Search for Lepton Flavor Violation \( \tau \) Decay at Belle experiment

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for the Belle Collaboration

Contents

Introduction
(Motivation, Analysis method, Belle detector)
Results for LFV \( \tau \) decay
Summary
Introduction

- Quark mixing
  - Flavor mixing in quark sector have been studied well
  - Beautifully described by CKM matrix including CPV
- Neutrino mixing
  - Discovered
  - Provides hints of new physics beyond SM
- Lepton Flavor Violation (mixing) decays for charged lepton
  - Not observed yet
  - Very small probability via neutrino oscillation.

\[ \mathcal{B} \propto (\Delta m^2_{\nu}/m_W^2)^2 \simeq 10^{-49} \sim 10^{-52} \]

\[ \Rightarrow \text{So, difficult to observe } \tau \text{ LFV at current experiment.} \]

\[ \downarrow \]

If we observed LFV decays in charged lepton, they would be a clear signature of New Physics.
Many extensions of the SM predict LFV decays
⇒ SUSY(+Seesaw), Extra dimension etc.

SUSY-GUT or SUSY-Seesaw model

Charged lepton mixing would occur through the mixing of slepton mass matrix

\[ \mathcal{B} \propto ((m_{\tilde{L}})^2)_{ij}^2 \]

⇒ enhanced up to the current experimental sensitivity

LFV depends on the some powers of lepton mass \((m_\ell)^n\)
⇒ \(\tau\) is the heaviest lepton and have strongly couplings to New Physics

Previous experimental results for LFV \(\tau\) decays
CLEO sensitivities on \(\mathcal{B} < \mathcal{O}(10^{-6})\)
Expected branching fraction for LFV $\tau$ decay

**SUSY**
- Gauge mediated (MSSM)
- Higgs mediated (MSSM)
- R-parity-V

**SO(10) with $\nu_R$**

**Extra dimension**

Will show various LFV $\tau$ decay modes at Belle experiment:
- $\tau^- \rightarrow \ell^- \gamma$
- $\tau^- \rightarrow \ell^- \eta/\eta'/\pi^0$
- $\tau^- \rightarrow \ell^- K^0_S$
- $\tau^- \rightarrow \ell h h'$
- $\tau^- \rightarrow \ell^- V^0$

$\mathcal{B}(\text{LFV})$
Analysis method for LFV $\tau$ decay (1)

Procedure for LFV $\tau$ decay
- Select low multiplicity track events with a zero net charge
- Separate into two hemispheres using thrust axis
  → signal and tag
- Reduce background using PID and kinematic informations
  - lepton ID, $K/\pi$ separation
  - missing momentum
  - # of $\gamma$'s etc.

Complete reconstruction

$M_{\text{inv}} \approx m_\tau = 1.777$ GeV

$\Delta E = E_{\text{rec}}^{CM} \sqrt{s}/2 \approx 0$ GeV

1-prong decay (85%) (or 3-prongs (15%))
Signal extraction in $M_{\text{inv}}$ and $\Delta E$ plane
- $M_{\text{inv}} \sim m_\tau = 1.777$ GeV/$c^2$
- $\Delta E = E^{\text{CM}} - E_{\text{beam}}^{\text{CM}} \sim 0$ GeV

Blind the signal region
- Estimate the background in signal region using sideband data
  ↓
After open the blinded region
- counting # of events in signal region.
- apply maximum likelihood fit and extract # of events in signal region.

Set an upper limits if no excess of signal events compared expected background.

$$B(\text{LFV } \tau \text{ decay}) < \frac{890\%C.L.}{2\varepsilon N_{\tau\tau}}$$
Belle Detector

KEKB: $e^+(3.5\,\text{GeV})e^-(8\,\text{GeV})$

$\sqrt{s} = 10.58\,\text{GeV}$

$\sigma(\tau\tau) \sim 0.9\,\text{nb}$

$(\sigma(B\bar{B}) \sim 1.0\,\text{nb})$

B-factory is also $\tau$ factory!!!

Integrated luminosity:

$>650/\text{fb}$ collected

$\Rightarrow 5.8 \times 10^8 \tau^+\tau^-$

For lepton ID

$e$ efficiency 93%

$\mu$ efficiency 88%

F/B asymmetric detector

Good vertex resolutions and particle ID capabilities
$\tau \rightarrow \mu \gamma$ is the most attractive mode in new physics.

e.g. MSSM + Seesaw model

$- \mathcal{B}(\tau \rightarrow \mu ee)/\mathcal{B}(\tau \rightarrow \mu \gamma) \sim 1/94$

$- \mathcal{B}(\tau \rightarrow \mu \mu \mu)/\mathcal{B}(\tau \rightarrow \mu \gamma) \sim 1/440$

Assuming $|\delta_{\tau \mu}^R| = |\delta_{\tau \mu}^L| = 1$

$\mathcal{B}(\tau \rightarrow \mu \gamma) = 3.0 \times 10^{-6} \times \left(\frac{\tan \beta}{60}\right)^2 \times \left(\frac{1\, \text{TeV}}{M_{\text{SUSY}}}\right)^4$

(hep-ex/0406701)

<table>
<thead>
<tr>
<th>model</th>
<th>$\mathcal{B}(\tau \rightarrow \mu \gamma)$</th>
<th>$\mathcal{B}(\tau \rightarrow 3\ell)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>mSUGRA+Seesaw</td>
<td>$&lt;10^{-7}$</td>
<td>$&lt;10^{-7}$</td>
</tr>
<tr>
<td>SUSY+SO(10)</td>
<td>$&lt;10^{-8}$</td>
<td>$&lt;10^{-10}$</td>
</tr>
<tr>
<td>SM+seesaw</td>
<td>$&lt;10^{-9}$</td>
<td>$&lt;10^{-10}$</td>
</tr>
<tr>
<td>SUSY+Higgs</td>
<td>$&lt;10^{-10}$</td>
<td>$&lt;10^{-7}$</td>
</tr>
</tbody>
</table>

Previous analysis @ Belle

$\mathcal{B}(\tau \rightarrow \mu \gamma) < 3.1 \times 10^{-7}@86.3/\text{fb}$
$\tau \rightarrow \mu \gamma (2)$

$e^+ e^- \rightarrow \tau^+ \tau^- \rightarrow \mu \gamma$ (signal side)

$\leftarrow$ 1-prong + missing (tag side)

veto $\mu$ for rejecting $\mu \mu (+\gamma)$ events

Data: 535/fb
BG: $\tau \tau \gamma$ (ISR), $\mu \mu \gamma$ (ISR)

Applying tighter cuts compared with previous analysis

- $m^2_{\text{miss}}$ vs. $p_{\text{miss}}$ correlation
- $m^2_{\nu} (= (E_{\mu\gamma} - E_{\text{tag}})^2 - p^2_{\text{miss}})$ cut
- others

(a) Thrust

(b) $m^2_{\nu}$

\[ m^2 (\text{GeV}^2/c^4) \]

\[ \Delta E (\text{GeV}) \]

\[ M_{\mu\gamma} (\text{GeV}/c^2) \]

preliminary
Remaining events:
54 eve. (@86/fb) → 94 eve. (@535/fb)

Efficiency
11% → 6.7%

Signal region
5σ box → 2σ ellipse

Signal extraction
Unbinned maximum likelihoods method:
\[ \mathcal{L} = \frac{\exp(- (s + b))}{N!} \prod_{i=1}^{N} (sS_i + bB_i) \]

\( s = -3.9 \) events and \( = 13.9 \) events
(allow negative s and its prob. \( \sim 25\% \))
\[ \Rightarrow s_{90\% CL} = 2.0 \] events

\[ \mathcal{B}(\tau \rightarrow \mu \gamma) < 4.5 \times 10^{-8} @ 90\% C.L. \]
(Preliminary hep-ex/0609049)
MSSM+Seesaw Model

\[ \mathcal{B}(\tau \rightarrow \mu \gamma) = 3.0 \times 10^{-6} \times \left( \frac{\tan \beta}{60} \right)^2 \times \left( \frac{1\text{TeV}}{M_{\text{SUSY}}} \right)^4 \]

\[ \tan \beta \]

\[ m_{\text{SUSY}} \ (\text{TeV}/c^2) \]

\[ \text{Belle} \]

\[ \text{Babbar} \]

Excluded region

⇒ Improve a factor of 7.1 compared old results

<table>
<thead>
<tr>
<th></th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int. Lum.</td>
<td>86/fb</td>
<td>535/fb</td>
</tr>
<tr>
<td>Upper Lim.</td>
<td>$3.1 \times 10^{-7}$</td>
<td>$4.5 \times 10^{-8}$</td>
</tr>
</tbody>
</table>
Same methods as $\tau \to \mu \gamma$ analysis

$s = -0.14$ events and $= 5.14$ events (allow negative $s$ and its prob. $\sim 48\%$)

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

(Previous: $\mathcal{B}(\tau \to e\gamma) < 3.9 \times 10^{-7}$ @ 86/fb (PLB 613, 20(2006)))

$\Rightarrow$ Improve a factor of 3.3 compared previous results
LFV in Higgs mediated model is sensitive to $\mu \eta$ and $\mu \mu \mu$ decay

$$\mathcal{B}(\tau \rightarrow \mu \eta) = 8.4 \times 10^{-7} \left( \frac{\tan \beta}{60} \right)^6 \left( \frac{100 \text{GeV}/c^2}{m_A} \right)^4$$

(M. Sher, PRD 66, 057301 (2002))

Comparison with $\mu \mu \mu$

- enhanced as $(m_s/m_\mu)^2$
- color ($\times 3$)
- larger phase space than $\mu \mu \mu$ decay

$\Rightarrow \tau \rightarrow \mu \eta$ is improved by factor of 8.4 compared $\tau \rightarrow \mu \mu \mu$ decay.

$$\mathcal{B}(\tau \rightarrow \mu \eta) : \mathcal{B}(\tau \rightarrow \mu \gamma) : \mathcal{B}(\tau \rightarrow 3\mu) = 8.4 : 1.5 : 1$$

Previous analysis@ Belle

$$\mathcal{B}(\tau \rightarrow \mu \eta) < 1.5 \times 10^{-7}@154/\text{fb} \ (\text{PLB B622, 218}(2005))$$
Analysis

Data: 401/fb
Decay mode: $\eta \rightarrow \gamma \gamma$ and $\eta \rightarrow \pi^+ \pi^- \pi^0$
BG: $\tau \tau$ and $q \bar{q}$ events

Cut: Similar cuts as previous analysis, but applying tighter cuts
For example,
BG rejection by $m^2_{\text{miss}}$ vs $p_{\text{miss}}$
Separate two cut using tag informations
Hadronic tag $\Rightarrow$ one $\nu$
Leptonic tag $\Rightarrow$ two $\nu$s
$\Rightarrow$ Effective cuts to reduce BG
Signal region: 90% ellipse:
(a region which contains 90% # of signal MC events)
Signal extraction: Counting method

<table>
<thead>
<tr>
<th>mode</th>
<th>$\eta \rightarrow \gamma \gamma$</th>
<th>$\eta \rightarrow \pi^+\pi^-\pi^0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eff.</td>
<td>6.4%</td>
<td>6.8%</td>
</tr>
<tr>
<td>Expected #</td>
<td>0.40±0.20</td>
<td>0.24±0.24</td>
</tr>
<tr>
<td>Obs. #</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UL$_{90%\text{C.L.}}$</td>
<td>$&lt;1.2 \times 10^{-7}$</td>
<td>$&lt;2.0 \times 10^{-7}$</td>
</tr>
</tbody>
</table>

$\Rightarrow B(\tau \rightarrow \mu\eta) < 6.5 \times 10^{-8}$

(Preliminary hep-ex/0609013)

Improve a factor of 2.3 compared with previous analysis
Constraint on $\tan \beta$ and $M_A$

Prediction with MSSM with seesaw

$$\mathcal{B}(\tau \rightarrow \mu \eta) = 8.4 \times 10^{-7} \left( \frac{\tan \beta}{60} \right)^6 \left( \frac{100 \text{ GeV}/c^2}{m_A} \right)^4$$

(M. Sher, PRD 66, 057301 (2002))

(CDF and DØ results: $p\bar{p} \rightarrow h/H/Ab\bar{b} \rightarrow b\bar{b}b\bar{b}$ from RUN II)

(LEP results: LEP Higgs Working Group)
Apply similar cuts as $\tau \to \mu \eta$ analysis  

(Preliminary hep-ex/0609013)

$\mathcal{B}(\tau \to e\eta) < 9.2 \times 10^{-8}$ \hspace{1cm} $\mathcal{B}(\tau \to \mu\eta') < 1.3 \times 10^{-8}$ \hspace{1cm} $\mathcal{B}(\tau \to e\eta') < 1.6 \times 10^{-7}$ \hspace{1cm} $\mathcal{B}(\tau \to \mu\pi^0) < 1.2 \times 10^{-7}$

BG: $\tau \to \pi\pi^0\nu$ for $\tau \to \mu\pi^0$ and negligible for others.

$\mathcal{B}(\tau \to e\pi^0) < 8.0 \times 10^{-8}$
\( \tau \rightarrow \ell K^0_S \) (1)

\( \tau \rightarrow \ell K^0_S \) (where \( K^0_S \rightarrow \pi^+\pi^- \))

Dataset for this analysis @ 281 fb\(^{-1}\)

Event selection

- \( p_{\text{miss}} > 0.4 \) GeV/c
  - within the fiducial volume
- \( 10 > E_{\text{total}}^{CM} > 5.29 \) GeV
- \( \cos \theta_{\text{tag-miss}} > 0.0 \)
- \# of \( \gamma \) in signal side \( \leq 1 \)
- \# of \( \gamma \) in tag side \( \leq 2 \)
- \( \cos \theta_{\ell K^0_S} \) vs. \( p_{\ell K^0_S} \) cut
  - See plot on the right

\[ \cos \theta_{\ell K^0_S} < 0.14 \log (p_{\ell K^0_S} - 2.7) + 0.7 \] cut

Eff. of \( \cos \theta_{\ell K^0_S} \) vs. \( p_{\ell K^0_S} \) cut for each MC

- Signal 99%
- \( \tau \tau \) 0.7%, uds 16%
After events selections $\varepsilon = 11.8\%$ for $eK_S^0$ 
$\varepsilon = 13.5\%$ for $\mu K_S^0$

Background:
$D^{(*)\pm} \rightarrow \ell^\pm \nu K_S^0$
$\pi^\pm K_S^0$

In signal region
— Expected background
0.2 ± 0.2 events
— Data
No events in either mode
↓
Set upper limits on branching fraction at 90% C.L.

$\mathcal{B}(\tau \rightarrow eK_S^0) < 5.6 \times 10^{-8}$  
$\mathcal{B}(\tau \rightarrow \mu K_S^0) < 4.9 \times 10^{-8}$
(PLB369, 159(2006))
Improved by a factor of 16 and 19 compared with CLEO
(Previous upper limits: 9.1(9.5)×10^{-7} for $eK_S^0(\mu K_S^0)$)
\[ \tau \to \ell hh' \text{ and } \ell + \text{Vector meson} \ (1) \]

\[ \ell h^+h^- \ (h, h' = \pi \text{ or } K) \]

\[ e^+e^- \to \tau^+\tau^- \to \ell + (\rho^0, K^*, \bar{K}^*, \phi) \text{ (signal side)} \]

\[ \leftrightarrow 1\text{-prong + missing (tag side)} \]

(Including lepton number violation, e.g. \( \tau^- \to \ell^+h^-h'^- \))

Data: 158/\text{fb}

BG suppression

by flight length and R2

Two-dimensional PDF:

\[ \frac{L_{\text{signal}}}{L_{\text{signal}} + L_{\text{uds}}} > 0.45 \]

\[ \Rightarrow \text{signal } 90\% \text{ remained} \]

uds 60\% removed
Dataset for this analysis @ 158 fb$^{-1}$

Signal region: 90% reactangle

$\mathcal{B}(\tau \rightarrow l hh') < (1.8 \sim 8.0) \times 10^{-7}$

$\mathcal{B}(\tau \rightarrow l V^0) < (2.0 \sim 7.7) \times 10^{-7}$  

(PLB640, 138 (2006))

Background: $\tau\tau$, uds and 2photon
Summary

We have searched for a lepton flavor violating $\tau$ decay at Belle. No observation and sensitivity to lepton flavor violating $\tau$ decay branching fraction is approaching $10^{-7} \sim 10^{-8}$

$\quad \Rightarrow$ Improvement of 1–2 orders over CLEO

$\quad \Rightarrow$ Reached the level of some new physics

$\quad \Rightarrow$ Provide constraints on the new physics models

$B$-factory is a good $\tau$ factory!

Thus, in additional to new physics search in $B$ decay, we provide sensitivities to new physics via lepton flavor violation and precision measurements also in $\tau$ decay
BACKUP
— High luminosity
— Asymmetric energy collider
\(e^- \ 8 \text{ GeV} / \ e^+ \ 3.5 \text{ GeV} \)
\(\sqrt{s} = 10.58 \text{ GeV} \) (\(\Upsilon(4s)\))
Integrated lum. > 650/fb @ 2006/10
## Upper limits for $\tau \rightarrow lhh$ and $\ell V^0$

<table>
<thead>
<tr>
<th>Mode</th>
<th>$\Delta \varepsilon/\varepsilon$ (%)</th>
<th>Detection efficiency $\varepsilon$ (%)</th>
<th>Expected background</th>
<th>Observed events</th>
<th>Upper limit on BF (90% CL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau \rightarrow e^- e^+ e^-$</td>
<td>5.3</td>
<td>7.5</td>
<td>5.80</td>
<td>2.62±0.07</td>
<td>5</td>
</tr>
<tr>
<td>$\tau \rightarrow e^+ e^- e^-$</td>
<td>2.3</td>
<td>5.8</td>
<td>5.14</td>
<td>0.60±0.26</td>
<td>1</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^- \mu^+ \mu^-$</td>
<td>2.1</td>
<td>8.8</td>
<td>4.57</td>
<td>0.76±0.26</td>
<td>2</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-\mu^+\mu^-$</td>
<td>7.7</td>
<td>11.5</td>
<td>4.44</td>
<td>0.76±0.30</td>
<td>1</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-\pi^+\pi^-$</td>
<td>20.5</td>
<td>21.2</td>
<td>3.99</td>
<td>0.91±0.25</td>
<td>3</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-\pi^-K^+$</td>
<td>17.4</td>
<td>18.2</td>
<td>4.11</td>
<td>1.27±0.41</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-\pi^-K^-$</td>
<td>12.8</td>
<td>13.9</td>
<td>4.03</td>
<td>0.76±0.22</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-K^-\bar{K}^+$</td>
<td>21.9</td>
<td>22.5</td>
<td>3.12</td>
<td>0.34±0.20</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-K^-\bar{K}^-$</td>
<td>5.4</td>
<td>7.6</td>
<td>3.06</td>
<td>0.09±0.06</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-\pi^+\pi^-$</td>
<td>15.8</td>
<td>18.0</td>
<td>3.43</td>
<td>2.36±0.44</td>
<td>1</td>
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<tr>
<td>$\tau \rightarrow \mu^-\pi^-K^+$</td>
<td>19.1</td>
<td>20.9</td>
<td>3.52</td>
<td>1.85±0.32</td>
<td>3</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-\pi^-K^-$</td>
<td>25.4</td>
<td>26.8</td>
<td>3.53</td>
<td>2.55±0.38</td>
<td>1</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-K^-\bar{K}^+$</td>
<td>8.7</td>
<td>12.2</td>
<td>2.76</td>
<td>0.48±0.19</td>
<td>2</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-K^-\bar{K}^-$</td>
<td>38.2</td>
<td>39.2</td>
<td>2.70</td>
<td>0.09±0.06</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-\rho^0$</td>
<td>5.3</td>
<td>7.5</td>
<td>5.04</td>
<td>2.55±0.10</td>
<td>5</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-K^*(892)^0$</td>
<td>17.4</td>
<td>18.2</td>
<td>4.12</td>
<td>0.76±0.34</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-K^*(892)^0$</td>
<td>20.5</td>
<td>21.2</td>
<td>3.68</td>
<td>0.16±0.10</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow e^-\phi$</td>
<td>21.9</td>
<td>22.5</td>
<td>2.04</td>
<td>0.04±0.04</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-\rho^0$</td>
<td>2.1</td>
<td>8.8</td>
<td>4.30</td>
<td>0.24±0.12</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-K^*(892)^0$</td>
<td>19.1</td>
<td>20.9</td>
<td>3.61</td>
<td>0.37±0.14</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-K^*(892)^0$</td>
<td>15.8</td>
<td>18.0</td>
<td>3.42</td>
<td>0.49±0.19</td>
<td>0</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu^-\phi$</td>
<td>8.7</td>
<td>12.2</td>
<td>2.58</td>
<td>0.00±0.18</td>
<td>0</td>
</tr>
</tbody>
</table>
Distribution of obtaining the number of signal \( s \) in the null signal case

\[ s = -3.21 \]

⇒ Probability 25% if \( s \) is \(<-3.21\)
Search for $\tau$ decay with Lepton and Baryon number violation process

($\tau \to \Lambda \pi, pK_s, p\gamma, p\pi^0$ and so on)

$\Rightarrow$ Important for cosmology (Baryon Asymmetry Universe)

$\Rightarrow$ Sensitive to new physics (SUSY etc.)

We consider two types from $\tau \to \Lambda \pi$ decay

- $B - L$ conserving mode
  $\Rightarrow \tau^- \to \bar{\Lambda}\pi^- (\bar{\Lambda} \to \bar{p}\pi^+)$

- $B - L$ violating mode
  $\Rightarrow \tau^- \to \Lambda\pi^- (\Lambda \to p\pi^-)$

We can distinguish between these two modes using a charge between two pions

- $B - L$ conserving mode
  $\Rightarrow$ Opposite charge

- $B - L$ violating mode
  $\Rightarrow$ Same charge
Dataset for this analysis @ 154 fb$^{-1}$

Event selection
- $\Lambda$ selection using vertex informations and proton ID
- $p_{\text{miss}} > 0.4$ GeV/c within the fiducial volume
- $10.5 > E_{\text{total}}^{CM} > 5.29$ GeV
- $\cos \theta_{\text{tag-mis}}^{CM} > 0.0$
- Kaon and Proton veto against tag-side and $\pi$ from $\tau \rightarrow \Lambda''\pi''$
- # of $\gamma$ in signal side $\leq 1$
- # of $\gamma$ in tag side $\leq 2$
- $m_{\text{miss}}^2$ vs. $p_{\text{miss}}$ cut
  $\Rightarrow$ See plot on the right
Require $p_{\text{miss}}^{\text{lab}} > 1.5m_{\text{miss}}^2 - 1$
After events selections
$\varepsilon = 11.8\%$ for both modes

Background:
uds: including real $\Lambda$
$\tau\tau$: fake $\Lambda$ from 3-prongs decay

In signal region
— Expected background
1.7 $\pm$ 0.8 events in both modes
— Data
1 event for $B - L$ conserving mode
0 events for $B - L$ violating mode

\[ \downarrow \]
Set upper limits on branching fraction at 90\% C.L.

\[ \mathcal{B}(\tau \rightarrow \bar{\Lambda}\pi^-) < 1.4 \times 10^{-7} \quad \mathcal{B}(\tau \rightarrow \Lambda\pi^-) < 7.2 \times 10^{-8} \]
(B - L conserving) \quad (B - L violating)

(PLB 632, 51 (2006))
These results are the first searches ever performed.
Recent results on Belle’s LFV search (Upper Limit on Br at 90% CL)

This year’s publications