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DIFFRACTION DISSOCIATION OF ANTIPROTONS IN $\bar{p}p$-COLLISIONS AT 22.4 GeV/c

Dubna-Alma-Ata-Erevan-Helsinki-Moscow-
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B.V.Batyunya, I.V.Boguslavsky, I.M.Gramenitsky, Z.Zlatanov,
R.Lednicky, L.A.Tikhonova, V.Vrba
Joint Institute for Nuclear Research, Dubna.

E.G.Boos, D.I.Ermilova, T.Temiraliev
Institute of High Energy Physics, Alma-Ata, USSR

P.Villanen, J.Ervanne, E.Hannula
Department of High Energy Physics, University of Helsinki,
Helsinki, Finland

R.K.Dementiev, E.M.Leikin, A.G.Puzyrny, I.A.Korzhavina,
V.I.Rud
Institute for Nuclear Physics Research of the Moscow State
University, Moscow, USSR

I.Herynek, M.Lokajicek, J.Řidky, V.Šimak
Institute of Physics, ČSAV, Prague, ČSSR

A.Valkarova, M.Šuk
Nuclear Center of Charles University, Prague, ČSSR

G.O.Kuratashvili, T.P.Topuriya, V.D.Tsintsadze, A.N.Khudzhadze
Tbilisi State University, Tbilisi, USSR

N.B.Dashian
Erevan Institute of Physics, Erevan, USSR

S.V.Levonian
Lebedev Physical Institute, Moscow, USSR

1. INTRODUCTION

In inclusive reactions the diffractive component is usually separated simply by making a cutoff in the effective mass M_x of the excited system or in the momentum-transfer t [1,2].

However, the diffractive (d) and nondiffractive (nd) components are significantly overlapped at energies of $\lesssim$ 30 GeV [3] and therefore it is essential to separate these components event by event.

In this paper we develop and apply an event-by-event method of separating the diffractive component in inclusive reactions. The method is based on the technique of the maximum rapidity gap between the secondaries [8,9].

Diffraction dissociation of the beam antiproton is measured using the above-mentioned method in $\bar{p}p$ reactions at 22.4 GeV/c. In this experiment the upper limit for the $\bar{p}$ diffraction dissociation has been previously estimated to be $(3.68^{+0.45}_{-0.15})$ mb [4].

2. SEPARATION OF THE $\bar{p}$ DIFFRACTION DISSOCIATION

The data for this analysis come from exposures of the 2m HBC Ludmila to a separated antiproton beam of 22.4 GeV/c at the Serpukhov accelerator. General information regarding the experiment is given elsewhere [5,4]. From the total amount of about 29000 inelastic $\bar{p}p$ events (which corresponds to 1.2 μb /event) the events were analysed having ionization identified proton.

In the reaction $\bar{p}p \to p+X$, the produced antibaryon is assumed to be either an antiproton or a neutral antibaryon $(\bar{B}^{\circ})$ (see fig. 1). To discriminate the diffraction dissociation of a beam antiproton in the $\bar{p}p \to pX$ reaction, information on the non-excited target proton is quite sufficient. But in the case of discriminating the target diffraction dissociation one must be able to obtain as full information on fast unidentified antiproton as possible. Analysis of the processes involving double pomeron exchange necessitates some information on the production of $(\bar{p})$ or neutral antibaryon $(\bar{B}^{\circ})$ in the final state as well. As far as we are going further to investigate the above processes and diffractive

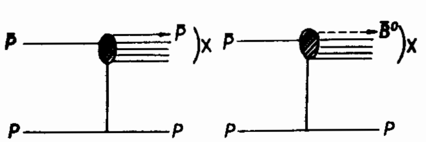

Fig. 1. Diagrams for antiproton dissociation in $\bar{p}p$-interactions.

resonance production, we make an attemp to "identify" a fast secondary antiproton.

The $x = 2p_L^*/\sqrt{S}$ distributions for positive and negative secondary particles should be symmetrical for the events with $\bar{p}$ produced in the beam fragmentation region. In fig. 2a there are shown the x-distributions for positive and negative particles of all events with an identified proton. The evident asymmetry in the spectra is due to the events with a secondary neutral antibaryon.

The separation of the events with $\bar{p}$ from those with $\bar{B}^\circ$ can be made by determining "identification regions" (see fig. 3). The events with an identified proton are divided into two groups: the invariant mass of the neutral system M_0 being either greater or less than 0.9 GeV. The relation between x_0 (Feynman x of the neutral system with mass M_0) and x^-_{max} (Feynman x of the fastest negative particle in the event) was examined for different charged multiplicities n in both groups. It is assumed that the event with $M_0 \geq 0.9$ GeV involves $\bar{B}^\circ$ if x^-_{max} does not exceed the boundary of the fragmentation region Δ_n at any x_0 or if $x^-_{max} > \Delta_n$ and $x_0 > x^-_{max}$. Otherwise the fastest negative particle was "identified" to be an antiproton. In the group with $M_0 < 0.9$ GeV the fastest negative particle was "identified" as $\bar{p}$ if $x^-_{max} \geq \Delta_n$, and the event was excluded from the analysis if $x^-_{max} < \Delta_n$.

Comparing the x-spectra for positive and negative particles in both hemispheres, we determined the values of Δ_n which give symmetrical x-spectra for the events with an antiproton (see table 1). The resulting x-distributions of positive and negative particles for inelastic events without neutral antibaryon are shown in fig. 2b.

After this the d-component was separated, as in refs.[3,9], by ordering the secondary particles (including the system of neutral particles) according to their longitudinal rapidities $y_i = \frac{1}{2}\ln\frac{E_i + p_{Li}}{E_i - p_{Li}}$. The particles in the diffractively produced system tend to group within a limited rapidity interval. Therefore only those events were taken to be diffractive in which the proton rapidity is the smallest one and in which maximum rapidity gap $\Delta y_{max} = \max\{y_{i+1} - y_i\}$ separates the proton from the other secondaries.

Table 1

The values of Δ_n giving symmetry in x-spectra

n	2	4	6	8	10	12	14
Δ_n	0.5	0.33	0.30	0.26	0.30	0.30	0.30

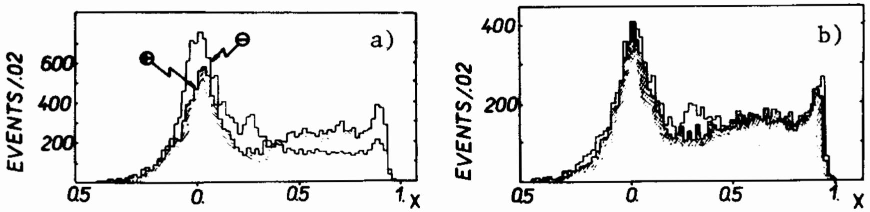

Fig. 2. x-distributions of charged secondaries for: a) all events with identified proton; b) events with an antiprotons in final state.

To make the separation between the d- and nd-events more rigorous, we introduce the variable: $\eta = 1 - e^{-\xi}$, where $\xi = -\prod_{i=1}^{n_{eff}-2}\frac{\Delta y_{max} - \Delta y_i}{\langle \Delta y \rangle}$, n_{eff} is the effective multiplicity ($n_{eff} = n + 1$ for the events with $M_0 > 0.1$ GeV), Δy_i is the rapidity gap between two neighbouring particles in the diffractively produced system and $\langle \Delta y \rangle$ is their mean value. For diffractive events $\Delta y_{max} \gg \Delta y_i$ and therefore $\eta \approx 1$ and for nondiffractive events $\Delta y_{max} \approx \Delta y_i$ and $\eta \approx 0$.

From the η-distribution in fig. 4a it can be seen that our sample still contains nd-events and that d- and nd-contributions overlap at intermediate values of η. Therefore to minimize this ambiguity, we have fitted functions of the form $\frac{dN}{d\eta} = e^{a_1 + b_1\eta} + e^{a_2 + b_2\eta}$ for different topologies to find the best cutoff value of $\eta_c^{(n)}$. The parameters of the fits are given in table 2, and fig. 4b shows the η-distributions for different topo-

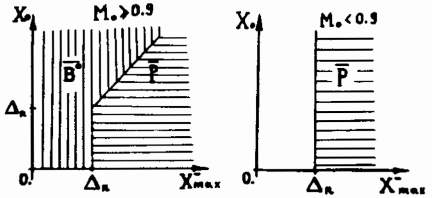

Fig. 3. "Identification" regions for secondary antibaryon.

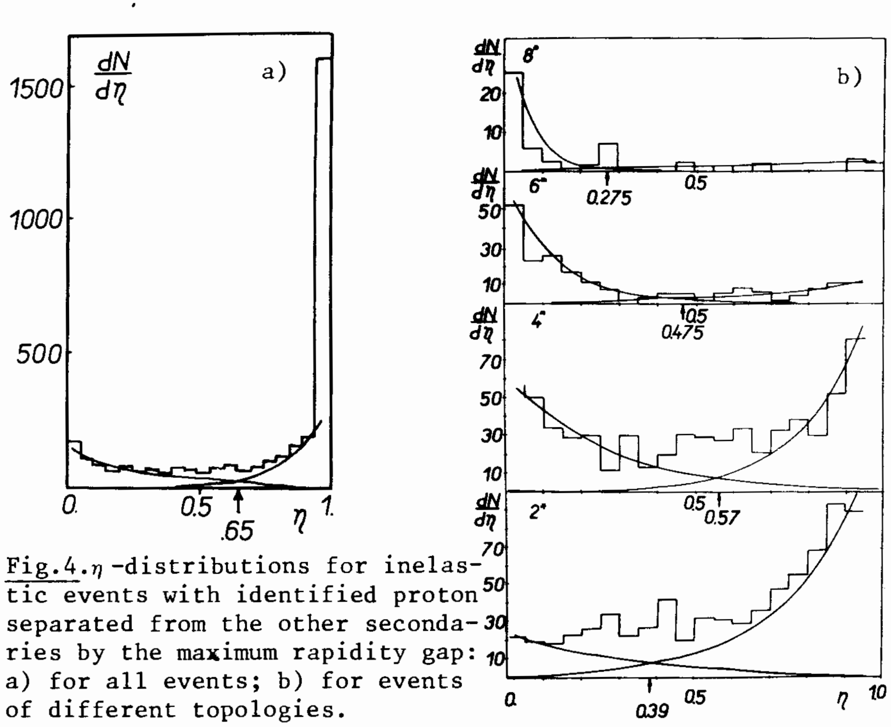

Fig.4. η -distributions for inelastic events with identified proton separated from the other secondaries by the maximum rapidity gap: a) for all events; b) for events of different topologies.

Table 2

The parameters of the fit $\frac{dN}{d\eta} = e^{a_1+b_1\eta} + e^{a_2+b_2\eta}$

n	a_1	a_2	b_1	b_2
2	3.09	0.34	-2.93	4.74
4	4.04	-1.30	-3.54	6.33
6	3.95	-0.48	-7.30	3.20
8	3.26	-0.07	-15.4	1.10

logies with the corresponding cutoff values of $\eta_c^{(n)}$. The obtained topological cross sections for the diffraction are given in table 3.

To check the cleanness of our diffractive sample, the effective masses of proton and pion combinations are studied. Figure 5a shows the $(p\pi^+)$ mass spectrum for all events and

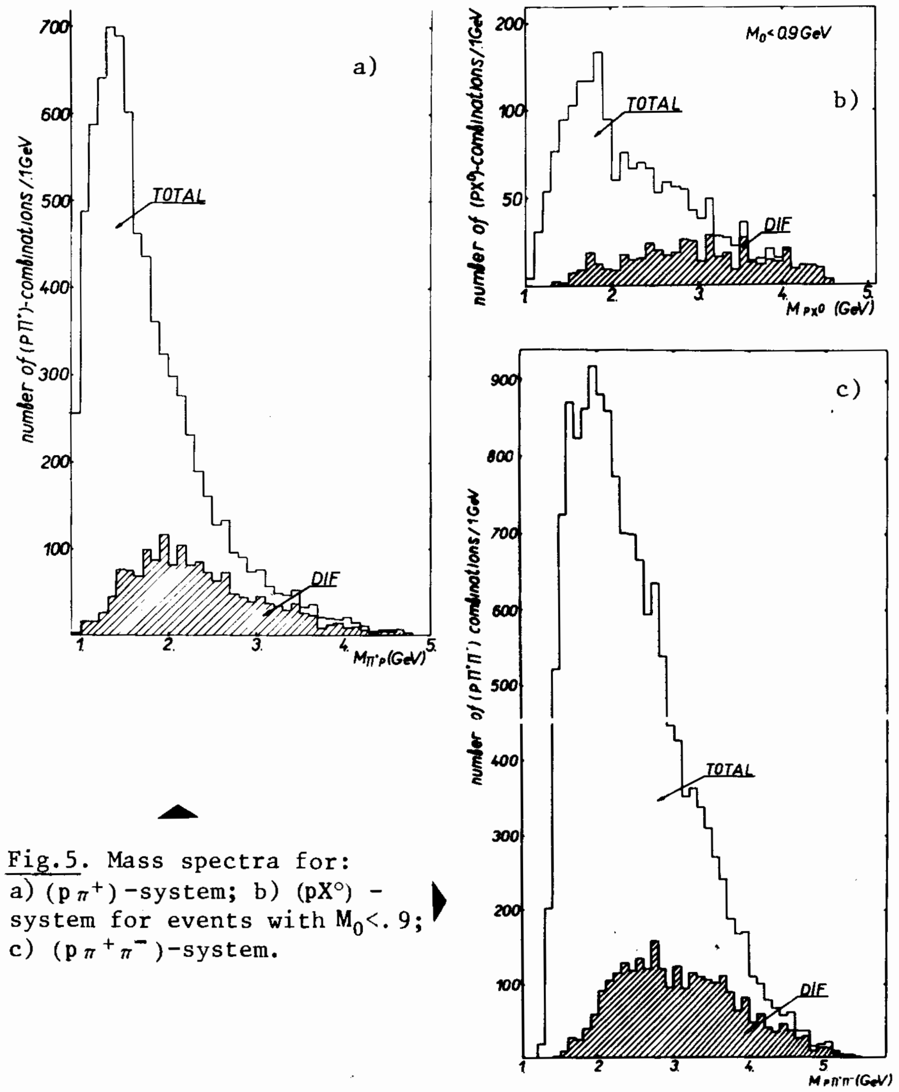

Fig.5. Mass spectra for:
a) $(p\pi^+)$-system; b) (pX°) - system for events with $M_0<.9$;
c) $(p\pi^+\pi^-)$-system.

for the diffractive sample. No signals from $\Delta^{++}(1232)$ and heavier isobars are observed in diffractive events. The absence of resonances in the diffractive sample is verified also for the mass distributions of the combinations (pX°) and $(p\pi^+\pi^-)$ as is seen in figures 5b and c, respectively.

Table 3

Topological cross sections of $\bar{p}$ diffraction dissociation

Charged multiplicity	σ^d(mb)
2	2.001±0.060
4	1.393±0.051
6	0.248±0.021
8	0.018±0.008

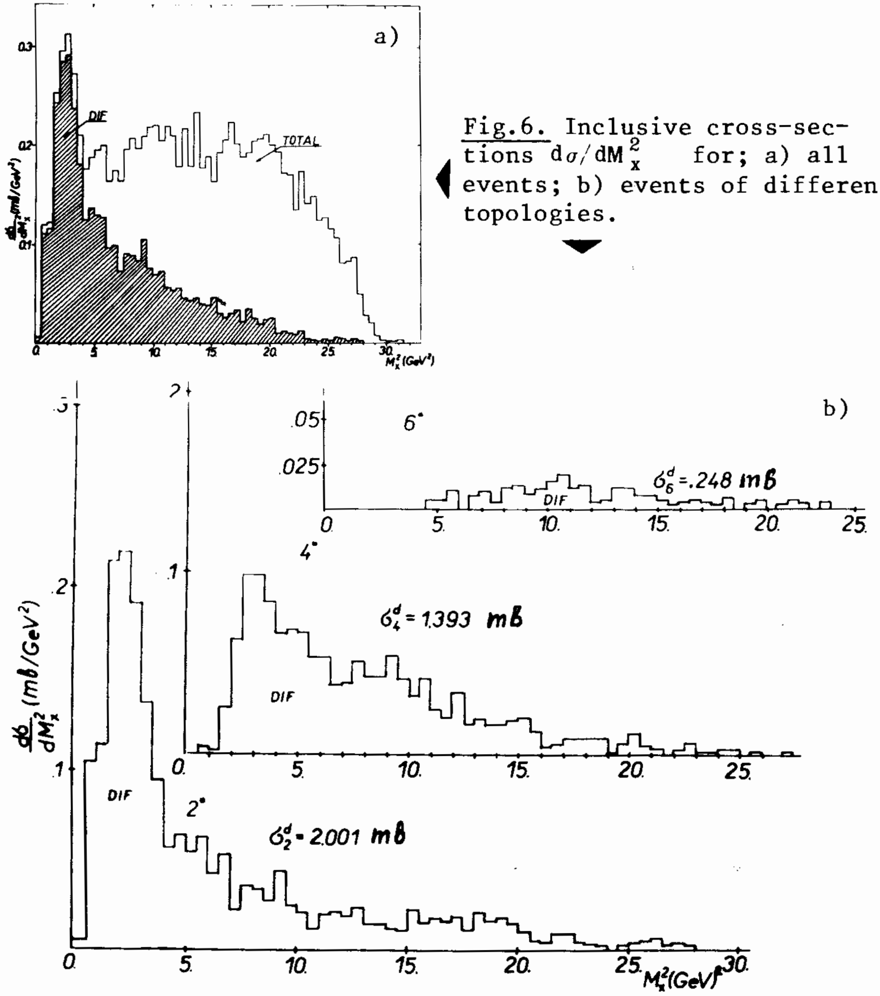

Fig.6. Inclusive cross-sections $d\sigma/dM_x^2$ for; a) all events; b) events of different topologies.

3. RESULTS

3035 inelastic events were selected as diffractive ones with the procedure described in chapter 2. This corresponds to a diffractive cross section of (3.660+0.082) mb, which is in agreement with other experiments[1,2,3].

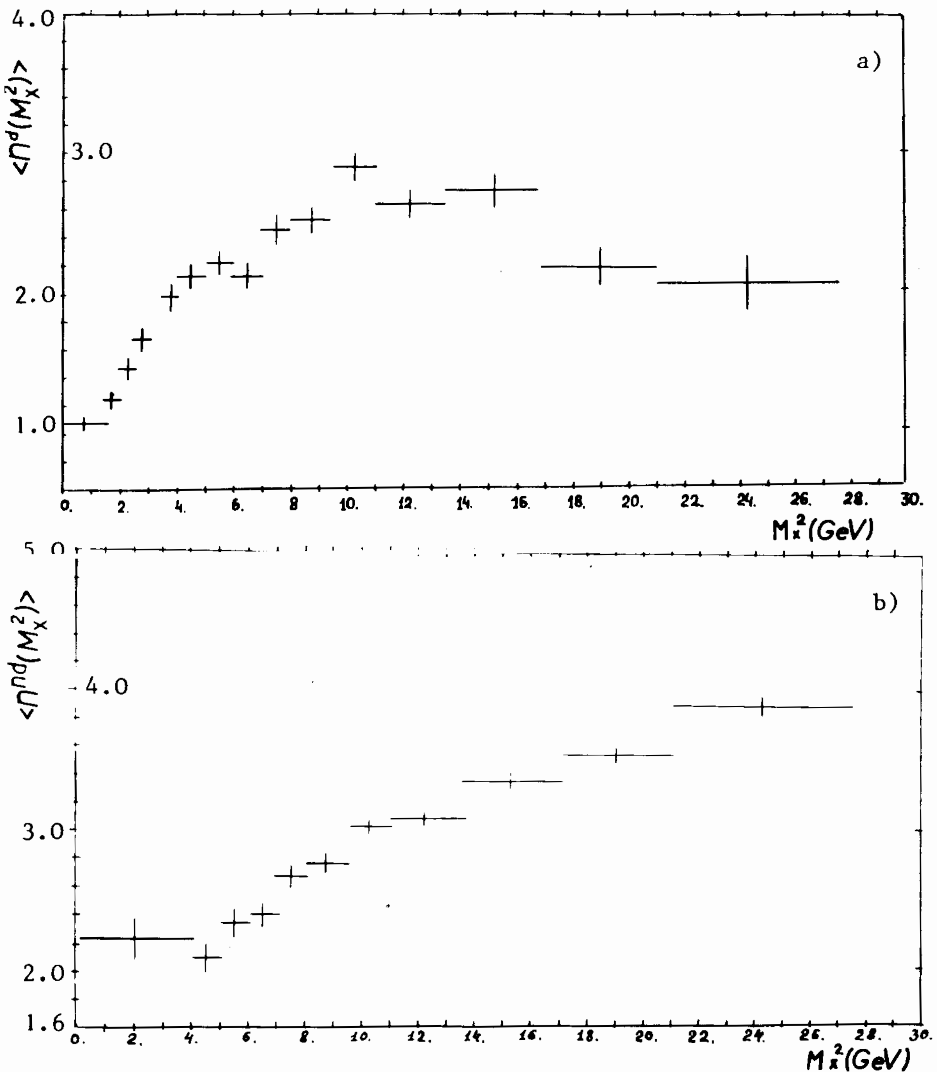

Fig.7. Square mass dependence of the mean multiplicity of charged particles for: a) diffractive events; b)non-diffractive events.

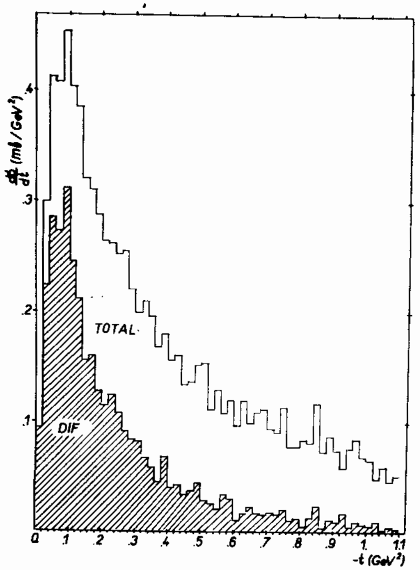

Fig.8. Momentum transfer distributions.

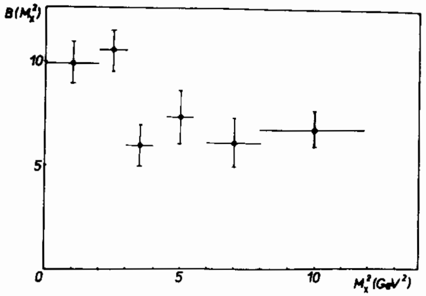

Fig.9. Slope-mass correlation.

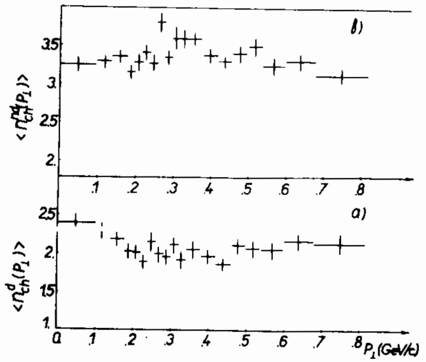

Fig.10. p_T dependence of the mean multiplicity of charged particles for: a) diffractive events; b) non-diffractive events.

Figure 6a shows the mass distribution $\frac{d\sigma}{dM_x^2}$ for all inelastic events containing protons and for the diffractive sample. Both distributions exhibit clear diffractive peak at $M_x^2 \approx 3$ GeV^2. Above this peak the diffractive spectrum decreases with increasing M_x^2. The non-diffractive background is significant at values higher than $M_x^2 = 4$. GeV^2 whereas below it the nondiffractive cross section is only 0.17 mb.

For the diffractive component the mass spectra are shown with respect to topology in fig. 6b, where it is seen that the main contribution to the diffraction cross section comes from the events with two (55%) and four (38%) charged particles.

It has been shown /1,2,3,6/ that the mean charged multiplicity of the particles associated with a proton increases

with increasing the mass of the associated system. In this experiment the dependence of the mean associated multiplicity $\langle n(M_x^2)\rangle^d$ of the d-component on M_x^2 is shown in fig.7. It can be seen that $\langle n(M_x^2)\rangle^d$ increases at first rapidly, then, from $M_x^2 \approx S/10$, more slowly, and at $M_x^2 \simeq S/4$ in starts to decrease. This decrease can partly be explained by the loss of protons and, mainly, by the fact that the low multiplicities ($n = 2,4$) dominate in the d-component at high M_x^2. These effects are absent for the nd-component as can be seen from fig.7b.

Figure 8 shows the differential cross section $\frac{d\sigma}{dt}$ for all inelastic events with protons and for the diffractive sample, for the latter the slope parameter is (6.7 ± 0.4) GeV^{-2} in an interval of 0.04 GeV$^2 \leq |t| \leq 0.28$ GeV^2. For diffractive events the dependence of the slope of the differential cross section on the mass of the excited system M_x shown in fig.9 at 22.4 GeV/c is in good agreement with other experiments /2,3/.

The mean multiplicity associated with a proton as a function of the proton transverse momentum for the d- and nd-components is shown in Fig.10. In both cases the distributions are almost flat. It is of interest to note that the increase of $\langle n_{ch}\rangle$ with p_T was experimentally found in pp-interactions at 30 GeV/c /7/ and at ISR energies /8/, and no dependence of $\langle n_{ch}\rangle$ on p_T was found when studying the $\bar{p}p$-interactions at 32 GeV/c /2a/.

4. CONCLUSIONS

The developed method for analysis of the reaction $\bar{p}p \to p + X$ has given a sufficiently reliable separation of diffractive and non-diffractive events at 22.4 GeV/c. The results obtained are in good agreement with other experiments.

For diffractive events the M_x^2 distribution has a sharp peak near $M_x^2 \approx 3$ GeV^2, and the high-mass tail extends up to 28 GeV^2. The mean charged multiplicities of diffractive and non-diffractive events increase similarly only in the interval $s/10 \leq M_x^2 \leq s/3$. The slope of the t-distribution shows a strong dependence on M_x^2. The mean multiplicity associated with a proton shows no clear dependence on the proton transverse momentum either in diffractive or in non-diffractive events.

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Батюня Б.В. и др. Дифракционная диссоциация антипротонов в $\bar{p}p$-столкновениях при 22,4 ГэВ/с E1-82-79

На основе экспериментальных данных по $\bar{p}p$-взаимодействиям при импульсе 22,4 ГэВ/с проведено выделение дифракционной диссоциации антипротонов. Разработана количественная оптимизация метода быстротных интервалов и проведена оценка его погрешности. Полученное сечение однократной дифракции составляет /3,66±0,08/мб. Анализируется зависимость параметра наклона t-распределения от массы дифракционно образованной системы M_X. Исследуется зависимость средней зарядовой множественности от M_X и поперечного импульса протона

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Batyunya B.V. et al. Diffraction Dissociation of Antiprotons in $\bar{p}p$-Collisions at 22.4 GeV/c E1-82-79

The antiproton diffraction dissociation is separated using the experimental data on $\bar{p}p$-interactions at 22.4 GeV/c. The quantitative optimization of the rapidity-gap method is proposed and used to estimate the errors of the method. The cross section of single diffraction (for one vertex) obtained is(3.66±0,08)mb. The dependence of the slope of the t distribution on the mass of the diffractively produced system M_X is analysed. The mean charged multiplicity is studied as a function of M_X and transverse momentum of the proton.

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

Communication of the Joint Institute for Nuclear Research. Dubna 1982