B_s^0 decays at Belle

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on High Energy Physics

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For the Belle collaboration

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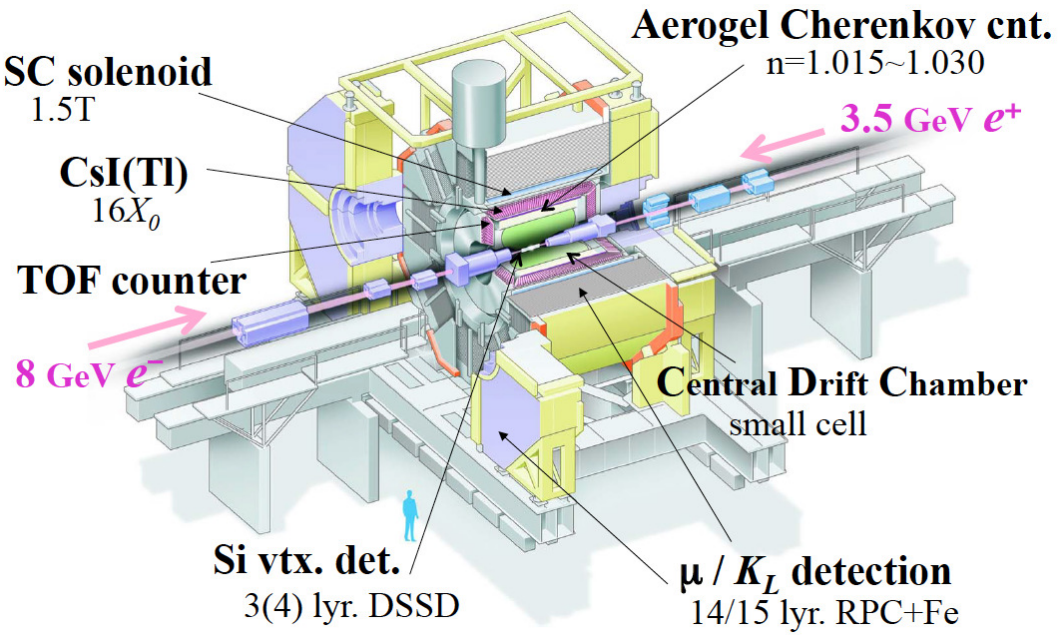
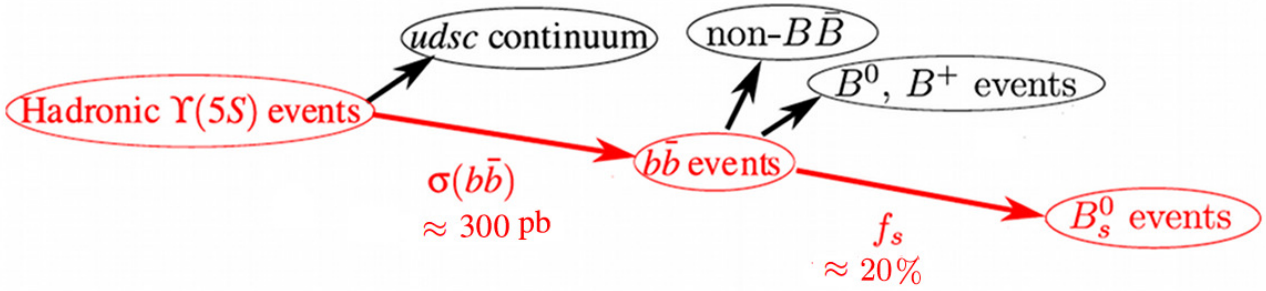
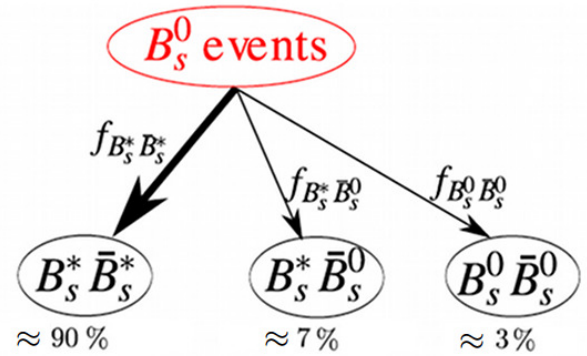
Outline

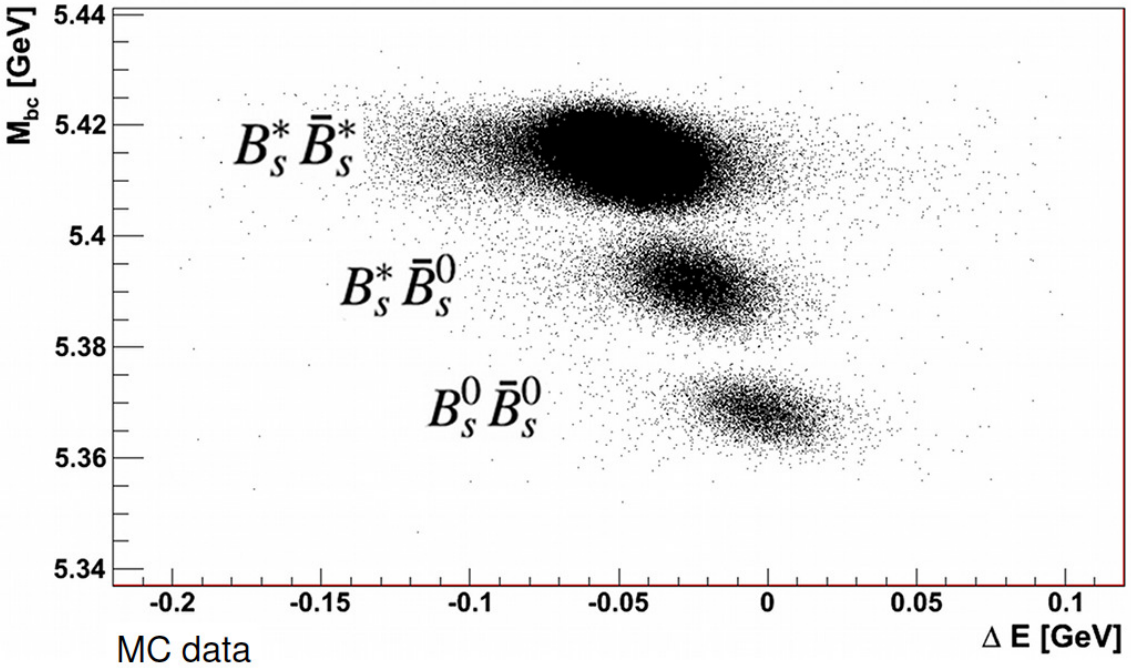
1. Introduction
2. $B_s^0 \to J/\psi\, K^+K^-$ NEW!
   present final results
3. $\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$
   NEW!
   published in
   arXiv:1304.6931 [hep-ex]
   submitted to Phys.Lett.B



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!

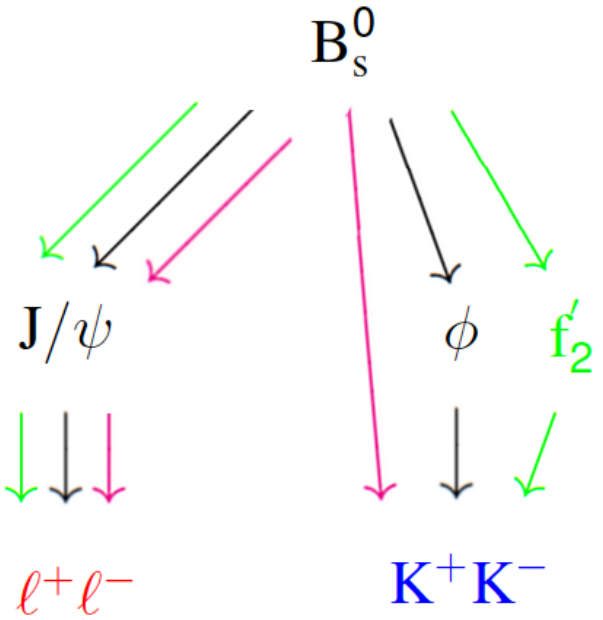
- full reconstruction of B_s^0 meson
- no reconstruction of $B_s^* \rightarrow B_s^0 \gamma$
- using two nearly independent kinematic variables for extracting B_s^0 signal:

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

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

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

- $B_s^0 \to J/\psi\, \phi$
  important mode for CP violation:
  ϕ_s sensitive to new physics
  $\phi_s = 0.01 \pm 0.07\,(\mathrm{stat}) \pm 0.01\,(\mathrm{sys})$ rad
- $B_s^0 \to J/\psi\, f_2'(1525)$
  branching ratio measured by LHCb:
  $B = \left(2.61 \pm 0.20^{+0.52}_{-0.46} \pm 0.20\right) \times 10^{-4}$
- $B_s^0 \to J/\psi\, K^+K^-$
  only measurement by LHCb
  $\mathcal{B} = (7.70 \pm 0.08 \pm 0.39 \pm 0.60) \times 10^{-4}$



- S-wave contriubion in ϕ mass region

Advantage of Belle measurement

Absolute measurement of branching fractions instead of measurement relative to reference decay channel as used by hadron collider experiments.

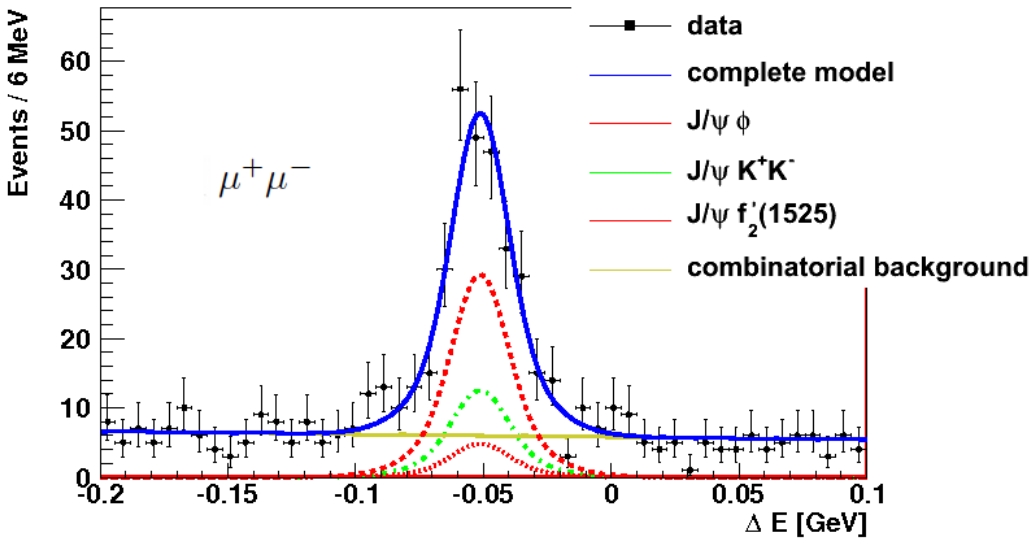
$B_s^0 \to J/\psi\, K^+K^-$ $(121\,fb^{-1})$ final results

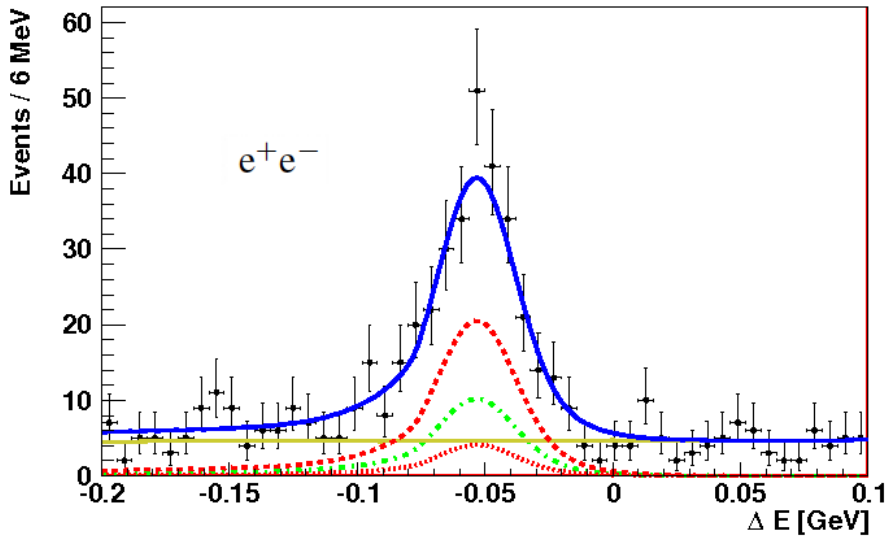
Applied PDF model for signal components ($J/\psi \to \mu^+\mu^-$):

channel	$J/\psi\,\phi$	$J/\psi\, K^+K^-_{other}$	$J/\psi\, f'_2(1525)$
ΔE	double Gaussian	double Gaussian	double Gaussian
$m(K^+K^-)$	nonrelativistic Breit Wigner	Argus	nonrelativistic Breit Wigner

- double Gaussian is replaced by sum of Crystal Ball and Gaussian pdf for the $J/\psi \to e^+e^-$ channel
- combinatorial background described by first order polynom in ΔE, Argus function in $m(K^+K^-)$
- PDF model was tested extensively on generic MC data

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

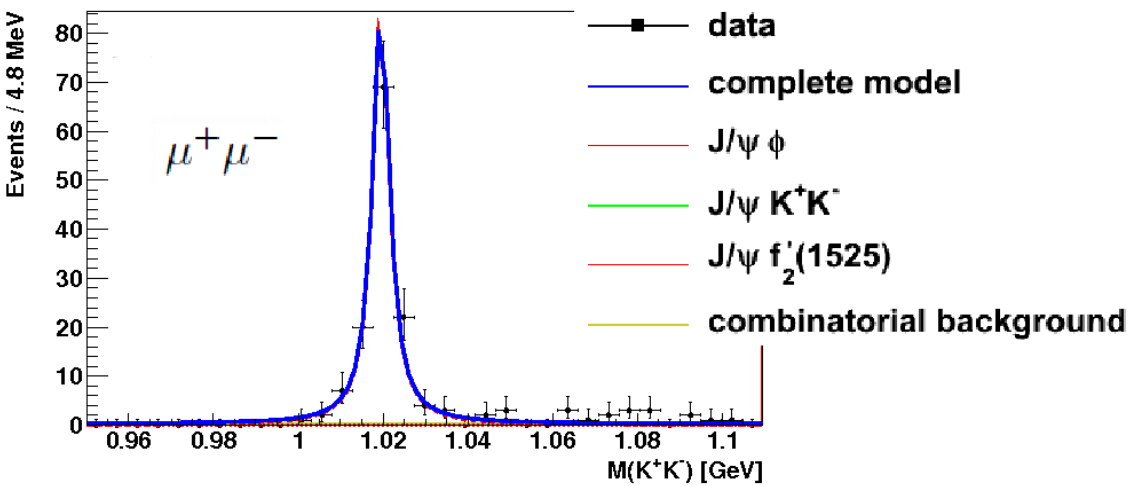


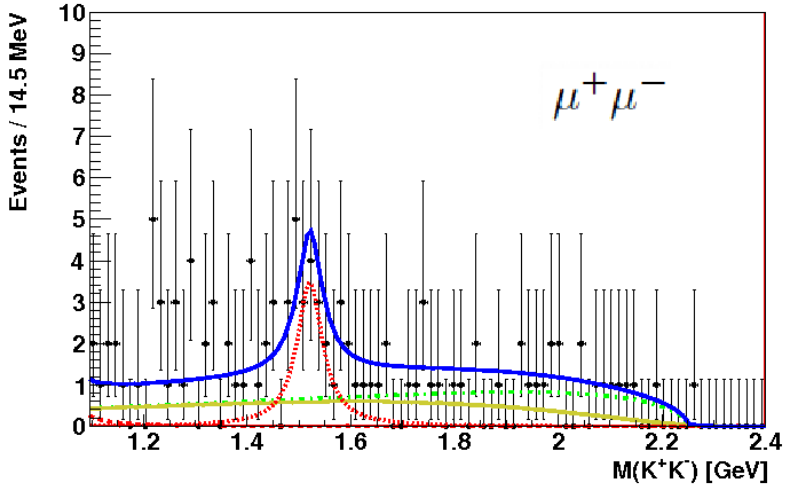


Obtained signal yields:

Channel	e^+e^-	$\mu^+\mu^-$
$J/\psi\,\phi$	168 ± 13.5	158 ± 13
$J/\psi(K^+K^-)_{\mathrm{other}}$	83 ± 17	67 ± 14
$J/\psi\, f_2'(1525)$	34 ± 10	26 ± 8
Background	232 ± 19	300 ± 20

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





Obtained branching fractions:

$$\mathcal{B}\left(B_s^0 \to J/\psi\, \phi\right) = (1.25 \pm 0.07\,(\mathrm{stat}) \pm 0.08\,(\mathrm{syst}) \pm 0.22\,(f_s)) \times 10^{-3}$$

$$\mathcal{B}(B_s^0 \to J/\psi\, f_2'(1525)) = (0.26 \pm 0.06\,(\mathrm{stat}) \pm 0.02\,(\mathrm{syst}) \pm 0.05\,(f_s)) \times 10^{-3}$$

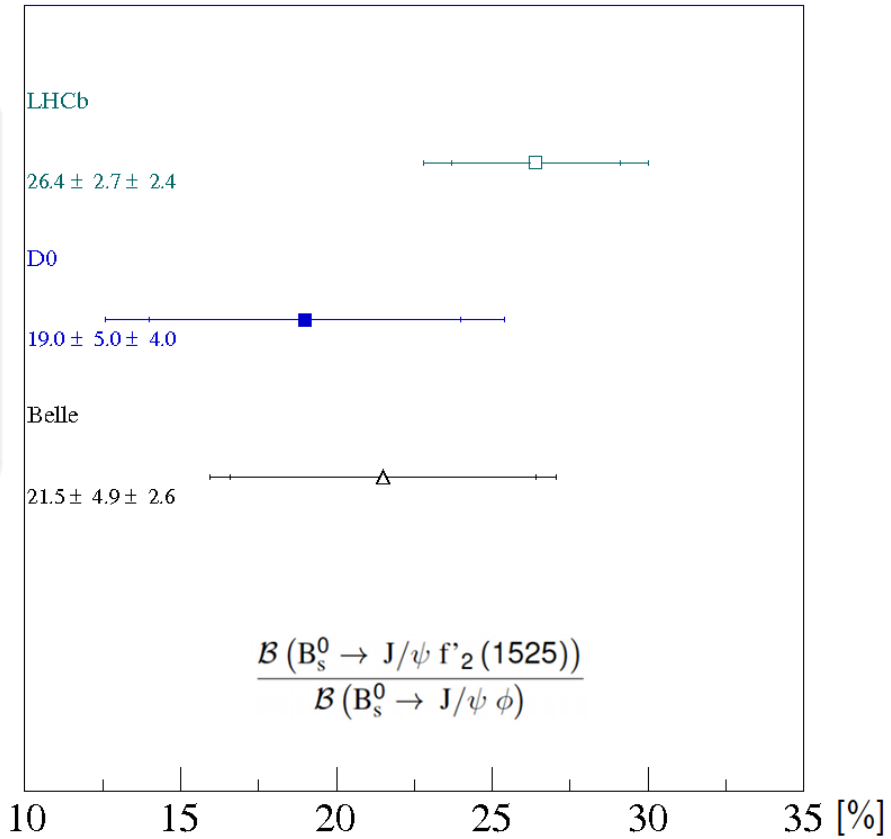
$$\mathcal{B}\left(B_s^0 \to J/\psi\, K^+K^-\right) = (1.01 \pm 0.09\,(\mathrm{stat}) \pm 0.10\,(\mathrm{syst}) \pm 0.18\,(f_s)) \times 10^{-3}$$

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

Relative branching fraction:

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

$$(21.5 \pm 4.9\,(\mathrm{stat}) \pm 2.6\,(\mathrm{syst}))\%$$



LHCb Collaboration, Phys. Rev. Lett. 108, 151801 (2012)
D0 Collaboration, Phys. Rev. D 86, 092011 (2012)

All determined branching ratios are in good agreement with the results from hadron collider experiments!

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

S-wave contribution within ϕ mass region

S- and P-wave distinguished via $M(K^+K^-)$ distribution instead of performing angular analysis as used by LHCb and CDF

Assumptions:

- S-wave contribution originates from $B_s^0 \to J/\psi\, K^+K^-$
- P-wave contribution originates from $B_s^0 \to J/\psi\, \phi$

Assumptions verified on helicity angular distributions for $B_s^0 \to J/\psi\, K^+K^-$ and $B_s^0 \to J/\psi\, \phi$

Mass range	1.009 GeV − 1.028 GeV
CDF	$(0.8 \pm 0.2)\%$
this analysis	$(0.47 \pm 0.07\,(\text{stat}) \pm 0.05\,(\text{syst})^{+4.5}_{-0}\,(f_0))\%$
Mass range	1.007 GeV − 1.031 GeV
LHCb	$(1.1 \pm 0.1^{+0.2}_{-0.1})\%$
This analysis	$(0.57 \pm 0.09\,(\text{stat}) \pm 0.06\,(\text{syst})^{+4.4}_{-0}\,(f_0))\%$

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

Include $B_s^0 \to J/\psi\, f_0(980)$ (S-wave) component:

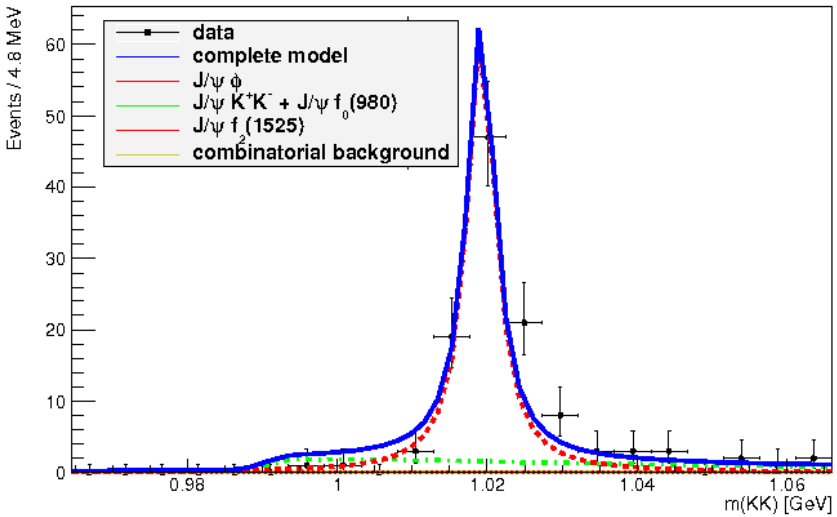
$$PDF(S-wave) = a^2 \cdot Flatte + Argus + 2a \cdot \cos(\theta) \cdot \sqrt{Flatte \cdot Argus}$$

$a = 1.96$: relative normalization between $f_0(980)$ and K^+K^-

$\theta = -259°$: phase (due to interference)

Alternative PDF model in $m(K^+K^-)$:

$J/\psi\, \phi$	$J/\psi\, K^+K^-_{other}$ + $J/\psi\, f_0(980)$	$J/\psi\, f'_2$
nonrelativistic Breit Wigner	$PDF(S-wave)$	nonrelativistic Breit Wigner



Results:

- Signal yields vary approximately within 1 σ
- Strong enhancement of the S-wave contribution in ϕ mass region

$\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$ $(121\,\mathrm{fb}^{-1})$ arXiv:1304.6931 [hep-ex]

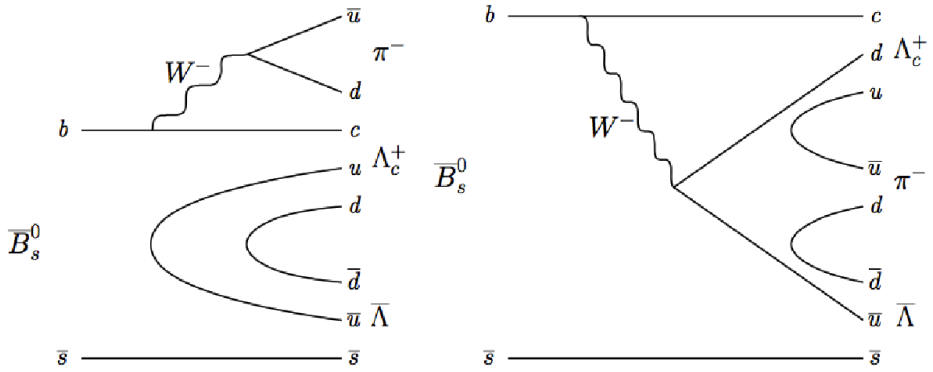
Hierarchy in baryonic B decays:

2-(1), 3-, 4-(2) and 5-body(3) final states observed; smaller branching fractions observed for low multiplicity final states

3-body baryonic B decays:

Near threshold peak in invariant baryon-antibaryon mass distribution

(1) Belle Collaboration, Phys. Rev. Lett. 97, 242001 (2006)
(2) BaBar Collaboration, Phys. Rev. D 78, 112003 (2008)
(3) Cleo Collaboration, Phys. Rev. D 66, 091101 (2002)



This analysis: First evidence for $\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$

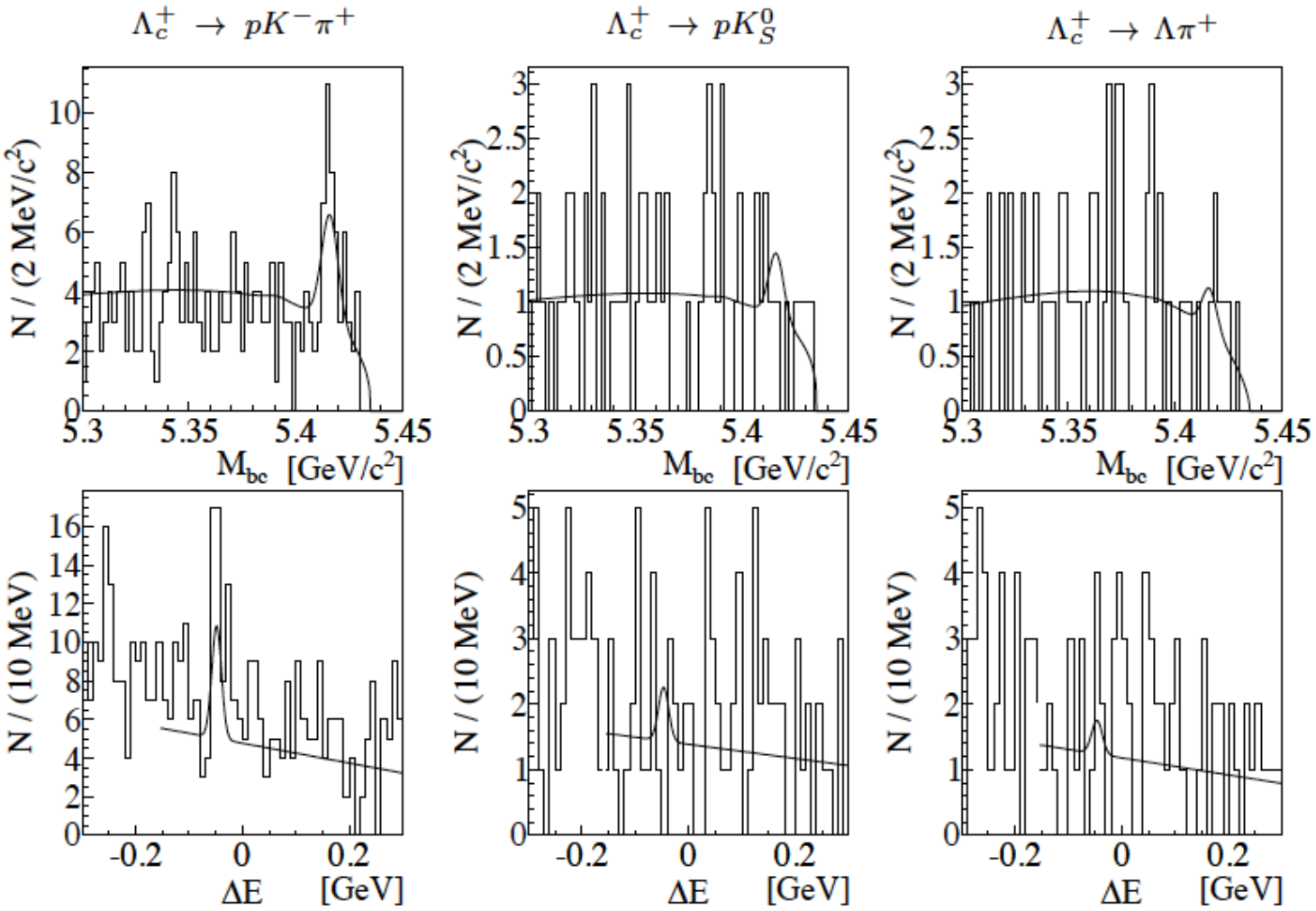
1. measure $\mathcal{B}(\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda})$ and compare with $\mathcal{B}(B^- \to \Lambda_c^+ \bar{p} \pi^-)$
2. search for near threshold peak

$\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$ $(121\,\mathrm{fb}^{-1})$ arXiv:1304.6931 [hep-ex]

Reconstruction modes for K_S^0, Λ and Λ_c^+ and applied selection criteria.

Parameter	Selection criterion
IP (charged tracks)	$\lvert dr\rvert < 0.25\,\mathrm{cm}$ and $\lvert dz\rvert < 1\,\mathrm{cm}$
$K_S^0 \to \pi^+\pi^-$	$\lvert M(\pi^+\pi^-) - M(K_S^0)\rvert < 10\,\mathrm{MeV}/c^2$
$\Lambda \to p\,\pi^-$	$\lvert M(p\,\pi^-) - M(\Lambda)\rvert < 4\,\mathrm{MeV}/c^2$
$\Lambda_c^+ \to p\,K^-\pi^+$ $\Lambda_c^+ \to p\,K_S^0$ $\Lambda_c^+ \to \Lambda\,\pi^+$	$\lvert M(rec) - M(\Lambda_c^+)\rvert < 10\,\mathrm{MeV}/c^2$
M_{bc}	$M_{bc} > 5.3\,\mathrm{GeV}/c^2$
ΔE	$\lvert\Delta E\rvert < 0.3\,\mathrm{GeV}$

$\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$ $(121\,\mathrm{fb}^{-1})$ arXiv:1304.6931 [hep-ex]



fit projections for $-71\,\mathrm{MeV} < \Delta E < -23\,\mathrm{MeV}$ and $5.405\,\mathrm{GeV}/c^2 < M_{bc} < 5.427\,\mathrm{GeV}/c^2$

$\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$ $(121\,\mathrm{fb}^{-1})$ arXiv:1304.6931 [hep-ex]

Obtained signal yields:

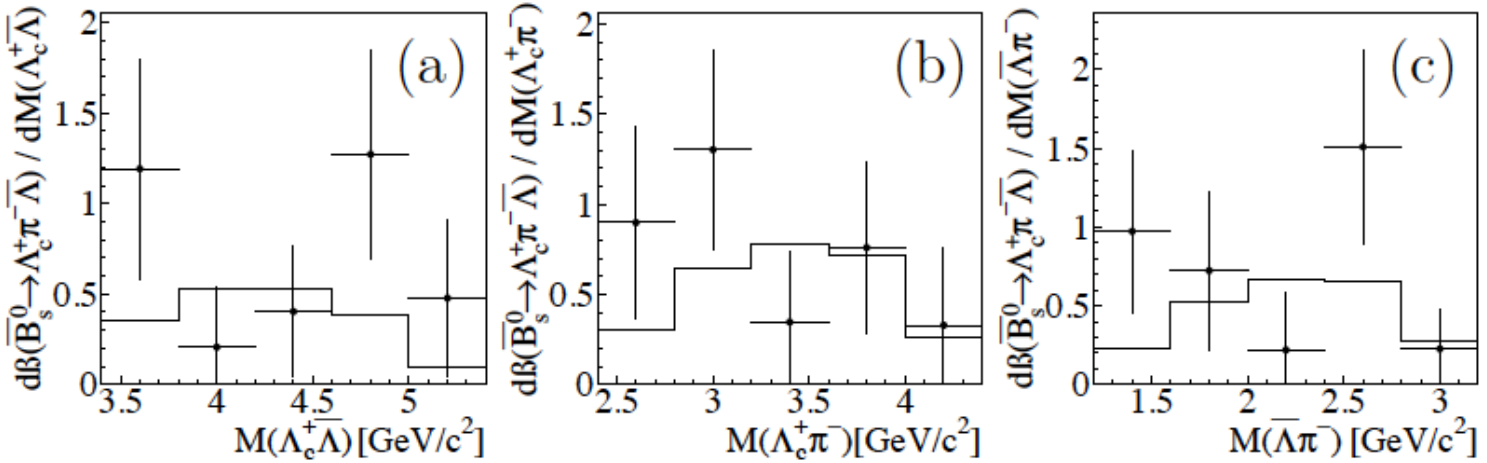
Channel	$\Lambda_c^+ \to p\,K^-\pi^+$	$\Lambda_c^+ \to p\,K_S^0$	$\Lambda_c^+ \to \Lambda\,\pi^+$
rec. efficiency [%]	12.5	5.9	8.7
Yield [events]	20.3	3.0	1.9

Obtained branching ratio

$$\mathcal{B}(\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}) = (3.6 \pm 1.1(\mathrm{stat})^{+0.3}_{-0.5}(\mathrm{sys}) \pm 0.9(\Lambda_c^+) \pm 0.7(N_{\bar{B}_s^0})) \times 10^{-4}$$

measured at $4.4\,\sigma$ significance (systematic included)
similar to $\mathcal{B}(B^- \to \Lambda_c^+ \bar{p} \pi^-) = (2.8 \pm 0.8) \times 10^{-4}$

$\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$ $(121\,\mathrm{fb}^{-1})$ arXiv:1304.6931 [hep-ex]



Near threshold enhancement

- extract signal yield in baryon-antibaryon mass bins, apply efficiency correction, calculate differential branching fractions
- hint of threshold enhancement, however, statistic is too low to observe effect

Summary

$B_s^0 \to J/\psi K^+K^-$

- absolute measurement of the branching ratios for $B_s^0 \to J/\psi \phi$, $B_s^0 \to J/\psi f_2'(1525)$ and $B_s^0 \to J/\psi K^+K^-$
- all branching ratios in agreement with hadron collider results
- results for S-wave contribution in ϕ mass region smaller than LHCb values but in agreement with CDF results
- S-wave contribution strongly depends on a possible $B_s^0 \to J/\psi f_0(980)$ component and the applied model

$\bar{B}_s^0 \to \Lambda_c^+ \pi^- \bar{\Lambda}$

- first evidence for baryonic B_s^0 decay
- obtained branching ratio similar to $B^- \to \Lambda_c^+ \bar{p} \pi^-$
- statistic too low to observe threshold enhancement

Thank you for your attention!