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CHARGED PARTICLE MULTIPLICITY DISTRIBUTION IN $\bar{p}$P-INTERACTIONS AT 22.4 GeV/c

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

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This paper presents final data on the topological cross sections for charged particle production in antiproton-proton interactions at 22.4 GeV/c (Preliminary data have been published elsewhere[1]). The present results are obtained in scanning more than 260 thousand pictures from the JINR two-meter hydrogen bubble chamber "LUDMILA" irradiated with a separated antiproton beam at the Serpukhov accelerator. The channel and the scheme of beam separation are described in refs.[2-4]. The momentum spread of particles in the beam is 0.25%. The upper limit of an admixture of negative mesons in the beam is obtained on the basis of the number of interactions registered at the switched-off separators and does not exceed 2%.

In order to obtain the topological cross sections, the films were scanned independently two times. During scanning, interactions with any multiplicity of secondaries on beam tracks were recorded. The third test scan was undertaken to settle the differences between the two previous scans. The efficiency of finding the events with a given number of prongs and the true number of interactions of a given topology were obtained from the data of the two scans. The overall number of interactions of all topologies made up nearly 128 thousands.

The effect of factors distorting the observed results was established when determining the true number of interactions of any multiplicity. The following factors distorting the observed results were

1. A loss of alow (invisible in the picture) protons in elastic and inelastic two-prong events. The method to correct this loss is explained in ref.[5] and used in the present paper. The correction for the cross section for elastic interaction $\Delta_{el}=(2.6\pm0.1)$ mbarn and for inelastic two-prong events $\Delta_{inel}=(0.30\pm0.05)$ mbarn.

2. The presence of non-discriminated Dalitz pairs in the events leads to the overestimated charged particle multiplicity. According to the results of scan, the Dalitz pairs were revealed in 1.27% events. But if the mean number of neutral particles produced in $\bar{p}p$-interactions at 22.4 GeV/c[6] and probability of production of a Dalitz pair of the π^0-meson

decay are used, the Dalitz pairs must be observed in 2.14% events. Thus, the Dalitz pairs were not revealed in 0.87% events, and this number with the inclusion of the cross section of π°-meson production in the events of different topology/6/ was used to obtain corrections (in per cent) to the cross sections of $\bar{p}p$-interactions of different multiplicity (n) presented in Table 1.

Table 1

Corrections for non-identified Dalitz pairs

n	0	2	4	6	8	10	12
%	+1.1	+0.50	+0.38	-0.36.	-1.5	-2.9	-3.3

3. Overestimation of the multiplicity can be due to the prong from the neutral particle decay (Λ, K°) the vertices of which are merged with the vertices of primary interactions. This was obtained from the data of ref./6/. As the probable corrections to the topological cross sections did not exceed 0.2% which was several times smaller than the statistical errors, they were not introduced.

4. Scanning revealed the events with the odd number of prongs. They can be due to (a) non-discrimination of secondary interactions the vertices of which are merged with the vertices of primary interactions (the multiplicity is overestimated) or (b) loss of very short tracks in scanning (the multiplicity is underestimated).

In order to find a correction for non-discriminated secondary interactions, the distribution of the number of secondary interactions depending on the distance of the secondary vertex from the primary vertex was built after measurements and geometrical reconstruction of the events. The correction did not exceed 0.2% and was neglected since the number of events with the odd number of prongs was not higher than 0.2% either and the sign of correction was undetermined.

5. The presence of negative mesons (π^-, K^-) in the beam can cause a distortion of the multiplicity distribution. However, in virtue of a small admixture of negative mesons ($\leq 2\%$) such a distortion is within the limits of statistical uncertainty of the results.

The corrected numbers of interactions of different multiplicity were rescaled to the topological cross sections using normalization to the total $\bar{p}p$-interaction cross section $\sigma_{tot} = (48 \pm 0.5)$ mbarn from ref./7/. In this case use was made of the above value of the loss of two-prong events and of the elastic interaction cross section $\sigma_{el} = (8.9 \pm 0.2)$ mbarn from ref./8/.

To check possible systematic differences in the results obtained at different laboratories of the collaboration, the summed data were divided into 17 statistically equal groups, each containing the data of one laboratory. A comparison is made between the topological cross sections calculated in each group and with the results obtained on the basis of the summed data. The comparison has shown that for some topologies the spread in the results with respect to the average exceeds considerably the statistical errors (by a factor of 1.8 for 2-prong events, by a factor of 1.6 for 4-prong events, by a factor of 1.5 for 10-prong events and by a factor of 1.4 for 0- and 6-prong events). For five topologies the spread of the corresponding cross sections with respect to average of 17 groups did not satisfy the Fisher criterion at a 5% level of significance. For the remaining topologies the spread was actually not higher than the statistical uncertainty. It should be noted that the maximum spread of the results was observed for 2-prong events. The spread for 0-prong events was also substantial. This can be due to the fact that the efficiency of finding these events is different at various laboratories. In calculating the topological cross sections with normalization to the total cross section, the increase of the spread in one topology should cause an increase of the spread in the remaining topologies and it was therefore reasonable to exclude 0- and 2-prong events from the normalization procedure and to accept the values obtained on the basis of the overall statistics as cross sections for these events. As a result, the spread in the cross sections for the events with $n \geq 4$ decreased sharply and only for $n=10$ the spread in the cross sections with respect to the average did not satisfy, as before, the Fisher criterion at a 5% level of significance. Therefore, the topological cross sections for all n, except for $n=0,2$ and 10, are listed in Table 2 with the errors conditioned by the statistical accuracy of the results for a given n (the normalization error equal to ~1% is not included in the present error). In Table 2 the mean-square deviations from the average of 17 groups of data (without the normalization error) are taken as errors for σ_n at $n = 0,2$ and 10. Thus, a II-fold increase of the overal statistics, as compared with the preliminary results (1), decreased the errors in σ_n by more than three times for most of the topologies.

Table 2

22.4 GeV/c $\bar{p}p$ and pp topological cross section

n charge	Events found	Corrected number a)	Cross section (22.4 GeV/c), σ_n, mb $\bar{p}p$		Cross section (22.4 GeV/c), σ_n, mb pp b)		$\sigma_n^{\bar{p}p} - \sigma_n^{pp}$, mb 22.4 GeV/c	
0	1647	1666	0.59	± 0.02				
2_{tot}	44403	44628	18.65	± 0.17	16.91	± 0.30		
2_{inel}			9.75	± 0.26	8.85	± 0.25	0.14 c)	
4	39376	39525	13.95	± 0.07	12.77	± 0.13	1.18	± 0.15
6	26398	26302	9.280	± 0.057	6.45	± 0.10	2.83	± 0.11
8	11519	11353	4.01	± 0.04	1.97	± 0.07	2.04	± 0.08
10	3535	3436	1.21	± 0.03	0.32	± 0.03	0.89	± 0.04
12	777	754	0.266	± 0.009	0.032	± 0.009	0.234	± 0.012
14	149	146	0.0515	± 0.0041	0.0048	± 0.0028	0.046	± 0.005
16	13	13	0.0046	± 0.0013	0.0016	± 0.0008	0.0030	± 0.0015
18	5	5	0.0018	± 0.0008	0.0006	± 0.0006	0.0012	± 0.0010

a) corrections are explained in the text
b) from ref. /10/.
c) the value of σ_2^{ANN} is obtained by extrapolation from the energy region <10 GeV according to /11/: $\sigma_2^{ANN} = 1540 \cdot S^{-2.46}$

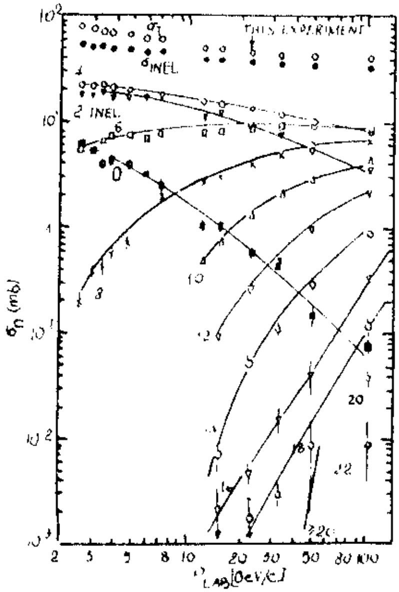

Fig.1. P_{lab} - dependences of the topological $\bar{p}p$-cross sections. The data at 22.4 GeV/c are the results of the present paper, the remaining results are from ref. /9/.

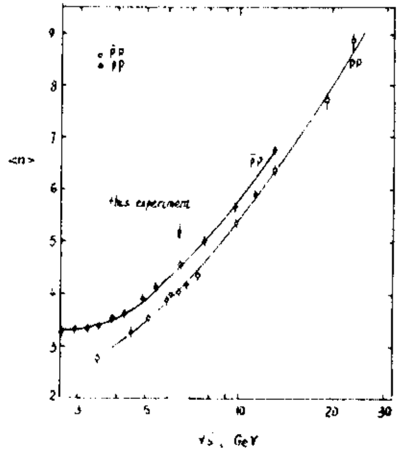

Fig.2. $\sqrt{s}$ -dependence of the mean charged particle multiplicity for $\bar{p}p$ - and pp -interactions.

The values of σ_n changed slightly as well (within three errors). The new data are closer to the smooth curves of the P_{lab}-dependences of σ_n in Fig.1 borrowed from paper /9/. In Table 2 are also given the topological cross sections for - interactions at 22.4 GeV/c /10/ and the differences of the cross sections $\sigma_n^{\bar{p}p}-\sigma_n^{pp}$ presented here and in ref. /10/. Table 3 presents the mean multiplicity of charged particles, dispersion and higher moments of the multiplicity distribution obtained from the topological cross sections. The mean multiplicity of charged particles <n> is found to be 4.582 ± 0.021 which is larger than $\langle n\rangle = 4.25 \pm 0.03$ for pp-interactions even at 24 GeV/c (for 22.4 GeV the interpolation gives ~4.15). This excees of <n> for $\bar{p}p$ over <n> for pp is observed for the region from the threshold up to 100 GeV as seen from Fig.2 presenting the dependence <n> on P_{lab} for $\bar{p}p$ - and pp -interactions. Our value of D also exceeds the value of D for the distribution in pp-interactions at 24 GeV ($D_{pp} = 2.05 \pm 0.03$). In accord with

Table 3

Moments of the 22.4 GeV/c $\bar{p}p$ multiplicity distribution

Moments	$\bar{p}p$ 22.4 GeV/c	$\bar{p}p-pp$ 22.4 GeV/c
$\langle n \rangle$	4.582 ± 0.021	6.89 ± 0.17
$\langle n_- \rangle$	2.29 ± 0.01	3.44 ± 0.09
D	2.28 ± 0.02	2.19 ± 0.08
$\langle n \rangle /D$	2.01 ± 0.02	3.14 ± 0.09
C_2	1.247 ± 0.0026	1.01 ± 0.014
C_3	1.816 ± 0.0097	1.32 ± 0.07
C_4	3.033 ± 0.029	1.70 ± 0.16
f_2	0.615 ± 0.012	-2.08 ± 0.06
f_2^-	-0.993 ± 0.016	-2.24 ± 0.12
f_3	0.72 ± 0.09	4.01 ± 0.24

the other data for $\bar{p}p$-interactions at >15 GeV/c, the ratio $\langle n \rangle /D$ is very close to 2.0, which this ratio tends to for the pp-data at high energies. For $n \leq 10$ the values of the function $\langle n \rangle \sigma_n / \sigma_{inel}$, in the error limits, are the same as the values of the KNO-function $\Psi(Z) = (3.79Z - 33.7Z^3 - 6.64Z^5 - 0.332Z^7) \exp(-3.04Z)$, where $Z = n/\langle n \rangle$. Yet, for $n > 10$ the deviations are too large and indicate the effect of another process, possibly, annihilation. Therefore, the dependence of $\langle n_{ann} \rangle \sigma_n^{ann} / \sigma_{inel}^{ann}$ on $n/\langle n_{ann} \rangle$ was calculated on the assumption that the annihilation cross sections σ_n^{ann} are equal to $\sigma_n^{\bar{p}p} - \sigma_n^{pp}$, and was compared with the data from ref. [11]. Within the error limits, our data agree with the data [11] for 9-100 GeV/c which suggests the existence of KNO scaling for $\bar{p}p$-annihilation.

The difference of the KNO-distributions for $\bar{p}p$-annihilation and pp-interactions corresponds to predictions of the theoretical scheme of dual topological unitarization (DTU) [13]. According to the DTU scheme, the narrowing of the KNO-distributions in $\bar{p}p$-annihilation is due to hadronization of a larger number of valence quarks as compared to pp-interactions. According to ref. [14], the ratio $R_n = (\sigma_n^{\bar{p}p} - \sigma_n^{pp}) / \sigma_n^{pp}$ given in Fig.3

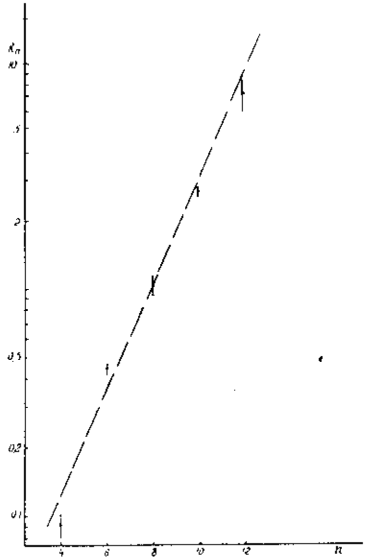

Fig.3. $R_n = \frac{\sigma_n^{\bar{p}p} - \sigma_n^{pp}}{\sigma_n^{pp}}$ versus n at P_{lab} =22.4 GeV/c.

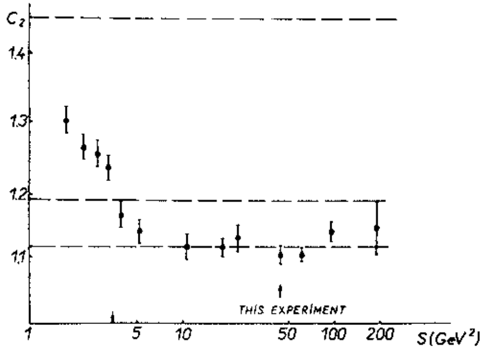

Fig.4. s-dependence of the normalized moment $C_2 = \langle n^2 \rangle / \langle n \rangle^2$ for $\bar{p}p$-annihilation. The arrow marks annihilation at rest. The values of C_2 below the threshold are from ref./17/ and above the threshold are calculated either from the $\bar{p}p$-annihilation or from the difference $\sigma_n^{\bar{p}p} - \sigma_n^{pp}$ /12/. The point at P_{lab} =22.4 GeV/c is the present result.

versus n can be approximated by the expression $R_n = A \cdot \beta^n$, where β =1.5. In our case β =1.67±0.03.

The normalized moments $C_k = \langle n^k \rangle / \langle n \rangle^k$ for inelastic $\bar{p}p$-interactions and the differences of $\bar{p}p$- and pp-cross sections, which characterize $\bar{p}p$-annihilation (Table 3), also support our previous conclusions /15,16/ of the correctness of the DTU scheme predictions. However, it should be noted that, according to /14/ the three-jet annihilation dominates at high energies only. The contribution from the two- and one-jet annihilation would be observed at decreasing energy.

Figure 4 illustrates the energy dependence of the normalized moment C_2. The horizontal lines represent values corresponding to one-, two- and three-jet processes, respectively. The arrow marks the annihilation at rest. As is seen from the figure, the multiplicity distribution moments support qualitatively the predictions of the DTU scheme.

REFERENCES

1. Abesalashvili L.N. et al. Phys.Lett., 1974, B52, p. 236.
2. Samoilov A.V. et al. In: Proc.II Conf.on Charged Particle Accelerators, "Nauka", Moscow, 1972, v.II, p. 190.
3. Levin V.M. et al. In: Proc. II Conf. on Charged Particle Accelerators, "Nauka", Moscow, 1972, v. II, p. 229.
4. Myznikov R.P. et al. Preprint IHEP 68-57, Serpukhov, 1968; Alferov V.N. et al. Preprint IHEP OP 74-53, OP 74-54 Serpukhov, 1974.
5. Boos E.G. et al. Nucl.Phys., 1977, B121, p. 381.
6. Boos E.G. et al. JINR, E1-11665, Dubna, 1978.
7. Bracci E. et al. CERN/HERA 73-1.
8. Antipov Yu.M. et al. Nucl.Phys., 1973, B57, p. 333.
9. Ward C.P. et al. Nucl.Phys., 1979, 153B, p. 299.
   Hanumaya B. et al. Preprint IHEP 80-102, Serpukhov, 1980.
   Zissa D.E. et al. Phys.Rev., 1980, 21D, p. 3060.
   Flaminio V. et al. CERN-HERA 79-03, Geneva. 1979.
10. Blobel V. et al. Nucl.Phys., 1975, B92, p. 221;
    Boggied et al. Nucl.Phys, 1971, B27, p. 285.
    D'Innocenzo A. et al. Lett.Nuovo Cim., 1980, 28, p. 369.
11. Ruchbrooke J.C. et al. Phys.Lett., 1975, B59, p. 303.
12. Rushbrooke J.G., Webber B.R. Phys.Reports, 1978, 44, p.3.
13. Chew G., Rosenzweig C. Phys.Reports, 1978, 41, p. 263.
14. Eylon Y., Harari H. Nucl.Phys., 1974, B80, p. 349.
15. Boos E.G. et al. Phys.Lett., 1979, 85B, p. 424.
16. Dementiev R.K., Leikin E.M. Yad.Fiz., 1979, 30, p. 775.
17. de la Vaissiere Ch. et al. Zeitsch. f.Phys., 1979, C1, p. 3.

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