provide the best limit on LFV Z decays. The detection of a signal in the $Z^0 \rightarrow \ell\ell'$ channel, in combination with the information from charged lepton LFV decays, would also allow one to learn about features of the underlying LFV dynamics. An explicit example is provided by the Inverse Seesaw (ISS) and “3+1” effective models which add one or more sterile neutrinos to the particle content of the SM [407] (see also, e.g., Ref. [408–410]).

5.2.1 Lepton Flavour Violation in $\tau$ decays

Tau decays offer a rich landscape to search for CLFV. The $\tau$ lepton is heavy enough to decay into hadrons. Until now already 48 LFV modes have been bounded at the level of $10^{-8}$ [196], as can be seen in Fig. 35.

![Fig. 35: Bounds on Tau Lepton Flavour Data from the existing experiments are compiled by HFLAV [196]; projections of the Belle-II bounds were performed by the Belle-II collaboration assuming 50 ab$^{-1}$ of integrated luminosity [195].](image)

The $B$ factories, BaBar and Belle, have improved by more than an order of magnitude [411–423] the previous CLEO bounds [424–426] for a significant number of modes. Some of the modes, for instance, $\tau \rightarrow \ell\omega$, have been bounded for the first time [412].

Table 23 shows a list of limits obtained for the $\tau \rightarrow 3\mu$ channel by different experiments. The strongest limits come from the $B$-factories, with a competitive limit obtained by LHCb [427]. Table 23 also contains the recent measurement by ATLAS [428], as well as the expected limit from the Belle-II experiment at the SuperKEKB collider, which will improve current limits by almost two orders of magnitude [195]. Finally, Table 23 also summarizes the expected limits from the HL-LHC that we discuss in more detail below.

The physics reach and model-discriminating power of LFV tau decays is most efficiently analyzed above the electroweak scale using SMEFT, and in a corresponding low-energy EFT when below the weak scale [429]. Several classes of dimension-six operators contribute to LFV tau decays at the low-scale, with effective couplings denoted by $C_l/\Lambda^2$. Loop-induced dipole operators mediate radiative decays $\tau \rightarrow \ell\gamma$ as well as purely leptonic $\tau \rightarrow 3\ell$ and semi-leptonic decays. Four-fermion – both four-lepton and semi-leptonic – operators with different Dirac structures can be induced at tree-level or loop-level, and contribute to $\tau \rightarrow 3\ell$ and $\tau \rightarrow \ell + \text{hadrons}$. As a typical example, we note that current limits on $\tau \rightarrow \mu\gamma$ probe scales on the order of $\Lambda/\sqrt{C_{\text{Dipole}}} \sim 500$ TeV. Besides probing high scales, LFV $\tau$ decays offer two main handles to discriminate among underlying models of NP, i.e., to identify which operators are present at low energy and what is their relative strength: (i) correlations among different LFV $\tau$ decay rates [429]; (ii) differential distributions in higher multiplicity decays, such as the $\pi\pi$ invariant mass in $\tau \rightarrow \mu\pi\pi$ [429] and the Dalitz plot in $\tau \rightarrow 3\mu$ [430,431].