Search for Lepton Flavor Violating (LFV) $B \to K\tau l$ decays at *Belle* and *Belle II*

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BELLE

Belle II

Outline

- Motivation
- Experimental setup
- Signal B and tag B meson reconstruction
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- Initial results for control channel modes
- Summary

Motivation

- Lepton Flavor (LF) is a conserved quantum number in standard model (SM), however its conservation is challenged in various measurements [1].

- Its violation in the neutral lepton sector is confirmed [2].

- In the minimal extension of the SM, charged LFV (CLFV) is enabled, however it is heavily suppressed by GIM mechanism leading to branching ratios ~ 10^{-50}.

- Some vector lepto-quark models predict the lower bound on the branching ratios ~ 10^{-7} for CLFV processes [3].

- Searching for these processes, will provides us important insight about these models.

1. D. London and J. Matias, “B Flavour Anomalies: 2021 Theoretical Status Report,” Ann. Rev. Nucl. Part. Sci. 72 (2022) 37–68, [2110.13270].
2. Y. Fukuda, et al., “Evidence for oscillation of atmospheric neutrinos,” Phys. Rev. Lett., vol. 81, no. 8, p. 1562, 1998.
3. A. Angelescu, et al., “Single leptoquark solutions to the B-physics anomalies,” Phy. Rev. D 104, 055017 (2021).

Motivation

- B-factories provide very clean environment to study the CLFV processes in the B-physics.

- We are searching for the following decays

$$B^{\pm} \rightarrow K^{\pm} \tau^{\pm} l^{\mp} \quad (l = e,\mu)$$

$$\tau^{\pm} \rightarrow \pi^{\pm} \nu_{\tau}$$

- Upper limit on branching ratios for them, is (0.59-2.45) x 10^{-5} (main contributions by the τ leptonic decay modes) [4], calculated by using hadronic tagging.

- With more Belle II data at our hand, we are expecting interesting results for this search.

- Any evidence for such decays will be a direct evidence of physics beyond SM.

4. S. Watanuki et al.(Belle Collaboration),Search for the Lepton Flavor Violating Decays $B^+ \rightarrow K^+ \tau^{\pm} \ell^{\mp}$ (ℓ = e,μ) at Belle PhysRevLett.130.261802

Belle II Experimental setup

- Based on an asymmetric e^+e^- collider.

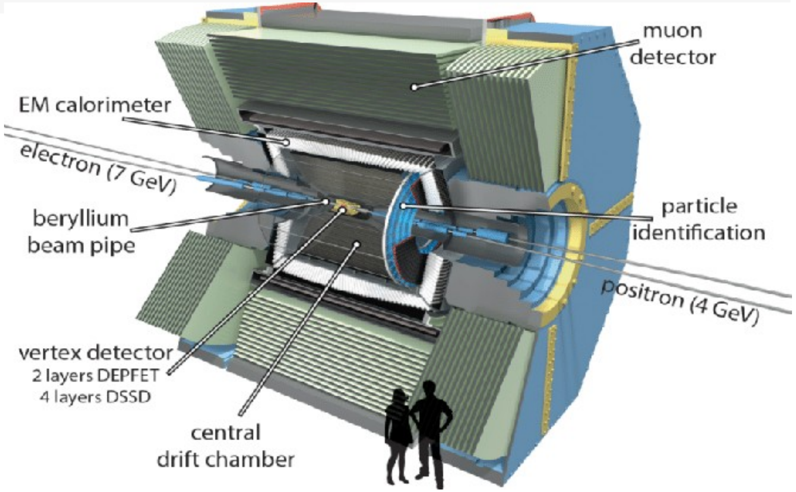
$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$$

- One B is named as signal B (B_{sig}) and the other as tag B (B_{tag}).

- We use the information from the B_{tag} when B_{sig} is not fully re constructable.

- Belle has collected 772 millions $B\bar{B}$ pairs data and Belle II has an ambitious goal of collecting multi-ab^{-1} data.

- Belle II has achieved the peak luminosity of 4.7×10^{34} cm^{-2} s^{-1} which is current world record.



Reconstruction of B_{sig}

- In B factories, when we have a single missing particle, we can constrain the momentum of the missing particle on a cone. e.g

$B^+ \rightarrow Xl^+\nu_l$ $\qquad E_\nu = E_B - E_{Xl}$

- In our case

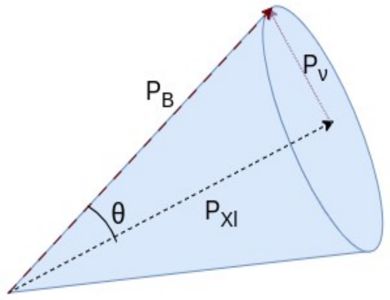
$B^+ \rightarrow K^+ \tau^- \mu^+$

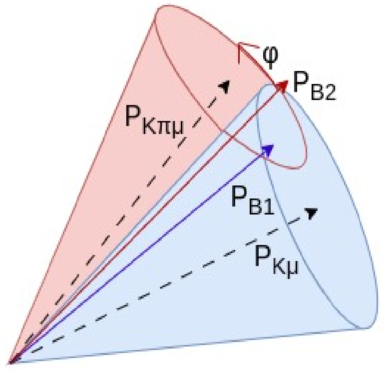
$\tau^- \rightarrow \pi^- \nu_\tau$ (single missing neutrino)

- We can reconstruct the B_{sig} momentum from the two cones and their intersection leads to two possible solutions.

- By this approach, **we can recover the B_{sig} momentum without reconstructing the B_{tag} .**

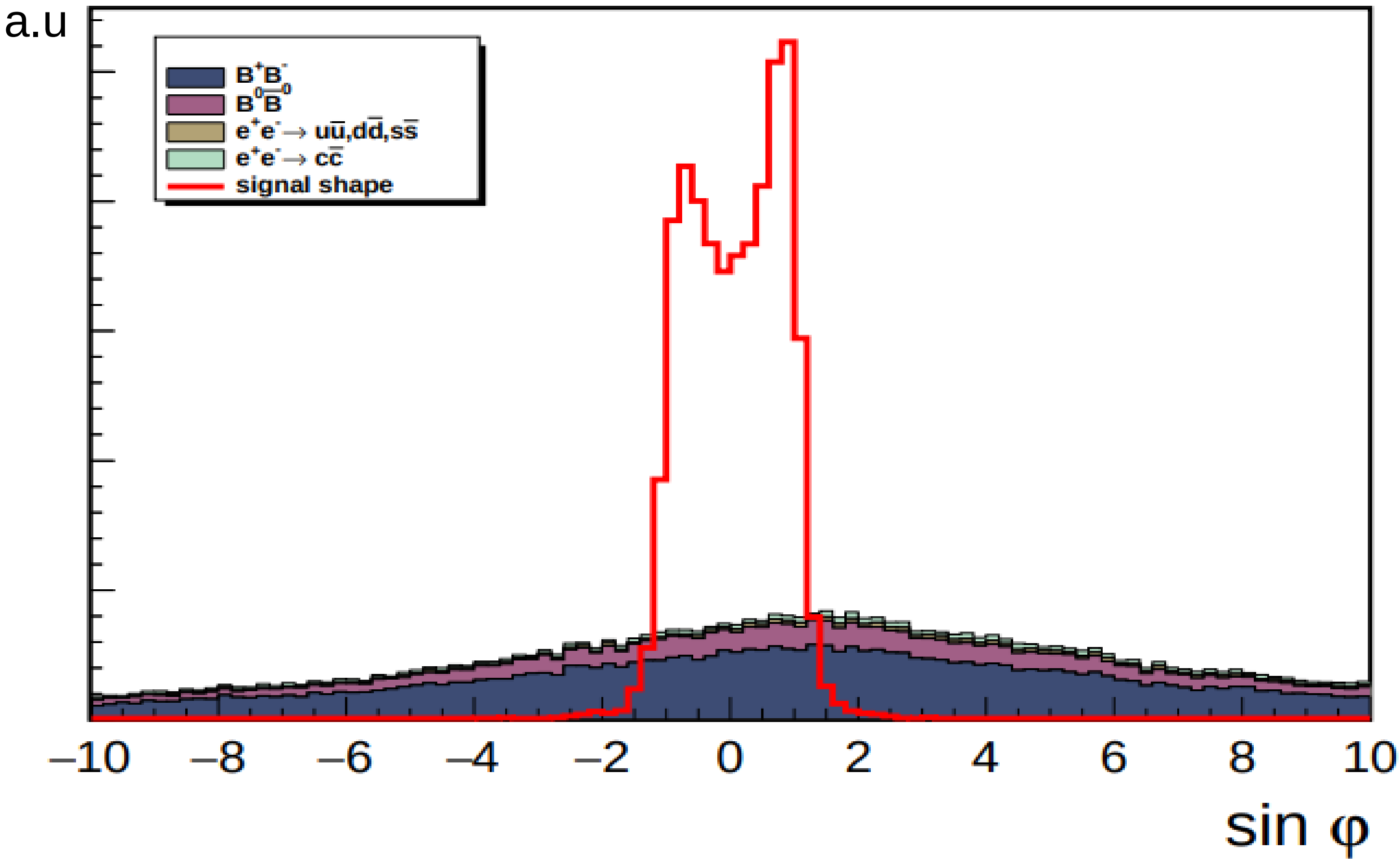
- Intersection of two cones, gives us a discriminator variable which can be used for background suppression((0.5-0.7)% background, signal eff:77%) [5].





5. M. Kaleta, M.S thesis, Belle Collaboration.

$B^+ \to K^+ \tau^-(\to \pi^- \nu_\tau)\mu^+$



M. Kaleta, M.S thesis, Belle Collaboration.

Signal Vs Inclusive hadronic tag side

- In this case, B_{sig} is reconstructed first and then we combine all the remaining tracks and clusters (rest of events (ROE)) to form the B_{tag} candidate.

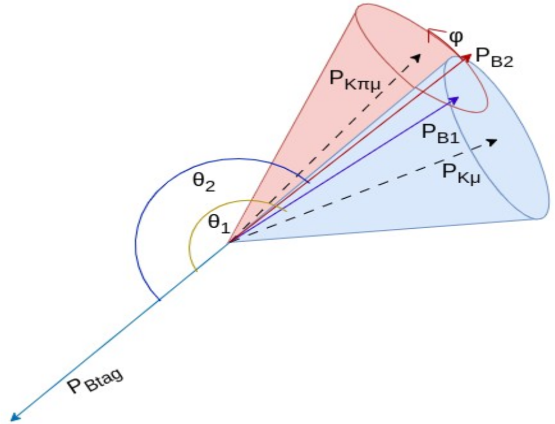
  $B^+ \rightarrow K^+\tau^-(\rightarrow \pi^- \nu_\tau)\, \mu^+$

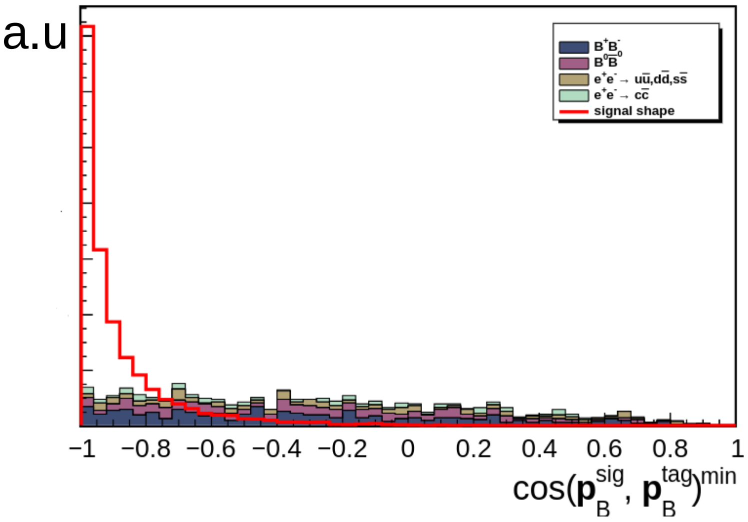
  $B^- \rightarrow$ all possible final states(ROE)

- When B_{tag} decays hadronically, we have the complete information about the B_{tag} momentum.

- Based on the best cosine angle distribution for θ_1 and θ_2, we can further suppress the background events and extract the signal.

  $\cos(p_B^{sig}, p_B^{tag})^{min} = \min(\cos\theta_1, \cos\theta_2)$





Signal Vs Inclusive semi-leptonic tag side

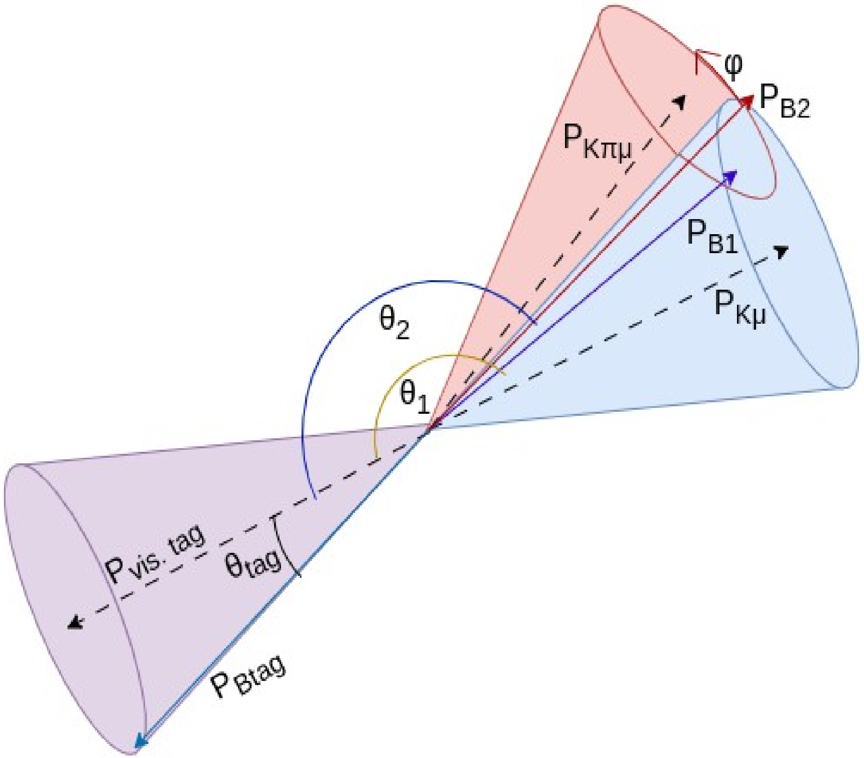
- In this case the B_{tag} decays to a hadron, lepton and a neutrino. For example

$$B^+ \rightarrow K^+ \tau^- (\rightarrow \pi^- \nu_\tau) \mu^+$$

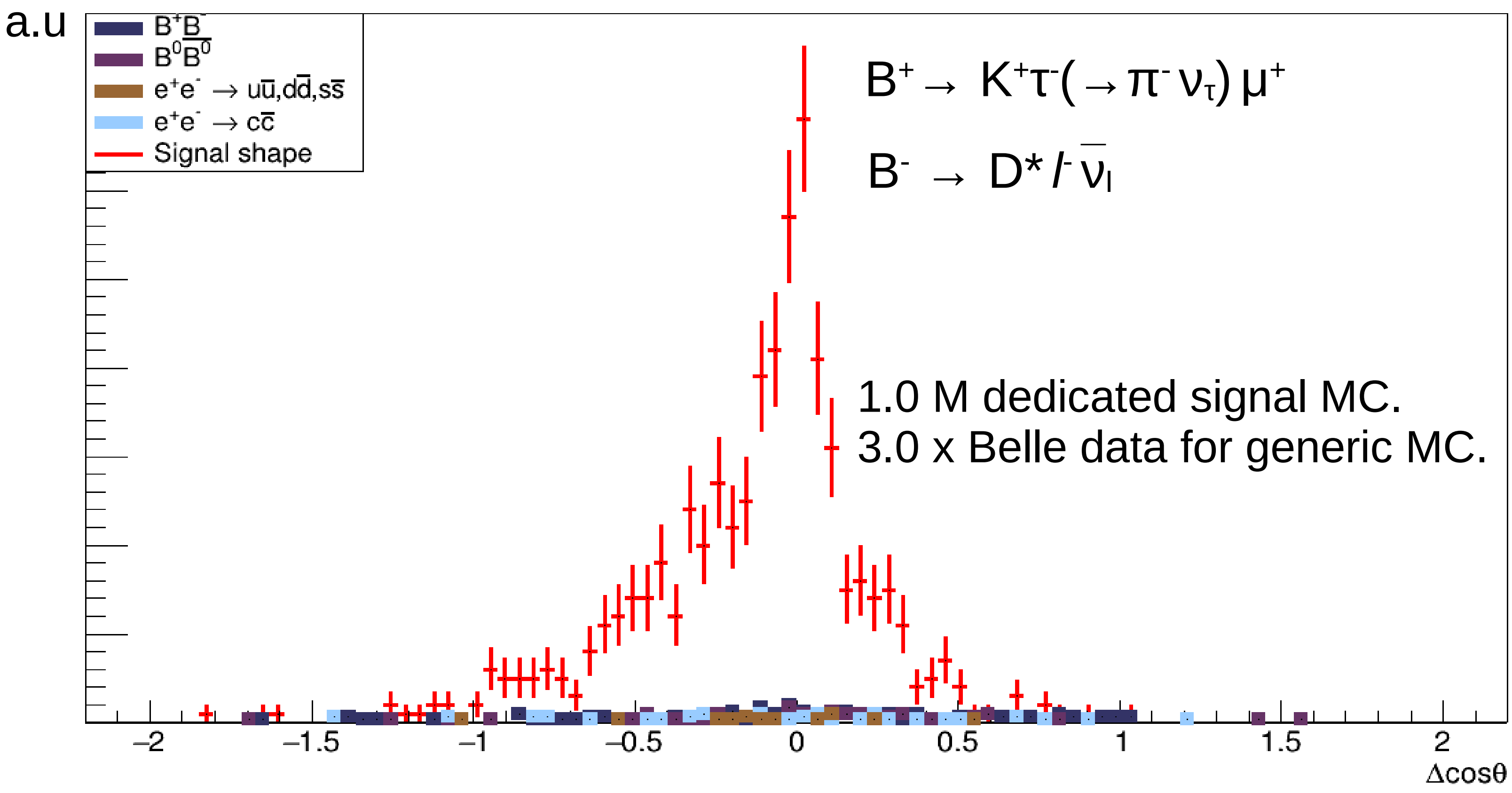
$$B^- \rightarrow D^* l^- \bar{\nu}_l$$

- Because of a missing neutrino on the tag side, we can only partially reconstruct B_{tag} momentum(cone around the visible momentum on tag side).

- Based on the sum of $\cos\theta_1$,$\cos\theta_2$ and $\cos\theta_{tag}$, we expect the signal should peak at zero and by using this fact we can suppress the background and extract signal.



Signal Vs Inclusive semi-leptonic tagging



Control channel modes

- To validate our results we use the different control channel modes.

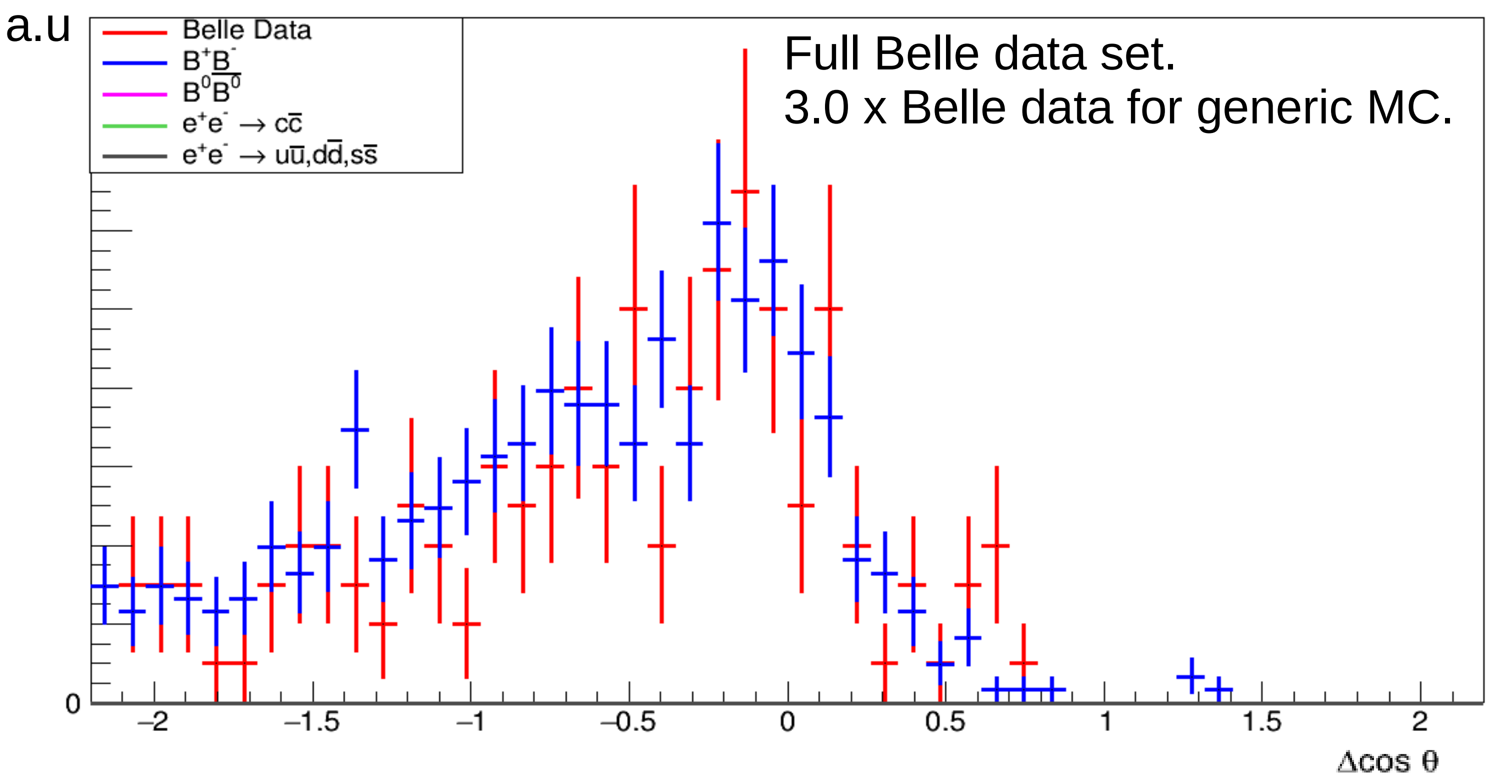
$$B^+ \rightarrow J/\psi\ (\rightarrow \mu^+\mu^-)\ K^+$$

$$B^+ \rightarrow \psi(2S)(\rightarrow \mu^+\mu^-)\ K^+$$

$$B^+ \rightarrow \psi(2S)(\rightarrow J/\psi(\rightarrow \mu^+\mu^-)\ \pi^+\pi^-)\ K^+$$

$$B^+ \rightarrow \overline{D}^0\ (\rightarrow K^+\pi^-)\pi^+$$

$B^+ \rightarrow J/\psi\ (\rightarrow \mu^+\mu^-)\ K^+$



Summary

- By using the semi-leptonic tau decay ($\tau^- \rightarrow \pi^- \nu_\tau$) mode and exploiting the kinematic conditions of the experiment,we have found the promising results for this approach in the Belle MC and data studies.

- We will include more decay modes in this study and validate our results on more control channel modes.

- Finally, we will apply this approach on the complete Belle and Belle II available dataset to get our final results.


thank you
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