Search for $\tau \rightarrow e\gamma / \mu\gamma$

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Introduction

- Lepton Flavour Violating (LFV) process: forbidden in SM $\leftrightarrow$ probe of new physics
- SUSY model predicts:
  - most sensitive mode in the LFV decays.
- We **SHOULD** search for
  - not only for $\tau \rightarrow \mu \gamma$ but also for $\tau \rightarrow e \gamma$. 
KEKB accelerator/Belle detector

- asymmetric collider
- Peak Lum. $1.4 \times 10^{34}$ (cm$^{-2}$s$^{-1}$)
- Total Logged Lum. 288fb$^{-1}$
- cross section@ $s \sim 110$GeV$^2$
  $\sigma(b\bar{b}) : \sigma(\tau\tau) = 1.05 : 0.912$

- asymmetric detector
  - $\mu$-ID: eff. 87.5%
  - $e$-ID: eff. 92.4%

▷ A B-factory is also a $\tau$-factory!

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Signatures of the Signal and of the BGs

- **Signal Event**
  - \((e+\gamma)+(\phi+n\gamma)\)
  - \(\text{generic decay}\)

- **Expected BG Events**
  - Bhabha process
  - \(\tau\tau\) process
Selection Criteria

- 2 charged tracks + more than 1 $\gamma$
  - signal side: 1 charged + 1 photon
  - tag side: 1 charged + $n$ photons
- e-ID > 0.9 & e-ID < 0.1
- restrict kinematical variables
  - momentum $e, tag, \gamma, missing$
  - polar angle $e, tag, \gamma, missing$
  - opening angle
    - $e$-tag, $e-\gamma$, tag-missing
    - missing mass vs missing mom.
- analysis for 87 fb$^{-1}$ data sample

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Nagoya Cut

- $P_{\text{miss}}$ vs $m_{\text{miss}}^2$

$\tau\tau$ events have large missing mass

98% of the $\tau^+\tau^-$ bkg is removed.

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**M_{e\gamma} and \Delta E resolutions**

- All selections applied for signal MC events

\[ M_{e\gamma} = \sqrt{(P_e + P_\gamma)^2} \]

\[ \Delta E = E_e + E_\gamma - E_{\text{beam}} \] @CM

- Asymmetric Gaussian

25.7/14.3 MeV/c^2 84.8/36.0 MeV

6.5\%

±5σ region

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Blind Analysis

- Signal dominant region is masked.

\[ \Delta E(\text{GeV}) \]
\[ M_{\tau\tau}(\text{GeV/c}^2) \]

\[ \tau\tauBG \ : \ \tau\tauMC \]

Bhabha BG : data

Shape of BG distribution is evaluated.

Its height is decided with data distribution of the side-band region.

side-band region
BG distribution (MC)

- Estimate BG distribution from $\tau\tau$ MC

curve (Landau+Gauss)

reproduce BG distribution by function
BG distribution (data)

- Estimate from MC and side-band of data

data(side band)

$64 \quad \tau\tau \quad MC \quad ee \quad 61 \quad 3 \quad \tau\tau MC$

Masked!

Profile plot

Curve (Landau+Gauss)
Final Candidates ($\tau \rightarrow e\gamma$)

- 60 events found. (# of estimated BG: 64)
- 20 events survived in $\pm 5\sigma$ region

**Diagram:**
- Signal MC
  - $\pm 5\sigma$
- Signal events dominate
- 5 plots showing $M_{\gamma}(\text{GeV}/c^2)$ distributions with different $\Delta E$ ranges:
  - 1.5 - 1.6
  - 1.6 - 1.7
  - 1.7 - 1.8
  - 1.8 - 1.9
  - 1.9 - 2.0

**Legend:**
- signal MC
- surviving data

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Evaluation of signal events

- fit by unbinned expanded maximum likelihood with signal and BG shape \( s_0 = 0, b_0 = 20 \)
- Estimation for U.L. of \( s_{90} \) @ 90%CL
  by Toy MC: generate 10000 events

**Result**

- \( s_{90} = 3.8 \) events

**Branching fraction**

\[ \text{Br} = s_0 / 2 \varepsilon N_{\tau\tau} < 3.8 \times 10^{-7} \]

\( \varepsilon \): detection efficiency

\( N_{\tau\tau} \): total event number

<table>
<thead>
<tr>
<th>Signal yield: ( s_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-ID ineff. 0.01/0.02 ev.</td>
</tr>
<tr>
<td>BG function 0.13 ev.</td>
</tr>
</tbody>
</table>

Efficiency & Luminosity:

\[ 2 \varepsilon N_{\tau\tau} \]

| Track rec. eff. | 2.0% |
| Photon rec. eff. | 2.8% |
| Selection criteria | 2.5% |
| Luminosity | 1.4% |
| Trigger eff. | 5.0% |
| MC statistics | 0.2% |
| Total | 6.8% |
Search for $\tau \rightarrow \mu \gamma$

- Almost same selection criteria as $\tau \rightarrow e \gamma$
  - for tag side track, require not to be $\mu$
- Main BG: $\tau \tau \gamma$ & $\mu \mu \gamma$ (from $\mu$-ID ineff.)

Data

- $\tau$ pair MC ($\mu \mu$)
- Data ($\mu \mu$)

$M_{\text{inv}}$(GeV)

$\Delta E$ (GeV)

$\Delta E$ (GeV)

1.4~1.5

2.1~2.2

1.9~2.0

1.8~1.9

1.7~1.8

1.6~1.7

1.5~1.6

1.4~1.5

20

10

0

-10

-20

-0.5 0.0 0.5

-0.5 0.0 0.5

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Final Candidates \((\tau \rightarrow \mu \gamma)\)

- 54 events survived in \(\pm 5\sigma\) region

\[
\begin{array}{c|c|c}
\Delta E (GeV) & \text{# of events} \\
-0.4 & 10 \\
-0.2 & 5 \\
0 & 0 \\
0.2 & 5 \\
0.4 & 10 \\
\end{array}
\]

- \(1.71 < M_{inv} < 1.82 GeV/c^2\)

- \(s=0\)

- Evaluation for U.L.
  - \(s=5.1 ev. @ 90\% C.L.\)
  - \(Br < 3.1 \times 10^{-7} @ 90\% C.L.\)

- \textit{fitting result (UEML)}

- \textit{including systemaric uncertainties}

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Conclusion & Summary

- Obtain BR UL’s with **blind analyses**.
- BG distributions are modeled well.
- Results are 10 times more sensitive than CLEO’s.

$\tau \rightarrow e\gamma (86.7 \text{fb}^{-1})$
- $N_{\tau\tau} = 7.90 \times 10^7$
- 20 observed events
- $\varepsilon = 6.5\%$
- $s = 3.8 \text{ev. @90\%C.L.}$
- $\text{Br} < 3.8 \times 10^{-7} \text{ @90\%C.L.}$

$\tau \rightarrow \mu\gamma (86.3 \text{fb}^{-1})$
- $N_{\tau\tau} = 7.87 \times 10^7$
- 54 observed events
- $\varepsilon = 11\%$
- $s = 5.1 \text{ev. @90\%C.L.}$
- $\text{Br} < 3.1 \times 10^{-7} \text{ @90\%C.L.}$


cf. $\text{Br} < 2.7 \times 10^{-6} \text{ @90\%C.L. (CLEO)}$

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