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JINR — E1 - 12298

A STUDY OF AZIMUTHAL CORRELATIONS IN MULTIPARTICLE $\bar{P}P$ INTERACTIONS AT 22.4 GeV/c

Alma-Ata - Dubna - Helsinki - Moscow - Prague Collaboration

1979

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A STUDY OF AZIMUTHAL CORRELATIONS IN MULTIPARTICLE $\bar{P}P$ INTERACTIONS AT 22.4 GeV/c

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Submitted to Nuovo Cimento

Батюня Б.В. и др. **E1 - 12298**

Излучение азимутальных корреляций в многочастичных $\bar{p}p$ -взаимодействиях при 22,4 ГэВ/с

В работе изучались инклюзивные распределения по азимутальным углам пар пионов в $\bar{p}p$ -взаимодействиях при 22,4 ГэВ/с. Изучалась также зависимость параметра асимметрии B от переменных n_C, Δy^*, $\Delta p^*_{\parallel}$ и $\Delta p_{\perp}$. Было оценено влияние рождения ρ° и Δ^{++} -резонансов. Результаты показывают, что экспериментальные данные не могут быть объяснены ни рождением резонансов, ни эффектом Бозе- Эйнштейн симметрии.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1979

Batyunya B.V. et al. **E1 - 12298**

A Study of Azimuthal Correlations in Multiparticle $\bar{p}p$ Interactions at 22.4 GeV/c

The inclusive azimuthal distributions of pion pairs are studied in $\bar{p}p$ interactions at 22.4 GeV/c. The dependence of the asymmetry parameter B on n_C, Δy^*, $\Delta P^*_{\parallel}$ and $\Delta P_{\perp}$ -variables is studied. The influence of ρ° and Δ^{++} resonance production is estimated. The results show that neither the resonance production nor the Bose-Einstein symmetry effect suffice to explain the data.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1979

1. INTRODUCTION

Two-particle correlations have been recently studied in various multiparticle reactions of hadrons. Special consideration has been given to the angular correlations both in the exclusive[1-9] and inclusive or semi-inclusive[10-18] framework and to invariant mass dependence of the correlation function[19]. Our previous results on this subject were published elsewhere[19a]. The question which still draws attention is which mechanism is responsible for the difference between the distributions of like and unlike charged pion pairs. Two explanations are usually given: the Bose-Einstein symmetry effect[20] and the influence of resonances. The global effect of resonances on the opening angle asymmetry has been found[21] to be more pronounced than the Bose-Einstein effect but, e.g., the authors of paper[22] conclude that resonance production accounts for only 30% of the observed phenomenon. The purpose of this work is to present data on azimuthal correlations and to estimate the effect of resonance production on these correlations in $\bar{p}p$ interactions at 22.4 GeV/c.

2. DATA SAMPLE

Our results are based on a sample of 25321 interactions obtained from an exposure of the 2m HBC "Ludmila" to a 22.4 GeV/c antiproton beam at Serpukhov. Details of the experiment have been published elsewhere [23,24] in connection with a study of topological cross section and single particle distributions. The reaction studied is $\bar{p}+p\to$ two charged pions + anything. The charged particles with laboratory momenta of ≤ 1.2 GeV/c were identified by ionization. To study the correlations between two charged pions, we excluded the identified protons and particles with $|x| > 0.5$. The latter cut is based on results of the single distributions showing that the positive particles with $x< -0.5$ are mostly identified protons. Assuming charge invariance, all negative particles with $x > 0.5$ are taken as antiprotons. Except a study of the multiplicity dependence of B, we used only events with charged multiplicity $n_c \geq 6$. There are 7000 such events in our sample.

3. AZIMUTHAL DISTRIBUTIONS

In this section we present results on the distribution of azimuthal angle $\phi_{ij} = \arccos[(\bar{P}_{\perp i}\cdot\bar{P}_{\perp j})/|\bar{P}_{\perp i}|\cdot|\bar{P}_{\perp j}|]$ for both like and unlike pion pairs. These distributions $p(\phi_{ij})$ are characterized by the asymmetry parameter

$$B^{ij} = [\int_{\pi/2}^{\pi} P(\phi_{ij})d\phi_{ij} - \int_0^{\pi/2} P(\phi_{ij})d\phi_{ij}] / \int_0^{\pi} P(\phi_{ij})d\phi_{ij}$$

denoted as B^{++}, B^{--}, B^{+-} for the $|+,+|$, $|-,-|$ and $|+,-|$ charged pion combinations, respectively. The errors presented in the figures are statistical only.

Results on the multiplicity dependence of the asymmetry parameter B are given in Table 1 and plotted in fig. 1. The decrease of B with multiplicity is a general feature of multiparticle processes caused by kinematic constraints on transverse momenta [1]. The difference between B^{++} and B^{--} indicates experimental biases, but in our sample it is significant only for four-

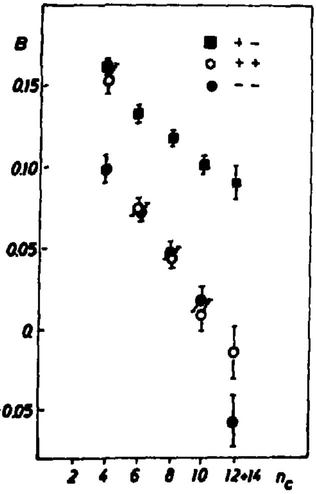
Table 1

Asymmetry parameters as a function of a charged multiplicity

n_C	B^{++}	B^{--}	B^{L}	B^{U}	$B^{U} - B^{L}$
4	0.153±0.013	0.097±0.013	0.124±0.008	0.160±0.006	0.036±0.010
6	0.073±0.007	0.070±0.007	0.071±0.006	0.132±0.004	0.061±0.007
8	0.044±0.008	0.047±0.008	0.046±0.006	0.116±0.004	0.070±0.007
10	0.009±0.011	0.018±0.011	0.013±0.008	0.100±0.005	0.087±0.009
12+14	−0.014±0.023	−0.058±0.023	−0.037±0.016	0.090±0.010	0.127±0.019
$n_C \geq 6$	0.046±0.005	0.046±0.005	0.046±0.003	0.120±0.003	0.074±0.004

prong events. Later on we shall study the dependence of B only for like (L) and unlike (U) charged pion pairs.

Figure 2 shows the increase of $\Delta B = B^U - B^L$ with multiplicity. For the total sample of 7000 events



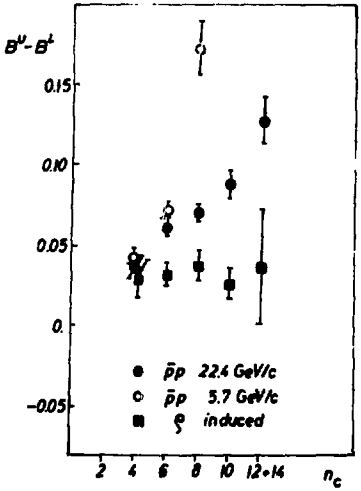


Fig.1. Asymmetry parameter B as a function of charged multiplicity for (++), (-,-) and (+,-) pion pairs, respectively.

Fig.2. $B^U - B^L$ as a function of n_c. Comparison is made with the $\bar{p}p$ experiment at 5.7 GeV/c and with the values obtained from the like pion pair distribution by the method described in the text.

with $n_c \geq 6$ we get $B^{++} = 0.046 \pm 0.005$, $B^{--} = 0.046 \pm 0.005$ $B^L = 0.046 \pm 0.003$ and $B^U = 0.120 \pm 0.003$. To localize the region where this difference originates from, we present in fig. 3a the dependence of azimuthal asymmetry on rapidity difference $\Delta y^* = |y_i^* - y_j^*|$. The difference between unlike and like pion pairs is the largest for particles with small rapidity gap, but it persists up to $\Delta y^* \sim 2$ in agreement with the results obtained in other reactions and at other energies /8,20,21/.

Батюня Б.В. и др. **E1 - 12306**

Сопоставление распределений по множественности заряженных частиц в $\bar{p}p$- и pp-взаимодействиях и проверка схемы дуальной унитаризации

На основе распределения по множественности заряженных частиц в $\bar{p}p$-взаимодействиях при 22,4 ГэВ/с получены характеристики процесса аннигиляции антипротонов. Сопоставление этих характеристик с аналогичными характеристиками недифракционного pp-взаимодействия подтверждает справедливость предсказаний схемы дуальной унитаризации.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1979

B.V.Batyunya et al. **E1 - 12306**

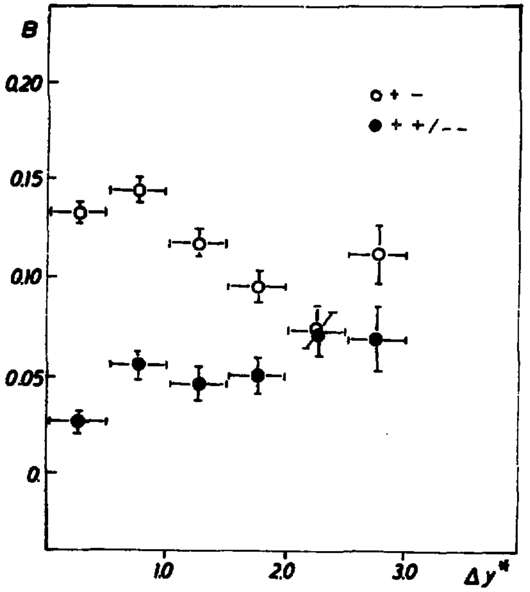
Comparison of Charged Particle Multiplicity Distributions in $\bar{p}p$ and pp Interactions and Verification of the Dual Unitarization Scheme

Charged particle multiplicity distributions in $\bar{p}p$ interactions at 22.4 GeV/c were used to obtain antiproton annihilation characteristics. The comparison of these characteristics with those of non-diffractive pp-interactions confirms the validity of dual unitarization scheme predictions.

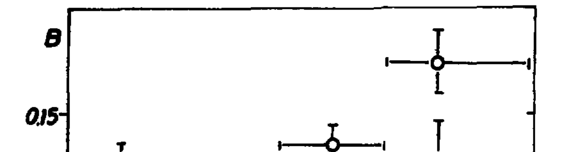
The investigation has been performed at the Laboratory of High Energies JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1979

3a)



3b)



3c)

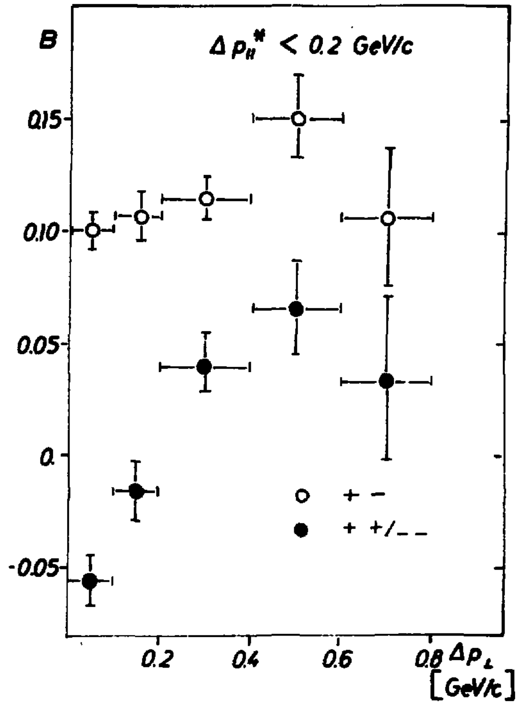


Fig.3. B as a function of (a) Δy^*, (b) $\Delta p_\parallel^*$, (c) $\Delta p_\perp$ for $n_c \geq 6$.

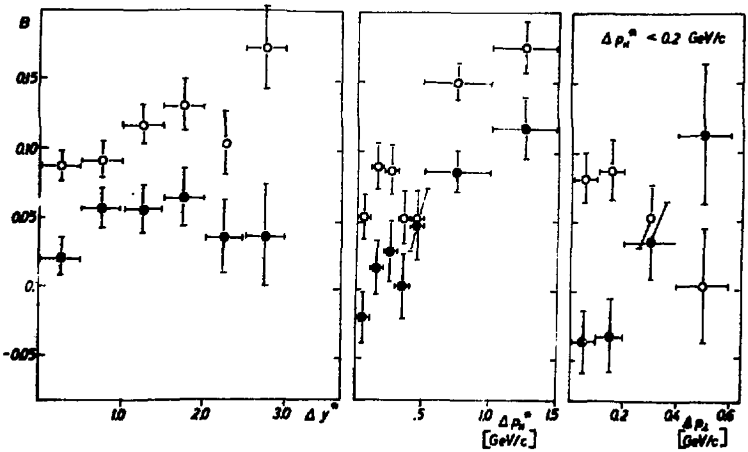


Fig.4. B as a function of (a) Δy^*, (b) $\Delta p_\parallel^*$ and (c) $\Delta p_\perp$ for events which do not contain $(\pi^+\pi^-)$ pairs with 0.70 GeV $< M_{\pi\pi} <$ 0.82 for $n_c \geq 6$.

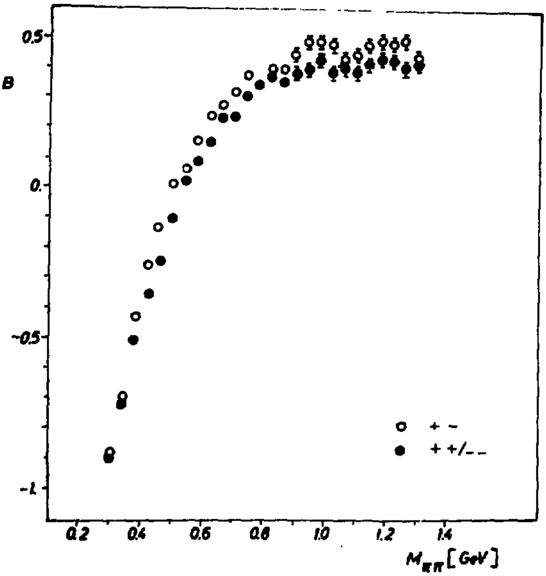


Fig.5. B^U and B^L as a function of invariant mass $M_{\pi\pi}$ for $n_c \geq 6$.

In our experiment the inelastic cross section for the identified protons with $p_{lab} < 1.2$ GeV/c was found to be 7.00 ± 0.15 mb for events with $n_c \geq 4$. The inclusive cross section for the production of Δ^{++} with proton having $P_{lab} < 1.2$ GeV/c was found to be 2.47 ± 0.17 mb /25/. This means that the Δ^{++} resonance is produced roughly. The cross section of Δ^{o} for these events is approximately 3.5 times smaller than that of Δ^{++} /25/. If the difference in azimuthal angle distributions is the reflection of resonance production, we can expect that the value of B for $p\pi^+$ combination (p stands for identified protons) is affected by the presence of Δ^{++} resonance. We have obtained $B^{p\pi^+} = 0.099 \pm 0.028$ and $B^{p\pi^-} = 0.012 \pm$ ± 0.037 in the region 1.20 GeV $< M_{p\pi} <$ 1.28 GeV. The difference between them is smaller than that seen in adjacent regions. For all combinations we got $B^{p\pi^+} = 0.196 \pm 0.011$ and $B^{p\pi^-} = 0.179 \pm 0.010$ implying no difference within errors. A similar result was obtained when studying the reaction $\bar{p}p \to \bar{p}p\pi^+\pi^-$ at 5.7 GeV/c [26].

The fact, which seems to us to be in contradiction to the idea that resonance production is the only factor responsible for the difference between azimuthal distributions of like and unlike pion pairs, is the increase of this difference with multiplicity (fig. 2). This phenomenon was observed in $\bar{p}p$ interactions at 5.7 GeV/c as well.[29] The average number of ρ^o's per event, $\langle N(\rho^o)\rangle$, is given in [30] for different topologies in our experiment. As the mean number of $\pi^+\pi^-$ combinations per event, $\langle N(\pi^+\pi^-)\rangle$, for a given topology is experimentally known as well, we can calculate the resonant to nonresonant pair ratio, $\langle N(\rho^o)\rangle / \langle N(\pi^+\pi^-)\rangle$, for all topologies. These numbers are given in Table 2. Whereas the average number of ρ^o's per

Table 2

ρ^o Production parameters as a function of charged multiplicity

n_c	$\langle N(\rho^o)\rangle$/event [30]	$\langle N(\rho^o)\rangle / \langle N(\pi^+\pi^-)\rangle$
4	0.08 ± 0.04	0.031 ± 0.015
6	0.26 ± 0.13	0.034 ± 0.017
8	0.61 ± 0.12	0.040 ± 0.008
10	0.63 ± 0.35	0.026 ± 0.014
12+14	1.25 ± 1.25	0.035 ± 0.035

event steadily increasses with multiplicity, the ratio $<N(\rho^o)>/<N(\pi^+\pi^-)>$ remains constant within errors. To establish if this fact is in accordance with the increase of B with topology, we performed a simple calculation. Taking the experimental distribution of unlike pion pairs, we calculated number of ρ^o-resonance pairs from the ratio $<N(\rho^o)>/<N(\pi^+\pi^-)>$, then subtracted this number from that of total unlike pion pairs and normalized the like pion distribution to the number of the pairs left. Then we assumed that all ρ^o- resonant $\pi^+\pi^-$ pairs had azimuthal angle ϕ greater than $\pi/2$, added these pairs to the normalized like pion distribution and calculated the asymmetry parameter (plotted as "ρ-induced" in fig. 2) for this distribution. This is the maximum influence which the ρ^o-resonance $\pi^+\pi^-$ pairs could have on B^L. The difference between B^U thus calculated and experimental B^L does not, however, reproduce the increase of the experimental B^U-B^L difference with multiplicity.

The interference effect using the Kopylov-Podgoretsky approach was studied in [27]. An excess of like pion pairs over unlike ones was observed in the region where $q_0<0.05$ GeV and $q_T<0.20$GeV/c ($q_0=|E_1-E_2|$; $q_T=|(\bar{p}_1-\bar{p}_2)\times\bar{n}|$, where E_1, E_2 are the energies; $\bar{p}_1, \bar{p}_2$ are the momenta of the two pions and $\bar{n}=(\bar{p}_1+\bar{p}_2)/|(\bar{p}_1+\bar{p}_2)|$. These variables were proposed in [28]. In this region the mean ratio of like to unlike pion pairs was 1.25 (normalization was carried out so that the ratio should be equal to 1 outside the region). Therefore it is interesting to look how the interference effect is connected with the difference in azimuthal distributions.

The distributions for pairs from the interference region are the same for like and unlike pion pairs and show that in this region small azimuthal angles are preferred ($B^L=-0.670\pm0.020$, $B^U=-0.634\pm0.020$). This is a consequence of strong q_0 and q_T constraints. Due to the smallness of azimuthal angles in the interference region, the relative excess of like pairs lowers

B^L more than B^U for the total distribution. However, our data are not explained by this mechanism because pairs from the interference region form only a small fraction (2%) of the total number of pairs. Moreover, the parameters B for pairs, which are outside the interference region are $B^L = 0.036 \pm 0.004$ and $B^U = 0.133 \pm 0.003$. Thus, we can conclude that the relative excess of like pion pairs in the interference region (in the sence of Kopylov's variables) can influence on the parameters B for our total sample of pairs only very slightly and that a main contribution to the difference between B^L and B^U comes from the pairs which fall outside the interference region.

4. CONCLUSIONS

The main results of our study of inclusive azimuthal correlations can be summarized as follows. The difference in the behaviour of like and unlike pion pairs comes mainly from the region where $\bar{p}_i - \bar{p}_j$ is small (the strongest effect was observed for $\Delta p^*_{\parallel}$ and $\Delta p_{\perp}$ simultaneously in the interval (0. -0.2 GeV/c)). We have estimated the influence of the ρ°-resonance by including the events with $\pi^+\pi^-$ pairs in the ρ°-enhancement region. In the sample of the remaining events the difference between the asymmetry parameters B is smaller but still persists. The difference ΔB for these events is 0.055 ± 0.008, and it is 0.078 ± 0.005 for the events containing $\pi^+\pi^-$ pairs with the invariant mass in the ρ°-region. The peak was not observed in the region of small values of Δy^* and $\Delta p^*_{\parallel}$ for the dependence of ΔB on Δy^* and $\Delta p^*_{\parallel}$ in the sample of events without ρ° in contradiction to the total sample of events.

The above results, the increase of ΔB with multiplivity, the dependence of B on the invariant mass, $M_{\pi\pi}$, of the pion pair and the fact that Δ^{++} production has no visible influence on B for $(p\pi^+)$ combinations have led us to the conclusion that taking into account only resonance production is insufficient to explain the observed differences in the behaviour of like and unlike pion pairs. On the other hand, we see that the interference effect has only a slight influence on these distributions and cannot explain the difference at higher values of $\Delta p_\parallel^*$ and Δy^*. Probably, due to this mechanism, we see the difference between like and unlike pion pairs for $\Delta p_\parallel^* < 0.2$ GeV/c and for small values of $\Delta p_\perp$ even for events without any $(\pi^+\pi^-)$ pair in the ρ^0-region.

The results of our study show that the data available do not allow unambiguous determination of the mechanism responsible for the observed differences in azimuthal distributions of like and unlike pion pairs.

The authors want to express their gratitude to the staff responsible for the operator of the Serpukhov accelerator and of the beam channel number 9 and to the technical staff of the Ludmila HBC. We also thank the technicians and assistants at all the Laboratories for their excellent work.

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Received by Publishing Department
on March 15 1979.

Издательский отдел Объединенного института ядерных исследований.
Заказ 26355. Тираж 660. Уч.-изд. листов 1,07.
Редактор Э.В. Ивашкевич. Подписано к печати 12.04.79 г.
Корректор Р.Д. Фомина.