Flavor Physics and CP Violation 2010
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Lepton Flavor Violation at B-factories

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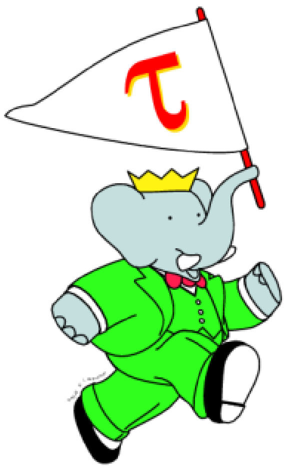
(on behalf of
Belle and Belle Collaboration)

BELLE



Nagoya University
タウ・レプトン物理研究センター
Tau Lepton Physics Research Center

Introduction

Introduction

LFV in SUSY

Comparison between NP models

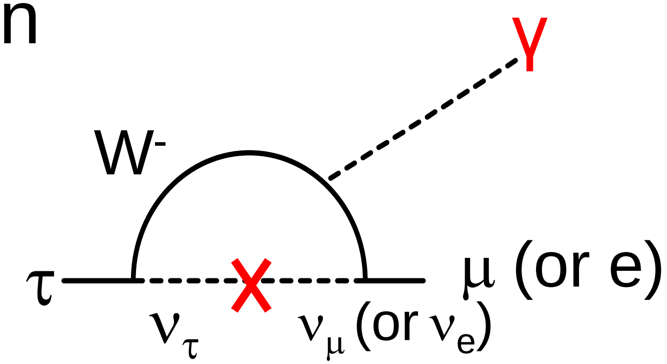
Introduction

Lepton flavor violation (LFV) in charged lepton

⇒negligibly small probability in the Standard Model (SM) even including neutrino oscillation

- Br($\tau \to l\gamma$) <O(10^{-54})
- Br($\tau \to$3leptons) <O(10^{-14})

(PRL95 41802(2005), EPJC8 513(1999))



Many extensions of the SM predict LFV decays.
These branching fractions could be enhanced as high as current experimental sensitivity

⇒Observation of LFV is a clear signature of New Physics (NP)

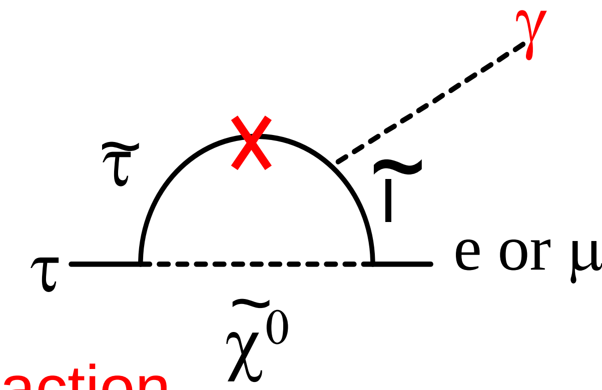
Tau lepton :
- The heaviest charged lepton
- Many possible LFV decay modes

⇒Ideal place to search for LFV

LFV in SUSY

SUSY is the most popular candidate among new physics models

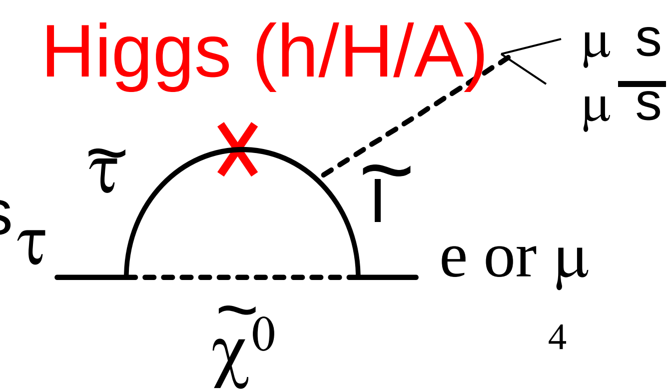
induce naturally LFV at one-loop due to slepton mixing



$\tau \to l\gamma$ mode has the largest branching fraction in SUSY-Seesaw (or SUSY-GUT) models

When sleptons are much heavier than weak scale

LFV associated by neutral Higgs boson (h/H/A)



Higgs coupling is proportional to mass

⇒μμ or $s\bar{s}$ ($K\bar{K}$, η, f_0(980) and other) are favored

Comparison between NP models

Ratios of LFV decay Br allow to discriminate between new Physics models.

	SUSY+GUT (SUSY+Seesaw)	Higgs mediated	Little Higgs	non-universal Z' boson
$\left(\frac{\tau\to\mu\mu\mu}{\tau\to\mu\gamma}\right)$	$\sim 2\times 10^{-3}$	0.06~0.1	0.4~2.3	~16
$\left(\frac{\tau\to\mu ee}{\tau\to\mu\gamma}\right)$	$\sim 1\times 10^{-2}$	$\sim 1\times 10^{-2}$	0.3~1.6	~16
Br($\tau\to\mu\gamma$) @Max	$<10^{-7}$	$<10^{-10}$	$<10^{-10}$	$<10^{-9}$

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

Favorite modes $\tau\to l\gamma$ ⟷ $\tau\to$3leptons

⇒ Model independent searches for various LFV modes are very important

Analysis

B-factories

Analysis method

Signature of signal and background

B-factories

B-factoy: E at CM = Υ(4S)

e^{+}(3.5 (3.1) GeV) e^{-}(8 (9) GeV) for KEKB (PEP II)

$\sigma(\tau\tau)$~0.9nb,$\sigma(bb)$~1.1nb

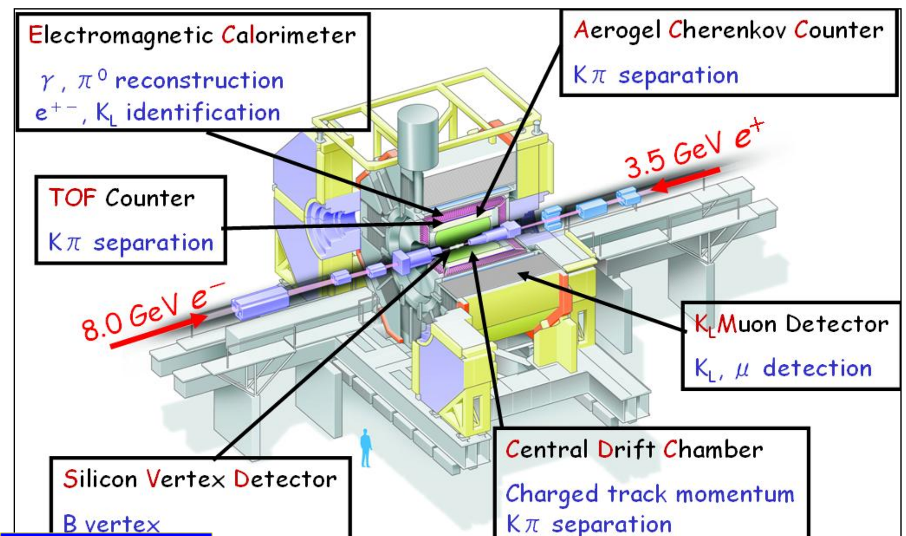
Other Υ(nS) and Energy scan are also collected by B-factories

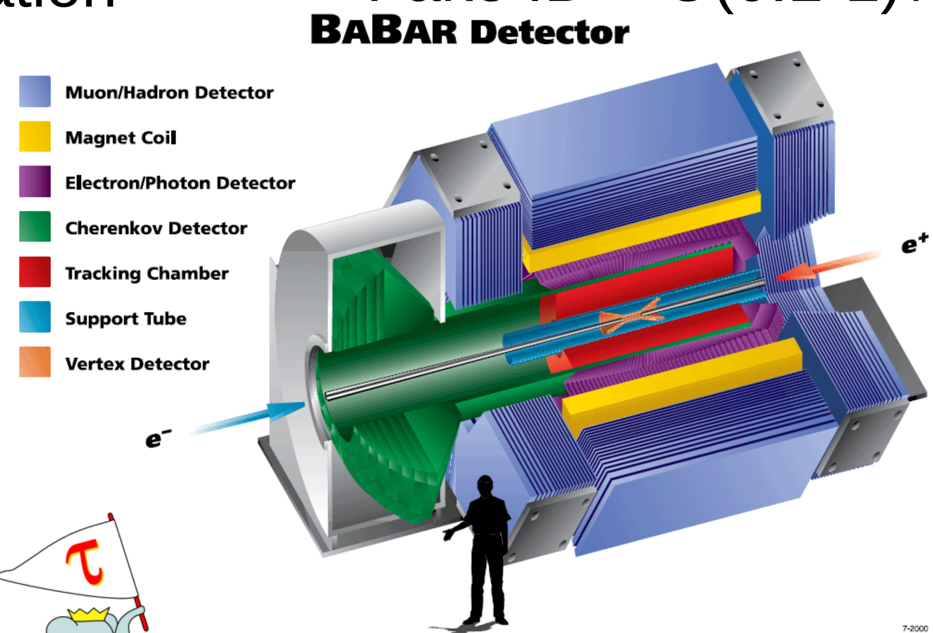
A B-factory is also a τ-factory!

Detector: Good track reconstruction and particle identification

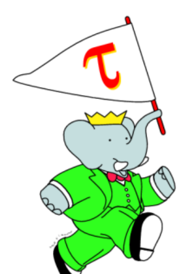
Lepton ID ~ (80-90)%

Fake ID ~ O(0.1-1)%





~9x10^{8} ττ at Belle

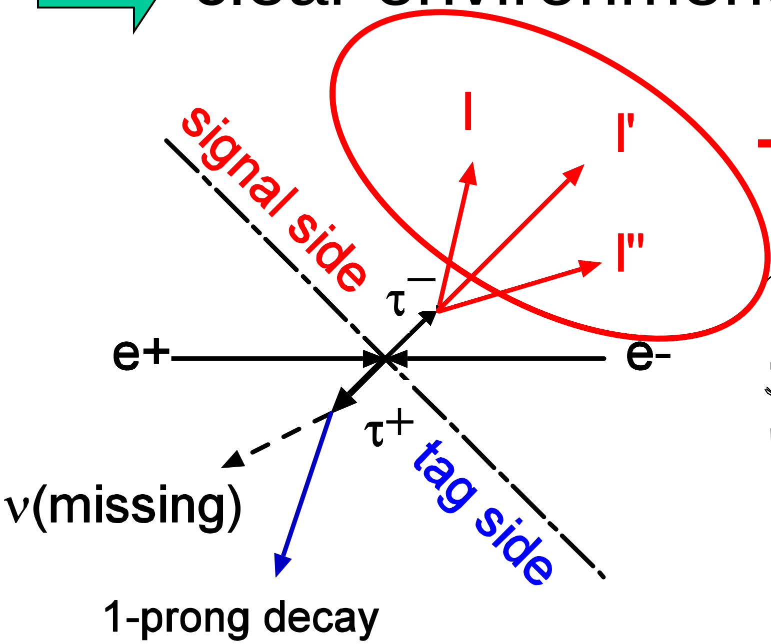


~4.8x10^{8} ττ at BaBar

Analysis method

$e^+e^- \rightarrow \tau^+\tau^-$

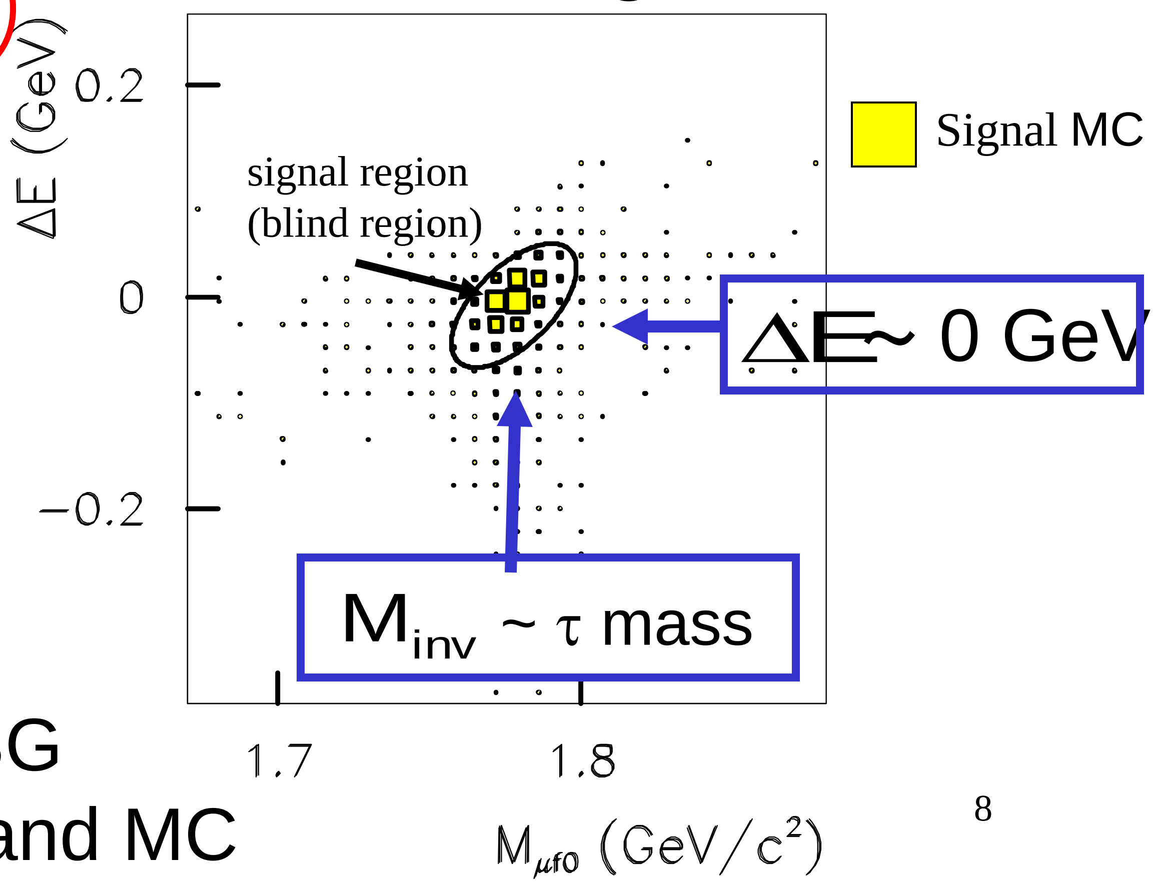
clear environment



Signal Extraction

$$M_{inv} = \sqrt{E_{signal}^2 - p_{signal}^2}$$

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



Blind analysis

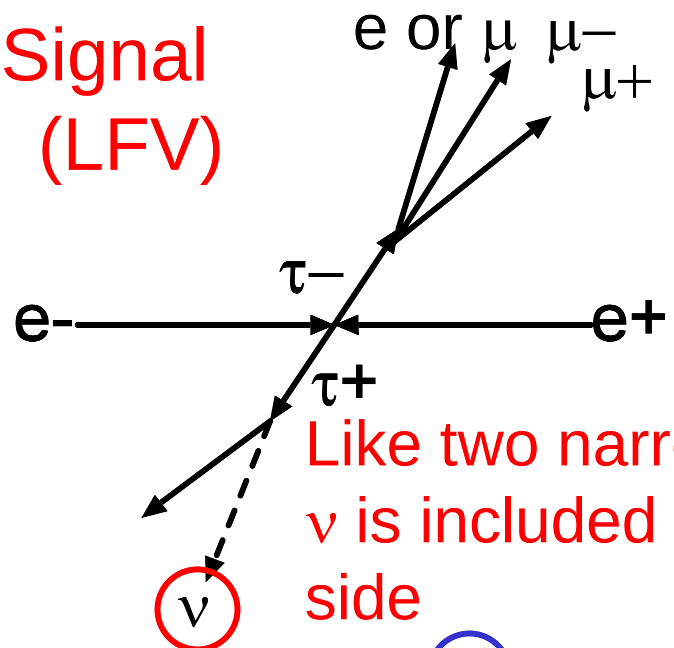
⇒Blind signal region

Estimate number of BG

using sideband data and MC

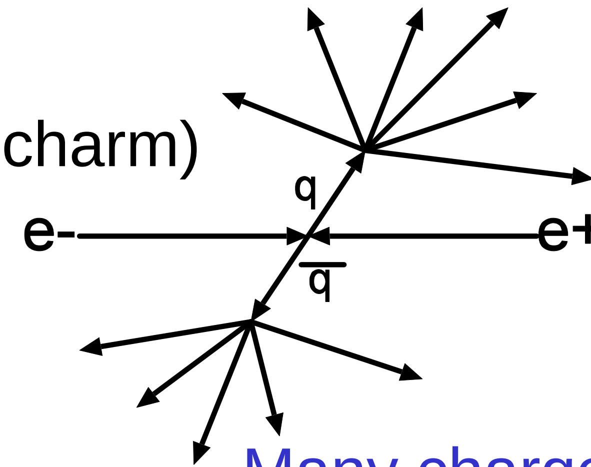
Signature of signal and background

Signal
(LFV)



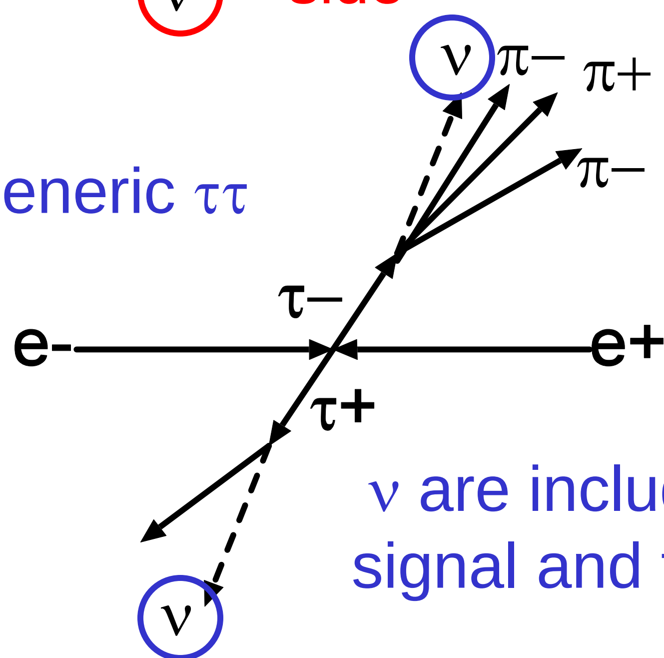
Like two narrow-jets
ν is included in only tag side

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



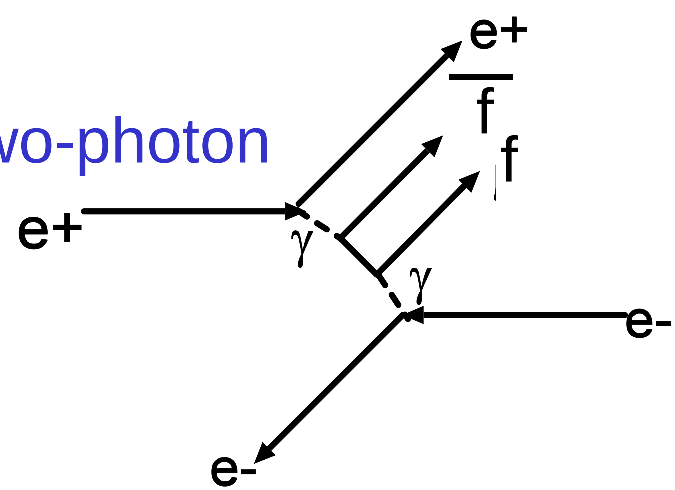
Many charged tracks and γ

Generic ττ



ν are included in signal and tag side

Two-photon



Electrons are included in signal and tag side

Results

$l\gamma$

3lepton

lhh’

lKsKs and lKsKs

Y (ns)$\rightarrow l^{\pm}\tau^{+}$

$\tau \to l\gamma$

$\tau \to \mu\gamma, e\gamma$ (PLB666,16(2008))

Data: 492M τ pairs

$Br(\tau \to \mu\gamma) < 4.5 \times 10^{-8}$ at 90%C.L.

$Br(\tau \to e\gamma) < 1.2 \times 10^{-7}$ at 90%C.L.

$\tau \to \mu\gamma, e\gamma$ (PRL104,021802(2010))

Data: 482M τ pairs (including Y(2,3S) data)

Use Neural network for event selection

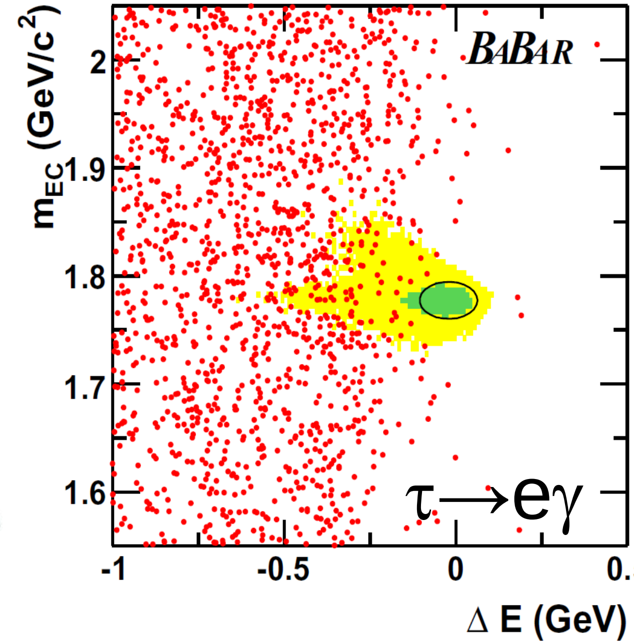
Decay modes	2σ signal ellipse		ε	UL ($\times 10^{-8}$)	
	obs	exp	(%)	obs	exp
$\tau^{\pm} \to e^{\pm}\gamma$	0	1.6±0.4	3.9±0.3	3.3	9.8
$\tau^{\pm} \to \mu^{\pm}\gamma$	2	3.6±0.7	6.1±0.5	4.4	8.2

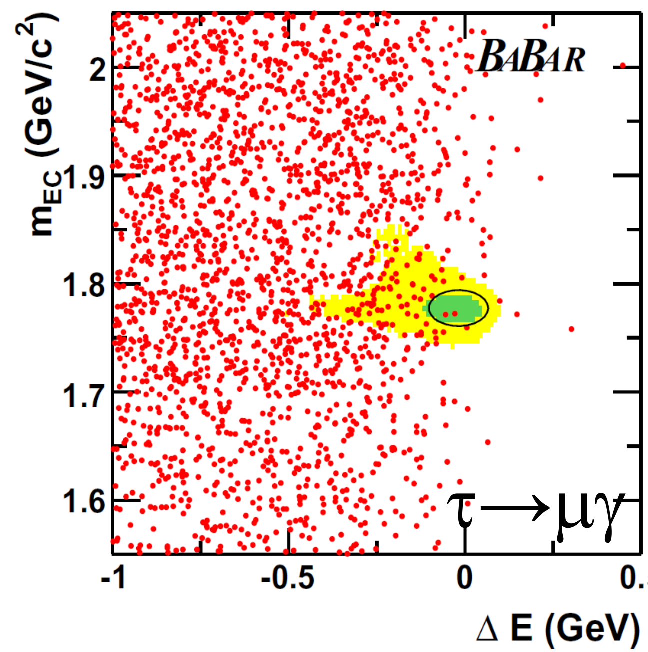
$Br(\tau \to \mu\gamma) < 4.4 \times 10^{-8}$ at 90%C.L.

$Br(\tau \to e\gamma) < 3.3 \times 10^{-8}$ at 90%C.L.

Remaining many BG from $e^+e^- \to \tau^+\tau^-\gamma$

sensitivity is limited by the background





τ→3leptons @ BaBar

Update analysis from 376fb^{-1} →477fb^{-1}

arxiv::1002.4550
(submitted to. PRD-RC)

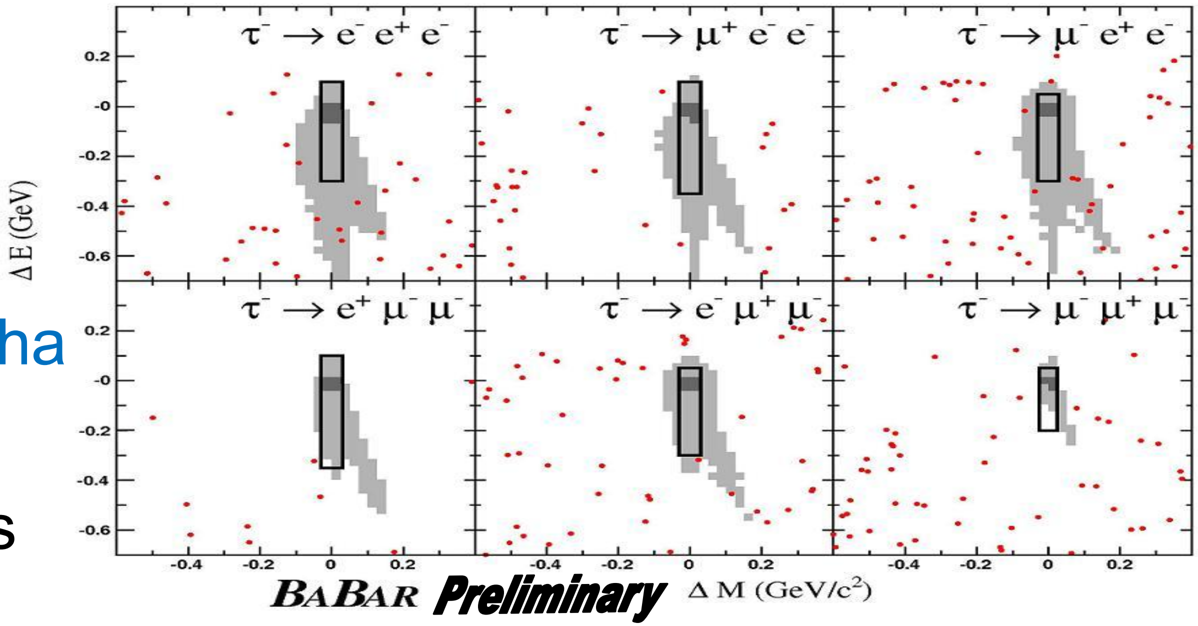
Improve lepton ID eff.

- μ: 66%→77%
- e: 89%→91%

→Better BG rejection

BG : two-photon Bhabha

→ no events in signal region for all modes



Br<(1.8-3.3)x10^{-8}

Improved by a factor of 2-3 from previous results

Channel	Efficiency (%)	N_{bgd}	Exp. UL	N_{obs}	UL
$e^+e^-e^+$	8.6 ± 0.2	0.12 ± 0.02	3.4×10^{-8}	0	2.9×10^{-8}
$e^+e^-\mu^+$	8.8 ± 0.5	0.64 ± 0.19	3.7×10^{-8}	0	2.2×10^{-8}
$e^+e^+\mu^-$	12.6 ± 0.7	0.34 ± 0.12	2.2×10^{-8}	0	1.8×10^{-8}
$e^+\mu^-\mu^+$	6.4 ± 0.4	0.54 ± 0.14	4.6×10^{-8}	0	3.2×10^{-8}
$e^-\mu^+\mu^+$	10.2 ± 0.6	0.03 ± 0.02	2.8×10^{-8}	0	2.6×10^{-8}
$\mu^+\mu^-\mu^+$	6.6 ± 0.6	0.44 ± 0.17	4.0×10^{-8}	0	3.3×10^{-8}

τ→3leptons @ Belle

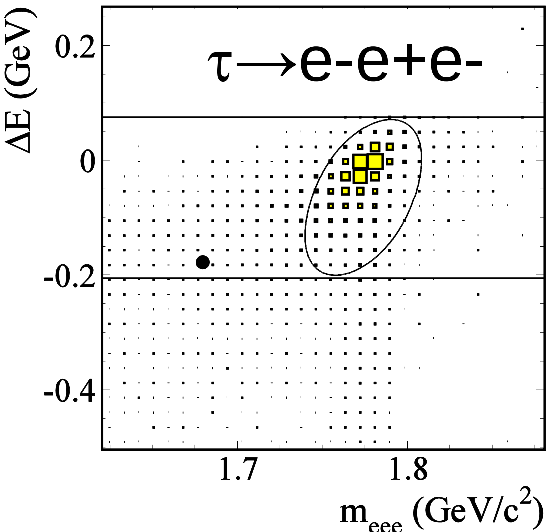
Update analysis from 543fb^{-1} →782b^{-1}

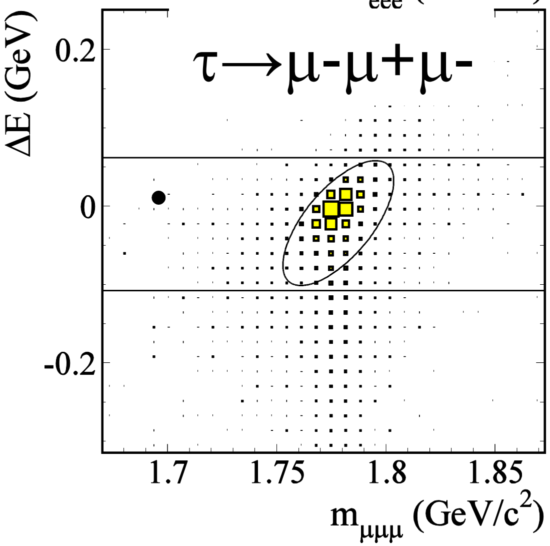
Apply almost same event selection as previous analysis

We observe no events in signal region for all modes

PLB 687, 139 (2010)

Mode	ε (%)	N_{BG}^{EXP}	σ_{syst} (%)	UL (x10^{-8})
$e^-e^+e^-$	6.0	0.21+-0.15	9.8	**2.7**
$\mu^-\mu^+\mu^-$	7.6	0.13+-0.06	7.4	**2.1**
$e^-\mu^+\mu^-$	6.1	0.10+-0.04	9.5	**2.7**
$\mu^-e^+e^-$	9.3	0.04+-0.04	7.8	**1.8**
$\mu^-e^+\mu^-$	10.1	0.02+-0.02	7.6	**1.7**
$e^-\mu^+e^-$	11.5	0.01+-0.01	7.7	**1.5**





We obtain upper limit as Br(τ→3leptons) < (1.5-2.7)x10^{-8}

⇒ Obtained lower ULs than BaBar's ones(< (1.8-3.3)x10^{-8})

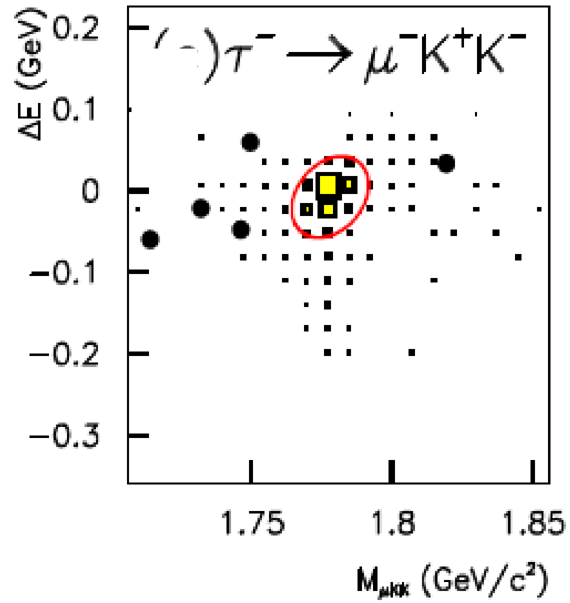
$\tau \to lhh'$

Update from 157 fb^{-1} to 671fb^{-1} @Belle

14 modes are investigated ($h,h'=\pi^{\pm}$ and $K^{\pm}$)

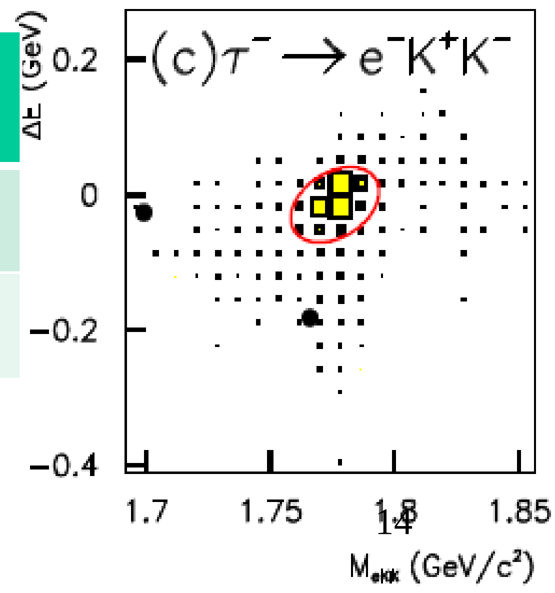
- lepton flavor violation ($\tau^- \to l^- h^+ h'^-$)
- lepton number violation ($\tau^- \to l^+ h^- h'^-$)

Main BG: generic τ, uds for μhh
two-photon for ehh'



PLB 682, 355 (2010)

mode	eff (%)	BG	obs	UL ($\times 10^{-8}$)
$\mu hh'$	2.0 - 3.8	0.0 - 1.4	0 - 2	(3.4-16)
ehh'	2.8 - 4.0	0.0 - 0.6	0 - 1	(4.4-8.8)

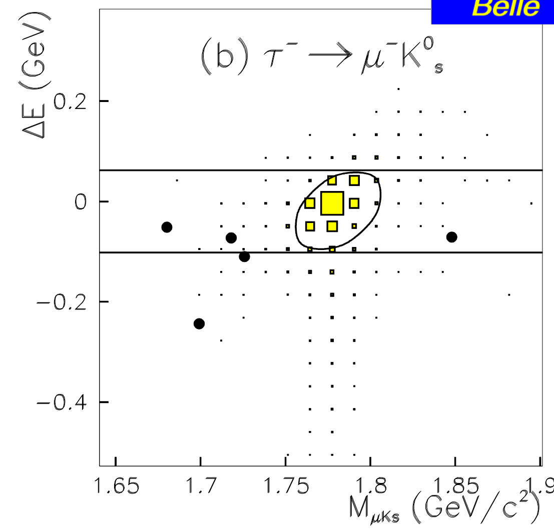


- improve upon previous UL by a factor of (1.6-8.8)

lKs and lKsKs @ Belle

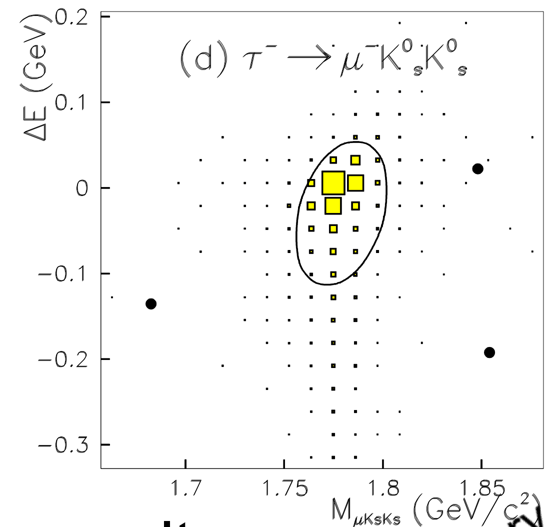
Data : 671 fb^{-1} @ Belle

arXiv::1003.1183
submitted to PLB



Dominant BG in signal region
⇒ Fake lepton + real Ks from
ee→$q\overline{q}$(=u,d,s and c) for both modes

We observe no events in signal region
⇒Set upper limits at 90% C.L.



Mode	ε (%)	$N_{\rm BG}$	$\sigma_{\rm syst}$ (%)	$N_{\rm obs}$	s_{90}	$\mathcal{B}$ ($\times 10^{-8}$)
$\tau^- \to e^- K^0_S$	10.2	0.18±0.18	6.6	0	2.25	2.6
$\tau^- \to \mu^- K^0_S$	10.7	0.35±0.21	6.8	0	2.10	2.3
$\tau^- \to e^- K^0_S K^0_S$	5.82	0.07±0.07	11.2	0	2.44	7.1
$\tau^- \to \mu^- K^0_S K^0_S$	5.08	0.12±0.08	11.3	0	2.40	8.0

B(τ→lK^{0}sK^{0}s) < (7.1-8.0)x10^{-8}
⇒ improve by a factor of (31-43) from CLEO's results

- B(τ→lK^{0}s) < (2.3-2.6) x 10^{-8}
⇒ Obtain lower ULs than BaBar's ones (3.3-4.4)x10^{-8}

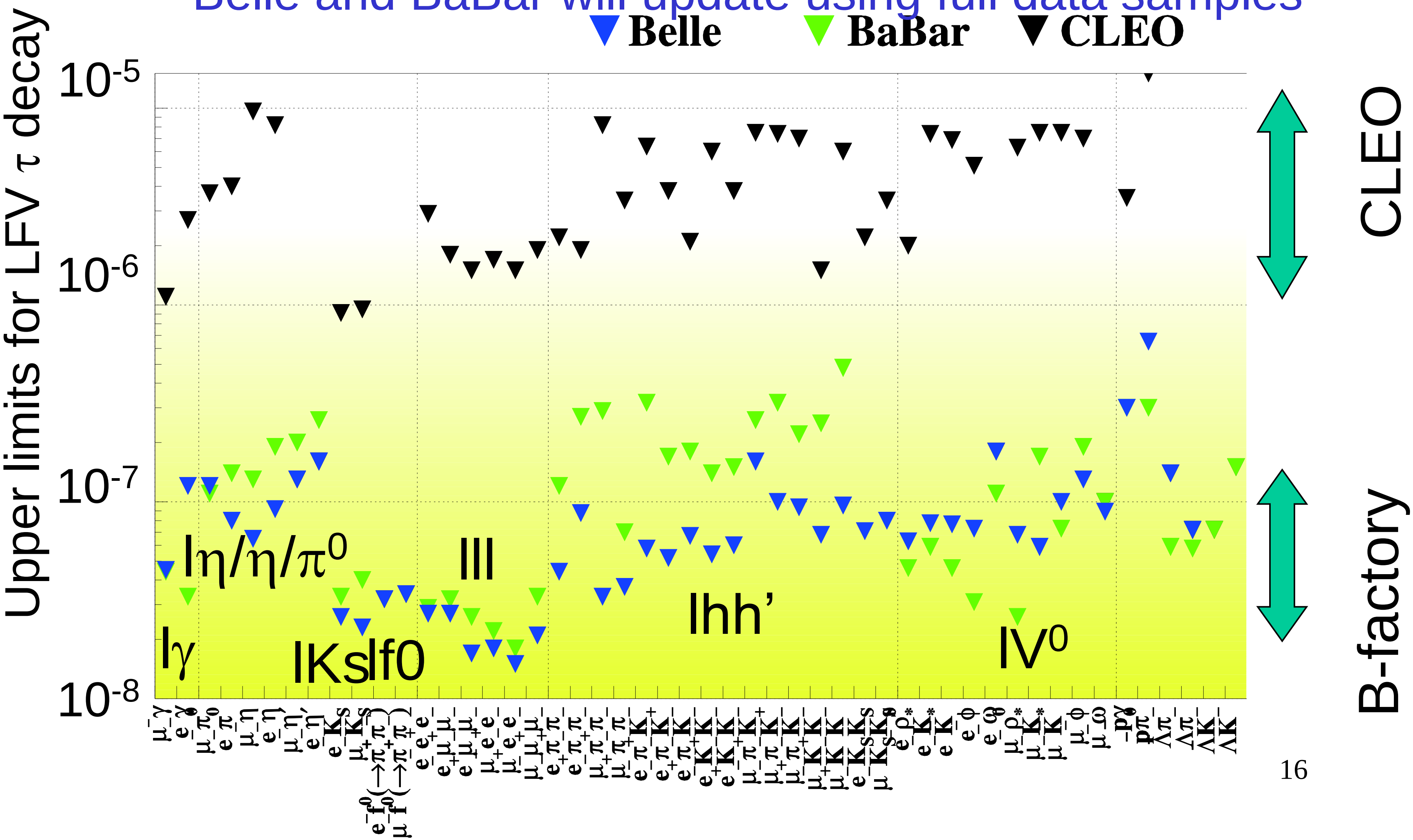
Preliminary

New Upper Limits on LFV τ Decay

Reach upper limits around 10^{-8}

Improve by factor ~100 from CLEO

Belle and BaBar will update using full data samples



LFV in Υ decays @BaBar

PRL 104.151802(2010)

Search for Υ(nS)→$l^{\pm}\tau^{\mp}$

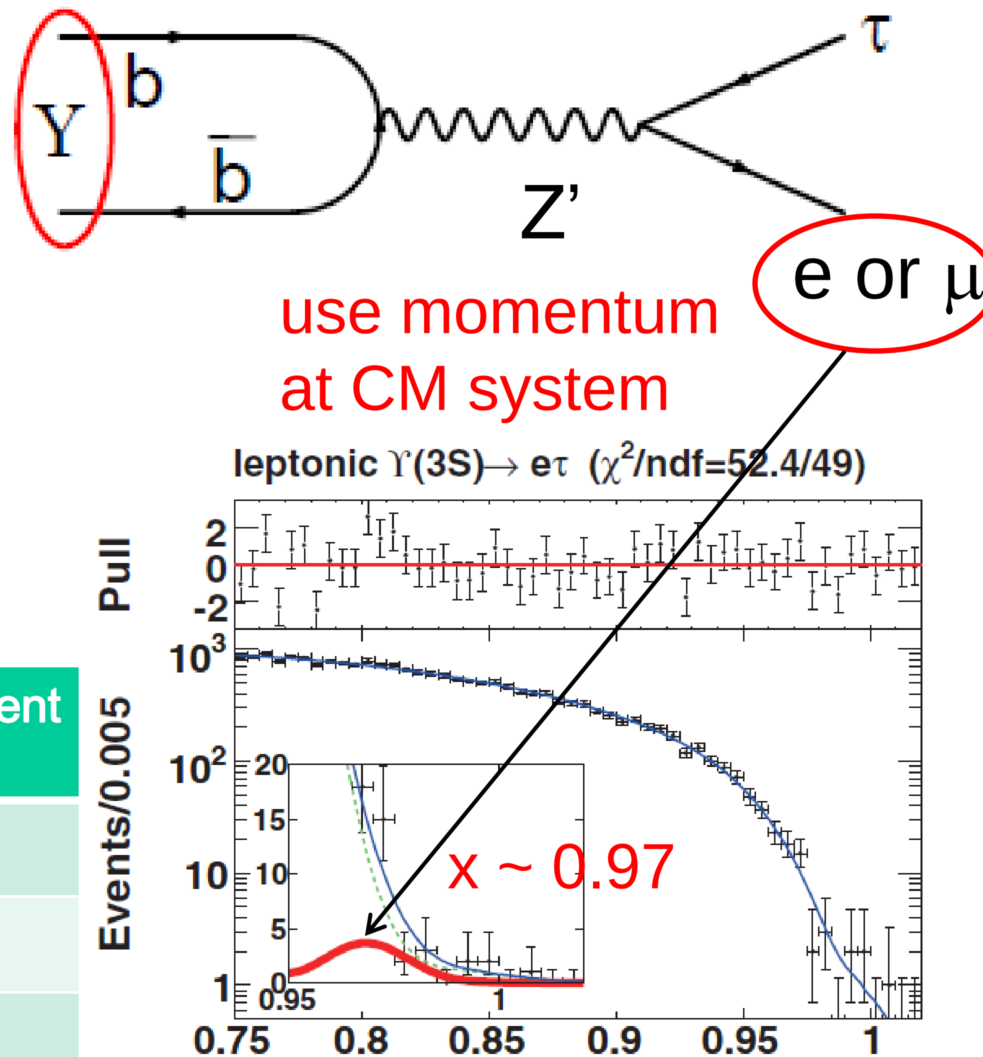
Data collected by BaBar

- 117×10^6 Υ(2S) ($14fb^{-1}$)
- 99×10^6 Υ(3S) ($27fb^{-1}$)

BG

- Bhabha, μμ and ττ
- multi-π and additional γ

modes	UL(10^{-6})	improvement factor
Υ(2S)→eτ	< 3.2	first!
Υ(2S)→μτ	< 3.3	5.5
Υ(3S)→eτ	<4.2	first
Υ(3S)→μτ	<3.1	3.7



$x=p_e/E_{beam}$

Future Prospects

LFV sensitivity for future prospect

Super B-factory

LFV Sensitivity for future prospects

LFV sensitivity

→ depends on background level

- $\tau \rightarrow l\gamma$,

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

  → scale as $\sim 1/\sqrt{L}$

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

  Negligible background at 1ab^{-1}

  due to - Good particle identification
  - Mass restriction to select meson

Expected to remain a few or less BG event at 10 ab^{-1}

→ scale as $\sim 1/L$

Super B-factory

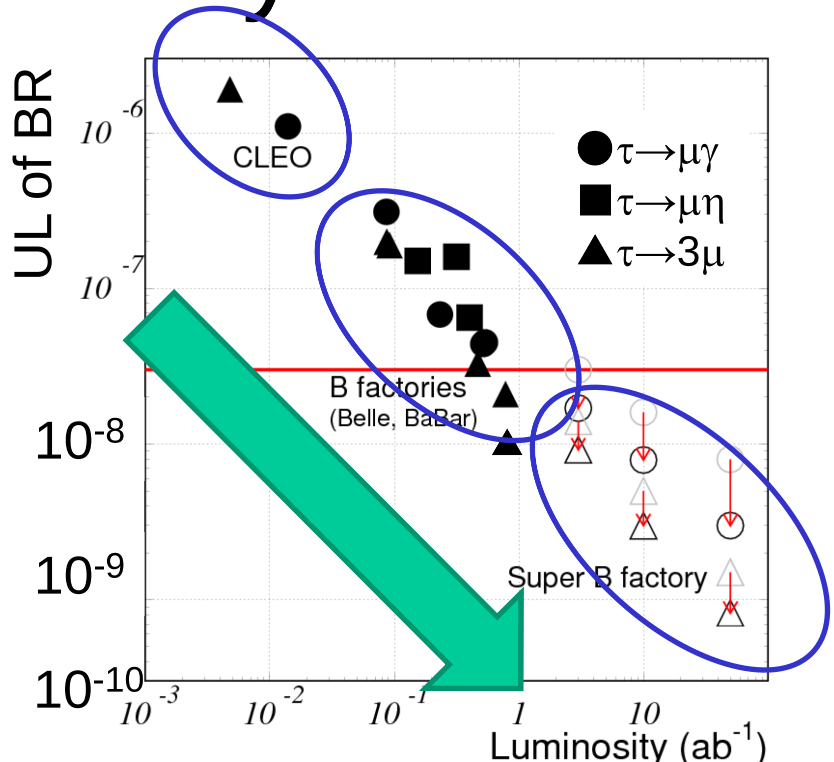
Super B-factory:(10~50) ab^{-1}

Expected sensitivity

$\tau \to l\gamma$ Br~O($10^{-(8-9)}$)

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

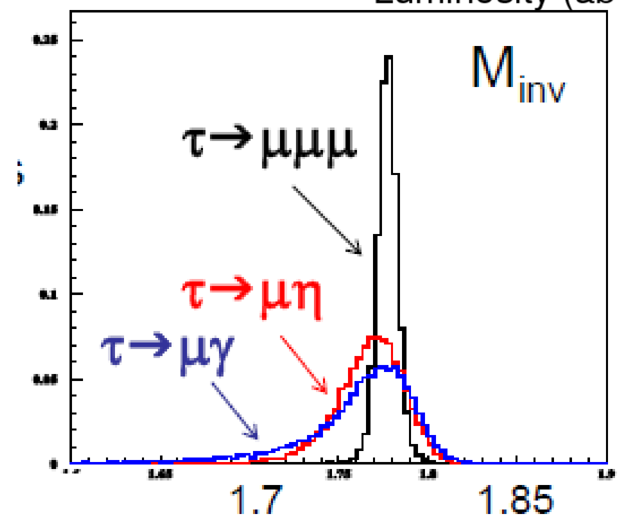
⇨ Provide valuable information for understanding of New Physics



For example,

to improve sensitivity of lγ modes

- Reduce beam BG
- Improve resolution of γ
  - ⇒ Reduce material in front of EM calorimeter



Summary

Summary

Lepton flavor violation is a good signature of NP.

We have searched for LFV τ and Y(ns)decay using a large data sample obtained by B-factories

No LFV signals are observed yet and we set limits of branching faction around $O(10^{-8})$ for τ decays

- Improve sensitivity by factor ~100 from CLEO

⇒rejected BG effectively because of detailed BG study

Other process : UL< $O(10^{-6})$ for Y(nS) decays

⇨ Will update results using full data samples

Super B-factories will make LFV sensitivity to reach $O(10^{-9\sim10})$ with 50 ab^{-1}