Charged Lepton Flavor Violation in the τ Sector

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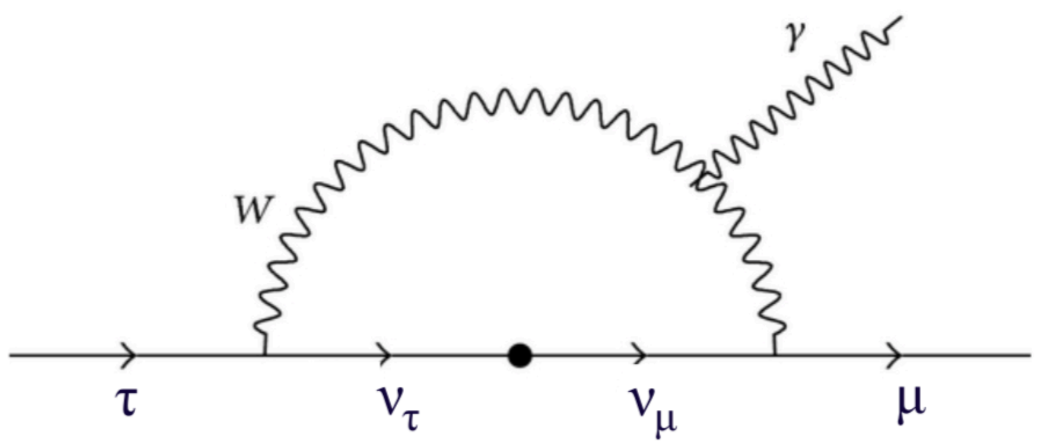
Charged Lepton flavor violation (LFV) in τ decays

LFV is not forbidden by any continuous symmetry
$\Rightarrow$ most new physics (NP) models naturally include LFV



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

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

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

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

many orders below experimental sensitivity!

Any observation of LFV $\Rightarrow$ unambiguous signature of NP

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:	$BR(\mu \to e\gamma) / BR(\tau \to \mu\gamma) \sim \lvert V_{us}\rvert^6 \sim 10^{-4}$

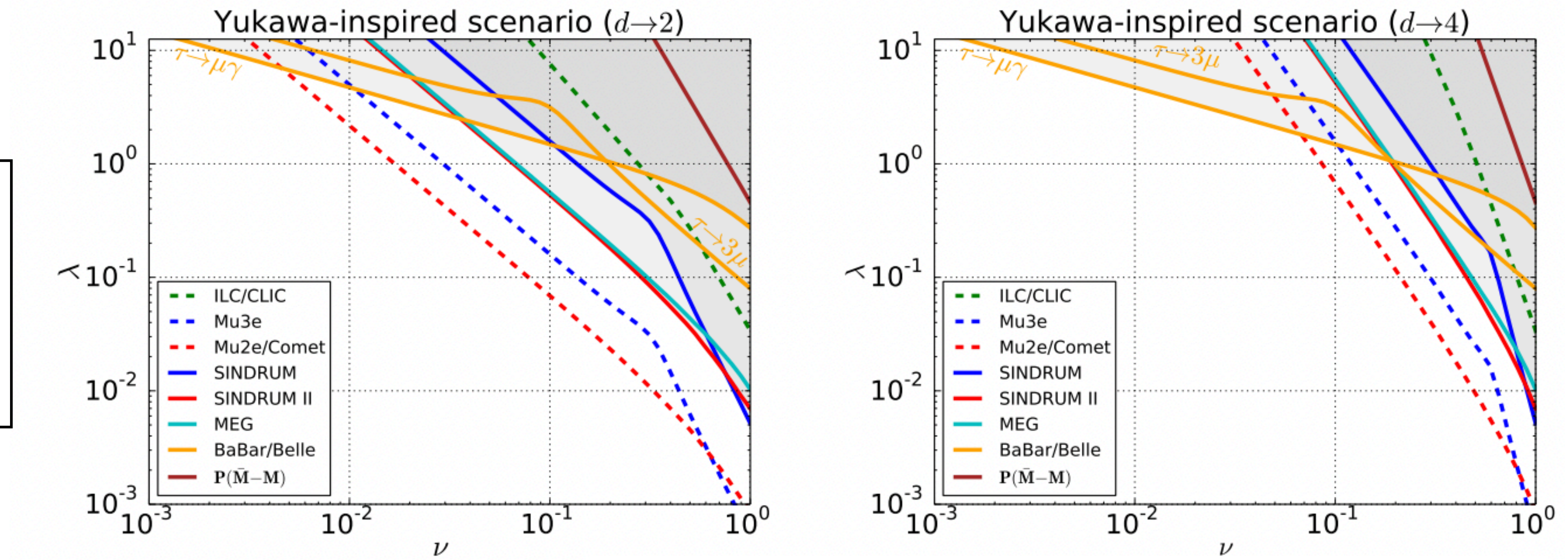
Vincenzo Cirigliano, Benjamin Grinstein, Gino Isidori, Mark B. Wise: hep-ph/0507001 [hep-ph], hep-ph/0608123 [hep-ph]
R. Barbieri, L. Hall, A. Strumia: hep-ph/9501334 [hep-ph]

New Physics expectations

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

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

A. Crivellin et. al. Phys. Rev. D 99, 035004 (2019)



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

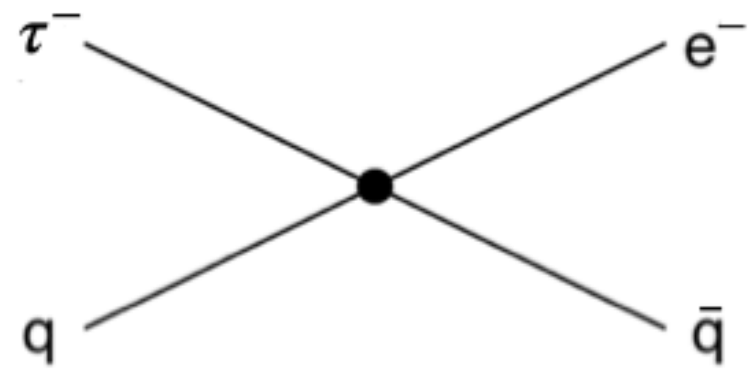
$$\lambda_{ab} = \lambda \begin{pmatrix} \pm 1 & \nu^2 & \nu^3 \\ \nu^2 & \nu^4 & \nu^5 \\ \nu^3 & \nu^5 & \nu^6 \end{pmatrix}$$

- Some models predict LFV up to existing experimental bounds
- eg. SUSY models: non-diagonal slepton mass matrix $\Rightarrow$ LFV
- Normal (Inverted) hierarchy for slepton $\Rightarrow \tau \to \mu\gamma$ ($\tau \to e\gamma$)
- Neutrinoless 2 and 3 body τ decays have different sensitivity

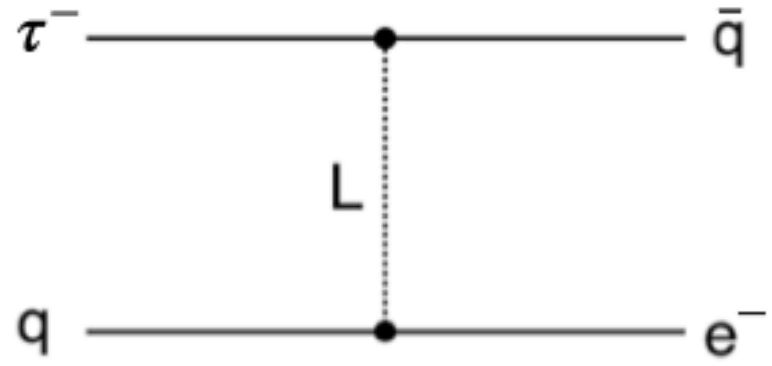
	$\mathcal{B}(\tau \to \ell\gamma)$	$\mathcal{B}(\tau \to \ell\ell\ell)$
SUSY SO(10) (NPB649(2003)189, PRD68(2003)033012)	10^{-8}	10^{-10}
SUSY Higgs (PLB549(2002)159, PLB566(2003)217)	10^{-10}	10^{-8}
Non-Universal Z′ (PLB547(2002)252)	10^{-9}	10^{-8}
SM+Seesaw (NPB437(1995)491, PRD66(2002)034008)	10^{-9}	10^{-10}

☞ Search for $\tau \to \ell\gamma/P^0$, $\tau \to \ell\ell\ell$, $\tau \to \ell h h'$ decays $(\ell = e, \mu; h = \pi, K)$

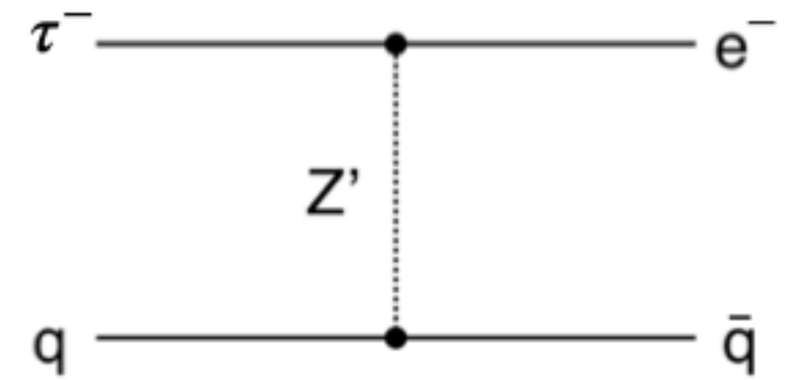
Tree level :



Compositeness

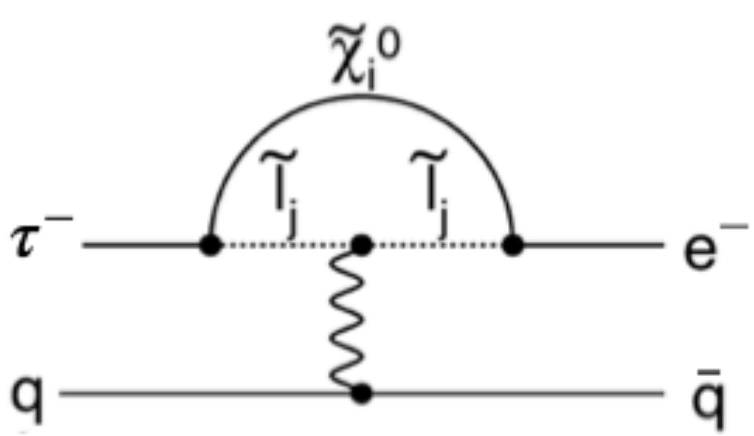


Leptoquarks

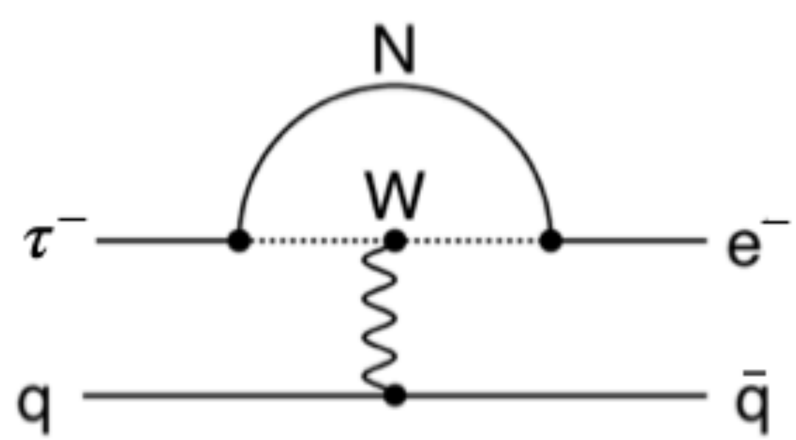


Heavy gauge bosons

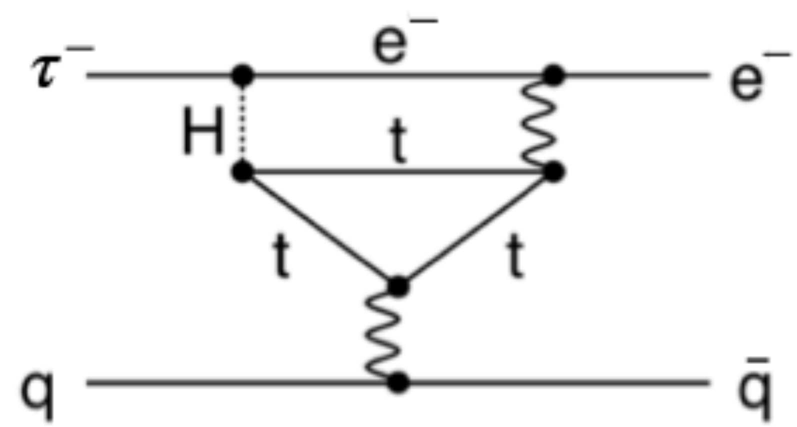
Loop induced :



Supersymmetry



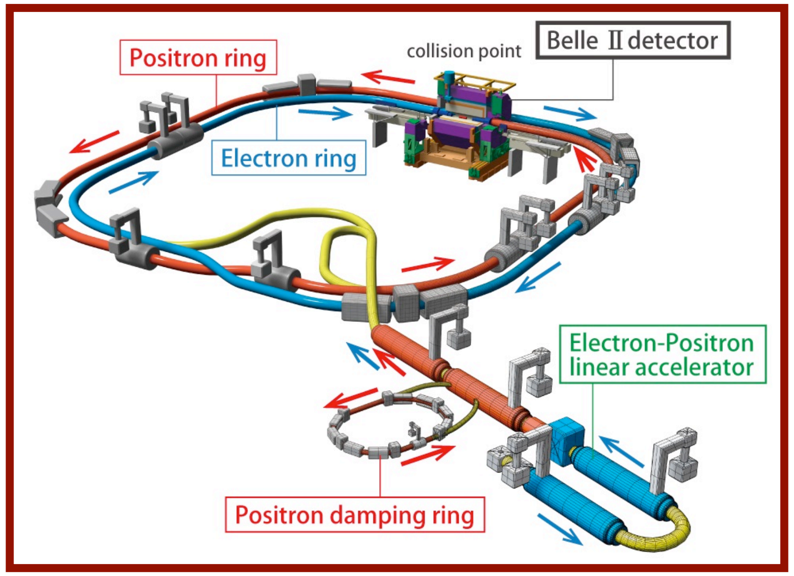
Heavy neutrinos



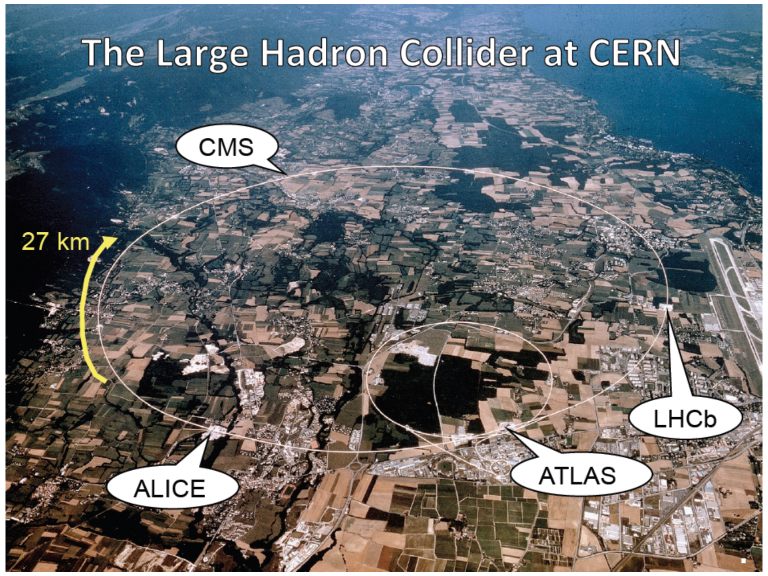
Extended Higgs models

Current and future experiments

Belle II at SuperKEKB

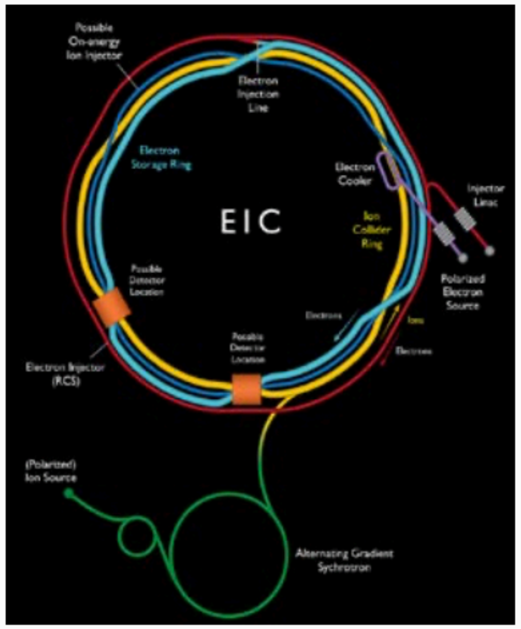


ATLAS, CMS, LHCb at LHC

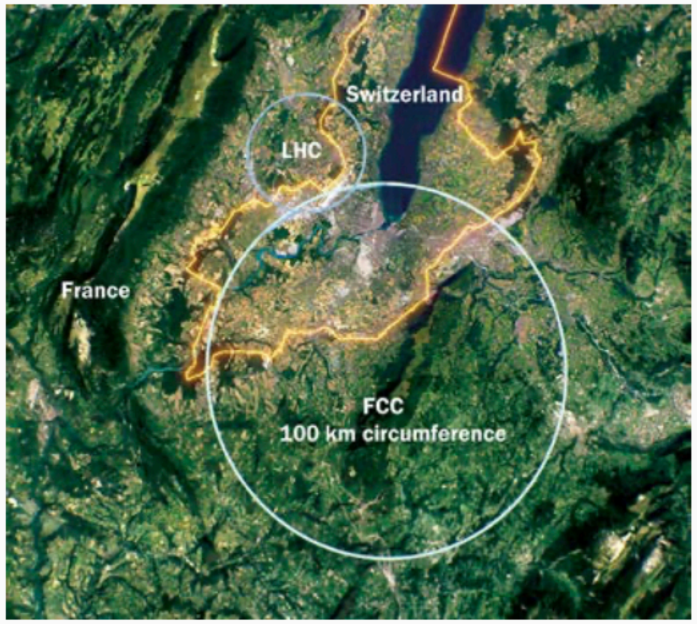


STCF proposal at China/Novosibirsk

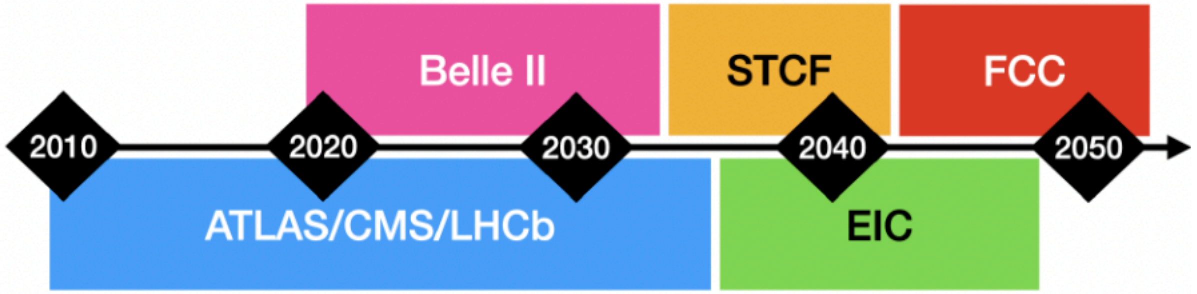
EIC at Brookhaven



FCC-ee proposal – CERN



Tentative timeline



Snowmass 2021 White Paper:

Charged lepton flavor violation in τ sector

e-Print: 2203.14919 [hep-ph]

About fifty τ decay modes & many transitions with τ in the final state

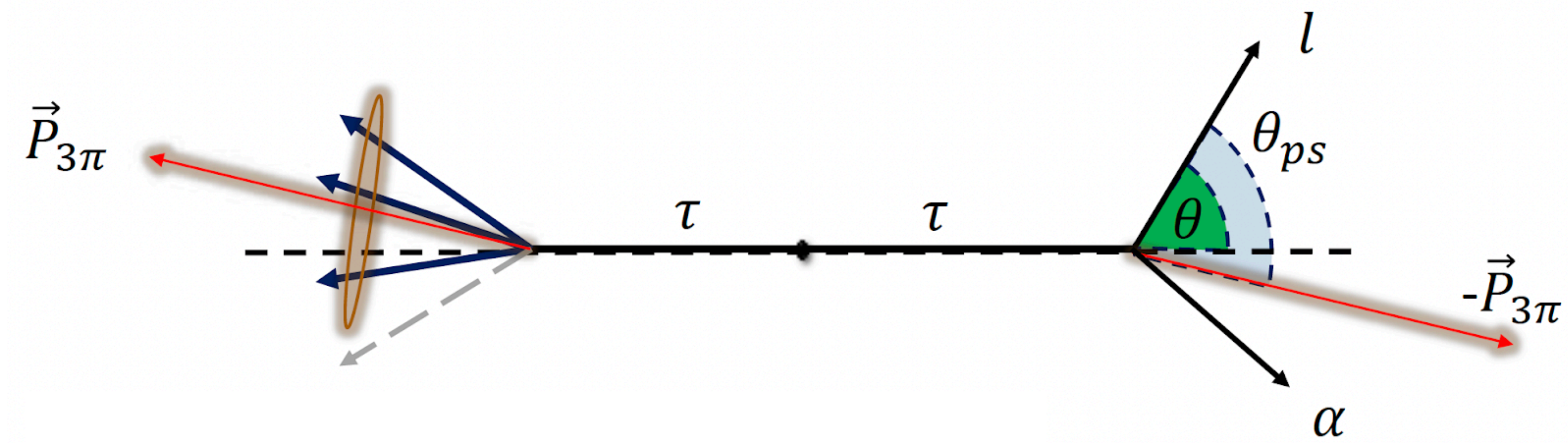
- **Lepton flavor violation (charge conjugate modes implied)**
  - $\tau \to e/\mu\ \gamma$ (Belle II, STCF, FCC-ee)
  - $\tau \to e/\mu$ (scalar/pseudoscalar/vector mesons) (Belle II)
  - $\tau \to e\ e\ e$ (Belle II)
  - $\tau \to \mu\ \mu\ \mu$ (Belle II, ATLAS, CMS, LHCb, STCF, FCC-ee)
  - $\tau \to e\ \mu\ \mu$, $\mu\ e\ e$ (Belle II)
  - $\tau \to e/\mu\ h\ h$ (non-resonant final states with $h=\pi/K$) (Belle II, STCF)
  - New $\tau \to e/\mu$ invisible (α) (Belle II) arXiv:2212.03634 [hep-ex], Submitted to PRL
  - $H \to e\ \tau$, $\mu\ \tau$ (ATLAS, CMS)
  - $Z(Z') \to e\ \tau$, $\mu\ \tau$ (ATLAS, CMS)
  - $e \to \tau$ transitions (EIC)

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

- **Baryon number violation**
  - $\tau^- \to \Lambda\ \pi^-$, $\bar{\Lambda}\ \pi^-$ (Belle II)
  - $\tau^- \to \bar{p}\ \mu^+\ \mu^-$, $p\ \mu^-\ \mu^-$ (Belle II, LHCb)

$\tau \to \ell\alpha$ 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.

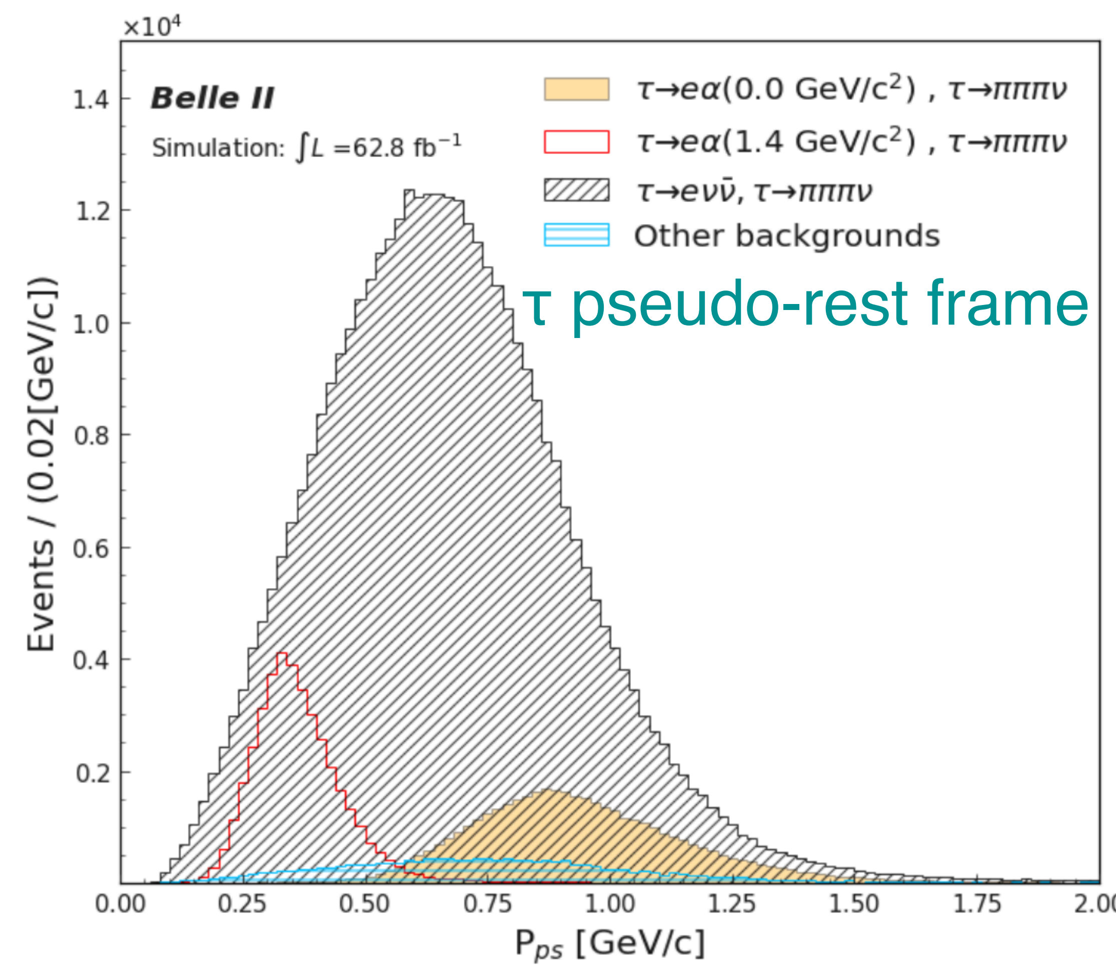


L. Calibbi, D. Redigolo, R. Ziegler, J. Zupan, JHEP 09 (2021) 173 arXiv:2006.04795 **[hep-ph]**

Signature of the signal process

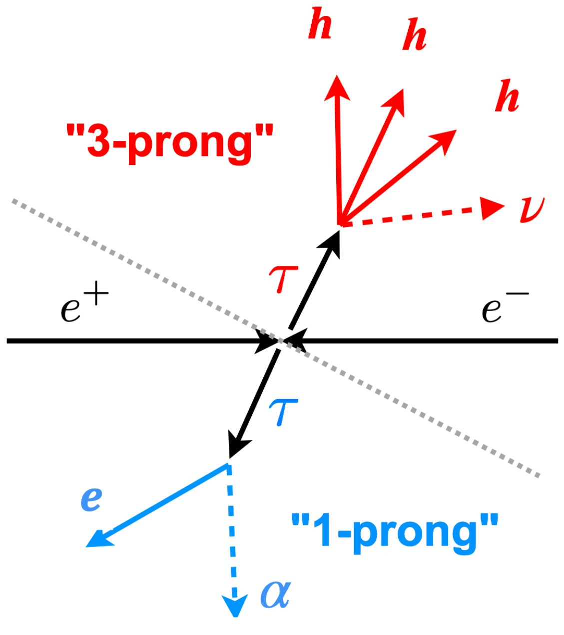
2-body $\tau \to \ell\alpha$ decay will appear as a bump against the SM 3-body $\tau \to \ell\nu\bar{\nu}$ background in the p_ℓ distribution in the τ pseudo-rest frame:

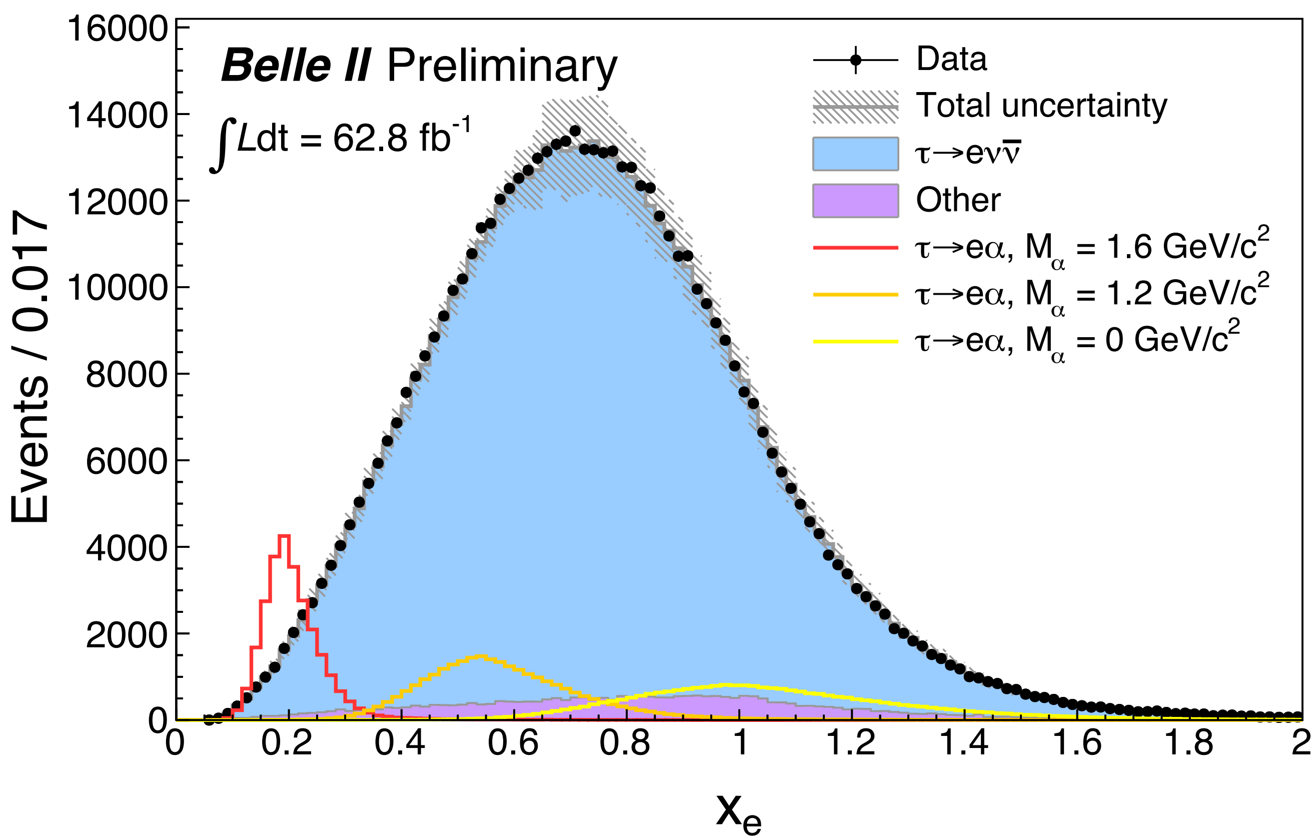
$$\hat{p}_\tau \approx -\frac{\vec{p}_{tag}}{|\vec{p}_{tag}|}, \quad E_\tau \approx \sqrt{s}/2$$

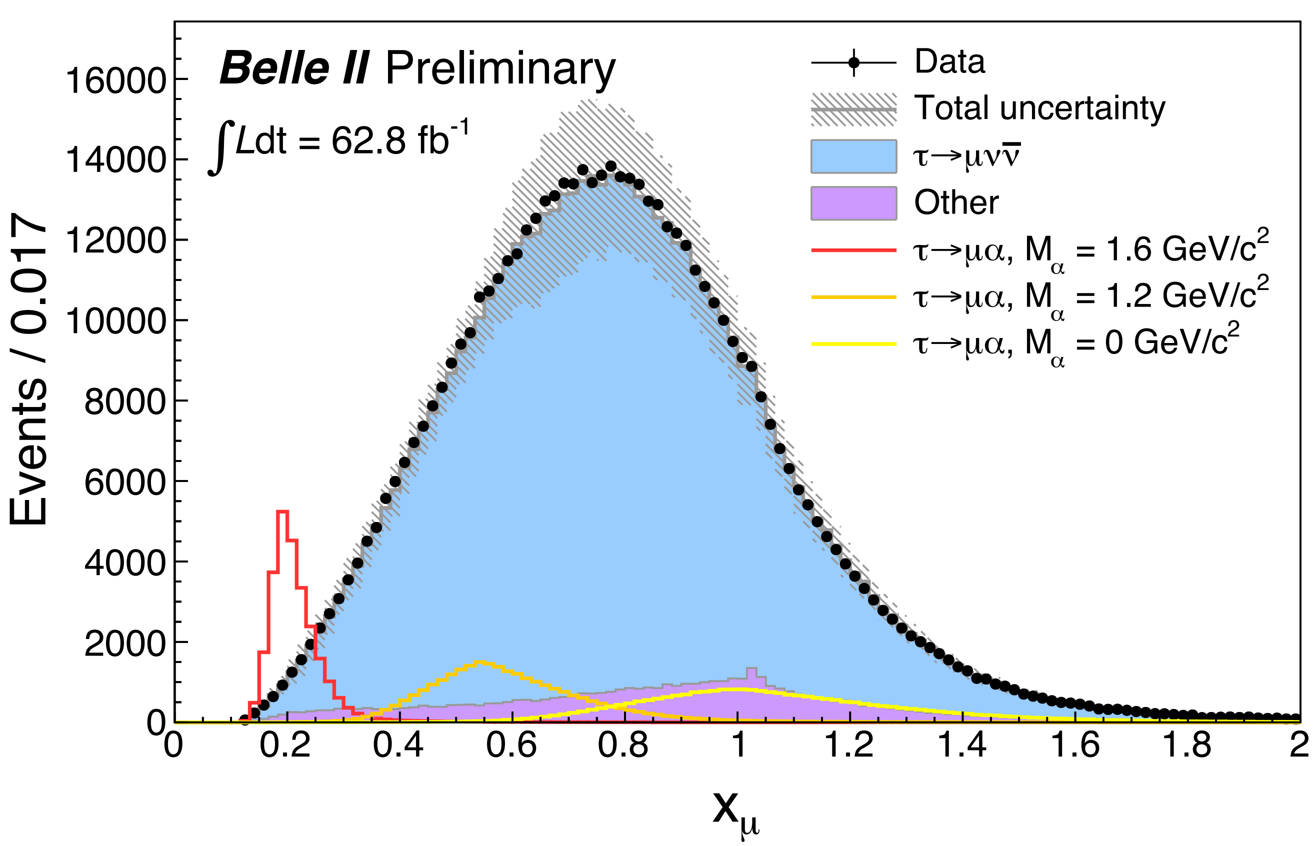


$\tau \to \ell\alpha$ at Belle II

- Event reconstruction:
  - Split event into hemispheres ⊥ to thrust axis ($\hat{n}_T$) which maximizes Thrust = $\max\left(\sum|\vec{p}_i|\cdot\hat{n}_T\right)/\left(\sum|\vec{p}_i|\right)$
  - Require exactly 4 tracks: 1 in signal-side, 3 in tag-side
  - Veto neutrals (π^0,γ) to suppress hadronic background.
- Backgrounds reduced by cuts:
  - $q\bar{q}$, $\ell^+\ell^-$, $\ell^+\ell^-\ell^+\ell^-$, $\ell^+\ell^-h^+h^-$ and $\tau^+\tau^-$ with misidentified signal (e.g. $\tau \to \pi\nu$)
- Data-MC agreement in the discriminating variable: $x_\ell = 2E_\ell^{ps}/m_\tau$

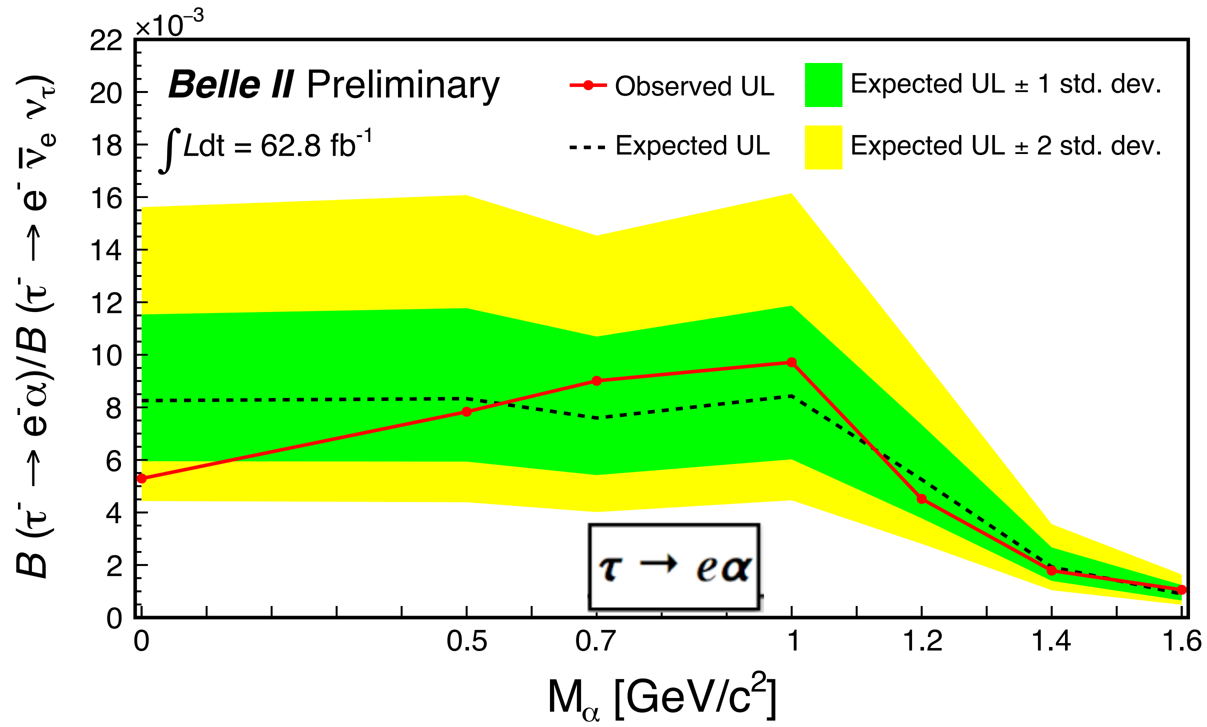


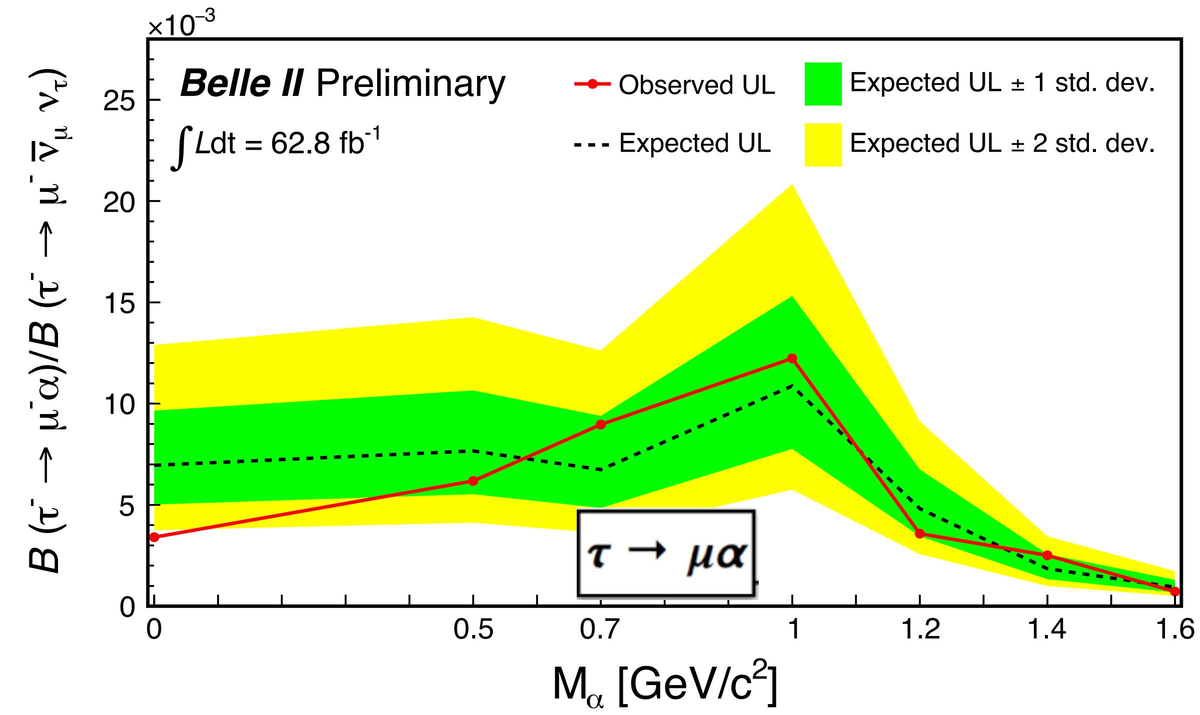




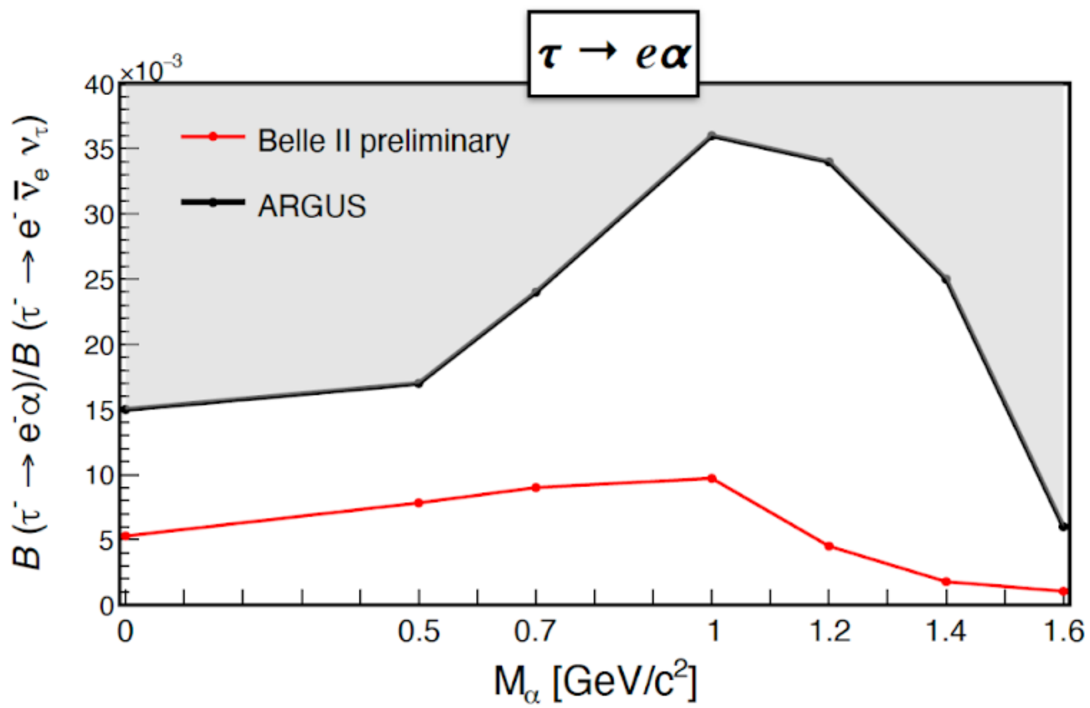
$\tau \rightarrow \ell\alpha$ at Belle II

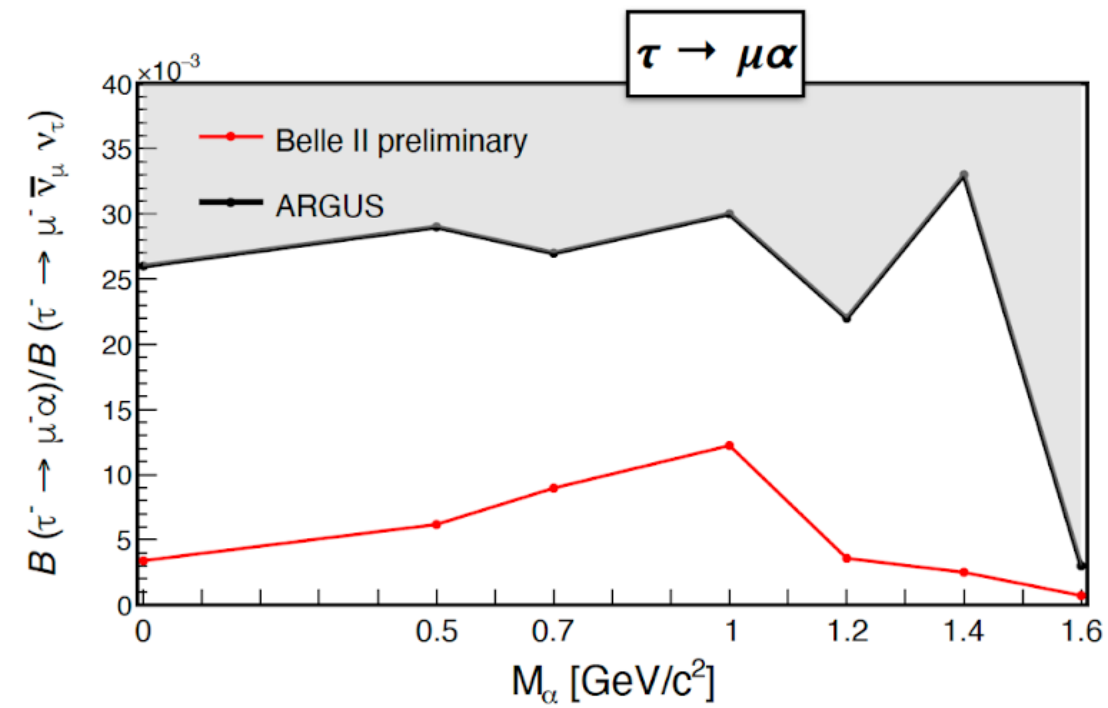
95% C.L. upper limits from Belle II [arXiv:2212.03634 (hep-ex), Subm. to PRL]





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**

Trigger	Reco	Topology	PID	Cuts	Signal–Box
90%	70%	70%	50%	50%	50%

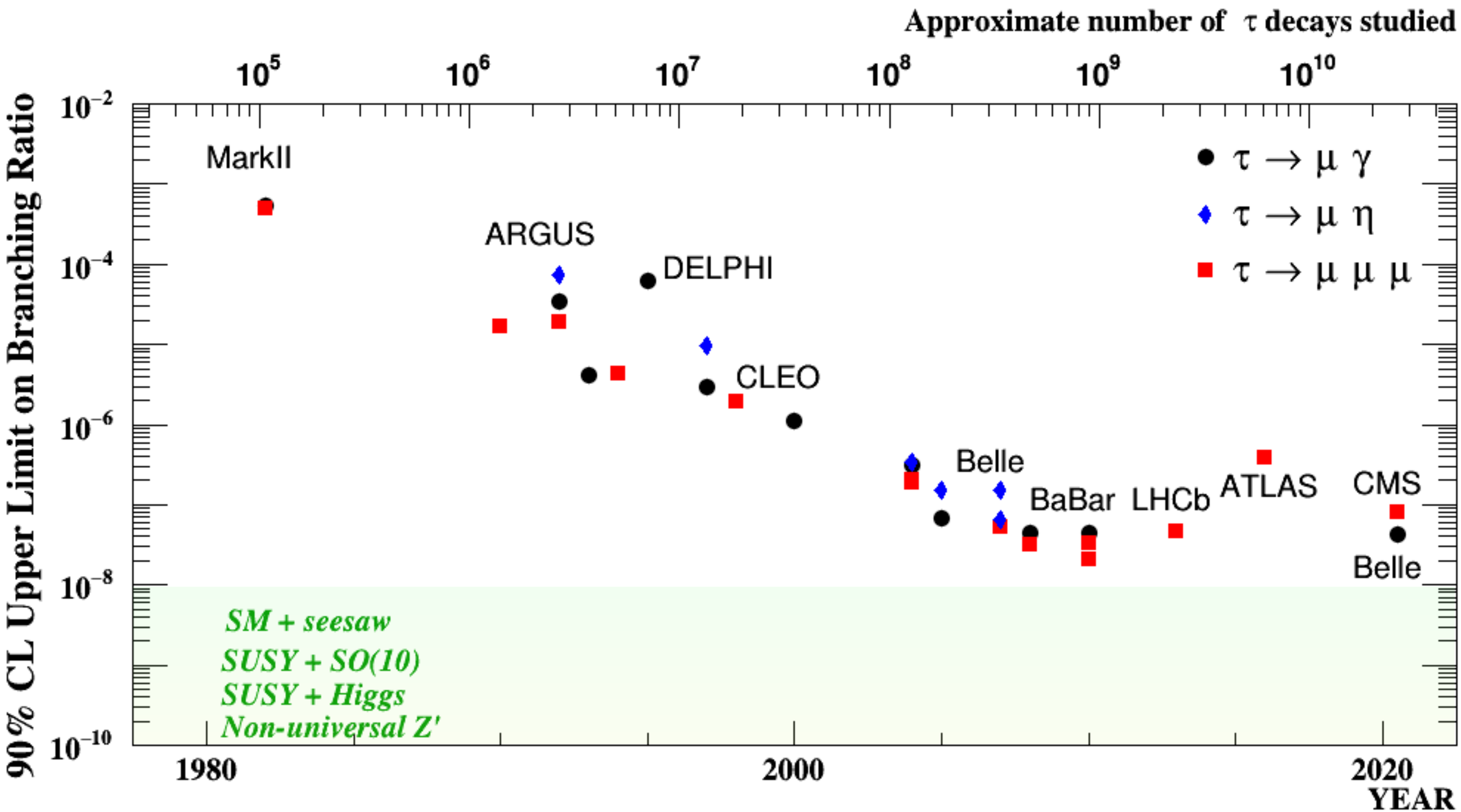
Cumulative:

Trigger	Reco	Topology	PID	Cuts	Signal–Box
90%	63%	44%	22%	11%	~5%

	$\sqrt{s}$	Luminosity (L)	$N_\tau = 2L\sigma$
Belle II	10.58 GeV	50 ab^{-1}	9.2×10^{10}
HL-LHC	14 TeV	3 ab^{-1}	$\mathcal{O}(10^{15})$
STCF	2-7 GeV	1 ab^{-1}	7.0×10^{9}
FCC-ee	91.2 GeV	150 ab^{-1}	3.4×10^{11}

(Efficiency much lower)

Current status of LFV τ decays ~ 10^{-7}



$\tau \to \mu\mu\mu$ at Belle II

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

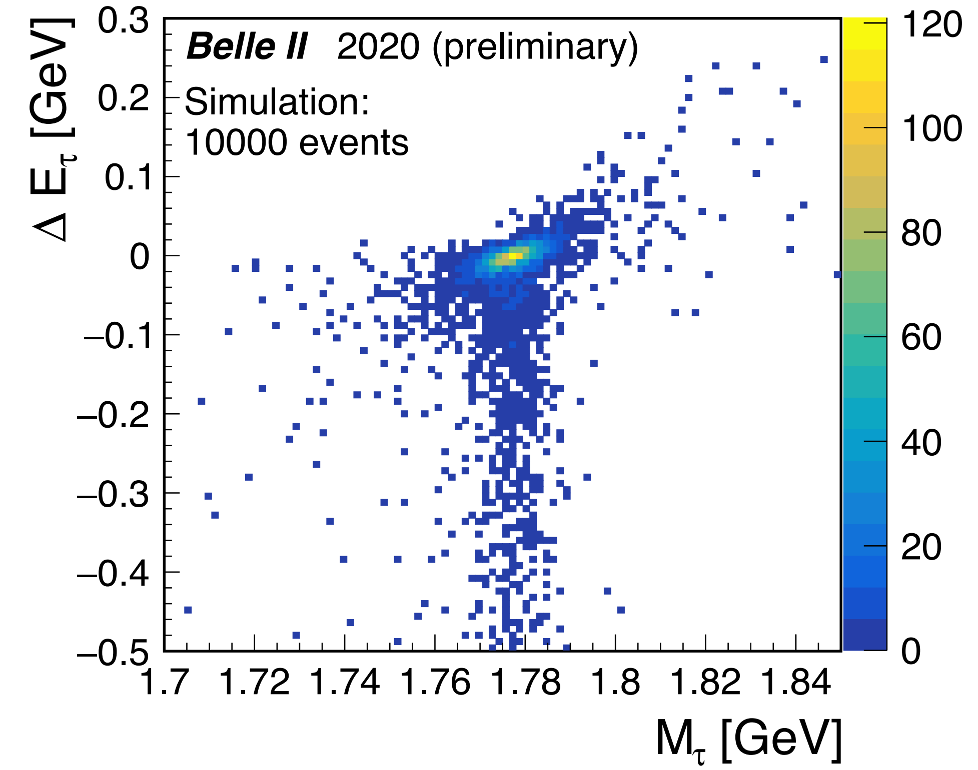
Two independent variables:

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

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

➡ 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

- **higher trigger efficiencies**
- **improved vertexing detectors**
- **upgraded tracking /calorimetry**
- **momentum dependent particle identification optimizations**

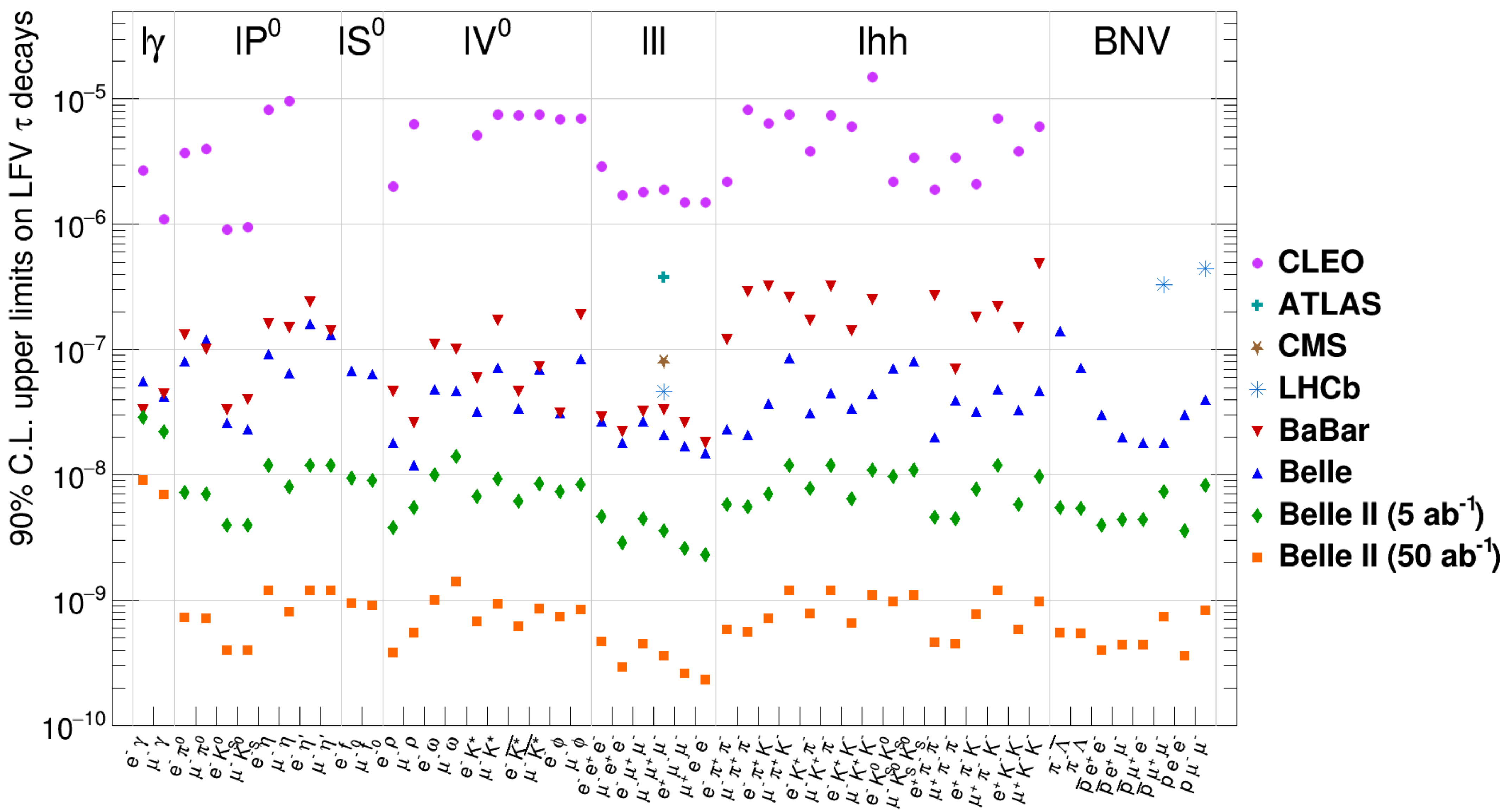
Expected Belle II sensitivity: $\mathscr{B}(\tau \to \mu\mu\mu) < 3.6 \times 10^{-10}$ with 50 ab^{-1}

Projected limits at Belle II

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

2207.06306 [hep-ex]

	Background limited search	*Background free search*
$N_{\rm UL}^{90}$	$\sqrt{\mathcal{L}}$	2.44 [Feldman – Cousins for $N_{obs} = 0$]
$B_{\rm UL}^{90}$	$\propto 1/\sqrt{\mathcal{L}}$	$\propto 1/\mathcal{L}$

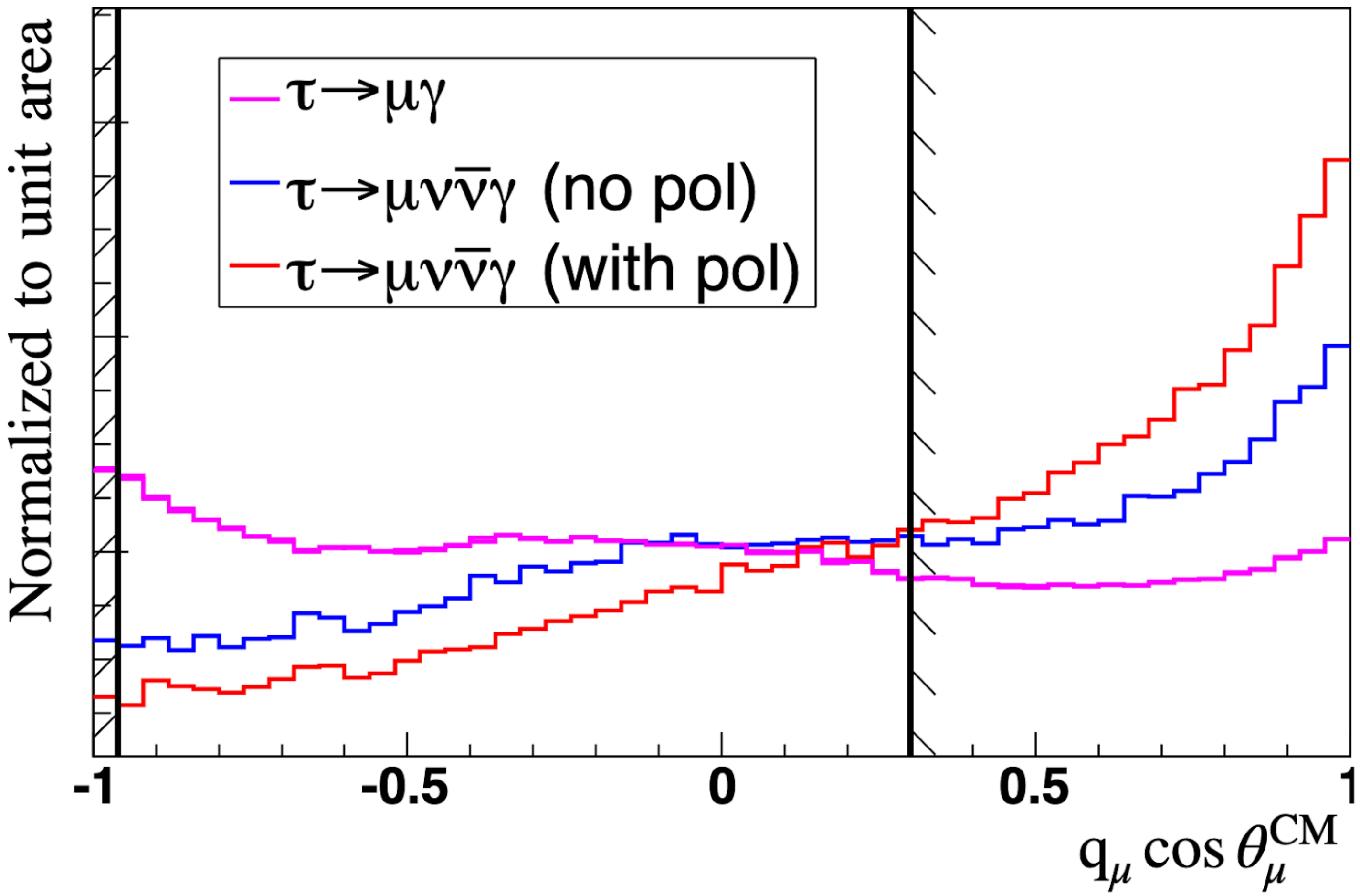


Projections

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

Beam polarization upgrade at SuperKEKB/Belle II

- Further improvements are expected with polarized beams
- With beam polarization, helicity distributions can suppress backgrounds
- Optimization study shows at least 10% improvement in $\tau \to \ell\gamma$ sensitivity



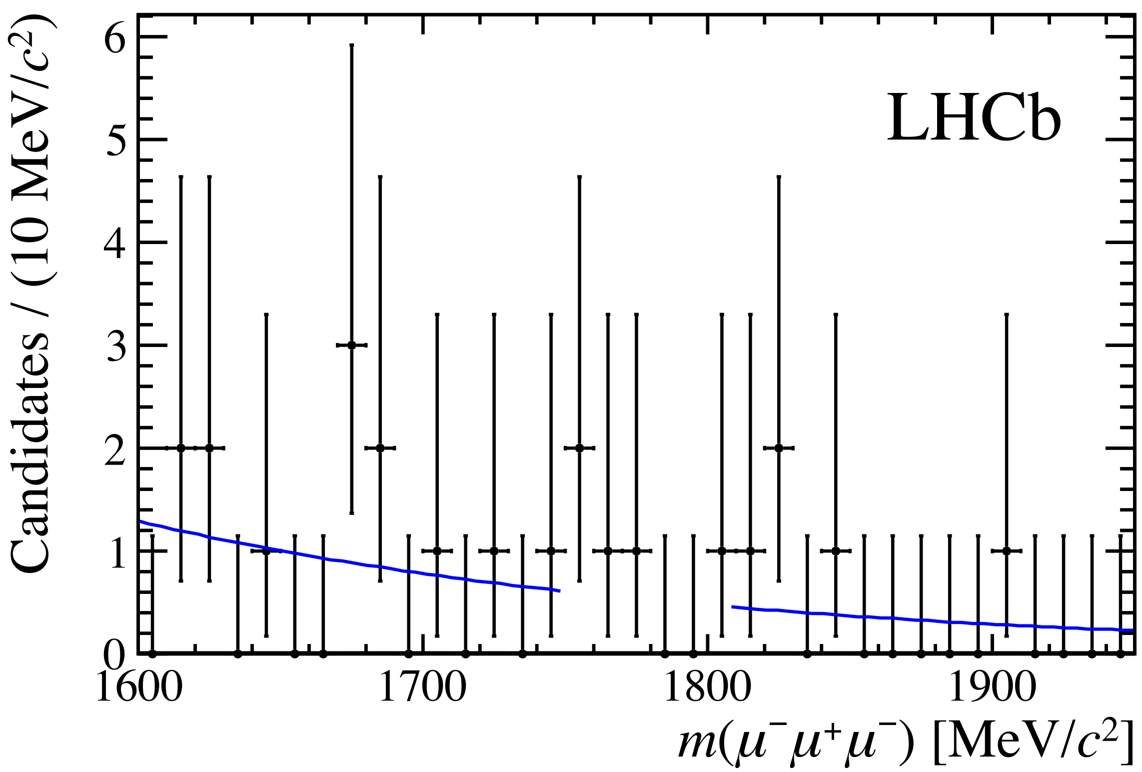
https://arxiv.org/pdf/0810.1312.pdf

$\tau \to \mu\gamma$: model assumes uniform phase space, no preferential direction with unpolarized beams

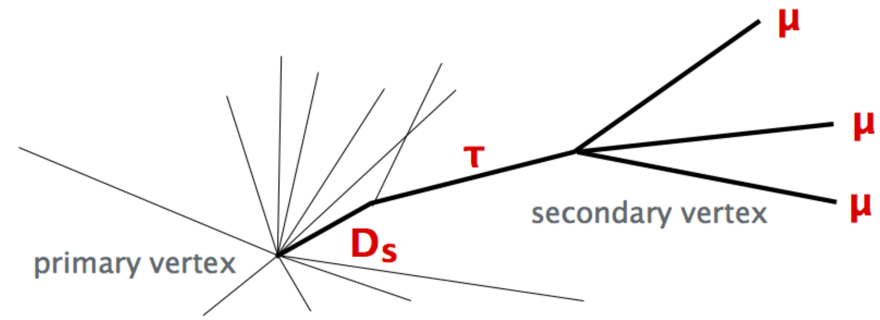
$\tau \to \mu\nu\bar{\nu}\gamma$: polarized e- beams $\Rightarrow$ forward peaking helicity distribution, which can enhance background suppression.

Intriguing aspect of having the polarization is the possibility to determine the helicity structure of the LFV coupling in $\tau \to \mu\mu\mu$ from Dalitz plots.

$\tau \to \mu\mu\mu$ at LHCb



Using D decays (3fb^{-1} at 7/8 TeV)



$$\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) = \frac{\mathcal{B}(D_s^- \to \phi(\mu^+\mu^-)\pi^-)}{\mathcal{B}(D_s^- \to \tau^-\bar{\nu}_\tau)} \times f_\tau^{D_s} \times \frac{\epsilon_{\rm cal}^{\rm R}}{\epsilon_{\rm sig}^{\rm R}} \times \frac{\epsilon_{\rm cal}^{\rm T}}{\epsilon_{\rm sig}^{\rm T}} \times \frac{N_{\rm sig}}{N_{\rm cal}} \equiv \alpha N_{\rm sig}$$

- LHCb limit on the $\tau^- \to \mu^-\mu^+\mu^-$ branching ratio

$$\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 4.6 \times 10^{-8} \quad @ \ 90\% \text{ C.L.}$$

JHEP 02 (2015) 121

LHCb-PUB-2018-009

The cross-section is five orders of magnitude larger than at Belle II. This compensates for the higher background levels and lower integrated luminosity. As pointed out in [76], during the HL-LHC era, the LHCb Upgrade II detector will allow to collect 300 fb^{-1}. With this large data sample, LHCb will be able to probe the branching ratio down to $O(10^{-9})$, and either independently confirm any Belle II discovery or significantly improve the limit.

$\tau \to \mu\mu\mu$ at ATLAS & CMS

- ATLAS limit on the $\tau^- \to \mu^-\mu^+\mu^-$ branching ratio

$$\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 3.76 \times 10^{-7} \quad @\,90\%\ \text{C.L.}$$

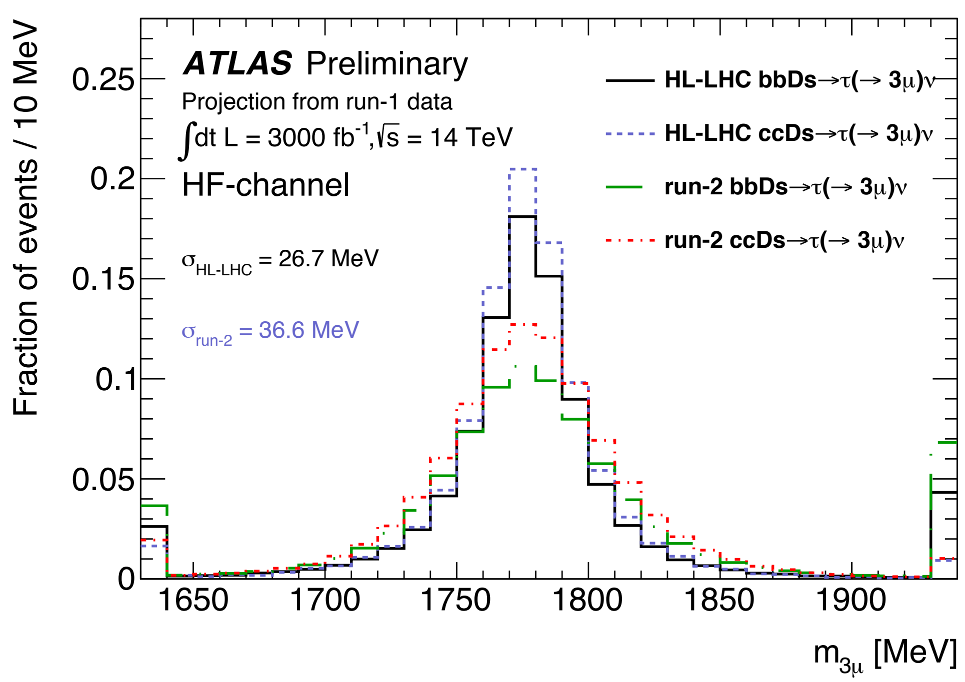
(20 fb^{-1} at 8 TeV)
Eur. Phys. J. C (2016) 76:232

- CMS limit on the $\tau^- \to \mu^-\mu^+\mu^-$ branching ratio

$$\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 8.0 \times 10^{-8} \quad @\,90\%\ \text{C.L.}$$

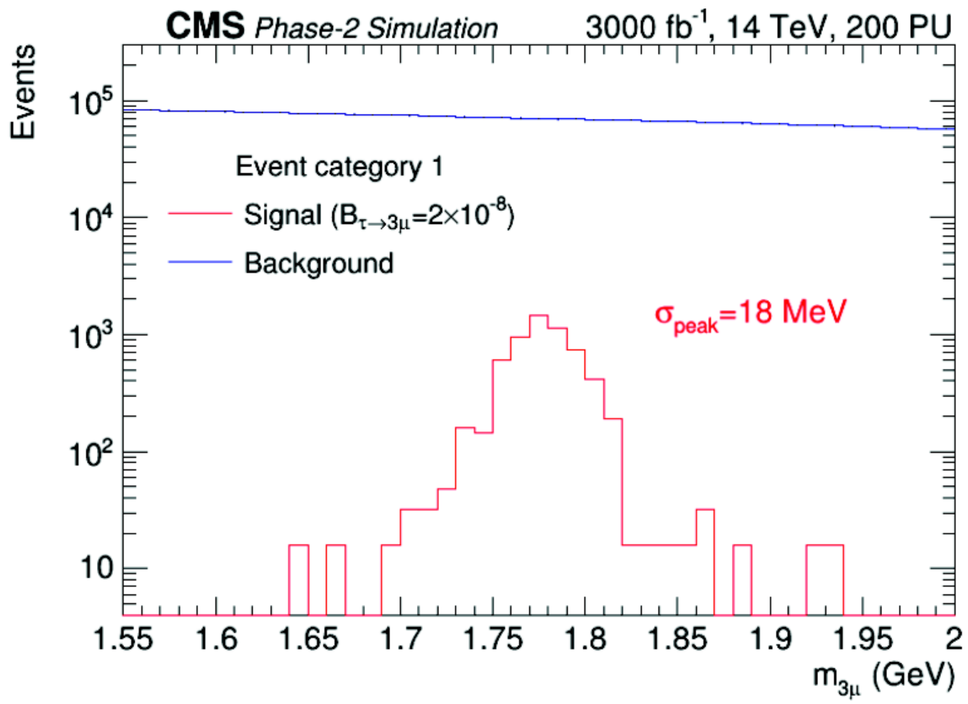
(33 fb^{-1} at 13 TeV)
JHEP 01 (2021) 163

Future prospects using D & B decays (3 ab^{-1} at 14 TeV) :



ATL-PHYS-PUB-2018-032

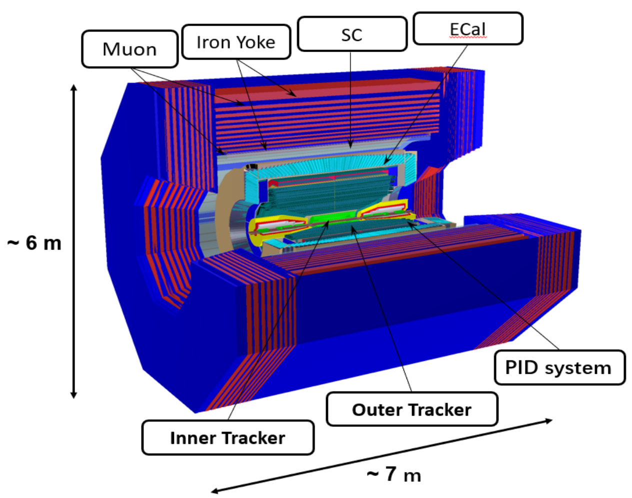
Scenario	$\mathcal{A} \times \epsilon$ [%]	N^{exp}_{bkg}	90% CL UL on BR($\tau \to 3\mu$) [10^{-9}]
High background	0.88	507.05	6.40
Medium background	0.88	152.12	2.31
Low background	0.88	50.71	1.03



CMS-TDR-016

	Category 1	Category 2
Number of background events	2.4×10^6	2.6×10^6
Number of signal events	4 580	3 640
Trimuon mass resolution	18 MeV	31 MeV
$B(\tau \to 3\mu)$ limit per event category	4.3×10^{-9}	7.0×10^{-9}
$B(\tau \to 3\mu)$ 90%C.L. limit	3.7×10^{-9}	

Super Tau-Charm Facility

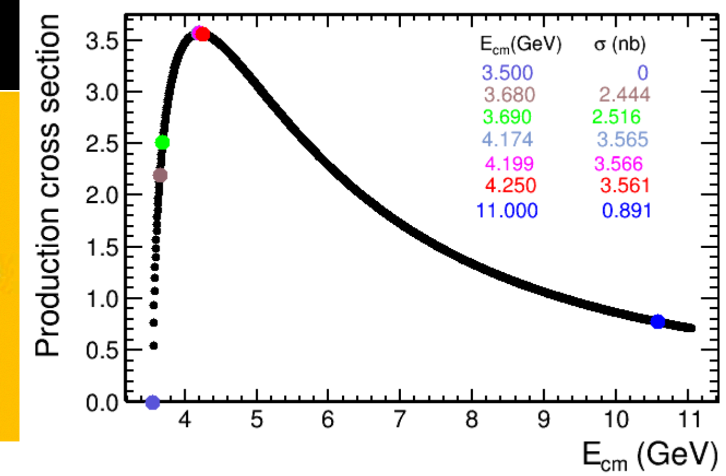


"Physics Potential of a Super tau-Charm Facility" (RF/SNOWMASS21-RF7_RF1_STCF-013.pdf)

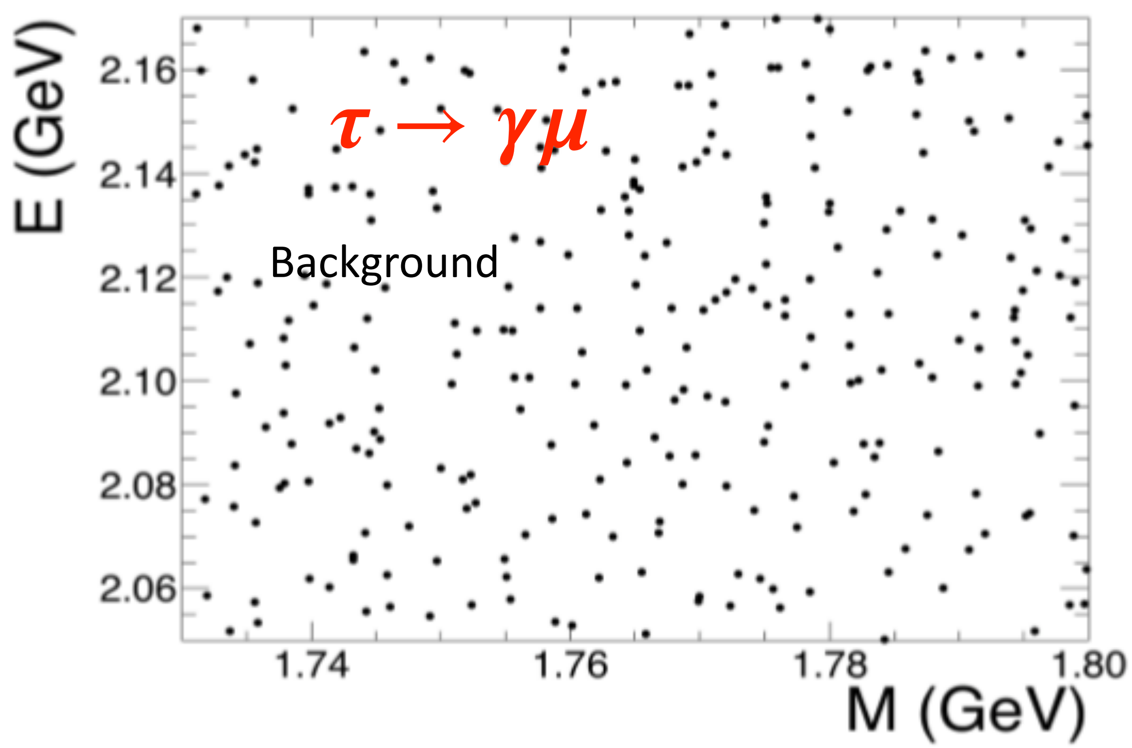
- Peaking luminosity >0.5×10^{35} $cm^{-2}s^{-1}$ at 4 GeV
- Energy range E_{cm} = 2-7 GeV
- Potential to increase luminosity and realize beam polarization
- A nature extension and a viable option for China accelerator project in the post BEPCII/BESIII era

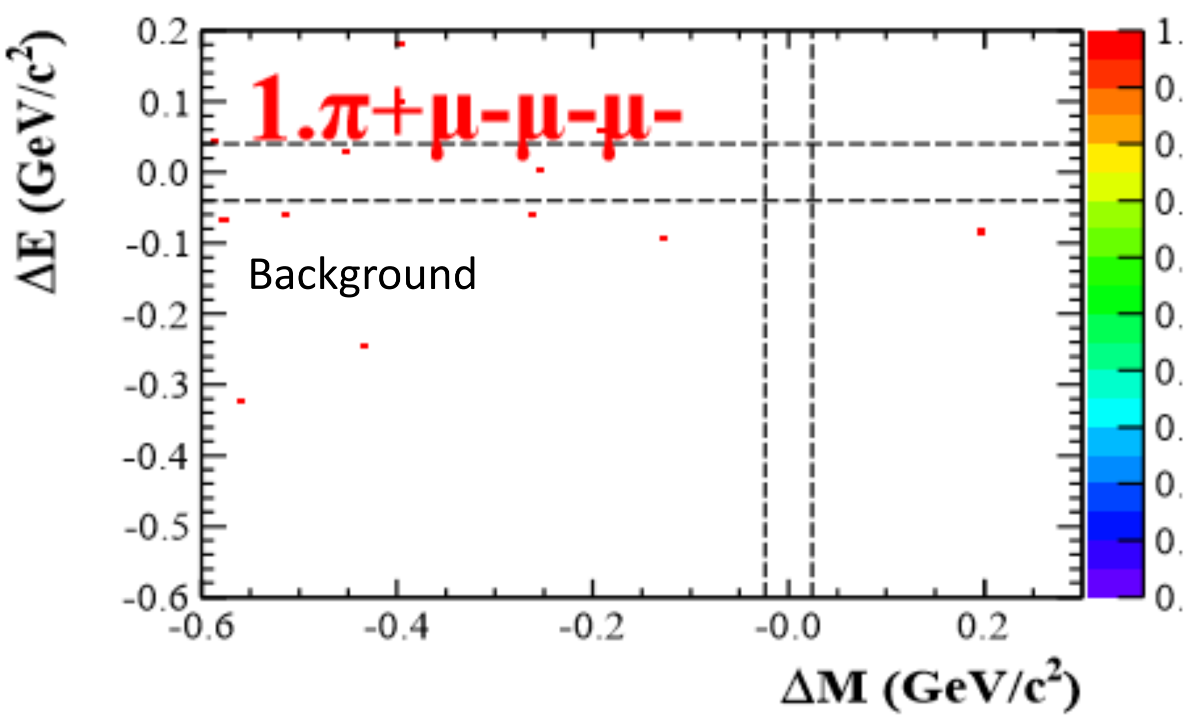
PoS CHARM2020 (2021), 007

Physics 49 (2020) 8, 513-524



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





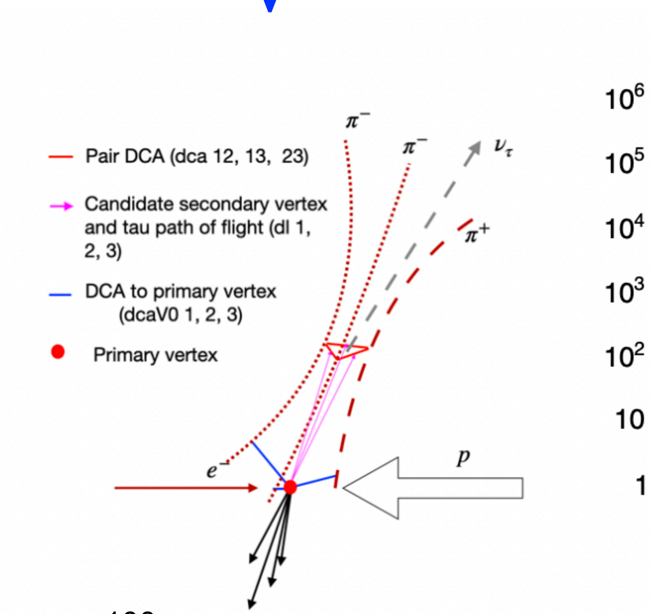
➢ **STCF with 1ab^-1:**

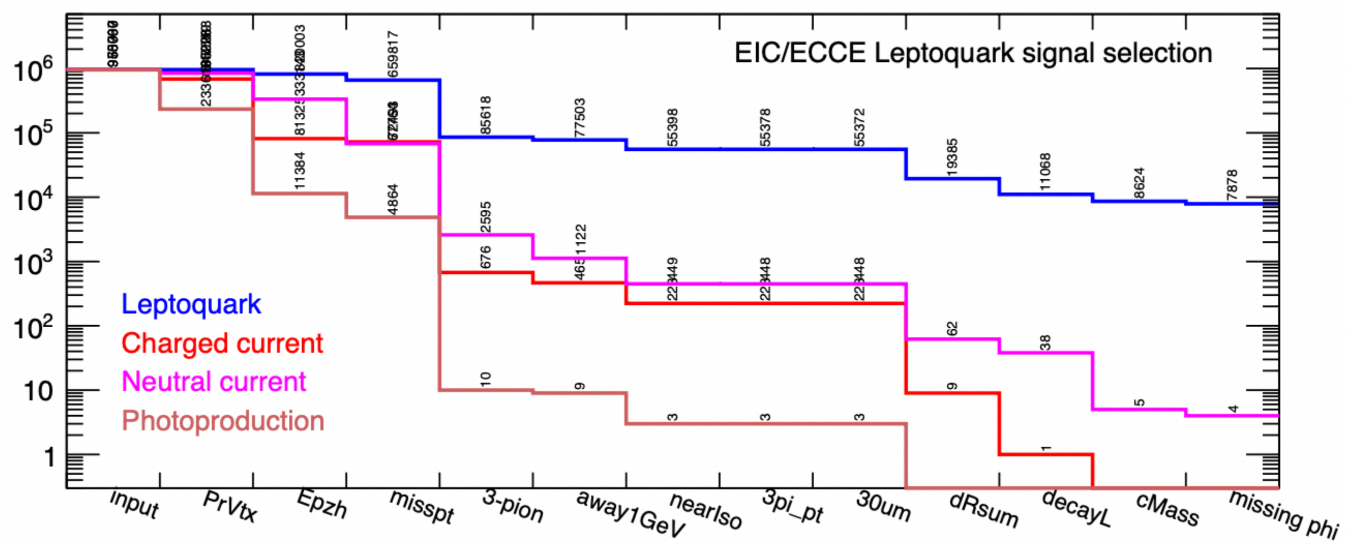
$$\mathcal{B}^{90}_{UL}(\tau\to\gamma\mu) < \frac{N^{90}_{UL}}{2\varepsilon N_{\tau\tau}} \sim 1.2\times10^{-8}$$

➢ **STCF with 1ab^-1:**

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

Sensitivity study with 100 fb^{-1} of data to be collected at $\sqrt{s}$ =140 GeV (18 GeV electron on 275 GeV protons)

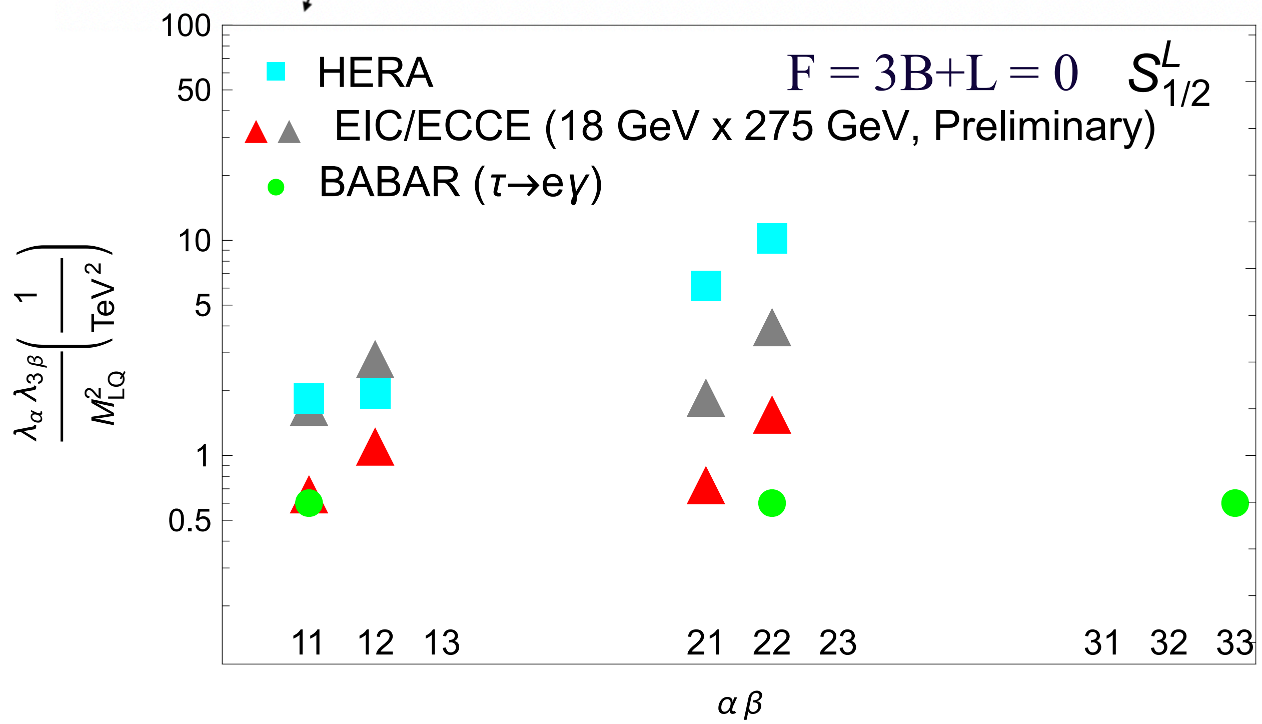


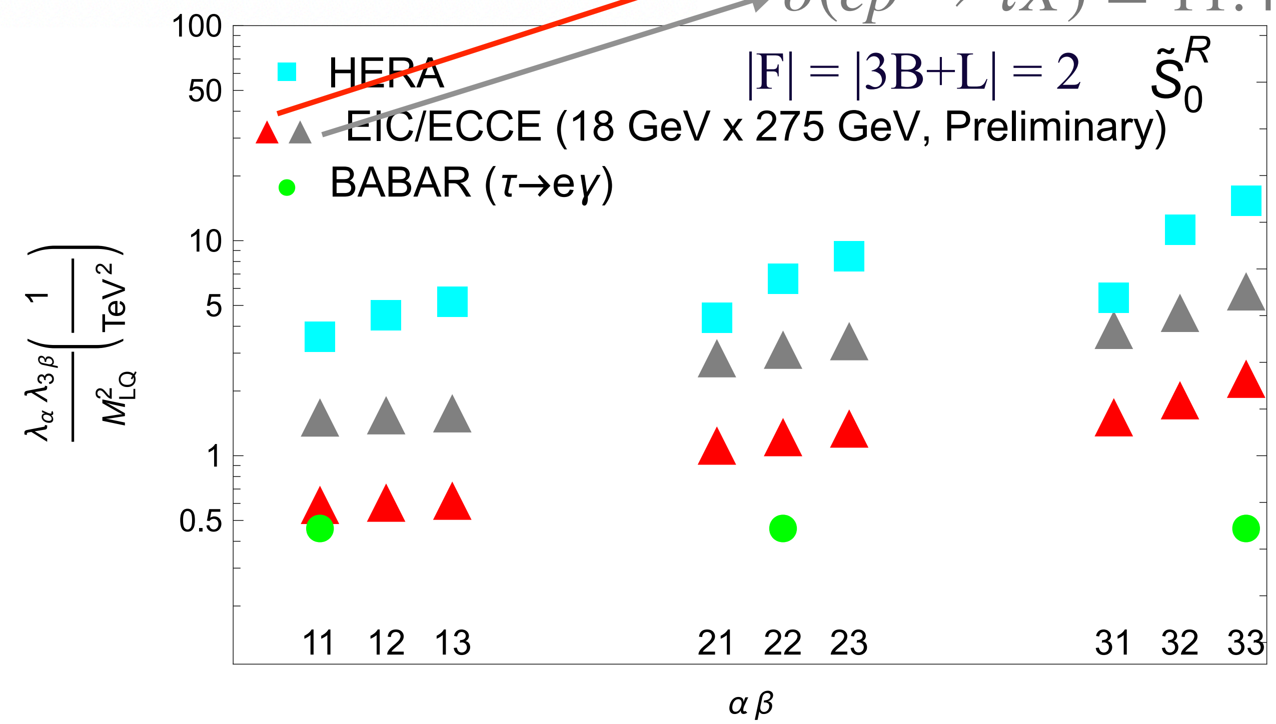


e-Print: 2207.10261 [hep-ph]

$\sigma(ep \to \tau X) = 1.7\ fb$

$\sigma(ep \to \tau X) = 11.4\ fb$



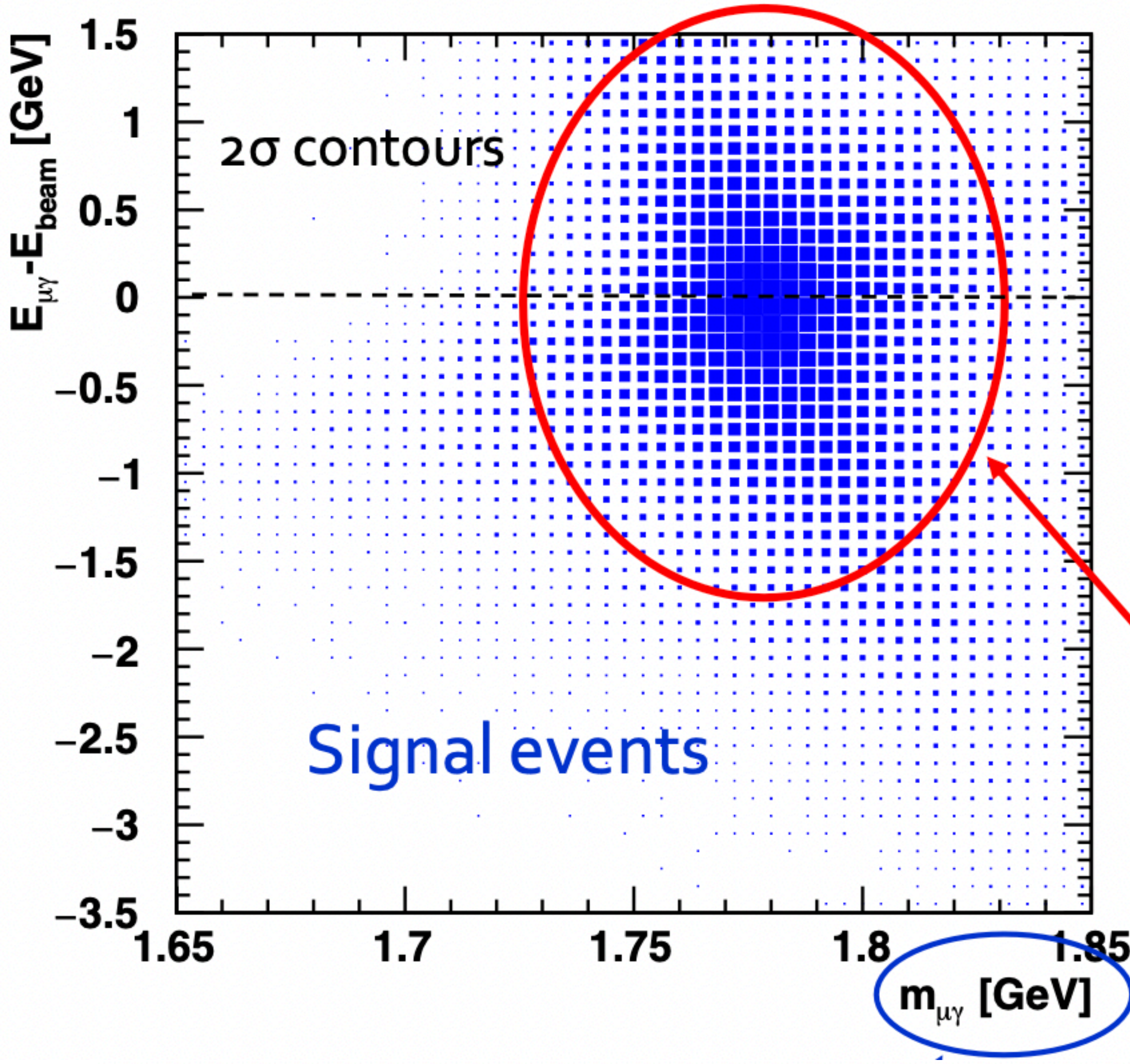


Expect to improve current sensitivity by an order of magnitude

FCC-ee

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

e-Print: 1811.09408 [hep-ex]



- **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

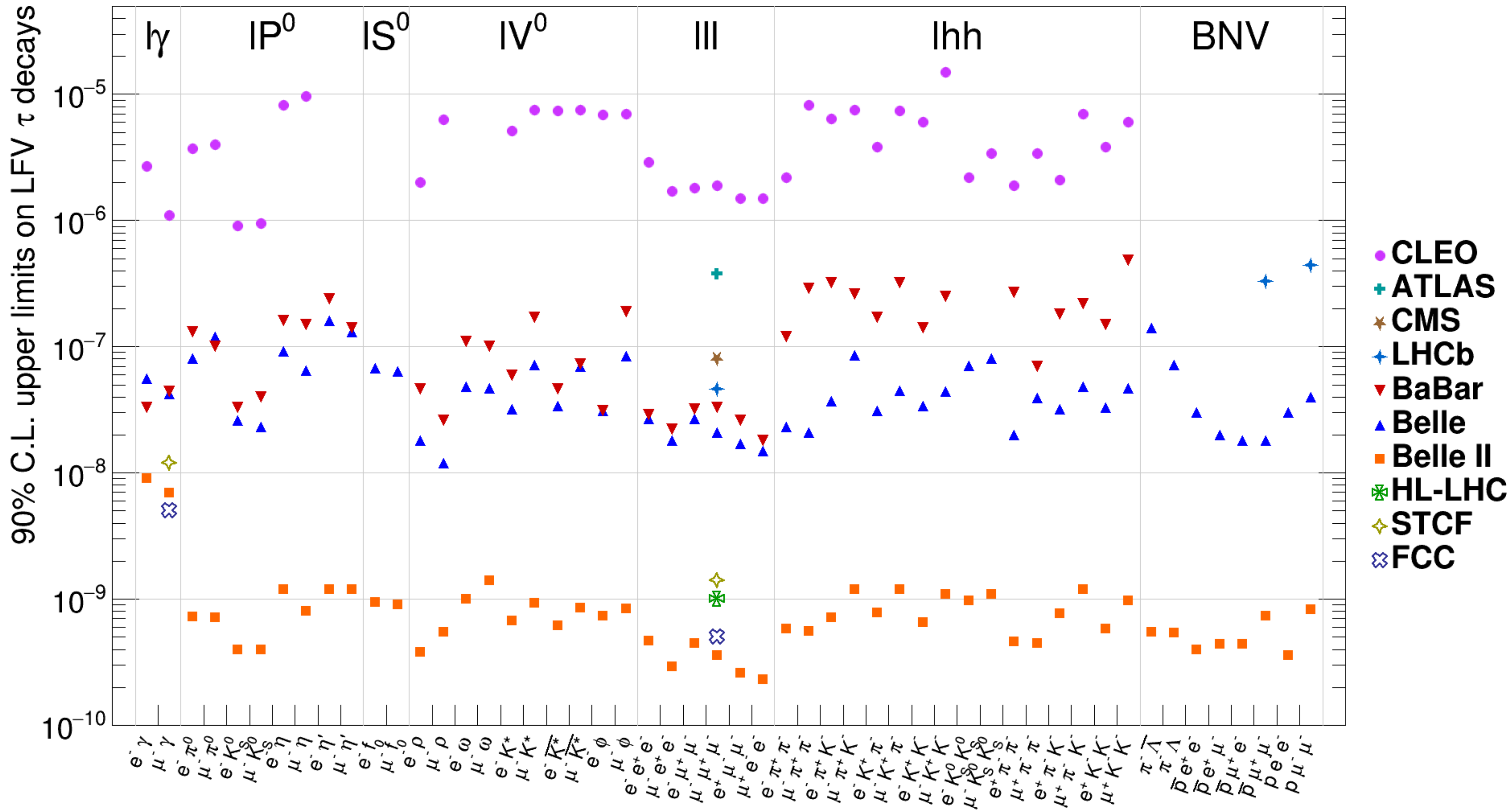
- From study (assuming 25% signal & background efficiency), projected BR sensitivity **2×10^{-9}**

$\mathcal{B}(\tau \to \mu\mu\mu)$

- Expect this search to have *very low* background, even with FCC-ee like statistics
- Should be able to have sensitivity down to BRs of $\lesssim 10^{-10}$

Summary of experimental prospects of τ decays

Snowmass 2021 White Paper: Charged lepton flavor violation in τ sector



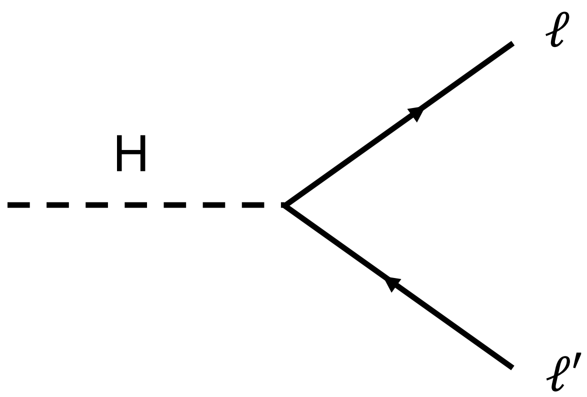
[e-Print: 2203.14919 [hep-ph]]

Summary of transitions with τ in the final state

Channel	Upper limit	Experiment [Ref.]
$J/\psi \to e^\pm\tau^\mp$	7.5×10^{-8}	BES III [108]
$J/\psi \to \mu^\pm\tau^\mp$	2.0×10^{-6}	BES [109]
$B^0 \to e^\pm\tau^\mp$	2.8×10^{-5}	BaBar [110]
$B^0 \to \mu^\pm\tau^\mp$	2.2×10^{-5}	BaBar [110]
	1.2×10^{-5}	LHCb [62]
$B^+ \to \pi^+e^\pm\tau^\mp$	7.5×10^{-5}	BaBar [111]
$B^+ \to \pi^+\mu^\pm\tau^\mp$	7.2×10^{-5}	BaBar [111]
$B^+ \to K^+e^\pm\tau^\mp$	3.0×10^{-5}	BaBar [111]
$B^+ \to K^+\mu^\pm\tau^\mp$	4.8×10^{-5}	BaBar [111]
$B^+ \to K^+\mu^-\tau^+$	3.9×10^{-5}	LHCb [63]
$B_s^0 \to \mu^\pm\tau^\mp$	3.4×10^{-5}	LHCb [62]
$\Upsilon(1S) \to e^\pm\tau^\mp$	2.7×10^{-6}	Belle [112]
$\Upsilon(1S) \to \mu^\pm\tau^\mp$	2.7×10^{-6}	Belle [112]
$\Upsilon(2S) \to e^\pm\tau^\mp$	3.2×10^{-6}	BaBar [113]
$\Upsilon(2S) \to \mu^\pm\tau^\mp$	3.3×10^{-6}	BaBar [113]
$\Upsilon(3S) \to e^\pm\tau^\mp$	4.2×10^{-6}	BaBar [113]
$\Upsilon(3S) \to \mu^\pm\tau^\mp$	3.1×10^{-6}	BaBar [113]
$Z \to e^\pm\tau^\mp$	5.0×10^{-6} (*)	ATLAS [69]
$Z \to \mu^\pm\tau^\mp$	6.5×10^{-6} (*)	ATLAS [69]
$H \to e^\pm\tau^\mp$	0.47% (*)	ATLAS [65]
	0.22% (*)	CMS [66]
$H \to \mu^\pm\tau^\mp$	0.28% (*)	ATLAS [65]
	0.15% (*)	CMS [66]
	26% (*)	LHCb [64]

Table 2: Bounds on selected LFV decays with τ in the final state are shown at 90% CL, except for limits on those decays marked with a $(*)$, which are quoted at 95% CL.

e-Print: 2203.14919 [hep-ph]



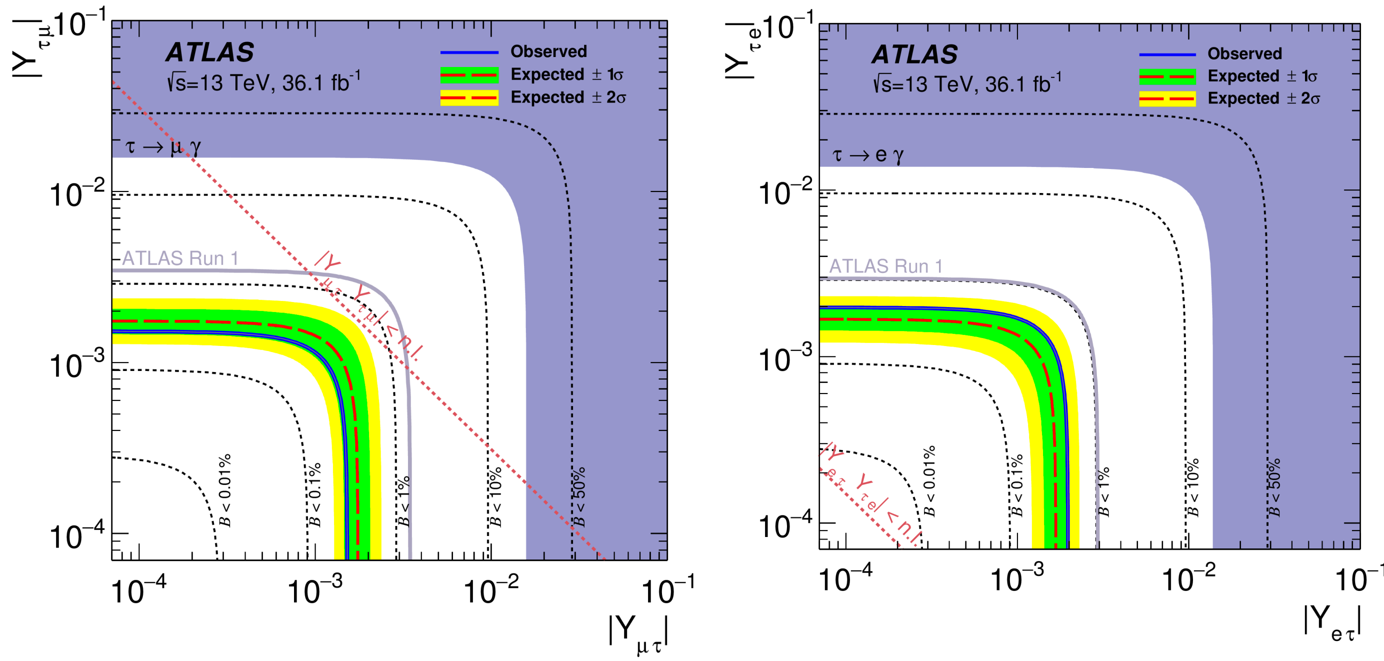
Yukawa off-diagonal terms

$$\mathcal{L}_Y = -m_i \bar{f}_L^i f_R^i - Y_{ij} (\bar{f}_L^i f_R^j) h + h.c. + \cdots ,$$

In the SM: $Y_{ij} = (m_i / v) \delta_{ij}$

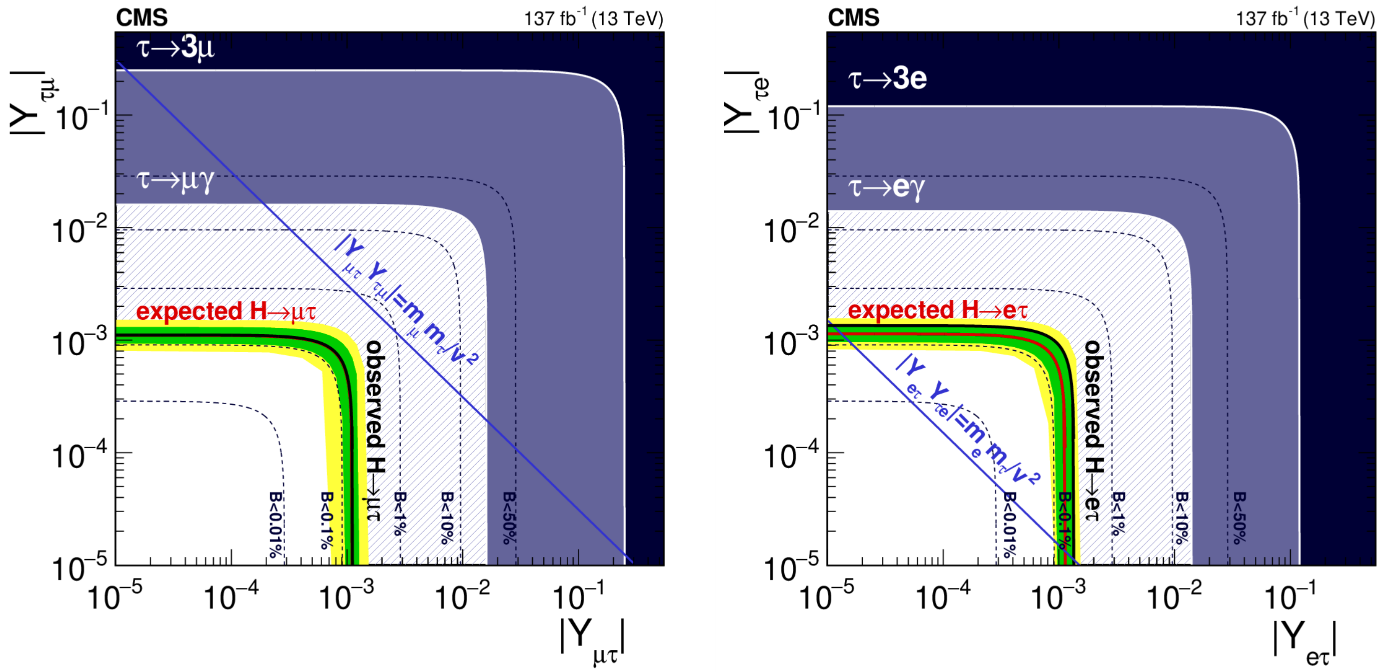
ATLAS

[Phys. Lett. B 800 (2020) 135069]



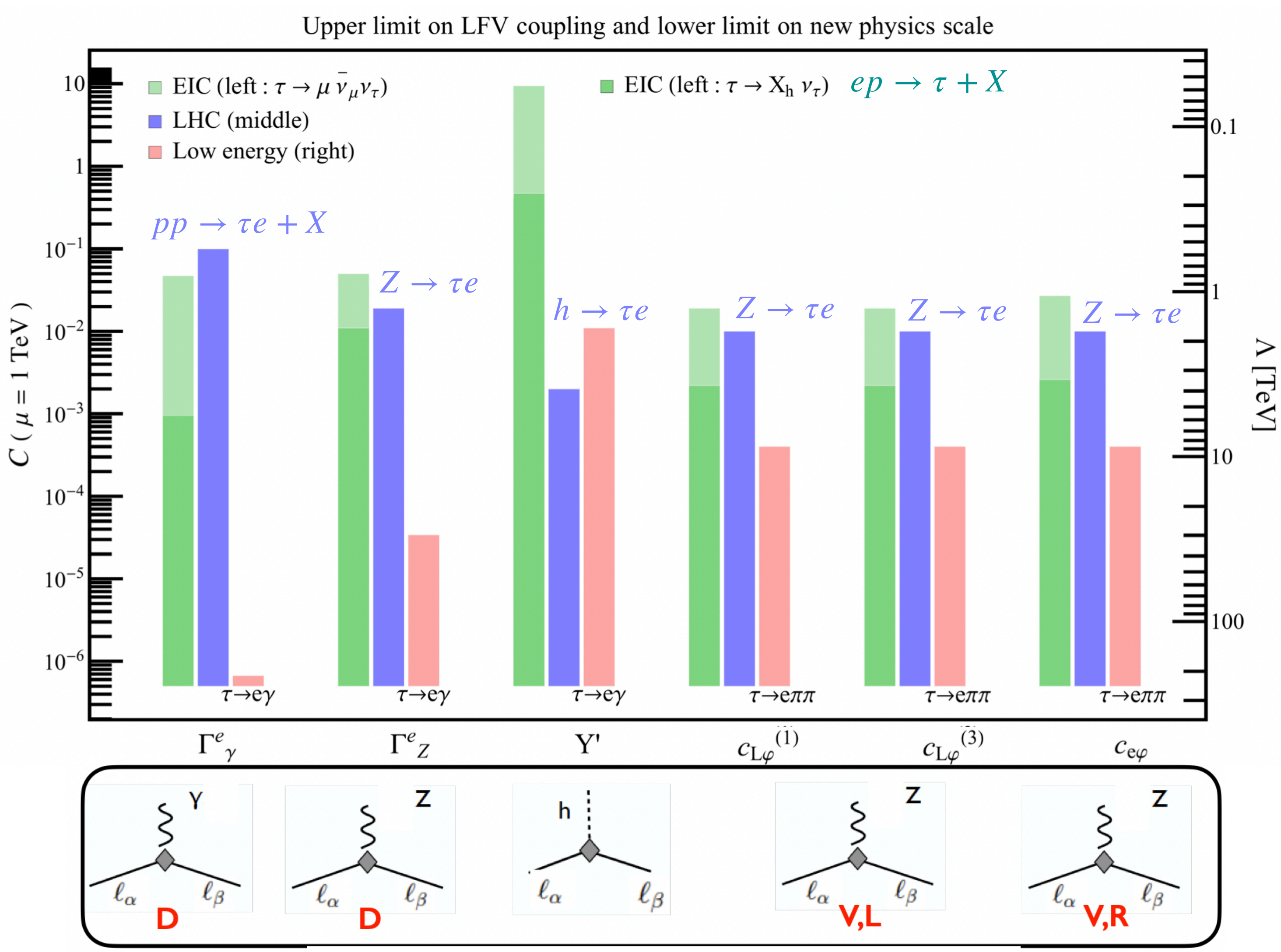
CMS

[Phys. Rev. D 104 (2021) 032013]

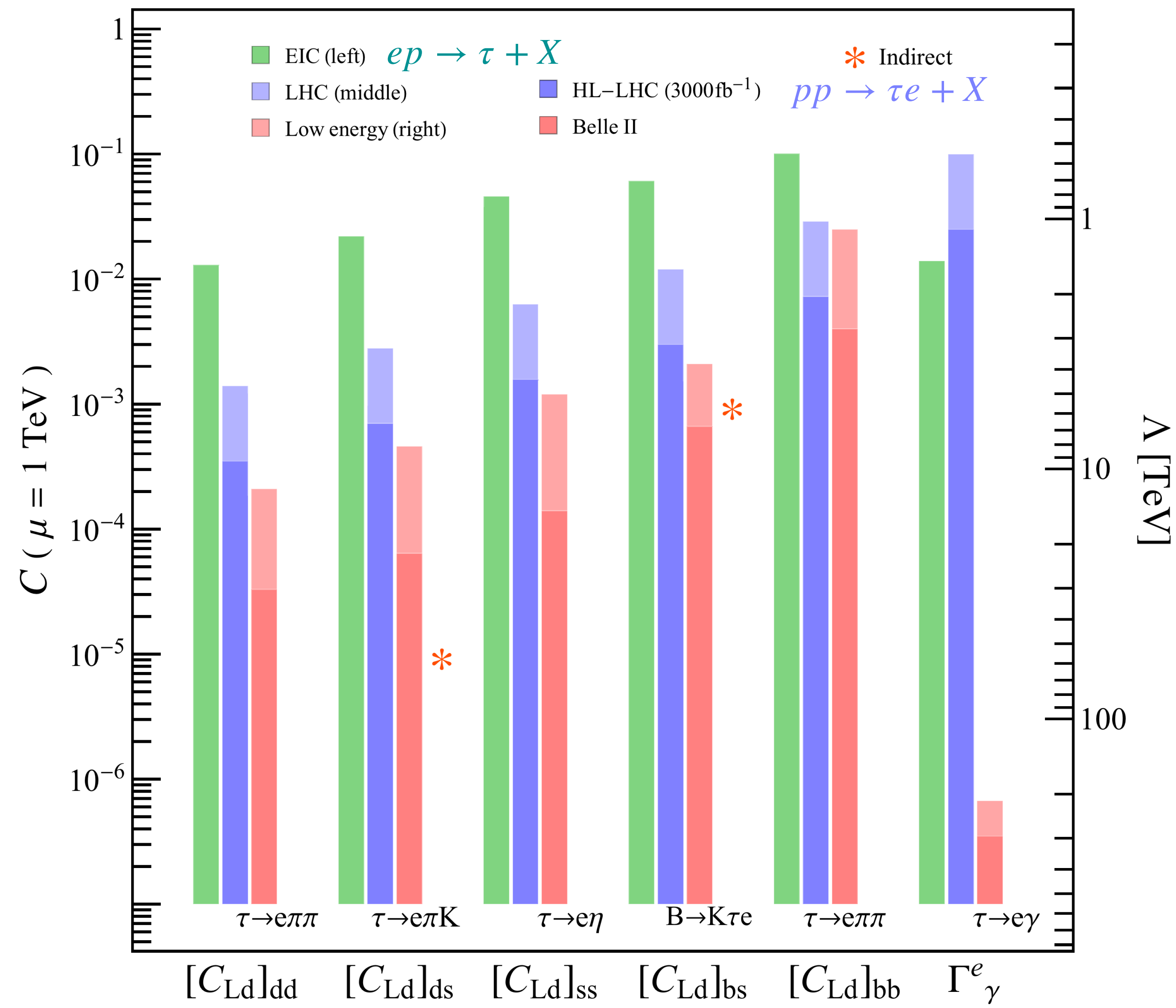


Global fit: $\tau \to e$ decays and transitions with τ in the final state

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 many other operators, bounds dominated by τ and B-decays.



e-Print: 2102.06176 [hep-ph]

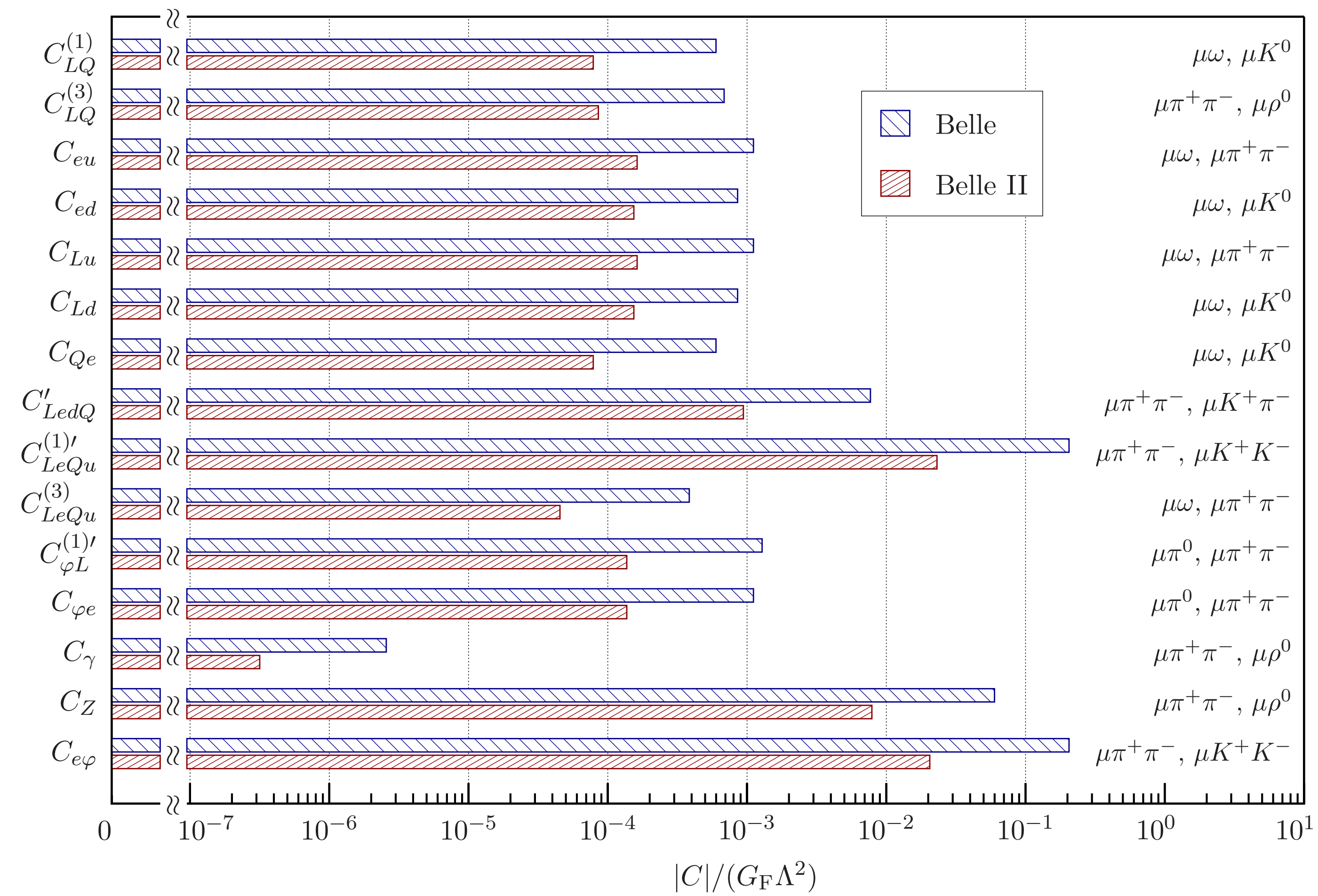


e-Print: 2203.14919 [hep-ph]

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 many other operators, bounds dominated by τ and B-decays.

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}	$(\bar{L}_p^j e_r)\,(\bar{d}_s Q_t^j)$		
$C_{LeQu}^{(1)}$	$(\bar{L}_p^j e_r)\,\varepsilon_{jk}\,(\bar{Q}_s^k u_t)$		
$C_{LeQu}^{(3)}$	$(\bar{L}_p^j\sigma_{\mu\nu}e_r)\,\varepsilon_{jk}\,(\bar{Q}_s^k\sigma^{\mu\nu}u_t)$		



e-Print: 2203.14919 [hep-ph]

Summary and outlook

	Observed Limits			Expected Limits		
$\tau^- \to$	Experiment	Luminosity	UL (obs)	Experiment	Luminosity	UL (exp)
$\mu^-\gamma$	Belle [93]	988 fb^{-1}	4.2×10^{-8}	Belle II [54]	50 ab^{-1}	6.9×10^{-9}
	BaBar [83]	516 fb^{-1}	4.4×10^{-8}			
				STCF [74]	1 ab^{-1}	1.8×10^{-8}
				FCC-ee [87, 91]	150 ab^{-1}	$\mathcal{O}(10^{-9})$
$\mu^-\mu^+\mu^-$	Belle [102]	782 fb^{-1}	2.1×10^{-8}	Belle II [54]	50 ab^{-1}	3.6×10^{-10}
	BaBar [103]	468 fb^{-1}	3.3×10^{-8}			
	LHCb [61]	3 fb^{-1}	4.6×10^{-8}	LHCb [76]	300 fb^{-1}	$\mathcal{O}(10^{-9})$
	CMS [67]	33 fb^{-1}	8.0×10^{-8}	CMS [77]	3 ab^{-1}	3.7×10^{-9}
	ATLAS [68]	20 fb^{-1}	3.8×10^{-7}	ATLAS [78]	3 ab^{-1}	1.0×10^{-9}
				STCF [74]	1 ab^{-1}	1.4×10^{-9}
				FCC-ee [87, 91]	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 experiment. Polarized beams can further improve the sensitivity.**

- **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 the tau sector, also with the possibility of beam polarization.**