

Preliminary studies of the LFV decay $\tau \rightarrow \mu\gamma$ at Belle II

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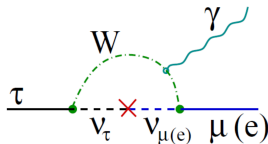
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Introduction

- The $\tau \rightarrow \mu\gamma$ is a Lepton Flavor Violating (LFV) process (\mathcal{L}_τ ($1 \rightarrow 0$) and \mathcal{L}_μ ($0 \rightarrow 1$)) and one of the most promising candidates to search for physics beyond the Standard Model (SM) at Belle II.



- This process is very suppressed within the SM, $\mathcal{B} \sim 10^{-45}$ [1, 2, 3], however, it has been studied in different new physics models and predictions had been made on the range of $10^{-8} - 10^{-10}$ [1, 2, 3, 4, 5, 6, 7, 8].
- The current limit is 4.4×10^{-8} at 90 % C.L. reported by Belle with an integrated luminosity of 535 fb^{-1} [9].
- We performed a sensitivity study of the upper limit on the branching ratio of $\tau \rightarrow \mu\gamma$ using simulated MC samples for 1 ab^{-1} under the Belle II framework.

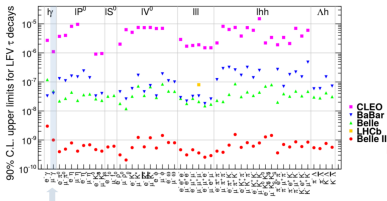
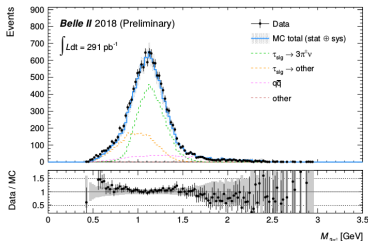
τ at Belle II

The Belle II experiment is perfectly suited to study τ physics. It will collect 50 times more data than Belle, equivalent to 5×10^{10} b , c and τ pairs over a period of 8 years [3].

The physics data taking has already started this year and we have already re-discovered the τ lepton.

For the LVF decay

$\tau \rightarrow \mu\gamma$, we expect to reduce the upper limit on its branching ratio to $\lesssim 10^{-9}$.

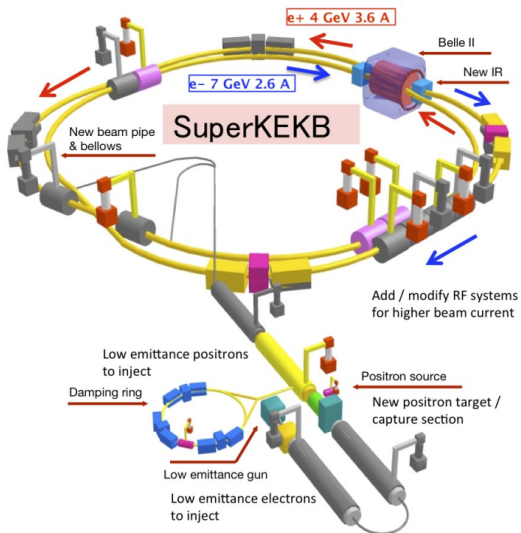


SuperKEKB

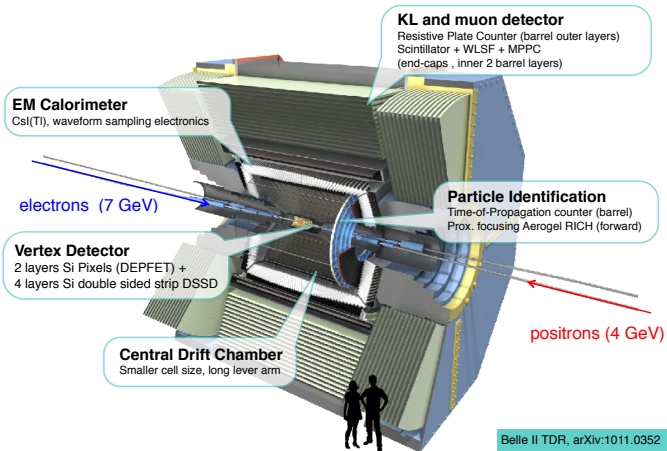
Electrons
HER (7 GeV)

Positrons
LER (4 GeV).

Designed to collide at a E_{CM} around the $\Upsilon(4S)$ resonance, ~ 10.58 GeV

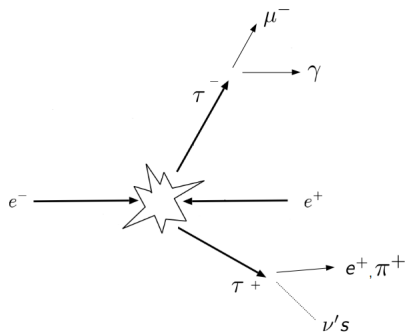


Belle II Detector



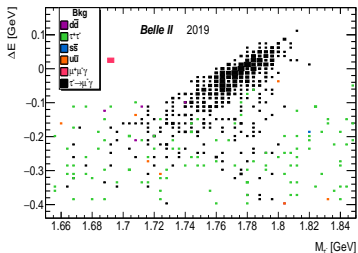
Analysis

- MC signal sample: $\tau^- \rightarrow \mu^- \gamma$ (PHSP) including beam background.
- MC background samples: $q\bar{q}$ ($q = b, c, s, d, u$), $\tau^+\tau^-$, e^+e^- , $\mu^+\mu^-$, $e^+e^-e^+e^-$, $e^+e^-\mu^+\mu^-$ and $\gamma\gamma$.
- Two charged tracks and zero net charge in the event.
- We apply similar selection requirements as in previous Belle analyses [10, 9], including new variables (e.g. event shape).

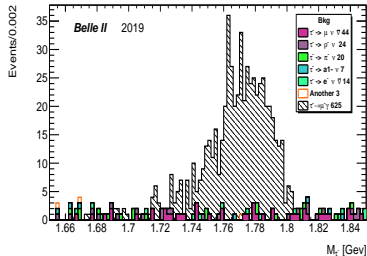


Signal region

$M_{\tau^-} \equiv M_{\mu\gamma} = \sqrt{E_{\mu\gamma}^2 - P_{\mu\gamma}^2}$ and $\Delta E = E_{\mu\gamma}^{CM} - E_{beam}^{CM}$ are used to define a signal region.



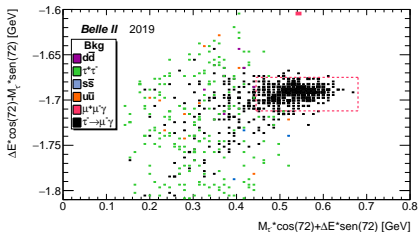
(a) $M_{\tau^-} - \Delta E$



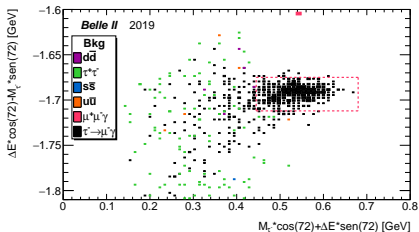
(b) Classification of τ -pair decays

Signal region

A 72° rotation is applied to the $M_\tau - \Delta E$ plane to obtain a final signal region with **no background events in 2.4 ab^{-1}** . The signal efficiency in this region is $\epsilon_{sig} = 4.34\%$.



(c) 2.4 ab^{-1}



(d) 1 ab^{-1}

Upper limit

We performed the calculation of the upper limit on the branching ratio of $\tau \rightarrow \mu\gamma$, assuming that the background distributions follow a Poisson statistics. For $n_{bkg}^{expected} = 0$, this sets an upper limit (sensitivity) of $n_{events} < 2.3$ at 90% CL and:

1 ab⁻¹

$$B(\tau^- \rightarrow \mu^- \gamma) = \frac{n_{events}}{2L_{int}\epsilon_{signal}\sigma(e^+e^- \rightarrow \tau^+\tau^-)} < 2.883 \times 10^{-8} \quad @ 90\%CL,$$

consistent with 2.726×10^{-8} estimated in the Belle II Physic Book [3].

Data Challenge

- The Data Challenge sample is equivalent to 1 ab^{-1} of collision simulated data, where the truth information was removed to be treated like real data. New physics signals have been injected in these samples (this information remains secret).
- Previous described selection criteria was applied to the Data Challenge samples (the signal efficiency varies slightly due to a different data preprocessing, $\epsilon_{sig} = 3.88\%$):

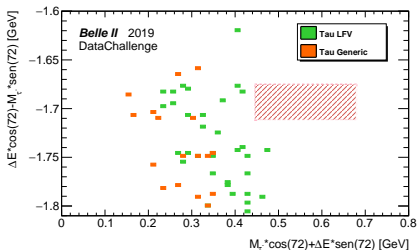


Figure: Rotated M_{T-} - ΔE plane

The signal box remains blinded. The analysis is under review by the Belle II Collaboration. Several improvements are being implemented.

Summary

- A sensitivity study of the $\tau \rightarrow \mu\gamma$ decay in Belle II is performed using MC samples for an integrated luminosity of 1 ab^{-1} .
- A signal region with NO background events was found after tight selection requirements in 1 ab^{-1} (and up to 2.4 ab^{-1}).

Collaboration		$\mathcal{B}(\tau \rightarrow \mu\gamma)$
BELLE (2008)	535 fb^{-1}	$< 4.5 \times 10^{-8}$
BABAR (2009)	$9.6 \times 10^8 \tau$	$< 4.4 \times 10^{-8}$
BELLE II (Book 2018)	MC (1 ab^{-1})	$< 2.726 \times 10^{-8}$
This analysis	MC (1 ab^{-1})	$< 2.883 \times 10^{-8}$
This analysis (assuming 0 observed events)	Data Challenge (1 ab^{-1})	$< 3.225 \times 10^{-8}$

Table: Summary of the branching ratio for $\tau \rightarrow \mu\gamma$.

- The selection criteria is being improved to increase the signal efficiency (e.g BDT selection).
- “Data Challenge” samples are being analyzed to improve the analysis techniques.

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BACKUP

MC10 samples	Cross section [nb]
$B\bar{B}$ (mixed /charged)	1.05 ± 0.10
$u\bar{u}(\gamma)$ (uubar)	1.61
$d\bar{d}(\gamma)$ (ddbar)	0.40
$s\bar{s}(\gamma)$ (ssbar)	0.38
$c\bar{c}(\gamma)$ (ccbar)	1.30
$\tau^+ \tau^- (\gamma)$ (taupair)	0.919
Low multiplicity	
$e^+ e^-$ (ee)	300 ± 3
$\mu^+ \mu^-$ (mm)	1.152
$e^+ e^- e^+ e^-$ (eeee)	39.8 ± 3
$e^+ e^- \mu^+ \mu^-$ (eemumu)	19.1 ± 0.1
$\gamma\gamma$ (gg)	25.3 ± 0.1

Table: Summary of the cross section for the MC samples.