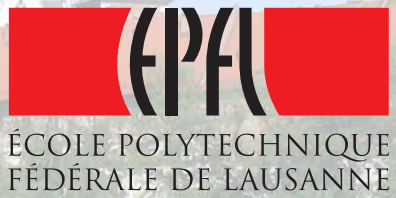
B_s^0 Decays at Belle

Remi Louvot



The 2009 Europhysics Conference
on High Energy Physics
Krakow, 16 July 2009

Outline

The Belle detector – The Belle $\Upsilon(5S)$ sample

Three dominant B_s^0 modes

$B_s^0 \to D_s^{*-}\pi^+$
$B_s^0 \to D_s^-\rho^+$
$B_s^0 \to D_s^{*-}\rho^+$

CP-eigenstate modes

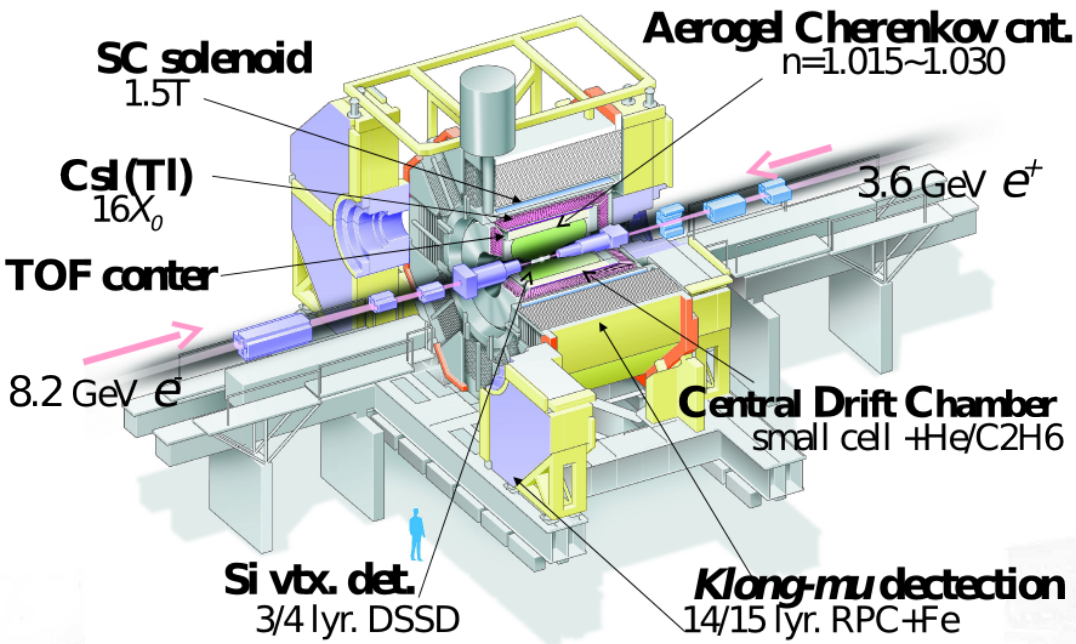
$B_s^0 \to J/\psi\eta$
$B_s^0 \to hh'$, $h^{(\prime)} = \pi, K$

Conclusion

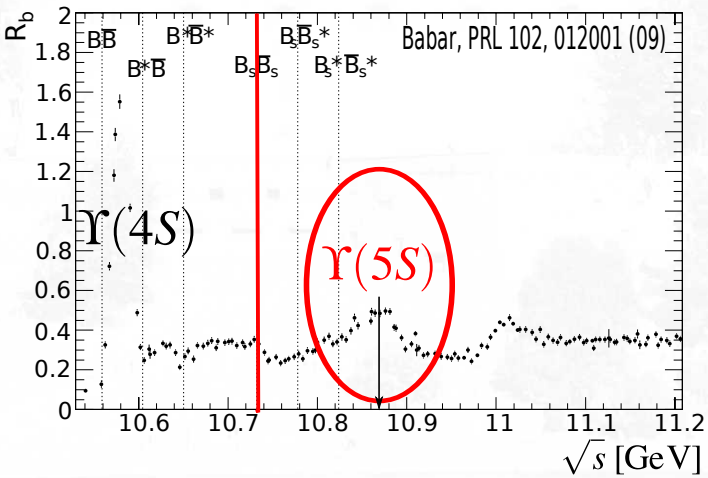
The Belle Experiment

The Belle detector

- Located at KEK B factory (Tsukuba, Japan)
- Large-solid-angle ($\sim 92\%$)
- Efficient particle ID (p, $\pi^{\pm}$, $K^{\pm}$, γ, μ, e, K_L^0)
- High luminosity ($\mathbf{L_{peak} = 21.1\,nb^{-1}s^{-1}}$)



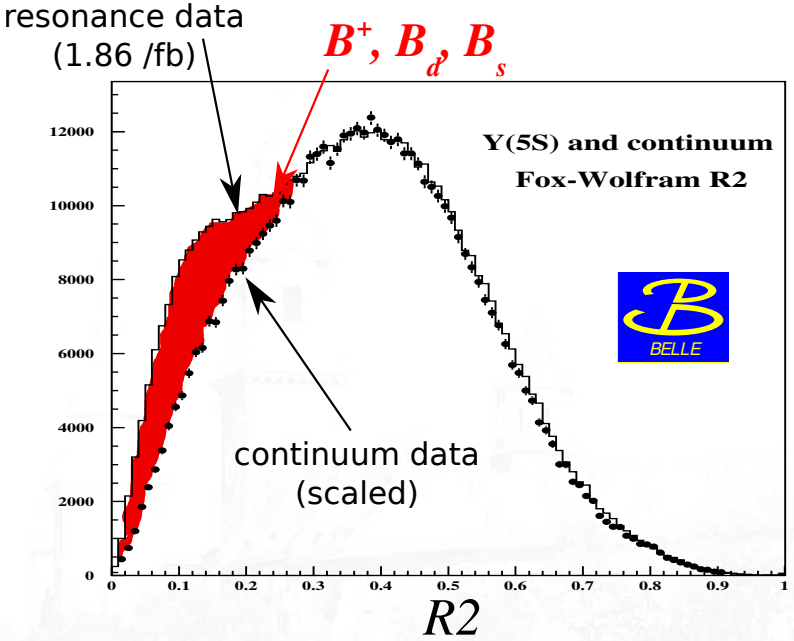
- Data taken at $\Upsilon(5S)$ ($\sqrt{s} = 10867 \pm 1$ MeV)
- World Largest sample:
  - $\sim \mathbf{23.6\,fb^{-1}}$ (06/05 & 06/06) $\rightarrow$ **this talk**
  - Total sample: $\sim \mathbf{100\,fb^{-1}}$ (up to now)
- $\Upsilon(5S)$ is above $B_s^0\bar{B}_s^0$ threshold
  Study of B_s^0 meson possible !

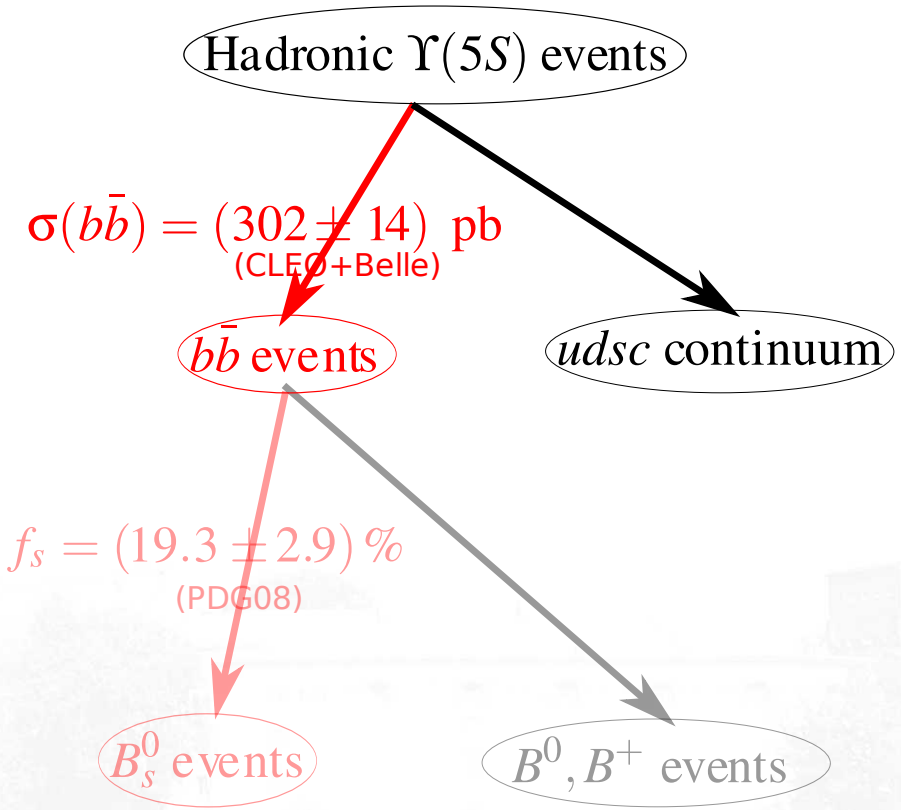


Physics at $\Upsilon(5S)$: B_s^0 production

- $b\bar{b}$ cross section: subtraction of data taken below open-beauty threshold

(done in PRL **98**, 052001)





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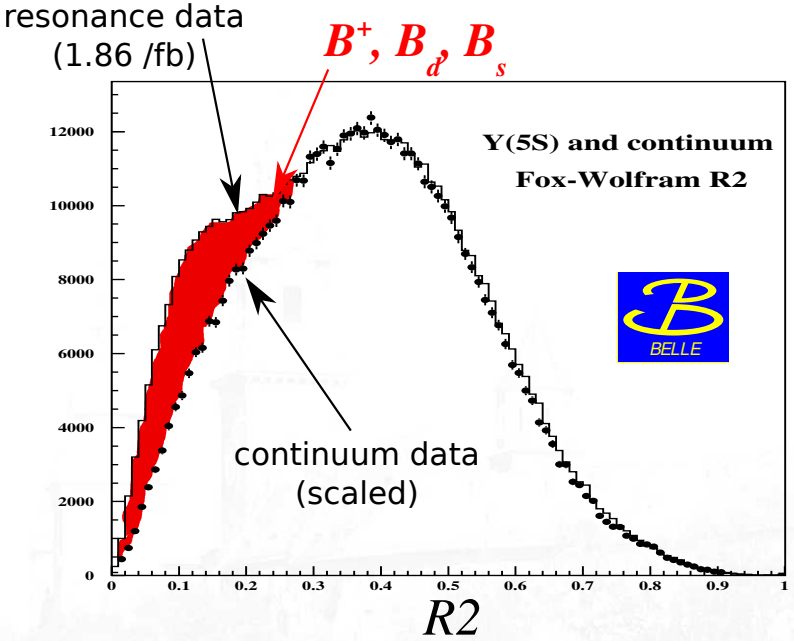
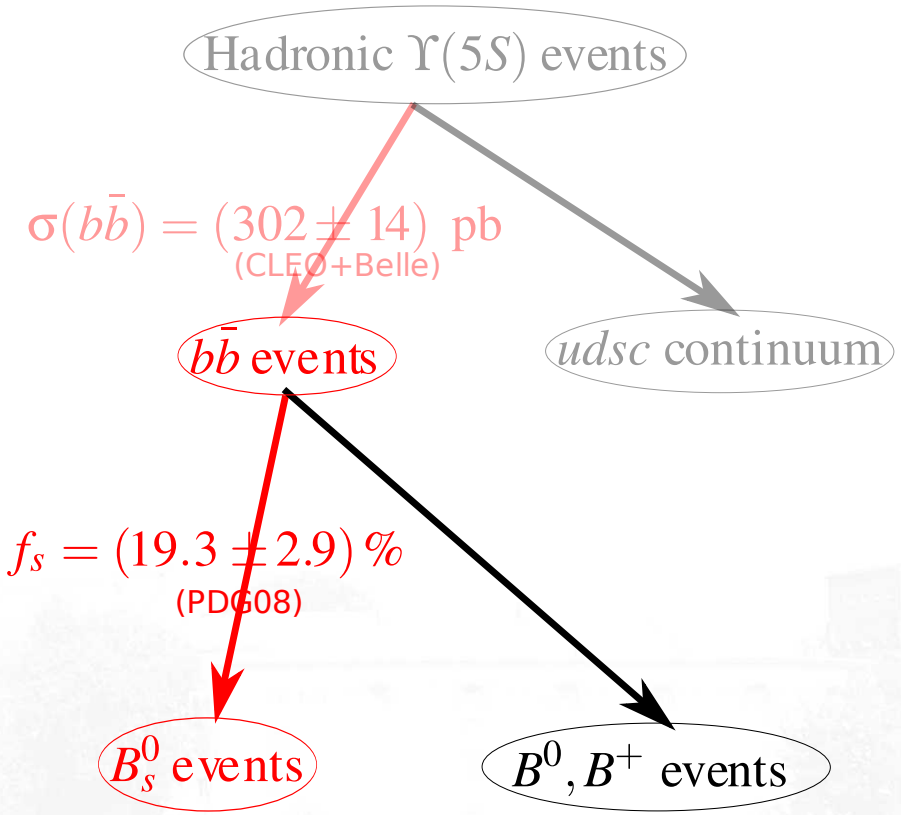




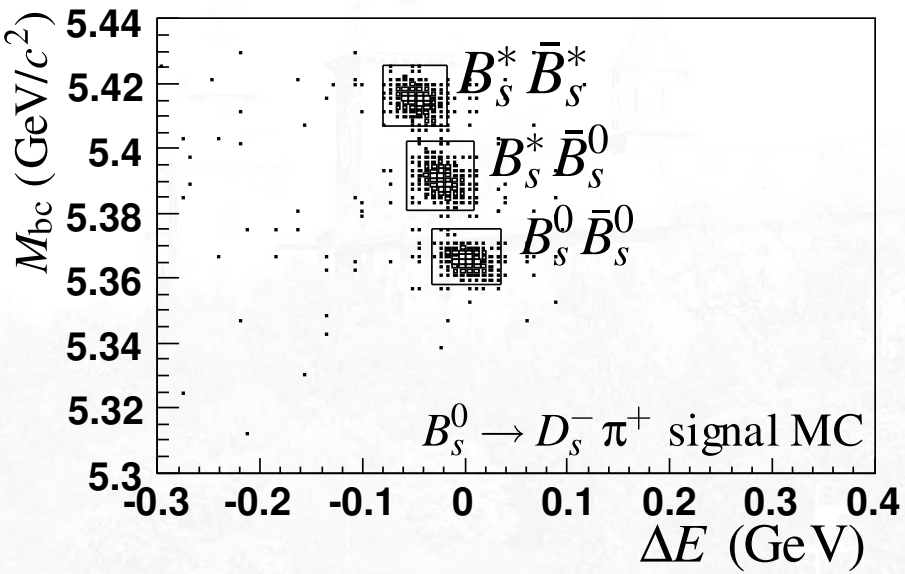
- $f_s = N_{B_s^0}/N_{b\bar{b}}$: inclusive method:

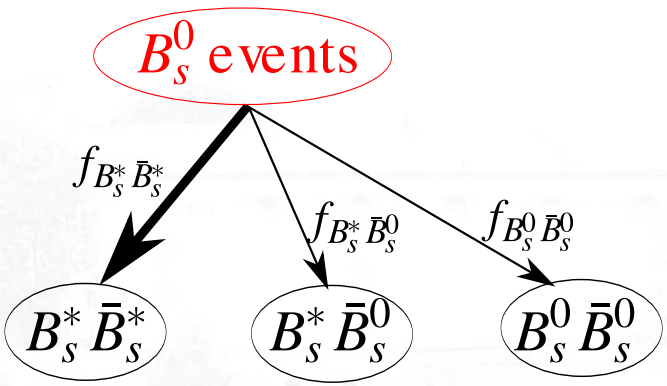
$$\frac{1}{2}\overbrace{\mathcal{B}(\Upsilon(5S)\to D_s X)}^{\Upsilon(5S)\text{ data}} = f_s \times \overbrace{\mathcal{B}(B_s\to D_s X)}^{\text{Model dep. estimate}} + (1-f_s)\times \overbrace{\mathcal{B}(B\to D_s X)}^{\Upsilon(4S)\text{ data}}$$

$$\text{In } 23.6\ \text{fb}^{-1}\text{: } N_{B_s^0} = 2\cdot L_{\text{int}}\cdot\sigma(b\bar{b})\cdot f_s \approx 2.8\cdot 10^6$$

Physics at $\Upsilon(5S)$: B_s^0 production

- Observables: $(2 \times E_{\rm b}^* = \sqrt{s})$
  - Beam-constrained mass: $M_{\rm bc} = \sqrt{{E_{\rm b}^*}^2 - {p_{B_s^0}^*}^2}$
  - Energy difference: $\Delta E = E_{B_s^0}^* - E_{\rm b}^*$
- $\Upsilon(5S) \to B_s^* \bar{B}_s^*$, $B_s^* \bar{B}_s^0$, $B_s^0 \bar{B}_s^0$: 3 signal regions in $(M_{\rm bc}, \Delta E)$ plane:





$f_{B_s^* \bar{B}_s^*} = \left(90.1^{+3.8}_{-4.0} \pm 0.2\right)$ %

(Belle, PRL **100**, 021801, 2009)

- Signal yield extraction: 2D unbinned minimum likelihood fit

Why dominant B_s^0 decay modes?

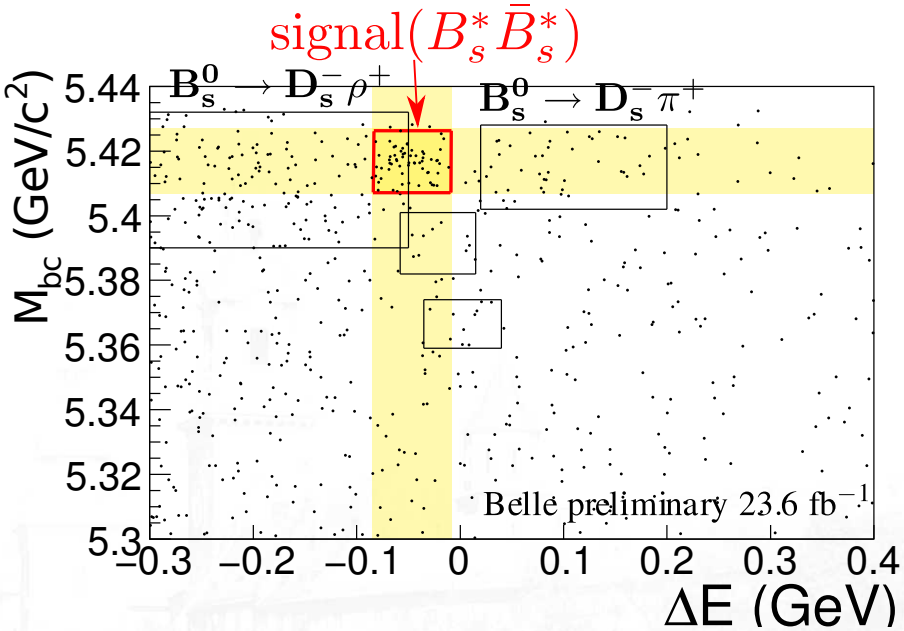
- CKM-favored modes provide a lot of fully-reconstructed B_s^0.
  It's useful for:
  - Measurements of specific modes (absolute B.F.)
  - Measurements of B_s^0, B_s^* properties
    (comparison between B^0 and B_s^0 is theoretically interesting)
  - Measurements of $\Upsilon(5S) \to B_s^{(*)}\bar{B}_s^{(*)}$ properties.
- Results with only $\sim$160 $B_s^0 \to D_s^- \pi^+$ events:

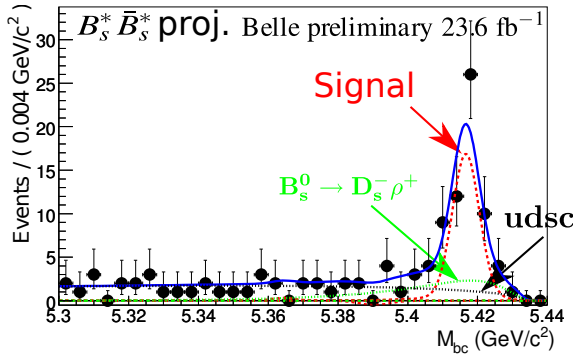
(Belle, R. Louvot et al., PRL **102**, 021801)

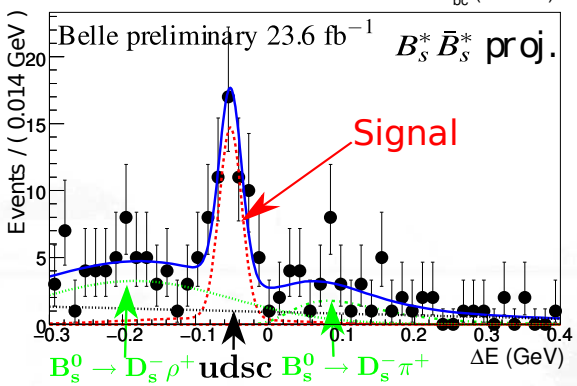
  - the world's most precise values for $\mathcal{B}(B_s^0 \to D_s^- \pi^+)$ and $m(B_s^*)$
  - the second most precise value for $m(B_s^0)$
  - $f_{B_s^* \bar{B}_s^*} = N(B_s^* \bar{B}_s^*)/N(B_s^{(*)}\bar{B}_s^{(*)}) \sim 90\%$ measured with $\sim 4\%$ precision.
  - the first measurements of $f_{B_s^* \bar{B}_s^0} = N(B_s^* \bar{B}_s^0)/N(B_s^{(*)}\bar{B}_s^{(*)})$ and $f_{B_s^0 \bar{B}_s^0} = N(B_s^0 \bar{B}_s^0)/N(B_s^{(*)}\bar{B}_s^{(*)})$

Observation of $B_s^0 \to D_s^{*-}\pi^+$

Shown for the first time





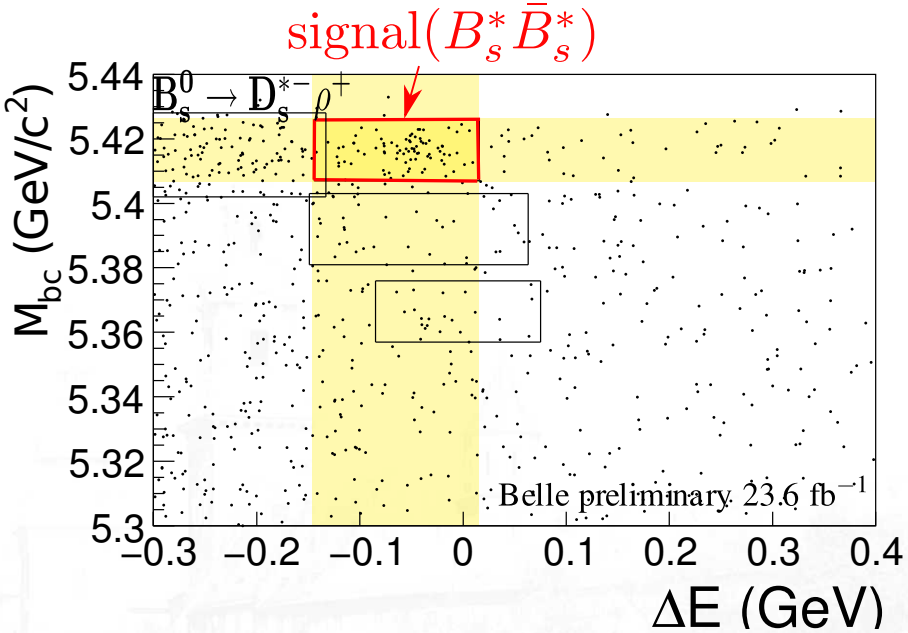


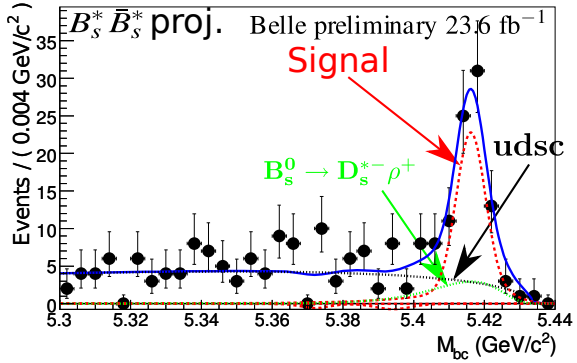
- Contamination from $B_s^0 \to D_s^- \pi^+$ and $B_s^0 \to D_s^- \rho^+$
- $N(B_s^* \bar{B}_s^*) = 53.4^{+10.3}_{-9.4}(\text{stat.})^{+2.4}_{-2.6}(\text{fit})$ events (8.4σ)
- $\mathcal{B}(\mathbf{B_s^0 \to D_s^{*-}\pi^+}) =$

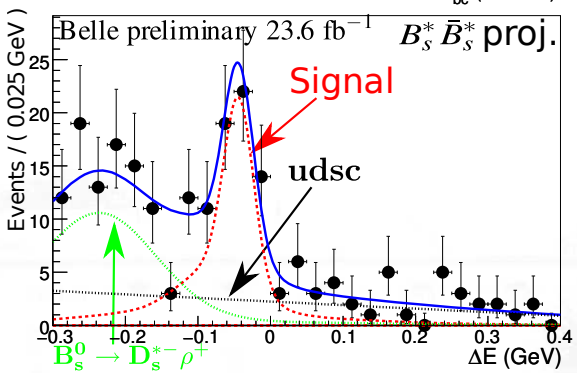
$$\left(\mathbf{2.4^{+0.5}_{-0.4}(stat.) \pm 0.3(syst.) \pm 0.4(f_s)}\right) \times \mathbf{10^{-3}}$$

Observation of $B_s^0 \to D_s^- \rho^+$

Shown for the first time





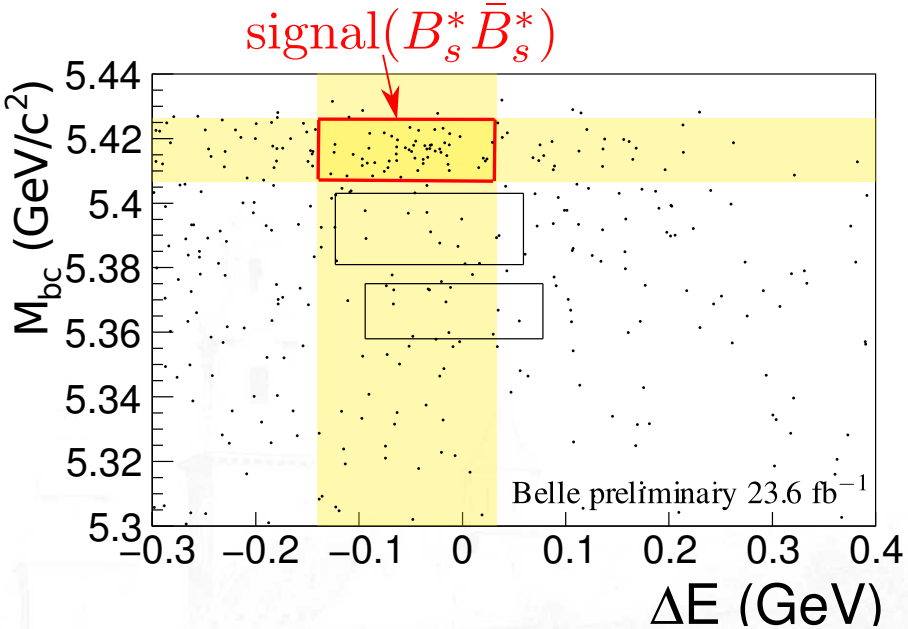


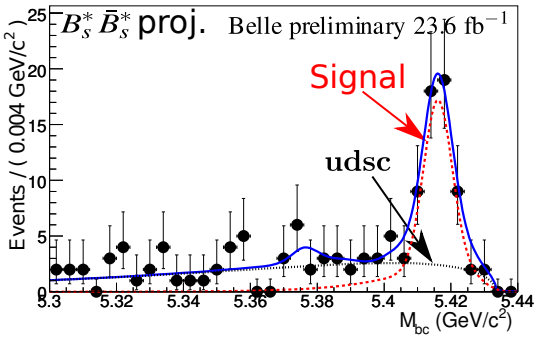
- Contamination from $B_s^0 \to D_s^{*-} \rho^+$
- $N(B_s^* \bar{B}_s^*) = 87.1^{+13.9}_{-12.9}(\text{stat.})^{+4.0}_{-4.2}(\text{fit})$ events (10.1σ)
- $\mathcal{B}(\mathbf{B_s^0 \to D_s^- \rho^+}) =$

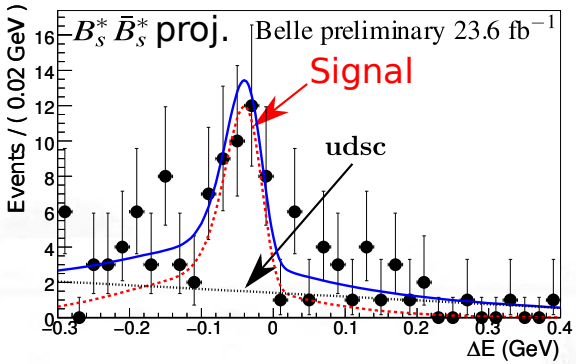
$$\left(\mathbf{8.5^{+1.3}_{-1.2}(stat.) \pm 1.1(syst.) \pm 1.3(f_s)}\right) \times \mathbf{10^{-3}}$$

Observation of $B_s^0 \to D_s^{*-}\rho^+$

Shown for the first time







- $N(B_s^* \bar{B}_s^*) = 73.7^{+13.5}_{-12.4}(\text{stat.}) \pm 3.7(\text{fit})$ events (8.6σ)
- $\mathcal{B}(\mathbf{B_s^0 \to D_s^{*-}\rho^+}) =$
$$\left(\mathbf{13.0^{+2.3}_{-2.1}(stat.) \pm 1.7(syst.) \pm 1.7(pol.) \pm 1.9(f_s)}\right) \times \mathbf{10^{-3}}$$
- "pol.": error from decay polarization uncertainties
  Enough signal to measure helicity amplitudes (will be done)

Why *CP*-eigenstate B_s^0 decay modes?

- Charmless $B_s^0 \to K^+K^-$ decay
  - may be sensitive to NP

    London & Matias, PRD **70**, 031502 (hep-ph/0404009)
  - can measure CKM-angle γ via comparision with $B^0 \to \pi^+\pi^-$

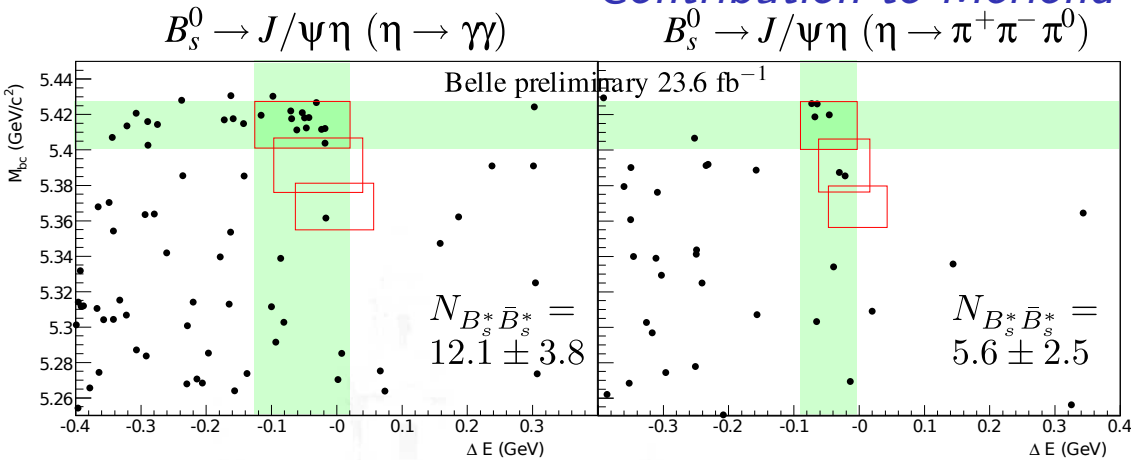
    Fleischer, PLB **459**, 306 (hep-ph/9903456)

- Generally, *CP*-eigenstates final states (like $B_s^0 \to J/\psi\eta$)
  - are useful for *CP*-violation parameters (β_s, $\Delta\Gamma_s/\Gamma_s$, ...)

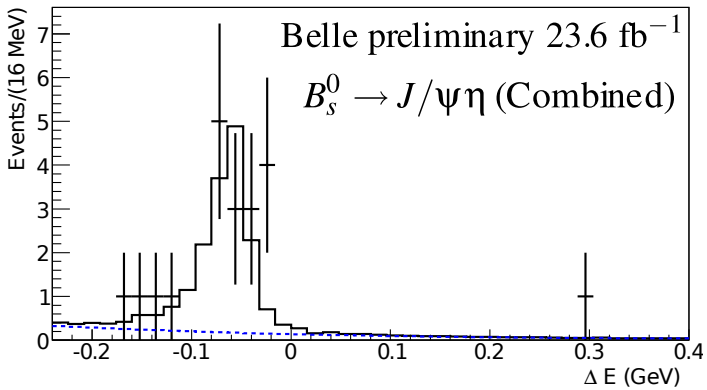
    Dunietz, Fleicher & Nierste, PRD **63**, 114015 (hep-ph/0012219)

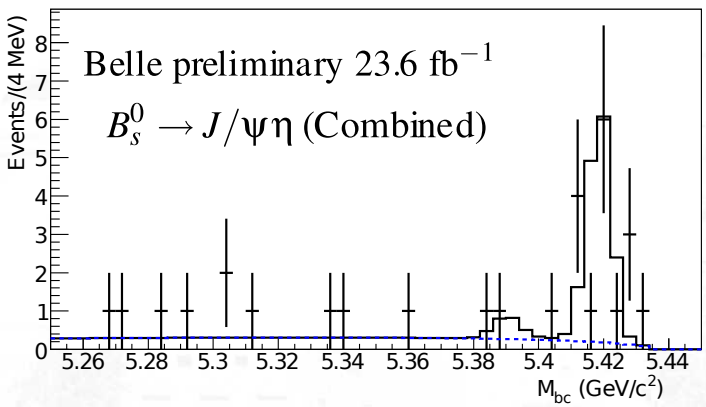
Observation of $B_s^0 \to J/\psi\eta$

Contribution to Moriond QCD09



Projection in $B_s^*\bar{B}_s^*$ box:





- $\eta \to \gamma\gamma$ channel (5.9σ)

$$\mathcal{B}\left(B_s^0 \to J/\psi\eta\right) = \left(3.44 \pm 1.07^{+0.62}_{-1.08}\right) \times 10^{-4}$$

- $\eta \to \pi^0\pi^+\pi^-$ channel (4.0σ)

$$\mathcal{B}\left(B_s^0 \to J/\psi\eta\right) = \left(4.60 \pm 2.06^{+0.89}_{-1.29}\right) \times 10^{-4}$$

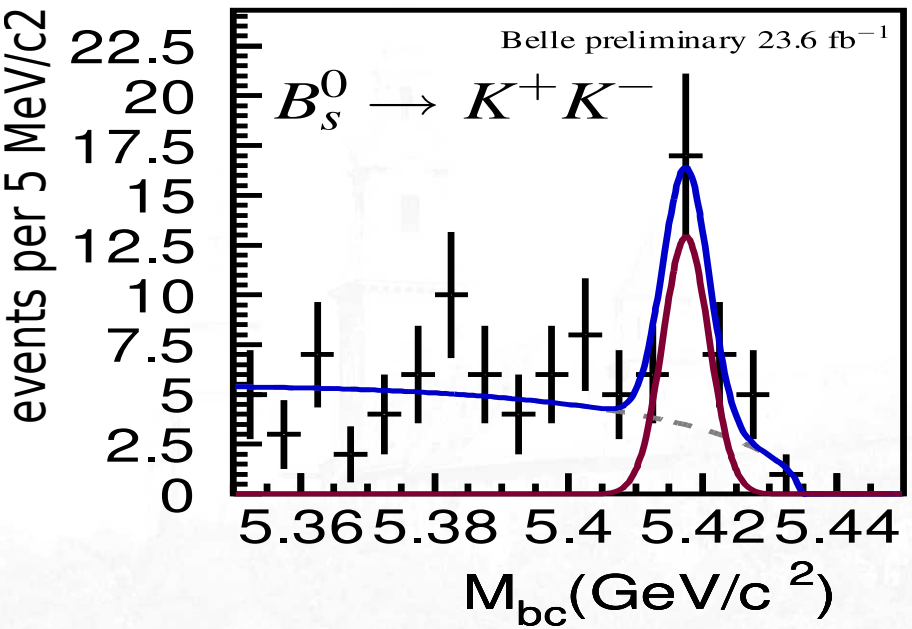
- Combined

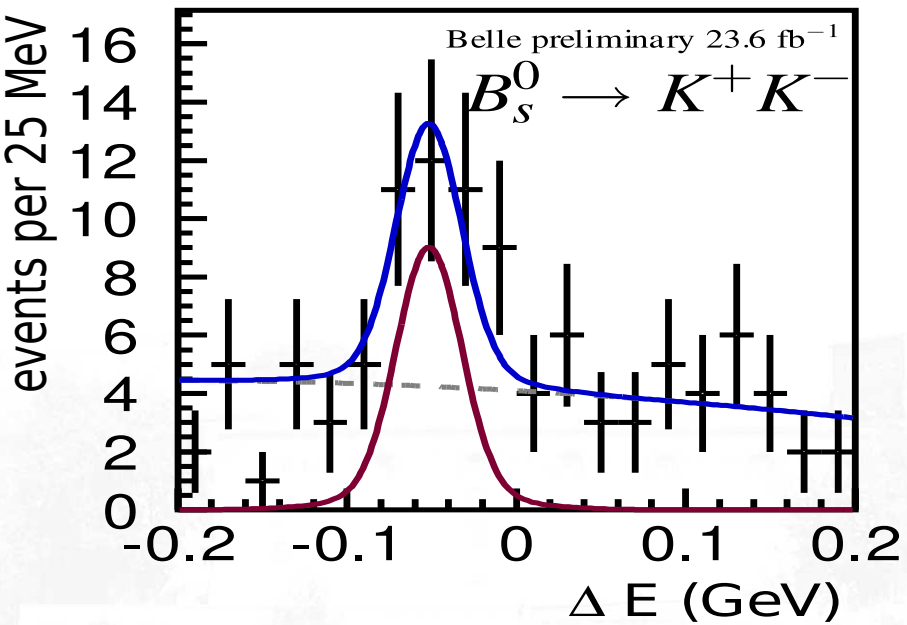
$$\mathcal{B}\left(\mathbf{B_s^0 \to J/\psi\eta}\right) = \left(\mathbf{3.69 \pm 0.95^{+0.65}_{-0.95}}\right) \times \mathbf{10^{-4}}$$

$B_s^0 \to K^+K^-$

Shown for the first time

- Observation of 23 $B_s^0 \to K^+K^-$ events (5.8σ)





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

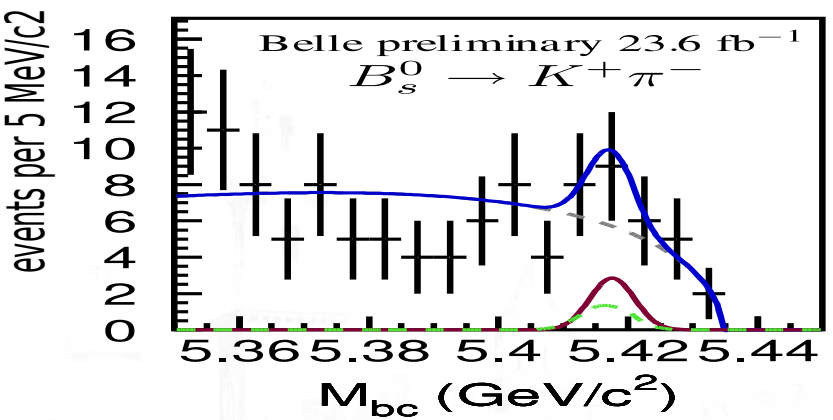
CDF: $(3.3 \pm 0.6 \pm 0.7) \times 10^{-5}$ (PRL **97**, 211802)

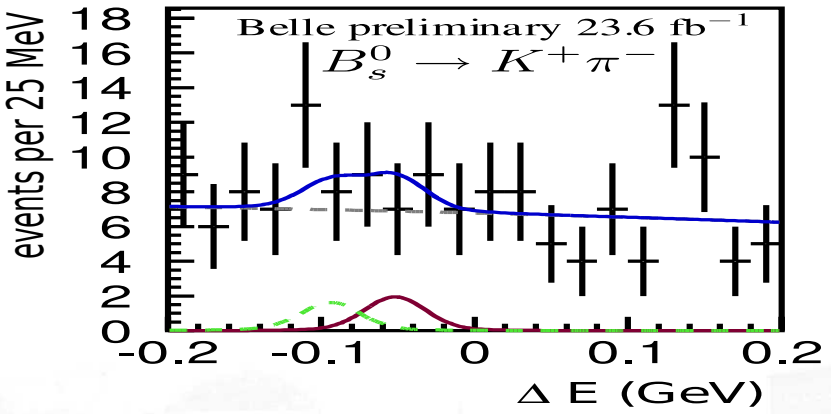
$B_s^0 \to h^+\pi^-,\ h^+ = \pi^+, K^+$

Shown for the first time

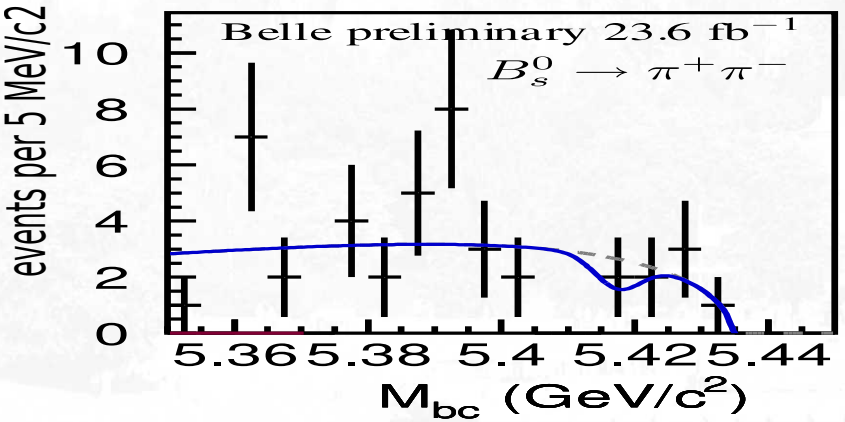
Upper limits (90% C.L.) for suppressed decays:

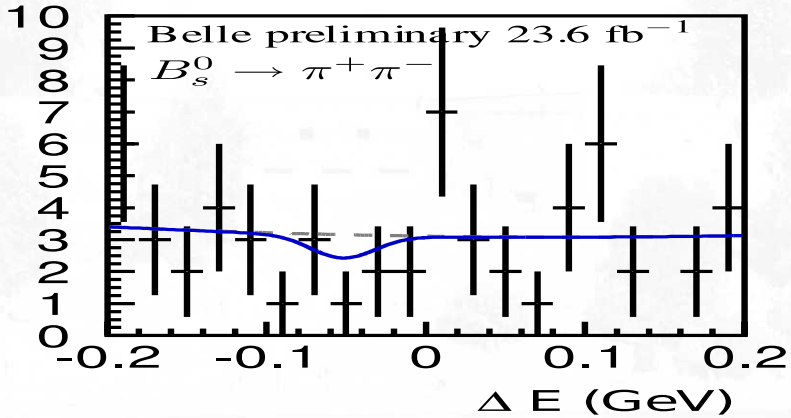
- $\mathcal{B}(B_s^0 \to K^+\pi^-) < 2.6 \times 10^{-5}$ (1.2σ)





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

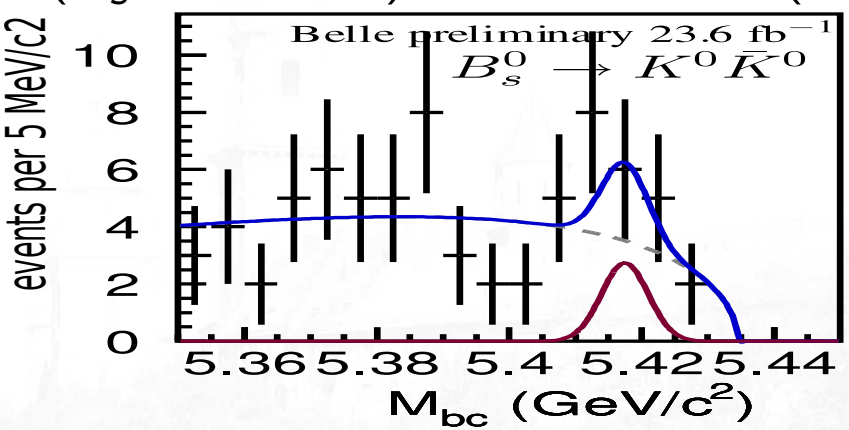


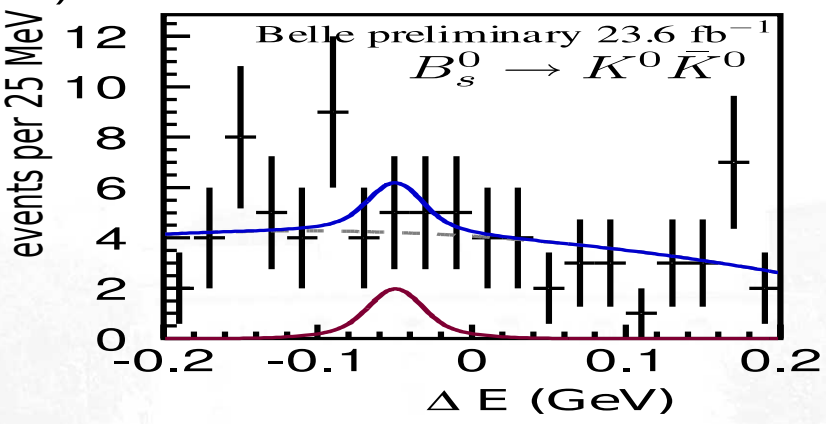


$B_s^0 \to K^0 \bar{K}^0$

Shown for the first time

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





Conclusion:

- In $23.6\,\mathrm{fb}^{-1}$ of $\Upsilon(5S)$ data: new results:
  - CKM-favored (First observations):
    - $\mathcal{B}(B_s^0 \to D_s^{*-}\pi^+) = \left(2.4^{+0.5}_{-0.4}(\mathrm{stat.}) \pm 0.3(\mathrm{syst.}) \pm 0.4(f_s)\right) \times 10^{-3}$
    - $\mathcal{B}(B_s^0 \to D_s^{-}\rho^+) = \left(8.5^{+1.3}_{-1.2}(\mathrm{stat.}) \pm 1.1(\mathrm{syst.}) \pm 1.3(f_s)\right) \times 10^{-3}$
    - $\mathcal{B}(B_s^0 \to D_s^{*-}\rho^+) =$ $\left(13.0^{+2.3}_{-2.1}(\mathrm{stat.}) \pm 1.7(\mathrm{syst.}) \pm 1.7(\mathrm{pol.}) \pm 1.9(f_s)\right) \times 10^{-3}$
  - $B_s^0 \to CP$ eigenstate + charmless decays
    - $\mathcal{B}(B_s^0 \to J/\psi\,\eta) = \left(3.69 \pm 0.95^{+0.65}_{-0.95}\right) \times 10^{-4}$ (First observation)
    - $\mathcal{B}(B_s^0 \to K^+K^-) = \left(3.8^{+1.0}_{-0.9} \pm 0.7\right) \times 10^{-5}$
    - $\mathcal{B}(B_s^0 \to \pi^+\pi^-) < 1.2 \times 10^{-5}$ (90% C.L.)
    - $\mathcal{B}(B_s^0 \to K^0\bar{K}^0) < 6.6 \times 10^{-5}$ (90% C.L.)
    - $\mathcal{B}(B_s^0 \to K^+\pi^-) < 2.6 \times 10^{-5}$ (90% C.L.)

- $100\,\mathrm{fb}^{-1}$ of data are now available
  - Better precision expected
  - A lot of new interesting results!

Thank you.