

Recent results from $\Upsilon(5S)$ at Belle

DPF 2009, Detroit

Li, Jin

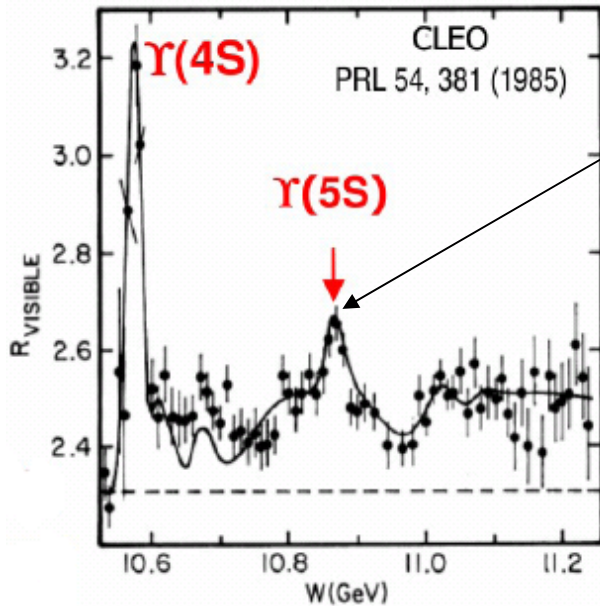
University of Hawaii



- $\Upsilon(5S) \rightarrow B^{(*)}B^{(*)}(\pi)\pi$ study.
- Two body B_s decay to $D_s^{(*)} X$ ($b \rightarrow c$).
- $B_s \rightarrow hh$, CP eigenstate decay.

$\Upsilon(5S)$ and B_s

e^+e^- hadronic cross section



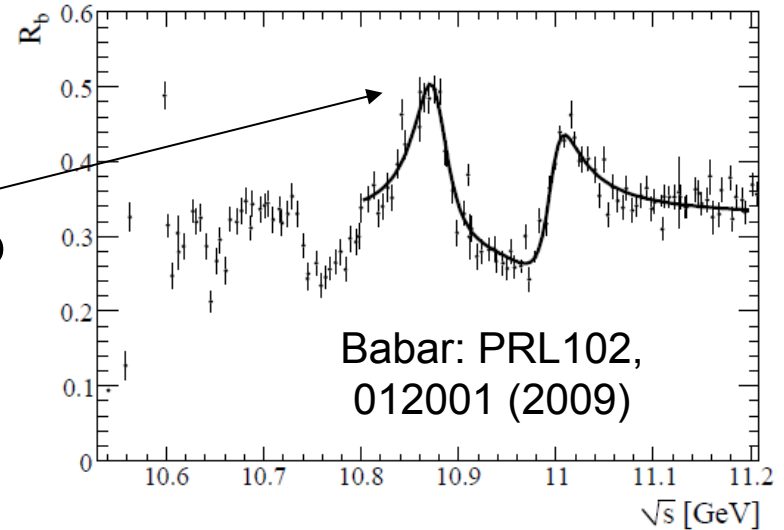
$\Upsilon(5S)$:

1^{--} Bottomonium: $b\bar{b}$

PDG:

$$M(\Upsilon(5S)) = 10865 \pm 8 \text{ MeV}/c^2$$

$$\Gamma(\Upsilon(5S)) = 110 \pm 13 \text{ MeV}/c^2$$

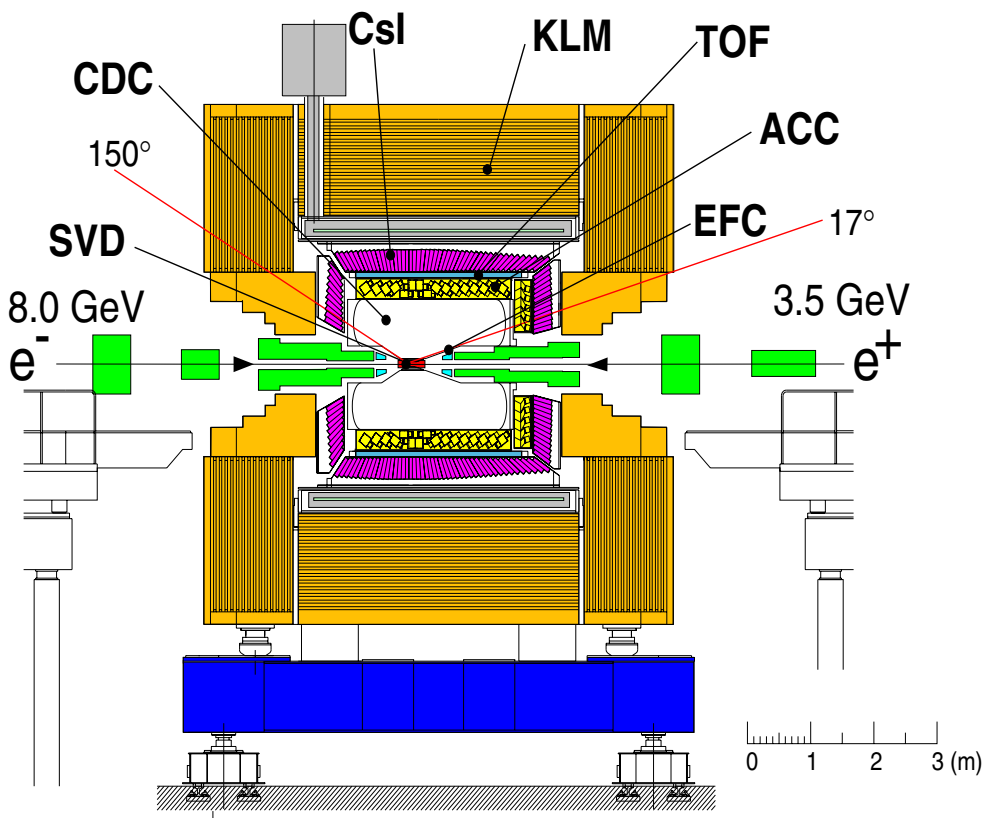


$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B} \quad (B = B_u^+, B_d^0)$$

$\Upsilon(5S)$: Analogous to $\Upsilon(4S)$, but with more modes

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

$\Upsilon(5S)$ data at Belle



KEKB & Belle runs
very smoothly in $\Upsilon(5S)$

Keep the same boost $\beta=0.425$
as in $\Upsilon(4S)$ case

- $E(e^+)$: 3.500 GeV \rightarrow 3.595 GeV
- $E(e^-)$: 7.996 GeV \rightarrow 8.211 GeV

2005: 1.86 fb $^{-1}$

2006: 21.7 fb $^{-1}$

2008: 28.2 fb $^{-1}$

2009: 50+ fb $^{-1}$

Total \sim 120 fb $^{-1}$

New luminosity record: 2.11×10^{34} cm $^{-2}$ sec $^{-1}$ (Jun.15)

Integrated Lum. record: 1.48fb $^{-1}$ /day, 8.01fb $^{-1}$ /week

CLEO 2003: 0.42 fb $^{-1}$



B_s production

All results from 23.6 fb⁻¹ (1.39 M B_s^(*)B_s^(*) pairs)

• e⁺e⁻ → Υ(5S) → B_s^{*}B_s^{*}, B_s^{*}B_s, B_sB_s; B_s^{*} → B_sΥ; Υ not reconstructed.

• Two kinematic variables:

$$M_{bc} = \sqrt{E_{\text{beam}}^{*2} - P_B^{*2}}$$

$$\Delta E = E_B^* - E_{\text{beam}}$$

$$\sigma_{bb}^{5S} = 0.302 \pm 0.015 \text{ nb}$$

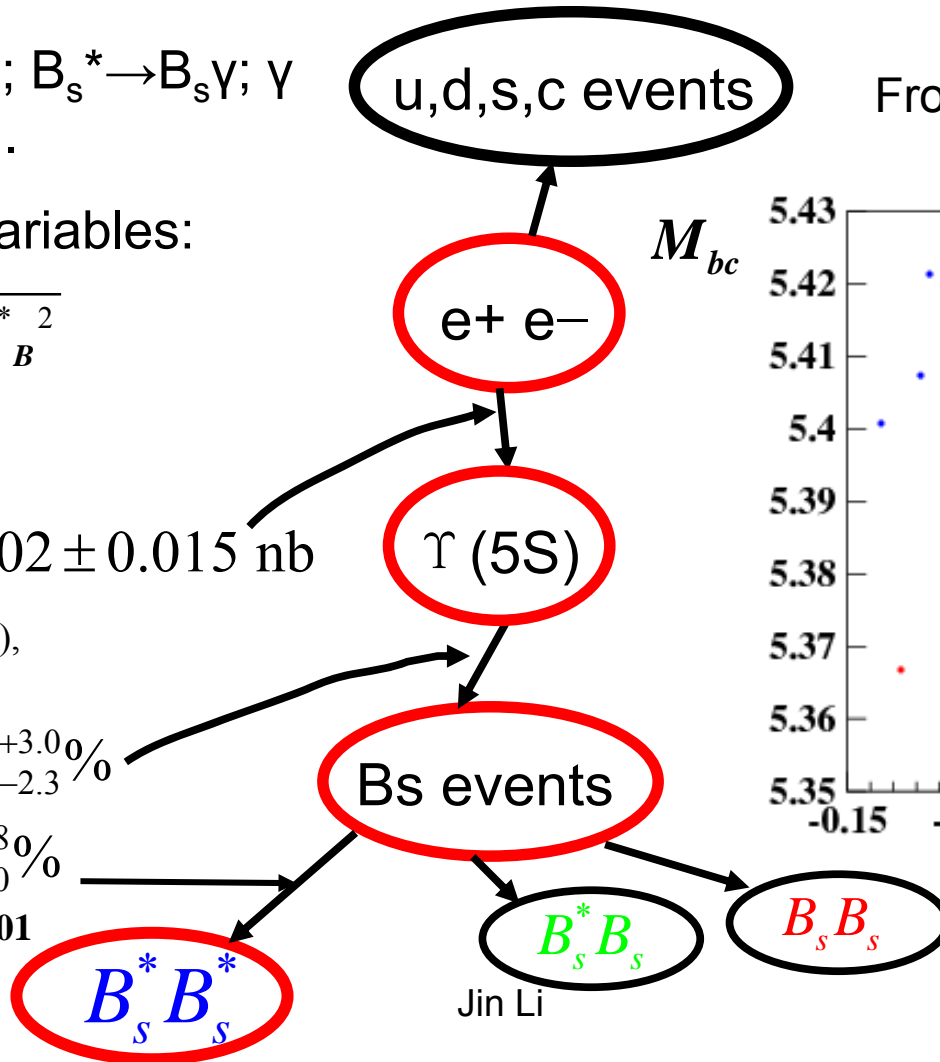
A. Drutskoy et al. (Belle),
PRL 98, 052001 (2007)

$$f_s = 19.5_{-2.3}^{+3.0} \%$$

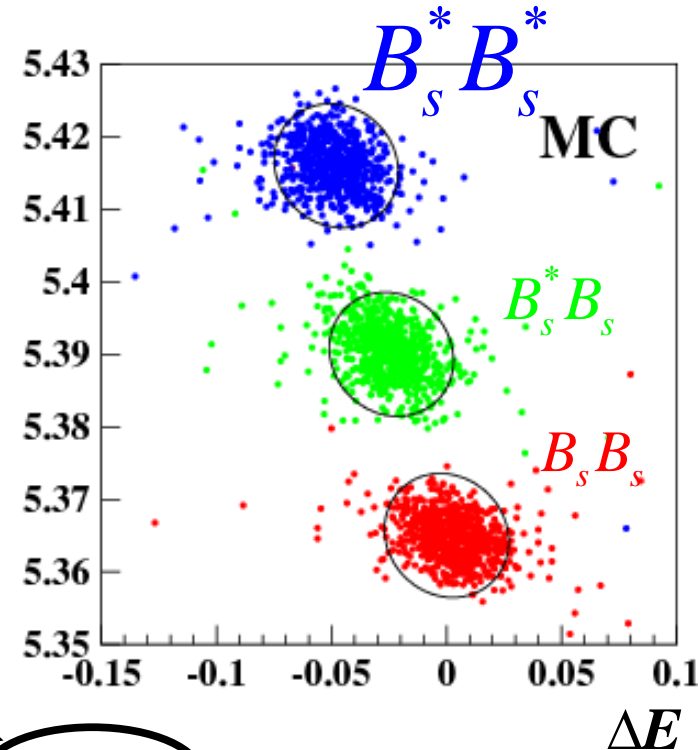
$$f_{B_s^* B_s^*} = 90.1_{-4.0}^{+3.8} \%$$

PRL 102,021801

DPF2009, Detroit



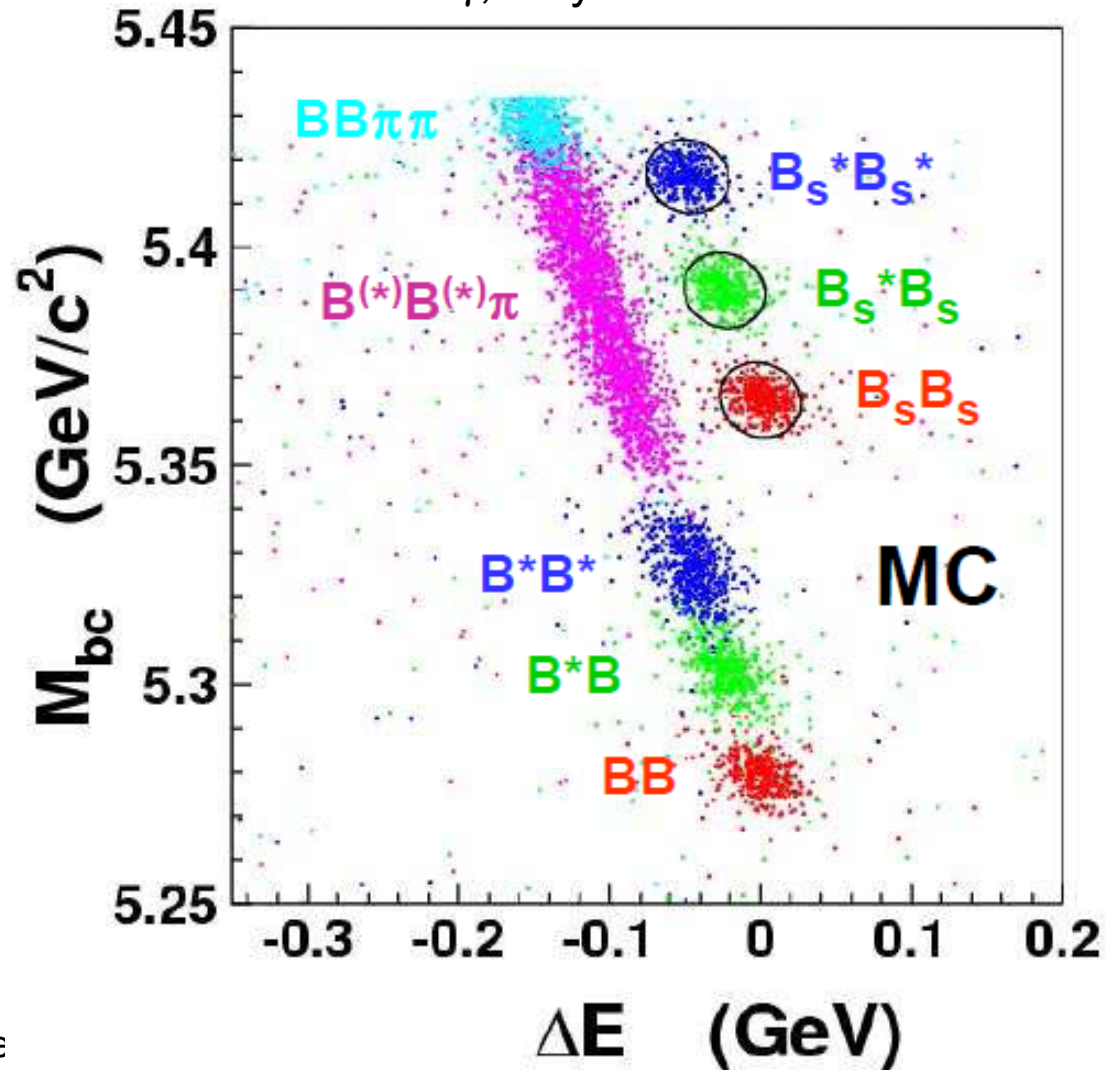
From MC of B_s → D_s⁻ π⁺



Jin Li

$\Upsilon(5S)$ decay to B^0 and B^+

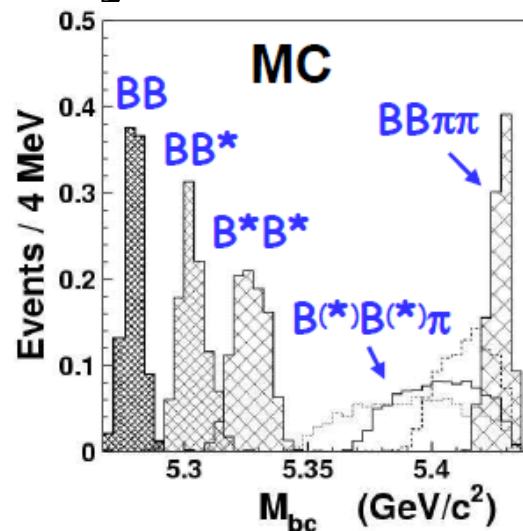
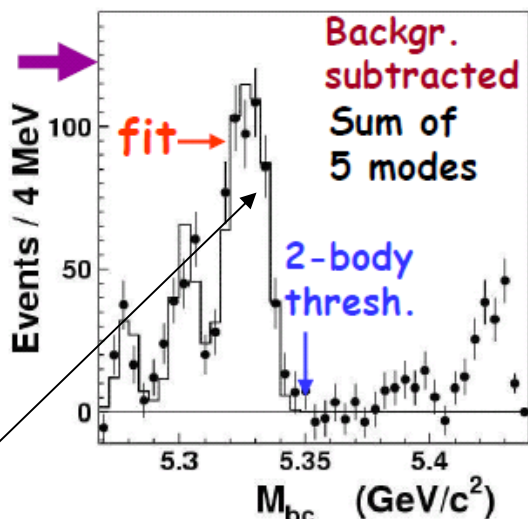
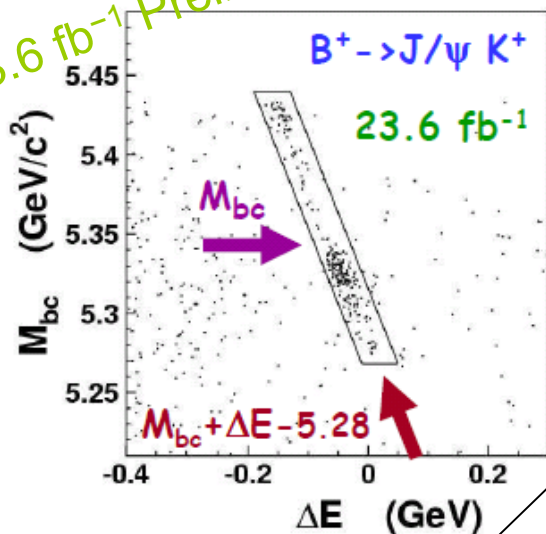
$B \rightarrow B^* \gamma$, only reconstruct B





$\Upsilon(5S)$: large branching fraction to 3/4 body B^{+0} decays

23.6 fb⁻¹ Preliminary



- $B^+ \rightarrow J/\psi K^+$
- $B^+ \rightarrow D^0(K\pi)\pi^+$
- $B^+ \rightarrow D^0(K3\pi)\pi^+$
- $B^0 \rightarrow J/\psi K^{*0}$
- $B^0 \rightarrow D^-(K+\pi^-\pi^-)\pi^+$

$BB:$	$5.1 \pm 0.9 \pm 0.4 \%$
$B^*B:$	$12.6 \pm 1.2 \pm 1.0 \%$
$B^*B^*:$	$34.5 \pm 1.9 \pm 2.7 \%$
$B^{(*)}B^{(*)}\pi(\pi):$	$16.4 \pm 1.6 \pm 1.2 \%$

Not predicted by theory:

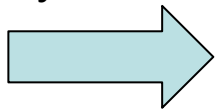
Yu.Simonov et al.,
arxiv:0805.4518

~ 0.03%

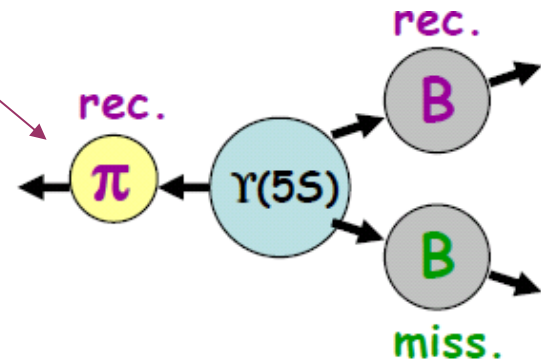
Decompose 3,4 body $B^{(*)}B^{(*)}\pi, BB\pi\pi$

Reconstruct additional π^+

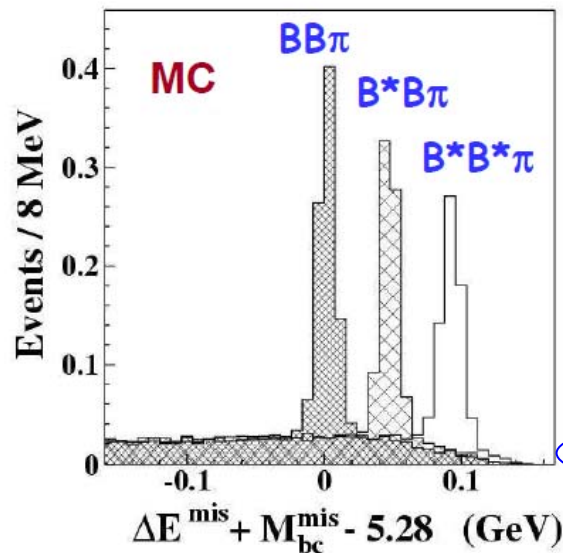
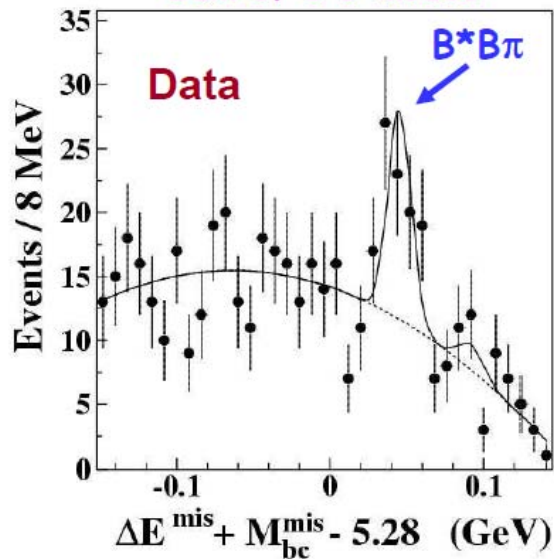
We have **missing** 4-momentum of the B system other than detected B and π



Obtain $\Delta E^{\text{miss}}, M_{bc}^{\text{miss}}$



Sum of 5 B modes



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

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

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

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

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

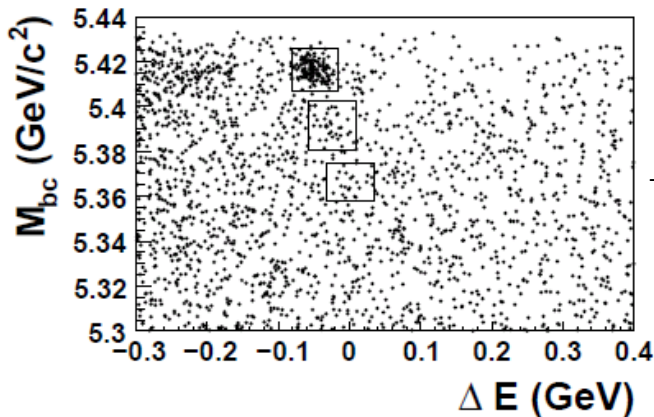
Only B candidates from signal region $M_{bc}^{\text{rec}} > 5.37 \text{ MeV}/c^2$ are used

B_s CKM favored (b→c) decay

B_s decays are poorly known.

- Provide absolute BF as reference point.
- Measure B_s and B_s^{*} properties (m(B_s^{*}), m(B_s)).
- Measure $\Upsilon(5S) \rightarrow B_s^{(*)} B_s^{(*)}$ properties:

$f(B_s^{(*)} B_s^{(*)}) = \Gamma(B_s^{(*)} B_s^{(*)}) / \Gamma(B_s \text{ total})$, B_s angular distribution.



Previous B_s → D_s⁻π⁺ study:

$$\rightarrow \mathcal{B}(B_s \rightarrow D_s^- \pi^+) = (3.67^{+0.35}_{-0.33} \pm 0.65) \times 10^{-3}$$

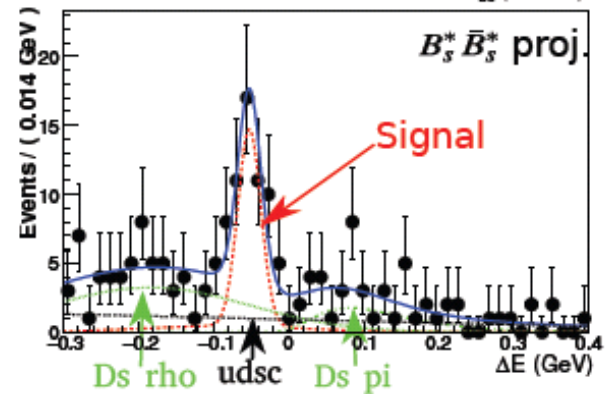
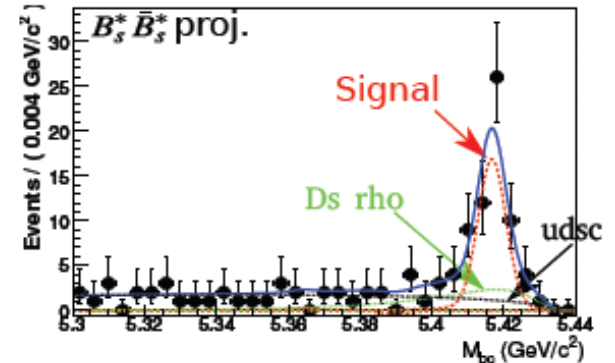
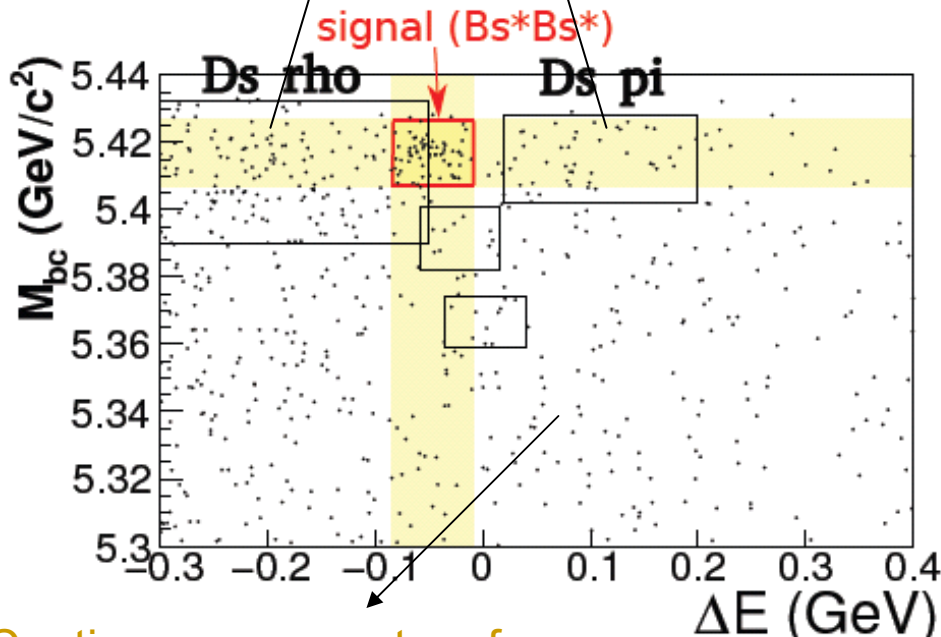
R.Louvot *et al*, PRL102,021801 (2009)

Now: More results from B_s → D_s^{*-}π⁺, D_s^{*(-)}ρ⁺

Observation of $B_s \rightarrow D_s^{*-} \pi^+$

Preliminary

Yields floated, shape from MC



Continuum parameters free

Fit components: Signals + $D_s^- \rho^+$ + $D_s^- \pi^+$ + Continuum

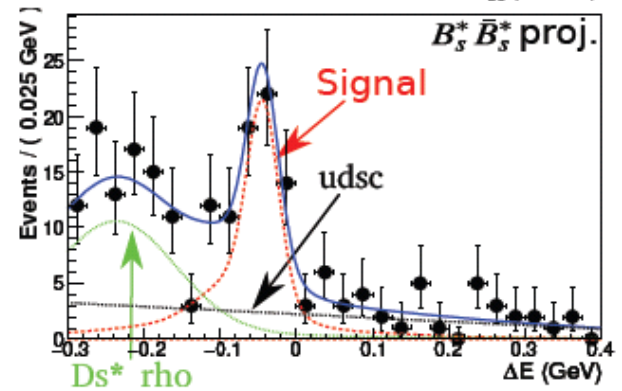
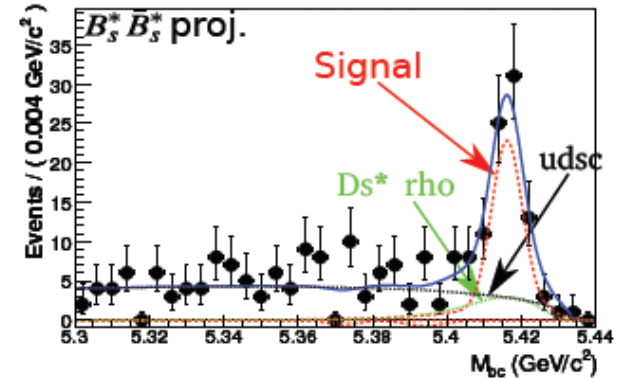
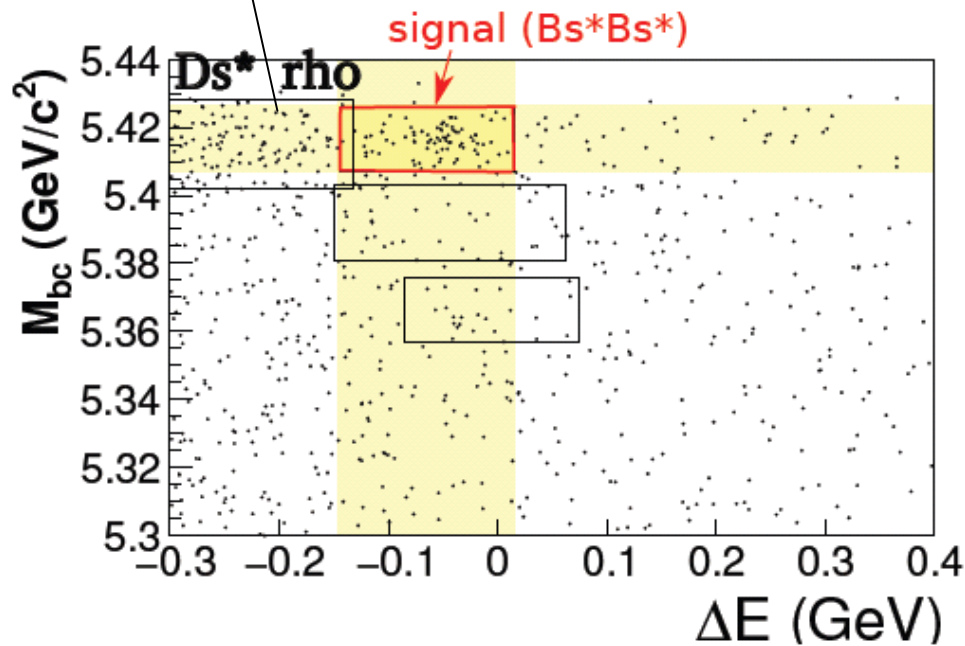
$$N(B_s^* \bar{B}_s^*) = 53.4_{-9.4}^{+10.3} (\text{stat.})_{-2.6}^{+2.4} (\text{fit}) (8.4\sigma)$$

$$\mathcal{B}(B_s^0 \rightarrow D_s^{*-} \pi^+) = (2.4_{-0.4}^{+0.5} (\text{stat}) \pm 0.3 (\text{syst.}) \pm 0.4 (f_s)) \times 10^{-3}$$

Observation of $B_s \rightarrow D_s^- \rho^+$

Preliminary

Yield floated, shape from MC



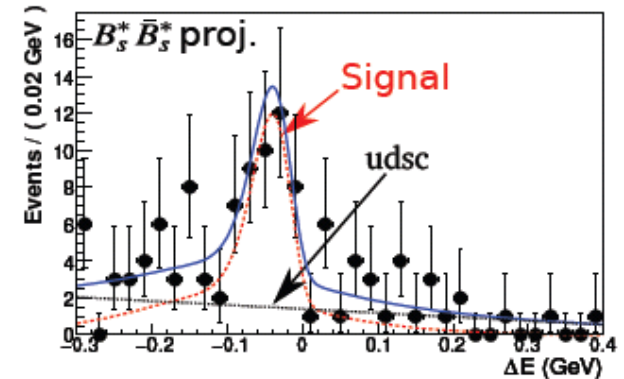
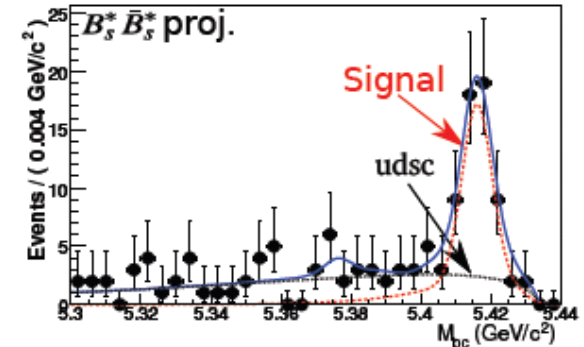
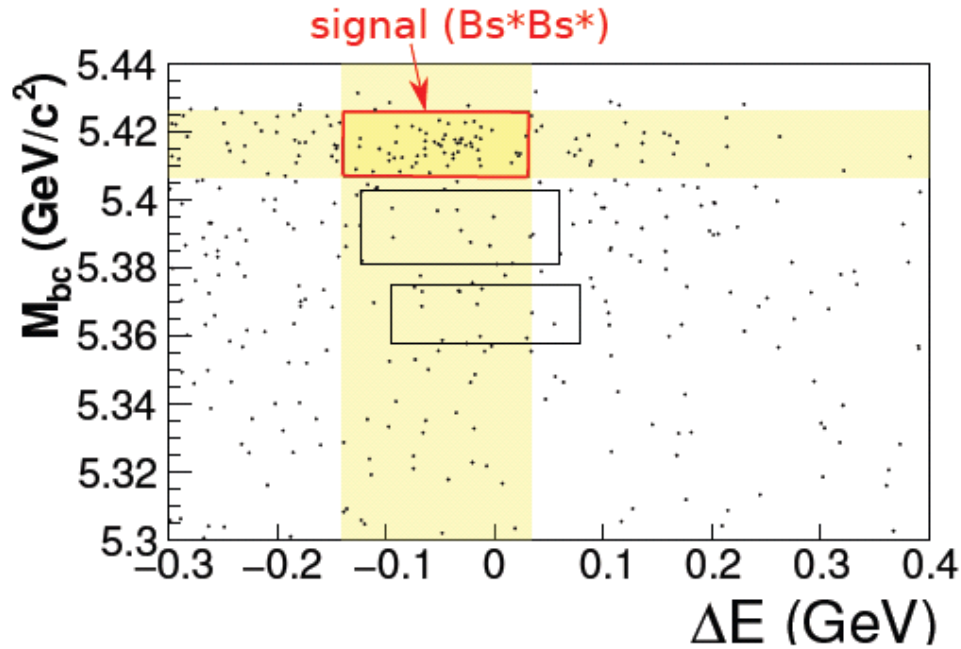
Fit components: Signals + $D_s^* \rho^+$ Continuum

$$N(B_s^* \bar{B}_s^*) = 92.2_{-13.2}^{+14.2} (\text{stat.})_{-4.2}^{+4.3} (\text{fit}) \quad (10.6\sigma)$$

$$\mathcal{B}(B_s^0 \rightarrow D_s^- \rho^+) = (8.5_{-1.2}^{+1.3} (\text{stat.}) \pm 1.1(\text{syst.}) \pm 1.3(f_s)) \times 10^{-3}$$

Observation of $B_s \rightarrow D_s^{*-} \rho^+$

Preliminary



$$N(B_s^* \bar{B}_s^*) = 86.6^{+15.1}_{-14.0} (\text{stat.})^{+3.6}_{-3.5} (\text{fit}) (8.7\sigma)$$

$$\mathcal{B}(B_s^0 \rightarrow D_s^{*-} \rho^+) \quad \text{Polarization as systematics (will be measured)}$$

$$= (13.0^{+2.3}_{-2.1} (\text{stat.}) \pm 1.7 (\text{syst.}) \pm 1.7 (\text{pol.}) \pm 1.9 (f_s)) \times 10^{-3}$$

$B_s \rightarrow hh$, CP eigenstate decay

- BF , A_{dir} , A_{mix} for $B_s^0 \rightarrow K^+ K^- (K^0 \bar{K}^0)$ sensitive to New Physics in $b \rightarrow s$ transition, by comparing to $B_d^0 \rightarrow \pi^+ \pi^-$ in SU(3) limit.

London & Matias, PRD 70, 031502

London, Matias & Virto, PRD 71, 014024

- CPV for $B_s \rightarrow K^+ \pi^-$ directly related to CPV for $B^0 \rightarrow K^+ \pi^-$.

Lipkin, PLB 621, 126.

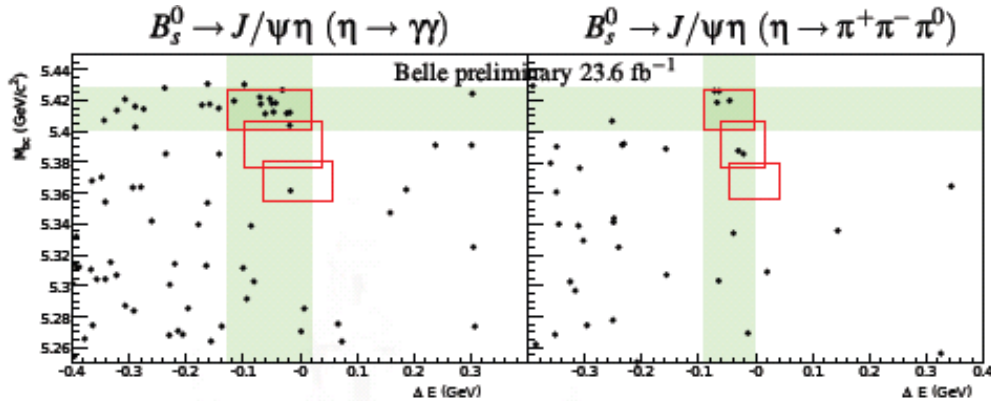
- Pure CP-eigenstate $B_s \rightarrow J/\psi \eta$, $K^+ K^-$ enable direct measurement of mixing and CPV parameters ($\Delta\Gamma_s$, β_s) via lifetime distribution.

Dunietz, Fleischer, Nierste, PRD 63, 114015

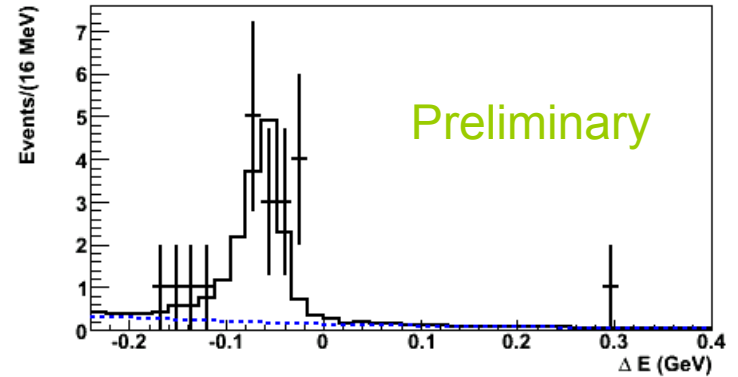
Observation of $B_s \rightarrow J/\psi \eta$

$$\eta = (uu + dd - ss) / \sqrt{3} \Rightarrow$$

$$\mathcal{B}(B_s \rightarrow J/\psi \eta) \approx 1/3 \mathcal{B}(B \rightarrow J/\psi \phi)$$



Projection in $B_s^* B_s^*$ signal region:



$$\mathcal{B}(B_s \rightarrow J/\psi \eta):$$

$$\eta \rightarrow \gamma\gamma \quad 5.9\sigma$$

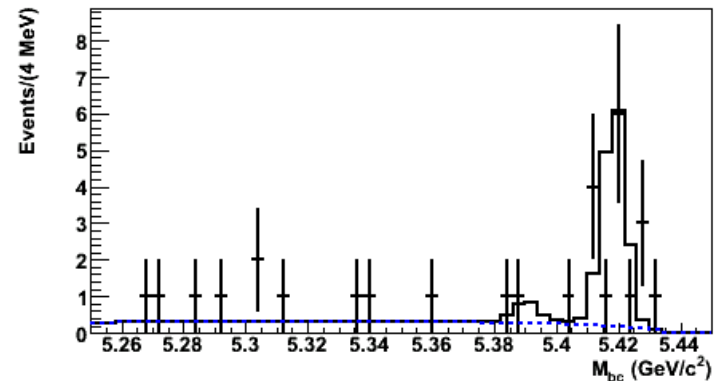
$$(3.44 \pm 1.07(\text{stat.})_{-0.30}^{+0.62} (\text{syst.})) \times 10^{-4}$$

$$\eta \rightarrow \pi^+ \pi^- \pi^0 \quad 4.0\sigma$$

$$(4.60 \pm 2.06(\text{stat.})_{-0.30}^{+0.89} (\text{syst.})) \times 10^{-4}$$

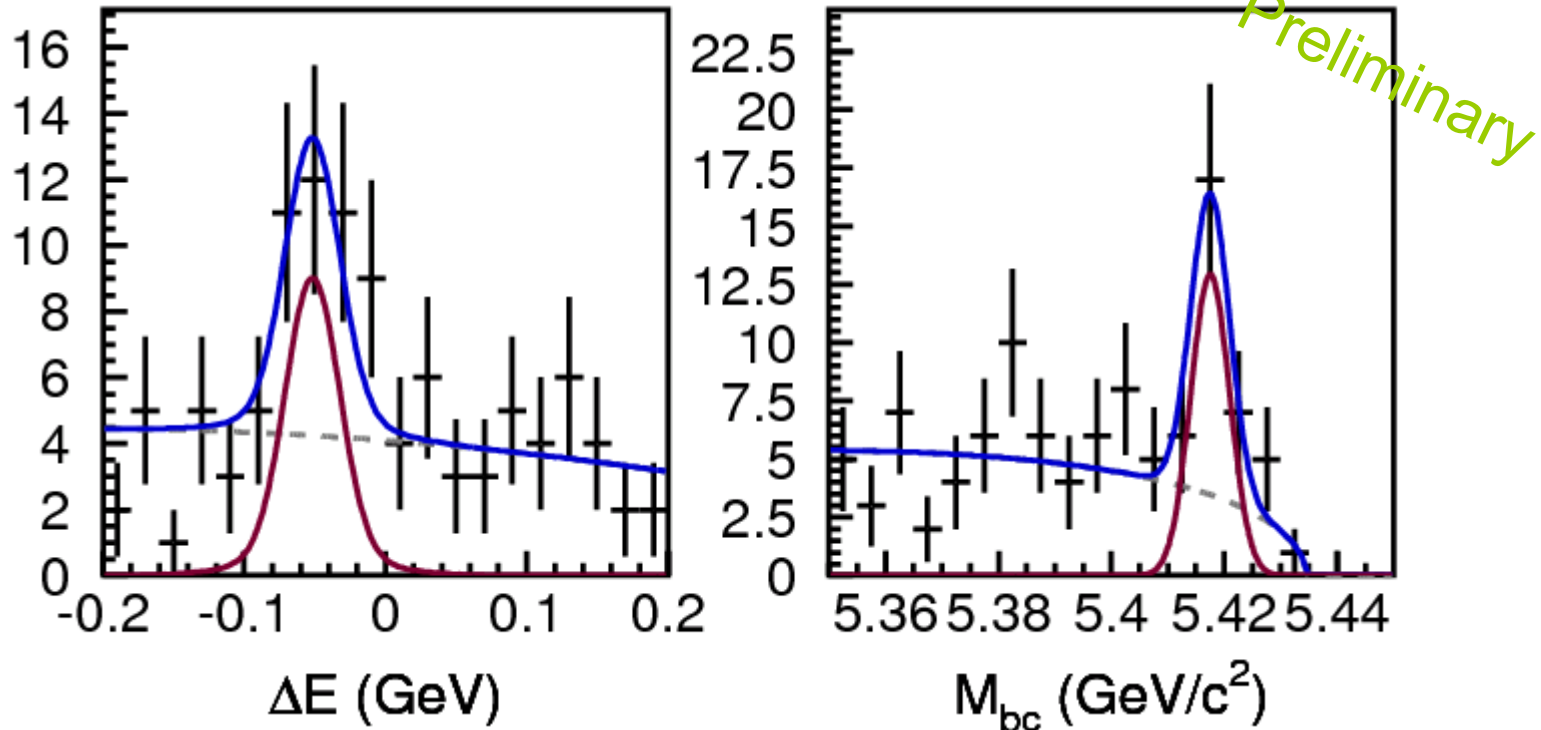
Combined

$$(3.69 \pm 0.95(\text{stat.})_{-0.30}^{+0.65} (\text{syst.})) \times 10^{-4}$$



$B_s \rightarrow hh$: Observation of $B_s \rightarrow K^+K^-$

Continuum BG suppressed by event-shape variables.

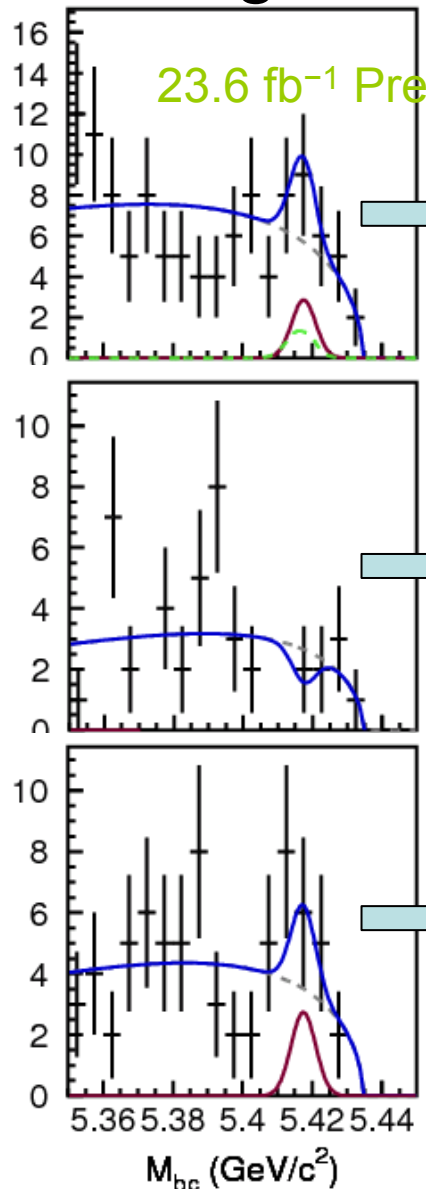
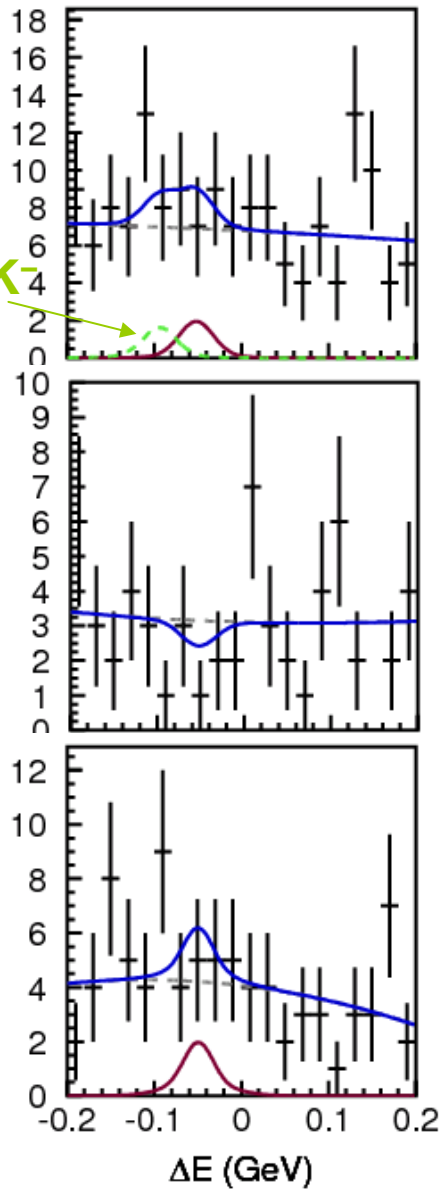


23 ± 6 $B_s \rightarrow K^+K^-$ events observed (5.8σ).

$$\mathcal{B}(B_s^0 \rightarrow K^+K^-) = (3.8_{-0.9}^{+1.0} \pm 0.7) \times 10^{-5}$$

CDF: $(3.3 \pm 0.6 \pm 0.7) \times 10^{-5}$ (PRL97, 211802)

Search for $B_s \rightarrow K^+\pi^-, \pi^+\pi^-, K^0\bar{K}^0$



23.6 fb^{-1} Preliminary

Upper Limits (90% CL):

$$\mathcal{B}(B_s^0 \rightarrow K^+\pi^-) < 2.6 \times 10^{-5} \quad (1.2\sigma)$$

$$\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-) < 1.2 \times 10^{-5}$$

$$\mathcal{B}(B_s^0 \rightarrow K^0\bar{K}^0) < 6.6 \times 10^{-5} \quad (1.2\sigma)$$



Summary

For 23.6 fb^{-1} $\Upsilon(5S)$ data at Belle:

□ First observations in CKM favored B_s decay:

$$\mathcal{B}(B_s^0 \rightarrow D_s^{*-} \pi^+) = (2.4_{-0.4}^{+0.5} (\text{stat}) \pm 0.3 (\text{syst.}) \pm 0.4 (f_s)) \times 10^{-3}$$

$$\mathcal{B}(B_s^0 \rightarrow D_s^- \rho^+) = (8.5_{-1.2}^{+1.3} (\text{stat.}) \pm 1.1 (\text{syst.}) \pm 1.3 (f_s)) \times 10^{-3}$$

$$\mathcal{B}(B_s^0 \rightarrow D_s^{*-} \rho^+) = (13.0_{-2.1}^{+2.3} (\text{stat.}) \pm 1.7 (\text{syst.}) \pm 1.7 (\text{pol.}) \pm 1.9 (f_s)) \times 10^{-3}$$

□ Large BF of $\Upsilon(5S) \rightarrow B^* B \pi$, $B B \pi \pi$ found.

□ $B_s \rightarrow hh$, CP eigenstate decay:

$$\mathcal{B}(B_s^0 \rightarrow J / \psi \eta) = (3.69 \pm 0.95 (\text{syst.})_{-0.95}^{+0.65}) \times 10^{-4} \text{ (First observation)}$$

$$\mathcal{B}(B_s^0 \rightarrow K^+ K^-) = (3.8_{-0.9}^{+1.0} \pm 0.7) \times 10^{-5}$$

$$\mathcal{B}(B_s^0 \rightarrow K^+ \pi^-) < 2.6 \times 10^{-5}$$

$$\mathcal{B}(B_s^0 \rightarrow \pi^+ \pi^-) < 1.2 \times 10^{-5}$$

$$\mathcal{B}(B_s^0 \rightarrow K^0 \bar{K}^0) < 3.3 \times 10^{-5}$$

More results will come from 120 fb^{-1} .

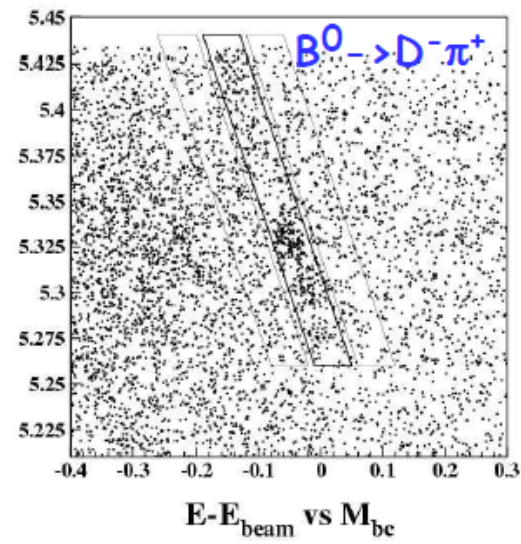
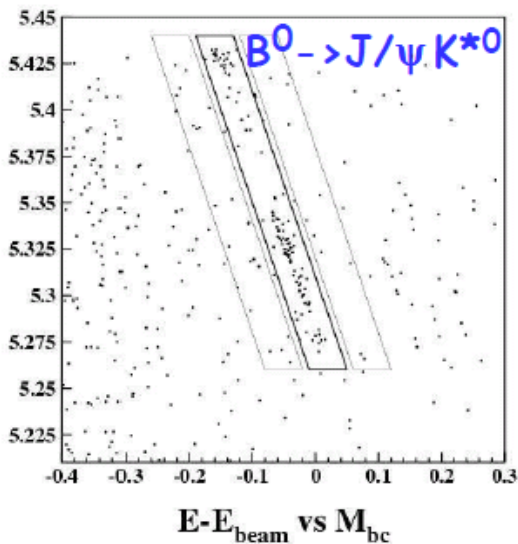
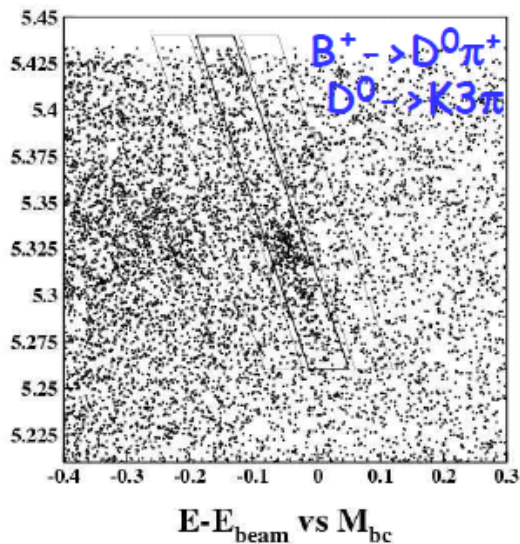
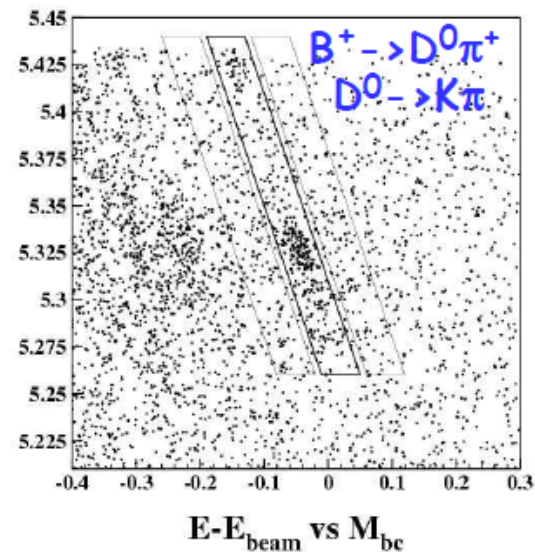
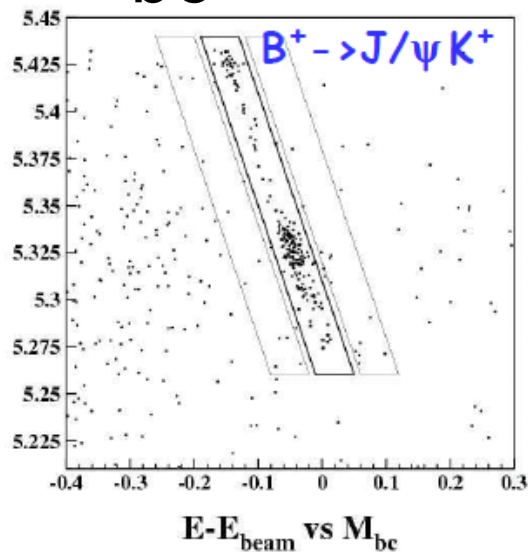
BACKUP

ΔE v.s. M_{bc} distributions

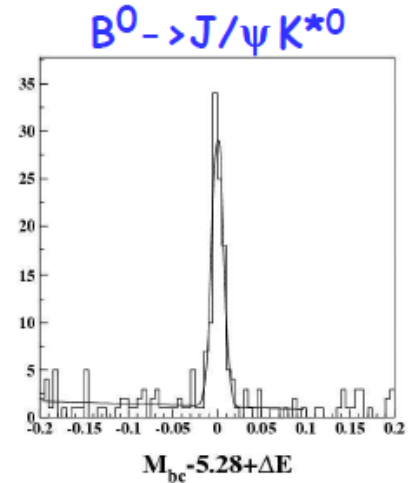
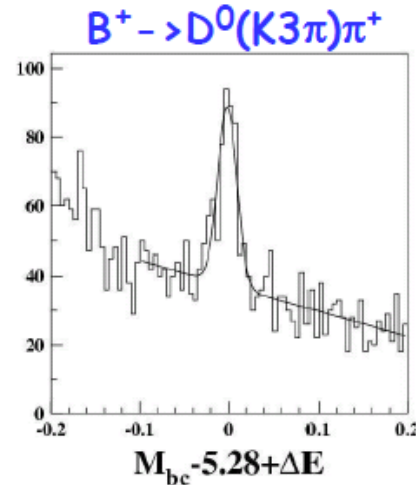
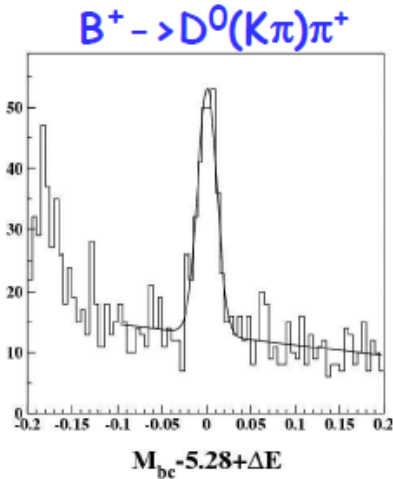
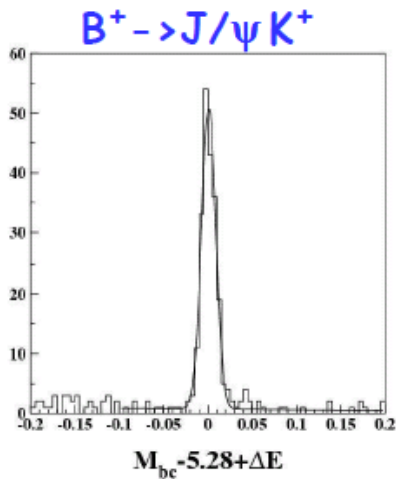
$L=23.6 \text{ fb}^{-1}$, preliminary

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

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



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



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

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

$83.8 \pm 5.9 \pm 7.2 \%$

$67.5 \pm 3.6 \pm 4.8 \%$

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

$59.2 \pm 5.7 \pm 5.1 \%$

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

$68.5 \pm 3.0 \pm 5.0 \%$

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

$77.1 \pm 8.3 \pm 7.8 \%$

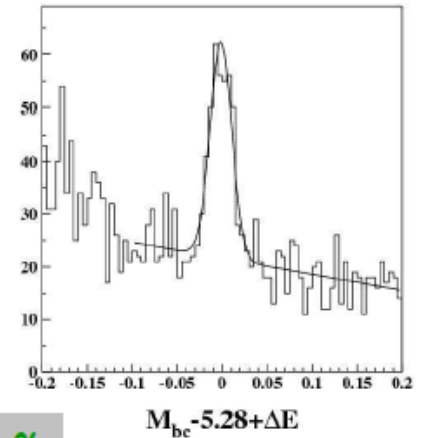
CLEO: $58.9 \pm 10.0 \pm 9.2 \%$

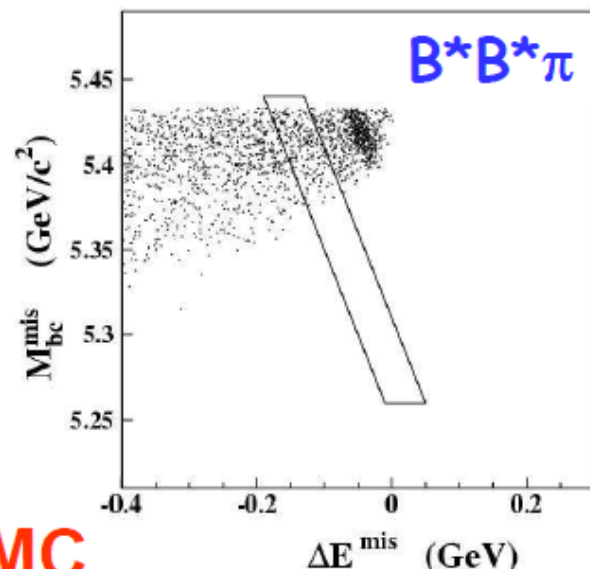
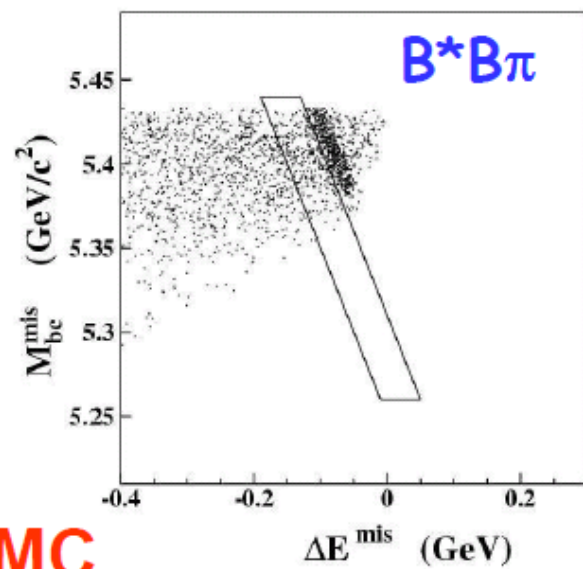
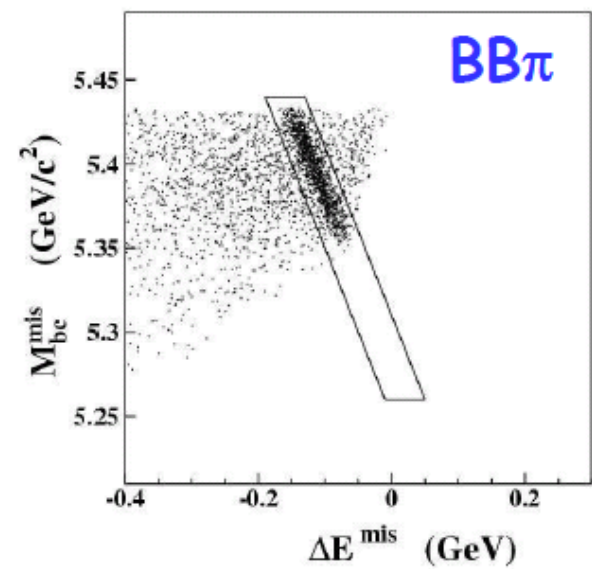
$B^0 \rightarrow D^-(K+\pi^-\pi^-)\pi^+$

$65.3 \pm 6.7 \pm 7.2 \%$

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

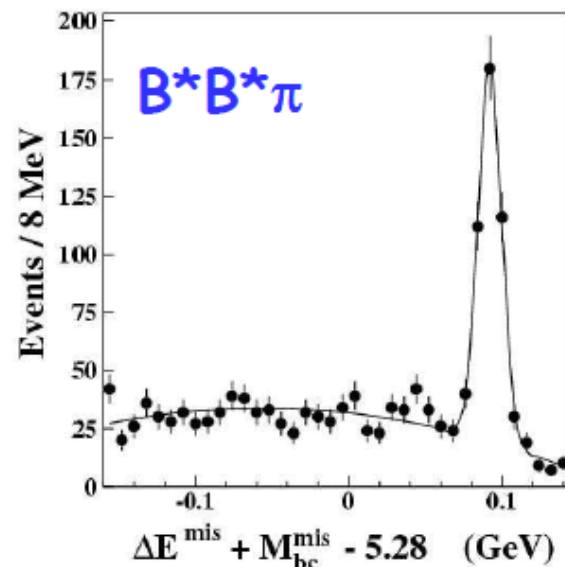
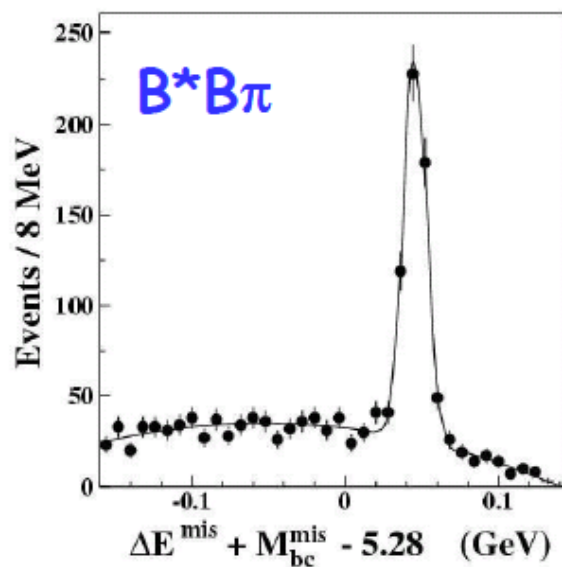
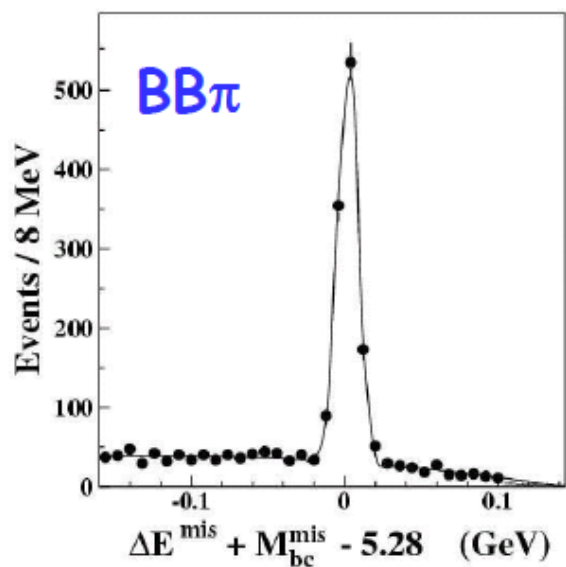
$B^0 \rightarrow D^-(K+\pi^-\pi^-)\pi^+$





MC

MC





Systematic error

 The summary of systematic error study:

(%)	Trk. Eff	KID cut	sig. MC	Ks	LR cut	NBs*Bs*	Signal PDF	Bck PDF	Feed-across	Total
KK	2	1	0.4	0	12.3	15	2.3	0.7	0	19.7
Kπ	2	1	0.5	0	16.5	15	11.2	0.9	9.3	26.9
ππ	2	0.9	0.6	0	21.1	15	10.3	3.9	0	28.2
KsKs	0	0	0.6	9.8	9.5	15	6.8	6.3	0	22.3