Search for Lepton Flavour Violating $B^0 \to K^{*0}\tau\ell$ decays with the Belle and Belle II experiments

59th Rencontres de Moriond, La Thuile

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on behalf of the Belle II collaboration

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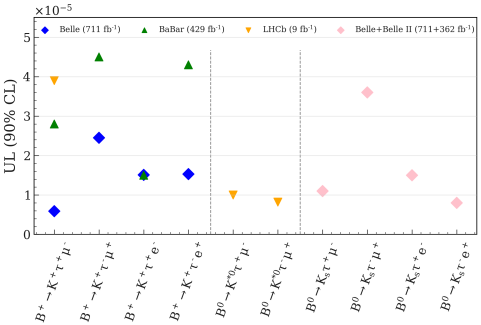
Belle II

Motivation

Search of LFV in $B \to s\tau\ell$ transitions

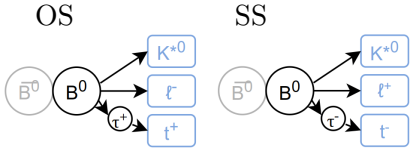


- LFV forbidden in SM but predicted in many NP models
- Theoretical NP predictions at level of 10^{-6}, 10^{-7} for $\mathcal{B}(B^0 \to K^{*0}\tau\mu)$ [e.g. arXiv:2407.19060]
- Modes with τ more challenging due to missing energy in τ decay
- No experimental results for $B^0 \to K^{*0}\tau e$ yet

Four modes to analyse $B^0 \to K^{*0}(\to K^+\pi^-)\tau^\pm\ell^\mp$: (OS, SS)×(e, μ)

> **OS:** Opposite sign between K from K^* and prompt lepton

> **SS:** Same sign between K from K^* and prompt lepton

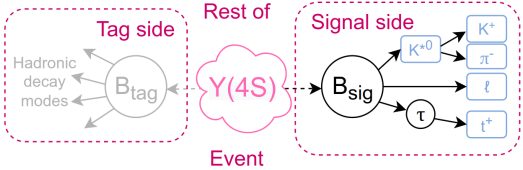


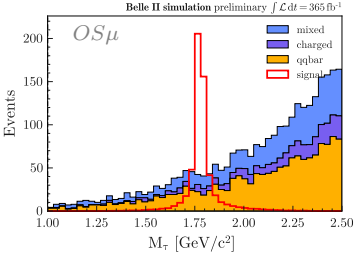
Analysis strategy

- Use 2019-2022 Belle II data (365 fb^{-1}) and full Belle dataset (711 fb^{-1})
- Hadronic tagging: the partner B meson is reconstructed through hadronic decays
  $\Rightarrow$ No missing energy in the tag side
- Signal reconstruction: $K^{*0}(\rightarrow K^+\pi^-)\ell + 1$ track from τ for background rejection
- Signal extraction from a Belle and Belle II simultaneous fit to the τ recoil mass

$$M_\tau^2 = m_B^2 + m_{K^*\ell}^2 - 2(E^*_{beam}E^*_{K^*\ell} + |p^*_{Btag}||p^*_{K^*\ell}|cos\theta^*_{Btag\text{-}K^*\ell})$$

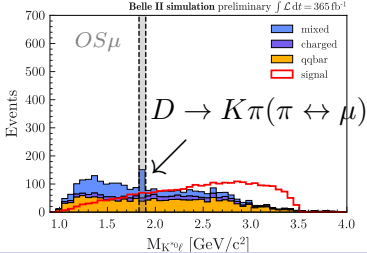
- $\mathcal{B}(B^0 \rightarrow K^{*0}\tau\ell) = \frac{N_{sig}}{\epsilon_{sig}\times 2\times N_{\Upsilon(4S)}\times f_{00}\times \mathcal{B}r(K^{*0}\rightarrow K^+\pi^-)}$

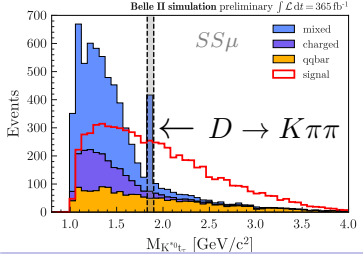


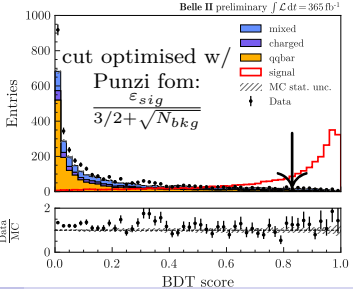


Selection and background rejection

- Require one track t_τ from τ decay for background rejection
- Loose cut-based selection on B_{tag} quality and Rest Of Events (ROE)
- Dominant backgrounds: $B \to DX, D \to K^{*0}\ell\nu_\ell$ in OS modes, $B \to D\ell\nu_\ell, D \to K^{*0}t_\tau$ in SS modes ($D \to K\pi\pi$ vetoes are applied)
- BDT-based selection with 8 BDTs ($OS\ell/SS\ell\times$Belle/Belle II) using $M(K^{*0}\ell)$, $M(K^{*0}t_\tau)$, ROE information, event shape variables





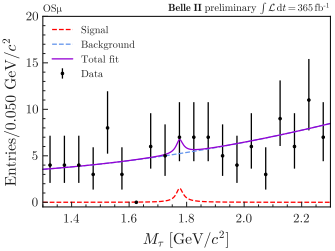


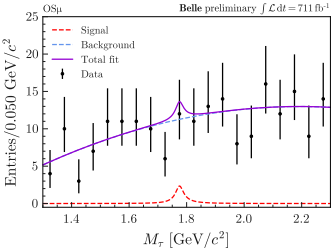
Fit to the τ recoil mass

- Unbinned simultaneous extended maximum likelihood fit of the branching fraction on Belle and Belle II datasets
- Signal parameters fixed to the ones in simultation, background coefficients are free
- Use control channel $B^0 \to D^- D_s^+ (\to \bar{K}^{*0} K^+ / \phi\pi)$ for BDT and signal shape systematic uncertainties

	$\varepsilon_{sig}^{\text{Belle II}}$ [%]	$\varepsilon_{sig}^{\text{Belle}}$ [%]	$\mathcal{B}^{\text{fit}}$ ($\times 10^{-5}$)
OSe	0.075	0.046	-0.24±1.44
SSe	0.056	0.038	1.11±2.65
$OS\mu$	0.060	0.052	0.98±1.74
$SS\mu$	0.051	0.024	0.47 ± 2.59

- No signal is observed

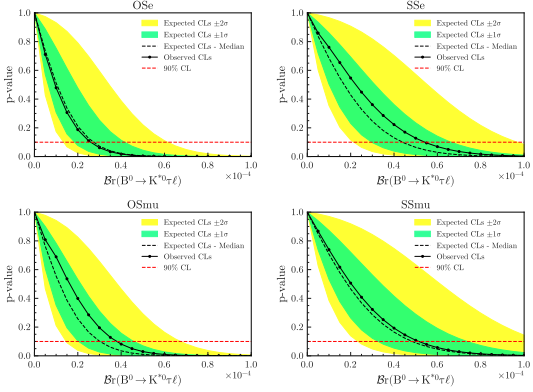




Upper Limits

- Upper limits at 90%CL on $\mathcal{B}(B^0 \to K^{*0}\tau\ell)$ are derived using asymptotic CLs approach

$$\mathcal{B}(B^0 \to K^{*0}\tau^+e^-) < 2.7 \times 10^{-5}$$
$$\mathcal{B}(B^0 \to K^{*0}\tau^-e^+) < 5.6 \times 10^{-5}$$
$$\mathcal{B}(B^0 \to K^{*0}\tau^+\mu^-) < 3.9 \times 10^{-5}$$
$$\mathcal{B}(B^0 \to K^{*0}\tau^-\mu^+) < 5.1 \times 10^{-5}$$



- First result on electron modes, not competitive with LHCb result for muon modes [1]
- First search for $B^0 \to K^{*0}\tau\ell$ LFV decays at B factories

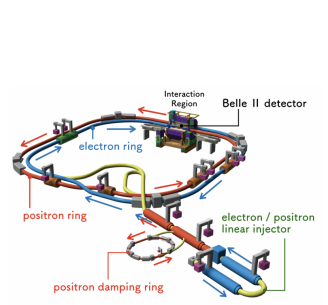
[1]10.1007/jhep06(2023)143

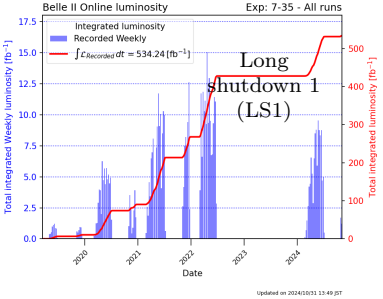
Backup

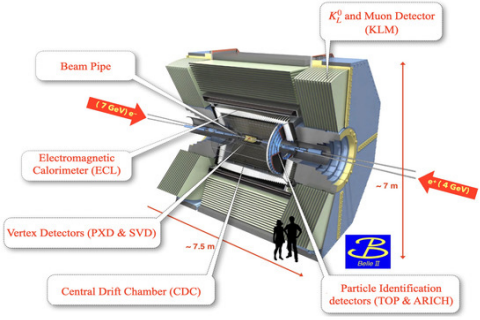
Backup

The Belle II experiment at SuperKEKB

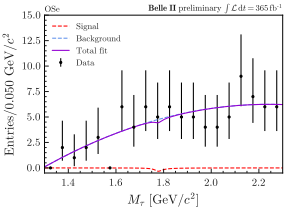
- Asymmetric e^+e^- collider at $\sqrt{s} = 10.58$ GeV corresponding to $\Upsilon(4S)$ resonance
- Holds instantaneous luminosity world record: 5.1×10^{34} cm^{-2}s^{-1}
- Pre-LS1 (2019-2022) on-resonance data : 365 fb^{-1}
- Hermetic and almost 4π detector : Reconstruction of missing energy

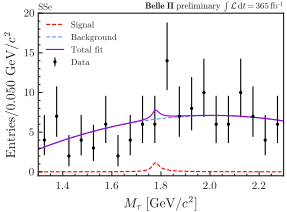


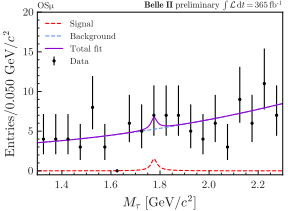


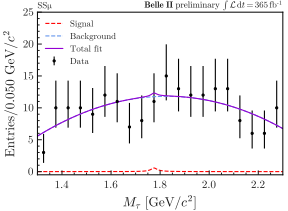


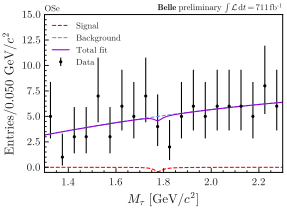
Belle and Belle II simultaneous fit – All modes

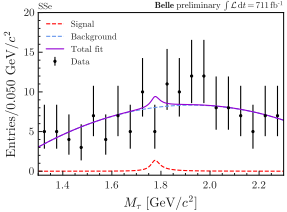


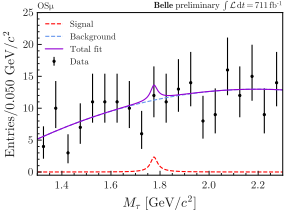


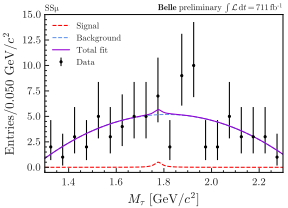










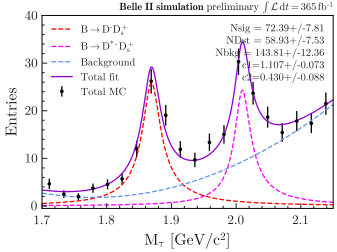


OSe *SSe* *OSμ* *SSμ*

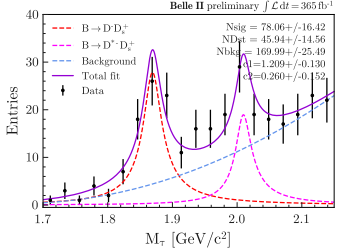
Control channels: $B^0 \to D^- D_s^+ (\to \bar{K}^{*0} K^+ / \phi\pi)$

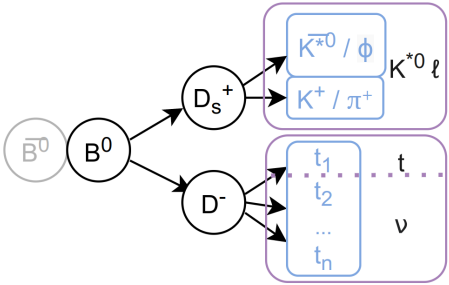
- $\bar{K}^{*0} K^+ / \phi\pi$ mimics $K^{*0}\ell$ system
- D mimics τ: reconstruct 1 track with correct charge from D decay, the other ones account for ν_τ missing energy and additional τ tracks in case of $\tau \to 3-prongs$
- Used for BDT and signal shape systematic uncertainties

Generic MC



Data





Systematic uncertainties summary

Source	Belle				Belle II			
	OSe	SSe	$OS\mu$	$SS\mu$	OSe	SSe	$OS\mu$	$SS\mu$
FEI efficiency [%]	4.9	4.9	4.9	4.9	6.2	6.1	6.1	6.2
Lepton ID efficiency [%]	2.0	2.4	2.2	2.2	0.7	1.1	0.7	0.6
Hadron ID efficiency [%]	1.9	2.0	1.9	2.0	3.7	3.7	3.6	3.7
BDT efficiency [%]	27	21	18	23	29	31	34	31
Tracking efficiency [%]	1.4				1.1			
Total efficiency [%]	27.6	21.8	18.9	23.7	29.8	31.8	34.7	31.7
Signal PDF μ ($\times 10^{-5}$)	0.04	0.00	0.01	0.01	0.04	0.00	0.01	0.01
Signal PDF λ ($\times 10^{-5}$)	0.11	0.01	0.04	0.01	0.11	0.01	0.04	0.01
Background PDF ($\times 10^{-5}$)	0.11	0.28	0.09	0.02	0.11	0.28	0.09	0.02
$N_{\Upsilon(4S)}$ [%]	1.4				1.6			
f^{00} [%]	0.8							
$\mathcal{B}(K^{*0} \to K^+\pi^-)$ [%]	0.021							
Total impact on UL ($\times 10^{-5}$)	0.1	0.3	0.1	0.1	0.1	0.3	0.1	0.1