-Part 3-
Search for LFV in *B* meson decays:
$B^0 \to K^{*0}\tau\ell$

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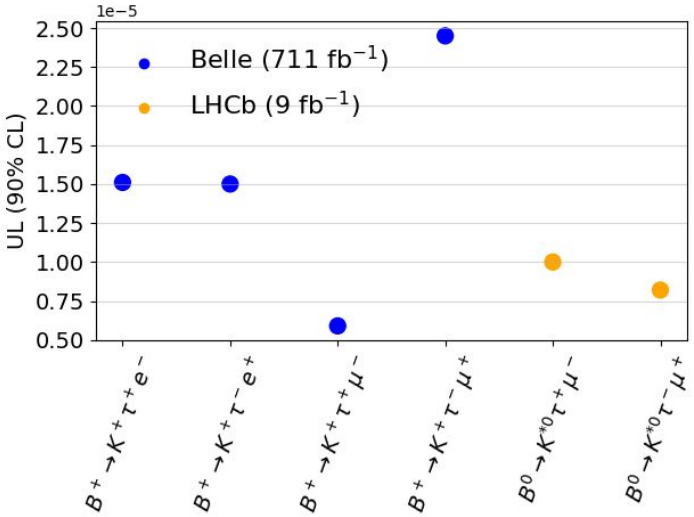
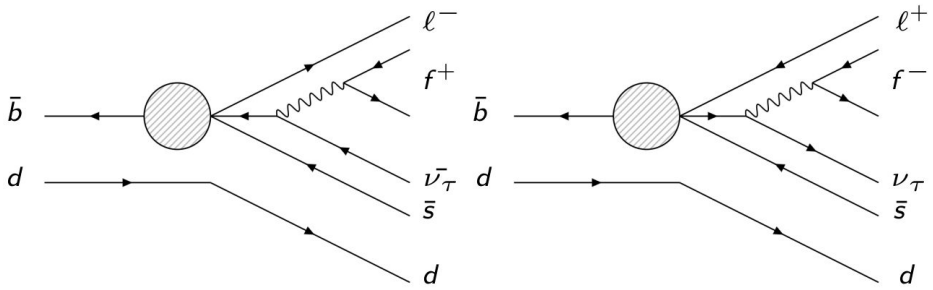
Search for LFV at Belle II, GDR-InF, Strasbourg, 7/11/2023

Motivation

Search of LFV in $b \to s\tau\ell$ **transitions**



- LFV **forbidden in SM** but predicted in many NP models
- Modes with τ more challenging due to **missing energy in τ decay**
- No results for $B^0 \to K^{*0}\tau e$ yet
- If no signal : set an **upper limit on the branching fraction**

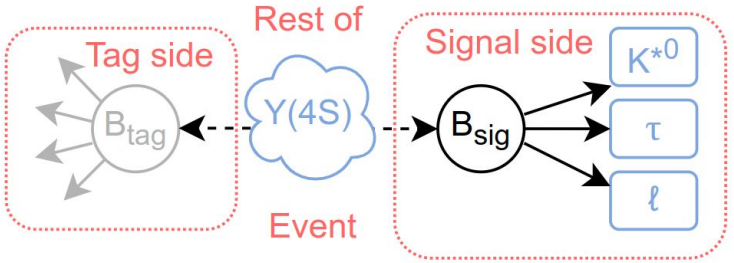


Four modes to analyse: (OS,SS)x(e, μ)
> **OS**: Opposite sign between K from K^* and prompt lepton
> **SS**: Same sign between K from K^* and prompt lepton

Analysis strategy

Data Sample: Use collected data from **Belle** experiment (**711fb^{-1}**) and **Belle II** (**362fb^{-1}**)

- Allow to fully exploit the available statistics



Tagged analysis: the full event is reconstructed

- **Hadronic** tagging
- ☺ No missing energy in the tag side
- ☹ Very low efficiency (B^0 hadronic tag has ~0.1% efficiency)

Measurement:

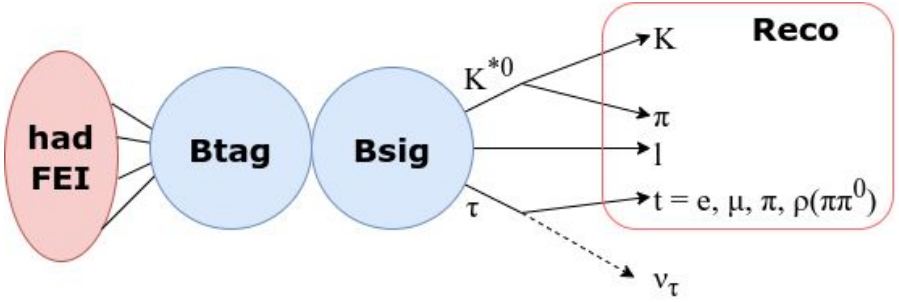
- Extract the signal from a fit to the ***τ*** **recoil mass**

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

Reconstruction idea

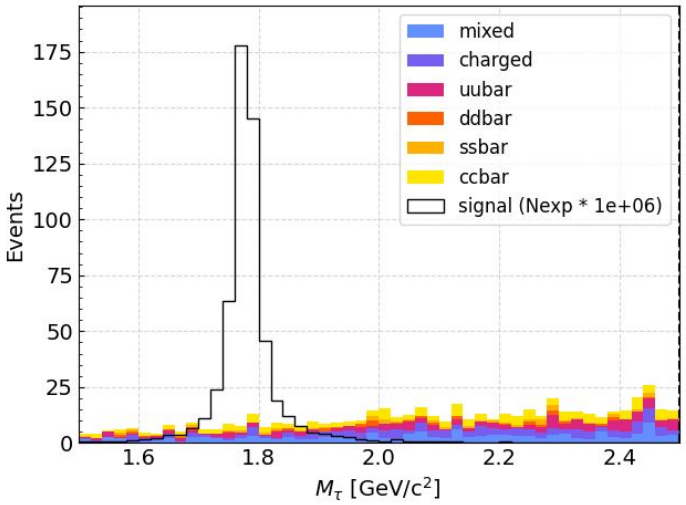
Tag side:

- Hadronic decay



Signal side:

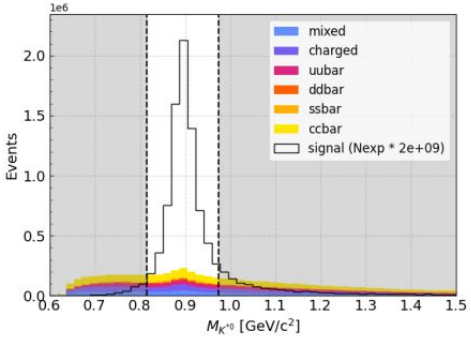
- Reconstruction of $K^{*0}\ell$ ($K^{*0} \rightarrow K\pi$)
- Reconstruction of t, $t = e, \mu, \pi, \rho(\pi\pi^0)$ for background rejection purpose (not used in τ recoil mass)
- Select only $\tau \rightarrow$1-prong (~80% of τ decays)
- Require 0 track left in the event after signal and tag reconstructions

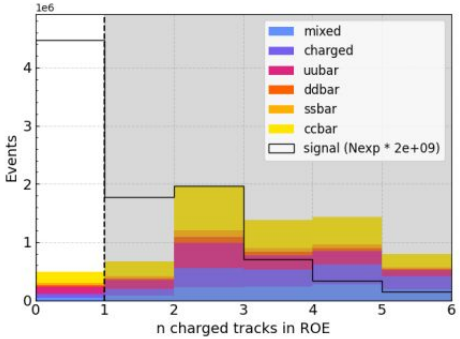


Preselection

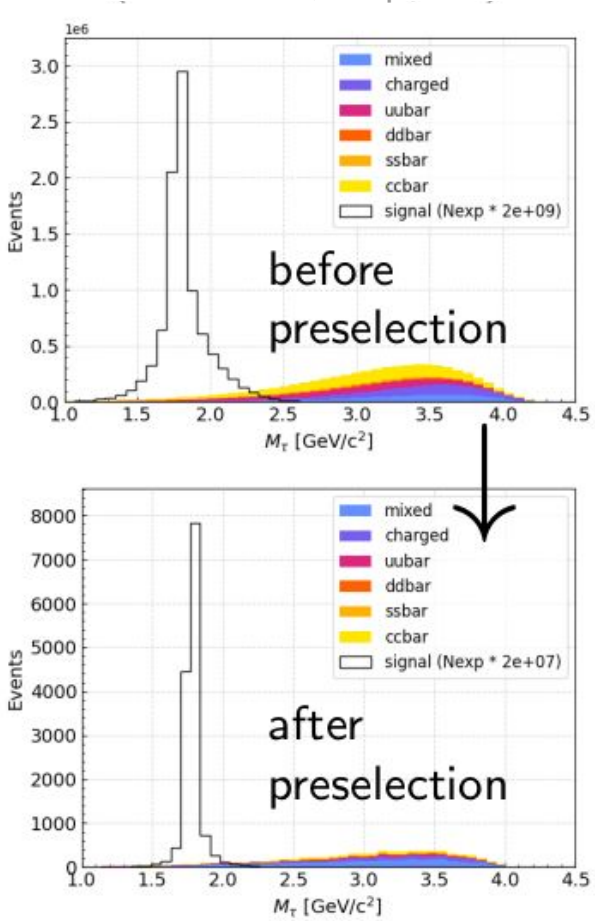
Preselection based on:

- **Track selection**:
  - Tracks from the interaction point
  - Particle identification
- **Tagging quality**:
  - *Mbc* : Beam constrained mass of Btag
  - *ΔE* : Difference between Btag energy and √*s*/2
  - P_{sig}*(FEI)* : Probability of correct Btag reconstruction
- Additional selection **specific to this analysis:**
  - K^{*0} mass window
  - No track left in the event after signal and tag reconstruction
- **Event shape**:
  - Sphericity





Belle II MC, OSμ



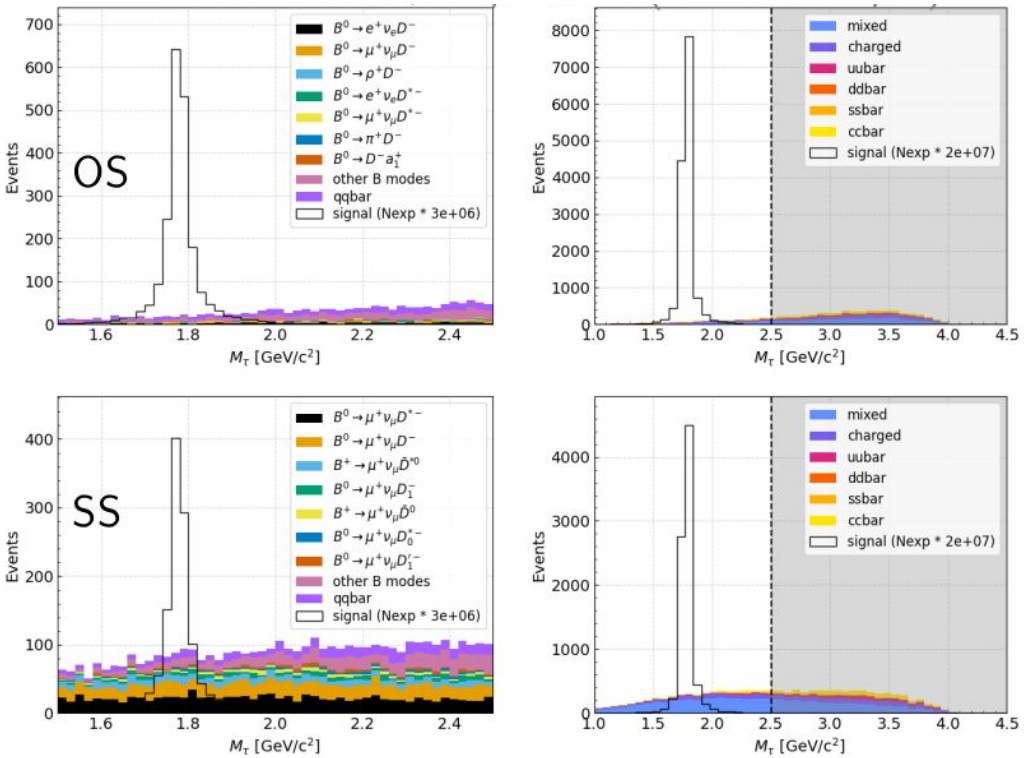
Signal efficiency : **0.06%**

Signal region and dominant backgrounds

Belle II MC, μ mode

Signal region: $M\tau \in [1, 2.5]\text{GeV}/c^2$

- Background dominated by **decays with a *D* meson component**
- OS mode dominated by semi-leptonic $B \to D(\to K^*\ell)t$
- SS mode dominated by semi-leptonic $B \to D(\to K^*t)\ell$
- J/ψ **peak** (and **photon pole** for *e* mode) in $M(\ell t)$

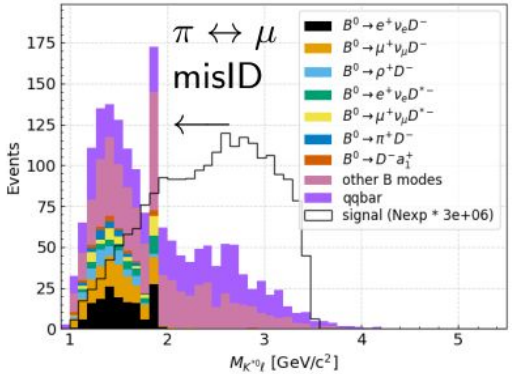


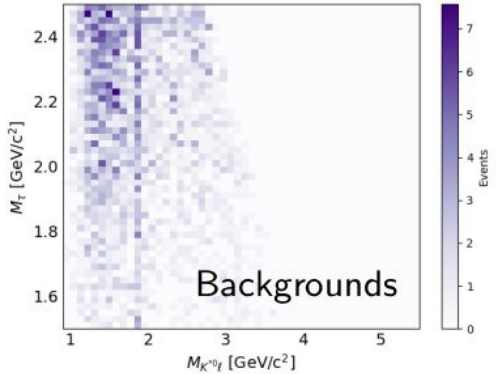
OS *D* semi-leptonic background

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

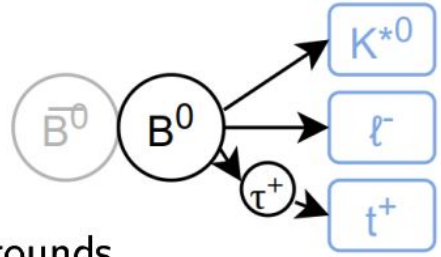
- Cut on ***M(K*ℓ)*** could remove almost all *D* semi-leptonic backgrounds

Belle II MC, μ mode

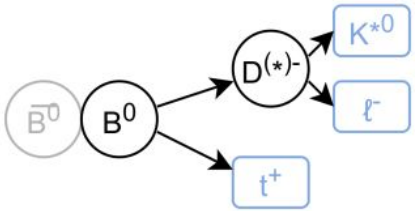


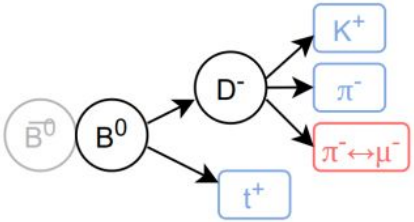


Signal

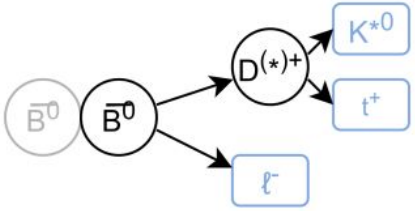


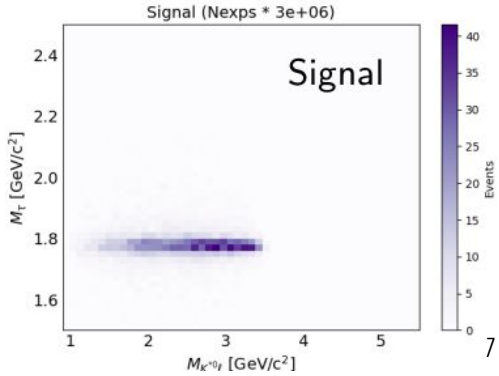
Backgrounds





If mixing

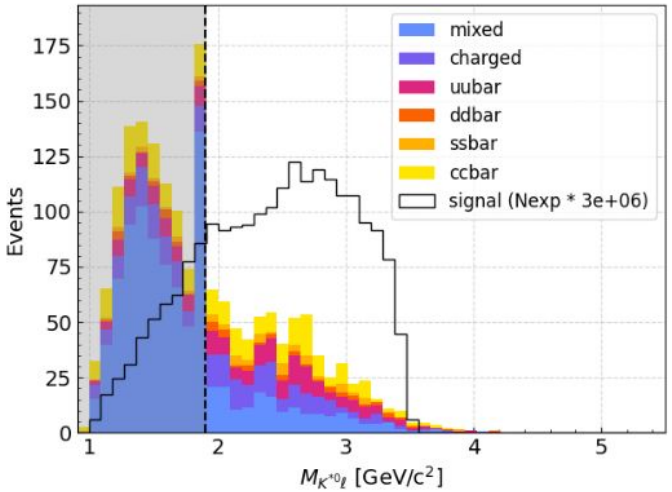




OS *D* semi-leptonic background

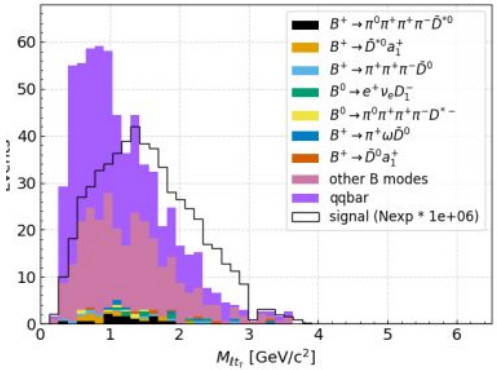
D SL decays suppression:
***M(K*ℓ)* > 1.9 GeV/c²**

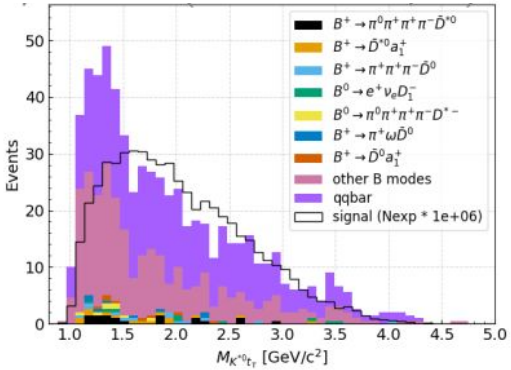
- Cut not optimised yet

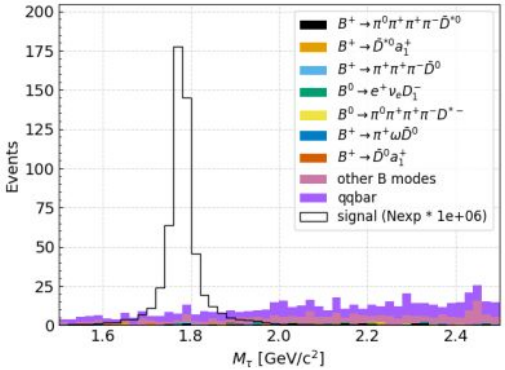


After selection cut

Belle II MC, μ mode





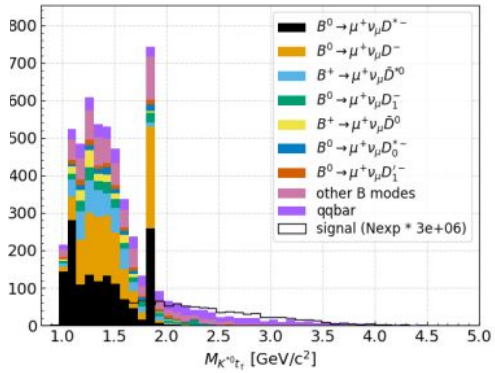


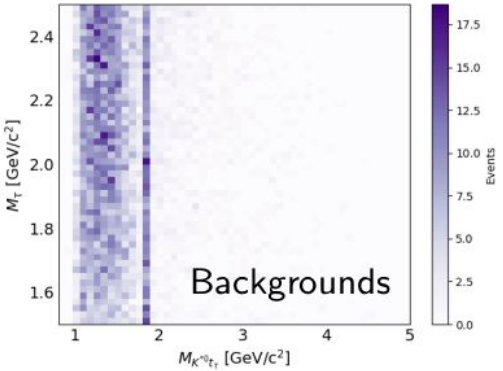
- No more really peaking background

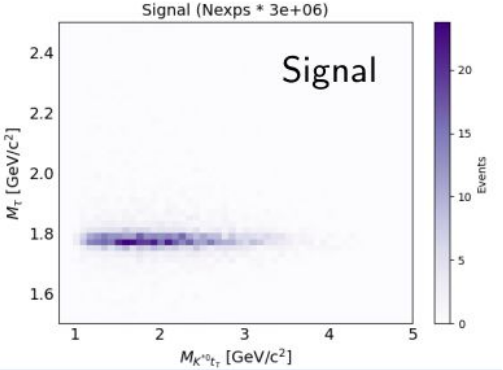
SS *B* semi-leptonic background

- *M(K*t)* and *Mτ* are not correlated, as expected
- Cut on ***M(K*t)*** could remove almost all *B* SL backgrounds, but costing **large loss of signal**

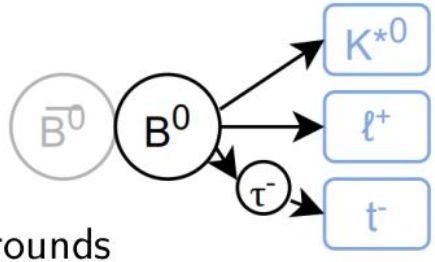
Belle II MC, μ mode



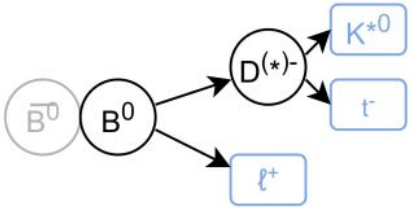


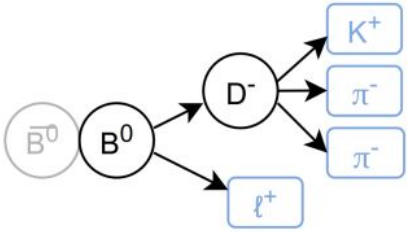


Signal



Backgrounds



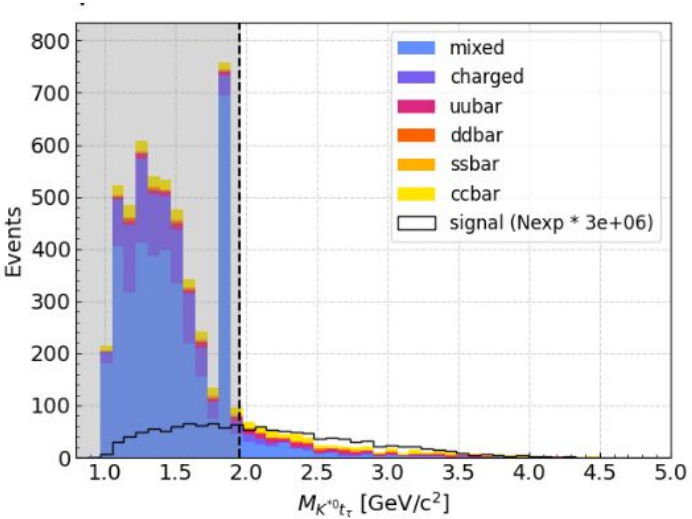


SS *B* semi-leptonic background

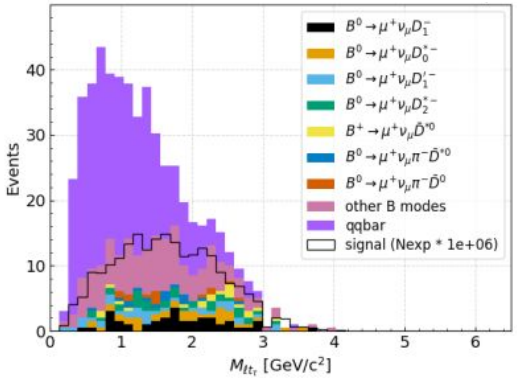
Belle II MC, μ mode

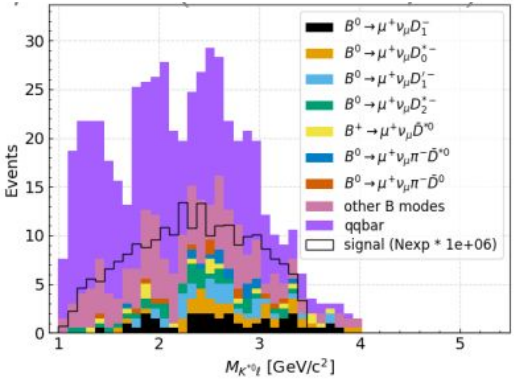
B SL decays suppression:
***M(K*t)* > 1.95 GeV/c²**

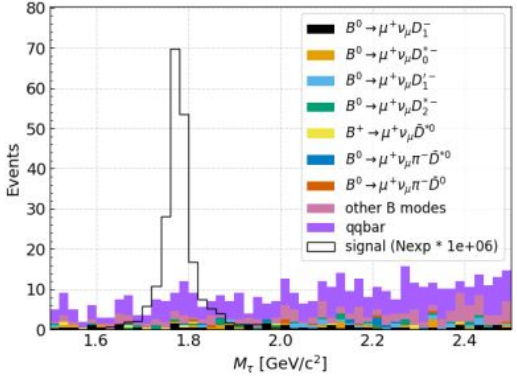
- Cut not optimised yet



After selection cut







- No more really peaking background

Signal efficiency and background rejection

OS μ	Sig. efficiency	Nbkg (pre-BDT)	Expected sig. events (pre-BDT)
After preselection	(0.058±0.001)%	(7.98±0.09)x10³	
After presented selection	(0.044±0.001)%	636±25	1.3
In tight sig. region	**(0.043±0.001)%**	**166±13**	1.3

SS μ	Sig. efficiency	Nbkg (pre-BDT)	Expected sig. events (pre-BDT)
After preselection	(0.058±0.001)%	(12.16±0.11)x10³	
After presented selection	(0.028±0.001)%	538±23	0.8
In tight sig. region	**(0.027±0.001)%**	**137±12**	0.8

- Further background rejection will be performed by **applying a BDT**
- Can expect a reduction of background by factor ~10 after BDT

Assuming Br(sig)=10^{-5}

Tight sig. region : $M\tau \in [1.6, 2]\text{GeV}/c^2$

Yields scaled to Belle II data luminosity

Summary and next steps

Background study path

- **Preselection** applied
- Backgrounds are mainly due to **semi-leptonic decays containing a *D* meson**
  - **Strategy for their suppression** to be decided
- ***J/ψ* and photon pole vetoes** applied
- A **BDT will be developed** to reject the remaining backgrounds

done
in progress
to do

Rejection options for *D* SL and *B* SL backgrounds

- **Cut-based approach**
  - No more peaking background and ***O*(150) background events** left in tight signal region with a signal efficiency of **0.043% for OS mode and 0.027% for SS mode**
  - Cuts need to be optimised
- Use ***M(K*ℓ)* and/or *M(K*t)* in the BDT** without the cut to avoid too large decreasing of signal efficiency

Thank you for your attention !

Backup

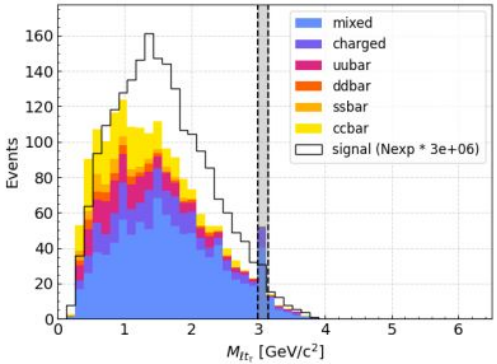
J/ψ Veto

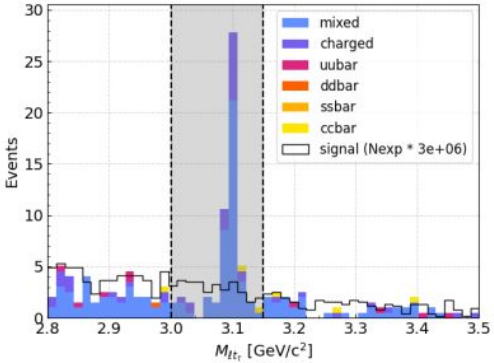
Belle II MC, mu mode

J/ψ veto:

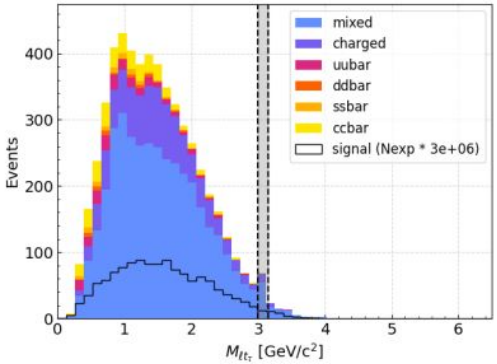
$M(\ell t_\tau) \notin [3.0, 3.15]\text{GeV}/c^2$

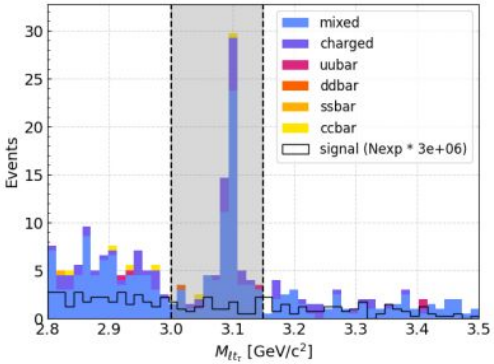
OS



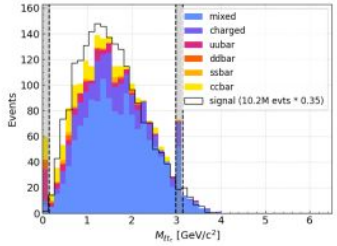


SS



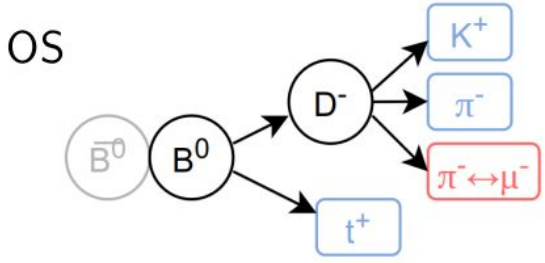


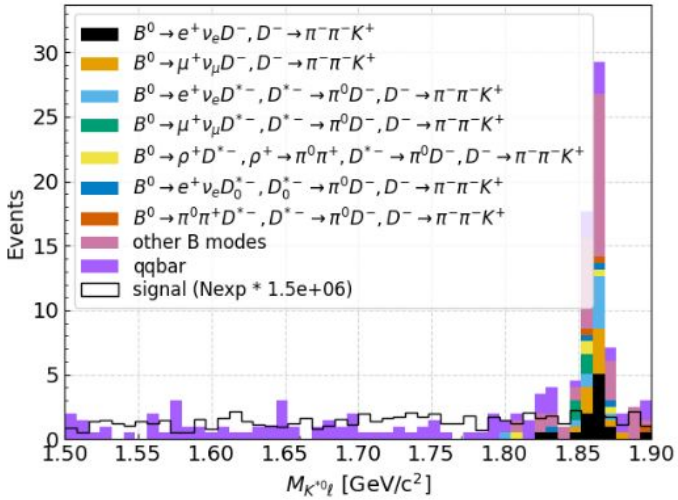
NB: + photon veto for e mode

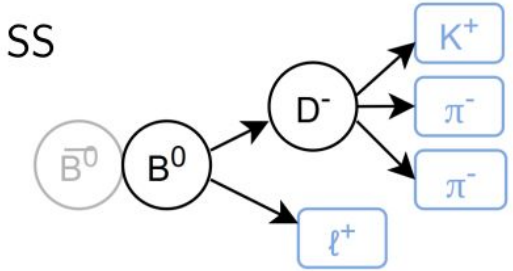


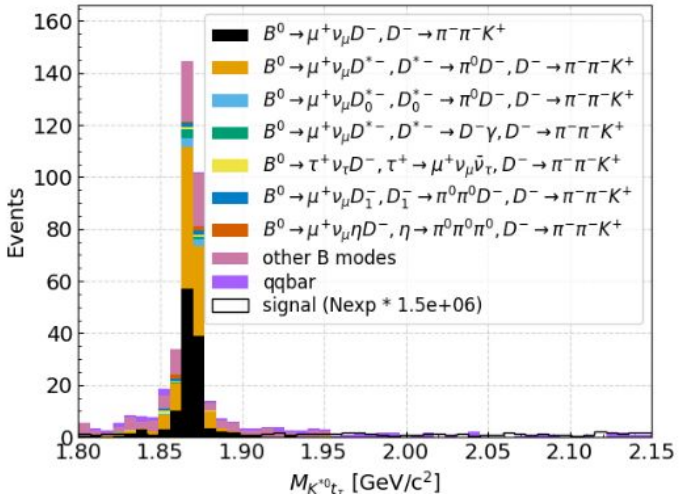
$K\pi\pi$ peak in $M(K^*\ell)/M(K^*t\tau)$

Belle II MC, mu mode









Preselection variables

Sphericity : quantity related to the ellipsoid that best matches with the particle distribution in the event

Mbc : Beam mass constrained

ΔE : Difference between Btag energy and sqrt(s)/2

log(P_{sig}(FEI)) : probability of correct reconstruction of tag