BES Analysis Memo

$\psi' \to b_1^+\pi^-$ and $J/\psi \to b_1^+\pi^-$

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-ABSTRACT-

We report on a study of $\psi' \to b_1^+\pi^-$ and $J/\psi \to b_1^+\pi^-$, using 3.4 million ψ' events observed in the BES detector. The J/ψ's are produced via the cascade decay $\psi' \to \pi^+\pi^- J/\psi$ in the same data sample. We confirm the DM2 group's observation of a shift in the mass of b_1's produced by $J/\psi \to b_1^+\pi^-$ decays, but see no corresponding mass shift for b_1's produced via ψ' decays. This is consistent with the DM2 group's conjecture that the mass shift seen in J/ψ decays is due to interference with the ωf_2 decay channel, a channel that is suppressed in ψ' decays. We determine a $J/\psi \to b_1\pi$ branching fraction that is consistent within errors with the current PDG value.

1 Technique

We determine the $\psi' \to X$ branching fraction to a final state $(f.s.)$ via the relation

$$Br(\psi' \to X) = \frac{N(\psi' \to X \to f.s.)}{N_{\psi'}\eta_{\psi' \to X \to f.s.} Br(X \to f.s.)}, \tag{1}$$

where $N_{\psi'}$ is the total number of ψ's in the data sample, $\eta_{\psi' \to X \to f.s.}$ is the detection efficiency for the particular final state and $Br(X \to f.s.)$ is the branching fraction to that final state. For this analysis, $X = b_1^+\pi^- \; + \; cc$, $f.s. = \pi^+\pi^-\pi^+\pi^-\pi^0$, and $Br(X \to f.s.) = Br(b_1^+ \to \omega\pi^+) \times Br(\omega \to \pi^+\pi^-\pi^0)$.

When using cascade decay events to determine the $J/\psi \to X$ branching fraction, the corresponding relation is

$$Br(J/\psi \to X) = \frac{N(\psi' \to \pi^+\pi^- J/\psi; J/\psi \to X \to f.s.)}{N_{\psi'}\eta_{J/\psi \to X \to f.s.} Br(X \to f.s.)\eta_{\pi^+\pi^-} Br(\psi' \to \pi^+\pi^- J/\psi)}, \tag{2}$$

where $\eta_{\pi^+\pi^-}$ is the efficiency for detecting the cascade $\pi^+\pi^-$ pair.

The efficiency for the cascade $\pi^+\pi^-$ pair has been well studied in conjunction with the $J/\psi \to \ell^+\ell^-$ branching ratio measurement, and, for a $|\cos\theta| \leq 0.8$ acceptance cut, is $\eta(\pi^+\pi^-) = 0.59 \pm 0.02$ [5].

The number of ψ's we use is $N_{\psi'} = (3.44 \pm 0.31) \times 10^6$, as determined in ref. [9]. We obtain from the PDG: $Br(\psi' \to \pi^+\pi^- J/\psi) = 0.324 \pm 0.026$ [4], and $Br(\omega \to \pi^+\pi^-\pi^0) = 0.888 \pm 0.006$ [4]

2 DM2 results for $J/\psi \to b_1^+\pi^-$

The PDG entry for $J/\psi \to b_1^+\pi^-$ is dominated by a large statistics measurement by the DM2 experiment [6]. They find a large enhancement in the $\omega\pi^\pm$ mass spectrum but at a mass $M = 1.190 \pm 0.010$ GeV and with a width $\Gamma = 0.210 \pm 0.019$ GeV that differ significantly from the PDG values of $M = 1.232 \pm 0.010$ GeV and $\Gamma = 0.142 \pm 0.008$ GeV. (The only other reported study of $J/\psi \to b_1\pi$, by the PLUTO group, also finds a low mass for the b_1, namely $M = 1.182 \pm 0.032$ GeV [7].) The DM2 group suggests that this may be due to interference with the ωf_2 decay channel. Since the latter channel is suppressed for ψ' decays [8], this mechanism would not be nearly as effective and such a dramatic mass shift would not be expected.

3 Event selection

3.1 $J/\psi \to \omega\pi^+\pi^-$

For $J/\psi \to \omega\pi^+\pi^-$, we select events with 6 charged tracks with net charge zero and 2 or more neutral tracks. We require all the tracks to be within the polar angle region $|\cos\theta| \leq 0.8$. The 6 charged tracks and each $\gamma\gamma$ pair with prefit mass below 1 GeV are submitted to a 6-constraint fit to the hypothesis

$$\begin{array}{lllllll} \psi' & \to & \pi^+\pi^- J/\psi & & & & \\ & & J/\psi & \to & \pi^+\pi^-\pi^+\pi^-\pi^0 & & \\ & & & & \pi^0 & \to & \gamma\gamma. \end{array} \tag{3}$$

In addition to applying the fit to each pair of γ's, we try each of the four possible combinations of the two lowest momentum positive and negative tracks as the $\pi^+\pi^-$ pair from the $\psi' \to \pi^+\pi^- J/\psi$ cascade decay. The combination with the best χ^2 value that is below 20 is selected. The surviving $M_{\gamma\gamma}^{prefit}$ distribution has a peak at the π^0 mass but a small tail that extends to higher masses. This tail is removed by requiring $M_{\gamma\gamma}^{prefit} < 0.4$ GeV.

Table 1: A tabulation of the $J/\psi \to \omega\pi^{\pm}$ selection cuts.

Numbers of events surviving each requirement

	Data	Monte Carlo
Generated		10000
6 chrgd trks		4937
$\sum q = 0$		4718
$2 \geq N_{\gamma} \leq 10$	854941	2785
$\lvert\cos\theta\rvert \leq 0.8$	580672	1660
$\chi^2_{6c} \leq 20$	3918	610
$M_{2\gamma}^{prefit} < 0.4$GeV	3720	608
$\lvert M_{\pi^+\pi^-\pi^0} - 0.782\rvert < 0.04$GeV	609	621
$M_{\pi^+\pi^-} > 1.55$GeV	189	303

A scatterplot of $M_{\pi^+\pi^-\pi^0}$ (vertical) vs $M_{\pi^+\pi^-\pi^{\pm}\pi^0}$ (horizontal) is shown in Fig. 1a. Here there are eight entries/event. The $\omega(780)$ is evident as a horizontal band near the bottom. Figure 1b shows the $M_{\pi^+\pi^-\pi^0}$ distribution (four entries/event). The ω peak is well fit with a Breit Wigner with $\sigma = 0.031 \pm 0.002$ GeV (See Fig 5). Like the DM2 experiment, we define events with $|M_{\pi^+\pi^-\pi^0} - 0.782| < 0.05$ GeV to be ω's. Figure 1c shows the distribution of $M_{\pi^+\pi^-}$, the mass of the $\pi^+\pi^-$ recoiling against the ω. Here the $f_2(1270)$ is evident. Following DM2, we eliminate the f_2 by requiring $M_{\pi^+\pi^-} > 1.55$ GeV. The resulting $\omega\pi^{\pm}$ mass spectrum, shown in Fig. 1d, shows a clear peak at low masses, as expected for the $b_1(1235)$. For each event, it was chosen the $\pi^+\pi^-\pi^0$ combination which has the invariant mass closer to the ω mass.

The effects of the various selection cuts on the data and the simulated event sample are summarized in Table 1. The last two cuts include all the $\pi\pi\pi^0$ combinations, not only the one closest to the ω. In the table are also the results that we obtain when the same analysis is applied to a sample of Monte Carlo events.

3.2 $\psi' \to \omega\pi^+\pi^-$

For $\psi' \to \omega\pi^+\pi^-$, we select events with 4 charged tracks with net charge zero and 2 or more neutral tracks. We require all the tracks to be within the polar angle region $|\cos\theta| \leq 0.8$. The 4 charged tracks and each $\gamma\gamma$ pair with prefit mass below 1 GeV are

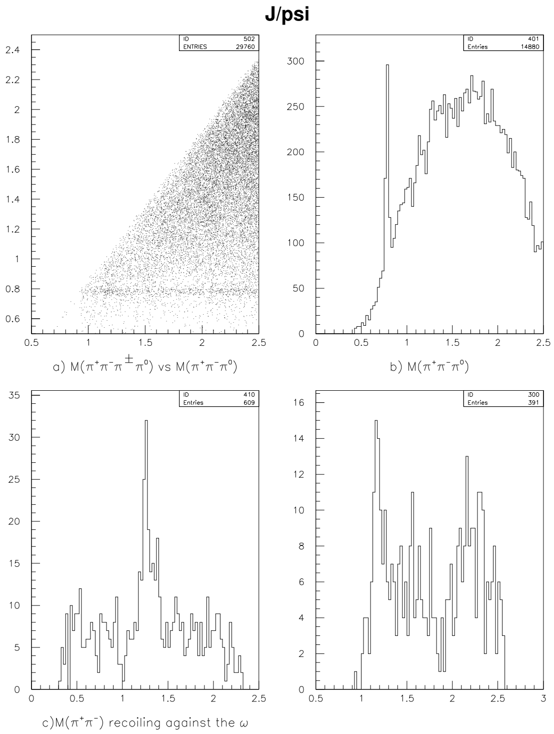

Figure 1: J/ψ **data**, **a)** A scatterplot of $M_{\pi^+\pi^-\pi^0}$ (vertical) vs $M_{\pi^+\pi^-\pi^\pm\pi^0}$ (horizontal). **b)** The $M_{\pi^+\pi^-\pi^0}$ distribution. **c)** The distribution of $M_{\pi^+\pi^-}$, the $\pi^+\pi^-$ mass recoiling against the ω. **d)** The $\omega\pi$ mass distribution for $M_{\pi^+\pi^-} > 1.55$ GeV, best ω combination.

submitted to a 5-constraint fit to the hypothesis

$$\begin{aligned} \psi' &\rightarrow \pi^+\pi^-\pi^+\pi^-\pi^0 \\ &\qquad\qquad \pi^0 \rightarrow \gamma\gamma \end{aligned} \tag{4}$$

The $\gamma\gamma$ combination with the best χ^2 value below 50 is selected. We reject events where the recoil mass against any $\pi^+\pi^-$ pair is within 0.05 GeV of the J/ψ, or where $M_{\gamma\gamma}^{prefit} > 0.4$ GeV. Events from $\psi' \rightarrow \eta J/\psi$ followed by $J/\psi \rightarrow \ell^+\ell^-$ and $\eta \rightarrow \pi^+\pi^-\pi^0$ are eliminated by requiring all $\pi^+\pi^-$ invariant mass combinations to be below 2.9 GeV. The remaining sample has a considerable number of events of the type $\psi' \rightarrow \gamma\chi_c$ followed by $\chi \rightarrow \pi^+\pi^-\pi^+\pi^-$, where the γ is split by the cluster routine and fit to a π^0. These events are removed by requiring the missing mass against the fit $\gamma\gamma$ pair to be less than 3.3 GeV. Finally, we require $\chi^2(5c) < 20$.

A scatterplot of $M_{\pi^+\pi^-\pi^0}$ (vertical) vs $M_{\pi^+\pi^-\pi^\pm\pi^0}$ (horizontal) is shown in Fig. 2a. Figure 2b shows the $M_{\pi^+\pi^-\pi^0}$ distribution (four entries/event). The ω peak is well fit with a gaussian with $\sigma = 0.016$ GeV. As in the J/ψ analysis, we define events with $|M_{\pi^+\pi^-\pi^0} - 0.782| < 0.04$ GeV to be ω's. Figure 2c shows the distribution of $M_{\pi^+\pi^-}$, the mass of the $\pi^+\pi^-$ recoiling against the ω. Here there is no evident $f_2(1270)$. Nevertheless, for symmetry with the J/ψ analysis, we require $M_{\pi^+\pi^-} > 1.55$ GeV. 60% of the events survive this cut. (See Table 2, Monte Carlo column) The resulting $\omega\pi^\pm$ mass spectrum (one entry per event), shown in Fig. 2d, shows a clear $b_1(1235)$ signal. The correspondent distributions drawn from the 4.03 GeV data, for a luminosity of $23pb^-1$, yields 9.8 ± 4.6 number of events. See Fig. 3, and Fig. 4. This value makes a negligible contribution to the systematic error (See section on the Systematic Error Study).

The effects of the various selection cuts on the data and the simulated event sample are summarized in Table 2. The last two cuts include all the $\pi\pi\pi^0$ combinations, not only the one closest to the ω. In the table there are also the results that we obtain when the same analysis is applied to a sample of Monte Carlo Simulated events.

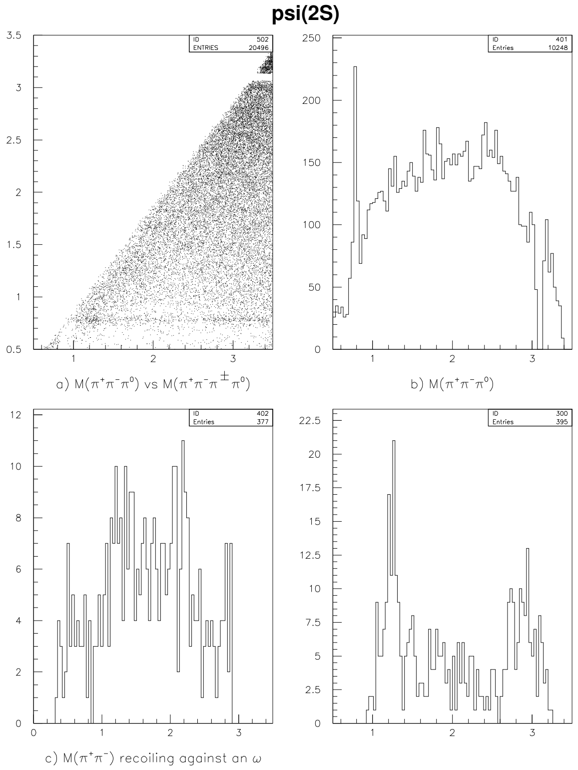

Figure 2: $\psi(2S)$ **data**, **a)** A scatterplot of $M_{\pi^+\pi^-\pi^0}$ (vertical) vs $M_{\pi^+\pi^-\pi^\pm\pi^0}$ (horizontal). **b)** The $M_{\pi^+\pi^-\pi^0}$ distribution. **c)** The distribution of $M_{\pi^+\pi^-}$, the $\pi^+\pi^-$ mass recoiling against the ω. **d)** The $\omega\pi$ mass distribution for $M_{\pi^+\pi^-} > 1.55$ GeV, best ω combination.

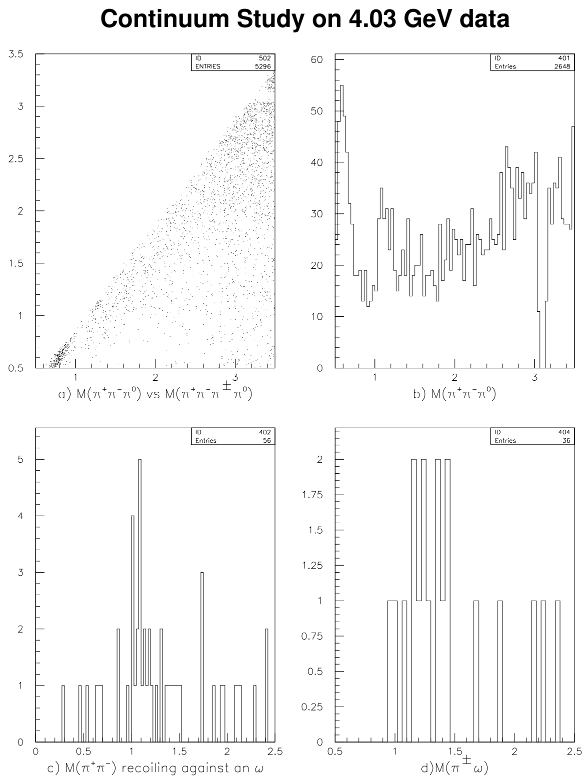

Figure 3: **4.03 GeV data**, **a)** A scatterplot of $M_{\pi^+\pi^-\pi^0}$ (vertical) vs $M_{\pi^+\pi^-\pi^\pm\pi^0}$ (horizontal) **b)** The $M_{\pi^+\pi^-\pi^0}$ distribution. **c)** The distribution of $M_{\pi^+\pi^-}$, the $\pi^+\pi^-$ mass recoiling against an ω. **d)** The $\omega\pi$ mass distribution for $M_{\pi^+\pi^-} > 1.55$ GeV.

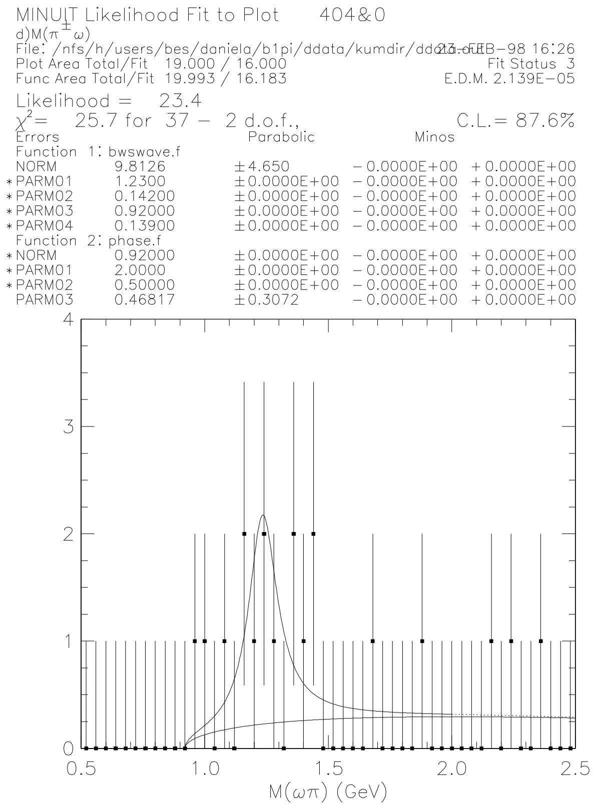

Figure 4: **4.03 GeV data**: Fit to the $\omega\pi$ mass distribution.

Table 2: A tabulation of the $\psi' \to \omega\pi^{\pm}$ selection cuts.

Numbers of events surviving each requirement

	Data	Monte Carlo
Generated		5000
4 chrgd trks		1942
$\sum q = 0$		
$2 \geq N_{\gamma} \leq 10$	733132	1880
$\vert\cos\theta\vert \leq 0.8$	514999	1376
$\chi^2_{5c} \leq 50$	18749	760
$\vert M^{recoil}_{\pi^+\pi^-} - 3.096\vert > 0.05\text{GeV}$	9470	692
$M^{prefit}_{2\gamma} < 0.4\text{GeV}$	8591	691
$M_{\pi^+\pi^-} < 2.90\text{GeV}$	7095	690
$M^{recoil}_{2\gamma} < 3.3\text{GeV}$	4067	441
$\chi^2_{5c} \leq 20$	2319	402
$\vert M_{\pi^+\pi^-\pi^0} - 0.782\vert < 0.04\text{GeV}$ [1]	339	456
$M_{\pi^+\pi^-} > 1.55\text{GeV}$	233	267

4 Fit functions

We fit the $\omega\pi^{\pm}$ mass distributions to an s-wave Breit Wigner (BW) function. On the data, we add a smooth background function of the form

$$\begin{aligned} f_{bkg}(Q) &= A\ Q^{\alpha}\ e^{-\lambda Q} \quad Q > 0 \\ &= 0 \qquad\qquad\quad\ Q \leq 0, \end{aligned} \tag{5}$$

where $Q = M_{\omega\pi} - M_{\omega} - M_{\pi}$, and we normally use $\alpha = 1/2$. We restrict the region of the fit to $0.9 \leq M_{\omega\pi} \leq 2.0$ GeV for ψ' and to $0.9 \leq M_{\omega\pi} \leq 1.75$ GeV for J/ψ.

5 Monte Carlo study

5.1 $J/\psi \rightarrow b_1\pi$

In the simulated experiment, 10,000 generated events result in $N^{mc}_{J/\psi} = 293.8 \pm 17.5$ detected events, for a combined acceptance of $\eta_{\pi^+\pi^-}\eta_{J/\psi\rightarrow b_1\pi} = 0.029 \pm 0.002$. The fit is extended up to 1.75 GeV both for Montecarlo and data. (see Fig. 6).

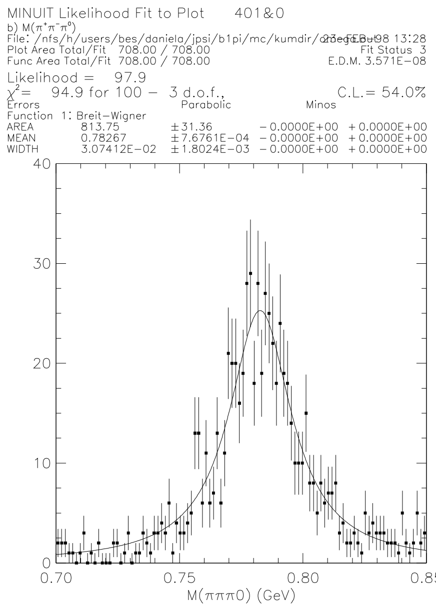

Figure 5: **MC on J/ψ decay**, a fit to the ω mass distribution.

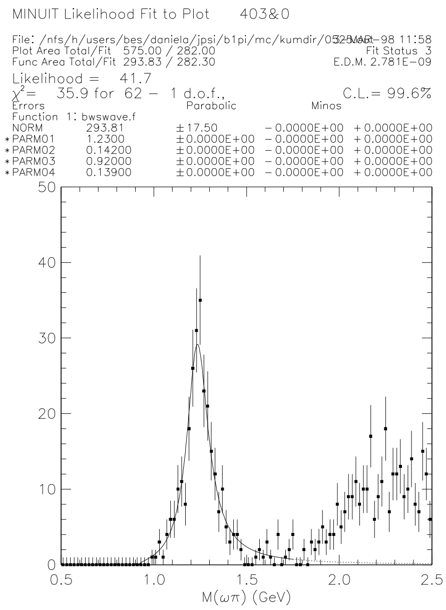

Figure 6: **MC on J/ψ decay**, a fit to the $\omega\pi$ mass distribution. (10,000 events)

5.2 $\psi' \to b_1\pi$

Fig. 7a) shows the Dalitz plot of $M^2(\pi^+\pi^0)$ versus $M^2(\pi^-\pi^0)$ in the ω rest frame. $\frac{dN}{d\cos\theta}$ is distributed as $\sin^2(\theta)$ in Fig. 7c). θ is the angle between the direction of π^+ in the $\pi^+\pi^-$ rest frame, and the direction of π^0 in the ω rest frame.
The $\omega\pi$ Monte Carlo distribution (see Fig. 7d) is well fit by an s-wave Breit Wigner (BW) function. The 5000 generated events result in $N^{mc}_{\psi'} = 236.0 \pm 15.4$ detected events, for an acceptance of $\eta_{\psi' \to b_1\pi} = 0.047 \pm 0.003$. The fit is extended from 0.5 to 2.0 GeV, both for Montecarlo and data.

6 Data results

6.1 $J/\psi \to b_1\pi$

Figure 11 shows the results of a fit to the J/ψ data where the mass and the width of the BW is fixed at the PDG values for the $b_1(1235)$. The confidence level is 87.6 % and the data clearly peak below the BW maximum.
The confidence level of the fit improves to 99.8% when we allow the mass of the BW to vary. The fit, shown in Fig. 10, gives a mass of $M_{b_1} = 1.187 \pm 0.014$ GeV, which is consistent with the DM2 and the PLUTO values. $N_{J/\psi \to b_1\pi} = 67.8 \pm 13.8$ events, as

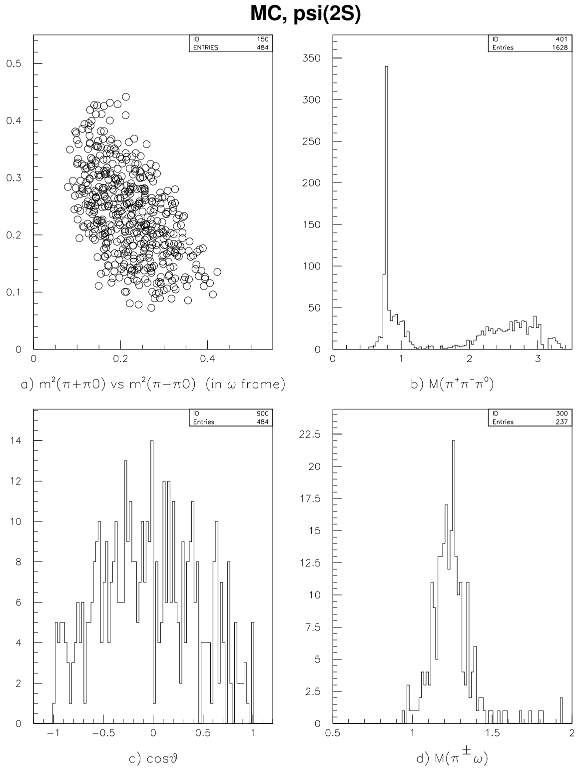

Figure 7: **a)** Dalitz plot in the ω rest frame. **b)** The $M_{\pi^+\pi^-\pi^0}$ distribution. **c)** Distribution of the cosine of the angle between π^+ in the $\pi^+\pi^-$ rest frame, and π^0 in the ω rest frame. **d)** The $\omega\pi$ mass distribution for $M_{\pi^+\pi^-} > 1.55$ GeV, best ω combination.

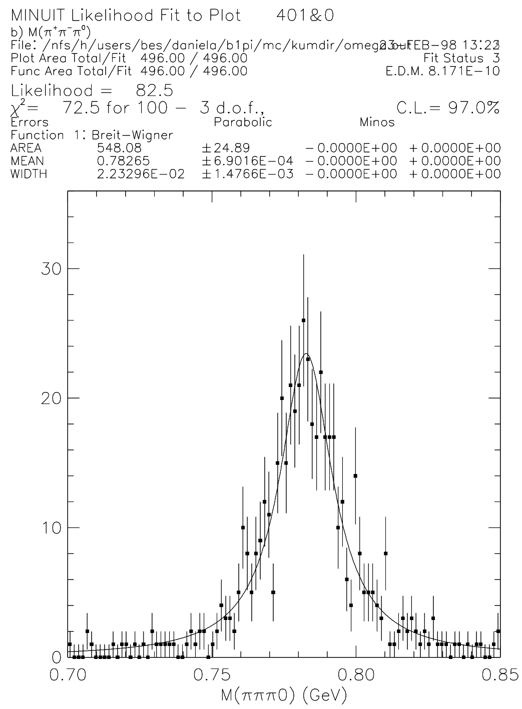

Figure 8: **MC on $\psi(2S)$ decay**, the ω mass distribution.

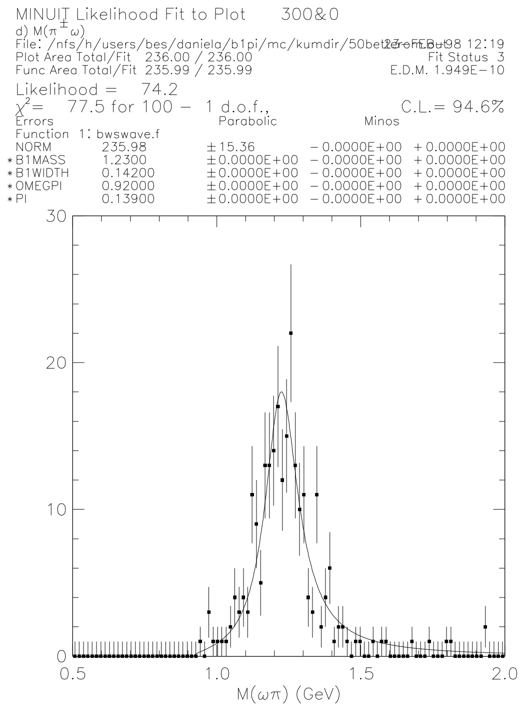

Figure 9: **MC on $\psi(2S)$ decay**, the $\omega\pi$ mass distribution. (5,000 events)

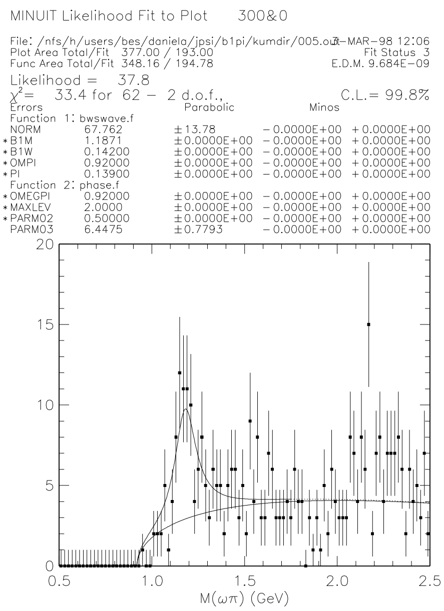

Figure 10: J/ψ **data**, a fit to the $\omega\pi$ mass distribution with the mass of the BW allowed to vary.

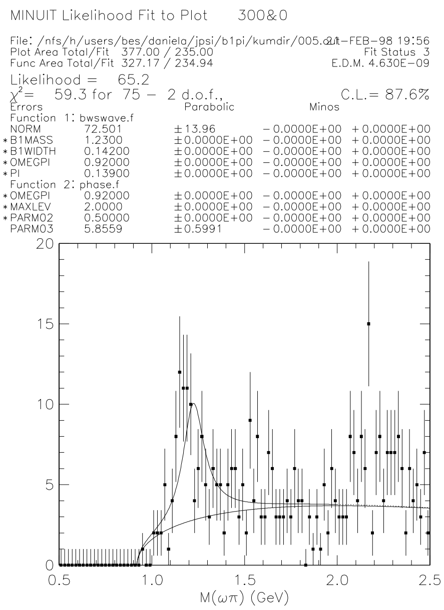

Figure 11: J/ψ **data**, a fit to the $\omega\pi$ mass distribution with the mass of the BW fixed at the nominal values for the b_1.

shown in Fig. 10.

6.2 $\psi' \to b_1\pi$

Figure 12 shows the results of a fit to the ψ' data where the mass and width of the BW are fixed at the PDG values for the $b_1(1235)$. The confidence level is 99.5% and the number of events from the fit is $N_{\psi' \to b_1\pi} = 88.7 \pm 13.6$. The confidence level of the fit decreases when the mass is taken to be a free parameter.

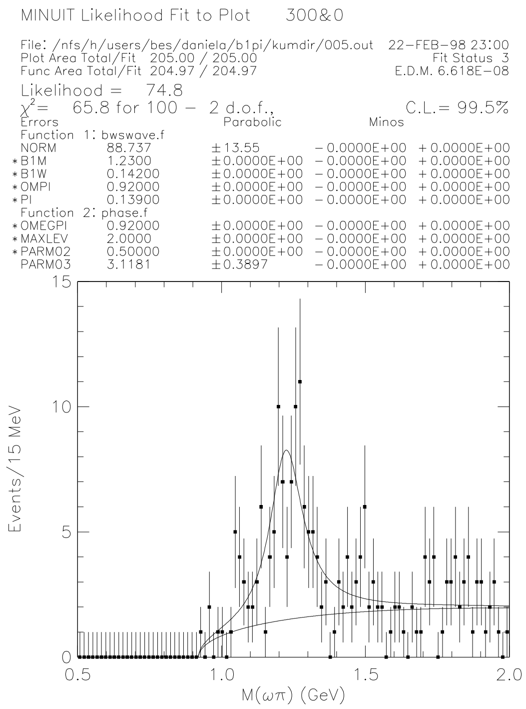

Figure 12: $\psi(2S)$ **data**, a fit to the $\omega\pi$ mass distribution with the mass and width of the BW fixed at the nominal values for the b_1.

Table 3: $J/\psi \to b_1^{\pm}\pi^{\mp}$

	Acceptance	Signal N events	$Br(J/\psi \to b_1^{\pm}\pi^{\mp})$
	0.029 ± 0.002	67.8 ± 13.8	$(2.4 \pm 0.5) \times 10^{-3}$

Table 4: $\psi' \to b_1^{\pm}\pi^{\mp}$

	Acceptance	Signal N events	$Br(\psi' \to b_1^{\pm}\pi^{\mp})$
	0.047 ± 0.003	88.7 ± 13.6	$(6.2 \pm 0.9) \times 10^{-4}$

7 Systematic Error Study

7.1 Technique

In order to evaluate the systematic error, we measure how much each of the major cuts or methods, taken by itself, affects the branching fractions of $\psi' \to b_1^+\pi^-$, and $J/\psi \to b_1^+\pi^-$.

We take the r.m.s deviation of the branching fractions, calculated with more extreme cuts, and we combine it to the error on the number of ψ''s.

7.2 Reference Values

In tables 3 and 4, we summarize the results of the $\psi' \to b_1^+\pi^-$, and $J/\psi \to b_1^+\pi^-$ analysis, without the systematic error.

7.3 Data

Fig. 13 show the $\omega\pi$ data distribution for $J/\psi \to b_1\pi$, with understimated background. Same procedure is followed with the ψ'. (See Fig. 14) The plots that we choose to calculate the branching fractions, are the ones with the overestimated background, respectively in Fig. 10 and Fig. 12.

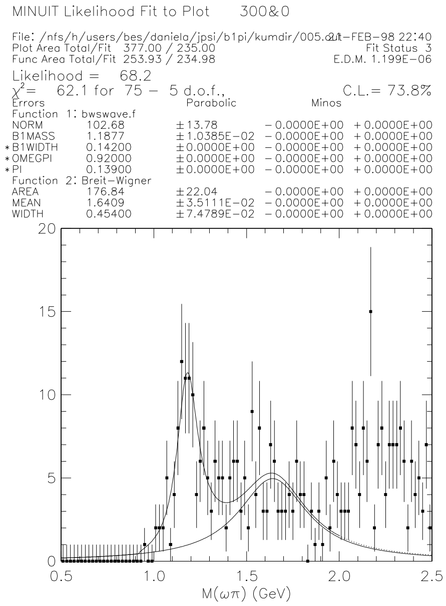

Figure 13: J/ψ **data**, a fit to the $\omega\pi$ mass distribution, with underestimated background.

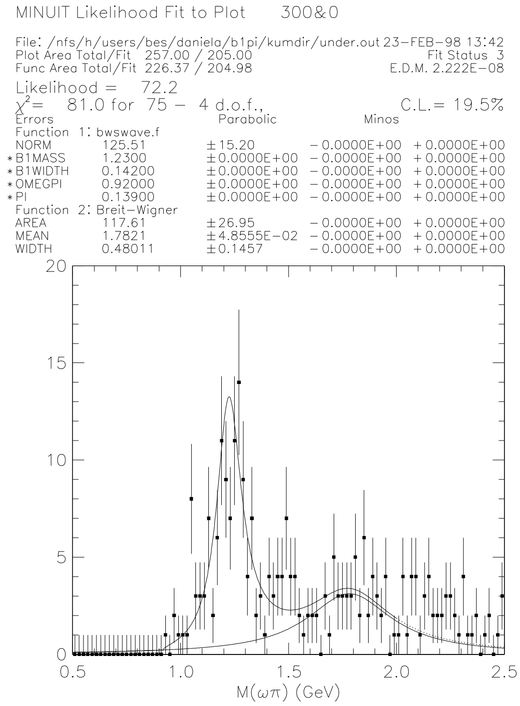

Figure 14: $\psi(2S)$ **data**, a fit to the $\omega\pi$ mass distribution with underestimated background.

Table 5: Systematic Error Study for $J/\psi \to b_1^{\pm}\pi^{\mp}$

	Acceptance	Signal N events	$Br(J/\psi \to b_1^{\pm}\pi^{\mp}$
(1) Best Omega	0.029 ± 0.002	$67.8 \pm 13.8(fit)$	$(2.4 \pm 0.5) \times 10^{-3}$
Double Counting	0.032 ± 0.002	87.1 ± 14.1	$(2.8 \pm 0.5) \times 10^{-3}$
(2) $\lvert M_{\pi^+\pi^-\pi^0} - 0.782\rvert < 0.05$ GeV	0.029 ± 0.002	67.8 ± 13.8	
$\lvert M_{\pi^+\pi^-\pi^0} - 0.782\rvert < 0.06$ GeV	0.028 ± 0.002	73.3 ± 13.6	$(2.4 \pm 0.5) \times 10^{-3}$
(3) PPGEN generator	0.029 ± 0.002	67.8 ± 13.8	
HOWL generator	0.021 ± 0.001	"	$(3.5 \pm 0.6) \times 10^{-3}$
(4) $M_{\pi^+\pi^-} > 1.55$ GeV cut	0.029 ± 0.002	67.8 ± 13.8	
no $M_{\pi^+\pi^-} > 1.55$ GeV cut	N/A	N/A	N/A
(5) overestimated bkgnd	0.029 ± 0.002	67.8 ± 13.8	
underestimated bkgnd	"	100.9 ± 13.6	
two bkgnds average	"	$86.7 \pm 14.2(\sigma)$	$(3.1 \pm 0.5) \times 10^{-3}$

8 Systematic Error Study

In tables 3 and 4, we report the effects of each cut or criteria on the analysis of J/ψ and the ψ' respectively. (1),(2),(3),(4) and (5) refer to the cuts and methods we have chosen for our result. Each feature is changed one at the time.

We measure the overall contribution, by taking the r.m.s deviation of each branching fraction, in respect to the reference values, as given in tables 1 and 2. We find 0.7 for the J/ψ, and 0.9 for the ψ'.

When we combine each contribution with the continuum level (11% for ψ', and 13% for J/ψ), and with the error on the number of ψ's ($N_{\psi'} = (3.44 \pm 0.31) \times 10^6$, as in [10], and [9])), we obtain respectively 0.7 for J/ψ, and 0.9 for ψ'.

9 Conclusion

We observe strong signals for $\psi' \to b_1^+\pi^-$ and $J/\psi \to b_1^+\pi^-$ among the 3.4 million $\psi(2S)$ events observed in the BES detector. The mass of the b_1's produced in $J/\psi \to b_1^+\pi^-$ decays is $M_{b_1} = 1.187 \pm 0.014$, which is substantially lower than the standard values.

Table 6: Systematic Error Study for $\psi' \to b_1^{\pm}\pi^{\mp}$

	Acceptance	Signal N events	$Br(\psi' \to b_1^{\pm}\pi^{\mp})$
(1) Best Omega	0.047 ± 0.003	$88.7 \pm 13.6(fit)$	$(6.2 \pm 0.9) \times 10^{-4}$
Double Counting	0.056 ± 0.003	108.9 ± 15.0	$(6.4 \pm 0.9) \times 10^{-4}$
(2) $\lvert M_{\pi^+\pi^-\pi^0} - 0.782\rvert < 0.04$ GeV	0.047 ± 0.003	88.7 ± 13.6	
$\lvert M_{\pi^+\pi^-\pi^0} - 0.782\rvert < 0.06$ GeV	0.047 ± 0.003	94.6 ± 13.9	$(6.6 \pm 1.0) \times 10^{-4}$
(3) PPGEN generator	0.047 ± 0.003	88.7 ± 13.6	
HOWL generator	0.042 ± 0.002	"	$(6.9 \pm 1.0) \times 10^{-4}$
(4) $M_{\pi^+\pi^-} > 1.55$ GeV cut	0.047 ± 0.003	88.7 ± 13.6	
no $M_{\pi^+\pi^-} > 1.55$ GeV cut	0.079 ± 0.004	116.3 ± 16.9	$(4.8 \pm 0.7) \times 10^{-4}$
(5) overestimated bkgnd	0.047 ± 0.003	88.7 ± 13.6	
underestimated bkgnd	"	125.5 ± 15.2	
two bkgnds average	"	$107.1 \pm 18.4(diff/2)$	$(7.4 \pm 1.3) \times 10^{-4}$

This is similar to shifts in the mass of b_1's from J/ψ reported by the DM2 and PLUTO groups [6][7]. There is no corresponding mass shift for b_1's from ψ' decays. These results are consistent with the DM2 group's conjecture that the mass shift seen in J/ψ decays is due to interference with the ωf_2 decay channel, a channel that is suppressed in ψ' decays. Using conventional techniques, we find branching fractions of

- $Br(J/\psi \to b_1^+\pi^- \ + \ cc) \times Br(b_1^+ \to \omega\pi^+) = (2.4 \pm 0.5 \pm 0.7) \times 10^{-3}$, and
- $Br(\psi' \to b_1^+\pi^- \ + \ cc) \times Br(b_1^+ \to \omega\pi^+) = (6.2 \pm 0.9 \pm 0.9) \times 10^{-4}$.

10 Acknowledgements

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