Measurement of CPV with $B^0 \to (c\bar{c})K^0$ and $B_s \to J/\psi h^0$ decays

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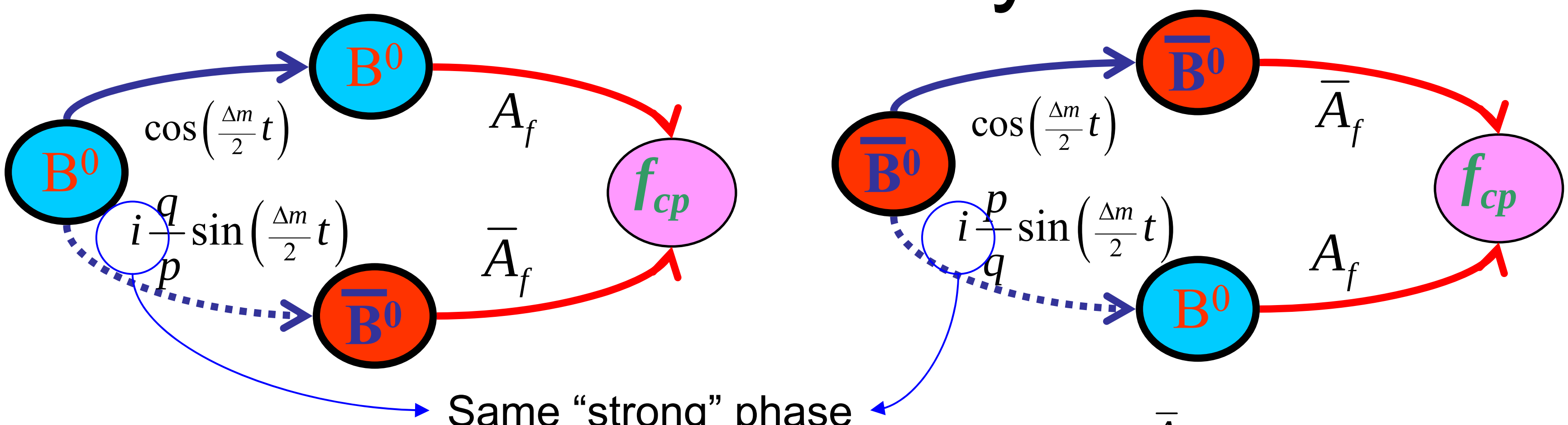
Contents

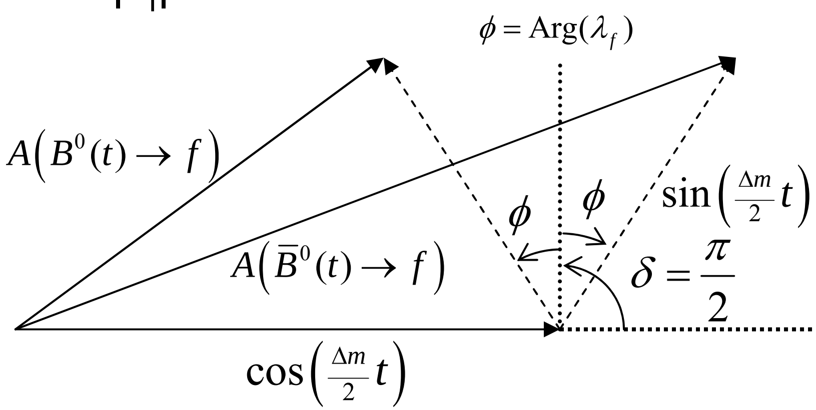
- $\sin(2\phi_1)$ measurements from $b \to c\bar{c}s$ processes.
- $\Upsilon(5S)$ at Belle
  $\Upsilon(5S) \to B_s^* \overline{B_s}^* (\to J/\psi\ h^0)$

Time-dependent CP violation in $c\bar{c}K^0$ decays



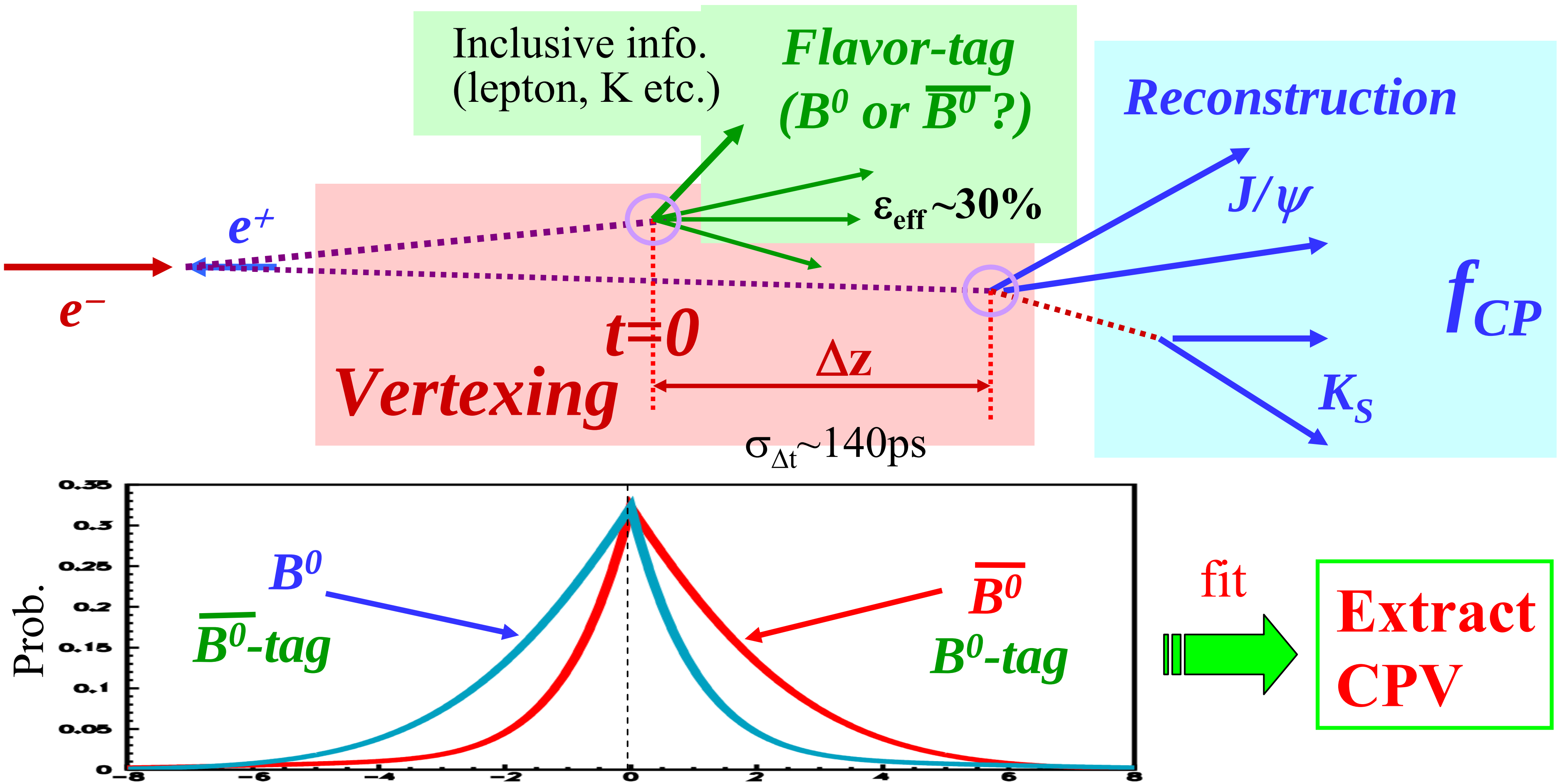
$$\lambda_f = \frac{q\bar{A}_f}{pA_f} = \xi_f e^{-2i\phi_1}$$

Case $|\lambda_f| = 1$



$$A_{CP}(t) = \frac{\Gamma(B^0(t) \to f) - \Gamma(\bar{B}^0(t) \to f)}{\Gamma(B^0(t) \to f) + \Gamma(\bar{B}^0(t) \to f)} = \mathrm{Im}(\lambda_f)\sin(\Delta m t)$$

Measurement method in B-factories



$$\Delta t \approx \Delta z / c\beta\gamma$$

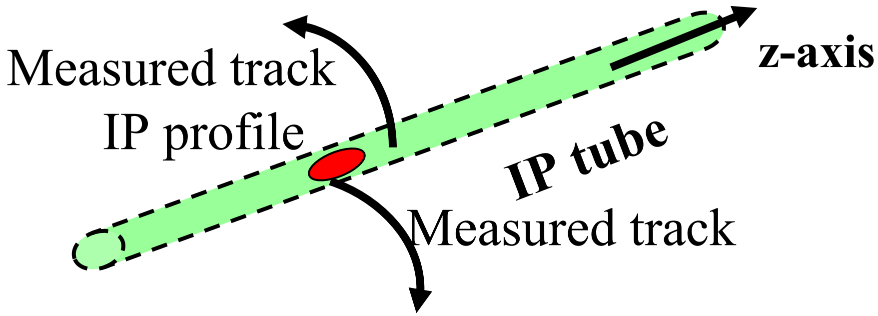
βγ=0.425 (KEKB)
0.56 (PEP-II)

Experimental considerations in Δt distribution

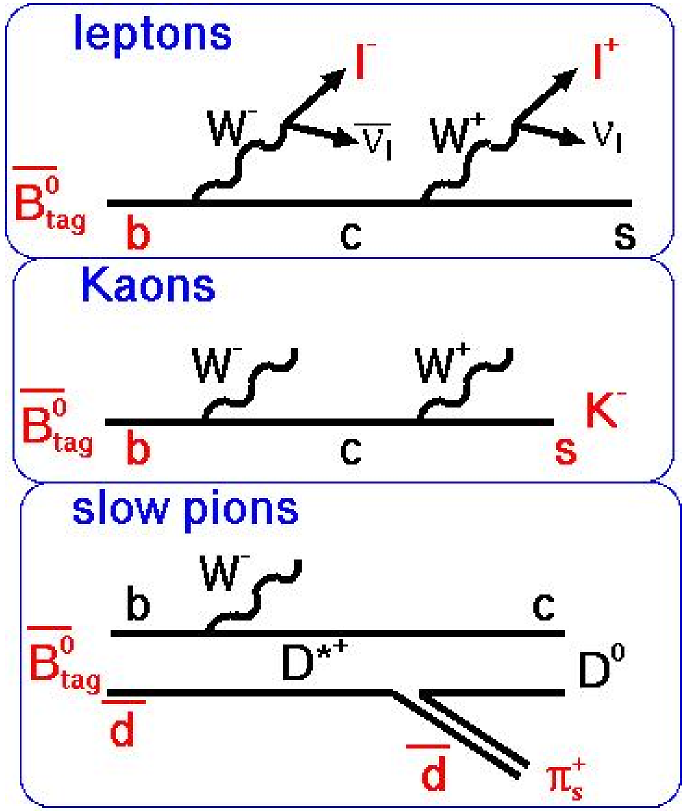
Vertex fit

IP (interaction point) tube constraint fit for B decay vertices

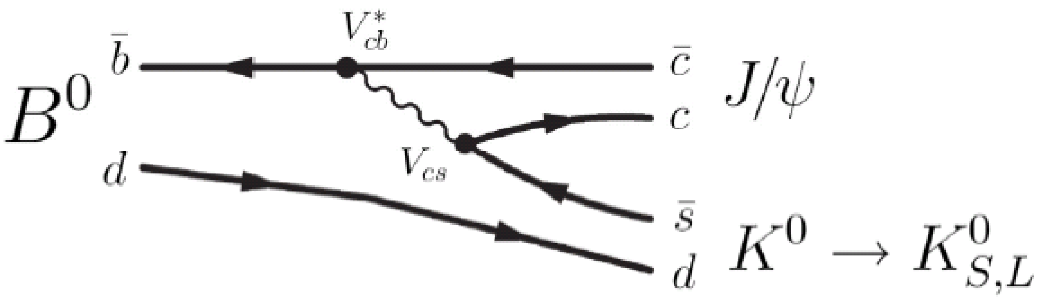
X-Y Size: $\sigma_x \sim 100\mu m$, $\sigma_y \sim 5\mu m \oplus$ B-flight smearing



Flavor Tagging



B →J/ψK⁰ modes

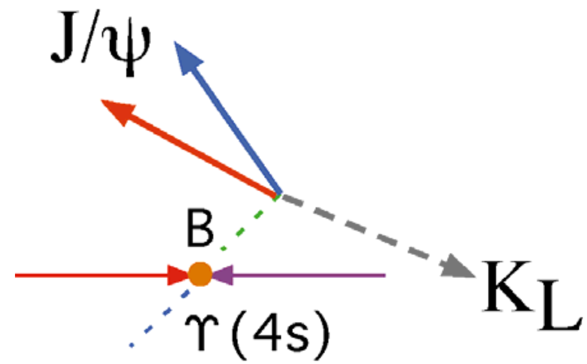


- Theoretically clean
- Clear experimental signatures
- Relatively large BF

$$\lambda_{J/\psi K^0_{S,L}} = \mp e^{-2i\phi_1}$$

$$A^{CP}_{J/\psi K^0_{S,L}}(t) = \mathrm{Im}(\lambda_{J/\psi K^0_{S,L}})\sin(\Delta m t) = \pm \sin 2\phi_1 \sin(\Delta m t)$$

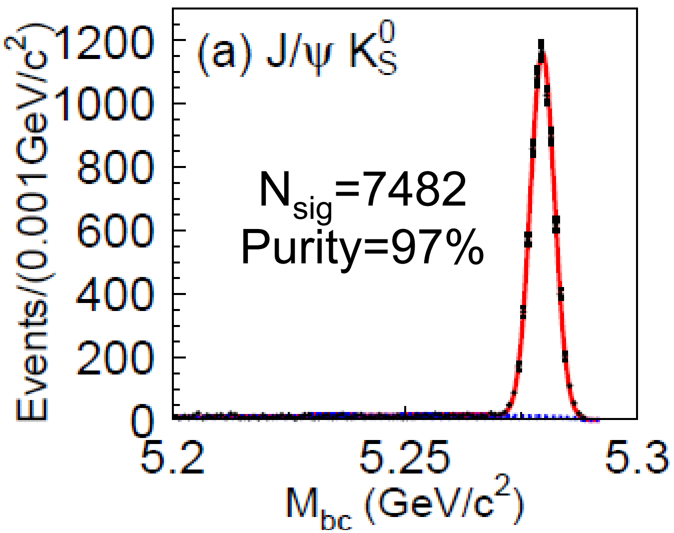
K_L reconstruction



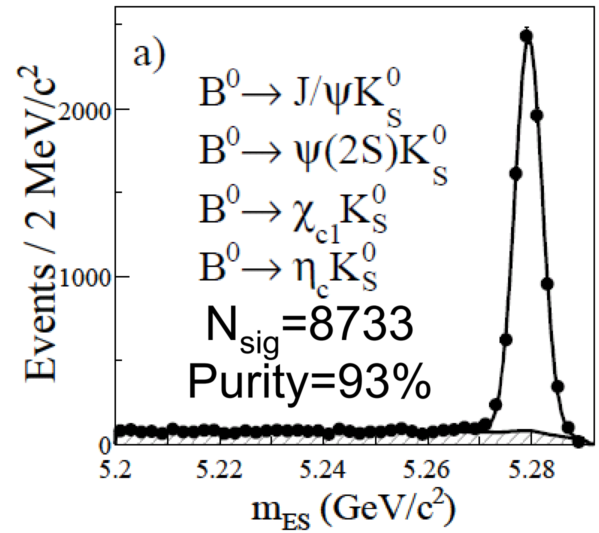
- Only detect direction by KLM (ECL).
- Calculate KL energy using M_B constraint.
- Use p_B^* (B momentum in CMS) to fit.

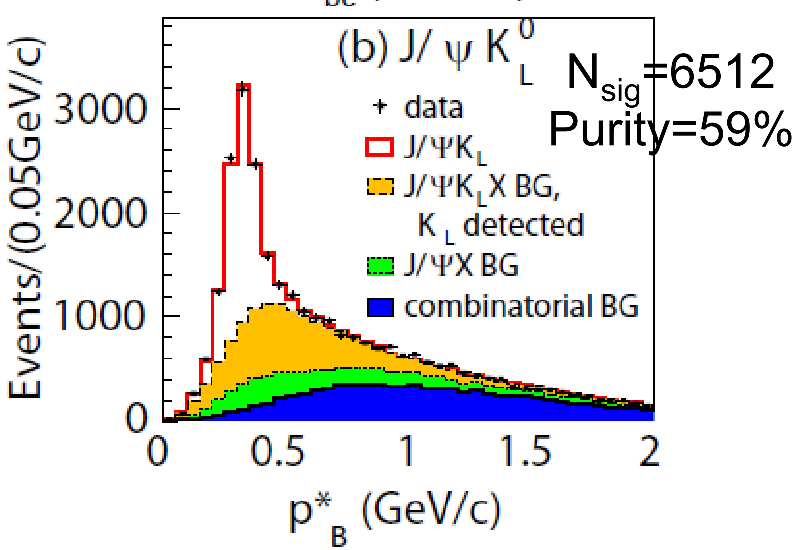
B->J/ψ K^0 events in B-factories

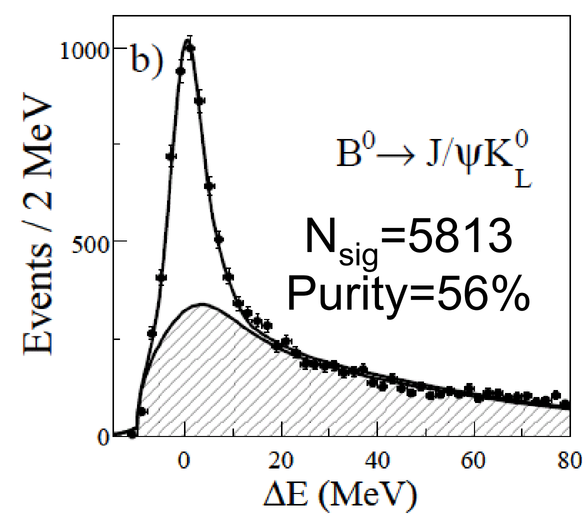
535M $B\bar{B}$



465M $B\bar{B}$



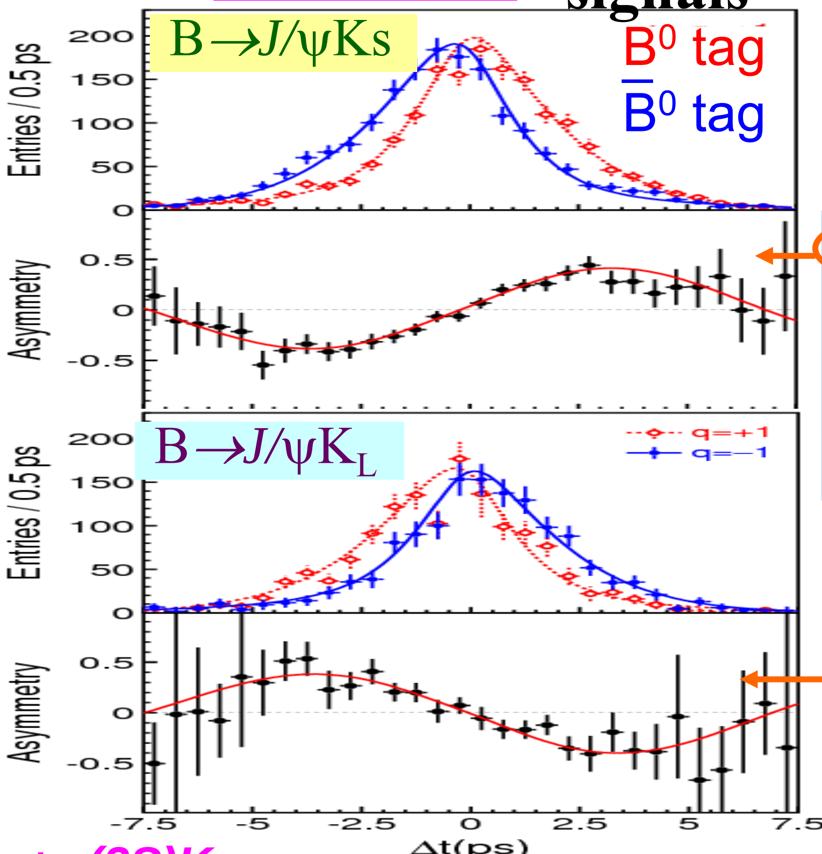




Precise measurement

535M $B\bar{B}$

14000 signals



CP-odd

- $J/\Psi\ K_S$
- $\Psi(2S)\ K_S$
- $\chi_{c1} K_S$
- $\eta_c K_S$

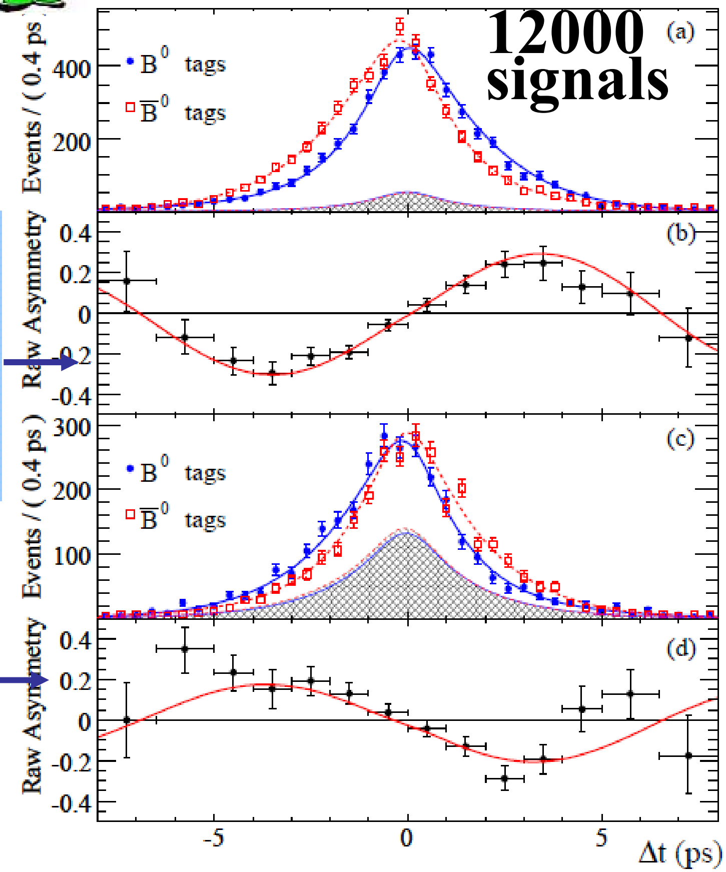
CP-even

- $J/\Psi\ K_L$

465M $B\bar{B}$

$(c\bar{c})K^{(*)0}$

12000 signals



$+\psi(2S)K_S$

$\sin 2\phi_1 = 0.650 \pm 0.029 \pm 0.018$

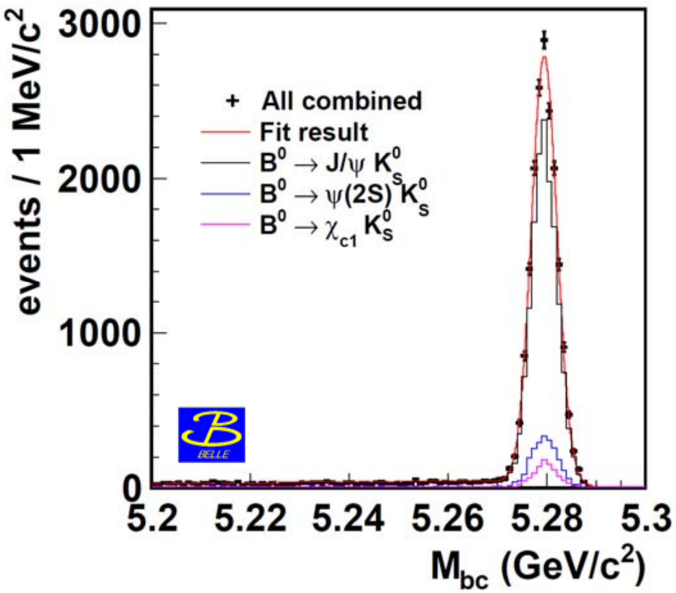
$0.687 \pm 0.028 \pm 0.012$

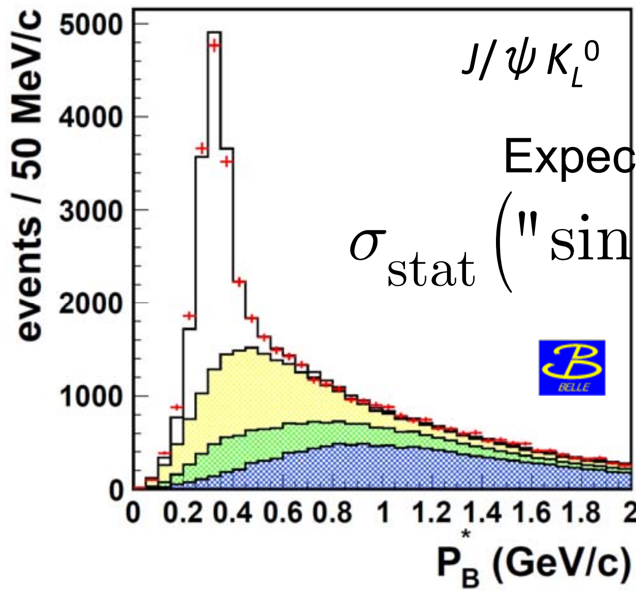
[PRL 98,031802(07)+PRD77 091103(08)]

[PRD 79,072009(2009)]

Coming soon : Final Belle sample

$b \to c\bar{c}s$ **from 772 x 10^6 *BB* pairs = final Belle data sample**





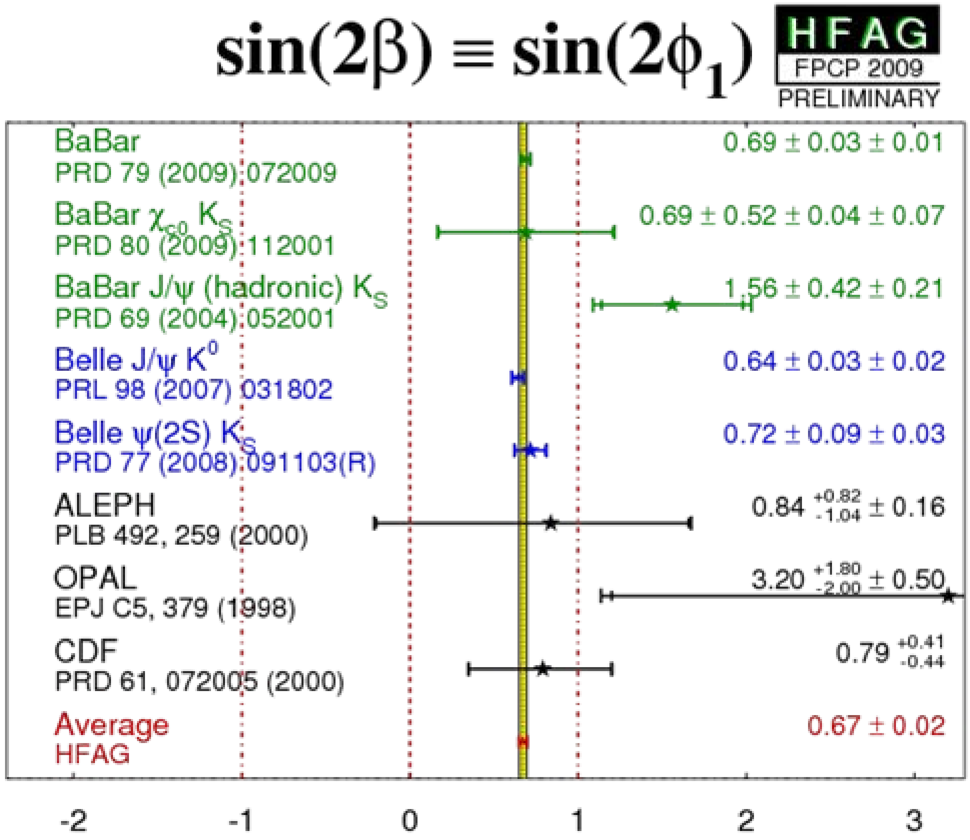
Expected sensitivity:

$$\sigma_{\rm stat}\left(\text{"}\sin 2\phi_1\text{"}\right) \approx 0.024$$

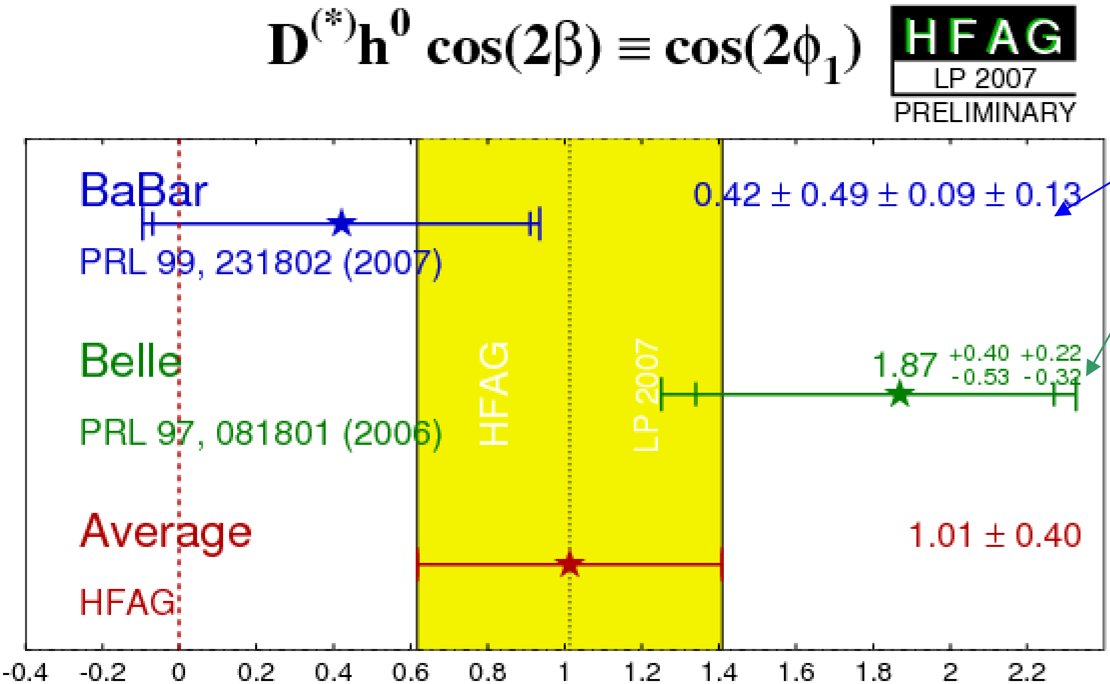
	$J/\psi K_S^0$	$J/\psi K_L^0$	$\psi(2S)K_S^0$	$\chi_{c1}K_S^0$	N_{BB} (x 10^6)
Signal yield ('10)	**12727±115**	**10087±154**	**1981±46**	**943±33**	**772**
Purity ('10) [%]	**97**	**63**	**93**	**89**	
Signal yield ('06)	7484±87	6512±123	–	–	535
Purity ('06) [%]	97	59	–	–	

New tracking software helps to increase signal yield.

$\sin 2\phi_1$ combined

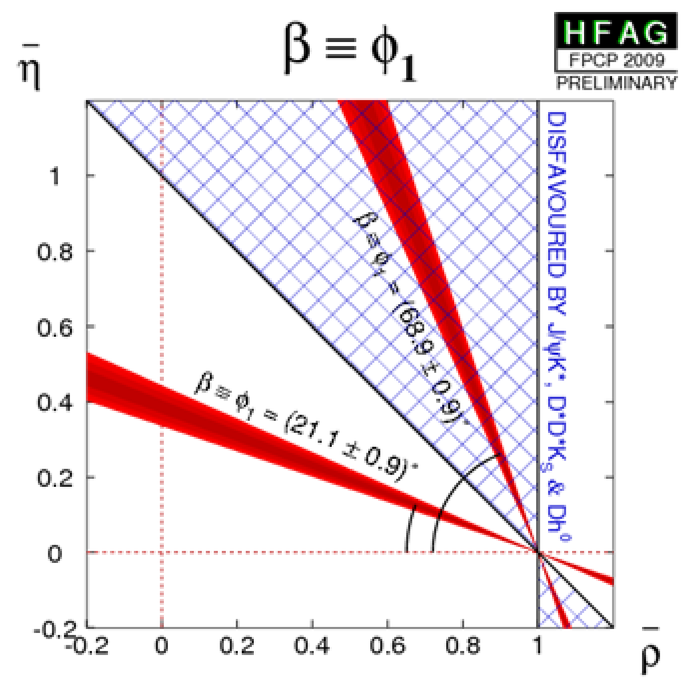


ϕ_1 measurement



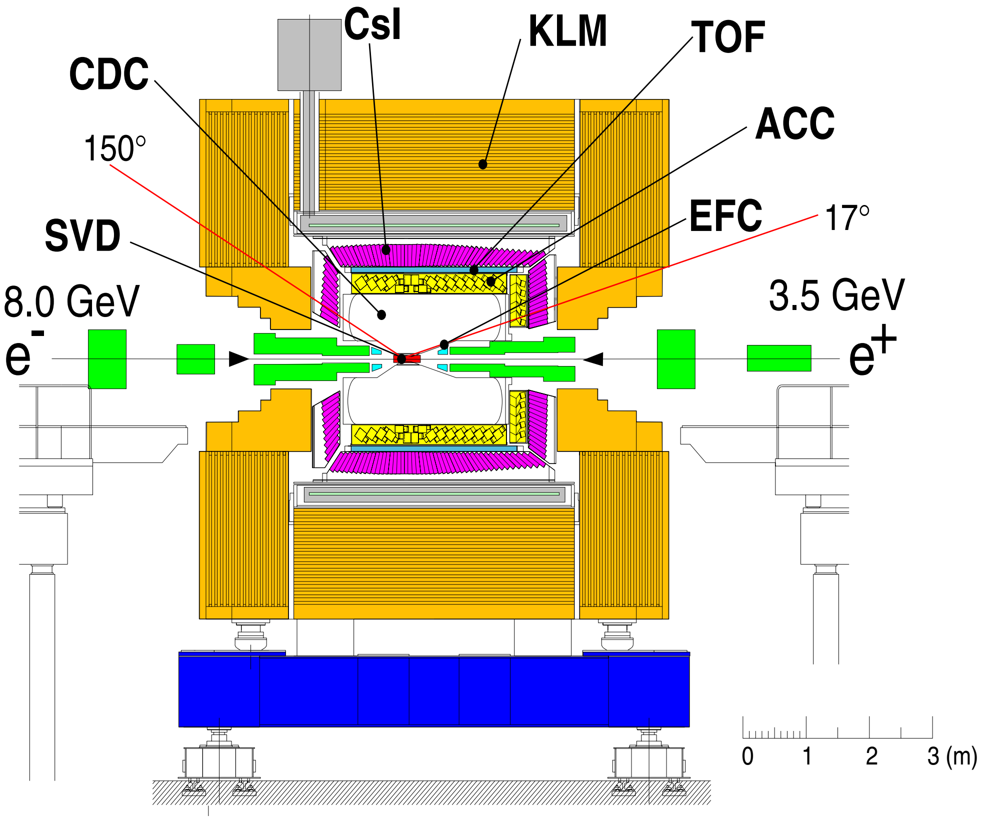
cos $2\phi_1$>0 at 86% C.L.

cos $2\phi_1$>0 at 98.3% C.L.



Other modes $J/\psi\ K^{*0}$ ($K^{*0} \rightarrow K_S\pi^0$), $D^{*+}D^{*-}K_S$ also help.

Belle's large $\Upsilon(5S)$ data sample



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

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

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

2005: 1.86 fb^{-1}

2006: 21.7 fb^{-1}

2008: 27.2 fb^{-1}

2009: 70.8 fb^{-1}

Total: 121 fb^{-1}

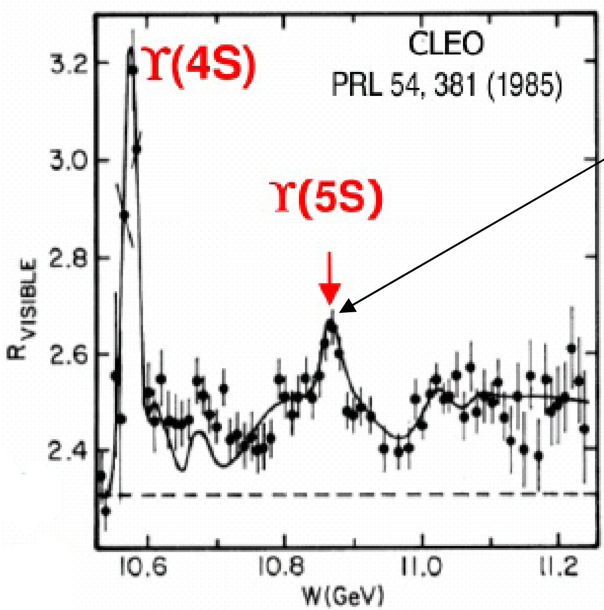
Luminosity record: 2.11×10^{34} $cm^{-2}sec^{-1}$ (Jun, 2009)

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

CLEO 2003: 0.42 fb^{-1}

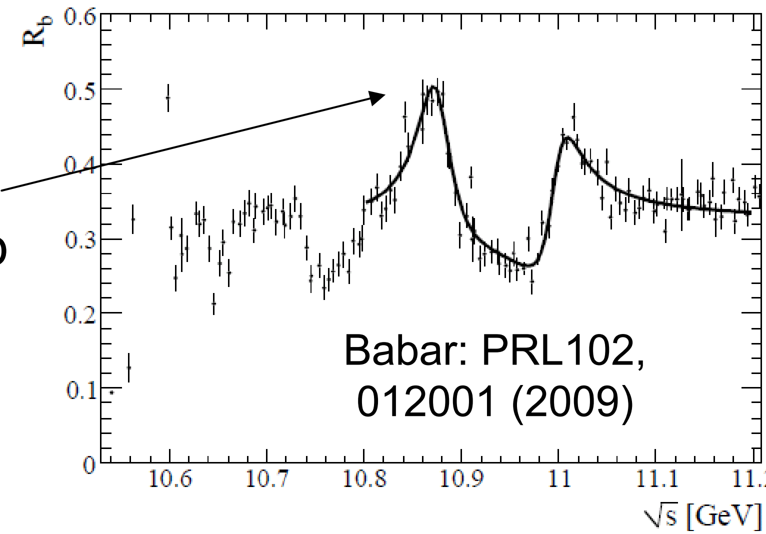
$\Upsilon(5S)$ and B_s

e^+e^- hadronic cross section



$\Upsilon(5S)$:

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



PDG:

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

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

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

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

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

B_s production mechanism

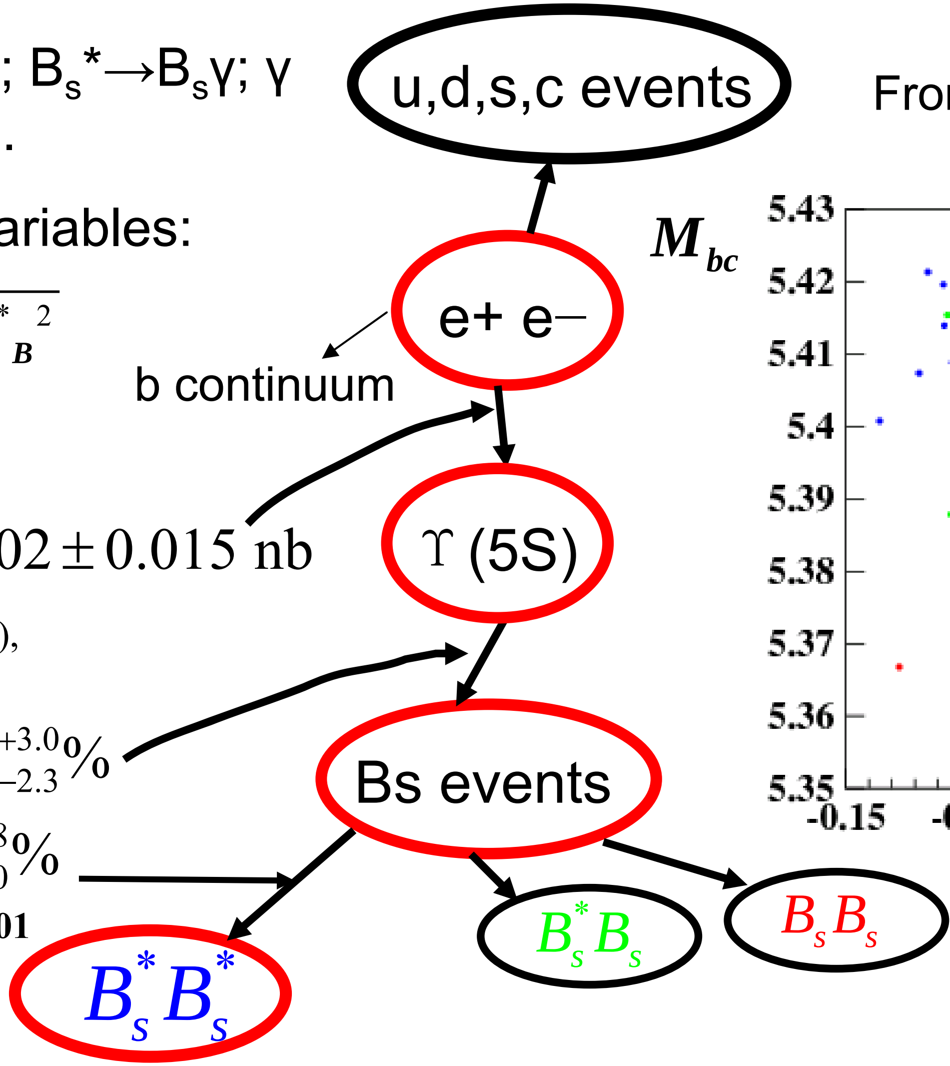
Results from 23.6 fb^{-1} (1.39 M $B_s^{(*)}B_s^{(*)}$ pairs)

- $e^+e^- \to \Upsilon(5S) \to B_s^*B_s^*, B_s^*B_s, B_sB_s$; $B_s^* \to B_s\gamma$; γ not reconstructed.

- Two kinematic variables:

$$M_{bc} = \sqrt{E^{*2}_{beam} - P^{*2}_{B}}$$

$$\Delta E = E^*_B - E^*_{beam}$$



$$\sigma^{5S}_{b\bar{b}} = 0.302 \pm 0.015 \text{ nb}$$

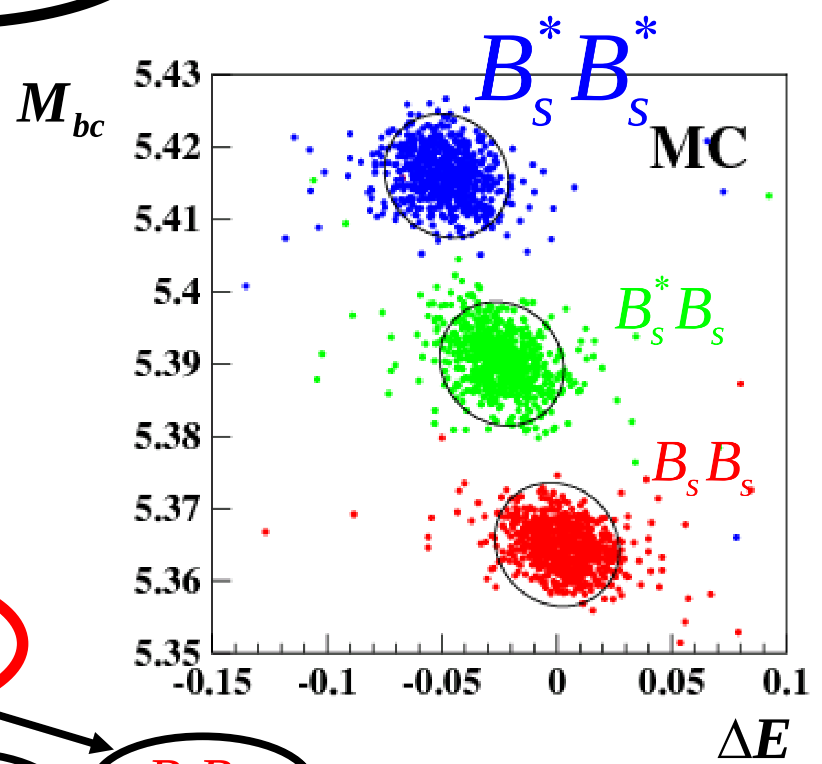
A. Drutskoy et al. (Belle), PRL 98, 052001 (2007)

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

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

PRL 102,021801

From MC of $B_s \to D_s^- \pi^+$



$B_s \to$CP eigenstate decay

•Pure CP-eigenstate $B_s \to J/\psi(\eta('),f_0)$, K^+K^- enable direct measurement of mixing and CPV parameters ($\Delta\Gamma_s$, β_s) via lifetime distribution.

- Dunietz, Fleischer, Nierste, PRD 63,114015

•$\Delta\Gamma/\Gamma$ is accessible without the need of tagging Bs mesons.

•Unlike $J/\psi\Phi$, no need to disentangle CP eigenstates using angular distribution.
•Neutral detection is clean in e^+e^- environment.
•Quantum-correlated B_s pairs make it possible to measure just using single CP eigenstate to obtain $\Delta\Gamma$.

Compared to hadron collider.

B_s Time distribution (1)

Master Equation for untagged quantum correlated B_s decay time difference Δt

$$\Gamma(B(t)\to f) = \frac{\Gamma(B\to f)}{2} e^{-|\Delta t|\Gamma} \left\{ (1+|\lambda|^2)\cosh\frac{\Delta\Gamma\Delta t}{2} + 2\,\mathrm{Re}(\lambda)\sinh\frac{\Delta\Gamma\Delta t}{2} \right\}$$

$$\lambda = \frac{q\bar{A}_f}{pA_f} = \eta_f e^{-i\phi}$$

$$\phi = -2\beta_s = -2\arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$

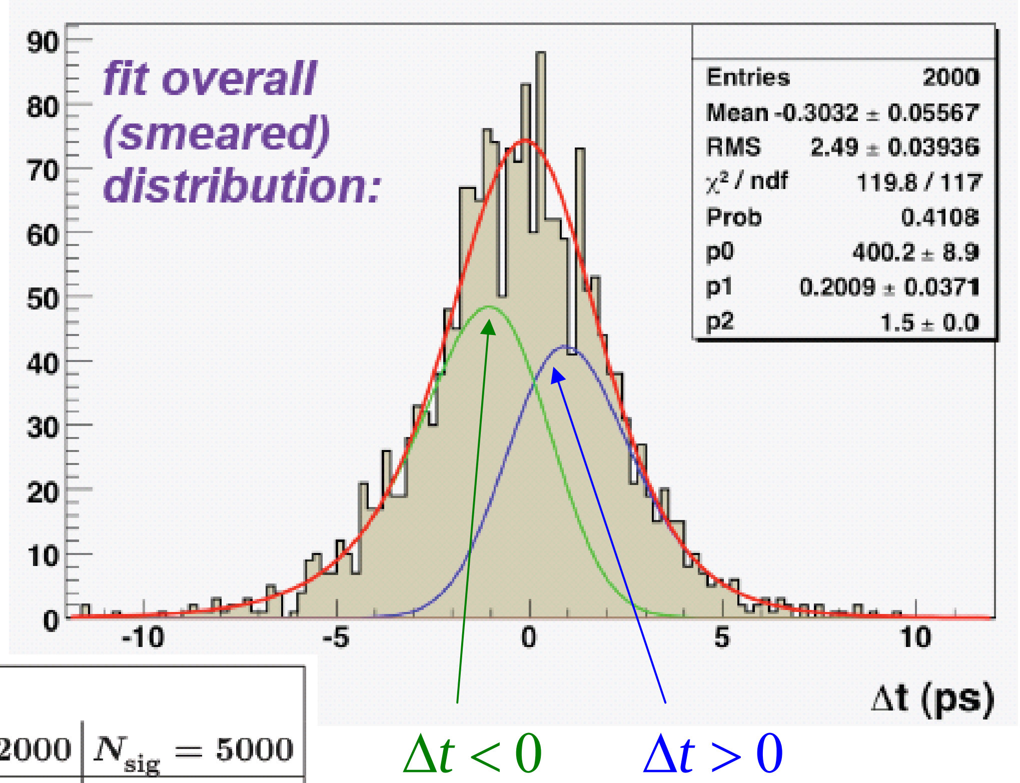
$$|\langle f_{CP+} \mid B_s^0 \rangle|^2 = \begin{cases} e^{-\left(\Gamma+\frac{\Delta\Gamma\cos\phi}{2}\right)\Delta t} \approx e^{-\Gamma_H \Delta t} & \Delta t < 0 \\ e^{-\left(\Gamma-\frac{\Delta\Gamma\cos\phi}{2}\right)\Delta t} \approx e^{-\Gamma_L \Delta t} & \Delta t > 0 \end{cases}$$

B_s Time distribution (2)

Toy MC study

$$\left|\left\langle f_{CP+} \mid B_s^0 \right\rangle\right|^2 = \begin{cases} e^{-\Gamma_H \Delta t} & \Delta t < 0 \\ e^{-\Gamma_L \Delta t} & \Delta t > 0 \end{cases}$$

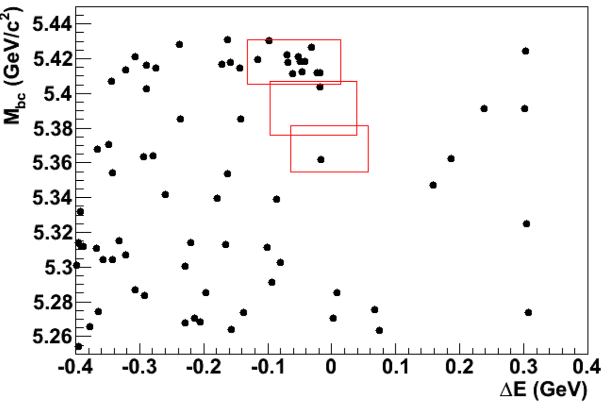
~ 300 fb^{-1} $\Upsilon(5S)$ data, using pure CP $J/\psi(\eta,\eta',f_0)$,DsDs (40 events in 23.6 fb^{-1})



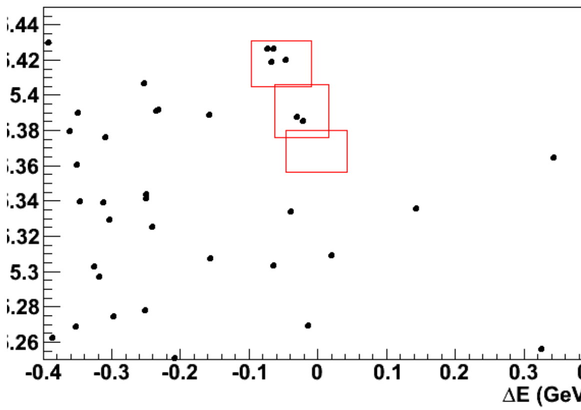
	$\delta(\Delta\Gamma/\Gamma)\times 100$			
	$N_{sig}=500$	$N_{sig}=1000$	$N_{sig}=2000$	$N_{sig}=5000$
$S/B=0.40$	7.45 ± 0.17 (7.42 ± 0.17)	5.25 ± 0.12 (5.21 ± 0.12)	3.80 ± 0.09 (3.69 ± 0.08)	2.42 ± 0.05 (2.29 ± 0.05)
$S/B=1.0$	6.88 ± 0.15 (6.89 ± 0.15)	4.91 ± 0.11 (4.66 ± 0.10)	3.38 ± 0.08 (3.53 ± 0.08)	2.18 ± 0.05 (2.17 ± 0.05)
$S/B=2.0$	6.62 ± 0.15 (6.63 ± 0.15)	4.70 ± 0.11 (4.62 ± 0.10)	3.24 ± 0.07 (3.30 ± 0.07)	2.09 ± 0.05 (2.04 ± 0.05)

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

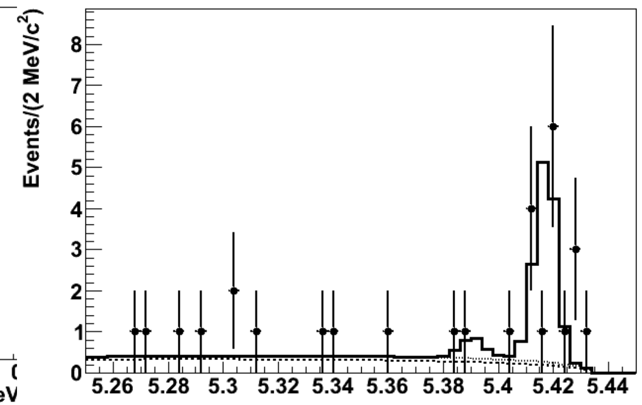
$\eta \to \gamma\gamma$

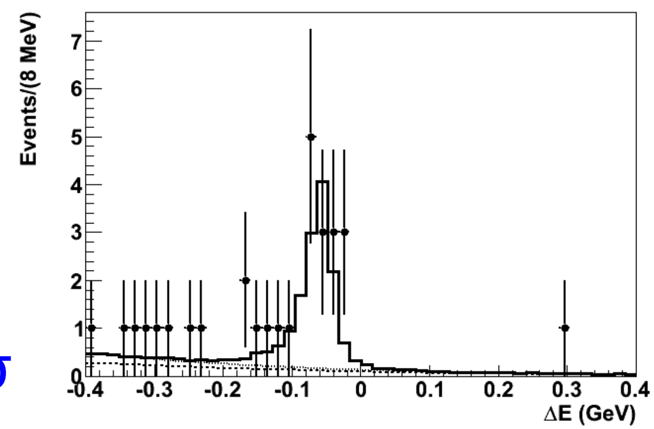


$\eta \to \pi^+\pi^-\pi^0$



combined





First observation

Simultaneous fit to two η decays.

Little background from continuum and B → J/ψ X

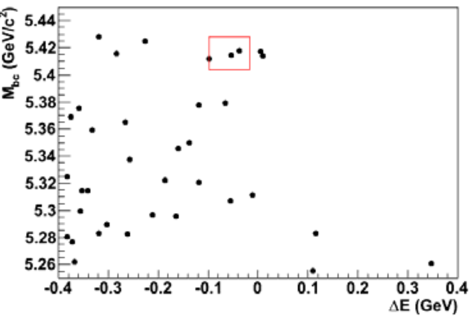
15±4 events in the $B_s^*B_s^*$ region, 7.3σ

$$\mathcal{B}(B_s^0 \to J/\psi\eta) = (3.32 \pm 0.87(\text{syst.})^{+0.32}_{-0.28} \pm 0.42(f_s)) \times 10^{-4}$$

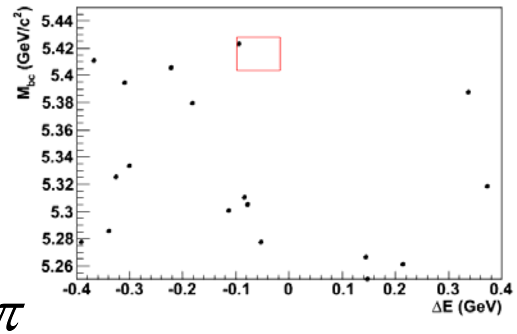
arXiv:0912.1434 (2009); 23.6 fb^{-1}

Evidence for $B_s \to J/\psi\eta'$

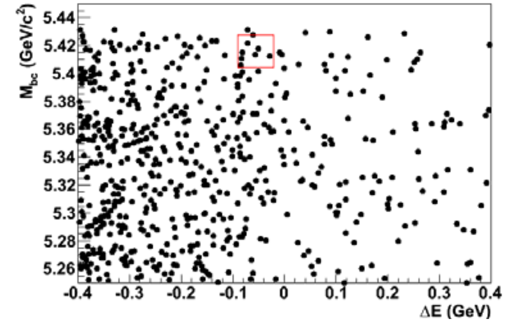
$\eta' \to \eta(\gamma\gamma)\pi\pi$



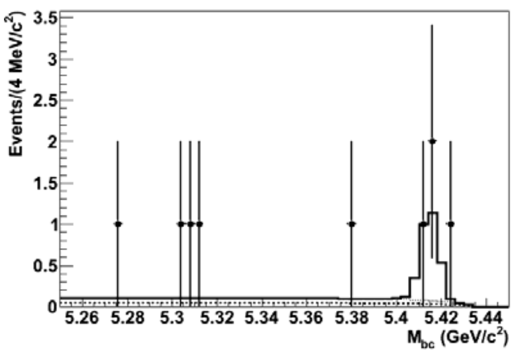
$\eta' \to \eta(\pi\pi\pi^0)\pi\pi$

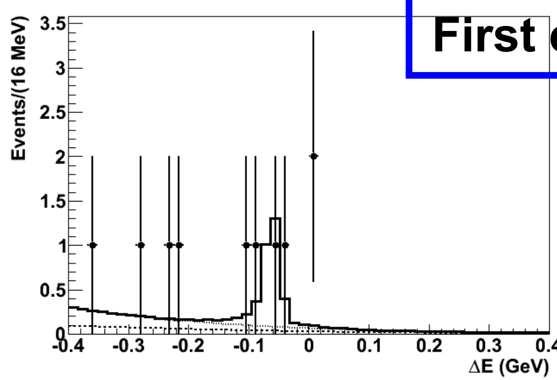


$\eta' \to \rho^0\gamma$

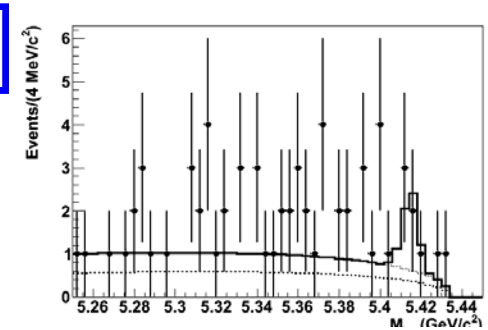


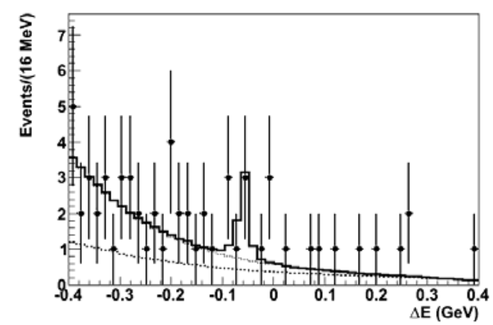
$\eta' \to \eta\pi\pi$





First evidence





Simultaneous fit to 3 η’ sub modes.

11±5 events in the $B_s^*B_s^*$ region, 3.8 σ

$$\mathcal{B}(B_s^0 \to J/\psi\eta') = (3.1 \pm 1.2(\text{syst.})^{+0.5}_{-0.6} \pm 0.38(f_s)) \times 10^{-4}$$

arXiv:0912.1434 (2009); 23.6 fb^{-1}

$B_s \to J/\psi f_0(980)$

- Extrapolation from $B_s \to J/\psi\Phi$

$$\frac{\mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-)}{\mathcal{B}(B_s^0 \to J/\psi\phi)\mathcal{B}(\phi \to \pi^+\pi^-)}$$

$$\approx 0.2 - 0.3$$

Stone et al., PRD79, 074024 (2009)

$$= 0.42 \pm 0.11$$

CLEO D_s+ -> $f_0 e^+ \nu$, PRD80,052009 (2009)

CDF: $B(B_s \to J/\psi\Phi\ ;\ \Phi \to K^+K^-) = (6.4\pm2.0)\times10^{-4}$

$\Rightarrow B(B_s \to J/\psi f_0\ ;\ f_0 \to \pi^+\pi^-) =$ **$(1.3\text{-}2.7)\times10^{-4}$**

- Theory (QCD @ LO)

$B(B_s \to J/\psi f_0; f_0 \to \pi^+\pi^-) = (3.4\pm2.4)\times10^{-4} \cdot (50^{+7}_{-9})\%$

QCD(LO), PRD81,074001 (2010)

BES, PRD80, 052009 (2009)

= **$(1.6\pm0.3)\times10^{-4}$**

Strategy to fit

In Mbc signal region:

- We choose a reduced ΔE region (avoid B^0,B^+ band) :
  -0.1 GeV< ΔE<0.20 GeV.
  - To get rid of correlations, and reduce yields in $B_s \to J/\psi\phi$, $J/\psi\eta$.
  - To reduce correlations in $B_s \to J/\psi\eta'$.
  - To remove $J/\psi K_S$, $J/\psi\rho^0$,$J/\psi\pi^+\pi^-$ BG.

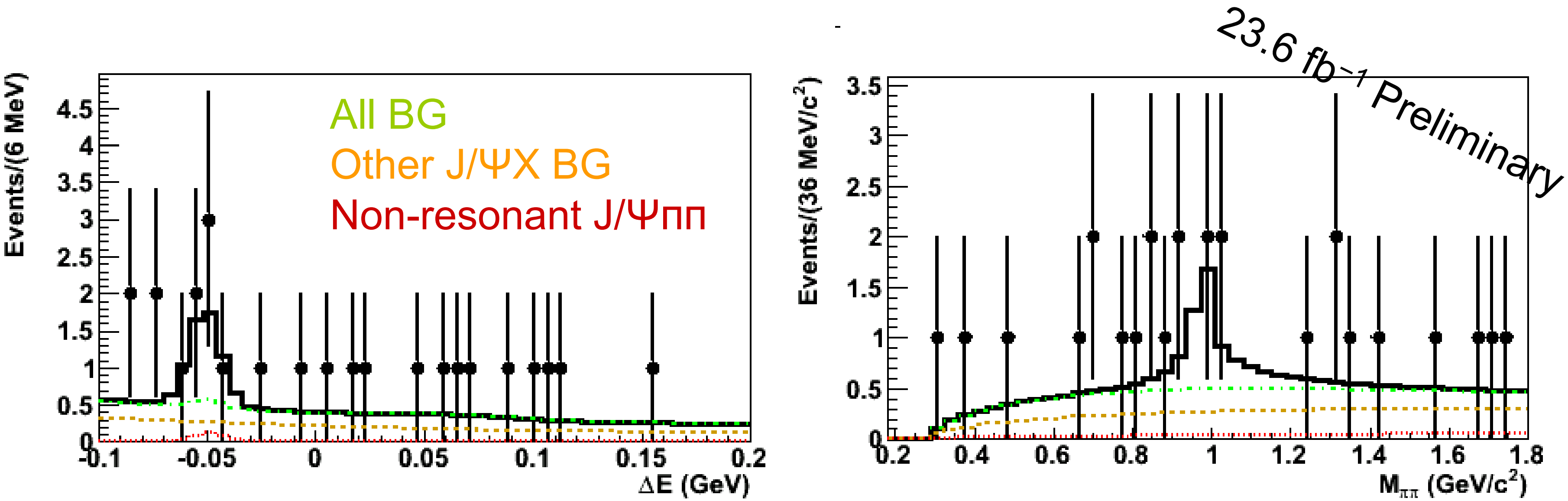
Fit region

-0.1 GeV< ΔE<0.20 GeV, $m(\pi^+\pi^-)$<1.8 GeV,

- The **final background categories** in fitting:
- $Bs \to J/\psi\eta'$.
- Non-resonant $Bs \to J/\psi\pi^+\pi^-$.
- $J/\psi K^+$, $J/\psi\pi^+$.
- Other $J/\psi X$ BG (does not peak in ΔE and $m(\pi^+\pi^-)$), no correlation)
- Continuum BG.

$B_s \to J/\psi f_0(980)$ Results

2D fit to ΔE and $m(\pi^+\pi^-)$



6.0±4.4 events

1.6σ

$$\mathcal{B}(B_s^0 \to J/\psi\, f_0)\mathcal{B}(f_0 \to \pi^+\pi^-) < 1.63\times10^{-4}\ (90\%\ \mathrm{CL})$$

update with 5 times more data (121 fb^{-1}) on going

Summary

- $\sin(2\phi_1)$ measurements from $b \rightarrow c\bar{c}s$ processes soon to be updated.
- Expect hundreds of clean signals for $B_s \rightarrow J/\psi\ h^0(\eta('),f_0)$… from full 121 fb^{-1} Belle data with improved tracking.

More open modes for B_s decays

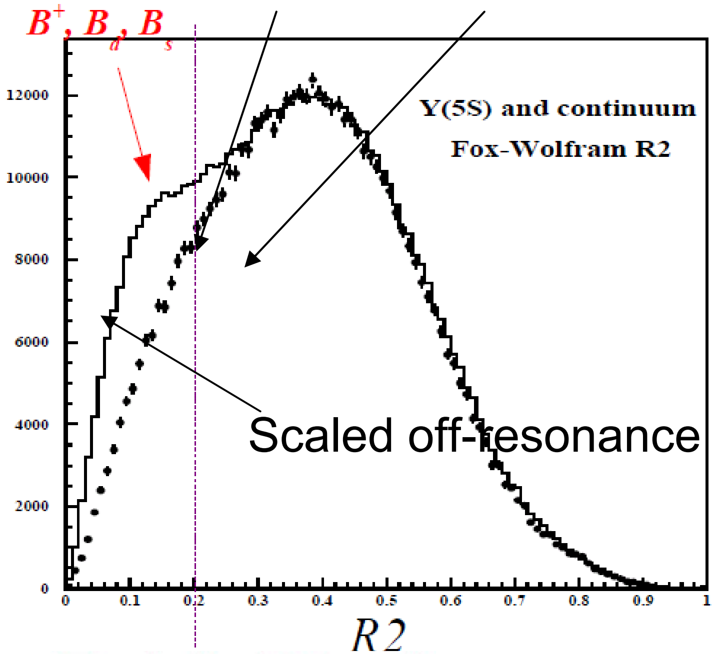
Expect more results from full 121 fb^{-1} data.

- $B \to D_s \bar{D}_s$ (BF = $1.0^{+0.4}_{-0.3}{}^{+0.3}_{-0.2}$ % by Belle)
- $B_s \to D_{CP} K_S (K^{*0})$, $D_{CP}\eta$. $D_{CP} = D^0$ decay to CP eigenstates.
  Pure CP eigenstate.
  (C.F.: $BF(B^0 \to \bar{D}^0 \pi^0) = (2.61 \pm 0.24) \times 10^{-4}$)
- B_s exclusive and inclusive semileptonic decays.
- B_s rare decays to $K\rho$,$\eta(')\eta(')$, $\Phi\Phi$
- $B_s \to D_{sJ}\,\pi$, …

$b\bar{b}$ cross-section at $\Upsilon(5S)$

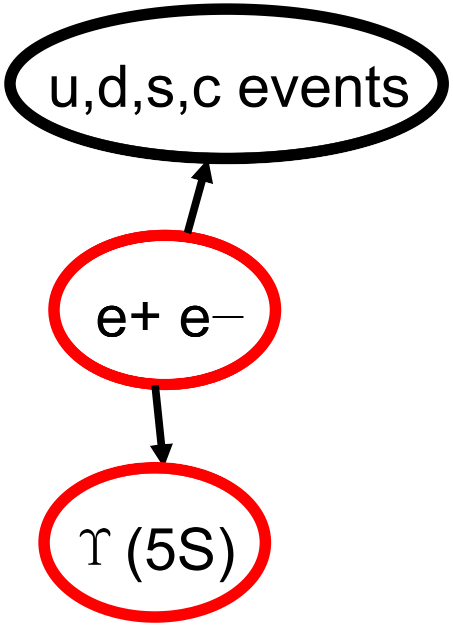
Drutskoy et al. (Belle),PRL 98, 052001(2007)

$$N_{5S}^{b\bar{b}} = \frac{1}{\epsilon_{5S}^{b\bar{b}}}\left(N_{5S}^{\rm had} - N_{\rm cont}^{\rm had}\,\frac{\mathcal{L}_{5S}}{\mathcal{L}_{\rm cont}}\,\frac{E_{\rm cont}^2}{E_{5S}^2}\,\frac{\epsilon_{5S}^{\rm con}}{\epsilon_{\rm cont}^{\rm con}}\right).$$



$$R_2 = \frac{\sum_{i,j} |p_i||p_j|P_2(\cos\theta)}{\sum_{i,j} |p_i||p_j|P_0(\cos\theta)}$$

Fox-Wolfram moments



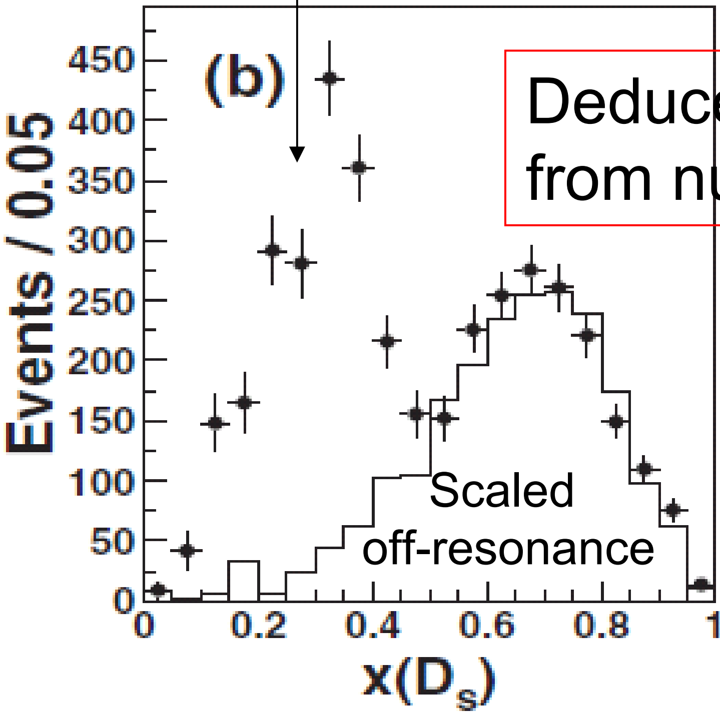
$$\sigma_{b\bar{b}}^{\Upsilon(5S)} = (0.302 \pm 0.015)\ \mathrm{nb}$$

B_s production fraction f_s

$$\underbrace{\mathcal{B}(\Upsilon(5S) \to D_s X)}_{\Upsilon(5S)}/2 = f_s \times \underbrace{\mathcal{B}(B_s \to D_s X)}_{\text{theory}} + (1-f_s) \times \underbrace{\mathcal{B}(B \to D_s X)}_{\Upsilon(4S),\ \text{Babar}}$$

Close to 100%

Small number: ~8. 7%



Normalized D_s momentum

Deduce number of B_s events from number of D_s events.

Υ (5S) → Bs events

$$f_s = (18.0 \pm 1.3 \pm 3.2)\%$$

BACKUP

Charmless: $B_s \rightarrow K^+K^-$, $K^0\overline{K}^0$

In addition to being CP eigenstates:

By relating to $B0 \rightarrow \pi^+\pi^-$ by SU(3) symmetry and U-spin symmetry:

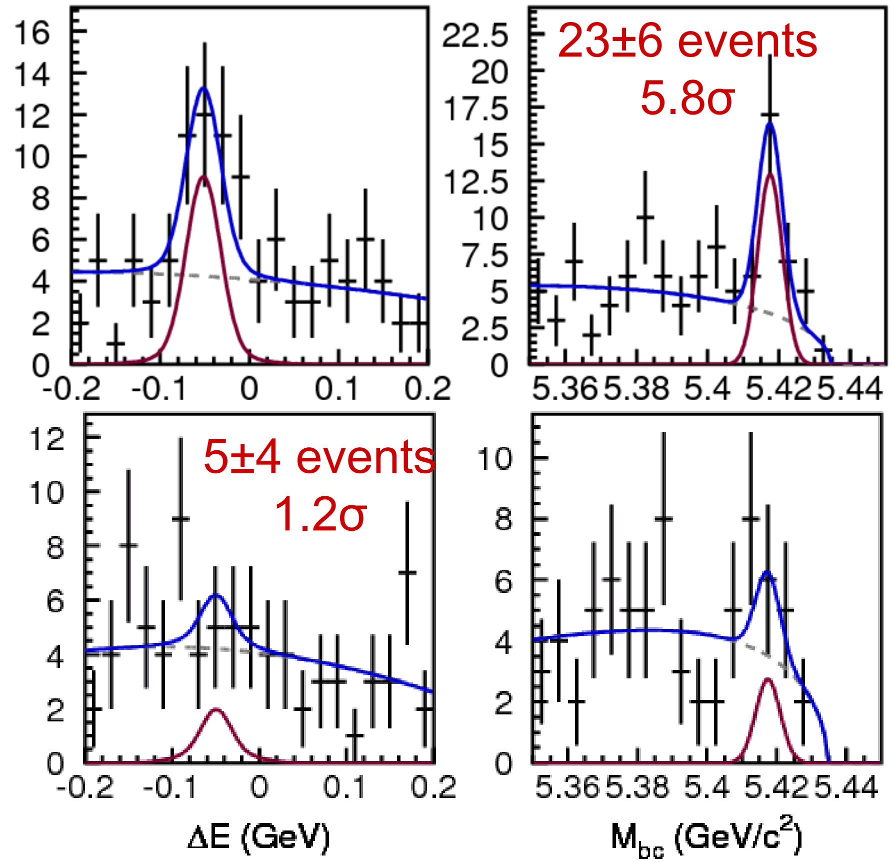
- BF and CP asymmetries sensitive to New Physics.- London et al., PRD 70, 031502 (2004)
- Sensitive to Φ_3/γ of CKM angle.
  - Fleischer, PLB 459, 306 (1999)

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

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

C.C.Peng et al., arXiv:1006.5115

$$\mathcal{B}(B_s^0 \rightarrow K^0\overline{K}^0) < 6.6 \times 10^{-5}$$

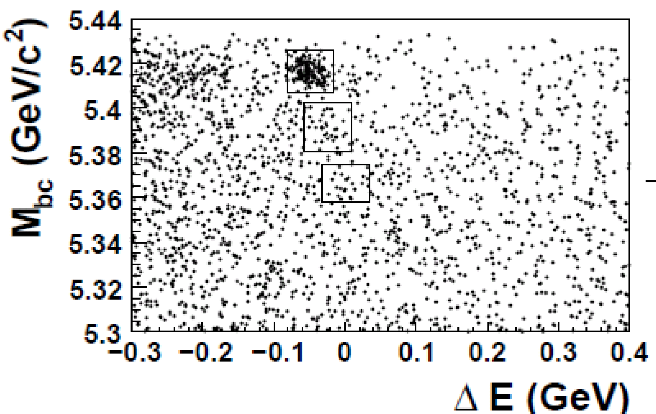


B_s CKM favored ($b \rightarrow c$) decay

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 $B_s \rightarrow D_s^- \pi^+$ study:

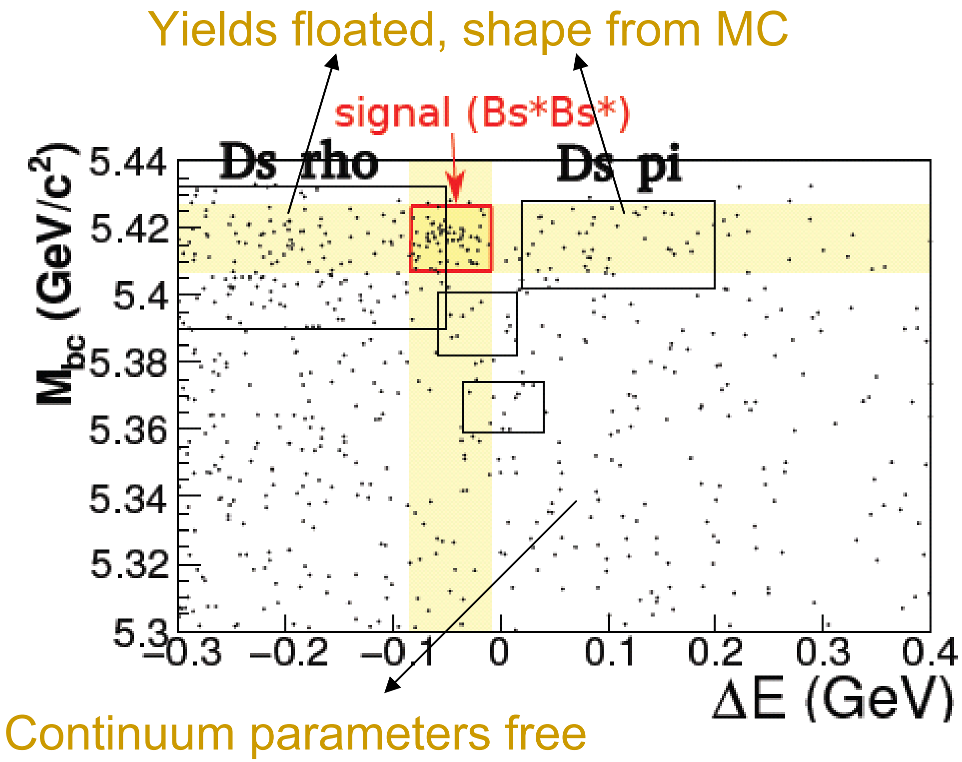
$$\rightarrow \mathcal{B}(B_s \rightarrow D_s \pi^-) = (3.67^{+0.35}_{-0.33} \pm 0.65) \times 10^{-3}$$

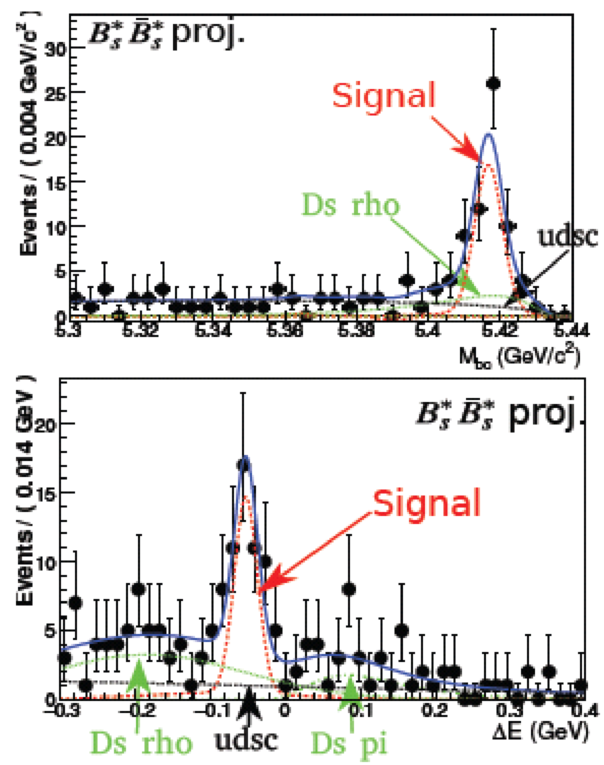
R.Louvot *et al*, PRL102,021801 (2009)

Now: More results from $B_s \rightarrow D_s^{*-}\pi^+$, $D_s^{*(-)}\rho^+$

D_s^*, ρ are difficult in hadron colliders (neural detection).

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





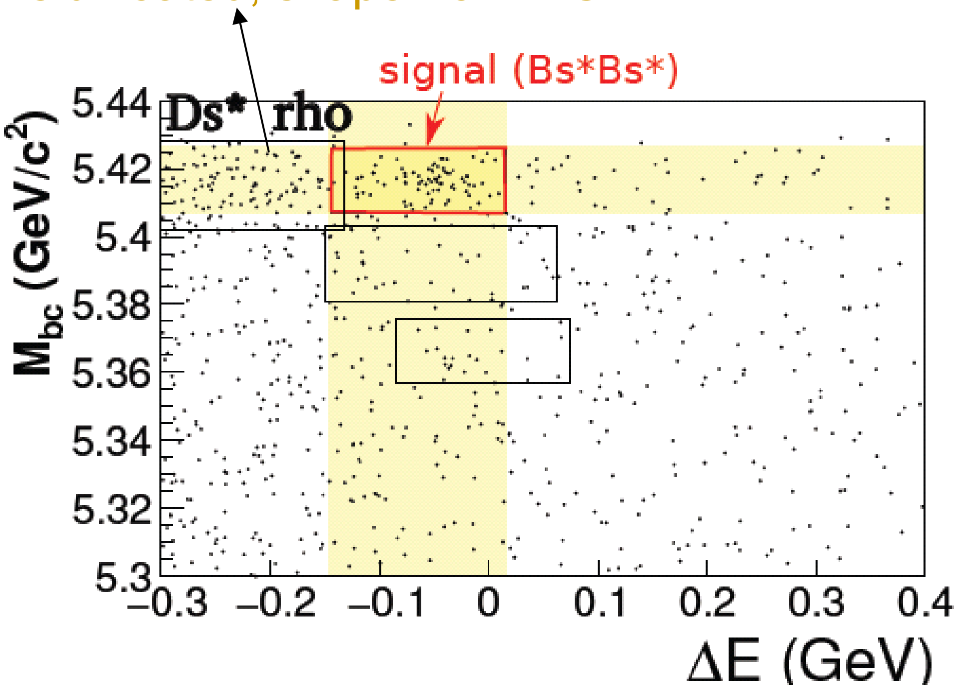
Fit components: Signals + $D_s^-\rho^+$ + $D_s^-\pi^+$ + Continuum

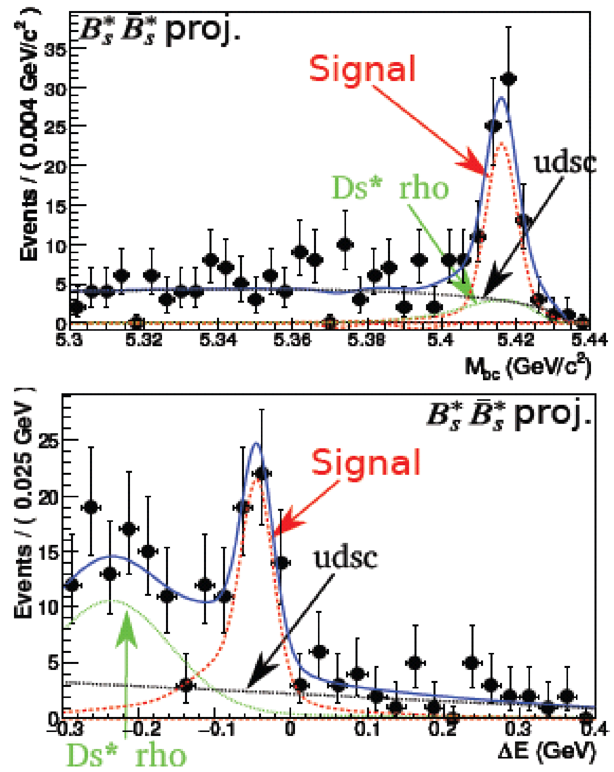
$$N(B_s^* \overline{B}_s^*) = 53.4^{+10.3}_{-9.4}(\text{stat.})^{+2.4}_{-2.6}(\text{fit})\ (7.1\sigma)$$

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

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

Yield floated, shape from MC





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

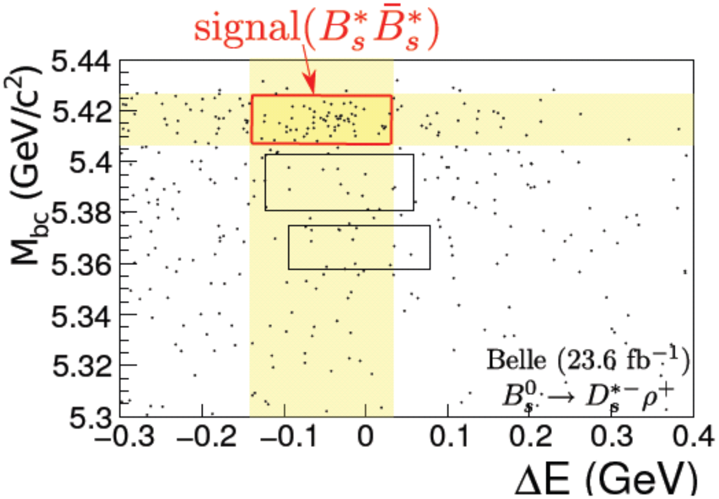
$$N(B_s^* \overline{B}_s^*) = 92.2^{+14.2}_{-13.2}(\text{stat.})^{+4.3}_{-4.2}(\text{fit})\ (8.2\sigma)$$

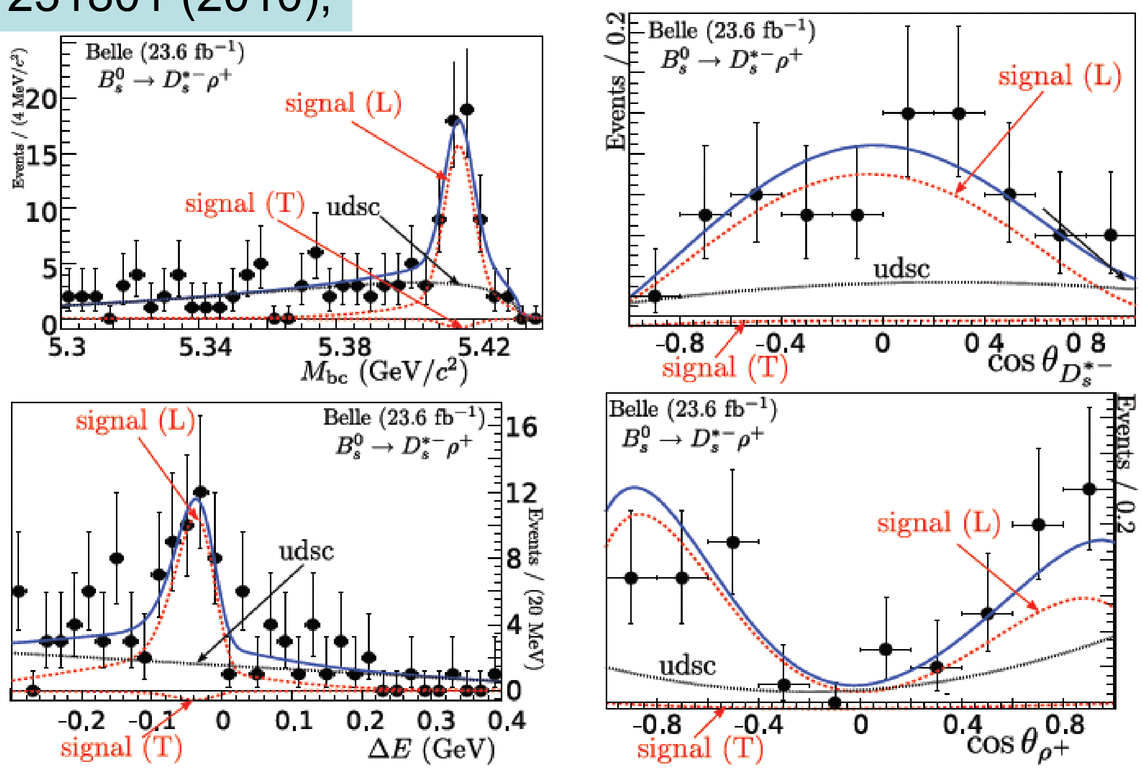
$$\mathcal{B}(B_s^0 \rightarrow D_s^- \rho^+) = (8.5^{+1.3}_{-1.2}(\text{stat.}) \pm 1.1(\text{syst.}) \pm 1.3(f_s)) \times 10^{-3}$$

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

R. Louvot et al. (Belle), PRL 104, 231801 (2010);

4D fit on Mbc, ΔE, $\cos\theta_\rho$, $\cos\theta_{D^*}$



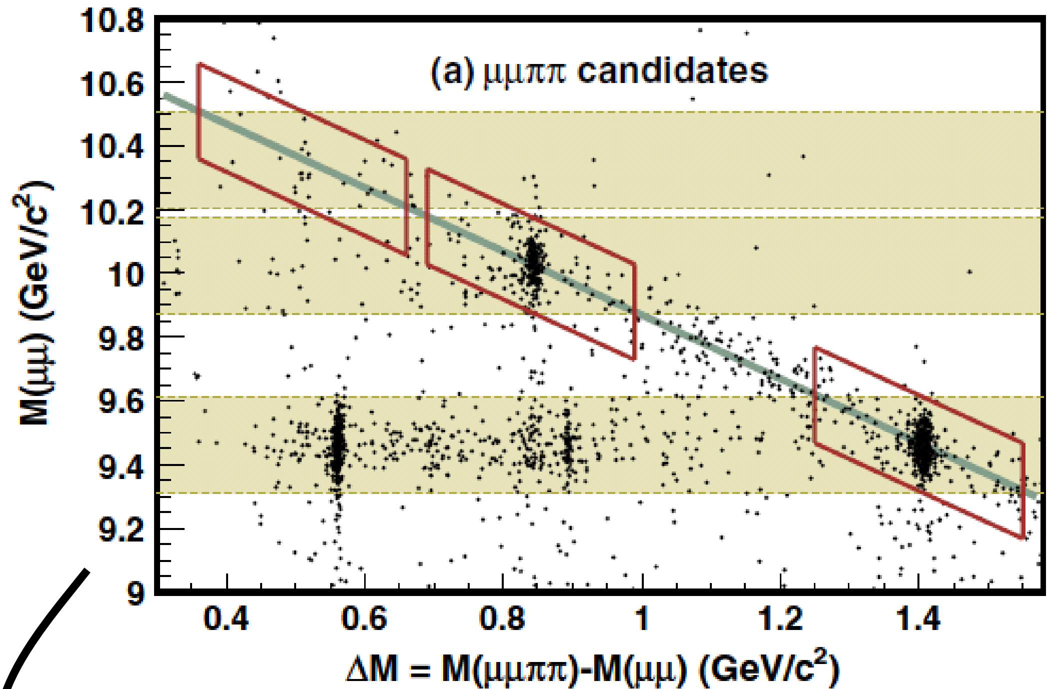


- $N(B_s^* \bar{B}_s^*) = 77.8^{+14.5}_{-13.4}(\text{stat.}) \pm 3.3(\text{fit})$ events (7.4σ significance)

$$\mathcal{B}(B_s^0 \to D_s^{*-}\rho^+) = \left(11.8^{+2.2}_{-2.0}(\text{stat.}) \pm 1.7(\text{syst.}) \pm 1.8(f_s)\right) \times 10^{-3}$$

$$f_L = 1.05^{+0.08}_{-0.10}{}^{+0.03}_{-0.04}$$ or $f_L \in [0.93, 1.00]$ at 68% C.L.

Υ(5S): large branching fraction to Υ(1/2S)ππ



Process	$\Gamma_{\Upsilon(1S)\pi^+\pi^-}$
$\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$	0.0060 MeV
$\Upsilon(3S) \to \Upsilon(1S)\pi^+\pi^-$	0.0009 MeV
$\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-$	0.0019 MeV
$\Upsilon(10860) \to \Upsilon(1S)\pi^+\pi^-$	0.59 MeV

$e^+e^- \to \Upsilon(1S/2S)\,\pi^+\pi^-$

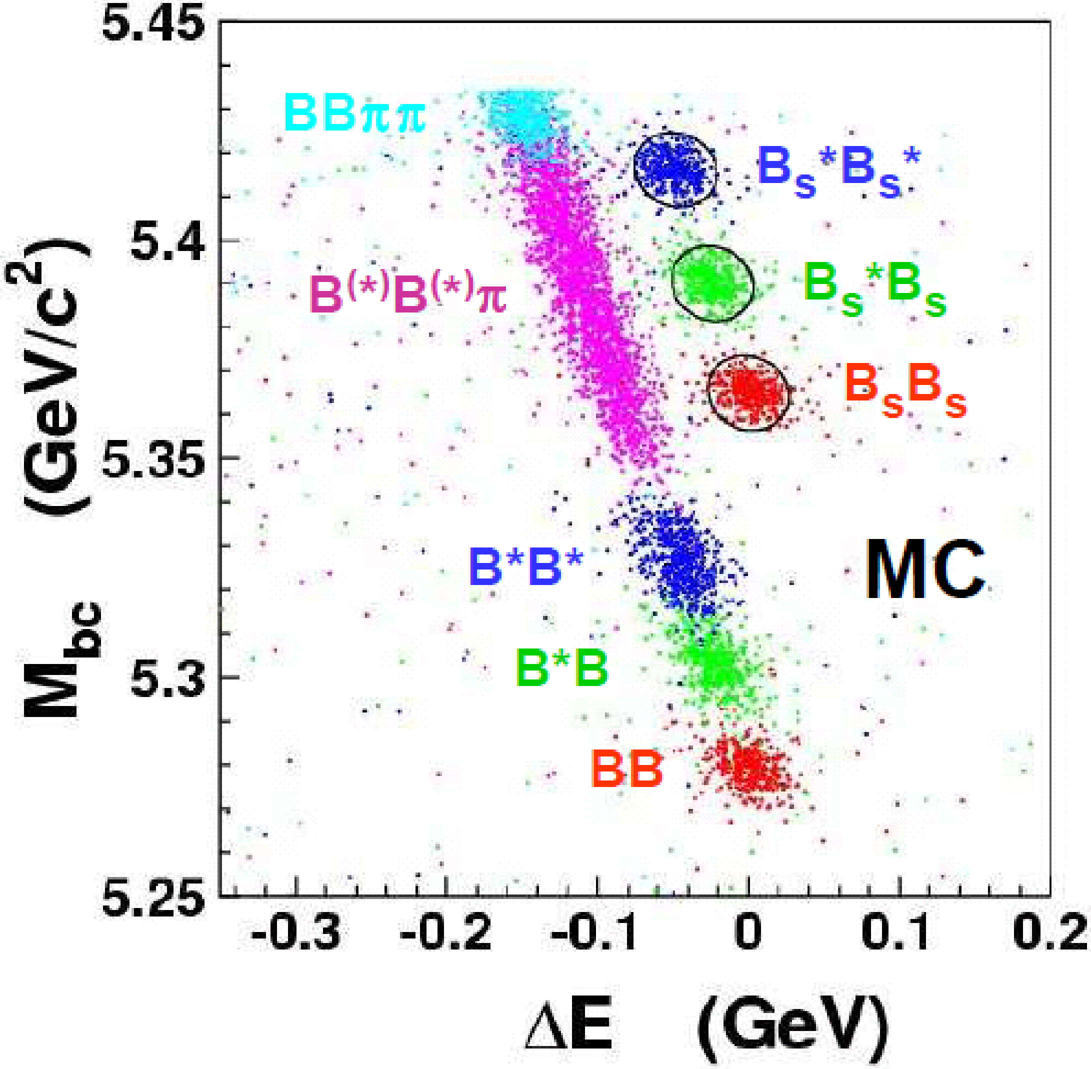
Υ(5S) result:

Process	σ (pb)	Γ (MeV)
$\Upsilon(1S)\pi^+\pi^-$	$1.61 \pm 0.10 \pm 0.12$	$0.59 \pm 0.04 \pm 0.09$
$\Upsilon(2S)\pi^+\pi^-$	$2.35 \pm 0.19 \pm 0.32$	$0.85 \pm 0.07 \pm 0.16$
$\Upsilon(3S)\pi^+\pi^-$	$1.44^{+0.55}_{-0.45} \pm 0.19$	$0.52^{+0.20}_{-0.17} \pm 0.10$
$\Upsilon(1S)K^+K^-$	$0.185^{+0.048}_{-0.041} \pm 0.028$	$0.067^{+0.017}_{-0.015} \pm 0.013$

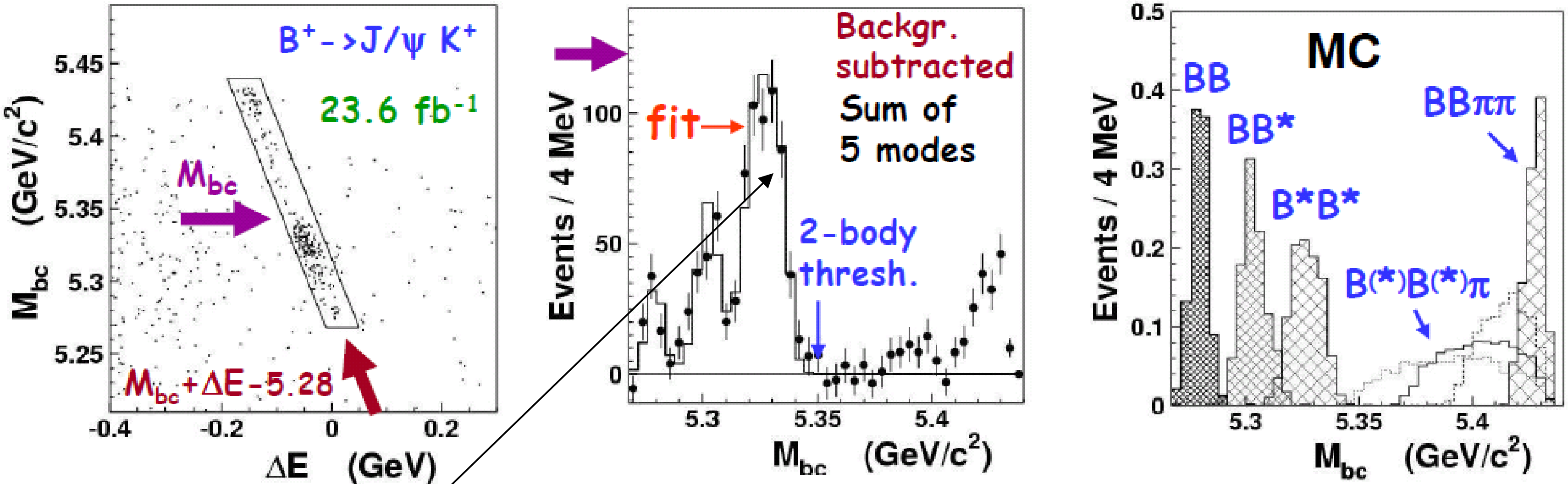
K.F. Chen et al.
PRL 100, 112001 (2008)

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

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



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



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

$B\bar{B}$:	$5.5 \pm^{1.0}_{0.9} \pm 0.4$ %
$B^*\bar{B}$:	$13.7 \pm 1.3 \pm 1.1$ %
$B^*\bar{B}^*$:	$37.5 \pm^{2.1}_{1.9} \pm 3.0$ %
$M_{bc} > 5.35$ GeV/c:	$17.5 \pm^{1.8}_{1.6} \pm 1.3$ %

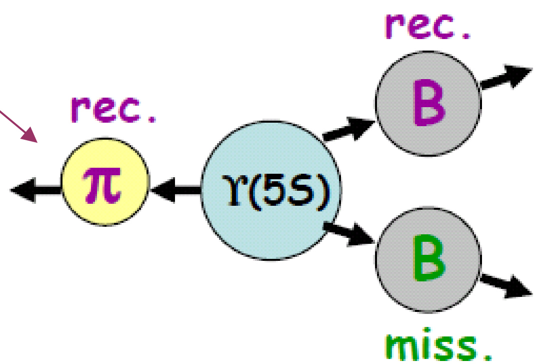
Not predicted by theory:

Yu.Simonov et al., arxiv:0805.4518

~ 0.03%

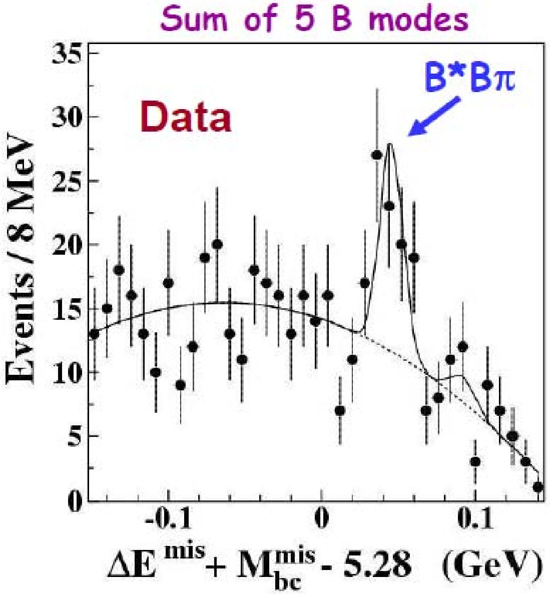
Decompose 3,4 body $B^{(*)}B^{(*)}\pi, BB\pi\pi$

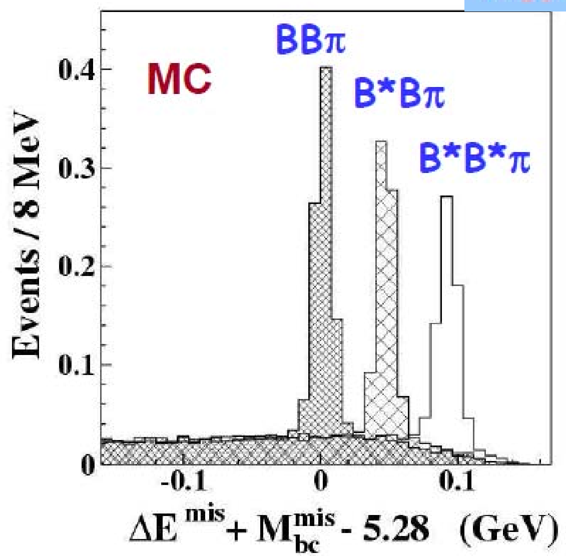
Reconstruct additional π^+



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

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





$M_{bc}>5.35$ GeV/c: $17.5 \pm^{1.8}_{1.6} \pm 1.3$ %

$B\bar{B}\pi^+$	$(0.0 \pm 1.2 \pm 0.3)$ %
$B^*\bar{B}\pi^+$	$(7.3 \pm^{2.3}_{2.1} \pm 0.8)$ %
$B^*\bar{B}^*\pi^+$	$(1.0 \pm^{1.4}_{1.3} \pm 0.4)$ %
Residual	$(9.2 \pm^{3.0}_{2.8} \pm 1.0)$ %

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

Summary & Outlook

- Bs decays have been studied.
  - CP eigenstates: $B \rightarrow J/\psi\eta$ (first observation), $J/\psi\eta'$ (evidence).
  - CKM-favoured: $B_s \rightarrow D_s^{*-}\pi^+$, $D_s^-\rho^+$, $D_s^{*-}\rho^+$ (first observations).
- B^+ and B^0 production at $\Upsilon(5S)$ resonance: Surprising new result
  - Large branching fraction of 3 and 4 body decays of $\Upsilon(5S)$ observed.
- Other modes being studied:
  - Another pure CP eigenstate: $B_s \rightarrow J/\psi f_0(\pi\pi)$.
- Data set increase ~5 times, with new tracking:
  - All the previous results will be updated.
  - More channels to be observed. (e.g.: $B_s \rightarrow D_s^{(*)}D_s^{(*)}$, K^0K^0)