K-Meson production in n-\bar{n} annihilation computed

with a statistical theory

by

F. Cerulus
K-MESON PRODUCTION IN N-Ñ ANNIHILATION COMPUTED

WITH A STATISTICAL THEORY

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K-meson production in N-\bar{N} annihilation computed with a statistical theory.

It was pointed out recently\(^1\) that a Fermi-type statistical theory could account reasonably well for the multiplicity and the spectra of pions observed in p-\bar{p} and \bar{p}-n annihilation at rest. In order to fit experiment with a "normal" interaction volume one has to assume a strong \(\bar{\eta}-\eta\) interaction in the final state.

The same type of computation can be applied to events in p-\bar{p} and \bar{p}-n annihilation in which K-mesons are produced. There seems to be an interest in this calculation in various laboratories, so it was decided to publish them somewhat in detail.

The main results are summarized in Table I.

The left part of the table applies to a statistical theory with the conventional interaction volume

\[
\langle \eta \rangle_0 = \frac{4\eta}{3} \left(\frac{\eta}{\mu_c}\right)^3
\]

and the assumed existence of a \(\eta-\bar{\eta}\) isobar of mass 4\(\mu\), J=1 and T=1.

The right part gives the same quantities, computed with a statistical theory without isobar, but with the large interaction volume \(\langle \eta \rangle = 10\langle \eta \rangle_0\) which then is necessary to fit the average number of pions produced in annihilation events.

The main feature which distinguishes between the two hypotheses seems to be the multiplicity distribution, and to a lesser extent the average number of pions produced (and their average energy).
In particular, the pure 2-K decay should be an exceedingly rare event in the no-\( \pi^* \) hypothesis (0.3\% of all stars producing K-mesons), and not too rare (7\%) in the \( \pi^* \) hypothesis.

These conclusions are of course quite independent of the assumptions made about the K-interaction volume, because the number of K's is always two in the reactions considered.

Another indication for the \( \pi^* \) might be found in angular correlation between the \( \pi \)'s in 2\( \pi \) events. Indeed, 70\% of the 2\( \pi \) events are due to the channel

\[
N+\bar{N} \rightarrow \pi^* + 2K \rightarrow 2\pi + 2K
\]

Reconstructing the event one should find the total energy of the two pions, in their common C M.S., showing a maximum around their resonance energy. Because, always assuming the \( \pi^* \) hypothesis, 90\% of all events are one or two \( \pi \) events a "missing pionic mass" spectrum should show a narrow peak around \( m=\mu \) and another (broader) around \( m=4\mu \).

By "missing pionic mass" spectrum we mean:

1) select events in which the two K's are identified;

2) attribute the difference between the available energy and the K-mesons' energy to a single particle, and compute its mass.

Spectra of K-mesons and pions for each endstate have been computed by a Monte-Carlo Method, with \( \approx 25\% \) accuracy. They can be communicated to interested laboratories. There is no marked difference between the spectra computed by assuming a \( \pi^* \) and taking \( \Theta =\Theta_0 \), and those computed taking \( \Theta =10\Theta_0 \), without any \( \pi^* \).
The charge distribution between the different particles of a given channel can be computed using the published tables of statistical weights in isospin space. A slight complication arises in the \( j^* \)-case, because one has to know the relative weight of the reaction which yield a given endstate, e.g.

\[
\bar{p} + n \rightarrow 2K + \pi^- \rightarrow 2K + 2\Lambda
\]

These weights are displayed in table II.
## Table I

<table>
<thead>
<tr>
<th>Total Isospin of N+$\bar{N}$</th>
<th>(\pi^{*}) hypothesis</th>
<th>(\Omega_{-}=\Omega_{0})</th>
<th>no (\pi^{*}) hypothesis</th>
<th>(\Omega_{-}=10\Omega_{0})</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textbf{T=1}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2K</td>
<td>0.465</td>
<td>0.144</td>
<td>0.465</td>
<td>0.006</td>
</tr>
<tr>
<td>2K+ (\pi)</td>
<td>0.225</td>
<td>0.873</td>
<td>0.351</td>
<td>0.436</td>
</tr>
<tr>
<td>2K+2 (\pi)</td>
<td>0.124</td>
<td>0.936</td>
<td>0.203</td>
<td>0.933</td>
</tr>
<tr>
<td>2K+3 (\pi)</td>
<td>0.055</td>
<td>0.049</td>
<td>0.132</td>
<td>0.073</td>
</tr>
<tr>
<td>Sum over all events</td>
<td>0.191</td>
<td>0.245</td>
<td>1.44</td>
<td>0.136</td>
</tr>
<tr>
<td>\textbf{T=0}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2K</td>
<td>0.465</td>
<td>0.269</td>
<td>0.465</td>
<td>0.013</td>
</tr>
<tr>
<td>2K+ (\pi)</td>
<td>0.225</td>
<td>0.814</td>
<td>0.351</td>
<td>0.407</td>
</tr>
<tr>
<td>2K+2 (\pi)</td>
<td>0.124</td>
<td>0.874</td>
<td>0.203</td>
<td>0.871</td>
</tr>
<tr>
<td>2K+3 (\pi)</td>
<td>0.054</td>
<td>0.044</td>
<td>0.132</td>
<td>0.066</td>
</tr>
<tr>
<td>Sum over all events</td>
<td>0.209</td>
<td>0.245</td>
<td>1.34</td>
<td>0.139</td>
</tr>
</tbody>
</table>

Average kinetic energies, \(\langle \vec{v} \rangle\), (in units of 938 MeV) and average particle numbers, \(\langle n \rangle\), of \(K\)-mesons and pions produced in N-\(\bar{N}\) annihilation events containing \(K\)-mesons (annihilation at rest).

The \(\pi^{*}\) is assumed to have \(m=4\mu\), \(T=1\), \(J=1\).

\[ I_{0} = \frac{4\pi}{3} \left( \frac{1}{\mu_{0}} \right)^{3} = \text{"normal" interaction volume} \]
TABLE II

Weights of reactions producing K-mesons in N-\bar{N} annihilation at rest.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>weights S</th>
<th>relative weights in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T=0</td>
<td>T=1</td>
</tr>
<tr>
<td></td>
<td>γ⁺/²</td>
<td>no γ⁺/²</td>
</tr>
<tr>
<td>2K</td>
<td>33.4</td>
<td>1200</td>
</tr>
<tr>
<td>2K+ η</td>
<td>101.</td>
<td>35700</td>
</tr>
<tr>
<td>2K+2 η</td>
<td>32.1</td>
<td>111000</td>
</tr>
<tr>
<td>2K+3 η</td>
<td>1.1</td>
<td>37300</td>
</tr>
<tr>
<td>2K+ η*</td>
<td>76.5</td>
<td>153</td>
</tr>
<tr>
<td>2K+ η*+ η</td>
<td>4.4</td>
<td>485</td>
</tr>
<tr>
<td></td>
<td>248.7</td>
<td>185400</td>
</tr>
</tbody>
</table>

The weights are computed according to the formula \(^3\)

\[
S = \sum_{\eta} \frac{n_{\eta} \times n_{\eta^*}}{T} \sum_{K} \frac{2^{K}}{n_{\eta^*}} \sqrt{W_{\eta_{\eta + n_{\eta^*}}, C(T)}} \sqrt{\rho_{\eta, \eta^*}} \sqrt{E \gamma}
\]

where

\[
\sum_{\eta} = \frac{4}{3} \left( \frac{\hbar}{\sqrt{m}} \right)^5 = 5.1 \text{ in units } \gamma = c = 1 \text{ Nucleon} = 1
\]

\[
\sum_{\eta^*} = a \sum_{\eta}
\]

\[
a = \begin{cases} 1 & \text{in the hypothesis of a } \eta^* \\ 10 & \text{and } n_{\eta^*} = 0 \text{ in the hypothesis of no } \eta^* \end{cases}
\]

\[n_{\eta}, \quad n_{\eta^*}\] numbers of \(\eta\) and \(\eta^*\) respectively.

\[W_{\eta, \beta, C}(T)\] number of independent isospin functions made with

- isospin \(\frac{1}{2}\) and \(\frac{3}{2}\) isospin \(1\) particles, coupled to a total isospin \(T\).

\[\gamma \left( E = \gamma \right)\] phase space integral for annihilation at rest.

The relative weights are computed by dividing through with the sum of weights displayed on the last line.
REFERENCES

1) F. Cerulus, Nuovo Cimento 14, 827 (1959)
2) F. Cerulus, Statistical Weights of Many-Particle Systems in Spin or Isospin Space (to appear in Suppl. Nuovo Cimento)