B_s decays at Belle

36th International Conference on High Energy Physics

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For the Belle collaboration

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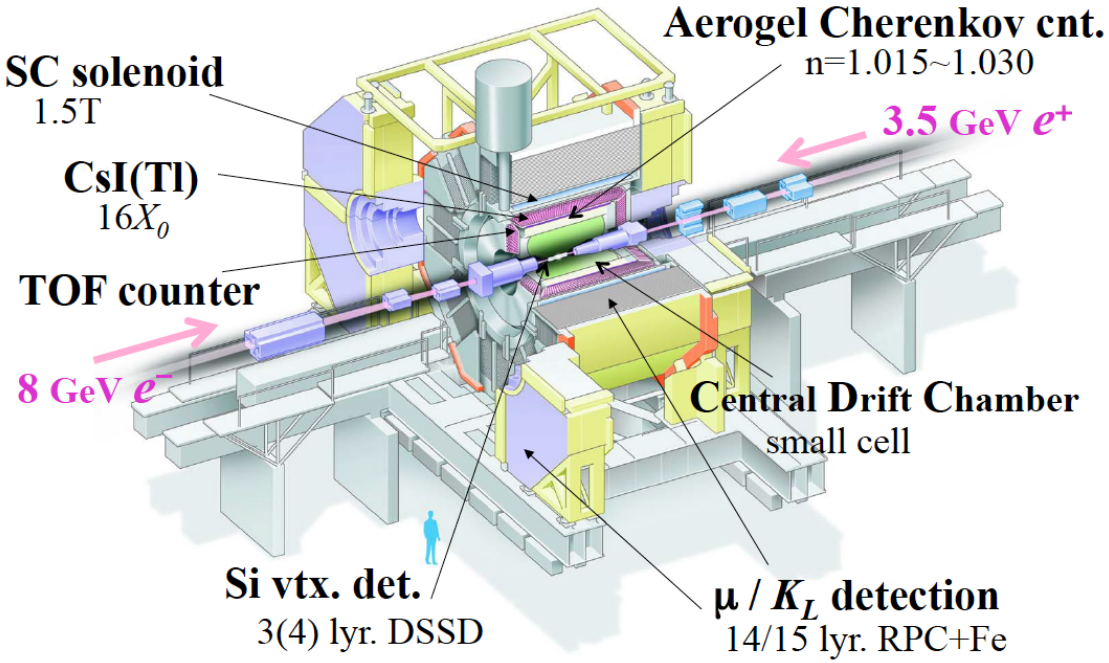
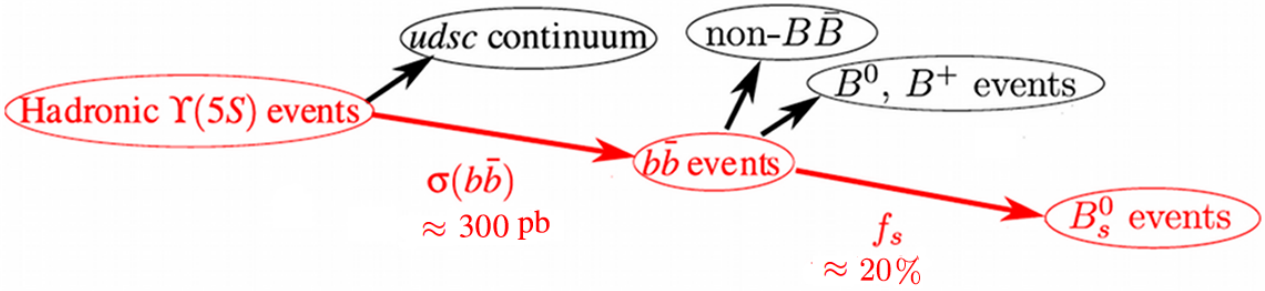
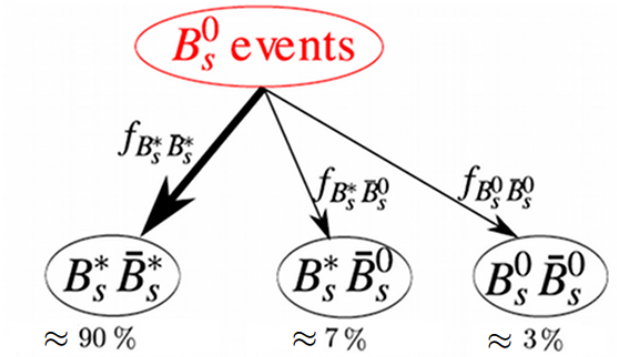
Outline

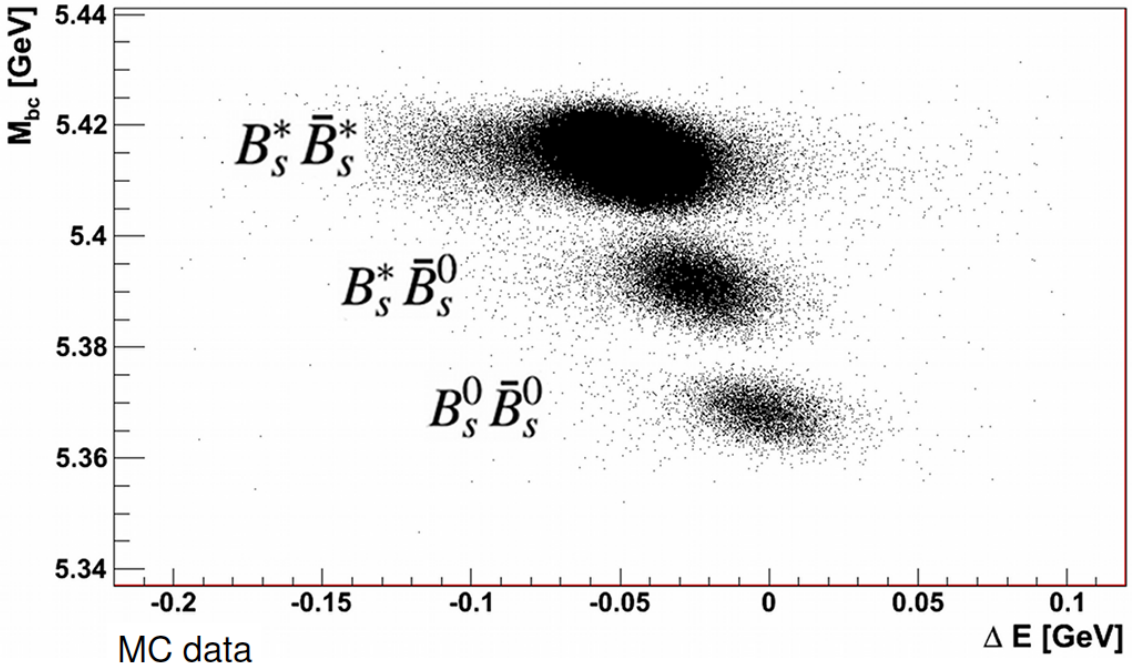
1. Introduction
2. $B_s^0 \to J/\psi\, K^+K^-$ NEW!
3. $B_s \to J/\psi\, \eta,\ J/\psi\, \eta'$
4. $B_s^0 \to D_s^{(*)+} D_s^{(*)-}$



The $\Upsilon(5S)$ data sample







$\Upsilon(4S)$ @ 10.58 GeV $\rightarrow 711\,\mathrm{fb}^{-1}$ B decays

$\Upsilon(5S)$ @ 10.87 GeV $\rightarrow 121\,\mathrm{fb}^{-1}$ B_s spectroscopy

unique!

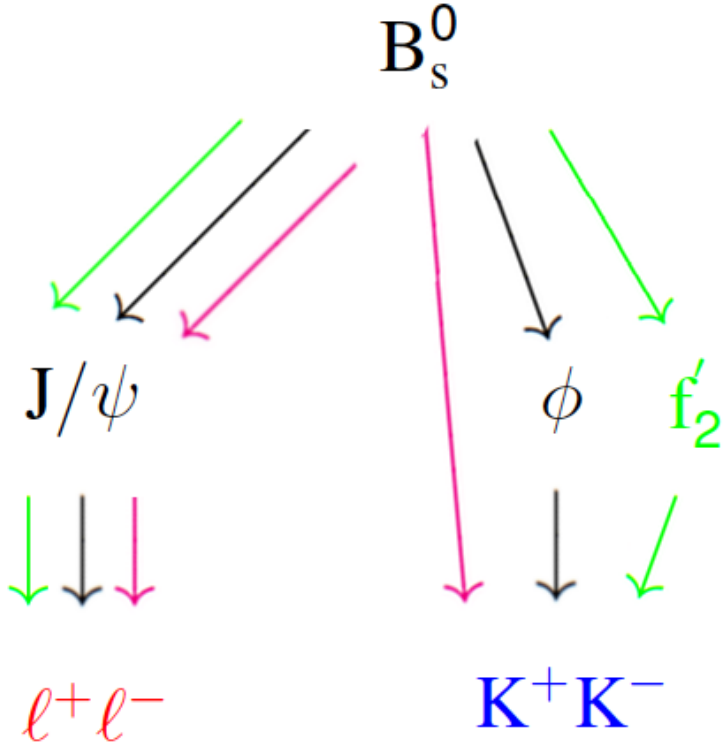
- full reconstruction of B_s^0 meson
- no reconstruction of $B_s^* \rightarrow B_s^0 \gamma$
- using two nearly independent kinematic variables for extracting B_s^0 signal:

$$M_{bc} = \sqrt{(E_{beam})^2 - (p_B^*)^2}$$

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

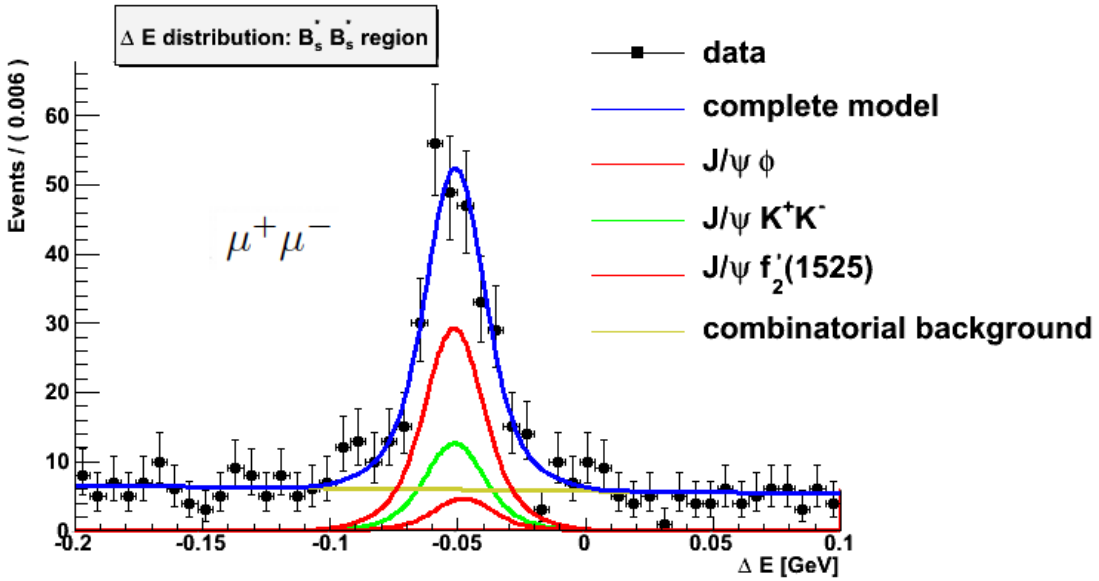
$B_s^0 \to J/\psi\, K^+K^-$ $(121\,fb^{-1})$ ICHEP preliminary

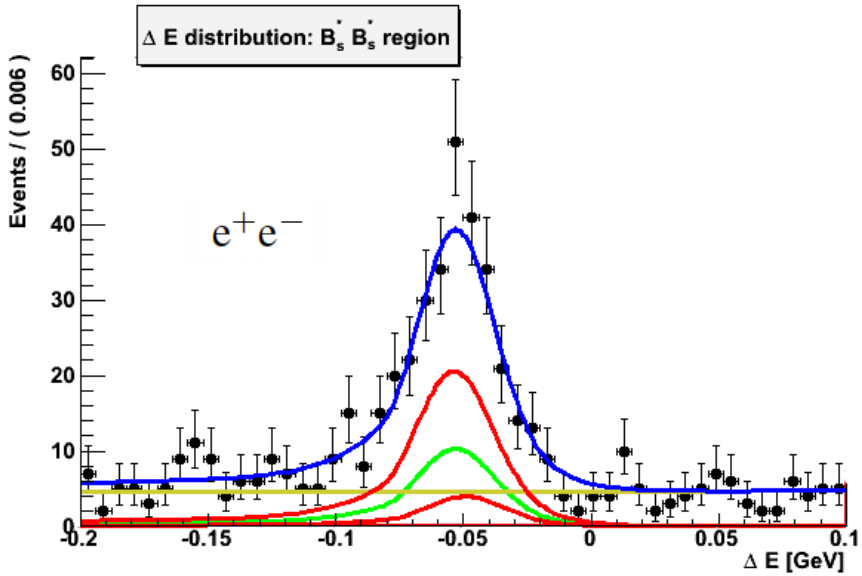
- $B_s^0 \to J/\psi\, \phi$:
  important mode for CP violation:
  ϕ_s sensitive to new physics
  $\to$ LHCb (2012): $\Delta\Gamma_s > 0$ @ 4.7σ,
  compatible with Standard Model prediction
- additional measurement of
  $\mathcal{B}\left(B_s^0 \to J/\psi\, K^+K^-\right)$
  $\to$ not measured so far



  - $B_s^0 \to J/\psi\, f_2'(1525)$:
    relative branching fraction measured by LHCb and D0
    $\to$ should be visible in Belle data sample

$B_s^0 \to J/\psi\, K^+K^-$ $(121\,\mathrm{fb}^{-1})$ ICHEP preliminary





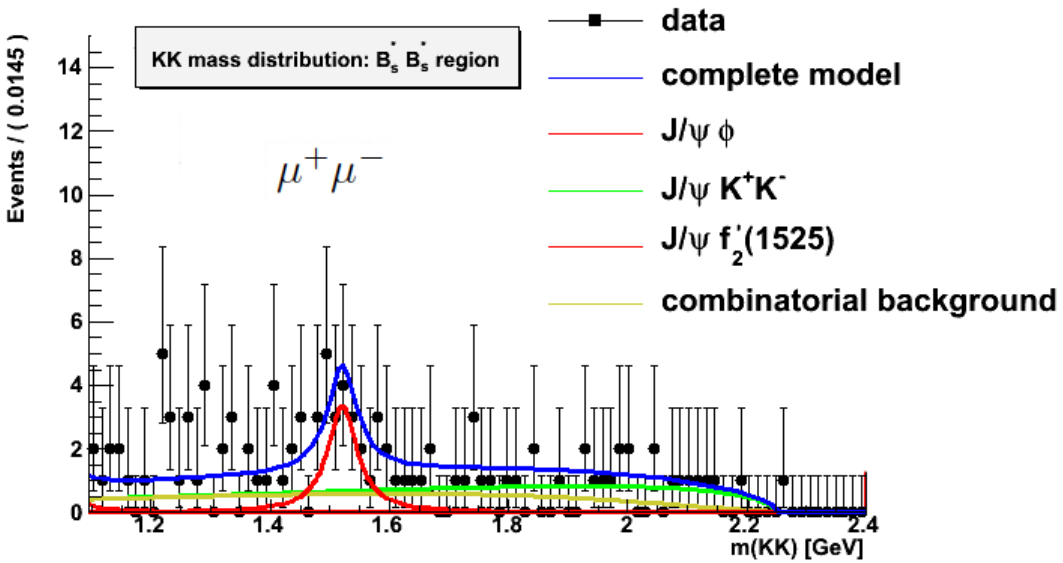
$$\mathcal{B}\left(B_s^0 \to J/\psi\,\phi\right) = \left(1.25 \pm 0.07_{\mathrm{stat}} \pm 0.20_{\mathrm{sys}}\right) 10^{-3}$$

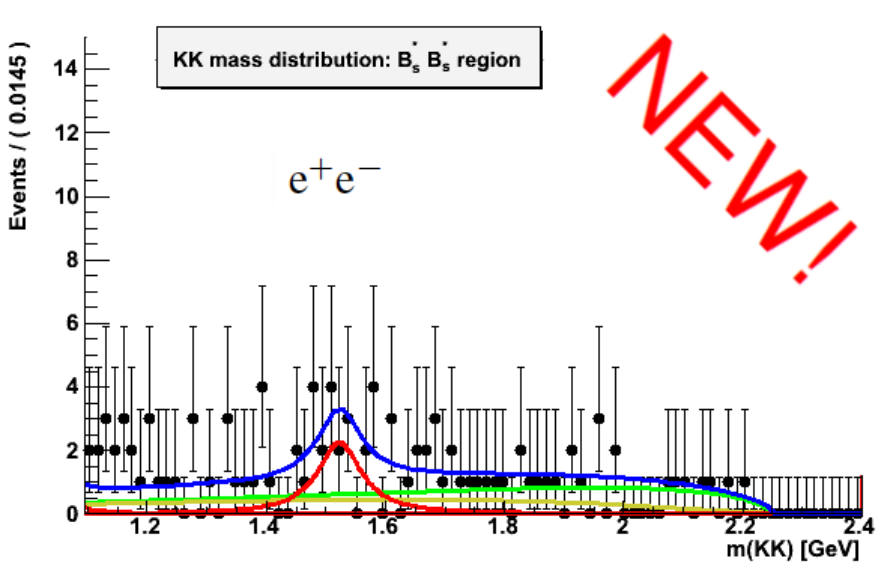
systematic dominated by uncertainty in f_s;
$B_s^0 \to J/\psi\,\phi$ not including $B_s^0 \to J/\psi\, K^+K^-$ or $B_s^0 \to J/\psi\, f_2'(1525)$

$$\mathcal{B}\left(B_s^0 \to J/\psi\, K^+K^-\right) = \left(0.36 \pm 0.04_{\mathrm{stat}} \pm 0.08_{\mathrm{sys}}\right) 10^{-3}$$

systematic dominated by uncertainty in f_s and pdf shape;
$B_s^0 \to J/\psi\, K^+K^-$ including $B_s^0 \to J/\psi\, f_2'(1525)$, but not $B_s^0 \to J/\psi\,\phi$

$B_s^0 \to J/\psi\, K^+K^-$ $(121\,\mathrm{fb}^{-1})$ ICHEP preliminary





signal yield for $B_s^0 \to J/\psi\, f_2'(1525)$:
25.3 ± 8.5 events $(\mu^+\mu^-)$ and 32.6 ± 10.5 events (e^+e^-)

$$\mathcal{B}\left(B_s^0 \to J/\psi_{\mu^+\mu^-}\, f'_2(1525)\right) = \left(0.21 \pm 0.07_{\mathrm{stat}} \pm 0.04_{\mathrm{sys}}\right) 10^{-3}$$

$$\mathcal{B}\left(B_s^0 \to J/\psi_{e^+e^-}\, f'_2(1525)\right) = \left(0.29 \pm 0.09_{\mathrm{stat}} \pm 0.05_{\mathrm{sys}}\right) 10^{-3}$$

consistent within statistical error

$B_s^0 \to J/\psi\, K^+K^-$ $(121\,\mathrm{fb}^{-1})$ ICHEP preliminary

combined result:

$$\mathcal{B}\left(B_s^0 \to J/\psi\, f_2'(1525)\right) = (0.24 \pm 0.06_{\mathrm{stat}} \pm 0.04_{\mathrm{sys}})\, 10^{-3}$$

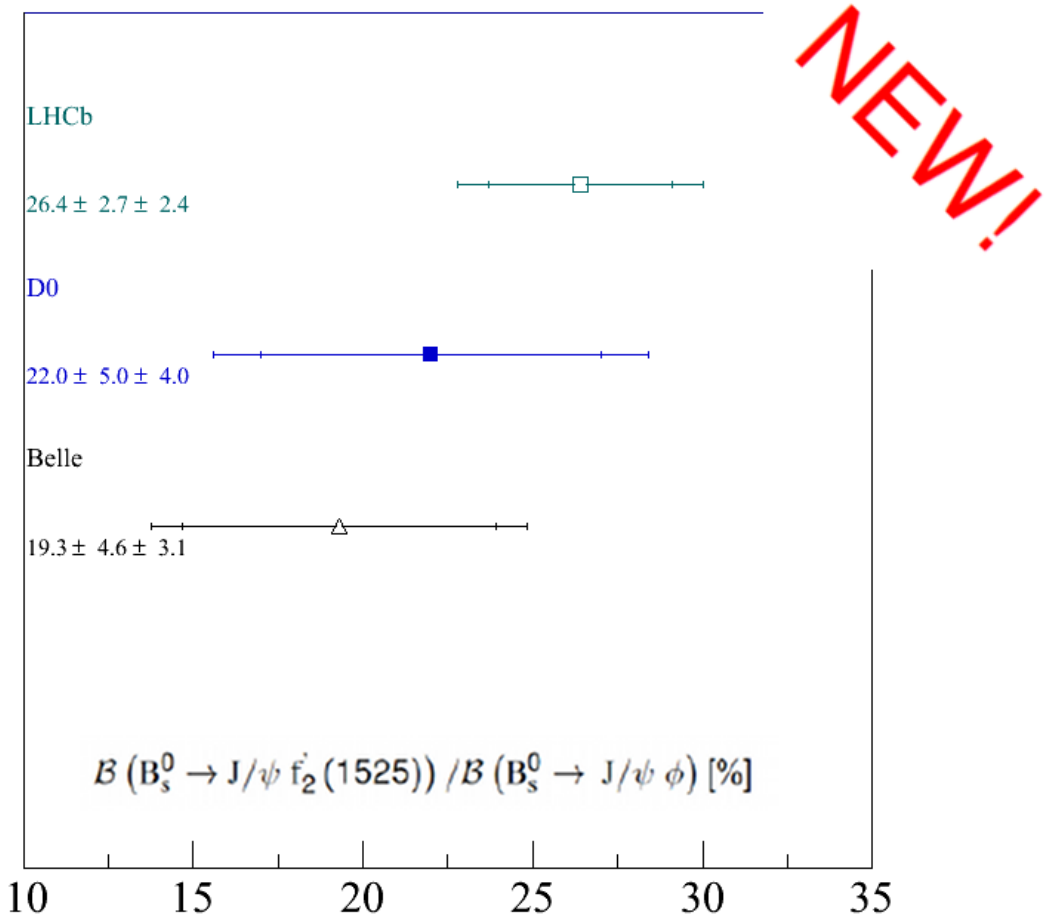
@ 4.0 σ including systematic uncertainty;
systematic dominated by uncertainty in f_s and pdf shape;

relative branching fraction:

$$\frac{\mathcal{B}\left(B_s^0 \to J/\psi\, f'_2(1525)\right)}{\mathcal{B}\left(B_s^0 \to J/\psi\, \phi\right)} =$$

$$19.3 \pm 4.6_{\mathrm{stat}} \pm 3.1_{\mathrm{sys}}\ \%$$

$\to$ in agreement with LHCb and D0



Systematic Uncertainties $B_s^0 \to J/\psi_{e^+e^-}\ K^+K^-$ ICHEP preliminary

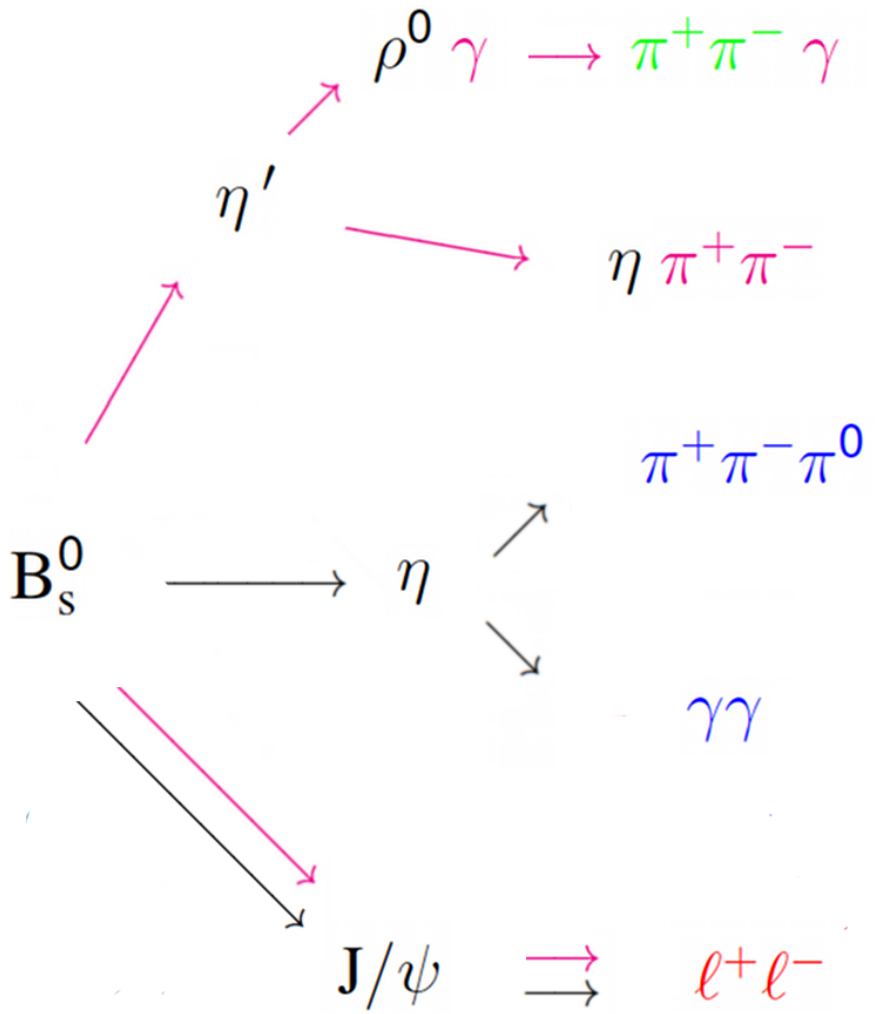
Parameter	Error	%
Luminosity	0.847 fb^{-1}	0.7
$\sigma_{b\bar{b}}^{\Upsilon(5S)}$	0.014 nb	4.6
f_s	0.029	15.0
$\mathcal{B}\left(J/\psi \to \mu^+\mu^-\right)$	0.0006	1.0
$\mathcal{B}\left(J/\psi \to e^+e^-\right)$	0.0006	1.0
$\mathcal{B}\left(\phi \to K^+K^-\right)$	0.005	1.0
$\mathcal{B}\left(f'_2\,(1525) \to K^+K^-\right)$	0.011	2.5
$\epsilon_{\text{MC statistic}}\left(\mu^+\mu^-\right)$	0.001	0.2
$\epsilon_{\text{MC statistic}}\left(e^+e^-\right)$	0.001	0.3
$\epsilon_{\text{Polarisation}}\left(\mu^+\mu^-\right)$	0.005	1.5
$\epsilon_{\text{Polarisation}}\left(e^+e^-\right)$	0.004	1.3
tracking		1.4
lepton and kaon ID		2.0
PDF shape $B_s^0 \to J/\psi_{\mu^+\mu^-}\ \phi$	3.7 events	2.3
PDF shape $B_s^0 \to J/\psi_{e^+e^-}\ \phi$	4.6 events	2.7
PDF shape $B_s^0 \to J/\psi_{\mu^+\mu^-}\ K^+K^-$	10.5 events	11.8
PDF shape $B_s^0 \to J/\psi_{e^+e^-}\ K^+K^-$	22.6 events	20.5
PDF shape $B_s^0 \to J/\psi_{\mu^+\mu^-}\ f'_2\,(1525)$	1.9 events	7.7
PDF shape $B_s^0 \to J/\psi_{e^+e^-}\ f'_2\,(1525)$	3.3 events	10.2

$B_s \longrightarrow J/\psi\,\eta,\ J/\psi\,\eta'$ PRL 108, 181808 (2012)

- new CP-even eigenstates
- previous upper limit (by L3):
  $\mathcal{B}(B_s \to J/\psi\,\eta) < 3.8 \cdot 10^{-3}$
  @ 90% C.L.
- SU(3) flavor symmetry predicts:

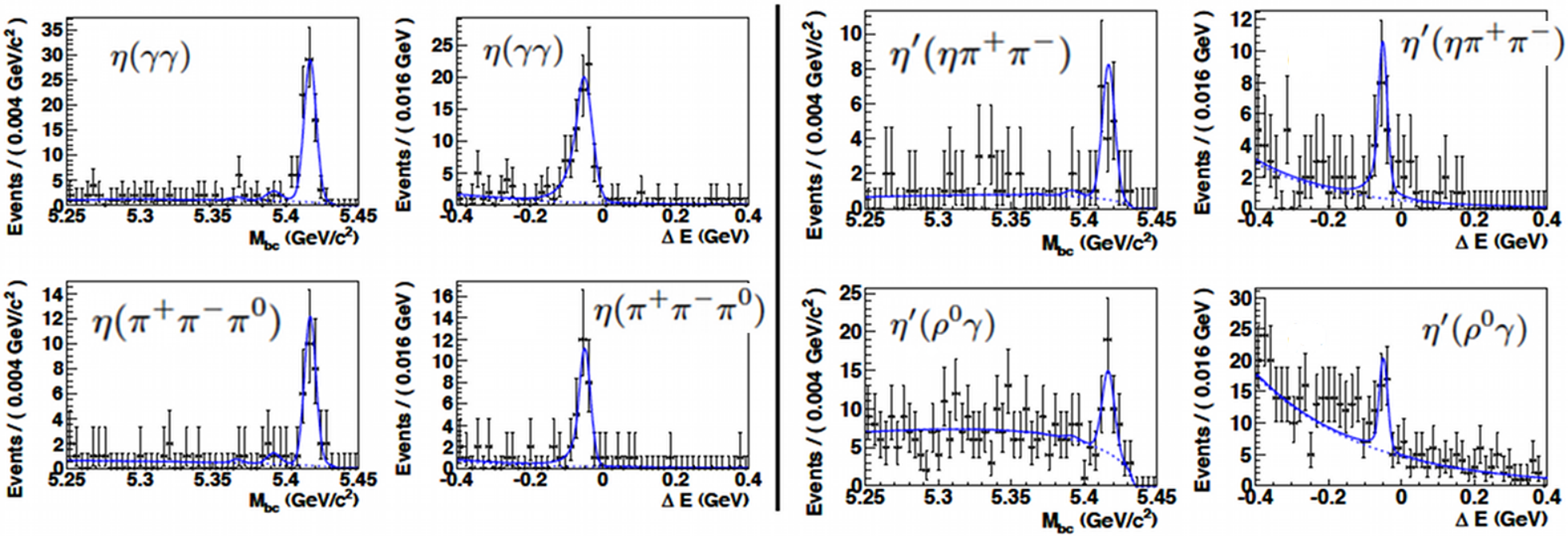
$$\frac{\mathcal{B}(B_s \to J/\psi\,\eta')}{\mathcal{B}(B_s \to J/\psi\,\eta)} = 1.04 \pm 0.04$$

$\Rightarrow$ test SU(3) symmetry and $\eta - \eta'$ mixing



FOR REFERENCE:
M. ACCIARRI ET AL. [L3 COLLABORATION], PHYS. LETT. B 391, 481 (1997);
P. Z. SKANDS, JHEP 0101, 008 (2001)
A. DATTA, H. J. LIPKIN AND P. J. O'DONNELL, PHYS. LETT. B 529, 93 (2002);
C. E. THOMAS, JHEP 0710, 026 (2007);
R. FLEISCHER, R. KNEGJENS AND G. RICCIARDI, ARXIV:1110.5490 [HEP-PH] (2011);

$B_s \longrightarrow J/\psi\,\eta,\ J/\psi\,\eta'$ PRL 108, 181808 (2012)



$B_s \rightarrow J/\psi\,\eta$ signal yield:

141 ± 14 events @ $21.9\,\sigma$

$B_s \rightarrow J/\psi\,\eta'$ signal yield:

86 ± 14 events @ $10.3\,\sigma$

all three $\Upsilon(5S) \rightarrow B_s^{(*)} B_s^{(*)}$ signal regions considered

$B_s \longrightarrow J/\psi\,\eta,\ J/\psi\,\eta'$ PRL 108, 181808 (2012)

determined branching fractions:

$$\mathcal{B}\left(B_s \to J/\psi\,\eta\right) = \left(5.10 \pm 0.50_{\text{stat}} \pm 0.25_{\text{sys}}\ {}^{+1.14}_{-0.79}(N_{B_s^{(*)}\overline{B}_s^{(*)}})\right)\cdot 10^{-4}$$

$$\mathcal{B}\left(B_s \to J/\psi\,\eta'\right) = \left(3.71 \pm 0.61_{\text{stat}} \pm 0.18_{\text{sys}}\ {}^{+0.83}_{-0.57}(N_{B_s^{(*)}\overline{B}_s^{(*)}})\right)\cdot 10^{-4}$$

systematic dominated by uncertainty in f_s

relative branching fraction:

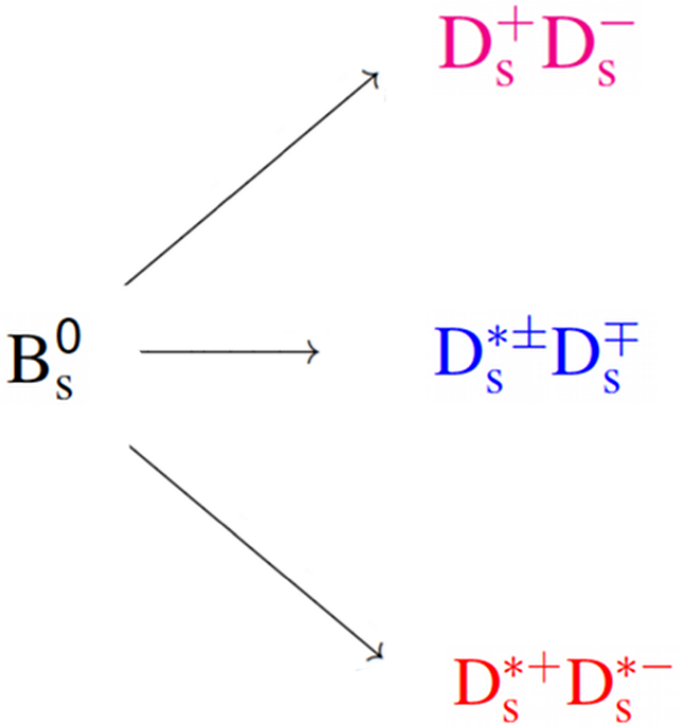
$$\frac{\mathcal{B}\left(B_s \to J/\psi\,\eta'\right)}{\mathcal{B}\left(B_s \to J/\psi\,\eta\right)} = 0.73 \pm 0.14_{\text{stat}} \pm 0.02_{\text{sys}}$$

$\to$ deviation at 2.1σ level with respect to prediction

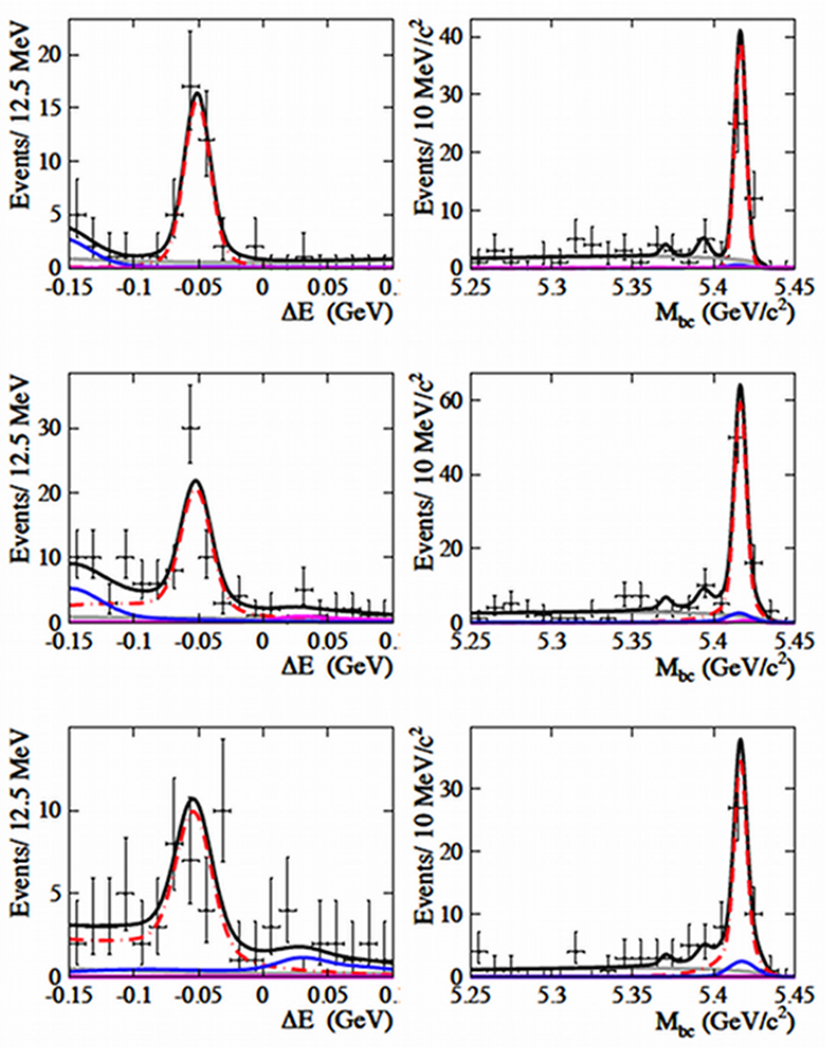
Systematic Uncertainties $B_s \longrightarrow J/\psi\,\eta,\ J/\psi\,\eta'$

Source	$\mathcal{B}(J/\psi\eta)$	$\mathcal{B}(J/\psi\eta')$
Signal shape calibration	$+0.4, -0.5$	$+1.1, -1.3$
Track reconstruction	0.8	1.4
Electron identification	1.5	1.5
Muon identification	1.8	1.7
Pion identification	0.5	2.1
$\eta(\pi^0) \to \gamma\gamma$ selection	4.0	2.8
$\mathcal{B}(J/\psi \to ll)$	0.7	0.7
$\mathcal{B}(\eta^{(\prime)} \to$ final states)	0.5	1.2
Total (without $N_{B_s^{(*)}\bar{B}_s^{(*)}}$)	4.8	4.8
$N_{B_s^{(*)}\bar{B}_s^{(*)}}$	$+22.4, -15.5$	

$B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ $(121\,\mathrm{fb}^{-1})$ to be submitted to PRL



REFERENCE FOR RESULTS ON 23.6 FB^{-1}:
S. ESEN, A. J. SCHWARTZ ET AL.(BELLE COLLABORATION),
PRL 105, 201802 (2010)



$$D_s^+ \to \phi\pi^+,\ K_S^0 K^+,\ \overline{K}^{*0} K^+,\ \phi\rho^+,\ K_S^0 K^{*+},\ \overline{K}^{*0} K^{*+}$$

$B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ $(121\,\mathrm{fb}^{-1})$ to be submitted to PRL

$D_s^+ D_s^-$ signal yield: $33.1\,^{+6.0}_{-5.4}$ events

$$\mathcal{B}\left(B_s^0 \to D_s^+ D_s^-\right) = \left(0.58\,^{+0.11}_{-0.09\,\mathrm{stat}} \pm 0.13_{\mathrm{sys}}\right)\% \qquad @11.5\,\sigma$$

$D_s^{*\pm} D_s^{\mp}$ signal yield: $44.5\,^{+5.8}_{-5.5}$ events

$$\mathcal{B}\left(B_s^0 \to D_s^{*\pm} D_s^{\mp}\right) = \left(1.8 \pm 0.2_{\mathrm{stat}} \pm 0.4_{\mathrm{sys}}\right)\% \qquad @10.1\,\sigma$$

$D_s^{*+} D_s^{*-}$ signal yield: $24.4\,^{+4.1}_{-3.8}$ events

$$\mathcal{B}\left(B_s^0 \to D_s^{*+} D_s^{*-}\right) = \left(2.0 \pm 0.3_{\mathrm{stat}} \pm 0.5_{\mathrm{sys}}\right)\% \qquad @7.8\,\sigma$$

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sum: total yield $102.0\,^{+9.3}_{-8.6}$ events

$$\mathcal{B} = \left(4.3 \pm 0.4_{\mathrm{stat}} \pm 0.5_{\mathrm{sys}} \pm 0.9\,[\mathcal{B}]_{\mathrm{sys}}\right)\%$$

$B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ $(121\,\mathrm{fb}^{-1})$ to be submitted to PRL

- $b \to c\bar{c}s$ saturates decay width
- final states are CP-even eigenstates
- $\phi_s = 0$

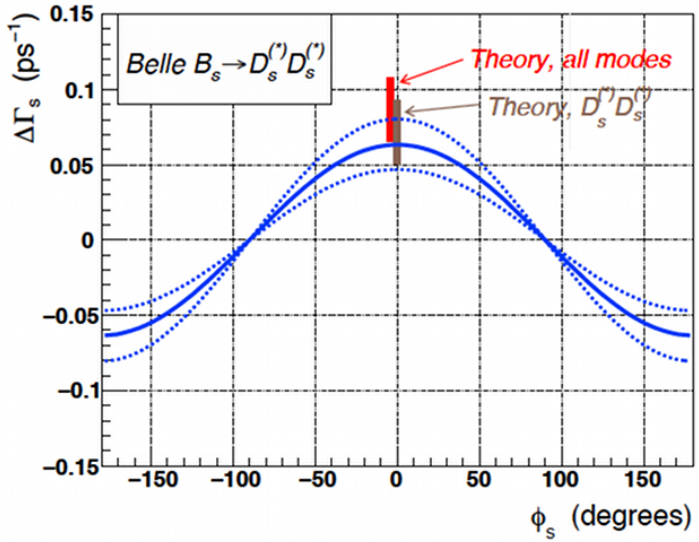
determined from branching ratio:

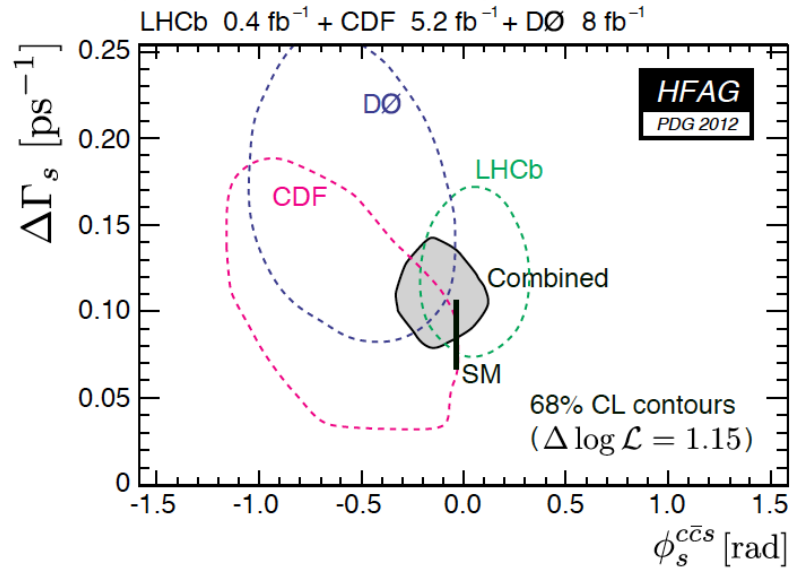
$$\frac{\Delta\Gamma_s}{\Gamma_s} = \frac{2\mathcal{B}}{1-\mathcal{B}}$$

$$\frac{\Delta\Gamma_s}{\Gamma_s} = 0.090 \pm 0.009 \pm 0.022$$

consistent with theory prediciton and comparable with hadron collider results

A. Lenz and U. Nierste, Jour. High Energy Phys. 0706, 072 (2007)





Systematic Uncertainties $B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ to be submitted to PRL

Source	$D_s^+ D_s^-$		$D_s^* D_s$		$D_s^{*+} D_s^{*-}$	
	$+\sigma$	$-\sigma$	$+\sigma$	$-\sigma$	$+\sigma$	$-\sigma$
Signal PDF shape	2.7	2.2	2.2	2.4	5.1	3.8
Background PDF shape	1.5	1.3	1.3	1.4	2.9	2.8
WC + CF fraction	0.5	0.5	4.7	4.5	11.0	9.7
$\mathcal{R}$ requirement ($q\bar{q}$ suppression)	3.1	0.0	0.0	2.7	0.0	2.1
Best candidate selection	5.5	0.0	1.5	0.0	1.5	0.0
$\pi^\pm/K^\pm$ identification	7.0	7.0	7.0	7.0	7.0	7.0
K_S reconstruction	1.1	1.1	1.1	1.1	1.1	1.1
π^0 reconstruction	1.1	1.1	1.1	1.1	1.1	1.1
γ	-	-	3.8	3.8	7.6	7.6
Tracking	2.2	2.2	2.2	2.2	2.2	2.2
Polarization	0.1	0.1	0.8	0.7	0.5	1.0
MC statistics for ε	0.2	0.2	0.4	0.4	0.5	0.5
$D_s^{(*)}$ branching fractions	8.6	8.6	8.6	8.6	8.7	8.7
$N_{B_s^{(*)}B_s^{(*)}}$			18.3			
$f_{B_s^* \overline{B}_s^*}$			2.0			
Total	22.7	21.8	22.7	22.8	26.2	25.5

Summary

- $B_s^0 \to J/\psi\, K^+K^-$
  - precise measurement of $\mathcal{B}\left(B_s^0 \to J/\psi\, \phi\right)$
  - first measurement of absolute branching ratio of $B_s^0 \to J/\psi\, K^+K^-$
  - measurement of $\mathcal{B}\left(B_s^0 \to J/\psi\, f_2'(1525)\right)$ at $4.0\,\sigma$; relative branching fraction consistent with current results from LHCb and D0
- first observation of $B_s \to J/\psi\, \eta$, $J/\psi\, \eta'$
  - calculated branching fractions consistent with SU(3) expactations
  - relative branching fraction shows deviation at 2.1σ level with respect to prediction
- observation of $B_s^0 \to D_s^{(*)+} D_s^{(*)-}$
  - $\Delta\Gamma_s$ consistent with SM theory prediction and comparable with hadron collider results

Thank you for your attention!