Charged Lepton Flavor Violation at e^+e^- experiments

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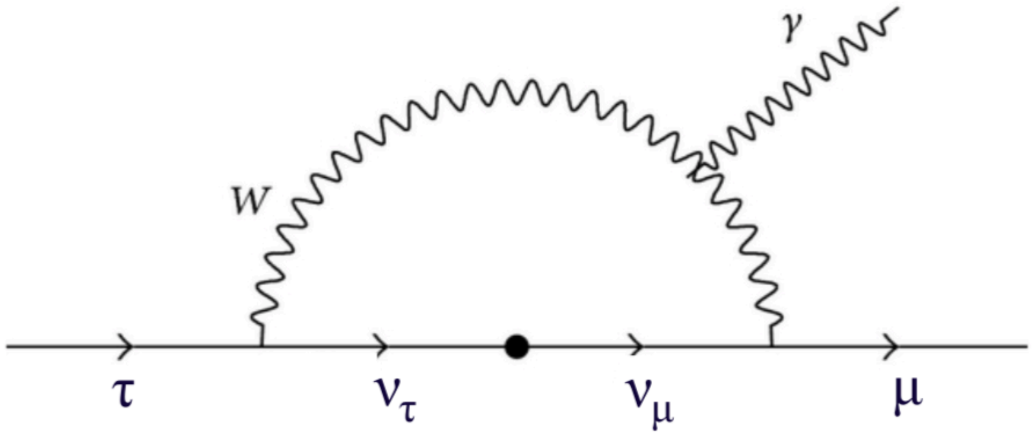
Charged Lepton Flavor Violation (cLFV)

cLFV does not mean LFV via ν mixing, which is too small to be seen

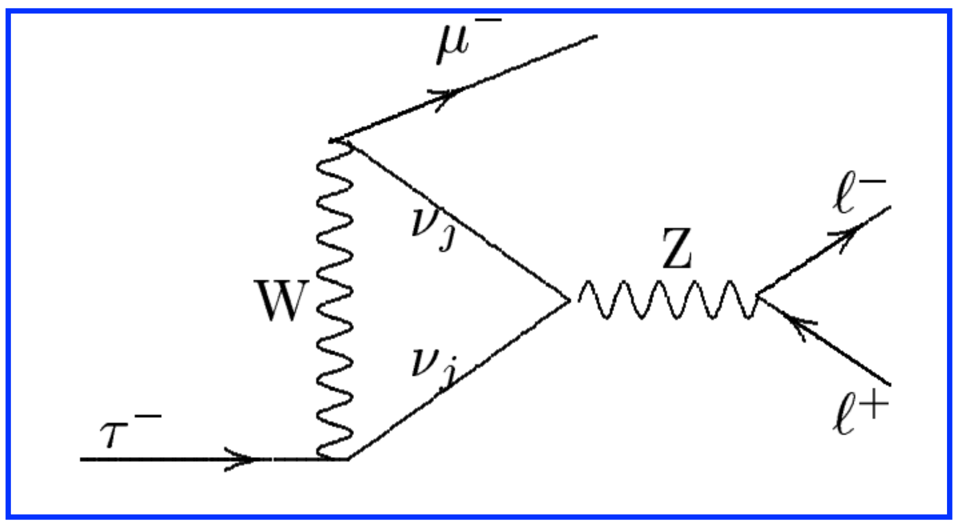


$\mathcal{B}(\tau^\pm \to \mu^\pm \gamma)$ Lee & Shrock: Phys.Rev.D 16 (1977) 1444

$= \frac{3\alpha}{128\pi}\left(\frac{\Delta m^2_{23}}{M^2_W}\right)^2 \sin^2 2\theta_{\rm mix}\mathcal{B}(\tau \to \mu\bar{\nu}_\mu\nu_\tau)$

With $\Delta \sim 10^{-3}\,{\rm eV}^2$, $M_W \sim \mathcal{O}(10^{11})\,{\rm eV}$

$\approx \mathcal{O}(10^{-54})$ ($\theta_{\rm mix}$: max)



X.Y. Pham: Eur.Phys.J.C8:513-516,1999

$\mathscr{B}(\tau^\pm \to \mu^\pm \ell^+ \ell^-) \simeq 10^{-14}$ ⊗

P. Blackstone, M. Fael, E. Passemar : Eur.Phys.J.C 80 (2020) 6, 506

G. Hernández-Tomé, G. López Castro, P. Roig:
Eur.Phys.J.C 79 (2019) 1, 84, Eur.Phys.J.C 80 (2020) 5, 438 (erratum)

$\mathscr{B}(\tau^\pm \to \mu^\pm \ell^+ \ell^-) \leq 10^{-54}$ ✓

Defining total lepton number $L \equiv L_e + L_\mu + L_\tau$, the global symmetry

$U(1)_B \times U(1)_{L_e} \times U(1)_{L_\mu} \times U(1)_{L_\tau} = U(1)_{B+L} \times U(1)_{B-L} \times \mathbf{U(1)_{L_\mu - L_\tau}} \times \mathbf{U(1)_{L_\mu + L_\tau - 2L_e}}$

cLFV conserves L and B but violates $U(1)_{L_\mu - L_\tau} \times U(1)_{L_\mu + L_\tau - 2L_e}$

$\Rightarrow$nice classification of all cLFV processes J. Heeck: Phys. Rev. D 95, 015022 (2017)

LFV in τ vs μ sector

LFV in tau sector is complementary to muon sector in NP parameter space:
current limit on $\mathscr{B}(\mu \to e\gamma) \sim 10^{-13}$ does not forbid $\mathscr{B}(\tau \to \ell\gamma) \sim 10^{-8}$

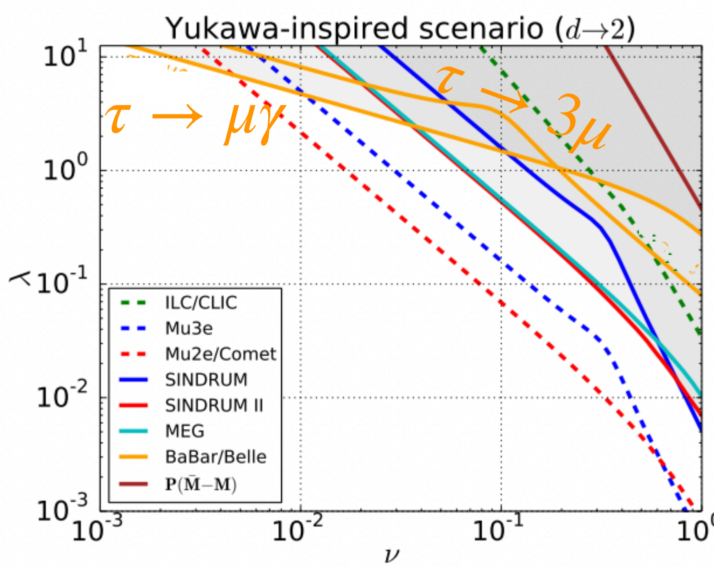
Leptonic MFV:	$BR(\mu \to e\gamma) / BR(\tau \to \mu\gamma) \sim s_{13}^2 \sim 10^{-2}$
GUT models:	$BR(\mu \to e\gamma) / BR(\tau \to \mu\gamma) \sim \lvert V_{us}\rvert^6 \sim 10^{-4}$

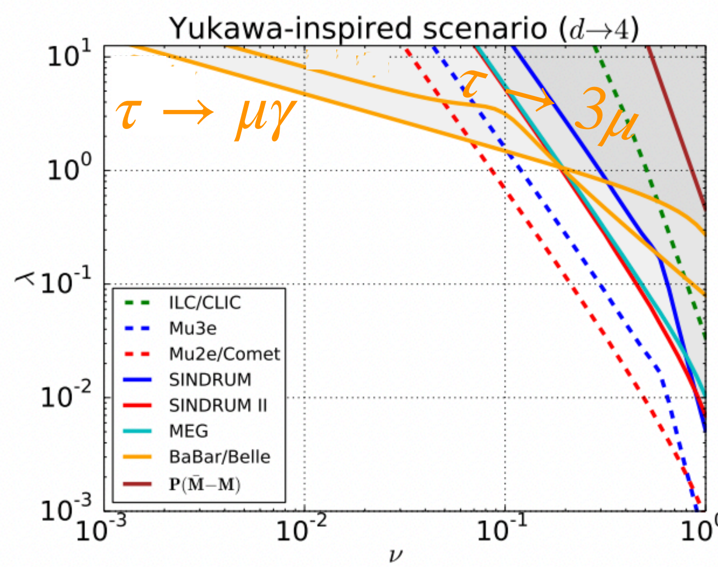
Vincenzo Cirigliano, Benjamin Grinstein, Gino Isidori, Mark B. Wise: hep-ph/0507001 [hep-ph], hep-ph/0608123 [hep-ph]
R. Barbieri, L. Hall, A. Strumia: hep-ph/9501334 [hep-ph]

- Mass dependent couplings enhance tau LFV w.r.t. lighter leptons

$$\lambda_{ab} \sim (y_a^l y_b^l)^{-1}$$

$$\lambda_{ab} = \lambda \begin{pmatrix} \pm 1 & \nu^2 & \nu^3 \\ \nu^2 & \nu^4 & \nu^5 \\ \nu^3 & \nu^5 & \nu^6 \end{pmatrix}$$

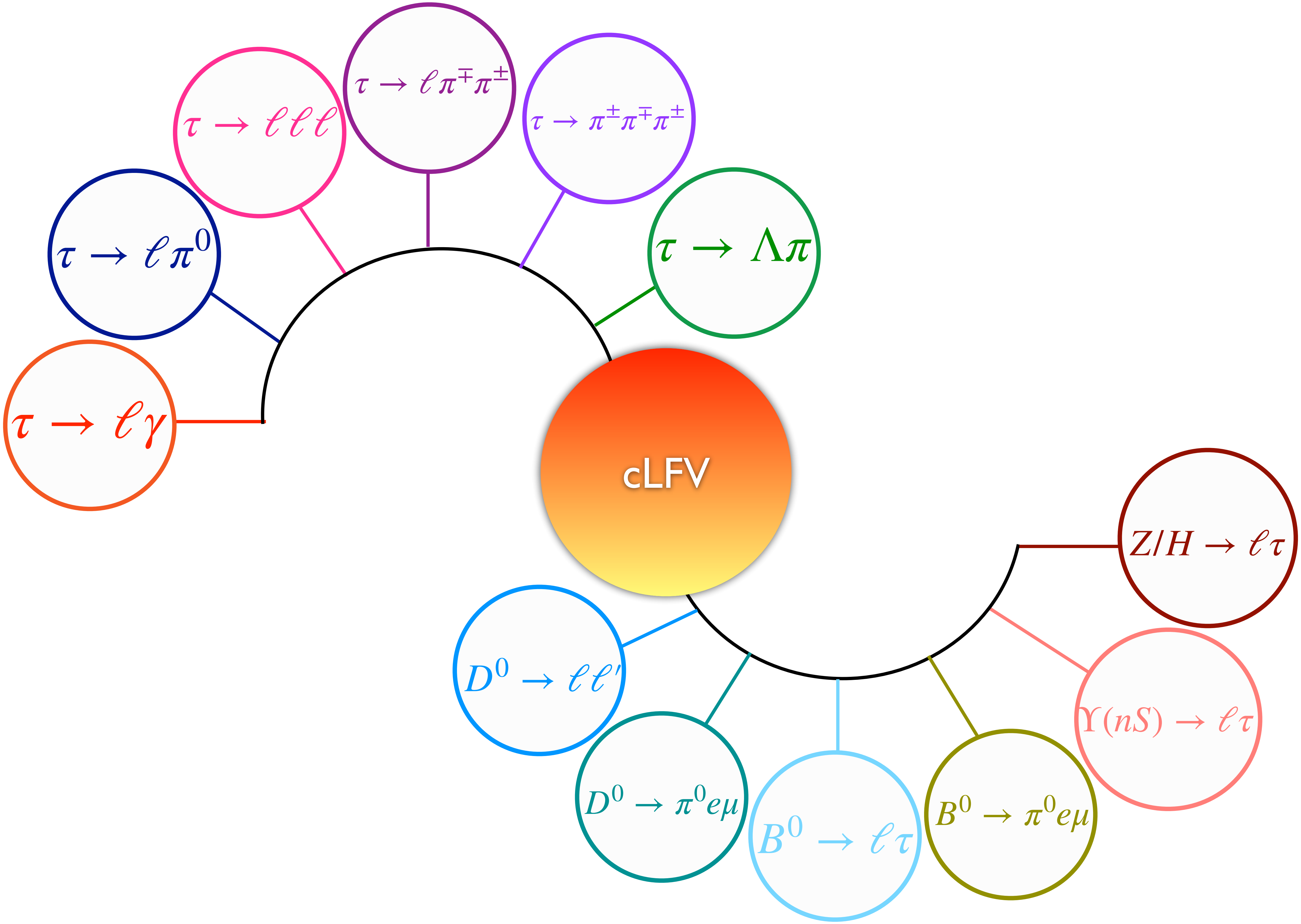




Low- and high-energy phenomenology of a doubly charged scalar

A. Crivellin et. al. Phys. Rev. D 99, 035004 (2019)
arXiv:1807.10224 [hep-ph]

Some of LFV processes probed in e^+e^- experiments



About 50 τ decay modes & many transitions with τ in final state

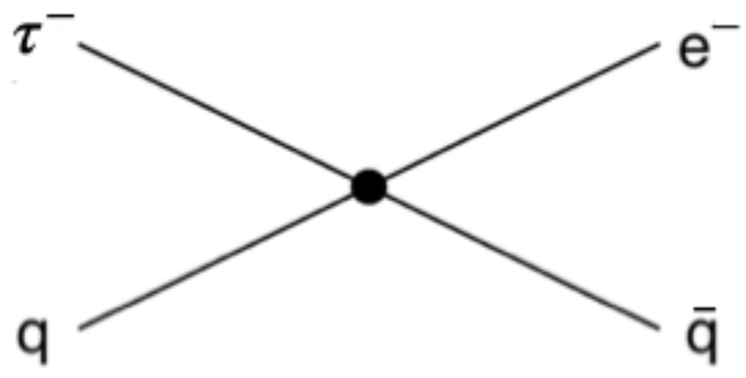
- **Lepton flavor violation (charge conjugate modes implied)**
  - **$\tau \to e/\mu\, \gamma$ (BaBar, Belle (II), STCF, FCC-ee)**
  - **$\tau \to e/\mu$ (scalar/pseudoscalar/vector mesons) (BaBar, Belle II)**
  - **$\tau \to e\, e\, e$ (BaBar, Belle II)**
  - **NEW! $\tau \to \mu\, \mu\, \mu$ (BaBar, Belle II, STCF, FCC-ee)**
  - **$\tau \to e\, \mu\, \mu$, $\mu\, e\, e$ (BaBar, Belle II)**
  - **$\tau \to e/\mu\, h\, h$ (non-resonant states with $h=\pi/K$) (BaBar, Belle (II), STCF)**
  - **New $\tau \to e/\mu$ invisible (α) (Belle II)**
  - **$B/D/\Upsilon(nS) \to e\, \tau$, $\mu\, \tau$ (BaBar, Belle (II), LEP, FCC-ee)**
  - **$B/D \to e\, \tau\, h$, $\mu\, \tau\, h$ (where $h=\pi/K$)(BaBar, Belle II)**
  - **$H/Z/Z' \to e\, \tau$, $\mu\, \tau$ (FCC-ee)**

- **Lepton number violation**
  - **$\tau^- \to e^+\, h^-\, h^-$ (non-resonant final states with $h=\pi/K$) (BaBar, Belle (II))**
  - **$\tau^- \to \mu^+\, h^-\, h^-$ (non-resonant final states with $h=\pi/K$) (BaBar, Belle (II))**

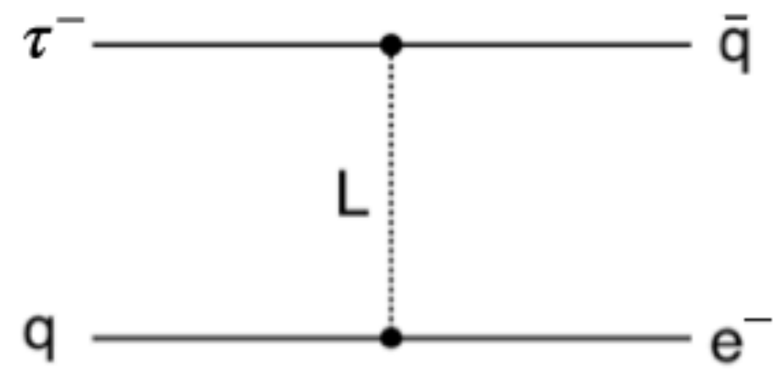
- **Baryon number violation**
  - **$\tau^- \to \Lambda\, \pi^-$, $\bar{\Lambda}\, \pi^-$ (Belle II)**
  - **$\tau^- \to \bar{p}\, \mu^+\, \mu^-$, $p\, \mu^-\, \mu^-$ (Belle)**
  - **$D^0 \to e^-/\mu^-\, p$ (Belle)**
  - **$B^- \to e^-/\mu^-\, \Lambda$ (BaBar)**

New Physics illustrations for LFV in τ decays

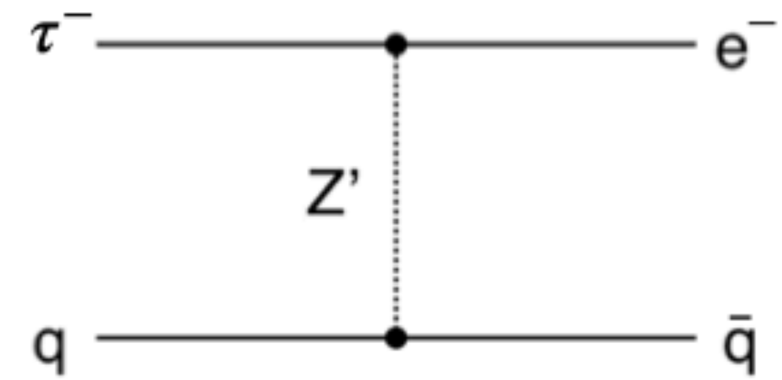
Tree level:



Compositeness

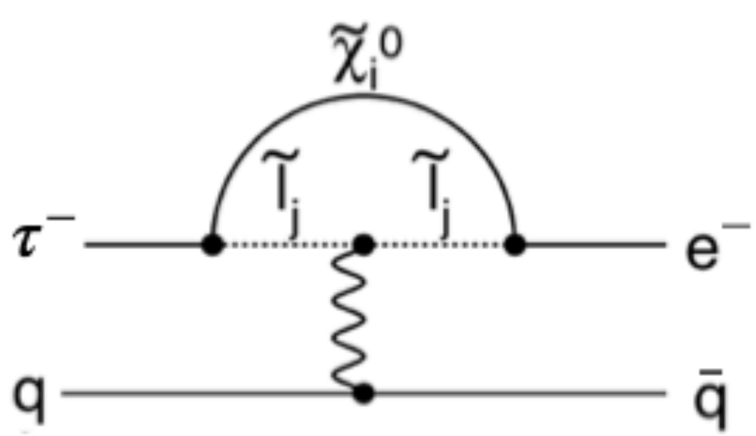


Leptoquarks

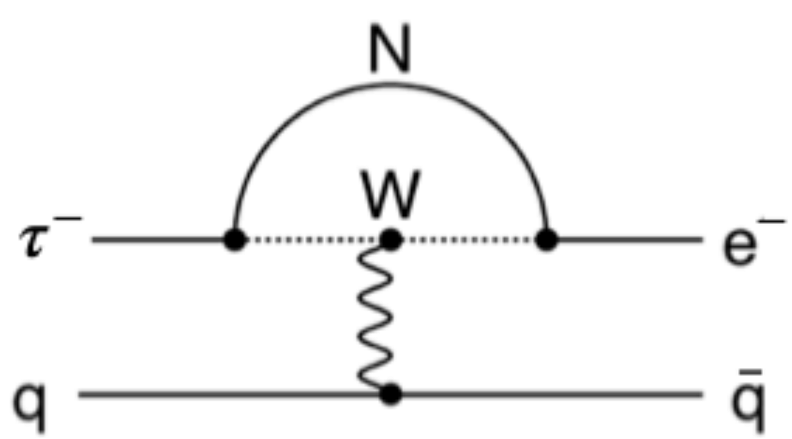


Heavy gauge bosons

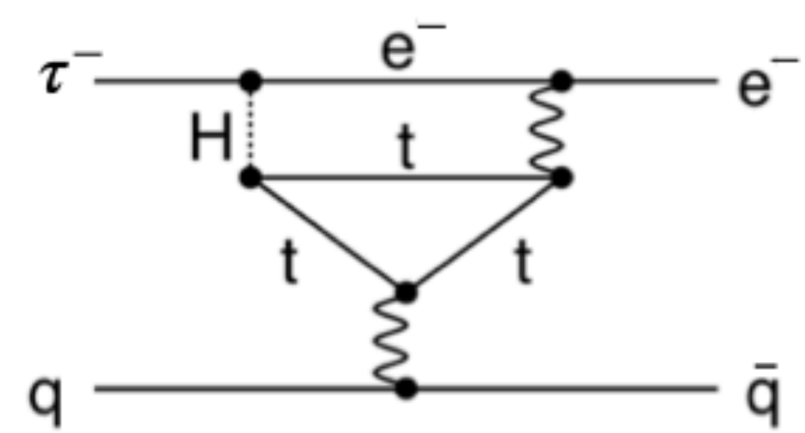
Loop induced:



Supersymmetry



Heavy neutrinos

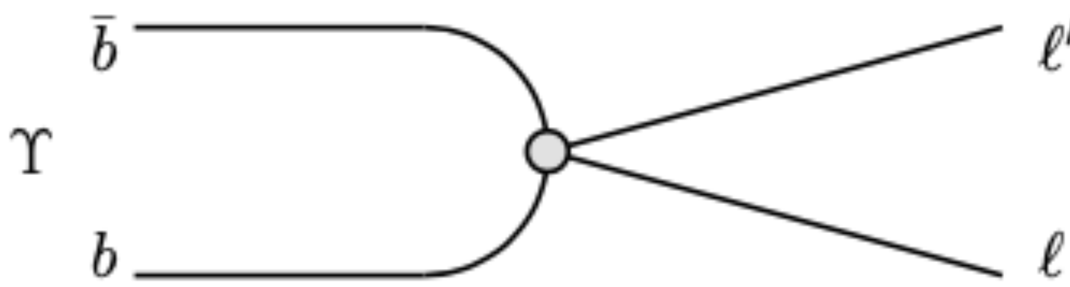


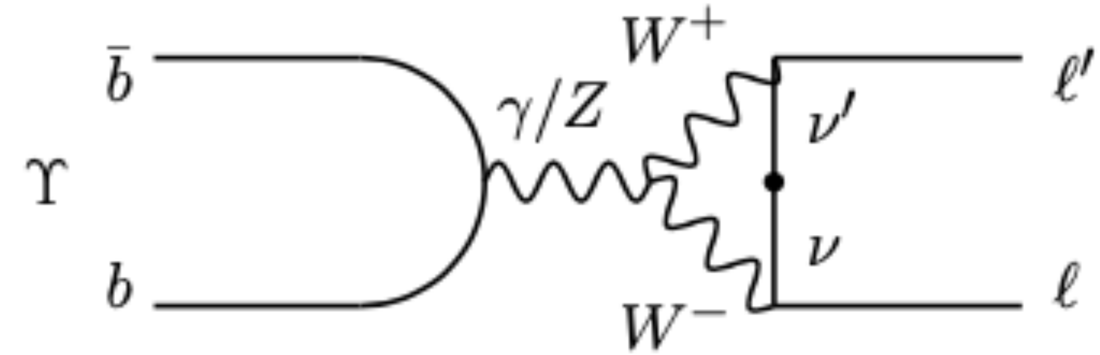
Extended Higgs models

- **Expected rates from New Physics are slightly less than current experimental bounds.**

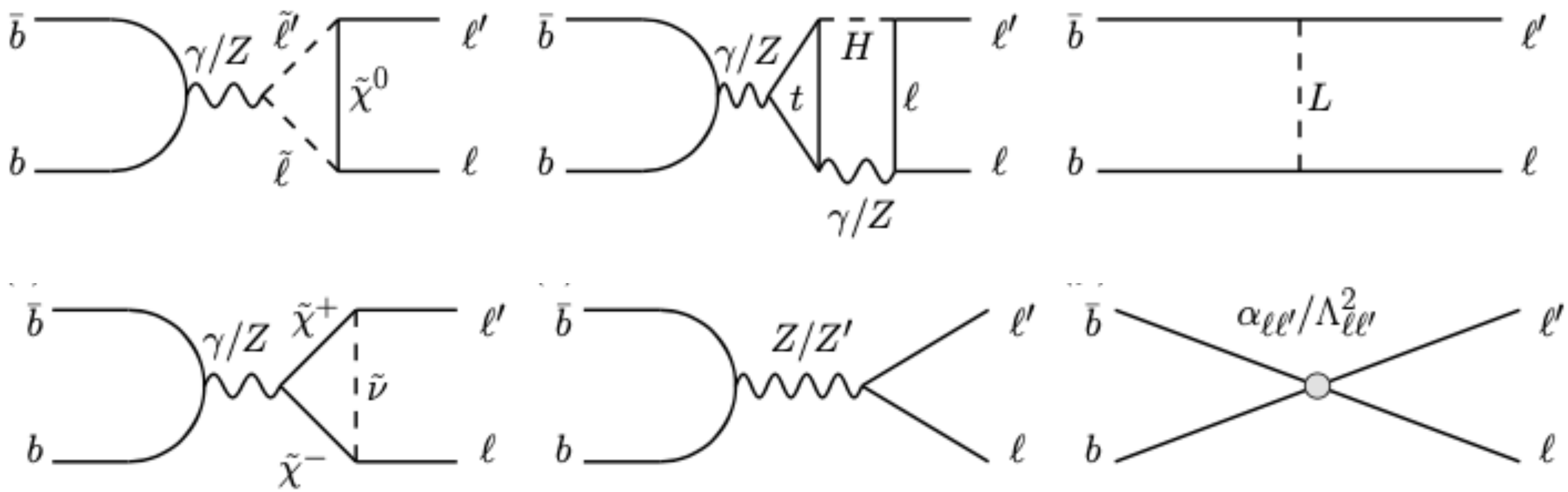
Illustrative Scenarios for LFV in decays b mesons

- **Suppressed Standard Model contributions**





- **New Physics scenarios**



- **Expected rates from New Physics are slightly less than current experimental bounds.**

Salient features of LFV in τ decays from e^+e^- colliders

$e^+e^- \to \tau^+\tau^-$

- Known initial conditions (beam energy constraint)
- Clean environment (fewer backgrounds)

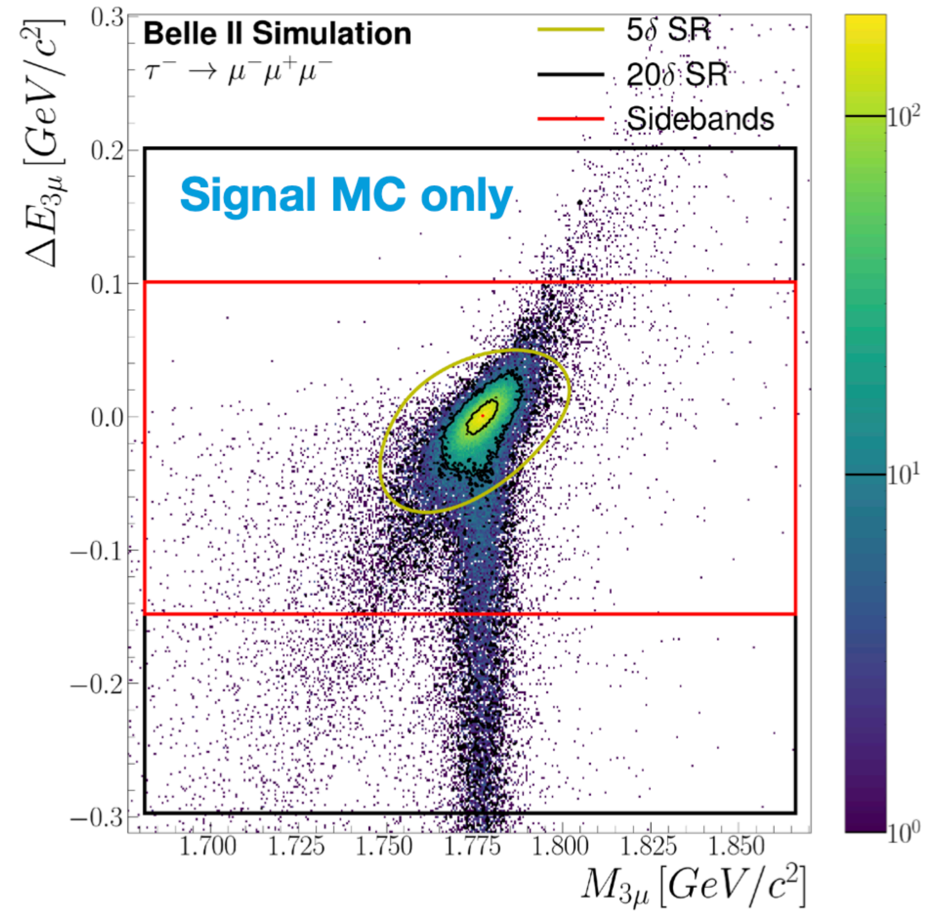
Two independent variables:

$$M_\tau = \sqrt{E^2_{\mu\mu\mu} - P^2_{\mu\mu\mu}}$$

$$\Delta E = E^{CMS}_{\mu\mu\mu} - E^{CMS}_{\text{beam}}$$

➡ ΔE close to 0 for signal

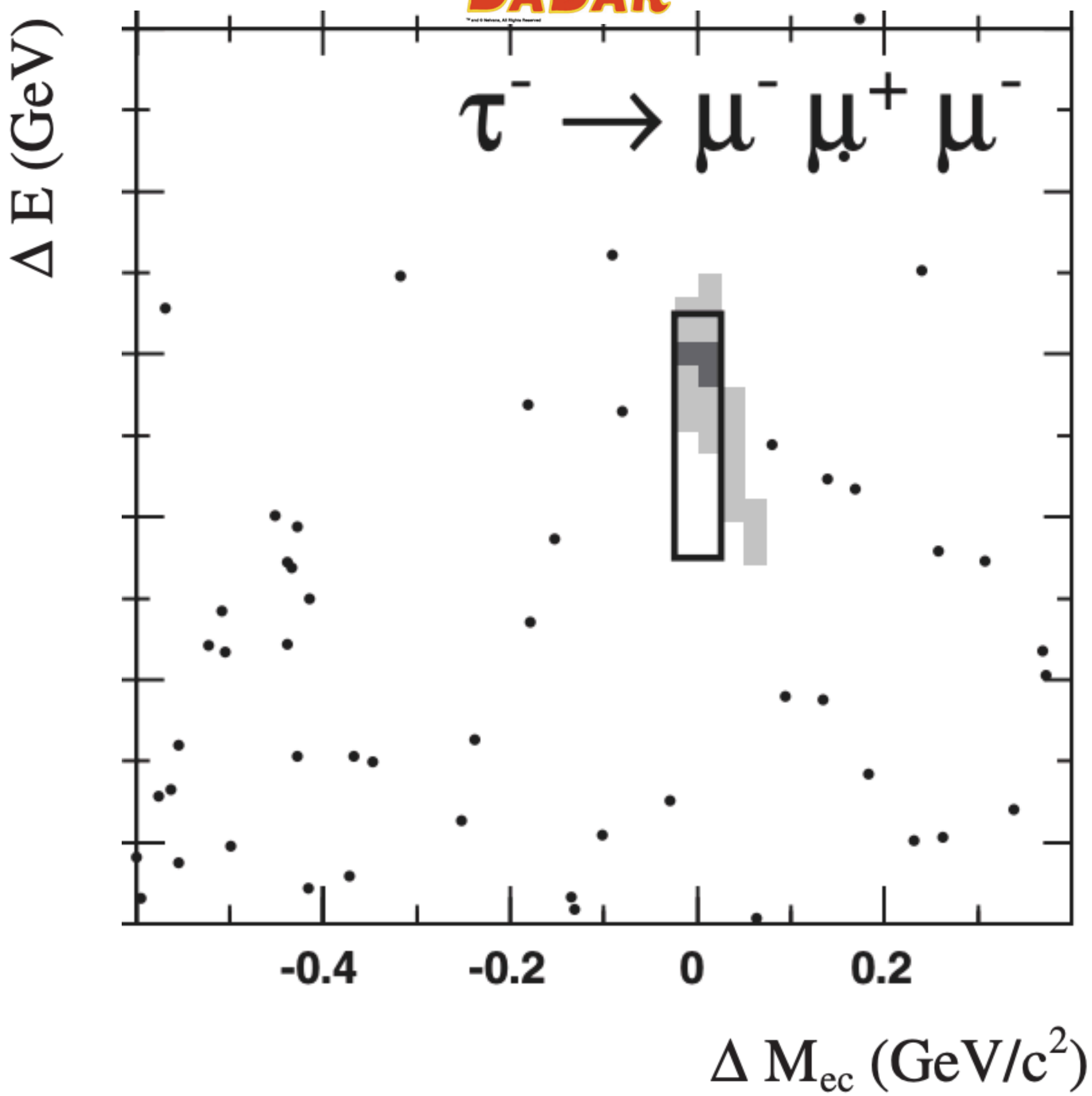
➡ Mass of tau daughters close to τ mass

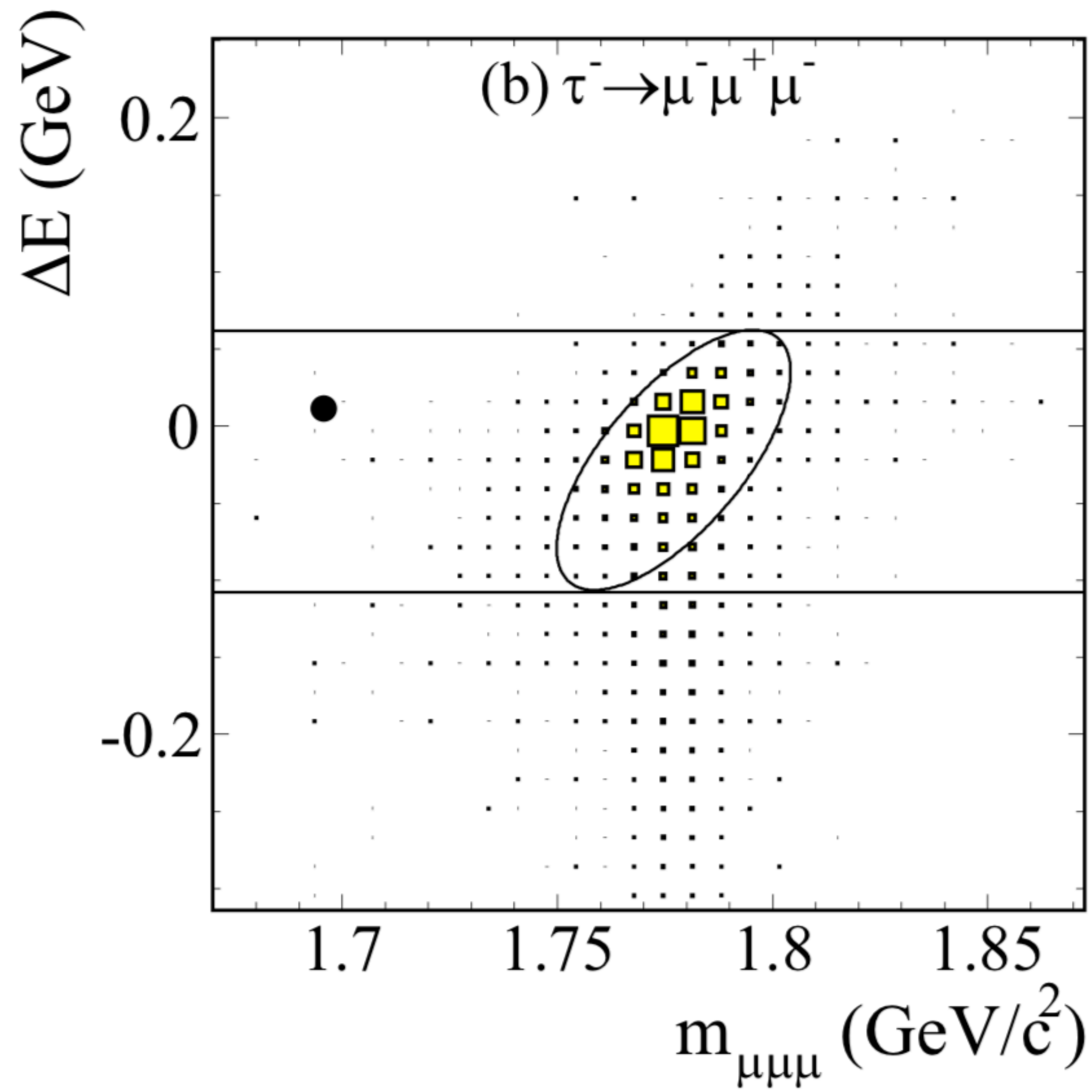


Higher signal efficiency is foreseen at Belle II than at Belle or BaBar

- **improved vertex tracking / calorimetry / muon detectors**
- **momentum dependent particle identification optimizations**
- **inclusive tagging for tau-pair reconstruction, Boosted Decision Trees**

$\tau \to \mu\mu\mu$ at B-Factories





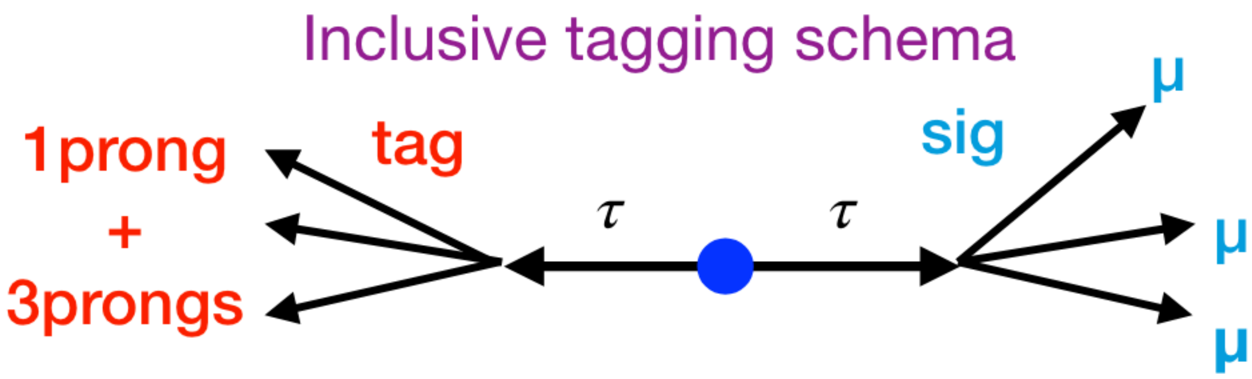
$\mathcal{B}(\tau \to \mu\mu\mu) < 3.3 \times 10^{-8}$ at 90% C.L. with 468 fb^{-1}

Phys.Rev.D 81 (2010) 111101

$\mathcal{B}(\tau \to \mu\mu\mu) < 2.1 \times 10^{-8}$ at 90% C.L. with 782 fb^{-1}

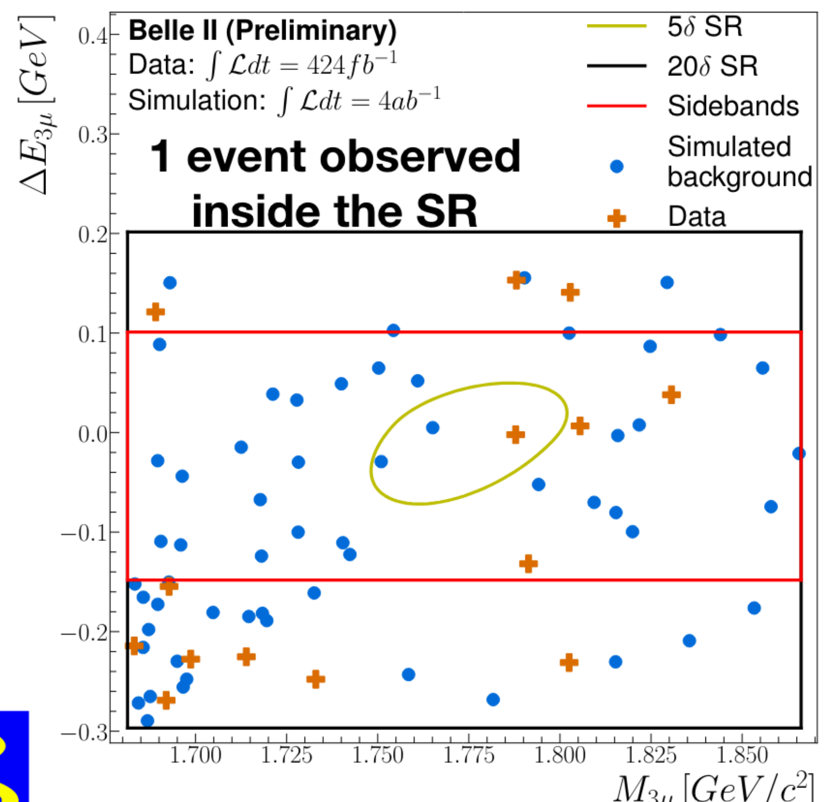
Phys. Lett. B687 (2010) 139

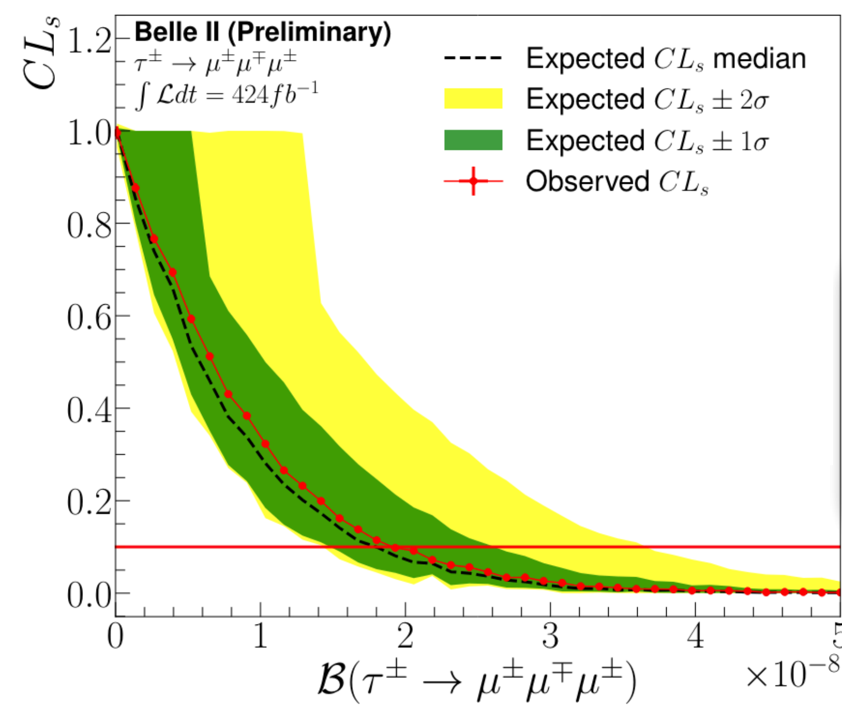
$\tau \to \mu\mu\mu$ at B-Factories



ε_{sig}= **20.42** ± 0.06% ~3x larger than Belle & Expected BKG: $0.5^{+1.4}_{-0.5}$ events

No significant excess in 424 fb⁻¹ of data → 90% C.L. upper limits using the CLs method





Dominant syst. from lepton ID efficiency
Negligible impact on the limit

Obtained most stringent limit

1.9×10^{-8}

Belle II

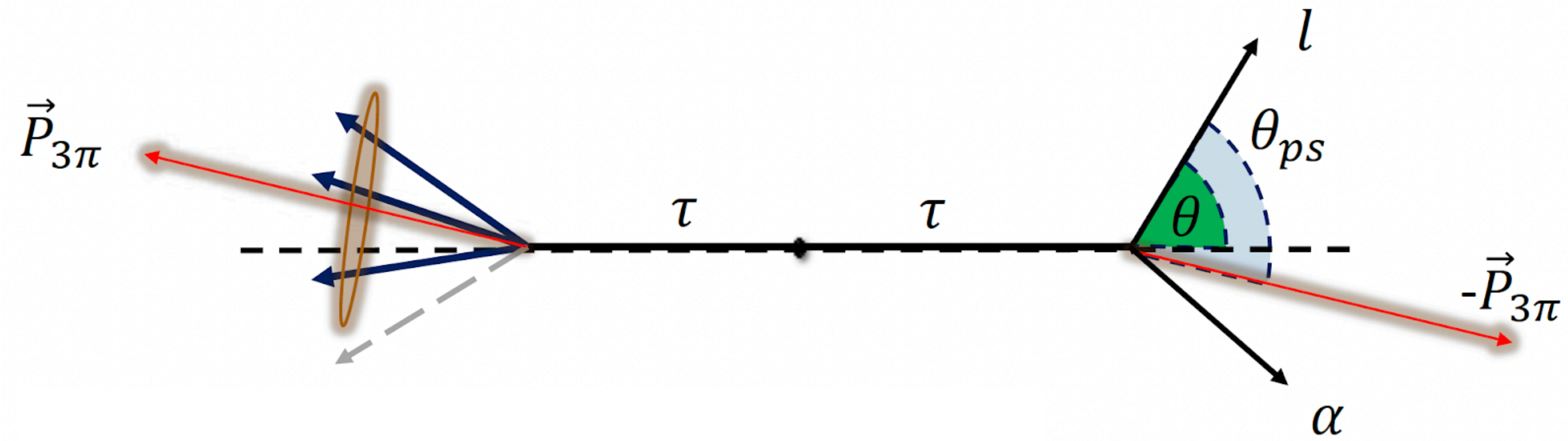
17th International Workshop on τ Lepton Physics: τ2023 - Alberto Martini for Belle II - 5 December 2023, Louisville Kentucky USA 17

CMS: $\mathscr{B}(\tau \to \mu\mu\mu)$ < 2.9 x 10⁻⁸ at 90% C.L. with 131 fb⁻¹ Phys.Rev.D 81 (2010) 111101 arXiv:2312.02371 [hep-ex]

LHCb: $\mathscr{B}(\tau \to \mu\mu\mu)$ < 4.6 x 10⁻⁸ at 90% C.L. with 3 fb⁻¹ JHEP 02 (2015) 121 arXiv:1409.8548 [hep-ex]

$\tau \to \ell\alpha$ at Belle II

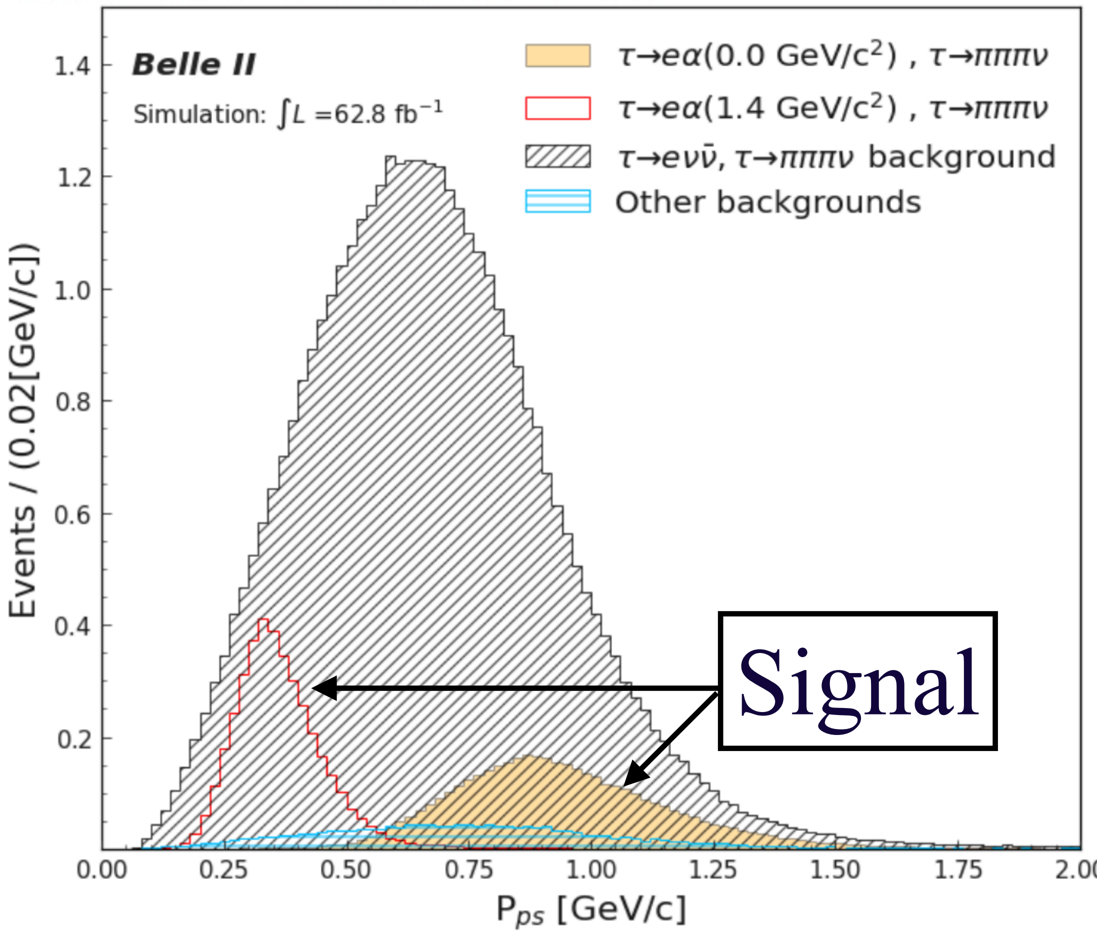
- LFV decay: $\tau \to \ell\alpha$ (where ℓ = e or μ, and α is an invisible boson)
- α can enter from new physics models, eg. light axion like particles (ALP), Z', etc.



τ pseudo-rest frame

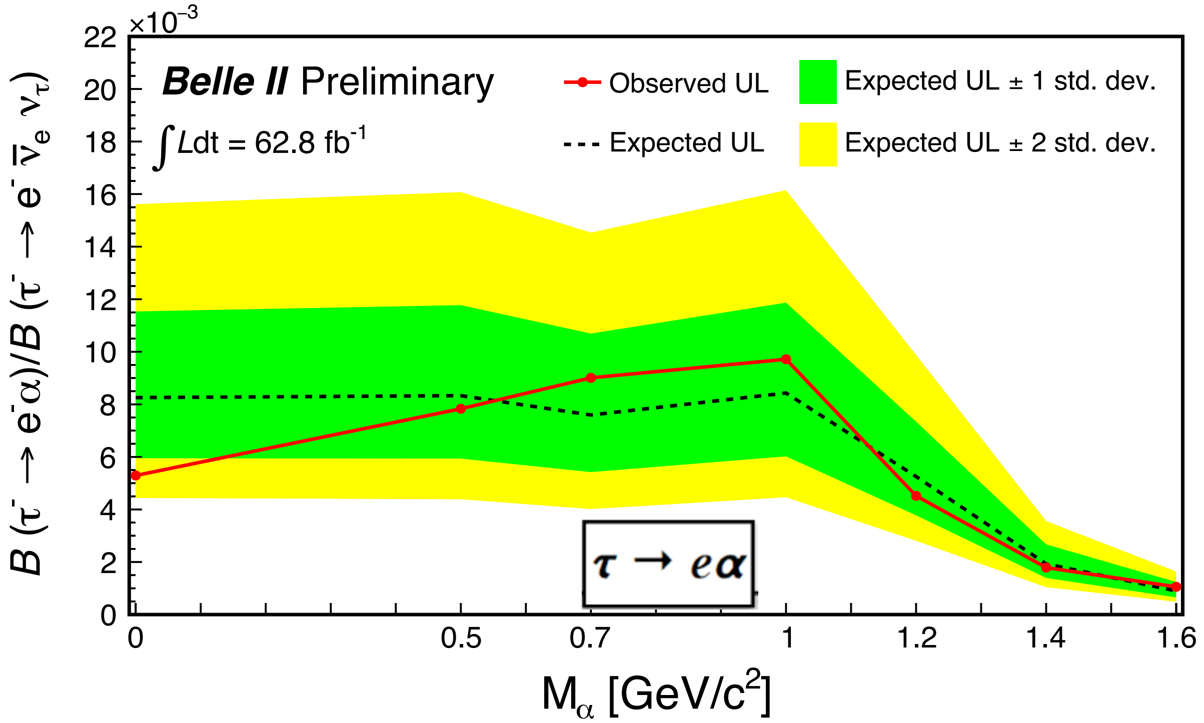
2-body $\tau \to \ell\alpha$ decay will appear as a bump against the SM 3-body $\tau \to \ell\nu\bar{\nu}$ background in the p_ℓ distribution in the τ pseudo-rest frame

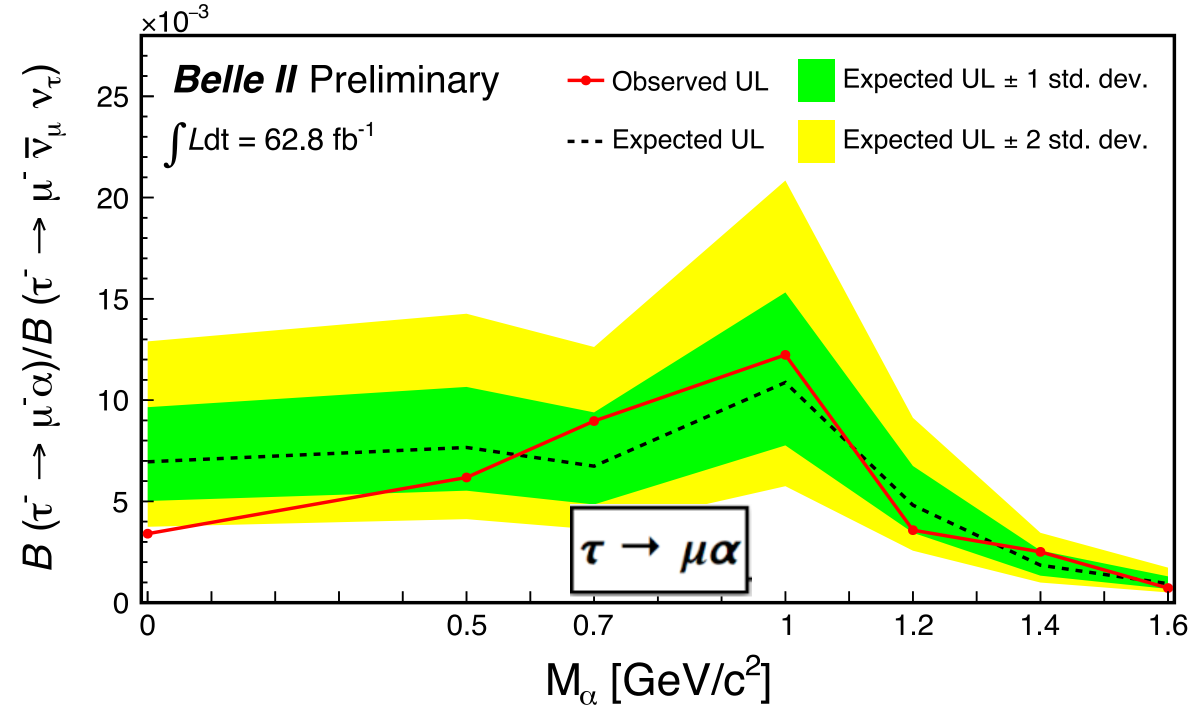
$$\hat{p}_\tau \approx -\frac{\vec{p}_{3\pi}}{|\vec{p}_{3\pi}|}, \quad E_\tau \approx \sqrt{s}/2$$



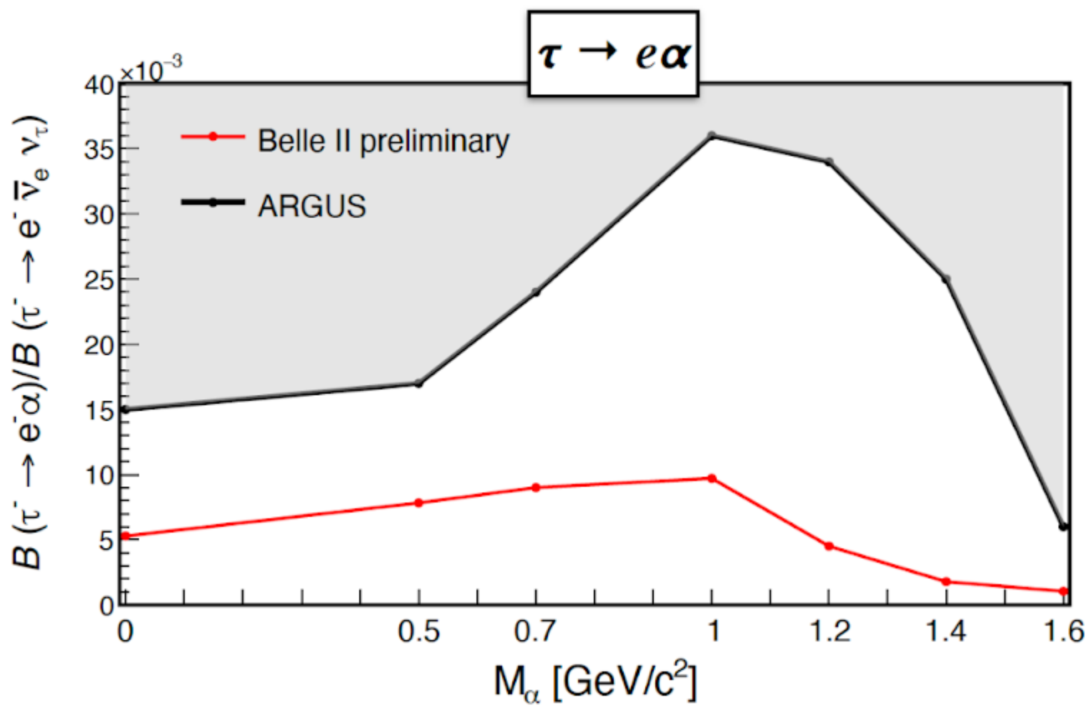
$\tau \to \ell\alpha$ at Belle II

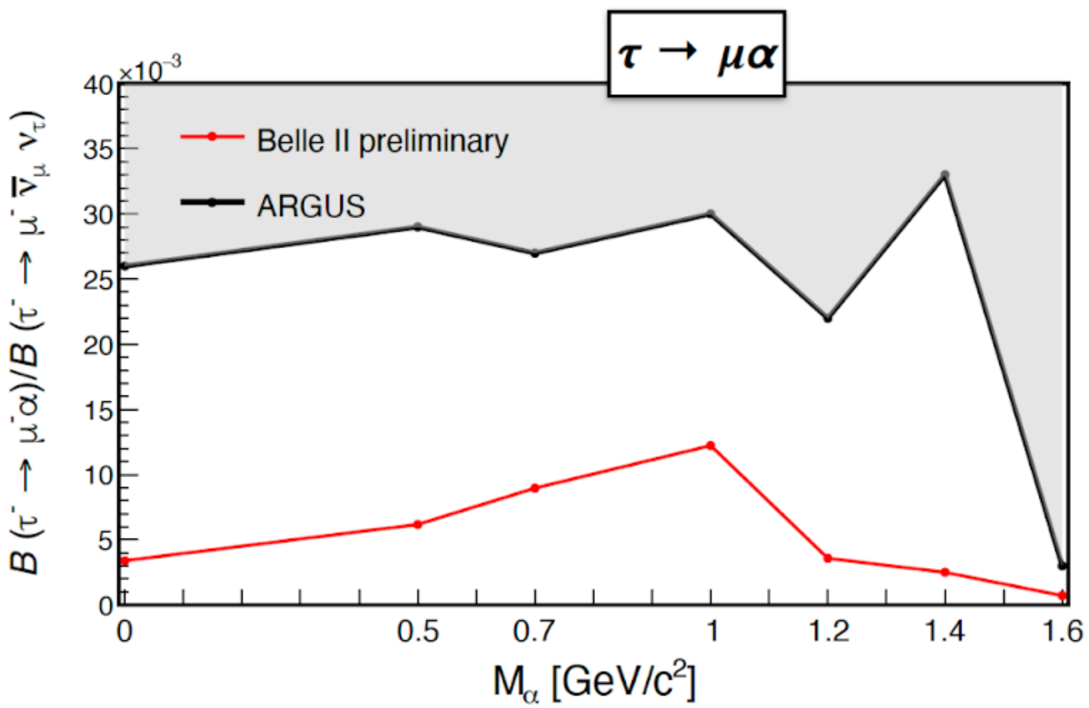
95% C.L. upper limits from Belle II [arXiv:2212.03634, PRL 130, 181803 (2023)]





Comparison with previous limits from ARGUS (0.472 fb^{-1}) [Z. Phys. C68 (1995) 25]





Estimates of experimental sensitivity in LFV searches

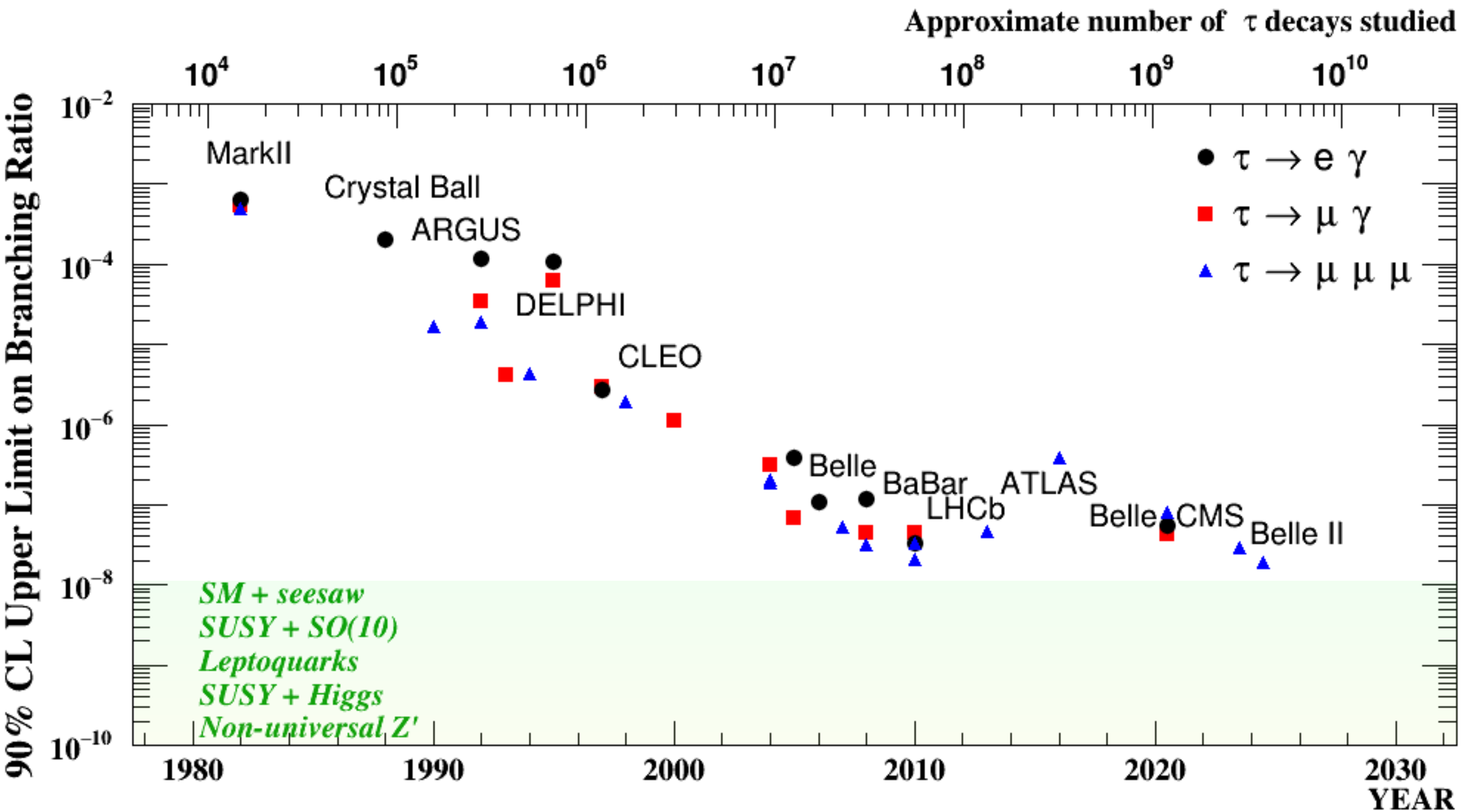
$$B^{90}_{\mathrm{UL}} = N^{90}_{\mathrm{UL}} / (N_\tau \times \varepsilon)$$

- ε: *high statistics signal MC simulated for different Data-taking periods*

ε =	Trigger .	Reco .	Topology .	PID .	Cuts .	Signal–Box
	90%	70%	70%	50%	50%	50%
Cumulative:						
	90%	63%	44%	22%	11%	~5%

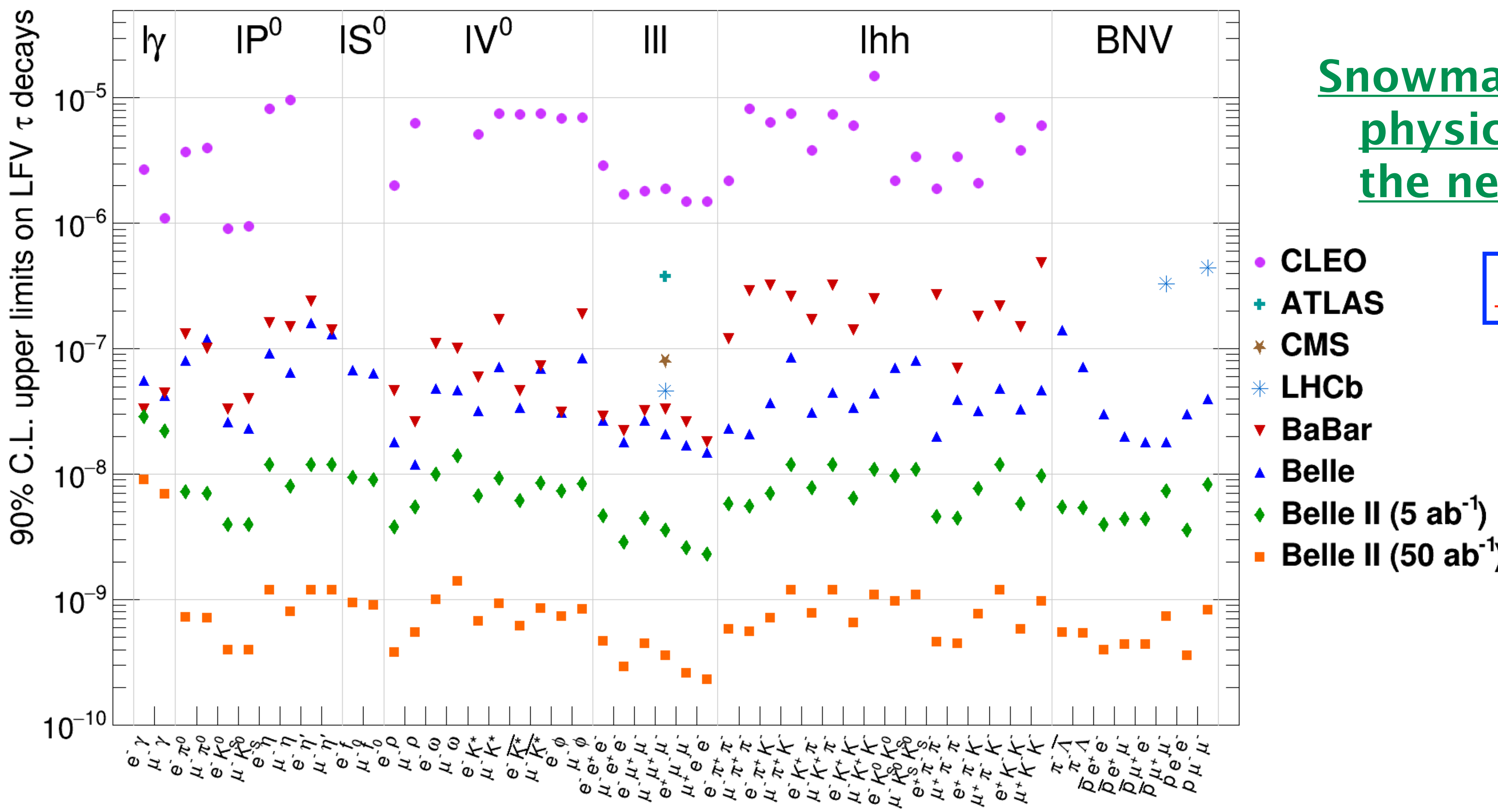
	$\sqrt{s}$	Luminosity (L)	$N_\tau = 2L\sigma$
BaBar	10.58 GeV	0.5 ab^{-1}	9 $\times 10^{8}$
Belle	10.58 GeV	1 ab^{-1}	2 $\times 10^{9}$
Belle II	10.58 GeV	50 ab^{-1}	9 $\times 10^{10}$
STCF	2-7 GeV	1 ab^{-1}	7 $\times 10^{9}$
FCC-ee	91.2 GeV	150 ab^{-1}	3 $\times 10^{11}$

Current status of LFV τ decays



Projected limits at Belle II

	Background limited search $\tau \to \ell\gamma$	*Background free search* ($N_{bkg} < 1$) (all other LFV τ decays shown below)
$N^{90}_{\rm UL}$	$\sqrt{\mathcal{L}}$	2.44 [Feldman – Cousins for $N_{obs} = 0$]
$B^{90}_{\rm UL}$	$\propto 1/\sqrt{\mathcal{L}}$	$\propto 1/\mathcal{L}$



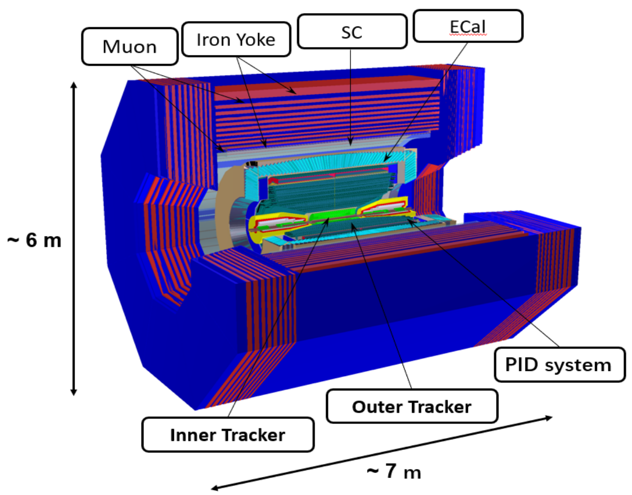
Snowmass White Paper: Belle II physics reach and plans for the next decade and beyond

2207.06306 [hep-ex]

Projections

Belle II to probe LFV in several channels ≃ $\mathcal{O}(10^{-10})$ to $\mathcal{O}(10^{-9})$ with 50 ab^{-1}

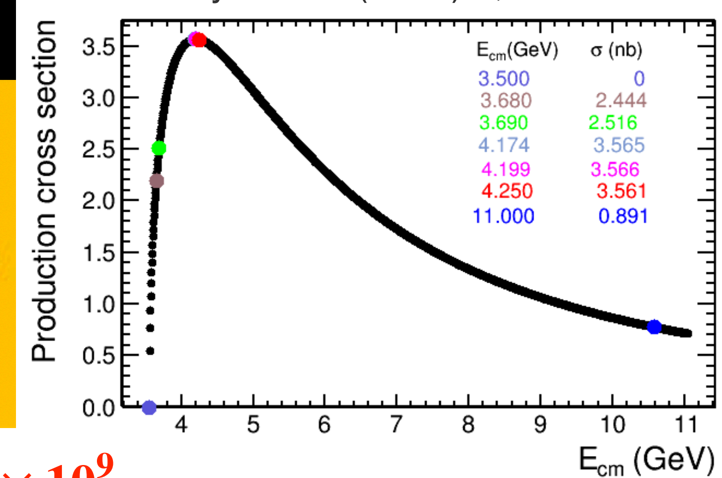
Super Tau-Charm Facility



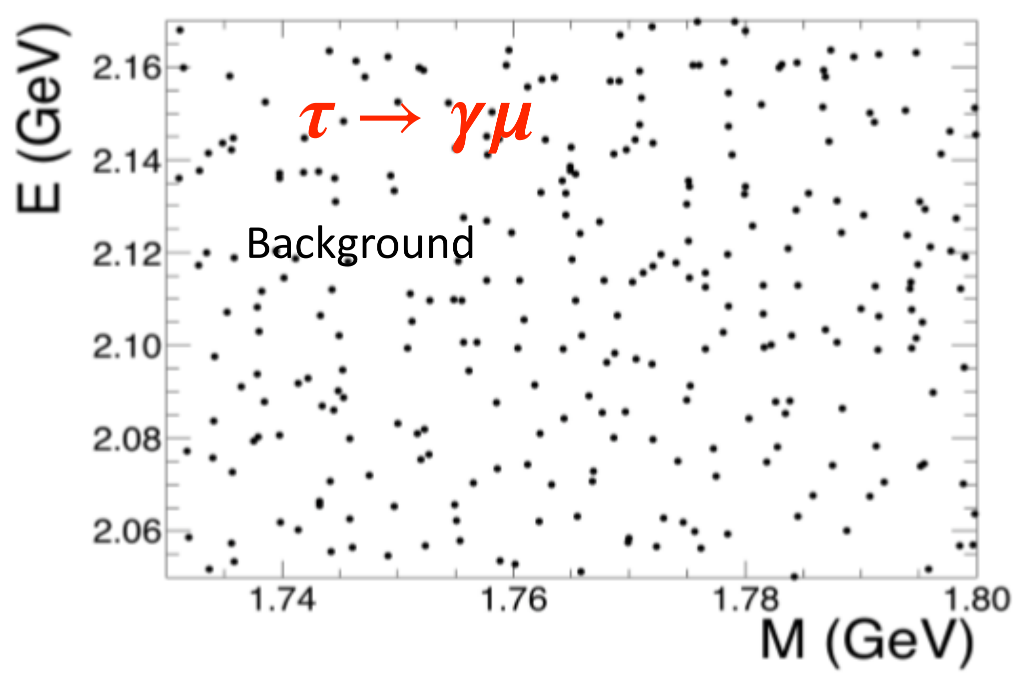
"Physics Potential of a Super tau-Charm Facility" (RF/SNOWMASS21-RF7_RF1_STCF-013.pdf)

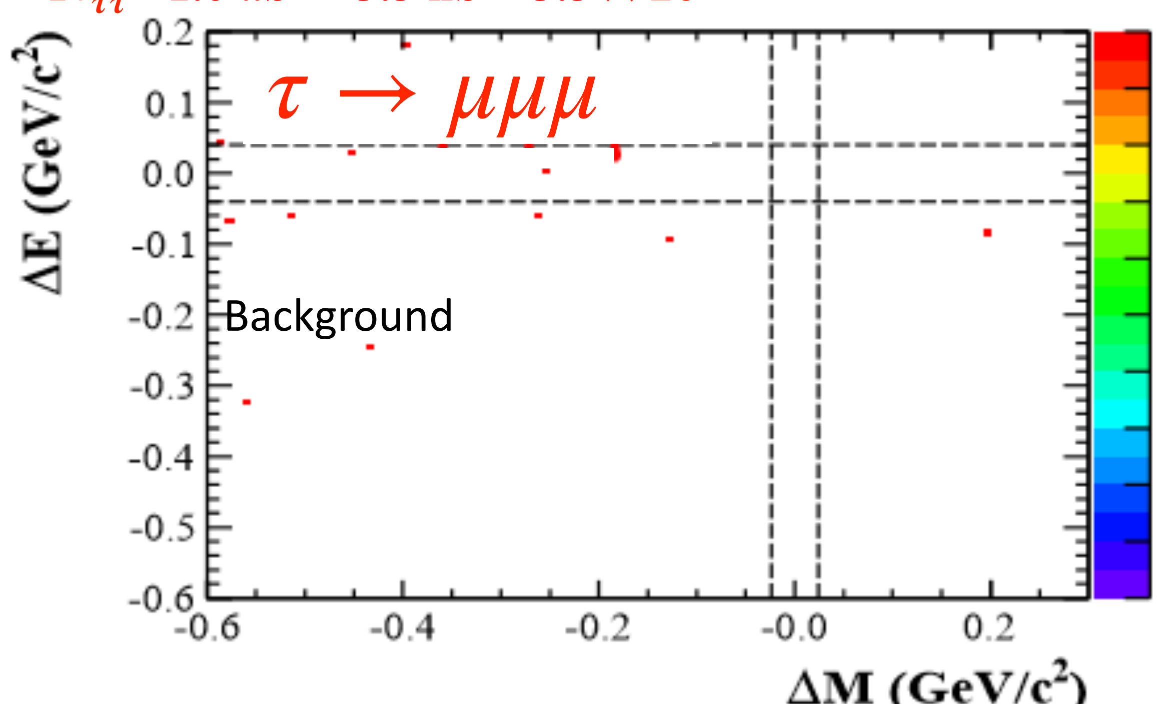
- Peaking luminosity $>0.5\times10^{35}$ cm^{-2}s^{-1} at 4 GeV
- Energy range E_{cm} = 2-7 GeV
- Potential to increase luminosity and realize beam polarization
- A nature extension and a viable option for China accelerator project in the post BEPCII/BESIII era

PoS CHARM2020 (2021), 007
Physics 49 (2020) 8, 513-524



At 4.26 GeV, number of tau pairs per year: $N_{\tau\tau}\sim$ 1.0 ab^{-1} ×3.5 nb = 3.5×10^{9}





➢ **STCF with 1ab^{-1}:**

$$\mathcal{B}^{90}_{UL}(\tau\to\gamma\mu) < \frac{N^{90}_{UL}}{2\varepsilon N_{\tau\tau}} \sim 2.8\times10^{-8}$$

➢ **STCF with 1ab^{-1}:**

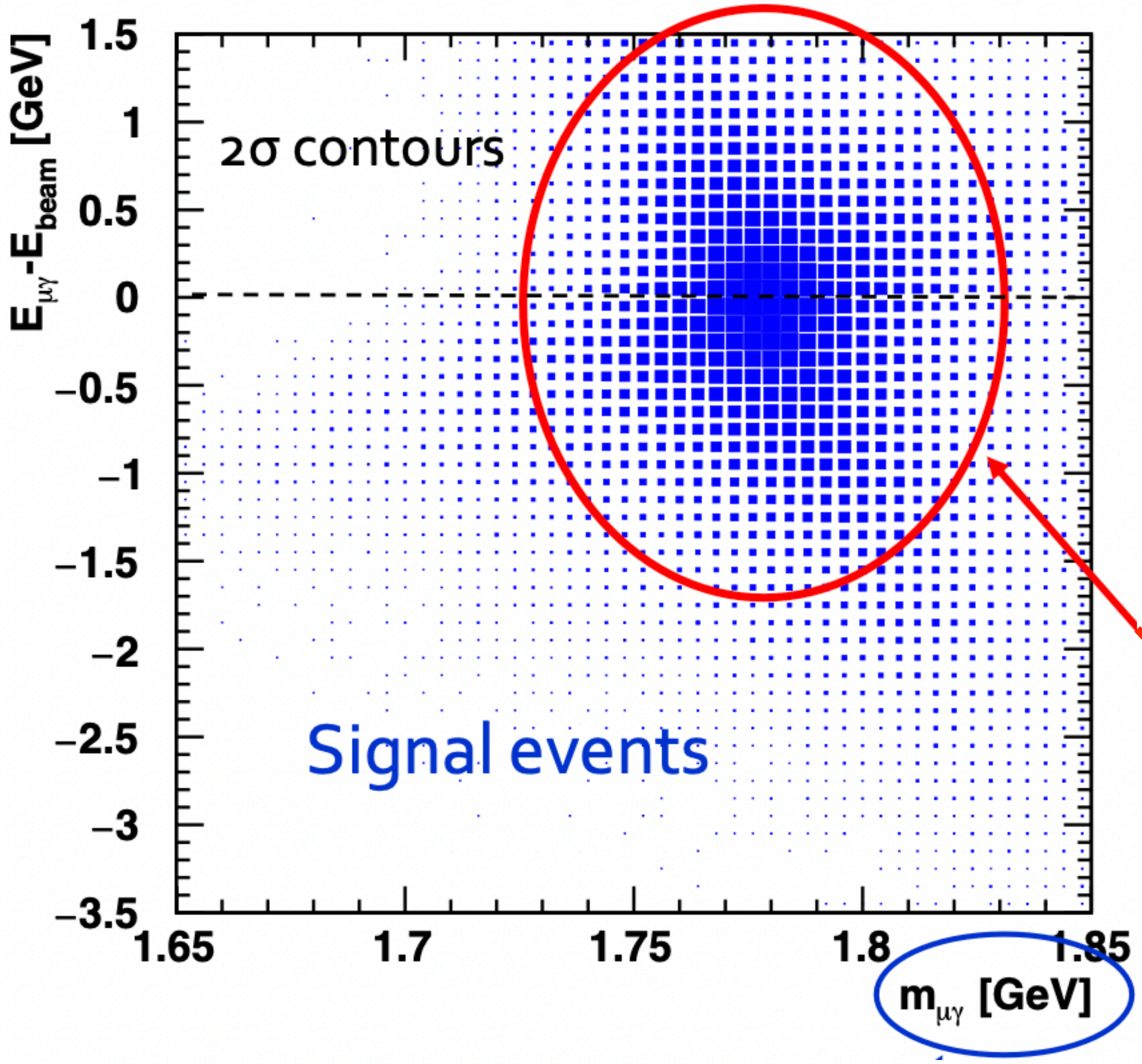
$$\mathcal{B}^{90}_{UL}(\tau\to\mu\mu\mu) < \frac{N^{90}_{UL}}{2\varepsilon N_{\tau\tau}} \sim 1.4\times10^{-9}$$

With 10 ab^{-1}: $\mathcal{B}^{90}(\tau\to\gamma\mu) < 8.8\times10^{-9}$

Teng Xiang, Xiao-Dong Shi, Da-Yong Wang, Xiao-Rong Zhou
Eur.Phys.J.C 83 (2023) 10, 908 arXiv: 2305.00483 [hep-ex]

FCC-ee

$\mathscr{B}(\tau \to \mu\gamma)$



- **Main background:** Radiative events (IRS+FSR), $e^+e^- \to \tau^+\tau^-\gamma$
  - $\tau \to \mu\gamma$ decay faked by combination of γ from ISR/FSR and μ from $\tau \to \mu\nu\bar{\nu}$

Smear with assumed FCC-ee detector resolutions (ILC-like detector):

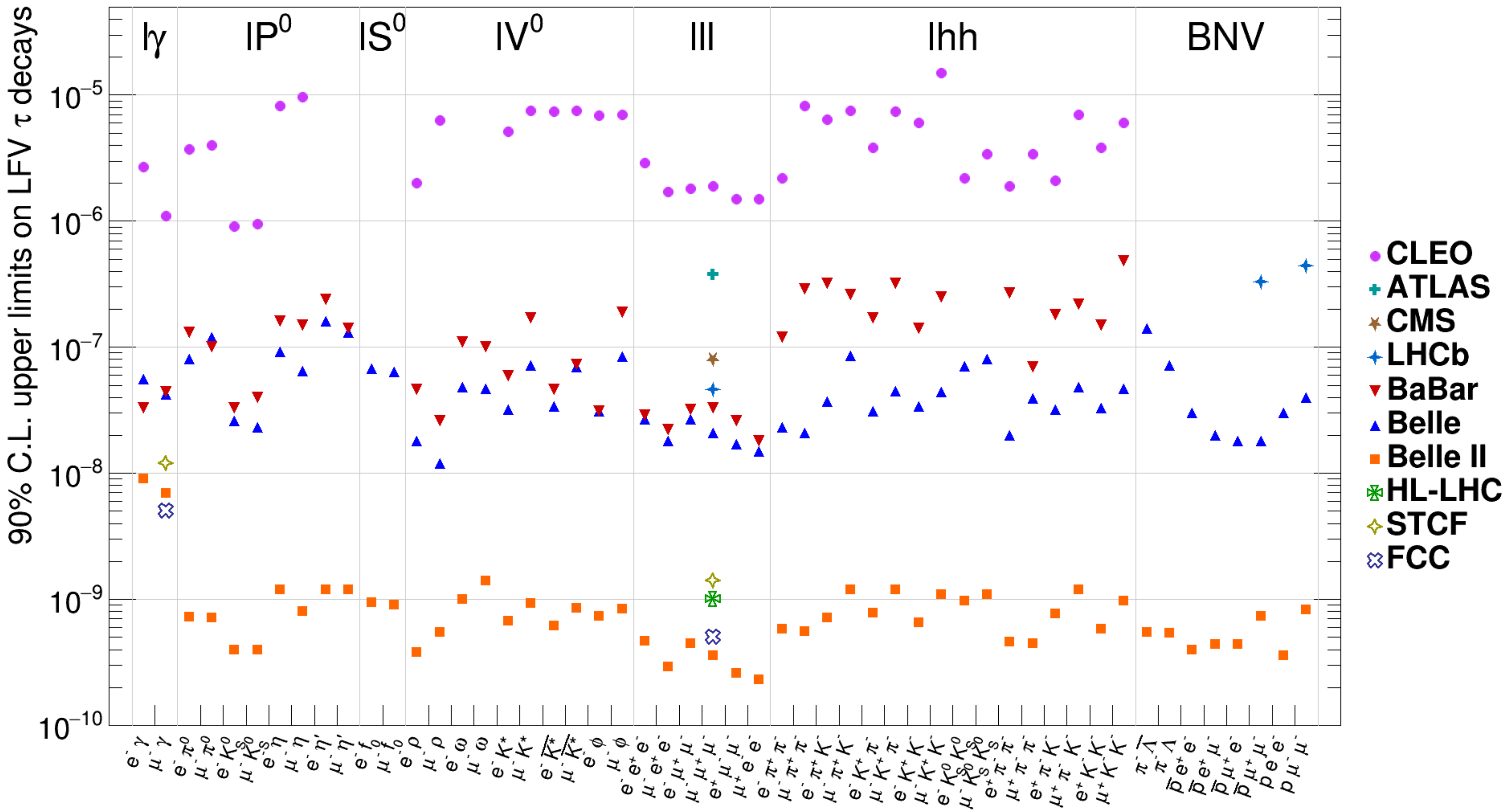
- Muon momentum [GeV]
  $\sigma(p_T)/p_T = 2\text{x}10^{-5} \text{x}\ p_T \oplus 1\text{x}10^{-3}$
- Photon ECAL energy [GeV]
  $\sigma(E)/E = 0.165/\sqrt{E} \oplus 0.010/E \oplus 0.011$
- Photon ECAL spatial [mm]
  $\sigma(x) = \sigma(y) = (6/E \oplus 2)$ mm

$\sigma(m_{\gamma\mu})$ = 26 MeV; $\sigma(E_{\gamma\mu})$ = 850 MeV

- From study (assuming 25% signal & background efficiency), projected BR sensitivity **2 x 10^{-9}**
- Expect this search to have *very low* background, even with FCC-ee like statistics
- Should be able to have sensitivity down to BRs of $\mathscr{B}(\tau \to \mu\mu\mu) \simeq 10^{-10}$

Mogens Dam, arXiv: 1811.09408 [hep-ex]

Summary of experimental prospects of τ decays



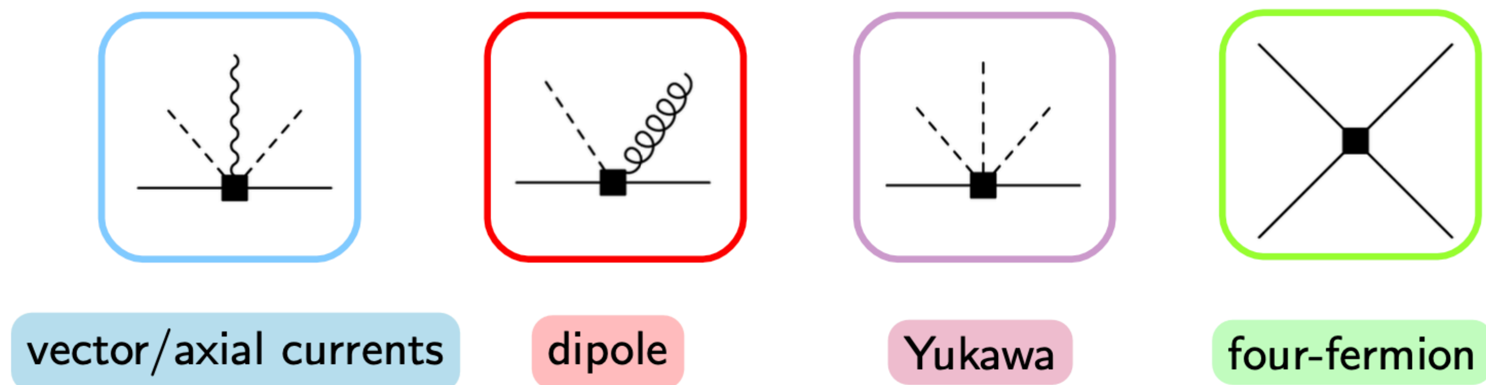
Snowmass 2021: cLFV in τ sector e-Print: 2203.14919 [hep-ph]

Summary of transitions with τ in the final state

Channel	Upper limit at 90% C.L.	Experiment [Reference]
$D^0 \to e^\pm\mu^\mp$	3.3×10^{-7}	BABAR [Phys.Rev.D 86 (2012) 032001]
$D^0 \to pe^-$	5.5×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$\bar{D}^0 \to pe^-$	6.9×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$D^0 \to \bar{p}e^+$	7.2×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$\bar{D}^0 \to \bar{p}e^+$	7.6×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$D^0 \to p\mu^-$	5.1×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$\bar{D}^0 \to p\mu^-$	6.5×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$D^0 \to \bar{p}\mu^+$	6.3×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$\bar{D}^0 \to \bar{p}\mu^+$	6.5×10^{-7}	Belle [Phys.Rev.D 109 (2024) 3, L031101]
$D^0 \to \pi^0e^\pm\mu^\mp$	8.0×10^{-7}	BABAR [Phys.Rev.D 101 (2020) 11, 112003]
$D^0 \to \rho^0e^\pm\mu^\mp$	5.0×10^{-7}	BABAR [Phys.Rev.D 101 (2020) 11, 112003]
$D^0 \to \phi e^\pm\mu^\mp$	5.1×10^{-7}	BABAR [Phys.Rev.D 101 (2020) 11, 112003]
$D^0 \to K^0_S e^\pm\mu^\mp$	8.6×10^{-7}	BABAR [Phys.Rev.D 101 (2020) 11, 112003]
$D^+ \to \pi^+e^+\mu^-$	2.9×10^{-6}	BABAR [Phys.Rev.D 84 (2011) 072006]
$D^+ \to \pi^+e^-\mu^+$	3.6×10^{-6}	BABAR [Phys.Rev.D 84 (2011) 072006]
$D^+ \to \pi^-e^+\mu^+$	2.0×10^{-6}	BABAR [Phys.Rev.D 84 (2011) 072006]
$D^+ \to K^+e^+\mu^-$	1.2×10^{-6}	BABAR [Phys.Rev.D 84 (2011) 072006]
$D^+ \to K^+e^-\mu^+$	2.8×10^{-6}	BABAR [Phys.Rev.D 84 (2011) 072006]
$D^+ \to K^-e^+\mu^+$	1.9×10^{-6}	BABAR [Phys.Rev.D 84 (2011) 072006]
$B^0 \to e^\pm\tau^\mp$	1.6×10^{-5}	Belle [Phys.Rev.D 104 (2021) 9, L091105]
$B^0 \to \mu^\pm\tau^\mp$	1.5×10^{-5}	Belle [Phys.Rev.D 104 (2021) 9, L091105]
$B^0 \to \pi^0e^\pm\mu^\mp$	1.4×10^{-7}	BABAR [Phys.Rev.Lett. 99 (2007) 051801]
$B^0 \to K^0e^\pm\mu^\mp$	2.7×10^{-7}	BABAR [Phys.Rev.D 73 (2006) 092001]
$B^0_s \to e^\pm\tau^\mp$	14×10^{-4}	Belle [JHEP 08 (2023) 178]
$B^0_s \to \mu^\pm\tau^\mp$	7.3×10^{-4}	Belle [JHEP 08 (2023) 178]
$\Upsilon(1S) \to e^\pm\mu^\pm$	3.9×10^{-7}	Belle [JHEP 05 (2022) 095]
$\Upsilon(1S) \to e^\pm\tau^\pm$	2.7×10^{-6}	Belle [JHEP 05 (2022) 095]
$\Upsilon(1S) \to \mu^\pm\tau^\pm$	2.7×10^{-6}	Belle [JHEP 05 (2022) 095]
$\Upsilon(2S) \to e^\pm\tau^\pm$	1.1×10^{-6}	Belle [JHEP 02 2024, 187 (2024)]
$\Upsilon(2S) \to \mu^\pm\tau^\pm$	2.3×10^{-7}	Belle [JHEP 02 2024, 187 (2024)]
$\Upsilon(3S) \to e^\pm\mu^\pm$	3.6×10^{-7}	BABAR [Phys.Rev.Lett. 128 (2022) 9, 091804]
$\Upsilon(3S) \to e^\pm\tau^\pm$	4.2×10^{-6}	BABAR [Phys.Rev.Lett. 104 (2010) 151802]
$\Upsilon(3S) \to \mu^\pm\tau^\pm$	3.1×10^{-6}	BABAR [Phys.Rev.Lett. 104 (2010) 151802]

Global analysis of all LFV data

SMEFT for CLFV



τ and B CLFV decays

Constrain $\tau \to e$ transitions

Decay mode	V					A					S					P					T	
	$q^{(0)}$	$q^{(1)}$	s	c	b	$q^{(0)}$	$q^{(1)}$	s	c	b	$q^{(0)}$	$q^{(1)}$	s	c	b	$q^{(0)}$	$q^{(1)}$	s	c	b	u	c
$\tau \to e\gamma$																					✓ (loop)	✓ (loop)
$\tau \to e\ell^+\ell^-$				✓ (loop)	✓ (loop)				×	×												
$\tau \to e\pi^0$							✓		×	×							✓					
$\tau \to e\eta, \eta'$						✓		✓	×	×						✓		✓	✓ (loop)	✓ (loop)		
$\tau \to e\pi^+\pi^-$		✓		✓ (loop)	✓ (loop)				×	×	✓		✓	✓ (loop)	✓ (loop)						✓	
$\tau \to eK^+K^-$	✓	✓	✓	✓ (loop)	✓ (loop)				×	×	✓		✓	✓ (loop)	✓ (loop)						✓	
	ds	db	sb		cu	ds	db	sb		cu	ds	db	sb		cu	ds	db	sb		cu	cu	
$\tau \to eK_S^0$						✓										✓						
$\tau^- \to e^- K\pi$	✓										✓											
$B^0 \to e\tau$							✓										✓					
$B^+ \to \pi^+ e\tau$		✓										✓										
$B^+ \to K^+ e\tau$			✓										✓									

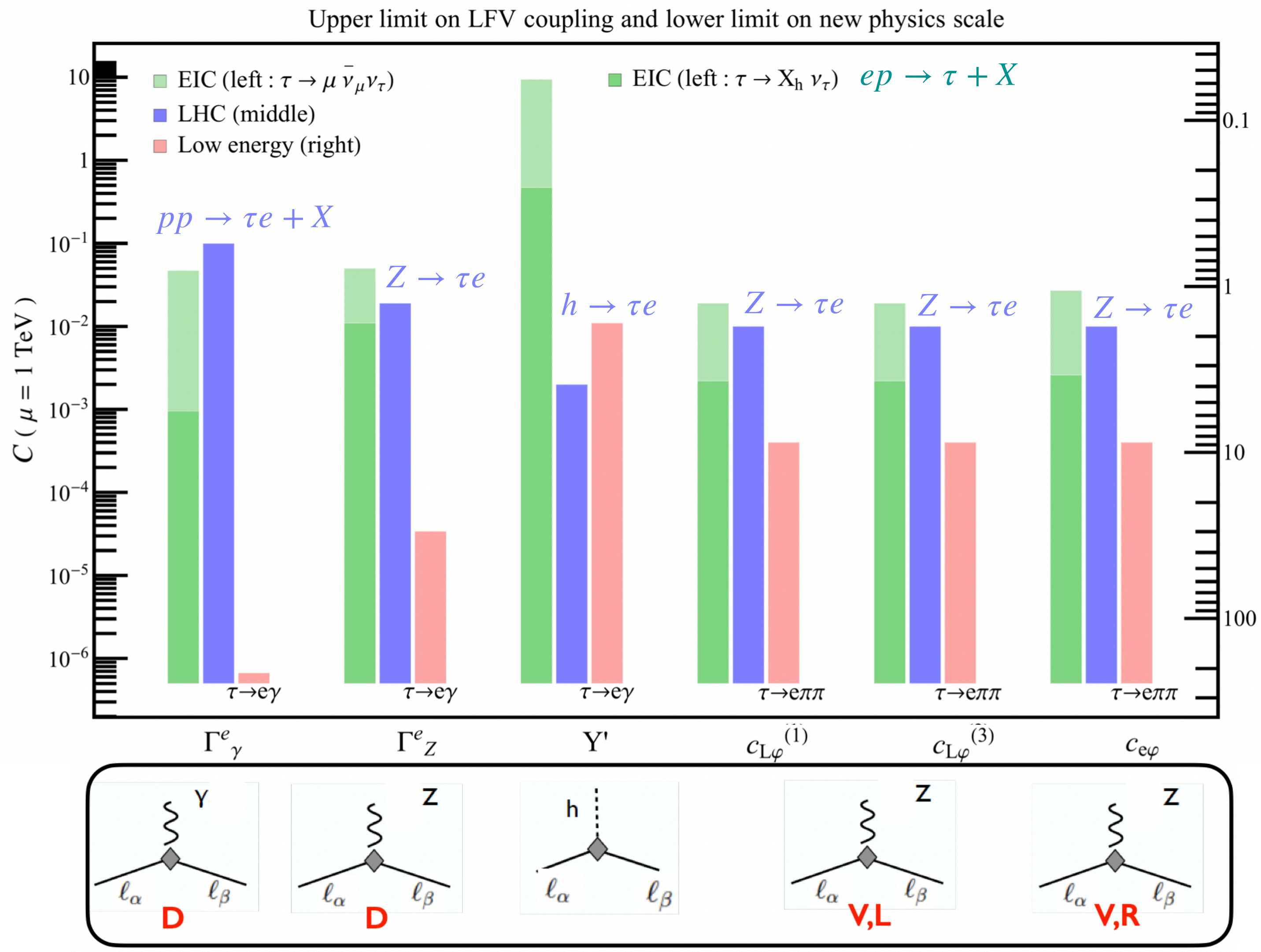
✓ = tree ✓ = loop

V.Cirigliano, K.Fuyuto, C.Lee, E.Mereghetti, B.Yan, JHEP03, 256 (2021) arXiv:2102.06176 [hep-ph]

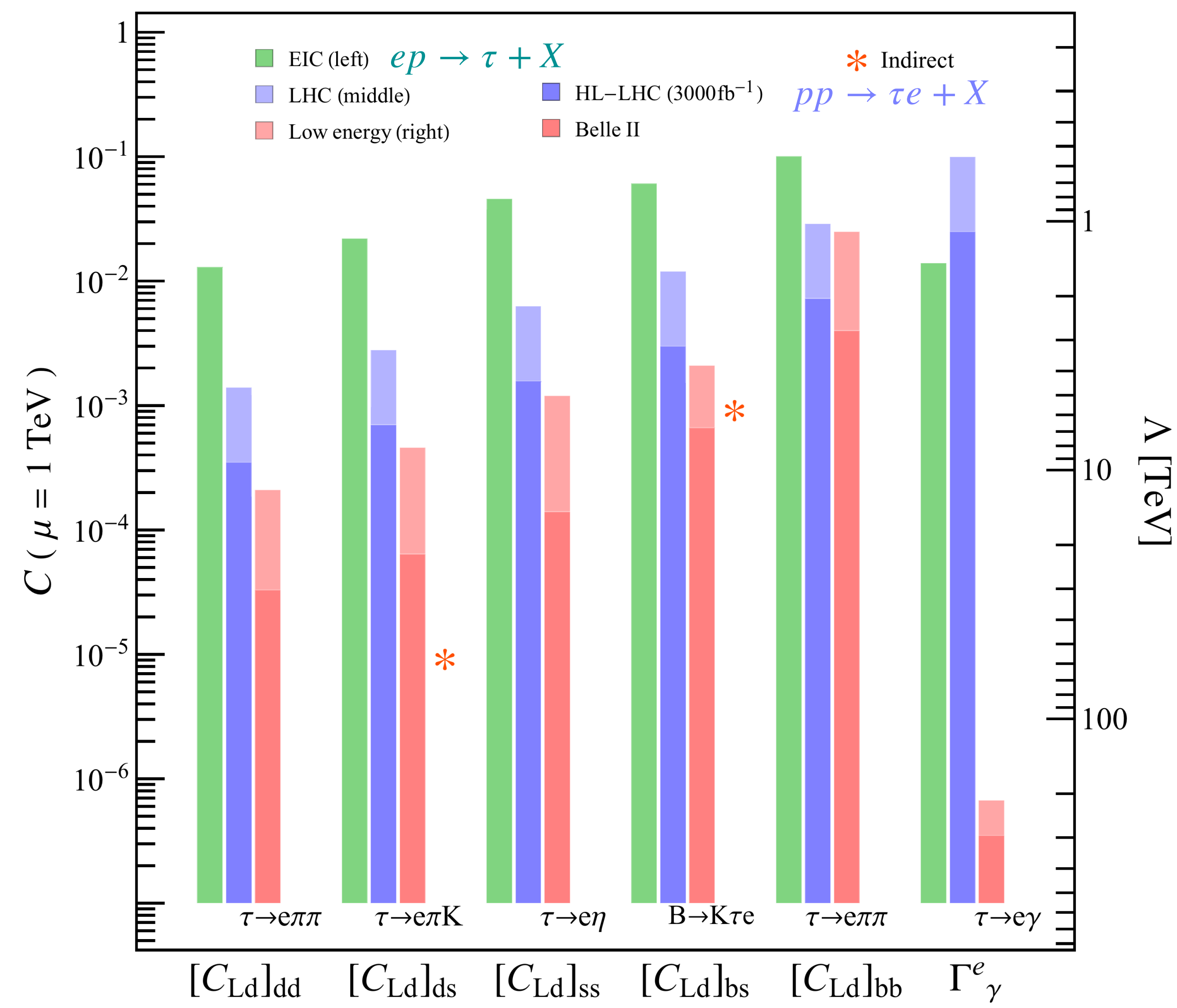
Global fit: $\tau \to e$ decays and transitions with τ in the final state

Model-independent probes of new physics at scale (Λ) encoded as Wilson coefficients (C_n) via EFT approach.
For certain operators, Higgs decay and LFV Drell-Yan compete, which are assumed to scale by factor of 4 at HL-LHC.

For all other operators, sensitivity dominated by τ and B-decays @ Belle II



V.Cirigliano et. al. arXiv: 2102.06176 [hep-ph]



Sw. Banerjee, et.al. arXiv: 2203.14919 [hep-ph]

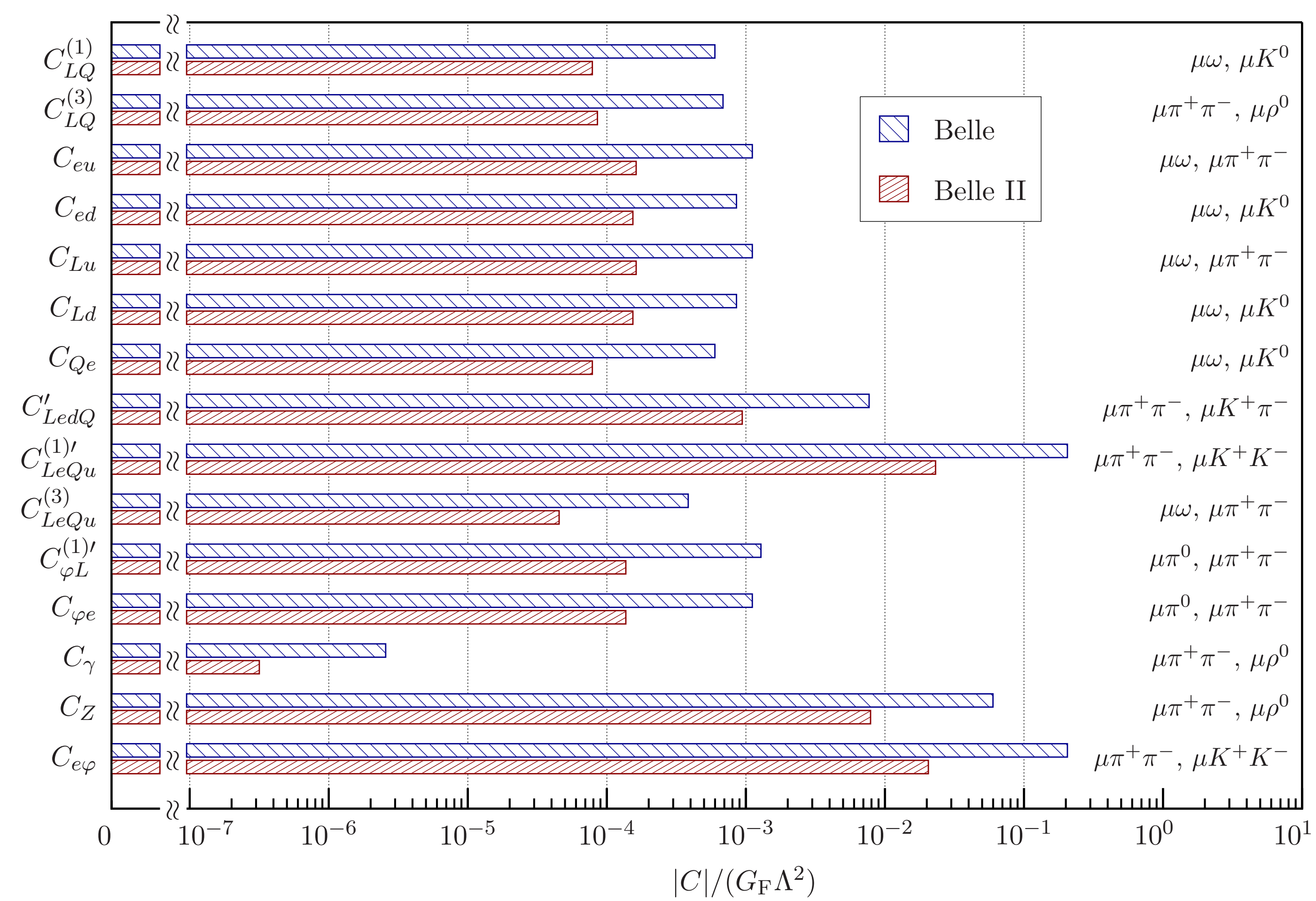
Global fit: $\tau \to \mu$ decays and transitions with τ in the final state

Model-independent probes of new physics at scale (Λ)
encoded as Wilson coefficients (C_n) via EFT approach.
For certain operators, Higgs decay and LFV Drell-Yan compete,
which are assumed to scale by factor of 4 at HL-LHC.

For all other operators, sensitivity dominated by τ and B-decays @ Belle II

WC	Operator	WC	Operator
$C_{LQ}^{(1)}$	$(\bar{L}_p\gamma_\mu L_r)(\bar{Q}_s\gamma^\mu Q_t)$	$C_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar{L}_p e_r\varphi)$
$C_{LQ}^{(3)}$	$(\bar{L}_p\gamma_\mu\sigma^I L_r)(\bar{Q}_s\gamma^\mu\sigma^I Q_t)$	$C_{\varphi e}$	$\left(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi\right)(e_p\gamma^\mu e_r)$
C_{eu}	$(\bar{e}_p\gamma_\mu e_r)(\bar{u}_s\gamma^\mu u_t)$	$C_{\varphi L}^{(1)}$	$\left(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi\right)(\bar{L}_p\gamma^\mu L_r)$
C_{ed}	$(\bar{e}_p\gamma_\mu e_r)(\bar{d}_s\gamma^\mu d_t)$	$C_{\varphi L}^{(3)}$	$\left(\varphi^\dagger i\overleftrightarrow{D}_{I\mu}\varphi\right)(\bar{L}_p\sigma_I\gamma^\mu L_r)$
C_{Lu}	$(\bar{L}_p\gamma_\mu L_r)(\bar{u}_s\gamma^\mu u_t)$	C_{eW}	$(\bar{L}_p\sigma^{\mu\nu}e_r)\,\sigma_I\varphi W_{\mu\nu}^I$
C_{Ld}	$(\bar{L}_p\gamma_\mu L_r)(\bar{d}_s\gamma^\mu d_t)$	C_{eB}	$(\bar{L}_p\sigma^{\mu\nu}e_r)\,\varphi B_{\mu\nu}$
C_{Qe}	$(\bar{Q}_p\gamma_\mu Q_r)(\bar{e}_s\gamma^\mu e_t)$		
C_{LedQ}	$(\bar{L}_p^j e_r)(\bar{d}_s Q_t^j)$		
$C_{LeQu}^{(1)}$	$(\bar{L}_p^j e_r)\,\varepsilon_{jk}\,(\bar{Q}_s^k u_t)$		
$C_{LeQu}^{(3)}$	$(\bar{L}_p^j\sigma_{\mu\nu}e_r)\,\varepsilon_{jk}\,(\bar{Q}_s^k\sigma^{\mu\nu}u_t)$		

Husek, Monsalvez-Pozo, Portoles
JHEP 04 (2022) 165 arXiv: 2111.06872 [hep-ph]



Sw. Banerjee, et.al. arXiv: 2203.14919 [hep-ph]

Summary & Outlook

	Observed Limits			Projected Limits		
	Experiment	Luminosity	UL (obs)	Experiment	Luminosity	UL (exp)
$\tau^- \to e^-\gamma$	Belle [JHEP 10 (2021) 19]	988 fb^{-1}	5.6×10^{-8}	Belle II [2207.06307]	50 ab^{-1}	9.0×10^{-9}
	BaBar [Phys.Rev.Lett. 104 (2010) 021802]	516 fb^{-1}	3.3×10^{-8}			
$\tau^- \to \mu^-\gamma$	Belle [JHEP 10 (2021) 19]	988 fb^{-1}	4.2×10^{-8}	Belle II [2207.06307]	50 ab^{-1}	6.9×10^{-9}
	BaBar [Phys.Rev.Lett. 104 (2010) 021802]	516 fb^{-1}	4.4×10^{-8}			
				STCF [Eur.Phys.J.C 83 (2023) 10, 908]	10 ab^{-1}	8.8×10^{-9}
				FCC-ee [1811.09408]	150 ab^{-1}	$\mathcal{O}(10^{-9})$
$\tau^- \to \mu^-\mu^+\mu^-$	Belle II [Tau2023]	424 fb^{-1}	1.9×10^{-8}	Belle II [2207.06307]	50 ab^{-1}	3.6×10^{-10}
	Belle [Phys.Lett.B 687 (2010) 139]	782 fb^{-1}	2.1×10^{-8}			
	BaBar [Phys.Rev.D 81 (2010) 111101]	468 fb^{-1}	3.3×10^{-8}			
	LHCb [JHEP 02 (2015) 121]	3 fb^{-1}	4.6×10^{-8}	LHCb [1808.08865]	300 fb^{-1}	$\mathcal{O}(10^{-9})$
	CMS [Phys. Lett. B 853 (2024) 138633]	131 fb^{-1}	2.9×10^{-8}	CMS [CMS-TDR-016]	3 ab^{-1}	3.7×10^{-9}
	ATLAS [Eur.Phys.J.C 76 (2016) 5, 232]	20 fb^{-1}	3.8×10^{-7}	ATLAS [ATL-PHYS-PUB-2018-032]	3 ab^{-1}	1.0×10^{-9}
				STCF [Eur.Phys.J.C 83 (2023) 10, 908]	1 ab^{-1}	1.4×10^{-9}
				FCC-ee [1811.09408]	150 ab^{-1}	$\mathcal{O}(10^{-10})$

- **Observation of LFV in the charged lepton sector would completely change our understanding of physics and herald a new period of discoveries in particle physics. Synergies between different experiments compliment discovery potential/confirmation.**
- **Now is a very interesting era in the searches for LFV in decays of the τ lepton, as the current limits will improve by an order of magnitude down to a few parts in 10^{-10} to 10^{-9} at the Belle II and other experiments.**
- **Similar sensitivities will be probed at ATLAS, CMS & LHCb with high luminosity upgrade.**
- **Proposed experiments at STCF, EIC & FCC-ee will continue searches for LFV in tau sector.**