Romanian Reports in Physics, Vol. 67, No. 3, P. 831–836, 2015

COMPARISONS AMONG THE HADRON PRODUCTION IN ULTRA RELATIVISTIC HEAVY ION COLLISIONS IN DIFFERENT TRANSVERSE MOMENTUM RANGES. PRELIMINARY RESULTS*

A. DANU[1], O. RISTEA[2], C. BESLIU[2], Al. JIPA[2], I.S. ZGURA[1], C. RISTEA[1,2], A. SEVCENCO[1], C.M. MITU[1], T. ESANU[2]

[1]Institute of Space Science, Magurele, Romania
E-mail: ada@spacescience.ro
[2]University of Bucharest – Faculty of Physics, Romania

Received September 25, 2013

Abstract. In the last period the experiments from the two relativistic heavy ion colliders published significant experimental results. Some of these results are related to the conditions of quark-gluon plasma formation and the evolution of the fireball after formation. A picture in this field of the hadrons matter is essential for the connection of Nuclear Physics phenomena with some cosmological processes.In such perspective, a comparison of the experimental results published by the different collaborations at the two colliders in a enough large energy range allows to analyze some noticeable aspects as the time dependence reflected in dynamics models, tendency to the chiral symmetry restoration, hadrons to anti-hadrons ratios, etc. This work is focused on the mentioned, comparisons being related tothermal aspects as are reflected by transverse momentum distributions for charged hadrons produced in Au+Au collisions at 200 A GeV, in Centre of Mass System (cms), (results obtained, mainly, by BRAHMS Collaboration from RHIC-BNL) and Pb+Pb collisions at 2.76 A TeV, in cms (results obtained, mainly, by ALICE Collaboration from LHC-CERN). The main contribution of this work consists in the investigation of nuclear evolution time from different physical quantities related to charged hadron production, like: multiplicities, transverse masses, hadron to anti-hadron ratios, strange and baryonic chemical potentials.

Key words: hadron production, ultra relativistic heavy ion collisions.

The experimental results published by the different collaborations form the two relativistic heavy ion colliders, RHIC-BNL and LHC-CERN, indicated new interesting behavior of the nuclear matter formed in the overlapping region of the two colliding nuclei. Therefore, an exploration of the experimental data from both colliders is necessary. In the present work a few experimental results from Au+Au collisions at 200 AGeV, in center of mass system (cms) and Pb+Pb at 2.76 ATeV, in cms, are compared. We use published data from the BRAHMS Collaboration

* Paper presented at the Annual Scientific Session of Faculty of Physics, University of Bucharest, June 21, 2013, Bucharest-Magurele, Romania.

from RHIC-BNL [1] and ALICE Collaboration from LHC-CERN [2]. Preliminary comparisons using physical quantities related to the transverse momentum distributions, p_t, seem to privilege thermal dynamics. For this work the statistics of the used experimental results is presented in Table 1. Here the number of participants depending on the centrality at BRAHMS and ALICE experiments is presented, too.

Table 1

The statistics of N_{part} as a function of centrality collisions from both experiments which is used in the present work

Centrality	BRAHMS Au+Au	ALICE Pb+Pb
0-10%	328 ± 6	2895 ± 109
10-20%	239 ± 10	966 ± 37
20-40%	140 ± 11	1075 ± 38
40-60%	62 ± 10	410 ± 15

In Fig. 1 we present a comparison between the centralities for the two collisions (Au+Au and Pb+Pb) using its dependence on the spectator to the participant ratio. We see that the difference is reduced at the two incident energies, although its energy values are different (one order of magnitude).

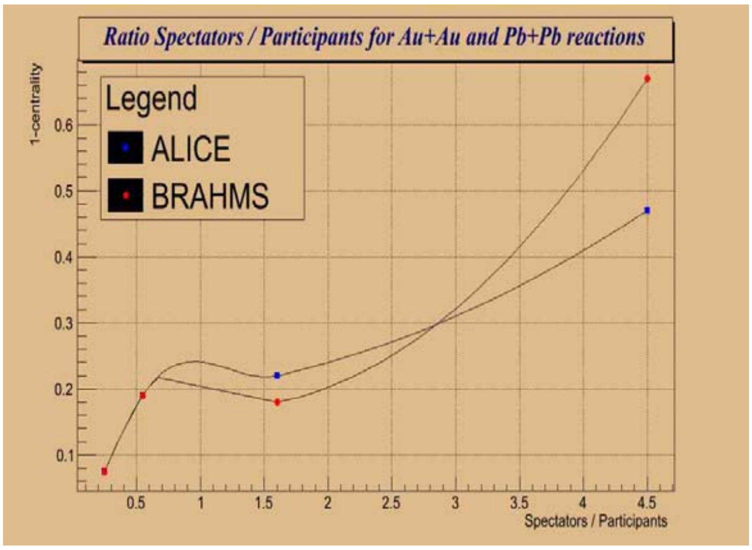

Fig. 1 – The 1-centrality as a function of the ratio of the numbers of the spectators *vs.* participants.

Other physical aspects investigated in this comparative analysis are:

• The dependence of the transverse momentum distribution, p_t, on the collision centrality, including the behaviors of the transverse masses, of the hadron types taken into account;

• Introducing the nuclear time of reaction, in Hubble type modulation of the fireball evolution and hadron emission [3]; this can be related to the quark gluon plasma formation and decay;

• The problem of hadron to antihadron symmetry, in temporal reaction evolution;

• Investigation of hadrons chemical potentials, baryonic and strange, as functions of the incident energy and the reaction time.

If we are looking at the transverse mass distributions (Figs. 2 and 3), we see that for the case of Au+Au collisions at 200 AGeV, in cms, the shape of the transverse mass spectra is linear in a logarithmic scale (both for $K^{\pm}$ and $p^{\pm}$). A relative independence of the slopes of the centrality class is observed. Some differences among hadron types could be considered, too.

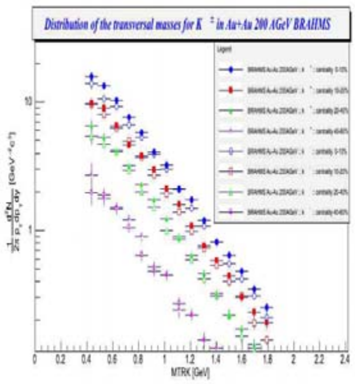

Fig. 2 – Distribution of the transversal masses for $K^{\pm}$ in BRAHMS experiment.

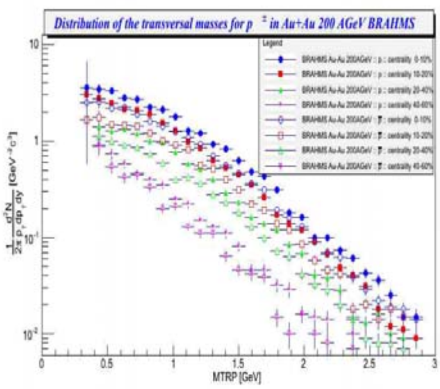

Fig. 3 – Distribution of the transversal masses for $P^{\pm}$ in BRAHMS experiment.

The Hubble general algorithm is extended for the evolution of the fireball, by the introduction of the "Hubble time" Eq. (1.1) and Eq. (1.2) [3]:

$$TH_{E\_i} = \left(E_{cin\_tr\_\min} \Big/ E_{cin\_tr\_i} \right)^2 * \tau \tag{1.1}$$

$$TH_{th\_i} = \left(\beta_{tr\_\min} \Big/ \beta_{tr\_i} \right)^2 * \tau, \tag{1.2}$$

where τ is 3.5 fm/c.

We consider the sum of a few hadron types, ($K^+ + K^- + p + \bar{p}$), and we compare the dependencies of yields on the "Hubble time". These dependencies are shown in the Fig. 4.

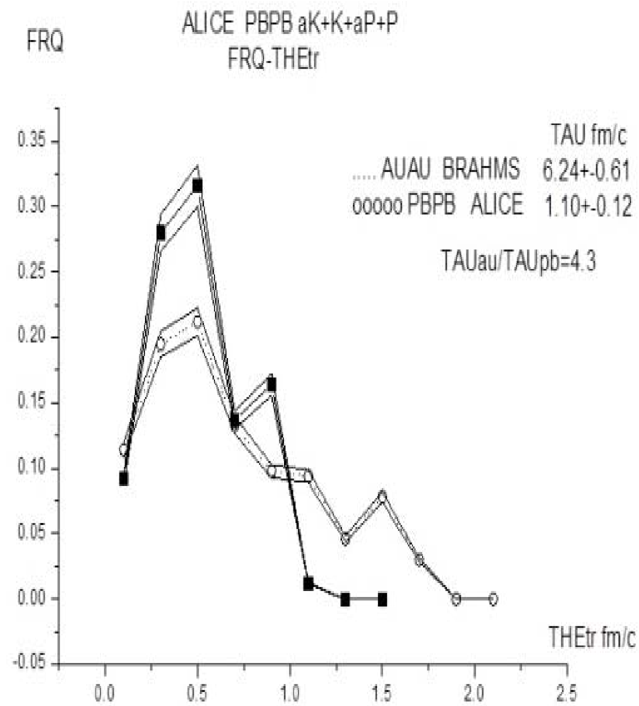

Fig. 4 – Dependence of the yields of hadron sums (see text) on Hubble time for both experiments.

The comparisons of the asymmetry between hadron and antihadron yields in the two selected collisions (Au+Au at 200 A GeV and Pb+Pb at 2.76 A TeV, both in cms), for different centralities, could offer interesting information for cosmological scenarios. The results included in Table 2 indicate an asymmetry of antiproton to proton ratio in the studied collisions.

Table 2

Ratio of $\bar{p}/p$ in both reactions

	Centrality 0–10%	**Centrality 40–60%**
Pb-Pb 2.76 ATeV	1.02 ± 0.06	0.48 ± 0.07
Au-Au 200 A GeV	0.7 ± 0.07	0.44 ± 0.1

Except the case of reaction times expected being close to the quark-gluon plasma formation time, where strong fluctuations suggest an explosion, differences between the values of the positive kaon to negative kaon ratio, K^+/K^-, and the proton to antiproton ratio, $p/\bar{p}$, are observed: the asymmetry is maximum and almost constant for K^+, K^- pairs. For pions emission, the asymmetry is very low $((\pi^-/\pi^+) \rightarrow 1)$ in mentioned collisions, at both energies.

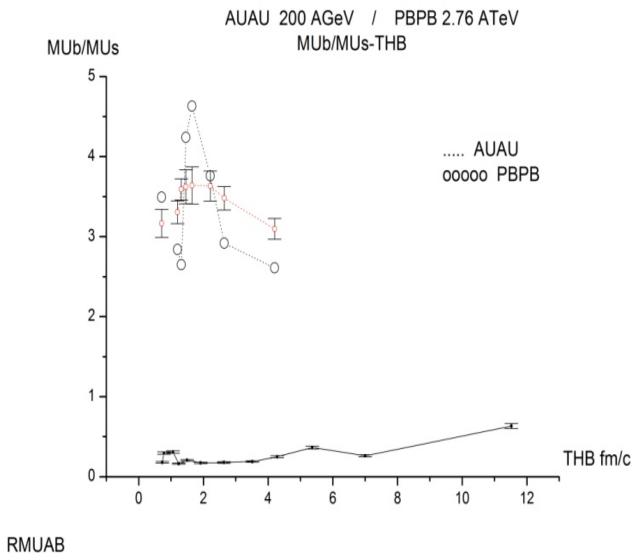

Fig. 5 – Chemical potentials in both reactions.

In the systematic analysis of the two types of chemical potentials, baryonic (μ_B) and strange (μ_s), we see a decrease of the values, of μ_s, and μ_B, in Pb+Pb collisions compared with those obtained in Au+Au collisions (Table 3). The tendency to zero value for the chemical potentials can be observed in Pb+Pb collisions at 2.76 A TeV, in cms. This can be an indication of possible chiral symmetry restoration, at higher energies.

Table 3

Chemical potentials for both reactions

Centrality [%]	**μ_s [MeV]**		**μ_B [MeV]**	
	Pb-Pb 2.76 A TeV	Au-Au 200 A GeV	Pb-Pb 2.76 A TeV	Au-Au 200 AGeV
0–10	1.85±0.004	8.2±0.01	0.2±0.00002	48±0.24
40–60	3±0.02	11.2±0.3	1.2±0.0004	52±0.47

The main conclusions of this preliminary analysis are the following:

- Transverse momentum distributions and transverse mass distributions (p_t, m_t) in the two analyzed collisions at the two energies do not differ significantly in form;
- Temporal evolution reflected by the thermalization time values indicates the small possible lifetime of a new state of nuclear matter, like quark-gluon plasma;
- The analysis of the antihadron to hadron ratios indicated an increased asymmetry for the evolution time in the range $t_h \leq 1.5$ fm/c;
- The chemical potentials – strange, μ_s, and baryonic, μ_B, – could offer information on the tendency of approaching the chiral symmetry restoration for energies higher than 2.76 A TeV, in cms.
- With the increase of the energy, an increase of the strange hadron production can be observed; this is stronger for small evolution times ($t_h < 0.8$ fm/c). This can be related to the formation time of the quark-gluon plasma;
- Further analysis is necessary, on a wider range of collisions and energies, for additional information on the highly excited and dense nuclear matter behavior.

REFERENCES

1. BRAHMS Collaboration (I.Arsene, I.Beardean, C.Besliu, …, Al. Jipa, … C. Ristea, O. Ristea, …, F. Videbaek, …, I.S. Zgura, *Centrality dependent particle production at y = 0 and y = 1 in Au + Au collisions at sNN = 200 GeV*, Phys. Rev. **C72**, 014908 (2005) nucl-ex/0503010.
2. ALICE Collaboration (…., Danu A.,….., Mitu C., …, Sevcenco A., …, Zgura I.S., …), *Pion, Kaon and Proton Production in central Pb-Pb collisions at sNN = 2.76 TeV*, Phys. Rev. Lett., **109**, 252301 (2012) arXiv:1208.1979 [hep-ex].
3. C. Ristea, A. Jipa, I. Lazanu, O. Ristea, C. Besliu, V. Baban, V. Covlea, *Hubble flow in relativistic heavy ion collisions*, Journal of Physics Conference Series, **420**, 012040 (2013) an references quoted there. DOI: 10.1088/1742-6596/420/1/012040.