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Method to evidence the contributions of the spectator and participant regions to the particle production in relativistic nuclear collisions

Călin Beşliu, Alexandru Jipa
Atomic and Nuclear Physics Department, Faculty of Physics, University of Bucharest,
P.O.Box MG-11, R-76900 Bucureşti-Măgurele, ROMANIA
E-mail: ajip@scut.fizica.unibuc.ro

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Abstract. In nucleus-nucleus collisions at high energies the collision geometry is very important. The participant-spectator picture is used to obtain information on the collision dynamics from the experimental results. In this paper a method to find the contributions of the two regions to the multiplicity distributions of the negative and charged particles is discussed. The ordinary moments associated to the distribution functions in the two regions are used. The calculations are compared with experimental results obtained in nucleus-nucleus collisions at 4.5A GeV/c. The experiments have been performed at the Syncrophasotron from the JINR Dubna.

Key words: particle production GeV energy range, nucleus- nucleus collisions multiplicity.

INTRODUCTION

The dynamics of the nucleus-nucleus collisions at high energies is related to the collision geometry. This feature of these collisions has been evidenced from the beginning of the field [1]. The most used picture for the collision geometry in nucleus-nucleus collisions at energies higher than 1 GeV/A is the participant-spectator picture [2].

In this context, it is very important to separate the contributions of the two kinds of regions at the dynamics of these collisions. Many experimental results suggest the possible influences of the phenomena from the two regions on the collision dynamics [3-9]. Among the physical quantities reflecting these influences the multiplicity and the multiplicity distribution are interesting.

A method based on two different unknown distribution functions for the two kinds of regions is presented in the paper. The first ordinary non-central moments for the convoluted distribution function - formed from the distribution functions that describe each region - can be calculated; the calculations are compared with the experimental results and the contributions of the two regions can be established [10]. *This method completes the phenomenological geometric picture proposed for relativistic nuclear collisions and can be related to the different simulation codes, like HIJING, VENUS, NEXUS and RQMD* [11-13].

The calculations are compared, especially, with the experimental results obtained at the Syncrophasotron from JINR Dubna (Russia), in the frame of the SKM 200 Collaboration [4,5,7,14-16].

The method presentation

Experimental results on multiplicity, participants, pionic interferometry, angular distributions, momentum spectra, rapidity spectra suggested a phenomenological geometric picture of the collisions at energies of a few GeV/A [4,5,7,8,17,18]. In the overlapping region of the two colliding nuclei a hot central region is created. This region flows through colder peripheral spectator regions. These regions slow down the flow and can absorb some particles created in the hot region, especially those emitted at transverse angles in center of mass system; it seems to be important what's happen in the contact area between the two kinds of regions during the flow [10,19].

Some physical quantities can be calculated in the phenomenological geometric model using the following working assumptions:

(i) the nucleons are spheres of radii r_o , and the nuclei are spheres of radii $R = r_o A^{1/3}$;

(ii) initially, in the target nucleus a spherical zone occurs whose volume depends on the impact parameter b and on the beam energy;

(iii) the ratio $\dfrac{Z_P + Z_T}{A_P + A_T}$ remains constant for the hot region;

(iv) the spherical zone evolves into a hot sphere, the volume remaining the same.

In these assumptions the total number of participant nucleons, Q_N, and the number of participant protons, Q, are calculated using the following relations:

$$Q_N = \frac{h(3r_1^2 + 3r_2^2 + h^2)}{8r_o^3} \quad , \quad (1)$$

$$Q = \frac{Z_P + Z_T}{A_P + A_T} Q_N \quad , \quad (2)$$

where: $r_{1,2}^2 = | R_T^2 - (b \pm R_P)^2 |$, $h = 2R_P$, with R_P and R_T the radius of the projectile nucleus, respectively, the radius of the target nucleus.

The spectator regions slow down the flow and can absorb some particles created in the hot region, especially those emitted at transverse angles in center of mass system. Therefore, *it is important to know what's happen in the contact area between the two kinds of regions during the flow and participant region expansion*. Consequently, two types of spectators must be considered: *primordial spectators* and *absolute spectators*. The primordial spectators are those existing at the initial collision time, defined by the collision geometry, and the absolute spectators are those which remain uninvolved in interaction process up to the freeze-out. Usually, the primordial spectators and absolute spectators do not differ significantly for very central and symmetric collisions. *Important differences could appear for less central and asymmetric collisions.*

The possible phenomena at the contact area between the two types of regions and the absorption, in spectator regions, of some particles emitted from the participant region can influence the collision dynamics, during the participant region expansion. Therefore, a method to separate the contributions of the two regions is proposed in this work.

Let be $f_p(n_p)$ the distribution function of the charged particles emitted from the participant region, and let be $f_s(n_s)$ the distribution function of the charged particles emitted from the spectator region. Here, n_p is the multiplicity of the charged particles emitted from the participant region and n_s the multiplicity of the same kind of particles emitted from the spectator region.

We make the hypothesis that the distribution function of the all charged particles emitted in a collision event, has the following form:

$$f(n_{ch}) = f_p(n_p) + f_s(n_s) \quad . \quad (3)$$

The following relationship between the three average multiplicities is expected: $\langle n_{ch} \rangle = \langle n_p \rangle + \langle n_s \rangle$. Taking into account the absorption in spectator regions negative values of the average multiplicity $\langle n_s \rangle$ could be expected.

With this distribution function we can calculate the ordinary non-central moments, using the standard methods [20,21]. Distinct summations for the two regions are considered.

The zeroth order moment, namely the area under curve, used to normalise at the unit, has the following form, if all collision events are considered:

$$m'_o = \sum_{n_{ch}} f(n_{ch}) = \sum_{n_p} f_p(n_p) + \sum_{n_s} f_s(n_s) \quad , \quad (4)$$

with $\sum_{n_p} f_p(n_p) \equiv F_p$ and $\sum_{n_s} f_s(n_s) \equiv F_s$. In these notations the equation (4) can be written as follows:

$$m'_o = F_p + F_s \quad . \quad (5)$$

The next two ordinary non-central moments can be calculated without additional assumptions. They have the following forms:

$$m'_1 = \sum_{n_{ch}} n_{ch} f(n_{ch}) = \sum (n_p + n_s)[f_p(n_p) + f_s(n_s)] = \langle n_p \rangle F_p + \langle n_s \rangle F_s \quad , \quad (6)$$

$$m'_2 = \sum_{n_{ch}} n_{ch}^2 f(n_{ch}) = \sum_{n_p, n_s} (n_p + n_s)^2 [f_p(n_p) + f_s(n_s)] = (\sigma_p^2 + \langle n_p \rangle^2) F_p + (\sigma_s^2 + \langle n_s \rangle^2) F_s \, .$$

(7)

In the last equation the following relation is used:

$$\sum_{n_i}(n-n_i)^2 f_i(n_i)=\sigma_i^2 F_i \quad , \quad (8)$$

with i = p, respectively, s. Here , $<n_p>$ and $<n_s>$ are mean values, and σ_p^2 and σ_s^2 are dispersions.

To calculate the third non-central ordinary moment the following assumption is made:

$$\sum_{n_i}(n-n_i)^3 f_i(n_i)=0 \quad , \quad (9)$$

where i = p, respectively, s. In this assumption the symmetric distributions are assumed. The third moment has the following form:

$$m'_3=(3<n_p>\sigma_p^2+<n_p>^3)F_p+(3<n_s>\sigma_s^2+<n_s>^3)F_s \quad . \quad (10)$$

The fourth order non-central ordinary moment can be calculated in the assumption:

$$\sum_{n_i}(n-n_i)^4 f_i=\sigma_i^4 F_i \quad . \quad (11)$$

Now, the form of this moment is the following:

$$m'_4=(<n_p>^2-\sigma_p^2)^2 F_p+(<n_s>^2-\sigma_s^2)^2 F_s \quad . \quad (12)$$

Because the last two non-central ordinary moments are calculated in some restrictive assumptions, for simplicity, two methods to solve the system are considered. This simplification could affect the results of the interactions between the emitted particles, as well as those with the two types of regions.

First of them uses all these moments and the assumption $\sigma_p = \sigma_s = \sigma$, *restrictive, also.*

The second method uses the moments up to the second order, as well as the relationship with the central ordinary moments, namely:

$$m_k=\sum_{j=1}^{k} C_k^j m'_{k-j}(-m'_1)^j \quad , \quad (13)$$

where m_k are the central moments, and $C_k^j=\frac{k!}{(k-j)!\,j!}$.

In the first approach the following notations are introduced:

$$a=\frac{F_p}{F_p+F_s} \quad , \quad (14)$$

$$b=1-a=\frac{F_s}{F_p+F_s} \quad . \quad (15)$$

Using previous equations - namely, (5)-(7), (10) and (12) - the following relations for normalised ordinary non-central moments are obtained:

$$m'_{1n}=\frac{m'_1}{m'_o}=<n_p>.a+<n_s>.(1-a) \quad , \quad (16)$$

$$m'_{2n}=\frac{m'_2}{m'_o}=(\sigma^2+<n_p>^2).a+(\sigma^2+<n_s>^2).(1-a) \quad , \quad (17)$$

$$m'_{3n}=\frac{m'_3}{m'_o}=(3<n_p>\sigma^2+<n_p>^3).a+(3<n_s>\sigma^2+<n_s>^3).(1-a) \quad , \quad (18)$$

$$m'_{4n}=\frac{m'_4}{m'_o}=(<n_p>-\sigma^2).a+(<n_s>-\sigma^2).(1-a) \quad . \quad (19)$$

From this equation system the values for the variables $<n_p>$, $<n_s>$, σ and a can be obtained using the experimental values of the normalised ordinary non-central moments, m'_{in}, *i = 1,4.* It is important to stress here the following fact: *the first method involves few restrictive assumptions.* The experimental results do not present, usually, symmetry for multiplicity distributions. This observation is confirmed by the skewness parameter experimental values [19,22]. Therefore, the second method, method that uses only the non-central and central moments up to the second order, without restrictive assumptions, seems more useful to analyze experimental results. The analysis methods proposed here can be used for different kinds of charged particles, too, because they have similar behaviours [3-10,19,22]. By the using of *a* and *b* quantities the absorption in the spectator regions and the phenomena at the contact area between the two region types could be considered as included.

Experimental results and discussions

The calculations presented previously have been compared with experimental results obtained in nucleus-nucleus collisions at 4.5 A GeV/c. The considered experimental results present the advantage that all are obtained in the same experimental conditions, namely, the conditions offered by the SKM 200 Spectrometer from the JINR Dubna (Russia) [3-10,14-16]. This spectrometer presents the advantage to detect both central and peripheral (inelastic) collisions, too. A disadvantage of the SKM 200 Spectrometer is related to the limited possibilities to identify different particles [5,6,23]. Therefore, in this work we present experimental results for negative pion multiplicity and its multiplicity distribution [3-10,19]. The negative pions with momenta smaller than 50 MeV/c have been neglected to separate them on other lighter particles [3-10,14-16].

The experimental values of the non-central ordinary moments obtained in peripheral collisions are included in the Table I. The similar experimental results for central collisions are included in the Table II.

Using these experimental results contributions of the spectator and participant regions have been evaluated. For the three central collisions the average values of the negative pion multiplicities from the participant region are the following: $\langle n_\pi\rangle^p_{ONe} = 7.72$, $\langle n_\pi\rangle^p_{CCu} = 9.00$, $\langle n_\pi\rangle^p_{OPb} = 14.45$. The average negative pion multiplicities from the spectator region are the following: $\langle n_\pi\rangle^s_{ONe} = 2.81$, $\langle n_\pi\rangle^s_{CCu} = 2.45$, $\langle n_\pi\rangle^s_{OPb} = 2.62$. The ratios between the average negative pion multiplicities from the spectator, respectively, participant region are the following: $(\langle n_\pi\rangle^s/\langle n_\pi\rangle^p)_{ONe} = 0.36$, $(\langle n_\pi\rangle^s/\langle n_\pi\rangle^p)_{CCu} = 0.27$, $(\langle n_\pi\rangle^s/\langle n_\pi\rangle^p)_{OPb} = 0.18$. The values of the ratio suggest that the absorption in the spectator regions is higher for the lower particle source velocities, in agreement with our geometric model and previous experimental results [4,5,7,8,17,18].

First of all, the negative pion absorption can be related to both types of regions: participant and spectator. The negative pion absorption in the participant region is related to its space-time characteristics, generation point inside the participant region. In the spectator region can be absorbed, especially, the negative pions emitted from the participant region on the transverse direction in comparison with the beam direction. To estimate the participant nucleon number in a given collision different methods could be used [4,7,8,24]. Taking into account these aspects it is important to know the nucleon numbers in each region [24].

Usually, the participant nucleons are those outside of the Fermi's spheres for the fragmentation of the colliding nuclei [8,24,25]. For the SKM 200 Spectrometer the participant proton number is established with the following relation:

$$Q = n_{ch} - 2n_{\pi-} - (n_{s1} + n_r^+ + n_R^+ + n_{p>pF}) \quad . \quad (20)$$

Here, n_{ch} is the charged particle multiplicity and $n_{\pi-}$ is the negative pion multiplicity. n_{s1} is the multiplicity of the particles with momenta higher than 3.5 GeV/c, generated in an angular range according to the triggering mode of the streamer chamber, n_r^+ is the number of positive fragments with ionisation greater than 1 - minimum ionisation - which have the length of the track chord smaller than r, n_R^+ is the number of positive fragments with ionisation greater than 1 which have the length of the track chord between r and R, with r<R; $n_{p<pF}$ is the number of positive fragments with ionisation greater than 1 which go out and have momenta p smaller than the Fermi's momentum p_F.

The problem of the participants in the nucleus-nucleus collisions at high energy is related to some interesting directions in the study of the dynamics of these collisions. In a few previous works different methods to obtain the number of participant protons, few relationships of this number with the number of participant nucleons, as well as some methods to establish the number of participants from the projectile and target nuclei have been presented [8,24].

The average number of participant protons from the projectile nucleus can be established - from the experimental data - using the following relationship [26,21,22]:

$$\langle Q_p \rangle = Z_P - \langle n_{strip} \rangle \sum_{Z=1}^{Z_P} Z W(Z) \quad , \quad (21)$$

where W(Z) is the distribution of the stripping fragments of the projectile nucleus in relation to its charges.

The average number of participant nucleons from the target nucleus are given by the next relation:

$$\langle Q_N^T \rangle = (\langle Q \rangle - \langle Q_p \rangle)\frac{A_T}{A_P} \quad . \quad (22)$$

Using the phenomenological geometric model [4,5,7,8,17,18] the total number of participant nucleons, Q_N [Eq.(1)], and the number of participant protons, Q [Eq.(2)], are calculated. For inelastic collisions seems to be useful to take as a starting point the geometrical relation for cross sections [24,25]. The geometric cross section for two colliding nuclei is:

$$\sigma_G = \pi r_o^2 (A_P^{1/3} + A_T^{1/3})^2 \quad . \quad (23)$$

The cross sections (areas) of the two colliding nuclei are: $\sigma_P = \pi r_o^2 A_P^{2/3}$ and $\sigma_T = \pi r_o^2 A_T^{2/3}$, respectively. The number of participant protons from the projectile nucleus, respectively, from the target nucleus should be proportional with the ratios between areas and the geometrical cross section, as well as with the atomic numbers. As proportionally constants are suggested a factor 1/δ - for projectile nucleus - and a factor 1/γ - for target nucleus. Here, δ is the parameter that takes in consideration the "softness" of the surface layers of the nuclei, and γ is the Lorentz factor for nucleon-nucleon collisions relative to the center of mass system. The value of the parameter δ is given by the fit of the all inelastic cross sections for nucleus-nucleus collisions at 4.5 A GeV/c total momentum, obtained by the SKM 200 Collaboration; this value is δ=0.65 [4,5,7,8,24,25]. The final relations are:

$$< Q_p > = \frac{Z_P A_T^{2/3}}{\delta(A_P^{1/3} + A_T^{1/3})^2} \quad , \quad (24)$$

$$< Q_t > = \frac{Z_T A_P^{2/3}}{\gamma(A_P^{1/3} + A_T^{1/3})^2} \quad , \quad (25)$$

The number of participant protons from the overlapping region of the two colliding nuclei is:

$$< Q > = < Q_p > + < Q_t > . \quad (26)$$

A complete analysis of the experimental values and the calculated values for the participant protons, as well as the calculated values and the estimated values for the total number of participant nucleons, obtained in 11 central collisions at 4.5A GeV/c total momentum, in the T(2,0) triggering mode, have be done [8,24,26]. A satisfactory agreement between the experimental results and calculations has been observed. Previous, for symmetrical and quasi-symmetrical collisions has been considered proper the approximation $Q_{N2}^{es} = 2 < Q >^{ex}$, and for non-symmetrical collisions the approximation $Q_{N2.5}^{es} = 2.5 < Q >^{ex}$ [2]. The assumption (iii) is justified. Similar results are obtained for more central collisions. Good agreements are observed [8,24,26]. For a given projectile nucleus that collide different target nuclei a change in behaviour is observed for $\frac{R_T}{R_P} \approx 1.5$. With the increase of the mass number of the projectile nucleus increases the role of the contact areas and the role of the features of the nuclear surfaces.

These results are useful in studies on some thermodynamic and hydrodynamic characteristics of relativistic nuclear collisions (nuclear density, size of the fireball, flow of the fireball) [10,17,19,27-29].

An additional analysis for non-symmetric nucleus-nucleus collisions has been considered [26]. The excess of neutron number from the target nucleus, Q_T^n, has been estimated using the following relationship [24,26]:

$$Q_n^T = \frac{A_T}{Z_T} Q_p^T + A_P \quad , \quad (27)$$

where the proton participant number from the target nucleus, Q_p^T, has been calculated as follows:

$$Q_p^T = Q - Z_P \quad , \quad (28)$$

Here, as in the previous relations, $A_{P,T}$, respectively, $Z_{P,T}$, are the mass numbers, respectively, atomic numbers, of the projectile and target nuclei.

To obtain information on the collision dynamics from the multiplicity distribution and momentum spectra it is important to take into account the possible pion interactions in the final state. It is important, too, to establish the region from which the pion is generated [10,19]. Significant subthreshold pion production is possible, too [30]. Therefore, a spectator region could be considered, taking into account the absorption in spectator regions and the phenomena at the contact areas between participant and spectator regions, as a possible source for relative slow negative pion, too. Generally, the pion multiplicity can be correlated with the thermal energy per baryon and compression energy, taken as half from the available energy [31,32].

The pion production can be possible by direct processes, as well as by the baryonic resonance production and decay. An important decay channel is the following: $\Delta \rightarrow \pi$+N [22,26,33]. Some calculations based on the intranuclear cascade models [34,35] indicated that the equilibrium among nucleons, pions and Δ resonances is established in the first 8-10 Fm/c after collision. The RQMD simulations confirm these results. After this time, in nucleus-nucleus collisions at 4.5 A GeV/c a behaviour like-saturation appears. This equilibrium suffers some modifications during the fireball expansion, and different pion production mechanisms could be reflected by the momentum spectra.

The first systematic studies on the pion generation in symmetric collisions have been evidenced some characteristic features [36-38]. The most interesting are: pion multiplicity increases with the proton participant number and the available energy per nucleon for thermalization in center of mass system; linear correlation between multiplicity and thermal energy available in the center of mass system is presented from the beam energies higher than 100 A MeV. This linear correlation is presented for different nucleus-nucleus collisions at energies - in laboratory system - up to 4.5 A GeV [4,7,8,16,26,39]. For non-symmetric collisions an enhanced pion absorption in participant and spectator regions is expected. Experimental results obtained in asymmetric and very asymmetric nucleus-nucleus collisions at 4.5 A GeV/c indicated a behaviour like-saturation for pion multiplicity dependence on the nucleon participant number [4,7,8,26,40]. Such behaviour can be related to the pion absorption in massive spectator regions, as well as on the decrease of the thermal energy per participant.

The thermal energy available in CMS can be estimate using the following relationship [26]:

$$E_{Th} = E_{CM} - Q_N m_N \quad , \quad (29)$$

with Q_N given by the Eq.(1) and m_N the bound nucleon mass (931 MeV/c^2).

The available energy in CMS, E_{CM}, has been estimated as follows:

$$E_{CM} = \sqrt{(E_P + E_T)^2 - p^2} \quad , \quad (30)$$

where p is momentum per nucleon of the projectile nucleus multiplied by the atomic mass of the projectile nucleus. For a rest target nucleus the next relation has been used to calculate the available energy:

$$E_T = Q_N^T m_N \quad , \quad (31)$$

with Q_N^T the nucleon number from the target nucleus [8,24].

Taking into account previous experimental results related to the almost complete stopping of the projectile nucleus in the target nucleus [19] and the phenomenological model for these collisions [4-10,17,19,24,25,27] we calculated the negative pion multiplicity and compared the calculations with experimental results. For a few asymmetric nucleus-nucleus collisions at 4.5 A GeV/c a higher calculated pion multiplicity in comparison to the experimental pion multiplicity has been observed [26].

The difference between calculations and experimental results could be higher if the assumption that the target nucleus spectators take a fraction from the incident energy. There is not a simple way to take into account this energy transfer. It is expected that the difference between calculations and experimental results be higher if all types of pions are taken into account. The behaviour of the ratio π^-/π^+ and the isospin asymmetry in the pion production mechanisms [6,39,41-43] could offer an additional support for the assumption of pion absorption in the spectator regions.

The method presented here gives such support, too. The geometric model allows calculate the fireball velocities at different moments from its evolution, in laboratory system [4-10,17,19,23,24,44]. The initial velocity values, respectively, the velocity values of the fireball at the negative pion emission are, for the three mentioned collisions, the following: $v_i^{ONe} = 0.455c$, $v_i^{CCu} = 0.437c$, $v_i^{OPb} = 0.397c$, respectively, $v_\pi^{ONe} = 0.380c$, $v_\pi^{CCu} = 0.374c$, $v_\pi^{OPb} = 0.352c$. These results could be related to the assumption that a better consideration of the free expansion of the fireball is from the moment when the contact between the participant and spectator regions ceases [4-10,17,19,23,24,44].

For the six peripheral collisions the average negative pion multiplicities from the spectator region are the following: $\langle n_\pi \rangle^s_{HeLi} = 1.09$, $\langle n_\pi \rangle^s_{HeC} = 1.24$, $\langle n_\pi \rangle^s_{HeNe} = 1.14$, $\langle n_\pi \rangle^s_{HeAl} = 1.19$, $\langle n_\pi \rangle^s_{HeCu} = 1.35$, $\langle n_\pi \rangle^s_{HePb} = 1.44$. A weak increase with the mass number of the target nucleus can be observed. The corresponding average negative pion multiplicities for participant region have the values: $\langle n_\pi \rangle^p_{HeLi} = 1.94$, $\langle n_\pi \rangle^p_{HeC} = 2.29$, $\langle n_\pi \rangle^p_{HeNe} = 2.28$, $\langle n_\pi \rangle^p_{HeAl} = 2.52$, $\langle n_\pi \rangle^p_{HeCu} = 3.00$, $\langle n_\pi \rangle^p_{HePb} = 3.31$. In this case the ratio between the average negative pion multiplicities from the spectator, respectively, participant region takes values between 0.56 (for He-Li) and 0.43 (for He-Pb). The influence of the fireball velocity remains (initial velocities between 0.382c and 0.386c, fireball velocities between 0.323c and 0.382c). The increase of the ratio between the negative pion multiplicities from the two types of regions in He-A_T peripheral collisions in comparison with the central collisions could be related to the next aspects: higher asymmetry of the two colliding nuclei, decrease of the fireball flow velocity, collision geometry.

The experimental results obtained in central and peripheral nucleus-nucleus collisions at 4.5 A GeV/c suggest an important contribution of the spectator regions at the collision dynamics. The importance of the colliding nuclei asymmetry, collision geometry and flow velocity is evidenced, again.

These results can reflect better the behaviour of the π^-/π^+ ratio in different nucleus-nucleus collisions, being an additional support for the previous conclusion. The preliminary results obtained for stopped charged particles in the streamer chamber of the SKM 200 Spectrometer are promising [6,42,43]. Taking into account the observed flow of the nuclear matter in nucleus-nucleus collisions at 4.5 A GeV/c [27,28,44-47], as well as the reported effects of the flow on the strangeness production [43,48-51], an analysis of the $\langle\pi^-\rangle/\langle\pi^+\rangle$ ratio in the interesting collisions is useful.

Before to present the experimental values for this ratio a short discussion on the identification method is necessary.

The identification method takes into account the *charged particles stopped in the streamer chamber having the same minimum ionisation as the negative pions*. Two selection criteria are important: ionisation and momentum. Therefore, only the tracks of the particles having minimum ionisation and momentum higher than 50 MeV/c have been considered, to avoid the presence of the electrons in the samples chosen [3-10,14-16].

The main steps in the identification are the following:

(i) selection, by scanning, of the charged particles with minimal ionisation, positive and negative; electrons have been neglected;

(ii) calculation, in the reconstruction program, of the z-coordinate of the end of the considered particle, using the next relation:

$$z[cm] = \{(27.8*PAR[mm])/[(B[cm]/K + (PAR[mm]/10)]\} - 66 \quad , \quad (32)$$

where PAR is the parallax between the ends of the considered particles on two projections, B is the basis of the stereo-photographic system, and K is the reduction coefficient; for this experiment B = 39.1 cm, and K = 180 cm/L_{fr} [cm], with L_{fr} the distance between the extreme fiducial marks on the scanning table;

(iii) selection of the stopped particles in the streamer chamber, taking into consideration the target z-coordinate (z_T = - 23.0 cm) and the height of the streamer chamber (60.0 cm); therefore, z = 0 cm is the upper limit, and z = - 60 cm is the lower limit for the ends of the charged particles trajectories;

(iv) calculation of the ratio range-momentum using the values of the quantities from the reconstruction program;

(v) identification of the particles; the range-momentum ratio and the scale invariance of the different types of particles which move with the same velocity in a certain substance are used.

Cumulative [52] and non-complete stopped particles (z-coordinate in the proximity of 0.0 cm or -60.0 cm) have been neglected.

The geometrical chamber dimensions and the position of the target in the chamber allow establish the maximal range of a particle in the chamber, namely 225 cm. The maximum momentum corresponding to the mentioned maximum range is related to the nature of the particle; for example: p_π = 275 MeV/c, p_K = 750 MeV/c, p_p = 1750 MeV/c, p_d = 3500 MeV/c. To obtain these values the following relations have been used [6,39,40]:

$$L_{arc} = K\{[(l^2 + h^2)/4h]*[\arcsin(4lh/(l^2 + h^2))]\} \quad , \quad (33)$$

$$r = Kl^2/8h \quad , \quad (34)$$

$$p[MeV/c] = 300*r[m]*B[T] \quad , \quad (35)$$

with *l* and *h* the length of the chord, respectively, the sag of the track for the considered particle; here r is the curvature radius, *B* is the magnetic field, *p* is the momentum and L_{arc} is the range of the stopped particle.

The highest value of the real length chord, $L = Kl$, is 177 cm, and the highest associated sag, $H = Kh$, is 60 cm. For each quantity the standard deviation has been calculated, using the formulae for the error propagation [20,21]. Only the measurements with $\sigma(L_{arc}) / L_{arc} \geq 1/3$ have been used to increase the confidence in the experimental results.

For the same reason, the increase in the confidence in the obtained experimental results, the "survival" probability of a particle having a mass *M* and a mean life τ, moving on a distance L_{arc}, has been calculated [6,42,43]:

$$P = \exp[-(MLarc*10^{-10})/3\tau p] \quad . \quad (36)$$

Therefore, 12 particle types can be considered, namely: $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, p, $\Sigma^{\pm}$, Ω^{-}, Ξ^{-}, d. For muons, protons and deuterons this probability is 1.

The ratio between the charged particle range, L_{arc}, and the momentum *p* of the same particle, as well as the scale invariance relation for particles with charge $q = \pm 1$ have been used to identify finally the stopped particles. An identification program has been created.

It is important to stress here the fact that the absolute error in angle is constant for all angles (2.2^{o}), and the relative error in momentum is constant, too (5%) [4-10,42,43]. Taking into account the fact that the identification method used only stopped charged particles emitted at angles higher than 2^{o}, and the range-momentum dependencies, the rapidity ranges for different kinds of identified particles are the following: (i) pions: $y_{\pi} \in (-0.51,+1.43)$; (ii) kaons: $y_K \in (-0.57,+1.20)$; (iii) protons: $y_p \in (-0.60,+1.38)$; (iv) deuterons: $y_d \in (-0.60,+1.38)$. In average, for all types of particles, the rapidity range is between -0.5 and 1.5. The average transverse momenta, for the same types of identified particles, in O-Pb central collisions, are: $\langle p_T^{\pi} \rangle = 183 \pm 11$ MeV/c, $\langle p_T^{K} \rangle = 212 \pm 15$ MeV/c, $\langle p_T^{p} \rangle = 234$ MeV/c, $\langle p_T^{d} \rangle = 253 \pm 10$ MeV/c. These values reflect the streamer chamber geometry and the $T(2^{o},0^{o})$ central triggering mode of the detection system in these collisions.

The acceptance of the 2 m streamer chamber for *stopped charged particles* must be done. The charged particles emitted at the backward and transverse angles, in the laboratory system, have smaller space to stop. In these cases the maximum range is about three times smaller that for the particles emitted in the forward direction (maximum range is about 76.0 cm). These behaviours are very well reflected in the range-momentum plots: after a 80 cm range the error increases because of the experimental data statistics decreasing. Taking into account this behaviour and the experimental observation of the events pictures (multiplicity of the charged particles emitted in different directions) a *stopped charged particle efficiency of 0.20* for the streamer chamber have been obtained. This cut in the range for charged particles emitted at backward and transverse angles could explain the small dependence of the transverse momentum on the particle type [6,42,43].

Two numbers for stopped pion multiplicities can be considered, namely: the number of stopped pions without the consideration of the "survival" probability (36), n_{π} , and the number of stopped pions taking into consideration the "survival" probability (36), n_{π}^{P}. To establish the average multiplicity we can consider 5 situations, namely: (a) the total number of charged particles investigated, N_t (3105 - for O-Pb, 1429 - for C-Cu, 370 - for O-Ne); (b) the number of charged particles considered initially as stopped, N_{st}^{a} (1614 - for O-Pb, 752 - for C-Cu, 182 - for O-Ne); (c) the number of stopped charged particles, N_{st} (1434 - for O-Pb, 571 - for C-Cu, 159 - for O-Ne); (d) the number of stopped positive particles, N_{st}^{+} (1172 - for O-Pb, 531 - for C-Cu, 149 - for O-Ne), or, taking into account the two charge types, the number of stopped negative particles, N_{st}^{-} (262 - for O-Pb, 40 - for C-Cu, 10 - for O-Ne); (e) the number of stopped positive particles with "survival" probability P>0.5, N_{st}^{+P} (1107 - for O-Pb, 507 - for C-Cu, 109 - for O-Ne), respectively, the number of stopped negative particles with "survival" probability P>0.5, N_{st}^{-P} (234 - for O-Pb, 32 - for C-Cu, 7 - for O-Ne) (see Tables III and IV). Similar situation is in the kaon production case.

In O-Pb central collisions at 4.5 A GeV/c 434 positive pions have been identified as stopped. Their "survival" probabilities have values between 0.5 and 1.0. Taking into account the 5 different ways to calculate the average multiplicity of the charged pions we have the following values: (a) 0.140±0.007; (b) 0.269±0.014; (c) 0.302±0.016; (d) 0.370±0.021; (e) 0.392±0.022.

196 negative pions have been identified as stopped, in the same collision. All have the "survival" probability between 0.7 and 0.9. Their average multiplicities are the following: (a) 0.063±0.004; (b) 0.121±0.009; (c) 0.137±0.010; (d) 0.748±0.070; (e) 0.837±0.081.

Using the previous values of the average multiplicities for negative and positive stopped pions in O-Pb collisions at 4.5 A GeV/c the followings values for $\langle \pi^{-} \rangle / \langle \pi^{+} \rangle$ ratio are obtained: (a) 0.450±0.036; (b) 0.450±0.041; (c) 0.454±0.041; (d) 2.022±0.221; (e) 2.135±0.239.

The last two ratios reflect the situation for stopped pions. Their maximum momentum is 270 MeV/c, as we mentioned previously. Our experimental results reflect the isobar model predictions [53] and the isospin asymmetry [54-56]. For O-Pb collisions the predictions of the isobar model suggest 2.04, and the isospin asymmetry is 2.31.

In C-Cu central collisions at 4.5 AGeV/c 201 stopped positive pions, with "survival" probabilities between 0.5 and 1.0, and 27 stopped negative pions, with "survival" probabilities between 0.6 and 0.9, have been identified. Using the same procedure as for O-Pb, the following experimental values for $\langle \pi^{-} \rangle / \langle \pi^{+} \rangle$ ratio have been obtained: (a) 0.134±0.030; (b) 0.135±0.028; (c) 0.133±0.028 (d) 1.786±0.468; (e) 2.130±0.583. The increase of the errors on the experimental values of the $\langle \pi^{-} \rangle / \langle \pi^{+} \rangle$ ratio is related to the significant decrease of the statistics for negative pions in C-Cu central collisions. The relative errors in $\langle \pi^{-} \rangle / \langle \pi^{+} \rangle$ ratio do not exceed 30 %. For this collision the predictions of the isobar model suggest 1.37, and the isospin asymmetry is 1.83.

The experimental values of this ratio, for the two interesting situations, in O-Ne central collisions at 4.5 A GeV/c are: 1.292±0.724, respectively, 1.386±0.814. The low statistics, especially for stopped negative pions, increases very much the experimental errors.

An interesting problem is that if these experimental results are in agreement with those obtained for this ratio in different nucleus-nucleus collisions at different beam energies.

At GSI Darmstadt, in Au-Au central collisions at 1 A GeV, for low momenta region of the spectrum, a global $<\pi^->/<\pi^+>$ ratio of 1.94±0.10 is reported, and, for pions with very low momenta, $p<200$ MeV/c, a higher experimental value of this ratio is reported, namely: 2.80 [35,54]. In the same collision, Au-Au, but at higher energy, namely 10.7 A GeV, in an experiment performed at the AGS from BNL the $<\pi^->/<\pi^+>$ ratio for pions with low transverse momenta a global experimental value of 1.5 is reported [56]. In other asymmetric collisions, Ar-Pb, at 2.1 A GeV, in an experiment performed at LBL the experimental value of the $<\pi^->/<\pi^+>$ ratio is 1.47±0.05 [39]. Interesting results are reported in experiments performed at CERN. In symmetric and asymmetric collisions, Pb-Pb at 158 A GeV and S-S at 200 A GeV, respectively, S-Pb at 200 A GeV, only in Pb-Pb collisions at 158 A GeV, for pions with very low momenta, significant increase of the $<\pi^->/<\pi^+>$ ratio can be observed [57-59]. The experimental results obtained in ^{40}Ca-^{40}Ca collisions at 1.05 A GeV reflect the same behaviour of the $<\pi^->/<\pi^+>$ ratio, for low pion momentum ($p<350$ MeV/c), at different angles in laboratory system [60].

Taking into account our experimental results, as well as the other experimental results we can observe that the $<\pi^->/<\pi^+>$ ratio decreases with the decrease of the number of participant protons. In the three central collisions at 4.5 A GeV/c the experimental values of the $<\pi^->/<\pi^+>$ ratio - in the two interesting cases - are in the proximity of the ratio between the atomic number of the target nucleus and the number of participant protons (2.07, 1.48, respectively, 1.04). These values are in the proximity of the ratio between the sum of the atomic numbers of the two colliding nuclei and the number of participant protons (2.27, 1.78 and 1.54), too. The experimental results on the $<\pi^->/<\pi^+>$ ratio, as well as some experimental results obtained by pionic interferometry and some estimations [61,62], suggest influences of this ratio on the pionic source size and the nuclear matter flow. The increase of the particle source velocity (which increases with the beam energy) involves the decrease of the $<\pi^->/<\pi^+>$ ratio, too [35,54].

The different behaviours of the $<\pi^->/<\pi^+>$ ratio suggest the importance of the Coulomb effects in nucleus-nucleus collisions at high energies [54,63]. Taking into account the dependence of this ratio on the pion momentum some connections with the specific conditions (ρ,T) of the nuclear matter at the pion emission could be obtained. The pions with low momenta could be related to lower values of the density and temperature, as well as to the formation of the resonance matter [19,33]. The presence of significant percent of Δ resonance in nuclear matter formed in relativistic nuclear collisions could explain the high component of low momentum of the negative pion spectrum. Recent experimental results obtained in Ni-Ni collisions at energies between 1 and 2 A GeV indicate a 10% up to 20 % proportion of the Δ resonance [64]. In Si-Pb collisions at 14 A GeV values between 30% and 40 % higher are reported [65]. In our collisions values between 10% and 20% are obtained [23,33]. The formation of the resonance matter could be related to some strange particle production mechanisms in nuclear matter, too. It is important to stress here that the resonance formation probability increase with the beam energy, and the presence of the resonances modify the temperature of the nuclear matter, especially [22]. These facts could change the critical parameters for different phase transitions.

These experimental results could help to a better explanation of the nucleus-nucleus collisions dynamics at high energy, reflecting the role of the Coulomb interaction, nuclear matter flow and resonance matter formation. The importance of the flow effects in the understanding of the experimental signals of the different phase transitions is stressed [66]. A competition among different particle production mechanisms was observed [28,67]. Therefore, it is important to continue the effort to find explicit formulae for the distribution functions included in the equation (3). These formulae could be in agreement with the results of different simulation codes. The absorption in spectator regions of some particles emitted from the participant region and the phenomena at the contact areas between spectator and participant regions can influence the collision dynamics. There are differences between primordial and absolute spectators, especially for asymmetric collisions and less central collisions.

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REFERENCES

1. D.K.Scott - Prog.Part.Nucl.Phys.IV(1980)5

2. S.Nagamiya - Prog.Part.Nucl.Phys.XV(1985)363
3. C.Beşliu et al - Prog.Part.Nucl.Phys.XV(1985)353
4. C.Beşliu, Al.Jipa - Rév.Roum.Phys.33(1988)409
5. Al.Jipa - Ph.D.Thesis, University of Bucharest, Faculty of Physics, 1989
6. Al.Jipa - Turkish Journal of Physics 19(1995)846
7. C.Beşliu, Al.Jipa - Rom.J.Phys.37(1992)1011
8. C.Beşliu, Al.Jipa - Il Nuovo Cimento A106(1993)317
9. El.Al-Baaj, S.Al-Baaj, C.Besliu, Al.Jipa - Il Nuovo Cimento A107(1994)1611
10. Al.Jipa, R.Zaharia - Paper Abstracts of the National Physics Conference, Constanta (Romania), October, 13-15, 1993, page 1
11. M.Gyulassy, Xin-Nian Wang - Preprint LBL, LBL-34246(2000)
12. NEXUS Code - http://www-subatech.in2p3.fr/~theo/nexus
13. UrQMD - http://www.th.physik.uni-frankfurt.de/~urqmd/urqmd.html
14. A.Kh.Abdurakhimov et al - Nucl.Phys.A362(1981)376
15. M.Kh.Anikina et al - Z.Phys.C9(1981)105
16. M.Kh.Anikina et al - Phys.Rev.C33(1986)895
17. Al.Jipa - J.Phys.G: Nucl.Part.Phys.22(1996)231
18. Al.Jipa, C.Beşliu, Maria Iosif, R.Zaharia - Il Nuovo Cimento A112(1999)179
19. Al.Jipa, C.Beşliu, R.Zaharia, A:M.David - J.Phys.G: Nucl.Part.Phys.22(1996)221
20. B.R.Martin - Statistics for Physicists - Plenum Press, London and New York, 1971
21. P.Carruthers, C.C.Shih - Int.J.Mod.Phys.A2(1987)1447
22. V.Metag - International School of Heavy Ion Physics "Probing the Nuclear Paradigm", Erice (Italy), 6-16.X.1993
23. Fl.Constantin, Al.Jipa, Gh.Ilie - Nucl.Instr.Meth.Phys.Res.A418(1998)440
24. Al.Jipa - Il Nuovo Cimento A108(1995)1271
25. Al.Jipa - Scientific Annals of the Bucharest University, Physics XL-XLI(1991-1992)41
26. Al.Jipa, Radu Mărginean - Romanian Reports in Physics 50(7-9)(1998)475
27. C.Beşliu et al - European Physical Journal A1(1998)65
28. C.Beşliu et al - Rom.J.Phys.43(1998)489
29. S.DasGupta, A.Z.Mekjian - Phys.Rep.72(1981)131
30. T.Suzuki et al - Phys.Lett.B257(1991)27
31. J.P.Vary - Phys.Rev.Lett.40(1977)295
32. D.Hahn, H.Stöcker - Nucl.Phys.A452(1986)723
33. C.Beşliu, Nicoleta Ioneci, Al.Jipa, R.Zaharia - Romanian Reports in Physics 48(1998)425
34. J.Cugnon, J.Van der Meulen - Proceedings of the Winter College on Fundamental Nuclear Physics, Trieste, Italy, 1984, World Scientific, Singapore, New Jersey, London, Hong Kong, 1984, pag.1372
35. H.Oeschler - Technische Universität Darmstadt Preprint - IKDA98/20(1998) - and invited lecture at International Nuclear Physics Conference, 24-28.VIII.1998, Paris, France
36. A.Sandoval et al - Phys.Rev.Lett.45(1980)874
37. J.W.Harris et al - Phys.Lett.B153(1985)378
38. Cheuk-Yin Wong - Introduction to High Energy Heavy Ion Collisions, World Scientific, Singapore, New Jersey, London, Hong Kong, 1994
39. S.Nagamiya et al - Phys.Rev.C24(1981)971
40. T.Murakami et al - Proceedings of the 10th International Conference on Nuclear Reactions Mechanisms, Varenna, Italy, 9-15.VI.1997 (Editor: E.Gadioli)
41. T.Alber et al (NA 35 Collaboration) - Z.Phys.C73(1997)443
42. Al.Jipa, Coralia Labu, Cleopatra Simion - Romanian Reports in Physics 48(1996)459
43. Al.Jipa - Strangeness production in nucleus-nucleus collisions at 4.5 A GeV/c - Physics of Strangeness Program at National Institute for Nuclear Theory at University of Washington, Seattle (USA), 8.XI.-4.XII.1998 Preprint University of Washington, Seattle, USA, Institute for Nuclear Theory DOE/ER/40561-36-INT98(1998)
44. C.Beşliu, Al.Jipa - Rom.J.Phys.44(1999)237
45. P.J.Bussey, I.G.Knowles (editors) - Proceedings of the XXVII International Conference on High Energy Physics, Glasgow, Scotland, U.K., 20-27 July 1994, Institute of Physics Publishing, Bristol and Philadelphia, 1995
46. C.Beşliu et al - Rom.Rep.Phys.48(1996)407
47. C.Beşliu et al - Proceedings of the International Conference on Large Scale Collective Motion of Atomic Nuclei, Brolo (Messina), Italy, 15-19.X.1996 (G.Giardina, G.Fazio, M.Lattuada, - editors), World Scientific, Singapore, New Jersey, Hong Kong and London, 1997, 307-317
48. C.Dover - Nucl.Phys.A590(1995)333c

49. C.A.Ogilvie - Phys.Let.B436(1998)238
50. Tai An, Sa Ben-Hao - Phys.Rev.C57(1998)261
51. S.A.Bass et al - Phys.Rev.Lett.81(1998)4092
52. C.Beşliu et al - Prog.Part.Nucl.Phys.XX(1988)243
53. C.Muentz et al - Z.Phys.A357(1997)399
54. A.Wagner et al - Phys.Lett.B420(1998)20
55. J.Cleymans et al - Phys.Rev.C57(1998)3319
56. L.Ahle et al - Nucl.Phys.A610(1996)139c
57. J.Stachel - Nucl.Phys.A610(1996)509c
58. Nu Xu et al (NA 44 Collaboration) - Nucl.Phys.A610(1996)175c
59. D.Di Bari et al (WA85 Collaboration) - Nucl.Phys.A590(1995)307c
60. J.W.Harris et al - Phys.Rev.C41(1990)147
61. D.Beavis et al - Phys.Rev.C27(1983)910
62. S.A.Voloshin, W.E.Cleland - Phys.Rev.C53(1996)917
63. H.W.Barz, J.P.Bondorf, J.J.Gaardhöje, H.Heiselberg - Phys.RevC57(1998)2536
64. B.Hong et al (FOPI Collaboration) - Phys.Lett.B407(1997)115
65. J.Barrette et al (E814 Collaboration) - Phys.Lett.B351(1995)93
66. Al.Jipa et al - Influences of the flow, correlations, and collision geometry on the signals of the anomal states and phase transitions in nuclear matter - Physics of Strangeness Program at National Institute for Nuclear Theory at University of Washington, Seattle (USA), 8.XI.-4.XII.1998
Preprint University of Washington, Seattle, USA, Institute for Nuclear Theory DOE/ER/40561-38-INT98(1998)
67. C.Beşliu et al – accepted for publication in Nuclear Physics A

Table 1

Experimental results for non-central ordinary moments obtained in peripheral nucleus-nucleus collisions at 4.5 A GeV/c

A_P-A_T	*He-Li*	*He-C*	*He-Ne*	*He-Al*	*He-Cu*	*He-Pb*
m'_{1exp}	*0.85±0.02*	*1.05±0.05*	*1.14±0.05*	*1.33±0.05*	*1.65±0.08*	*1.87±0.08*
m'_{2exp}	*1.57±0,05*	*2.14±0.13*	*2.59±0.17*	*3.35±0.19*	*4.67±0.30*	*5.82±0.31*
m'_{3exp}	*3.63±0.18*	*5.46±0.44*	*7.46±0.67*	*10.73±0.87*	*16.37±1.43*	*22.01±1.54*
m'_{4exp}	*10.29±0.77*	*16.42±1.79*	*25.76±3.14*	*41.28±5.07*	*67.22±8.04*	*95.65±8.58*
N_{ev}	*4026*	*1099*	*988*	*1239*	*804*	*1048*

Tabel 2

Experimental results for non-central ordinary moments obtained in central nucleus-nucleus collisions at 4.5 A GeV/c

A_P-A_T	*O-Ne*	*O-Pb*	*C-Cu*
N	*290*	*2693*	*100*
M_{1exp}'	*4.91±0.22*	*11.83±0.25*	*6.55±0.24*
M_{2exp}'	*27.69±0.33*	*150.13±3.36*	*48.83±3.44*
M_{3exp}'	*168.90±15.98*	*2009.62±49.15*	*401.53±42.11*
M_{4exp}'	*1091.40±96.85*	*28073.4±756.7*	*3572.6±502.2*

Table 3

The number of stopped charged particles identified, with different probabilities (eq.(5)), for $L_{arc}\pm\sigma(L_{arc})$, in O-Pb central collisions at 4.5 A GeV/c

P [%]	Nr part	p	Σ^+	Σ^-	Ω^-	Ξ^-	π^+	π^-	K^+	K^-	d	μ^+	μ^-
≤10	75	-	50	12	3	10	-	-	-	-	-	-	-
(10,20]	6	-	3	1	-	2	-	-	-	-	-	-	-
(20,30]	7	-	-	-	-	-	-	-	2	5	-	-	-
(30,40]	5	-	-	-	-	-	-	-	3	2	-	-	-
(40,50]	10	-	-	-	-	-	-	-	7	3	-	-	-
(50,60]	11	-	-	-	-	-	-	-	5	6	-	-	-
(60,70]	63	-	-	-	-	-	47	-	8	8	-	-	-
(70,80]	184	-	-	-	-	-	60	86	38	-	-	-	-
(80,90]	358	-	-	-	-	-	230	110	18	-	-	-	-
(90,100)	102	-	-	-	-	-	97	-	5	-	-	-	-
100	613	422	-	-	-	-	-	-	-		136	41	14

Table 4

The number of stopped charged particles identified, with different probabilities (eq.(5)), for $L_{arc} \pm \sigma(L_{arc})$, in C-Cu central collisions at 4.5 A GeV/c

P [%]	Nr part	p	Σ^+	Σ^-	Ω^-	Ξ^-	π^+	π^-	K^+	K^-	d	μ^+	μ^-
≤10	26	-	20	4	1	1	-	-	-	-	-	-	-
(10,20]	-	-	-	-	-	-	-	-	-	-	-	-	-
(20,30]	1	-	-	-	-	-	-	-	1	-	-	-	-
(30,40]	1	-	-	-	-	-	-	-	1	-	-	-	-
(40,50]	3	-	-	-	-	-	-	-	2	1	-	-	-
(50,60]	22	-	-	-	-	-	20	-	2	-	-	-	-
(60,70]	39	-	-	-	-	-	24	8	6	1	-	-	-
(70,80]	46	-	-	-	-	-	29	7	9	1	-	-	-
(80,90]	105	-	-	-	-	-	88	12	5	-	-	-	-
(90,100)	41	-	-	-	-	-	40	-	1	-	-	-	-
100	287	223	-	-	-	-	-	-	-	-	43	17	4