HIGH MASSES TRIGGERED BY J/ψ

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Summary

Some preliminary results are presented on high masses including J/ψ. These results, obtained in pion production at 150 and 175 GeV/c, include the well-known $J/\psi\pi^+\pi^-$ decay of ψ′, clear evidence for the contribution of the χ(3510) to the cascade $\chi \to J/\psi + \gamma$, and a 5.3 GeV/c^2 peak, mainly in J/ψKπ, possibly the first observation of naked beauty.

Introduction

The aims of the experiment were to study the J/ψ hadroproduction and to look for hadronic states associated or including J/ψ. The basis of the trigger was to ask for the two muons from the J/ψ. We used both 150 and 175 GeV/c π^- beams at the CERN SPS.

The Apparatus

The apparatus is shown in Fig. 1. Downstream from the beryllium target (18.8 g/cm^2 in three parts)

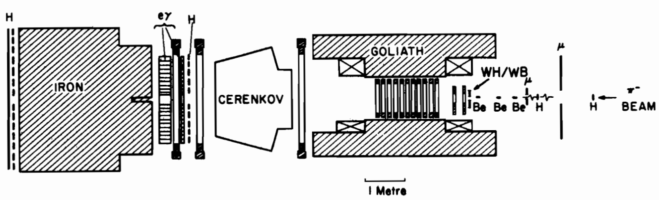


Fig. 1 Side view of the apparatus.

we have first a magnetic vertex detector: 50 proportional planes (30,000 wires, 1.8 × 0.72 m) inside the "Goliath" magnet (3.6 T•m, ∅ = 2.2 m, 1.05 m gap). This is followed by a forward lever arm (8 planes of large proportional chambers, 6600 wires, 3 × 2.2 m) sandwiching a 28-cell Čerenkov counter filled with CO_2 at atmospheric pressure. At the end we have a muon filter, consisting of 3.4 m of iron between two sets of horizontal trigger hodoscopes, arranged in 4 quadrants. For part of the data taking we had a lead-scintillator sandwich e/γ calorimeter of 17 radiation lengths.

The Trigger Principle

The trigger requires a high $\mu^+\mu^-$ mass ($\gtrsim$ 1 GeV/c^2) with a sufficient free path to measure the associated hadrons well. That is, we have 8 m from the target to the μ filter. Our set-up is not a beam-dump, but an open-geometry arrangement. The problem of avoiding triggers coming from $\pi^+\pi^-$ decays into $\mu^+\mu^-$ has been solved by requiring that the two muons hit diagonally opposite quadrants, point towards the target and have $p_T(\mu) > 0.2$ GeV/c and $p_L(\mu) > 5$ GeV/c.

The Analysis

The analysis was done in three steps:

i) A fast filter was used to select $\mu^+\mu^-$ masses larger than 2 GeV/c^2 using only the lever arm and the μ filter. This took 0.02 s of CDC 7600 time per event.

ii) A complete reconstruction of all tracks (up to 20) was made using the information of the whole set of proportional chambers (≃ 1 s/evt).

iii) Particle identification was carried out using the Čerenkov counter and the e/γ calorimeter.

Brief Summary of Results

Dimuons

Figure 2 shows the $\mu^+\mu^-$ spectrum. The clean J/ψ-ψ′ separation is seen with a logarithmic scale (Fig. 2b). A fit has been made with a sum of two exponentials for the background and two Gaussians for the resonances. No magnetic field adjustment was made to get the correct J/ψ mass. Our results are given in Table 1. The dimuon mass resolution at the J/ψ mass is σ(M)/M = 1.2%.

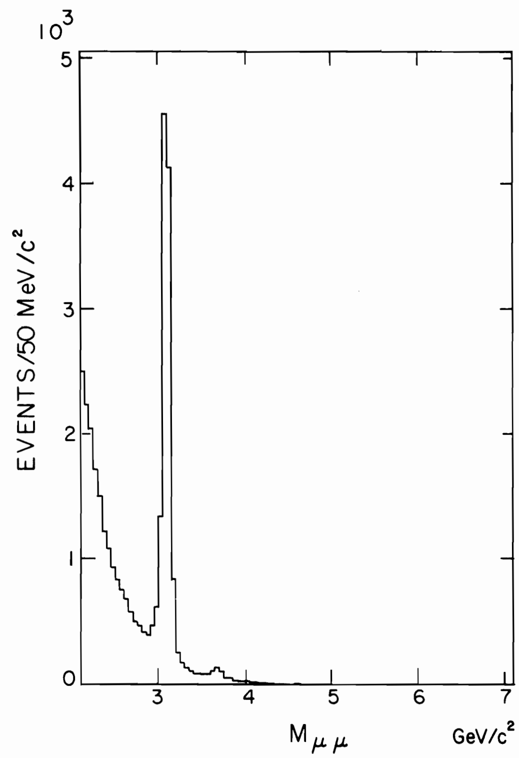


Fig. 2a $\mu^+\mu^-$ mass spectrum (linear scale).

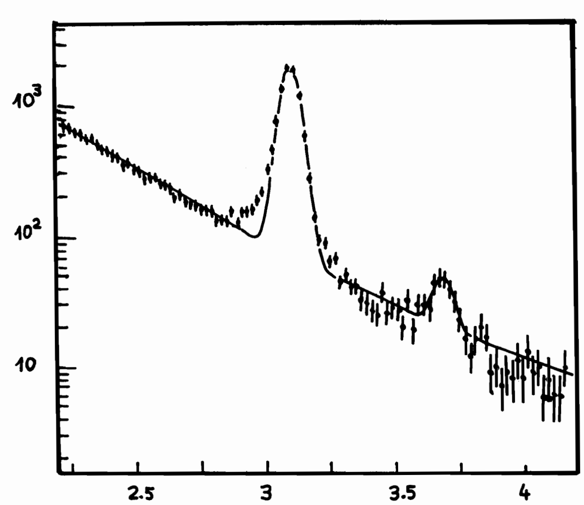


Fig. 2b $\mu^+\mu^-$ mass spectrum (log. scale) with fit.

Table 1

	Mass (MeV/c^2)	σ (MeV/c^2)	Events	Table value[1]
J/ψ	3095.44 ± 0.46	37.5 ± 0.4	9000	3097.
J/ψ′	3683 ± 6	35 ± 6	140	3686.

The first high mass triggered by J/ψ which we can study is the ψ′(3686) decaying into $J/\psi\pi^+\pi^-$. Figure 3

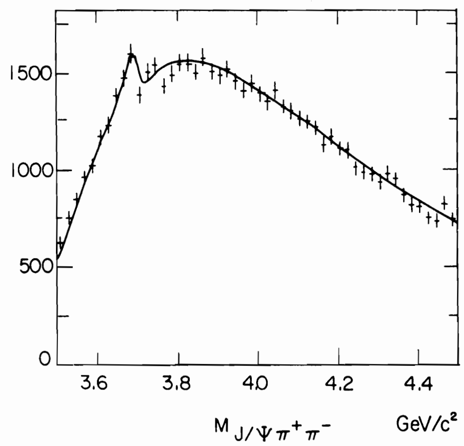


Fig. 3 $J/\psi\pi^+\pi^-$ mass spectrum.

shows the spectrum. With a resonance plus background fit, we obtained:

$$M(\psi') = 3682 \pm 2\ \text{MeV/c}^2\ , \quad \sigma = 12 \pm 4\ \text{MeV/c}^2\ ,$$

$$N = 280\ \text{evts}\ .$$

After correction for geometrical acceptance, the numbers of events from both channels $J/\psi\pi^+\pi^-$ (350 events) and $\mu^+\mu^-$ (140 events) are consistent with known branching ratios. See other papers[2−5] for more details.

V^0's

We have an average 0.25 reconstructed V^0's per event. In Fig. 4, the scatter plot ($\pi^+\pi^-$ versus e^+e^-)

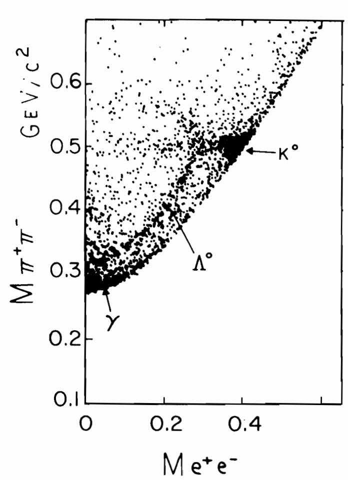


Fig. 4 Scatter plot $M\pi^+\pi^-/Me^+e^-$.

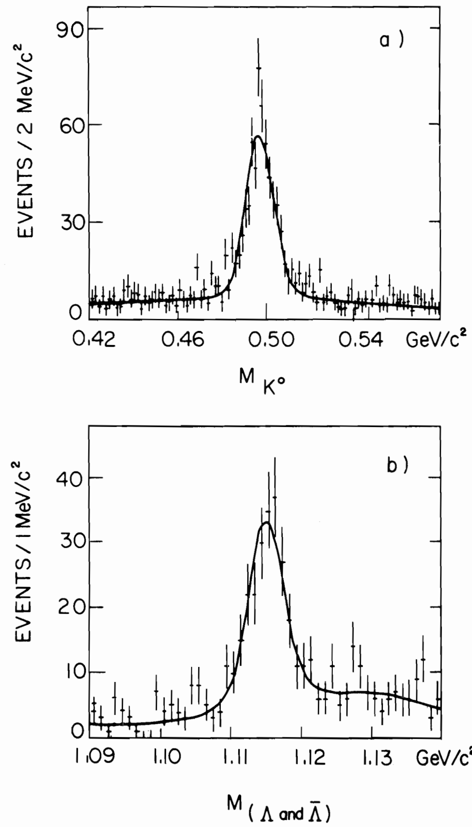


Fig. 5 a) K^0 fit.
b) Λ,$\bar{\Lambda}$ fit.

clearly shows K^0 and γ signals, and also a Λ,$\bar{\Lambda}$ zone. The results of fits (see Fig. 5) are given in Table 2. These values were also obtained without any field adjustment.

Table 2

	Events	Fitted mass (MeV/c^2)	σ (MeV/c^2)	Table value[1]
K^0	528	497.7 ± 0.5	8.1 ± 0.4	497.7 ± 0.13
Λ,$\bar{\Lambda}$	180	1115.3 ± 0.2	2.6 ± 0.3	1115.6 ± 0.05

We have also selected 445 γ-events with $M_{e^+e^-} <$ < 55 MeV/c^2, which allow us to look for the cascade $\chi \to J/\psi + \gamma$.

The Cascade $\chi \to J/\psi + \gamma$

We observe γ's in two ways.

In the first method γ's are obtained by conversion inside the spectrometer itself (≃ 15% radiation lengths). The constraints are: zero mass for the e^+e^- pairs selected as γ's; 3097 MeV/c^2 for the $\mu^+\mu^-$ in the J/ψ region. Electron energy losses are also taken into account.

In Fig. 6 we show the J/ψ-γ spectrum obtained and also the background simulated by combining the γ's with J/ψ's from previous events. A resonance plus background fit gives: 15 events above background, M(χ) = 3520 MeV/c^2, σ = 22 MeV/c^2 FWHM (consistent with our experimental resolution).

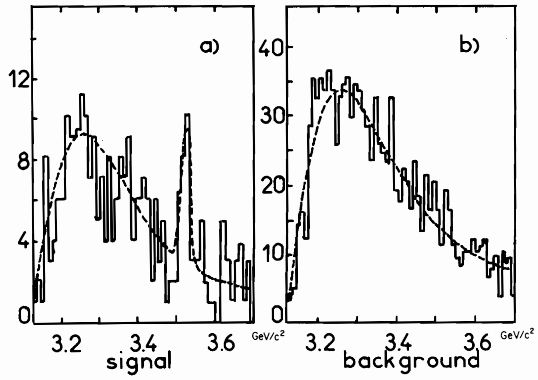


Fig. 6 J/ψ-γ mass spectrum.
a) Resonance plus background fit.
b) Background simulation (see text).

We conclude that the χ(3515) is the main contributor to the cascade down to the J/ψ. It is not the χ(3555) shifted down by energy losses, because this would require ∿ 2.3 times more radiation length inside the spectrometer.

When acceptance is taken into account we find the ratio:

$$\frac{\chi \to J/\psi + \gamma}{\chi \to \text{all}} = 11 \pm 4\% \text{ (statistical error only)}$$

to be compared with previous results[6].

We have also done an independent analysis with a conventional lead-scintillator e/γ calorimeter. Using 25% of the statistics, we obtained the spectrum of Fig. 7. The spectrum is quite inconsistent with a large proportion of J/ψ's coming from χ. This is consistent with the previous result.

Thus, the χ(3515) was our second high mass triggered by J/ψ.

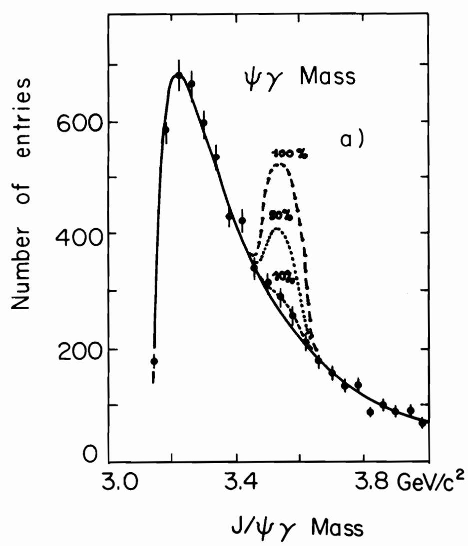


Fig. 7 J/ψγ mass spectrum obtained with an e/γ calorimeter. Predictions from 100, 50 and 10% ratios are shown.

Beauty?

What do we know about the beauty meson B?

- We expect a mass a bit larger than half of the Υ″ but not far from threshold (5.25-5.3 GeV/c).
- The probability of a B decaying into J/ψ is predicted to be about 3% [7].
- The J/ψKπ decay could be favoured[8].

In the first way to look for beauty we assume the J/ψ in the signal, i.e. $B(\bar{B}) \to J/\psi K\pi$ according to the diagram:

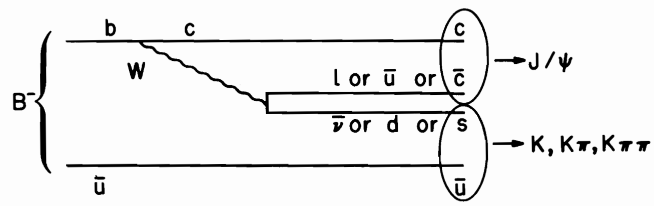


Figure 8 shows the spectrum J/ψKπ obtained for 9000 J/ψ events. The binning is 20 MeV. A resonance plus background fit gives: 45 ± 14 events at M = 5300 ± 7 MeV/c^2,

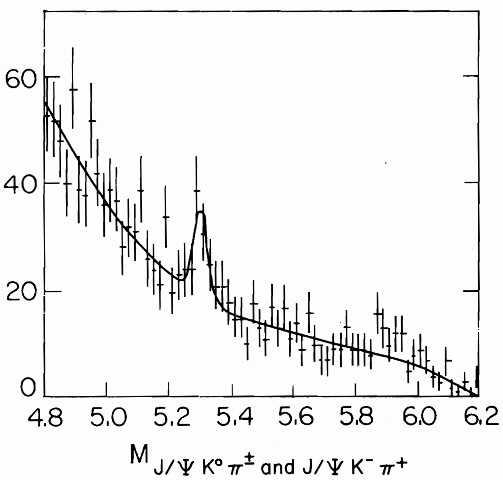


Fig. 8 J/ψKπ mass spectrum with fit.

σ = 50 ± 17 MeV/c^2 (FWHM), consistent with our experimental resolution. This spectrum was obtained by adding the two channels $J/\psi K^0\pi^\pm$ and $J/\psi K^-\pi^+$. Figure 9 shows each channel separately in 40 MeV bins:

Figure 9a shows the mass spectrum $J/\psi K^0\pi^+$ for events with clean K^0 identification;

Figure 9b shows $J/\psi K^-\pi^+$ where we identify the K^- with the Čerenkov and where we require $p_T(K) > 0.5$ GeV/c (we have an excess of events in the same bin, as previously);

Figure 9c shows $J/\psi K^+\pi^-$, where no clear excess of events is seen, but the background is twice as big. We interpret this as due to proton contamination in the Čerenkov.

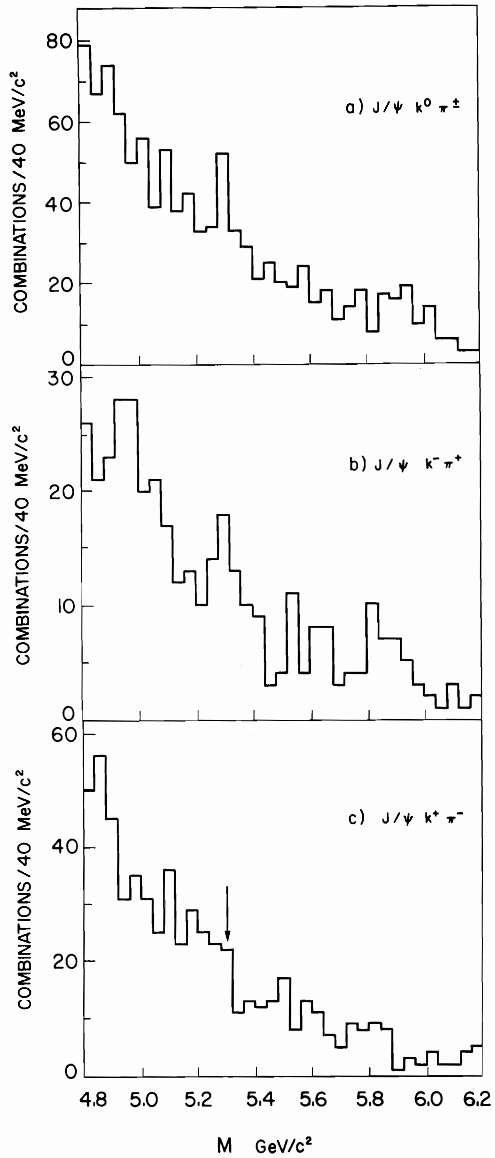
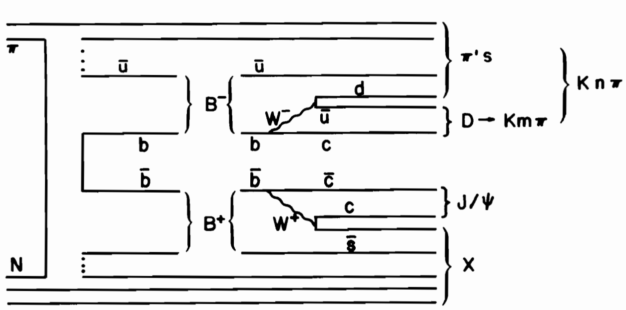


Fig. 9 a) $J/\psi K^0\pi^\pm$ mass spectrum.
b) $J/\psi K^-\pi^+$ mass spectrum with $p_T(K) > 0.5$ GeV/c^2.
c) $J/\psi K^+\pi^-$ mass spectrum with $p_T(K) > 0.5$ GeV/c^2.

More evidence? Let us assume now that one B has a J/ψ decay, while the other B gives a D plus a certain number of π's according to the diagram:



Summing all channels $Kn\pi$ with $2 < n < 5$ we see no signal, but if we require one combination $Km\pi$ $(1 < m < n-1)$ to be at the D mass ± 40 MeV/c^2, we have an excess of events at 5.3 GeV/c^2.

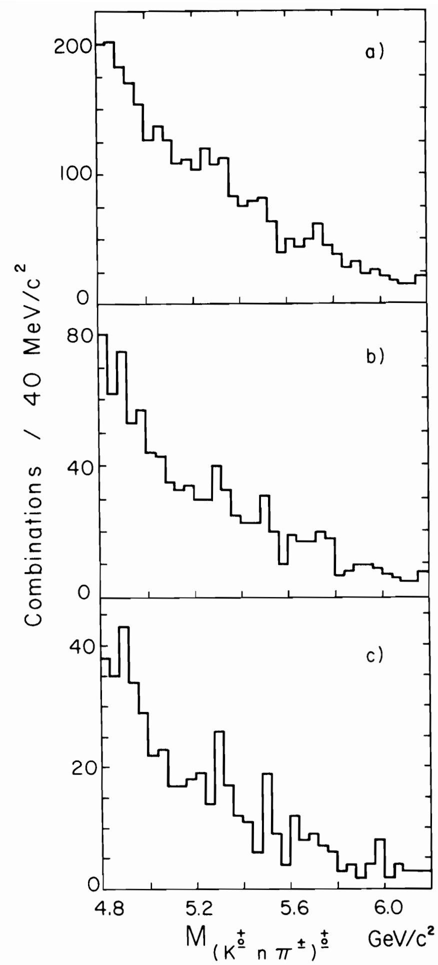


Fig. 10 $Kn\pi$ spectrum.
a) With no cuts.
b) D mass required.
c) D mass and $p_T(K) > 0.5$ required.

Figure 10a shows the spectrum $Kn\pi$ with no cuts. Figure 10b shows the spectrum $Kn\pi$ with the D mass required. Figure 10c shows the spectrum $Kn\pi$ with the D mass and $p_T(K) > 0.5$ GeV/c required. An excess of events appears in the same bin as the $J/\psi K\pi$ signal. Obviously this second method is not a proof, but it is an indication of the same effect in a different channel. More statistics are needed to confirm this 5.3 GeV/c^2 peak.

What order of magnitude for the cross-section? In this experiment, we have measured the π^- production cross-section for J/ψ's of 100 ± 10 nb, i.e. a sensitivity of 11 pb per J/ψ event. With a very crude acceptance calculation (we need models ...), we estimate: $B\cdot\sigma \simeq 2$ nb.

Plans For The Future

We have taken 10,000 J/ψ's in 2.5 years at the rate of 50-100 J/ψ's per day. At present, we are running with 200 J/ψ's per day at a somewhat higher energy and with a better spill and we hope to at least:

- double the statistics by the end of this year

- triple them before the SPS shut-down of June 1980.

We hope also to use a 7 m^2 lead-glass calorimeter by January 1980 in order to get a good identification of neutrals (π^0, η, ...) to have new beautiful channels available.

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Discussion

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Q. (Lane, Harvard) It seems to me you ought to be able to see the F^+ in the mode $\phi\pi^+$. The idea is to look for it in the mode $\phi\pi^+$. You trigger on the ϕ to reduce the background. Then make $\phi\pi^+$ mass combinations. Can you do that?

A. It is easier and more powerful to do a 2μ trigger than a 2K trigger: for a μ trigger you can use an iron filter, so that all particles going through have a good chance of being a μ. In our case, the only extra selection was $p(\mu) > 5$ GeV/c. For a K trigger you have to use a Čerenkov counter, which is not so powerful in rejecting unwanted triggers. Furthermore, you select kaons only in a narrow window in momenta between the π threshold and the K threshold.

In another part of the experiment, we have used a $K^+K^-\mu^\pm$ trigger for "direct charm" search purposes. Our trigger rate was 100 times higher than the $\mu\mu$ trigger. We have now 3 million triggers to analyse, which will require $\sim$ 200 hours of CDC 7600. The analysis is in progress now but it is not possible to reach the sensitivity of 11 pb per event which we have with the 2μ trigger!

Q. (Cooper, Yale) What kind of limit can you put on the lifetime of B by looking at vertex distributions for those events? The current limit is 10^{-8} s.

A. What is a vertex distribution?

Q. By looking at the distribution reconstructing your J/ψ's back to the vertex in the target and seeing if they are all consistent with coming from one point.

A. No, because we cannot achieve such a vertex resolution. We have something of the order of the target. We have 3 targets of 2 cm and we have a resolution on the target of the order of 1 cm. Up to now, no V^0 tracks are constrained to the 2μ vertex.

Q. So the limit is something like 10^{-23}?

A. Right now we cannot say anything about a lifetime limit.