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SMALL-ANGLE CORRELATIONS OF IDENTICAL PARTICLES IN CARBON-CARBON INTERACTIONS AT P = 4.2 GeV/c PER NUCLEON

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The determination of the size of the emission volume of secondary particles is one of the goals of studying correlations between identical particles with small relative momenta[1-7]. Several papers devoted to pion and proton interferometry applied to nucleus-nucleus collisions at relativistic energies have been published so far[8-11]. In this paper we investigate such $\pi^-\pi^-$ and pp correlations in C+C interactions at P = = 4.2 GeV/c per nucleon.

Experimental data have been obtained in the 2 m JINR propane bubble chamber. Our sample consists of 1191 C+C inelastic and 1394 C+C "central" events. As "central", we took events with no more than two positively charged particles having momenta $P_{lab} \geq 3$ GeV/c and emitted at angles $\theta \leq 4°$ with respect to the beam direction.

The reactions studied were:

$$(C + C)_{inel.} \to \pi^-\pi^- + X, \qquad (I)$$

$$(C + C)_{inel.} \to pp + X, \qquad (II)$$

$$(C + C)_{centr.} \to \pi^-\pi^- + X, \qquad (III)$$

$$(C + C)_{centr.} \to pp + X. \qquad (IV)$$

555 events of the type (I), 1179 of the type (II), 1091 of the type (III) and 1394 of the type (IV) were found.

It has been shown that in the case of identical pions two-particle small-angle correlations are satisfactorily described by quantum statistics alone[1-5], while for protons one should also take into account attractive strong and repulsive Coulomb interactions[6,7].

The experimental ratio $R(q,p) = D(q,p)/D^{backgr.}(q,p)$, where $D(q,p)$ is the density of pion (proton) pairs in phase space and $D^{backgr.}(q,p)$ is the corresponding density obtained by mixing together particles from different events, can be described with the formulae:

$$R_{\pi\pi}(q,p) = 1 + \lambda \exp(-\vec{q}^2 r_o^2 - \tau^2 q_o^2) \qquad (1)$$

for pions and

$$R_{pp}(q,p) = A_c(k^*)\,[1 + B_o(q,p,r_o,\tau) + B_i(q,p,r_o,\tau)] \qquad (2)$$

for protons.

The parameters r_0 and τ, which characterize the space-time size of the particle radiation volume, were introduced assuming a Gaussian distribution of particle emission sources. One should notice that the mean square radius of the particle emission region is by $\sqrt{3}$ larger than r_0.

The kinematical quantities used in formulae (1) and (2) are defined as: $P_{1,2}$ - four-momenta of particles, $q = P_1 - P_2$, $p = P_1 + P_2$, $q_0 = E_1 - E_2$, $k^* = 0.5\sqrt{-q^2}$.

The parameter λ ($\lambda \leq 1$) depends on the configuration of the particle emission region, their degree of coherence and on the specific dynamical correlations in the processes studied/5,12-14/. The limited statistics allowed us to study only one-dimensional ratios $R(q,p)$ (integrated over q_0), so the obtained value of λ has no clear sense, being affected by the integration over q_0. The functions $B_0(q,p,r_0,\tau)$, $A_c(k^*)$ and $B_i(q,p,r_0,\tau)$ in formula (2), describing effects of quantum statistics, Coulomb and final-state strong interactions, respectively, have been calculated according to formulae (8), (29) and (10-11) of ref./7/.

Experimental distributions for $\pi^-\pi^-$ pairs, together with fitted curves, are presented in Fig.1. The mean square radius $\langle r^2 \rangle^{1/2}$ in the nucleon-nucleon CM system has been found to be (2.75 ± 0.72) fm and (3.76 ± 0.88) fm for all inelastic and central events, respectively. Despite the fact that experimental errors are relatively large (which is caused by poor statistics), one can conclude that for a smaller impact parameters of the collision the size of the pion emission volume increases. Our results are consistent with those obtained for collisions of Ar nuclei of 1.8 GeV per nucleon with a heavy target/8/.

Correlations between protons have been searched for in two different groups of protons: those with $P_{lab} \leq 300$ MeV/c, which can be considered as target fragments and those emitted outside the fragmentation regions of colliding nuclei.

In Figs.2 and 3 we present experimental values of the ratio $R(q,p)$ for these two groups of protons. The full lines are results of calculations according to ref./7/ assuming $r_0 = 3$ fm, $q_0 = 0$ and the velocity of the proton pair in the rest frame of the sources $V = 0.2$ for target fragments (Fig.2) and $r_0 = 1.5$, 2.0, 2.5 fm, $q_0 = 10$ MeV, $V = 0.6$ for protons which are neither beam nor target fragments (Fig.3). The parameter τ is assumed to be equal to 1 fm/c. One can notice that the maximum of the experimentally obtained pp correlation function for target fragments is shifted to higher values of k^* with respect to theoretical predictions. This is probably due to the presence of misidentified deuterons and tritons in our sample of slow protons.

No difference between the correlation functions for target fragments in central and all inelastic collisions is observed.

Fig.1. The $\vec{q}^2$ distribution for pairs of pions produced in all inelastic and central collisions. The curves are fitted. The parameter τ is assumed to be equal to 1 fm/c.

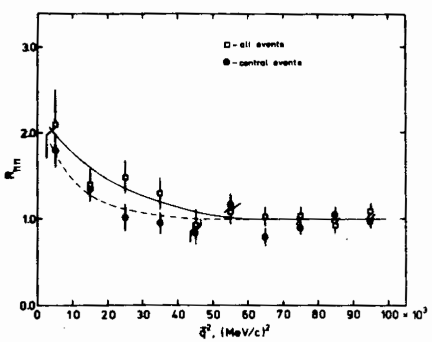
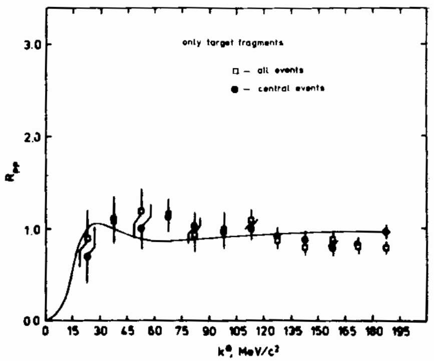


Fig.2. The k distribution for pairs of protons with $P_{lab} \leq 300$ MeV/c. The curve is calculated according to ref./7/ with parameters given in text.



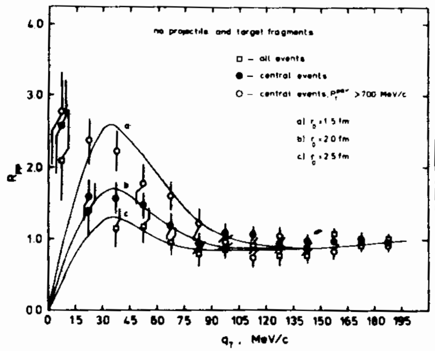


Fig.3. The q_T distribution ($\vec{q}_T = \vec{q} - \vec{n}\cdot(\vec{q}\cdot\vec{n})$, $\vec{n} = \frac{\vec{P}_1 + \vec{P}_2}{|\vec{P}_1 + \vec{P}_2|}$) for pairs of protons emitted outside fragmentation regions of colliding nuclei. The curves are calculated according to ref./7/ with parameters given in text.

The behaviour of the pp correlation function for protons emitted outside the fragmentation regions of colliding nuclei for $q_T < 15$ MeV/c differs from that predicted by theory, which is probably caused by the contamination of the sample by misidentified positive pions. This, however, should not change our conclusions because this part of the pp correlation function is mainly determined by Coulomb repulsion, which does not depend on the size of the radiation region.

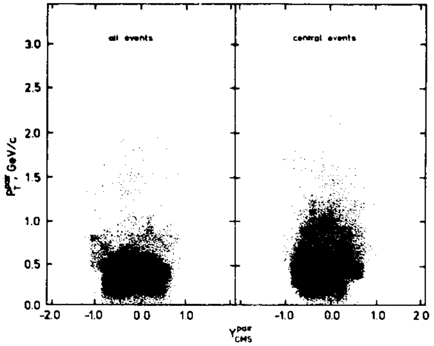


Fig.4. The scatter plot P_T vs Y for correlated ($q_0 \leq 300$ MeV, $q_T \leq 400$ MeV/c) pairs of protons emitted outside fragmentation regions of colliding nuclei.

One can conclude that protons produced outside the fragmentation regions of colliding nuclei in central events are emitted from smaller distances than those produced in all inelastic collisions. A similar effect has been observed by Zarbakhsh et al. in Ar + KCl interactions at 1.8 GeV per nucleon/11/.

Taking proton pairs with $P_T^{pair} \geq 700$ MeV/c, we can observe that in central collisions the radius of their emission volume is smaller than for all protons, while in all inelastic interactions only a small number of proton pairs with $P_T^{pair} \geq 700$ MeV/c has been found (see Fig.4), and no corresponding increase of the peak in the pp correlation function has been observed.

In Figs.5 and 6 are presented the rapidity distributions for correlated pairs of pions and protons. One can notice that for protons produced in all inelastic collisions the rapidity distribution is significantly wider than that for protons emitted in central events, and some structure is visible which allows to make the assumption about the existence of two fireballs. In such a case we would observe correlations between protons emitted from different fireballs as well as from the same one. As for a small impact parameter (central collisions) the separation of fireballs is smaller than in all inelastic collisions (which is caused by a smaller transparency of colliding nuclei), the radius of the proton radiation region should decrease with increasing the centrality of events. A more detailed analysis would require higher statistics.

The dependence of the size of the proton emission volume on their transverse momentum can be understood using the thermodynamical concept. Higher P_T of the proton pair corresponds to a higher temperature of the fireball, so taking such pairs, we observe the earlier stage of the expansion of the exciting volume.

In the case of pions, the situation is different. At energies of a few GeV per nucleon almost all pions are produced through Δ-isobars, so the radius of the pion radiation region is mainly

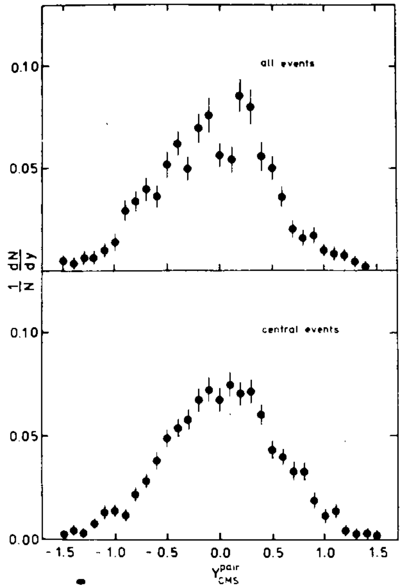


Fig.5. The rapidity distribution for pairs of pions in the kinematical region $q_0 \leq 300$ MeV, $\vec{q}^2 < 0.2$ (GeV/c)^2.

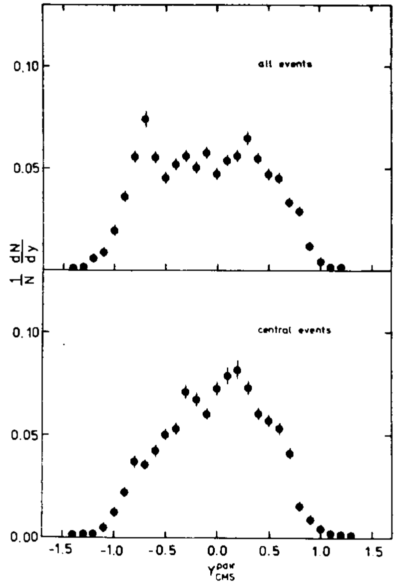


Fig.6. The rapidity distribution for correlated ($q_0 \leq 300$ MeV, $q_T \leq 400$ MeV/c) pairs of protons emutted outside fragmentation regions of colliding nuclei.

determined by their decay length, which is at least comparable to the separation of fireballs. The cross section for Δ-isobar production increases with decreasing the impact parameter of the collision, so the size of the pion emission volume should be larger rather in central events than in all inelastic ones.

CONCLUSIONS

Two-particle small-angle correlations between negative pions and between protons in all inelastic and central carbon-carbon interactions at P = 4.2 GeV/c per nucleon have been studied.

It has been shown that the size of the pion emission volume increases with increasing the centrality of events, while the radius of the proton radiation region seems to show the opposite dependence. It has been also found that protons with higher transverse momentum are emitted from smaller distances.

These observations can be qualitatively explained using the thermodynamical concept with two fireballs and taking the production of Δ-isobars into account.

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Ахабабян Н. и др. E1-83-670

Корреляции тождественных частиц в малых углах в углерод-углеродных взаимодействиях при P = 4,2 ГэВ/с

Изучаются двухчастичные корреляции тождественных частиц в малых углах в углеродных взаимодействиях при P = 4,2 ГэВ/с на нуклон. Делается сравнение экспериментальных $\pi^-\pi^-$ и pp корреляционных функций с теоретическими предсказаниями. Приводится указание на возможность существования двух файрболов в C+C-взаимодействиях при P = 4,2 ГэВ/с на нуклон.

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Small-Angle Correlations of Identical Particles in Carbon-Carbon Interactions at P = 4.2 GeV/c per Nucleon

Two-particle small-angle correlations between negative pions and between protons in all inelastic and "central" carbon-carbon collisions at P = 4.2 GeV/c per nucleon have been studied. A comparison of experimental $\pi^-\pi^-$ and pp correlation functions with theoretical predictions has been made. A possible evidence for the existence of two fireballs in C+C interactions at P = 4.2 GeV/c per nucleon is presented.

The investigation has been performed at the Laboratory of High Energies, JINR.

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