Observation of $B_s \to D_s^{*-}\pi^+$, $D_s^{(*)-}\rho^+$ and $D_s^{(*)+}D_s^{(*)-}$, and Estimate of $\Delta\Gamma_{CP}$ at Belle

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B_s^0 Decays @ Belle

- Confirmed large potential of B-factories for B_s^0 investigations
  - low multiplicities of charged and neutral particles
  - high reconstruction efficiencies

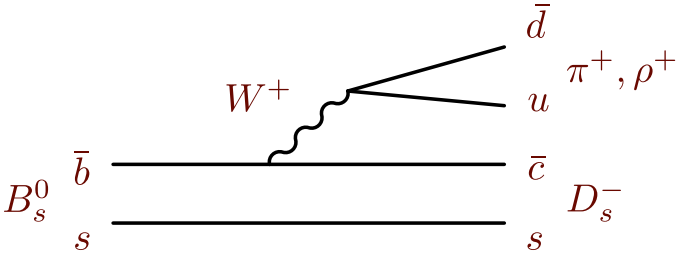
- Tests of HQET, factorization, etc.
  - similarities predicted between B^0 and B_s^0

- Precise measurements of exclusive modes
  - provides normalization for B_s^0 decay at LHC experiments

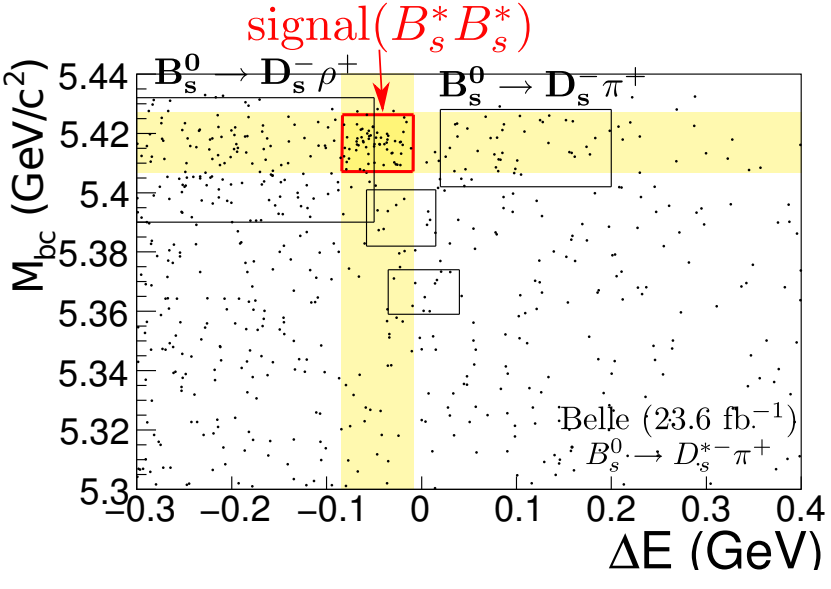
- Measurements of B_s^0 and B_s^* properties (masses, widths, angular distributions)

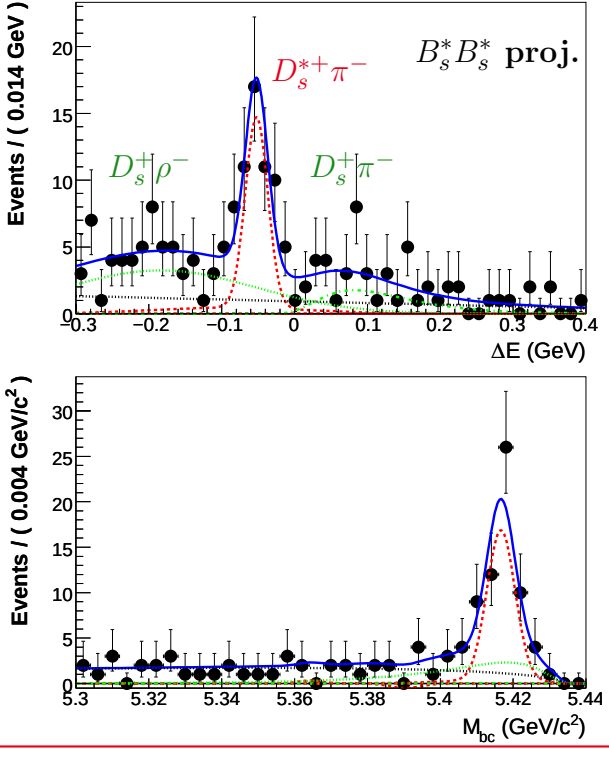
$B_s \to D_s^{*-}\pi$ and $D_s^{(*)-}\rho^+$: Motivation

- Cabibo-favored decays
  - relatively large branching fractions
- Dominated by spectator process
- neutral particles in the final states (photon, π^0)
- full reconstruction of the final states
  - $D_s^{*\pm} \to D_s^{\pm}\gamma$
  - $D_s^+ \to \phi\pi^+, K_S K^+, K^{*0}K^+$



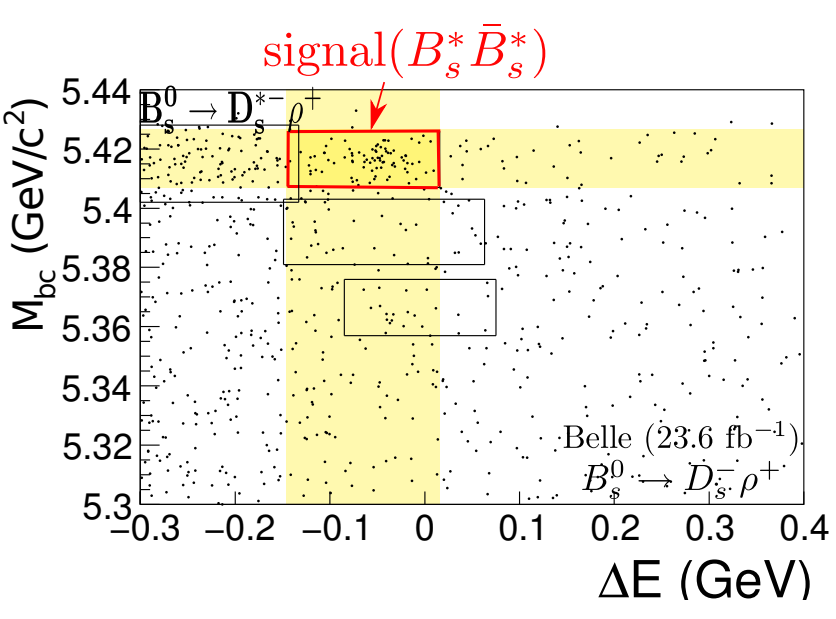
- $N(B_s^*\bar{B}_s^*) = 53.4^{+10.3}_{-9.4}(stat)^{+2.4}_{-2.6}(syst)$ (7.1σ)
- $\mathcal{B}(B_s^0 \to D_s^{*-}\pi^+) = (2.4^{+0.5}_{-0.4}(stat.) \pm 0.3(syst.) \pm 0.4(fs)) \times 10^{-3}$

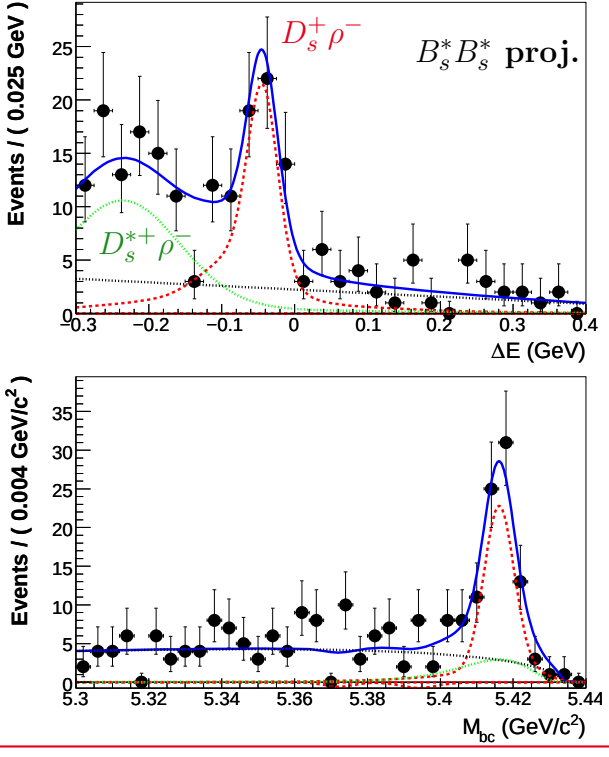




$B_s \to D_s^- \rho^+$: First Observation

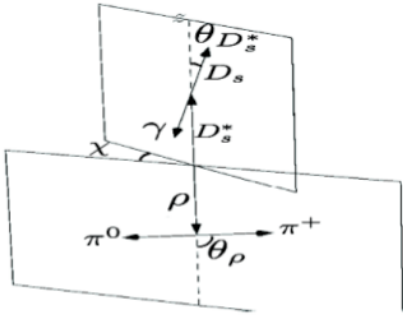
- $N(B_s^* \bar{B}_s^*) = 92.2^{+14.2}_{-13.2}(stat)^{+4.3}_{-4.2}(syst)$ (8.2σ)
- $\mathcal{B}(B_s^0 \to D_s^- \rho^+) = (8.5^{+1.3}_{-1.2}(stat.) \pm 1.1(syst.) \pm 1.3(fs)) \times 10^{-3}$

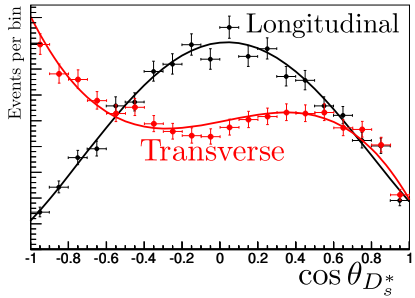


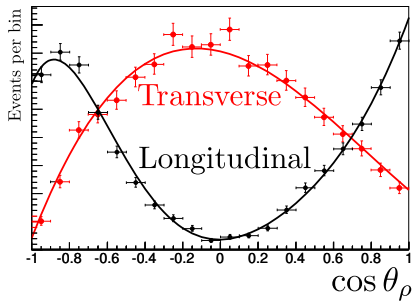


$B_s \to D_s^{*-}\rho^+$

- Longitudinal and Transverse polarizations are possible
- BF measurement depends on the polarization:
  - different reconstruction efficiency
  - different M_{bc} and ΔE signal shapes
- 4D fit (ΔE, M_{bc} , $cos\theta_{D_s^{*-}}$, $cos\theta_{\rho^+}$)
- Simultaneous extraction of $\mathcal{B}(B_s \to D_s^{*-}\rho^+)$ and $f_L(B_s \to D_s^{*-}\rho^+)$
- test of the factorization hypothesis

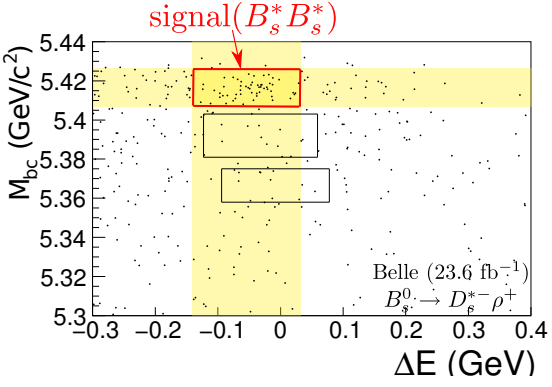


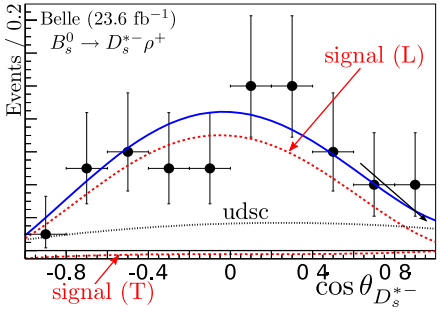


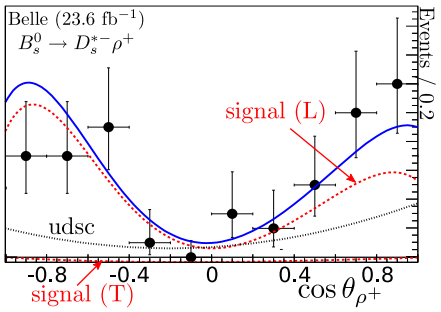


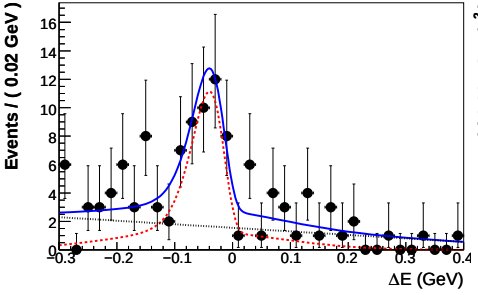
$B_s \to D_s^{*-}\rho^+$: First Observation

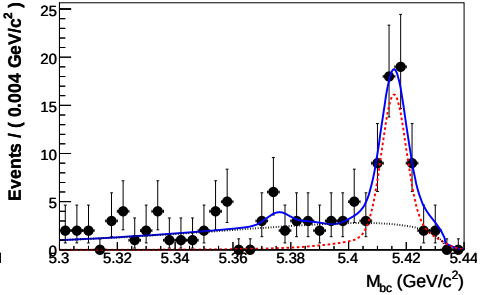
- $N(B_s^*\bar{B}_s^*) = 77.8^{+14.5}_{-13.4}$ (7.4σ)
- $\mathcal{B}(B_s^0 \to D_s^{*-}\rho^+) = (11.9^{+2.2}_{-2.0}(stat.) \pm 1.7(syst.) \pm 1.8(fs)) \times 10^{-3}$
- Fraction of longitudinal polarization: $f_L = 1.05^{+0.08+0.03}_{-0.10-0.04}$



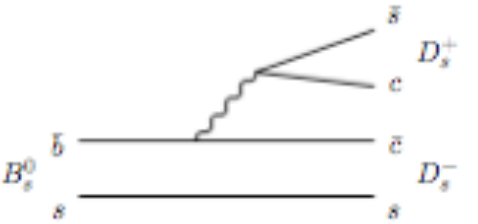








$B_s \to D_s^{(*)-} D_s^{(*)+}$: Motivation



- CP-even final states
  - $D_s^+ D_s^-$ pure CP-even
  - $D_s^* D_s^{(*)}$ predominantly CP-even
- In the heavy quark limit, while $(m_b - 2m_c) \to 0$ and $N_c \to \infty$
  - $b \to c\bar{c}s$ process saturates Γ_s
  - $\Gamma[B_s^0(CP+) \to D_s^{(*)-} D_s^{(*)+}]$ saturates $\Delta\Gamma_s^{CP}$
  - assuming negligible CP violation, we can estimate $\Delta\Gamma_s^{CP}/\Gamma_s$

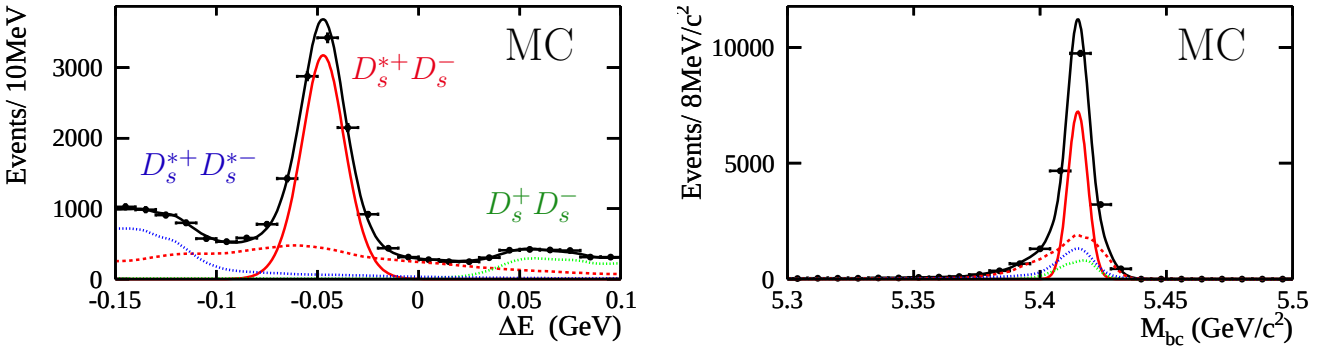
$$\frac{\Delta\Gamma_s^{CP}}{\Gamma_s} = \frac{2\mathcal{B}(B_s^0 \to D_s^{(*)-} D_s^{(*)+})}{1 - \mathcal{B}(B_s^0 \to D_s^{(*)-} D_s^{(*)+})}$$

Aleksan *et. al.*, PLB 316, 567 (1993) , Dunietz *et. al.* , PRD 63, 114015 (2001)

  - 3-body $D_s D_s X$ final states are not included

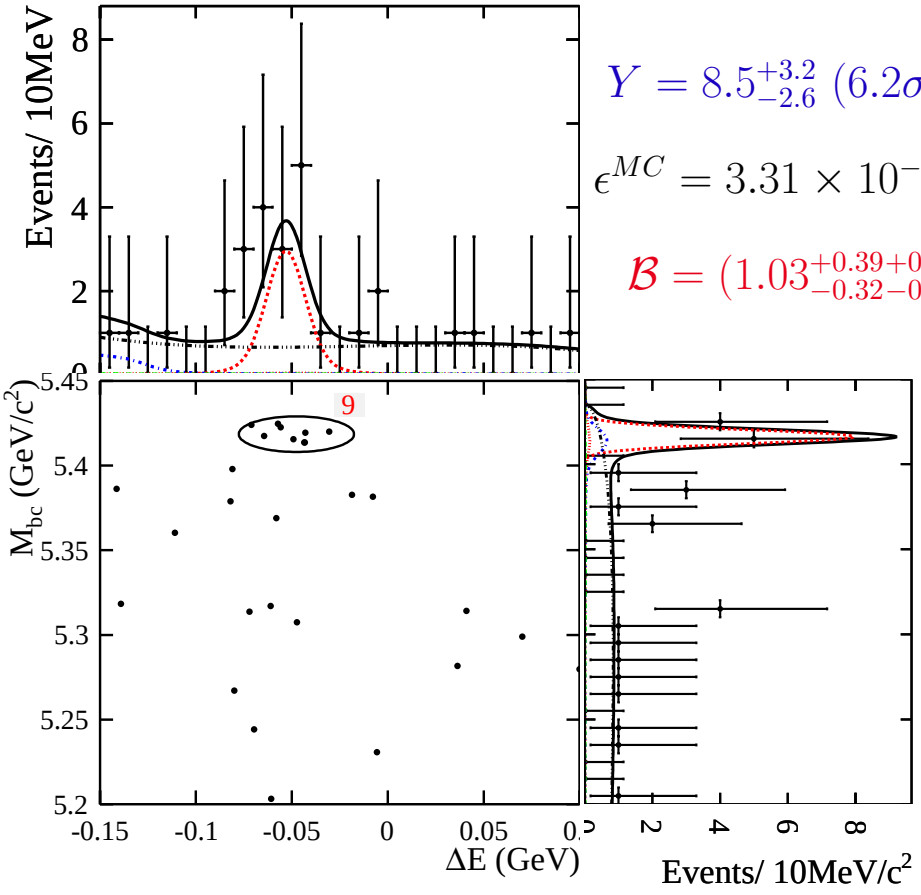
Study of $B_s \to D_s^{(*)-} D_s^{(*)+}$

- Exclusively reconstructed $D_s^+ D_s^-$, $D_s^{*\pm} D_s^{\mp}$ and $D_s^{*+} D_s^{*-}$ modes
  - $D_s^{*\pm} \to D_s^{\pm} \gamma$
  - $D_s^+ \to \phi\pi^+, K_S K^+, K^{*0} K^+, \phi\rho^+, K^{*+} K_S, K^{*+} K^{*0}$
- 2D simultaneous fit of three modes to count for large cross-feeds



- one candidate selection per event with minimum

$$\chi^2 = \frac{1}{2+N} \left\{ \begin{array}{l} \sum_{i=1}^{2} \left[(\widetilde{M}_{D_s^i} - M_{D_s})/\sigma_M \right]^2 + \\ \sum_{i=1}^{N} \left[(\widetilde{\Delta M}_{D_s^{*i} - D_s^i} - \Delta M_{D_s^* - D_s})/\sigma_{\Delta M} \right]^2 \end{array} \right\}$$



$Y = 8.5^{+3.2}_{-2.6}\ (6.2\sigma)$

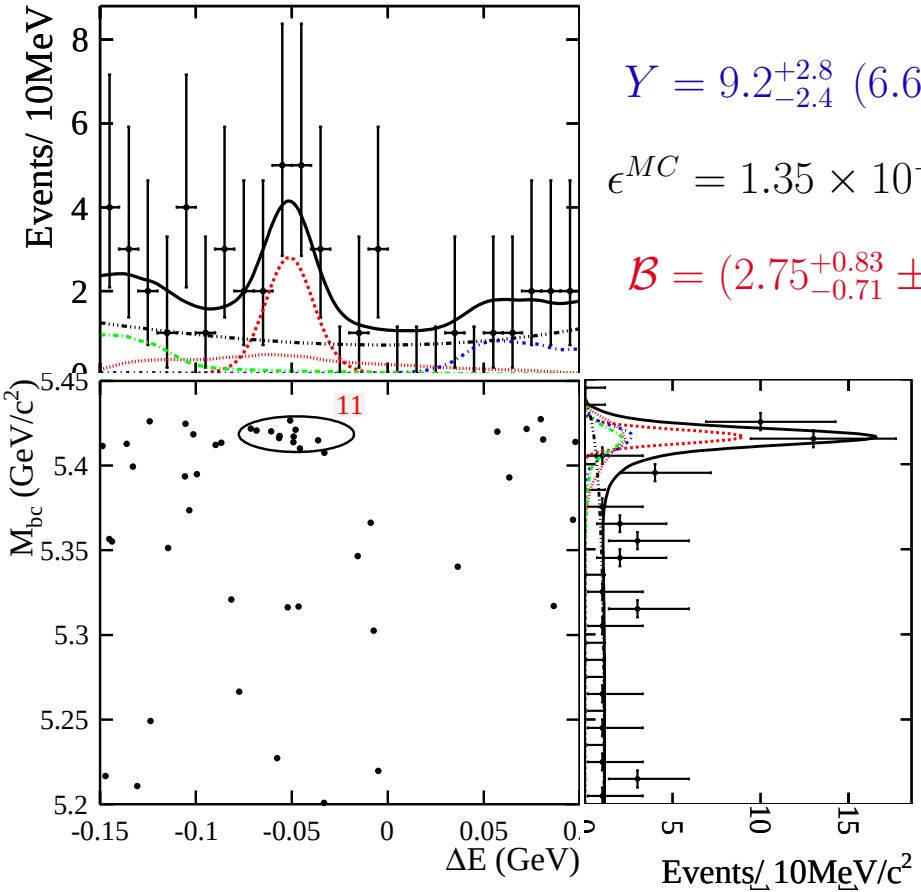
$\epsilon^{MC} = 3.31 \times 10^{-4}$

$\mathcal{B} = (1.03^{+0.39+0.15}_{-0.32-0.13} \pm 0.21)\%$

Consistent with PDG : $(1.1 \pm 0.4)\%$

CDF, 355 pb^{-1}, PRL 100, 021803 (2008)

$B_s \to D_s^{*\pm} D_s^{\mp}$: First Observation

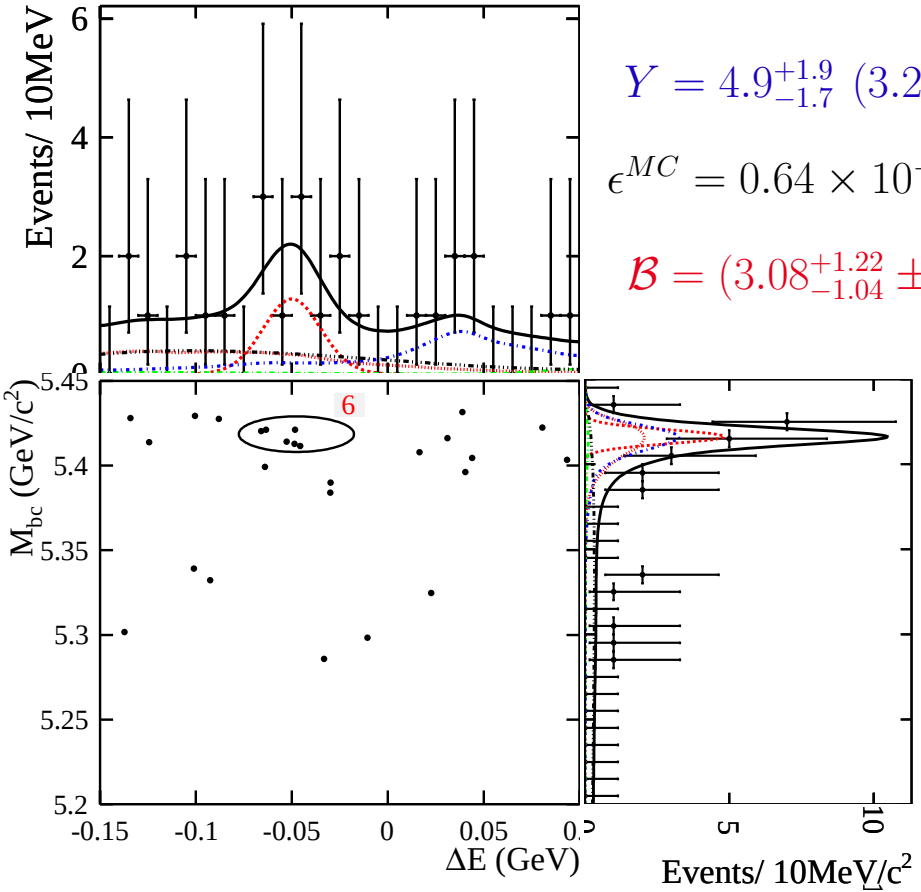


$$Y = 9.2^{+2.8}_{-2.4}\ (6.6\sigma)$$

$$\epsilon^{MC} = 1.35 \times 10^{-4}$$

$$\mathcal{B} = (2.75^{+0.83}_{-0.71} \pm 0.40 \pm 0.56)\%$$

$B_s \to D_s^{*-} D_s^{*+}$: First Evidence



$$Y = 4.9^{+1.9}_{-1.7}\ (3.2\sigma)$$

$$\epsilon^{MC} = 0.64 \times 10^{-4}$$

$$\mathcal{B} = (3.08^{+1.22}_{-1.04} \pm 0.56 \pm 0.63)\%$$

Estimation of $\Delta\Gamma_{CP}/\Gamma_{CP}$

- Using $22.6^{+4.7}_{-3.9}$ events in total, we obtain
  - $\mathcal{B}(B^0_s \to D^{(*)-}_s D^{(*)+}_s) = (6.85^{+1.53+1.26}_{-1.30-1.25} \pm 1.41)\%$
  - $\Delta\Gamma^{CP}_s/\Gamma_s = (14.7^{+3.6+4.4}_{-3.0-4.2})\%$
  - 1.3σ higher than D0 measurement
    V.M. Abazov *et. al.* Phys.Rev.Lett.102, 091801(2009)
  - Consistent with SM expectation : $(12.7 \pm 2.4)\%$
  - Theoretical error of $\pm 3\%$ expected
    Aleksan *et. al.*, PLB 316, 567 (1993)

Conclusion

- Results from Belle with $23.6 fb^{-1}$ data

- CKM-favored: $B_s^0 \to D_s^{*-}\pi^+$, $D_s^-\rho^+$ and $D_s^{*-}\rho^+$
  - First observations, large signals seen

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

- $B_s^0 \to D_s^{(*)+}D_s^{(*)-}$ exclusively studied: $\Delta\Gamma^{CP}/\Gamma^{CP}$ measured.
  - First observation of $D_s^{*+}D_s^-$ and first evidence of $D_s^{*+}D_s^{*-}$
  - Competitive measurement of $\Delta\Gamma_{CP}/\Gamma_{CP}$

    S. Esen et al. (Belle), arXiv:1005.5177 [hep-ex], submitted to PRL