Search for lepton-flavour-violating tau decays at FCC-ee(Z)

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We estimate experimental reach of the searches for the lepton-flavour-violating decays $\tau \to \mu\gamma$ and $\tau \to \mu\mu\mu$ at FCC-ee at the Z peak.

This work has been performed within the FCC collaboration.

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We summarize the estimates of the FCC-ee experimental reach on the searches for the lepton-flavour-violating tau decays $\tau \to \mu\gamma$ and $\tau \to \mu\mu\mu$, which has been documented in an FCC internal note [1][1]. We assume that FCC-ee will observe at the Z peak $N_Z^{\text{FCC}} = 6{\cdot}10^{12}$ Z decays [2], corresponding to $2.0{\cdot}10^{11}$ tau pairs, and to an integrated luminosity of $\mathscr{L}_{\text{int}}^{\text{FCC}} = 210\,\text{ab}^{-1}$.

1.1 Search for $\tau \to \mu\gamma$

A Monte Carlo simulation corresponding to $7{\cdot}10^{10}$ visible Z decays has been used to estimate how many $\tau \to \mu\gamma$ decay candidates from background sources are to be expected for $3{\cdot}10^{12}$ Z decays at an FCC-ee experiment [3, 4]. By assuming a reasonable reconstruction and selection efficiency, a sensitivity of $2{\cdot}10^{-9}$ has been estimated, corresponding to a signal equal to a double-sided 2σ fluctuation of the large number of expected background events, in the Gaussian approximation [5]. We recompute here the sensitivity in terms of the expected upper limit at 90% confidence level (CL) for a search of $\tau \to \mu\gamma$ on a sample of $6{\cdot}10^{12}$ Z decays at FCC-ee,

$$\mathscr{B}(\tau \to \mu\gamma) < 2.0{\cdot}10^{-9} \cdot \frac{qN\left[1-\frac{1}{2}(1-90\%)\right]}{2} \cdot \frac{\sqrt{3{\cdot}10^{12}}}{\sqrt{6{\cdot}10^{12}}} \simeq 1.2{\cdot}10^{-9} \quad \text{at 90\% CL}, \tag{1}$$

where $qN(p)$ is the inverse of $pN(x) = \int_{-\text{inf}}^{x} dN(x')dx'$, with $dN(x)$ being the Normal distribution. Figure 1(a) reports the present upper limits and the future expected upper limits for $\mathscr{B}(\tau \to \mu\gamma)$.

1.2 Search for $\tau \to \mu\mu\mu$

The Belle II collaboration reported a 90% CL upper limit of $1.9{\cdot}10^{-8}$ for the lepton-flavour-violating branching fraction $\mathscr{B}(\tau \to \mu\mu\mu)$ [6], using $390{\cdot}10^{6}$ tau pairs (corresponding to 424 fb^{-1} of integrated luminosity). The estimated selection efficiency is about 20.4%, significantly larger than the one attained by the previous Belle search [7], 7.6%, and is now comparable to the efficiency that has been reported at LEP 1 for the DELPHI $\tau \to \mu\gamma$ search [8], 24.5%, which is about 4 times the efficiency reported by the same $\tau \to \mu\gamma$ search by *BABAR* [9]. When assuming that for the $\tau \to \mu\mu\mu$ search an efficiency of 35.0% may be obtained at FCC-ee, we estimate that the expected upper limit at FCC-ee will be:

$$\text{UL}_{\text{exp}}^{90} = 1.8{\cdot}10^{-8} \frac{20.4\%}{35.0\%} \frac{390{\cdot}10^{6}}{2.0{\cdot}10^{11}} = 2.0{\cdot}10^{-11}\,, \tag{2}$$

by linearly scaling the reported expected upper limit at 90% CL by Belle II, $1.8{\cdot}10^{-8}$, to the FCC-ee number of tau pairs, $2.0{\cdot}10^{11}$, while also assuming that the search will not be background-limited, exploiting the highly efficient and pure muon selection at the Z peak energies. Figure 1(b) reports the present upper limits and the future expected upper limits for $\mathscr{B}(\tau \to \mu\mu\mu)$.

2 References

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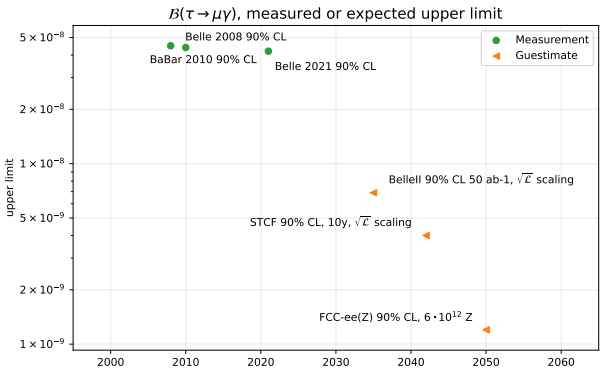
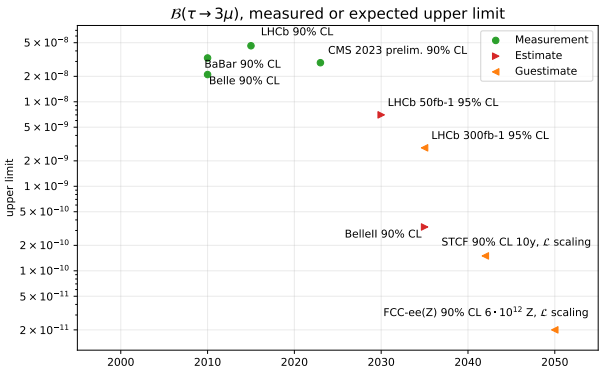
[1] Document in development, content restricted as of 20 October 2024, will eventually become public.



(a) Present and future expected upper limits for $\mathcal{B}(\tau \to \mu\gamma)$. The expected limits for Belle II and the Super Charm-Tau factories are personal conservative estimates based on the assumption that those searches will be mostly background-constrained from the statistics that has been simulated for both facilities.



(b) Present and future expected upper limits for $\mathcal{B}(\tau \to \mu\mu\mu)$.

Figure 1: Present and future experimental reach on tau lepton-flavour-violating decays. The dates of the future measurements are speculative and mainly chosen for plotting purposes.

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