



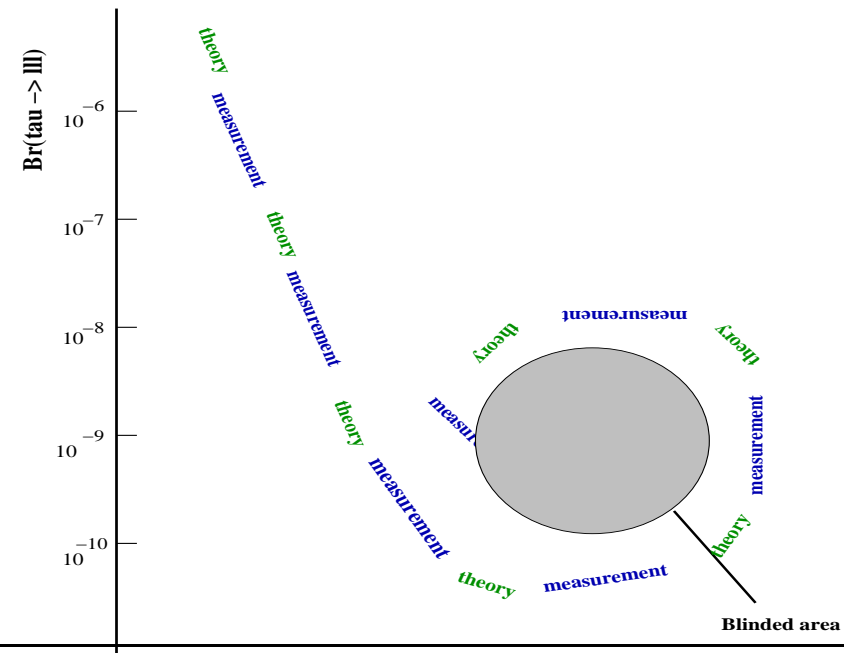
# Experimental study of tau LFV decays

O. Igonkina  
(University of Oregon)

October 24, 2003

## Outline:

- Motivation
- Projection from the current measurements
- Restricting theories
- How to measure more precise
- Conclusions





No Lepton Flavor Violation in Standard Model  
and no good reason for this.

Which gives a good reason to search for it.

Since neutrino oscillations are observed, the  
LFV tau decays must exist.

The measurements of  $\mathcal{B}(\tau \rightarrow \ell\gamma)$ ,  $\mathcal{B}(\tau \rightarrow \ell\ell\ell)$ ,  $\mathcal{B}(\tau \rightarrow \ell hh)$ ,  
 $\mathcal{B}(\tau \rightarrow \ell\alpha)$  ( $\ell = e, \mu$ ) will explore region sensitive to many  
extensions of SM and SUSY. The combination of measurements  
will discriminate between models.



Model	$\tau \rightarrow l\gamma$	$\tau \rightarrow lll$	Ref.
SM + lepton CKM	$10^{-40}$	$10^{-14}$	hep-ph/9810484
SM + left-h. heavy Dirac neutrino	$< 10^{-18}$	$< 10^{-18}$	SJNP25(1977)340
SM + right-h. heavy Majorana neutrino	$< 10^{-9}$	$< 10^{-10}$	PRD66(2002)034008
SM + left and right-h. neutral singlets	$10^{-8}$	$10^{-9}$	PRD66(2002)034008
MSSM + right-h. heavy Majorana neutrino	$10^{-10}$	$10^{-9}$	hep-ph/0306195
MSSM + seesaw	$10^{-7}$		hep-ph/0206110
left-right SUSY	$10^{-10}$	$10^{-10}$	hep-ph/0306195
SUSY $SO(10)$	$10^{-8}$		hep-ph/0209303
SUSY-GUT	$10^{-8}$		hep-ph/0307393
SUSY + neutral Higgs	$10^{-10}$	$10^{-10} - 10^{-7}$	more details later
SUSY + Higgs triplet		$10^{-7}$	hep-ph/0209170
gauge mediated SUSY breaking	$10^{-8}$		hep-ph/0310148
MSSM+universal soft SUSY breaking	$10^{-7}$	$10^{-9}$	hep-ph/9911459
MSSM+nonuniversal soft SUSY breaking	$10^{-10}$	$10^{-6}$	hep-ph/0305290
Non universal $Z'$ (technicolor)	$10^{-9}$	$10^{-8}$	PLB547(2002)252
two Higgs doublet III	$10^{-15}$	$10^{-17}$	hep-ph/0208117
seesaw with extra dimensions	$10^{-11}$		hep-ph/0210021
...			

See also E. Ma hep-ph/0209170 for a review

(Some of the numbers are guesses on base of given publication. For precise information, please, consult the reference)



No LFV decay was observed on experiment yet and the limits on the branching fractions (at 90%CL) are set so far:

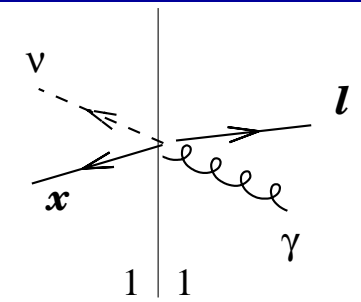
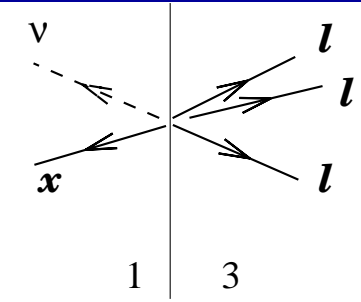
$\mathcal{B}(\tau \rightarrow \ell\gamma)$	$< 3 \cdot 10^{-6}$	CLEO	(4.8 fb <sup>-1</sup> )
$\mathcal{B}(\tau \rightarrow \mu\gamma)$	$< 2 \cdot 10^{-6*}$	BABAR(preliminary)	(63 fb <sup>-1</sup> )
$\mathcal{B}(\tau \rightarrow \mu\gamma)$	$< 5 \cdot 10^{-7\#}$	BELLE	(86.3 fb <sup>-1</sup> )
$\mathcal{B}(\tau \rightarrow \ell\ell\ell)$	$< 3 \cdot 10^{-7}$	BELLE (preliminary)	(48.6 fb <sup>-1</sup> )

\*) more events are observed than expected

#) recalculated according to Feldman Cousins method

The current measurements are close to the limits specified by theories. The gain in statistics of 100 might show a signal of 100 events and reject Standard Model.



$\tau \rightarrow l\gamma$	$\tau \rightarrow lll$
	
<p>1-1 topology  only 1 <math>l</math> and 1 <math>\gamma</math> on signal side  <math>M(l\gamma) \simeq M_\tau</math>  <math>E(l\gamma) \simeq E_{cms}/2</math></p>	<p>1-3 topology  only 3 <math>l</math> on signal side  <math>M(lll) \simeq M_\tau</math>  <math>E(lll) \simeq E_{cms}/2</math></p>

Main background for  $\tau \rightarrow l\gamma$  is usual  $\tau\tau$  events, for  $\tau \rightarrow lll$  it is hadronic events. (Bhabha is a problem for  $\tau \rightarrow eee$  only)

Most optimal condition for UL estimation is to have about 0.5-1 background event (assuming that efficiency does not change much)

# Upper Limit Calculations



$\tau \rightarrow lll$

	90 fb <sup>-1</sup>	0.5 ab <sup>-1</sup>	10 ab <sup>-1</sup>
Efficiency	8.5%	8%	7%
Background	0.4	1.	1%
	simple analysis	smart cuts	stricter PID
UL Sensitivity (FC)	$2 \cdot 10^{-7}$	$4 \cdot 10^{-8}$	$3 \cdot 10^{-9}$

$\tau \rightarrow l\gamma$

	63 fb <sup>-1</sup>	0.5 ab <sup>-1</sup>	10 ab <sup>-1</sup>
Efficiency	5%	4%	4%
Background	8	8.	180
	simple analysis	smart cuts	no good idea
UL Sensitivity (FC)	$1 \cdot 10^{-6}$	$2 \cdot 10^{-7}$	$3 \cdot 10^{-8}$

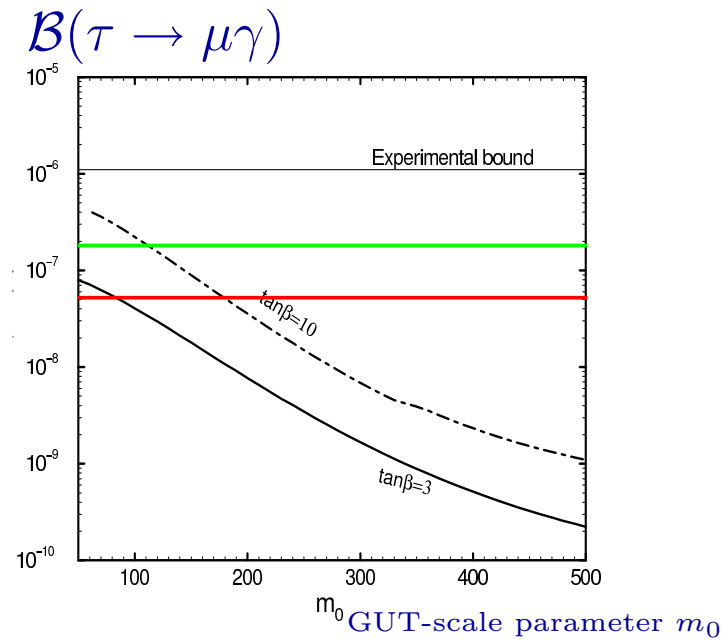


(Based on Babar knowledge of backgrounds and assuming Babar performance)



## Supergravity

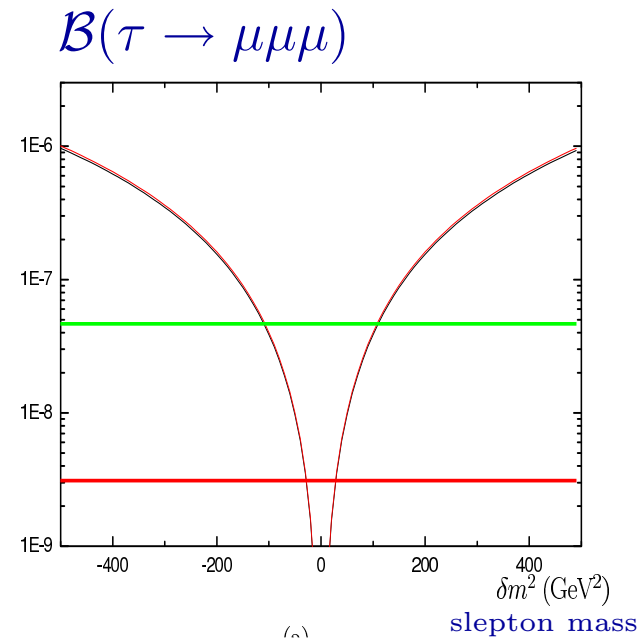
$\tau \rightarrow lll$  is not reachable



hep-ph/9911459

## Non-universal soft SUSY breaking

$\tau \rightarrow l\gamma$  is not reachable



hep-ph/0305290



Hot discussion - is LVF sensitive to **SUSY Higgs** or not.

With neutral Higgs triplet

- $\mathcal{B}(\tau \rightarrow 3\mu) \simeq 1 \times 10^{-7} \times \left(\frac{\tan\beta}{60}\right)^6 \times \left(\frac{100\text{GeV}}{m_A}\right)^4$ ,  
 $\mathcal{B}(\tau \rightarrow 3\mu) \gg \mathcal{B}(\tau \rightarrow \mu\gamma)$   
 ( if Higgs is light, sleptons are heavy and  $\tan\beta$  is large.)  
 (K.Babu, C.Kolda, hep-ph/0206310)
- $\mathcal{B}(\tau \rightarrow 3\mu) \simeq 1.6 \times 10^{-8} \times \left(\frac{\tan\beta}{60}\right)^6 \times \left(\frac{100\text{GeV}}{m_A}\right)^4$ ,  
 $\mathcal{B}(\tau \rightarrow 3\mu) \ll \mathcal{B}(\tau \rightarrow 3\mu)_\gamma \ll \mathcal{B}(\tau \rightarrow \mu\gamma)$ ,  
 (A.Dedes *et al.*, hep-ph/0209207)
- $\mathcal{B}(\tau \rightarrow 3\mu) \simeq 10^{-7} \times \left(\frac{\tan\beta}{50}\right)^6 \times \left(\frac{100\text{GeV}}{m_A}\right)^4 \left(\frac{|50\Delta_L|^2 + |50\Delta_R|^2}{10^{-3}}\right)$ ,  
 $\mathcal{B}(\tau \rightarrow 3\mu)_\gamma \sim 2.3 \times 10^{-3} \times \mathcal{B}(\tau \rightarrow \mu\gamma) \leq 1.4 \times 10^{-9}$   
 If  $M_{SUSY} > 1 \text{ TeV}$  (A.Brignole, A.Rossi. hep-ph/0304081)

Charged Higgs ( $\xi^{++}$ ) exchange :

$$\mathcal{B}(\tau \rightarrow 3\mu) \simeq 1.3 \times 10^{-7} \quad (\text{E.Ma, hep-ph/0209170})$$

# Going back to planning - Can we do better?



$$\epsilon_{tot} = \mathcal{B}(\tau \rightarrow 1\text{-prong}) \cdot \epsilon_{trig} \cdot \epsilon_{reco} \cdot \epsilon_{topology} \cdot \epsilon_{pid} \cdot \epsilon_{cuts} \cdot \epsilon_{sbox}$$

85%                      95%                      88%                      50%

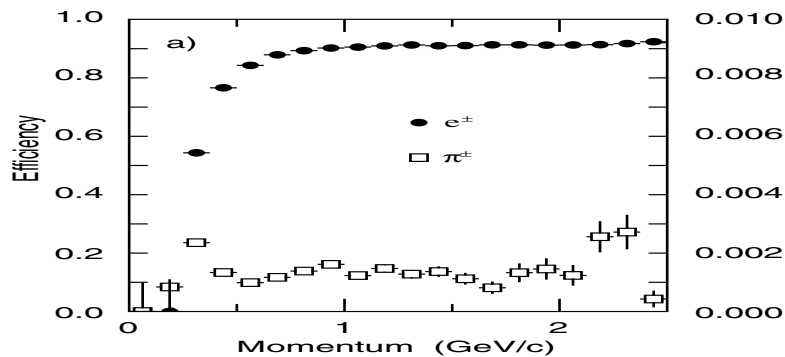
70%                      75-25%                      50-90%

Also related to PID

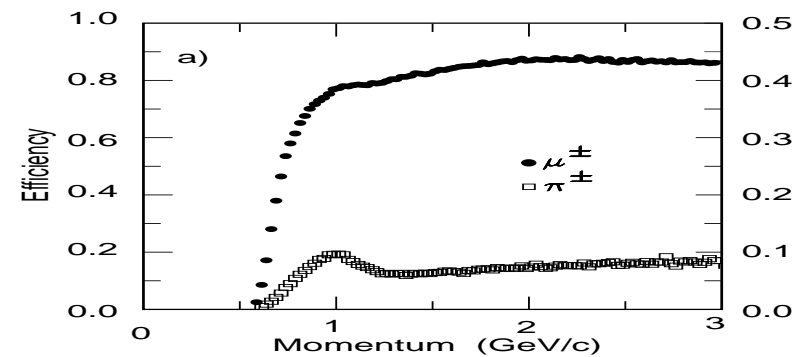
Asymmetrical acceptance?

$\delta E_\gamma$  is crucial for  $\tau \rightarrow \ell \gamma$

40% events  $\tau \rightarrow 3\ell$   
have  $\ell$  with  $p_{lab} < 0.5\text{GeV}$



electron PID



muon PID



- Many models (mostly SUSY) predict LFV tau decays of the order of  $10^{-10} - 10^{-7}$
- The measurements of different channels, e.g.  $\tau \rightarrow \ell\gamma$ ,  $\tau \rightarrow \ell\ell\ell$ , ( $\ell = e, \mu$ ) are important to distinguish between models
- Interesting to notice that **if** sparticles are too heavy to be observed at LHC or LC, B-factory still might register **SUSY Higgs** in LFV  $\tau \rightarrow \ell\ell\ell$  decays
- The upper limit sensitivity for 1 year of  $10^{36}$  luminosity is  $\mathcal{B}(\tau \rightarrow \ell\gamma) \sim 10^{-8}$ ,  $\mathcal{B}(\tau \rightarrow \ell\ell\ell) \sim 10^{-9}$ .
- The **lepton particle identification** and **photon energy measurement** are the crucial points for the measurement. The larger detector acceptance would help as well.
- What if the LFV tau decay exist ?