SOME STATISTICAL THEORY RESULTS ON $\bar{T}^*$ and $\bar{T}^{**}$ PRODUCTION
IN P-D COLLISIONS AROUND 2.3 GEV/C P-MOMENTUM

by

K.H. Michel

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SOME STATISTICAL THEORY RESULTS ON \( \pi^+ \) AND \( \pi^- \) PRODUCTION IN \( p-d \) COLLISIONS AROUND 2.3 GEV/C. P-MOMENTUM

by

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In order to have an idea for planning an experiment, Dr. Fidecaro of CERN asked us to carry out calculations according to the statistical theory \(^1,\,^2\) for the following reactions \(^*)\):

\[
\begin{align*}
p + d & \rightarrow T + n \bar{\nu} \quad (n = 1, 2, \ldots) \\
p + d & \rightarrow T + \bar{\nu}^* + n \nu \quad (n = 1, 2, \ldots) \\
p + d & \rightarrow T + \bar{\nu}^{**} + n \nu \quad (n = 1, 2, \ldots)
\end{align*}
\]

The assumptions we made were:

1) \(T, \, \bar{\nu}^*, \) and \(\bar{\nu}^{**}\) \(^3\) have to be considered as particles in the sense of statistical theory \(^4\).

\[
\begin{array}{|c|c|c|c|}
\hline
& \text{mass} & \text{isospin} & \text{spin} \\
\hline
\bar{\nu}^* & 740 \text{ MeV} & 1 & 1 \\
\bar{\nu}^{**} & 790 \text{ MeV} & 0 & 1 \\
T & 2805 \text{ MeV} & \frac{1}{2} & \frac{1}{2} \\
\hline
\end{array}
\]

2) For the Lorentz contracted interactions volume \(^1,\,^2\), we supposed

\[
\bigcup_n \bigcup \bar{\nu}^* \bigcup \bar{\nu}^{**} \bigcup T = \bigcup
\]

\(*)\) \(T\) stands for the isospin doublet \(H^3, \, He^3\).

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We did three series of calculations for different energies of the incoming proton.

\[ \vec{P}_{\text{prot}} = 2.25 \text{ GeV} \text{ } \frac{\text{o}}{\text{o}} ; \quad \overline{\rho} = 3.96 \]

For each of the different end states we obtained the non-normalized probability, \( P_b \), of the reaction.

Because we did not consider all possible final states of the p-d collision, the different \( P_b \) cannot serve to calculate the absolute probabilities, they can only give the branching ratios of the considered reactions.

<table>
<thead>
<tr>
<th>end state</th>
<th>( P_b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T + \pi )</td>
<td>214</td>
</tr>
<tr>
<td>( T + 2\pi )</td>
<td>252</td>
</tr>
<tr>
<td>( T + 3\pi )</td>
<td>18.5</td>
</tr>
<tr>
<td>( T + \pi^* )</td>
<td>381</td>
</tr>
<tr>
<td>( T + \pi^{**} )</td>
<td>322</td>
</tr>
</tbody>
</table>

(The other channels are negligible)

We calculated also the \( T \) spectra and superposed them in order to have the normalized spectrum of \( T \) coming from all considered reactions. Fig. 1 shows the total \( T \) spectrum, normalized to unity and averaged over all angles in the centre of mass system.

The spectrum is given in histogram form:

\[ \frac{\Delta n}{\Delta \zeta} \text{ with } \sum \frac{\Delta n}{\Delta \zeta} \Delta \zeta = 1 \]
where \( \Delta E = 4.21 \text{ MeV} \) is the kinetic energy interval used for computation.

Three peaks are present:

a) 25 MeV (kin. energy of T), this corresponds to the reaction

\[ T + \pi^* \]

b) 33.6 MeV corresponding to

\[ T + \pi^* \]

c) 105.25 MeV. Here we have the reaction

\[ T + \pi \]

B) Similar results were obtained for

\[ P^\gamma_{\text{prot}} = 2.35 \text{ GeV} \]

<table>
<thead>
<tr>
<th>end state</th>
<th>( P_b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T + \pi )</td>
<td>222</td>
</tr>
<tr>
<td>( T + 2\pi )</td>
<td>297</td>
</tr>
<tr>
<td>( T + 3\pi )</td>
<td>26</td>
</tr>
<tr>
<td>( T + \pi^* )</td>
<td>428</td>
</tr>
<tr>
<td>( T + \pi^* + \pi^* )</td>
<td>7.65</td>
</tr>
<tr>
<td>( T + \pi^{**} )</td>
<td>378</td>
</tr>
</tbody>
</table>

(The other channels are negligible)

The T spectrum (Fig. 2) has again three peaks:
a) 33.6 MeV for $T + \pi^{**}$
b) 42.1 MeV for $T + \pi^{*}$
c) 113.7 MeV for $T + \pi$

C) Similar conclusions hold for
\[
\frac{p_{\text{prot}}}{m_{\pi}} = 2.45 \frac{\text{GeV}}{c}
\]

<table>
<thead>
<tr>
<th>end state</th>
<th>$P_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T + \pi$</td>
<td>232</td>
</tr>
<tr>
<td>$T + 2\pi$</td>
<td>374</td>
</tr>
<tr>
<td>$T + 3\pi$</td>
<td>38.8</td>
</tr>
<tr>
<td>$T + \pi^{*}$</td>
<td>486</td>
</tr>
<tr>
<td>$T + \pi^{**}$</td>
<td>40.8</td>
</tr>
<tr>
<td>$T + \pi^{**} + \pi$</td>
<td>444</td>
</tr>
<tr>
<td>$T + \pi + \pi$</td>
<td>4.99</td>
</tr>
</tbody>
</table>

(The other channels are negligible)

Peaks are located at:

a) 46.31 MeV for $T + \pi^{**}$
b) 58.9 MeV for $T + \pi^{*}$
c) 126.3 MeV for $T + \pi$
The spectra show that under the assumption of $\Omega^* = \Omega^{**} = \Omega^{***}$ the peaks corresponding to production of one $\pi^*$ or one $\pi^{**}$ should be perfectly observable if the T-particle is looked at. The above assumption is not particularly justified by any experiment or theory but it seems hard to believe that the $\Omega$'s could differ by more than a factor 5. Even then the peaks will be clearly exhibited.

Figs. 4, 5 and 6 give the non-normalized T-spectra (corresponding to the case $p_{\text{prot}} = 2.35 \text{ GeV/}c$) in the lab. system. The angles are $8^\circ$ (Fig. 4), $11^\circ$ (Fig. 5) and $15^\circ$ (Fig. 6). Each peak of the c.m. spectrum appears twice here, since the c.m. velocity is larger than the velocities of the particles (at the peaks) in the c.m. system. The total numbers per steradian

$$\int \frac{dn}{d\Omega} (\theta) \, d\Omega = \int \frac{d^2n}{dpd\Omega} \, dp$$

have the following relative magnitudes

$$\frac{dn}{d\Omega} (8^\circ) : \frac{dn}{d\Omega} (11^\circ) : \frac{dn}{d\Omega} (15^\circ) = 1 : 1.115 : 1.24$$

It is a pleasure for me to thank Dr. R. Hagedorn for stimulating discussions and the use of his computer programmes.

I would also like to thank CERN for its kind hospitality and the D.D. Division for the computing work on the MERCURY computer.
REFERENCES


2) F. Cerulus and R. Hagedorn, CERN Report 59-3.


Fig. 1
Fig. 2
\[ \int \frac{d^2n}{d\alpha d\rho} \, d\rho = A \cdot 1 \]

**Fig. 4**

\[10\Delta \rho = 0.3 \text{ GeV/c}\]
\[
\int \frac{d^2n}{d\Omega \, dp} \, dp = A \cdot 4.115
\]

Fig. 5