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KINEMATICAL AND INTERFERENCE CORRELATIONS OF PIONS IN eA INTERACTIONS

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KINEMATICAL AND INTERFERENCE CORRELATIONS OF PIONS IN eA INTERACTIONS:
Preprint ITEP 14-95/

P.V.Degtyarenko, E.A.Doroshkevich, G.A.Lekhin, A.V.Stavinsky,
A.V.Vlassov - M., 1995 - 20 p.

We report here the results on two pions correlations in eA interactions at 5GeV. Interferometry method is used to determine the size of the interaction region. Large angle correlations are studied as a function of secondary momenta and proton multiplicity.

Fig. - 12, ref. - 19.

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1 Introduction.

Correlations between particles (both kinematical and interference) are the powerful tool for the investigation of the mechanism of high energy nuclear reactions. Indeed interference correlations are widely used for the determination of the sizes of the interaction region [1, 2, 3]. Kinematical correlations could characterize the number of particles (degrees of freedom) which take part in the reaction [4, 5]. Earlier in [6] the dependence of protons correlations on integral characteristics of eA interactions has been studied. The examples of such integral characteristics are the multiplicity of identifyed secondary protons N_p and total energy deposition E_h. In [6] it has been shown that both sizes of the interaction region and kinematical correlations are sensitive to variations of integral parameters N_p or E_h. This is in a good agreement with scenario [3, 5] of particle nucleus interaction at high energy.

There are at least two points which differ fast (kinetik energy $\gg$ binding energy of nucleus) pions and protons production mechanism in nuclear reactions. First of all pions are not a nuclear fragments. While hadronization into nucleon must to be different in the presence of the barion rich environment and in vacuum it is not the same for pion [7]. The second point is possible difference in the absorbtion effects for pions and protons in nuclear matter [8]. It is interesting to determine the influence of these effects on correlations.

Investigation of the neutron's correlations [9] shown strong dependence of the size of the interaction region on neutrons momentum. It was interpreted as follows:

the long characteristic time of the evaporation process gives a considerable contribution to the measuring size for slow nucleons. The role of evaporation process for slow pions is not clear but it is unlikely the same as that for nucleons. Soft pions correlations give the size of the interaction region of the order of nucleon size [10]. Other available data [11] for soft pions interference agree both nucleon size and nucleus size. Correlations between fast pions give the sizes which are in accordance with fast protons data [12, 13]. So it would be interesting to determine the sizes of pions source both for soft pions and for fast pions in the same experiment.

In this paper the investigation of kinematical and interference correlations between two pions is presented.

2 Data analysis procedure.

The interactions of the beam (5 GeV e^+ and e^-) with residual gas (mainly H_2O) in the vacuum beam pipe have been detected by product at the large acceptance magnetic spectrometer ARGUS [14]. This sample (approximetely 115000 events) has been kindly placed at our disposal for physics analysis by collaboration ARGUS.

The procedure for the selection of beam-gas events has been described in [6, 13]. Trigger conditions and selection criteria make preference to interactions with oxygen in comparison with hydrogen. Multiplicity distribution in events sample and protons inclusive spectra proved to be similar to that from hadron-nucleus collisions [13, 15]. Thus one can hope that hydrogen has a little contribution in our events sample. For the investigation of pions correlations we used kinematical region of identified pion $0.08 < p < 0.9 GeV/c$, $|\cos\theta| < 0,75$ where p and θ - momentum and polar angle for secondary particle.

The two pion correlation function R_2^D has been calculated as normalized ratio of two distribution

$R_2^D = N_{12}(x)/N_{mix}(x)$

Here x is kinematical variable like relative momentum $q = | p_1 - p_2 |$, divergence angle ψ, $\cos\psi = (\vec{p_1} \cdot \vec{p_2})/p_1 p_2$, etc; N_{12} is the two pions distribution for real pairs recorded by detector; N_{mix} is the distribution for pairs composed of pions from different events (non correlated pairs). The statistical errors in $N_{mix}(x)$ distribution are negligible. In spite of the single particle registration effeciency is canceled in the R_2^D, a part of efficiency caused by triggers and drift chambers efficiency with respect to close tracks registration does not canceled.

The examples of such triggers are: the presence of at least one pair of charged tracks in the barrel region ($|\cos\theta| < 0.75$) with the azimuthal difference $\Delta\phi > 120°$, or the presence of at least one charged track in each z-hemisphere.

We calculated detector efficiency using the following procedure. We generated events sample according to some phenomenological model [7]. The most essential features of the model are:

a) The energy lost by particles for excitation of the nuclear matter is pro- portional to the length of the path inside nucleus.

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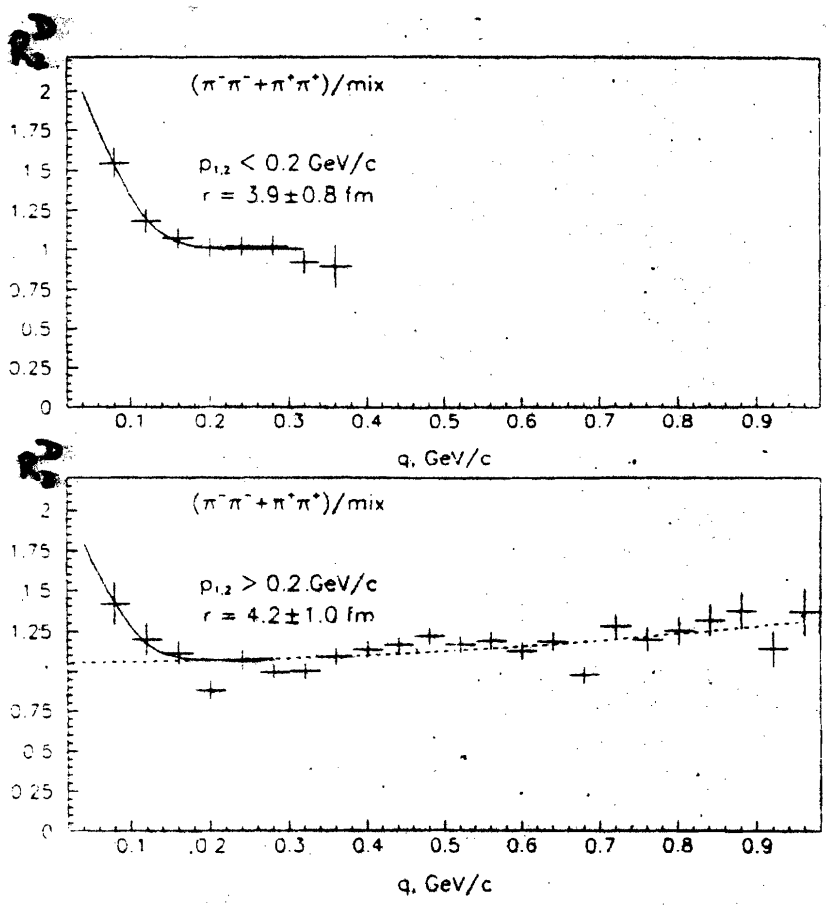

Fig. 12. The dependence of R_2^D on q for slow (see text,a) and fast (b) $\pi\pi$. Reference sample - mixing (see text).

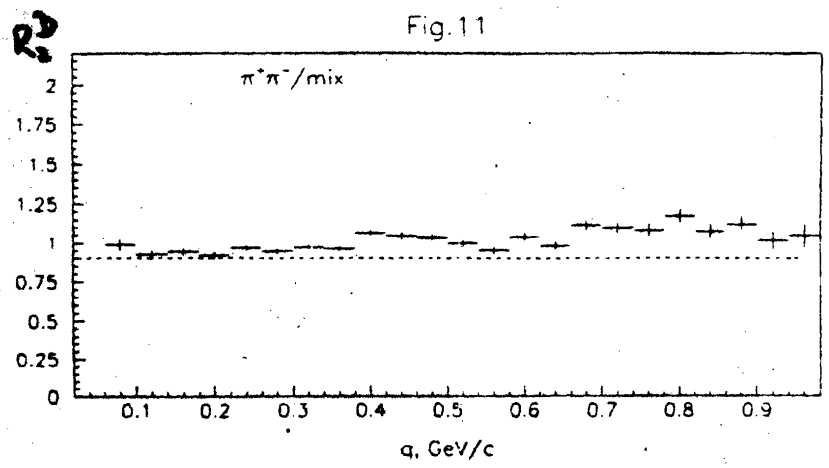

Fig. 11. The q dependencies of the ratio of distributions $N(\pi^+\pi^-)/N(\pi^+\pi^-)(mix)$

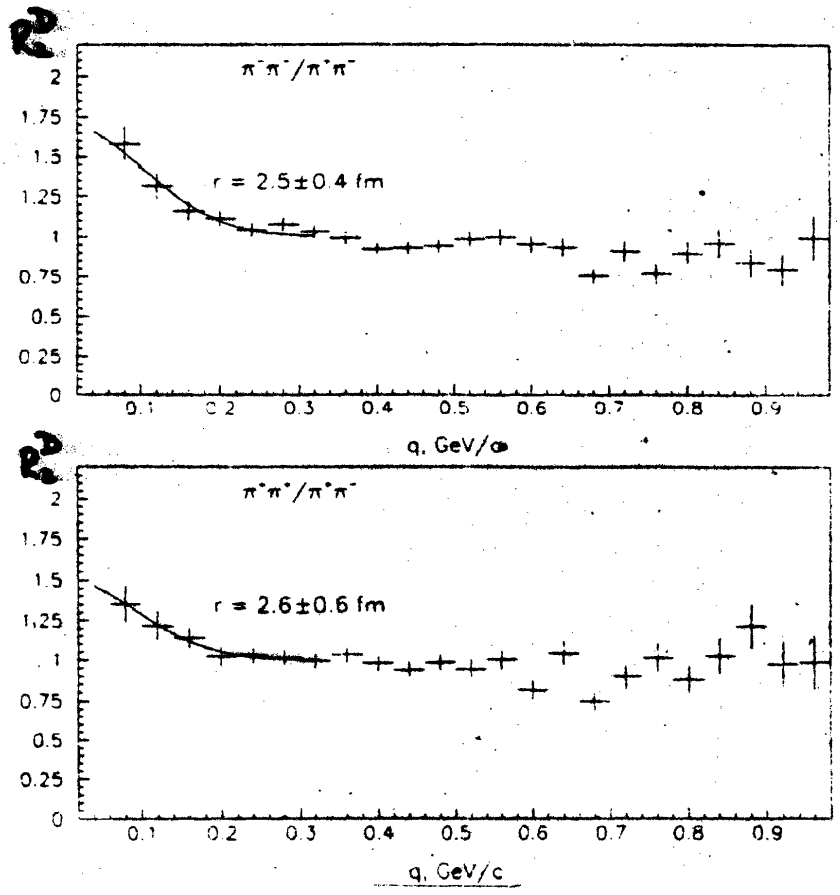

Fig. 10. The dependence of R_2^D on q for $\pi^-\pi^-$ (a) and for $\pi^+\pi^+$ (b). Reference sample - $\pi^+\pi^-$ (see text).

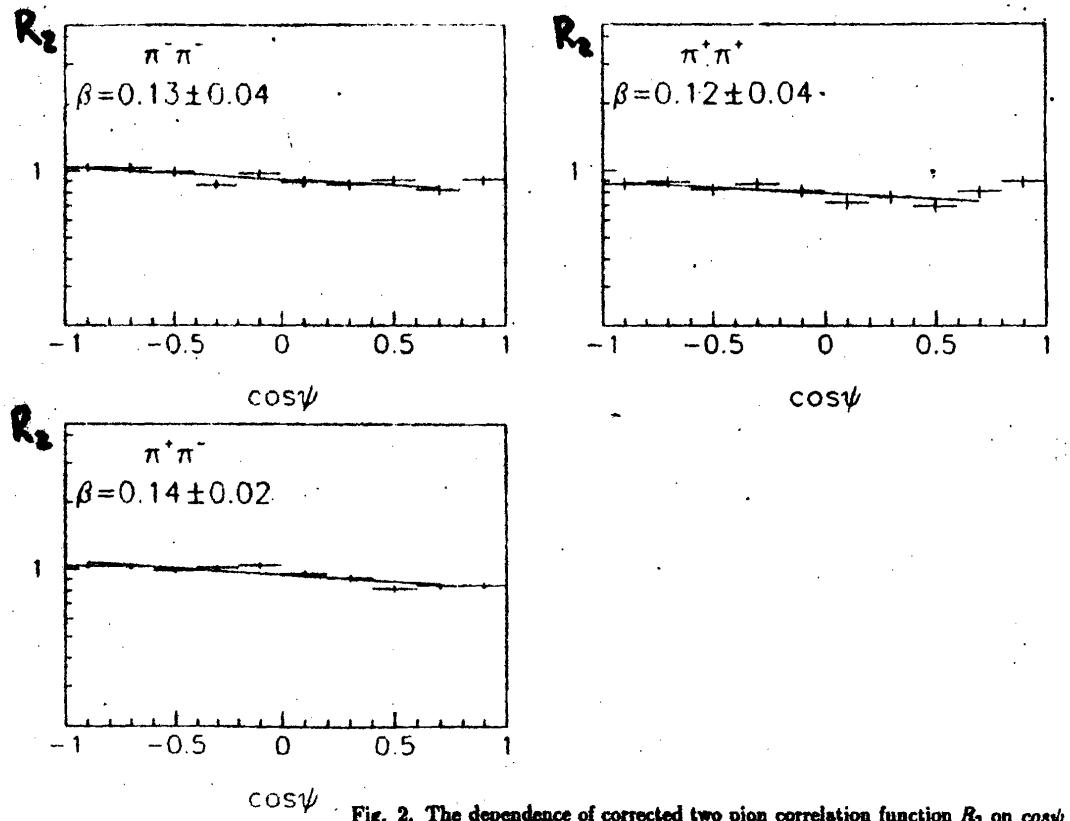

Fig. 2. The dependence of corrected two pion correlation function R_2 on $cos\psi$ for different pairs of pion.

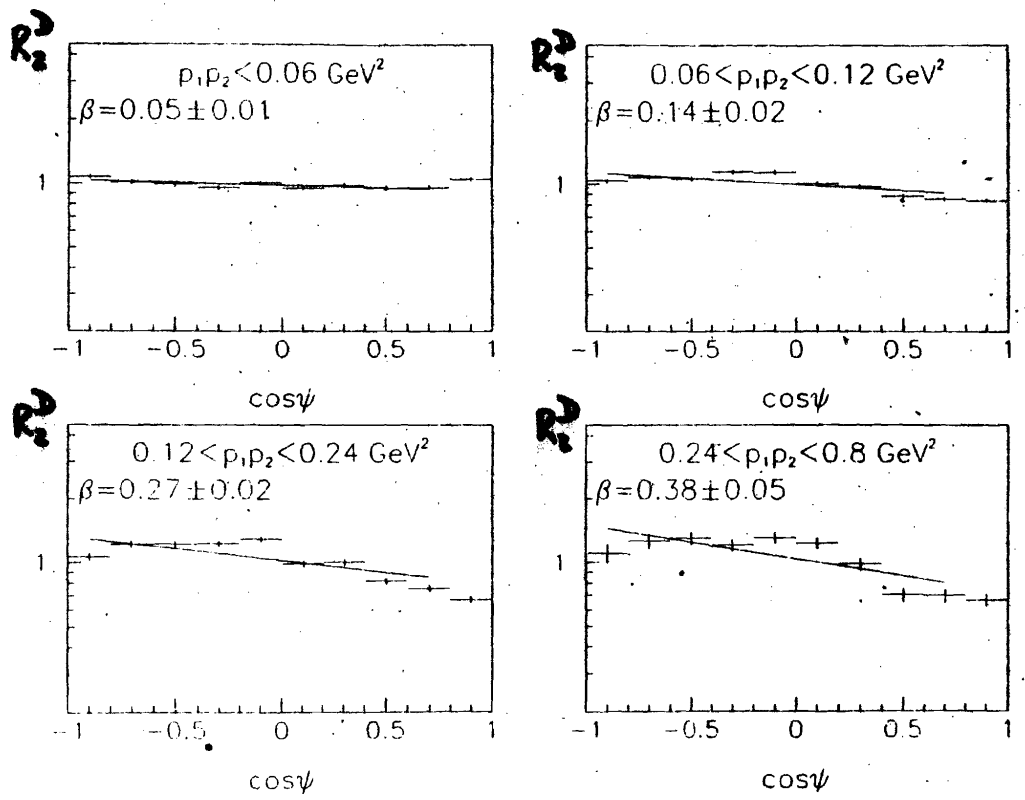

Fig. 3. The dependence of uncorrected two pion correlation function R_2^D on $\cos\psi$ for different intervals of $p_1 \cdot p_2$.

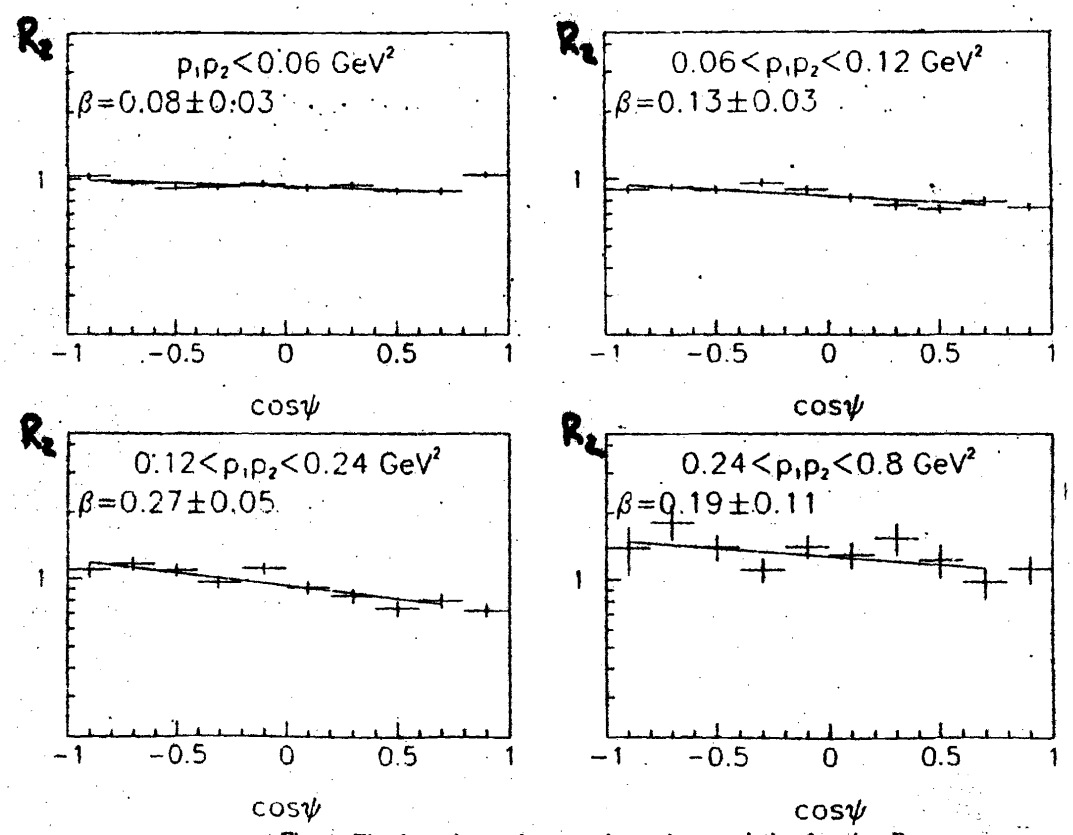

Fig. 4. The dependence of corrected two pion correlation function R_2 on $\cos\psi$ for different intervals of $p_1 \cdot p_2$.

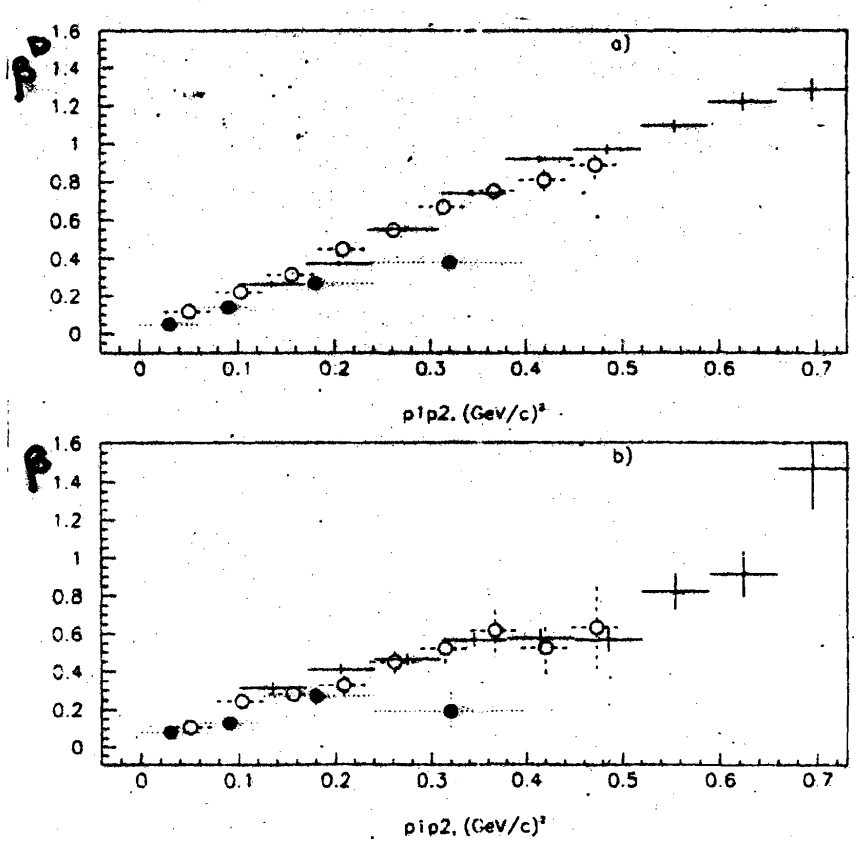

Fig. 5. The dependence of slopes β on p_1p_2 for pp – (+) [6], for πp – (o) [17], and for $\pi\pi$ – a pair. a) uncorrected data, b) corrected data.

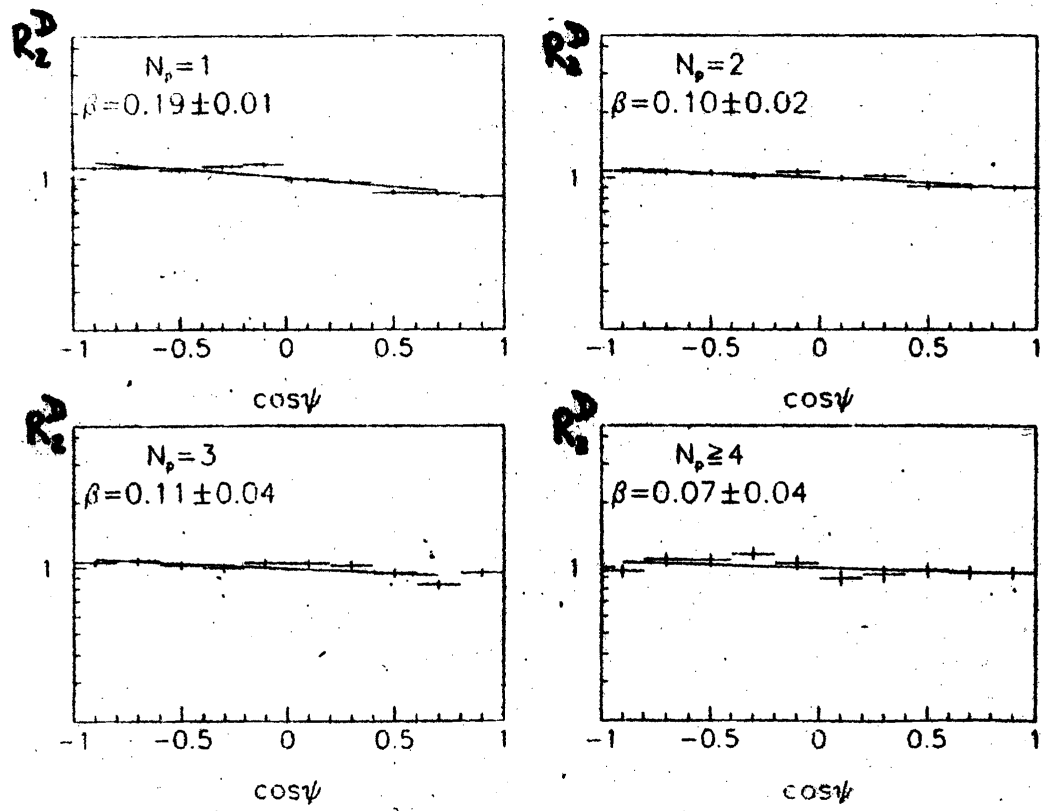

Fig. 6. The dependence of uncorrected two pion correlation function R_2^D on cosψ for different proton multiplicity N_p.

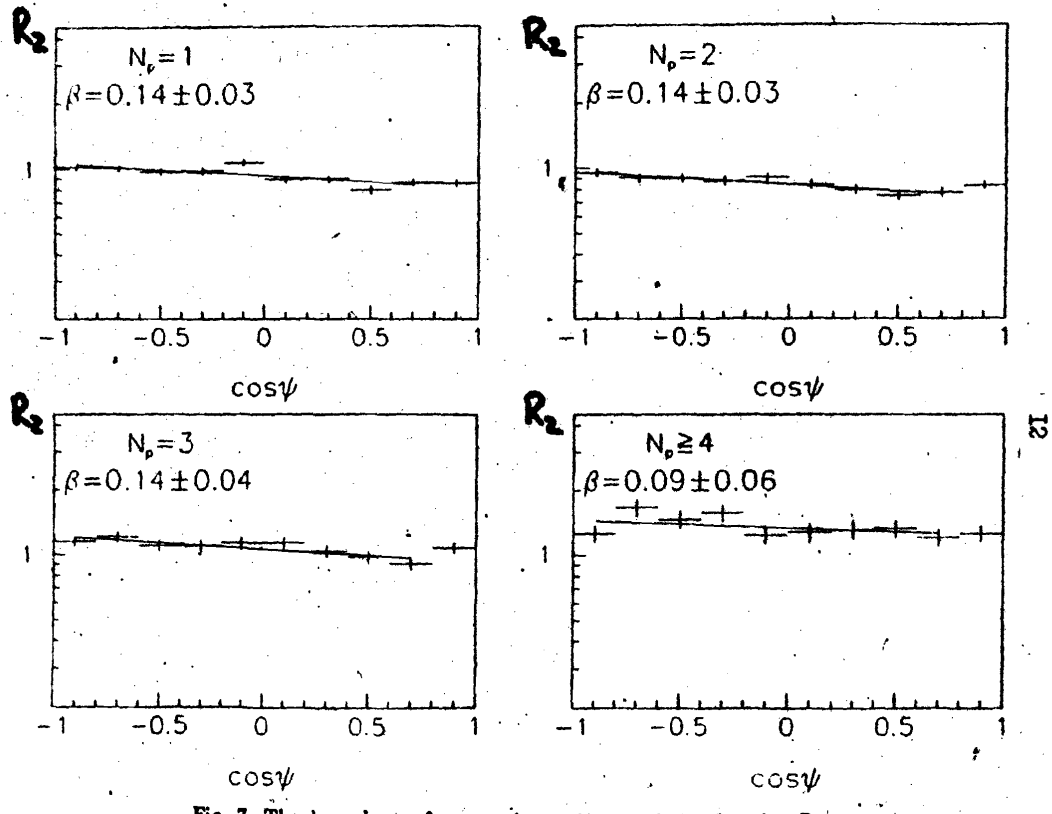

Fig. 7. The dependence of corrected two pion correlation function R_2 on $\cos\psi$ for different proton multiplicity N_p.

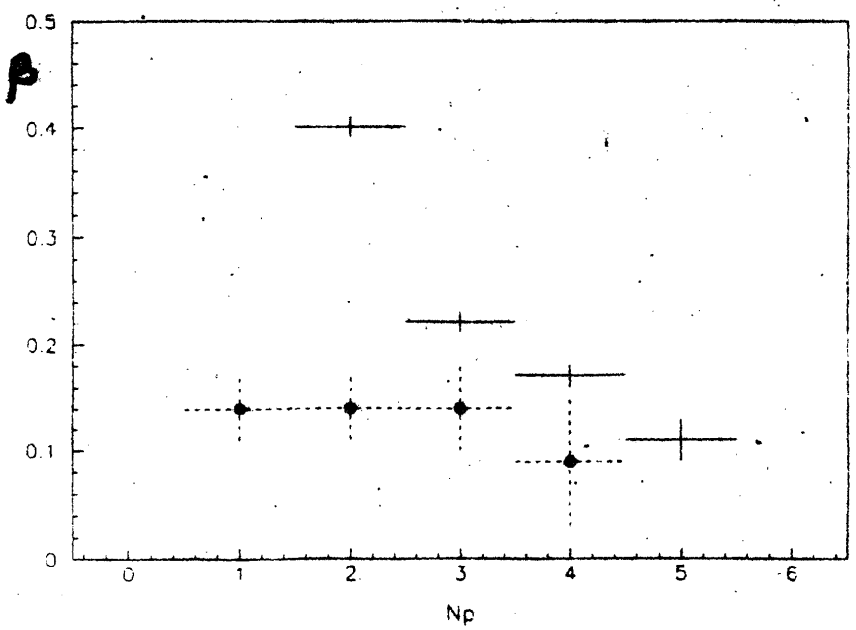

Fig. 8. The dependence of slopes β on N_p for $pp-(+)$ [6] and for $\pi\pi-e$ pair.(corrected data).

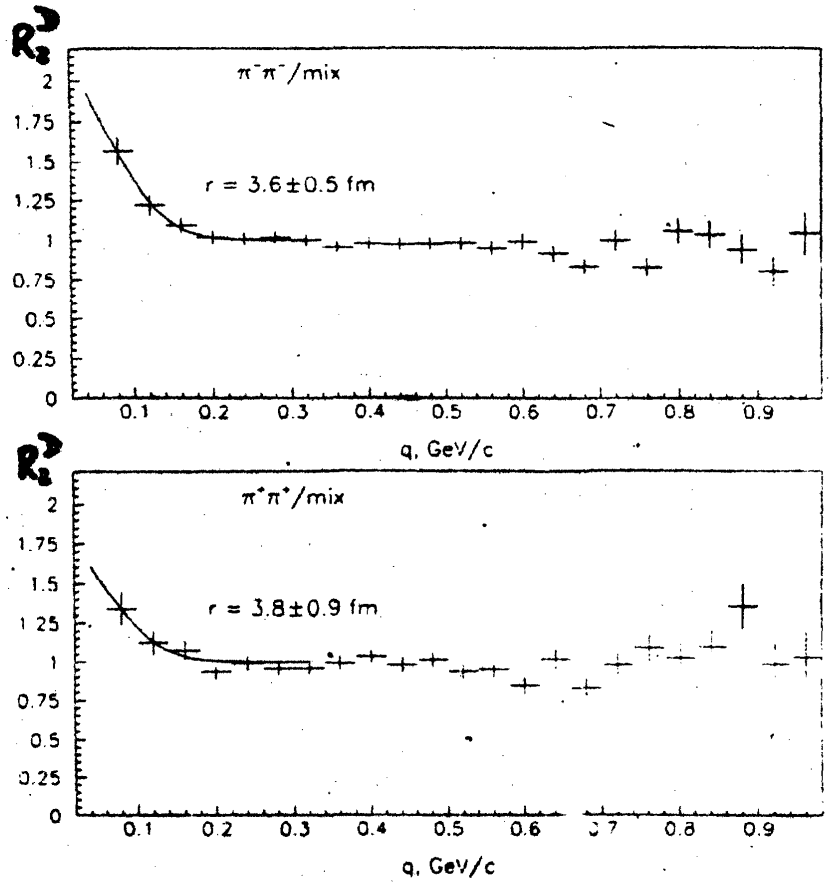

Fig. 9. The dependence of R_2^D on q for $\pi^-\pi^-$ (a) and for $\pi^+\pi^+$ (b). Reference sample - mixing (see text).

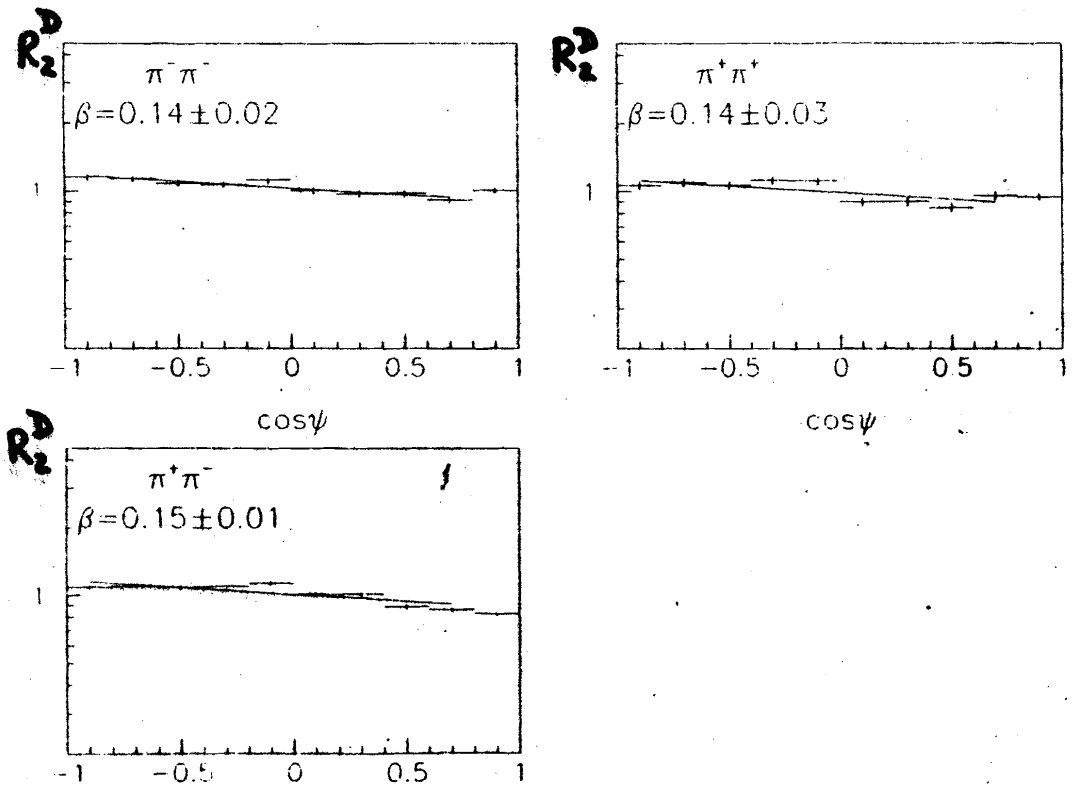

Fig. 1. The dependence of uncorrected two pion correlation function R_2^D on $\cos\psi$ for different pairs of pion.

$C \cdot (1 + exp(-q^2r^2/3))$. The r.m.s. radius for negative pions is equal to $3.6 \pm 0.6fm$ and for positive pions $3.8 \pm 0.9fm$.

Sometimes for the uncorrelated pions distribution pairs of unlike pions are used. The q dependencies of the ratios of distributions $N(\pi^{\pm}\pi^{\pm})/N(\pi^{+}\pi^{-})$ are shown in Fig. 10. The radius r for negative pions is equal $2.5 \pm 0.4fm$ and for positive pions - $2.6 \pm 0.6fm$. The difference between radius parameters obtained from Fig.9 and Fig.10 is due to reference sample only. Their ratio which is equivalent to correlation function for $\pi^{+}\pi^{-}$ is shown in Fig.11. One can see slow rize of R_2 with increasing of q.

If we select fast pions ($p > 0.2GeV/c$, see Fig.12) we find rize of R_2 at large q due to kinematical correlations. To detemine radius we will use parametrization $R_2(q) = C(1 + a \cdot q^2) \cdot (1 + exp(-q^2r^2/3))$. Radius r is equal to $4.2 \pm 1.0fm$. It corresponds to results have been published earlier [13]. Other results for fast pions emitting source size are $2.25 \pm 1.04fm$ [18] ($\pi(3.7GeV/c)C$ interactions), and $2.74 \pm 0.4fm$ [19] ($\pi(40GeV/c)C$ interactions).

Corelation function for slow pions ($p < 0.2GeV/c$) is shown in Fig.12. Parameter r for slow pions proved to be equal $3.9 \pm 0.8fm$. Other results for slow pions emitting source size are $0.8 \pm 0.4fm$ [10], and $1.3 \pm 0.4fm$ [11]. Both results were obtained for $p(7.5GeV/c)C \rightarrow \pi^{+}\pi^{+}X$) reaction.

4 Conclusion.

1.Small angle correlations between pions give the size of the interaction region compatible with target nucleus size both for fast and slow secondary pions.

2.The value of size extracted from data does not depend on the sign of pions but depend on reference sample.

3.Large angle correlations between pions show the angular and momentum dependence compatible with that for other secondaries.

4.Impact parameter dependence for large angle correlations between pions differ from that for secondary protons and could be related with absorbtion effects.

5 Acknowledgments

We would like to thank all members of ARGUS collaboration who made available for us the data set for beam-gas events analysis.

Table 2

$\overline{p_1 p_2}, (GeV/c)^2$	0.04	0.09	0.18	0.3
$\beta(uncorrected)$	0.05 ± 0.01	0.14 ± 0.02	0.27 ± 0.02	0.38 ± 0.05
$\beta(corrected)$	0.08 ± 0.03	0.13 ± 0.03	0.27 ± 0.05	0.19 ± 0.11

Correlation functions $R_2^D(cos\psi)$ and $R_2(cos\psi)$ for different intervals of pions momenta product $p_1 \cdot p_2$ ($p_1 \cdot p_2 < 0.06, \overline{p_1 \cdot p_2} = 0.04; 0.06 < p_1 \cdot p_2 < 0.12, \overline{p_1 \cdot p_2} = 0.09; 0.12 < p_1 \cdot p_2 < 0.24, \overline{p_1 \cdot p_2} = 0.18; p_1 \cdot p_2 > 0.24, \overline{p_1 \cdot p_2} = 0.3(GeV/c)^2$) are shown in Figs. 3,4. The slopes β are listed in Table 2. The Figures and table show that the larger mean value $p_1 \cdot p_2$ the stronger ψ-dependence of correlation function.

Earlier in [16] it has been shown that slopes β for pp and pd correlations are equal to each other within experimental errors at equivalent $p_1 \cdot p_2$. The analysis of beam gas events for studying of pp and πp correlations confirm such universality [17]. Comparison of slopes for $\pi\pi$, πp and pp correlations is shown in Fig. 5a,b. The dependence of β on $p_1 \cdot p_2$ for $\pi\pi$ correlations at $p_1 \cdot p_2 < 0.24(GeV/c)^2$ close to that for πp and pp correlations. The approximation of the momentum dependence of β for pions at $p_1 \cdot p_2 < 0.24(GeV/c)^2$ as $\beta = a \cdot (p_1 \cdot p_2)^b$ gives parameter $b = 0.9 \pm 0.4$. For πp and pp correlations (corrected data) parameters b are equal to 0.71 ± 0.06 and 0.74 ± 0.07 respectively [17].

In [8] it was found that pion azimuthal correlations for heavy nuclear target (Pb) have inverse dependence on azimuthal angle difference $\delta\phi$ while for light nucleus effect did not display explicitly. This effect was interpreted as absorbtion of pions produced at large impact parameter.

In this work we have only light nucleus target but we can try to select events sample with large impact parameter by choosing small protons multiplicity N_p events. Data on the dependence of uncorrected R_2^D (Fig.6) and corrected (Fig.7) two pion correlation function R_2 on $cos\psi$ for different proton multiplicity N_p are presented.

When N_p changes there are two tendency for pions: the increasing of β with decreasing N_p due to momentum conservation law and suppression of these increase due to pion absorbtion. Probably these two reasons compensate each other. The second reason is not important for two protons correlations. Therefore the dependence $\beta(N_p)$ for two pions differs from that for two protons (Fig.8).

b) Interference correlations.

It is well known that the correlations of identical pions at small relative momentum $\vec{q} = \vec{p_1} - \vec{p_2}$ are due to Bose-Einstein interference [1]. Interference effect allows to determine size of pion emission region. But the value of determined size affected by large angle correlations too. Another words it depends on the way of calculation of reference sample free of interference effects.

In this part of paragraph we use uncorrected data only because the phenomenological model does not fake into account interference effect.

In Fig. 9 correlation function $R(q)$ for $\pi^+\pi^+$ and $\pi^-\pi^-$ pais are shown. In this case reference distribution was obtained by mixing procedure (pions taken from different events). To determin r.m.s. radius r we use parametrization $R_2(q) =$

b) The massless nuclear constituents along the primary trajectory heat up to 200 Mev.

c) The energy and momentum are conserved during the hadronization stage.

d) The total transverse momentum of all secondaries equals 0., and the longitudinal component of the momentum results from the energy lost by the primary particle.

Discussion of the model is not the task of this paper. It is only important for us here that it reproduces inclusive [13] and correlation [6] characteristics sufficiently well.

We calculated two correlation functions: R_2^M for generated events and R_2^{MD} for the model enents passed through efficiency similation program. We used ratio $\epsilon = R_2^{MD}/R_2^M$ as the detector efficiency correction coefficient. We believe that this ratio provides a good estimate of efficiency, as the function R_2^{MD} is close to the function R_2^D.

Corrected correlation function R_2 is calculated as $R_2 = R_2^D/\epsilon$. Later both R_2 and R_2^D are presented.

3 Experimental results.

a) Large angle correlations.

Correlation functions $R_2^D(cos\psi)$ and $R_2(cos\psi)$ for $\pi^-\pi^-$,$\pi^+\pi^+$ and $\pi^+\pi^-$ pairs are shown in Fig.1,2. One can see that correlation functions decrease with increasing of $cos\psi$. We will parametrize correlation function as $R_2(cos\psi) = C \cdot exp{-}\beta cos\psi$ in the area $-1 < cos\psi < 0.8$, where β is slope parameter. In this parametrization we do not take into account interval $cos\psi > 0.8$ because of influence of interference correlations at small ψ (see next part.). For $\pi^+\pi^-$ pairs β does not variate for two fitting intervals: $-1 < cos\psi < 1$ and $-1 < cos\psi < 0.8$. It is expected result beccause of the absence of interference correlation for unlike pions. Slope parameters β proved to be independent on charge of pions in pair (see Table 1). So for the analysis of the kinematical correlations we will show results integrated over the charge of pions.

Table 1

particles	$\pi^+\pi^+$	$\pi^+\pi^-$	$\pi^-\pi^-$
$\beta(uncorrected)$	0.14 ± 0.03	0.15 ± 0.01	0.14 ± 0.02
$\beta(corrected)$	0.12 ± 0.04	0.14 ± 0.02	0.13 ± 0.04