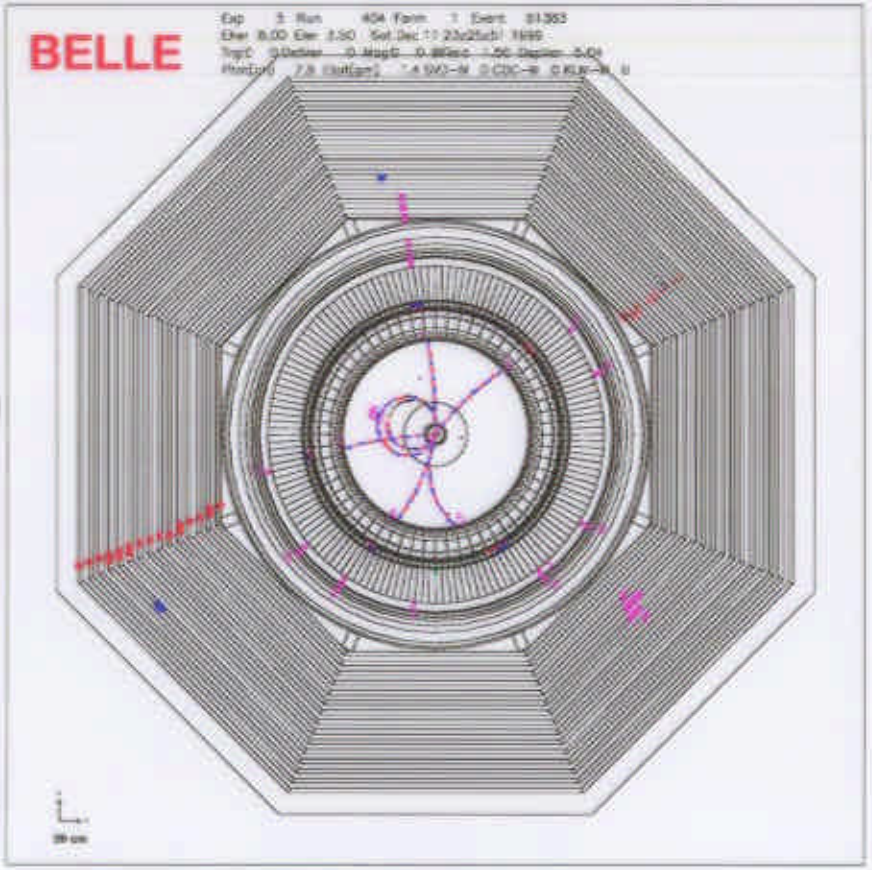
B Decays to Charmonium

Steve Schrenk
for the Belle Collaboration

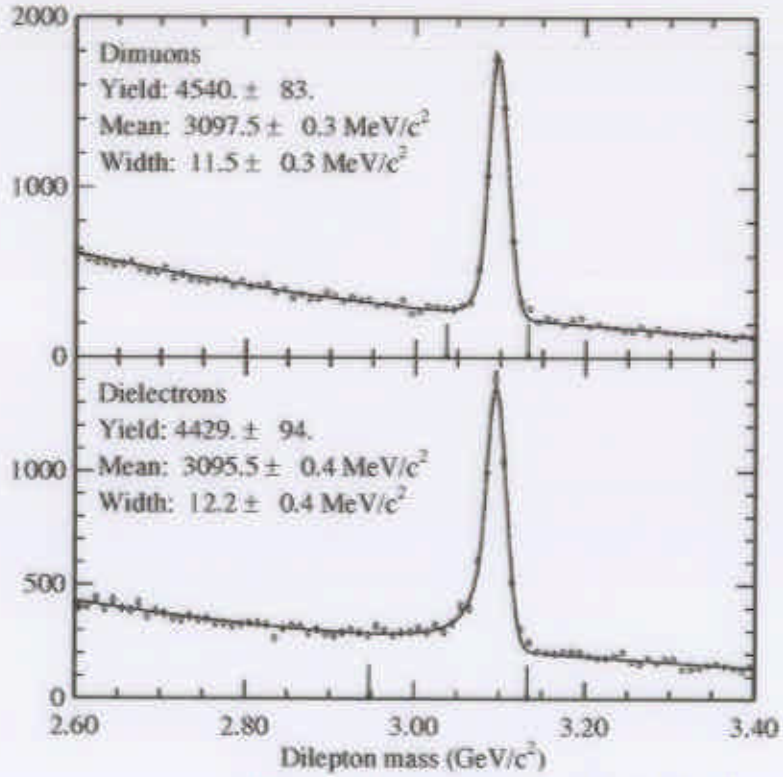
- Outline
  - Inclusive Charmonium
  - Exclusive Charmonium
    - CP Modes
    - Observation of J/ψ $K_1(1270)$
    - J/ψ K* Polarization
  - Conclusion



$B \rightarrow J/\psi K_L$ Candidate

Inclusive Charmonium

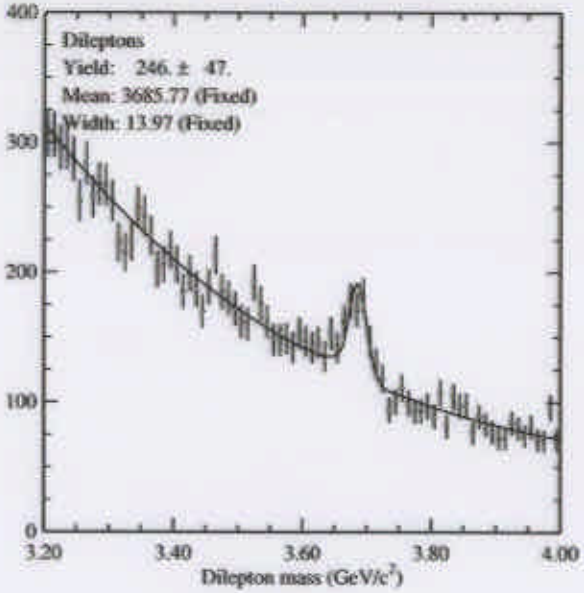
- $B \to J/\psi, J/\psi \to l^+l^-$
  - For electrons, include radiative photons.
  - Loose Lepton ID
    - Identify one track, lepton consistency for other.
    - Used for $J/\psi\ K$
  - Tight Lepton ID
    - Identify both tracks as leptons.
    - Used for all other modes.



Tight Lepton ID 6.2 fb^{-1}

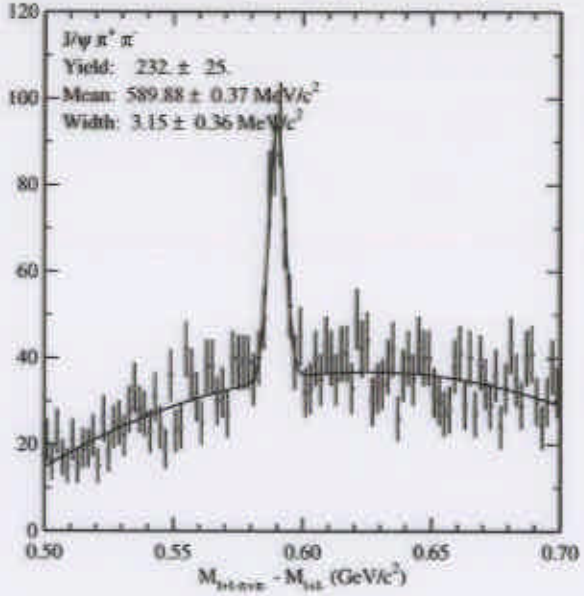
Inclusive Charmonium, Cont.

$B \to \psi' (l^+l^-)$



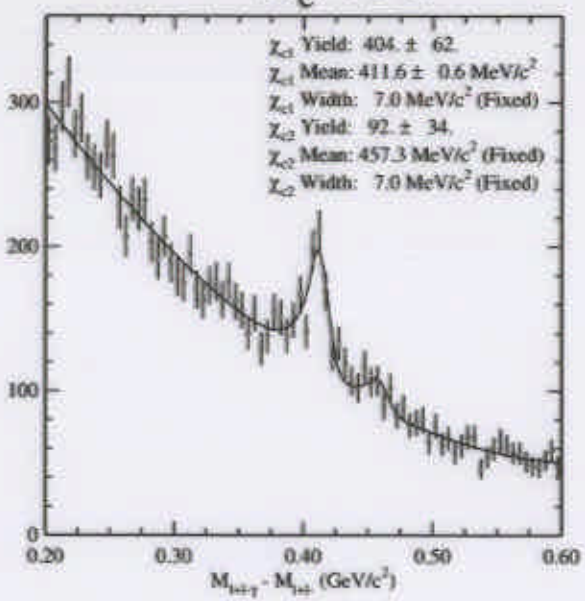
Tight Lepton ID
P* < 1.7 GeV/c

$B \to \psi' (\psi\pi^+\pi^-)$



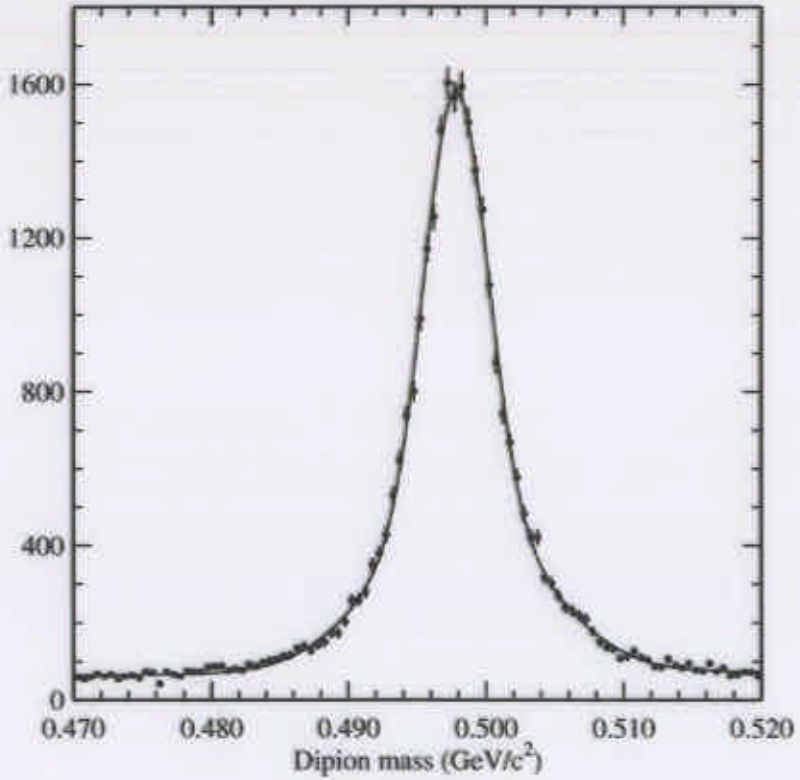
Tight Lepton ID
Dipion mass > 0.4 GeV/c²
P* < 1.7 GeV/c

$B \to \chi_c (\psi\gamma)$

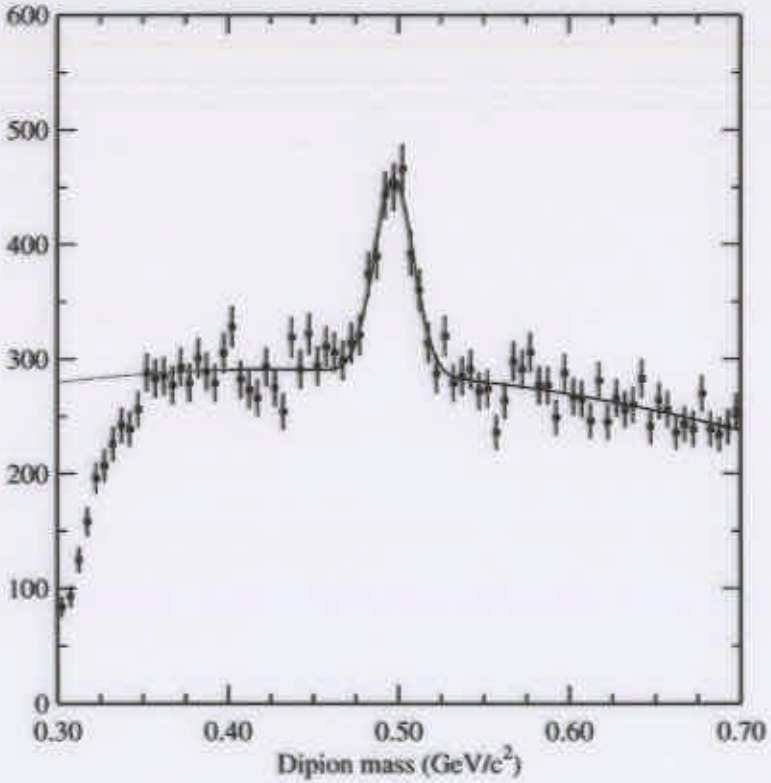


Tight Lepton ID
Eγ > 60 MeV
Monte Carlo Line Shape

Exclusive Charmonium: CP



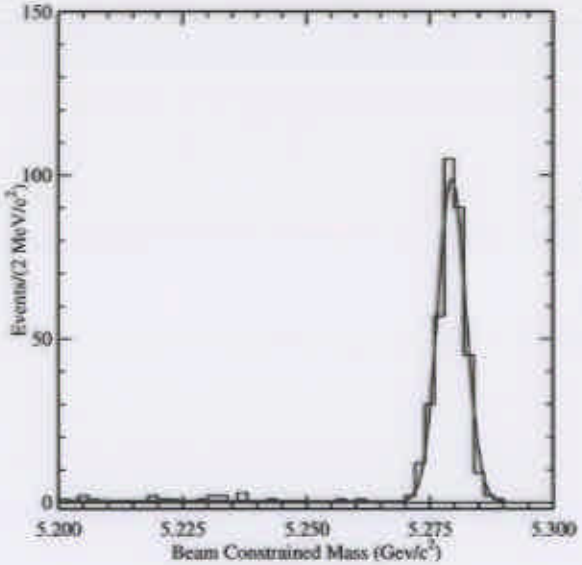
$K_S \to \pi^+\pi^-$



$K_S \to \pi^0\pi^0$

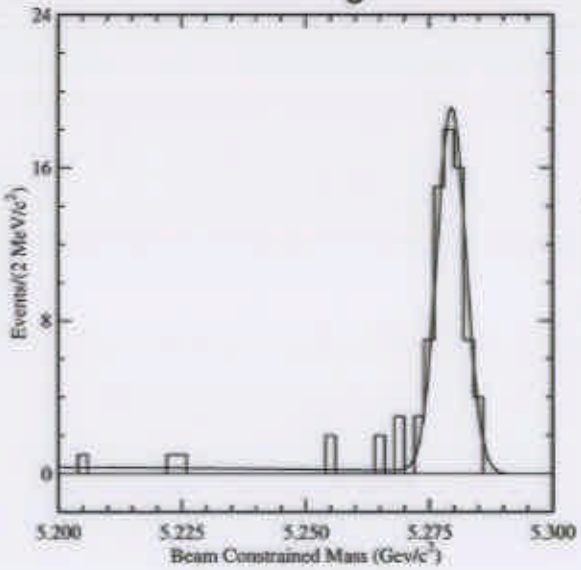
Exclusive Charmonium: CP

$B \rightarrow J/\psi K^{+/-}$



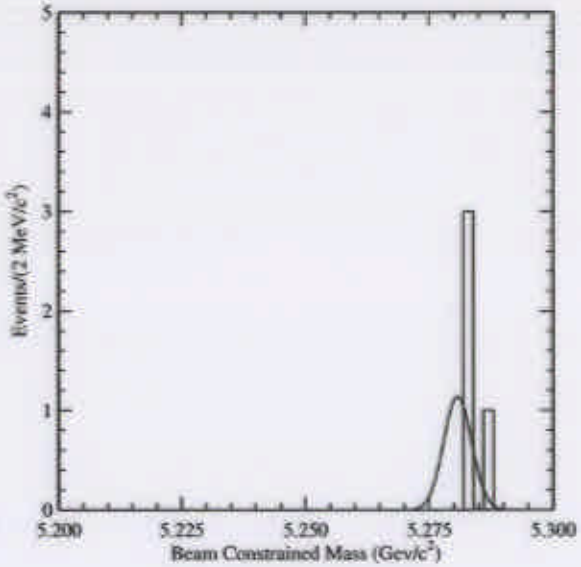
350+/-19

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



69.4+/-8.4

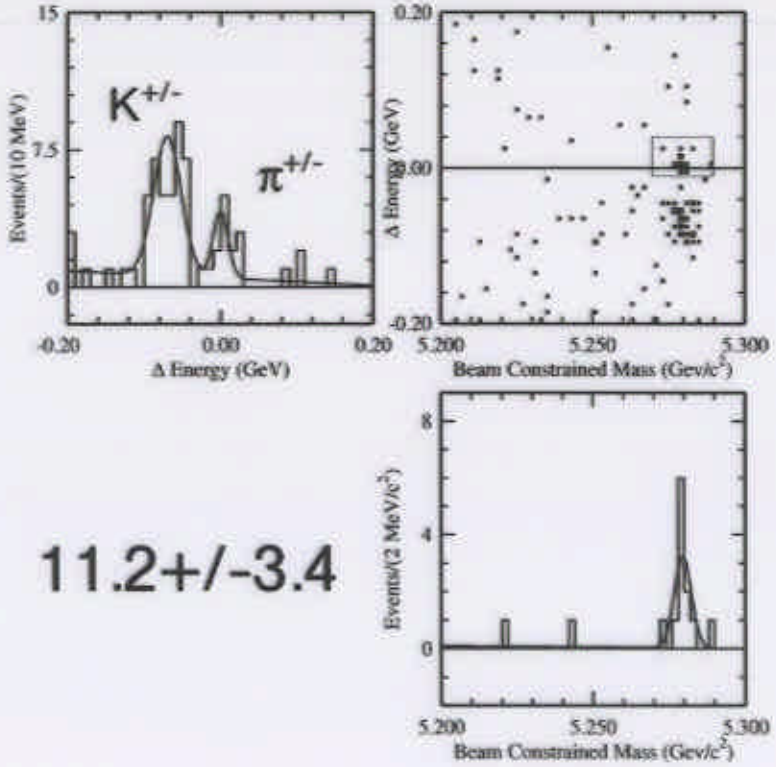
$B \rightarrow J/\psi Ks(\pi^0\pi^0)$



5.0+/-2.2

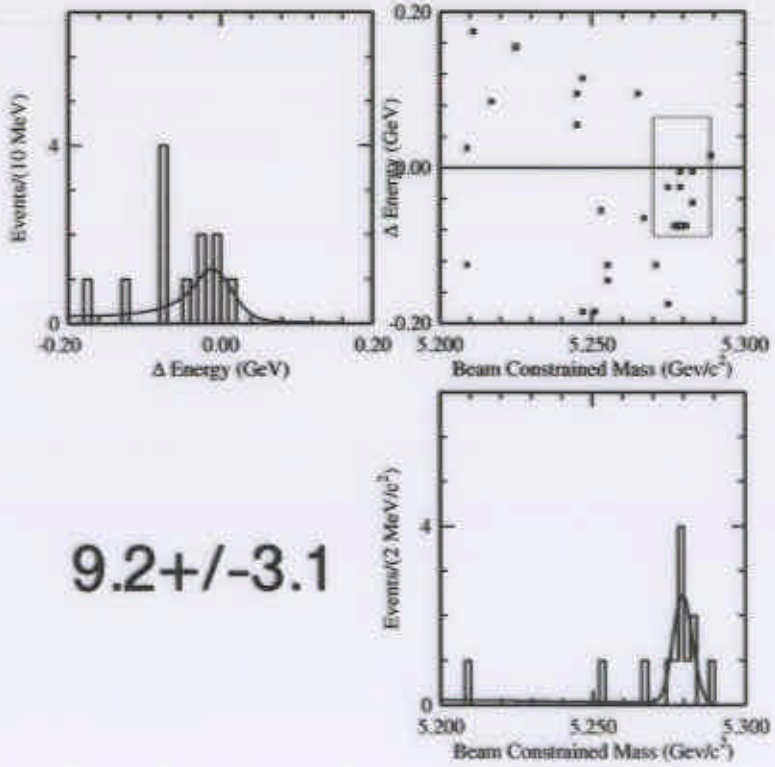
Exclusive Charmonium: CP

$B \to J/\psi\pi^{+/-}$



11.2+/-3.4

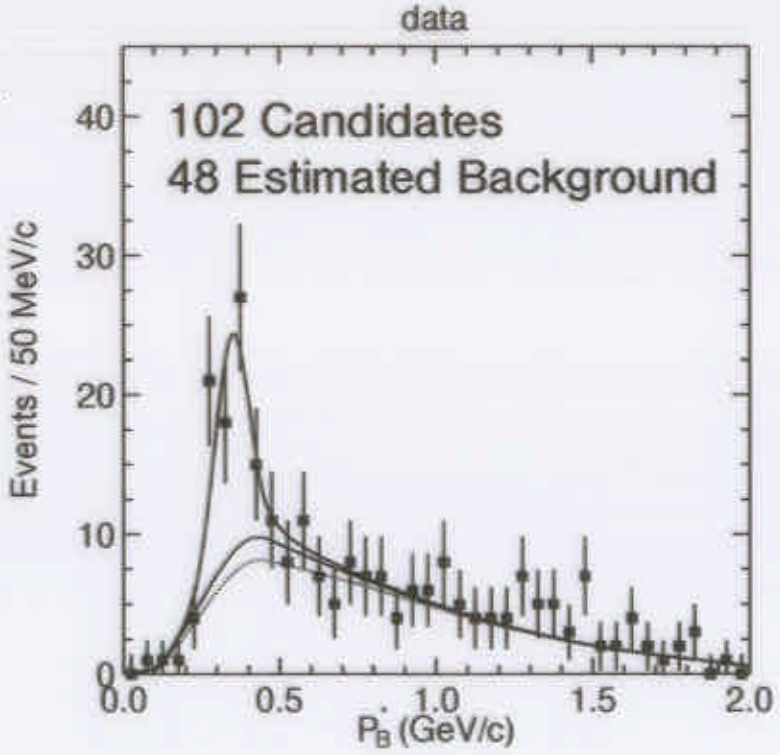
$B \to J/\psi\pi^{0}$



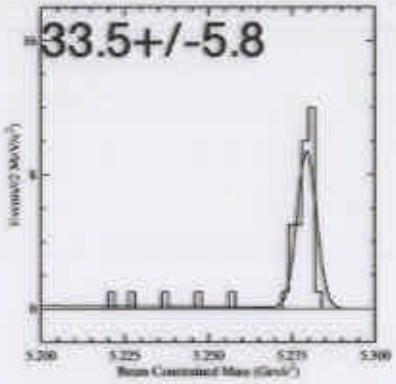
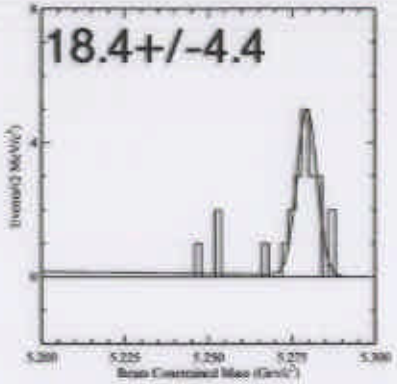
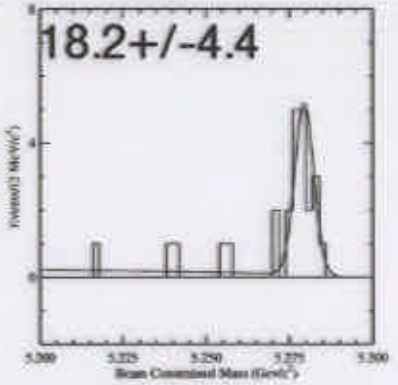
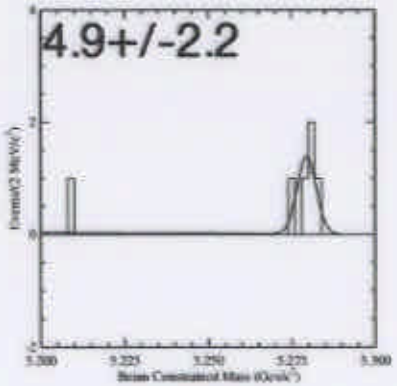
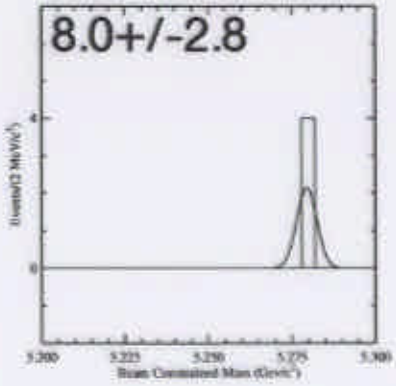
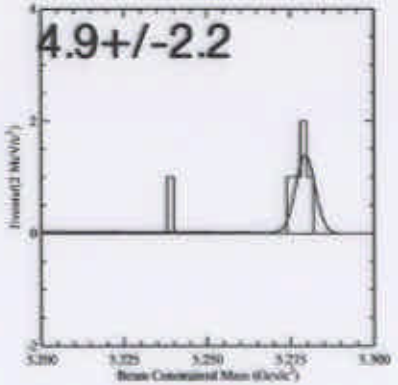
9.2+/-3.1

Exclusive Charmonium: CP Cont.

- $B \rightarrow J/\psi K_L$
  - Two body decay $\Rightarrow$ Use J/ψ momentum to predict K_L momentum.
  - Search for K_L shower.
  - Use shower position to calculate P^*_B (B momentum in center of mass of Y(4S)).
  - Plot P^*_B.

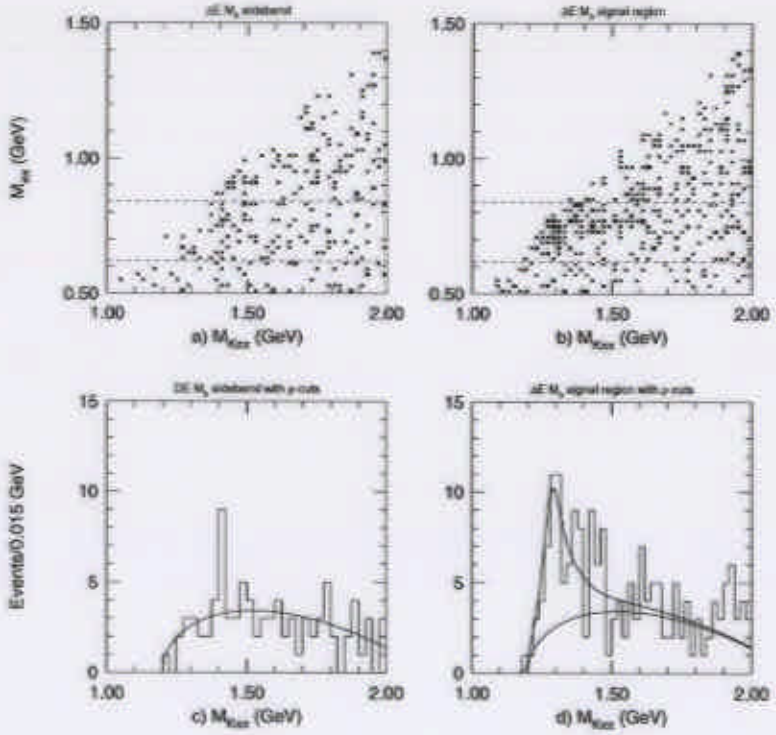


Exclusive Charmonium: CP

	$B \to \psi'(l^+l^-)K$	$B \to \psi'(\psi\pi^+\pi^-)K$	$B \to \chi_{c1}K$
$K^{+/-}$	33.5+/-5.8 	18.4+/-4.4 	18.2+/-4.4 
K_S	4.9+/-2.2 	8.0+/-2.8 	4.9+/-2.2 

Observation of $B \to J/\psi\ K_1(1270)$

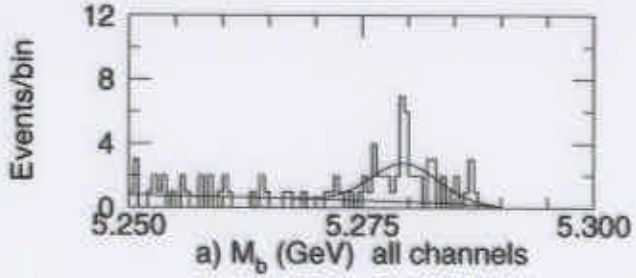
- Reconstruct K_1:
  - $K^+\pi^+\pi^-$, $K^+\pi^-\pi^0$, $K^0\pi^+\pi^-$
- Steps:
  - Select Events With Consistent ΔE and Beam Constrained Mass.
  - Study $M_{\pi\pi}$ vs. $M_{K\pi\pi}$.
  - Select $0.62 < M_{\pi\pi} < 0.84$ GeV, project onto $M_{K\pi\pi}$ plane.
    - Asymmetric around ρ mass due to kinematics.

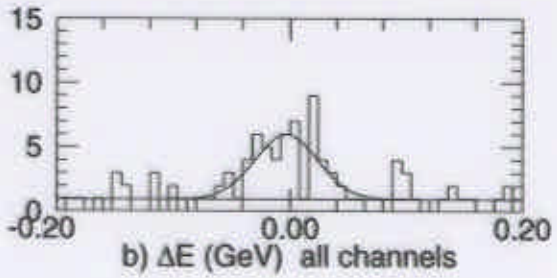


Observation of $B \to J/\psi\ K_1$ Cont.

- $\psi' \to J/\psi\pi\pi$ Vetoed.
- Background small from $K_1(1400)$, $K_1^*(1410)$ and $K^*(870)\pi$.
- Branching Fractions: Compare with $B \to J/\psi\ K^+$

$$\frac{BF(B^0 \to J/\psi\, K_1^0(1270))}{BF(B^+ \to J/\psi\, K^+)} = 1.4 \pm 0.4 \pm 0.4 \qquad \frac{BF(B^+ \to J/\psi\, K_1^+(1270))}{BF(B^+ \to J/\psi\, K^+)} = 1.5 \pm 0.4 \pm 0.3$$





Observation of $B \to J/\psi\, K_1$ Cont.

- Systematics:

Error Source	$K_1^+(1270)$	$K_1^0(1270)$
$K_1(1270)$ Branching Fractions	14%	14%
Other Kππ resonances	13%	13%
Non–resonant Kππ	10%	10%
f_+/f_0 (Neutral mode only)	–	8%
$\pi^+\pi^{-(0)}$ Data/MC differences	5%	10%
Quadrature sum	**22%**	**25%**

- Branching Fractions:

$$BF(B^0 \to J/\psi\, K_1^0(1270)) = (1.4 \pm 0.4 \pm 0.4) \times 10^{-3}$$

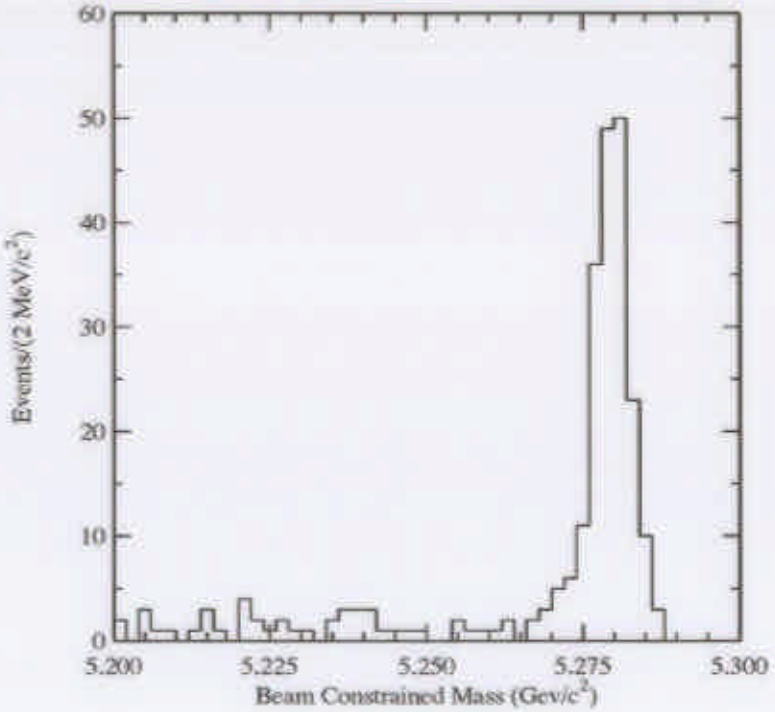
$$BF(B^+ \to J/\psi\, K_1^+(1270)) = (1.5 \pm 0.4 \pm 0.4) \times 10^{-3}$$

J/ψ K* Polarization

BELLE_CONF-0014

- $B^0 \to J/\psi K^{*0}\,(K^{*0} \to K_s \pi^0)$ useful for CP studies if decay dominated by even or odd CP.
- Steps:
  - Reconstruct: $K^{*0} \to K^+\pi^-$, $K^{*+} \to K_s\pi^+$, $K^{*+} \to K^+\pi^0$
  - Select Events With Consistent ΔE and Beam Constrained Mass.

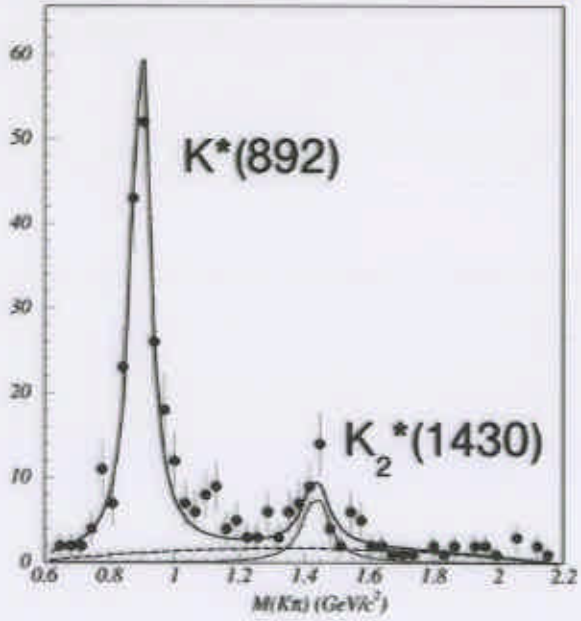
$B^0 \to J/\psi K^*$ Sum



176 Candidates

J/ψ K* Polarization Cont.

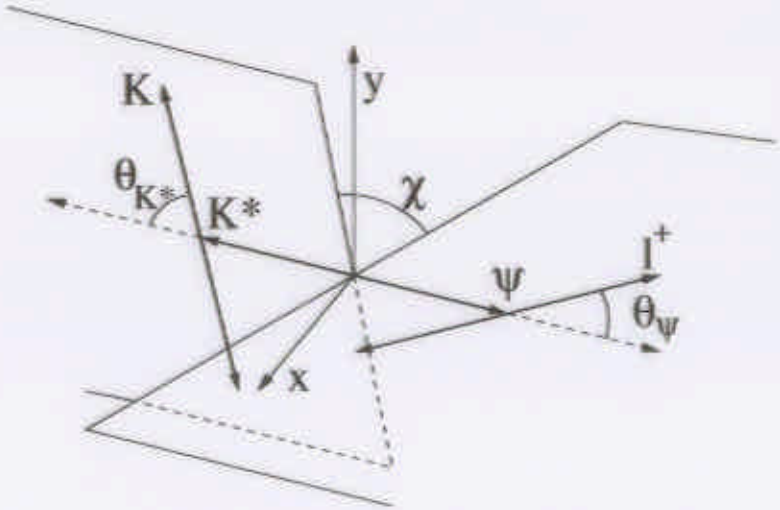
- Fits done using unbinned likelihood method.
- Backgrounds (6-12%) from:
  - Feed across (other K* modes)
  - Non-resonant $K\pi$
  - Combinatorial
  - Continuum
- Systematic Errors (largest):
  - Efficiency function
  - Polarization of feed across
  - Polarization of non-resonant $K\pi$

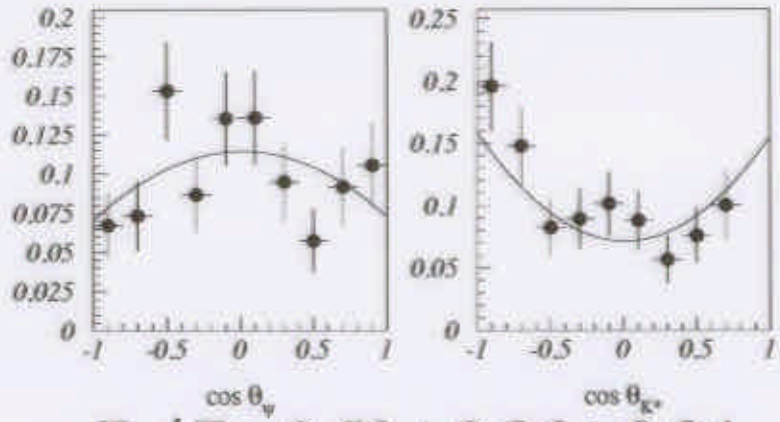


J/ψ K* Polarization: Longitudinal

- Use Helicity Basis:

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\vartheta_\phi\, d\cos\vartheta_{K^*}} = \frac{9}{32}(1+\cos^2\vartheta_\phi)\sin^2\vartheta_{K^*}\left(1-\frac{\Gamma_L}{\Gamma}\right)+\frac{9}{8}\sin^2\vartheta_\phi\cos^2\vartheta_{K^*}\frac{\Gamma_L}{\Gamma}$$





$$\Gamma_L/\Gamma = 0.52 \pm 0.06 \pm 0.04$$

$CDF\,(1995)\;\; 0.65 \pm 0.10 \pm 0.04$

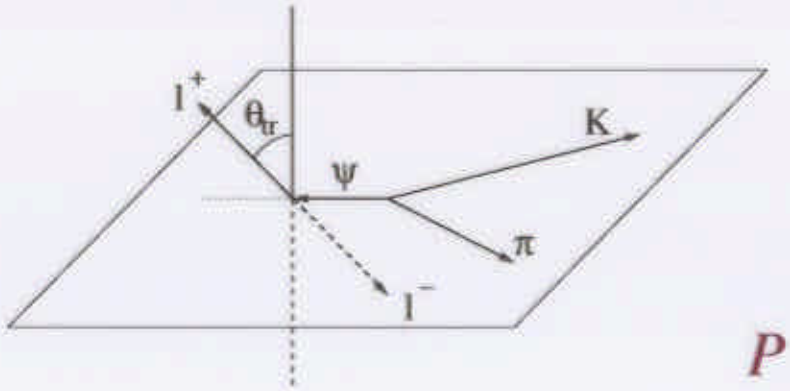
$CLEO\,II\,(1996)\;\; 0.52 \pm 0.07 \pm 0.04$

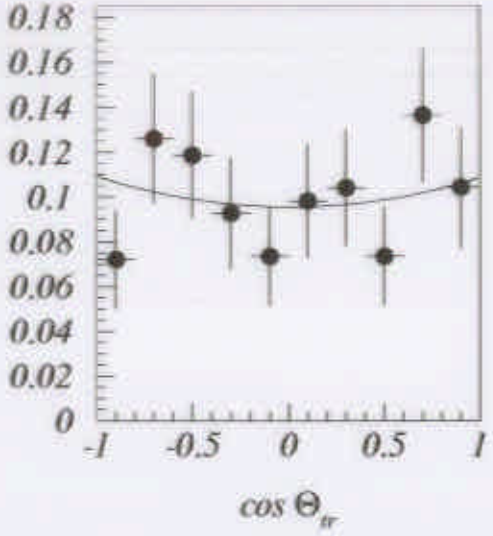
$CDF\,(2000)\;\; 0.59 \pm 0.06 \pm 0.01$

J/ψ K* Polarization: Transversity

- Use Transversity Basis:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\vartheta_{TR}} = \frac{3}{8}(1+\cos^2\vartheta_{TR})(1-|A_\perp|^2) + \frac{3}{4}|A_\perp|^2\sin^2\vartheta_{TR}$$





P Odd $\quad |A_\perp|^2 = 0.27 \pm 0.11 \pm 0.05$

CLEO II (1996) $0.16 \pm 0.08 \pm 0.04$

CDF (2000) $0.13^{+0.12}_{-0.9} \pm 0.06$

Summary

- With 6.2 fb^{-1} of data we have very nice signals in a variety of Inclusive and Exclusive B to charmonium modes.
- We measured the Branching Fraction for $B \to J/\psi K_1(1270)$ to be:

$$BF(B^0 \to J/\psi K_1^0(1270)) = (1.4 \pm 0.4 \pm 0.4) \times 10^{-3}$$

$$BF(B^+ \to J/\psi K_1^+(1270)) = (1.5 \pm 0.4 \pm 0.4) \times 10^{-3}$$

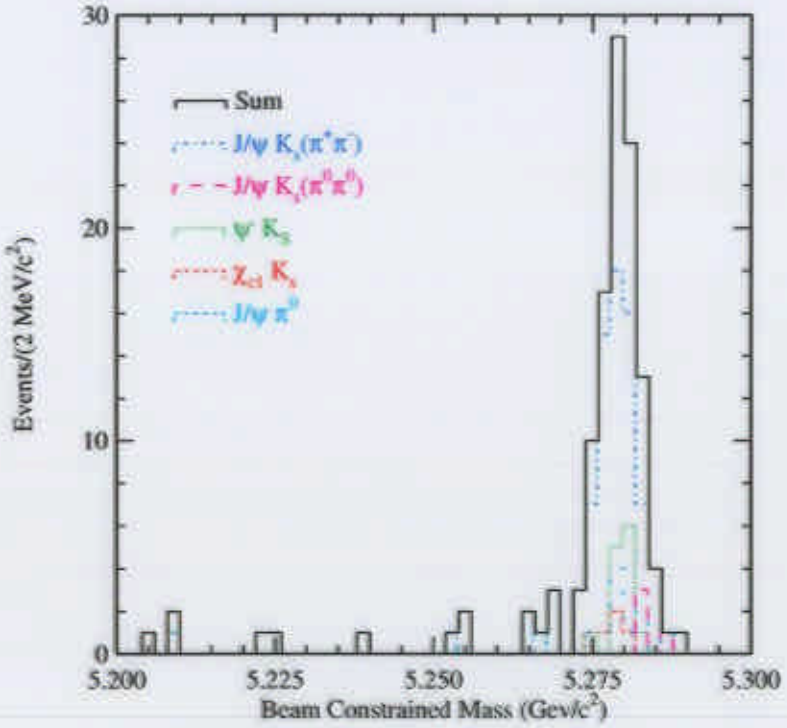
- We measured the Longitudinal Polarization of $B \to J/\psi K^*$ to be:

$$\Gamma_L/\Gamma = 0.52 \pm 0.06 \pm 0.04$$

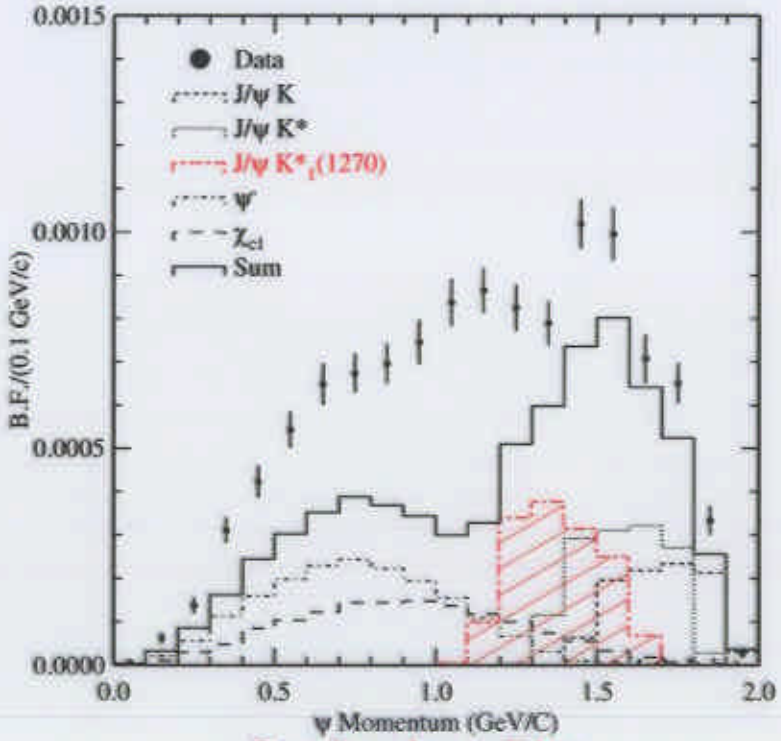
- We measured the P Odd component of $B \to J/\psi K^*$ to be:

$$|A_\perp|^2 = 0.27 \pm 0.11 \pm 0.05$$

Summary



B to Charmonium
CP Modes



Inclusive J/ψ
Momentum Spectrum