

## **A Study of Background Contributions to Partial Wave Intensities\***

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### **Abstract**

A simple study to determine the effect of including or not including a background in a Partial Wave Analysis is presented.

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# 1 Introduction

Two Partial Wave Analyses (PWA) have been performed with the only difference being the inclusion of a background in one and not in the other. As can be seen in figure 1 the background found by the PWA including this parameter is between 1% and 10%, depending on  $3\pi$  effective mass, of the total number of events in the coherent sum of all partial waves. The partial waves used are listed in table 1. This waveset, with background included, is the basis of the paper submitted to Physical Review Letters.

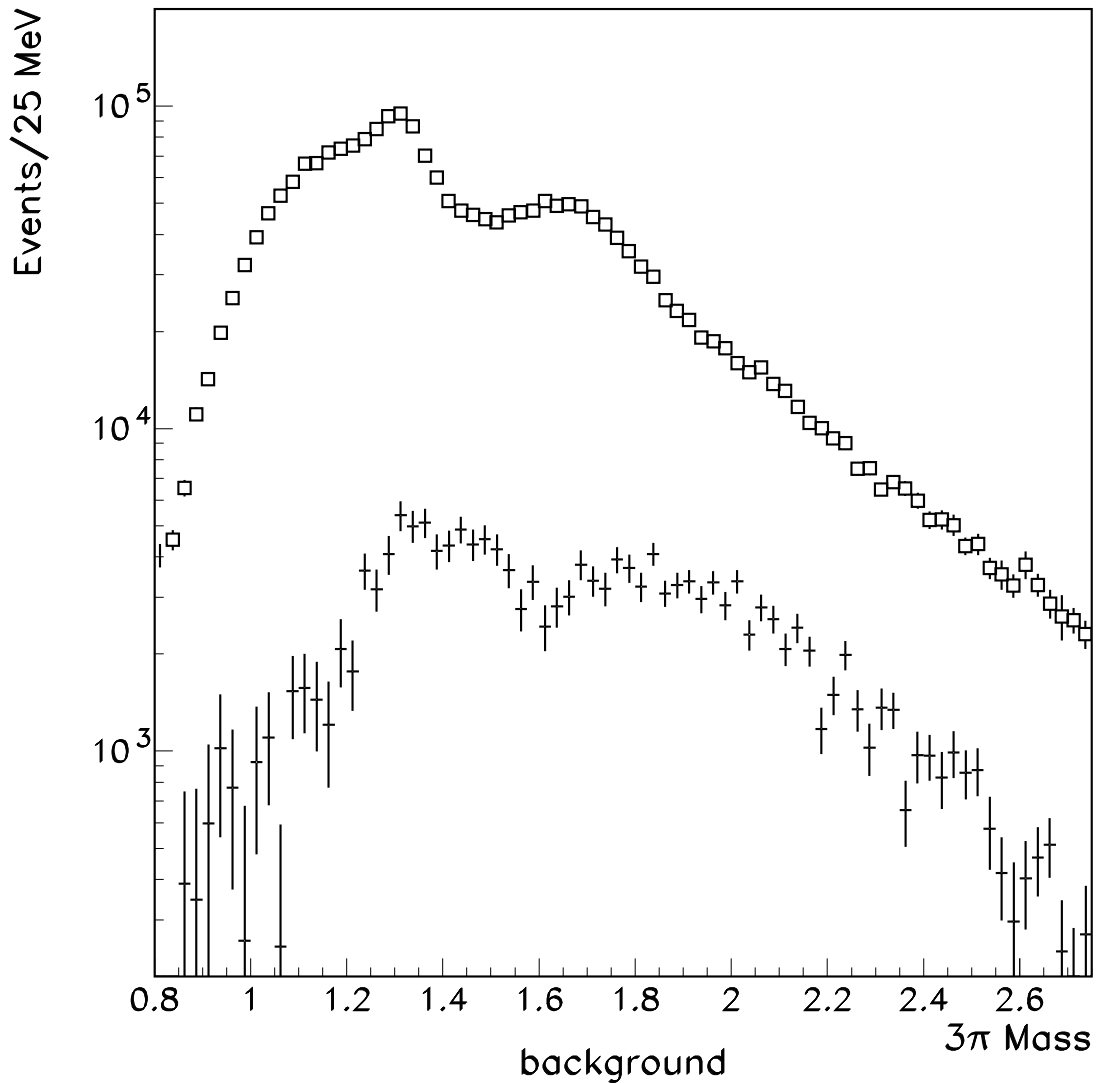


Figure 1: The background (points with error bars) compared to the total number of events (boxes)

The individual partial wave intensities from the two PWA were compared numerically and three

cases emerged and are discussed below.

1. The intensities were statistically indistinguishable (2 partial waves)
2. The intensities were different (3 partial waves)
3. The intensities differed by a single multiplicative factor (30 partial waves)

<i>J<sup>PC</sup>M<sup>ε</sup>Lisobar</i>				
$0^{-+}0^{+}S$ AMPM $\pi$	$1^{-+}0^{-}P$ $\rho\pi$	$2^{-+}0^{+}S$ $f_2\pi$	$3^{++}0^{+}S$ $\rho_3\pi$	$4^{-+}0^{+}P$ $\rho_3\pi$
$0^{-+}0^{+}S$ $f_0(980)\pi$	$1^{-+}1^{-}P$ $\rho\pi$	$2^{-+}0^{+}P$ $\rho\pi$	$3^{++}0^{+}P$ $f_2\pi$	$4^{-+}0^{+}F$ $\rho\pi$
$0^{-+}0^{+}P$ $\rho\pi$	$1^{-+}1^{+}P$ $\rho\pi$	$2^{-+}0^{+}P$ $\rho_3\pi$	$3^{++}0^{+}D$ $\rho\pi$	$4^{++}0^{+}D$ $\rho_3\pi$
	$1^{++}0^{+}S$ $\rho\pi$	$2^{-+}0^{+}D$ AMPM $\pi$		$4^{++}0^{+}F$ $f_2\pi$
	$1^{++}0^{+}P$ AMPM $\pi$	$2^{-+}0^{+}D$ $f_0(980)\pi$		$4^{++}0^{+}G$ $\rho\pi$
	$1^{++}0^{+}P$ $f_0(980)\pi$	$2^{-+}0^{+}D$ $f_2\pi$		
	$1^{++}1^{+}S$ $\rho\pi$	$2^{-+}0^{+}F$ $\rho\pi$		
	$1^{++}1^{+}P$ $f_2\pi$	$2^{-+}1^{+}S$ $f_2\pi$		
		$2^{-+}1^{+}P$ $\rho\pi$		
		$2^{-+}1^{+}P$ $\rho_3\pi$		
		$2^{-+}1^{+}D$ AMPM $\pi$		
		$2^{-+}1^{+}D$ $f_0(980)\pi$		
		$2^{-+}1^{+}D$ $f_2\pi$		
		$2^{-+}1^{+}F$ $\rho\pi$		
		$2^{++}0^{-}D$ $\rho\pi$		
		$2^{++}1^{+}D$ $\rho\pi$		

Table 1: The set of partial waves used in this analysis

## 1.1 Case 1: The unchanged partial waves

When the results of the PWA with and without a background included were compared it was found that two partial wave intensities were unchanged, the  $2^{++}1^+(\rho\pi)D$  and the  $1^{++}(\rho\pi)0^+S$ . Figures 2 and 3 show the comparison.

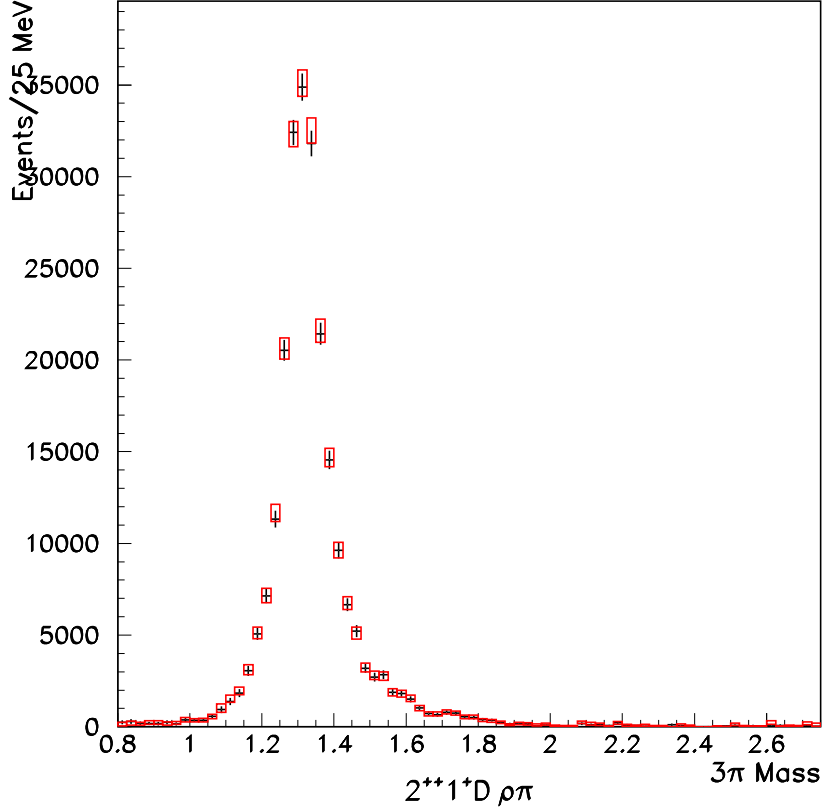


Figure 2: An unchanged partial wave. The points with error bars are the result of the PWA including a background term, the boxes are the result of the PWA without a background. The two results are statistically indistinguishable.

## 1.2 Case 2: The changed partial waves

Three partial waves were changed in a statistically significant way: the two  $1^{-+}$  waves in negative reflectivity and the  $1^{++}1^+(\rho\pi)S$  partial waves. Figures 4 through 6 show the results.

Also shown in these figures, in the lower panel, the the quantity  $\Delta^2$  defined as

$$\Delta^2 = \frac{(B - kN)^2}{\sigma_B^2 + (k\sigma_M)^2} \quad (1)$$

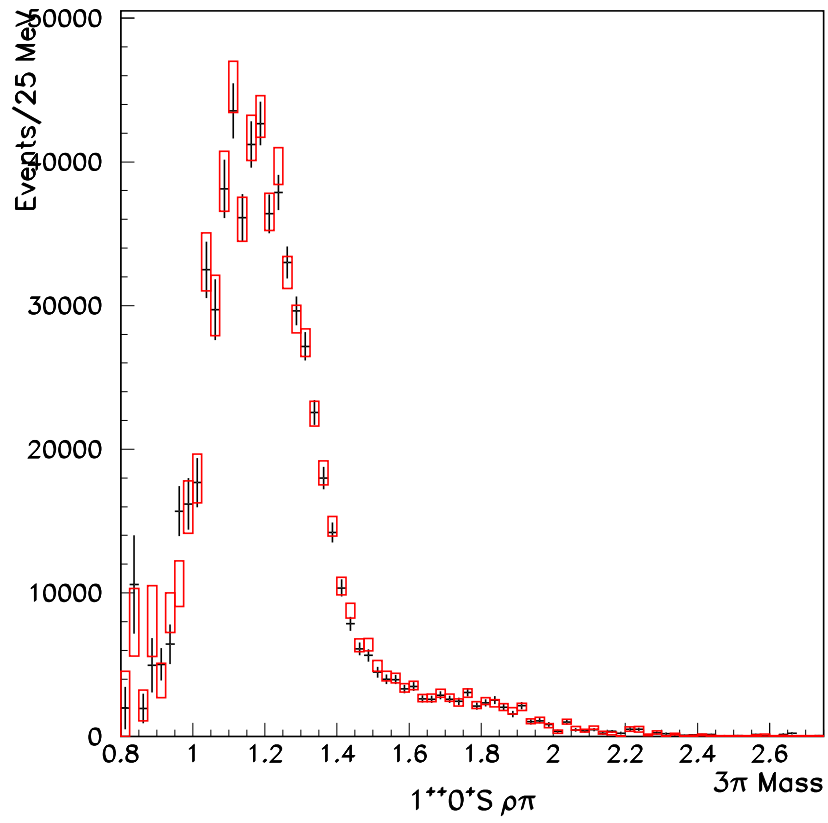


Figure 3: The second partial wave unchanged by inclusion/exclusion of a background. The boxes are the result of the PWA without a background. The two results are statistically indistinguishable.

where  $B$  is intensity of the partial wave shown at mass  $m$  calculated with the PWA including a background.  $\sigma_B$  is the error in  $B$  calculated by the fitting program.  $N$  is defined similarly but calculated with the PWA that did not include a background.  $k$  was chosen to minimize the summed values of  $\Delta^2$  over all partial waves compared.  $\Delta^2$  is a measure of the statistical significance of the difference of the two results being compared. The factor  $k$  is introduced to take into account the possibility that the two results are everywhere different by a simple multiplicative constant. significant deviations of  $\Delta^2$  from 2 is evidence for a statistically significant difference between the two results.

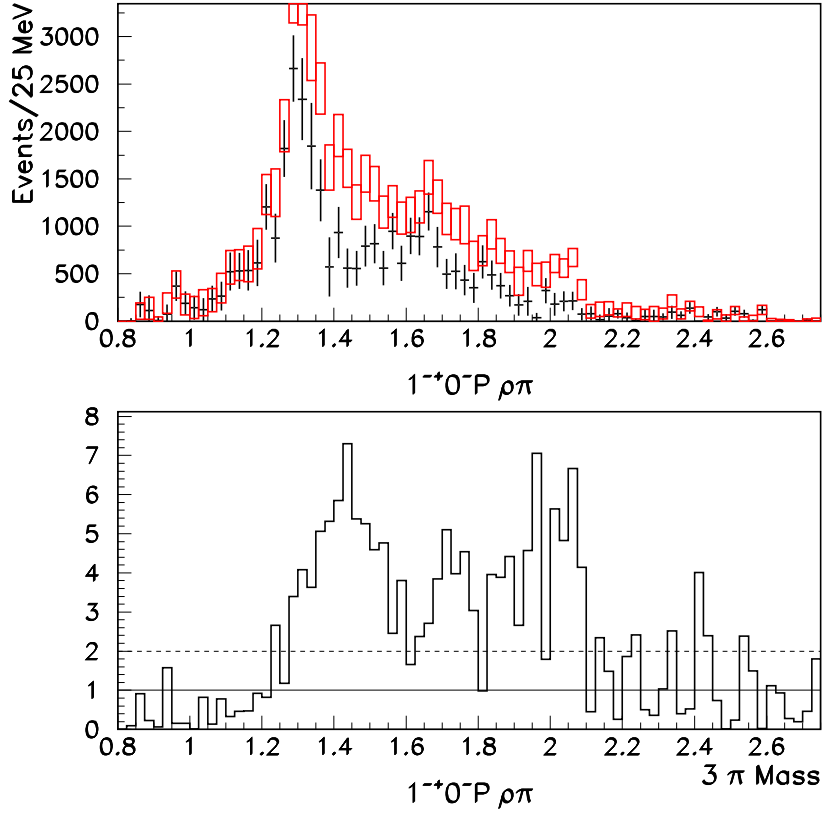


Figure 4: A changed partial wave. The points with error bars is the result of the PWA including a background term, the boxes are the results of the PWA not including a background scaled by the factor  $k$  discussed in the text. The lower panel shows the values of  $\Delta^2$  (defined in the text) for this partial wave.

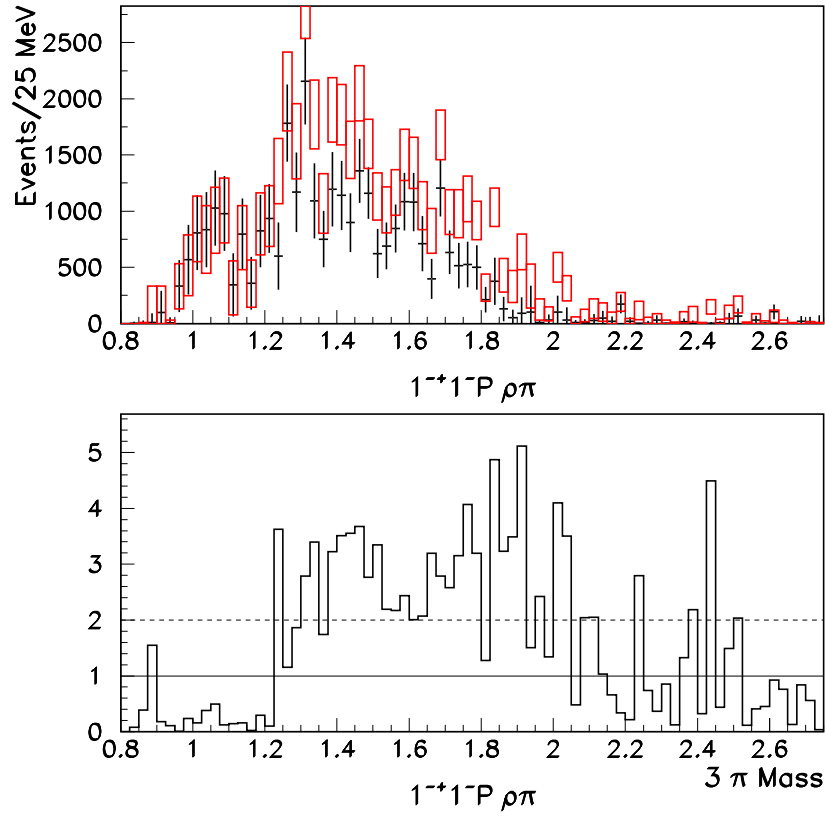


Figure 5: The second changed partial wave. The points with error bars is the result of the PWA including a background term, the boxes are the results of the PWA not including a background scaled by the factor  $k$  discussed in the text. The lower panel shows the values of  $\Delta^2$  (defined in the text) for this partial wave.

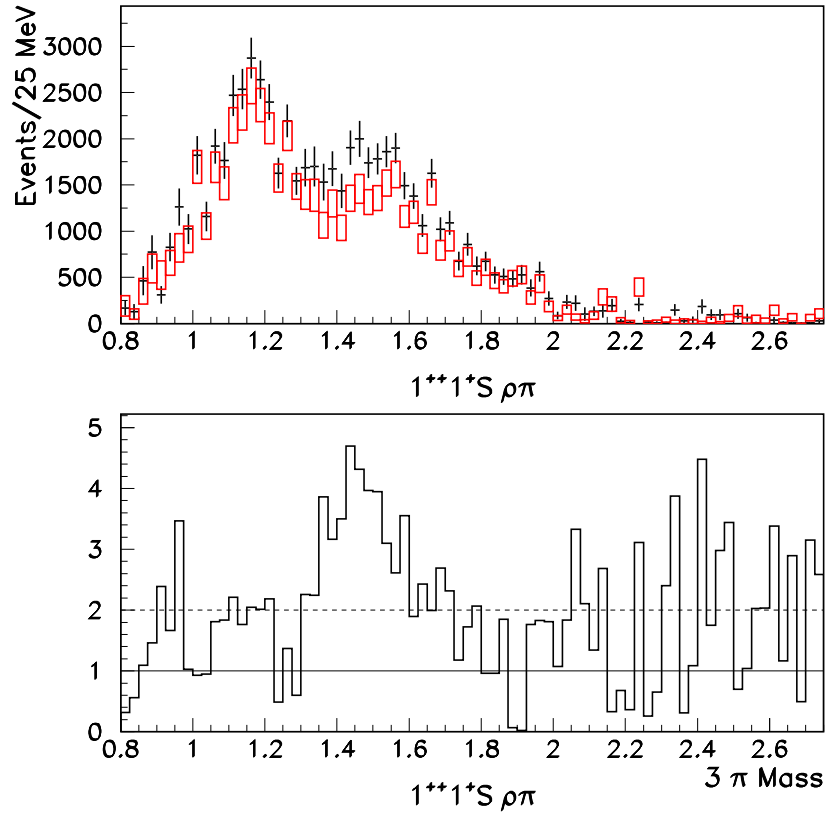


Figure 6: Only changed partial wave in positive reflectivity. The points with error bars is the result of the PWA including a background term, the boxes are the results of the PWA not including a background scaled by the factor  $k$  discussed in the text. The lower panel shows the values of  $\Delta^2$  (defined in the text) for this partial wave.

### 1.3 Case 3: Partial waves changed by a scale factor

The remaining 30 partial waves were changed by a scale factor found to be 0.89, that is the intensities from the PWA without a background were everywhere  $\approx 11\%$  larger than the intensities from the PWA without a background. Figures 7 through 11 show the five largest intensities of this type.

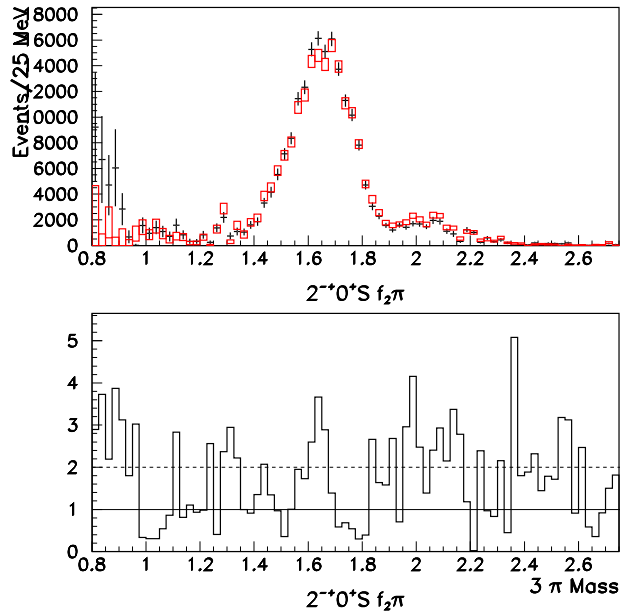


Figure 7: A partial wave changed by a scale factor after removal of the background term. The bottom panel shows  $\Delta^2$  for this partial wave. see the text for definitions.

## 2 Conclusion

It is demonstrated that background, when not included, does not concentrate in any particular partial wave. It has also been shown that including (or excluding) background does not change the shape of any of the partial waves showing resonant behavior.

The behavior of large majority of the partial wave intensities can be interpreted in such a way as to reveal the possible nature of the background: Some fraction of the events, in this case 11%, are taken from the signal intensities and assigned to the background by the fitting procedure.

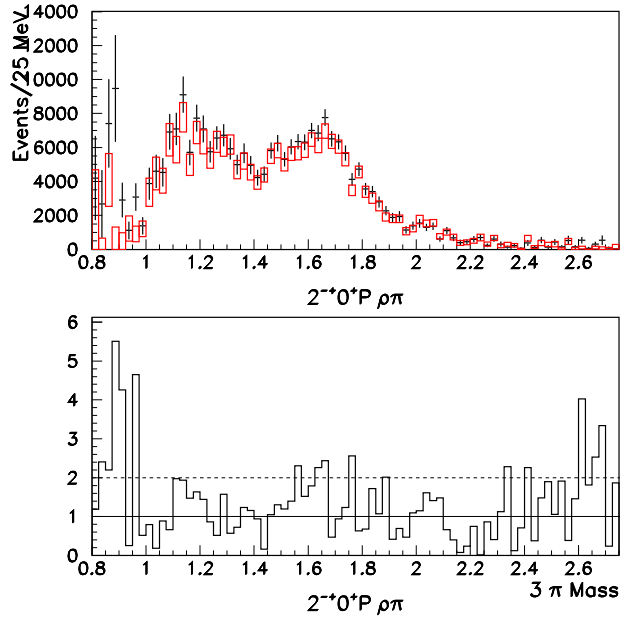


Figure 8: A partial wave changed by a scale factor after removal of the background term. The bottom panel shows  $\Delta^2$  for this partial wave. see the text for definitions.

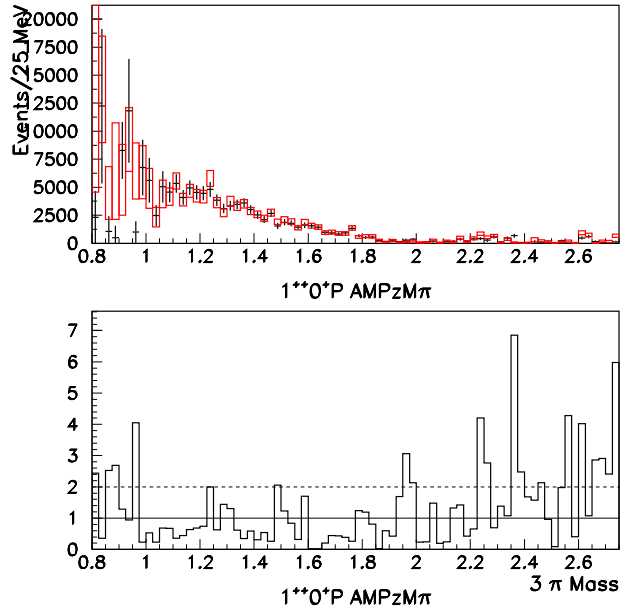


Figure 9: A partial wave changed by a scale factor after removal of the background term. The bottom panel shows  $\Delta^2$  for this partial wave. see the text for definitions.

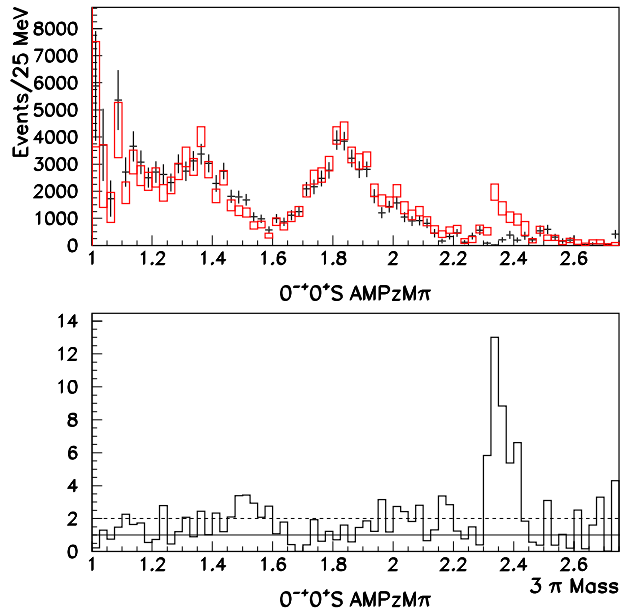


Figure 10: A partial wave changed by a scale factor after removal of the background term. The bottom panel shows  $\Delta^2$  for this partial wave. see the text for definitions.

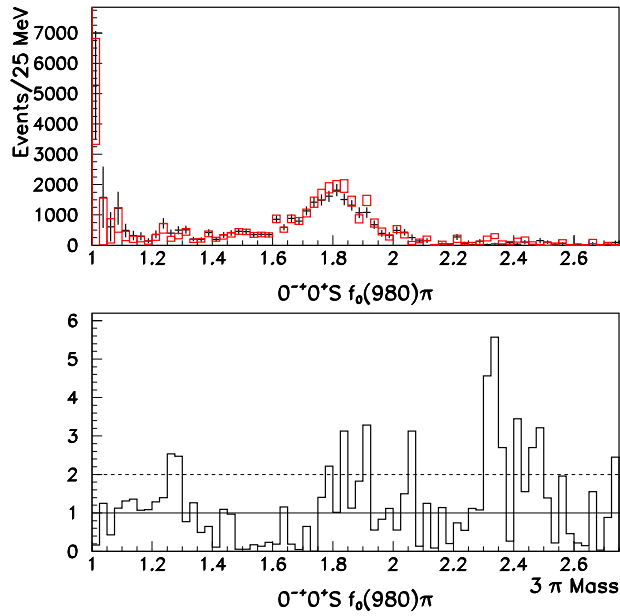


Figure 11: A partial wave changed by a scale factor after removal of the background term. The bottom panel shows  $\Delta^2$  for this partial wave. see the text for definitions.