (2000).

[8] M. Braun, R. Kolevatov, C. Pajares, and V. Vechernin, Eur. Phys. J. C 32, 535 (2004)

[9] V. Kovalenko, V. Vechernin, EPJ Web of Conferences 66, 04015 (2014).

[10] I. Altsybeev, KnE Energy and Physics ICPPA2017, 304-312, 2018, arXiv:1711.04844 [nucl-ex].

[11] V. Kovalenko, V. Vechernin. DESY Conf. Proc. 2014-04, 82 (pp. 691-694), DOI:10.3204/DESY-PROC-2014-04/82, arXiv:1410.3884 [hep-ph] (2014)

[12] V. Kovalenko, V. Vechernin, J. Phys. Conf. Ser. 668 (2016) no.1, 012065, arXiv:1509.06696 [hep-ph] (2015).

[13]. C. Flensburg, G. Gustafson, and L. Lönnblad, Eur. Phys. J. (C) 60, 233 (2009), arXiv:0807.0325.

[14] G. Gustafson, Acta Phys. Polon. B 40, 1981, 2009 arXiv:0905.2492 [hep-ph].

[15] V. Kovalenko, PoS (QFTHEP 2013) 052 (2013).

[16] B. Abelev, et al (ALICE Collaboration), Phys. Rev. Lett. 110 (2013) 152301, arXiv:1207.6068