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TRIPLE REGGE ANALYSIS AND $K\bar{K}$ OFF-SHELL

INTERACTIONS FROM $p \rightarrow K \rightarrow \Lambda$ AT 110 GeV/c

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ABSTRACT

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A study of Λ production has been made in the proton fragmentation region from $K\bar{p}$ interactions at 110 GeV/c. From a simultaneous fit to the missing mass distributions and the inclusive Λ -production cross section with $Plab \geq 10$ GeV/c, the intercept of the strange meson trajectory is determined to be ≈ -0.15 . The contribution of the Pomeron is found to be dominant at the $K\bar{K}$ vertex in 110 GeV/c $K\bar{p}$ interactions. The charged multiplicities and moments from off-shell $K\bar{K}$ interactions have been studied as a function of M^2 , the c.m. energy squared of the virtual $K\bar{K}$ system.

1. INTRODUCTION

Several studies have been made in the past for the inclusive production of Λ in the proton fragmentation region from K^-p interactions. It is known from triple Regge analyses of the low energy data upto 8 GeV [1-3] that the Regge trajectories responsible for $p \xrightarrow{K^-} \Lambda$ are the strange meson with strangeness +1, labelled as ' K^+ '. This has also led to the off-shell studies of ' K^+K^- ' interactions from 4.2 GeV/c [4] and 8.25 GeV/c [5] K^-p data.

The inclusive production of Λ in the proton fragmentation region can be subdivided into two parts from the point of view of ' K^+K^- ' interactions[6]:

(a) strangeness annihilation processes of the type

where the leading Regge trajectory at the $K\bar{K}$ vertex is expected to be the exchange degenerate ϕ -f' trajectory, and

(b) strangeness non-annihilation process of the type

where the leading trajectories at the $K\bar{K}$ vertex are expected to be the Pomeron and the normal meson trajectories. As a result the reaction (1) is supposed to decrease with energy as s^{-1} , where s is the square of the c.m. energy of the K^-p system and at high energies the reaction (2) is expected to be the dominant process.

In this paper we present results on inclusive production of Λ in the proton fragmentation region from 110 GeV/c K^-p interactions. The data presented here correspond to the highest energy for K^-p interactions studied so far. The proton fragmentation region is selected by cut on the 4-momentum transfer: $|t_{p\Lambda}| < 4.0 \text{ GeV}^2$. The plan of the paper is as follows. The experimental details are given in section 2. In section 3 we present the triple Regge formalism for the analysis of $p \xrightarrow{K^-} \Lambda$. In section 4 we give the experimental results. Multiplicity distributions from off-shell $K\bar{K}$ interactions are presented in section 5 in the framework of the KNO scaling; the range of M^2 covered in the present work is upto 170 GeV^2 . Results are summarised in section 6.

2. EXPERIMENTAL DETAILS

The data for this analysis are obtained from three exposures of BEBC filled with liquid hydrogen to the RF separated K^- beam tuned to 110 GeV/c. The details of the exposures are given in an earlier paper [7]. A beam tagging system consisting of two scintillator hodoscopes and two threshold Cerenkov counters was used to identify the kaons in the beam.

All the films from the first two exposures and a part of the film from the third exposure were scanned twice for interactions with tagged kaons in the beam. These events were then measured on automatic and manual measuring machines and processed through HYDRA chain of programs for geometric reconstruction and kinematic fitting of the associated V^0 decays

and γ conversions. The present sample consists of 1872 fitted Λ 's corresponding to a sensitivity of ~ 1.5 events/ μb . Only a fraction of these Λ 's ($\sim 50\%$) comes from unique fits. The rest of the Λ 's are ambiguous with the hypothesis of K^0 decay and/or γ conversion. The ambiguities were sorted out using the prescription described in reference [7]. In the subsequent analysis, only unique Λ 's have been used with proper ambiguity weight and decay potential weight.

Events in the proton fragmentation region were selected by imposing a cut in the 4-momentum transfer $t_{p\Lambda} = (p_p - p_\Lambda)^2$ as $|t_{p\Lambda}| < 4.0 \text{ GeV}^2$. This cut selects Λ 's with Feynman x as less than -0.2 . No attempt has been made to remove Λ 's coming from decays of Σ^0 and $\Sigma(1385)$. Lower energy experiments [8,9] have shown that this contamination does not introduce much bias to the analysis as one expects Σ^0 and $\Sigma(1385)$ to have similar production mechanisms to that of the Λ .

3. TRIPLE REGGE DESCRIPTION OF $p \xrightarrow{K^-} \Lambda$

The inclusive production of Λ in the proton fragmentation region can be written in terms of strangeness annihilation and strangeness non-annihilation processes, as in eqs. (1) and (2) of sect.1. The relevant triple Regge diagrams are shown in fig.1. The unpolarised Λ cross section in terms of these diagrams can be written as

$$\frac{d^2\sigma}{dt d(M^2/s)} = \sum_{i=p,M,\phi} G_i(t).s^{\alpha_i(0)-1} \cdot (M^2/s)^{-1} \alpha_i(0) - 2\alpha_{\text{eff}}^K(t) \quad (3)$$

where $s = (p_K + p_p)^2$, $M^2 = (p_K + p_{\bar{\Lambda}})^2$ with p_i standing for 4-momentum vectors and $G(t)$ contains the Regge residues and signature factors; for more details see review [10]. The strange Regge trajectories for $p\bar{\Lambda}$ vertices are denoted by an effective trajectory $\alpha_{\text{eff}}^K(t)$. The sum on the right-hand side of the eq.(3) is taken over the three leading trajectories at the $K\bar{K}$ vertex namely, Pomeron, meson and ϕ . In this analysis we have assumed the following forms for $G_i(t)$ and $\alpha_{\text{eff}}^K(t)$:

$$G_i(t) = A_i \cdot \exp(B_i t) \quad (4)$$

$$\alpha_{\text{eff}}^K(t) = \alpha_{\text{eff}}^K(0) + \alpha'_{\text{eff}} \cdot t \quad (5)$$

3.1. Triple Regge description of M^2/s distribution

The M^2/s distribution can be obtained from eq.(3) by integrating it over t ,

$$\frac{d\sigma}{d(M^2/s)} = \int_{t_{\text{min}}}^{t_{\text{max}}} dt. G_i(t).s^{\alpha_i(0)-1} \cdot (M^2/s)^{-1} \alpha_i(0) - 2\alpha_{\text{eff}}^K(t) \quad (6)$$

Since experimentally one obtains M^2/s distribution with a specified bin width over a t range, say t_1 and t_2 (t_1 and t_2 are upper and lower limits respectively), it is necessary to calculate the cross section for each (M^2/s) bin in order to take care of the phase space effect [11], otherwise one overestimates the intercept of $\alpha_{\text{eff}}^K(t)$. This can be done in the following way,

$$\alpha_j[(M^2/s)_j, (M^2/s)_{j+1}] = \int_{(M^2/s)_j}^{(M^2/s)_{j+1}} \int_{t_{\min}}^{t_{\max}} dt \cdot G_1(t) \cdot s^{\alpha_1(0)-1} \cdot (M^2/s)^j \cdot \alpha_1(0) - 2\alpha_{\text{eff}}^K(t) \quad (7)$$

where

$$t_{\max}^* = \text{Max}[t_1, \{m_p^2 + m_\Lambda^2 - 2E_p^* E_\Lambda^* - 2p_p^* p_\Lambda^*\}], \quad (8)$$

$$t_{\min}^* = \text{Min}[t_2, \{m_p^2 + m_\Lambda^2 - 2E_p^* E_\Lambda^* + 2p_p^* p_\Lambda^*\}]$$

$$E_\Lambda^* = (s + m_\Lambda^2 - M^2)/(2\sqrt{s});$$

E_p^* = c.m. energy of the target proton;

m_p, m_Λ = masses of proton and Λ respectively.

3.2. Energy dependence of inclusive Λ cross section

The inclusive cross section of Λ can be obtained [10]

by integrating eq.(3) over t and M^2/s ,

$$\sigma = \int_1^I \int_{(M^2/s)_{\min}}^{(M^2/s)_{\max}} \int_{t_{\min}}^{t_{\max}} dt \cdot G_1(t) \cdot s^{\alpha_1(0)-1} \cdot (M^2/s)^{\alpha_1(0)-2\alpha_{\text{eff}}^K(t)} \quad (9)$$

The values of $(M^2/s)_{\min}$ and $(M^2/s)_{\max}$ are the minimum and the maximum values of (M^2/s) allowed from the kinematic selection of events; $t_{\min}$ and $t_{\max}$ are the minimum and the maximum values of the 4-momentum transfer for a given value of M^2/s . When the data is selected with Feynman $|x| > x_{\text{cut}}$, the minimum and the maximum values of M^2/s are given by

$$(M^2/s)_{\min} = 4m_K^2/s, \quad \text{for Pomeron and meson trajectories} \\ = m_\pi^2/s, \quad \text{for } \phi \text{ trajectory}$$

$$(M^2/s)_{\max} = 1 + m_\Lambda^2/s - 2 \cdot s^{-\frac{1}{2}} \cdot [x_{\text{cut}}^2 \cdot p_{\text{max}}^2 + \langle p_{T\Lambda}^2 \rangle + m_\Lambda^2]^{\frac{1}{2}} \quad (10)$$

where p_{max} is the maximum momentum allowed to Λ in the c.m. system and $\langle p_{T\Lambda}^2 \rangle$ is the mean of the square of the Λ -transverse momentum which is known from experiments; m_K and m_π are masses of kaon and pion respectively.

4. EXPERIMENTAL RESULTS FROM TRIPLE REGGE ANALYSIS

We have selected the available Λ -data on missing mass distributions and inclusive cross sections with $p_{\text{lab}} \geq 10$ GeV/c for the present analysis. For the missing mass distributions the data used are: (i) 110 GeV/c from the present work at 4 t-intervals, figs 2(a) to 2(d) show $d\sigma/d(M^2/s)$ distributions; (ii) 10 and 16 GeV/c data [13] in the form of $d\sigma/dM$ distributions for 5 t-intervals; see figs. 3(a) to 3(e) for 10 GeV/c data and figs. 4(a) to 4(e) for 16 GeV/c data. For the energy dependence of the inclusive Λ cross section we have selected Λ 's with Feynman $x \leq -0.20$ (i.e., $x_{\text{cut}} = -0.2$) for p_{lab} at 10 GeV/c [13], 13 GeV/c [14], 14.3 GeV/c [15], 16 GeV/c [13], 32 GeV/c [9] and 110 GeV/c.

The data mentioned above have selection constraints only through Feynman x or t cuts and no selection on the final state particles. Therefore, all the three trajectories at the $K\bar{K}$ vertex - Pomeron, meson and ϕ - will contribute to the missing mass distributions as well as the inclusive Λ cross sections. At the $p\bar{\Lambda}$ vertex the exchanged trajectory is the strange meson as given by eq.(5).

A simultaneous fit to the data has been made using eqs.

(7) and (9). For the fit we have fixed the intercepts of the Pomeron, meson and ϕ trajectories to 1.0, 0.5 and 0.0 respectively. A total of eight parameters has been used for the fit: six parameters for $G_1(t)$ of eq. (4) and two parameters for strange trajectory $\alpha'_{\text{eff}}(t)$ of eq. (5). Results of the fit are shown as smooth curves in figs. 2 to 5. The total χ^2 is 560 for 181 data points. The fit is reasonable in a sense that we cover a broad energy range from 10 to 110 GeV/c. We note that for the three mass plots at low t values - figs. 2a, 3a and 4a - the data exhibit large fluctuations and the fit is poor. However the missing mass distributions at large t values and the energy dependence of the inclusive Λ cross section are reasonably reproduced by the fitted curves.

The values of the fitted parameters are listed in table

1. It may be mentioned that there is a weak correlation between the intercept $\alpha'_{\text{eff}}(0)$ and the slope α'_{eff} . The values listed in table 1 are for $\alpha'_{\text{eff}} = 0.8 \text{ GeV}^{-2}$; there is no significant change in the parameter values for α'_{eff} between 0.8 and 1.0 GeV^{-2} .

It is seen from the table 1 that the dominant contributions to the cross section are from Pomeron and ϕ trajectories. The contributions of Pomeron, meson and ϕ trajectories are respectively: =5%, =1% and =40% at 32 GeV/c; =88%, =0% and =12% at 110 GeV/c. Errors in these quantities are $\sim 15-20\%$.

4.1. Discussion of the results

The fitted parameters as obtained above should be able to reproduce the shape of the Feynman x distribution of Λ at x close to unity for large p_{lab} . They can also be used to predict the cross section for strangeness non-annihilation component. These are discussed below and we also present a comparison of our results with those obtained from similar studies.

(a) Shape of $d\sigma/dx$ distribution: From eq. (3) we can write the expression for $d\sigma/dx$ by using the relation $M^2/s = 1 - |x|$, which is valid for s + large and $|x| > 2 \cdot s^{-1/2} \cdot (p_{\text{TA}}^2 + m_{\Lambda}^2)^{1/2}$, and integrating over t ,

$$\frac{d\sigma}{d|x|} = \sum_{i=P,M,\phi} C_i \cdot (1 - |x|)^{1-2\alpha'_{\text{eff}}(0)} \quad (11)$$

with $C_i = A_i [B_i - 2\alpha'_{\text{eff}} \cdot \ln(1 - |x|)]^{-1} \cdot s \alpha_i(0) - 1$

At 110 GeV/c, where s is reasonably large, the shape of the x -distribution, for x close to unity, is expected to be: $d\sigma/d|x| \sim (1 - |x|)^{1.3 \pm 0.3}$. The exponent from the experimental data (not shown) for $-1.0 < x < -0.4$ is found to be 0.9 ± 0.4 which is in good agreement with the expected exponent. This gives an internal consistency check on the fitted value of the intercept of the strange trajectory.

(b) Strangeness non-annihilation cross section: In fig. 6 is shown the compilation of the strangeness non-annihilation cross section for $p_{\text{lab}} \geq 10 \text{ GeV/c}$ [7,9,14,15] with the constraint of Feynman $x < -0.2$. The solid curve represents the expectation from our fitted parameters. The agreement with the data is quite

reasonable.

(c) Comparison with other studies : The effective strange meson trajectory has also been obtained from triple Regge analyses of $p \xrightarrow{K^-} \Lambda$ at 4.2 and 8.25 GeV/c [1,3], $p \xrightarrow{K^+} \Lambda$ at 8.2 and 16 GeV/c [16], and $p \xrightarrow{P} \Lambda$ at 12, 19, 24 and 69 GeV/c [17-19]. The effective strange trajectory as deduced from these experiments are summarised in table 2 along with the present result. As can be seen from the table there is a reasonable agreement among the different analyses. From the value of the intercept (see table 2) it seems that the unnatural kaon trajectory ($\alpha_K^u(0) = -0.2$) is preferred over the natural kaon trajectory ($\alpha_K^{\text{eff}}(0) = +0.4$).

Recently a study has been made [20] on the cross section difference between $p \xrightarrow{K^-} \Lambda$ and $p \xrightarrow{K^+} \Lambda$ in the single Regge framework upto 70 GeV/c. Results of this study when extrapolated to 110 GeV/c for Feynman $x < -0.2$ yields $\approx 20\%$ contribution from non-Pomeron terms which is in agreement with the finding of $\approx 12\%$ contribution from the present analysis.

5. MULTIPLICITIES AND MOMENTS FROM 'K'K INTERACTIONS

The mean charged multiplicity $\langle n_{\text{ch}} \rangle$ from off-shell 'K'K interactions is plotted in figure 7 as a function of M^2 , which is the c.m. energy squared of the virtual 'K'K system. One sees that the average charged multiplicity increases with M^2 which is consistent with a fit of the type

$$\langle n_{\text{ch}} \rangle = (0.84 \pm 0.26) + (0.79 \pm 0.01) \ln M^2 + (0.09 \pm 0.01) \ln^2 M^2 \quad (12)$$

as shown by the solid line in fig. 7. The smallness of the last term indicates that the data points are consistent even with a simple logarithmic increase with c.m. energy squared. The dashed curve in fig. 7 shows such a fit with the following parametrisation:

$$\langle n_{\text{ch}} \rangle = (-0.41 \pm 0.43) + (1.97 \pm 0.10) \ln M^2 \quad (13)$$

The multiplicity moments C_q defined by

$$C_q = \langle n^q \rangle / \langle n \rangle^q \quad (14)$$

are listed in table 3 as a function of M^2 at 110 GeV/c. The values of C_2 , C_3 , C_4 are independent of M^2 within errors in the M^2 range upto 169 GeV² and thus indicating the existence of KNO scaling [21] in the off-shell 'K'K interactions. These values are in good agreement with off-shell 'K'K interactions studied earlier upto $M^2 = 8 \text{ GeV}^2$ [4,5].

To study the KNO scaling function [21], a plot of the function

$$\psi_n = \frac{\langle n^q \rangle}{\langle n \rangle^q} \frac{\sigma_{\text{ch}}}{\sigma_{\text{inel}}} \quad (15)$$

is made in fig. 8 as a function of $z = n_{\text{ch}} / \langle n_{\text{ch}} \rangle$ for different values of M . It is seen that within experimental uncertainties the data points from different M ranges seem to fall on a universal curve. The solid line in fig. 8 refers to the Slattery parametrisation [22] of pp inelastic scattering data and the dashed curve refers to the $\bar{p}p$ annihilation data at low energies (as done in reference [23]). The experimental points seem to agree better with the $\bar{p}p$ annihilation data, however the large

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experimental uncertainties cannot rule out the validity of the Slattery parametrisation.

6. SUMMARY

In this paper we have studied lambda production in the proton fragmentation region from 110 GeV/c K^-p interactions. The main aim has been to study the Λ production in the triple Regge framework and the off-shell study of $K^*\bar{K}$ interactions to deduce charge multiplicity moments. The main results from this analysis are as follows :

- (i) By making a simultaneous fit to the missing mass distributions and the inclusive Λ production cross section for $P_{lab} > 10$ GeV/c, the coupling parameters of the Pomeron, meson and ϕ trajectories are determined. The intercept of the strange meson trajectory is determined to be (-0.15 ± 0.15) .
- (ii) The Pomeron is found to contribute dominantly at 110 GeV/c and its contribution amounts to $\sim 88\%$.
- (iii) The energy dependence of the strangeness non-annihilation cross section and the shape of the x-distribution close to unity are reasonably well reproduced by the fitted parameters of the trajectories.
- (iv) Multiplicity moments and the KNO scaling functions are determined from the virtual $K\bar{K}$ interactions upto M^2 value of 169 GeV². It is found that the multiplicity moments and the KNO scaling function are in good agreement with those calculated from low energy K^-p data upto M^2 value of 8 GeV².

TABLE 1

Values of the fitted parameters from triple Regge analysis

Parameters	Values
A_p (mb.Gev ⁻²)	10.6 $\pm$ 1.6
A_M (mb.Gev ⁻²)	1.0 $\pm$ 0.2
A_ϕ (mb.Gev ⁻²)	223.0 $\pm$ 30.0
B_p (Gev ⁻²)	-0.04 $\pm$ 0.01
B_M (Gev ⁻²)	1.0 $\pm$ 0.3
B_ϕ (Gev ⁻²)	0.10 $\pm$ 0.04
$\alpha_{eff}^K(0)$	-0.15 $\pm$ 0.15
α_{eff}^A (Gev ⁻²)	0.8

TABLE 2

Strange meson trajectory as determined from triple Regge analyses

Interaction studied	P_{lab} (GeV/c)	$\alpha_{eff}^K(0)$	α_{eff}' (GeV) ⁻²	Upper limit of $ t $ used (GeV) ²	Reference
$p \xrightarrow{K^-} \Lambda$	4.2	-0.06 $\pm$ 0.04	1.02 $\pm$ 0.02	1.0	[1]
$p \xrightarrow{K^-} \Lambda$	8.25	-0.15 $\pm$ 0.04	0.86 $\pm$ 0.04	1.6	[3]
$p \xrightarrow{K^-} \Lambda$	10.0, 16.0 and 110.0	-0.15 $\pm$ 0.15	0.80	4.0	This work
$p \xrightarrow{K^+} \Lambda$	8.2, 16.0	-0.12 $\pm$ 0.15	0.77 $\pm$ 0.11	6.0	[16]
$p \xrightarrow{p} \Lambda$	12.0	-0.54 $\pm$ 0.07	0.89 $\pm$ 0.08	3.6	[17]
$p \xrightarrow{p} \Lambda$	19.0	-0.38 $\pm$ 0.11	1.15 $\pm$ 0.07	4.0	[18]
$p \xrightarrow{p} \Lambda$	24.0	-0.09 $\pm$ 0.04	1.04 $\pm$ 0.05	3.6	[17]
$p \xrightarrow{p} \Lambda$	69.0	0.20 $\pm$ 0.22	0.93 $\pm$ 0.08	11.0	[19]
$p \xrightarrow{p/\bar{p}} \Lambda$	>10.0	-0.20 $\pm$ 0.10	0.80 $\pm$ 0.10		[12]

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TABLE 3
Multiplicity parameters for offshell 'K'K interactions

M^2 range in GeV^2	$\langle n_{\text{ch}} \rangle$	$\langle n_{\text{ch}} \rangle / D$	C_2	C_3	C_4
0.0- 24.0	3.11 ± 0.25	1.97 ± 0.37	1.26 ± 0.10	1.73 ± 0.28	2.57 ± 0.66
24.0- 48.0	5.68 ± 0.22	2.86 ± 0.27	1.12 ± 0.02	1.39 ± 0.08	1.87 ± 0.18
48.0- 72.0	5.18 ± 0.18	2.15 ± 0.17	1.22 ± 0.03	1.73 ± 0.13	2.78 ± 0.36
72.0-100.0	6.02 ± 0.14	2.25 ± 0.12	1.20 ± 0.02	1.63 ± 0.08	2.42 ± 0.20
100.0-121.0	6.27 ± 0.16	2.80 ± 0.20	1.13 ± 0.02	1.39 ± 0.06	1.84 ± 0.14
121.0-144.0	6.67 ± 0.15	2.40 ± 0.13	1.17 ± 0.02	1.56 ± 0.07	2.29 ± 0.17
144.0-169.0	7.18 ± 0.28	2.07 ± 0.16	1.23 ± 0.04	1.77 ± 0.13	2.80 ± 0.37

FIGURE CAPTIONS

1. Illustration of the triple Regge diagram for $p \xrightarrow{K^-} \Lambda$. α_1 corresponds to the ϕ -trajectory for strangeness annihilation part and α_1 corresponds to the meson and the Pomeron trajectories for strangeness nonannihilation component.
2. $d\sigma/d(M^2/s)$ distributions from $p \xrightarrow{K^-} \Lambda$ at 110 GeV/c in four different t ranges (a) $-1.0 < t < 0.0$, (b) $-2.0 < t < -1.0$, (c) $-3.0 < t < -2.0$ and (d) $-4.0 < t < -3.0 \text{ GeV}^2$. The solid curves are results of simultaneous TR fit as described in the text.
3. $d\sigma/dM$ distributions for $p \xrightarrow{K^-} \Lambda$ at 10 GeV/c in five different t ranges (a) $-0.2 < t < 0.0$, (b) $-0.4 < t < -0.2$, (c) $-0.6 < t < -0.4$, (d) $-0.8 < t < -0.6$ and (e) $-1.0 < t < -0.8 \text{ GeV}^2$. The solid curves are results of simultaneous TR fit as described in the text.
4. $d\sigma/dM$ distributions for $p \xrightarrow{K^-} \Lambda$ at 16 GeV/c in five different t ranges (a) $-0.2 < t < 0.0$, (b) $-0.4 < t < -0.2$, (c) $-0.6 < t < -0.4$, (d) $-0.8 < t < -0.6$ and (e) $-1.0 < t < -0.8 \text{ GeV}^2$. The solid curves are results of simultaneous TR fit as described in the text.
5. Cross section for $K^- p \rightarrow \Lambda + \text{anything}$ with $x_A < -0.2$ plotted as a function of laboratory momentum of K^- . The solid curve is the results of the TR fit as described in the text.
6. Cross section for $K^- p \rightarrow \Lambda K K + \text{anything}$ with $x_A < -0.2$ as a function of laboratory momentum of K^- . The solid curve is the predictions of the TR fit as described in the text.
7. Average charged multiplicity for virtual 'K'K interactions as a function of M^2 - the c.m. energy squared of the 'K'K system. The solid and dashed curves are fits (12) and (13) as described in the text.

8. KNO scaling function $\psi_n = \langle n_{ch} \rangle \sigma_n / \sigma_{inel}$ for virtual $'K'\bar{K}$ interactions as a function of $z = n_{ch} / \langle n_{ch} \rangle$ for various M - the c.m. energy of $'K'\bar{K}$ system. The solid and dashed curves represent fits from pp inelastic [22] and $\bar{p}p$ annihilation [23] data.

FIG. 1

FIG. 2c

FIG. 2d

FIG. 3a

FIG. 3b

FIG. 3c

FIG. 3d

FIG. 3e

FIG. 4a

FIG. 4b

FIG. 4c

FIG. 4d

FIG. 4e

FIG.5

FIG. 6

FIG. 7