Production of $\rho^{+}, \rho^{-}, \rho^{0}(770)$, $\eta(550)$, $\omega(783)$ and $f_2(1270)$ mesons in $\bar{\nu}$ neon and $\nu$ neon charged current interactions

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Abstract. The production of the meson resonances $\rho(770)$ (all three charge states), $\eta(550)$, $\omega(783)$ and $f_2(1270)$ in $\bar{\nu}$ Ne and $\nu$ Ne charged current interactions is investigated in a bubble chamber experiment with BEBC at CERN. Except for the $f_2$, the main features of resonance production are reasonably well described by the Lund model, although the average resonance multiplicities are overestimated by the model by $(67 \pm 30)\%$. The average multiplicities of all resonances, including the $f_2$, are well reproduced by a semiempirical model, whose parameters were determined from hadron interaction data.

1 Introduction

It is known that the pions and kaons occurring in high energy interactions are to a large extent the decay products of resonances [1]. Resonance production characteristics are therefore expected to reflect the dynamics of the interactions more closely than the pion and kaon spectra and to provide a better ground for comparisons with theoretical models.

The present paper reports on the inclusive production of the non-strange meson resonances $\rho(770)$ (in all three charge states), $\eta(550)$, $\omega(783)$ and $f_2(1270)$ in $\bar{\nu}$ Ne and $\nu$ Ne charged current interactions. These interactions are unique in selecting particular types of quarks in the target: in $\bar{\nu}$ interactions the dominant process is the conversion of a $u$ quark into a $d$ quark, and in $\nu$ interactions the conversion of a $d$ quark into a $u$ quark. Thus the data provide information on the fragmentation of these quarks into meson resonances. They also serve as a test for the influence of nuclear reinteractions on the production of these resonances.

The outline of the paper is as follows. Section 2 deals with the experimental details and describes the procedure used to obtain the average multiplicities of the produced resonances from mass distributions.

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The experimental procedure followed in this paper is identical to the one described in [2]. Additional details about the neutrino energy estimation, the method of \( \pi^0 \) reconstruction, the treatment of low momentum protons (stubs) and the Monte Carlo calculations are also given in [2].

b) Reconstruction of \( \pi^0 \) mesons

Neutral pions are reconstructed by combining photons (\( \gamma \)) that converted into electron-positron pairs within the bubble chamber. A special procedure is applied to select from all \( \gamma \gamma \) pairs within an event those which very likely result from a \( \pi^0 \) decay. In this paper all selected \( \gamma \gamma \) pairs are called \( \pi^0 \). Monte Carlo calculations show that 80% of the \( \pi^0 \)'s obtained in this way are correctly combined \( \gamma \gamma \) pairs. These 80% correspond to 30% of all produced \( \pi^0 \). For further details of the \( \pi^0 \) reconstruction see [2].

c) Extraction of the resonance signals

The numbers of produced \( \rho^0, \rho^+, \rho^- \) and \( f_2 \) mesons are obtained by fitting the following expression to the respective invariant mass distribution (see Table 2):

\[
\frac{dN}{dm} = a_1 \cdot BG + a_2 \cdot BW_\rho + a_3 \cdot BG \cdot BW_f
\]  

with

\[
BG = (m - 2m_\pi)^2 \cdot \exp(\beta m + \gamma m^2),
\]

\[
BW_\rho = \frac{m}{q} \cdot \Gamma_\rho \cdot \frac{1}{(m_\rho^2 + (m - m_\pi)^2) + (m_\rho \Gamma_\rho)^2}
\]

\[
\Gamma_\rho = \Gamma_\rho \cdot \frac{q}{q_\rho} \cdot \frac{m_\rho}{m},
\]

\[
BW_f = \frac{m}{q} \cdot \Gamma_f \cdot \frac{1}{(m_\rho^2 + (m - m_\pi)^2) + (m_\rho \Gamma_f)^2}
\]

The experimental samples used (\( p_x > 5 \text{ GeV/c}, 1.5 \text{ GeV} < W < 10 \text{ GeV} \)) and average values of \( E_\nu \), \( W \) and \( Q^2 \) for the total event sample are listed in Table 1.

### Table 1. Experimental samples used (\( p_x > 5 \text{ GeV/c}, 1.5 \text{ GeV} < W < 10 \text{ GeV} \)) and average values of \( E_\nu \), \( W \) and \( Q^2 \) for the total event sample

<table>
<thead>
<tr>
<th>( \bar{\nu} \text{ Ne} )</th>
<th>( \nu \text{ Ne} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of events for</td>
<td></td>
</tr>
<tr>
<td>( 1.5 \text{ GeV} &lt; W &lt; 4.0 \text{ GeV} )</td>
<td>8336</td>
</tr>
<tr>
<td>( 4.0 \text{ GeV} &lt; W &lt; 10 \text{ GeV} )</td>
<td>5723</td>
</tr>
<tr>
<td>( 1.5 \text{ GeV} &lt; W &lt; 10 \text{ GeV} )</td>
<td>14059</td>
</tr>
<tr>
<td>( \langle E_\nu \rangle )</td>
<td>39 \text{ GeV}</td>
</tr>
<tr>
<td>( \langle W \rangle )</td>
<td>39 \text{ GeV}</td>
</tr>
<tr>
<td>( \langle Q^2 \rangle )</td>
<td>4.0 \text{ GeV}^2</td>
</tr>
</tbody>
</table>

In Sect. 3 the production of resonances is studied as a function of \( W, x_F, z \), and \( p_T \) and comparisons are made with predictions of the Lund model and of a semi-empirical model for high-energy inclusive reactions. A summary is given in Sect. 4.

### Table 2. Resonance parameters of two-pion resonances

<table>
<thead>
<tr>
<th>Reso-</th>
<th>Mass</th>
<th>Mass</th>
<th>PDG value of central mass</th>
<th>PDG value of width in fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>nance distribution at resonance (MeV)</td>
<td>(MeV)</td>
<td>(MeV)</td>
<td>(MeV)</td>
<td>(MeV)</td>
</tr>
<tr>
<td>( \rho^0 )</td>
<td>( \pi^+ \pi^- )</td>
<td>28</td>
<td>770</td>
<td>153</td>
</tr>
<tr>
<td>( \rho^+ )</td>
<td>( \pi^+ \pi^0 )</td>
<td>38</td>
<td>770</td>
<td>153</td>
</tr>
<tr>
<td>( \rho^- )</td>
<td>( \pi^- \pi^0 )</td>
<td>38</td>
<td>770</td>
<td>153</td>
</tr>
<tr>
<td>( f_2 )</td>
<td>( \pi^+ \pi^- )</td>
<td>36</td>
<td>1274</td>
<td>185</td>
</tr>
</tbody>
</table>

### Table 3. Resonance parameters of three-pion resonances

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Mass distribution at resonance (MeV)</th>
<th>Mass resolution of central value used (MeV)</th>
<th>PDG value of width in fit (MeV)</th>
<th>PDG value of width in fit (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta )</td>
<td>( \pi^+ \pi^- \pi^0 )</td>
<td>12</td>
<td>549</td>
<td>0</td>
</tr>
<tr>
<td>( \omega )</td>
<td>( \pi^+ \pi^- \pi^0 )</td>
<td>22</td>
<td>782</td>
<td>8.5</td>
</tr>
</tbody>
</table>

2 Experimental details

a) The experiment

The data come from an experiment in which the bubble chamber BEBC was exposed to the \( \bar{\nu} \) and \( \nu \) wide band beams from the SPS at CERN. BEBC was filled with a 75 mole % Ne-H\(_2\) mixture, whose radiation and hadronic collision lengths are 42 cm and 92 cm respectively.

Muons are identified with good efficiency (> 85%) for momenta above 5 GeV/c) by an external muon identifier and most of the protons with momenta below 800 MeV/c are identified on the basis of ionization and range in Ne-H\(_2\). Most of the remaining charged particles cannot be identified and thus are called pions.

For the present analysis only events with a momentum above 5 GeV/c and a total hadronic mass \( W \) between 1.5 and 10 GeV are accepted. The available statistics and the mean values of the quantities \( E_\nu \), energy of the incident (anti-)neutrino, \( W \) (effective mass of the total hadronic system), and \( Q^2 \) (squared four-momentum transfer between the incoming and outgoing lepton) are listed in Table 1.