BES Analysis Note

Search for New Vector Particles in $\psi' \to \pi\pi\rho\pi$

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Abstract

An explanation to the so-called $\rho\pi$ puzzle, which means that branching ratio of $J/\psi \to \rho\pi$ is extremely high compared with that of $\psi' \to \rho\pi$, is that there exists a vector glueball which mixes with J/ψ. Using a data sample of about 3.7 million ψ' enevnts collected by BES at BEPC, we have made a careful analysis of the decay process $\psi' \to \pi^+\pi^-\rho\pi$. In the near J/ψ range, the likelihood function method is employed to analyze the $\rho\pi$ spectrum, no evidence is found for the existence of the vector glueball O expected in the "$J/\psi - O$ mixing " model. With some reasonable assumptions we have finally ruled out the existence of the vector glueball O with most mass and decay width assignments allowed in this model.

We also search for any vector particle X with mass between $2.0GeV$ and $3.0GeV$ in the $\rho\pi$ spectrum. No obvious peak is observed, and upper limits for $Br(\psi' \to \pi^+\pi^-X) \times Br(X \to \rho\pi)$ are obtained with various masses and decay widths of X.

1 Introduction

According to NRQCD, for any exclusive hadronic final states h, one can expect

$$Q_h \equiv \frac{B(\psi' \to h)}{B(J/\psi \to h)} \approx \frac{B(\psi' \to e^+e^-)}{B(J/\psi \to e^+e^-)} = 0.147. \tag{1}$$

This is true for many hadronic final states, however, it fails for $\rho\pi$ and $K^*\bar{K} + c.c.$ final states. Latest experimental limits for $\psi' \to \rho\pi$ and $\psi' \to K^*\bar{K} + c.c.$ by BES [1] give

$$Q_{\rho\pi} < 0.0028 \quad and \quad Q_{K^*\bar{K}} < 0.0064, \tag{2}$$

which is much smaller than 0.147. This is the long standing "$\rho\pi - K^*\bar{K}$ puzzle" .

Many expanations have been proposed for this puzzle [2] . Hou and Soni [3] proposed that $J/\psi \to \rho\pi$ is enhanced by a mixing of J/ψ with a vector glueball O which decays to $\rho\pi$ copiously. Brodsky, Lepage and Tuan [4] emphasized that the decay $J/\psi \to \rho\pi$ is mediated by an intermediate glunioum states O, and hence $J/\psi \to O \to \rho\pi$ violates the hadronic helicity theorem of perturbative QCD. They claimed that O is required to be narrow and nearly degenerate with J/ψ and gave

$$|m_O - m_{J/\psi}| < 80MeV \quad and \quad \Gamma_O < 160MeV. \tag{3}$$

There is an excess of observed 0^{++} mesons between $1350 - 1750MeV$, Hou [5] argued that if $f_0(1500)$ is taken as 0^{++} glueball, according to potential model, 1^{--} glueball would be around $3.1GeV$, right in the ballpark of equation (2), the proximity of $m_O \approx m_{J/\psi}$ affects J/ψ decay and explains the $J/\psi, \psi' \to \rho\pi$ anomaly.

BES did a scan of $e^+e^- \to \rho\pi$, the result ruled out a vector glueball O with $\Gamma_O < 4MeV$, but the question whether the vector glueball O exists or not isn't answered from this experiment [1, 5]. To make this clear, more experiments are needed. Hou suggested $\psi' \to \pi\pi\rho\pi$ search should be done [5].

2 Amplitude of $\psi' \to \pi\pi\rho\pi$

According to this model, the physical states J/ψ and O are each admixtures of $c\bar{c}$ and $3g$ wavefunctions:

$$\begin{aligned} |J/\psi> &= cos\theta * |c\bar{c}> + sin\theta * e^{i\phi} * |3g> \\ |O> &= -sin\theta * e^{-i\phi} * |c\bar{c}> + cos\theta * |3g>, \end{aligned} \tag{4}$$

$c\bar{c}$ and $3g$ wavefunctions are orthogonal, hence

$$< c\bar{c}|3g >= 0, \tag{5}$$

and we have presumed that the $c\bar{c}$ decay to $\rho\pi$ is ignorable compared with that of $3g$, that is

$$< \rho\pi|c\bar{c} > \approx 0. \tag{6}$$

Then, we can write the amplitudes of $\psi' \to \pi\pi\rho\pi$ via two physical states O and J/ψ in term of their masses and decay widths.

The J/ψ contribution to the amplitude of $\psi' \to \pi\pi\rho\pi$ is

$$\begin{aligned} A_{J/\psi}(M_{\rho\pi}) &= < c\bar{c}|\pi\pi J/\psi >< \pi\pi J/\psi|\pi\pi\rho\pi > \\ &= l_1 * < c\bar{c}|J/\psi >< J/\psi|\rho\pi > \\ &= l_1 * (cos\theta) * (sin\theta e^{-i\phi} < ggg|\rho\pi >) \\ &= l_1 * h_1, \end{aligned} \tag{7}$$

where $l_1 = \frac{1}{M_{\rho\pi}^2 - M_{J/\psi}^2 - iM_{J/\psi}\Gamma_{J/\psi}}$.

The O contribution to the amplitude of $\psi' \to \pi\pi\rho\pi$ is

$$\begin{aligned} A_O(M_{\rho\pi}) &= < c\bar{c}|\pi\pi O >< \pi\pi O|\pi\pi\rho\pi > \\ &= l_2 * < c\bar{c}|O >< O|\rho\pi > \\ &= l_2 * (-sin\theta * e^{-i\phi}) * (cos\theta < ggg|\rho\pi >) \\ &= l_2 * h_2 \\ &= -l_2 * h_1, \end{aligned} \tag{8}$$

where $l_2 = \frac{1}{m_{\rho\pi}^2 - m_O^2 - im_O\Gamma_O}$.

Hence the amplitude of $\psi' \to \pi\pi\rho\pi$ has the form of

$$\begin{aligned} A(m_{\rho\pi}) &= A_{J/\psi}(m_{\rho\pi}) + A_O(m_{\rho\pi}) \\ &= h * (\frac{1}{m_{\rho\pi}^2 - m_{J/\psi}^2 - im_{J/\psi}\Gamma_{J/\psi}} - \frac{1}{m_{\rho\pi}^2 - m_O^2 - im_O\Gamma_O}). \end{aligned} \tag{9}$$

3 Limits for decay width of O

Since the model demands that the $J/\psi \to \rho\pi$ width of $1.1keV$ is saturated by the $J/\psi \to O \to \omega \to \rho\pi$ process, Hou [5] got the relation

$$f(m_{J/\psi}^2) \approx 0.0247GeV((m_O^2 - m_{J/\psi}^2)^2 + m_O^2\Gamma_O^2/4)^{1/4}, \tag{10}$$

and found the mixing angle of O with J/ψ to be

$$\begin{aligned} sin\theta_{O-J/\psi} &= f(m_{J/\psi}^2)/((m_O^2 - m_{J/\psi}^2)^2 + m_O^2\Gamma_O^2/4)^{1/2} \\ &\approx 0.0247GeV/((m_O^2 - m_{J/\psi}^2)^2 + m_O^2\Gamma_O^2/4)^{1/4}. \end{aligned} \tag{11}$$

We believe that the O is a quite clean glueball, which means O is mainly composed of $3g$ content, or $sin\theta$ is close to 1 and $cos\theta$ close to 0. Then we have

$$\Gamma_O \approx cos^2\theta * \Gamma_{3g} \approx \Gamma_{3g} \tag{12}$$

and

$$\begin{aligned} \Gamma_{J/\psi} &\approx cos^2\theta * \Gamma_{c\bar{c}} + sin^2\theta * \Gamma_{3g} \\ &\approx cos^2\theta * \Gamma_{c\bar{c}} + sin^2\theta * \Gamma_O, \end{aligned} \tag{13}$$

where the inteference between $3g$ part and $c\bar{c}$ part is ignored since they dominate different J/ψ decay modes according to the model. So the $3g$ contribution to J/ψ decay width is $sin^2\theta * \Gamma_O$, let x be the ratio of $sin^2\theta * \Gamma_O$ to J/ψ decay width

$$\begin{aligned} x &= (sin^2\theta * \Gamma_O)/\Gamma_{J/\psi} \\ &\approx 7.0GeV\Gamma_O/((m_{J/\psi}^2 - m_O^2)^2 + m_O^2\Gamma_O^2/4))^{1/2} \end{aligned} \tag{14}$$

We can see that the value of x depends on the mass and decay width of O. If we force some limits on the value of x, that is equivalent to limitting the region of O on

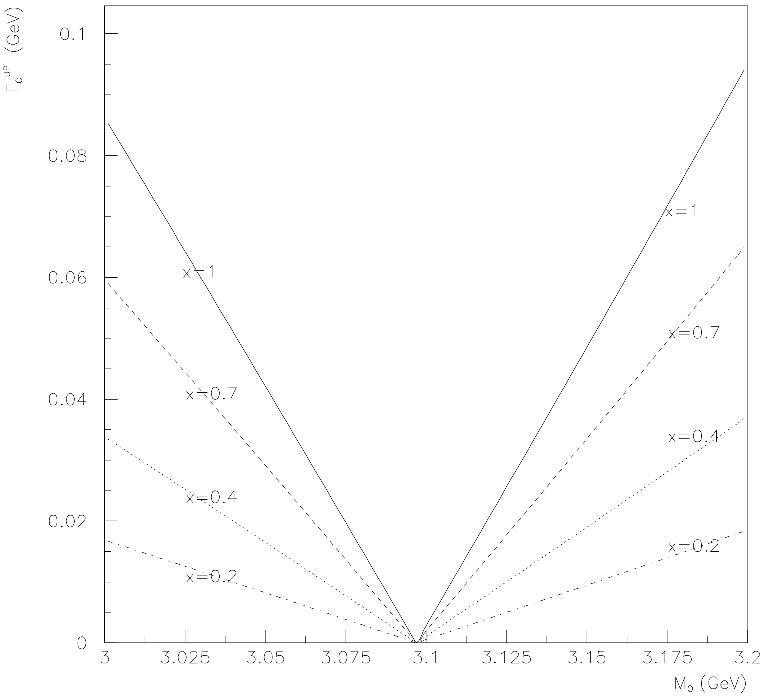


Figure 1: x value

the (m_O, Γ_O) plane. Figure 1 shows the lines corresponding to $x = 0.2, 0.4, 0.7, 1$ on the (m_O, Γ_O) plane.

Now we will begin to consider how large the value of x can be. We know $3g$ content of J/ψ has very small contribution to decay processes such as $J/\psi \to e^+e^-, \mu^+\mu^-$, radiative decays of J/ψ and $J/\psi \to virtual\ \gamma \to hadrons$, all these decay modes account for around 30% of J/ψ width. Hence, x should not be larger than 0.7. It is impossibe that the rest 70% hadronic decays of J/ψ come from the $3g$ content. According to the model, the $3g$ state decays to vector meson plus pseudo-scalar meson (VP) sizably. As we know, $Br(J/\psi \to VP) \approx Br(J/\psi \to \rho\pi) + Br(J/\psi \to K^*\bar{K}) \approx 2.2\%$, and we assume all of it come from $c\bar{c}$ content. Further more, we assume $3g$ has at most 10 types of decay modes including $VP, VT, VS, TT, VA^+, PA^-$, baryon-antibaryon and so on, and VP should be much larger than the other modes. Even if all of these decay modes are of the same order, we still have

$$x \sim 10 * 2.2\% \sim 0.2. \tag{15}$$

Conservatively, we have $x < 0.4$..

4 Events selection

To obtain $\psi' \to \pi^+\pi^-\pi^+\pi^-\pi^0$ events, the following selections are done:

1. Each event is required to have four charged tracks with high fit quality (MFIT=2) and have zero net charges.

2. Cosine of the polar angle θ of each charged track in MDC is required to be between -0.8 and 0.8: $|cos\theta| < 0.8$.

3. The probalility of each track as a π given by subroutine PARTID1 is larger than 0.001, and is larger than the probability as a K if track momentum $p > 0.65GeV$. The probabiliy as a proton should not be the largest.

4. Number of good γ is required to be 2 or 3. A good γ must satisfy:

a. at least two layers hitted in BSC,

b. $E_{BSC} > 30MeV$,

c. angle between γ and nearest charged track $> 10^o$,

d. angle between cluster and the direction from primary vertex to the first hit in BSC $< 40^o$, and

e. invariant mass with any higher energy cluster in BSC $> 50MeV$ if the angle between them $< 20^o$.

5.Do corrections to the value of magnetic field, momenta of charged tracks and position of primary vertex.

6.4C fit to the $\pi^+\pi^-\pi^+\pi^-$ and two good γ's ends with probability > 0.01.

7.Invariant mass of two γ's is between $85MeV$ and $185Mev$.

8.To remove events with leptonic pairs, require invariant mass of any $\pi^+\pi^-$ $<$

$2.9GeV$.

The reason why we require the number of good photons to be 2 or 3 can be seen in figure 2.

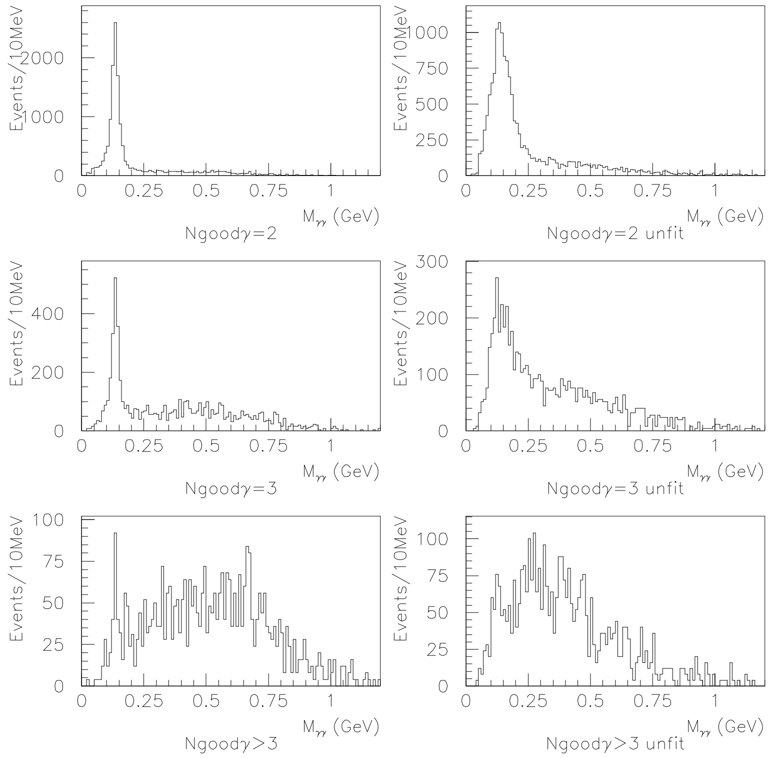


Figure 2: $m_{\gamma\gamma}$ with 2, 3 or greater than 3 good photons

To draw the $\rho\pi$ mass spectrum, plot the masses of any $\pi^+\pi^-\pi^0$ combinations if any $\pi\pi$ of the $\pi^+\pi^-\pi^0$ satisfy $|m_{\pi\pi} - m_\rho| < 150MeV$. It is possible that one event contributes more than once to the $\rho\pi$ mass spectrum, especially, the $\pi^+\pi^- J/\psi$ events form serious contamination in the section below $3.0GeV$. Figure 3 (a) and (b) show the entire $\rho\pi$ mass spectrum and multi-counting of J/ψ respectively.

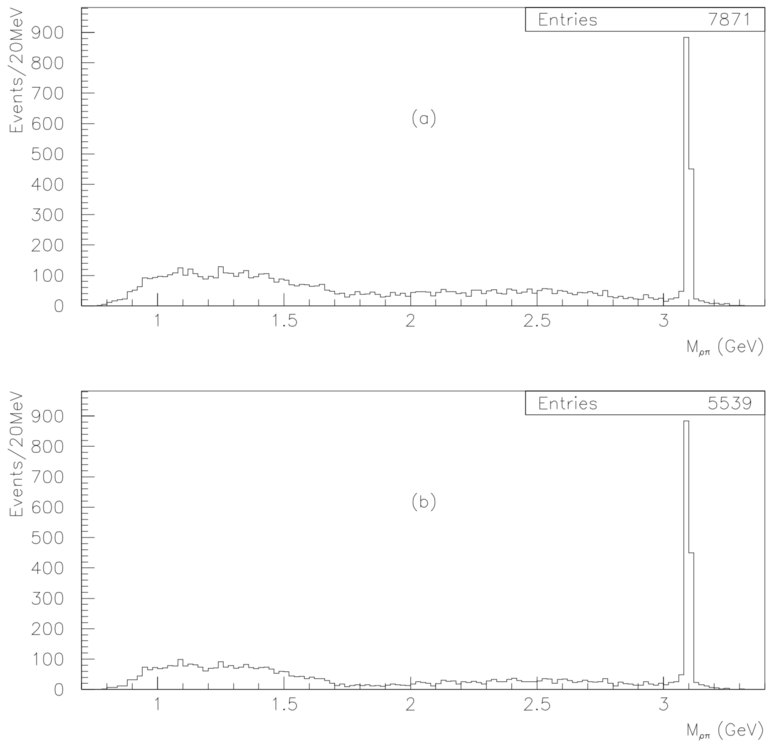


Figure 3: (a) $m_{\rho\pi}$ spectrum and (b) multi-counting of J/ψ

5 Search for new vector particle X with mass between $2.0- < 3.0GeV$

To remove all multi-counting of $\pi^+\pi^-J/\psi$ events, require invariant masses of any $\pi^+\pi^-\pi^0$ combinations to be $100MeV$ away from J/ψ mass. Figure 4 shows the result.

5.1 Monte Carlo simulation

Monte carlo simulation is made to determine acceptance and resolution of $m_{\rho\pi}$. 30000 events of $\psi' \to \pi^+\pi^-X, X \to \rho\pi$ are generated for each mass of X with zero decay width. The results are shown on figure 5 and figure 6.

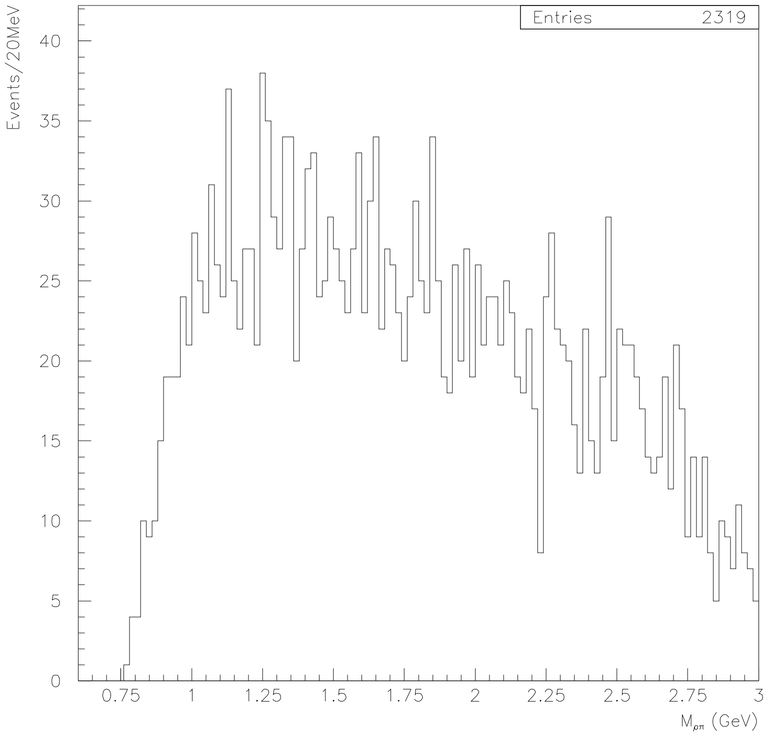


Figure 4: $m_{\rho\pi}$ spectrum without multi-counting of J/ψ

5.2 Fit result

Using a quadratic form background, fixing the mass and decay width of X, do Breit-Wigner fit to obtain N_{fit}, the number of events via assumed particle X, and N_{err}, the error of the number. Table 1 and table 2 are the results of N_{fit} and N_{err}

For an example, figure 7 shows the fit result for $m_X = 2.5GeV, \Gamma_X = 75MeV$. The significance of the assumed signal is very small. The likelihood value is 143.35, just a little smaller than the likelihood value of no-peak fit, which is 145.0.

5.3 calculate the upper limit

Suppose the fit number N_{fit} observes a Gauss probability distribution with N_{err}^2 as the variance and the true number as the mean. Then, we can calculate the upper

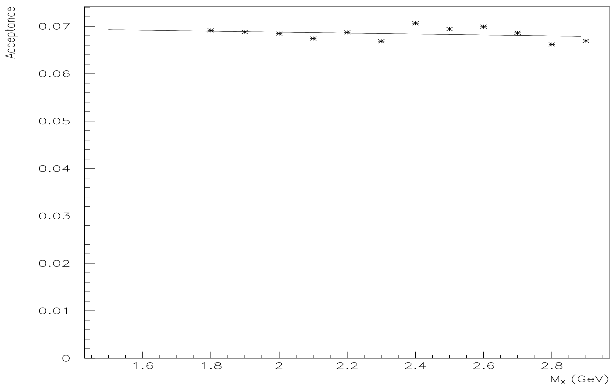


Figure 5: acceptance of $\psi' \to \pi^+\pi^- X, X \to \rho\pi$ below $3.0 GeV$

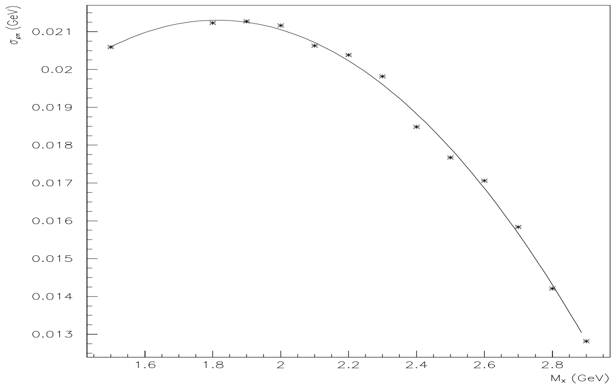


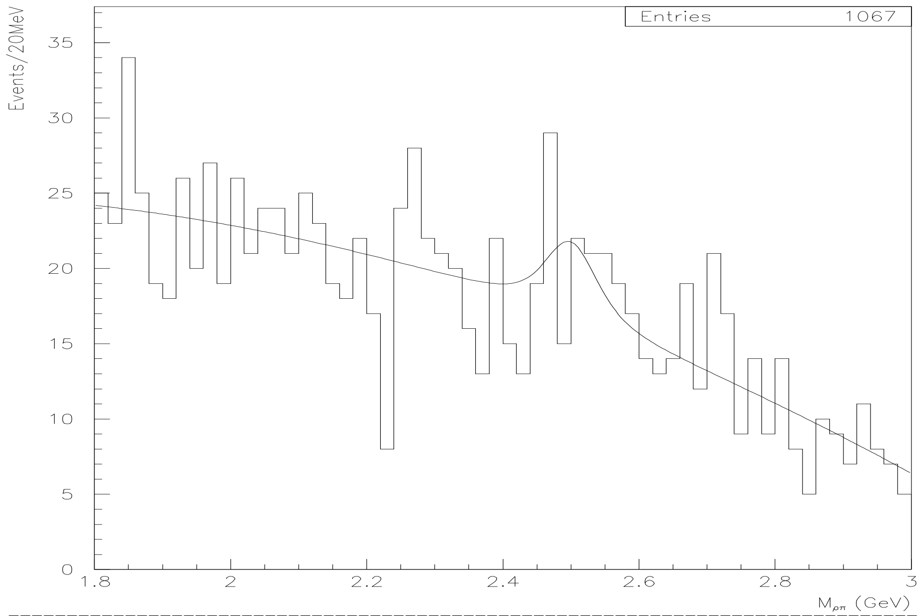
Figure 6: resolution of $m_{\rho\pi}$ below $3.0 GeV$

limit N_{up} for the "oberverd" N_{fit} at 90% confidence level by this equation

$$\int_0^{N_{up}} e^{-\frac{(x-N_{fit})^2}{2N_{err}^2}} dx = 0.9 \int_0^{\infty} e^{-\frac{(x-N_{fit})^2}{2N_{err}^2}} dx \tag{16}$$

But if N_{up} is smaller than the upper limit obtained by means of no-background Poisson distribution, replace N_{up} with the latter one. As a result, table 3 shows the calculated upper numbers N_{up}.

The upper limit for $Br(\psi' \to \pi^+\pi^- X) \times Br(X \to \rho\pi)$ can be written as $\frac{N_{up}}{N_{\psi'} * acceptance(m_X)}$. Table 4 and figure 8 shows the final results of upper limits for $Br(\psi' \to \pi^+\pi^- X) \times Br(X \to \rho\pi)$.

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                     Summary Of BWFIT Results

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Histogram ID=     1  UnBinned Breit-Wigner Fit using 1067 Points

Fit Parameters:Npoly=   3 Nbw=   1 Namp=   0 Range=      1.800 To      3.000

Hist. Chisq =      51.58 for   3 params &  56 DF.

Chisquare Probability =  64.26%. Mean and S.D. for pulls:     .0019     .9272

Likelihood ratio and probability             :     53.206        58.13%

Final Value of Log Likelihood                :       143.35

Error Correspond to a Function Chage         :      .50

Phase Space limits for tails corrections     :       .280GEV     2.817GEV

Breit-Wigner efficiency correction factors   :      .959

Include Breit-Wigner tails outside fit region :        .957

Efficiency-corrected events in fit region     :     1067.[average eff. :1.000]

---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---

LEG1    Value : -.51855    Error(Cov,-/+):    .528E-01 -.530E-01  .527E-01

LEG2    Value : -.11187    Error(Cov,-/+):    .755E-01 -.742E-01  .769E-01

Rat     Value :  .32736E-01Error(Cov,-/+):    .187E-01 -.183E-01  .190E-01

RESL1   Value :  .20713E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00

GAMA1   Value :  .75000E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00

MASS1   Value :  2.5000    Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
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Figure 7: Fit result for $m_X = 2.5GeV, \Gamma_X = 75MeV$

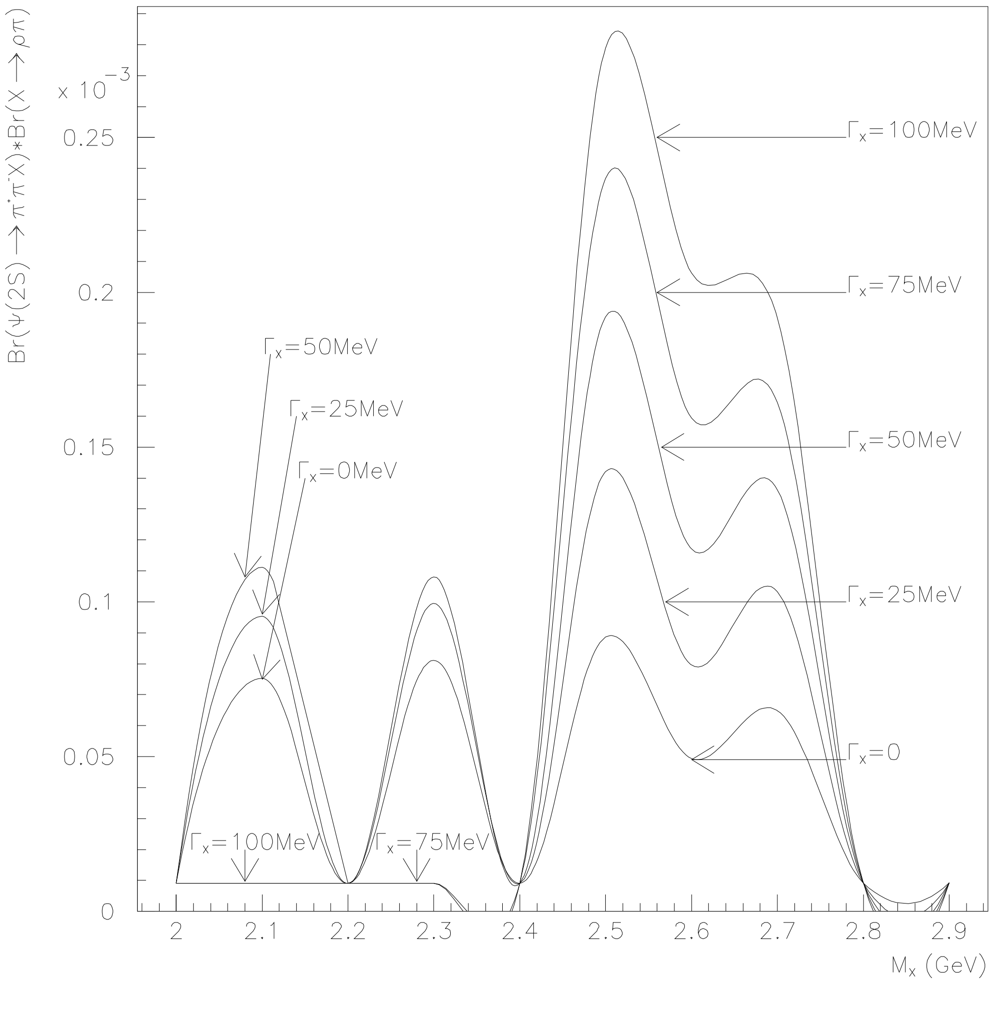

Figure 8: upper limits for $Br(\psi' \to \pi^+\pi^- X) \times Br(X \to \rho\pi)$

6 Search for O with mass close to $m_{J/\psi}$

6.1 Monte Carlo Simulation

30000 events of $\psi' \to \pi^+\pi^- X, X \to \rho\pi$ are generated for each X mass point. Figure 9 and figure 10 show the obtained acceptance and resolution of $m_{\rho\pi}$.

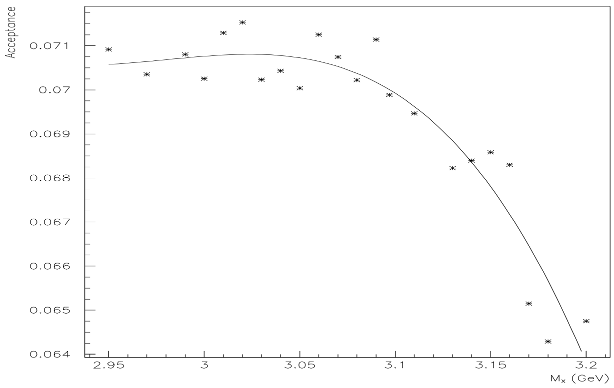

Figure 9: acceptance of $\psi' \to \pi^+\pi^- X, X \to \rho\pi$ near J/ψ

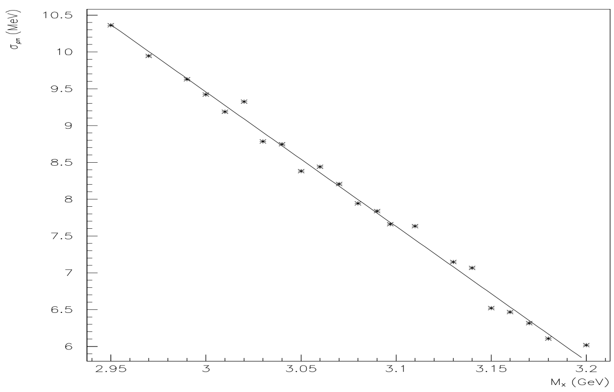

Figure 10: resolution of $m_{\rho\pi}$ near J/ψ

6.2 Technique

Likelihood function method is employed to study the $m_{\rho\pi}$ spectrum near J/ψ. Likelihood function is defined as

$$L(m_O, \Gamma_O) = ln(\prod_{i=1}^{N_{obs}} wt(m_i)), \tag{17}$$

where

$$wt(m_i) = background(m_i) + c_1 * \int |A(x)|^2 e^{-\frac{(m_i - x)^2}{2(\sigma m_{\rho\pi}(x))^2}} * acceptance(x)dx \qquad (18)$$

is the distribution function of $m_{\rho\pi}$,

$$A(x) = \frac{1}{x^2 - m_{J/\psi}^2 - i m_{J/\psi}\Gamma_{J/\psi}} - \frac{1}{x^2 - m_O^2 - i m_O \Gamma_O} \qquad (19)$$

is the decay amplitude obtained in section 2, $\sigma m_{\rho\pi}(x)$ is the resolution of $m_{\rho\pi}$ at $m_{\rho\pi} = x$, and N_{obs} is the total number of observed events in the studied range $2.95 - 3.25GeV$. There is a relation

$$\int wt(m)dm = N_{obs}. \qquad (20)$$

$background(m_i)$ is the distribution of phase space events , and is assumed to be in the form of $b_0 + b_1 * m_i$. b_0 and b_1 can be obtained by a simple fit to the $m_{\rho\pi}$ spectrum.

Then, the value of likelihood function $L(m_O, \Gamma_O)$ can be calculated for any specific $(m_{\rho\pi}, \Gamma_{\rho\pi})$. On the other hand, we can also calculate the value of likelihood function L_N for no vector glueball hypothesis just by giving up the term of O contributon in equation 19.

Compare the value of $L(m_O, \Gamma_O)$ with that of L_N to evaluate the possibility of a glueball O with (m_O, Γ_O). the larger $L(m_O, \Gamma_O) - L_N$ is, the larger the possibility is; the smaller $L(m_O, \Gamma_O) - L_N$ is, the smaller the possibility is.

If $L(m_O, \Gamma_O) - L_N < -0.82$, it means there is a 1.28σ difference between the (m_O, Γ_O) hypothesis and the no glueball hypothesis, then a glueball O with this (m_O, Γ_O) can be ruled out at 90% confidence level.

If $L(m_O, \Gamma_O) - L_N < -0.5(-4.5)$, it means there is a $1\sigma(3\sigma)$ differnce between the two hypothesises, and the no glueball hypohtesis fits the spectrum better.

6.3 Result

Figure 11 draws the contour lines for $L(m_O, \Gamma_O) - L_N = 0, -0.5, -0.82, -4.5$ respectively. It also draws the lines for $x = 0.2, 0.4$ and 0.6 respectively(x is defined in section 3).

There are two spots on the (m_O, Γ_O) plane satisfying $L(m_O, \Gamma_O) - L_N > 0$. They are

(a) $m_O \sim 3.118 GeV$, $\Gamma_O \sim 5 Mev$, marked with a $\star$ in figure 11,
$L(m_O, \Gamma_O) - L_N = 2.7$, the significance is 2.3σ, and $x \approx 0.28$;

(b) $m_O \sim 3.063 GeV$, $\Gamma_O \sim 8 MeV$, marked with a $\triangle$ in figure 11,
$L(m_O, \Gamma_O) - L_N = 1.4$, the significanceis 1.67σ, $x \approx 0.28$.
But their significance is not large enough to regard them as glueball candidates.

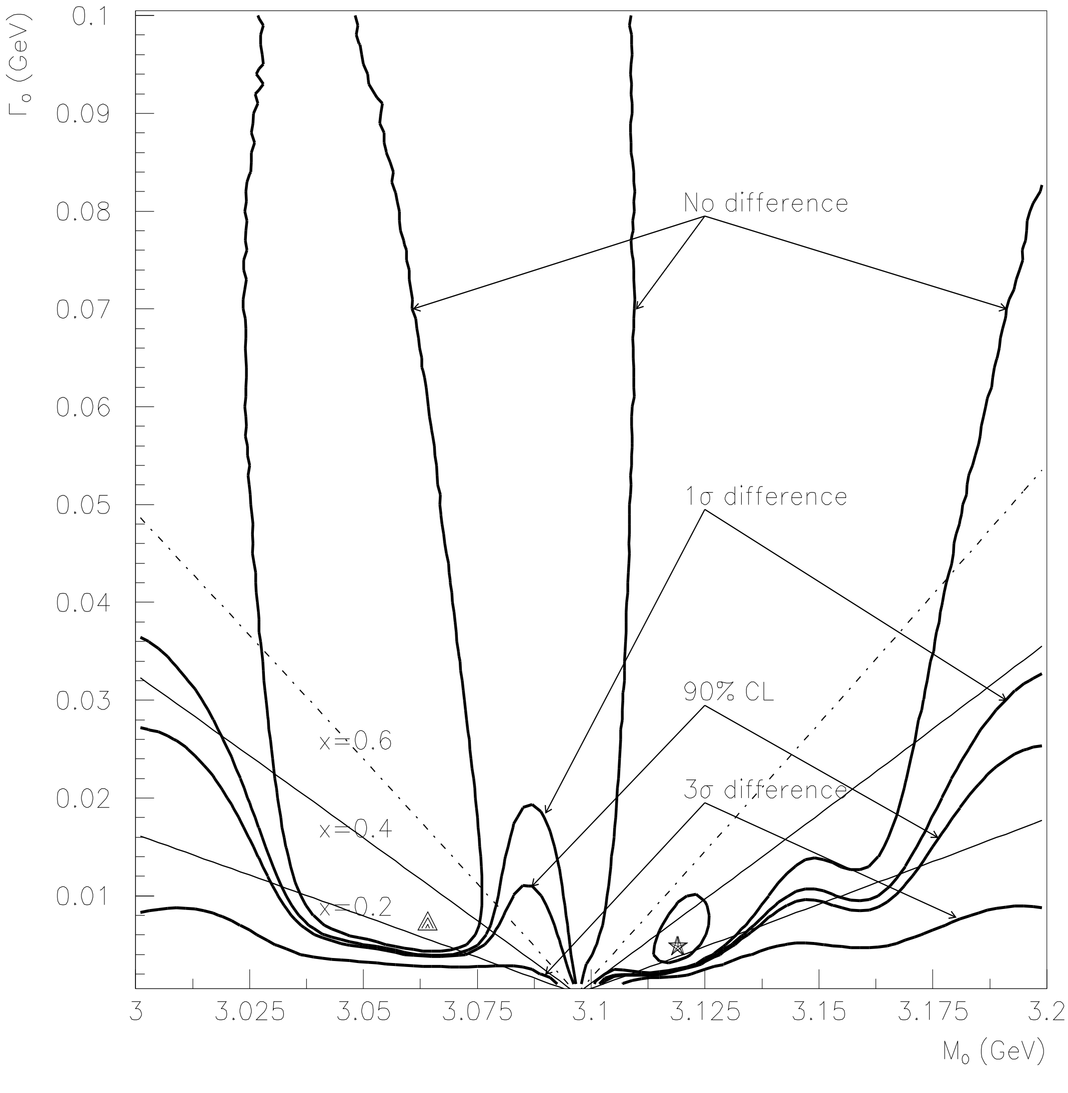

Figure 11: contour lines for $L(m_O, \Gamma_O) - L_N = 0, -0.5, -0.82, -4.5$

7 Discusions and conclusions

A vector glueball in the region under the line $L(m_O, \Gamma_O) - L_N = -0.82$ is ruled out by this experiment at 90% confidence level. This region includes almost all the area $x < 0.2$ and part of the area $0.2 < x < 0.4$.

In section 3, a glueball O is proved nearly impossible to have $x > 0.4$.

So, doubts only exist for $0.2 < x < 0.4$. The two spots with $L(m_O, \Gamma_O) - L_N > 0$ lie in this area. According to eqaution 19, the number of events via O (N_O) and via J/ψ ($N_{J/\psi}$) has the relation

$$\frac{N_O}{N_{J/\psi}} \approx \frac{\Gamma_O}{\Gamma_{J/\psi}}, \tag{21}$$

so

$$N_O \approx 120/\Gamma_O(MeV), \tag{22}$$

We found that the un-ruled-out area for O has $\Gamma_O \sim 5 - 20MeV$. A glueball O in this area will contribute $\sim 5 - 20$ events to the $m_{\rho\pi}$ spectrum, and this contribution is likely to enhance $L(m_O, \Gamma_O) - L_N$ from 0 to a small but perceivable value. So, we can hardly believe there exists a glueball in the un-ruled-out area except the two spots with $L(m_O, \Gamma_O) - L_N > 0$. But We know that there is no anomaly on these two spots in the BES experiments of a scan to $e^+e^- \to \rho\pi$. This may imply that the enhancements of likelihood function of these two spots are caused by casual factors such as statistical fluctuation.

Through an analysis to the $\psi' \to \pi^+\pi^-\rho\pi$ process, we draw the following conclusions :

(1)no evidence is found for the existence of an additional 1^{--} particle with mass between $2.0 - 3.0GeV$ and with sizable decay width to $\rho\pi$;

(2)a vector glueball O suggested by the $\rho\pi$ puzzle is nearly impossible except for a few (m_O, Γ_O) choices.

References

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Table 1: Fit numbers N_{fit}

M(GeV)	width=0	10MeV	25MeV	50MeV	75MeV	100MeV
2.0	0	0	0	0	0	0
2.1	4.25	4.37	4.03	2.18	0.123	0.132
2.2	0	0	0	0	0	0
2.3	6.84	7.11	6.38	2.78	0	0
2.4	0	0	0	0	0	0
2.5	10.46	14.01	19.29	27.30	34.20	40.37
2.6	0.40	1.34	3.35	8.27	14.80	22.46
2.7	6.27	8.63	11.87	16.33	19.87	22.97
2.8	0	0	0	0	0	0
2.9	0	0	0	0	0	0

Table 2: Fit errors N_{err}

M(GeV)	width=0	10MeV	25MeV	50MeV	75MeV	100MeV
2.0	0.08	0.72	0.08	0.2	0.06	0.15
2.1	9.90	11.2	13.1	16.3	0.18	0.12
2.2	0.023	0.030	0.03	0.03	0.04	0.03
2.3	9.58	10.88	12.70	15.58	0.048	0.05
2.4	0.15	0.25	0.36	0.47	0.41	0.90
2.5	8.81	10.39	12.59	16.21	19.63	23.05
2.6	7.41	8.80	10.88	14.51	18.03	21.55
2.7	7.19	8.53	10.41	13.33	16.00	18.78
2.8	0.16	0.05	0.04	0.05	0.04	0.05
2.9	0.05	0.05	0.04	0.05	0.04	0.05

Table 3: Upper limit numbers of events at 90% confidence level

M(GeV)	width=0	10MeV	25MeV	50MeV	75MeV	100MeV
2.0	2.3	2.3	2.3	2.3	2.3	2.3
2.1	19.12	21.32	24.22	28.23	2.3	2.3
2.2	2.3	2.3	2.3	2.3	2.3	2.3
2.3	20.6	21.8	25.2	27.4	2.3	2.3
2.4	2.3	2.3	2.3	2.3	2.3	2.3
2.5	22.4	22.9	35.9	48.5	59.8	70.4
2.6	12.5	15.3	20.1	29.5	40.2	52.0
2.7	16.3	20.4	26.0	34.3	41.4	48.3
2.8	2.3	2.3	2.3	2.3	2.3	2.3
2.9	2.3	2.3	2.3	2.3	2.3	2.3

Table 4: Upper limits for $Br(\psi' \to \pi^+\pi^- X) \times Br(X \to \rho\pi)$

M(GeV)	width=0	10MeV	25MeV	50MeV	75MeV	100MeV
2.0	9.0e-6	9.0e-6	9.0e-6	9.0e-6	9.0e-6	9.0e-6
2.1	7.5e-5	8.4e-5	9.5e-5	1.1e-4	9.1e-6	9.1e-6
2.2	9.1e-6	9.1e-6	9.1e-6	9.1e-6	9.1e-6	9.1e-6
2.3	8.1e-5	9.0e-5	9.9e-5	1.1e-4	9.1e-6	9.1e-6
2.4	9.1e-6	9.1e-6	9.1e-6	9.1e-6	9.1e-6	9.1e-6
2.5	8.6e-5	8.8e-5	1.4e-4	1.9e-4	2.4e-4	2.8e-4
2.6	4.9e-5	6.1e-5	8.0e-5	1.2e-4	1.6e-4	2.1e-4
2.7	6.5e-5	8.1e-5	1.0e-4	1.4e-4	1.6e-4	1.9e-4
2.8	9.1e-6	9.1e-6	9.1e-6	9.1e-6	9.1e-6	9.1e-6
2.9	9.2e-6	9.2e-6	9.2e-6	9.2e-6	9.2e-6	9.2e-6