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**ԵՐԵՎԱՆԻ ՖԻԶԻԿԱՅԻ ԻՆՍՏԻՏՈՒՏ**  
**ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ**

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R.G. BADAŁYAN, H.R. GULKANYAN, S.A. KORCHAGIN

INCLUSIVE SPECTRA OF HADRONIC RESONANCES IN THE  
FRAMEWORK OF MULTIPARTON RECOMBINATION MODEL:

1. PROTON FRAGMENTATION

**ЦНИИатоминформ**

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**Ռ.Գ.ԲԱԴԱԼՅԱՆ, Զ.Ռ.ԳՈՒԼՔԱՆՅԱՆ, Ս.Ա. ԿՈՐԶՄԿԻՆ**

**ՀԱԴՐՈՆԱՅԻՆ ՌԵՋՈՆԱՆՄԵՐԻ ԽՆՎՅՈՒՋԻՎ ՍՊԵՍԻՐԵՐԸ  
ԲԱԶՄԱՊԱՐՏՈՆԱՅԻՆ ՎԵՐԱԿԱԶՄՄԱՆ ՄՈԴԵԼԻ ՇՐՋԱՆԱԿՆԵՐՈՒՄ  
I. ՊՐՈՏՈՆԻ ՀԱՏՎԱԾԱՎՈՐՈՒՄԸ**

Բազմապարտոնային վերակազմման/ոեկոմբիանցման/ մոդելի շրջանակներում ստացված են պրոտոնի, , ուղղակի, , հատվածավորումից առաջացած փոքր լայնակի իմպուլս ունեցող Բարիոնային և մեզոնային ռեզոնանսների ինկլյուզիվ սպեկտրերը: Հաշվարկային սպեկտրերը Բաժարար կերպով են նկարագրում Բարձր էներգիաների  $\rho$ ,  $K^\pm$ ,  $\pi^\pm$  փոխազդեցություններում Բարիոնային՝  $\Delta^{++}/1232/$ ,  $\Sigma^\pm/1385/$ , և մեզոնային՝  $\rho^0$ ,  $K^+/1430/$ ,  $K^+/890/$ , ռեզոնանսների ինկլյուզիվ սպեկտրերի  $X$ -կախվածությունը պրոտոնի հատվածավորման լայն /ըստ  $X$ -ի/ տիրույթում:

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Р.Г.БАДАЛЯН, Г.Р.ГУЛКАНЯН, С.А.КОРЧАГИН

ИНКЛЮЗИВНЫЕ СПЕКТРЫ АДРОННЫХ РЕЗОНАНСОВ В РАМКАХ  
МНОГОПАРТОННОЙ РЕКОМБИНАЦИОННОЙ МОДЕЛИ: I. ФРАГМЕНТАЦИЯ  
ПРОТОНА

В рамках многопартонной рекомбинационной модели получены инклюзивные спектры "прямой" фрагментации протона в барионные и мезонные резонансы с малыми поперечными импульсами. Расчетные спектры удовлетворительно описывают имеющиеся экспериментальные данные по  $X$  - зависимости инклюзивных спектров барионных  $\Delta^{++}$  (1232),  $\Sigma^{\pm}$  (1385) и мезонных  $\rho^0$ ,  $K^+$  (1430),  $K^+$  (890) резонансов в широкой (по  $X$ ) области фрагментации протона во взаимодействиях  $pp$ ,  $K^{\pm}p$  и  $\pi^{\pm}p$  при высоких энергиях.

Ереванский физический институт

Ереван 1986

R.G. BADALYAN, H.R. GULKANYAN, S.A. KORCHAGIN

INCLUSIVE SPECTRA OF HADRONIC RESONANCES IN THE  
FRAMEWORK OF MULTIPARTON RECOMBINATION MODEL:

1. PROTON FRAGMENTATION

Spectra of "direct" fragmentation of proton into baryonic and mesonic resonances with small transverse momenta are obtained in the framework of multiparton recombination model. Calculations satisfactorily describe the available experimental data on the  $\bar{X}$ -dependence of inclusive spectra of baryonic  $\Delta^{++}(1232)$ ,  $\Sigma^{\pm}(1385)$  and mesonic  $\rho^0$ ,  $K^+(1430)$ ,  $K^+(890)$  resonances in a wide (over  $\bar{X}$ ) range of proton fragmentation in  $pp$ ,  $K^{\pm}p$  and  $\pi^{\pm}p$  interactions at high energies.

Yerevan Physics Institute

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In Refs. [1-3] a multiparton recombination model (MRM) is developed, in which, in contrast to recombination models (RM) [4-8], a general case of transition from an incident hadron into a final one of an arbitrary number of partons is considered. There a parameter  $W$  is introduced in the model, determining the probability of an incident hadron sea parton being included in the sea of the registered hadron. It is shown in Refs. [1,2] that the form of inclusive spectra of hadrons in the Feynman variable range of  $X \sim 1$  can determine the parameter  $W$ . It has been found [1,2], that  $W$  definitely depends on the number of valence quarks  $N_v$  common for incident and final hadrons. Thus, for proton fragmentation  $p \rightarrow h$  at  $N_v=3$  the parameter  $W$  is close to unity; at  $N_v=2$   $W \geq 2/3$ ; at  $N_v=1$   $0 \leq W < 1/3$ ; at  $N_v=0$   $W \approx 0$ .

The present work is devoted to the calculation of cross sections of hadronic resonances in the proton fragmentation region. In the MRM framework this cross section has the form:\*

$$\frac{\sqrt{x^2 + x_r^2}}{\sigma_{in}} \frac{d\sigma}{dx} (p \rightarrow h) = \sum_{N_v=0}^{N_v^{max}} \int F_{v_1 \dots v_{N_h}}(x_1, \dots, x_{N_h}; W_1, \dots, W_{N_h}) \times \\ \times R_h\left(\frac{x_1}{x}, \dots, \frac{x_{N_h}}{x}\right) \delta\left(1 - \sum_{j=1}^{N_h} \frac{x_j}{x}\right) \prod_{j=1}^{N_h} dx_j \quad (1)$$

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\* Summation over  $N_v$  in the Eq.(1) means, that to the inclusive

where,  $x_T = 4(m_h^2 + P_T^2)/S$ ,  $m_h$  is the mass of final hadron,  $P_T$  is its transverse momentum,  $\sqrt{S}$  is the invariant energy,  $\sigma_{in}$  is the cross section of inelastic interaction of the incident particle with proton. In further calculations  $P_T^2$  is substituted by its average value at small  $X$ :  $\langle P_T^2 \rangle = 0.1 \text{ GeV}^2/c^2$  (at large  $X$  the inclusive spectra (1) are not sensitive to  $P_T^2$ ).

Function  $F_{V_1 \dots V_{N_h}}(X_1, \dots, X_{N_h}; W_1, \dots, W_{N_h})$  characterizes the statistical weight of a multiparton substate in proton, which has the same quark composition  $V_1, \dots, V_{N_h}$  and longitudinal momentum  $X$  as the hadron  $h$  has, and which contains on an average  $W$  part of proton sea partons ( $W = \sum_{j=1}^{N_h} W_j$ ). This function [3] is expressed in terms of proton multiparton distribution function parameters [9,10] determined in deep inelastic processes.

According to a hypothesis used in the MRM, the multihadron substate recombination into hadron follows the formation of composite objects-valons  $V_1, \dots, V_{N_h}$ , which carry, correspondingly,  $X_1/X, \dots, X_{N_h}/X$  portions of the longitudinal momentum ( $X = \sum_{j=1}^{N_h} X_j$ ) and which contain, correspondingly, on the average  $W_1, \dots, W_{N_h}$  portions of proton sea partons. In concrete calculations for the processes considered

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spectrum of  $h$  hadron contribute processes where valence quarks from  $N_v=0$  to  $N_v=N_v^{\max}$  pass from the incident proton to  $h$  hadron, where  $N_v^{\max}$  is the maximum possible number of common valence quarks of the proton and the final hadron.

in this work, the latter's values have been fixed: for proton-meson or proton-baryon processes with  $N_v=0$  or 1  $W=0$  ( $W_1 = \dots = W_{N_h} = 0$ ); for proton-baryon processes with  $N_v=2$   $W_1 = W_2 = \frac{1}{2} W = \frac{1}{3}$  (for valons containing valence quarks of proton) and  $W_3=0$  (for a valon lacking a proton valence quark).

The hypothesis of valon formation, allows to introduce a function of their recombination into  $h$  hadron  $R_h(x_1/x, \dots, x_{N_h}/x)$ , which can be connected [7,8] with the two-(three)-valon distribution function  $G_h(z_1, \dots, z_{N_h})$  of the final meson (baryon)  $h$  :

$$R_h(z_1, \dots, z_{N_h}) = A_h \left( \prod_{j=1}^{N_h} z_j \right) G_h(z_1, \dots, z_{N_h}) \quad (2)$$

The two-(three)-valon distribution function  $G_h$  can be expressed [3] via the parameters of the multiparton distribution function of  $h$  hadron. So, the  $X$ -dependence of the inclusive spectrum (1) is fully determined by the parameters of parton structure functions of incident and final hadrons, fixed in deep inelastic processes and by  $W$  fixed from the behaviour of inelastic spectra at  $X \sim 1$ . The absolute value of the inclusive cross sections (1) also depends on proportionality coefficients  $A_h$  in the expression (2). It is assumed in MRM, that these coefficients are the same for hadrons in one and the same multiplet, their values being determined by comparison with the experiment.

Expressions for functions  $F_{v_1 \dots v_{N_h}}$  and  $G_h$  in Eqs. (1) and (2) for the proton fragmentation at  $N_v=2,1,0$  are given in Ref.[3]. The obtained with the help of these expressions theoretical inclusive spectra of hadronic resonances are

compared in Figs.1-5 with the available experimental data at energies higher than 30 GeV [11,21], covering a rather wide over the variable  $X$  range of proton fragmentation: baryonic resonances  $\Delta^{++}(1232)$ ,  $\Sigma^{\pm}(1385)$  and mesonic ones  $\rho^0$ , K(890), K(1430). The comparison of calculations with data on  $\rho^0$ -meson (in  $K^+p \rightarrow \rho^0 X$  and  $p p \rightarrow \rho^0 X$  reactions, where there are no subprocesses with annihilation of valence quarks) has shown, that the value of  $A_h = A_M$  is close to unity (see Fig.1). It means that the MRM correctly predicts not only the form, but also the absolute value of the inclusive spectrum of  $\rho^0$ -meson. The same value of  $A_M = 1$  is used for other mesonic resonances too: K(890) and K(1430) (Figs.2,3). In the spectrum of K(890), apart from the direct production, the contribution of  $K(1430) \rightarrow K(890)\pi$  decays is taken into account.

The comparison of calculations with the data on  $\Delta^{++}$  isobar yields values of  $A_h = A_B = 7.7$  (Fig.4; similar value of  $A_B$  is used in the calculation of spectra of  $\Sigma^{\pm}$  (1380) shown in Fig.5). Such difference in  $A_M$  and  $A_B$  is apparently due to the fact, that integration in (1) is carried out in the phase space of two and three valons, respectively (if assumed that the recombination functions  $R_\rho(z_1, z_2)$  and  $R_\Delta(z_1, z_2, z_3)$  have the same normalization, then  $A_\Delta/A_\rho = 8.2$ ).

In the spectra of strange particles, (Figs.2,3,5) for  $\lambda$ , a parameter characterizing the suppression of the proton strange sea with respect to the nonstrange one, the value of  $\lambda = 1/8 + 1/4$  is used in the whole variation range of  $X$ . Such a

wide spread of values is due to indefiniteness at extraction of parameters of strange sea quarks from experiments on deep inelastic lepton-nucleon scattering.

The calculated inclusive spectra shown in Figs.1-5 are mainly in satisfactory agreement with the experimental data in the proton fragmentation region at  $X \geq 0.3$ . The agreement is unsatisfactory for  $\rho^0$  and  $K(890)$  spectra in the range of  $X < 0.2$ , where the above mentioned recombination mechanism turns out to be imperfect due to the appreciable contribution of other mechanisms of meson production in the central region. Decays of the highest resonances may also make a certain contribution, though at present there are no experimental indications on their appreciable production at high energies.

The results obtained in this paper show, that the MRM can be used in the calculations of inclusive spectra of mesonic and baryonic resonances in fragmentation regions and thus - to determine the contribution of these resonances to inclusive spectra of stable hadrons, the results of calculations of which will be presented in the further publications.

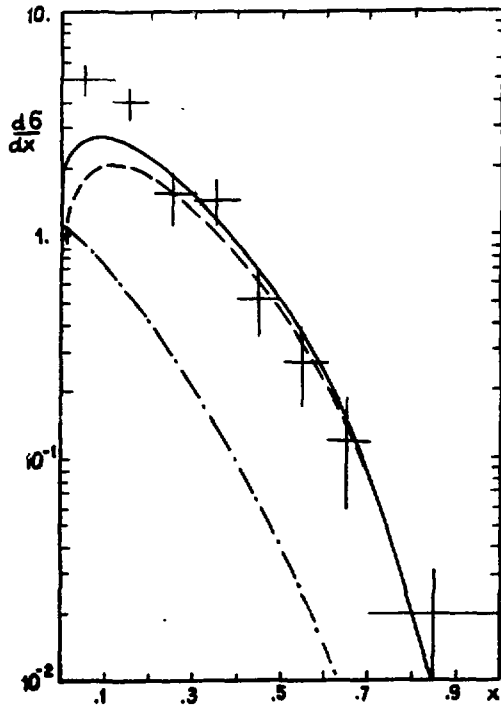


Fig. 1a

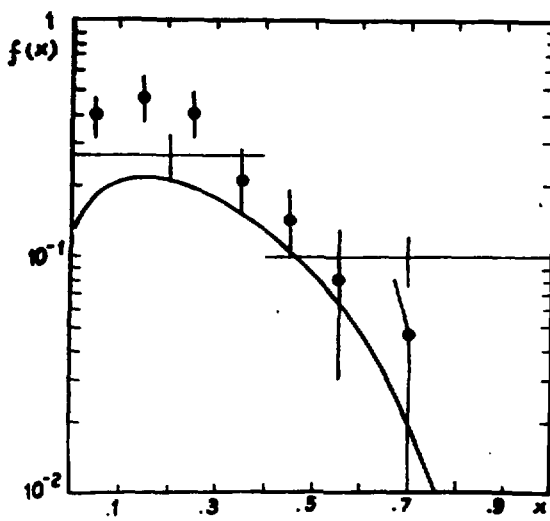


Fig. 1b

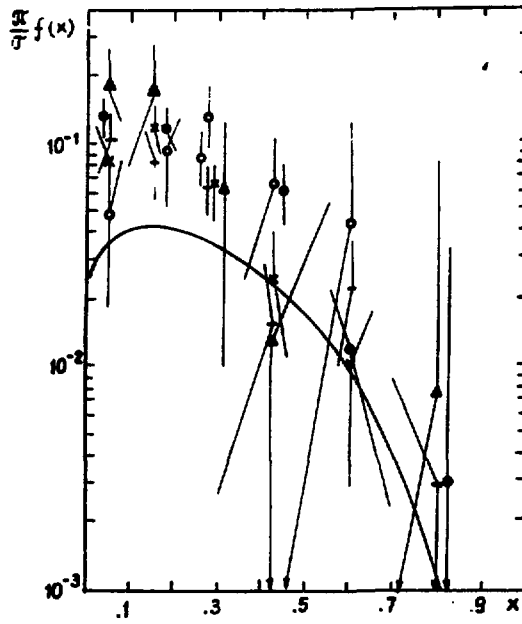


Fig. 1c

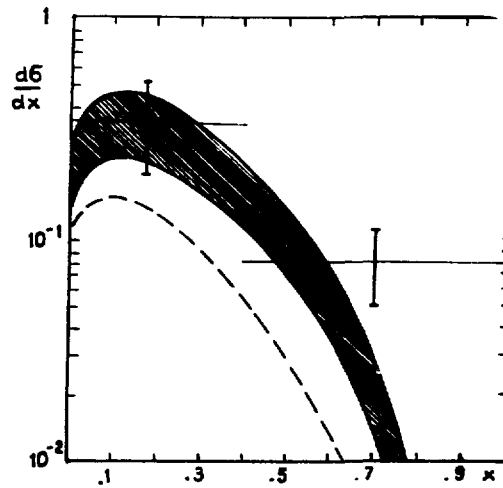


Fig. 2

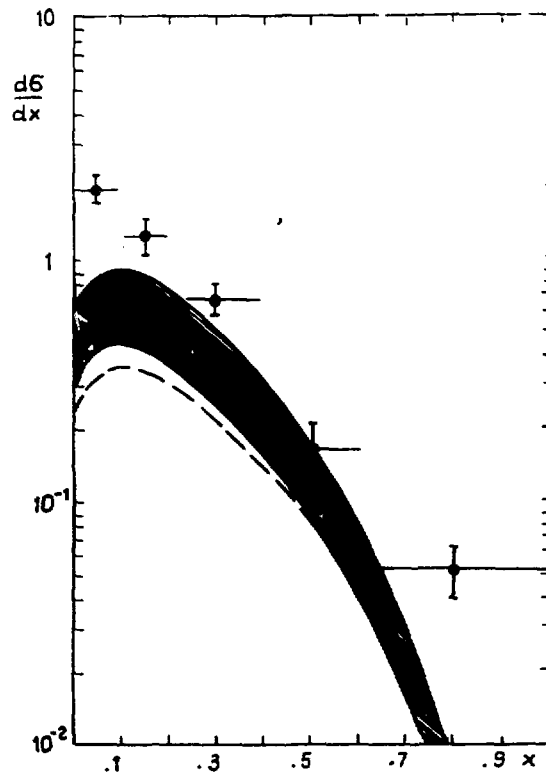


Fig. 3

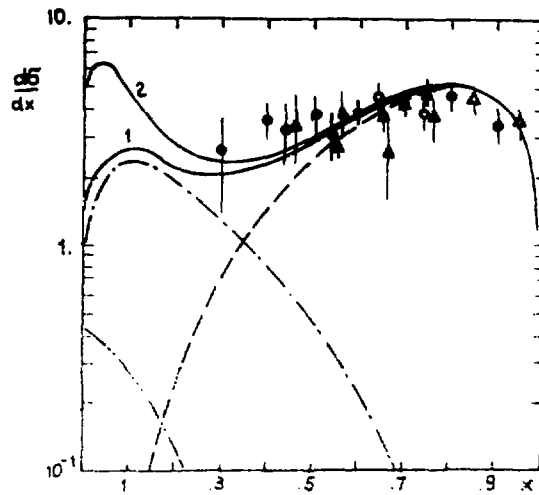


Fig. 4A

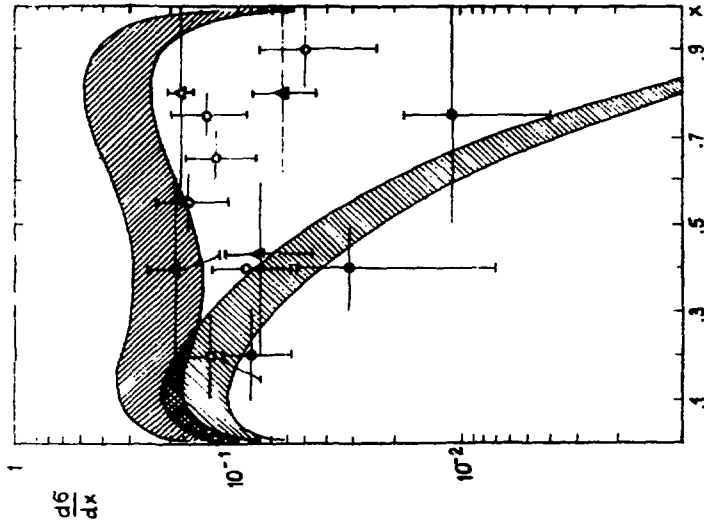


Fig. 5a

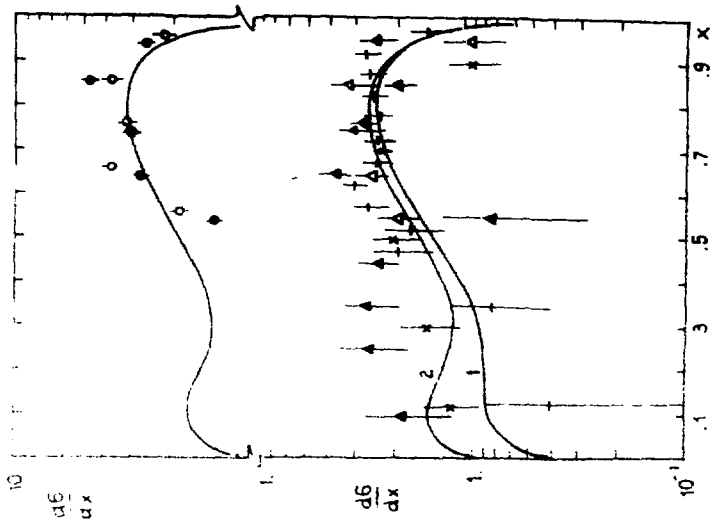


Fig. 4b

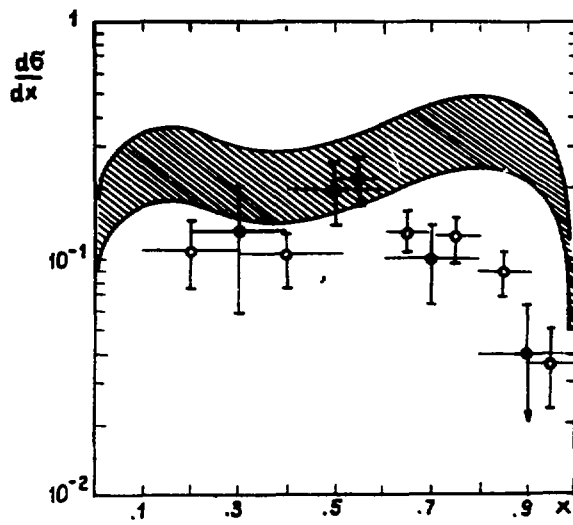


Fig. 5b

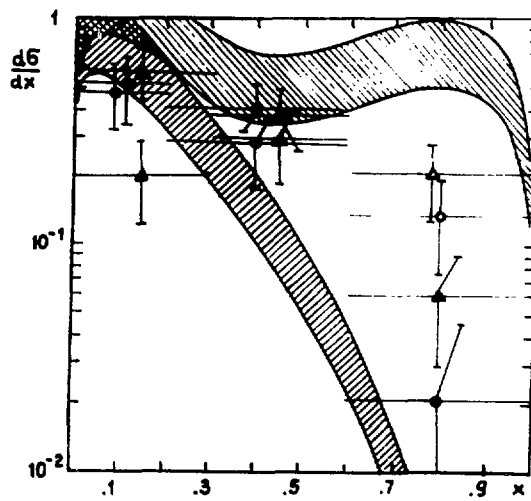


Fig. 5c

FIGURE CAPTIONS

Fig.1 Inclusive spectra of  $\rho^0$  meson in the proton fragmentation region.

Fig.1a  $p \xrightarrow{K^+} \rho^0$  : + - 32 GeV/c [11]. Calculated curves correspond to fragmentations at the total number of common valence quarks  $N_V=1$  (dotted line),  $N_V=0$  (dot-and-dash line); the solid curve is the total spectrum.

Fig.1b  $p \xrightarrow{K^-} \rho^0$  : ● - 32 GeV/c, + - 110 GeV/c [12].

Fig.1c  $p \xrightarrow{P} \rho^0$  : + - 147 GeV/c, X - 147 GeV/c;

$p \xrightarrow{\pi^+} \rho^0$  : ● - 147 GeV/c;  $p \xrightarrow{\pi^-} \rho^0$  : ○ - 147 GeV/c;

$p \xrightarrow{K^+} \rho^0$  : ▲ - 147 GeV/c [13].

Fig.2 Inclusive spectrum of  $K^+(1430)$  at  $\lambda = 1/8 + 1/4$  (shaded area) and  $K^0(1430)$  at  $\lambda = 1/8$  (dotted curve). Experiment:  $p \xrightarrow{K^+} K^+(1430)$ : + - 32 GeV/c [14].

Fig.3 Inclusive spectrum of  $p \xrightarrow{K^+} K^+(890)$ ; + - 32 GeV/c [14]. The dotted curve is the spectrum of "direct" fragmentation of proton into  $K^+(890)$  at  $\lambda = 1/8$ . The shaded area is the total spectrum with regard for the "direct" fragmentations and decays  $K^{\dagger}(1430) \rightarrow K^+(890)\pi^0$  at  $\lambda = 1/8 + 1/4$ .

Fig.4 Inclusive spectra of  $\Delta^{++}(1232)$  resonance in the proton fragmentation region.

Fig.4a  $p \xrightarrow{P} \Delta^{++}$  : ● -  $\sqrt{S}=65$  GeV, ○ -  $\sqrt{S}=45$  GeV, ▲ -  $\sqrt{S}=31$  GeV [15];  $\Delta$  - 147 GeV/c [16]. Calculated curves correspond to fragmentations at the total number of common valence quarks  $N_V=2$  (dotted line),  $N_V=1$  (dot-

-and-dash line) and  $N_V=0$  (dash-dash-and-dot line); the solid curve 1 is the total spectrum at 147 GeV/c, the curve 2 - at  $\sqrt{S}=65$  GeV

Fig.4b  $p \xrightarrow{\pi^+} \Delta^{++}$  : ● - 147 GeV/c;  $p \xrightarrow{\pi^-} \Delta^{++}$  : ○ - 147 GeV/c [16];  $p \xrightarrow{K^+} \Delta^{++}$  : + - 32 GeV/c [17], ▲ - 70 GeV/c [18], Δ - 147 GeV/c [16];  $p \xrightarrow{K^-} \Delta^{++}$  : × - 32 GeV/c [19]. The curve 1 is the calculated spectrum at 32 GeV/c. the curve 2 - at 147 GeV/c.

Fig.5 Inclusive spectra of  $\Sigma^\pm(1385)$  in the proton fragmentation region.

Fig.5a  $p \xrightarrow{K^+} \Sigma^+$  : ○ - 32 GeV/c;  $p \xrightarrow{K^+} \Sigma^-$  : ● - 32 GeV/c [17]  
 $p \xrightarrow{K^-} \Sigma^+$  : Δ - 32 GeV/c;  $p \xrightarrow{K^-} \Sigma^-$  : ▲ - 32 GeV/c [19].

Fig.5b  $p \xrightarrow{K^+} \Sigma^+$  : ○ - 32 GeV/c; ● - 70 GeV/c [18].

Fig.5c  $p \xrightarrow{P} \Sigma^+$  : ○ - 405 GeV/c;  $p \xrightarrow{P} \Sigma^-$  : ● - 405 GeV/c [20]  
 $p \xrightarrow{P} \Sigma^+$  : Δ - 360 GeV/c;  $p \xrightarrow{P} \Sigma^-$  : ▲ - 360 GeV/c [21].



11. Chliapnikov P.V. et al. Inclusive Production Of  $\rho^0$  And  $\varphi$  Mesons In  $K^+p$  Interactions At 32 GeV/c.- Nucl.Phys., 1980, vol.B176, p.303-320.
12. Gottgens R. et al. Proton Fragmentation Into Pions And Pion Systems In  $K^-p$  Interactions At 110 GeV/c And Comparison to Model Predictions.- Z.Phys., 1984, vol.C22, p.205-218.
13. Schouten M. et al. Inclusive And Semi-Inclusive  $\rho^0$  Production In  $\pi^+/\pi^-/K^+/pp$  Interactions At 147 GeV/c.- Z.Phys., 1981, vol.C9, p.93-104.
14. Ajinenko I.V. et al. Inclusive  $K^{*+}(890)$ ,  $K^{*+}(1430)$  And  $K^{*-}(890)$  Production In  $K^+p$  Interactions At 32 GeV/c.- Z.Phys., 1984, vol.C25, p.103-114.
15. Breakstone A. et al. Inclusive  $\Delta^{++}$  In pp Interaction At ISR Energies.- Z.Phys., 1984, vol. C21, p.321.
16. Brick D. et al. Inclusive  $\Delta^{++}$  Production in pp,  $K^+p$ ,  $\pi^+p$  and  $\pi^-p$  Interactions At 147 GeV/c.- Phys.Rev., 1980, vol.D21, p.632-640.
17. Ажиненко И.В. и др. ИнCLUSIVE рождение  $\Delta^{++}(1232)$  и  $\Sigma^{\pm}(1385)$  в  $K^+p$  - взаимодействиях при 32 ГэВ/с. Препринт ИФВЭ 80-129, 1980.
18. De Wolf E.A. et al. Inclusive Baryon Production In  $K^+p$  Interactions At 70 GeV/c.- Nucl.Phys., 1984, vol.B246, p.431-461.
19. Kriegel U. Recent Results On Inclusive Baryon Production In  $K^-p$  Interactions At 32 GeV/c.- Труды У Международного семинара по проблемам физики высоких энергий. Дубна, 1978, с.454-468.

20. Kichimi M. et al. Inclusive Study Of Strange-Particle Production In pp Interactions At 405 GeV/c.- Phys.Rev., 1979, vol.D20, p.37-52.
21. Aziz T. et al. Inclusive  $K^*$ 's and  $\Sigma^*$ 's Production In 360 GeV/c pp Interaction Using EHS.- CERN/EP 85-120,1985.

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Р.Г.БАДАЛЯН, Г.Р.ГУЛКЯНЯН, С.А.КОРЧАГИН

ИНКЛЮЗИВНЫЕ СПЕКТРЫ АДРОННЫХ РЕЗОНАНСОВ В РАМКАХ  
МНОГОПАРТОННОЙ РЕКОМБИНАЦИОННОЙ МОДЕЛИ: I. ФРАГМЕНТАЦИЯ  
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