Inclusive $f_2(1270)$ meson production in $\nu p$ and $\bar{\nu}p$ charged current interactions

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Abstract. Using data obtained with the bubble chamber BEBC at CERN, the inclusive $f_2(1270)$ meson production in $\nu p$ and $\bar{\nu}p$ charged current reactions is studied. It is found that $f_2$ production occurs mainly in events with a hadronic invariant mass $W > 7$ GeV. In these events, the average $f_2$ multiplicity is about half the average $\rho^0$ multiplicity, and the $x_F$ and $p_T$ distributions of the $f_2$ agree in shape with those of the $\rho^0$. The predictions of a semi-empirical model (Wells model) are in accord with the measured multiplicities at $W > 7$ GeV, whereas at lower $W$ the model predicts too large $f_2$ multiplicities.

1 Introduction

This paper reports on an analysis of the inclusive $f_2(1270)$ resonance production in $\nu p$ and $\bar{\nu}p$ charged current reactions. It is based on the complete event samples of the BEBC WA21 experiment, consisting, after selections, of 17750 $\nu p$ and 10452 $\bar{\nu}p$ charged current events with an estimated (anti-)neutrino energy ($E_\nu$) in the range 10 GeV to 200 GeV and with a muon momentum ($p_\mu$) greater than 3 GeV/c.

The $f_2(1270)$ is the lightest and most easily observable of the tensor mesons with spin-parity $= 2^+$. Its investigation is particularly interesting, since the experimental results on pseudoscalar and vector mesons [1–3] seem to indicate that the multiplicities of these particles are strongly influenced by the decays of higher resonances like the $f_2$.

2 Details of the analysis

The present analysis of $f_2$ production is closely related to the study of inclusive $\rho^0(770)$ production described in [1, 2]. In particular, the two analyses are identical with respect to

- the data samples used,
- the definition of the kinematical variables,
- the method used to estimate the (anti-)neutrino energy $E_\nu$,
- the determination of the resonance signals,
- the determination of the charged pion numbers,
- the correction for 1-prong events in the $\bar{\nu}p$ reaction and
- the Monte Carlo simulation.

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Only some of the experimental details specially relevant to the \( f_2 \) are given here. The reader is referred to \([1, 2]\) for a complete description of the experimental details.

Both the \( \rho^0 \) and the \( f_2 \) resonances decay predominantly into \( \pi^+ \pi^- \). The signals of both resonances are simultaneously determined by fitting the following expression to the \( \pi^+ \pi^- \) invariant mass \((m)\) distribution:

\[
\frac{dN}{dm} = [1 + \alpha_1 \text{BW}_\rho (m) + \alpha_6 \text{BW}_f (m)] \text{BG}(m),
\]

with two relativistic Breit-Wigner functions, \( \text{BW}_\rho \) and \( \text{BW}_f \) respectively, to describe the \( \rho^0 \) and the \( f_2 \) signal, and a background parameterisation \( \text{BG} \):

\[
\text{BW}_f (m) = \frac{m}{p} \left( \frac{m^2 - m_0^2}{2} \right)^{\frac{1}{2}, \frac{1}{2}} \Gamma(m),
\]

\[
\Gamma(m) = \text{IF} \left( \frac{p}{p_f} \right)^{2l+1},
\]

\[
\text{BG}(m) = \alpha_2 (m - 2m_0)^2 e^{\alpha_4 m + \alpha_5 m^2}.
\]

The formulae (1)-(4) contain the following quantities:

- \( N \): number of \( \pi^+ \pi^- \) combinations,
- \( m = m_{\pi^+ \pi^-} \): invariant mass of the \( \pi^+ \pi^- \) system,
- \( \alpha_1, \ldots, \alpha_6 \): free parameters,
- \( m_f = 1274 \text{ MeV} \), \( \Gamma_f = 185 \text{ MeV} \): central mass and width of the \( f_2 \) resonance \([4]\),
- \( p = \sqrt{\frac{m^2}{4} - m_0^2} \): pion momentum in the two-pion rest frame,
- \( p_f = p(m_f) \):
- \( l = 2 \): relative orbital angular momentum of the two pions.

\( \text{BW}_\rho \) is defined analogously to \( \text{BW}_f \) (see \([1]\)). The Breit-Wigner functions are multiplied by \( \text{BG} \) in (1) in order to account for the available phase-space \([5]\). The parameters \( \alpha_1 \) to \( \alpha_6 \) are determined in the \( \chi^2 \)-fit, which is performed in the mass range \( 0.3 \text{ GeV} < m < 1.8 \text{ GeV} \).

The number \( N_f \) of \( f_2 \) mesons produced is obtained by a numerical integration of \( \alpha_6 \text{BW}_f (m) \text{BG}(m) \) over the fitted mass range, with a correction for the branching ratio of the decay \( f_2 \to \pi^+ \pi^- \),

\[
\text{BR} (f_2 \to \pi^+ \pi^-) = (57.1 \pm 1.0)\% \quad [4].
\]

In order to study the \( f_2 \) production as a function of a kinematical variable, the set of \( \pi^+ \pi^- \) combinations in the data sample is divided into several bins in that variable, and the \( f_2 \) number in each bin is extracted by a fit to the corresponding \( \pi^+ \pi^- \) mass spectrum.

Throughout this paper, only the statistical errors of \( N_f \) are taken into account. With the available statistics, systematic errors can be assumed to be negligible. This is supported by test fits to \( \pi^+ \pi^- \) mass distributions from the Lund Monte Carlo simulation (in the version LEP-TO 4.3, JETSET 5.2 \([6]\)), which does not contain the \( f_2 \) meson; the test results are compatible with \( N_f = 0 \) within the statistical errors. Other tests, using the experimental data, show that the systematic influence of possibly occurring \( f_0 (1400) \), \( \rho_3 (1690) \) or \( f_4 (2050) \) resonance signals on the measured number of \( f_2 \) mesons does not exceed the statistical error. Conclusive evidence for the occurrence of any of these higher resonances is not found.

The experimental results presented in the following are compared to a semi-empirical model (Wells model) \([7]\), which is based on the quark-parton model and predicts the average multiplicities of various resonances, including the \( f_2 \), as functions of \( W \). Since the model parameters were determined from hadron interaction data, the comparison to (anti-)neutrino scattering results provides a real test of the model and of the underlying quark-parton model.

### 3 Results

In the data samples without a \( W \) cut or with \( W > 3 \text{ GeV} \), one observes small \( f_2 \) signals, emerging only weakly from the background (cf. Figs. 1a, b in \([1]\)). According to fits of function (1) and correcting for the branching ratio (5), the signals correspond to \( 615 \pm 226 \) and \( 123 \pm 130 \) \( f_2 \) mesons in the \( v \) and \( \bar{v}p \) data respectively with \( W > 3 \text{ GeV} \). Thus, the statistical significance of the \( f_2 \) signal in the \( v \) sample is 2.7 standard deviations, whereas the signal in the \( \bar{v} \) sample is compatible with zero. With the event numbers \( N_v = 13,205 \) and \( 7034 \pm 127 \) (corrected for 1-prong events) respectively, one obtains the average \( f_2 \) multiplicities \( \langle n_f \rangle = 0.047 \pm 0.017 \) and \( 0.017 \pm 0.018 \) in the \( v \) and \( \bar{v} \) event samples with \( W > 3 \text{ GeV} \). (The average \( W \) in these samples is \( 6.1 \text{ GeV} \) and \( 5.1 \text{ GeV} \) respectively.)

The corresponding predictions of the Wells model (with \( l_{\text{max}} = 1 \); see below), \( \langle n_f \rangle = 0.087 \) and \( 0.078 \) respectively for the \( v \) and \( \bar{v}p \) reactions, clearly exceed the experimental results.

The average \( f_2 \) multiplicity in the \( v \) data as a function of the hadronic mass squared, \( W^2 \), is presented in Fig. 1.