Recent Tau Decay Results at B Factories ~ Lepton Flavor Violating Tau Decays ~

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(on behalf of the Belle and BaBar Collaborations)

17/Jul/2010 22nd Rencontres de Blois

Introduction

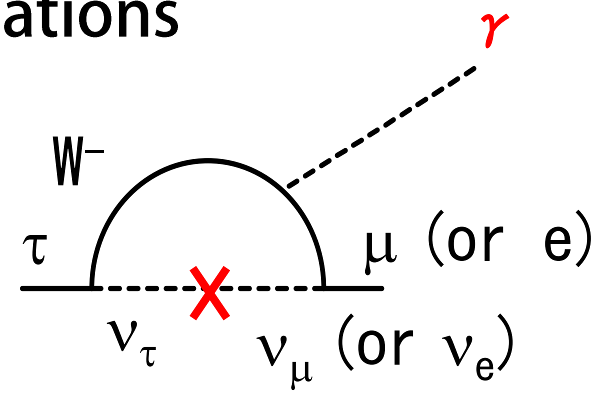
Lepton flavor violation (LFV) in charged leptons

⇒ **negligibly small probability in the Standard Model (SM)**

even taking into account neutrino oscillations

$$Br(\tau \to \ell\gamma)_{SM} \propto \left(\frac{\delta m_\nu^2}{m_W^2}\right)^2 < 10^{-54}$$

(EPJC8 513 (1999))



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

•Many extensions of the SM predict LFV decays.

→These branching fractions could be enhanced as high as current experimental sensitivity.

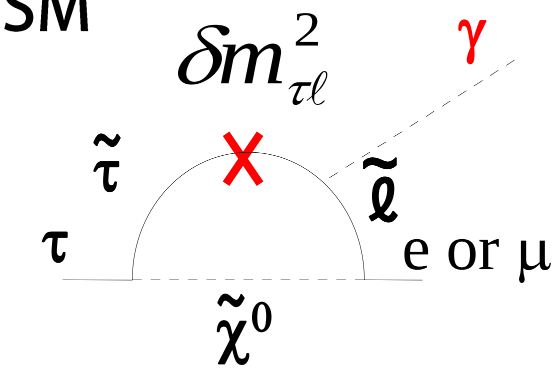
Tau lepton :

- The heaviest charged lepton
- Many possible LFV decay modes

⇒Ideal place to search for LFV

LFV IN SUSY

SUSY is the most popular candidate for BSM among new physics models

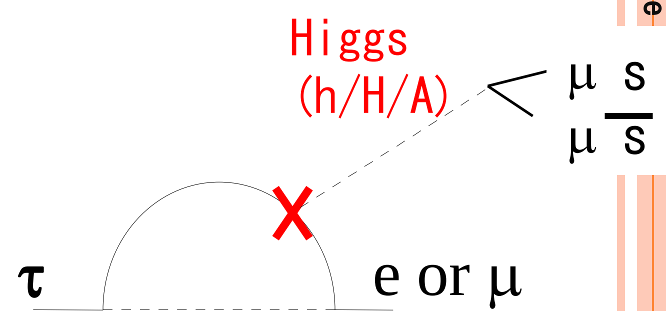


naturally induce LFV at one-loop due to slepton mixing

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

When sleptons are much heavier than weak scale

LFV associated with a neutral Higgs boson (h/H/A)



Higgs coupling is proportional to mass

$\Rightarrow \mu\mu$ or $s\bar{s}$ (η, η' and so on) are favored

and Br is enhanced more than that of $\tau \to \mu\gamma$.

To distinguish which model is favored, various searches for τ LFV are important!

B-FACTORIES

B-factory: E at CM = Υ(4S)

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

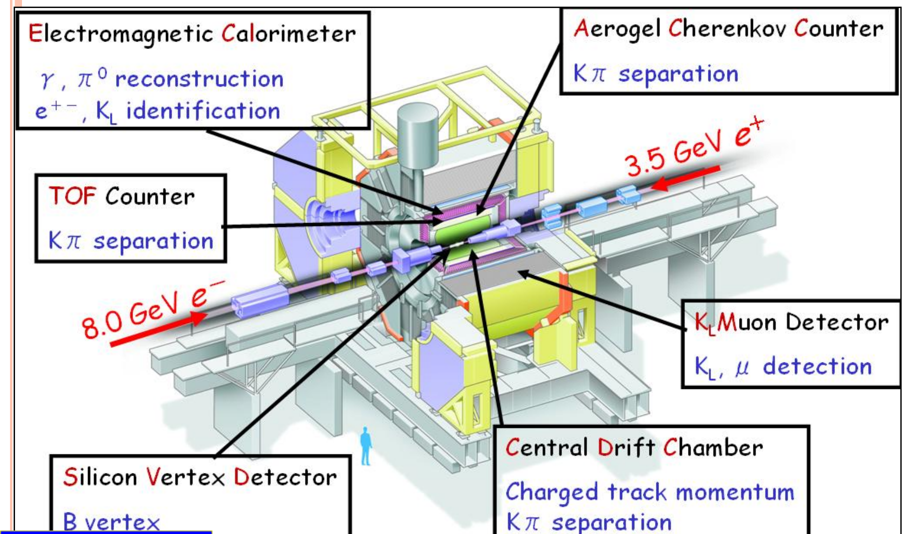
Other Y(nS) and Energy scan are also collected by B-factories

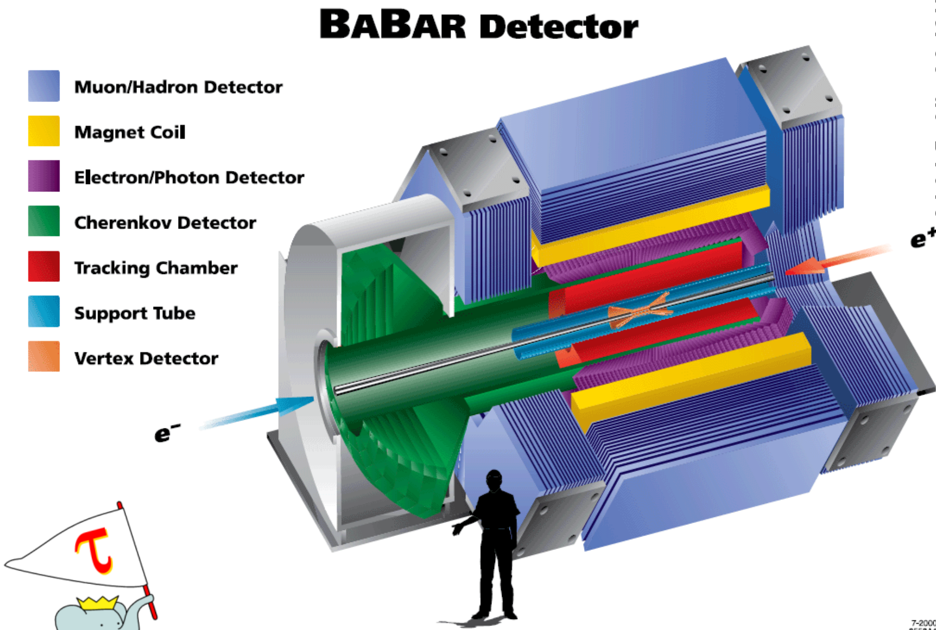
$\sigma(\tau\tau)$~0.9nb, $\sigma(b\bar{b})$~1.1nb

A B-factory is also a τ-factory!

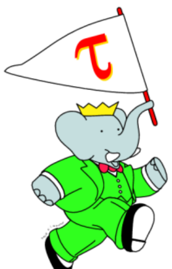
Detector: Good track reconstruction and particle identification

Lepton ID ~ (80-90)%
Fake ID ~ (0.1-3)%





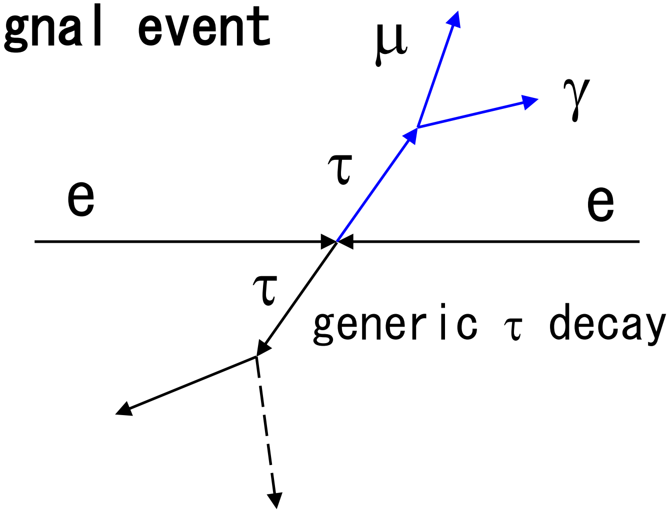
~9x10^8 $\tau\tau$ at Belle



~5x10^8 $\tau\tau$ at BaBar

ANALYSIS METHOD

- $e^+e^- \to \tau^+\tau^-$
  - → 1 prong + missing (tag side)
  - → $\mu+\gamma$ (signal side)



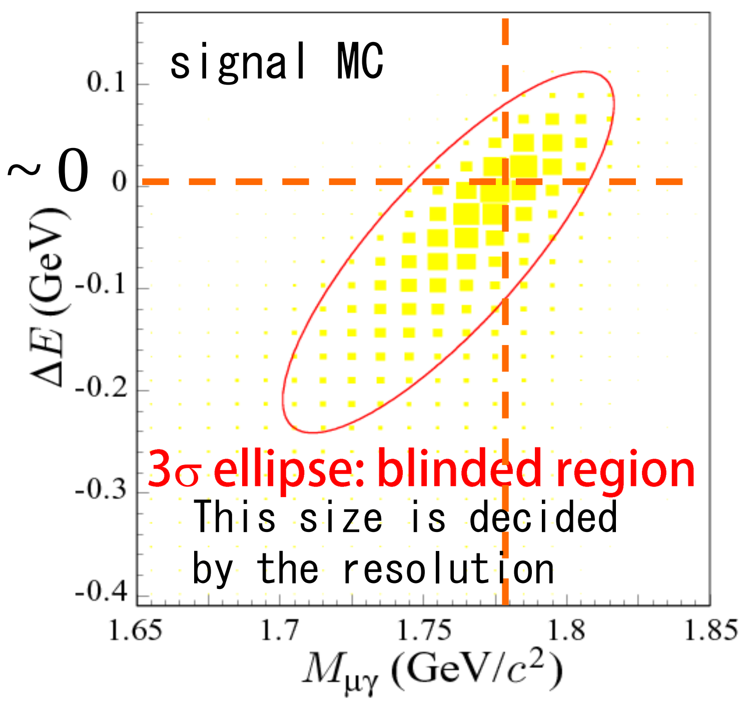
Signal extraction: $M_{\mu\gamma}$-ΔE plane

$$M_{\mu\gamma} = \sqrt{(E_{\mu\gamma}^2 - p_{\mu\gamma}^2)}$$

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

$M_{\mu\gamma} \sim m_\tau$

$\Delta E \sim 0$



Blind analysis
⇒Blind signal region

Estimate number of BG in the singal region using sideband data and MC

FEATURE OF ANALYSIS FOR $\tau \to \mu\gamma$, $\mu\eta$, $\mu\mu\mu$

Generally,

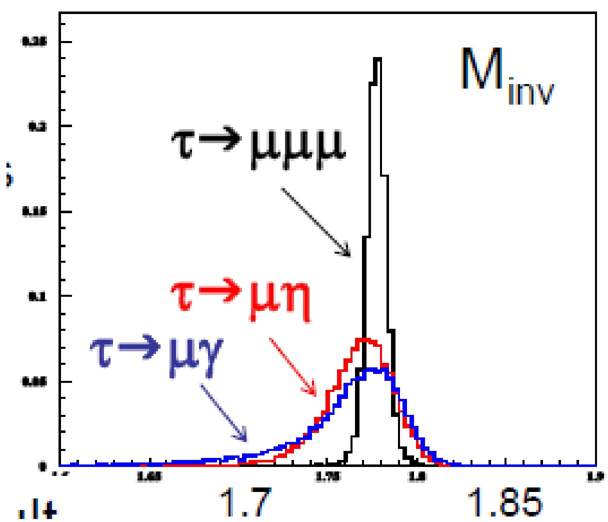
- γ in signal decay : difficult to distinguish from ISR or fake γ, makes resolution worse than in all-charged modes.
- lepton: good efficiency and low fake rate, good resolution.

	BG rejection	Mass resolution
$\tau \to \mu\gamma$	very hard	bad (γ)
$\tau \to \mu\eta$	hard (but η mass window helps)	bad (2γ, but η mass window helps)
$\tau \to \mu\mu\mu$	easy(μID x3)	good (only charged tracks)

Here, we discuss only $\eta \to \gamma\gamma$ subdecay mode.

Besides, since $\tau \to \mu\gamma$ has only 2 particles, less kinematical information than that for other decays

	Main BG
$\tau \to \mu\gamma$	$ee \to \mu\mu+\gamma$, $\tau \to \mu\nu\nu+\gamma$, $\tau \to \pi\nu+\gamma$
$\tau \to \mu\eta$	$ee \to \mu\mu+\gamma\gamma$, $\tau \to \mu\nu\nu+\gamma\gamma$, $\tau \to \pi\nu+\gamma\gamma$
$\tau \to \mu\mu\mu$	$ee \to \mu\mu\mu\mu$, $ee\mu\mu$



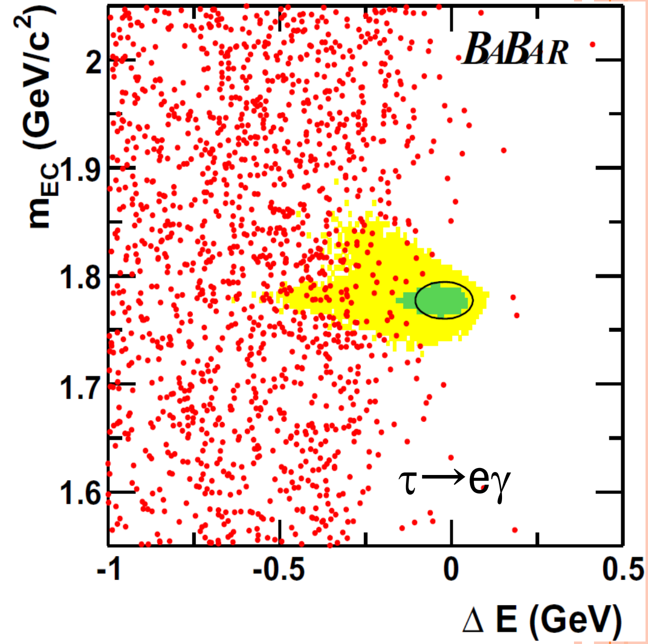
$\tau \to \ell\gamma$

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

Data: 492M τ pairs

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

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



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

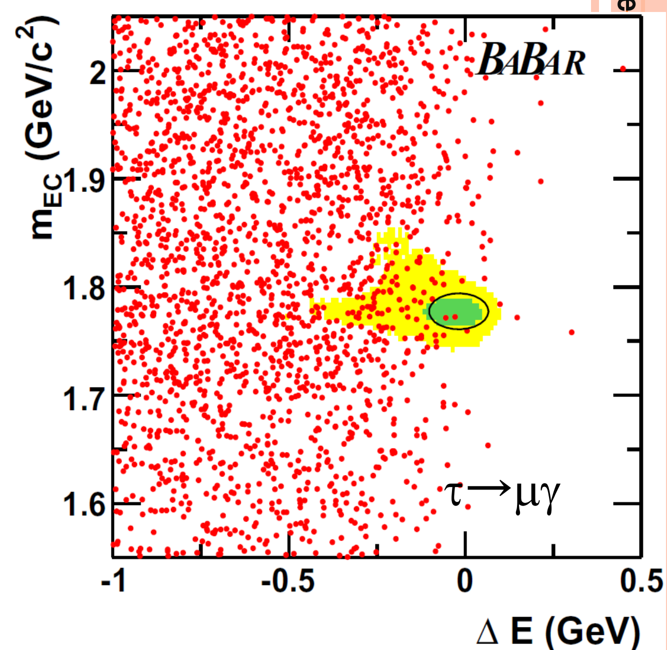
Data: 482M τ pairs (including Y(2,3S) data)

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($\tau \to \mu\gamma$)<4.4x10^{-8} at 90%C.L.

Br($\tau \to e\gamma$)<3.3x10^{-8} at 90%C.L.



$\tau \to \ell\ell\ell$@BaBar

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

(PR D81,111101(2010))

Improve lepton ID eff.

- μ: 66%→77%
- e: 89%→91%

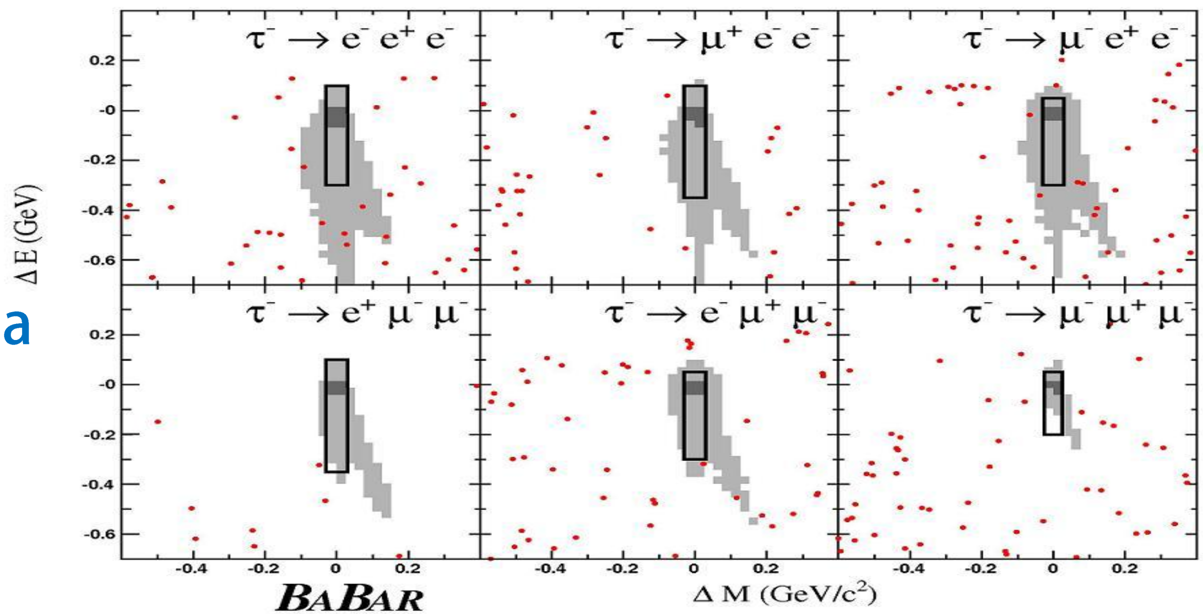
→Better BG rejection

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}

$\tau \to \ell\ell\ell$@Belle

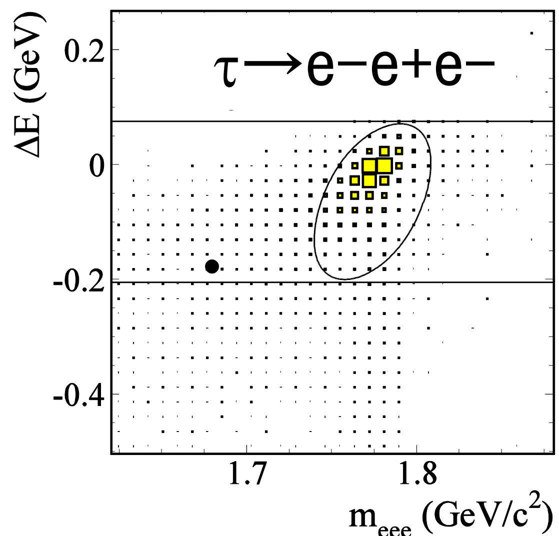
Update analysis from 543fb^{-1} → 782fb^{-1}

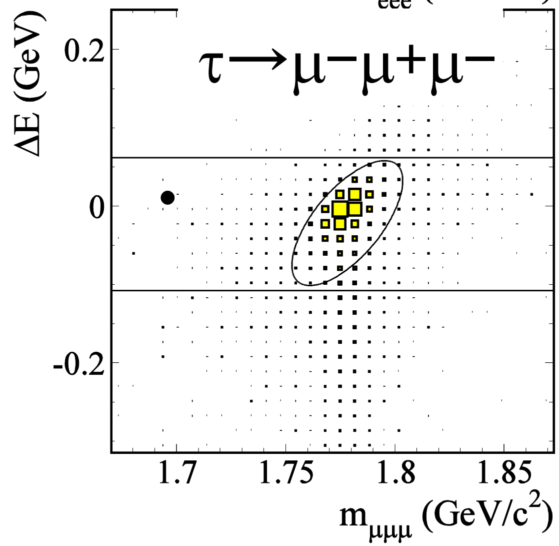
➡ Apply almost same event selection as previous analysis

We observe no events in signal region for all modes

PLB 687, 139 (2010)

Mode	Eff. (%)	N_{BG}^{EXP}	UL (x10^{-8})
$e^-e^+e^-$	6.0	0.21±0.15	2.7
$\mu^-\mu^+\mu^-$	7.6	0.13±0.06	2.1
$e^-\mu^+\mu^-$	6.1	0.10±0.04	2.7
$\mu^-e^+e^-$	9.3	0.04±0.04	1.8
$\mu^-e^+\mu^-$	10.1	0.02±0.02	1.7
$e^-\mu^+e^-$	11.5	0.01±0.01	1.5





⇒ Obtained the mort sensitive ULs

$\tau \rightarrow \ell P^0$ ($P^0 = \pi^0, \eta, \eta'$)

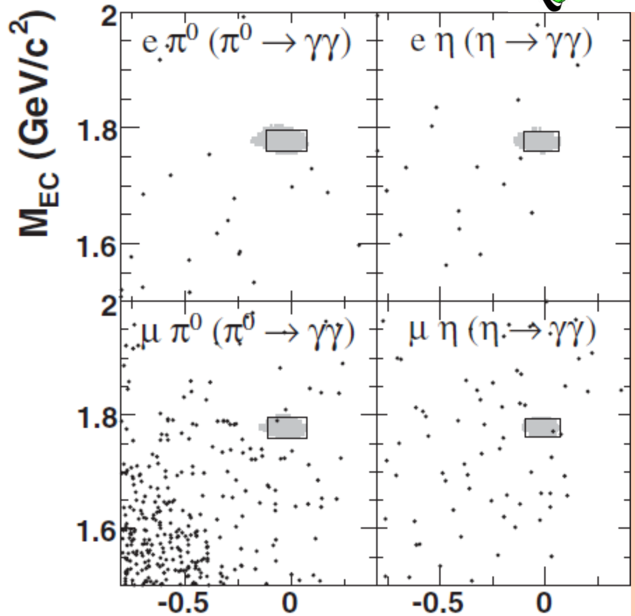
previous result

Data : 401 fb^{-1} @ Belle, 339 fb^{-1}@BaBar

(PLB648,341(2007)) (PRL98,061803(2007))

To increase sensitivity, two sub-decay modes are taken into account:

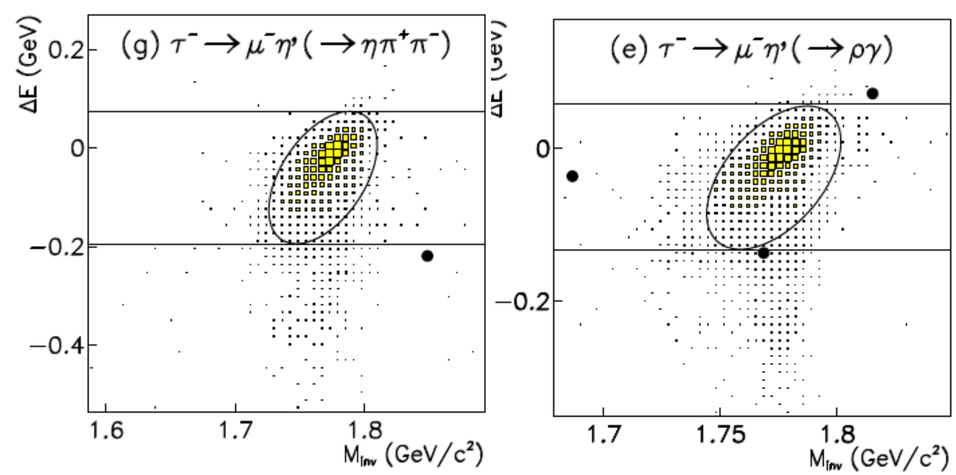
$\eta \rightarrow \gamma\gamma$, $\pi\pi\pi^0$, $\eta' \rightarrow \gamma\rho^0$, $\pi\pi\eta$



	Belle	BaBar
eff	3.9%–6.8%	2.8%–7.0%
N_{BG}^{exp}	0.0–0.58	0.01–1.3
N^{obs}	0–1	0–1
UL	(0.8–1.6)x10^{-7}	(1.1–2.4)x10^{-7}

B<(0.8-2.4)x10^{-7}

at 90%CL

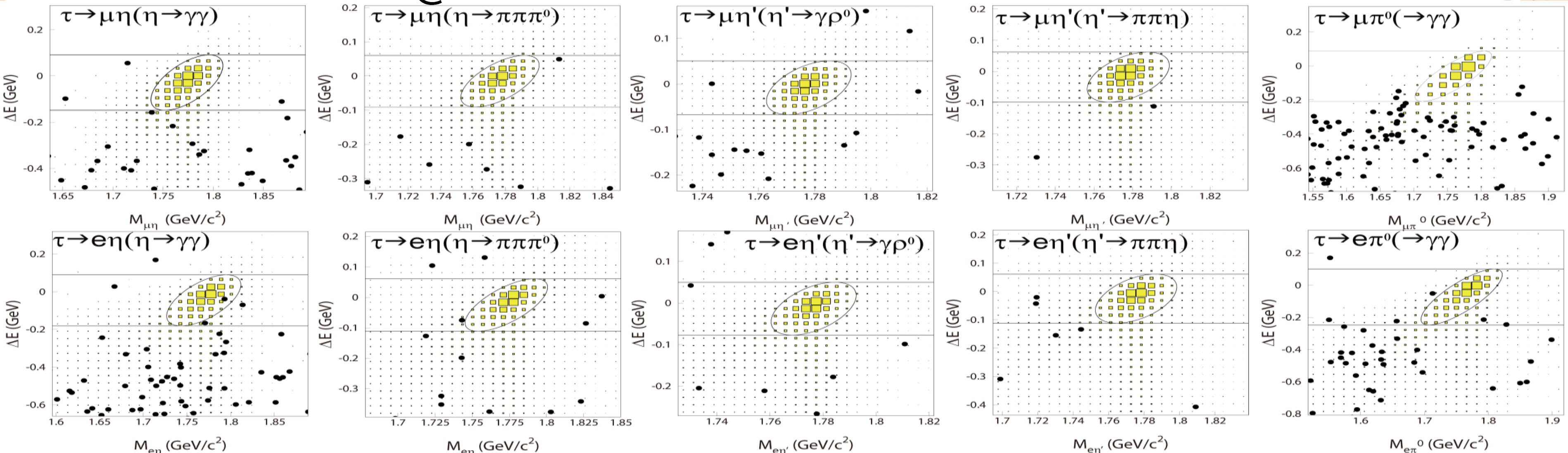


$\tau \to \ell P^0$@Belle ($P^0=\pi^0,\eta,\eta'$)

new result!

Data : 901 fb^{-1} @ Belle

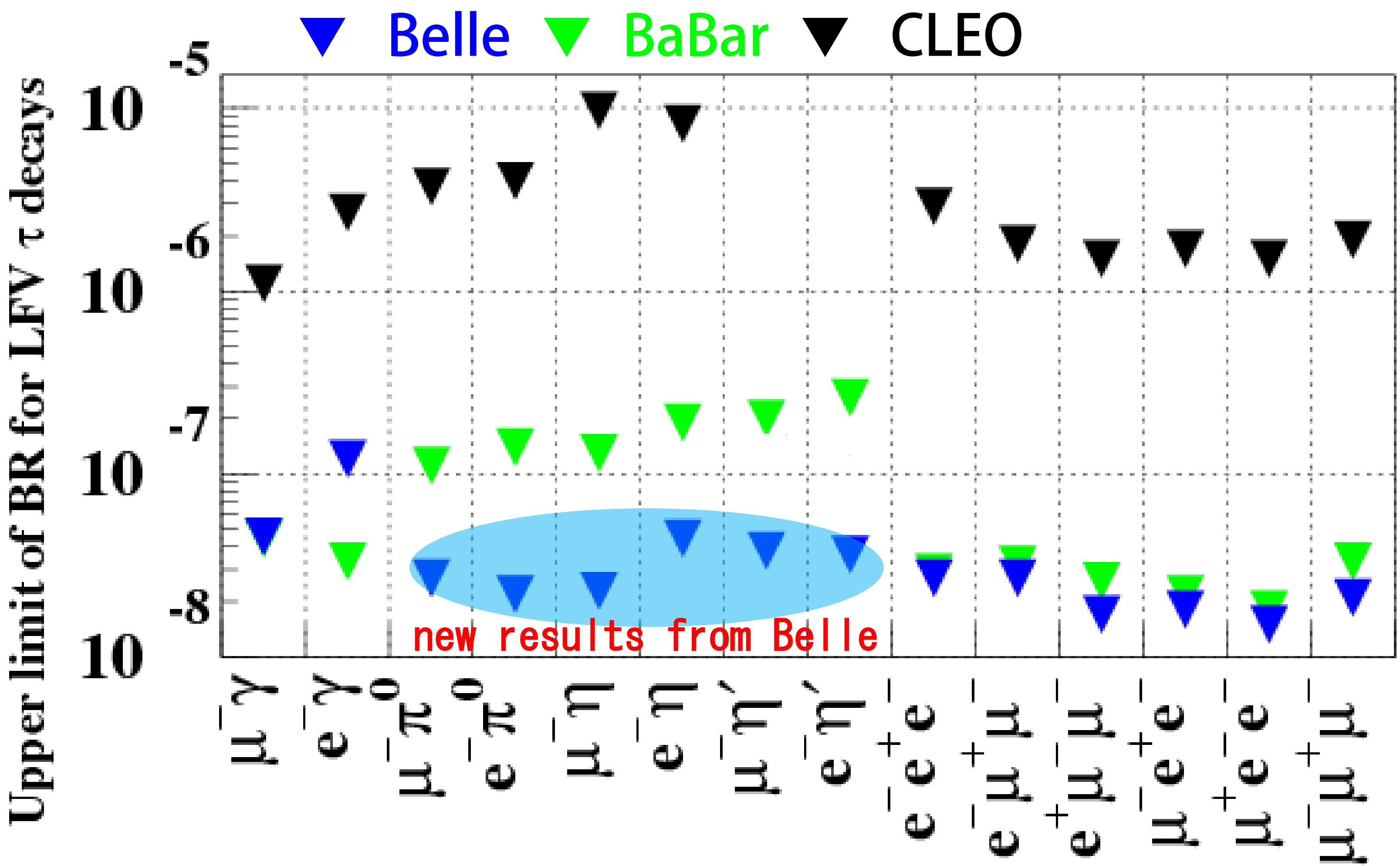
Belle preliminary result



$\tau\to$	Eff.	N_{BG}^{exp}	UL (x10^{-8})	$\tau\to$	Eff.	N_{BG}^{exp}	UL (x10^{-8})
$\mu\eta(\to\gamma\gamma)$	8.2%	0.63 ± 0.37	3.6	$\mu\eta'(\to\pi\pi\eta)$		$0.00+0.16-0.00$	10.0
$\mu\eta(\to\pi\pi\pi^0)$	6.9%	0.23 ± 0.23	8.6	$\mu\eta'(\to\rho^0\gamma)$		0.59 ± 0.41	6.6
$\mu\eta$(comb.)			2.3	$\mu\eta'$(comb.)			3.8
$e\eta(\to\gamma\gamma)$	7.0%	0.66 ± 0.38	8.2	$e\eta'(\to\pi\pi\eta)$		0.63 ± 0.45	9.4
$e\eta(\to\pi\pi\pi^0)$	6.3%	0.69 ± 0.40	8.1	$e\eta'(\to\rho^0\gamma)$		0.29 ± 0.29	6.8
$e\eta$(comb.)			4.4	$e\eta'$(comb.)			3.6
$\mu\pi^0(\to\gamma\gamma)$	4.2%	0.64 ± 0.32	2.7	$e\pi^0(\to\gamma\gamma)$	4.7%	0.89 ± 0.40	2.2

→(2.1-4.4) times more sensitive results than previously (401fb^{-1})

New Upper Limits on LFV tau Decays



Our sensitivity reaches a few x 10^{-8}!

LFV Sensitivity for Future Prospects

LFV sensitivity ➡ depends on background level

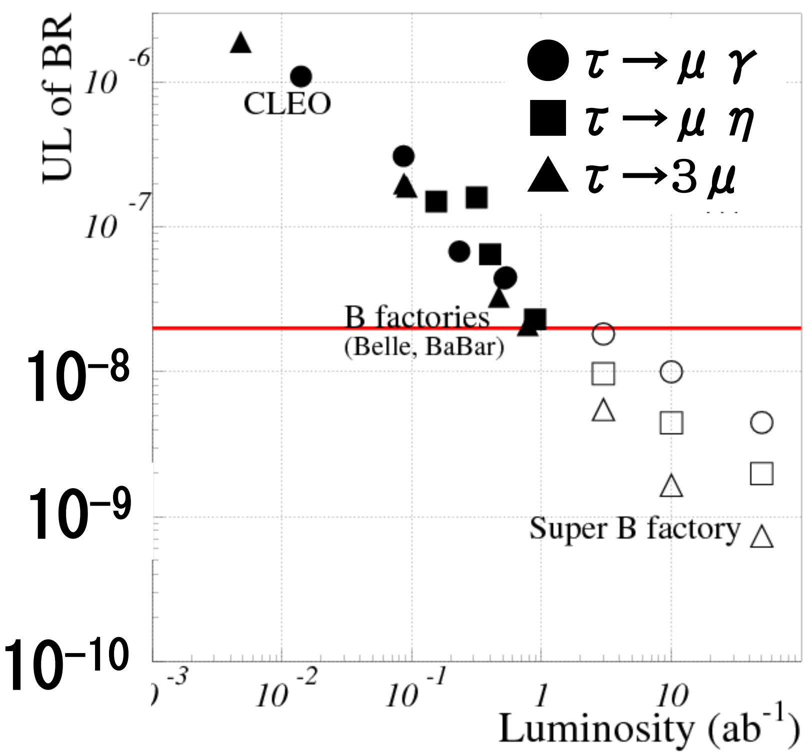
$50ab^{-1}$@next-generation B-factories is expected.

	N_{BG}@$1ab^{-1}$	N_{BG}@$50ab^{-1}$
$\tau\to\mu\gamma$	~7	~340
$\tau\to\mu\eta$	~0.7	~35
$\tau\to\mu\mu\mu$	~0.2	~8

simple extrapolation

$$\propto 1/\sqrt{Lum.}$$

$$\propto 1/Lum.$$



Expected sensitivity

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

$\tau\to\mu\mu\mu$, $\mu\eta$ Br~O($10^{-(9-10)}$)

to obtain improved sensitivity
- better particle identification
- better resolution for γ

SUMMARY

Lepton flavor violation is a good signature of NP.

We have searched for various τ LFV decays using a large data sample obtained by B-factories

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

→Improve sensitivity by factor ~100 from CLEO

- not only much larger data samples but also more effective BG rejection after detailed examination of the BG

- now updating results using full data samples for various τ LFV decays

→Belle and BaBar have finished taking data

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

tomorrow →SuperKEKB upgrade was approved and is included in the budget.

Review of Super KEKB, SuperB, and LHCb Upgrade - C.Kiesling (MPI, Munich)

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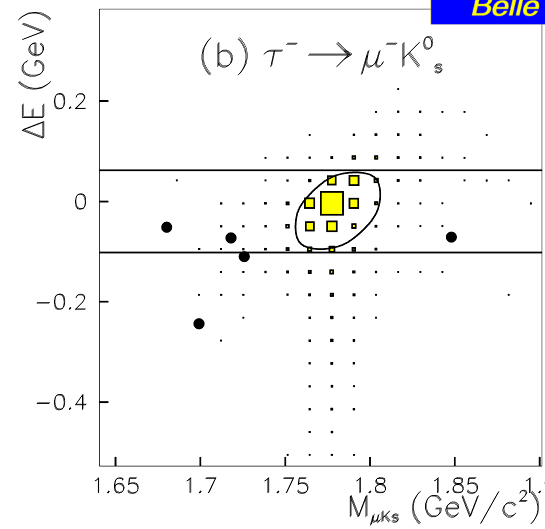
$\tau \to \ell K^0_S$, $\ell K^0_S K^0_S$@Belle

Data : 671 fb^{-1} @ Belle

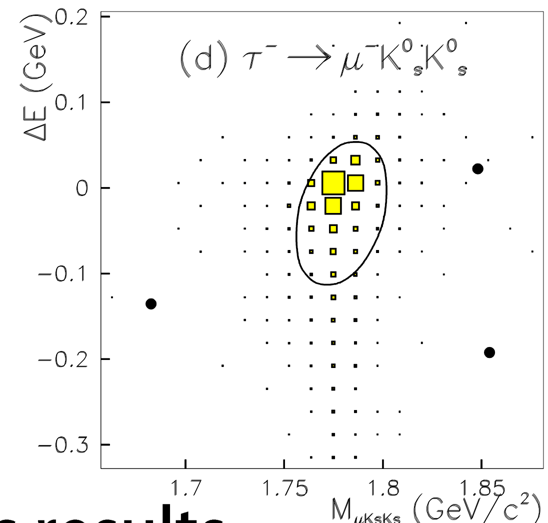
arXiv::1003.1183
to appear in PLB

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

We observe no events in signal region.



Mode	ε (%)	N_{BG}	σ_{syst} (%)	N_{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



Br($\tau \to \ell K^0_s K^0_s$) < (7.1-8.0)x10^{-8}

⇒ improve by a factor of (31-43) from CLEO's results

- Br($\tau \to \ell K^0_s$) < (2.3-2.6) x 10^{-8}

BaBar's ones: (3.3-4.4)x10^{-8} PR D 79, 012004 (2009)