The 9th China LHC Physics Workshop (CLHCP2023)

CEPC Flavour Physics

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A vast subject...

Flavor Physics at CEPC: a General Perspective

in preparation

Contents

White paper to appear soon!

Today, I can only mention few selected topics (guided by personal bias)

For some excellent talks, cf. the flavour session of the recent international CEPC workshop

CEPC Operation Plan

Particle	$E_{c.m.}$ (GeV)	Years	SR Power (MW)	Lumi. /IP ($10^{34}cm^{-2}s^{-1}$)	Integrated Lumi. /yr (ab^{-1}, 2 IPs)	Total Integrated L (ab^{-1}, 2 IPs)	Total no. of events
H*	240	10	50	8.3	2.2	21.6	4.3×10^6
			30	5	1.3	13	2.6×10^6
Z	91	2	50	192**	50	100	4.1×10^{12}
			30	115**	30	60	2.5×10^{12}
W	160	1	50	26.7	6.9	6.9	2.1×10^8
			30	16	4.2	4.2	1.3×10^8
$t\bar{t}$	360	5	50	0.8	0.2	1.0	0.6×10^6
			30	0.5	0.13	0.65	0.4×10^6

* Higgs is the top priority. The CEPC will commence its operation with a focus on Higgs.
** Detector solenoid field is 2 Tesla during Z operation, 3Tesla for all other energies.
*** Calculated using 3,600 hours per year for data collection.

2023 International Workshop on the Circular Electron Positron Collider

Talk by Yuhui Li
@CEPC workshop 2023

The Z-peak run of CEPC can deliver a few $\times 10^{12}$ visible Z decays

Plenty of flavour physics opportunities from $Z \to bb$, $Z \to cc$, $Z \to \tau\tau$:

Particle	BESIII	Belle II (50 ab^{-1} on $\Upsilon(4S)$)	LHCb (300 fb^{-1})	CEPC (4×Tera-Z)
B^0, $\bar{B}^0$	-	5.4×10^{10}	3×10^{13}	4.8×10^{11}
$B^\pm$	-	5.7×10^{10}	3×10^{13}	4.8×10^{11}
B_s^0, $\bar{B}_s^0$	-	6.0×10^8 (5 ab^{-1} on $\Upsilon(5S)$)	1×10^{13}	1.2×10^{11}
$B_c^\pm$	-	-	1×10^{11}	7.2×10^8
Λ_b^0, $\bar{\Lambda}_b^0$	-	-	2×10^{13}	1×10^{11}
D^0, $\bar{D}^0$	1.2×10^8	4.8×10^{10}	1.4×10^{15}	5.2×10^{11}
$D^\pm$	1.2×10^8	4.8×10^{10}	6×10^{14}	2.2×10^{11}
$D_s^\pm$	1×10^7	1.6×10^{10}	2×10^{14}	8.8×10^{10}
$\Lambda_c^\pm$	0.3×10^7	1.6×10^{10}	2×10^{14}	5.5×10^{10}
$\tau^\pm$	3.6×10^8	4.5×10^{10}		1.2×10^{11}

CEPC flavour WP, in preparation
cf. also CEPC CDR '18

Advantages of a high-energy e^+e^- collider as flavour factory:

Luminosity

$\mathcal{L}$=100/ab, O(10^{12}) Z decays ⇒ O(10^{11}) bb, cc, and $\tau\tau$ pairs

Energy

besides producing states unaccessible at Belle II
$M_Z \gg 2m_b$, $2m_\tau$, $2m_c$ ⇒ surplus energy, boosted decay products
(better tracking and tagging, lower vertex uncertainty etc.)

Cleanliness

as for any leptonic machine, full knowledge of the initial state
(e.g. Z mass constraint on invariant masses more powerful)
⇒ it enables searches involving neutral/invisible particles

What flavour physics can we study at a Tera Z?

flavour-violating Z decays

forbidden processes [lepton flavour (universality) violation, lepton/baryon number violation…]

precise measurements [CKM UT angles, CPV…]

rare decays [(semi-)leptonic B decays…]

charm physics

exotic hadrons spectroscopy

tau physics

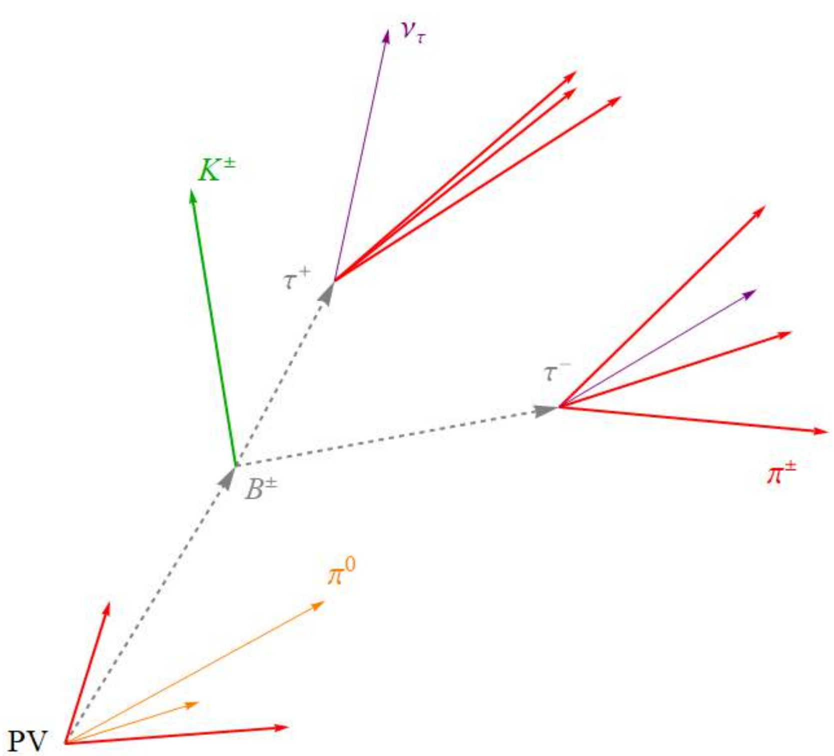
… in one word (almost) *everything*

$b \to s\tau\tau$

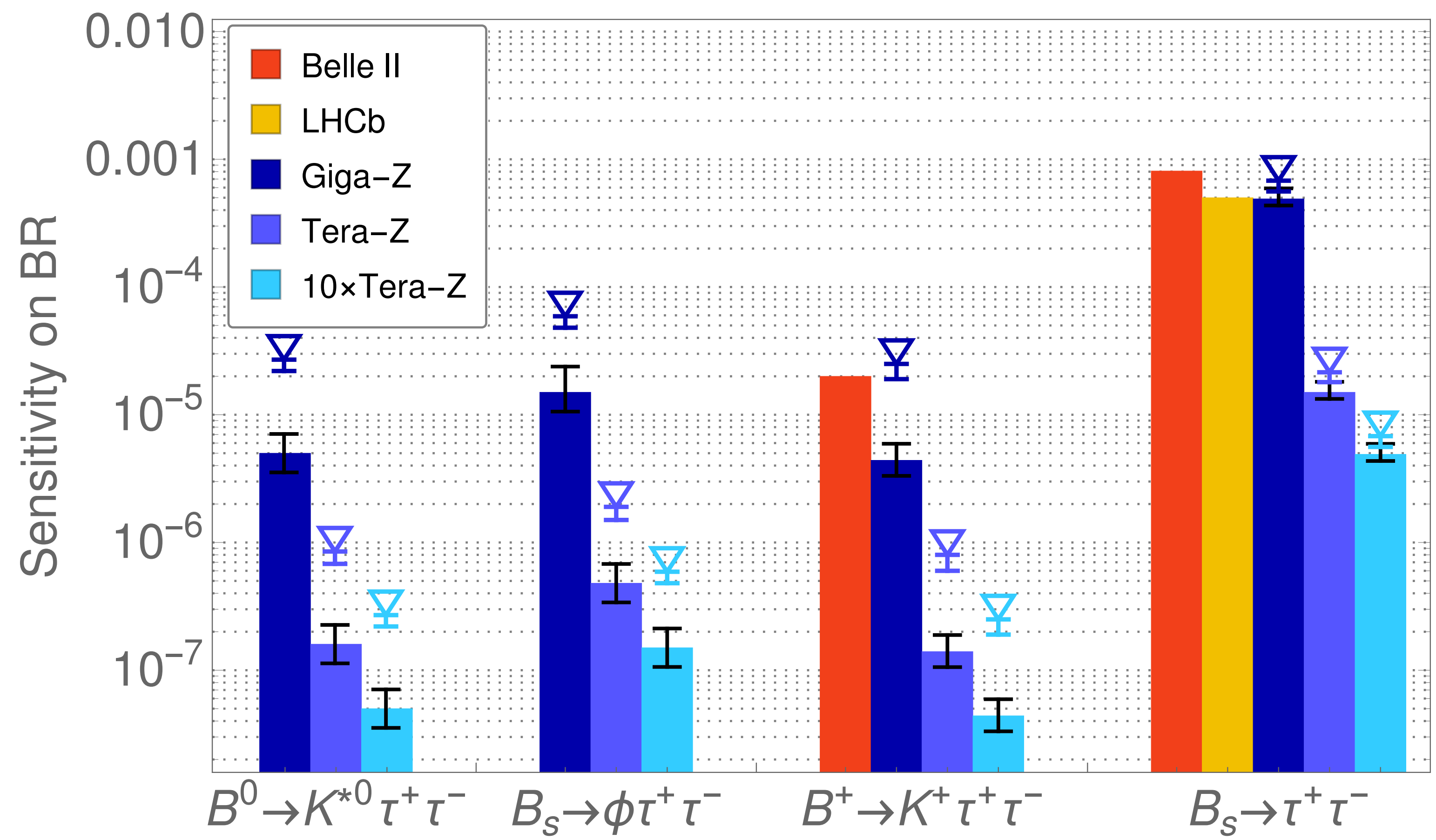
$$\text{BR}(B_s \to \tau\tau)_{\text{SM}} = (7.7 \pm 0.5) \times 10^{-7}$$ (Bobeth et al. 1311.0903)

$$\text{BR}(B \to K\tau\tau)_{\text{SM}} = (1.2 \pm 0.1) \times 10^{-7}$$ (Du et al. 1510.02349)

- Unobserved, weakly constrained (~10^{-4}-10^{-3} by Belle, Belle II can provide an O(10) increased sensitivity)
- They can have huge new-physics enhancement (especially in theories addressing the anomalies in semileptonic *B* decays)
- Tera Z prospect:



3-prong τ decays



Li L. and Liu T. '20

$b \to s\nu\nu$

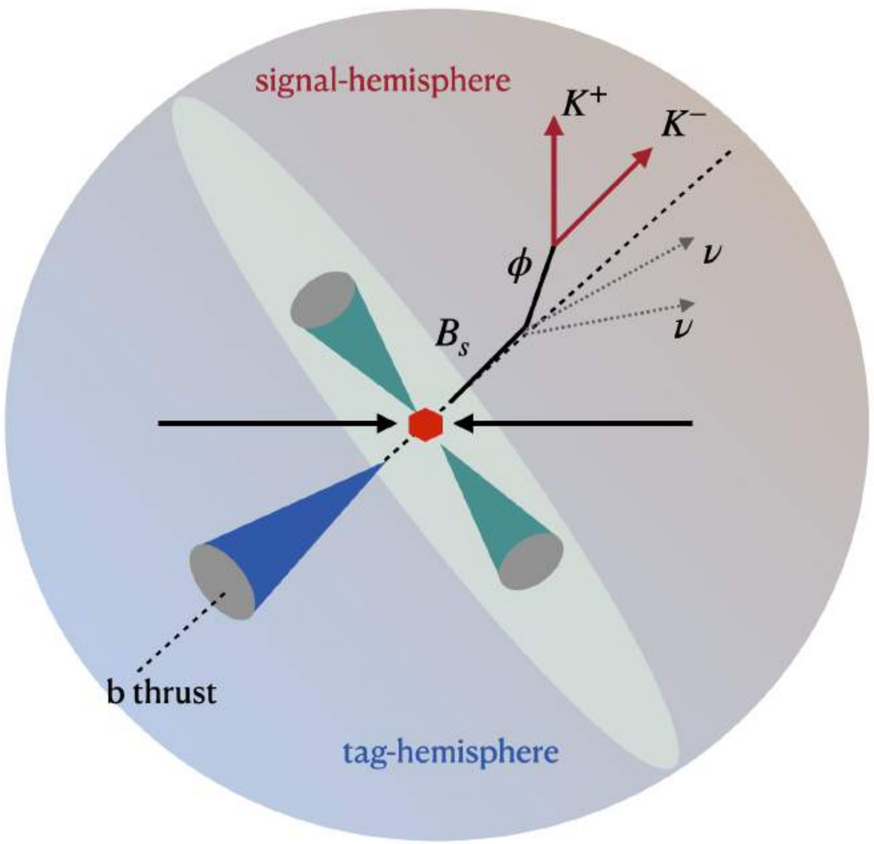
Li et al. '22

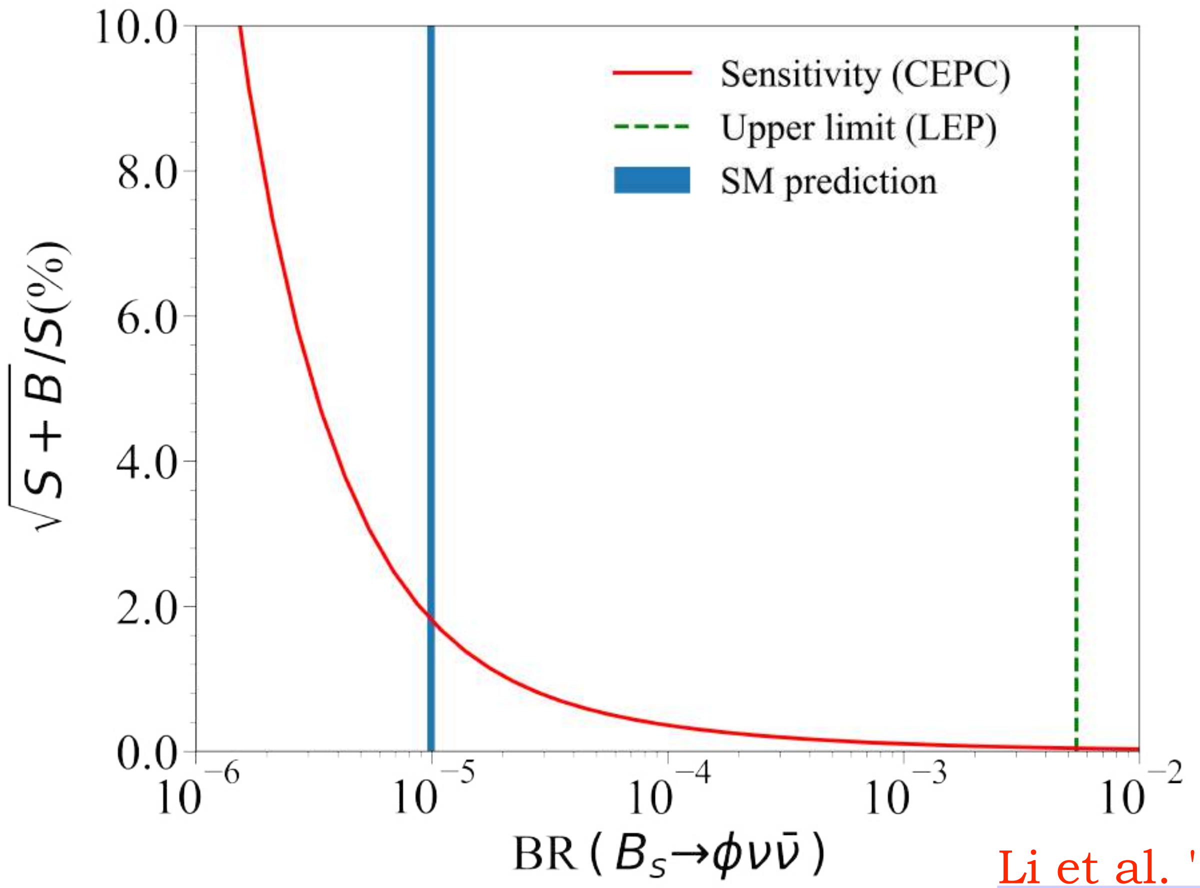
	Current Limit	Detector	SM Prediction
$\mathrm{BR}(B^0 \to K^0 \nu\bar{\nu})$	$< 2.6 \times 10^{-5}$ [3]	BELLE	$(3.69 \pm 0.44) \times 10^{-6}$ [1]
$\mathrm{BR}(B^0 \to K^{*0} \nu\bar{\nu})$	$< 1.8 \times 10^{-5}$ [3]	BELLE	$(9.19 \pm 0.99) \times 10^{-6}$ [1]
$\mathrm{BR}(B^\pm \to K^\pm \nu\bar{\nu})$	$< 1.6 \times 10^{-5}$ [4]	BABAR	$(3.98 \pm 0.47) \times 10^{-6}$ [1]
$\mathrm{BR}(B^\pm \to K^{*\pm} \nu\bar{\nu})$	$< 4.0 \times 10^{-5}$ [5]	BELLE	$(9.83 \pm 1.06) \times 10^{-6}$ [1]
$\mathrm{BR}(B_s \to \phi \nu\bar{\nu})$	$< 5.4 \times 10^{-3}$ [6]	DELPHI	$(9.93 \pm 0.72) \times 10^{-6}$

- Also these modes can be greatly enhanced by new physics responsible for the B anomalies

see e.g. LC Crivellin Ota '15

- A Tera Z can measure $B_s \to \phi\nu\nu$ with a percent level precision:





Li et al. '22

$B_c \to \tau\nu$

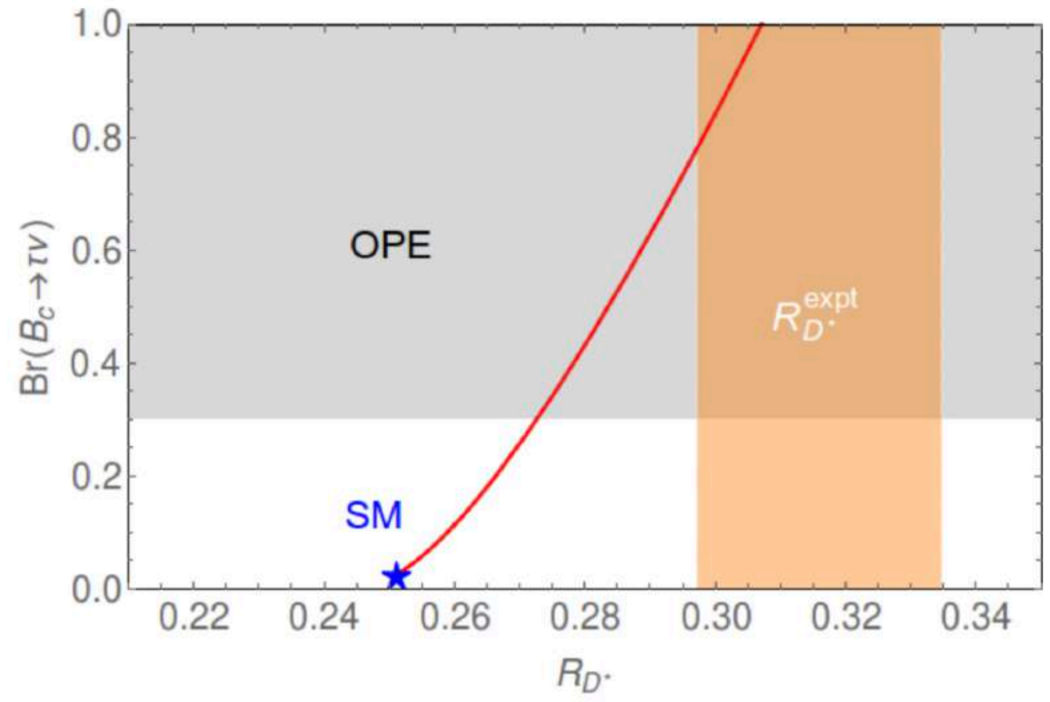
- Key observable to test the LFU anomalies in charged-current B decays

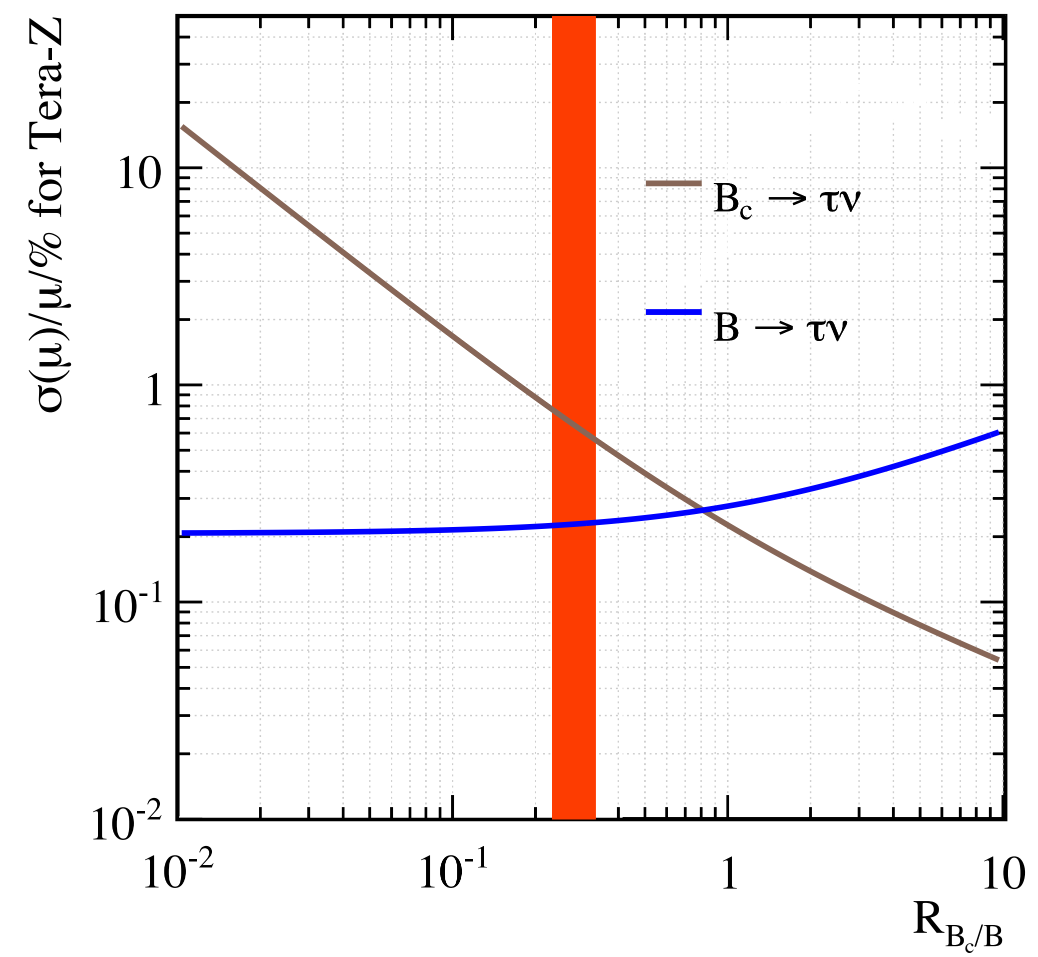
Alonso et al. '16

- SM prediction for the BR ~ 2%, beyond the reach of LHCb

- Tera Z could measure with percent level accuracy (thus providing also a percent level accurate measurement of V_{cb})

Zheng et al. '20





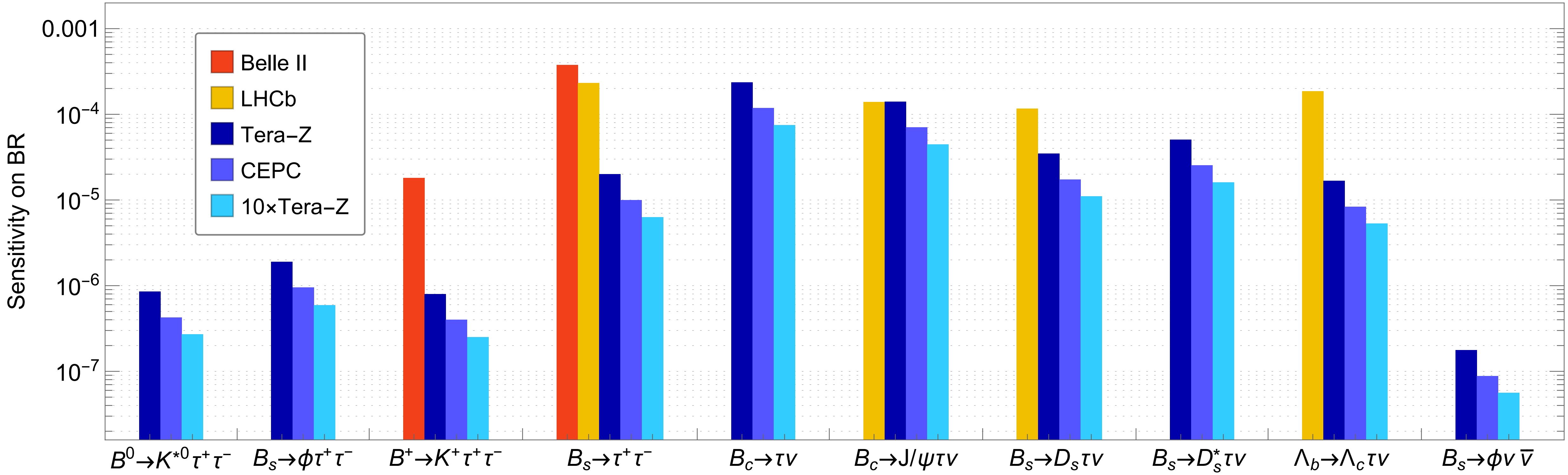


Figure 17: Projected sensitivities of measuring the $b \to s\tau\tau$ [71], $b \to s\nu\bar{\nu}$ [35] and $b \to c\tau\nu$ [37, 63] transitions at the Z pole. The sensitivities at Belle II @ 50 ab^{-1} [6] and LHCb Upgrade II [17, 72] have also been provided as a reference. Note, the LHCb sensitivities are generated by combining the analyses of $\tau^+ \to \pi^+\pi^-\pi^-(\pi^0)\nu$ and $\tau \to \mu\nu\bar{\nu}$. This plot is adapted from [37].

Ho et al. '22
CEPC flavour WP, in preparation

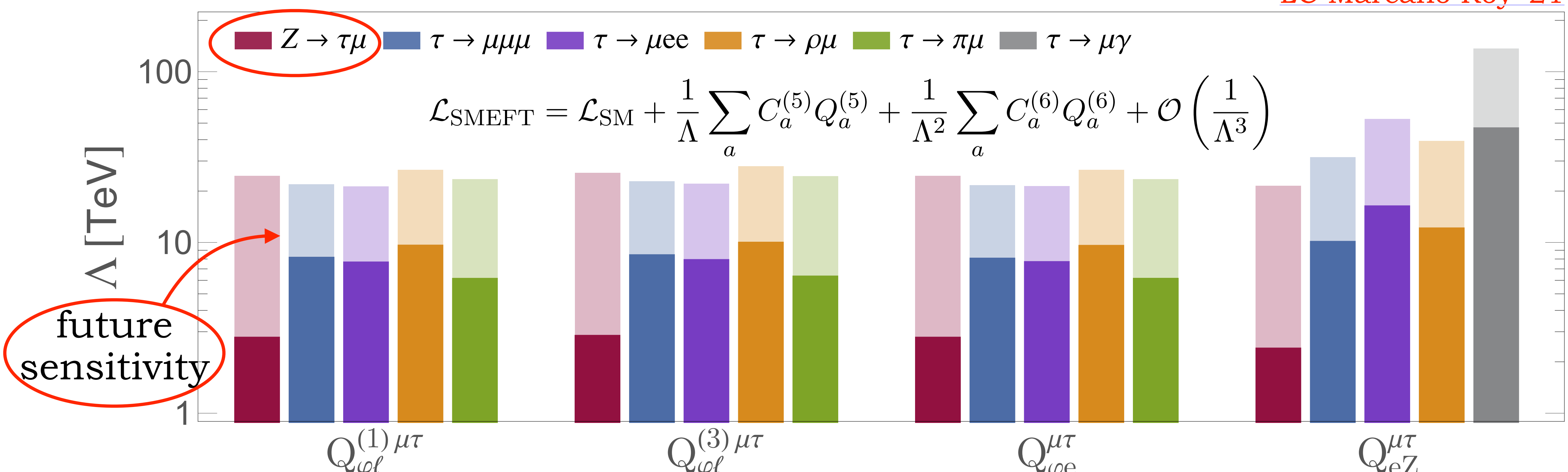
Lepton Flavour Violation in Z decays

Mode	LEP bound (95% CL)	LHC bound (95% CL)	CEPC/FCC-ee exp.
$\mathrm{BR}(Z \to \mu e)$	1.7×10^{-6} [2]	7.5×10^{-7} [3]	$10^{-8} - 10^{-10}$
$\mathrm{BR}(Z \to \tau e)$	9.8×10^{-6} [2]	5.0×10^{-6} [4, 5]	10^{-9}
$\mathrm{BR}(Z \to \tau \mu)$	1.2×10^{-5} [6]	6.5×10^{-6} [4, 5]	10^{-9}

M. Dam '18

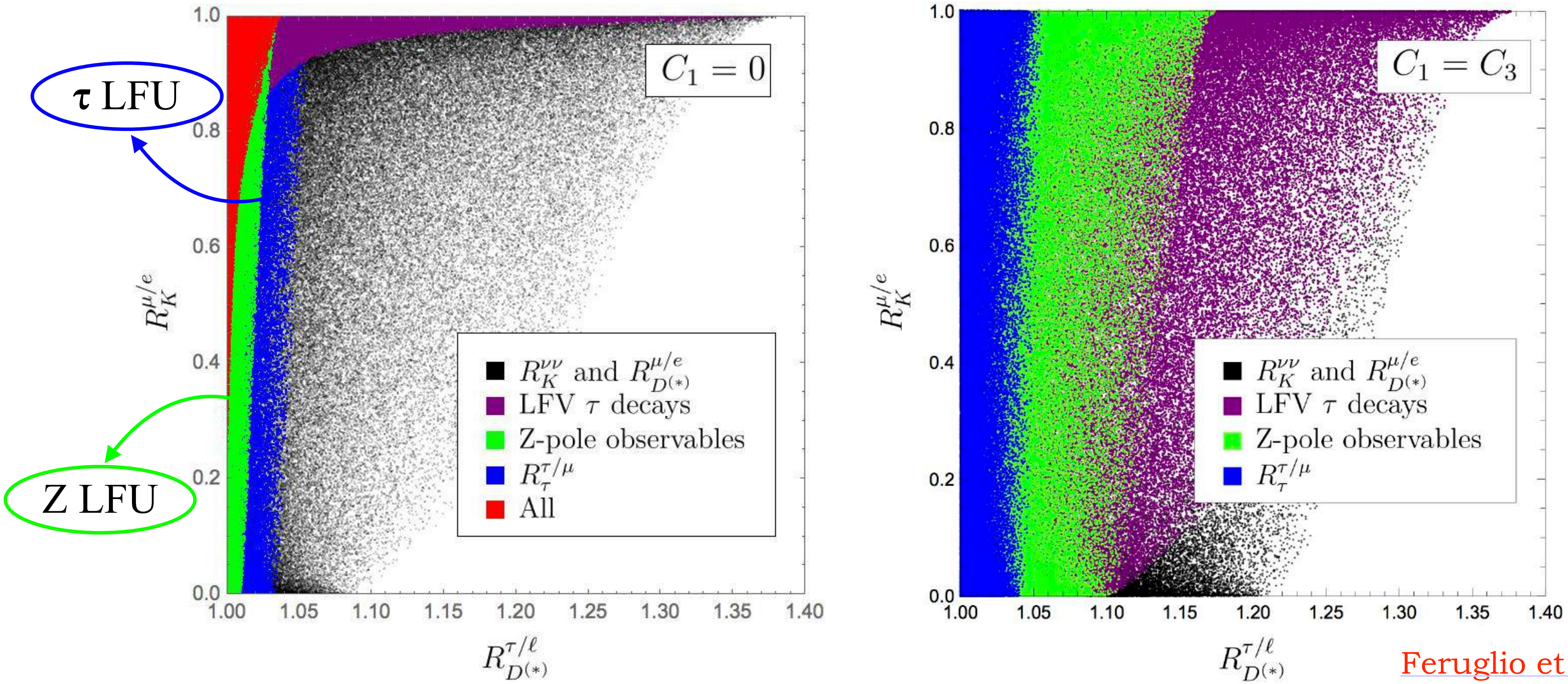
- LHC searches limited by backgrounds (in particular $Z \to \tau\tau$): max ~10 improvement can be expected at HL-LHC (3000/fb)
- A Tera Z can test LFV new physics searching for $Z \to \tau\,\ell$ at the level of what Belle II (50/ab) will do through LFV tau decays (or better)

LC Marcano Roy '21



Example: new physics inducing operators involving mainly 3rd family fermions

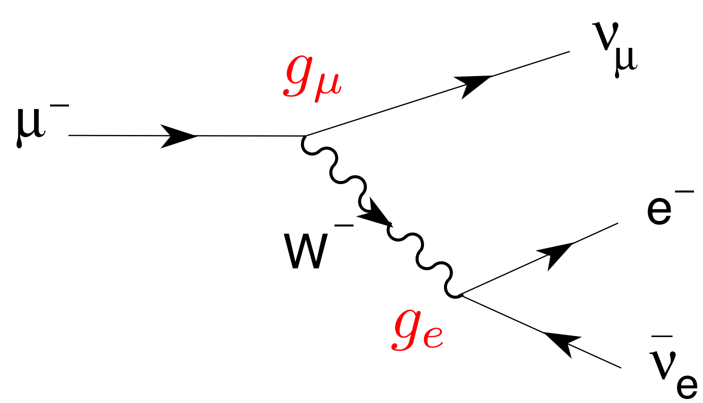
$$Q_{\ell q}^{(1)} = (\bar{L}_3 \gamma^\mu L_3)(\bar{Q}_3 \gamma_\mu Q_3)\ , \quad Q_{\ell q}^{(3)} = (\bar{L}_3 \gamma^\mu \tau_I L_3)(\bar{Q}_3 \gamma_\mu \tau^I Q_3)$$

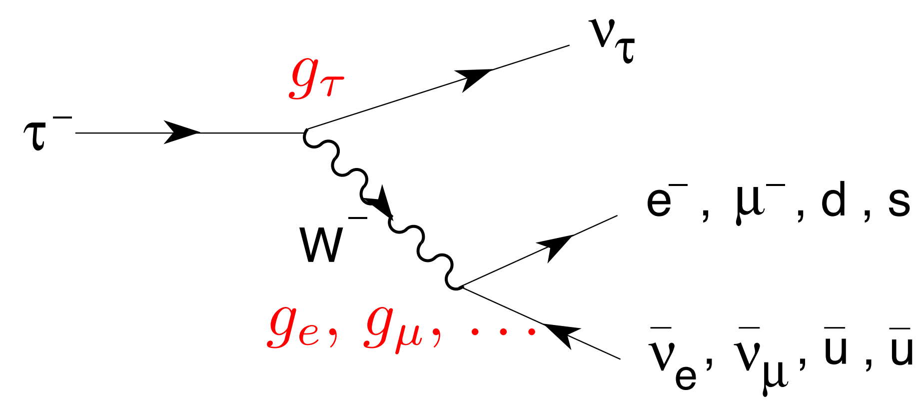


Feruglio et al. '17

Z and Tau LFU (and LFV) observables are a limiting factor
⇒ crucial test of the B anomalies!
(true also for more general flavour structures)

LFU tests in tau decays





phase-space factors

radiative corrections

$$\left(\frac{g_\mu}{g_e}\right)^2 = \frac{\mathrm{BR}(\tau\to\mu\nu\bar{\nu})}{\mathrm{BR}(\tau\to e\nu\bar{\nu})}\,\frac{f(m_e^2/m_\tau^2)}{f(m_\mu^2/m_\tau^2)}\,\frac{R_W^{\tau e}}{R_W^{\tau\mu}}\,,$$

$$\left(\frac{g_\tau}{g_\ell}\right)^2 = \frac{\tau_\mu}{\tau_\tau}\left(\frac{m_\mu}{m_\tau}\right)^5\frac{\mathrm{BR}(\tau\to\ell\nu\bar{\nu})}{\mathrm{BR}(\mu\to e\nu\bar{\nu})}\,\frac{f(m_e^2/m_\mu^2)}{f(m_\ell^2/m_\tau^2)}\,\frac{R_W^{\mu e}R_\gamma^\mu}{R_W^{\tau\ell}R_\gamma^\tau}\,,\qquad (\ell = e,\mu)$$

Currently LFU tested with per mil level precision:

HFLAV '22: $\left(\frac{g_\mu}{g_e}\right) = 1.0009 \pm 0.0014\,,\quad \left(\frac{g_\tau}{g_e}\right) = 1.0027 \pm 0.0014\,,\quad \left(\frac{g_\tau}{g_\mu}\right) = 1.0019 \pm 0.0014$

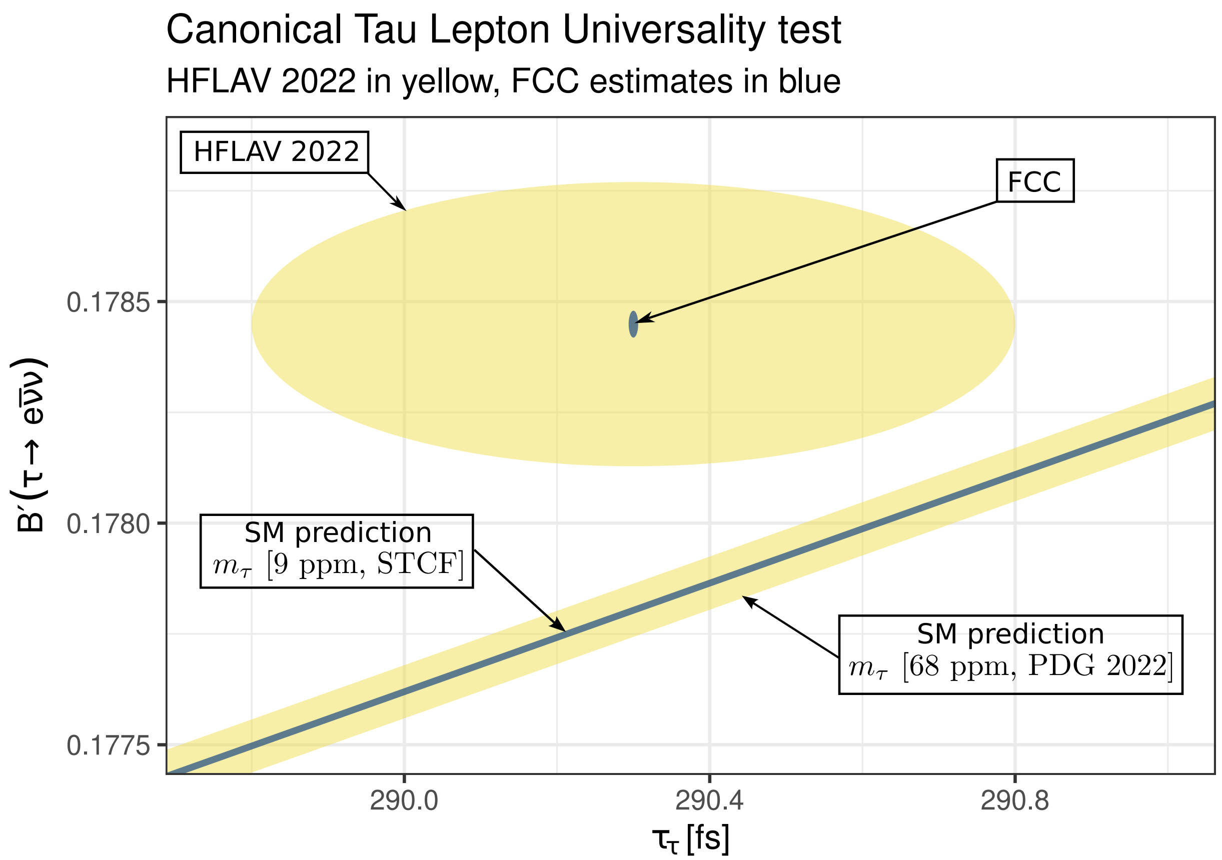
Uncertainty budget (g_τ/g_ℓ): $\mathrm{BR}(\tau\to\ell\nu\bar{\nu})$: 0.22% ; τ_τ : 0.09% ; m_τ : 0.02%

LFU tests in tau decays

Preliminary studies for the FCC-ee (10^{11} tau pairs):

Observable	Measurement	Current precision	FCC-ee **stat.**	**Possible syst.**	Challenge
m_τ [MeV]	Threshold / inv. mass endpoint	1776.86 **± 0.12**	**0.005**	**0.12**	Mass scale
τ_τ [fs]	Flight distance	290.3 **± 0.5 fs**	**0.005**	**< 0.040**	Vertex detector alignment
B(τ→eνν) [%]	Selection of $\tau^+\tau^-$, identification of final state	17.82 **± 0.05**	**0.0001**	**No estimate; possibly 0.003**	Efficiency, bkg, Particle ID
B(τ→μνν) [%]		17.39 **± 0.05**			

M. Dam @ Tau '18 & 1811.09408



A. Lusiani '23

Tera-Z factories could test tau LFU at the 0.1‰ level

This translates to a sensitivity to LFU new-physics operators up to scales ~20 TeV

LFU tests in Z decays

Universality presently tested at the per-mil level

LEP exps/SLD combination: hep-ex:0509008

$$\frac{\mathrm{BR}(Z \to \mu^+\mu^-)}{\mathrm{BR}(Z \to e^+e^-)} = 1.0009 \pm 0.0028\,, \qquad \frac{\mathrm{BR}(Z \to \tau^+\tau^-)}{\mathrm{BR}(Z \to e^+e^-)} = 1.0019 \pm 0.0032$$

(1.7×10^7 Z decays at LEP + 6×10^5 Z decays with polarised beams at SLC)

- Very important test in view of the LFU anomalies in B decays
- At LEP statistical and systematic uncertainties of the same order
- With 10^{12} Z, CEPC has no problem of statistics
- Can systematics be controlled e.g. at the 10^{-4} level?
- This would test new physics coupling preferably to tau up to scales of the order of 10-20 TeV

Summary of the tau and Z prospects

Measurement	Current [126]	FCC [115]	Tera-Z Prelim. [127]	Comments
Lifetime [sec]	$\pm 5 \times 10^{-16}$	$\pm 1 \times 10^{-18}$		from 3-prong decays, stat. limited
$\mathrm{BR}(\tau \to \ell\nu\bar{\nu})$	$\pm 4 \times 10^{-4}$	$\pm 3 \times 10^{-5}$		$0.1\times$ the ALEPH systematics
$\mathrm{m}(\tau)$ [MeV]	± 0.12	$\pm 0.004 \pm 0.1$		$\sigma(p_{\mathrm{track}})$ limited
$\mathrm{BR}(\tau \to 3\mu)$	$< 2.1 \times 10^{-8}$	$\mathcal{O}(10^{-10})$	same	bkg free
$\mathrm{BR}(\tau \to 3e)$	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
$\mathrm{BR}(\tau^{\pm} \to e\mu\mu)$	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
$\mathrm{BR}(\tau^{\pm} \to \mu ee)$	$< 1.8 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
$\mathrm{BR}(\tau \to \mu\gamma)$	$< 4.4 \times 10^{-8}$	$\sim 2 \times 10^{-9}$	$\mathcal{O}(10^{-10})$	$Z \to \tau\tau\gamma$ bkg , $\sigma(p_\gamma)$ limited
$\mathrm{BR}(\tau \to e\gamma)$	$< 3.3 \times 10^{-8}$	$\sim 2 \times 10^{-9}$		$Z \to \tau\tau\gamma$ bkg, $\sigma(p_\gamma)$ limited
$\mathrm{BR}(Z \to \tau\mu)$	$< 1.2 \times 10^{-5}$	$\mathcal{O}(10^{-9})$	same	$\tau\tau$ bkg, $\sigma(p_{\mathrm{track}})$ & $\sigma(E_{\mathrm{beam}})$ limited
$\mathrm{BR}(Z \to \tau e)$	$< 9.8 \times 10^{-6}$	$\mathcal{O}(10^{-9})$		$\tau\tau$ bkg, $\sigma(p_{\mathrm{track}})$ & $\sigma(E_{\mathrm{beam}})$ limited
$\mathrm{BR}(Z \to \mu e)$	$< 7.5 \times 10^{-7}$	$10^{-8} - 10^{-10}$	$\mathcal{O}(10^{-9})$	PID limited
$\mathrm{BR}(Z \to \pi^+\pi^-)$			$\mathcal{O}(10^{-10})$	$\sigma(\vec{p}_{\mathrm{track}})$ limited, good PID
$\mathrm{BR}(Z \to \pi^+\pi^-\pi^0)$			$\mathcal{O}(10^{-9})$	$\tau\tau$ bkg
$\mathrm{BR}(Z \to J/\psi\gamma)$	$< 1.4 \times 10^{-6}$		$10^{-9} - 10^{-10}$	$\ell\ell\gamma + \tau\tau\gamma$ bkg
$\mathrm{BR}(Z \to \rho\gamma)$	$< 2.5 \times 10^{-5}$		$\mathcal{O}(10^{-9})$	$\tau\tau\gamma$ bkg, $\sigma(p_{\mathrm{track}})$ limited

From the Snowmass report: The Physics potential of the CEPC

The Z-pole run of the CEPC would offer plenty of flavour physics opportunities

O(10^{12}) Z decays would enable us to study many processes with a much higher precision than (or inaccessible to) other experiments

If anomalies in B-physics, muon g-2 etc. will be confirmed, new physics should be "behind the corner"

However, it may be out of the reach of the LHC, we need to discriminate among the possible new physics options elsewhere

Tera Z provides a unique opportunity to study Z LFV decays, rare B decays, tests of LFU in tau decays or B_c decays etc.

谢谢大家! Thank you!

Additional slides

CLFV from heavy new physics: the SM effective field theory

If NP scale **Λ**≫m_W : $$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda}\sum_a C_a^{(5)} Q_a^{(5)} + \frac{1}{\Lambda^2}\sum_a C_a^{(6)} Q_a^{(6)} + \dots$$

Dimension-6 effective operators that can induce CLFV

4-leptons operators		Dipole operators	
$Q_{\ell\ell}$	$(\bar{L}_L\gamma_\mu L_L)(\bar{L}_L\gamma^\mu L_L)$	Q_{eW}	$(\bar{L}_L\sigma^{\mu\nu}e_R)\tau_I\Phi W^I_{\mu\nu}$
Q_{ee}	$(\bar{e}_R\gamma_\mu e_R)(\bar{e}_R\gamma^\mu e_R)$	Q_{eB}	$(\bar{L}_L\sigma^{\mu\nu}e_R)\Phi B_{\mu\nu}$
$Q_{\ell e}$	$(\bar{L}_L\gamma_\mu L_L)(\bar{e}_R\gamma^\mu e_R)$		
2-lepton 2-quark operators			
$Q^{(1)}_{\ell q}$	$(\bar{L}_L\gamma_\mu L_L)(\bar{Q}_L\gamma^\mu Q_L)$	$Q_{\ell u}$	$(\bar{L}_L\gamma_\mu L_L)(\bar{u}_R\gamma^\mu u_R)$
$Q^{(3)}_{\ell q}$	$(\bar{L}_L\gamma_\mu\tau_I L_L)(\bar{Q}_L\gamma^\mu\tau_I Q_L)$	Q_{eu}	$(\bar{e}_R\gamma_\mu e_R)(\bar{u}_R\gamma^\mu u_R)$
Q_{eq}	$(\bar{e}_R\gamma^\mu e_R)(\bar{Q}_L\gamma_\mu Q_L)$	$Q_{\ell edq}$	$(\bar{L}^a_L e_R)(\bar{d}_R Q^a_L)$
$Q_{\ell d}$	$(\bar{L}_L\gamma_\mu L_L)(\bar{d}_R\gamma^\mu d_R)$	$Q^{(1)}_{\ell equ}$	$(\bar{L}^a_L e_R)\epsilon_{ab}(\bar{Q}^b_L u_R)$
Q_{ed}	$(\bar{e}_R\gamma_\mu e_R)(\bar{d}_R\gamma^\mu d_R)$	$Q^{(3)}_{\ell equ}$	$(\bar{L}^a_i\sigma_{\mu\nu}e_R)\epsilon_{ab}(\bar{Q}^b_L\sigma^{\mu\nu}u_R)$
Lepton-Higgs operators			
$Q^{(1)}_{\Phi\ell}$	$(\Phi^\dagger i\overleftrightarrow{D}_\mu\Phi)(\bar{L}_L\gamma^\mu L_L)$	$Q^{(3)}_{\Phi\ell}$	$(\Phi^\dagger i\overleftrightarrow{D}^I_\mu\Phi)(\bar{L}_L\tau_I\gamma^\mu L_L)$
$Q_{\Phi e}$	$(\Phi^\dagger i\overleftrightarrow{D}_\mu\Phi)(\bar{e}_R\gamma^\mu e_R)$	$Q_{e\Phi 3}$	$(\bar{L}_L e_R\Phi)(\Phi^\dagger\Phi)$

Grzadkowski et al. '10; Crivellin Najjari Rosiek '13

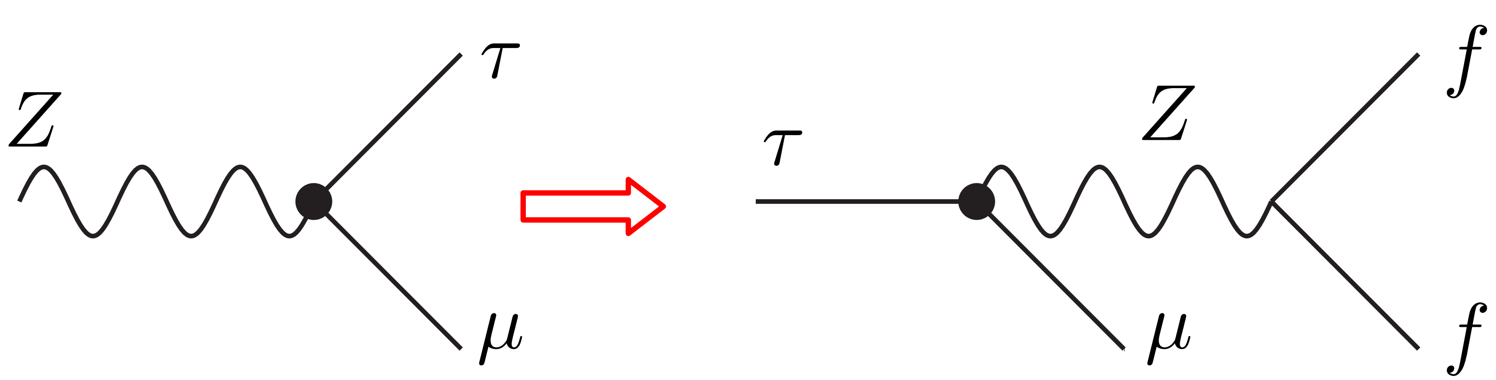
- CEPC can improve on present LHC (future HL-LHC) bounds up to 4 (3) orders of magnitude, at least for the $Z \to \tau\ell$ modes

- The question is: can CEPC searches find new physics with these modes?

- It depends on the indirect constraints from other processes

- In particular low-energy LFV processes are unavoidably induced

e.g. :



$\tau \to \mu\, \ell\ell$

$\tau \to \mu\, \pi$

$\tau \to \mu\, \rho$

$\dots$

Previous model-independent studies:

Nussinov Peccei Zhang ’00; Delepine Vissani ’01; Gutsche et al. ’11; Crivellin Najjari Rosiek ’13; ...

Model-independent indirect limits on Z LFV decays

Observable	Operator	Indirect Limit on LFVZD	Strongest constraint
lepton-Higgs ops	$(Q_{\varphi\ell}^{(1)} + Q_{\varphi\ell}^{(3)})^{e\mu}$	3.7×10^{-13}	$\mu \to e$, Au
$\mathrm{BR}(Z \to \mu e)$	$Q_{\varphi e}^{e\mu}$	9.4×10^{-15}	$\mu \to e$, Au
dipole ops	$Q_{eB}^{e\mu}$	1.4×10^{-23}	$\mu \to e\gamma$
	$Q_{eW}^{e\mu}$	1.6×10^{-22}	$\mu \to e\gamma$
$\mathrm{BR}(Z \to \tau e)$	$(Q_{\varphi\ell}^{(1)} + Q_{\varphi\ell}^{(3)})^{e\tau}$	6.3×10^{-8}	$\tau \to \rho\, e$
	$Q_{\varphi e}^{e\tau}$	6.3×10^{-8}	$\tau \to \rho\, e$
	$Q_{eB}^{e\tau}$	1.2×10^{-15}	$\tau \to e\gamma$
	$Q_{eW}^{e\tau}$	1.3×10^{-14}	$\tau \to e\gamma$
$\mathrm{BR}(Z \to \tau\mu)$	$(Q_{\varphi\ell}^{(1)} + Q_{\varphi\ell}^{(3)})^{\mu\tau}$	4.3×10^{-8}	$\tau \to \rho\, \mu$
	$Q_{\varphi e}^{\mu\tau}$	4.3×10^{-8}	$\tau \to \rho\, \mu$
	$Q_{eB}^{\mu\tau}$	1.5×10^{-15}	$\tau \to \mu\gamma$
	$Q_{eW}^{\mu\tau}$	1.7×10^{-14}	$\tau \to \mu\gamma$

LC Marcano Roy '21

LFU from 3rd generation 2q2l operators

Ops with only 3rd family: $Q_{\ell q}^{(1)} = (\bar{L}_3\gamma^\mu L_3)(\bar{Q}_3\gamma_\mu Q_3)$, $Q_{\ell q}^{(3)} = (\bar{L}_3\gamma^\mu \tau_I L_3)(\bar{Q}_3\gamma_\mu \tau^I Q_3)$

(in the interaction basis)

Flavour structure justified by:

- Theoretical considerations (SM hierarchies, MFV paradigm, …)
- Observed anomalies (3rd generation affected more than 2nd generation, 2nd generation more than 1st generation)

Glashow Guadagnoli Lane '14, Bhattacharya et al. '14, LC Crivellin Ota '15, Feruglio Paradisi Pattori '16,'17 …

Operators involving 2nd generations generated by rotations to the mass basis:

$$Y^f = V^{f\dagger}\hat{Y}^f W^f, \qquad f = u, d, e$$

Giving e.g. :

$$C_S(\bar{L}_3\gamma^\mu L_3)(\bar{Q}_3\gamma_\mu Q_3) \longrightarrow C_S V^d_{23} V^{d\,*}_{33} |V^e_{23}|^2 \; (\bar{L}_2\gamma^\mu L_2)(\bar{Q}_2\gamma_\mu Q_3)$$

$\Rightarrow$ $b \to s\mu\mu$ $\qquad \sim V_{cb} \times V_{tb}$

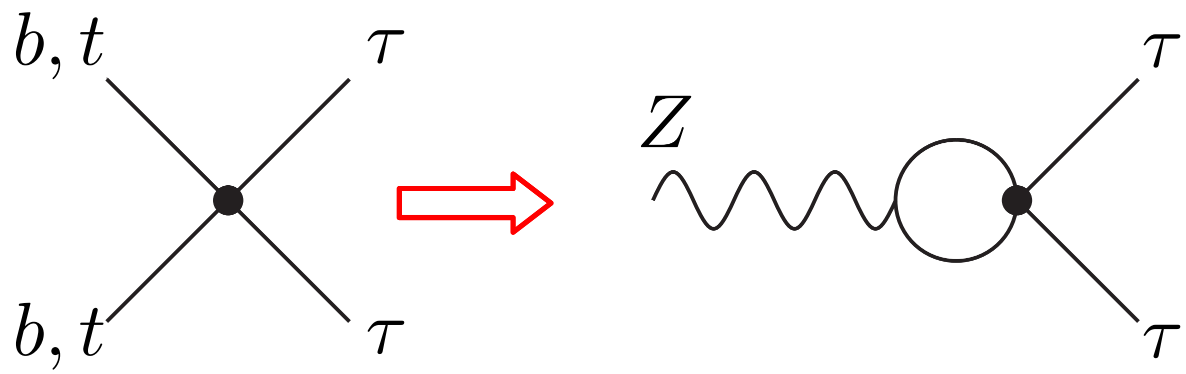
LFU in both NC and CC B decays are induced. However…

Radiatively generated LFV and LFUV effects

Ops with only 3[rd] family: $Q_{\ell q}^{(1)} = (\bar{L}_3 \gamma^\mu L_3)(\bar{Q}_3 \gamma_\mu Q_3)$, $Q_{\ell q}^{(3)} = (\bar{L}_3 \gamma^\mu \tau_I L_3)(\bar{Q}_3 \gamma_\mu \tau^I Q_3)$

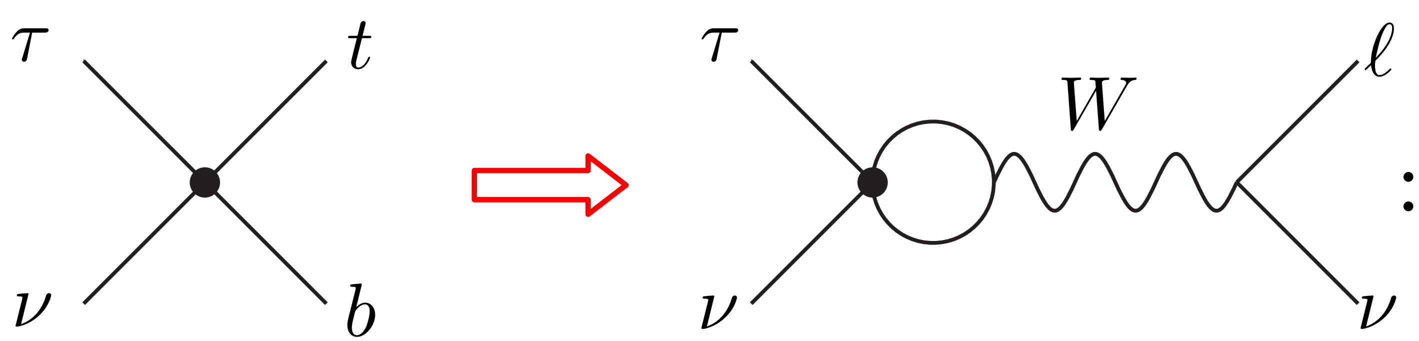
Important radiative effects:

Feruglio Paradisi Pattori '16 & '17



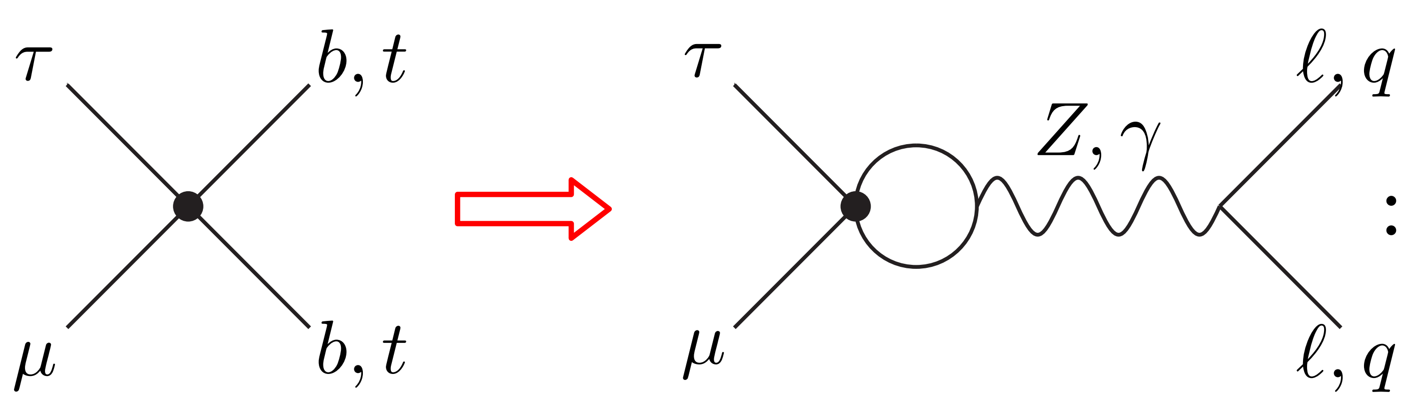
: $$\frac{\mathrm{BR}(Z \to \tau\tau)}{\mathrm{BR}(Z \to ee)}$$

(LFU in Z couplings tested at the permil level)



: $$\frac{\mathrm{BR}(\tau \to \ell\nu\bar{\nu})}{\mathrm{BR}(\mu \to e\nu\bar{\nu})}$$

(LFU in tau decays tested below the percent level)

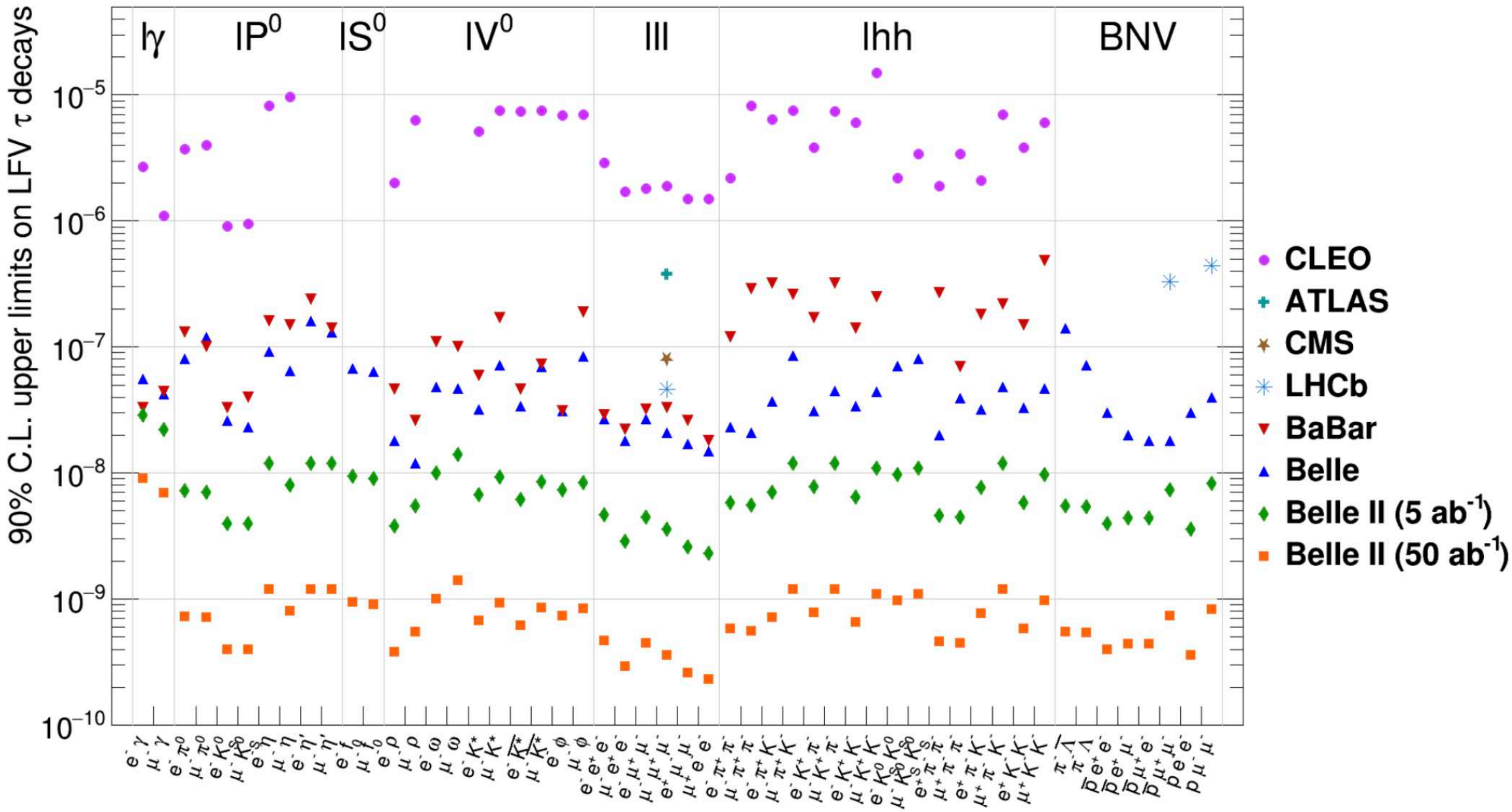


: $\tau \to \mu\ell\ell \quad \tau \to \mu\pi \quad \tau \to \mu\rho$

Tau CLFV!

Present/future limits on LFV tau decays

LFV tau decays:



Belle II Snowmass, arXiv:2207.06307