Search for $B_s \to J/\psi\, f_0(980)$ and $B_s \to hh$ at the $\Upsilon(5S)$

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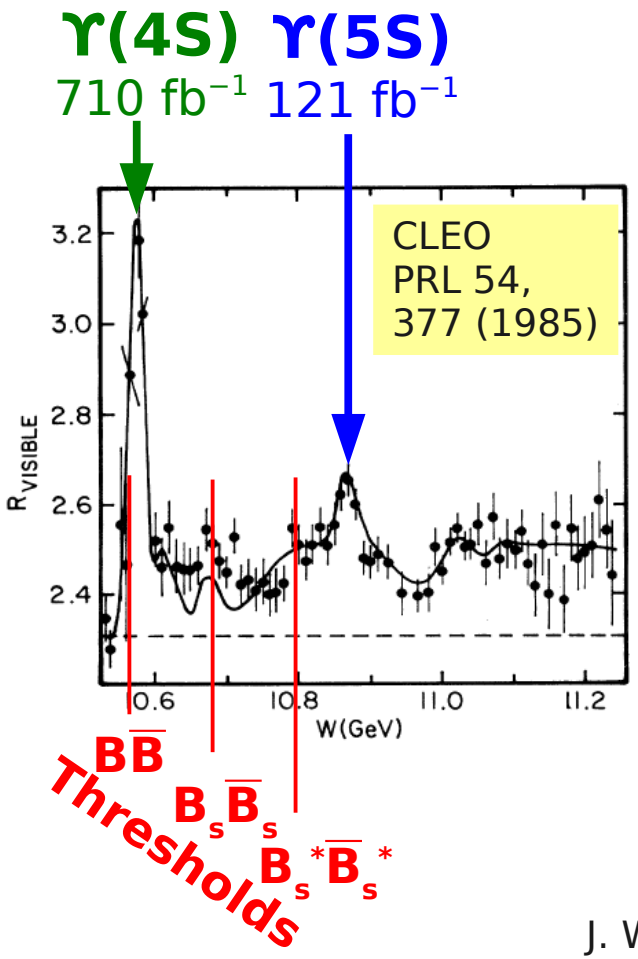
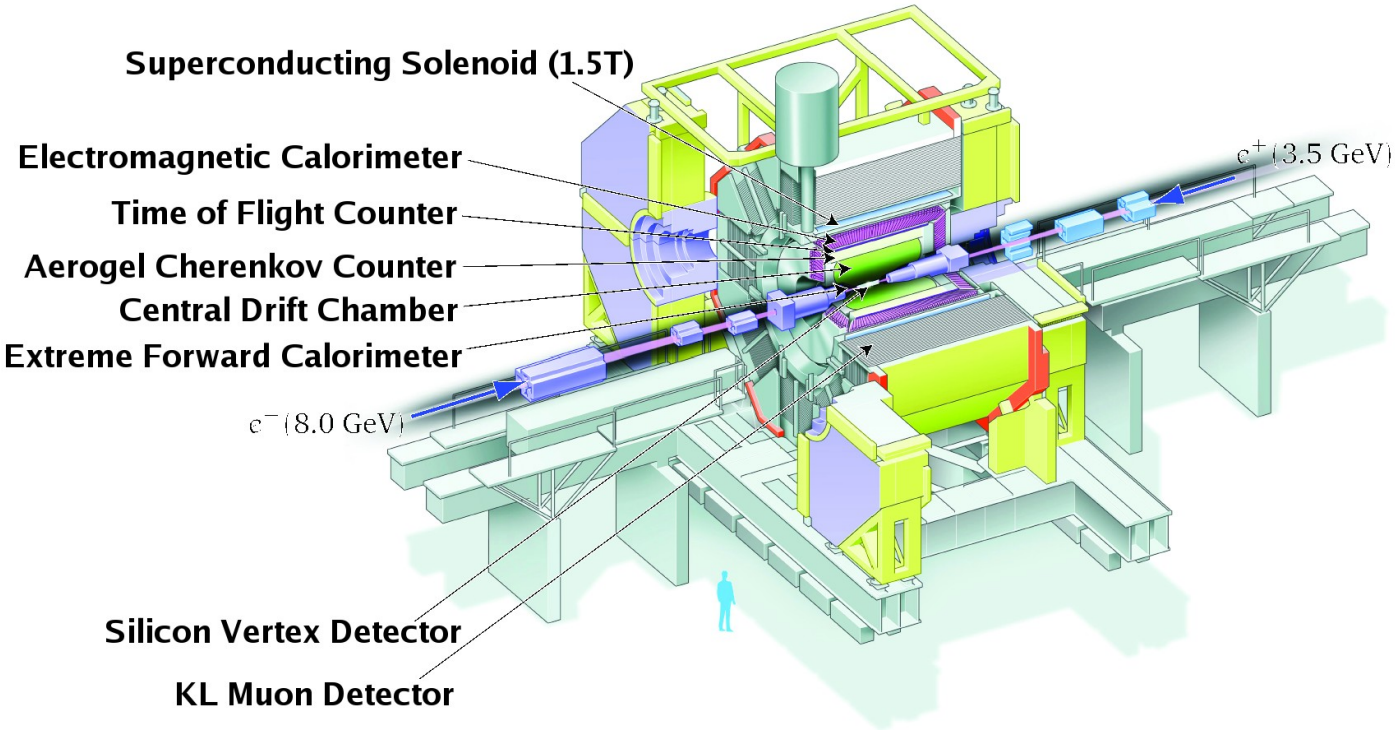
KEKB and Belle detector

KEKB : asymmetric e^+e^- collider (3.6 on 8.2 GeV for $\Upsilon(5S)$): Tsukuba, Japan
B meson factory: $e^+e^- \to \Upsilon(4S),\Upsilon(5S) \to B\bar{B}$

Final total integrated luminosity: ~1050 fb^{-1}

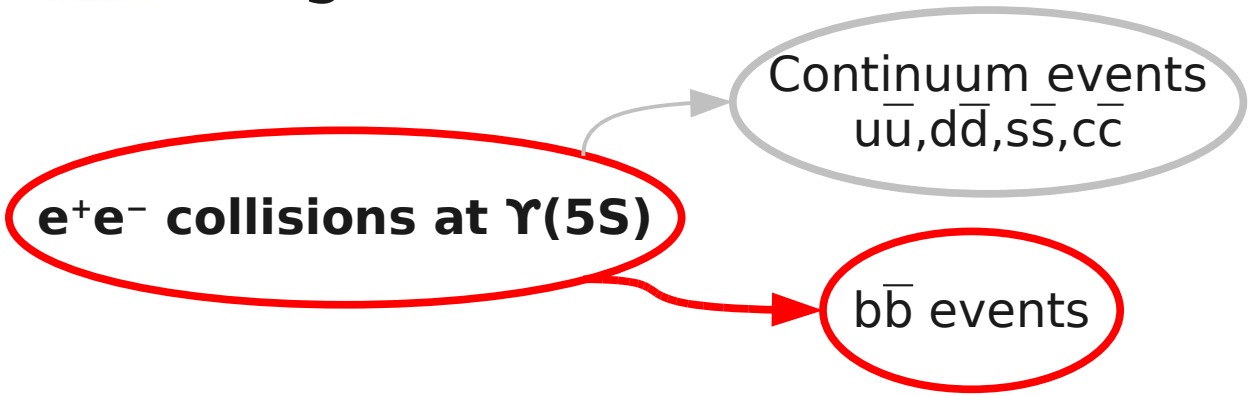
Solid angle coverage	~92%
Particle identification	π,K,e,μ,p





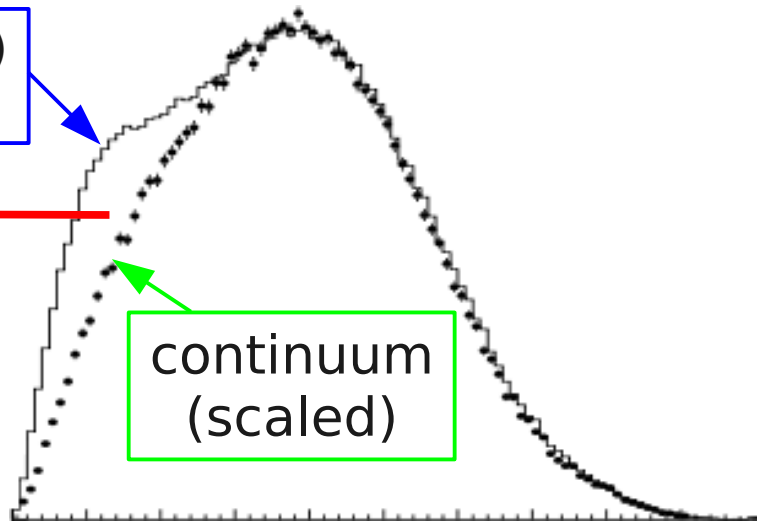
Today's results: 23.6 fb^{-1}

B_s production at the $\Upsilon(5S)$



$b\bar{b}$ cross-section measured with
$\Upsilon(4S)$ off-resonance data (continuum) subtraction

$$\sigma_{b\bar{b}}^{\Upsilon(5S)} = \frac{N_{b\bar{b}}^{\Upsilon(5S)}}{\mathcal{L}_{\Upsilon(5S)}} = \frac{1}{\mathcal{L}_{\Upsilon(5S)}} \frac{1}{\epsilon_{\Upsilon(5S)}^{b\bar{b}}} \left(N_{\mathrm{hadr}}^{\Upsilon(5S)} - N_{\mathrm{hadr}}^{\mathrm{cont}} \frac{\mathcal{L}_{\Upsilon(5S)}}{\mathcal{L}_{\mathrm{cont}}} \frac{E_{\Upsilon(5S)}^2}{E_{\mathrm{cont}}^2} \frac{\epsilon_{\Upsilon(5S)}^{\mathrm{rec}}}{\epsilon_{\mathrm{cont}}^{\mathrm{rec}}} \right)$$



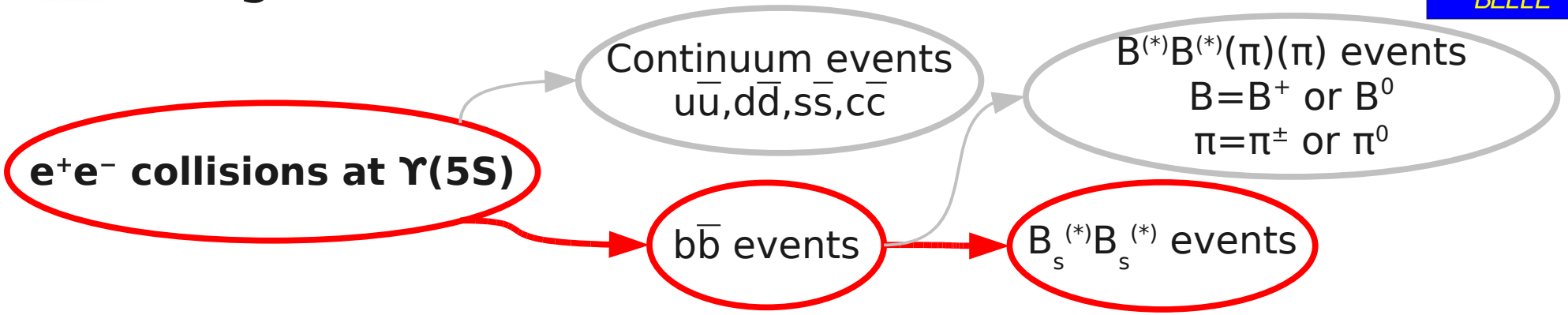
$$\sigma_{b\bar{b}}^{\Upsilon(5S)} = (0.302 \pm 0.015)\ \mathrm{nb}$$

$$\sigma_{b\bar{b}}^{\Upsilon(4S)} \sim 1.1\ \mathrm{nb}$$

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

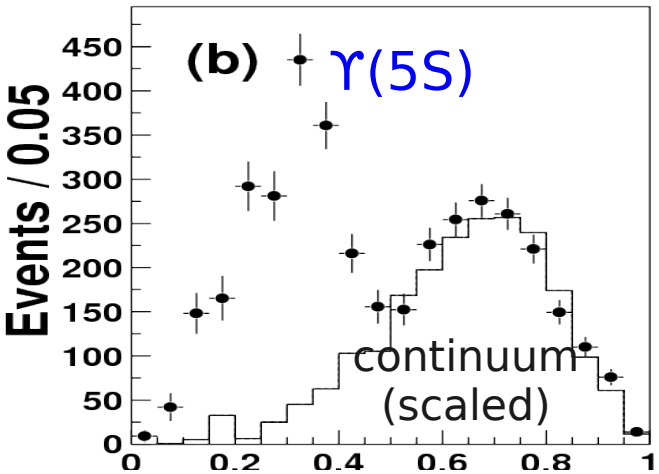
2nd Fox-Wolfram moment: ~ event is jet-like

B_s production at the $\Upsilon(5S)$



B_s meson production fraction (f_s) measured with inclusive D_s and D

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

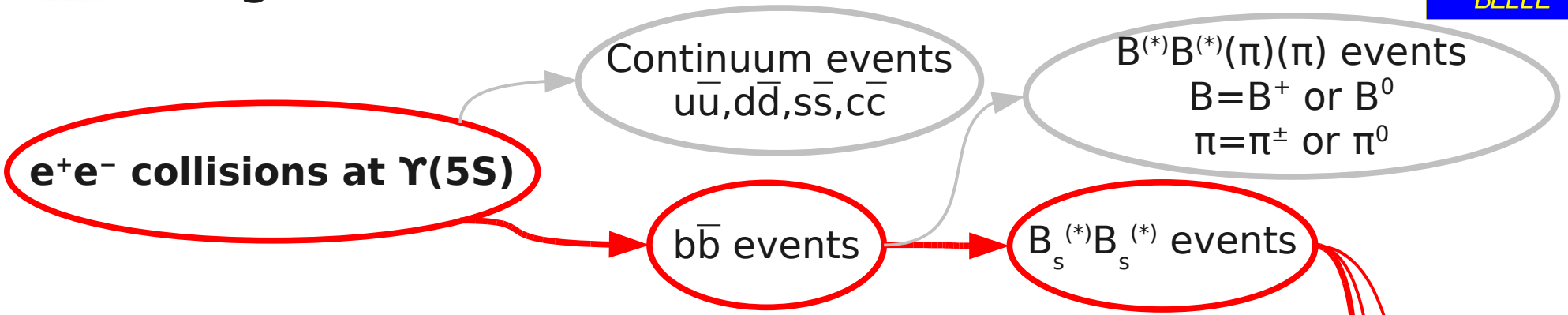


$$f_s = (18.0 \pm 1.3 \pm 3.2)\%$$

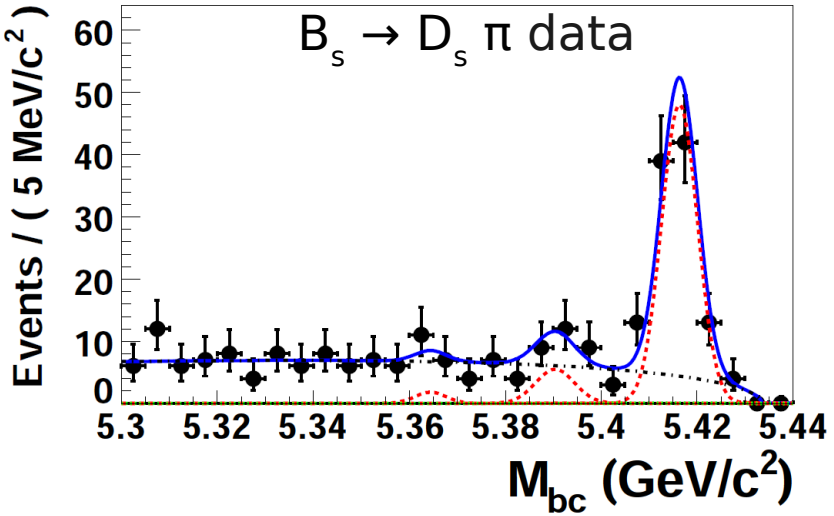
$$N_{B_s^0} = 2 \times \mathcal{L}_{\text{int}} \times \sigma_{b\bar{b}}^{\Upsilon(5S)} \times f_s$$

In 23.6 fb^{-1}, ~2.8 million B_s mesons
~15% uncertainty, mainly due to f_s

B_s production at the $\Upsilon(5S)$

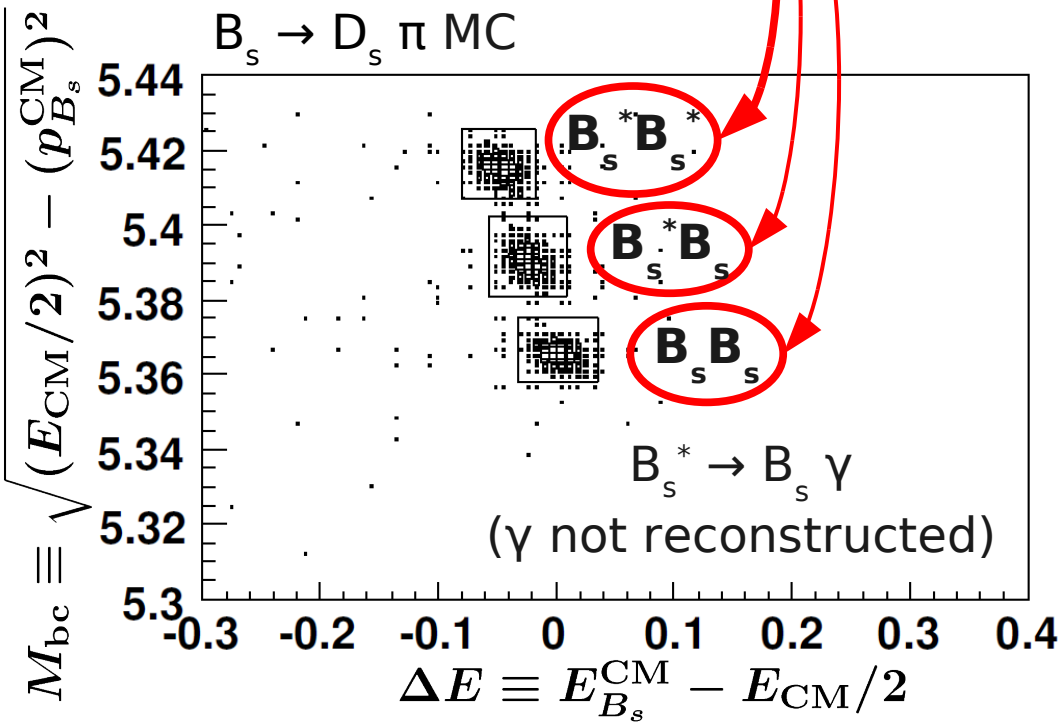


$B_s^{(*)}B_s^{(*)}$ production fractions measured with $B_s \to D_s \pi$ decays



$$f_{B_s^* B_s^*} = (90.1^{+3.8}_{-4.0} \pm 0.2)\%$$
$$f_{B_s^* B_s} = (7.3^{+3.3}_{-3.0} \pm 0.1)\%$$

Louvot et al. (Belle), PRL 102, 021801, 2009



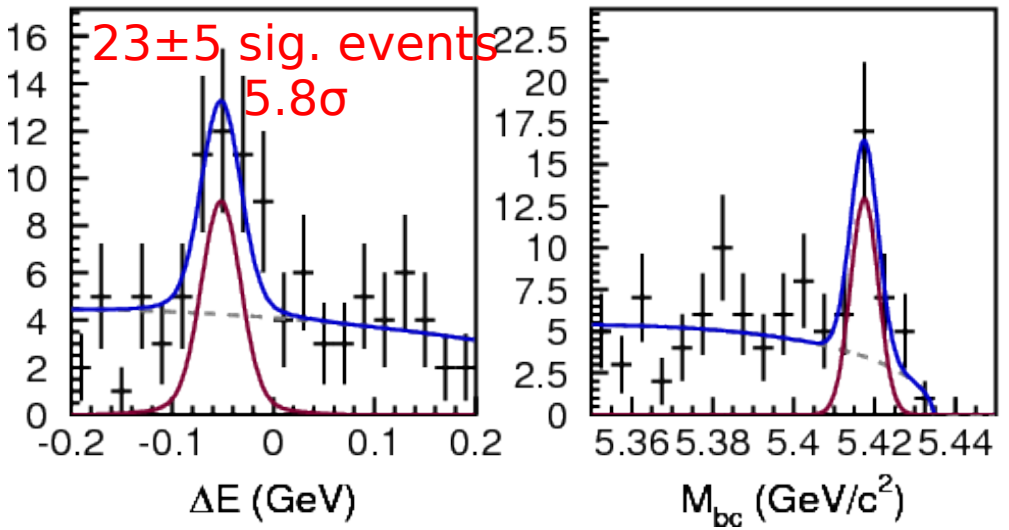
E_{CM}=10867±1 MeV

Charmless: $B_s \to K \bar{K}$

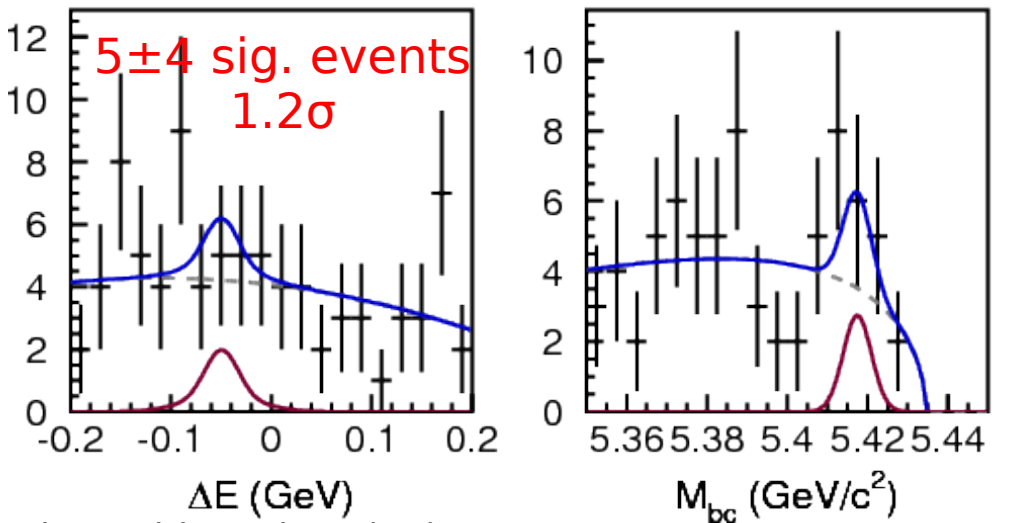
C.C.Peng et al. (Belle), arXiv:1006.5115, submitted to PRD; 23.6 fb^{-1}

- $B_s \to K^+ K^-$ and $B^0 \to \pi^+ \pi^-$ are related by SU(3)
  - Probe New Physics by comparing CP asymmetries
    London et al., PRD 70, 031502 (2004)
  - Sensitive to γ/ϕ_3 using the U-spin symmetry.
    Fleischer, PLB 459, 306 (1999)
- $B_s \to K^0 \bar{K}^0$: "same" BF as K^+K^- but more challenging because we have to search for two K_S
  - $BF(B_s \to K_S K_S) = BF(B_s \to K^0 \bar{K}^0)/2$
  - $BF(K_S \to \pi^+\pi^-) \sim 70\%$
  - Challenging at hadron-colliders!

$B_s \to K^+ K^-$



$B_s \to K_S K_S$

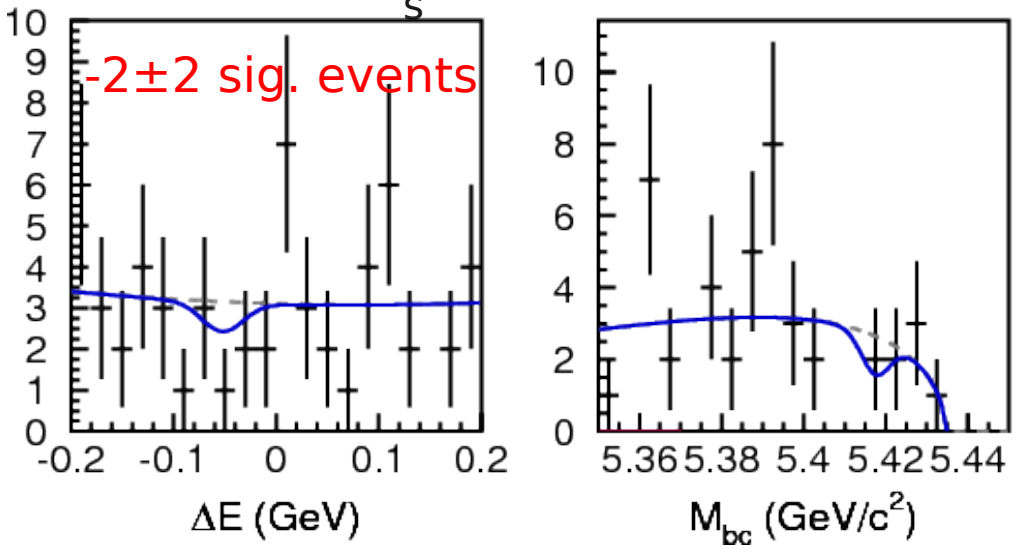


Charmless: $B_s \to h\ h$

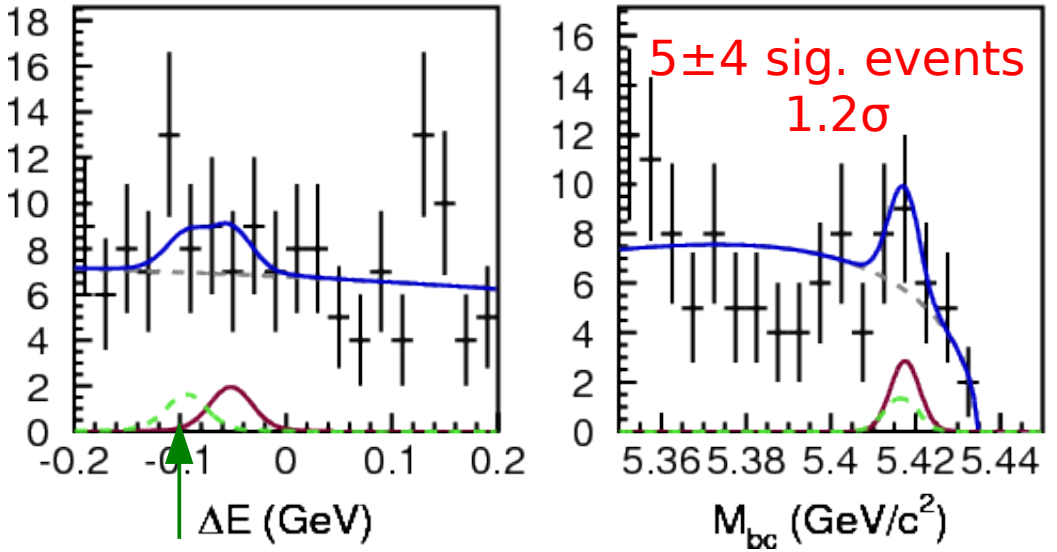
C.C.Peng et al. (Belle), arXiv:1006.5115, submitted to PRD; 23.6 fb^{-1}

$B_s \to \pi^+\pi^-$ and $B_s \to K^+\pi^-$ are suppressed compared to $B_s \to KK$

$B_s \to \pi^+\ \pi^-$



$B_s \to \pi^+\ K^-$



Mis-PID bkg $B_s \to K^+\ K^-$

$B_s^0 \to$	$\mathcal{B}\ (10^{-6})$
K^+K^-	$38^{+10}_{-9} \pm 7$
$K^0\bar{K}^0$	< 66
π^+K^-	< 26
$\pi^+\pi^-$	< 12

Agreement with CDF

More stringent upper limit

CDF has more stringent upper limits

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

- Silver mode for LHCb to measure β_s, the CP-violating phase in the B_s mixing Stone et al., arXiv:0909.5442 (2009)
  - BF smaller than $B_s \to J/\psi\, \varphi$ BUT $J/\psi\, f_0$ is a pure CP-eigenstate
    - No angular analysis required as in $B_s \to J/\psi\, \varphi$
- Branching fraction
  - Extrapolation from $B_s \to J/\psi\, \varphi$

$$\frac{\mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-)}{\mathcal{B}(B_s^0 \to J/\psi \phi)\mathcal{B}(\phi \to K^+K^-)} \approx 0.2 = 0.42 \pm 0.11$$

Stone et al., PRD 79, 074024 (2009)

CLEO ($D_s \to f_0 e\nu$), PRD 80, 052009 (2009)

CDF's $J/\psi\, \varphi \Rightarrow \mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-) = \boxed{(1.3 - 2.7)10^{-4}}$

  - Theory (QCD@LO)

$$\mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-) = (3.4 \pm 2.4)10^{-4} \times (50^{+7}_{-9})\%$$

QCD (LO) PRD 81, 074001 (2010)

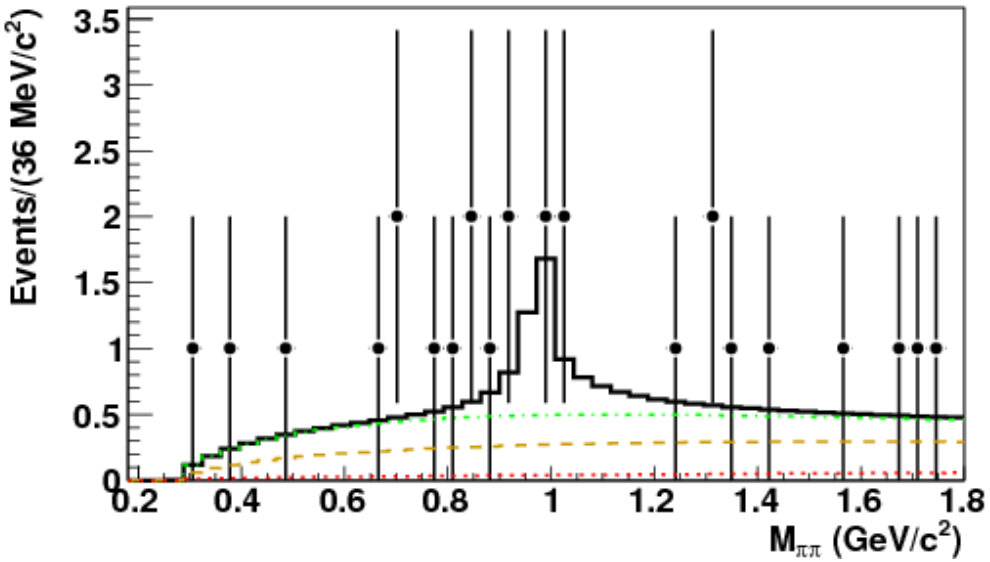
BES, PRD 80, 052009 (2009)

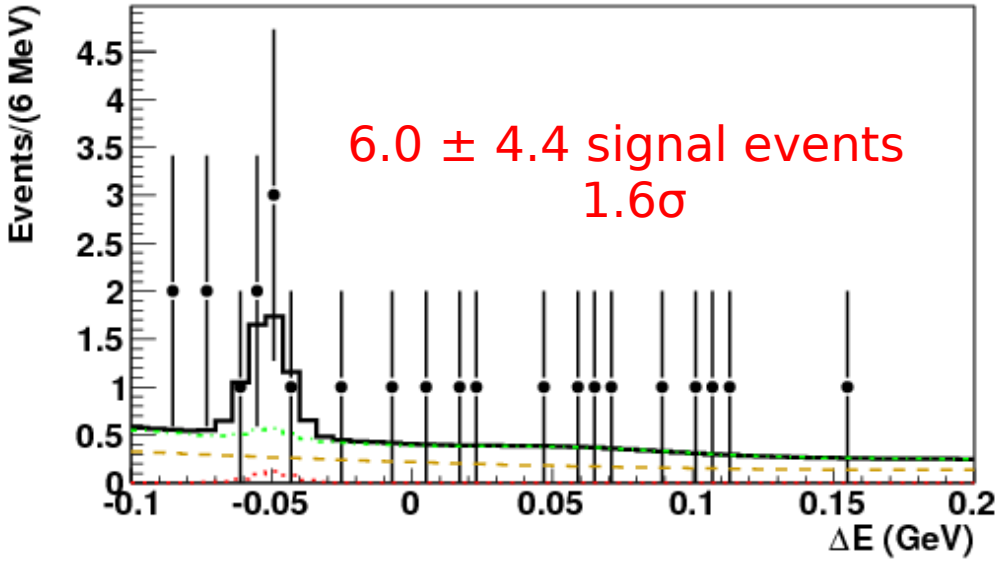
$$= \boxed{(1.6 \pm 1.3)10^{-4}}$$

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

Preliminary; 23.6 fb^{-1}

1. Reconstruct $J/\psi \to e^+e^-$ and $\mu^+\mu^-$ and $f_0 \to \pi^+\pi^-$
2. Cut on M_{bc}, and do a 2D-fit on $M_{\pi\pi}$ and ΔE
3. Include in the fit backgrounds from continuum (~50%), $B \to J/\psi X$ (~50%) and non-resonant $B_s \to J/\psi\pi\pi$ (small peak in ΔE).





$$\mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-) < 1.63 \times 10^{-4}\ (\mathrm{CL}\ 90\%)$$

Expectations: $\mathcal{B}(B_s^0 \to J/\psi f_0)\mathcal{B}(f_0 \to \pi^+\pi^-) = (1.3 - 2.7)10^{-4} = (1.6 \pm 1.3)10^{-4}$

Summary

- In a sample containing ~2.8 million B_s (23.6 fb^{-1})
  - Charmless $B_s \to hh$
    - $B_s \to K^+ K^-$ observed
    - Best upper limit on $B_s \to K^0 K^0$
    - No evidence for $B_s \to \pi^+ \pi^-$ and $B_s \to \pi^+ K^-$
  - CP-eigenstates
    - No evidence of $B_s \to J/\psi f_0(980)$. Need to update with our full data sample!
    - Belle has also obtained the first observation and evidence for $B_s \to J/\psi \eta$ and $B_s \to J/\psi \eta'$. arXiv:0912.1434 (2009)
- Five times more data available! More results in the pipeline!
  - Belle has also reprocessed its data! Tracking is improved: effective luminosity is more than five times larger!

BACKUP

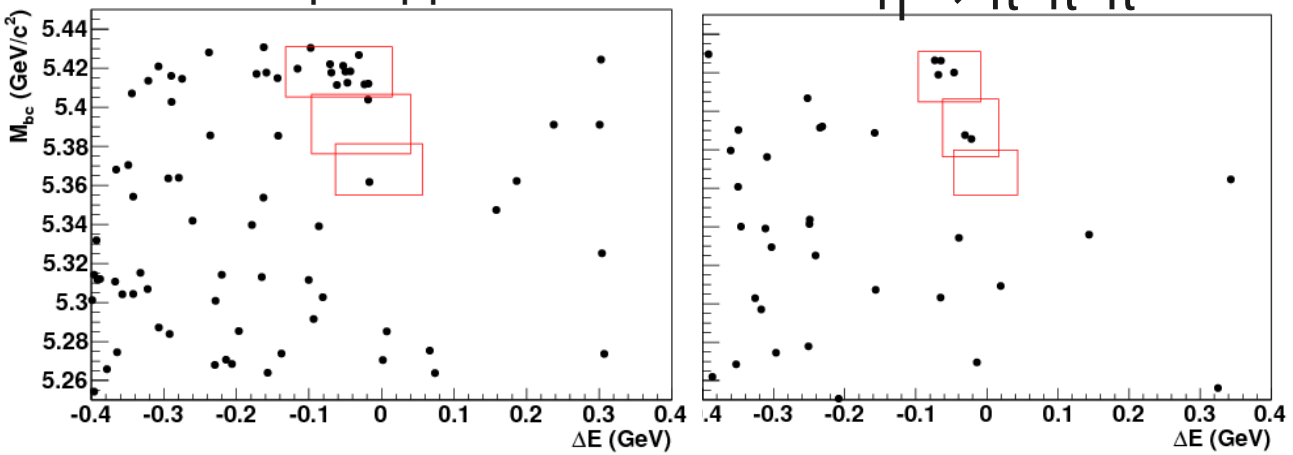
$B_s \to J/\psi\, \eta$

Adachi et al. (Belle), arXiv:0912.1434 (2009); 23.6 fb^{-1}

CP-eigenstate Dunietz et al., PRD 63, 114015 (2001)
measure CP violation parameters: β_s, $\Delta\Gamma_s/\Gamma_s$, ...

$J/\psi \to e^+e^-, \mu^+\mu^-$

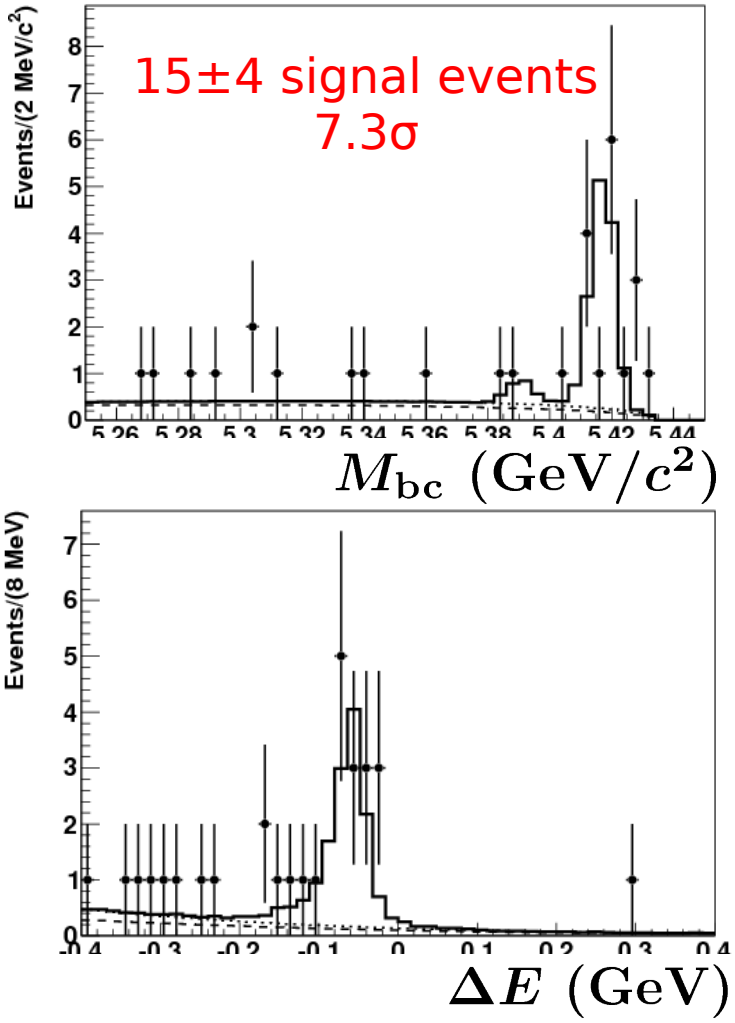
$\eta \to \gamma\gamma$ $\qquad$ $\eta \to \pi^+\pi^-\pi^0$



Simultaneous fit of the two η decays
Very little background from continuum and B → J/ψ

First observation!

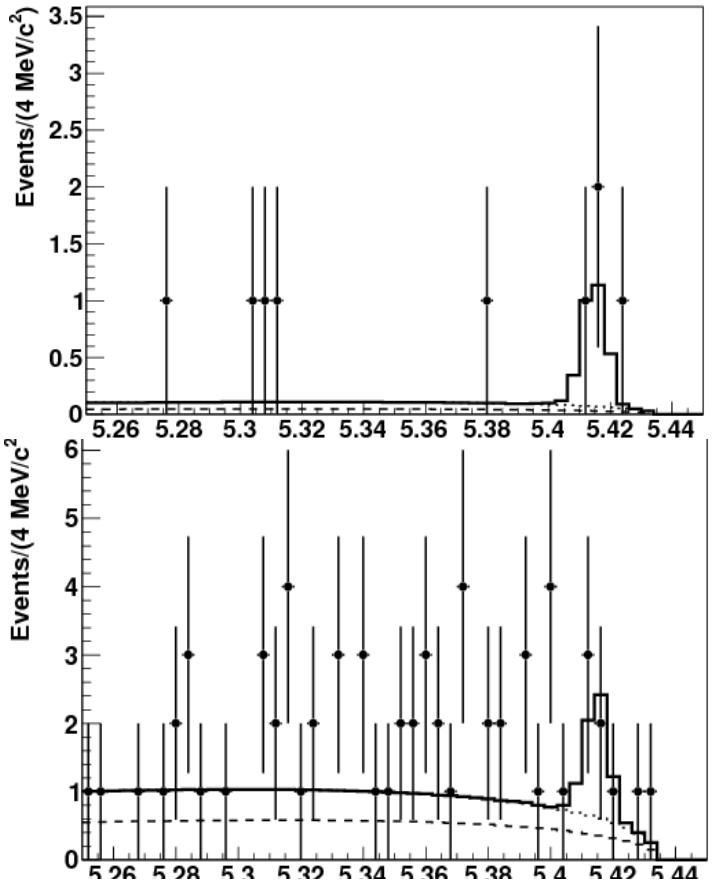
η modes combined



$$\mathcal{B}(B_s^0 \to J/\psi\eta) = (3.3 \pm 0.9(\text{stat.}) \pm 0.3(\text{syst.}) \pm 0.4(f_s)) \times 10^{-4}$$

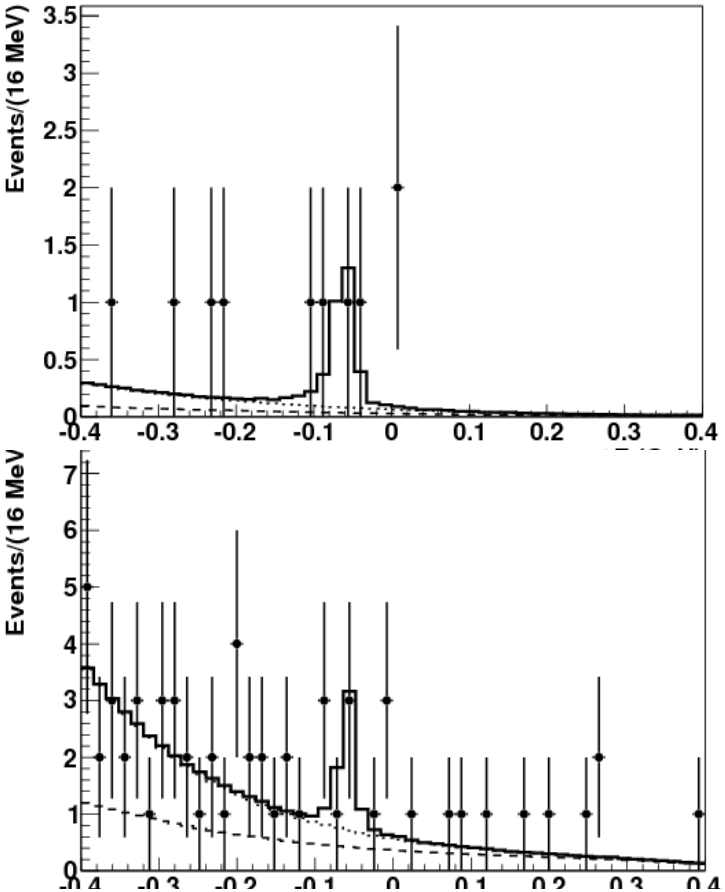
$B_s \to J/\psi\, \eta'$

Adachi et al. (Belle), arXiv:0912.1434 (2009); 23.6 fb^{-1}



$\eta' \to \eta\pi\pi$
with
$\eta \to \gamma\gamma$
$\eta \to \pi\pi\pi^0$

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



11±5 signal events
3.8σ

CP-eigenstate

First evidence!

$$\mathcal{B}(B_s^0 \to J/\psi\eta') = (3.1 \pm 1.2(\text{stat.})^{+0.5}_{-0.6}(\text{syst.}) \pm 0.4(f_s)) \times 10^{-4}$$