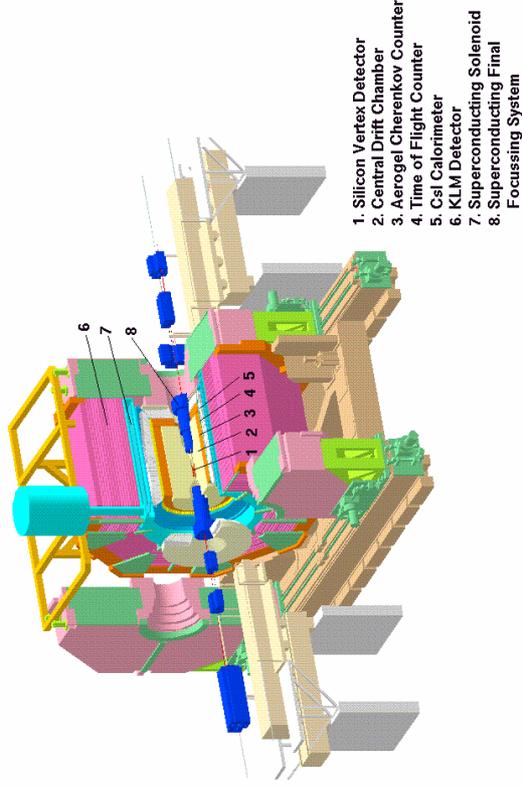




Charmonium production in B-decays

Takeo Kawasaki(Niigata) for the Belle collaboration

BELLE Detector



- B decays to Charmonium
 - Inclusive Charmonium
 - Exclusive Charmonium
- Charmonium production at $Y(4s)$ and in the continuum
- Conclusion



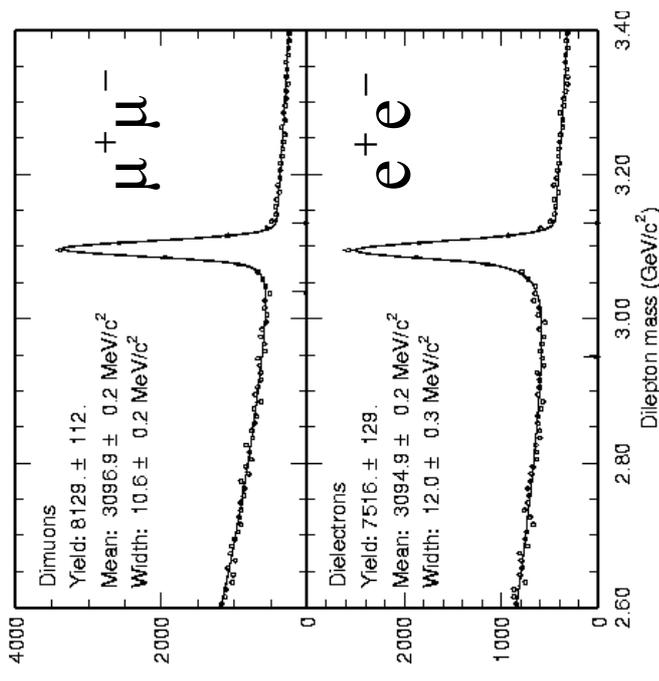
[1]B decays to Charmonium

- Using 10.5 /fb of data on resonance, 0.6/fb on continuum (–60MeV) taken during Oct 1999-Dec 2000
- Huge number of B meson decays to charmonium provide a testing ground for various physics process.
- QCD calculation of quark dynamics, B-quark production in hadronic decay.....
- Inclusive charmonium
 - $B \rightarrow J/\psi X, \psi' X, \chi_c X$
- Exclusive charmonium
 - $B \rightarrow J/\psi K, \psi' K, \chi_c K, \eta_c K, J/\psi \pi$
 - Neutral modes are used for CP measurement
 - Selection with
 - Δ Energy $\longrightarrow \Delta E \equiv E_B^{cms} - E_{beam}^{cms}$
 - Beam constraint mass $\longrightarrow M_{bc} \equiv \sqrt{(E_{beam}^{cms})^2 - (P_B^{cms})^2}$



Inclusive Charmonium

- $B \rightarrow J/\psi X, J/\psi \rightarrow l+l-$
- For electron, include radiative photons
- Loose lepton ID
 - Identify one track, lepton consistency for other
 - Used for $J/\psi K$
- Tight lepton ID
 - Identify both tracks as leptons
 - Used for all other modes



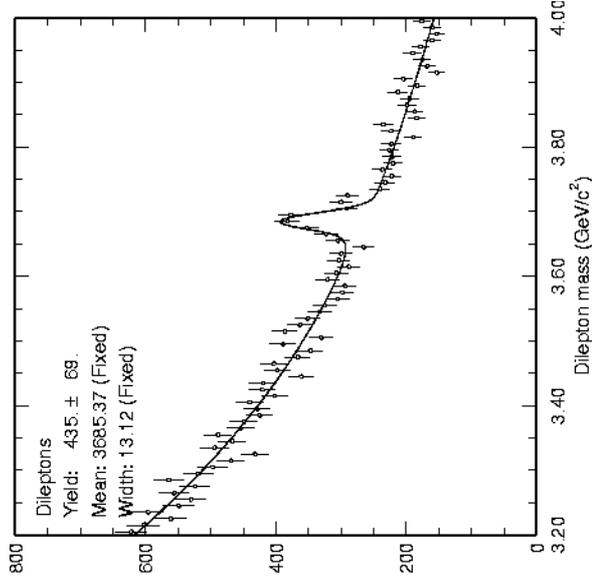
Particle ID

μ :RPC chamber(KLM)
 e :CsI crystal (ECL),
 K/π :TOF, dE/dx in CDC,
Aerogel chrenkov(ACC)



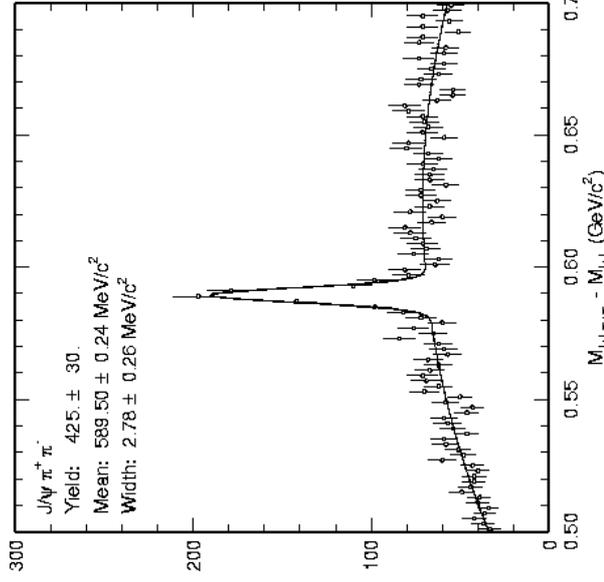
Inclusive Charmonium

$$B \rightarrow \psi'(\ell^+ \ell^-)X$$



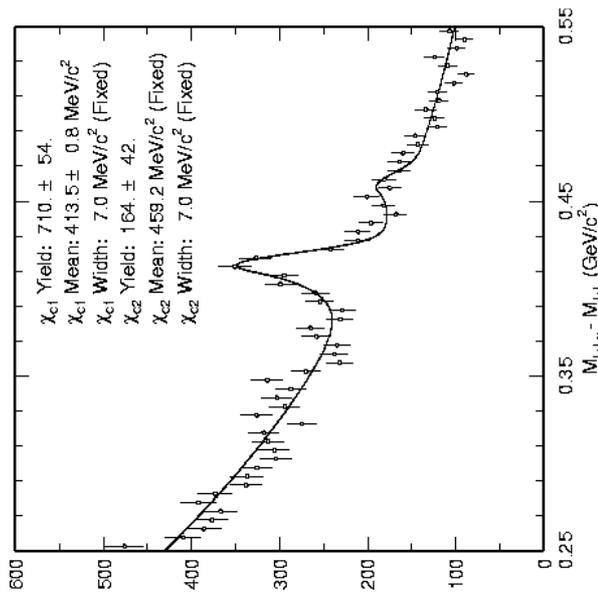
$$P^* < 1.7 \text{ GeV}/c$$

$$B \rightarrow \psi'(J/\psi \pi^+ \pi^-)X$$



$$P^* < 1.7 \text{ GeV}/c$$

$$B \rightarrow \chi_c(J/\psi \gamma)X$$



$$E_\gamma > 60 \text{ MeV}/c$$

$$0.4 < \text{Dipion mass} < 0.58 \text{ GeV}/c$$

- Vertex cut, Tight lepton ID for all modes

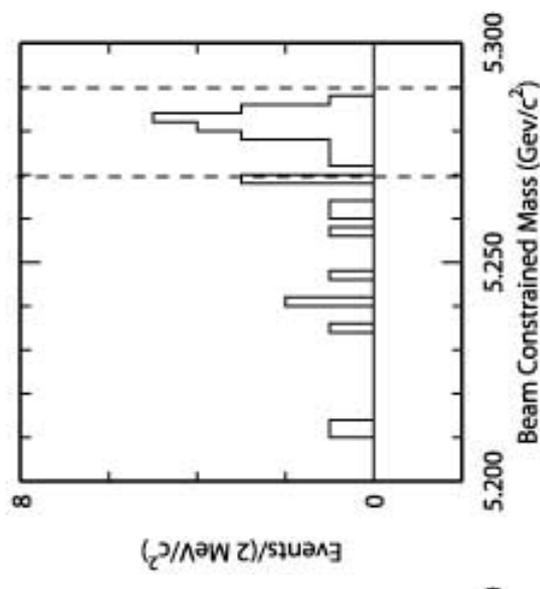
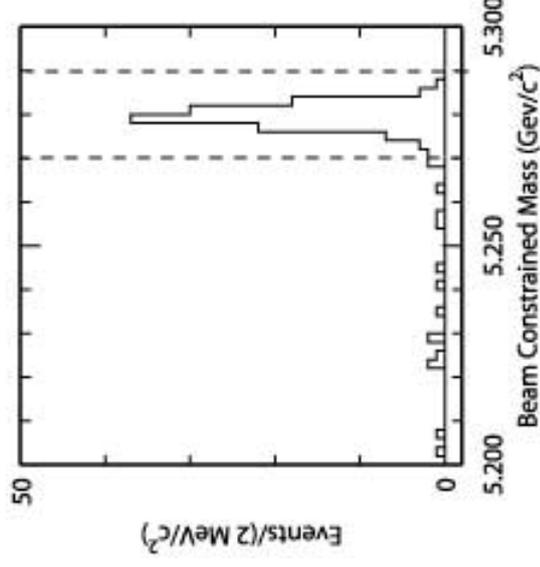
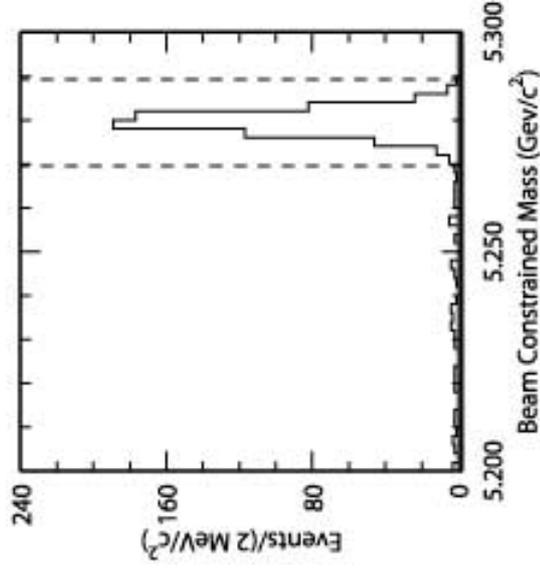


Exclusive Charmonium: CP

$$B \rightarrow J/\psi K^{\pm}$$

$$B \rightarrow J/\psi K_S(\pi^+\pi^-)$$

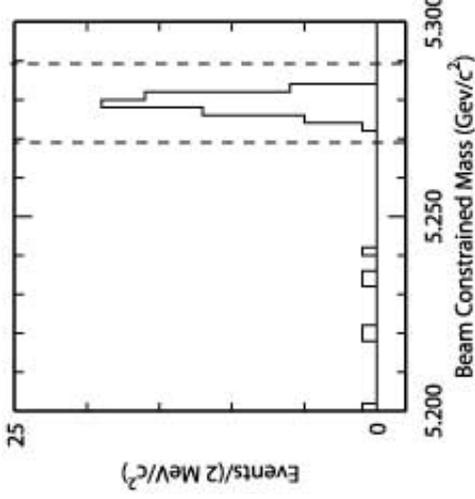
$$B \rightarrow J/\psi K_S(\pi^0\pi^0)$$





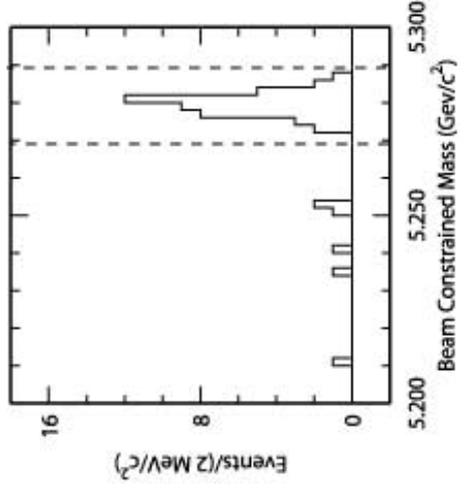
Exclusive Charmonium : CP

$$B \rightarrow \psi'(\ell^+ \ell^-)K$$

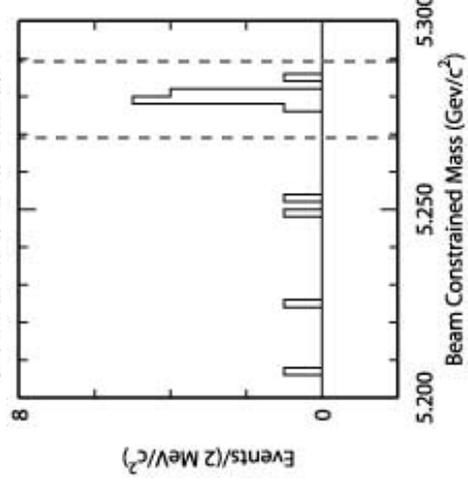
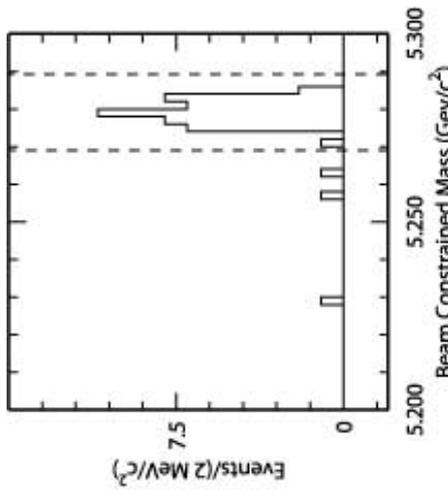


$K^{+/-}$

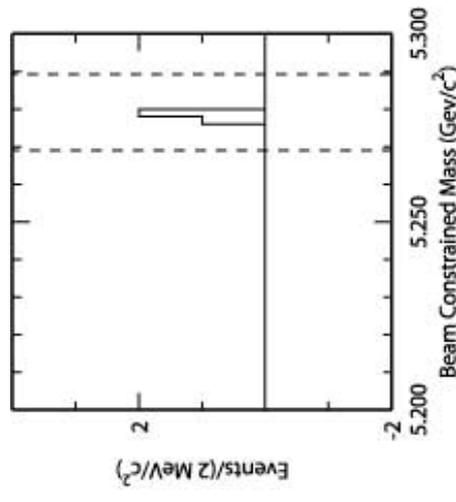
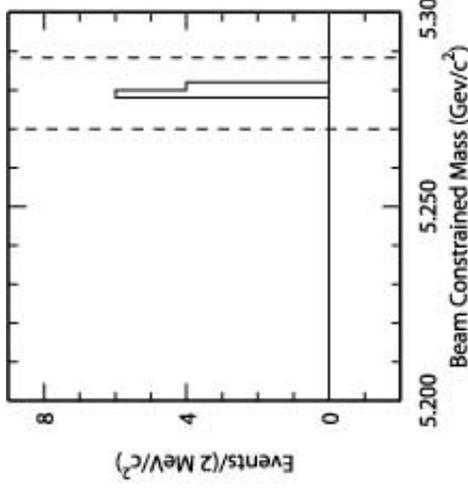
$$B \rightarrow \psi'(J/\psi \pi^+ \pi^-)K$$



$$B \rightarrow \chi_{c1}(J/\psi \gamma)K$$



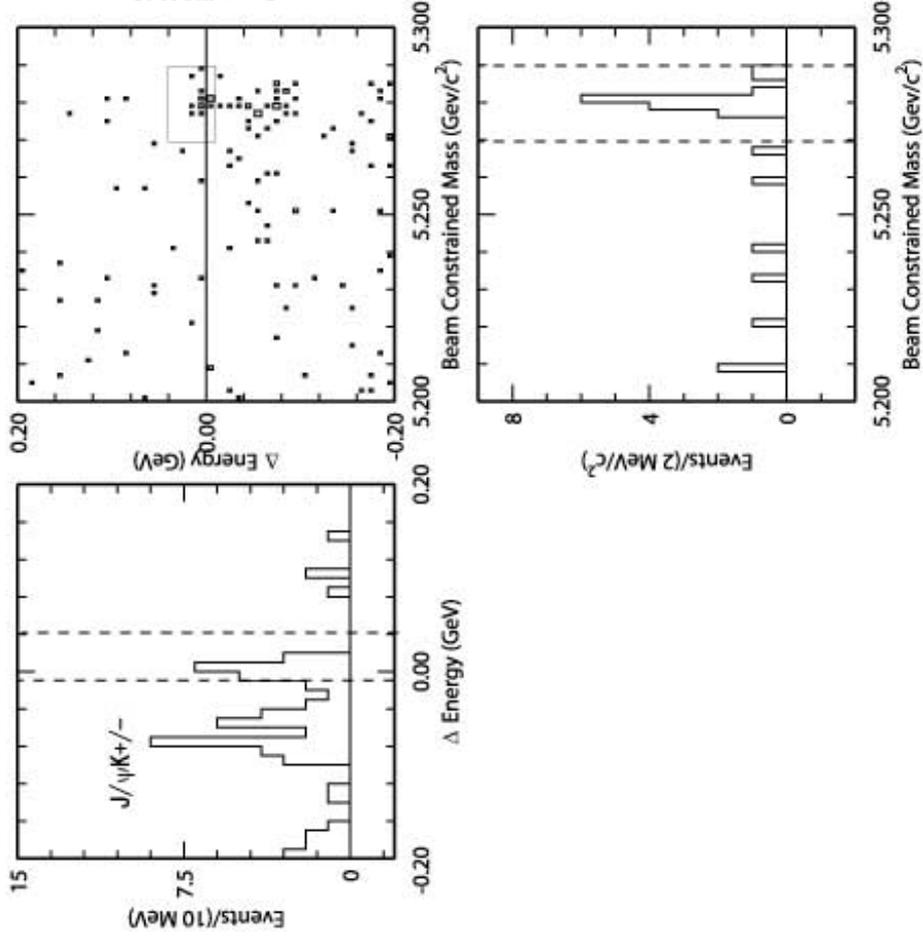
K_S



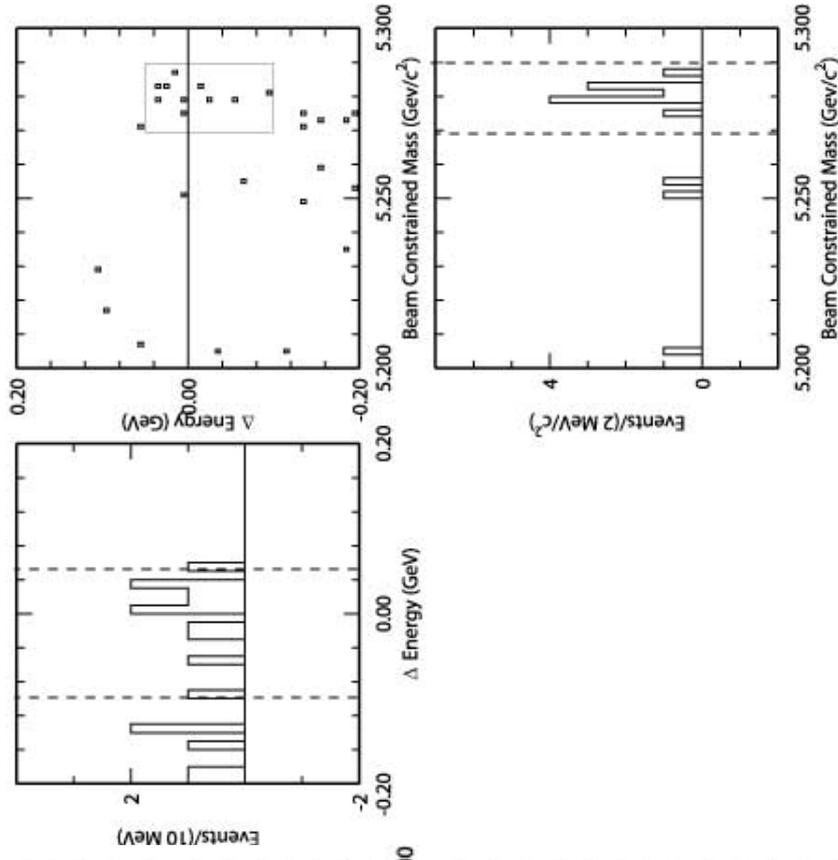


Exclusive Charmonium : CP

$$B \rightarrow J/\psi \pi^{\pm}$$

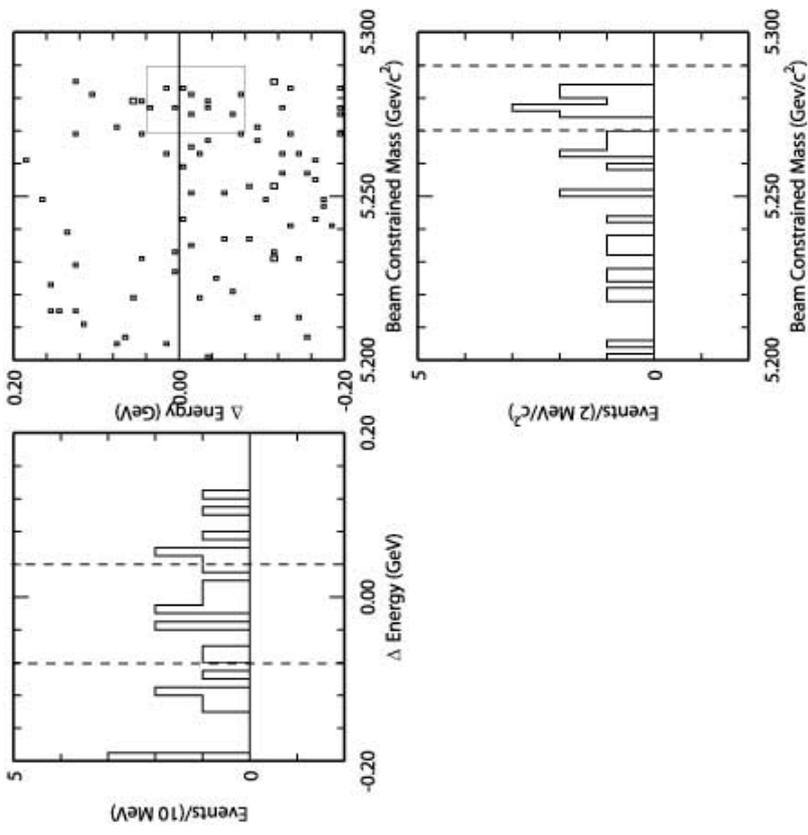
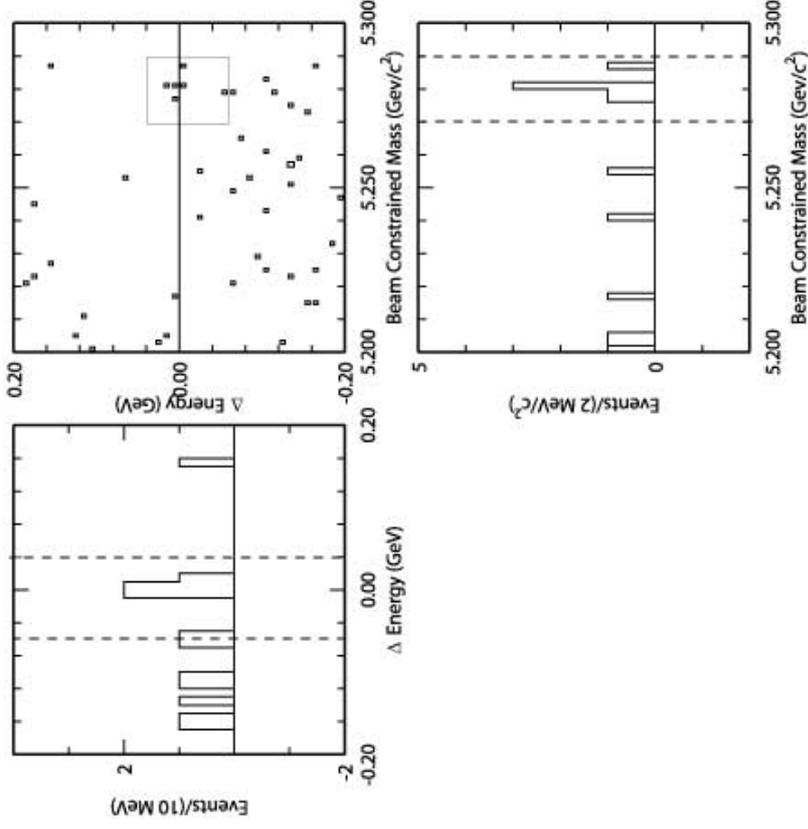


$$B \rightarrow J/\psi \pi^0$$





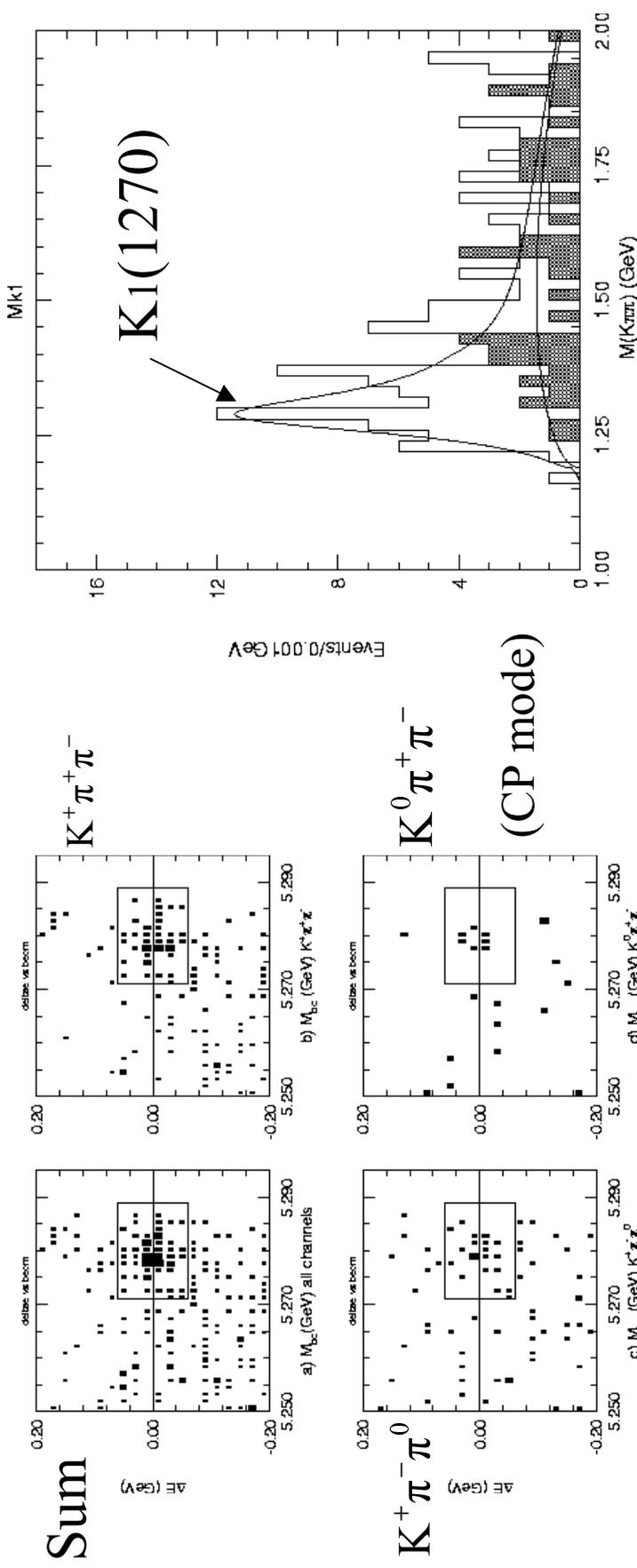
Exclusive Charmonium: New





Exclusive Charmonium: New

First observation of $B \rightarrow J/\psi K_1(1270)$



$$\text{Br}(B^+ \rightarrow J/\psi K_1^0(1270)) = (1.4 \pm 0.4 \pm 0.2) \times 10^{-3}$$

$$\text{Br}(B^+ \rightarrow J/\psi K_1^+(1270)) = (1.9 \pm 0.3 \pm 0.2) \times 10^{-3}$$



Summary 1: Inclusive Charmonium

Preliminary

	Yield	Br.	Stat. Err.	Syst. Err.	PDG value
$B \rightarrow J/\psi (e+e-) X$	7516 ± 129	1.06	± 0.02	$\pm 0.12\%$	$1.13 \pm 0.06 \%$
$J/\psi (\mu + \mu -) X$	8129 ± 112	0.97	± 0.01	$\pm 0.11\%$	\uparrow
$J/\psi (\text{sum}) X$	15645 ± 171	1.01	± 0.01	$\pm 0.11\%$	\uparrow
$\psi' (1+1-) X$	435 ± 69	0.25	± 0.04	$\pm 0.03\%$	$0.35 \pm 0.05 \%$
$\psi' (\psi \pi + \pi -) X$	425 ± 30	0.31	± 0.04	$\pm 0.04\%$	\uparrow
$\chi_{c1} X$	710 ± 54	0.39	± 0.03	$\pm 0.05\%$	$0.37 \pm 0.07 \%$
$\chi_{c2} X$	164 ± 42	0.18	± 0.05	$\pm 0.02\%$	$0.25 \pm 0.10 \%$



Summary2: Exclusive Charmonium

Preliminary

	Yield	Br	Stat. Error	Syst. Error	PDG value
J/ψ Ks	121.4 ± 11.1	(7.2	± 0.7	± 0.9) $\times 10^{-4}$	$(8.9 \pm 1.2) \times 10^{-4}$
J/ψ K $^{+/-}$	652 ± 26	(10.1	± 0.4	± 1.2) $\times 10^{-4}$	$(10.0 \pm 1.0) \times 10^{-4}$
J/ψ π^0	9.7 ± 3.2	(0.27	± 0.09	± 0.03) $\times 10^{-4}$	Not measured
J/ψ $\pi^{+/-}$	13.7 ± 3.8	(0.34	± 0.10	± 0.04) $\times 10^{-4}$	$(0.51 \pm 0.15) \times 10^{-4}$
$\psi'(\text{II})\text{Ks}$	12.8 ± 3.6	(6.3	± 1.8	± 0.9) $\times 10^{-4}$	Not measured
$\psi'(\psi \pi \pi)\text{Ks}$	10 ± 3.2	(5.9	± 1.9	± 1.0) $\times 10^{-4}$	\uparrow
$\psi'(\text{II})\text{K}^{+/-}$	61 ± 7.9	(7.6	± 1.0	± 1.1) $\times 10^{-4}$	$(5.8 \pm 1.0) \times 10^{-4}$
$\psi'(\psi \pi \pi)\text{K}^{+/-}$	41.3 ± 6.5	(5.6	± 0.9	± 0.8) $\times 10^{-4}$	\uparrow
χ_{c1} Ks	3 ± 1.7	(1.8	± 1.0	± 0.2) $\times 10^{-4}$	Not measured
χ_{c1} K $^{+/-}$	43.4 ± 6.6	(6.0	± 0.9	± 0.8) $\times 10^{-4}$	$(10.0 \pm 4.0) \times 10^{-4}$



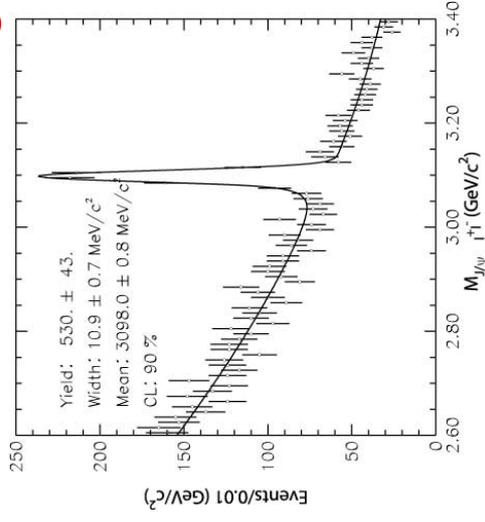
[2] Charmonium production at the Y(4s)

- Look for non-BB decay of Y(4s)
($Br(Y(4s) \rightarrow J/\psi + X) = (2.2 \pm 0.7) \times 10^{-3}$:CLEO in PDG)
- Study Charmonium production mechanism
 - ◆ There is theoretical uncertainty about charmonium production mechanism
 - ◆ Important to understand B decays to J/ψ .
- Selection criteria
 - ◆ Charge track multiplicity >4
 - ◆ J/psi reconstruction
 - ◆ Similar to $B \rightarrow J/\psi X$ exclusive analysis
 - ◆ $P_{J/\psi}^* > 2.0 \text{ GeV}/c$ since $\max(P_{J/\psi}^*) < 1.73 \text{ GeV}/c$ for $B \rightarrow J/\psi X$



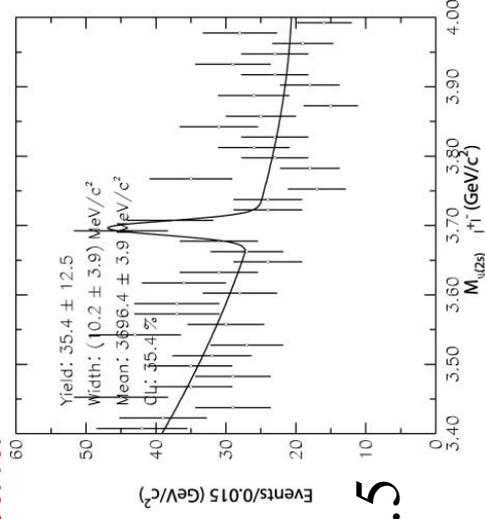
Charmonium candidates

On resonance data



$$J/\psi \rightarrow \ell^+ \ell^-$$

Yield
= 530 ± 43

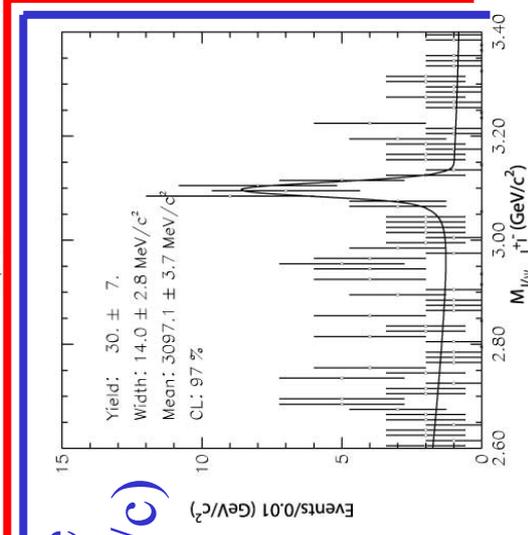


$$\psi' \rightarrow \ell^+ \ell^-$$

Yield
= 35.4 ± 12.5

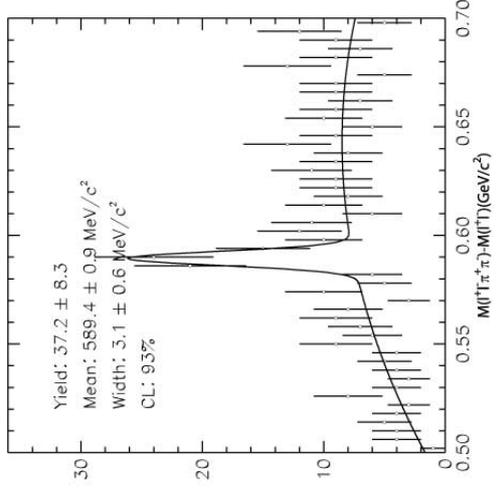
Off resonance

data(-60MeV/c)



$$J/\psi \rightarrow \ell^+ \ell^-$$

Yield
= 30 ± 7



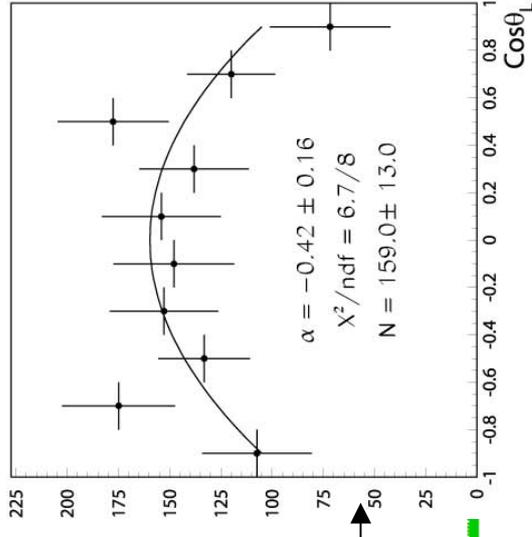
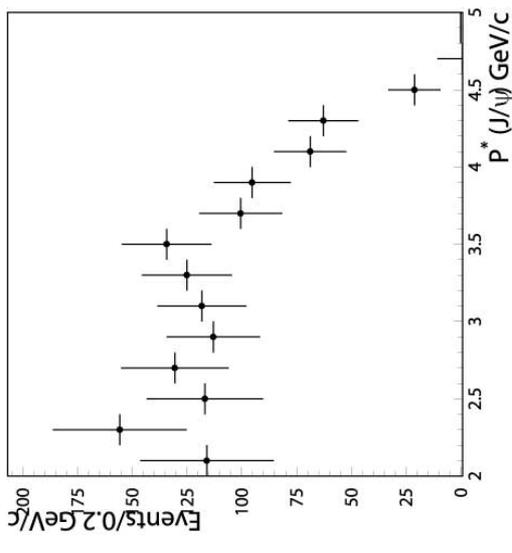
$$\psi' \rightarrow J/\psi \pi^+ \pi^-$$

Yield
= 37.2 ± 8.3



Results

J/ψ momentum in cms



$$Br(Y(4s) \rightarrow J/\psi + X) < 0.41 \times 10^{-3} (95\% \text{ C.L.})$$

$$(\text{CLEO} : Br(Y(4s) \rightarrow J/\psi + X) = (2.2 \pm 0.7) \times 10^{-3})$$

$$\sigma(e^+e^- \rightarrow J/\psi + X) = (1.02 \pm 0.08 \pm 0.12) \text{ pb}$$

$$\text{(corresponds to } R = \frac{\sigma(e^+e^- \rightarrow J/\psi)}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)} = (1.32 \pm 0.19) \times 10^{-3} \text{)}$$

CLEO; $(1.0 \pm 0.3 \pm 0.3) \times 10^{-3}$

$$\sigma(e^+e^- \rightarrow \psi' + X) = (0.54 \pm 0.12) \text{ pb}$$

Preliminary

$$F = 1 + \alpha \times \cos^2 \theta$$



[3] Conclusion

- With the 10.5 /fb of data we have very nice signals in a variety of inclusive and exclusive B to charmonium modes
 - We made preliminary measurement of branching ratio.
 - We need more study for systematic error estimation.
- J/ψ production at the $Y(4s)$
 - Our result is inconsistent with CLEO's measurement
 - We obtained

$$Br(Y(4s) \rightarrow J/\psi + X) < 0.41 \times 10^{-3} (95\% \text{ C.L.})$$

$$\sigma(e^+e^- \rightarrow J/\psi + X) = (1.02 \pm 0.08 \pm 0.12) \text{ pb}$$

Preliminary