Title
Dynamical and symmetry effects in the K\pi ratio in the central plateau

Permalink
https://escholarship.org/uc/item/8p70194f

Journal
Physical Review D, 9(7)

ISSN
0556-2821

Authors
Barnett, RM
Silverman, D
Scadron, MD
et al.

Publication Date
1974

DOI
10.1103/physrevd.9.2195

License
CC BY 4.0

Peer reviewed
Dynamical and symmetry effects in the $K/\pi$ ratio in the central plateau

R. M. Barnett and D. Silverman

Department of Physics, University of California, Irvine, California 92664

M. D. Scadron and R. L. Thews

Department of Physics, University of Arizona, Tucson, Arizona 85721

(Received 26 July 1973)

Produced-mass and internal-mass effects are used along with symmetry considerations in a general peripheral structure to account for the $K/\pi$ ratio in the central plateau with no free parameters. The increase of the ratio with increasing $q_\perp$ is accounted for.

A general peripheral structure for the inclusive single-particle spectrum in the central plateau region has recently been used\(^1\) to fit the pion's $q_\perp$ spectra at the highest CERN ISR energy.\(^3\) This peripheral structure, Fig. 1(a), leads to the inclusive single-particle cross section as a forward 3-3 absorptive part, Fig. 1(b). This structure has the proper 3-3 Regge analytic behavior and results in the Mueller-type diagram Fig. 1(c).

In this model we utilize SU(3), quark-model symmetry, and the dynamical effects of the masses of the produced particle and the exchanged particles to calculate the production of kaons versus pions. For a pion or kaon we then follow ABFST (Amati-Bertocchi-Fubini-Stanghellini-Tonin)\(^4\) and take the $t_i$ exchange to be a pseudoscalar meson ($P$) and $t_e$ to be an effective vector ($V$) or tensor ($T$) exchange. In this dynamical model we can apply the SU(3) assumptions on the $g_{P^0 P^0}$, $g_{P^0 T^0}$, and Pomeron couplings and treat the $\pi, K$ mass effects independently.

One mass-dependent effect is that the exchange of a pion pole in $t_i$ gives an enhancement over other exchanges and this occurs more often in pion than kaon production. This effect persists even at large $q_\perp$.

The other effect is that the mass of the produced particle $c$ kinematically limits the missing-mass phase space. This suppresses the production of heavier-mass particles at small $q_\perp$ (Refs. 5, 6) but has no effect at very large $q_\perp$.

The assumption of pure quark-model symmetry is supplemented by the inclusion of a small $u_8$ octet part to the predominantly unitary singlet Pomeron to include the effective $\pi p-Kp$ cross-section difference. We also relate the strengths of the vector and tensor exchanges experimentally. The decay $K_S^0 \rightarrow \pi^+\pi^-$ was calculated and found to be a small correction to the $K^*/\pi^*$ ratio.

The conclusion of our study is that the mass-dependent effects with the corrections from the other three effects lowers the $K/\pi$ ratio in the central plateau to about 0.20 at $q_\perp = 0.4$ GeV/c. The ISR experiments at $q_\perp = 0.4$ find the ratio to be 0.12 $\pm 0.03$.

We also demonstrate that at large $q_\perp$ the production of kaons becomes closer to that of pions and should approach about 0.7 at large $q_\perp > 4$ GeV/c.

First we examine the mass-dependent effects. For the internal damping factors of Fig. 1(a) we use the product of a propagator (or effective propagator) and a form factor:

$$\beta_i(t_i) = \frac{1}{(t_i - m_P^2)(t_i - \Delta^2)}$$

$$\beta_e(t_e) = \frac{1}{(t_e - \Delta^2)^2}.$$  

In $\beta_i$, for pion exchanges we take $m_P^2 = m_\pi^2$ to get the pion-pole-exchange effect while for kaon or other exchanges we take $m_P^2 = m_K^2$. We parametrize the other effective form factors and propagators by one parameter $\Delta^2$, which is determined by fitting to the pion spectrum. The fit with $\Delta^2 = 0.36$ GeV$^2$ is virtually identical to that of Ref. 2 where all four "masses" were taken to be the same.\(^7\)

The external-mass dependence occurs through\(^8\) $\eta = q_\perp^2 + m^2$ and in $e^{\pi^0}$ in Eq. (2.12) of Ref. 2. At large $q_\perp$, we find $e^{\pi^0} \approx 1$, $\eta \approx q_\perp^2$, and the effect of the external mass disappears. At small $q_\perp$, we find that the approximation\(^9\) of $m^2$ entering only through $\eta$ is good up to a factor of 2.

In Table I we show the effects in the spectrum of pion exchange versus other exchanges in $\beta_i$ and the effects of the pion or kaon external masses. The numbers are normalized to the pion exchange in pion production, column 2, for easy comparison. We see that the exchange-mass and produced-mass effects are independent since their results are approximately multiplicative. Also the exchanged-mass effect persists at large $q_\perp$ but the produced mass has no effect at large $q_\perp$.

For the symmetry effects\(^10\) we consider all allowed ($P, V$) and ($P, T$) exchanges in Fig. 1(c) for
producing a $\pi^+$ or $K^+$. We eliminate other exchanges in the spirit of ABFST. We also do not consider $V$- or $T$-resonance production in order to avoid double counting. The relative strengths of the couplings for vector nonet exchanges are calculated from $U(3)$ and similarly for tensor nonet exchanges. Using the quark model, we assume that the exchanged Pomerons couple with the same strength to the vector and tensor nonets.

Initially we assume that the Pomeron is a pure unitary singlet, and that the $V$ and $T$ couplings are equal by exchange degeneracy. From Fig. 1(c) we see that we need the squares of the coupling constants, and these are given in Table II under the above assumptions.

The important point to note is that the dynamically enhanced $\pi$ exchanges occur with twice as much total coupling in $\pi$ production as in $K$ production. Combining the strengths of $\pi$ exchange versus other pseudoscalar exchanges from Table II with the dynamical mass effects from Table I we obtain the result for full symmetry:

$$\frac{\rho_{\pi^+}(q_\perp)}{\rho_{\pi^+}(q_\perp)} = 0.30 \quad \text{at } q_\perp = 0.4 \text{ GeV}/c.$$

Since this is larger than the experimental results, we will introduce the observed breaking of exchange degeneracy by taking $g_{\pi^+\pi} = 0.6 g_{\pi^+\pi}$ for

<table>
<thead>
<tr>
<th>$q_\perp$ (GeV/c)</th>
<th>$\pi$ produced</th>
<th>$K$ produced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exchanged</td>
<td>Exchanged</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Other</td>
<td>$\pi$</td>
</tr>
<tr>
<td>0.4</td>
<td>1.0</td>
<td>0.20</td>
</tr>
<tr>
<td>2.0</td>
<td>1.0</td>
<td>0.54</td>
</tr>
<tr>
<td>9.0</td>
<td>1.0</td>
<td>0.59</td>
</tr>
</tbody>
</table>

TABLE II. Relative squares of the coupling constants.

<table>
<thead>
<tr>
<th>$V$</th>
<th>$T$</th>
<th>$V$</th>
<th>$T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_{\pi^+}$</td>
<td>4</td>
<td>$A_{\pi^+}^2$</td>
<td>0</td>
</tr>
<tr>
<td>$\rho_{\pi^+}$</td>
<td>4</td>
<td>$A_{\pi^+}^2$</td>
<td>0</td>
</tr>
<tr>
<td>$K_{\pi^+}$</td>
<td>2</td>
<td>$K_{\pi^+}^2$</td>
<td>2</td>
</tr>
<tr>
<td>$K_{\pi^+}$</td>
<td>2</td>
<td>$K_{\pi^+}^2$</td>
<td>2</td>
</tr>
<tr>
<td>$\rho_{\pi^+}$</td>
<td>0</td>
<td>$A_{\pi^+}^2$</td>
<td>$\frac{1}{3}$</td>
</tr>
<tr>
<td>$\rho_{\pi^+}$</td>
<td>0</td>
<td>$A_{\pi^+}^2$</td>
<td>$\frac{1}{3}$</td>
</tr>
<tr>
<td>$\rho_{\pi^+}$</td>
<td>0</td>
<td>$A_{\pi^+}^2$</td>
<td>$\frac{1}{3}$</td>
</tr>
</tbody>
</table>

the reduced matrix elements. To account for the difference between $\pi$ and $K$ production we include an $f$ part of the Pomeron $\phi$. This changes $g_{\pi^+\pi} = 0.83 g_{\pi^+\pi}$ to the effective couplings

$g_{\pi^+\pi} = 0.83 g_{\pi^+\pi}$, 

$g_{\pi^+\pi} = 0.89 g_{\pi^+\pi}$, 

$g_{\pi^+\pi} = 0.78 g_{\pi^+\pi}$.

Equivalent results obtain for the vector and tensor nonets.

The result of combining the above effects is

$$\rho_{\pi^+}(q_\perp) \rho_{\pi^+}(q_\perp) = \frac{0.37 c_4 + 0.96 c_3}{1 + 0.54 c_3},$$

FIG. 2. The single-particle spectrum at $x = 0$ and $\sqrt{s} = 53$ GeV. The experimental $\pi^+$ spectrum is indicated by the upper line. The $K^+$ data and our fit are shown below it. The point at large $q_\perp$ was for $\sqrt{s} = 44$ GeV.
DYNAMICAL AND SYMMETRY EFFECTS IN THE K/π RATIO...

The calculations of the decay spectra of η and η' are more difficult, and since they would have at most half the effect of the K_S^0, we have ignored them. However, at q_± < 0.2 GeV/c the contributions of K_S^0, η, and η' are greater and would have to be considered.

The preliminary results of the British-Scandinavian Collaboration\textsuperscript{14,15} for the K' spectra at x = 0 and √s = 53 GeV is shown in Fig. 2. At q_± = 0.4 GeV/c the K'/? ratio is 0.12 ± 0.03. With the effects described we can now calculate the entire K' spectrum with no free parameters (using the magnitude and a² that fit the π spectrum). This is shown in Fig. 2. The point at large q_± was found using the K'/π ratio of Ref. 16 for the bin 2.0 < q_± < 3.5 GeV/c. The point was positioned at the average (over the spectrum) value of q_± in the interval. In Fig. 3 we show the K/π ratio as a function of q_±.

At very large q_±, the spectra approach the limiting ratio ρ_±/ρ_± ~ 0.7. The experimental observation of K' at large q_± will be important since it probes the internal structure with the external-mass effect eliminated.

We wish to thank M. Bander, G. Lynch, and G. Shaw for helpful discussions.

\*Work supported in part by the National Science Foundation.
\textsuperscript{1}R. M. Barnett and D. Silverman, Phys. Lett. 44B, 251 (1973).
\textsuperscript{5}C. Arnold and E. L. Berger, Phys. Rev. D 5, 2733 (1972).
\textsuperscript{7}Since the fit can be obtained with many different sets of mass values, there are not enough data to justify using more than one effective mass.
\textsuperscript{8}The dependence on the external mass through the variable η has been noted by Arnold and Berger, Ref. 5.
\textsuperscript{15}H. Bøggild, private communication.