Search for $B_s^0 \to \ell^\mp \tau^\pm$ Decay

with semi-leptonic tagging method at Belle

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(Belle Collaboration)

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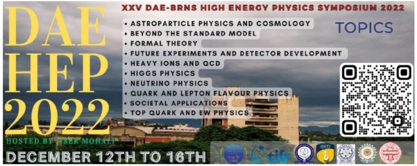

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BELLE

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Overview

Introduction

The lepton flavor violating (LFV) $B_s^0 \to e^{\mp}\tau^{\pm}, \mu^{\mp}\tau^{\pm}$ decays;

- forbidden at the tree-level in the standard model (SM).
- such decays can occur via neutrino mixing through loop and box diagrams.
- predicted to occur in "beyond SM theories" with $\mathcal{B}$ of order of 10^{-9}. [arXiv:1801.02895]
- So, observation of such decay would indicate new physics.

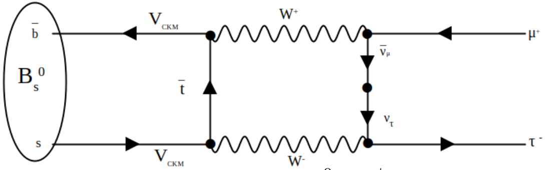


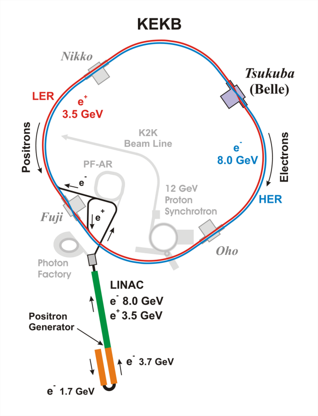
Figure 1: Feynman Diagram of $B_s^0 \to \mu^+\tau^-$

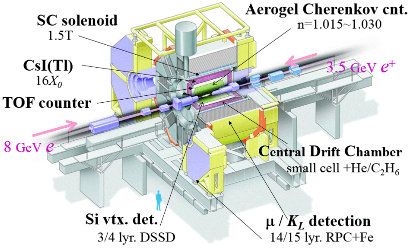
- An upper limit of B.F at 90% confidence level (CL) is obtained by LHCb Experiment :

	$B_s^0 \to e\tau$	$B_s^0 \to \mu\tau$
LHCb	——	3.4×10^{-5}

KEKB and Belle detector

KEKB : 8 GeV electrons collide with 3.5 GeV positrons, at a center-of-mass energy 10.58 GeV.





- Belle detector is placed around the interaction point of 2 beams which consists of six sub-detectors
- The integrated luminosity : $e^+e^- \to \Upsilon(5S) \to B_s^{(*)} B_s^{(*)}$ (121 fb^{-1}) $\sim (16.6 \pm 2.7) \times 10^6$ B_s mesons.
- Collected $\sim$ 1 ab^{-1} data at different resonances and off-resonances.

Search for $B_s^0 \to \ell^\mp \tau^\pm$ Decay at Belle

(Preliminary, paper to be submitted)

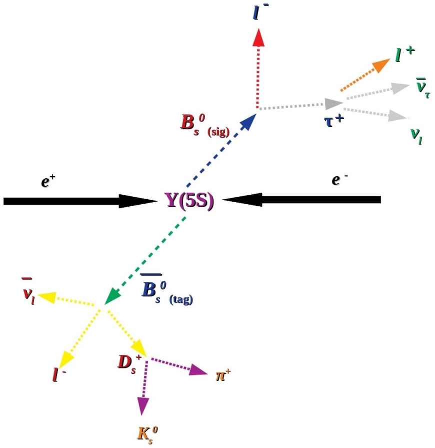
Analysis Overview

Data Sample:

- **20M** signal MC $(B_s\bar{B_s}, B_s^*\bar{B_s^*}, B_s^*\bar{B_s})$ events generated at $\Upsilon(5S)$ resonance.
- For Background Study :
  Data Sample : $121 fb^{-1}$
  Generic MC : bsbs, non-bsbs, uds, charm

Name	Process
bsbs	B_s^0 decays
non-bsbs	$B_{u,d}$ meson decays
charm	continuum $e^+e^- \to c\bar{c}$
uds	continuum $e^+e^- \to u\bar{u}, d\bar{d}, s\bar{s}$

- Because of missing informations from τ daughter neutrinos in the decay mode a full reconstruction of B_s^0 (signal-side) is difficult.
- So the $\bar{B_s^0}$ semi-leptonic tagging method is used to tag $B_s^0\bar{B}_s^0$ events using $B_s \to D_s\ell(X)\nu$ decay mode.



- Particles in one event are separated to two sides: Signal side and Tag side.

Signal-side:

- B_s meson is reconstructed with one non-τ lepton (e, μ) and another τ-lepton.

τ decay	B.F (%)
$\mu^+\nu_\mu\bar{\nu_\tau}$	17.39 ± 0.04
$e^+\nu_e\bar{\nu_\tau}$	17.82 ± 0.04
total	35.21

$\ell 1$: primary lepton, $\ell 2$: lepton from τ decay

$\ell 3$: lepton from $B_s \to D_s \ell \nu$ decay

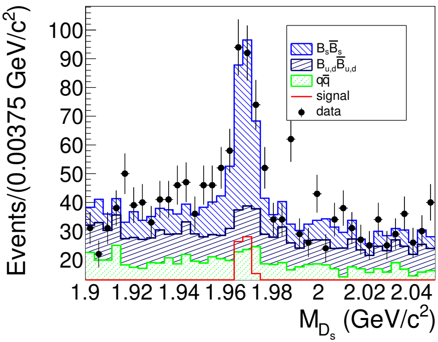
Tag-side:

- D_s meson and a charged lepton are combined to form a B_s meson.

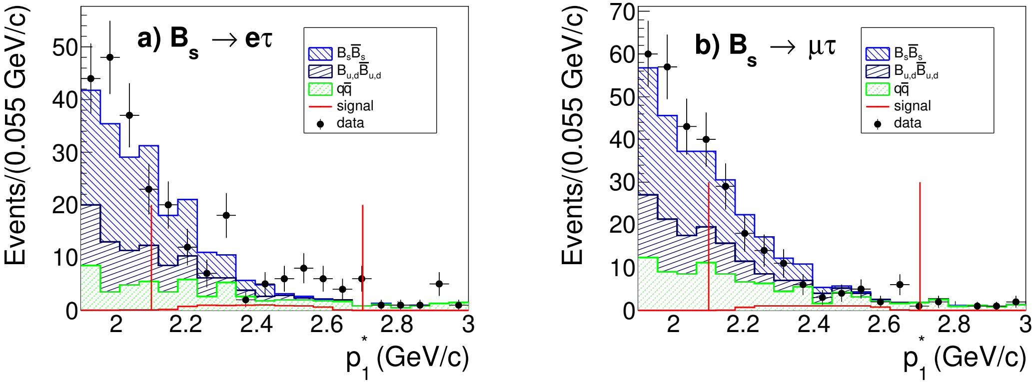
D_s decay	B.F (%)
$D_s^+ \to \phi(\to K^+K^-)\pi^+$	2.24±0.08
$D_s^+ \to \bar{K}^{*0}(\to K^+\pi^-)K^+$	2.61 ± 0.09
$D_s^+ \to \phi\rho^0\pi^+$	0.65 ± 0.13
$D_s^+ \to K_S^0 K^+$	1.40 ± 0.05
$D_s^+ \to \phi\rho^+$ $\phi \to K^+K^-, \rho^+ \to \pi^+\pi^0$	$8.4^{+1.9}_{-2.3}$
Total	15.30

Event Selection:
Charged tracks are selected using tracking selection cuts and PID information.

	Selections
p_1^*	> 1.9 GeV/c, $p_1^* > p_2^*, p_3^*$
M_{D_s}	$\in [1.96, 1.98]$ GeV/c^2
$M_{\ell 1 \ell 2}$	$\notin [3.05, 3.12]$ GeV ($B_s \to \mu\tau(\mu\nu\nu)$) and $\notin [3.01, 3.12]$ GeV ($B_s \to e\tau(e\nu\nu)$)



p_1^* after initial selections



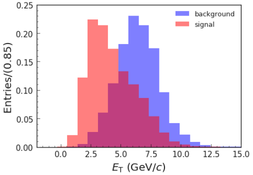
- signal MC is scaled to the data lumilosity with assumed $\mathcal{B} \sim 10^{-3}$.

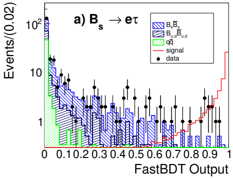
Background Suppression

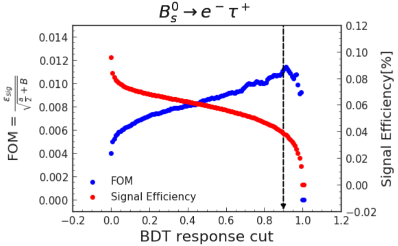
- Multivariate Analysis is performed to suppress the background.
- Equal amount of signal and background samples are used for training.

  Method: FastBDT

- The classifier is trained with 27 discriminating featured variables to separate the signal from the background.
- These variables do not have any significant correlation with the signal extraction variable p_1^*.
- The classifier output $\mathcal{O}_{\text{FastBDT}}$ ranges from zero, where background events peak, to one, where the signal events peak
- 8-9$\%$ of events have multiple signal candidates.
- Candidtaes with the highest FastBDT output is retained.

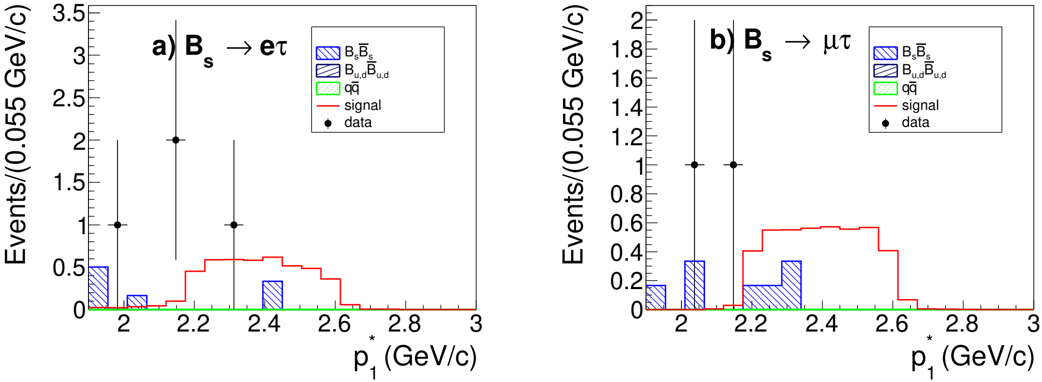






Optimized cuts: $0.90(B_s \to e\tau)$, $0.94(B_s \to \mu\tau)$

p_1^* after final selections



Estimation of $\mathcal{B}(UL)$

- $\mathcal{B} = \frac{(N_{\text{obs}} - N_{\text{exp}}^{\text{bkg}})}{(2 \times N_{B_s} \times \epsilon_{\text{sig}})}$,
  where N_{obs} = the number of the observed events
  $N_{\text{exp}}^{\text{bkg}}$ = the number of the expected data events in the signal region
  N_{B_s} = number of B_s mesons in the data
  ϵ_{sig} = signal efficiency
- $\Upsilon(5S) \to B_s^{(*)} B_s^{(*)}$ decay branching fraction
  $f_s = 0.201 \pm 0.031$
- Since the uncertainty in f_s is significant, we also give the upper limit on $f_s \times \mathcal{B}(B_s \to \ell^- \tau^+)$.

Systematic Uncertainties (%):

Source	$B_s \to e^- \tau^+$	$B_s \to \mu^- \tau^+$
$\overline{B}_s^0 \to D_s^+ \ell^- \overline{\nu}_\ell$ tag	15.0	15.0
FastBDT correction	3.3	3.7
PID	4.3	3.5
Tracking	0.7	0.7
$\tau \to \ell \nu_\tau \overline{\nu}_\ell$ BF	0.2	0.2
Number of B_s	16.1	16.1
Total	22.7	22.6

Results:

	ϵ_{sig} (%)	$N_{\text{bkg}}^{\text{exp}}$	N_{obs}	$\mathcal{B}$ ($\times 10^{-4}$)	$f_s \times \mathcal{B}$ ($\times 10^{-4}$)
$B_s \to e^- \tau^+$	0.0312 ± 0.0071	0.68 ± 0.69	3	< 14.1	< 5.5
$B_s \to \mu^- \tau^+$	0.0303 ± 0.0068	0.77 ± 0.78	1	< 7.3	< 2.9

First limit on the $B_s \to e\tau$ decay. (preliminary result)

Summary

- Searched for $B_s \to \ell\tau$ using $\Upsilon(5S)$ Belle data with semi-leptonic tagging method.
- No signal observed and obtained upper limits are
  $\mathcal{B}(B_s \to e\tau) < 1.4 \times 10^{-3}$ and $\mathcal{B}(B_s \to \mu\tau) < 7.3 \times 10^{-4}$ at 90% CL.
- First measurement on $B_s \to e\tau$ decay.

Thank You