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THE STUDY OF DIFFRACTIVE DISSOCIATION IN THE REACTION $\bar{p}p \to \bar{p}p\pi^+\pi^-$ AT 22.4 GeV/c

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The investigation of the reaction

$$\bar{p}p \to \bar{p}p\pi^+\pi^- \qquad (1)$$

at a wide interval of energies /1-5/ has demonstrated the dominance of two channels: double production of isobars and diffraction dissociation of proton and antiproton.

The results of studying the beam and target diffraction dissociation in reaction (1) at 22.4 GeV/c are presented. The data have been obtained on pictures from the Ludmila bubble chamber exposed to a separated antiproton beam at IHEP (Serpukhov).

The general characteristics of reaction (1) and of $\bar{p}p \to \Delta^{++}\bar{\Delta}^{++}$ channel at 22.4 GeV/c can be found in paper /6/.

2021 events of reaction (1)* were used to analyse the diffraction dissociation that corresponds to 1.44 events per μb.

The separation of proton and antiproton diffraction was performed by two methods: longitudinal phase space (LPS-analysis /7/) and method of maximum rapidity gap between secondaries /8/.

The two-dimensional plot of the reduced longitudinal momenta x^+ and x^- of $\pi^\pm$-mesons from reaction (1) is presented in fig.1 /7/.

The diagrams of the processes which dominate in the corresponding LPS-sectors are also shown here. The whole LPS-space was divided into cells $\delta x = 0.125 \times 0.125$ in size.

The occupation of the separated LPS-sectors by the events is clearly seen from fig.1. The weighted Δ_w distributions were obtained by the formula

$$\Delta_w = \sigma_0 N_t^{-1} s^{-1} \sum_\gamma \omega_\gamma, \qquad (2)$$

where σ_0 is the cross section of reaction (1); N_t, the total number of e[illegible] in [illegible]e experiment, [illegible] [illegible]otal energy squared

* The cross section of reaction (1) at 22.4 GeV/c is equal to 1.40±0.04 mb.

in the c.m.s.; γ , the number of events in each cell δx ; ω_γ ,the weight of each event as a function of longitudinal momenta and energies of particles in the c.m.s.

The number of events in the LPS-sectors and corresponding cross sections are given in table 1.

Table 1

LPS-sectors	Number of events	Cross section, mb
A[$(\bar{p}\pi^+\pi^-)p$]	598	0.41±0.02
B[$(\bar{p}\pi^+)(p\pi^-)$]	149	0.10±0.01
C[$\bar{p}(p\pi^+\pi^-)$]	599	0.41±0.02
D[$(\bar{p}\pi^-)(p\pi^+)$]	638	0.44±0.02

As can be seen from this, the numbers of events in sectors A and C coincide. This fact points to an equal fraction of the proton and antiproton dissociation in reaction (1).

The separation of diffraction by the maximal rapidity gap[8,11] method was performed by ordering the secondary particles of reaction (1) in each event according to their longitudinal rapidities in the laboratory system $y_i = \ln\frac{E_i + P_{\parallel i}}{E_i - P_{\parallel i}}$. Then rapidity intervals between neighbours were determined. The particles in the diffractively produced system tend to group within a limited rapidity interval. To separate diffractive and nondiffractive components, the variable η[9] was introduced:

$$\eta = 1 - e^{-\xi}, \quad \xi = \prod_{i=1}^{2} \frac{\Delta y_{max} - \Delta y_i}{\langle \Delta y \rangle}, \qquad (3)$$

where Δy_{max} is a maximum rapidity gap, Δy_i is a 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 $\eta \approx 1$, for nondiffractive events $\Delta y_{max} \approx \Delta y_i$ and $\eta \approx 0$.

The η distribution for antiproton dissociation at 22.4 GeV/c is shown in fig.2.

As can be seen from fig.2, the separated sample contains some fraction of nondiffractive events overlapping with diffractive ones at intermediate values of η .

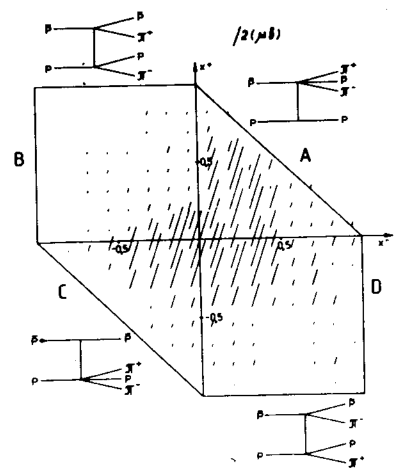


Fig.1. LPS-sectors for reaction $pp \to pp\pi^+\pi^-$.

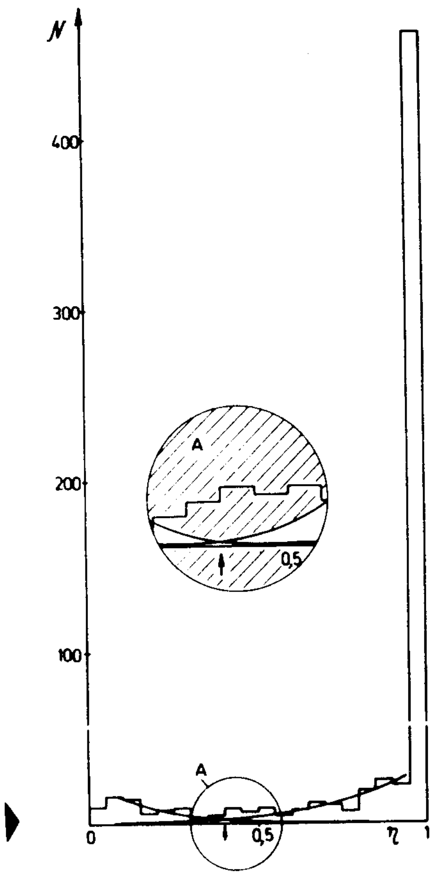


Fig.2. η -distribution for antiproton diffraction dissociation.

To minimize this ambiguity, the cutoff value of η_c was determined from the approximation of the η distribution by the function[9]

$$dN/d\eta = e^{a_1 + b_1\eta} + e^{a_2 + b_2\eta} . \qquad (4)$$

After such a cutoff procedure 598 events were selected for antiproton diffraction and 575 events for proton diffraction.

The corresponding cross sections were obtained as $\sigma_{\bar{p}} = 0.41 \pm 0.02$ mb and $\sigma_p = 0.40 \pm 0.02$ mb.

The comparison of these values with the data from table 1 shows an agreement between the results obtained by the methods.

The energy dependence of the single diffraction dissociation cross section for reaction (1) was successfully parametrized by the function

$$\sigma_D = C s^{-n} \qquad (5)$$

in a momentum interval from 7.2 GeV/c to 100GeV/c [3]. The values of the parameters were found to be $C = 1.7 \pm 0.4$ and $n = 0.36 \pm 0.06$. The value of σ_D at $p_{in} = 22.4$ GeV/c ($s = 43.8\ GeV^2$) for given values of n and C was estimated as 0.43 ± 0.14 mb. This result is in agreement with the previously mentioned cross sections of diffraction in one vertex.

The two peaks at $M \sim 1500$ MeV and at $M \sim 1700$ MeV were found in the effective mass distributions of the $(p\pi^+\pi^-)$ and $(\bar{p}\pi^+\pi^-)$-systems for events belonging to LPS-sectors A and C (see fig.3a,b).

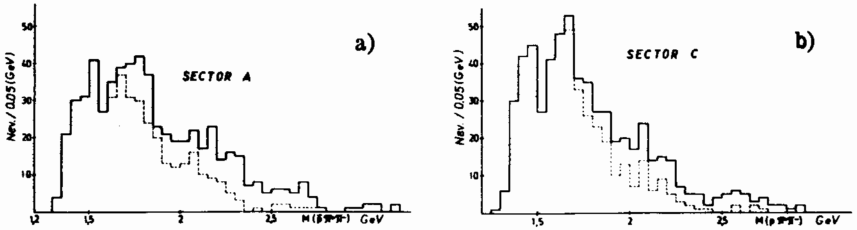


Fig.3. a) $M(\bar{p}\pi^+\pi^-)$ -distribution for events from LPS-sector A. b) $M(p\pi^+\pi^-)$ -distribution for events from LPS-sector C.

These enhancements were observed in reaction (1) at an antiproton momentum interval from 5.7 GeV/c [1] to 40 GeV/c [5] and in the diffractively produced $(p\pi^+\pi^-)$-system in πp, Kp and pp interactions at different energies up to ISR [10,11,12].

Many authors [5,11,14] connect the first peak according to decay angular distributions with the presence of N*(1470) and N*(1520) isobars; the second peak is considered as a superposition of several isobars with spin values 3/2 and 5/2.

The effective mass distributions of $(p\pi^+\pi^-)$ + C.C.-systems decaying into $\Delta^{++}(\overline{\Delta^{++}})$ isobar and π-meson are shown in fig.3a,b by dashed lines. The value of isobar mass is restricted by $1.06 \le M(\pi\pi N) \le 1.4$ GeV.

As is seen from fig.3 the first $(\pi\pi N)$ peak can be completely explained as a quasi-two-body decay $(\Delta\pi)$, and for the second peak such a kind of decay is dominant.

The $(p\pi^+)$ and $(\bar{p}\pi^-)$ effective mass spectrum for events belonging to the A- and C- LPS sectors are given in fig.4. The signal of $\Delta^{++}(\overline{\Delta}^{++})$ isobars is prominent.

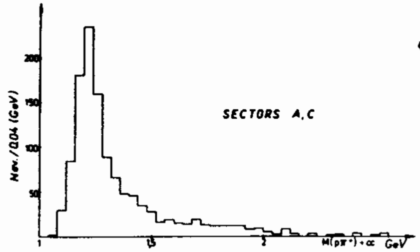
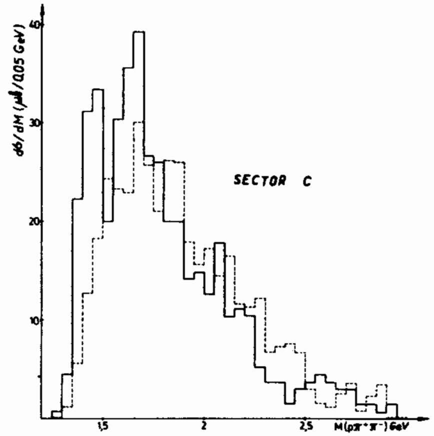


Fig.4. $M(p\pi^+)$ + C.C. -distribution for events from LPS-sectors A and C.

Fig.5. $M(p\pi^+\pi^-)$-distribution for events from LPS-sector C. The dashed line is the same distribution for events generated by the OPER-model.



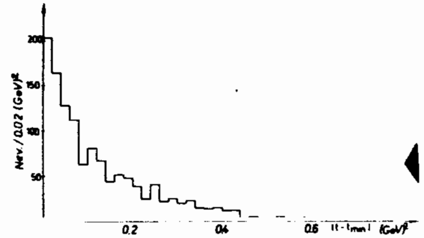
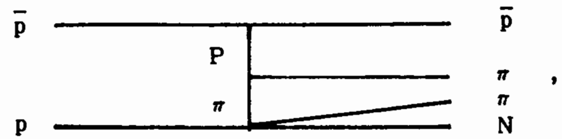


Fig.6. $|t - t_{min}|$ -distribution for events from LPS-sectors A and C.

The experimental $M(p\pi^+\pi^-)$ distribution was compared with predictions of the OPER-model which successfully describes a lot of exclusive reactions [13].

The OPER-model describes reaction (1) by means of the diagrams presented in fig.1 for LPS-sectors B and D. The fraction of Pomeron exchange is considered in the model only through the diagram



where no resonant states in the $(\pi\pi N)$-system are supposed.

This permits this model to be used for the calculation of background in describing $(p\pi^+\pi^-)$ mass enhancements.

The $p\pi^+\pi^-$ mass distribution for events from LPS-sector C is given in fig.5 by the solid line, and the dashed line presents the same distribution for events generated using the OPER-model. It is clear that the model does not describe the diffractive peaks at $M \sim 1500$ MeV and $M \sim 1700$ MeV; this means that they cannot be connected with the reflection of double $\Delta^{++}\bar{\Delta}^{++}$ and $\Delta^{\circ}\bar{\Delta}^{\circ}$-isobar production because the last processes are described by the model very well.

The parameters of resonant states in the $p\pi^+\pi^-$-system (listed in Table 2) were defined with the help of two Breit-Wigner functions and a background curve from the OPER-model.

Table 2

$M(\pi\pi N)$	M (MeV)	Γ(MeV)	%
M (1500)	1422 ± 22	65 ± 34	15 ± 4
M (1700)	1622 ± 21	185 ± 49	30 ± 6

One of the important characteristics of diffraction dissociation is the slope of the t' distribution ($t' = t - t_{min}$, t is the four-momentum squared transferred from target to $(p\pi^+\pi^-)$-system).

The t' distribution for events of LPS-sectors A and C is presented in fig.6. For $t' < 0.12$ GeV^2 this distribution was fitted by a simple exponential function

$$d\sigma/dt' = A e^{-bt'}. \tag{6}$$

The value of the slope b is received to be equal to 11.5 ± 1.2 (GeV)$^{-2}$ and is consistent with the slope for elastic $\bar{p}p$-scattering for which experimental values are concentrated near a value of 12 (GeV)$^{-2}$ /3,4/.

It is known that the slope of the t distribution in diffraction processes decreases with increasing the diffractive system /2,3,14/. The same effect is observed in reaction (1) at 22.4 GeV/c, and the data are given in table 3.

Table 3

Interval of effective masses (GeV)	Slope (GeV)$^{-2}$
$1.25 \le M(p\pi^+\pi^-) + C.C. \le 1.6$	15.0 ± 1.3
$1.6 \le M(p\pi^+\pi^-) + C.C. \le 1.8$	9.1 ± 1.3
$M(p\pi^+\pi^-) + C.C. \ge 1.8$	4.8 ± 1.1

The main results presented here can be summarized as follows:

1) The cross sections of the proton and antiproton diffractive dissociation in reaction (1) were determined by the two methods: LPS-analysis and rapidity gap.

2) The enhancements in $(p\pi^+\pi^-)$- and $(\bar{p}\pi^+\pi^-)$-systems were observed at $M \sim 1500$ MeV and $M \sim 1700$ MeV.

3) The dependence of the slope of the t' distribution on $(p\pi^+\pi^-)$ mass was found.

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Изучение дифракционной диссоциации в реакции $\bar{p}p \to \bar{p}p\pi^+\pi^-$ при 22,4 ГэВ/с

Для 2021 события реакции $\bar{p}p \to \bar{p}p\pi^+\pi^-$ было проведено выделение механизмов дифракционной диссоциации антипротона и протона методом LPS-анализа и методом быстротных интервалов. Полученное сечение одновершинной диссоциации составляет 0,41±0,02 мбн. Для параметра наклона дифференциального сечения $d\sigma/dt'$ было получено значение $b = 11,5 \pm 1,2$ /ГэВ/$^{-2}$ при $t' \leq 0,12$ /ГэВ/^{2}. В распределении эффективных масс дифракционно образованных систем $\bar{p}\pi^+\pi^-$ и $p\pi^+\pi^-$ обнаружены две особенности при $M \sim 1500$ МэВ и $M \sim 1700$ МэВ. Экспериментальные результаты сравнивались с предсказаниями OPER-модели для рассматриваемой реакции.

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The Study of Diffractive Dissociation in the Reaction $\bar{p}p \to \bar{p}p\pi^+\pi^-$ at 22.4 GeV/c

The proton and antiproton diffractive dissociation in the reaction $\bar{p}p \to \bar{p}p\pi^+\pi^-$ (2021 events) was separated by two methods: LPS-analysis and rapidity gap method. The obtained value of the single diffractive dissociation cross section equals 0.41 ± 0.02 mb. The slope of the differential distribution $d\sigma/dt'$ was estimated as $b = 11.5 \pm 1.2$ (GeV/c)$^{-2}$ at $t' < 0.12$ (GeV/c)^2. The production of two peaks at $M \sim 1500$ GeV and $M \sim 1700$ GeV was obserbed in the effective mass distributions of diffractive systems $p\pi^+\pi^-$ and $\bar{p}\pi^+\pi^-$. The experimental data were compared with the predictions of the OPER-model.

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

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