Updated search for Lepton-Flavor-Violating tau decays at Belle

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(on behalf of the Belle Collaboration)

KEKB and Belle

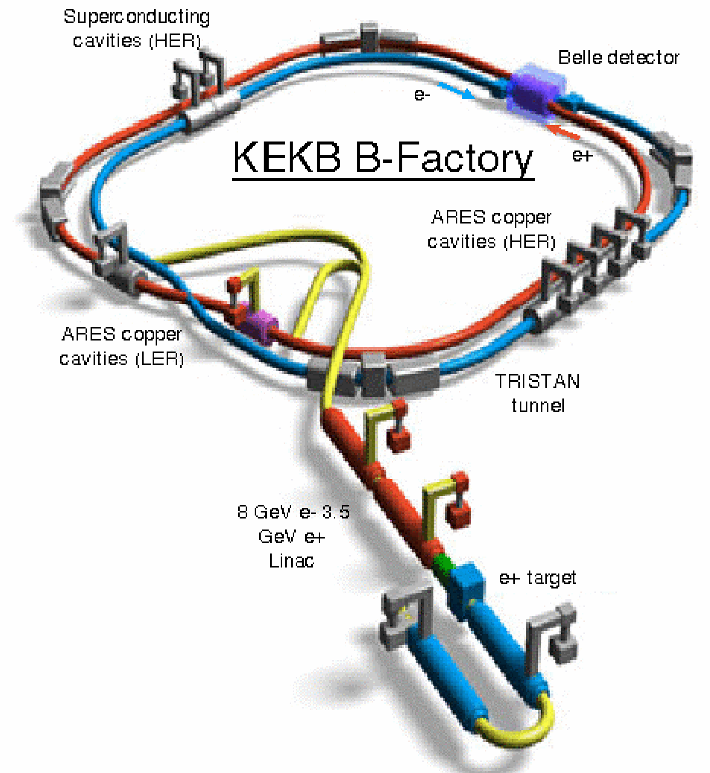
KEKB: e^+(3.5 GeV) e^-(8GeV)

$\sigma(\tau\tau)$~0.9nb,σ(bb)~1.1nb

A B-factory is also a τ-factory!

Peak luminosity: 2.1×10^{34} $cm^{-2}s^{-1}$

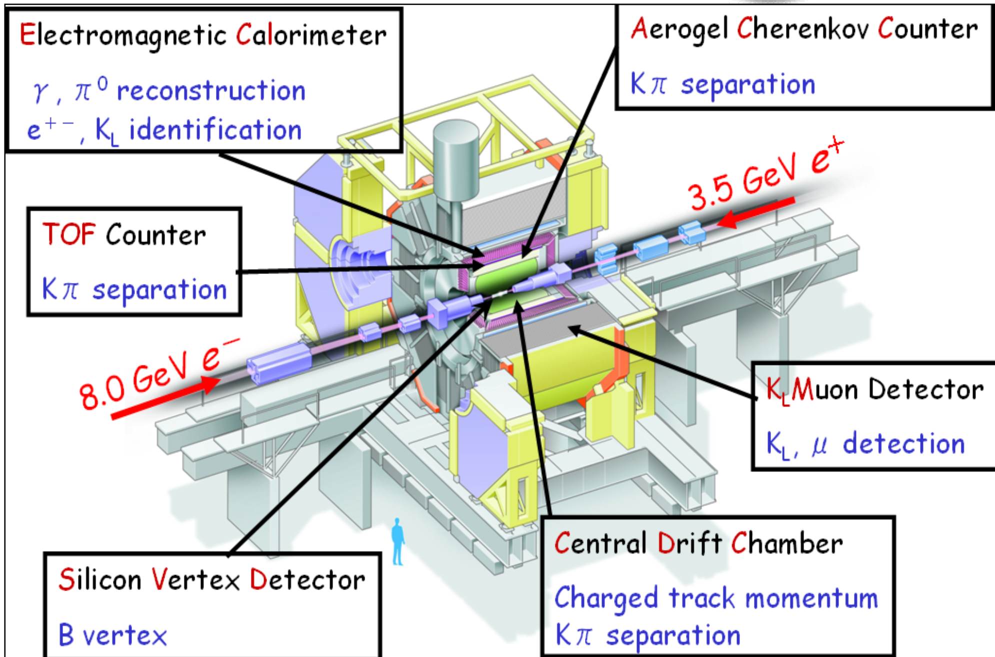
World highest luminosity!



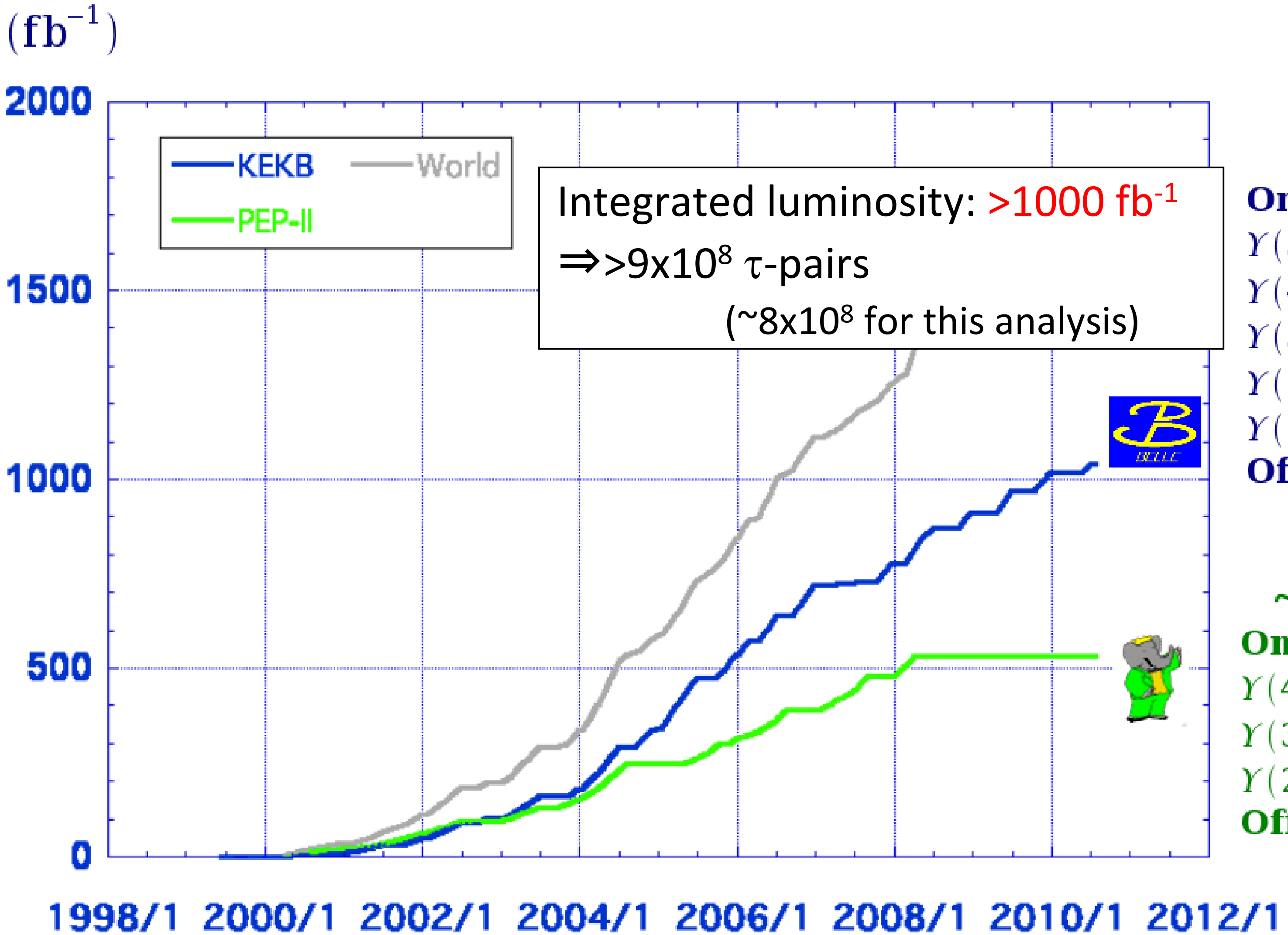
Belle Detector:

Good track reconstruction
and particle identifications

Lepton efficiency:90%
Fake rate : O(0.1) % for e
O(1)% for μ



Luminosity history



> 1 ab^{-1}

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1}

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 24 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan:

~ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

$\Upsilon(4S)$: 433 fb^{-1}

$\Upsilon(3S)$: 30 fb^{-1}

$\Upsilon(2S)$: 14 fb^{-1}

Off resonance:

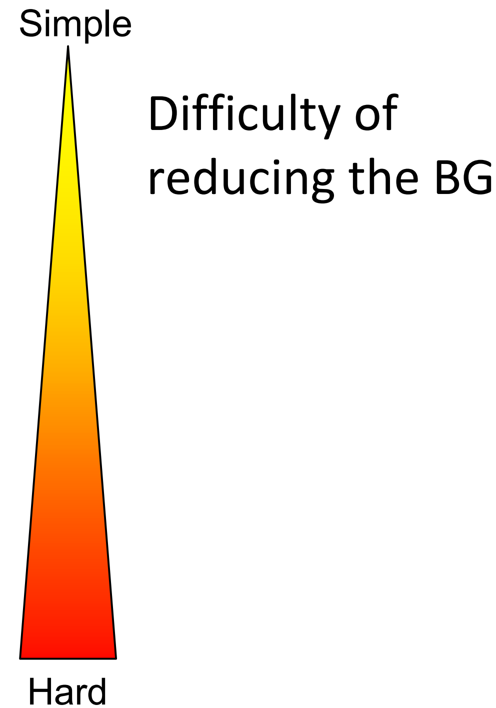
~ 54 fb^{-1}

Belle is finished in 2010/6/30. Belle-II upgrade started.

→ Analysis with full data sample is on going.

Recent analysis

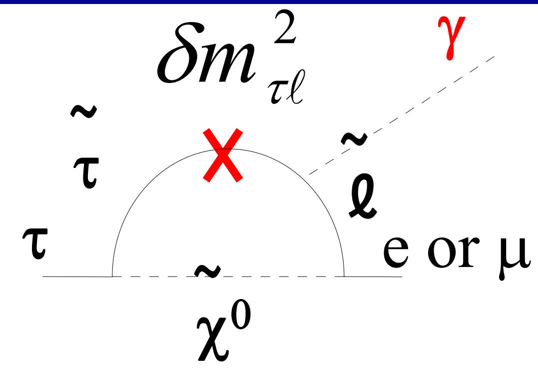
- $\tau \rightarrow lll$ (last summer)
- $\tau \rightarrow lK_S$ (671fb^{-1})
- $\tau \rightarrow lV^0(\rightarrow hh')$ (this summer)
- $\tau \rightarrow lP^0(\rightarrow \gamma\gamma)$ (this summer)
- $\tau \rightarrow lhh'$
- $\tau \rightarrow l\gamma$



  – Updating the searches using (almost) full data sample
  – Analyze the modes from simple selection to hard for background reduction
    - Provide feedback to next analysis of similar final state.

LFV in SUSY

SUSY is the most popular candidate among new physics models

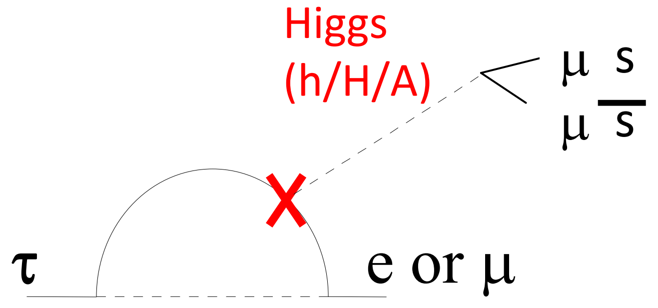


naturally induce LFV at one-loop due to slepton mixing

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

When sleptons are much heavier than weak scale

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



Higgs coupling is proportional to mass
⇒μμ or $s\bar{s}$ (η, η' and so on) are favored
and B.R. is enhanced more than that of $\tau \to \mu\gamma$.

To distinguish which model is favored, $\tau \to lM^0$ decays are also important.

Analysis procedure

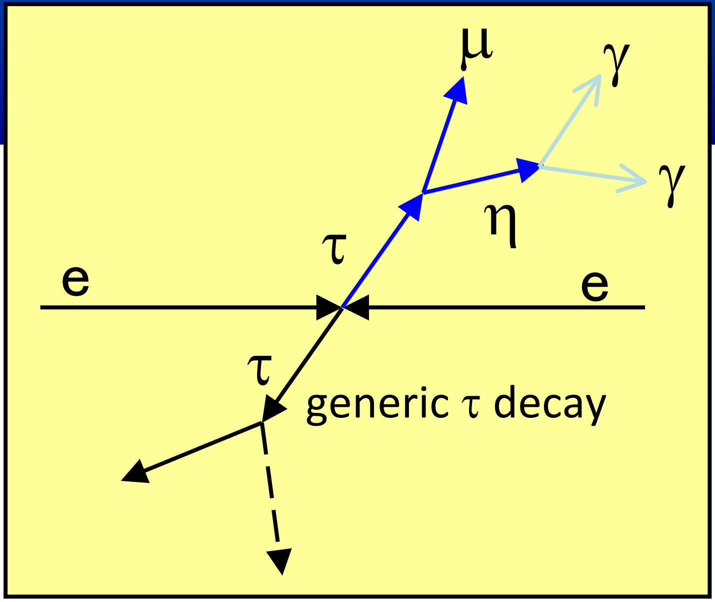
- $e^+e^- \rightarrow \tau^+\tau^-$

Br~85%

→1 prong + missing (tag side)

→$\mu+\eta$ (signal side)

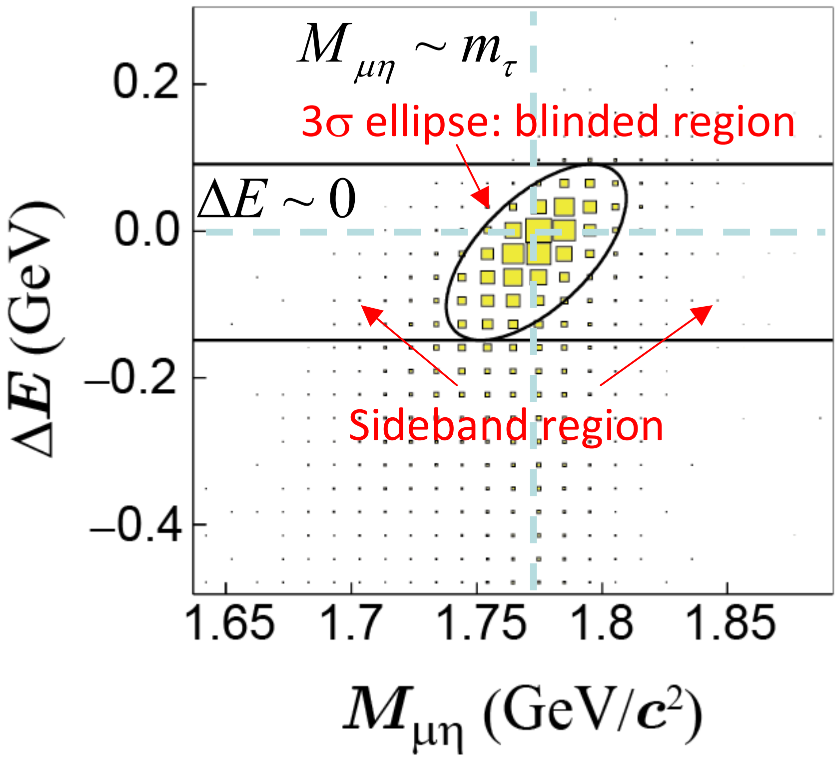
Fully reconstructed → $\gamma+\gamma$



Signal extraction: $M_{\mu\eta}-\Delta E$ plane

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

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

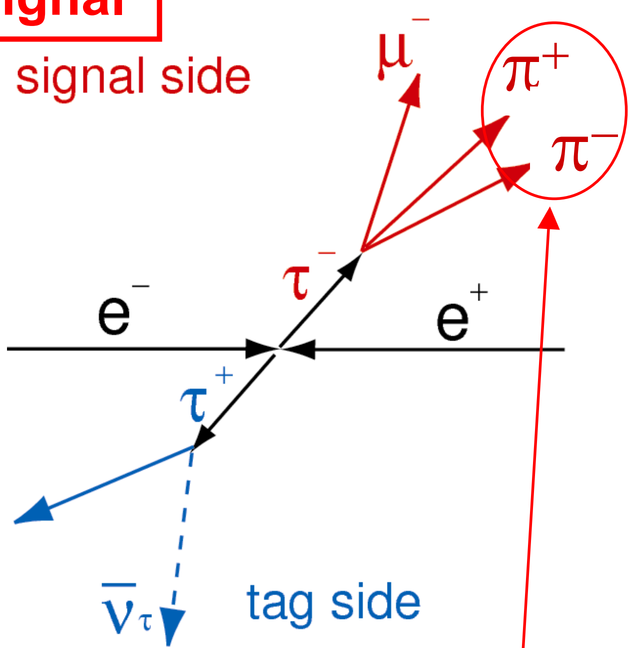


Blind analysis ⇒Blind signal region

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

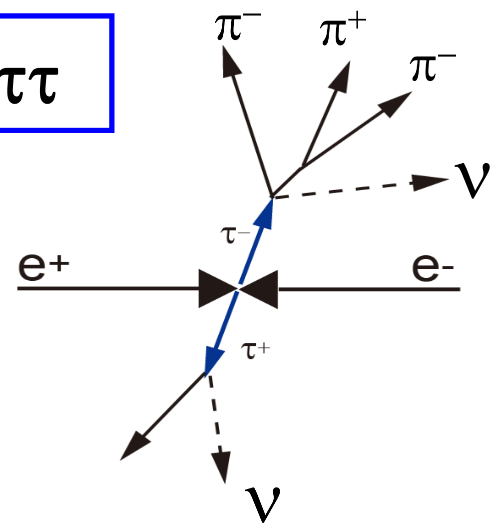
LFV τ decays; Signal and Background

signal



- Neutrino(s) in tag side
- Mass of mesons

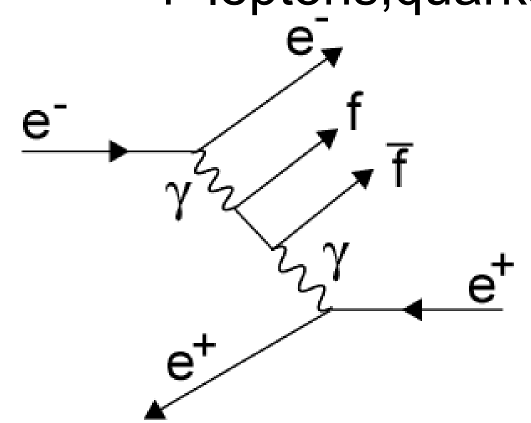
$\tau\tau$



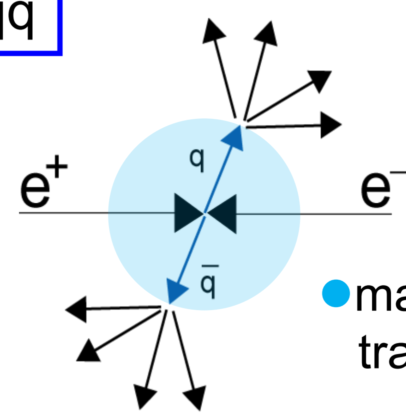
- Neutrinos in both side
- Missing energy in signal side

2photon process

f=leptons,quarks

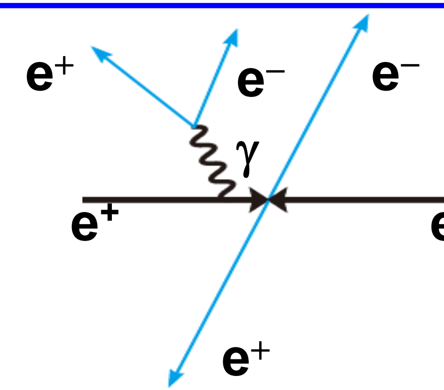


$q\bar{q}$



- many tracks

radiative Bhabha process



Search for $\tau \to \ell P^0(=\pi^0,\eta,\eta')$

Previous result

Data : 401 fb^{-1} @ Belle, 339 fb^{-1}@BaBar $\mathcal{B}<(0.8-2.4)\times10^{-7}$ at 90%CL

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

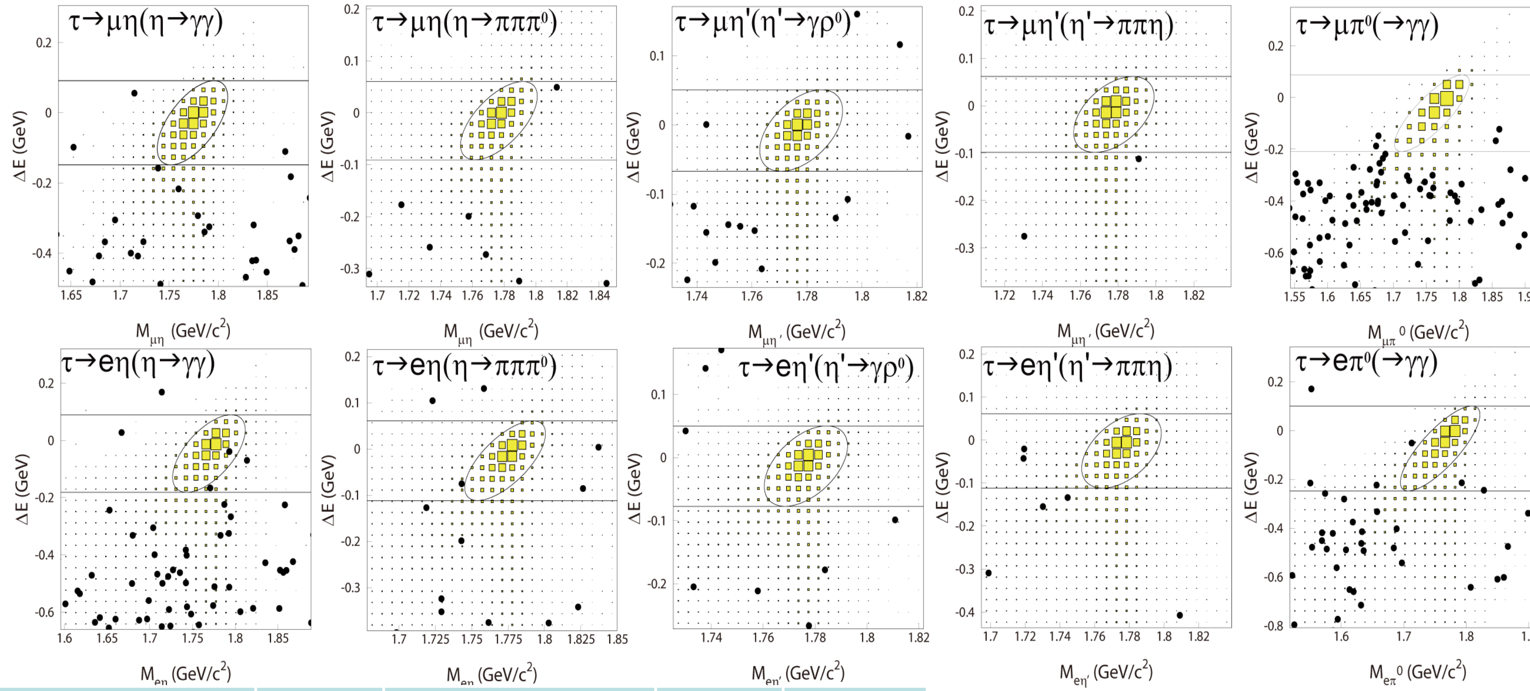
•To obtain high detection efficiency,
$\eta(\eta')$ is reconstructed from $\gamma\gamma(\rho^0\gamma)$ as well as $\pi\pi\pi^0(\pi\pi\eta)$.

- **New search with 901fb^{-1} data sample**
- To obtain better resolution, $\eta(\eta')$-momentum is evaluated using $\eta(\eta')$-mass-constrained fit.
- Differently from the previous analysis, selection criteria are set mode by mode.
- For $\tau\to\mu\eta$, neural network selection is also introduced.

Finally, the efficiency is higher than previous (around 1.5x in average), while <1 background event is achieved.

Result for $\tau \to \ell P^0 (=\pi^0, \eta, \eta')$

Belle preliminary



→(2.1-4.4) times more stringent results than previous Belle result (401fb^{-1})

$\tau\to$	Eff. %	N_{BG}^{exp}	$N_{obs.}$	UL x10^{-8}
$\mu\eta(\to\gamma\gamma)$	8.2	0.63 ± 0.37	0	3.6
$\mu\eta(\to\pi\pi\pi^0)$	6.9	0.23 ± 0.23	0	8.6
$\mu\eta$(comb.)				**2.3**
$e\eta(\to\gamma\gamma)$	7.0	0.66 ± 0.38	1	8.2
$e\eta(\to\pi\pi\pi^0)$	6.3	0.69 ± 0.40	0	8.1
$e\eta$(comb.)				**4.4**

$\mu\eta'(\to\pi\pi\eta)$	8.1%	$0.00^{+0.16}_{-0.00}$	0	10.0
$\mu\eta'(\to\rho^0\gamma)$	6.2%	0.59 ± 0.41	0	6.6
$\mu\eta'$ (comb.)				**3.8**
$e\eta'(\to\pi\pi\eta)$	7.3%	0.63 ± 0.45	0	9.4
$e\eta'(\to\rho^0\gamma)$	7.5%	0.29 ± 0.29	0	6.8
$e\eta'$ (comb.)				**3.6**
$\mu\pi^0(\to\gamma\gamma)$	4.2%	0.64 ± 0.32	0	**2.7**
$e\pi^0(\to\gamma\gamma)$	4.7%	0.89 ± 0.40	0	**2.2**

Search for $\ell V^0(=\rho^0,K^{*0},\omega,\phi)$

Previous result $\mathcal{B}<(0.3-1.9)\times10^{-7}$ at 90%CL

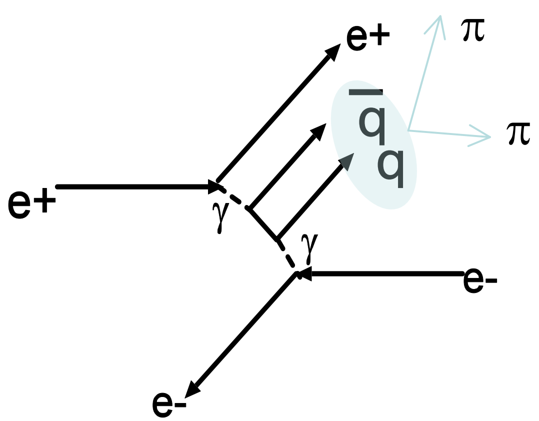
Data : 543 fb^{-1} @ Belle, 451 fb^{-1}@BaBar

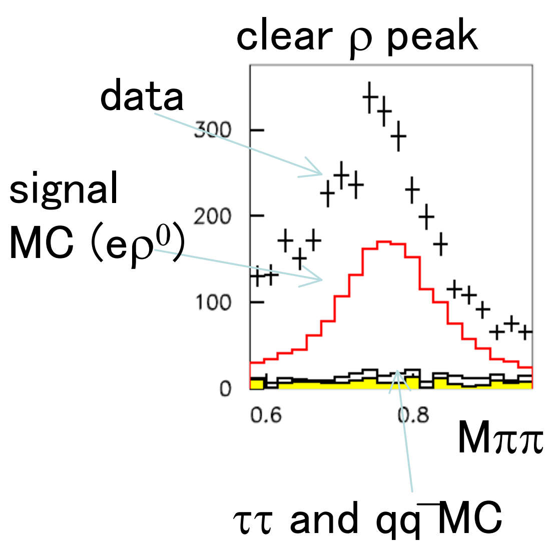
(PLB664,35(2008)) (PRL100,071802(2008),PRL103,021801(2009))

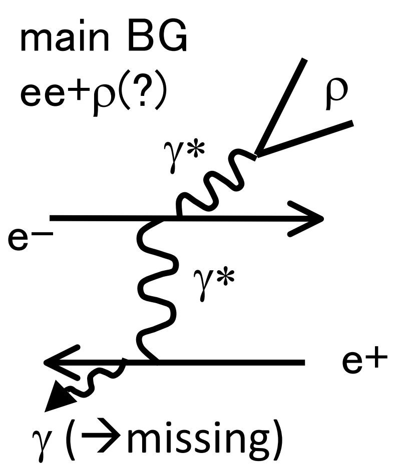
- Differently from ℓP^0, 2photon process could be large backgrounds for ℓ=e.

- **New search with 854fb^{-1} data sample**
  - Background study:

    It turns out that not only 2photon process but also ee+X process become large background. → Reduced using missing-momentum direction







eK*, e$\overline{K}$*, eρ modes

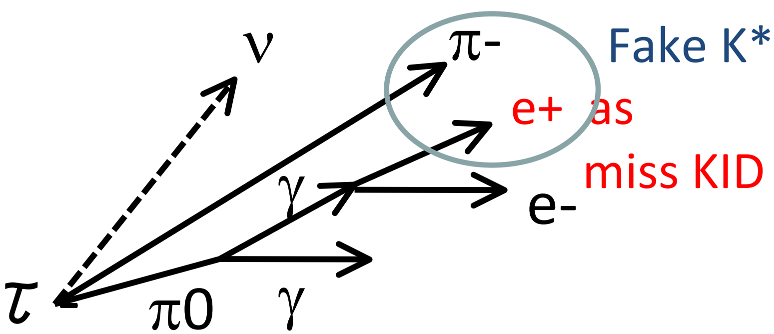
Other BG for eK*, e$\overline{K}$* and eρ

⇒ Event with γ-conversion

For example, eK*mode

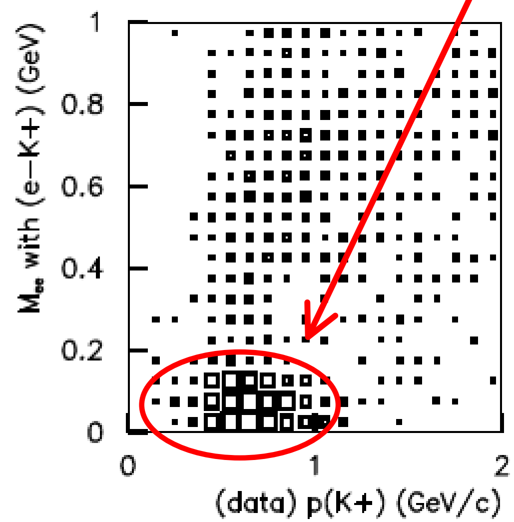
$\tau^- \rightarrow \pi^-\pi^0\nu$

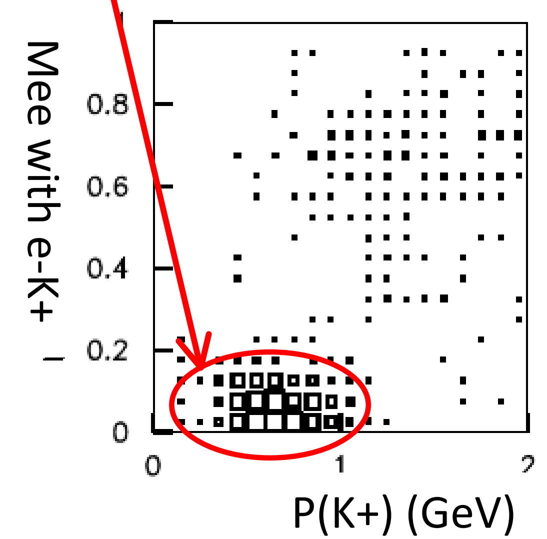
with γ conversion from π^0

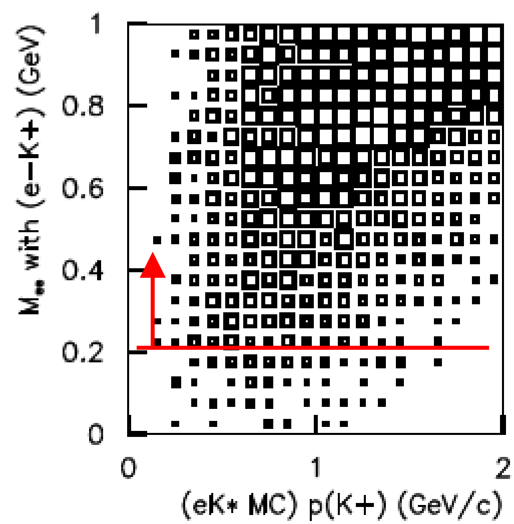


Finally, higher or similar efficiency is kept (around 1.2x in average), while similar background level is achieved.

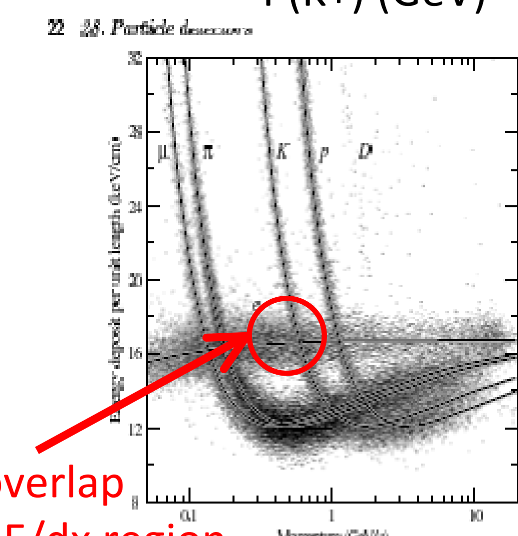
data γ-conversion generic ττ MC







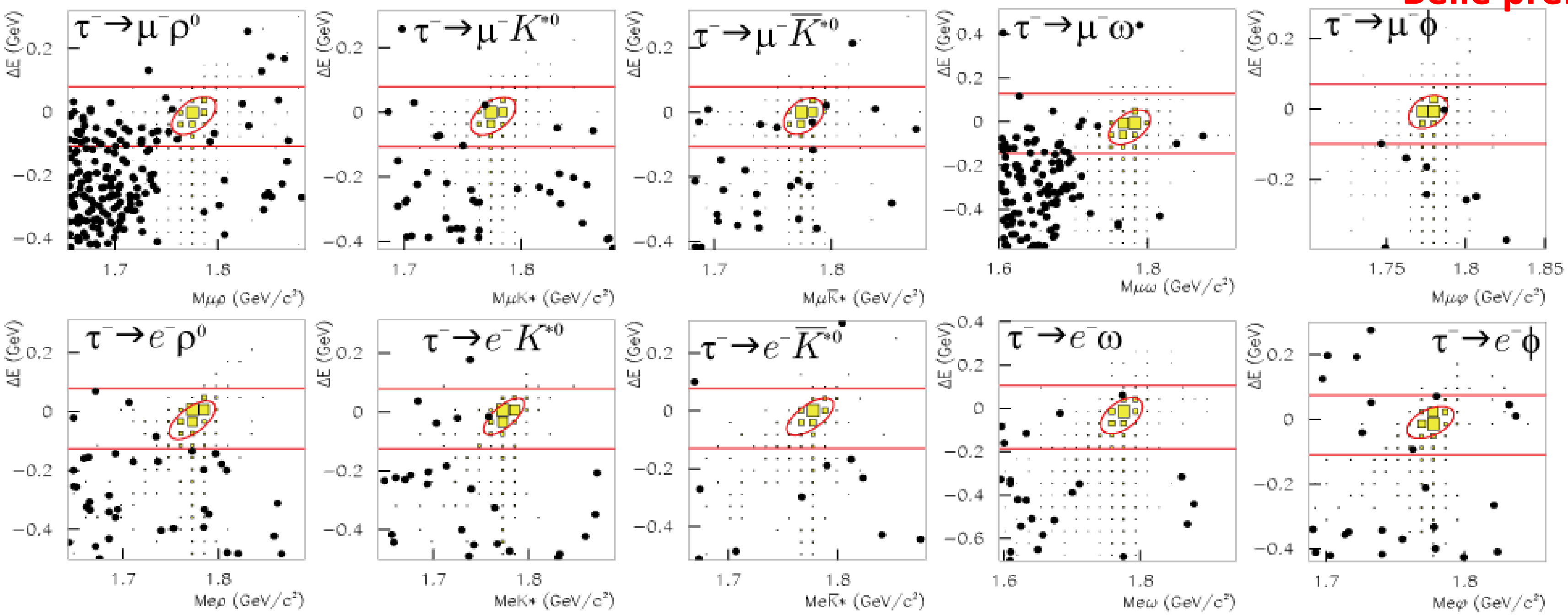
eK* MC



overlap dE/dx region between e and K

Result for $lV^0(=\rho^0, K^{*0}, \omega, \phi)$

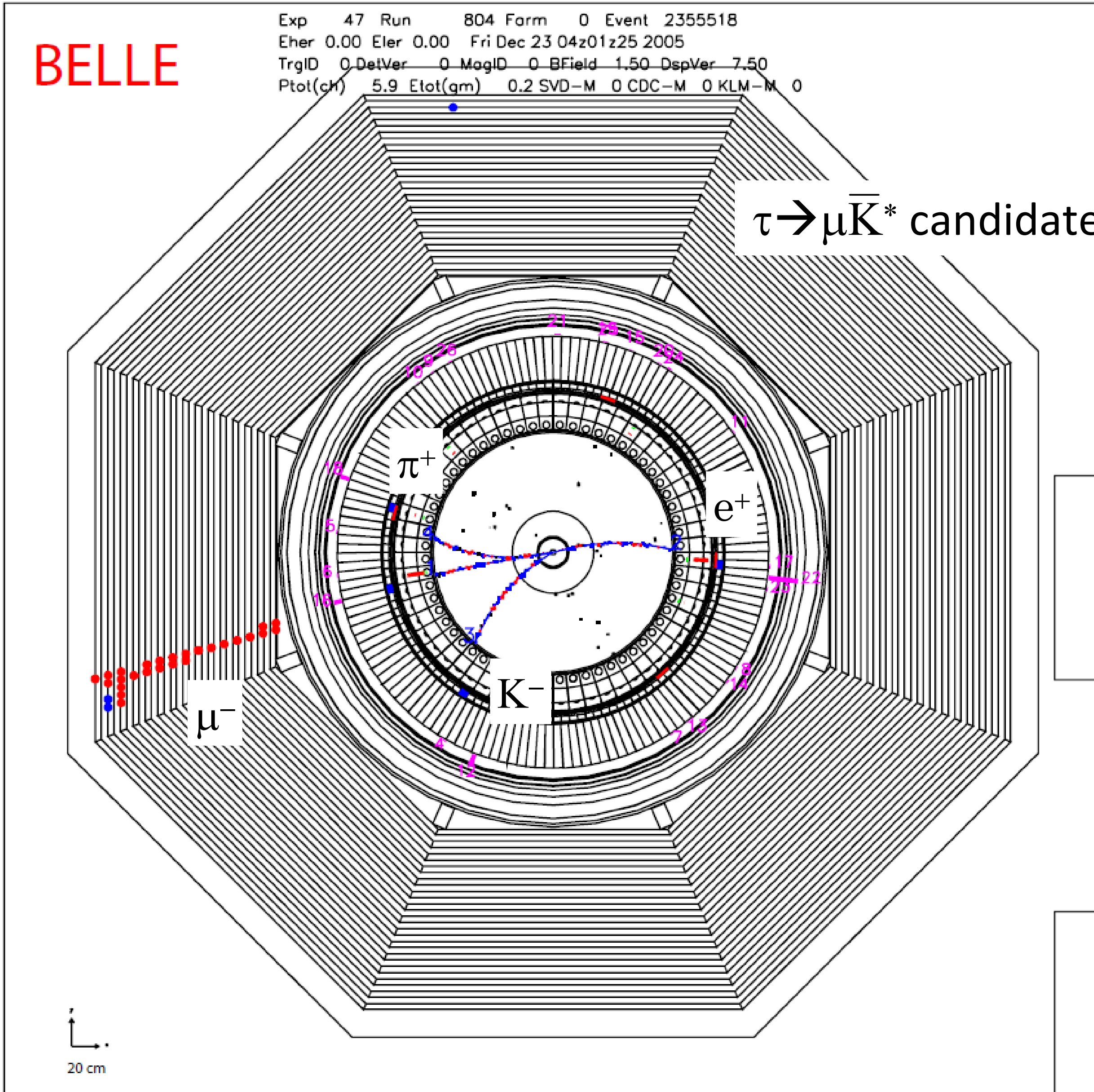
Belle preliminary

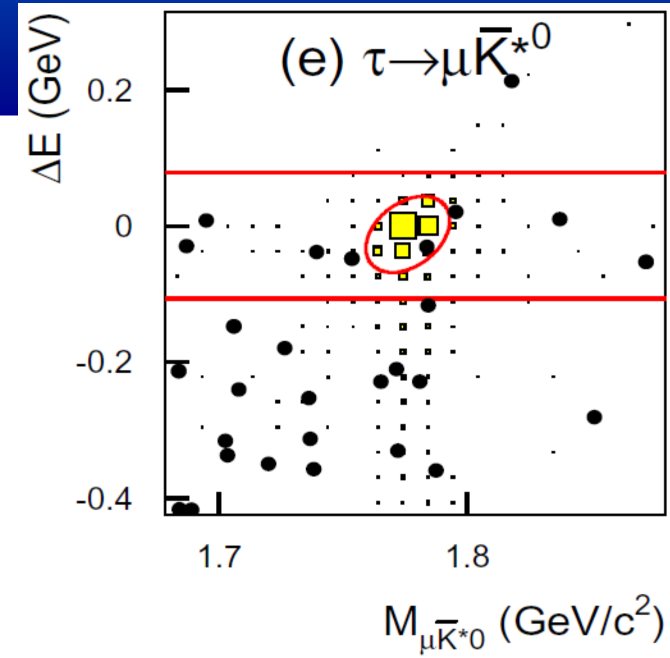


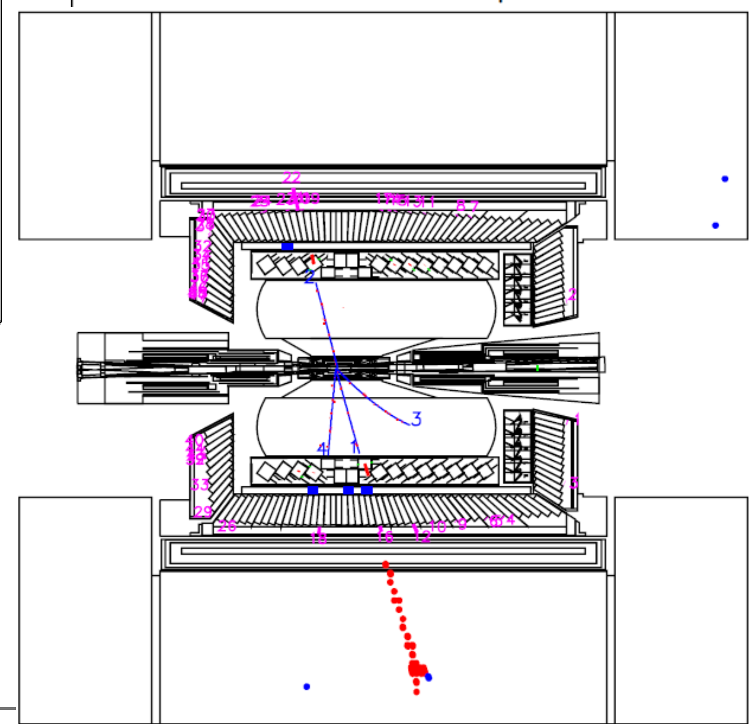
$\tau^-\to$	Eff.	N_{BG}^{exp}	$N_{obs.}$	UL $\times10^{-8}$	$\tau^-\to$	Eff.	N_{BG}^{exp}	$N_{obs.}$	UL $\times10^{-8}$
$e^-\rho^0$	7.6%	0.29±0.15	0	**1.8**	e^-K^{*0}	4.4%	0.39±0.14	0	**3.2**
$\mu^-\rho^0$	7.1%	1.48±0.35	0	**1.2**	μ^-K^{*0}	3.4%	0.53±0.20	1	**7.2**
$e^-\phi$	4.2%	0.47±0.19	0	**3.1**	$e^-\overline{K^{*0}}$	4.4%	0.08±0.08	0	**3.4**
$\mu^-\phi$	3.2%	0.06±0.06	1	**8.4**	$\mu^-\overline{K^{*0}}$	3.6%	0.45±0.17	1	**7.0**
$e^-\omega$	2.9%	0.30±0.14	0	**4.8**	$\mu^-\omega$	2.4%	0.72±0.18	0	**4.7**

UL for $\tau\to\mu\rho^0$ is the most stringent among all the τ-LFV decays

Event display

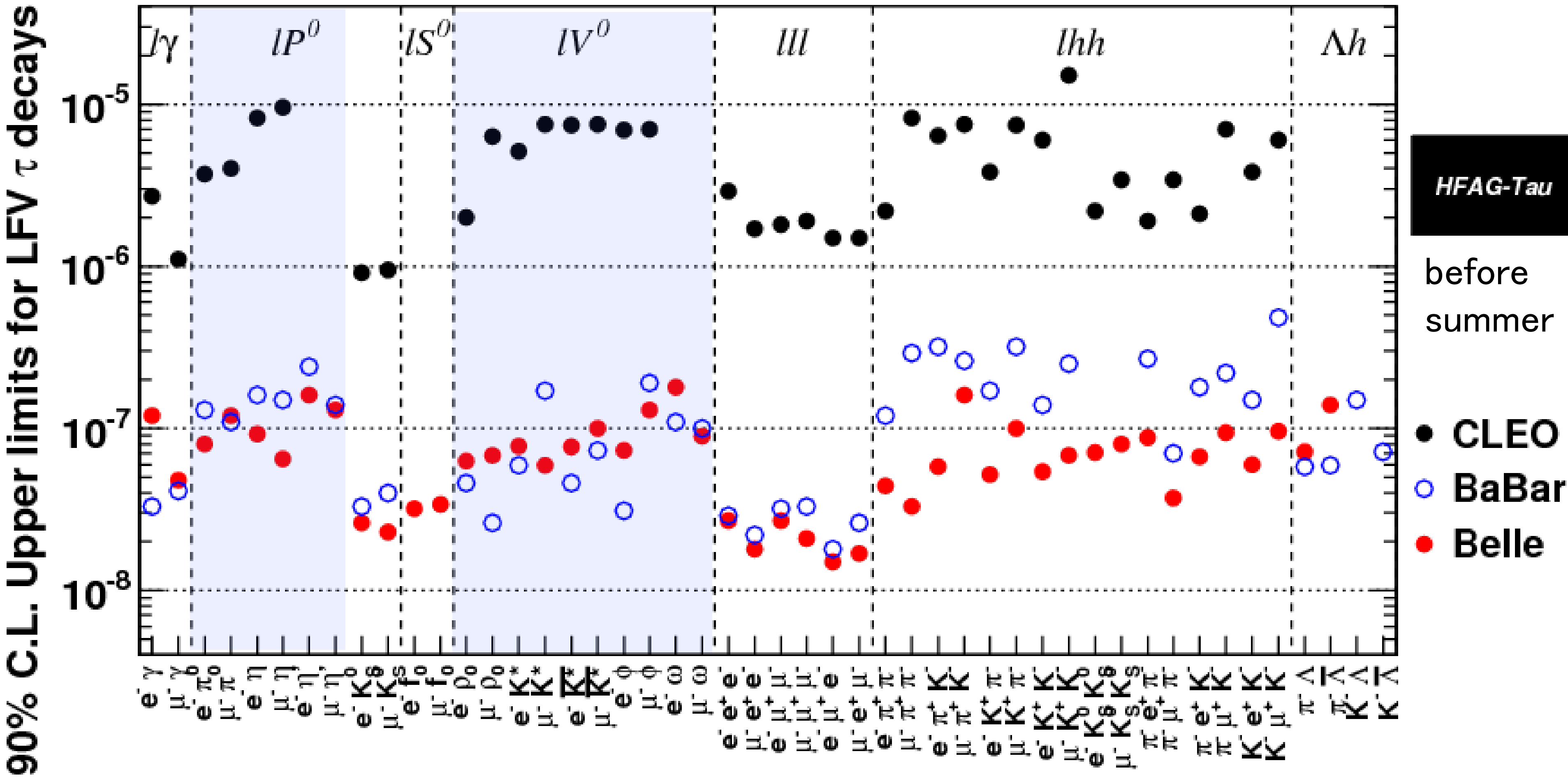




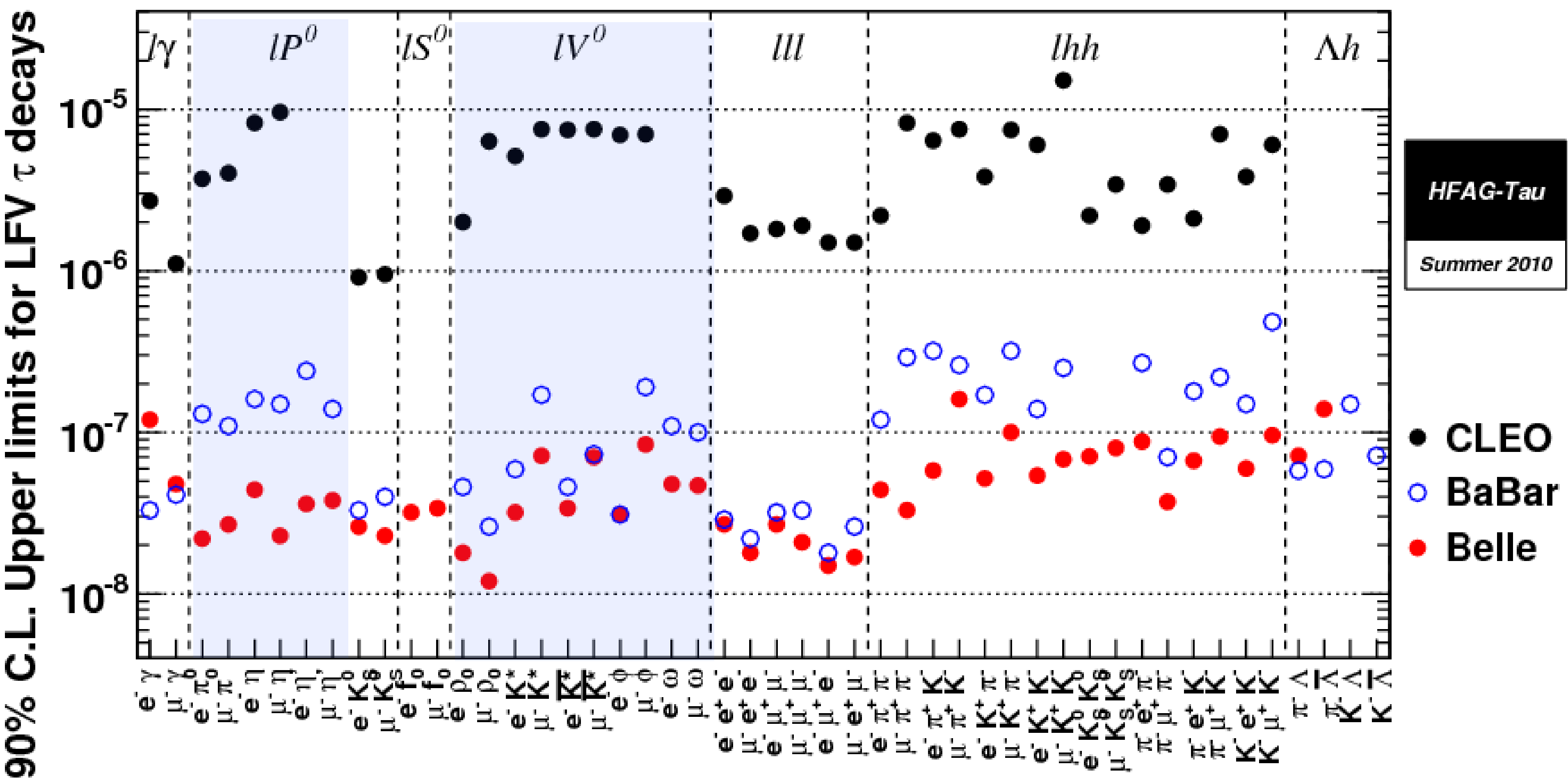


Upper limits on LFV τ decays

Before this summer,･･･



Upper limits on LFV τ decays



Summary

Lepton flavor violation is a good signature of New Physics.

We have updated search for τ LFV decays into

$\ell+M^0(=\pi^0,\eta,\eta',\rho^0,K^{*0},\overline{K^{*0}},\omega,\phi)$

using the world-largest data sample obtained by KEKB/Belle

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

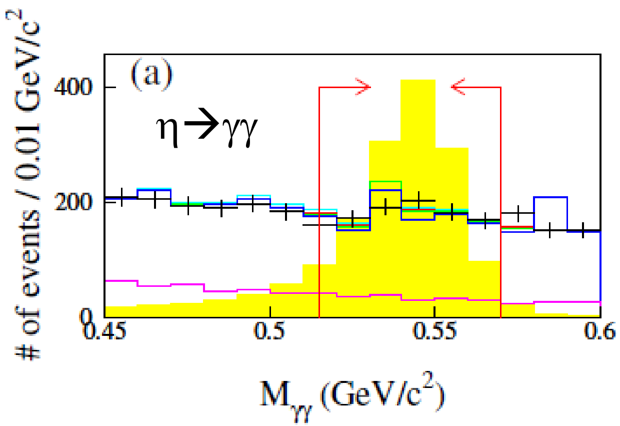
$\rightarrow$~World highest sensitivity!

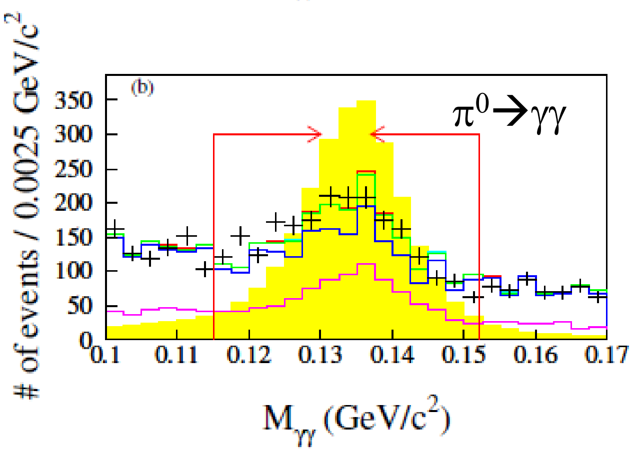
- UL for $\tau\rightarrow\mu\rho^0$ is the most stringent among all the τ-LFV decays
- Achieve improved sensitivity,
  not only much larger data samples but also more
  effective BG rejection after detailed examination of the BG

Belle is starting the analyses for the various modes using its full data sample! (>1ab^{-1})

Backup

- Selections by meson mass





black:data
yellow:signal
green:qq
blue:μμ
pink:ττ