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COMPARISON OF CHARGED PARTICLE MULTIPLICITY DISTRIBUTIONS IN $\bar{p}p$ AND pp INTERACTIONS AND VERIFICATION OF THE DUAL UNITARIZATION SCHEME

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

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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

In the framework of dual unitarization scheme /1/ there is a deep connection between the mechanisms of hadron production in various processes. According to this scheme, various processes of hadron production are based on the unique quark dynamics and differ only in the number of the quark pairs "hadronized", i.e., in the number of the produced jets of secondary hadrons. In particular, the main difference between the non-diffractive pp-interaction with leading pomeron exchange and antiproton annihilation is that in the first one two hadron jets are produced whereas in the second one, three hadron jets.

As the dual unitarization scheme predicts a purely quantitative difference between these processes, a study of the topological cross sections may turn out to be a more sensitive method of checking theoretical notions than a study of other characteristics, for example, inclusive spectra.

At high energies one fails to separate the process of antiproton annihilation in hydrogen bubble chamber experiments by fitting individual channels. Therefore the only possibility of studying this process is connected with comparision of the characteristics of $\bar{p}p$- and pp-interactions. In particular, there is some reason to suppose that the difference between the topological cross sections $\Delta\sigma_n = \sigma_n(\bar{p}p) - \sigma_n(pp)$ includes mainly the antiproton annihilation contribution /2/.

In this paper we investigate some properties of the topological cross section difference for $\bar{p}p$- and pp-interactions and compare the results with theoretical predictions. The charged particle multiplicity distribution in $\bar{p}p$-interactions at 22.4 GeV/c is based on the data obtained by means of the bubble chamber "Ludmila". The number of $\bar{p}p$-interactions used in this paper to calculate the topological cross sections is more than twice that of the first publication /3/, where the determination of the cross sections is described in detail. The values of $\sigma_n(\bar{p}p)$ are presented in table 1.

Table 1

Topological cross sections of $\bar{p}p$-interactions at 22.4 GeV/c

Number of prongs	0	2	4	6	8	10	12	14	16
σ_n, mb	0.60 ±.03	8.75 ±.19	14.21 ±.16	9.59 ±.13	4.28 ±.09	1.35 ±.05	0.25 ±.02	0.075 ±.012	0.0036 ±.0025

To calculate $\Delta\sigma_n$, we have used the data of paper /4/ based on about 100 000 pp-interactions at 24 GeV/c. The results are given in table 2.

Table 2

Differences of the topological cross sections of $\bar{p}p$- and pp-interactions

Number of prongs	0	2	4	6	8	10	12	14	16
$\Delta\sigma_n$, mb	0.60 ±.03	0.05 ±.31	1.66 ±.19	2.88 ±.15	2.11 ±.10	0.946 ±.052	0.209 ±.021	0.070 ±.012	0.0016 ±.0027

The subtraction of the cross sections removes automatically the diffraction component from $\Delta\sigma_n$. But this procedure does not change $\Delta\sigma_0$ which contains mainly the contribution from nonannihilation processes according to extrapolation from the region of lower energies. Therefore, estimating the characteristics of the annihilation process, $\Delta\sigma_0$ is assumed to be equal to zero. A small value of $\Delta\sigma_2$ does not contradict a similar extrapolation as well.

The figure compares the values of $\Delta\sigma_n$ with theoretical predictions of the Webber model /5/. This model is based on the interpretation of dual diagrams which satisfy the condition of unitarity. The interpretation is by analogy with the multiperipheral diagrams for the production of clusters ordered in rapidity. As is seen from the figure, the model predicts an excess of events with low multiplicity. The same effect was observed when using the data for 32 GeV/c /5/. Since the model of Webber contains a number of suppositions, it would be more instructive to perform a model-independent comparision of experimental data with the notion of the dual unitarization scheme. According to this scheme, there is a simple relation between the number of secondary hadron jets produced in processes

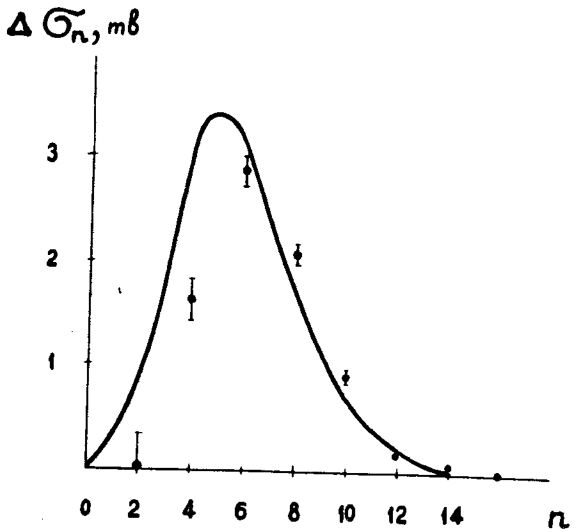

Fig. Comparison of the Webber theory predictions (solid line) with the experimental values of $\Delta\sigma_n$.

with leading pomeron exchange and annihilation. Assuming that the jets are produced independently and there is a uniform energy distribution between them, it is easy to get the relation between various characteristics of the multiplicity distributions for antiproton annihilation and pomeron processes by means of the formalism of generating functions. In contrast to paper /1/, we use for comparison the absolute distribution characteristics instead of the relative ones. For comparison of the absolute values it is necessary to fulfil the condition of strick equality of energy per jet in various processes. Meanwhile, the fulfilment of the relation 2/3 for c.m. energies of nondiffractive pp-interactions and annihilation does not really provide the equality of energy per jet because of the presence of leading baryons

in pp-interactions and of the possible relative motion of hadron jets. Therefore the results of comparison of the absolute characteristics even weakly dependent on energy cannot be considered as reliable.

So in the present paper we have used for comparison the relative momenta $C_K = \langle n^K\rangle/\langle n\rangle^K$, which exhibit a quasiscaling behaviour. This helps to weaken the influence of energy dependence of the characteristics and to make more clear the manifestation of statistics in going from two-jet to three-jet processes.

Let us present the relation between three lower momenta C_K^A and C_K^P for annihilation and pomeron processes, respectively:

$$C_2^A = \frac{2}{3}C_2^P + \frac{1}{3},$$

$$C_3^A = \frac{4}{9}C_3^P + \frac{2}{3}C_2^P - \frac{1}{9},$$

$$C_4^A = \frac{8}{27}C_4^P + \frac{16}{27}C_3^P + \frac{1}{9}(2C_2^P - 1)^2.$$

They supplement the known relations for the mean charge multiplicity $\langle n\rangle^A = \frac{3}{2}\langle n\rangle^P$ and the dispersion $D^A = \sqrt{3/2}\,D^P$, where $D = \sqrt{\langle n^2\rangle - \langle n\rangle^2}$.

Using these relations and data on the partial cross sections of nondiffractive pp-interactions, we can predict the characteristics of annihilation and then compare them with experimental values. To make this comparison more convincing, we include, besides the present results, some other experimental data. Some of these data are based on the topological cross sections of antiproton annihilation at 9.1 GeV/c, the others on $\Delta\sigma_n$ at 100 GeV/c together with the corresponding data on pomeron processes. In all cases the data have been chosen on condition of a rough equality of the c.m.s. energy per jet.

Table 3

Comparison of the characteristics of annihilation and pomeron processes[1)]

P_{lab}, GeV/c	12/4/		9.1/6/	24/4/		22.4	69/7/		100/8/
Type of process	non-diff. pp	ANN calc.	ANN exp.	non-diff. pp	ANN calc.	differ. $\bar{p}p$ - pp	non-diff. pp	ANN calc.	differ. $\bar{p}p$ - pp
$\langle n \rangle$	3.42±.02	5.13	5.32±.09	4.42±.03	6.63	6.84±.18	6.35±.10	9.53	9.43±1.25
D	1.44±.01	1.76	1.82±.14	1.97±.02	2.41	2.20±.32	2.71±.13	3.32	3.40±3.28
$\langle n \rangle / D$	2.37	2.91	2.92	2.24	2.75	3.11	2.34	2.87	2.77
C_2	1.18±.00	1.12	1.12±.01	1.20±.00	1.13	1.10±.02	1.18±.01	1.12	1.13±.11
C_3	1.59±.01	1.38	1.36±.04	1.66±.01	1.43	1.33±.05	1.59±.04	1.38	1.43±.30
C_4	2.40±.02	1.86	1.77±.08	2.56±.04	1.96	1.76±.12	2.86±.09	1.85	1.99±.68

1) Diffraction was extracted according to the data of paper /9/.

The results of comparison are collected in table 3. First of all, we see that calculated annihilation characteristics are very similar to experimental ones. Moreover, there are a marked uniformity of the characteristics for annihilation reactions and a marked difference of the formers from the characteristics of processes with pomeron exchange, which in turn are almost constant in a wide energy range. So, the data given in table 3 have proved the correctness of the initial assumption of a purely quantitative difference between the processes of secondary hadron production in antibaryon annihilation and nondiffractive hadron interactions with vacuum quantum number transfer in the t-channel. It should be mentioned that the formulae presented predict a more narrow (nearly by 18%) multiplicity distribution in the variables $n/\langle n \rangle$ for $\bar{p}p$-annihilation as compared to nondiffractive pp-interactions.

It should be concluded that modern notions of a fundamental role of quark dynamics which underline the dual unitarization scheme and reduce the difference of hadron processes to merely a quantitative difference in the number of hadron jets are not in contradiction to the available experimental data on $\bar{p}p$- and pp-interactions in a wide energy range.

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