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# Results on Tau Physics from BaBar



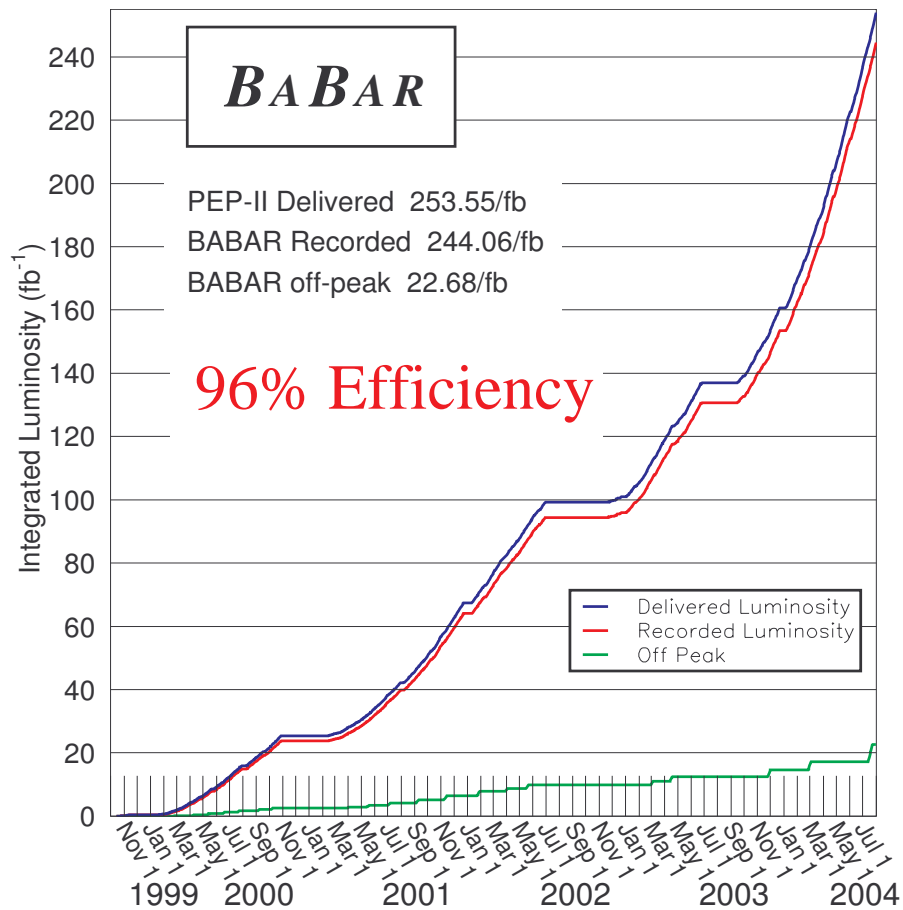
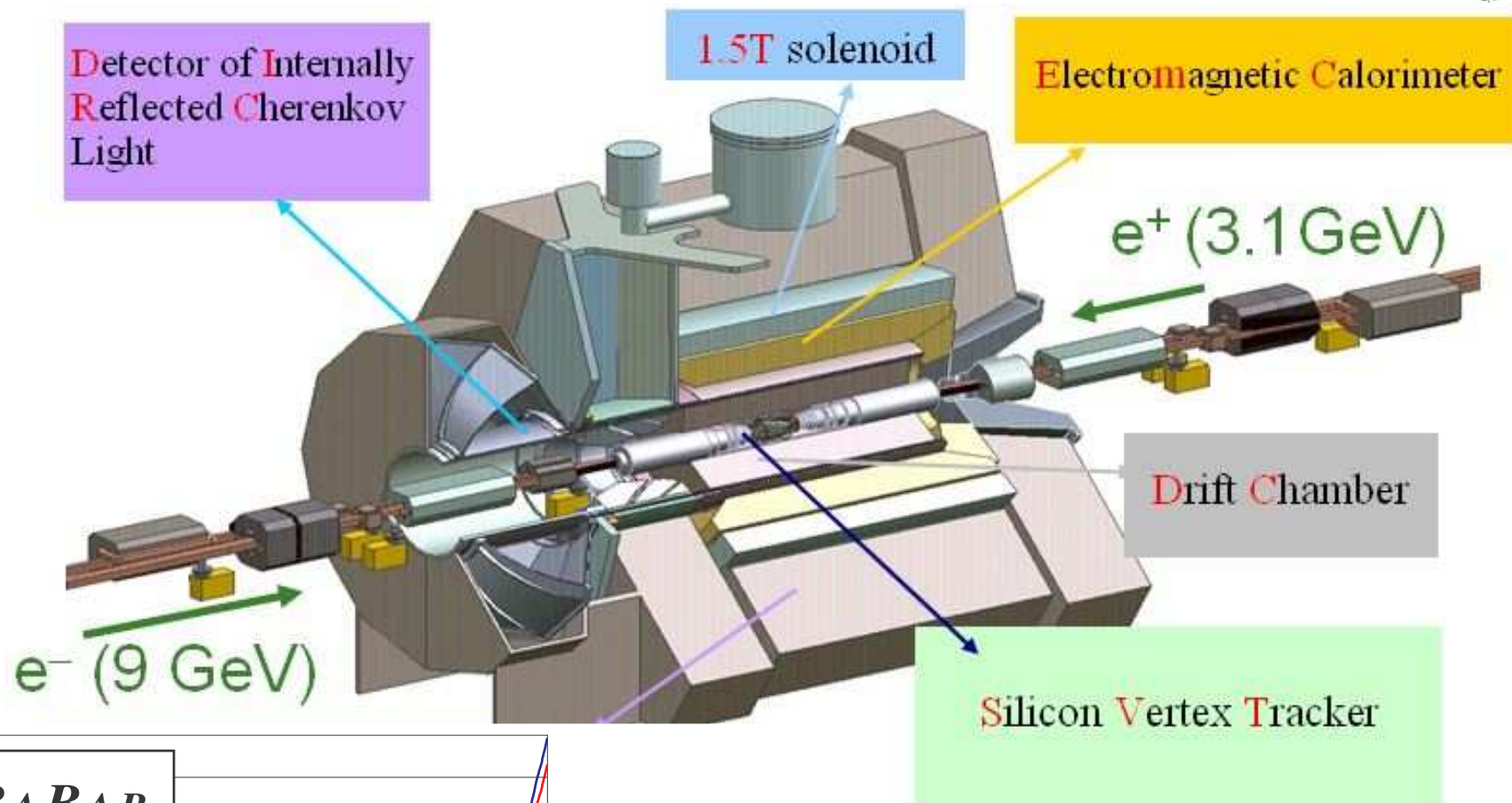
Eric Torrence  
University of Oregon



- Search for Lepton Flavor Violation
- Study of  $\tau^- \rightarrow 3h^-2h^+\nu_\tau$  (5 prong)
- Tau Lifetime



# The BaBar Experiment



244  $\text{fb}^{-1}$  recorded, more data on its way

$$\sigma(e^+e^- \rightarrow B\bar{B}) = 1.05 \text{ nb}$$

$$\sigma(e^+e^- \rightarrow \tau^+\tau^-) = 0.89 \text{ nb}$$

**Almost 220 million  $\tau^+\tau^-$  events!**

Results shown today use  $\sim 100 \text{ fb}^{-1}$



# Lepton Flavor Violation

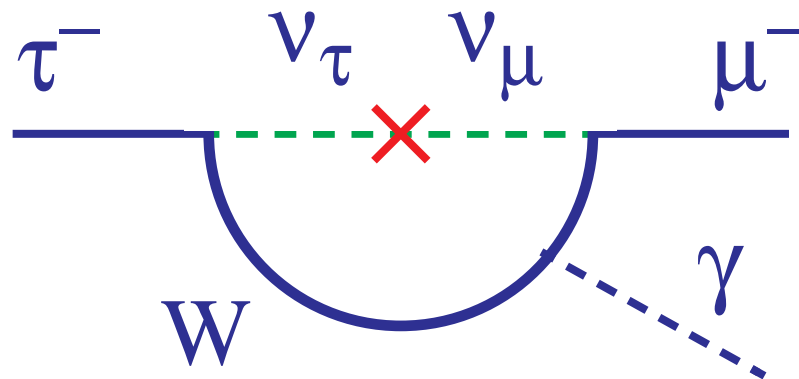


## Limits on Lepton Flavor Changing Decays before BaBar/Belle

- $B(\mu \rightarrow e\gamma) < 1.2 \times 10^{-11}$  at 90% CL [MEGA/LAMPF]
- $B(\mu \rightarrow eee) < 1.0 \times 10^{-12}$  at 90% CL [SINDRUM]
- $B(\tau \rightarrow \mu\gamma) < 1.1 \times 10^{-6}$  at 90% CL [CLEO]
- $B(\tau \rightarrow \mu\mu\mu) < 1.9 \times 10^{-6}$  at 90% CL [CLEO]

Forbidden in SM, but no good theoretical motivation

## Neutrino Oscillations

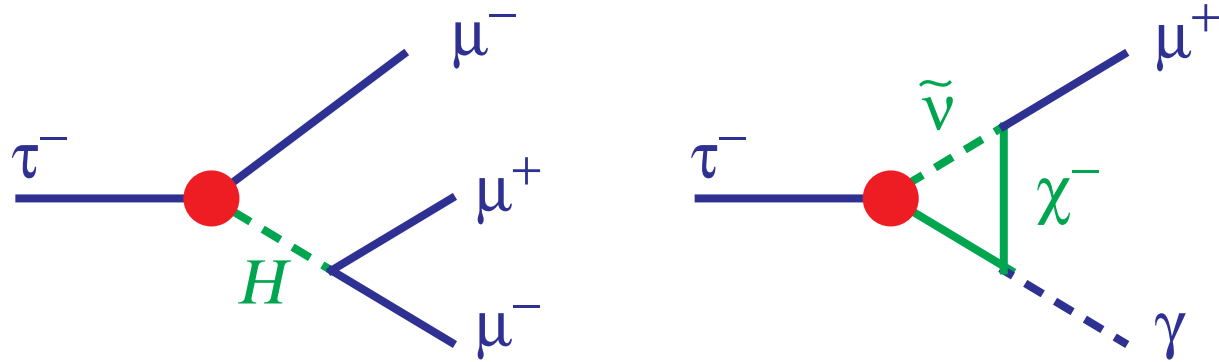


LFV allowed in principle, but rate is very, very small.  $O(10^{-40})$ ?

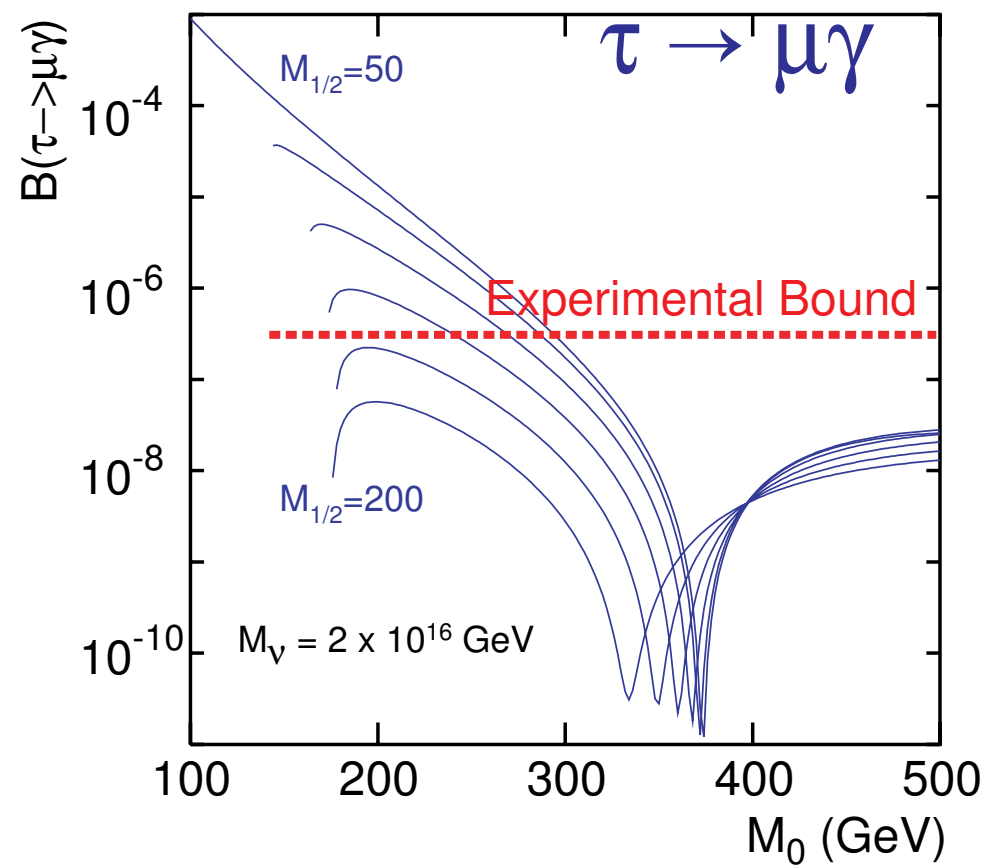
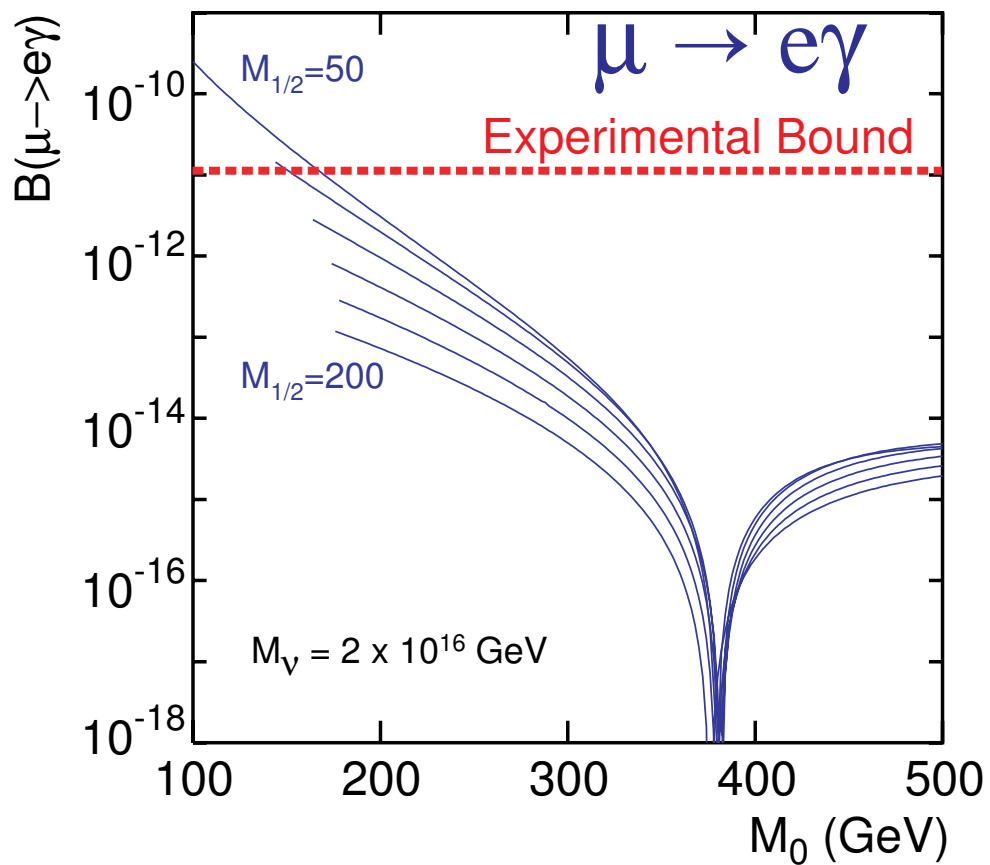
Signature of new physics! Search for  $\tau \rightarrow \mu\gamma$ ,  $\tau \rightarrow lll, \dots$



# LFV in Tau Decays



Natural part of many models of new physics,  
particularly those trying to explain neutrino data

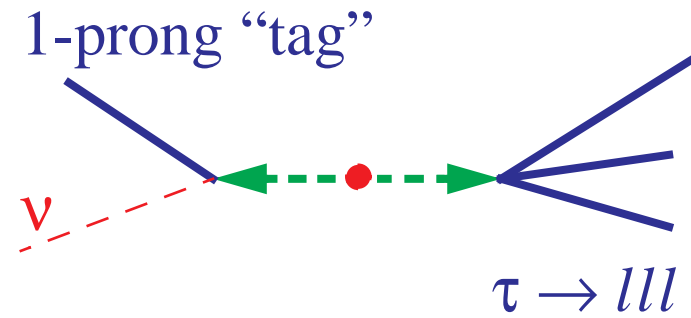
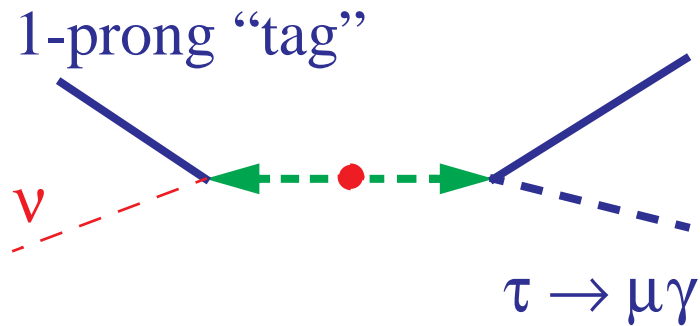


String inspired, heavy  $\nu_R$  SUSY [King and Oliveira, 1999]

See E. Ma Tau02 proceedings for concise review



# LFV Signature



- One prong on "tag" side ( $\pi\nu, \rho\nu, e\nu\nu, \mu\nu\nu, \dots$ )  $\sim 85\%$
- Strict lepton identification
- No missing momentum on signal side

## $\Delta E$ vs. $\Delta m$ for MC signal

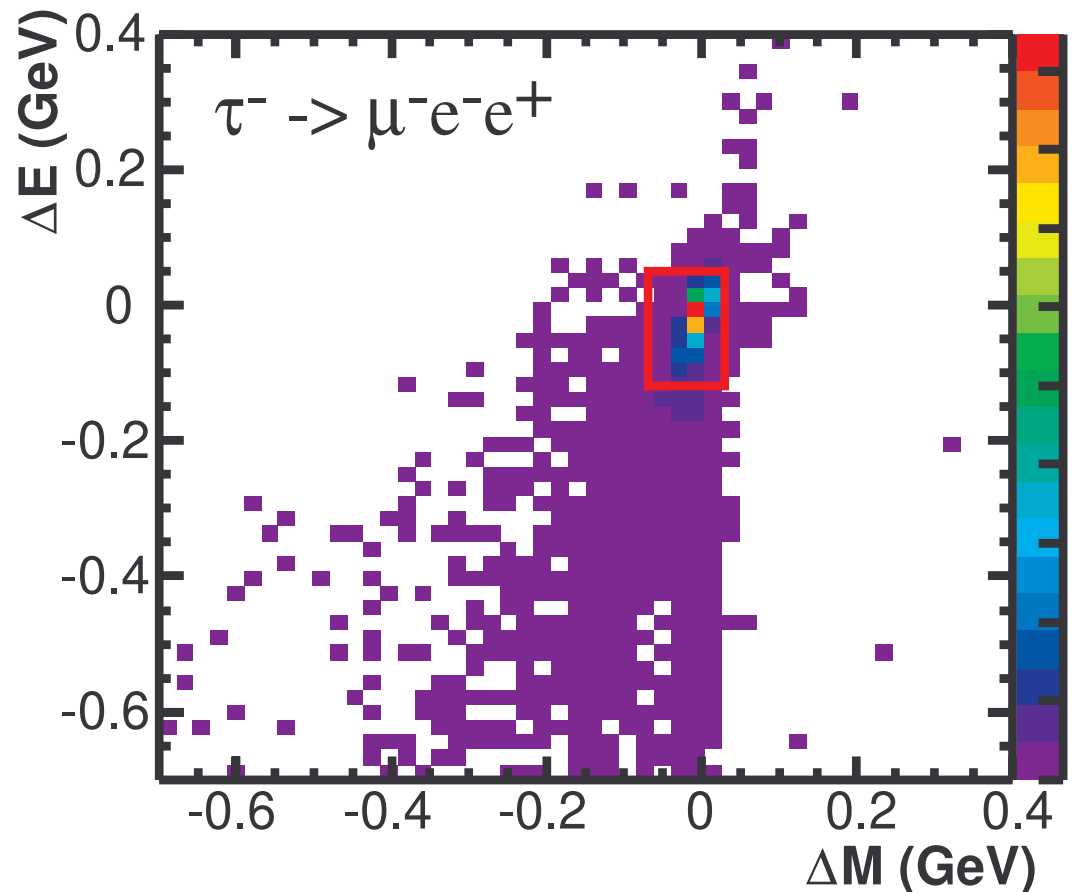
"Neutrinoless" Decay

$$\Delta m = m_{rec} - m_{\tau}$$

$$\Delta E = E_{rec} - E_{beam}$$

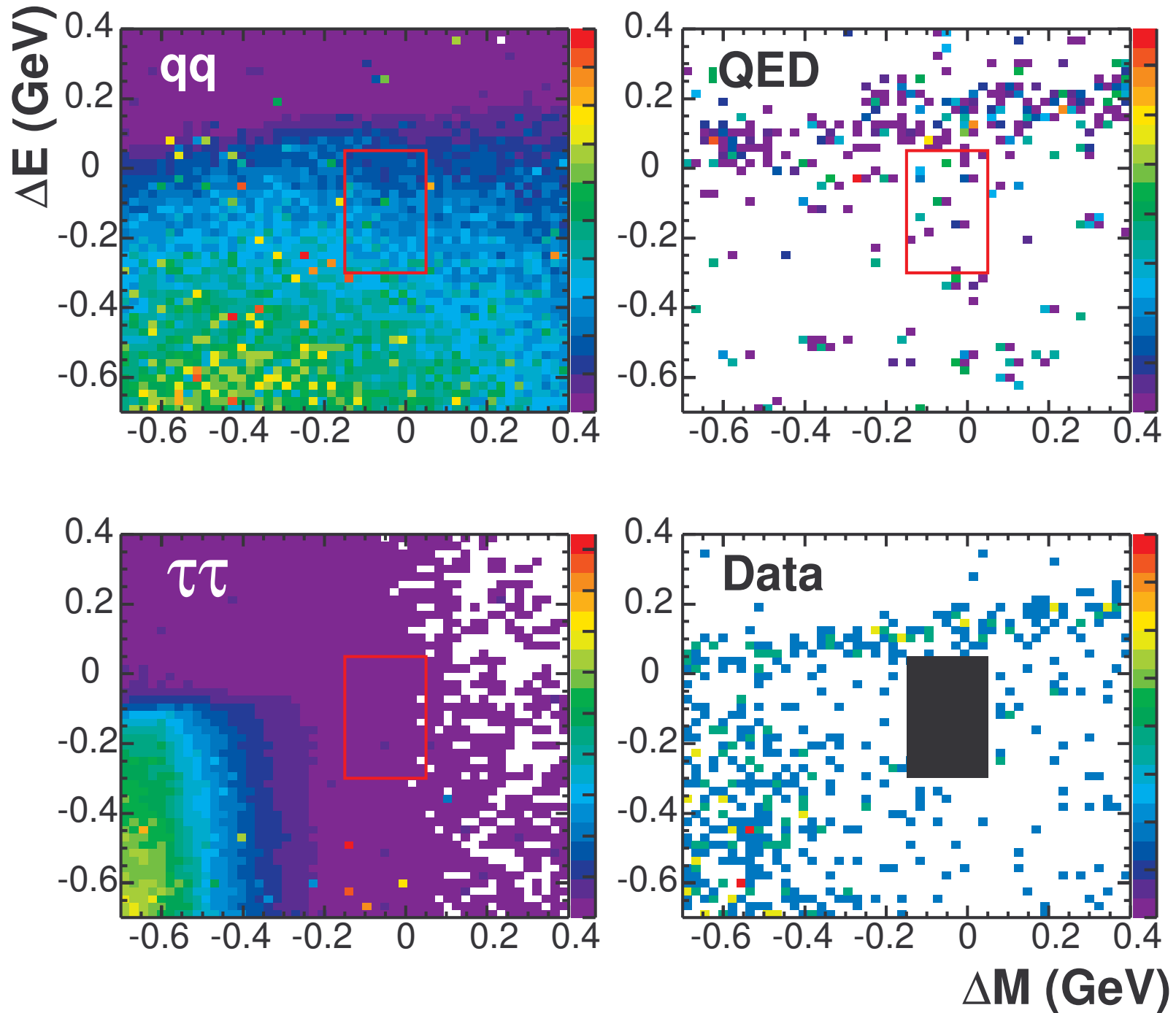
Smeared by resolution  
and radiative effects

Count events in signal box





# $\tau \rightarrow ll$ Analysis

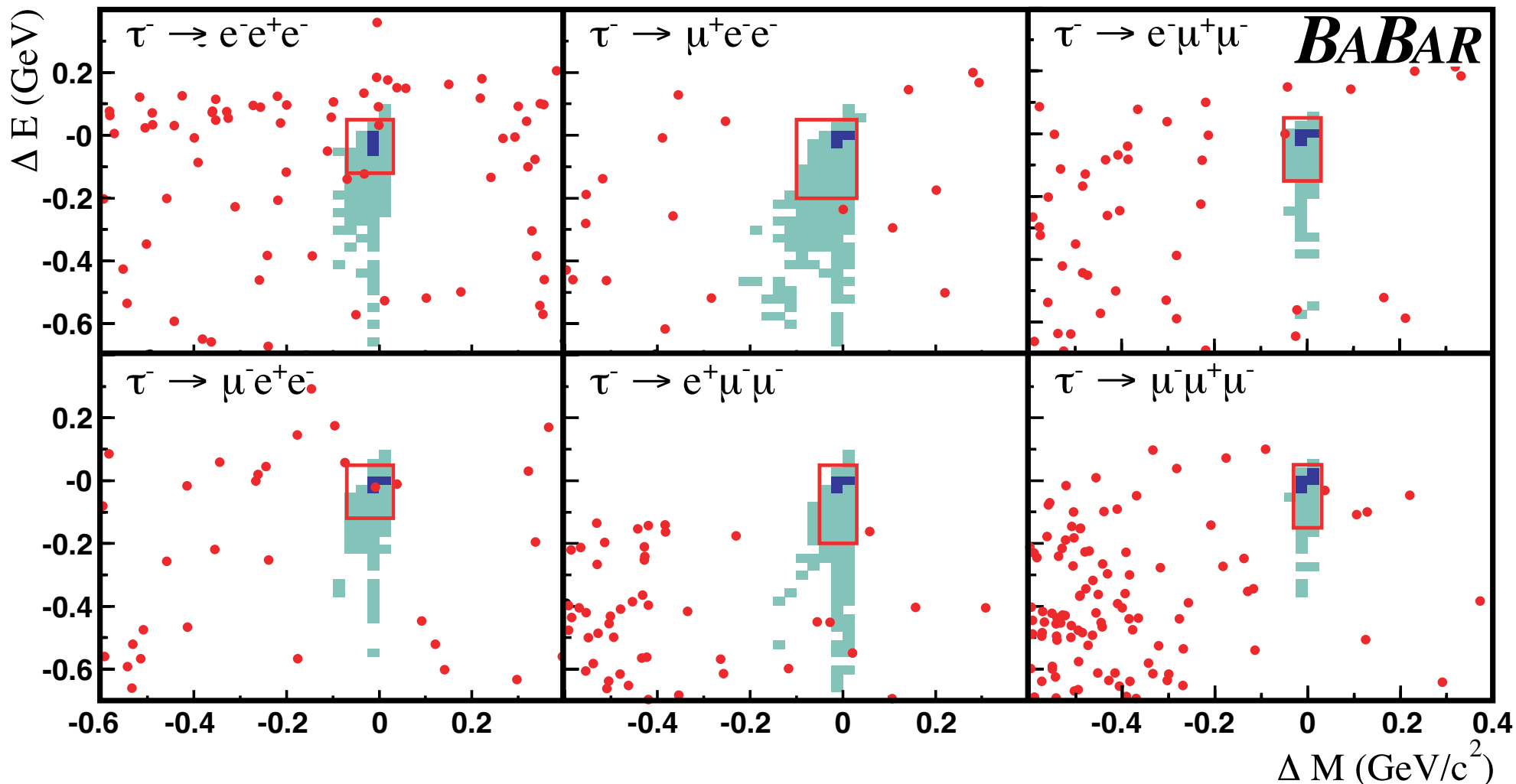


Require 1-3 topology, reject  $\gamma$  conversions, Particle ID, plus specific cuts per channel against major backgrounds

3 background PDFs, shape from MC/control, rate from data



# BaBar $\tau \rightarrow ll$ LFV Limits

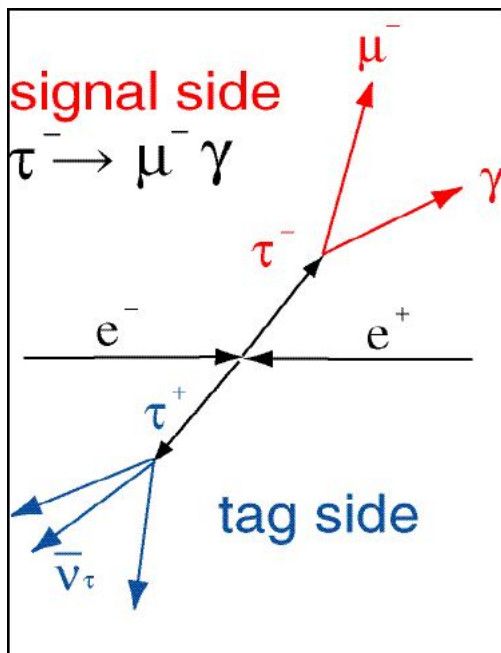


Mode	$e^-e^+e^-$	$\mu^+e^-e^-$	$\mu^-e^+e^-$	$e^+\mu^-\mu^-$	$e^-\mu^+\mu^-$	$\mu^-\mu^+\mu^-$
Eff [%]	$7.3 \pm 0.2$	$11.6 \pm 0.4$	$7.7 \pm 0.3$	$9.8 \pm 0.5$	$6.8 \pm 0.4$	$6.7 \pm 0.5$
$N_{\text{bgd}}$	$1.51 \pm 0.11$	$0.37 \pm 0.08$	$0.62 \pm 0.10$	$0.21 \pm 0.07$	$0.39 \pm 0.08$	$0.31 \pm 0.09$
$N_{\text{obs}}$	1	0	1	0	1	0
$\mathcal{B}_{\text{UL}}^{90}$	$2.0 \times 10^{-7}$	$1.1 \times 10^{-7}$	$2.7 \times 10^{-7}$	$1.3 \times 10^{-7}$	$3.3 \times 10^{-7}$	$1.9 \times 10^{-7}$

**No excess found!** Limits  $(1 - 3) \times 10^{-7}$  @ 90% CL  
 $L = 91.6 \text{ fb}^{-1}$ ,  $\sigma_{\tau} = 0.89 \text{ nb}$  **PRL 92, 121801 (2004)**



# Old Preliminary BaBar $\tau \rightarrow \mu\gamma$ Limits



Significant background from  
 $e^+e^- \rightarrow \mu^+\mu^-\gamma$  and  $\tau \rightarrow \mu\bar{\nu}_\mu\nu_\tau\gamma$

Require electron or rho tag  
(no muon or pion tags allowed)

$L = 63 \text{ fb}^{-1}$ ,  $\sigma_\tau = 0.89 \text{ nb}$

Bgd expected:  $7.8 \pm 1.4$

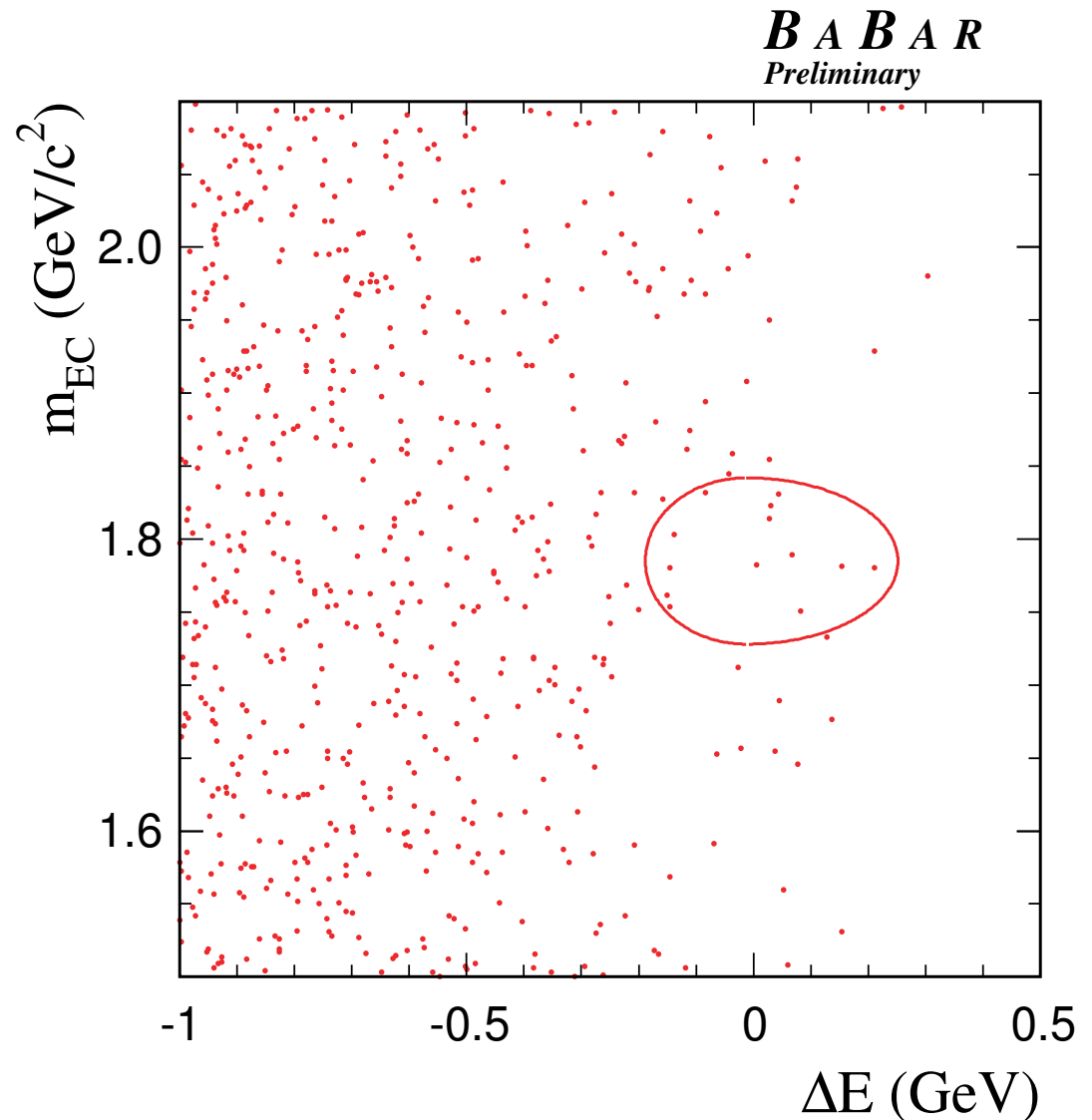
Data observed: **13**

$\epsilon = (5.2 \pm 0.5)\%$

Limit  $2.0 \times 10^{-6}$  @ 90% CL

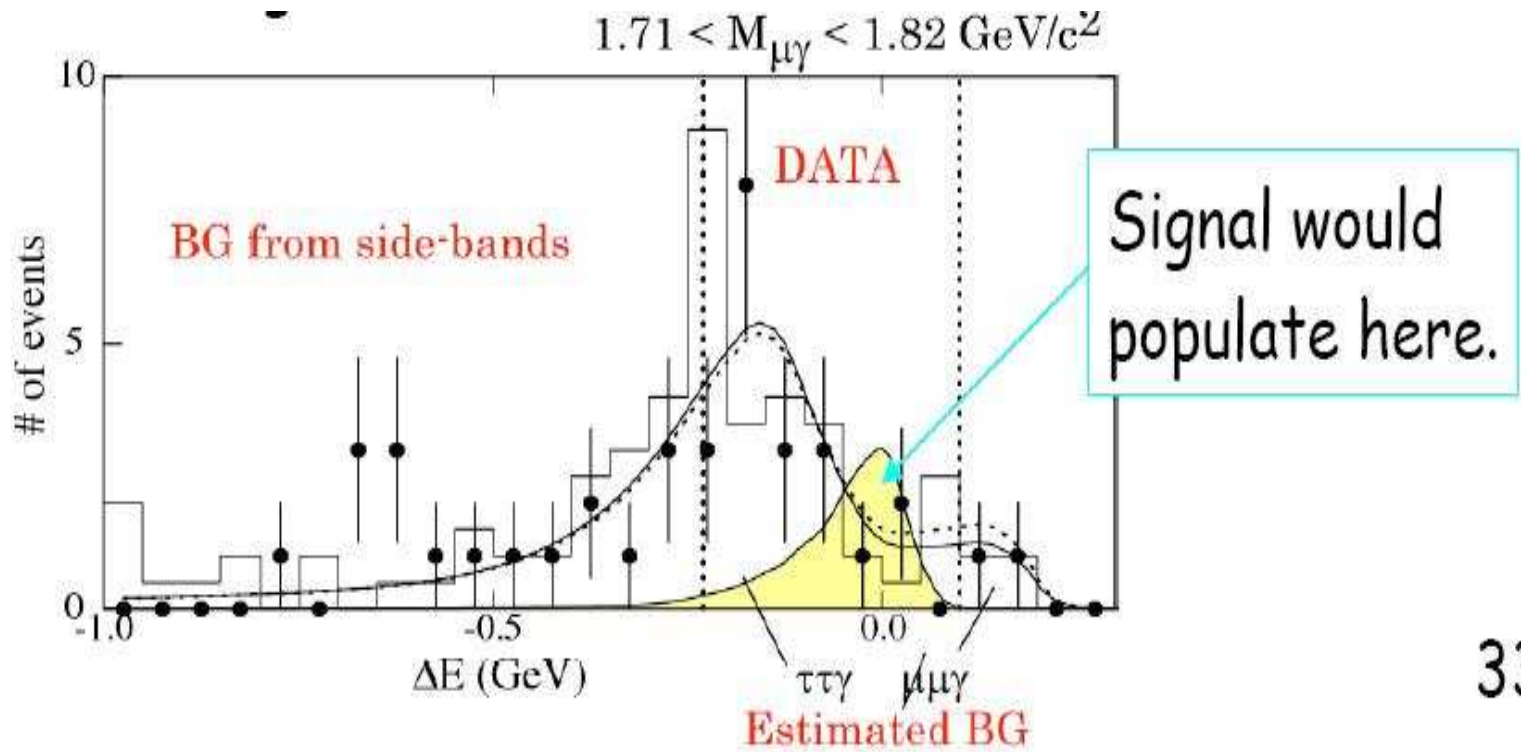
Not competitive due to fluctuation

Update with  $220 \text{ fb}^{-1}$  expected  
for Tau04...





# Published Belle $\tau \rightarrow \mu\gamma$ Limits



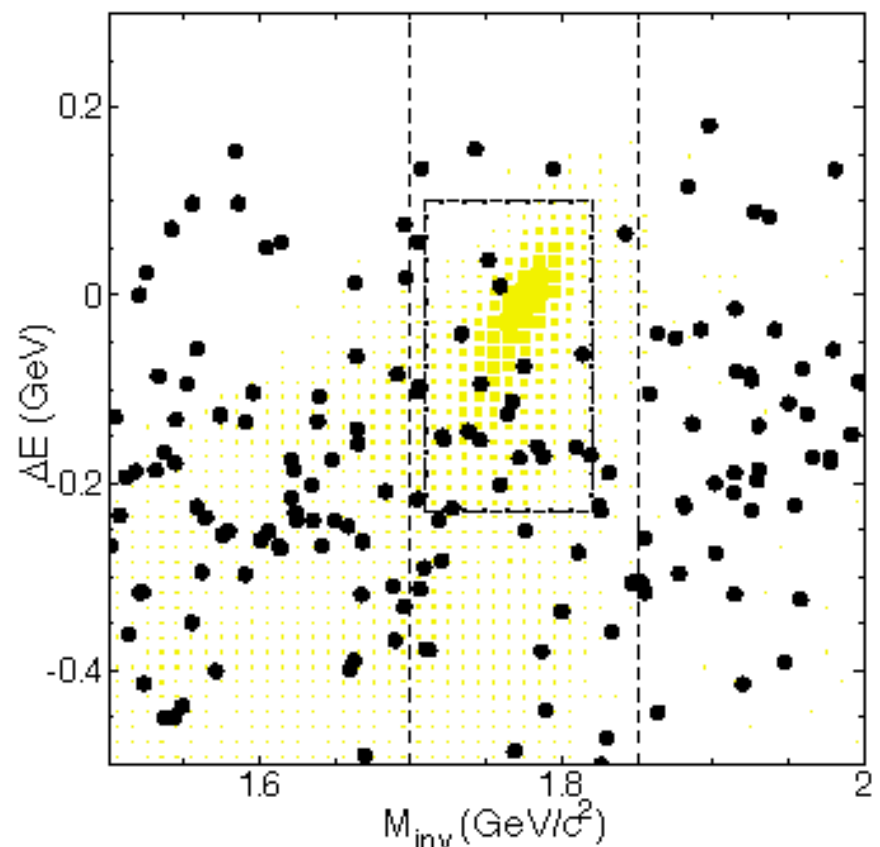
33

$L = 86.3 \text{ fb}^{-1}$ ,  $\epsilon = (11.0 \pm 0.5)\%$   
 Expected:  $20.2 \pm 2.1$  Observed: **19**

BF Limit  $3.1 \times 10^{-7}$  @ 90% CL  
**PRL 92, 171802 (2004)**

Also  $B(\tau \rightarrow \mu\eta) < 3.4 \times 10^{-7}$   
 Submitted to PRL

**Updates expected this week,  
 see BSM-5 2:30 Tuesday**





## Published Lepton Flavor Violation Limits



Limits (  $\times 10^{-7}$  ) at 90% CL based on  $\sim 90 \text{ fb}^{-1}$  per experiment

Mode	BaBar	Belle	My Combination
$B(\tau^- \rightarrow \mu^- \mu^+ \mu^-)$	1.9	2.0	0.8
$B(\tau^- \rightarrow \mu^- \mu^+ e^-)$	3.3	2.0	1.4
$B(\tau^- \rightarrow \mu^- e^+ \mu^-)$	1.3	2.0	0.7
$B(\tau^- \rightarrow \mu^- e^+ e^-)$	2.7	1.9	1.2
$B(\tau^- \rightarrow e^- \mu^+ e^-)$	1.1	2.0	0.6
$B(\tau^- \rightarrow e^- e^+ e^-)$	2.0	3.5	1.5

BaBar: **PRL 92**, 121801 (2004) Belle: **PLB 589**, 103 (2004)

Also  $B(\tau \rightarrow \mu \gamma) < 3.1 \times 10^{-7}$  and  $B(\tau \rightarrow \mu \eta) < 3.4 \times 10^{-7}$  (Belle)

**B-factories have lowered these limits  $10^{-6} \rightarrow 10^{-7}$**

Over  **$500 \text{ fb}^{-1}$  ( $0.5 \text{ ab}^{-1}$ )** expected in next few years

**50 distinct modes listed in PDG with LF, L, or B violation**

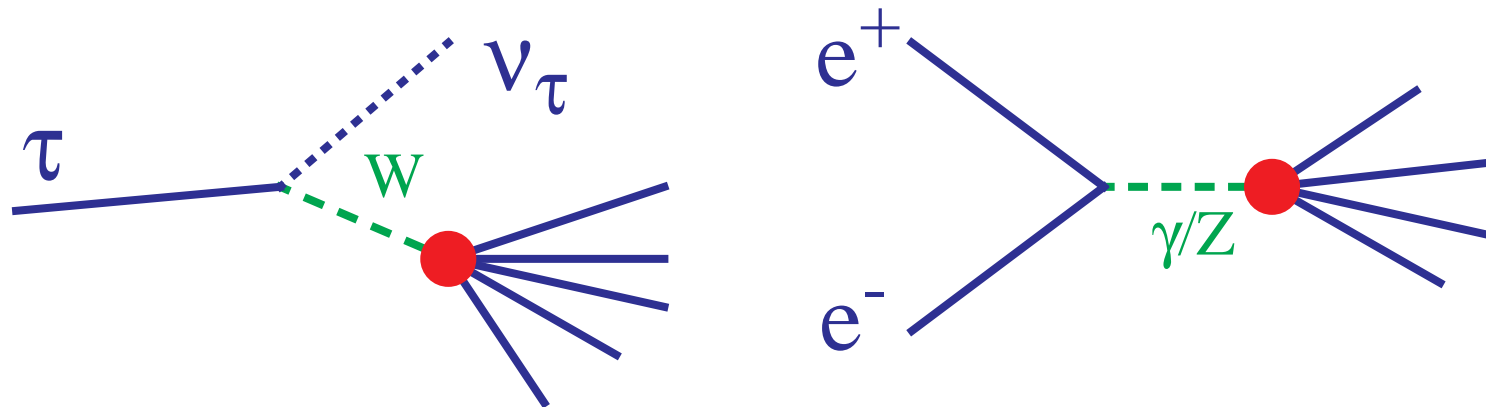
Many interesting channels:  $\tau \rightarrow lhh$ ,  $\tau \rightarrow \mu \eta'$ ,  $\tau \rightarrow p \gamma$ , ...

$\tau \rightarrow lll$  limits should approach  $O(10^{-8})$  soon

**Many models predictions are above this level!**

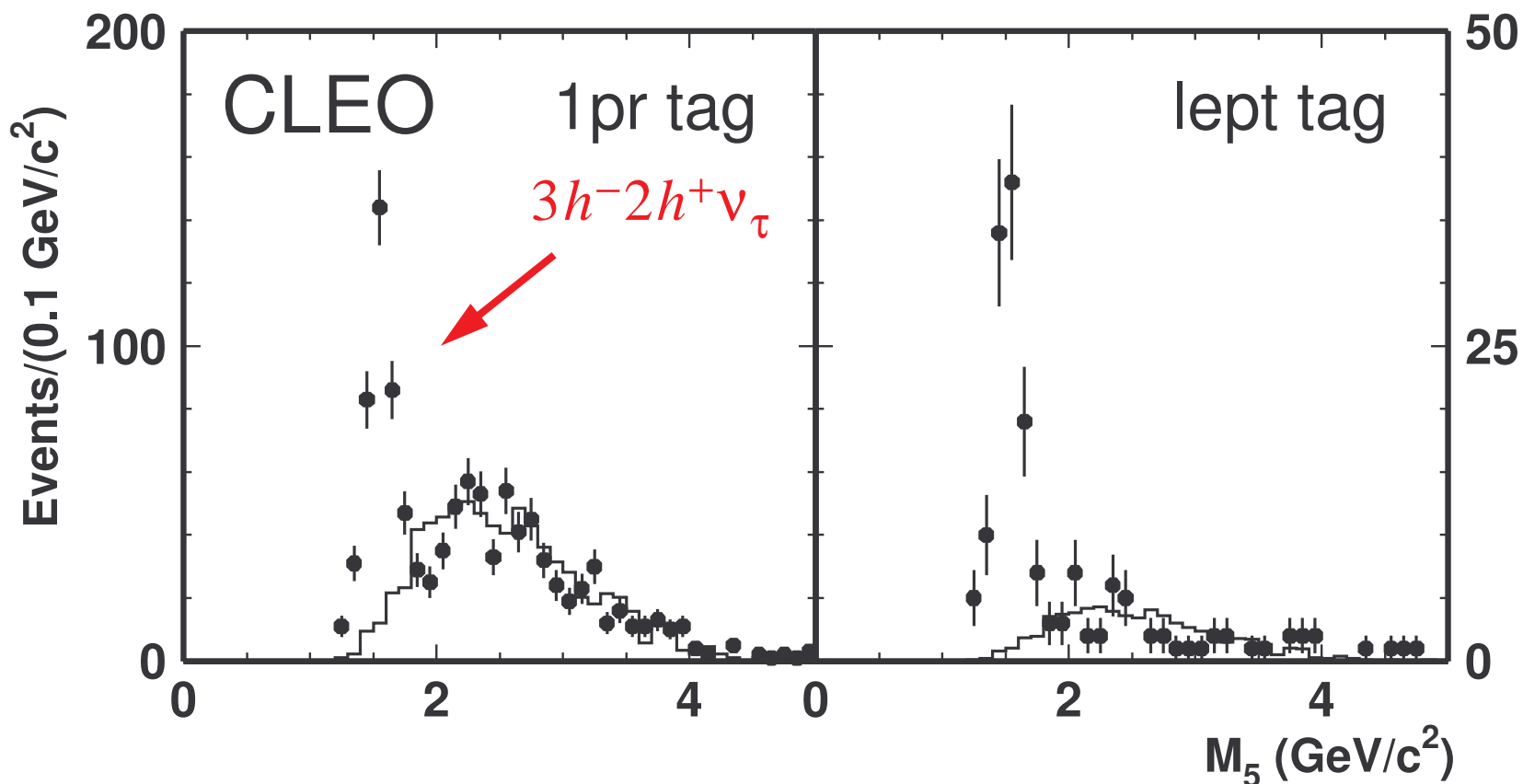


# Five Prong Tau Decays



Tau Decays provide a clean laboratory to study QCD

$\tau^- \rightarrow \pi^- \pi^0 \nu_\tau$  and  $\tau^- \rightarrow \pi^- \pi^+ \pi^- \nu_\tau$  extensively studied worldwide  
5-prong modes suffer from lack of statistics...

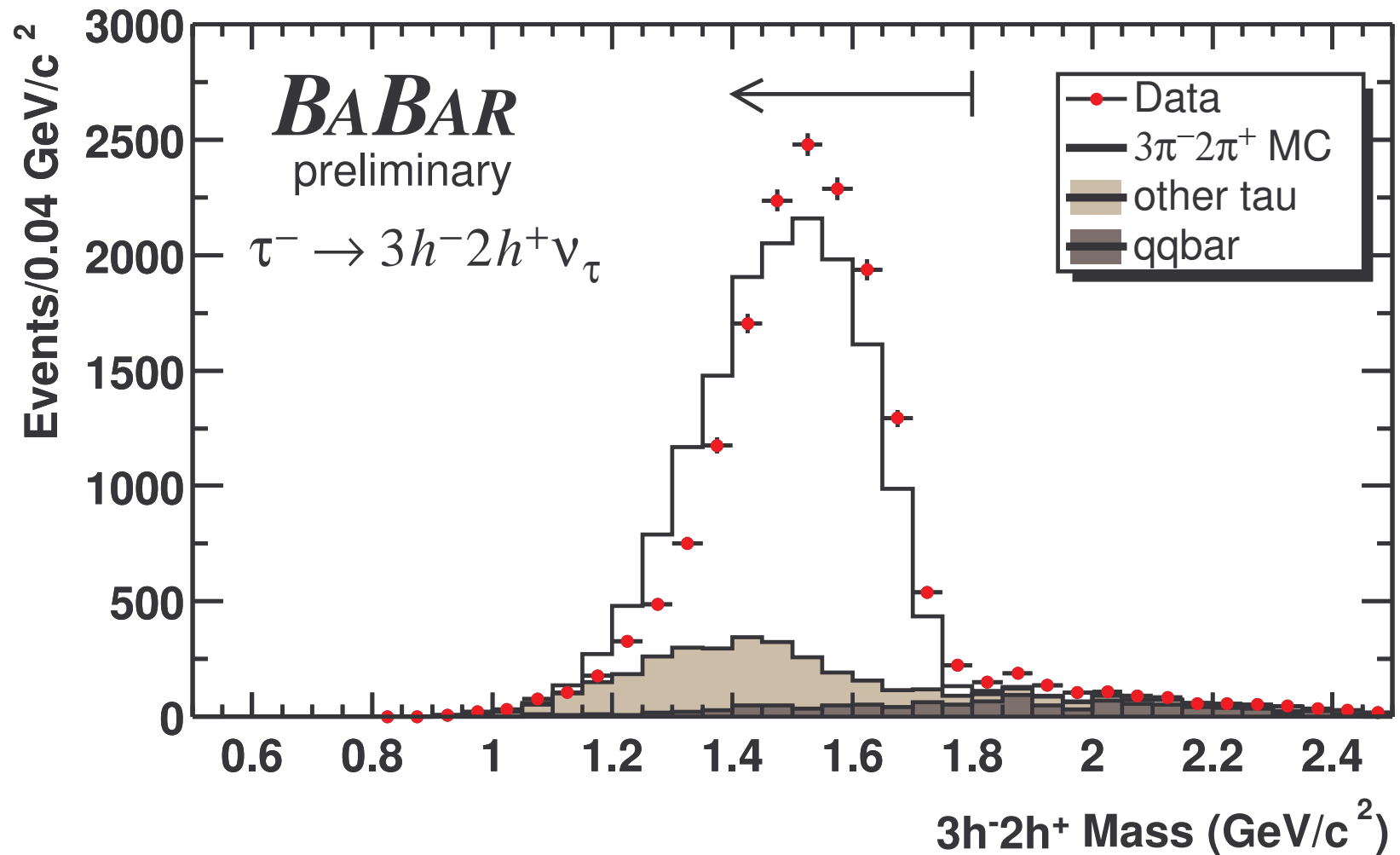




## BaBar 5-prong Analysis



$3h^-2h^+$  mass compared to TAUOLA (phase space)



1-5 topology, lepton tag, thrust,  $P_t/E_{\text{miss}}$ , no kaon id (yet)  
veto  $e^-$ ,  $\pi^0$ , and conversions from signal side

Efficiency: 7.5%, Purity: 79%, Events: 15,869, Lumi: 110.7 fb<sup>-1</sup>

Backgrounds mostly from other tau decays with  $\pi^0$  or  $K_s$



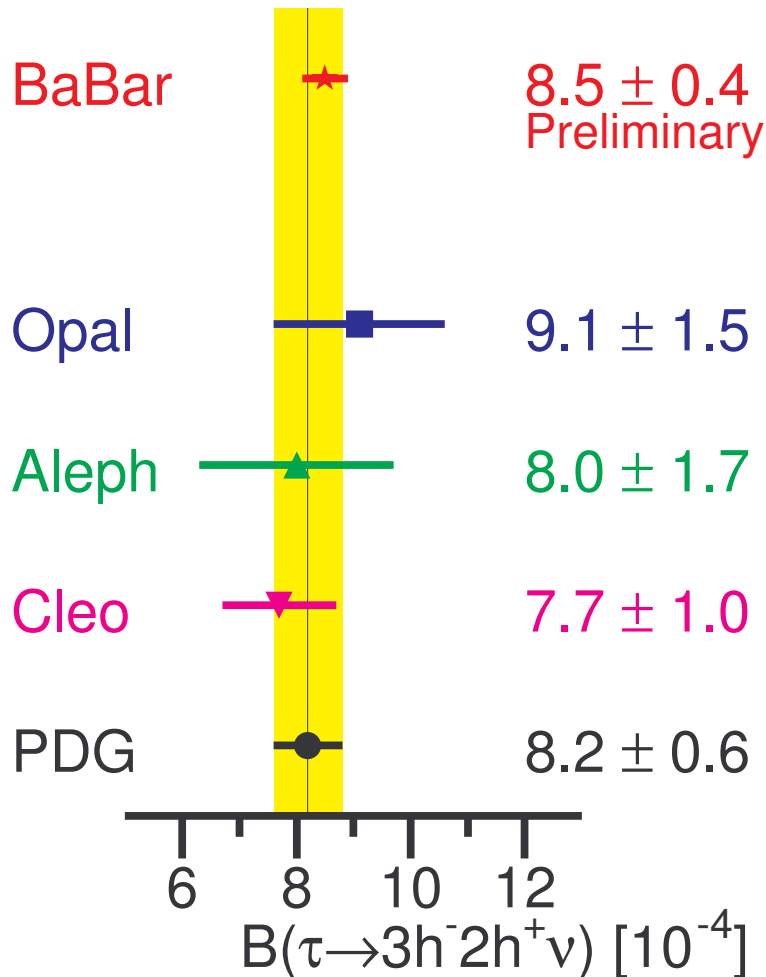
# Preliminary 5-prong Results



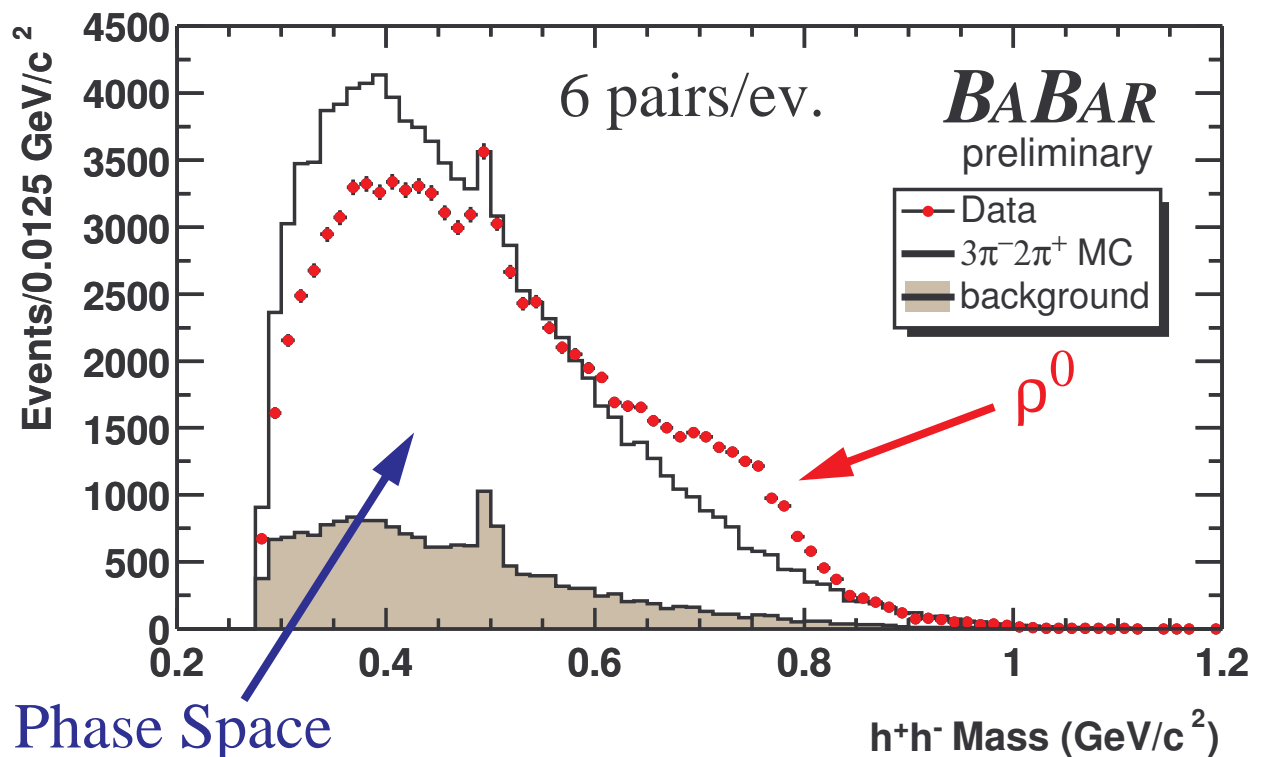
Tag	Efficiency [%]	Purity [%]	Events	$B(\tau^- \rightarrow 3h^- 2h^+ \nu_\tau)$
Electron	4.6	79	9668	$(8.52 \pm 0.09 \pm 0.40) \times 10^{-4}$
Muon	2.9	79	6201	$(8.54 \pm 0.11 \pm 0.45) \times 10^{-4}$

Babar Preliminary: hep-ex/0408050

## Branching Fraction



## Hadronic Structure in $h^+h^-$ pairs



Phase Space Monte Carlo

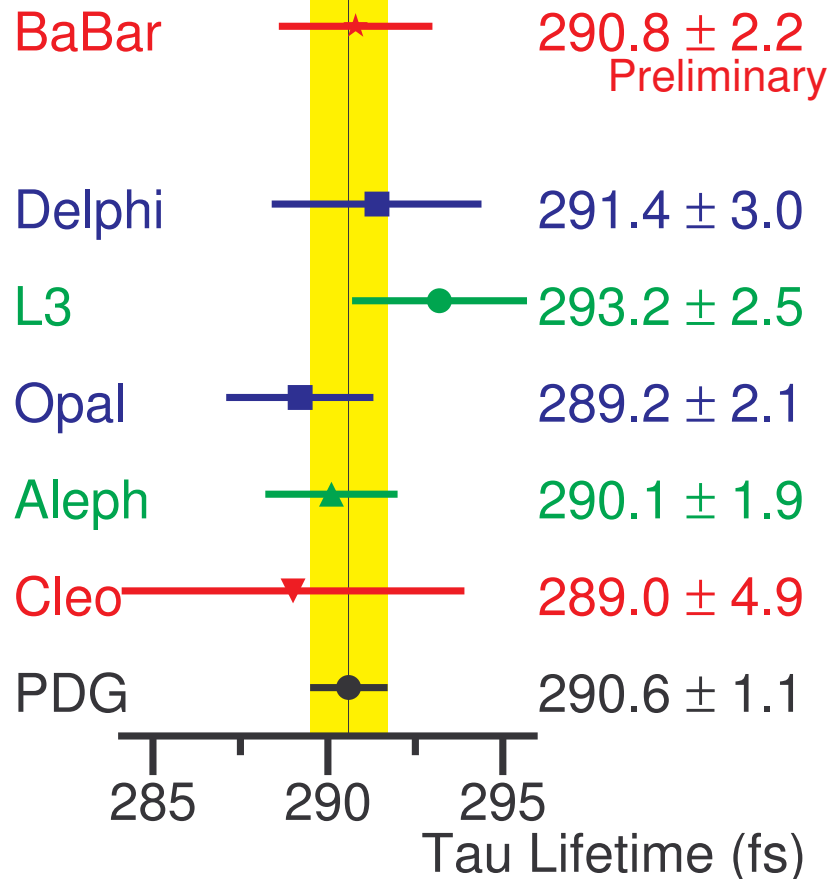
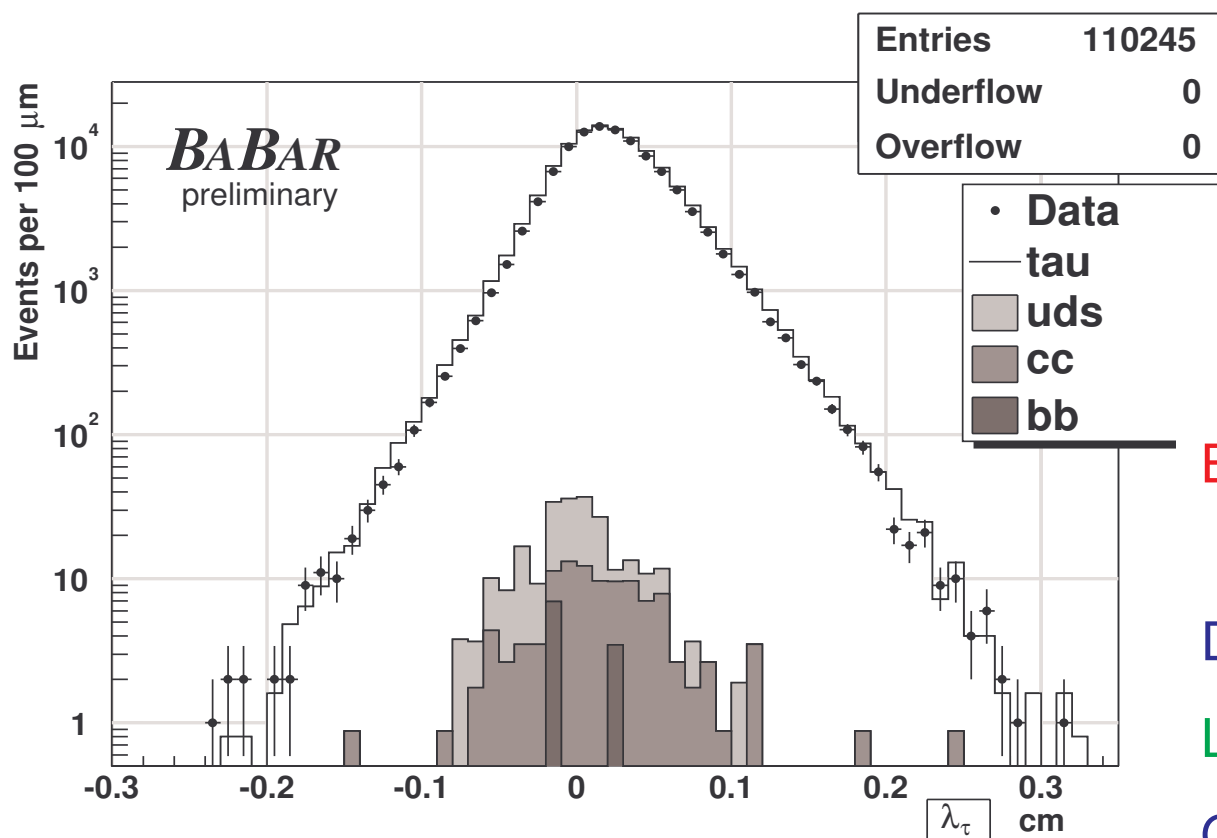
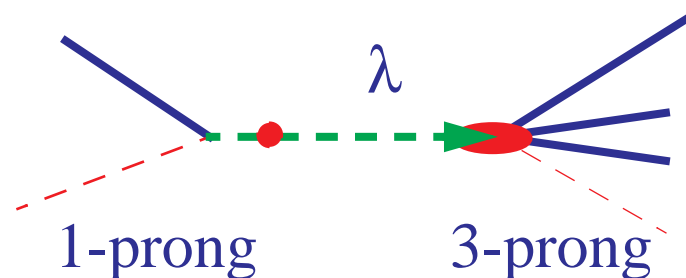
Future Plans:  
 Measure  $5h \pi^0$ ,  $5h 2\pi^0$  modes  
 Separate kaons from pions  
 Study hadronic structure in detail



# Preliminary Tau Lifetime



- Very clean 1-3 sample
- Reconstruct  $r$ - $\phi$  decay length from primary IP to 3-track vertex
- Use simple mean  $\langle \lambda \rangle$  to reduce syst.



Lifetime with  $30 \text{ fb}^{-1}$

$290.8 \pm 1.5(\text{stat}) \pm 1.6(\text{syst}) \text{ fs (prelim.)}$

Uncertainties will be significantly reduced for publication ( $80 \text{ fb}^{-1}$ )



# Summary

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## Lepton Flavor Violation

- $B(\tau \rightarrow lll) < (1 - 3) \times 10^{-7}$  published
- Prelim. result on  $B(\tau \rightarrow \mu\gamma)$  to be updated shortly

## Hadronic Structure

- Prelim. results with 16k  $\tau^- \rightarrow 3h^-2h^+\nu_\tau$  events
- Much more to come here

## Tau Lifetime

- Prelim. lifetime measurement among world's best
- Improvements and publication expected soon

First results on tau physics from BaBar are  
just now being published

**There is a lot of physics to be extracted  
from this huge data sample**

See Tau04 (Nara, Japan, September 14-17) for more