Searches for LFV at B factories

K.Hayasaka (Nagoya Univ.)

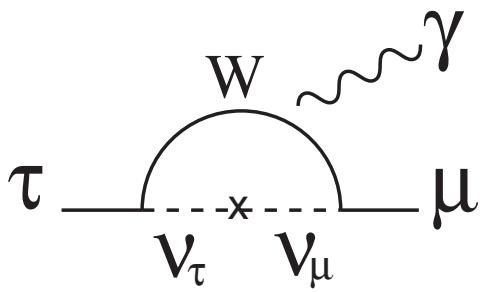
On behalf of Belle and BaBar

Lepton Flavor Violation (LFV)

- Standard Model (SM) exactly forbids LFV.
  - SM + ν mixing includes LFV.
    But, extremely small !

$$Br(\tau \to \mu\gamma) \propto \left(\frac{\Delta m_\nu^2}{m_W^2}\right) \cong 10^{-49} \sim 10^{-52}$$

(PLB67,303 (1977)/EPJ C8,513(1999))



Impossible to observe it!

- Many New Physics (NP) models include LFV process naturally.
- Observation of charged LFV
  - **= Clear signal of NP!**

Heaviest lepton

- Tau lepton has many possible LFV decay modes.
  - → Wide window to probe New Physics effects.

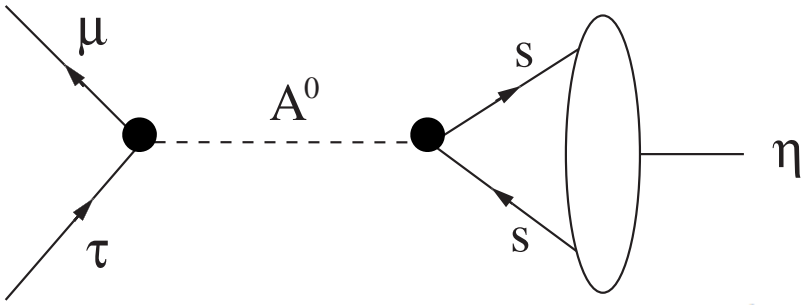
More than 40 decays are allowed.

LFV in Higgs mediated model

When sleptons are much heavier than weak scale

➡ **$\tau \to \mu\eta$ may be enhanced.**

LFV will be proceed via neutral Higgs (h/H/A)



$Br(\tau \to \mu\eta) : Br(\tau \to 3\mu) : Br(\tau \to \mu\gamma)$
$= 8.4 : 1 : 1.5$
(PRD66,057301(2002))

$$BR(\tau \to \mu\eta) = (0.84 \times 10^{-6}) \times \left(\frac{\tan\beta}{60}\right)^6 \times \left(\frac{100\ \text{GeV}}{m_A}\right)^4$$

Recently, detailed estimations for $\tau \to \mu p^0$ ($p^0 = \eta, \eta', \pi^0$)
and $\tau \to \mu hh'$ ($h = \pi, K$) are shown in JHEP06,079(2008), JHEP10,104(2007)

Signature of NP models

Ratios of LFV decay Brs in each NP model

	SUSY+GUT (SUSY+Seesaw)	Higgs mediated	Little Higgs	non-universal Z' boson
$\left(\frac{\tau \to \mu\mu\mu}{\tau \to \mu\gamma}\right)$	~2×10^{-3}	~0.1	0.4~2.3	~20
$\left(\frac{\tau \to \mu ee}{\tau \to \mu\gamma}\right)$	~1×10^{-2}	~1×10^{-2}	0.3~1.6	~20
Br($\tau \to \mu\gamma$) prediction	<10^{-7}	<10^{-10}	<10^{-10}	<10^{-9}

enhanced mode $\tau \to \mu\gamma$ ⟺ $\tau \to \mu\mu\mu$

(JHEP 0705, 013(2007), PLB54, 252 (2002))

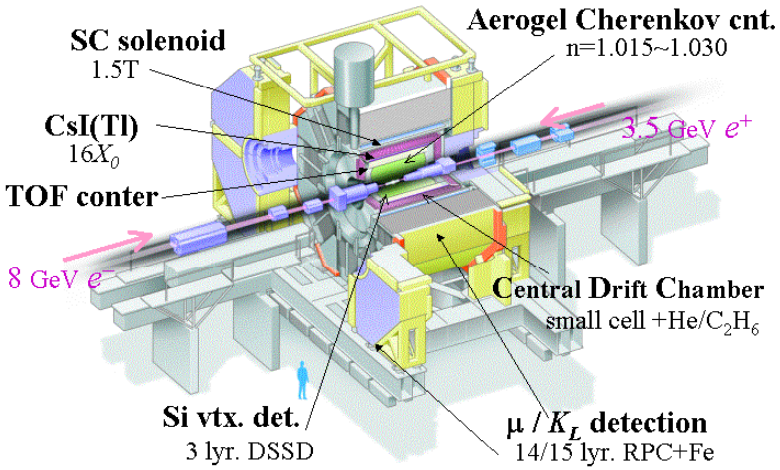
Various LFV mode searches help to discriminate models.

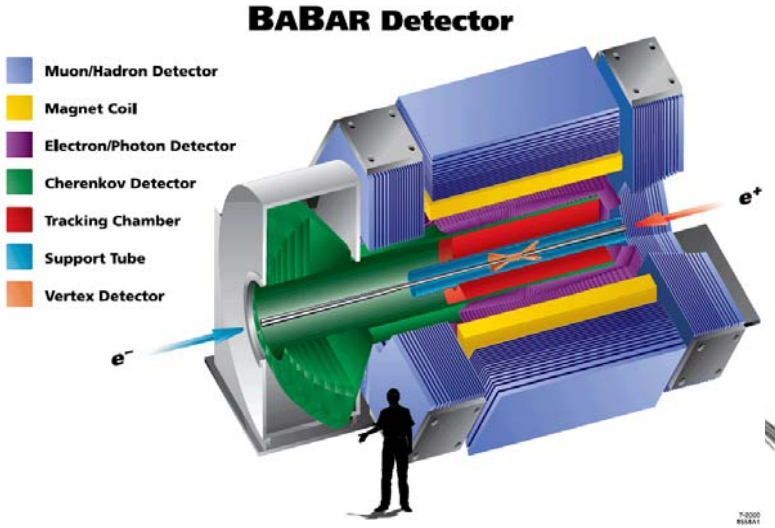
B-factories

- A B-factory is also a τ-factory!
  - $\sigma(\tau\tau)$~0.9nb, $\sigma(b\bar{b})$~1.1nb
- Detectors

  -F/B asymmetric -high momentum particle ID capability

Belle Detector





- Accumulated data:

  >7.5x10^8 τ-pairs at Belle, >5.1x10^8 τ-pairs at BaBar

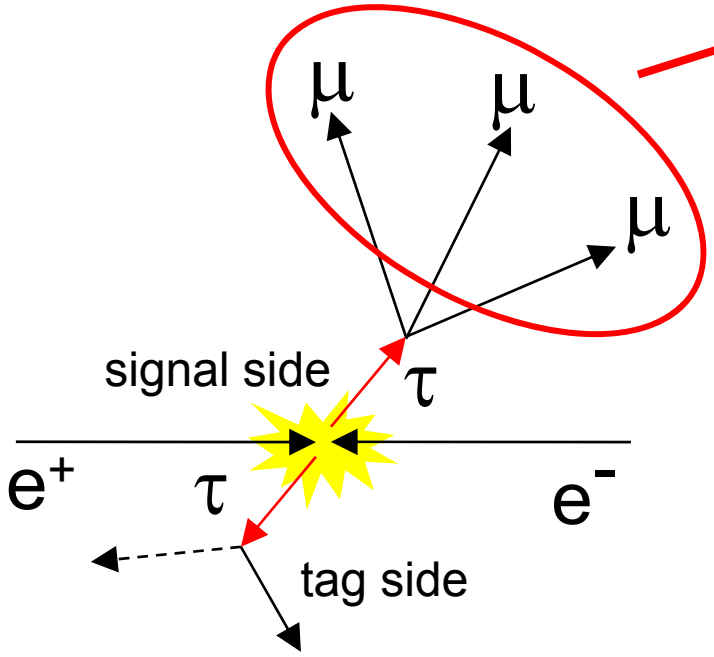
  ➔ Br~O(10^{-8}) sensitivity!

Analysis method

$e^+e^- \rightarrow \tau^+\tau^-$ ⇒ clear environment

→ Signal (3μ)

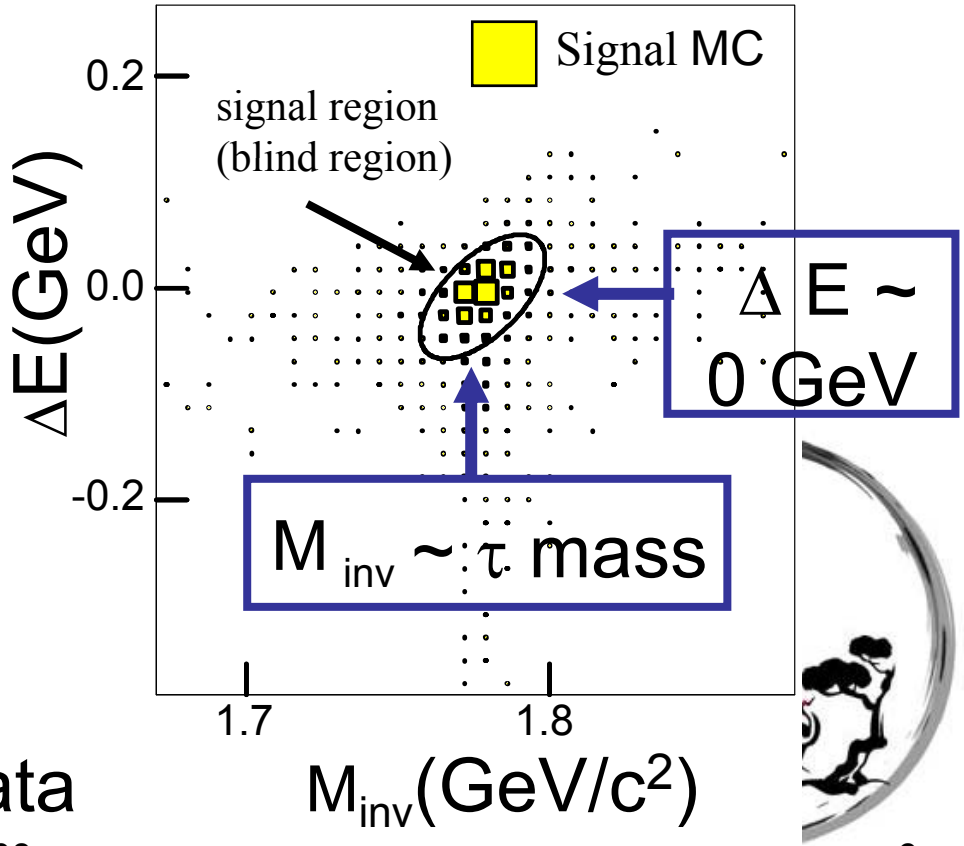
→ One charged (tag) +missing



Signal Extraction

$$M_{inv} = \sqrt{E^2_{signal} - p^2_{signal}}$$

$$\Delta E = E^{CM}_{signal} - E^{CM}_{beam}$$



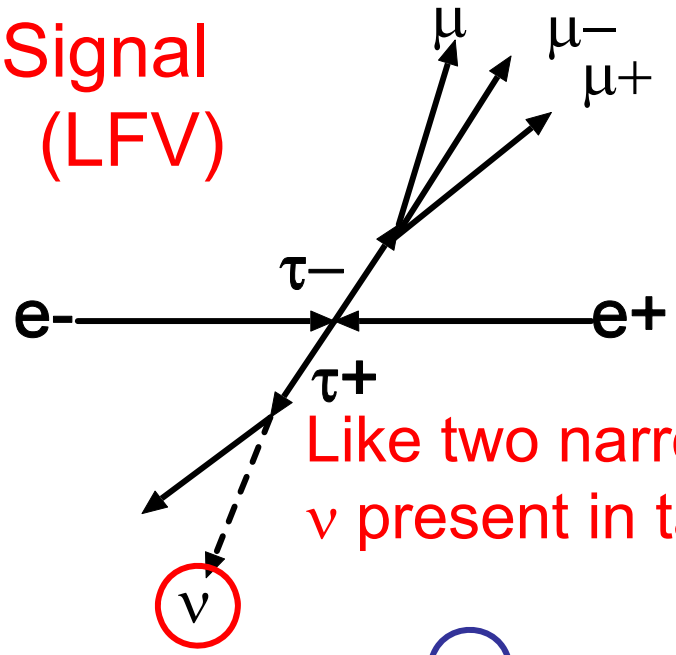
Blind analysis

⇒Blind signal region

BG estimation: sideband data

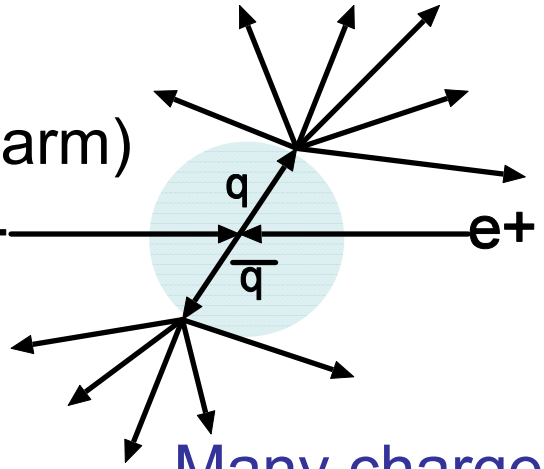
Signature of signal and background

Signal
(LFV)



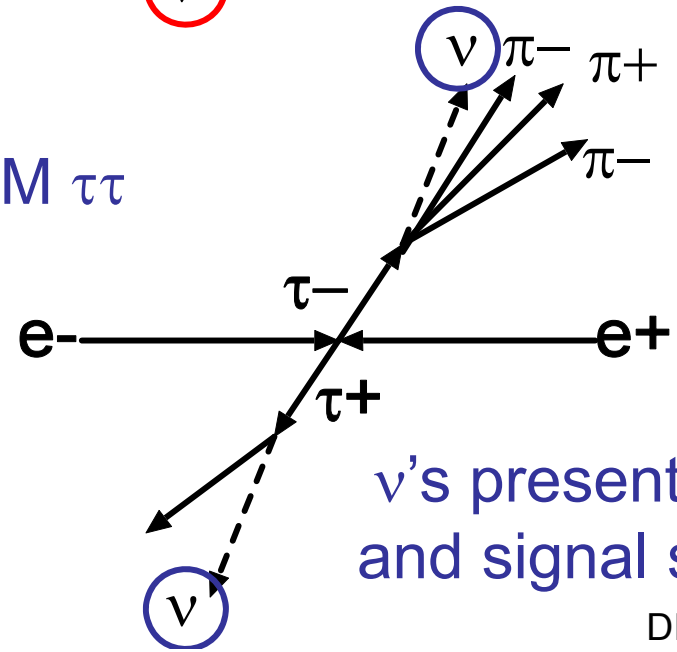
Like two narrow jets
ν present in tag side only

$q\bar{q}$
(uds, charm)



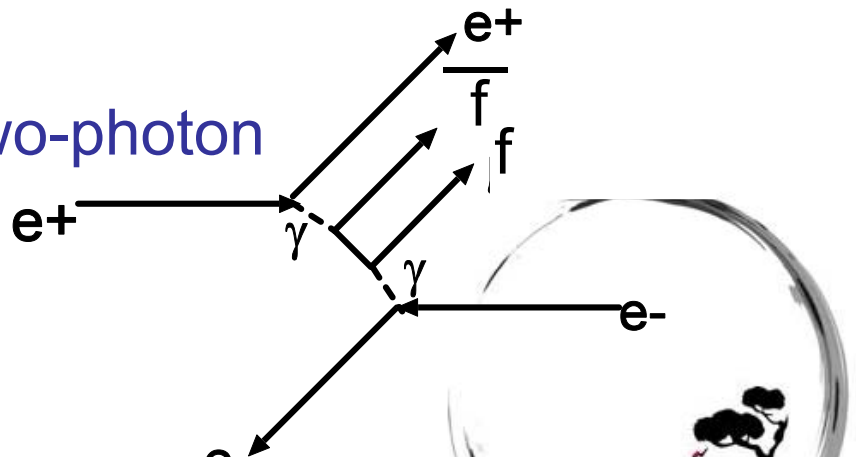
Many charged tracks
and γ

SM ττ



ν's present in tag
and signal side

Two-photon



Electrons are included
in signal and tag side

Results ($\tau \to l\gamma$)

Final state: 1-prong decays and photon

⇨ Major remaining BG from $e^+e^- \to \tau^+\tau^-\gamma$
sensitivity: limited by BG

Belle(PLB666,16(2008))

Data: 535fb^{-1}

Br($\tau \to \mu\gamma$)<4.5x10^{-8} at 90%C.L.

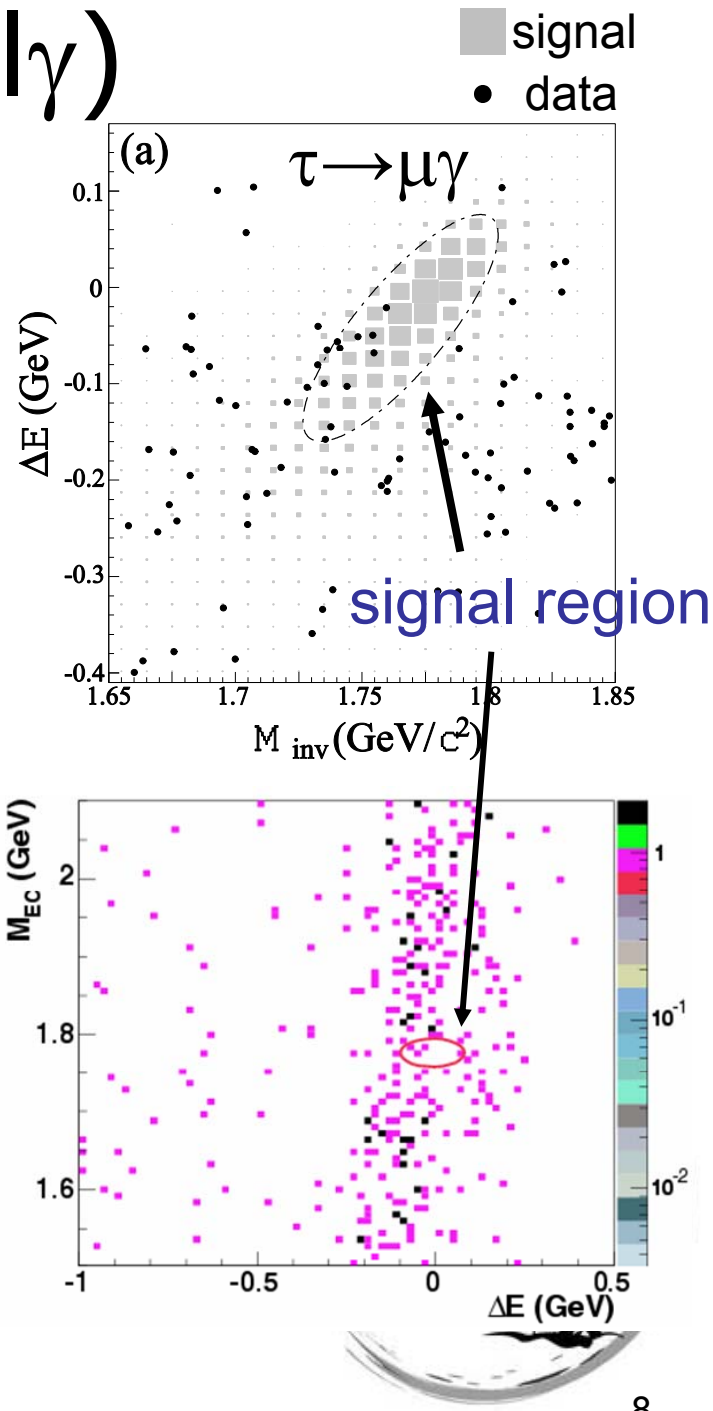
Br($\tau \to e\gamma$)<1.2x10^{-7} at 90%C.L.

BaBar(PRL 95, 041802 (2005))

Data: 232fb^{-1}

Br($\tau \to \mu\gamma$)<6.8x10^{-8} at 90%C.L.

Br($\tau \to e\gamma$)<1.1x10^{-7} at 90%C.L.



Results ($\tau \to lP^0$)

Final state: 1-prong decays and 2photons

$\tau \to e/\mu + (\eta, \eta', \pi^0)$

BaBar(PRL98, 061803 (2007))

Data:339fb^{-1}

Expected BG : (0.0-1.3) events

N_{obs} : 0-1 event

$Br(\tau \to \mu\eta, \mu\eta', \mu\pi^0) < (11\text{-}20) \times 10^{-8}$

$Br(\tau \to e\eta, e\eta', e\pi^0) < (14\text{-}26) \times 10^{-8}$

Belle(PLB648, 341 (2007))

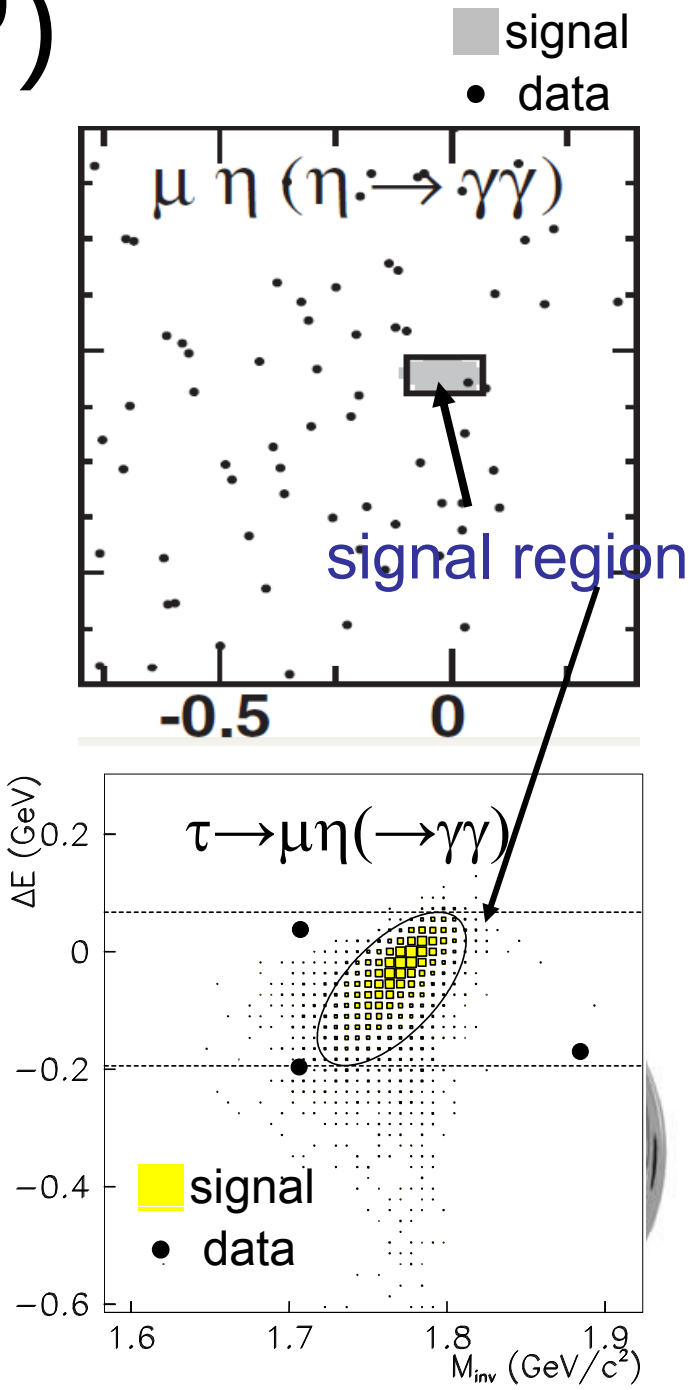
Data:401fb^{-1}

Expected BG : (0.0-0.6) events

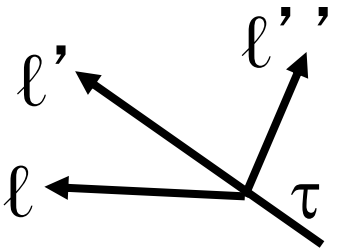
N_{obs} : 0-1 event

$Br(\tau \to \mu\eta, \mu\eta', \mu\pi^0) < (6.5\text{-}13) \times 10^{-8}$

$Br(\tau \to e\eta, e\eta', e\pi^0) < (8.0\text{-}16) \times 10^{-8}$



Results ($\tau \to 3l$)



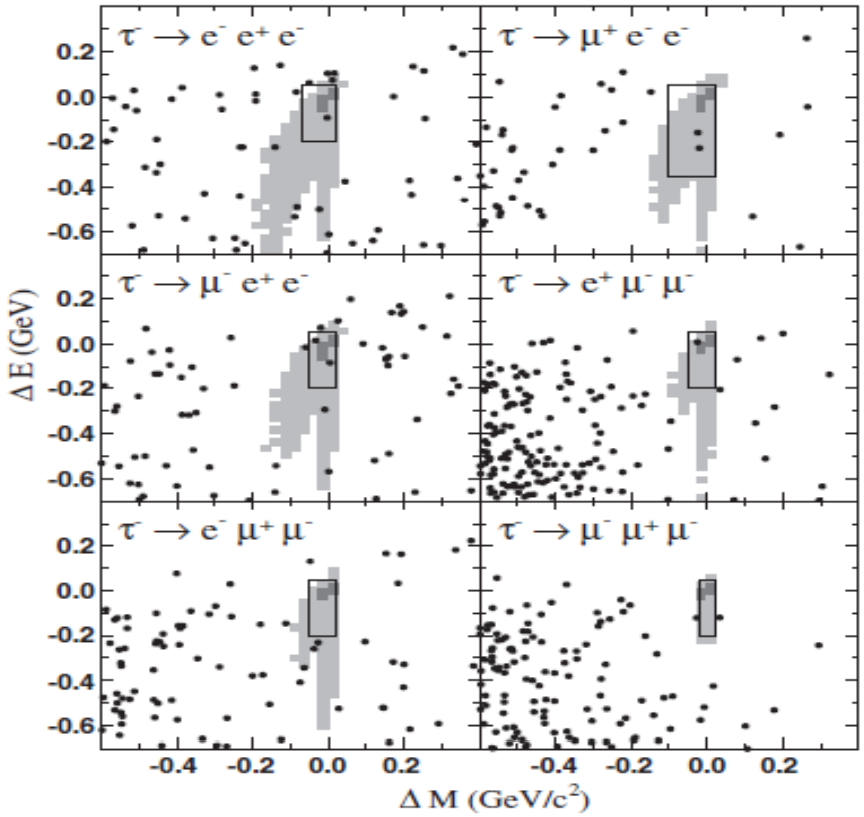
Final state: 3-charged tracks

⇒ good resolution of M_{inv} and ΔE

signal

- data

BaBar(PRL99, 251803(2007))



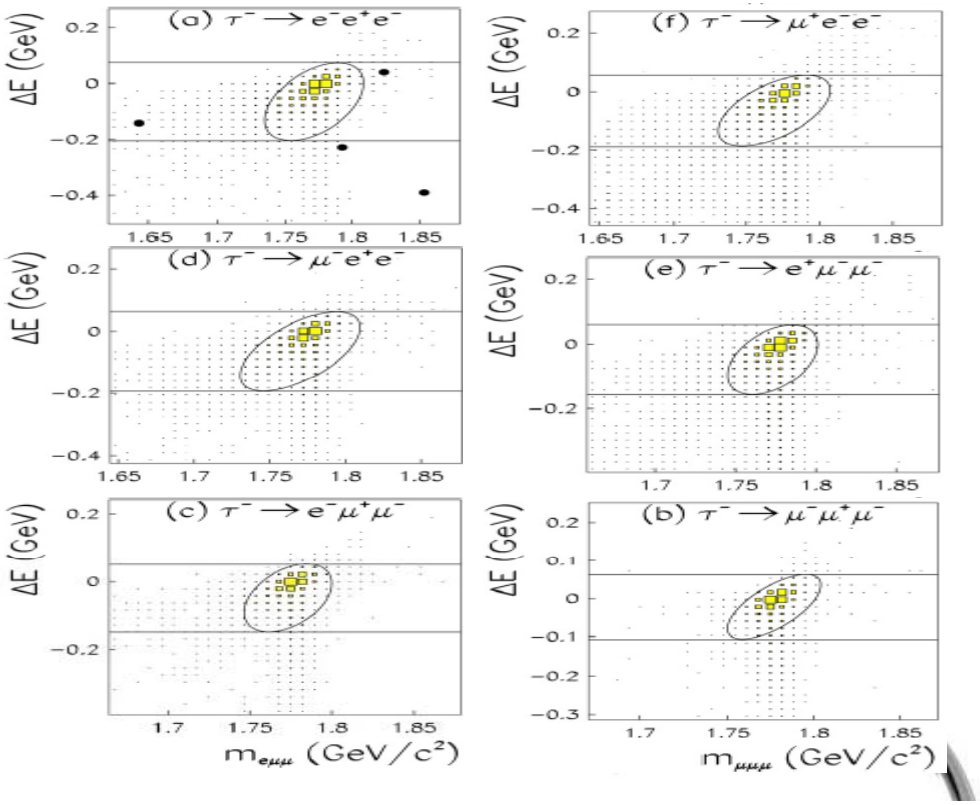
Data 339fb^{-1}, 0-2 ev. observed

Br($\tau \to$ 3leptons) <(3.7-8.0)x10^{-8}

signal

- data

Belle(PLB660,154(2008))

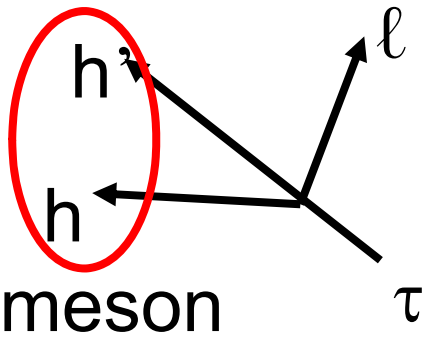


Data 543fb^{-1}, 0 ev. observed

Br($\tau \to$ 3leptons) <(2.0-4.1)x10^{-8}

$\tau^- \to \mu^+ e^- e^-$: currently the most stringent UL on τ LFV decay

Results ($\tau \to l f_0$)



Final state: lepton + neutral meson

⇒Small BG due to mass restriction of meson

Belle

- $\tau \to \ell f_0(980)$

  data: 671fb^{-1} (First search)

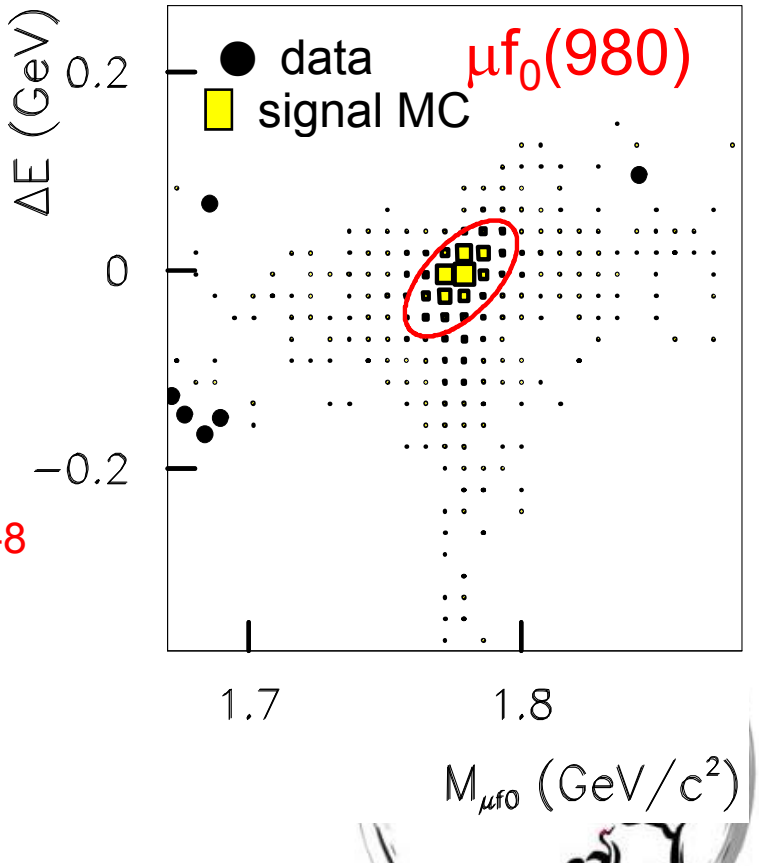
  Expected BG: 0.1 events

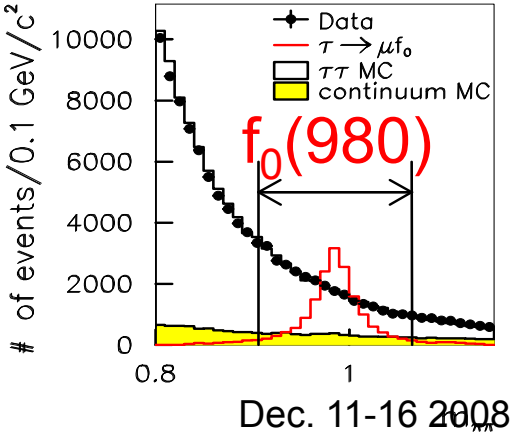
  from qq for $\mu f_0(980)$

  two-photon for $e f_0(980)$

  N_{obs} 0 events

⇒$Br(\tau \to \ell f_0(980)) \times Br(f_0(980) \to \pi^+\pi^-)$ $< (3.2\text{-}3.4) \times 10^{-8}$



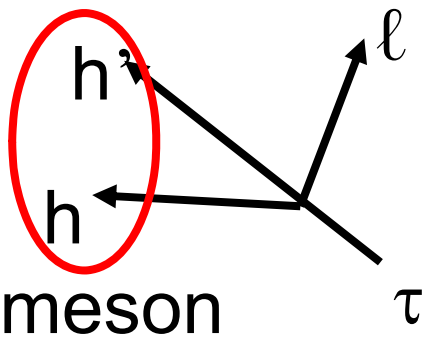


Submitted to PLB, arXive:0810.3159[hep-ex]

Results ($\tau \to l V^0$)

Final state: lepton + neutral meson

⇒Small BG due to mass restriction of meson



BaBar

- $\tau \to \ell V^0$ (Preliminary)

  data: 451fb^{-1}

  Expected BG: 0.6-2.8 events

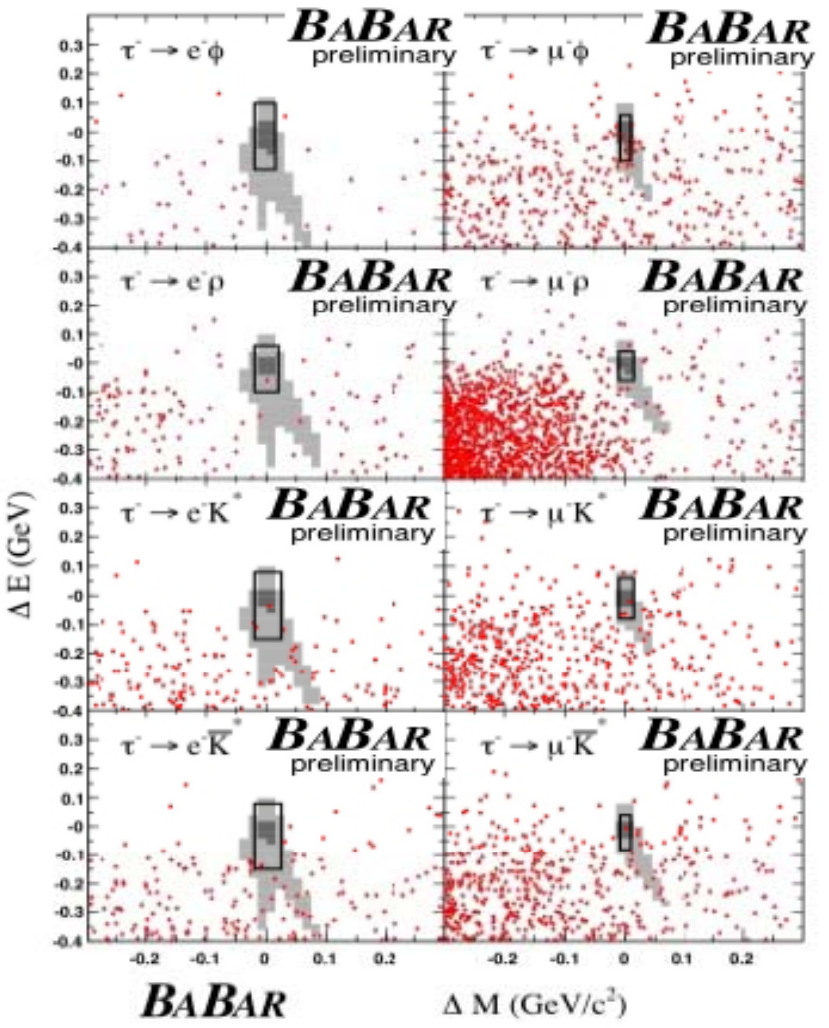
N_{obs} 0-6 events

⇒Br($\tau \to \ell V^0$)<(0.8-18)x10^{-8}

Belle(PLB664,35(2008))

data:543fb^{-1}

Br($\tau \to \ell V^0$)<(5.9-10)x10^{-8}

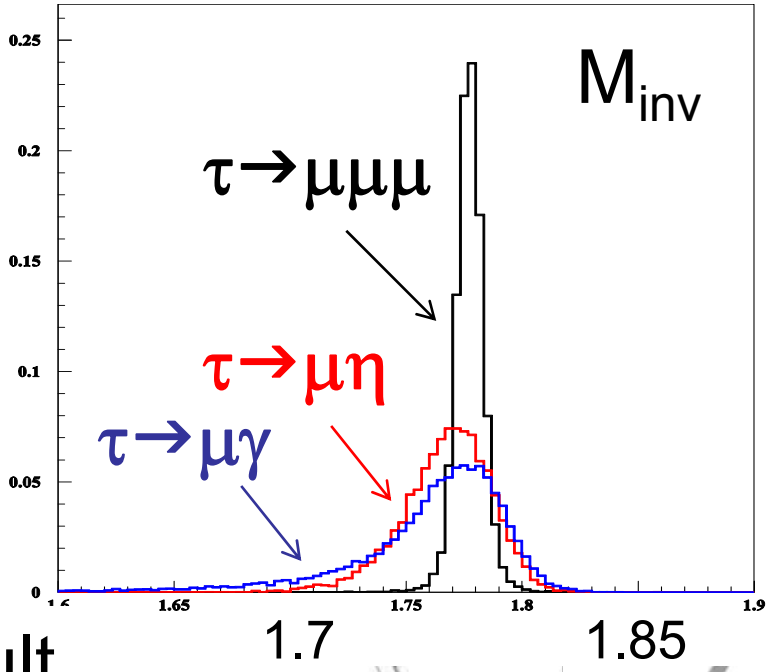


Resolution, BG and sensitivity

	# of photons	resolution	BG	sensitivity
$\tau \to \mu\gamma$	1	△	×	10^{-8}
$\tau \to \mu\eta$	2	△	○	10^{-8}
$\tau \to \mu\mu\mu$	0	○	○	10^{-8}

○:very good
△: good
×:not so good

- photon makes resolution of reconstructed tau mass worse.
- Narrow signal area effectively rejects BG's.
- Reconstruction of eta helps reject BG's and makes resolution not so bad.



Currently, we obtain similar result.
In the future, analysis for $\tau \to \mu\mu\mu$ has advantage.

Current ULs for tau LFV decays

	BaBar		Belle		CLEO
	Br($\times 10^{-8}$)	Lum(fb^{-1})	Br($\times 10^{-8}$)	Lum(fb^{-1})	Br($\times 10^{-8}$)
$\tau \to \mu/e+\gamma$	6.8/11	252	4.5/12	535	110/270
$\tau \to l+P^0$	11-16	339	7-12	401	370-960
$\tau \to \mu/e+Ks$	4.0/3.3	469	4.8/5.6	282	95/91
$\tau \to l+l'+l''$	3.7-8.0	376	2.0-4.1	535	150-290
$\tau \to l+h+h'$	7.0-48	221	20-160	158	190-820
$\tau \to l+V^0$	0.8-18	451	5.9-13	543	200-750
$\tau \to \mu/e+\omega$	10/11	384	8.0/18	543	---
$\tau \to h+\Lambda/\bar{\Lambda}$	5.8-15	237	7.2-14*	154	---

$l=e,\mu$, $P^0=\eta,\eta',\pi^0$, $V^0=\rho^0,K^{*0},\overline{K^{*0}},\phi$, $h=\pi,K$

*Belle result does not include $K\Lambda/K\bar{\Lambda}$

Other processes with LFV (Υ(ns))

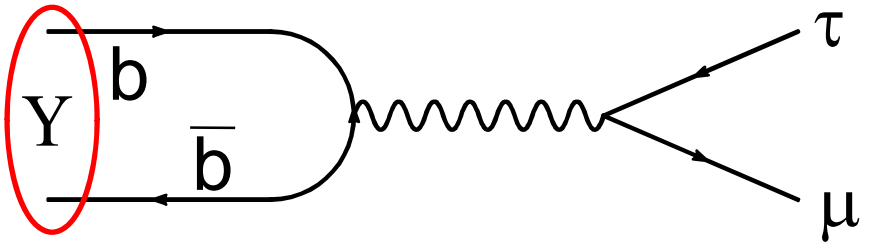
CLEO (PRL 101,201601(2008))

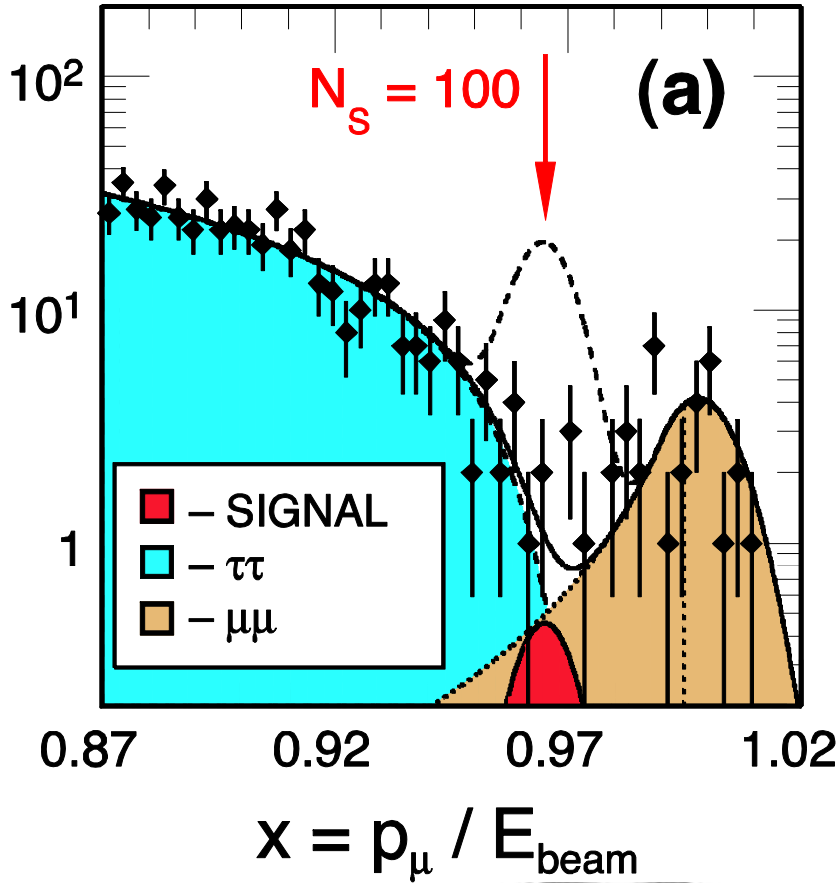
- Υ(ns) decay(n=1,2,3)
  - 1s:1.1fb^{-1},2s:1.3fb^{-1},3s:1.4fb^{-1}
- Br(1s→μτ)<6.0x10^{-6}
- Br(2s→μτ)<14.4x10^{-6}
- Br(3s→μτ)<20.3x10^{-6}

(95%CL)

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \frac{4\pi\alpha_N}{\Lambda^2}(\bar{\mu}\Gamma_\mu\tau)(\bar{b}\gamma^\mu b),$$

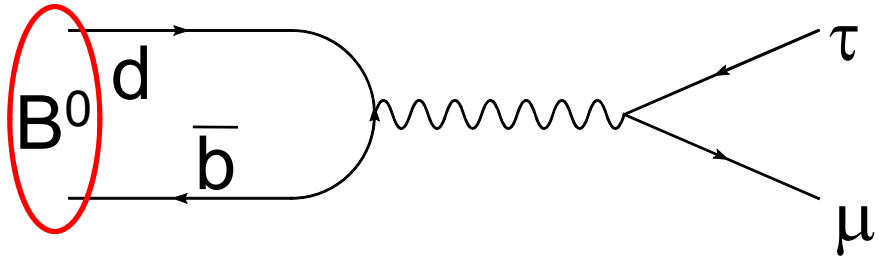
➡ Λ>1.3/0.98/0.98 TeV w/ α_N=1





Recently, BaBar reported the result:
Br(3s→e/μ τ) <5.0/4.1x10^{-6} at 90%CL
QWG6(arXiv:0812.1021 [hep-ex])

Other processes with LFV (B)



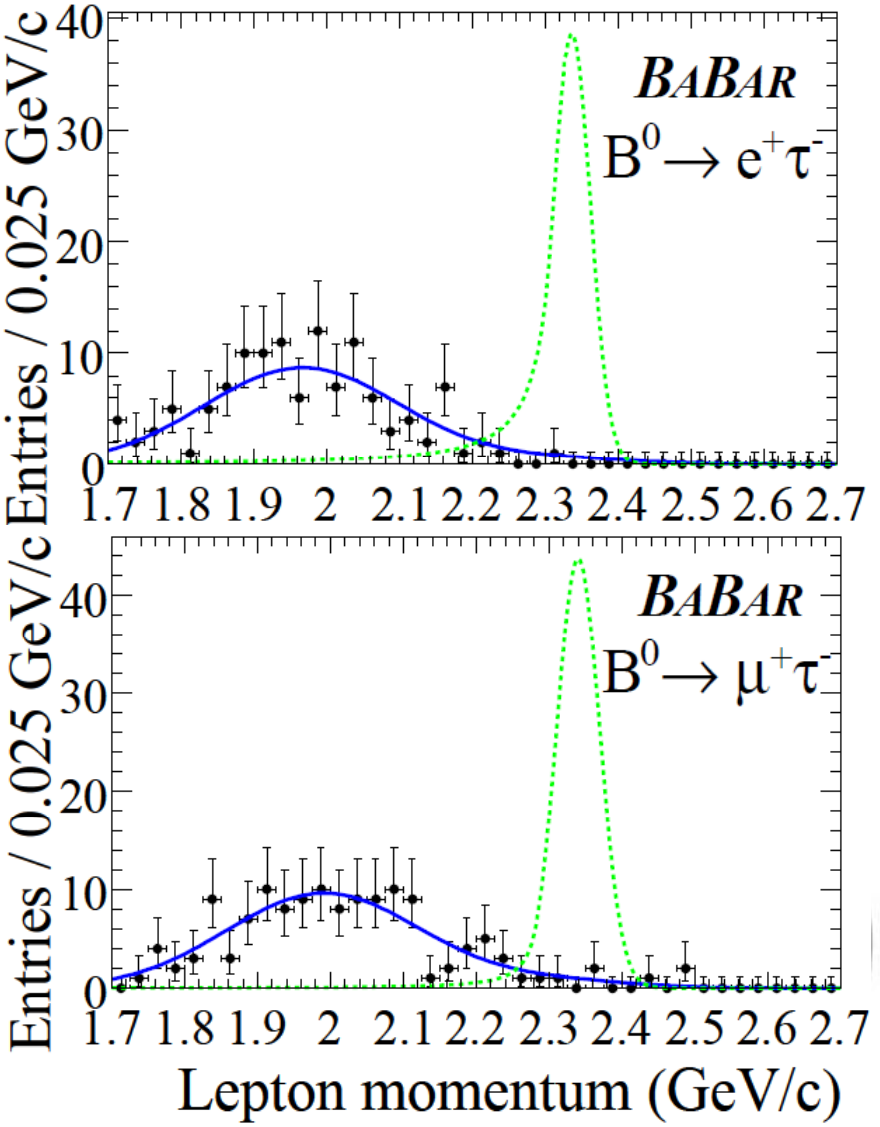
Mediated by non-SM Higgs

BaBar (PRD 77, 091104(R) (2008), PRL99,201801(2007))

- $Br(B^0 \rightarrow e\tau) < 2.8 \times 10^{-5}$
- $Br(B^0 \rightarrow \mu\tau) < 2.2 \times 10^{-5}$
- $Br(B \rightarrow K\tau\mu) < 7.7 \times 10^{-5}$ (90%CL)

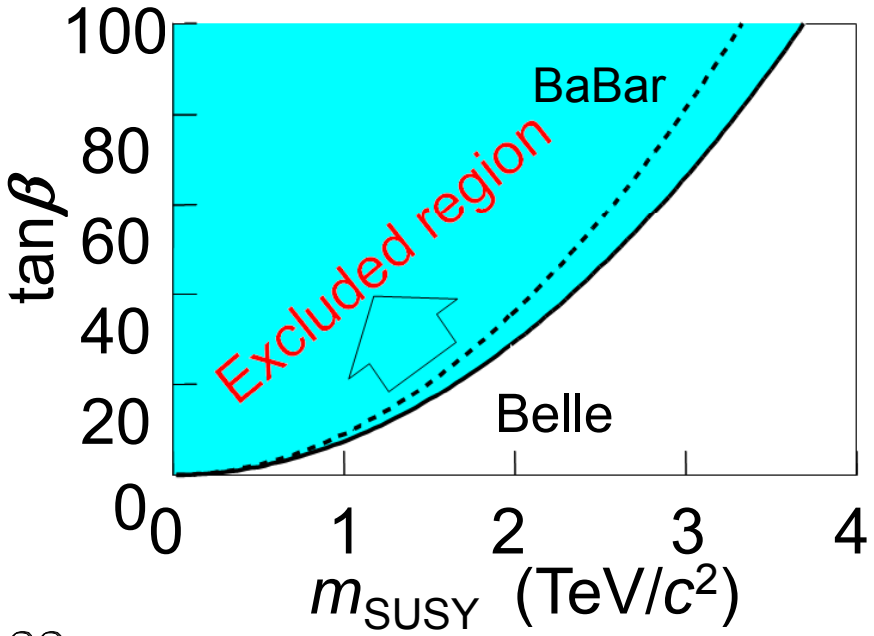
First search

$Br(D^0 \rightarrow e\,\mu) < 8.1 \times 10^{-7}$ @ 90% C.L. w/ $122 fb^{-1}$
PRL93,191801(2004)



New Physics constraints on τ LFV decay

Although NP models usually depend on many parameters, in order to illustrate the sensitivity of our results, we show examples based on the following formulae:



MSSM with seesaw

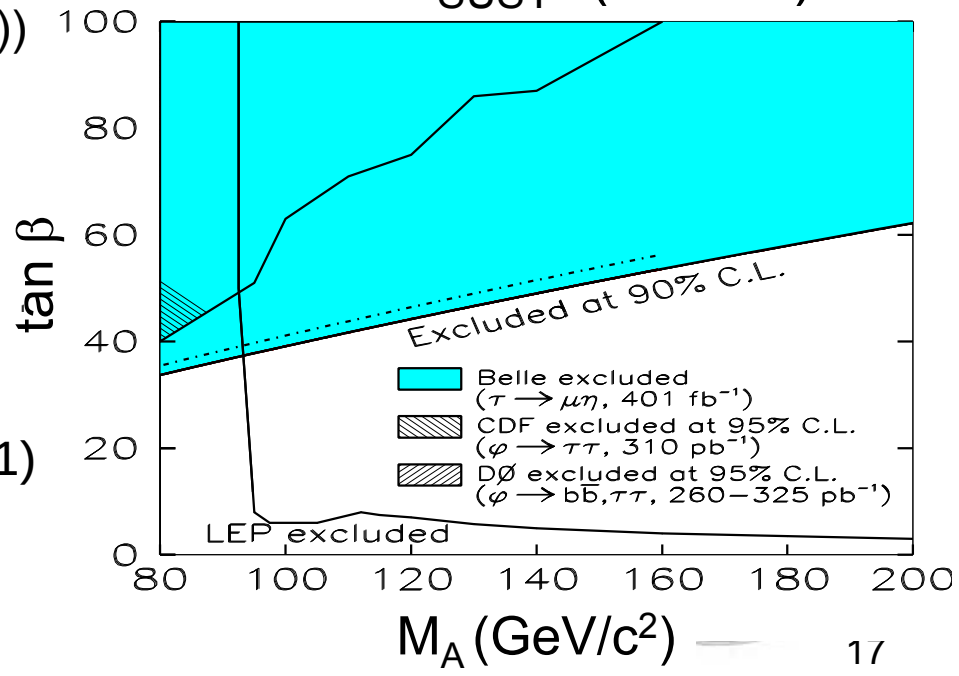
$$Br(\tau \to \mu\gamma) = 3.0\times10^{-6} \times \left(\frac{\tan\beta}{60}\right)^2 \times \left(\frac{M_{SUSY}}{1\text{TeV}}\right)^{-4}$$

(PRD60, 055008(1998))

Higgs-mediated model

$$Br(\tau\to\mu\eta) = 8.4\times10^{-7} \times \left(\frac{\tan\beta}{60}\right)^2 \times \left(\frac{M_A}{100\,\text{GeV}}\right)^{-6}$$

(PRD 66 (2002) 057301)



Future prospects for τ LFV decay

LFV sensitivity

⇨ depends on remaining background level

- $\tau \rightarrow \ell\gamma$,

  scales as ~$1/\sqrt{L}$

  Sensitivity is currently limited due to background from $\tau^+\tau^-\gamma$ events

- $\tau \rightarrow$ 3leptons, ℓ+meson

  scale as ~$1/L$

  Negligible background at 1ab^{-1}

  ⇒ a few BG events at 10 ab^{-1}

  Because of

  - Good particle identification
  - Mass restriction to select meson

Super B-factory

Super B-factory:(10~50) ab^{-1}

Expected sensitivity

$\tau \to \ell\gamma$ Br~O($10^{-8\sim9}$)

$\tau \to \ell\ell\ell$, ℓ+meson Br~O($10^{-9\sim10}$)

Current UL@Belle

Br($\tau \to \mu\mu\mu$) <3.2×10^{-8}@$543fb^{-1}$

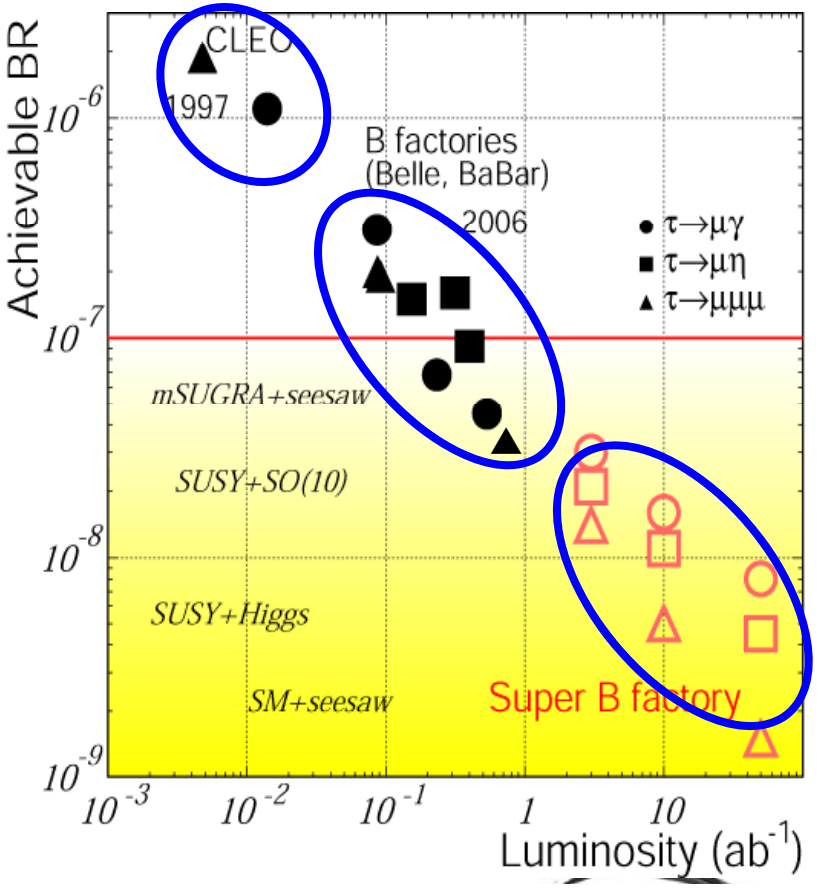
Br($\tau \to \mu\mu\mu$)<3×10^{-10}@$50ab^{-1}$

Expected UL @ LHC $30fb^{-1}$

Br($\tau \to \mu\mu\mu$)< 3.8×10^{-8} (W-source)

<3.4×10^{-7} (Z-source)

(from P.Rezvicev's talk@HQL08)



•$\tau \to \mu\mu\mu$

10x better sensitivity than @LHC

Provide valuable information for understanding of New Physics

Summary

LFV process= signature of NP

46 modes of LFV τ decays with 10^9 τ's are investigated at Belle and BaBar.

No LFV signal in any modes

set upper limits on branching factions: $O(10^{-8})$

($Br(\tau\to\mu\gamma)<4.5\times10^{-8}$, $Br(\tau\to\mu\mu\mu)<3.2\times10^{-8}$ etc.)

- Improved sensitivity: x100 from CLEO

  ⇒Effective BG rejection because of detailed BG study

- Reach some NP predictions

  ex. in MSSM with seesaw: excluded high tan β and small M_{susy}

  (exclude: tan β >29 @ M_{susy}= 2 TeV/c^2)

Other processes: $B^0\to e/\mu\ \tau$, $B\to K\tau\mu$, $\Upsilon(ns)\to\mu\ \tau$

At Super B-factories with 50 ab^{-1}

LFV sensitivity reach $O(10^{-9\sim10})$ → Very interesting regions for many NP scenarios