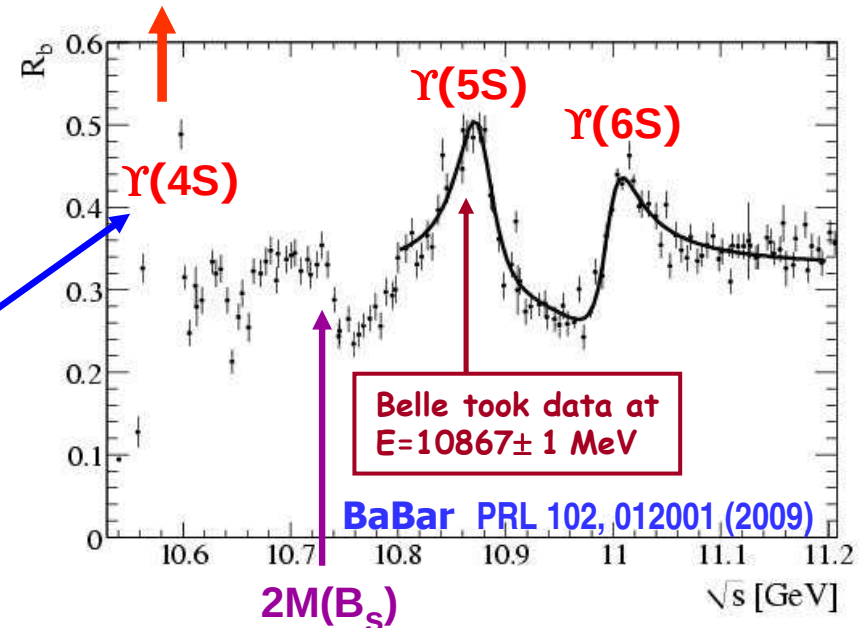
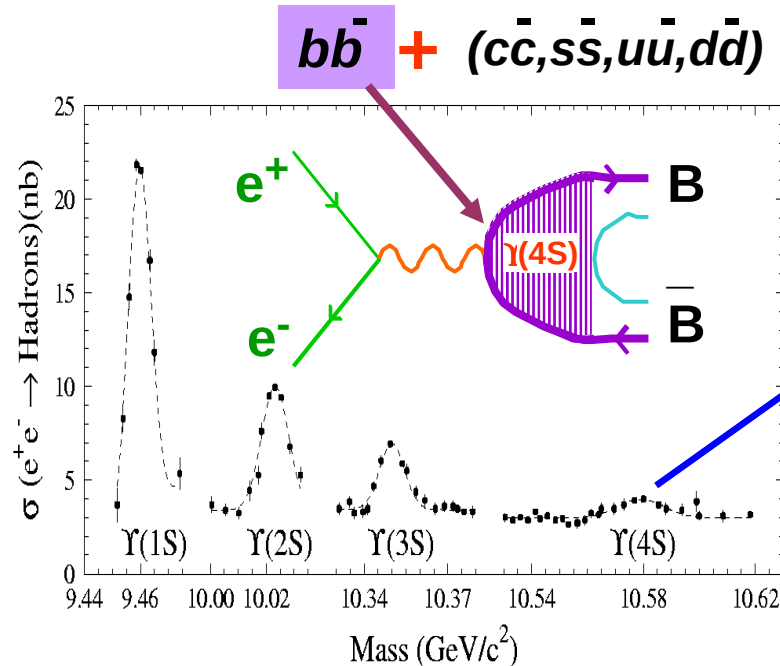




Study of $\Upsilon(5S)$ decays to B^0 and B^+ mesons

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$e^+ e^- \rightarrow Y(4S) \rightarrow B\bar{B}$, where B is B^+ or B^0 meson

$M(Y(5S)) = 10876 \pm 2 \text{ MeV}/c^2$

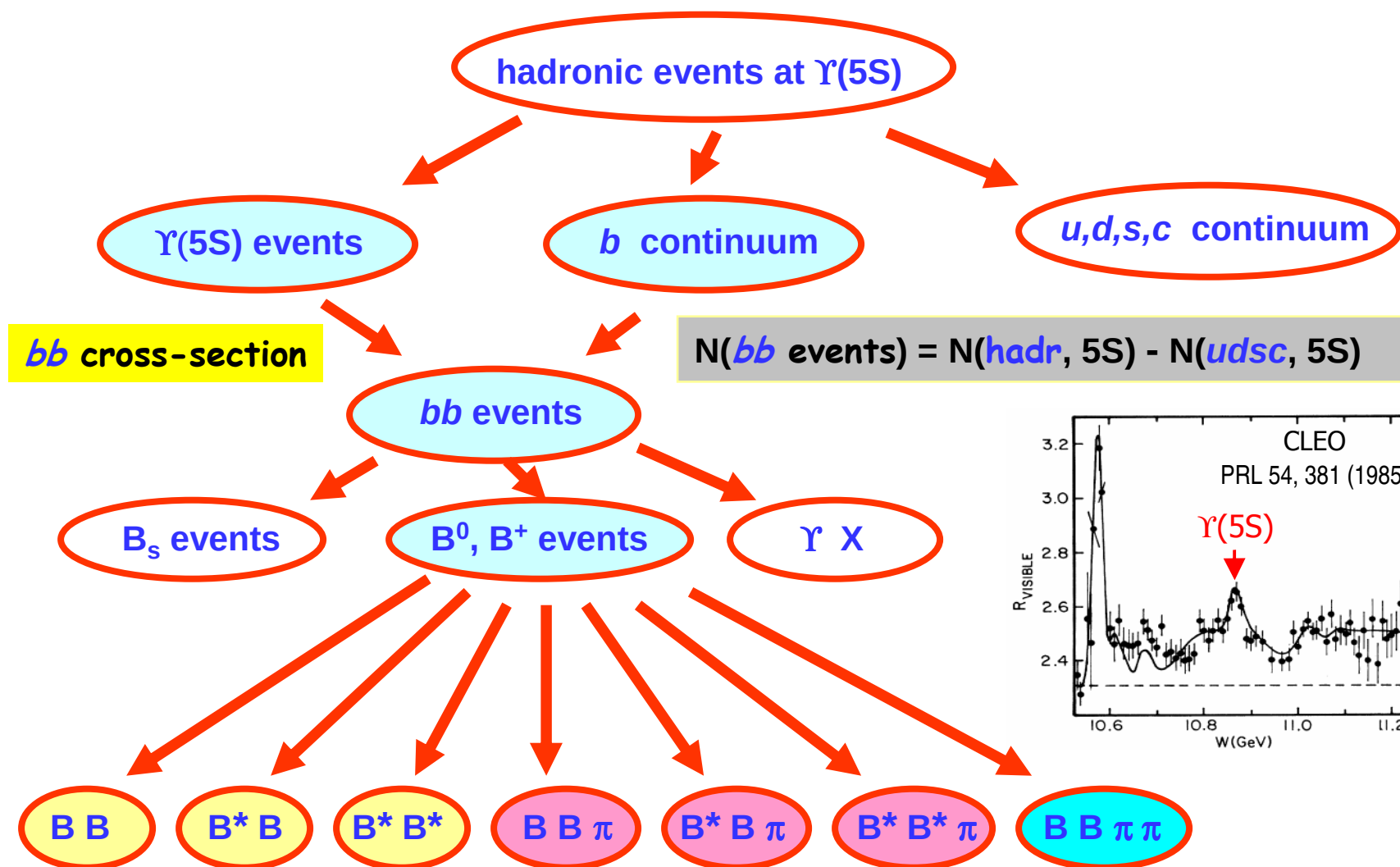
$\Gamma(Y(5S)) = 43 \pm 4 \text{ MeV}/c^2$ (BaBar)

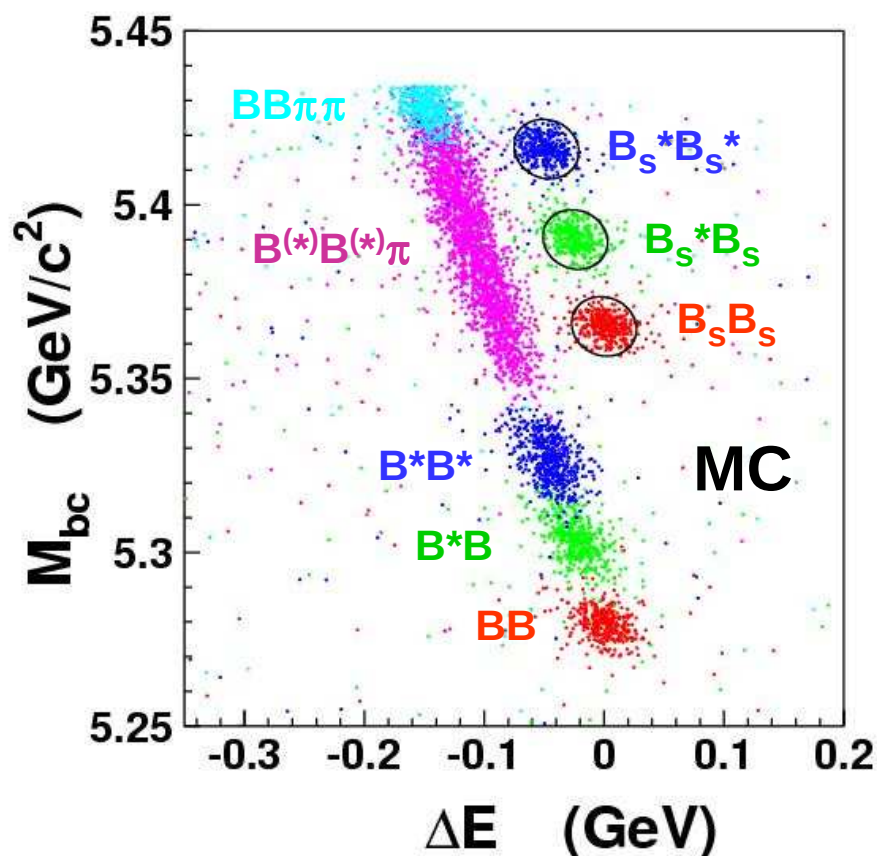
$e^+ e^- \rightarrow b\bar{b}(Y(5S)) \rightarrow B^{(*)}\bar{B}^{(*)}, B^{(*)}\bar{B}^{(*)}\pi, B\bar{B}\pi\pi, B_s^{(*)}\bar{B}_s^{(*)}, Y(1S)\pi\pi, Y X \dots$

where $B^* \rightarrow B \gamma$ and $B_s^* \rightarrow B_s \gamma$

CLEO: 2003: $\sim 0.42 \text{ fb}^{-1}$

Belle: 2005 1.86 fb^{-1} , 2006 21.7 fb^{-1} ,
2008 $\sim 28 \text{ fb}^{-1}$, 2009 $\sim 50 \text{ fb}^{-1}$





MC simulation:
 $B_S \rightarrow D_S^- \pi^+$ and $B^0 \rightarrow D^- \pi^+$.

$e^+ e^- \rightarrow \Upsilon(5S) \rightarrow B^{(*)} B^{(*)} (\pi)(\pi),$

where $B^* \rightarrow B \gamma$

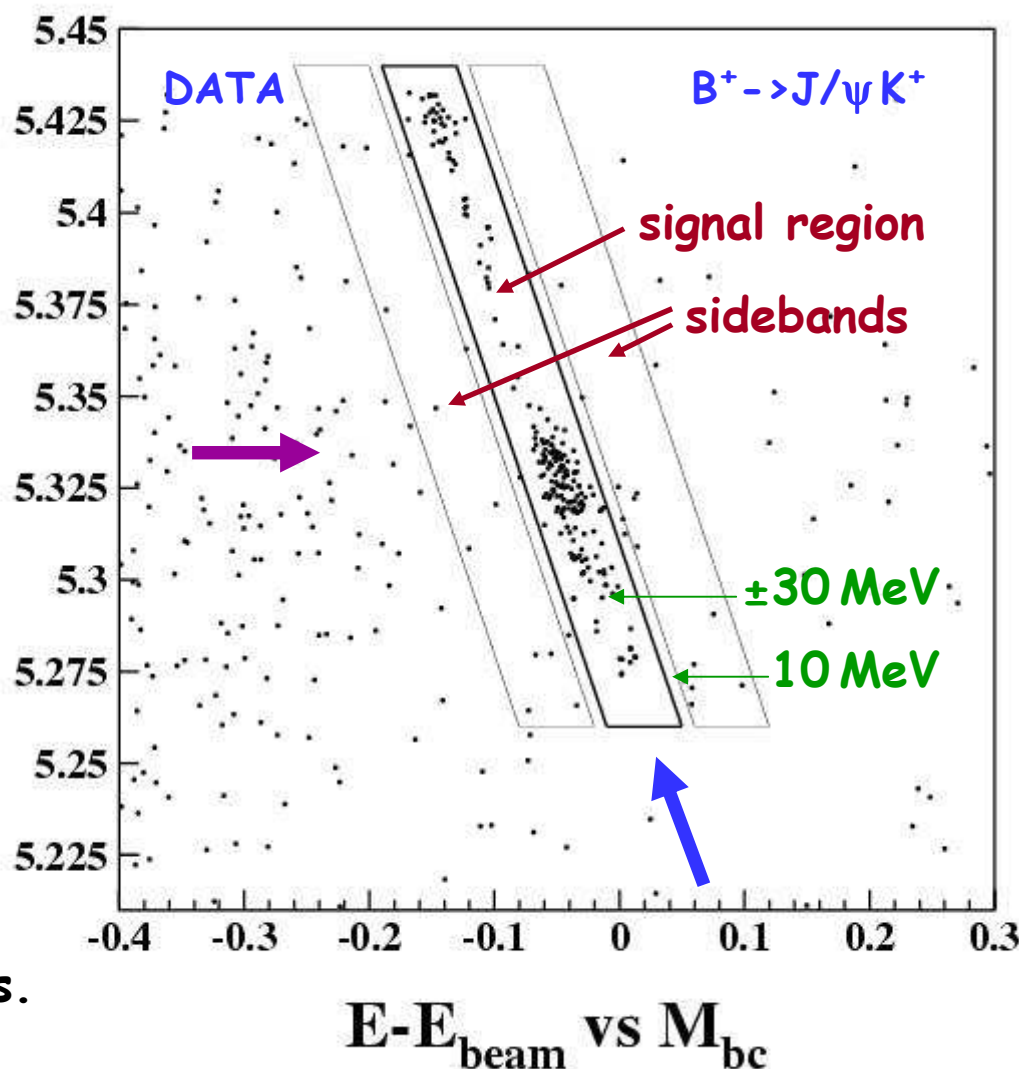
Only one B meson is reconstructed

Two variables calculated: $M_{bc} = \sqrt{E_{beam}^{*2} - P_B^{*2}}$, $\Delta E = E_B^* - E_{beam}^*$

B energy (E_B^*) and momentum (P_B^*) are reconstructed; no rec. γ from B^*

Two projections are studied:
 $M_{bc} + \Delta E - 5.28$ within full M_{bc} interval 5.27-5.44 MeV/c^2 , and M_{bc} projections within signal and sideband regions

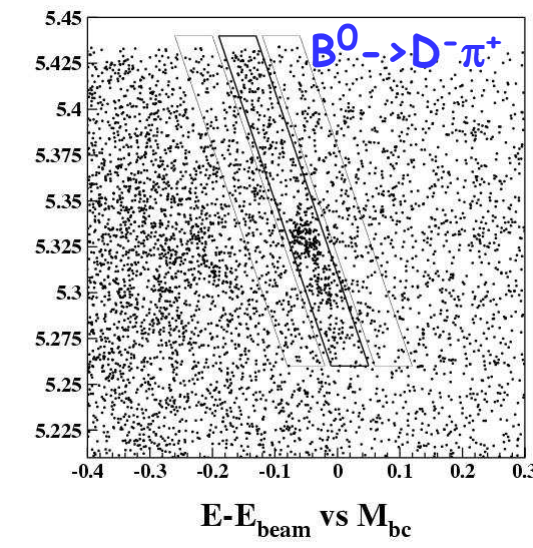
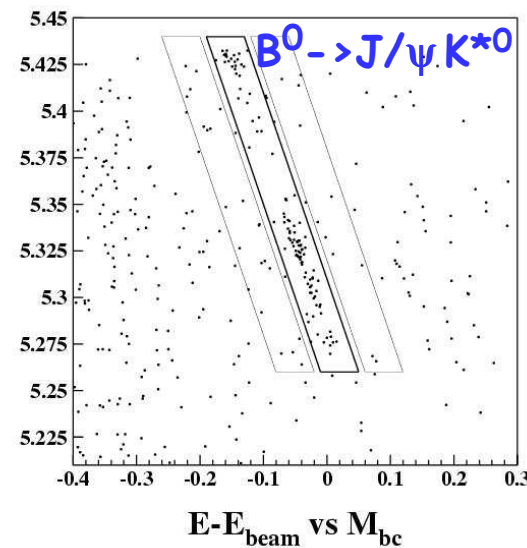
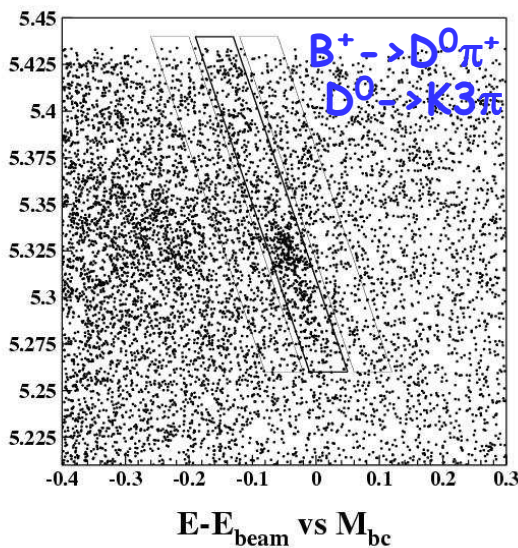
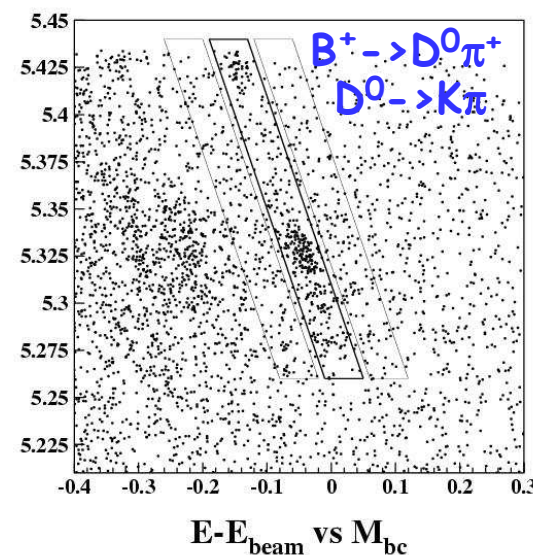
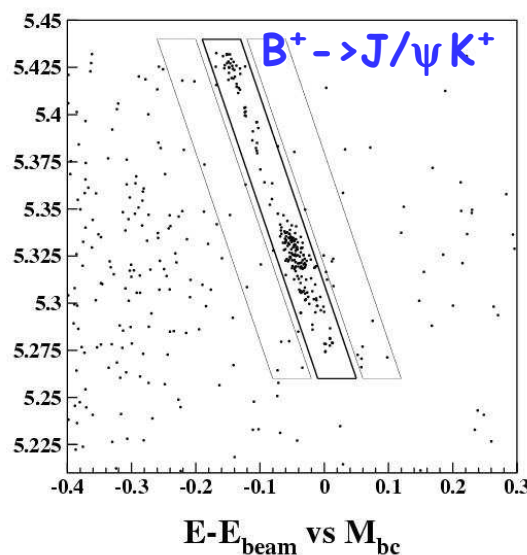
$M_{bc} + \Delta E - 5.28$: full number of B events.
 M_{bc} : separation between specific channels.



$L=23.6 \text{ fb}^{-1}$, preliminary

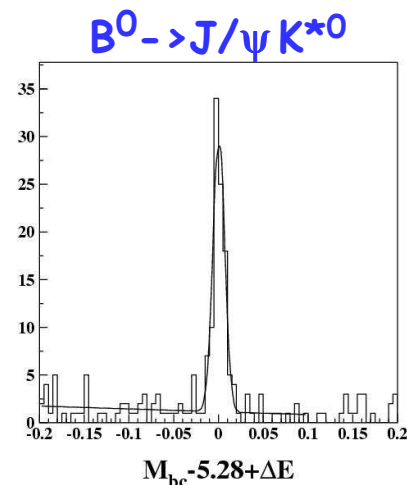
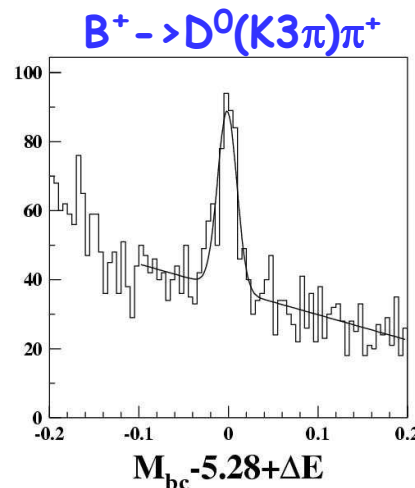
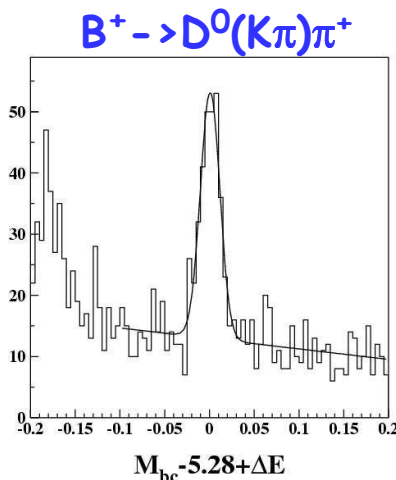
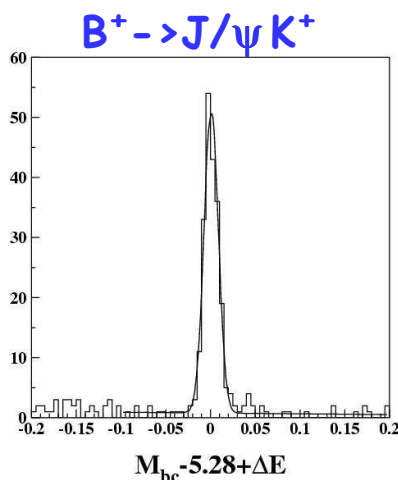
Five B modes are studied:
only charged tracks in
final state, PDG branching
fraction errors are 3-5%
 $\Rightarrow$ small systematic errors

Clear B signals are seen
in signal regions for all
5 studied B decays.





$M_{bc} + \Delta E - 5.28$ projections



$$f(X) = N(X)/N(bb)$$

$B^+ \rightarrow J/\psi K^+$

$83.8 \pm 5.9 \pm 7.2 \%$

B^+
 $67.5 \pm 3.6 \pm 4.8 \%$

$B^+ \rightarrow D^0(K\pi)\pi^+$

$59.2 \pm 5.7 \pm 5.1 \%$

B^0
 $70.4 \pm 5.2 \pm 6.2 \%$

$B^+ \rightarrow D^0(K3\pi)\pi^+$

$62.3 \pm 7.3 \pm 7.5 \%$

Σ

$B^0 \rightarrow J/\psi K^{*0}$

$77.1 \pm 8.3 \pm 7.8 \%$

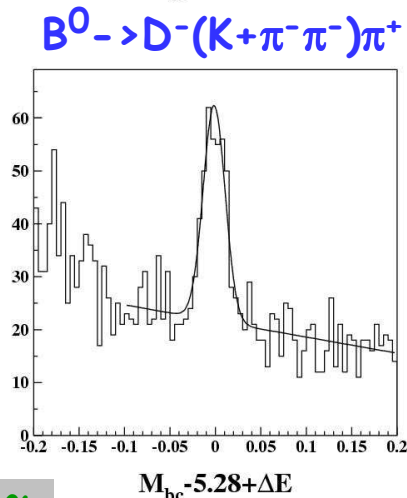
$68.5 \pm 3.0 \pm 5.0 \%$

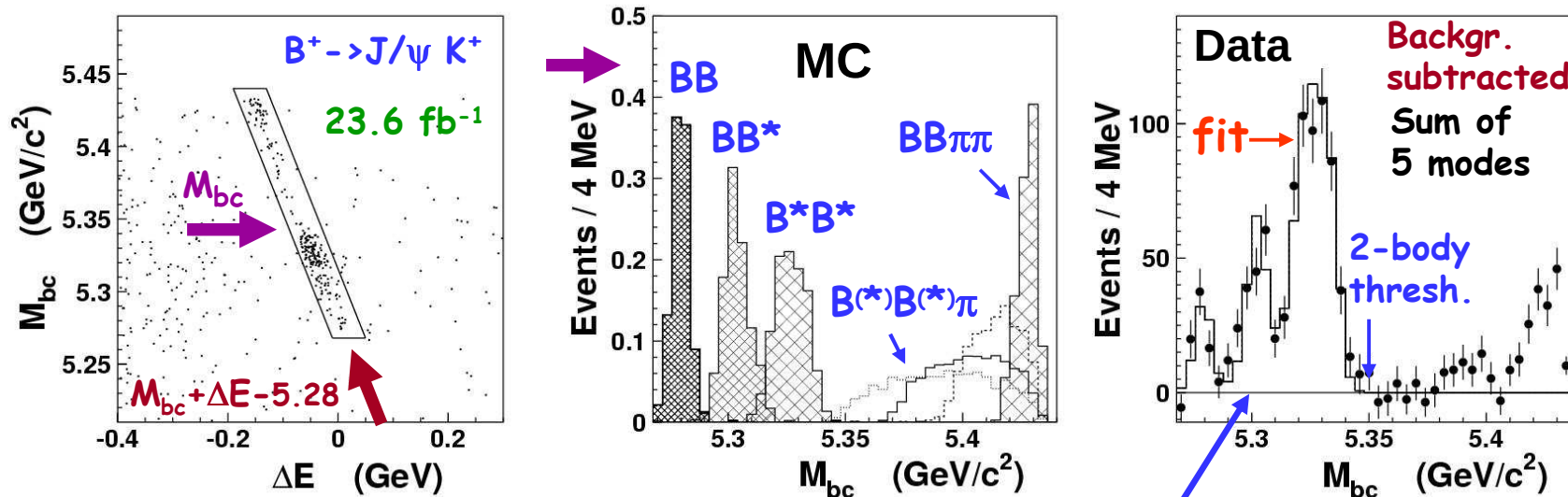
$B^0 \rightarrow D^-(K+\pi^-\pi^-)\pi^+$

$65.3 \pm 6.7 \pm 7.2 \%$

CLEO: $58.9 \pm 10.0 \pm 9.2 \%$

Sum B_s : $19.5 \pm 3.0 \pm 2.2 \%$ (PDG, Belle+CLEO).





Simultaneous fit of 5 B modes
in $M_{bc} < 5.35 \text{ GeV/c}^2$ region

Channel fractions per bb -pair:

BB: $5.1 \pm 0.9 \pm 0.4 \%$

B^*B : $12.6 \pm 1.2 \pm 1.0 \%$

B^*B^* : $34.5 \pm 1.9 \pm 2.7 \%$

$B^{(*)}B^{(*)}\pi(\pi)$: $16.4 \pm 1.6 \pm 1.2 \%$

Large fraction of (3+4)-body B^{+0} decays
=> not predicted by theory

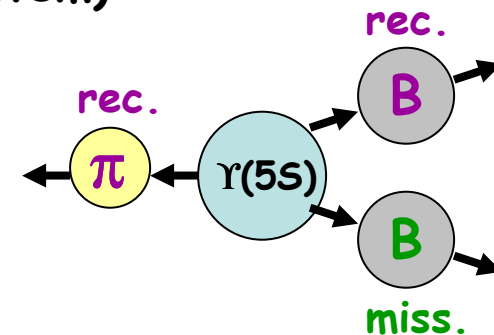
(3+4)-body fraction:

$\sim 0.3\%$: L.Lellouch et al Nucl Phys B405:55,1993
 $\sim 0.03\%$: Yu.Simonov et al hep-ph:0805.4518

We reconstruct directly produced pion in $B^{(*)}B^{(*)}\pi^+$ channels.
Then we calculate parameters (all in CM system):

Reconstructed B meson:

$$M_{bc}, \Delta E ; \quad \Delta X(\text{rec}) = M_{bc} + \Delta E - 5.28$$



Missing B meson:

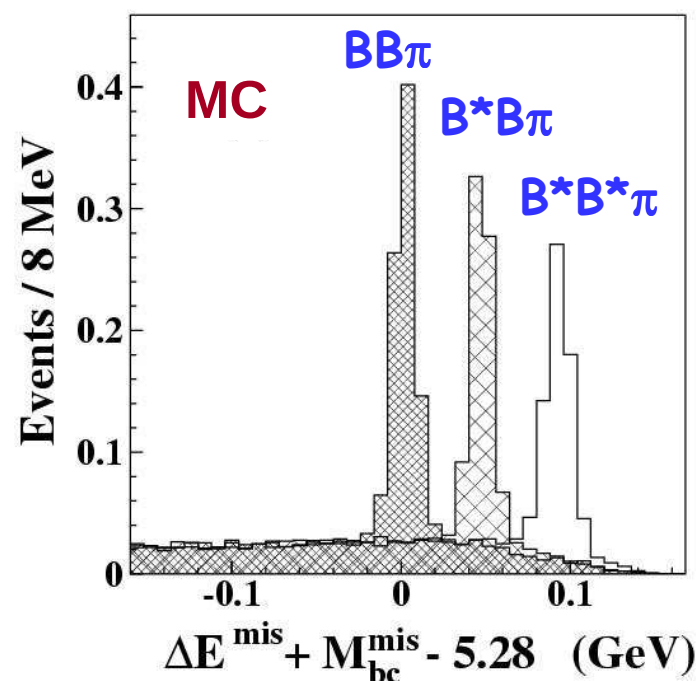
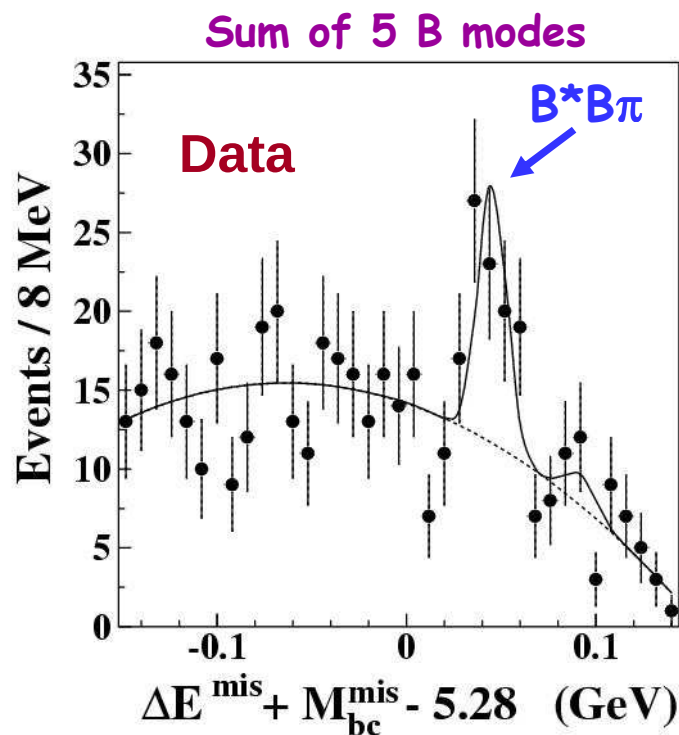
use momentum $P(B\pi)$ and energy $E(B\pi)$ of reconstructed B and π :

$$M_{bc}^{\text{miss}} = \text{sqrt}(E_{\text{beam}}^2 - P(B\pi)^2) , \quad \text{because } P(B_{\text{miss}}) = P(B\pi)$$

$$\Delta E^{\text{miss}} = E_{\text{beam}} - E(B_{\text{miss}}) = E(B\pi) - E_{\text{beam}}$$

$$\Delta X(\text{miss}) = M_{bc}^{\text{miss}} + \Delta E^{\text{miss}} - 5.28$$

$$\Delta X(\text{corr}) = \Delta X(\text{miss}) + \Delta X(\text{rec}) \quad \rightarrow \text{to decrease uncertainty}$$



Only B candidates from signal region $M_{\text{bc}}^{\text{rec}} > 5.37 \text{ MeV}/c^2$ are used

We assume Clebsch-Gordan coefficients in 3-body decays:

$$\text{Fr}(BB\pi^\pm)/\text{Fr}(BB\pi^0)=2:1$$

Pion efficiencies are not small, $P(\pi)=(50-300) \text{ MeV}/c$



Decomposition of 3- and 4-body channels



Fractions for different components averaged over 5 studied B decays (assuming equal B^+ and B^0 production):

	Events (π^+)	Fraction over 3+4	Fraction over bb
$BB \pi$	$0.2 \pm \frac{7.2}{6.9}$	$(0.2 \pm \frac{6.8}{6.5})\%$	$(0.0 \pm 1.1 \pm 0.2) \%$
$B^*B \pi$	$38.3 \pm \frac{10.5}{9.8}$	$(41.6 \pm \frac{12.1}{11.4})\%$	$(6.8 \pm \frac{2.1}{2.0} \pm 0.7) \%$
$B^*B^* \pi$	$4.8 \pm \frac{6.4}{5.9}$	$(5.9 \pm \frac{7.8}{7.2})\%$	$(1.0 \pm \frac{1.3}{1.2} \pm 0.3) \%$
Residual ($BB \pi \pi$)		$(52.3 \pm \frac{15.9}{15.0})\%$	$(8.6 \pm \frac{2.7}{2.6} \pm 0.9) \%$
All 3+4	$228.7 \pm \frac{22.9}{22.3}$	100%	$(16.4 \pm \frac{1.6}{1.5} \pm 1.2) \%$

Domination of $B^*B \pi$ channel is in reasonable agreement with expectations. Unexpectedly large rate of $BB\pi\pi$ events over all bb events is found. Phase space for $BB\pi\pi$ is very small **~ 37 MeV !**

- $\Upsilon(5S)$ decays to B^0 and B^+ mesons are studied (**preliminary results**).

- Rate of events with B^+ and B^0 mesons over bb events is:

$$B^+ : 67.5 \pm 3.6 \pm 4.8 \%$$

$$\text{Sum} : 68.5 \pm 3.0 \pm 5.0 \%$$

$$B^0 : 70.4 \pm 5.2 \pm 6.2 \%$$

- Two-body and multi-body fractions are measured:

$$BB: 5.1 \pm 0.9 \pm 0.4 \%$$

$$B^*B^*: 34.5 \pm 1.9 \pm 2.7 \%$$

$$B^*B: 12.6 \pm 1.2 \pm 1.0 \%$$

$$B^{(*)}B^{(*)}\pi(\pi): 16.4 \pm 1.6 \pm 1.2 \%$$

Theoretically unexpected large fraction of 3+4-body channels

- Three- and four-body channels are separated with slow π^+ :

$$BB\pi: (0.0 \pm 1.1 \pm 0.2) \%$$

$$B^*B^*\pi: (1.0 \pm 1.3 \pm 0.3) \%$$

$$B^*B\pi: (6.8 \pm 2.1 \pm 0.7) \%$$

$$BB\pi\pi: (8.6 \pm 2.7 \pm 0.9) \%$$

Unexpectedly large contribution of $BB\pi\pi$ channel.

- Theory cannot predict well behaviors of ("simple") bb -system



Background slides



Selections



Statistics : 5S data, 23.6 fb⁻¹

Particle ID:

π^- : $ID(K/\pi) < 0.6$; K^- : $ID(K/\pi) > 0.6$ (0.8 for K from D) ;
Muon and electron ID > 0.2.

Masses:

$$| M(D^0) - M(K^-\pi^+) | < 10 \text{ MeV}/c^2$$

$$| M(D^0) - M(K^-\pi^+\pi^+\pi^+) | < 10 \text{ MeV}/c^2$$

$$| M(D^+) - M(K^-\pi^+\pi^+) | < 10 \text{ MeV}/c^2$$

$$| M(J/\psi) - M(\ell^+\ell^-) | < 30 \text{ MeV}/c^2 \text{ (-100 MeV}/c^2 \text{ for } e^+e^-)$$

$$| M(K^*) - M(K^+\pi^-) | < 50 \text{ MeV}/c^2$$

Mass and vertex fit
to D and J/ψ

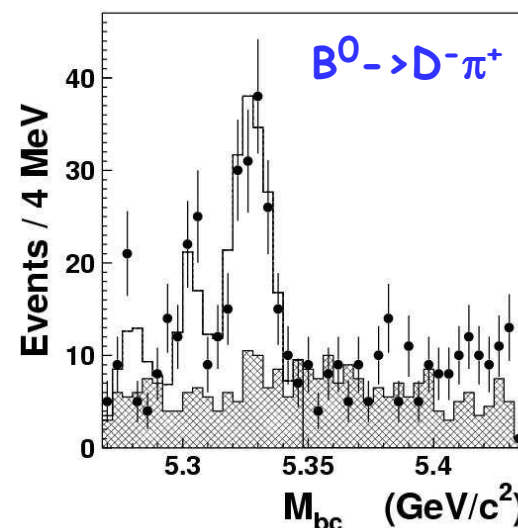
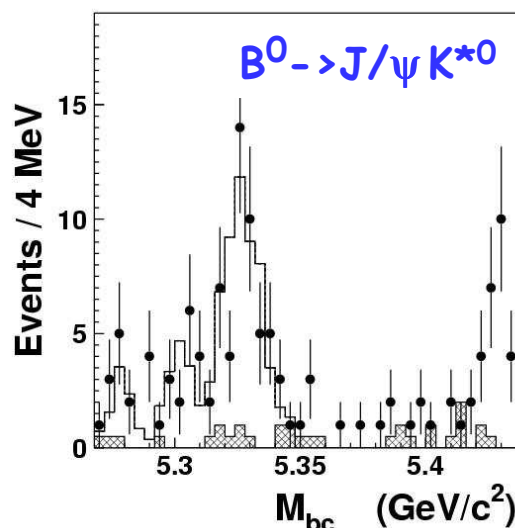
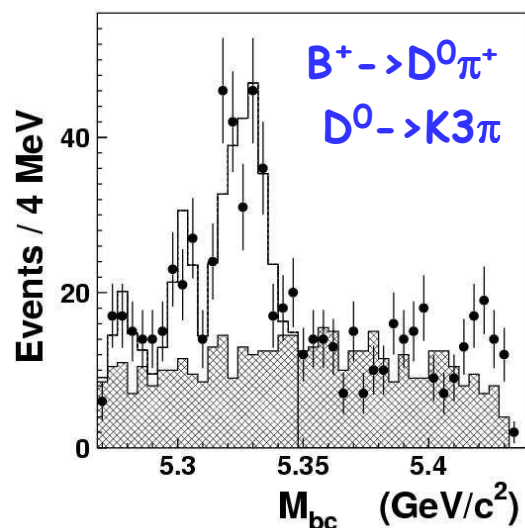
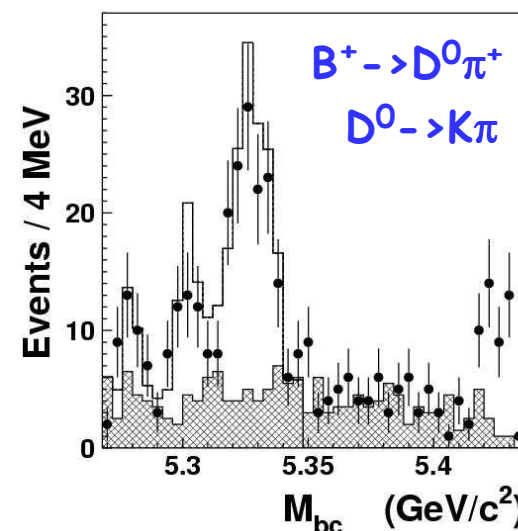
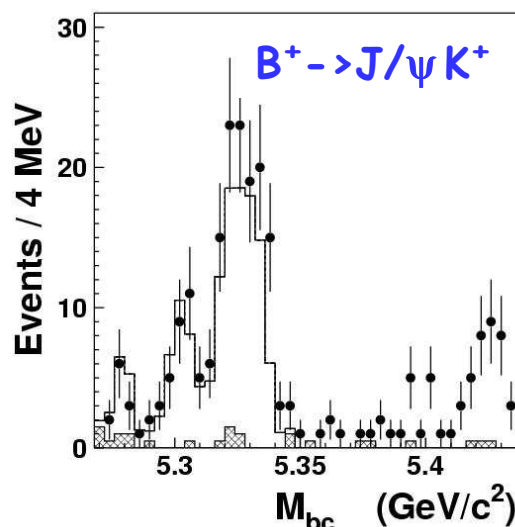
Continuum suppression:

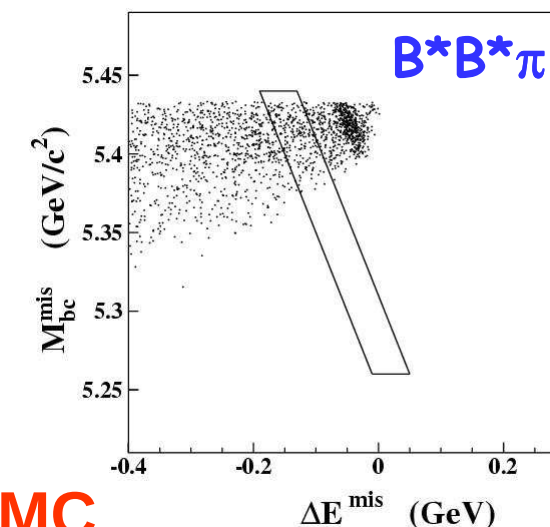
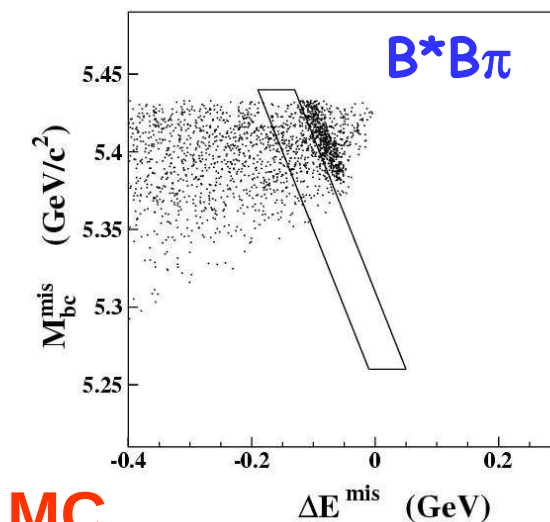
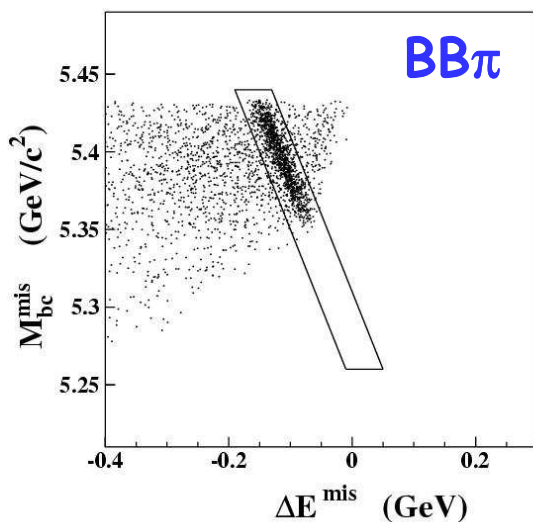
Angle between B thrusts and second Fox-Wolfram momentum:

$|\cos\theta| < 0.75$ and $Fox2 < 0.4$ for modes with D mesons

$|\cos\theta| < 0.9$ and $Fox2 < 0.5$ for modes with J/ψ mesons

For each B decay:
4 components in fits,
BB, B*B, B*B*
(shapes from MC),
and background
(shapes: sidebands).





MC

MC

