Tau Results from *BABAR*

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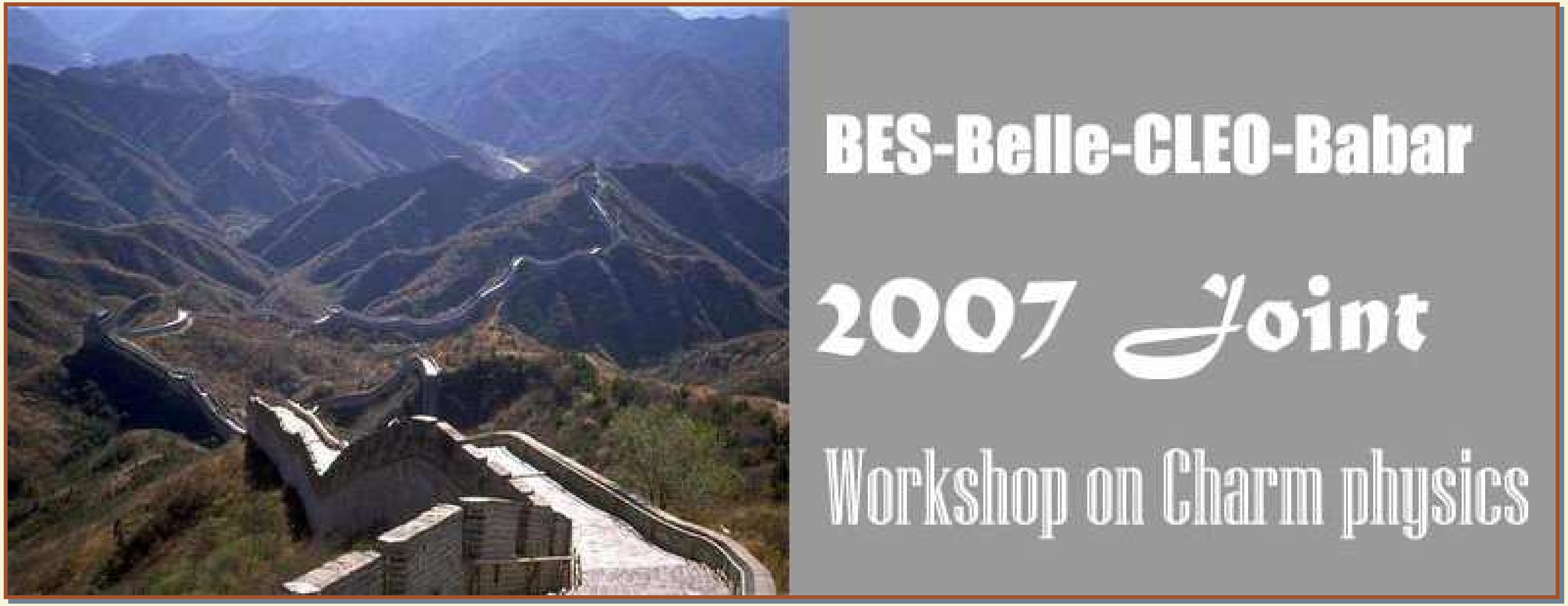
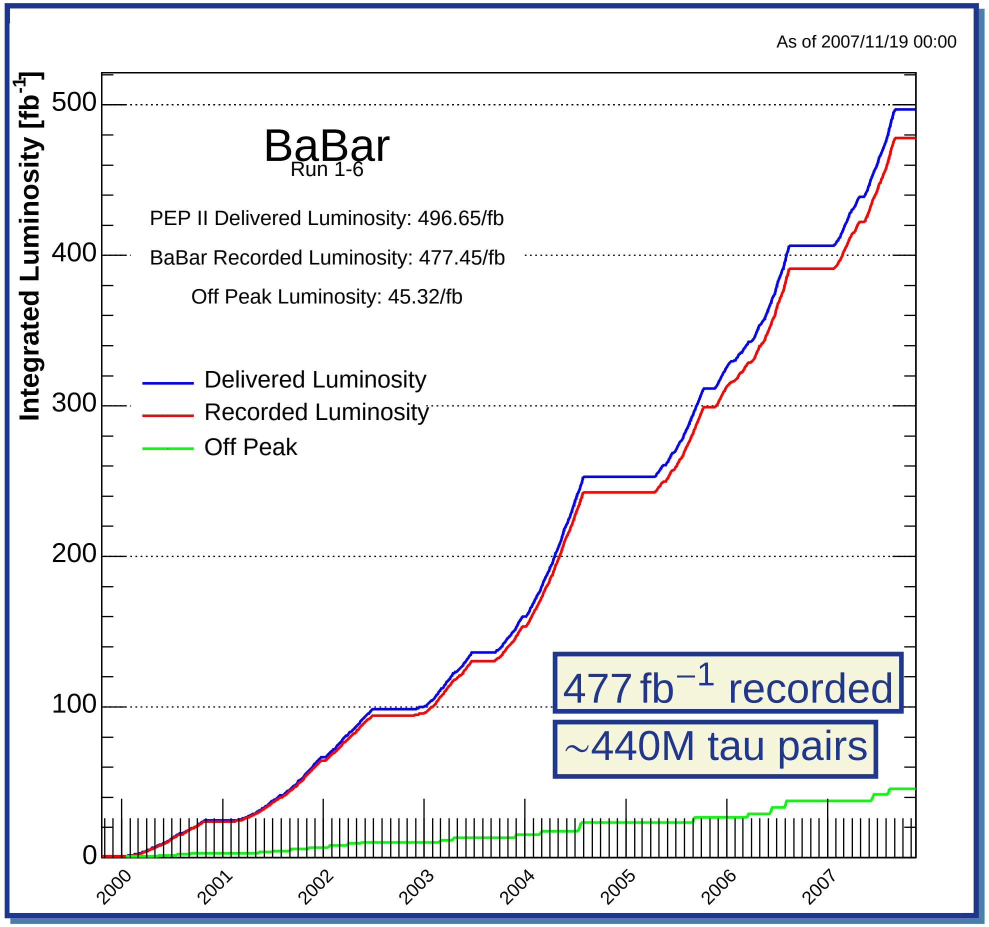
(on behalf of the *BABAR* collaboration)



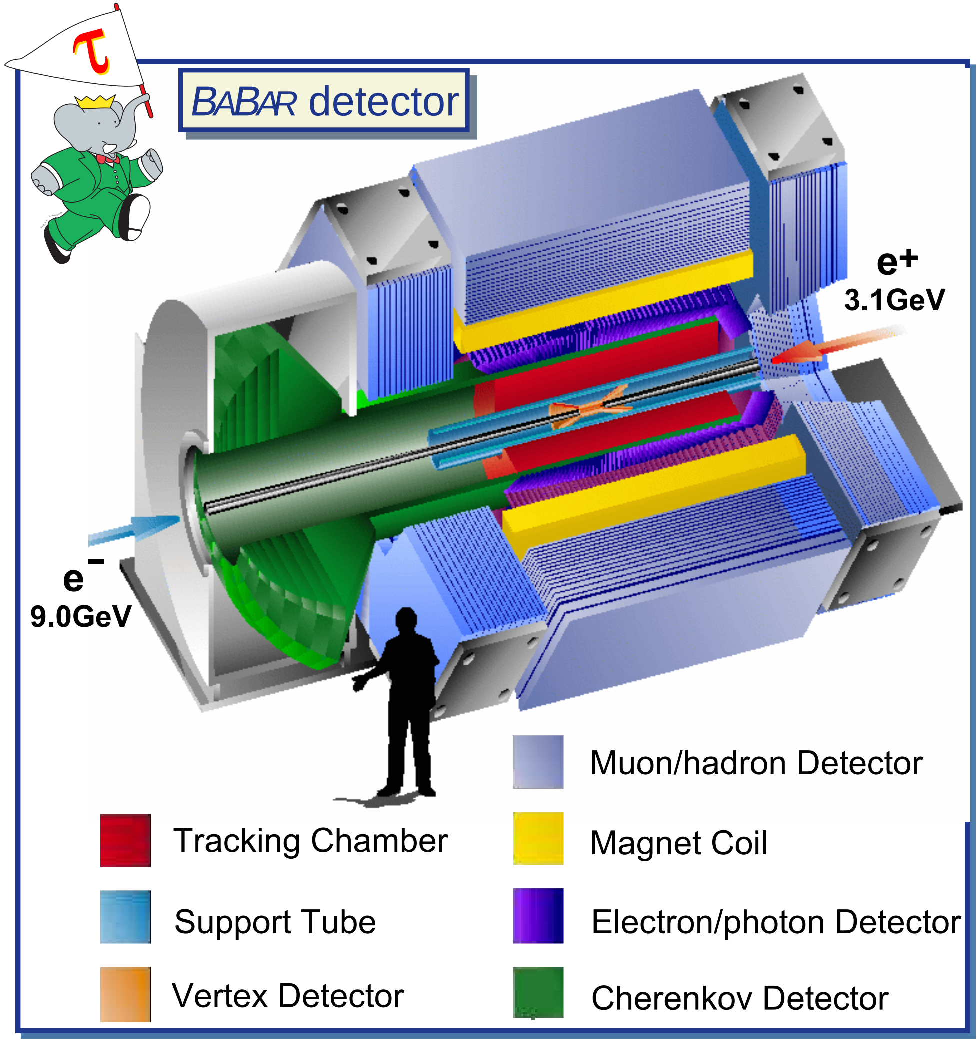
BABAR is a Tau Factory



$477\,\text{fb}^{-1}$ recorded

~440M tau pairs

$$\sigma(\tau^+\tau^-) \approx 0.9\,\text{nb} \approx \sigma(B\bar{B}) \approx 1.1\,\text{nb}$$



Areas of Tau Physics activity in BABAR

LFV Searches
- clean and unambiguous NP probes
- some NP models favor tau LFV vs. muon LFV

(semi-)hadronic decays
- $\tau \to 3\pi\eta\nu$ with $\eta \to \gamma\gamma$ work in progress
- $\tau \to 5\pi\nu$, $\tau^- \to f_1\pi^-\nu$
- $\tau \to 3\pi\pi^0\nu$, $\tau \to \omega\pi\nu$

2nd class current searches
- axial-vector / vector current + wrong G-parity
  → 20–10000 isospin symmetry suppression
- $\tau \to \eta'(958)\pi\nu$ update of Tau06 result

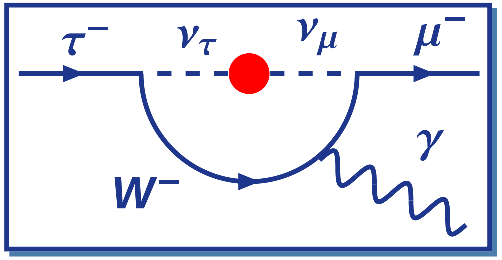
non-LFV rare decays
- $\tau \to$ 7-pions (SM predicts BF $\approx 10^{-11}$–10^{-10})

V_{us} from $\tau \to s$ inclusive
- $\tau \to s$ inclusive = $\sum_i$ BF($\tau \to s$-state$_i$)
- mass spectrum → simultaneous V_{us}&m_s fit
- $\tau \to K\pi^0\nu$ with $h = \pi, K$
- $\tau \to hhh\nu$ with $h = \pi, K$
- 3.4σ discrepancy w.r.t. kaons and unitarity

Lepton Universality
- tau lifetime (also CPT test)
- loosely connected to NuTeV anomaly

Lepton Flavour Violation Searches probe Physics beyond the Standard Model

- LFV forbidden in “classical” SM, highly suppressed in SM + ν-mixing
- LFV transitions “natural” in most New Physics models
- **tau decays at B-factories ideal place for LFV searches**



very small SM LFV amplitude

		$\tau\to\mu\gamma$	$\tau\to lll$
SM + ν mixing	Lee, Shrock, PRD 16 (1977) 1444 Cheng, Li, PRD 45 (1980) 1908 Pham EPJ C8 (1999) 513	10^{-54} – 10^{-40}	10^{-14}
SUSY Higgs	Dedes, Ellis, Raidal, PLB 549 (2002) 159 Brignole, Rossi, PLB 566 (2003) 517	10^{-10}	10^{-7}
SM + heavy Maj ν_R	Cvetic, Dib, Kim, Kim , PRD66 (2002) 034008	10^{-9}	10^{-10}
Non-universal Z’	Yue, Zhang, Liu, PLB 547 (2002) 252	10^{-9}	10^{-8}
SUSY SO(10)	Masiero, Vempati, Vives, NPB 649 (2003) 189 Fukuyama, Kikuchi, Okada, PRD 68 (2003) 033012	10^{-8}	10^{-10}
mSUGRA + Seesaw	Ellis, Gomez, Leontaris, Lola, Nanopoulos, EPJ C14 (2002) 319 Ellis, Hisano, Raidal, Shimizu, PRD 66 (2002) 115013	10^{-7}	10^{-9}

New Physics (NP) models predictions

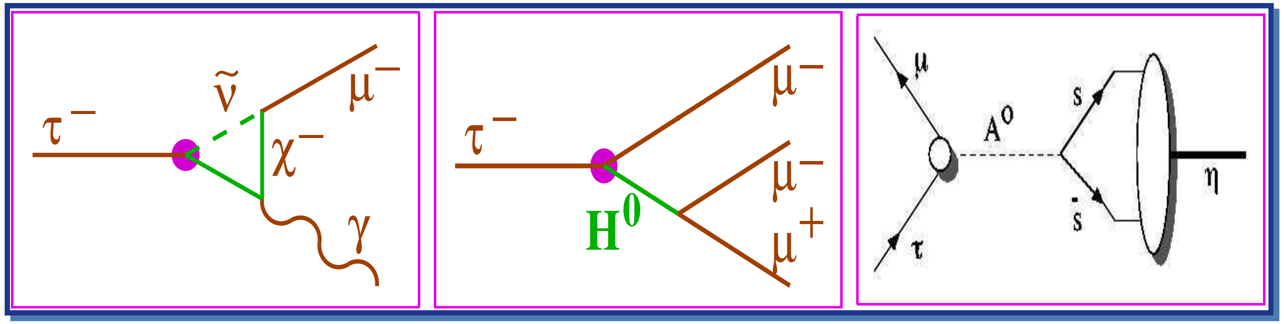


illustration of NP LFV graphs

BABAR LFV searches compared to Belle

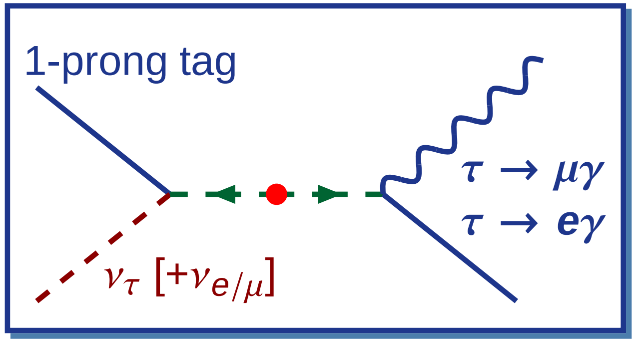
BABAR

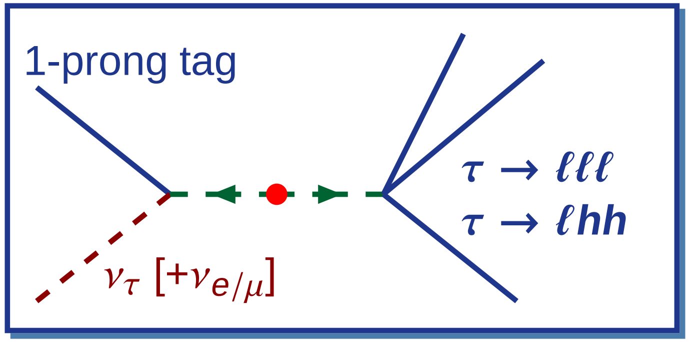
$\tau \to \mu\gamma$	PRL 95 (2005) 041802
$\tau \to e\gamma$	PRL 96 (2006) 041801
$\tau \to \ell(\pi^0, \eta, \eta')$	PRL 98 (2007) 061803
$\tau \to 3\ell$	update just accepted by PRL
$\tau \to \ell K^0_s$	in progress
$\tau \to \ell h h'$	PRL 95 (2005) 191801
$\tau \to \ell\omega$	just submitted to PRL
$\tau \to \overline{\Lambda}\pi, \overline{\Lambda}K, \Lambda\pi, \Lambda K$	hep-ex/0607040
$e^+e^- \to \ell\tau$	PRD 75 (2007) 031103

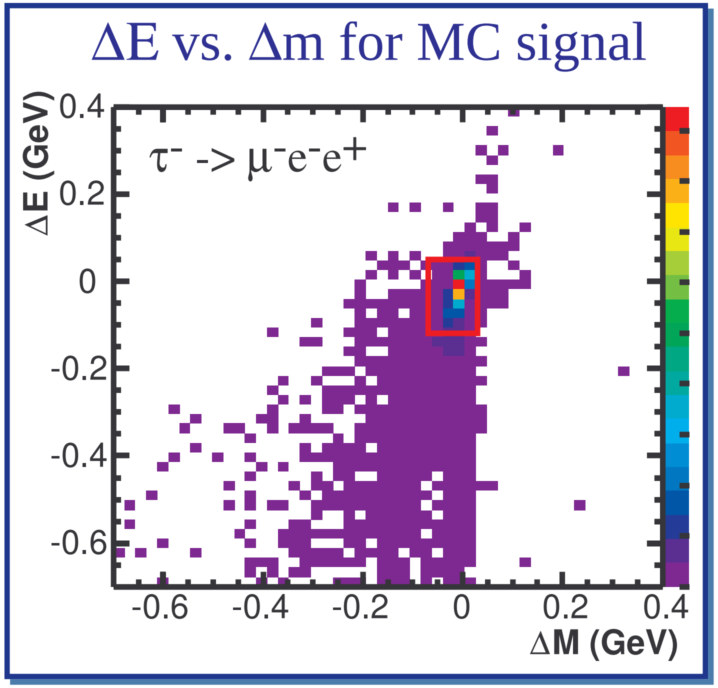
BELLE

$\tau \to \mu\gamma$	0705.0650[hep-ex]], $\Rightarrow$ PLB
$\tau \to e\gamma$	0705.0650[hep-ex], $\Rightarrow$ PLB
$\tau \to \ell^-(\pi^0, \eta, \eta')$	hep-ex/0703009v1
$\tau \to 3\ell$	PLB 598 (2004) 103
$\tau \to \ell K^0_s$	PLB 639 (2006) 159
$\tau \to \ell h h'$	PLB 640 (2006) 138
$\tau \to \ell V^0$	PLB 640 (2006) 138
$\tau \to \overline{\Lambda}\pi^-, \Lambda\pi^-$	PLB 632 (2006) 51

Properties of events with a LFV violating tau decay (in CM system)







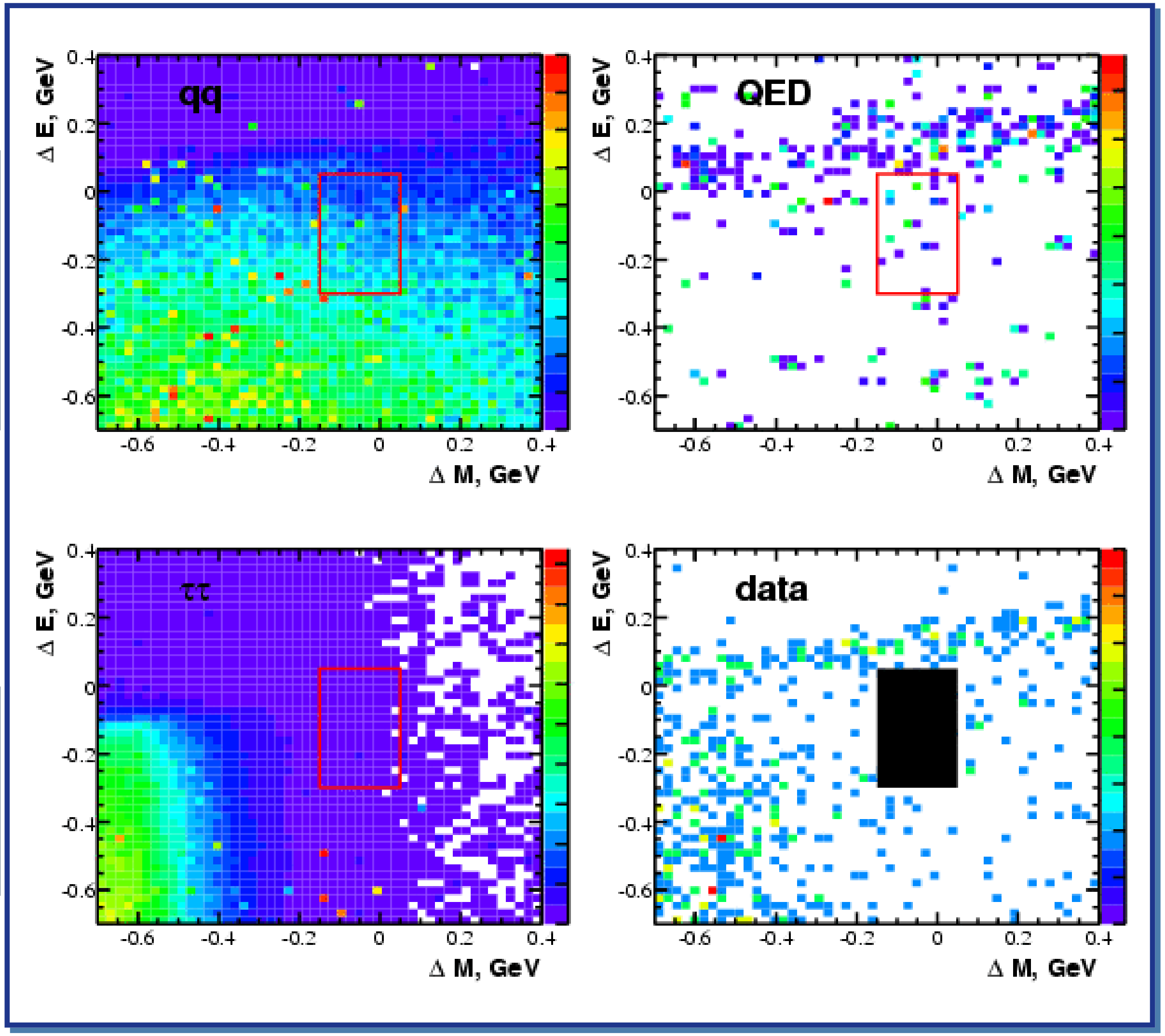
- at Υ(4*S*), separated $\tau^+\tau^-$ decay hemispheres
- neutrinoless tau decay
  → no missing 4-momentum on **signal side**
- **tag side** → undetected neutrino(s)
  → 1- or 3-prongs, $E<E_{\text{beam}}$, $M<M_\tau$

- $\Delta M = M_{\text{reco}} - M_\tau \approx 0$ $\Delta E = E_{\text{reco}} - E_{\text{beam}} \approx 0$
- smeared by resolution and radiative effects
- expected background from data side-bands
- count events in signal box, or max LH fit

Typical backgrounds for LFV violating tau decays

$q\bar{q}$ (uds, $c\bar{c}$, $b\bar{b}$)
($b\bar{b}$ is negligible)
uniform ΔM
$\Delta E < 0$

Bhabha, di-muon
uniform ΔM
$\Delta E \approx 0$ band

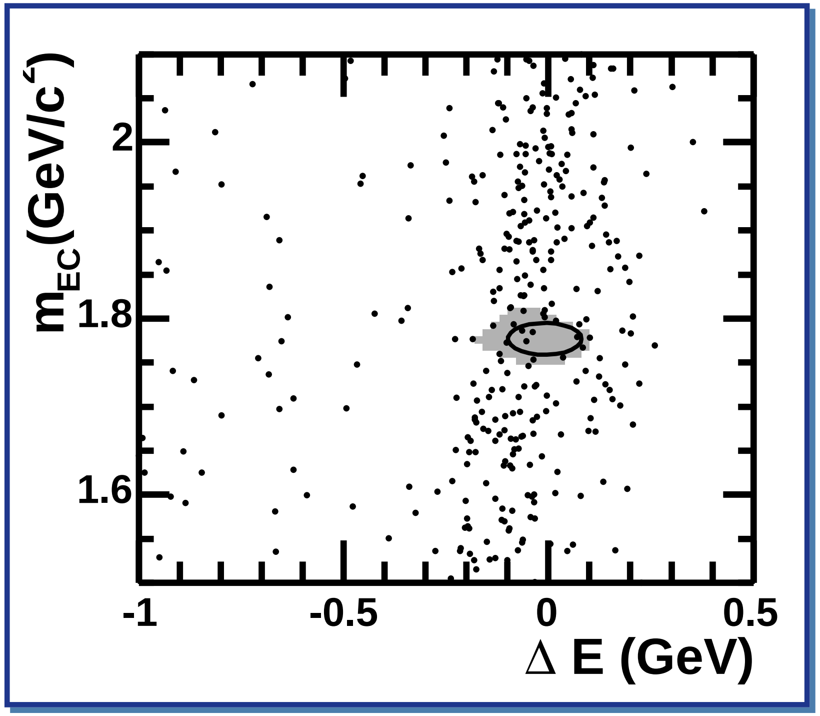


$\tau^+\tau^-$, two-photon
$\Delta M < 0$
$\Delta E < 0$

$\tau \to 3\ell$
data candidates

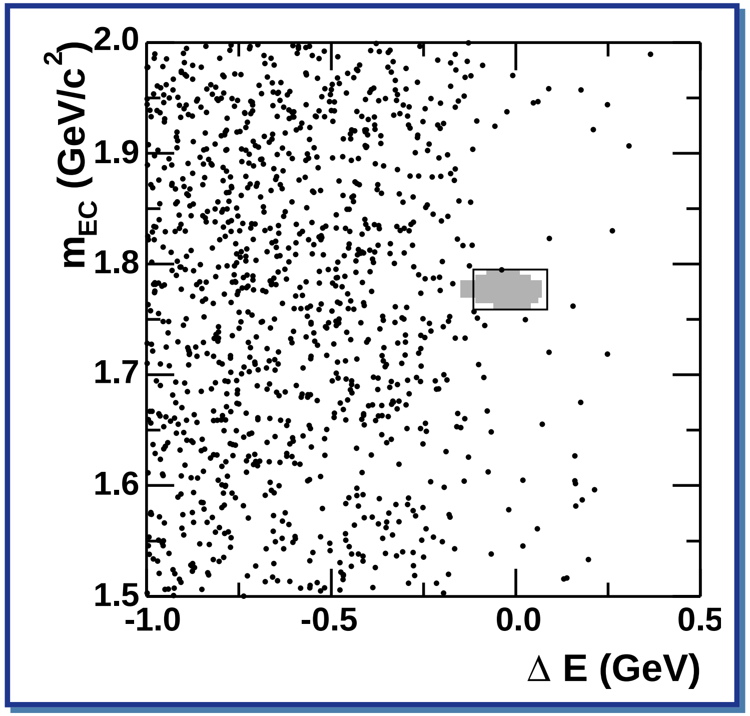
$\tau \rightarrow \mu\gamma$ LFV search

BABAR 232 fb^{-1}



- 3-prong tag in addition to 1-prong
- Exp. bkg. (6.2 ± 0.5) ev., Found 4 ev.
- ΔM LH fit in 2σ-ΔE band, frequentist
- **BF < $6.8{\cdot}10^{-8}$ (90%CL)** PRL 95 (2005) 41802

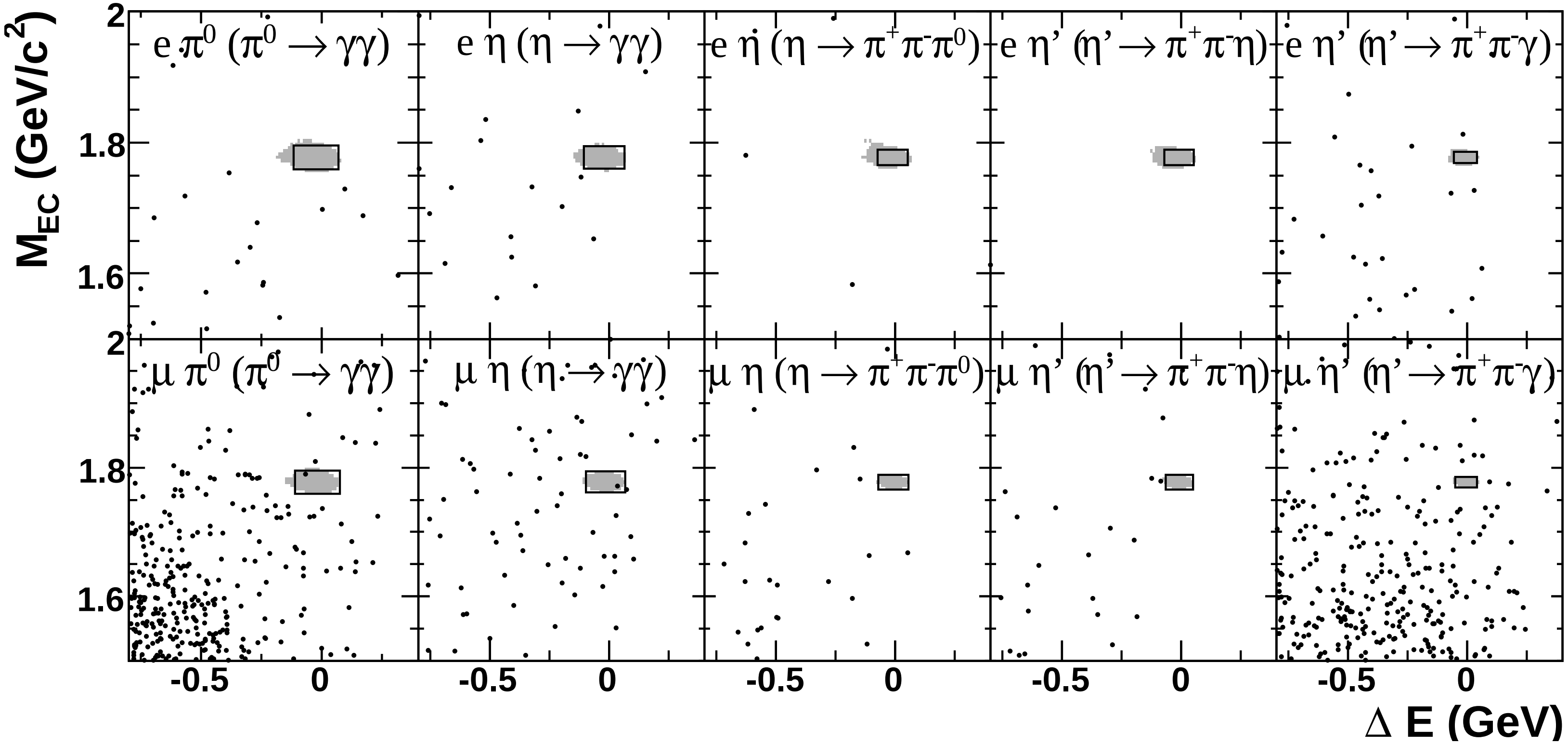
$\tau \rightarrow e\gamma$ LFV search



- 3-prong tag in addition to 1-prong
- Exp. bkg. (1.9 ± 0.4) ev., Found 1 ev.
- Cousins & Highland
- **BF < $1.1{\cdot}10^{-7}$ (90%CL)** PRL 96 (2006) 41801

$\tau \to \ell\pi^0, \ell\eta, \ell\eta'$ LFV search where $\ell = e, \mu$

BABAR 339 fb^{-1}



- expected BKG/channel: 0.1–1.3 events
- total expected BKG: 3.1 events, candidates: 2

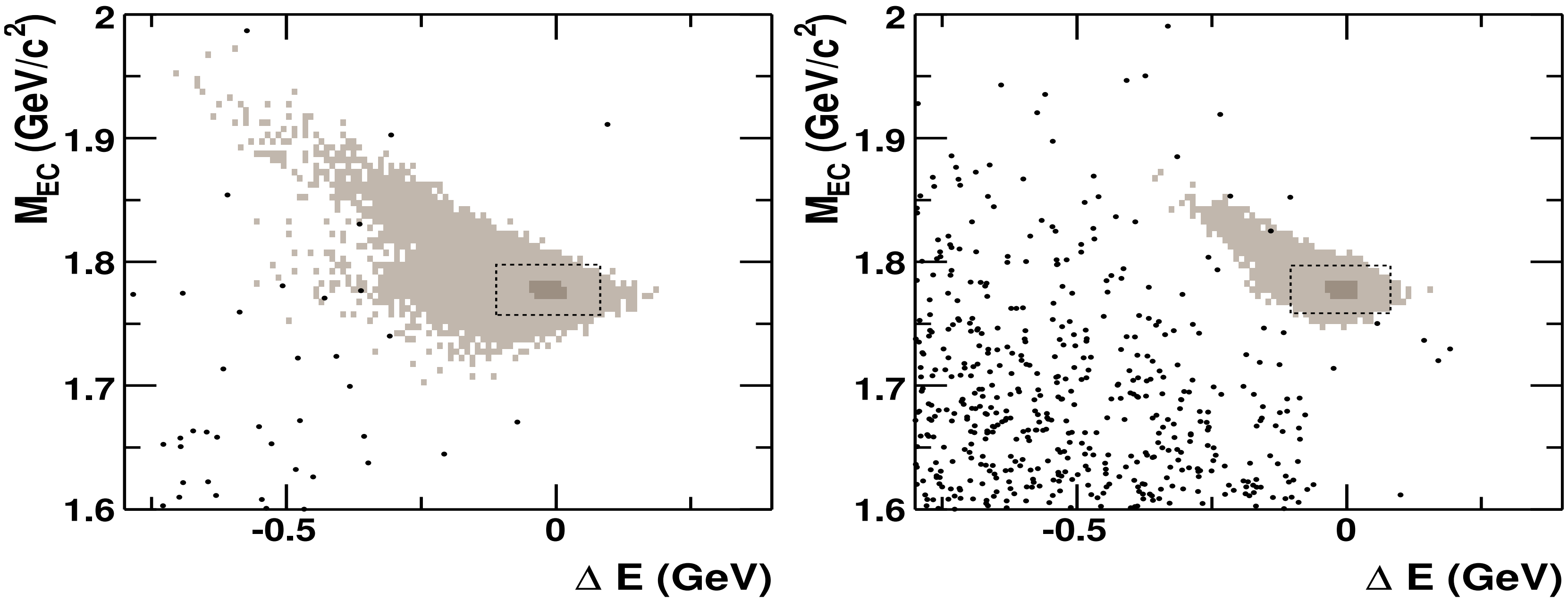
BF($\tau \to \ell\pi^0, \ell\eta, \ell\eta'$) < 1.1–2.4 · 10^{-7} (90% CL)

PRL 98 (2007) 061803

$\tau \to \ell\omega$ LFV search with $\ell = e, \mu$ and $\omega \to \pi^+\pi^-\pi^0$

BABAR

384 fb^{-1}



- expected BKG/channel: 0.35–0.73 events
- observed candidates: 0–0 events

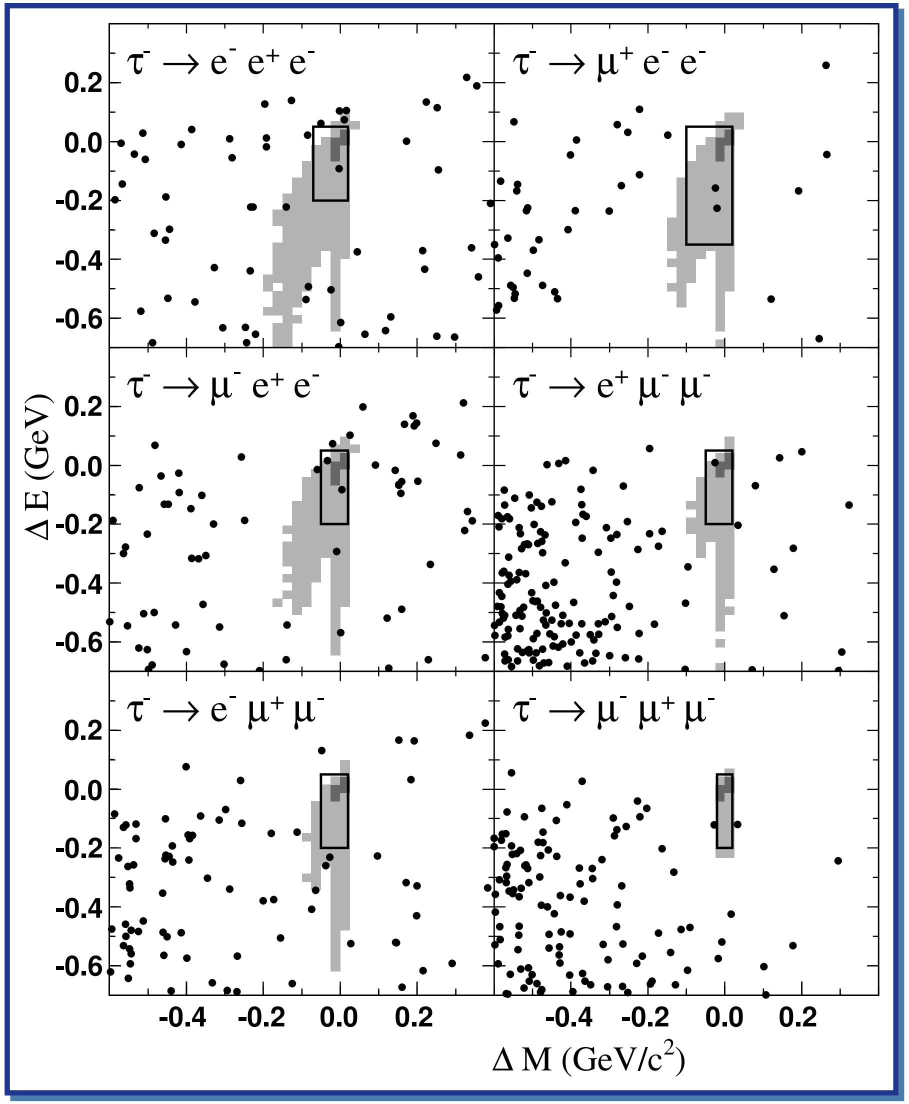
- **BF($\tau \to \ell\omega$) < 1.1–1.0 · 10^{-7} (90% CL)**
- arXiv:0711.0980 [hep-ex]
- recently submitted to PRL, preliminary

$\tau \to \ell\ell\ell$ LFV search

BaBar | 376 fb^{-1} | recently accepted by PRL

- selection and SB optimized for best exp. UL
- signal efficiency 5.5–12.4%
- background estimated with 2D ΔM-ΔE fit
- expected bkg: 0.3–1.3 events
- data candidates: 0–2 events
- Cousin & Highland
- **BF < 3.7–8.0·10^{-8} (90% CL)**
- arXiv:0708.3650 [hep-ex]

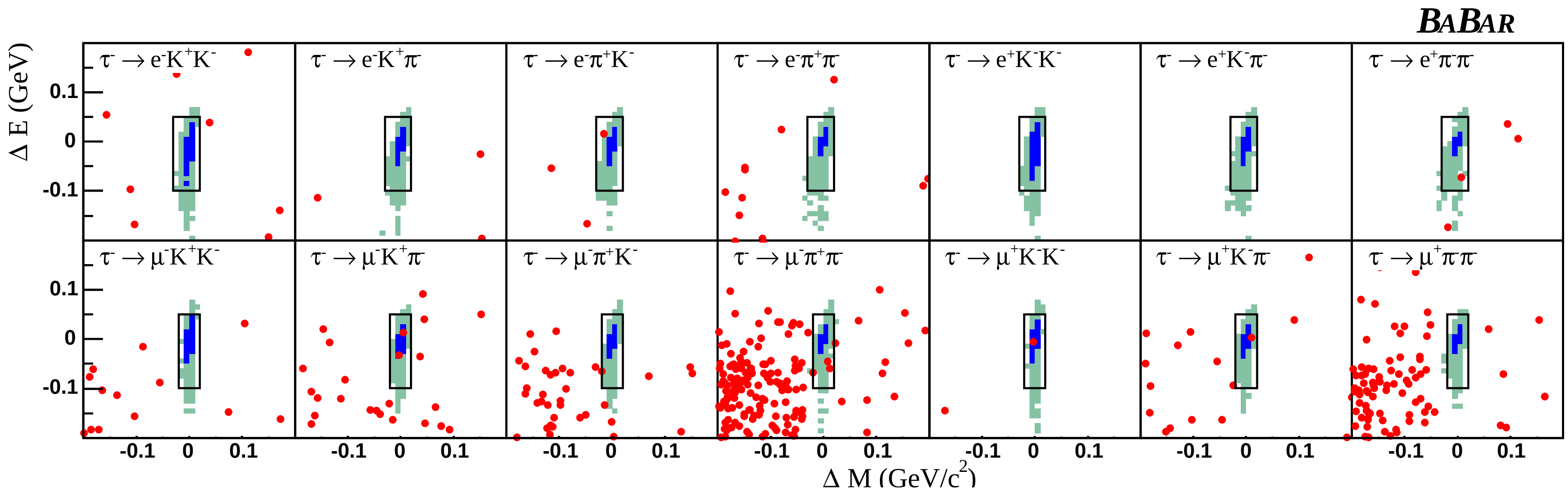
Mode	Eff. [%]	$N_{\rm bgd}$	$\rm UL^{exp}_{90}$	$N_{\rm obs}$	$\rm UL^{obs}_{90}$
$e^-e^+e^-$	8.9 ± 0.2	1.33 ± 0.25	4.9	1	4.3
$\mu^-e^+e^-$	8.3 ± 0.6	0.89 ± 0.27	5.0	2	8.0
$\mu^+e^-e^-$	12.4 ± 0.8	0.30 ± 0.55	2.7	2	5.8
$e^+\mu^-\mu^-$	8.8 ± 0.8	0.54 ± 0.21	4.6	1	5.6
$e^-\mu^+\mu^-$	6.2 ± 0.5	0.81 ± 0.31	6.6	0	3.7
$\mu^-\mu^+\mu^-$	5.5 ± 0.7	0.33 ± 0.19	6.7	0	5.3



$\tau \to \ell h h'$ LFV search

BABAR

221 fb^{-1}



- selection and SB optimized for best UL assuming no signal
- efficiency 2.1–3.8%
- expected background: 0.1–3.0 events, data candidates: 0–3 events
- background estimated with 2D ΔM-ΔE fit
- UL derived according to Cousins&Highland
- **BR's < (0.7–4.8)·10^{-7} (90% CL)** PRL 95 (2005) 191801

LFV in tau production

BABAR

- Some theories predict sizeable LFV in $e^+e^- \to \ell^+\tau^-$ production, even if stringent limits exist on LFV τ-decays
- J.Bordes, H.-M.Chan, S.T.Tsou, PRD65(2002)093006:

  at $\sqrt{s}$ = 10.58 GeV: $\sigma_{\mu\tau}/\sigma_{\mu\mu} \sim \mathcal{O}(10^{-4})$
- BaBar search: $\mathcal{L}$ = 211 fb^{-1} using $\tau \to \pi^-\nu$, $\tau \to 2\pi^-\pi^+\nu$

$\sqrt{s}$ (GeV)	$\sigma_{\mu\mu}$	$\sigma_{e\tau}/\sigma_{\mu\mu}$	$\sigma_{\mu\tau}/\sigma_{\mu\mu}$	Experiment
10.58	1.1 nb	8.9×10^{-6}	4.0×10^{-6}	BaBar, PRD75 (031103), 2007
29	0.2 nb	1.8×10^{-3}	6.1×10^{-3}	MARKII, 1991
91.2	3.3 nb	2.9×10^{-4}	5.1×10^{-4}	OPAL, 1995
91.2	3.3 nb	6.5×10^{-4}	3.6×10^{-4}	DELPHI, 1997
189	3.2 pb	3.0×10^{-2}	3.7×10^{-2}	OPAL, 2001
192-196	3.0 pb	4.9×10^{-2}	4.0×10^{-2}	OPAL, 2001
200-209	2.7 pb	2.9×10^{-2}	2.4×10^{-2}	OPAL, 2001

LFV and Baryon Number Violation, BABAR preliminary vs. Belle

- many SUSY and Superstring models predict *B*, *L* violation

mode	$B-L$	**BABAR hep-ex/0607040 237 fb^{-1}**	Belle PLB 632 (2006) 51 154 fb^{-1}
$\tau \to \overline{\Lambda}\pi$	conserving	**$5.9 \cdot 10^{-8}$**	$14 \cdot 10^{-8}$
$\tau \to \Lambda\pi$	violating	**$5.8 \cdot 10^{-8}$**	$7.2 \cdot 10^{-8}$
$\tau \to \overline{\Lambda}K$	conserving	**$7.2 \cdot 10^{-8}$**	
$\tau \to \Lambda K$	violating	**$15 \cdot 10^{-8}$**	

BABAR LFV results compared with Belle

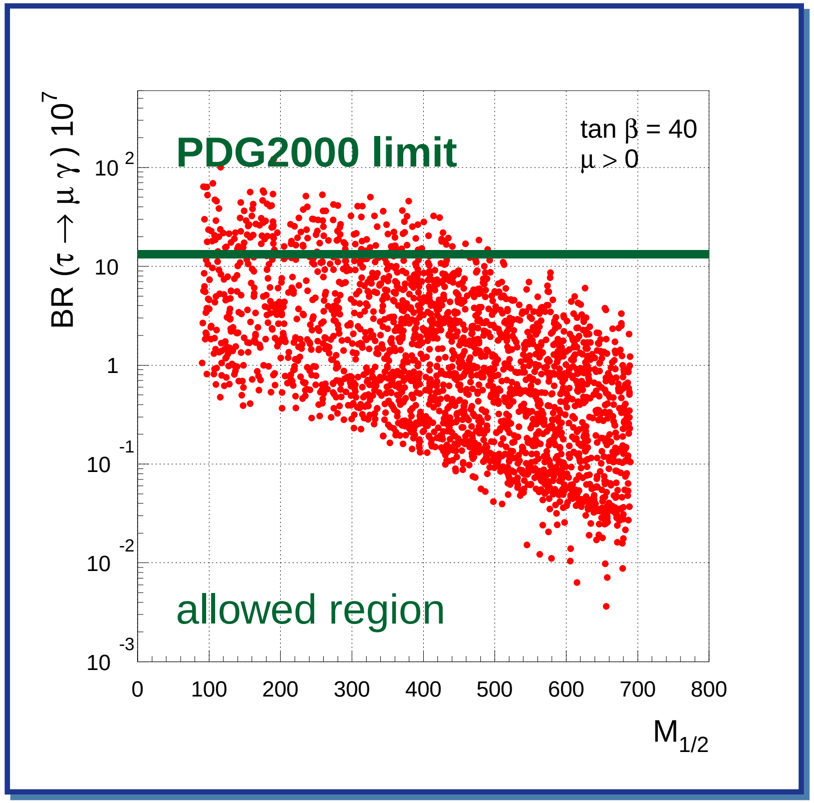
	Belle		BABAR	
	UL90 (10^{-7})	Lumi (fb^{-1})	**UL90 (10^{-7})**	**Lumi (fb^{-1})**
$\mu\gamma$	0.5*	535	**0.7**	**232**
$e\gamma$	1.2*	535	**1.1**	**232**
$\mu\eta$	0.65	401	**1.5**	**339**
$\mu\eta'$	1.3	401	**1.3**	**339**
$e\eta$	0.92	401	**1.6**	**339**
$e\eta'$	1.6	401	**2.4**	**339**
$\mu\pi^0$	1.2	401	**1.5**	**339**
$e\pi^0$	0.8	401	**1.3**	**339**
$\ell\ell\ell$	0.2–0.4	535	**0.4–0.8**	**376**
$\ell hh'$	2–16	158	**1–5**	**221**
μV^0	1.0–1.5	543	**1.1***	**384**
$e V^0$	0.8–1.9	543	**1.0***	**384**

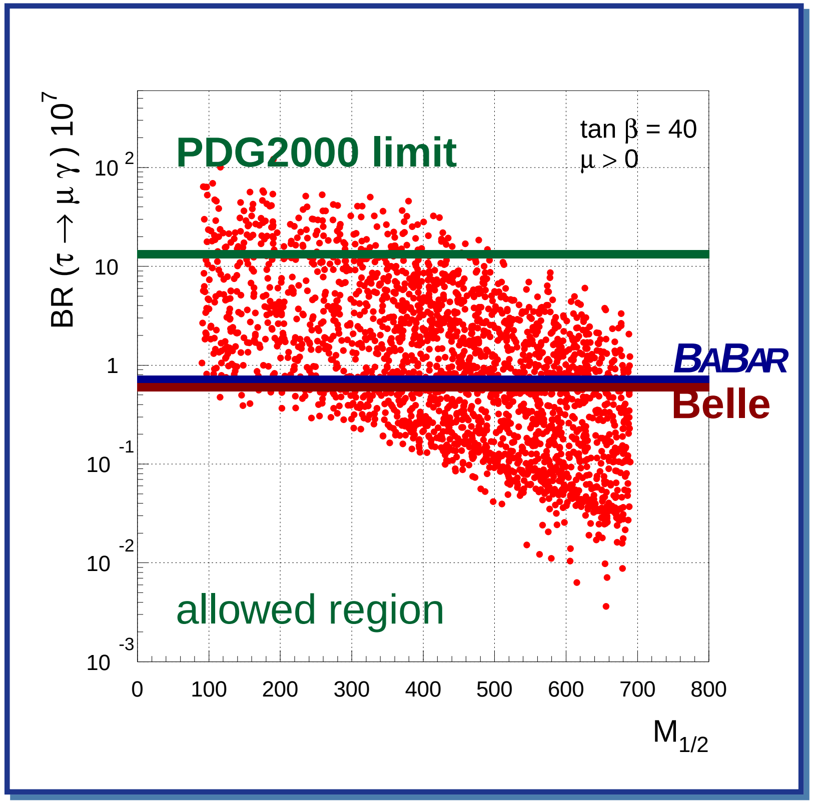
	Belle		BABAR	
	UL90 (10^{-7})	Lumi (fb^{-1})	**UL90 (10^{-7})**	**Lumi (fb^{-1})**
μK_S	0.49	281	**in progress**	
$e K_S$	0.56	281	**in progress**	
$\Lambda\pi, \overline{\Lambda}\pi$	0.72–1.4	154	**0.58–0.59***	**237**
$\Lambda K, \overline{\Lambda} K$			**0.72–1.5***	**237**
$\sigma_{\ell\tau}/\sigma_{\mu\mu}$			**40–89**	**211**

(* preliminary)

$V^0 = \omega$ for BABAR, $V^0 = \phi, \omega, \overset{(-)}{K}{}^{*0}$ for Belle

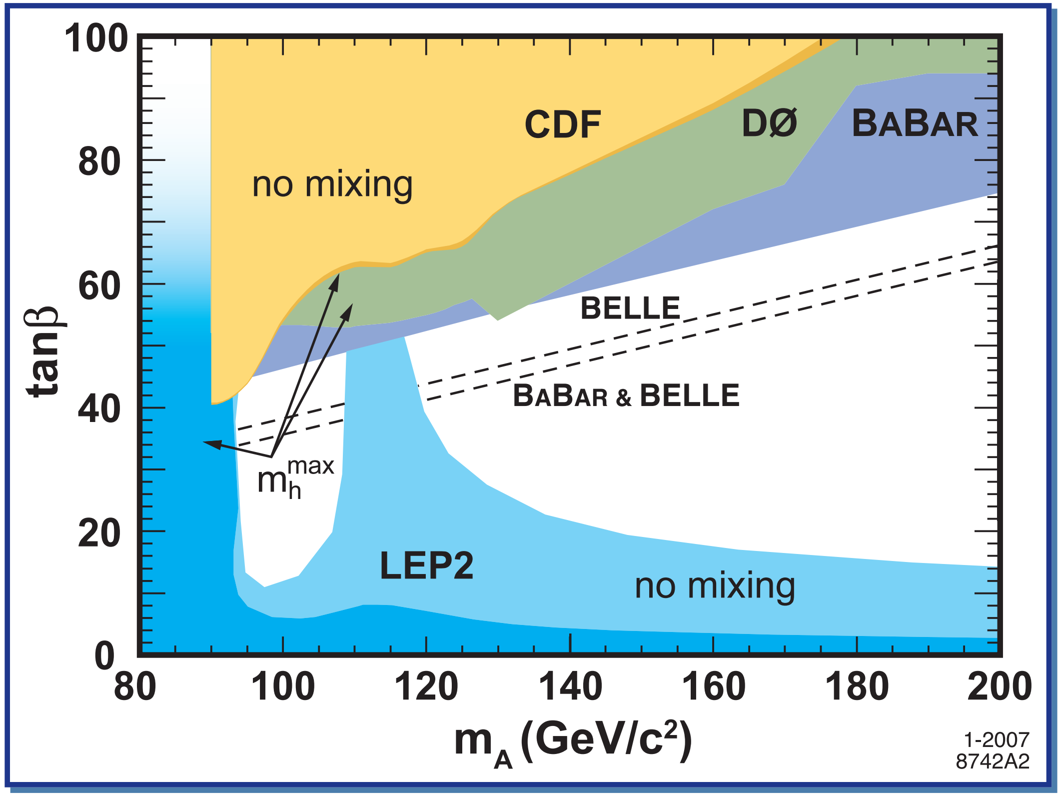
Progress on $\tau \rightarrow \mu\gamma$ since pre-B-factory era





SUSY SO(10) + seesaw – Masiero et al., NJP 6 (2004) 202

BABAR $\tau \to \mu\eta$ constraints on SUSY Higgs Mediated LFV



$BF(\tau^- \to \mu^-\eta) =$

$$= 8.4 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^6 \left(\frac{100\mathrm{GeV}/c^2}{m_A}\right)^4$$

M.Sher, Phys.Rev. D 66 (2002) 057301

plot by S.Banerjee

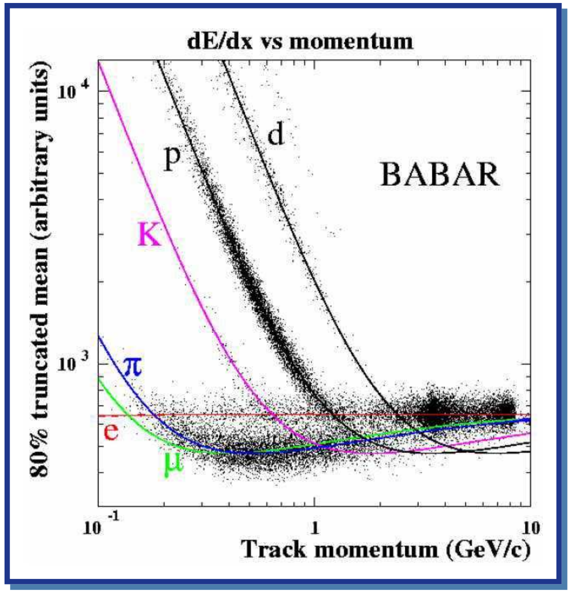
Nucl.Phys.Proc.Suppl. 169 (2007) 199

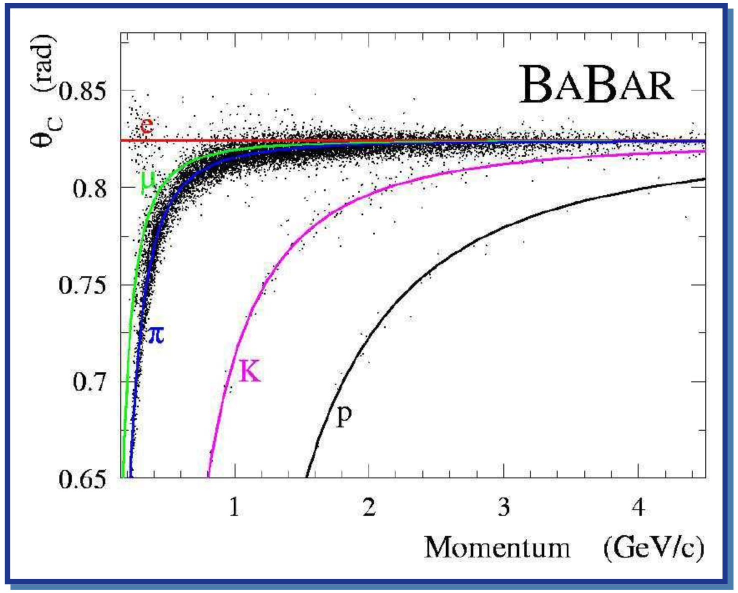
LFV Searches Prospects

- B-factories improved LFV tau BF limits by factor 10–100
  - expected background ≤ 1 (at $\approx$ constant efficiency) → UL improve $\propto \mathcal{L}$
    (channels with only charged tracks tend to be in this regime right now)
  - otherwise (BKG limited) → UL improve $\propto \sqrt{\mathcal{L}}$
    (channels with photons, e.g. $\tau \to \mu\gamma$, appear to be entering this regime now)
- limits can improve by factor 2–4 analyzing all planned B-Factories yield ($\sim$2 ab^{-1})
- Super B-Factories expected to improve LFV limits again by factor 10–100
  must care about:
  - detector hermeticity
  - resolution on neutral energy / angle

Tau Decays to final states with strangeness = 1

BABAR has good
$\pi - K$ separation,
useful to discriminate
Cabibbo-suppressed $\tau \to s$
from the $\tau \to ud$ background

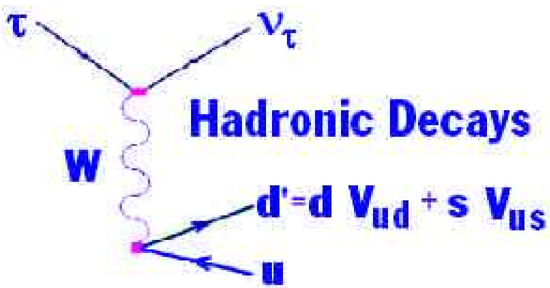




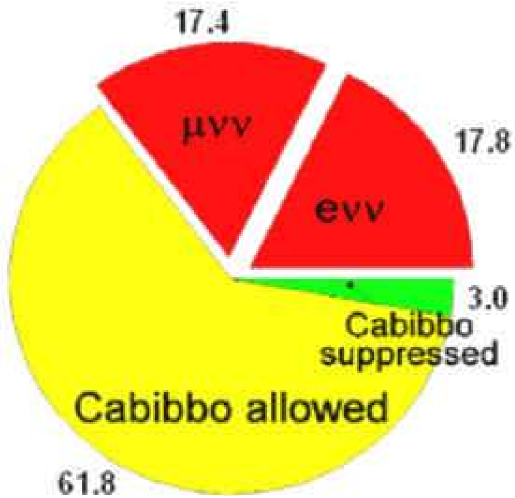
- inclusive BF($\tau \to s$) ➔ potentially most precise/ clean V_{us} measurement (0.7%)
- if spectral functions are also measured ➔ simultaneous fit of V_{us} and m_s
- $\Delta V_{us} \approx 1\%$ from 3-body K decays (limited by theory determination of K form-factor)
- $\Delta m_s \approx 10$ MeV from Lattice QCD

Inclusive BF($\tau \to s$) before B-Factories

$$B_{had} = 1 - B_e - B_\mu$$



$$R_{\tau,Strange} = R_\tau - R_{\tau,non-Strange}$$



Strange τ Decays:

Mode	$\mathcal{B}(10^{-3})$
K^-	6.81 ± 0.23
$K^-\pi^0$	4.54 ± 0.30
$\bar{K}^0\pi^-$	8.78 ± 0.38
$K^-\pi^0\pi^0$	0.58 ± 0.24
$\bar{K}^0\pi^-\pi^0$	3.60 ± 0.40
$K^-\pi^+\pi^-$	3.30 ± 0.28
$K^-\eta$	0.27 ± 0.06
$(\bar{K}3\pi)^-$ (estimated)	0.74 ± 0.30
$K_1(1270)^- \to K^-\omega$	0.67 ± 0.21
$(\bar{K}4\pi)^-$ (estimated) and $K^{*-}\eta$	0.40 ± 0.12
Sum	29.69 ± 0.86

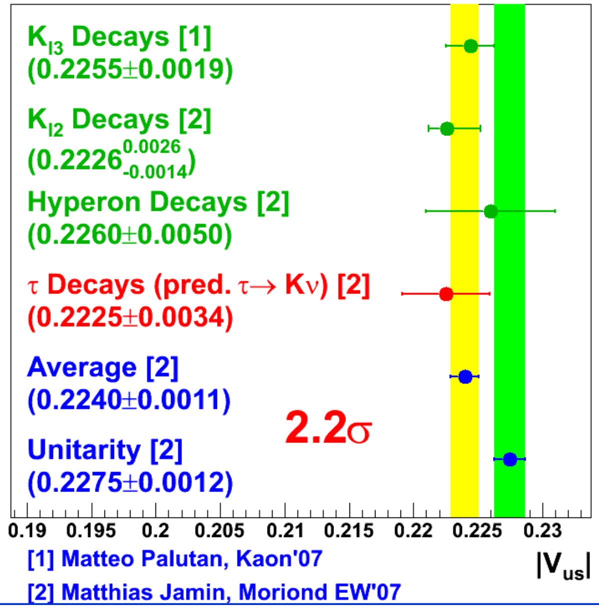
Davier, Hocker, Zhang(RMP 78, 1043, 2006)

V_{us} and m_s determination before B-Factories

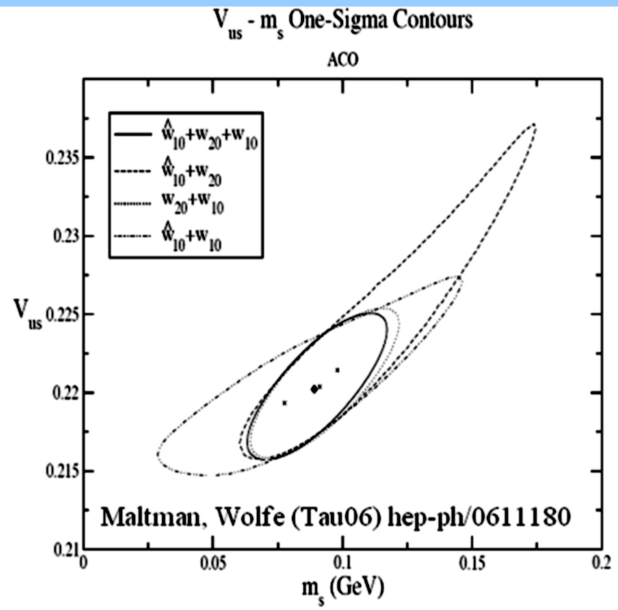
Hadronic Width: $R_\tau = \dfrac{\Gamma(\tau^- \to \upsilon_\tau \text{hadrons}^-)}{\Gamma(\tau^- \to \upsilon_\tau \bar{\upsilon}_e e^-)}$

Flavour SU(3) Breaking: $\delta R^{kl}_{\tau,\text{Theory}}(m_s) = \dfrac{R^{kl}_{\tau,\text{non-Strange}}}{|V_{ud}|^2} - \dfrac{R^{kl}_{\tau,\text{Strange}}}{|V_{us}|^2}$

Extract |Vus| with Fixed m_s



Simultaneously extract |Vus| and m_s

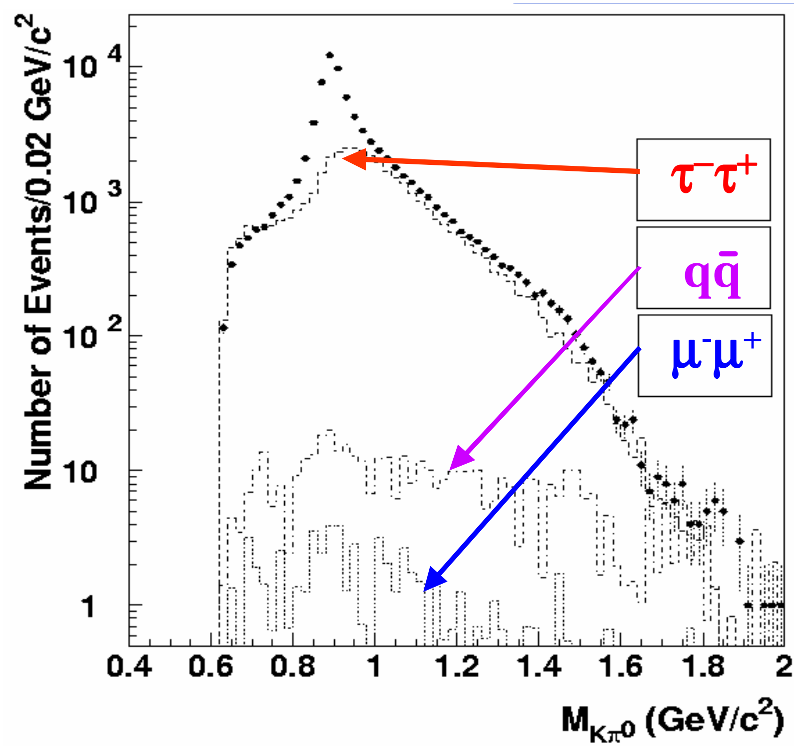


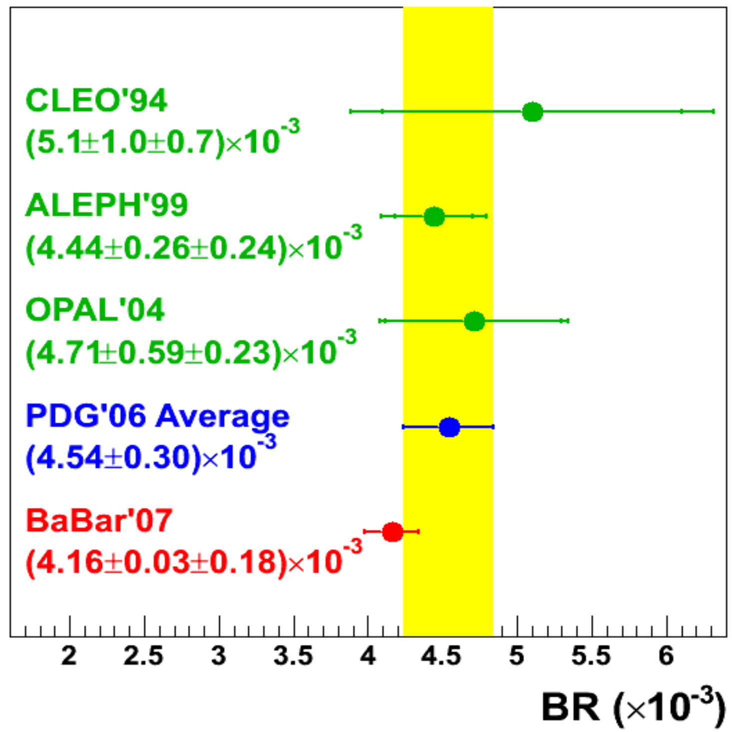
$\tau \rightarrow K\pi^0\nu$

BABAR

230 fb^{-1}

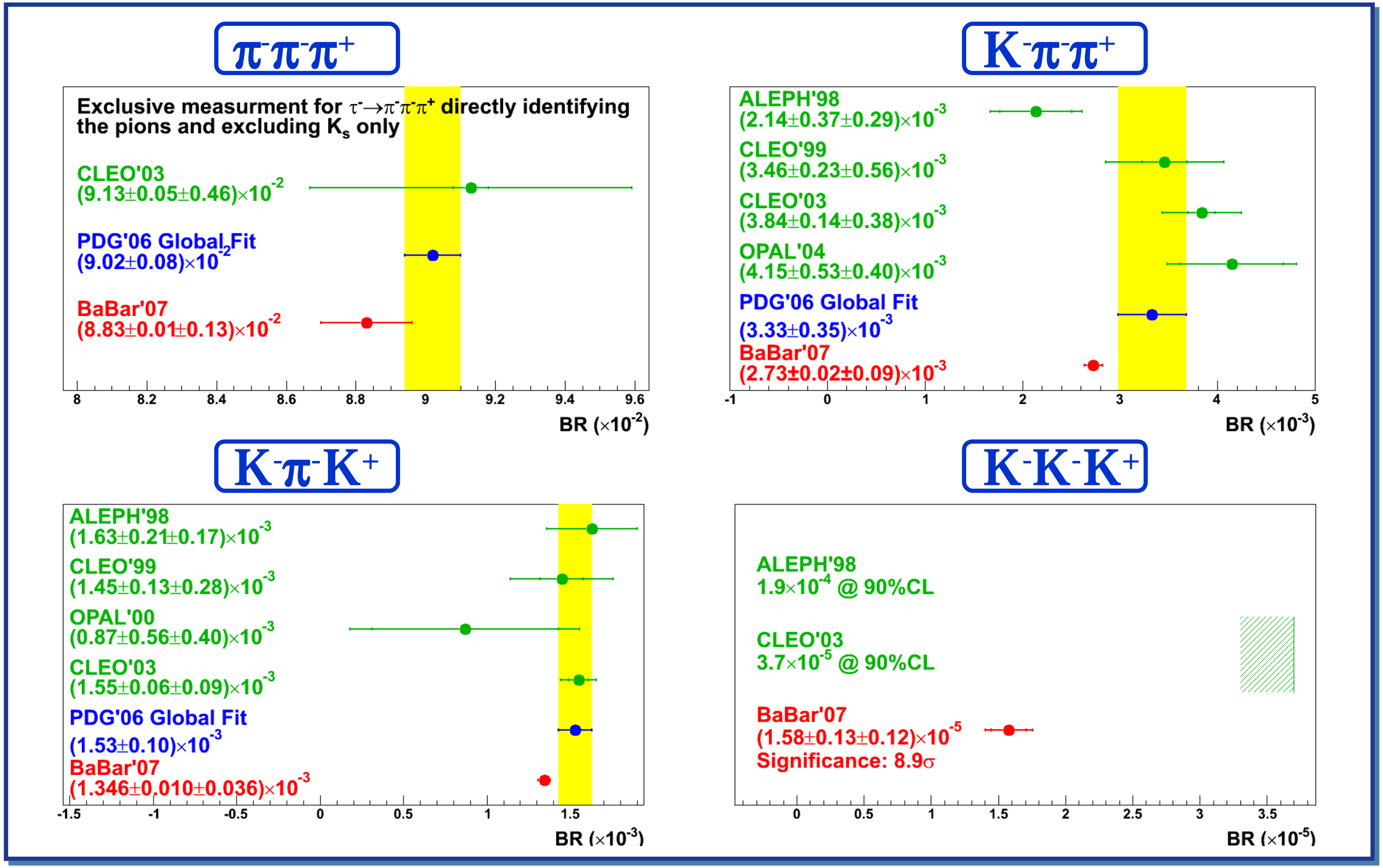
Phys.Rev.D76:051104,2007



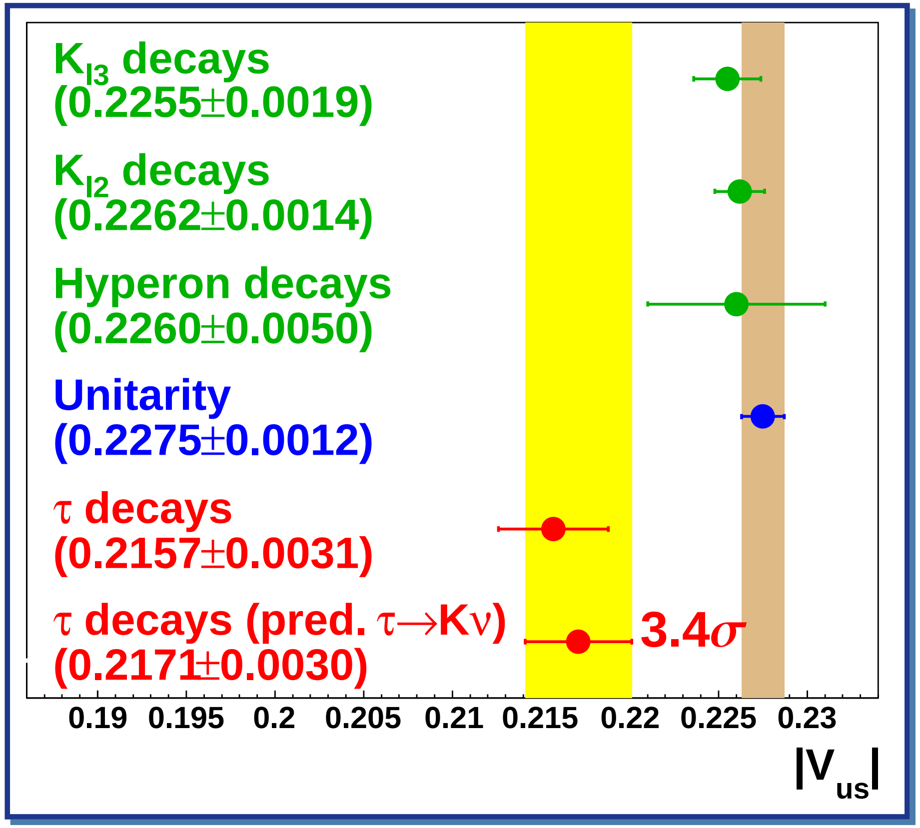


ε	(2.267±0.008)%
N^{Data}	78,112±280
N^{Bkg}	38,247±159

$\tau \rightarrow 3h\nu$ *BABAR* 342 fb^{-1} arXiv:0707.2981 [hep-ex], accepted by PRL



V_{us} update using *BABAR* and Belle results



S.Banerjee, arXiv:0707.3058v4 [hep-ex]

Updated $\tau \to s$ results

BABAR

- $\tau \to K\pi^0\nu$ Phys.Rev.D76:051104,2007
- $\tau \to K\pi\pi\nu$ arXiv:0707.2981 [hep-ex]

BELLE

- $\tau \to K^0\pi\nu$ Phys.Lett.B654:65-73,2007
- theory pred. BF($\tau \to K\nu$) from BF[$K \to \mu\nu(\gamma)$] assuming $\mu - \tau$ universality arXiv:0707.3058v4 [hep-ex]

Lepton Universality Tests

- Standard Model (SM) predicts that leptons have same weak charged current couplings
- B-Factories can measure **several relatively less known ingredients** for LU tests below

$$\frac{\Gamma_{\tau\to e}}{\Gamma_{\mu\to e}} \propto \left(\frac{g_\tau}{g_\mu}\right)^2 = \frac{\tau_\mu}{\tau_\tau} BF(\tau^- \to e^-\bar{\nu}_e\nu_\tau) \left(\frac{m_\mu}{m_\tau}\right)^5 \frac{f(m_e^2/m_\mu^2) r_{EW}^\mu}{f(m_e^2/m_\tau^2) r_{EW}^\tau}$$

$$\frac{\Gamma_{\tau\to \mu}}{\Gamma_{\mu\to e}} \propto \left(\frac{g_\tau}{g_e}\right)^2 = \frac{\tau_\mu}{\tau_\tau} BF(\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau) \left(\frac{m_\mu}{m_\tau}\right)^5 \frac{f(m_e^2/m_\mu^2) r_{EW}^\mu}{f(m_\mu^2/m_\tau^2) r_{EW}^\tau}$$

$$\frac{\Gamma_{\tau\to e}}{\Gamma_{\tau\to \mu}} \propto \left(\frac{g_e}{g_\mu}\right)^2 = \frac{BF(\tau^- \to e^-\bar{\nu}_\mu\nu_\tau)}{BF(\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau)} \frac{f(m_\mu^2/m_\tau^2)}{f(m_e^2/m_\tau^2)}$$

$f(x) = 1 - 8x + 8x^3 - x^4 - 12x \ln x$ (approximating all $m_\nu = 0$)

$r_{EW}^\ell = 0.9960$ (EW radiative corrections, Marciano-Sirlin)

Lepton Universality Tests (A.Pich, SuperB Workshop, Paris, May 2007)

- Δm_μ = 56 ppb, τ_μ = 2.197019(21)μs (9.6 ppm) 2007 WA using MuLan 2007 result
- PDG2006: Δm_τ = 0.015%, ΔBF($\tau \to e/\mu$) = 0.28–0.29%, $\Delta\tau_\tau$ = 0.34%

$|g_\tau / g_\mu|$

$B_{\tau\to e}\ \tau_\mu/\tau_\tau$	1.0004 ± 0.0022
$\Gamma_{\tau\to\pi}/\Gamma_{\pi\to\mu}$	0.996 ± 0.005
$\Gamma_{\tau\to K}/\Gamma_{K\to\mu}$	0.979 ± 0.017
$B_{W\to\tau}/B_{W\to\mu}$	1.039 ± 0.013

$|g_\mu / g_e|$

$B_{\tau\to\mu}/B_{\tau\to e}$	1.0000 ± 0.0020
$B_{\pi\to\mu}/B_{\pi\to e}$	1.0017 ± 0.0015
$B_{K\to\mu}/B_{K\to e}$	1.012 ± 0.009
$B_{K\to\pi\mu}/B_{K\to\pi e}$	1.0002 ± 0.0026
$B_{W\to\mu}/B_{W\to e}$	0.997 ± 0.010

$|g_\tau / g_e|$

$B_{\tau\to\mu}\ \tau_\mu/\tau_\tau$	1.0004 ± 0.0023
$B_{W\to\tau}/B_{W\to e}$	1.036 ± 0.014

Lepton Universality: loosely related issues

- NuTev anomaly: Neutral/Charged Current ratio in muon (anti)neutrino nucleon scattering: $g_L^2 = 0.30005 \pm 0.00137$, which is 3σ from SM prediction $g_L^2 = 0.3042$
- Loinaz et.al., hep-ph/0210193: $G_F = G_\mu(1+\epsilon)$; $\epsilon = 0.003$
- tau decays best place to check deviations $\approx \cdot 10^{-3}$ in EW couplings

- Probing New Physics through μ–e Universality in $K \to \ell\nu$, PRD 74 (2006) 011701
  - in the K case, NP effects enhanced by helicity suppression

Tau Lifetime Measurement

Selection
- tag side $\tau \rightarrow e\nu\nu$, signal $\tau \rightarrow$ 3-prong
- very high purity (99.4%), low efficiency (0.2%)

Mean Decay Length
- reconstruct transverse decay length λ_τ^t
- $\lambda_\tau = \lambda_\tau^t / \sin\theta_{\text{3-prong}}$ (approx: $P_\tau \parallel P_{\text{3-prong}}$)
- no weight based on λ_τ estimated errors
- weight to equalize ϕ acceptance in 60 bins
- average λ_τ measurements $\longrightarrow \langle\lambda_\tau\rangle$
- $\langle\lambda_\tau\rangle$ stat. error: variance in 100 sub-samples

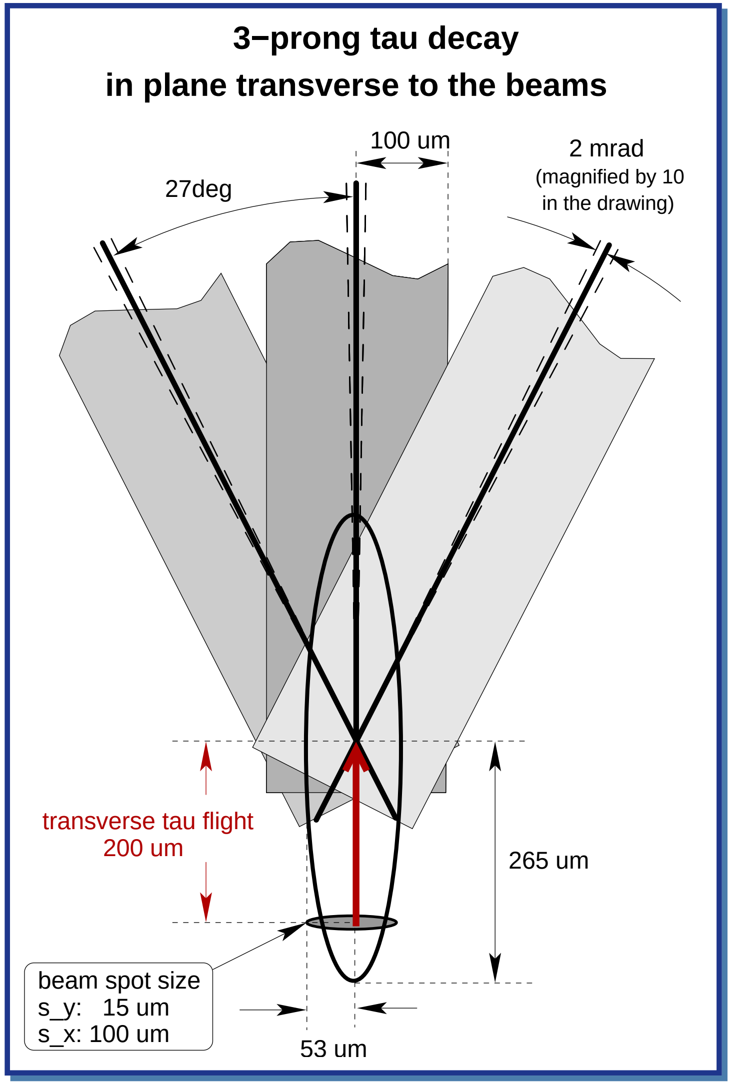
Mean Lifetime
- $\langle P_\tau \rangle$ from MC, using beam energies
- $\langle\tau_\tau\rangle = \langle\lambda_\tau\rangle \dfrac{M_\tau}{\langle P_\tau\rangle}$
- subtract measurement bias using MC

Hadronic backgrounds
- light quarks: $u\bar{u}, d\bar{d}, s\bar{s} = q\bar{q}$
- heavy quarks: $c\bar{c}$, $B\bar{B}$
- contamination from MC, with checks on data
- decay length distribution from MC
- $\longrightarrow$ subtract lifetime bias

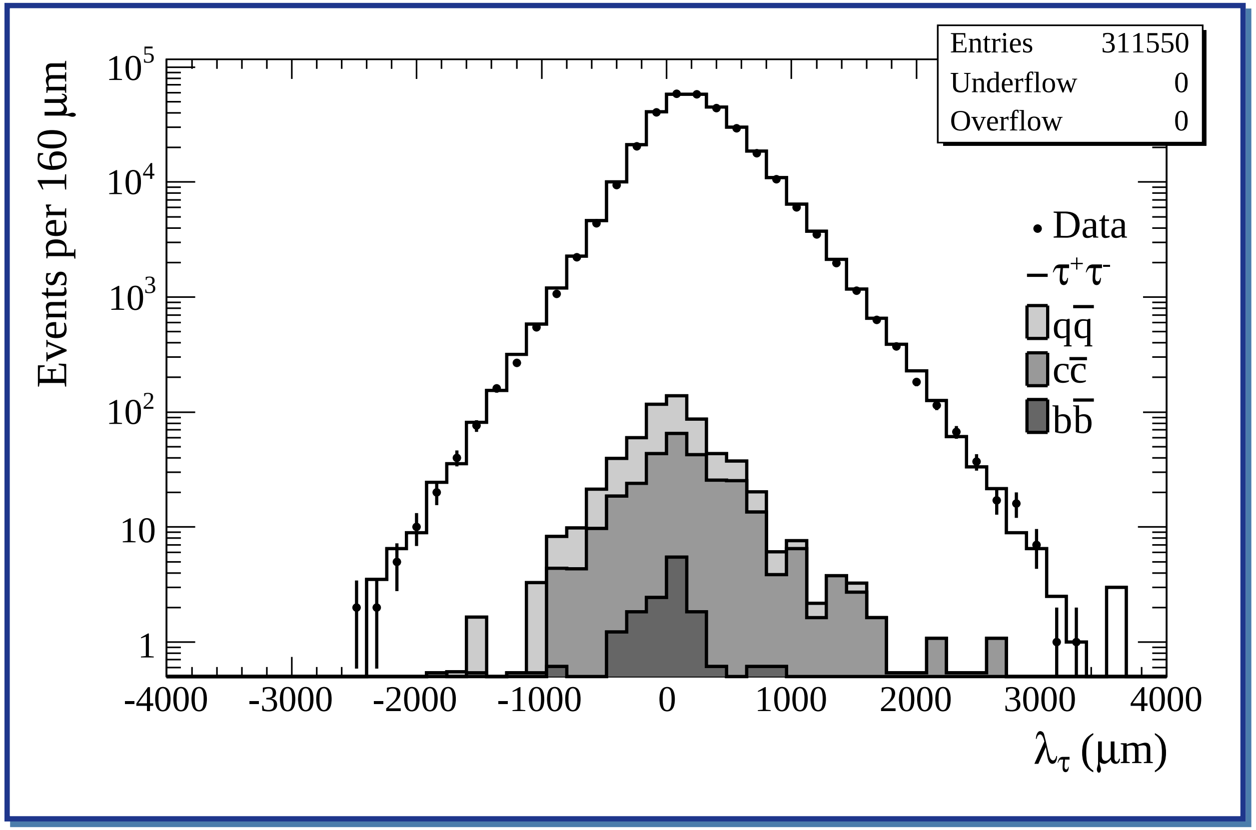
Bhabha and two-photon backgrounds
- determine contamination from data
- decay length from data control samples
- $\longrightarrow$ subtract lifetime bias

Blind analysis

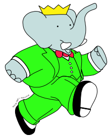
Tau Lifetime Measurement



Reconstructed τ decay length



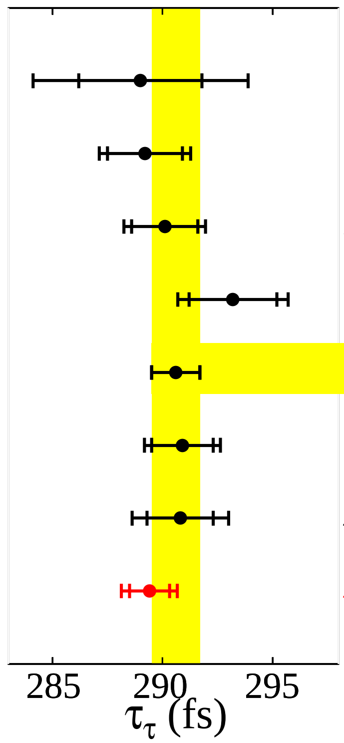
Tau Lifetime Measurement



BABAR preliminary 80 fb^{-1}

τ_τ = 289.40 ± 0.91 (stat.) ± 0.90 (syst.) fs preliminary

Tau04, Nara, Nucl.Phys. B (Proc.Suppl.) 144 (2005) 105



CLEO 1996	289.0 ± 2.8 ± 4.0 fs
OPAL 1996	289.2 ± 1.7 ± 1.2 fs
ALEPH 1997	290.1 ± 1.5 ± 1.1 fs
L3 2000	293.2 ± 2.0 ± 1.5 fs
PDG 2004	290.6 ± 1.1 fs
DELPHI 2004	290.9 ± 1.4 ± 1.0 fs
BABAR 2003, prelim.	290.8 ± 1.5 ± 1.6 fs
BABAR 2004, prelim.	289.40 ± 0.91 ± 0.90 fs

Tau Lifetime Measurement Systematics

- precision (0.44%) worse but comparable to PDG2006 (0.34%)
- first CPT test on τ^+ vs. τ^- lifetimes possible with good precision: $\Delta_{STAT}\left(\frac{\tau_{\tau-}-\tau_{\tau+}}{\tau_{\tau-}+\tau_{\tau+}}\right) = 0.32\%$

Systematic contribution	$\Delta\tau_\tau/\tau_\tau(\%)$ bias ± error
Measurement bias	0.336 ± 0.220
Background	–0.428 ± 0.142
Detector alignment and length scale	± 0.110
Beam spot position	± 0.043
Beam spot size	± 0.044
Beam energies and boost direction	± 0.043
Simulation of tau IFR/FSR energy loss	± 0.100
Tau mass	± 0.006
Total	–0.092 ± 0.310

- systematics relevant, but can be reduced with dedicated work
- no improvements expected outside B-Factories

Updated Lepton Universality Test using BABAR preliminary τ_τ result

Combine τ_τ = 290.6 ± 1.0 fs (PDG2006)

with **BABAR 2004 prelim. τ_τ**

(with no systematic error correlations)

$\tau_\tau = 290.15 \pm 0.79$ fs

Using PDG2006 world averages, assuming uncorrelated errors on BF($\tau \to e$) and BF($\tau \to \mu$)

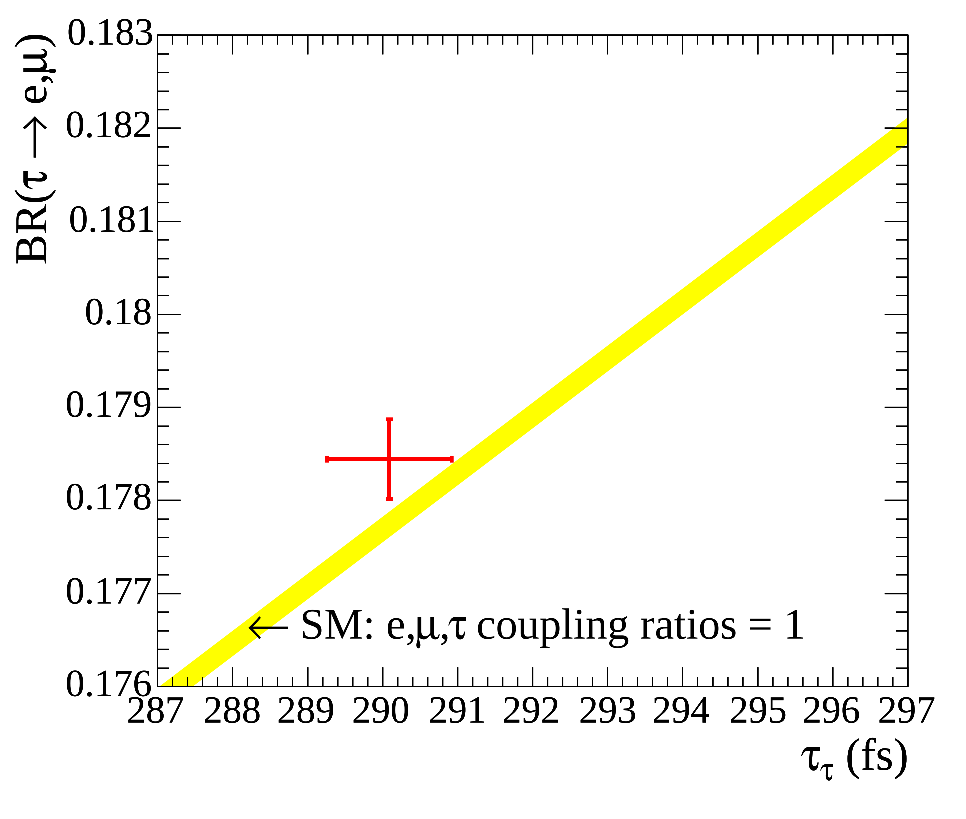
$$\frac{g_\mu}{g_\tau} = 0.9982 \pm 0.0020$$

$$\frac{g_e}{g_\tau} = 0.9980 \pm 0.0020$$

Assuming $g_e = g_\mu = g_{e,\mu}$:

$$\frac{g_{e,\mu}}{g_\tau} = 0.9981 \pm 0.0017$$

SM predicts BF($\tau \to e/\mu$) = $f(G_F, m_\tau, m_e, m_\mu) \cdot \tau_\tau$



yellow band thickness dominated by Δm_τ

Prospects on Lepton Universality Tests at B-Factories

- modest progress, systematics typically larger that at LEP, pure selection difficult

	LEP	B-Factories
Δ tau cross-section	≈ 0.1–0.2%	2.2% → 0.31% recently, arXiv:0706.3235 [hep-ph]
Δ luminosity	≈ 0.1%	≈ 1%
Δ efficiency	≈ 0.2%	≈ 1–4% ($\tau \to 5\pi\nu$ vs. $\tau \to K\pi^0\nu$)

[see for ALEPH: Physics Reports 421 (2005) 191-284]

- tau mass measurement useful check of threshold measurements
  - CPT test cannot be done at threshold
- tau lifetime: should aim at 0.1% precision, least precise ingredient in several tests
- leptonic BFs measurements also useful for μ/e universality
  - dedicated systematics studies can help

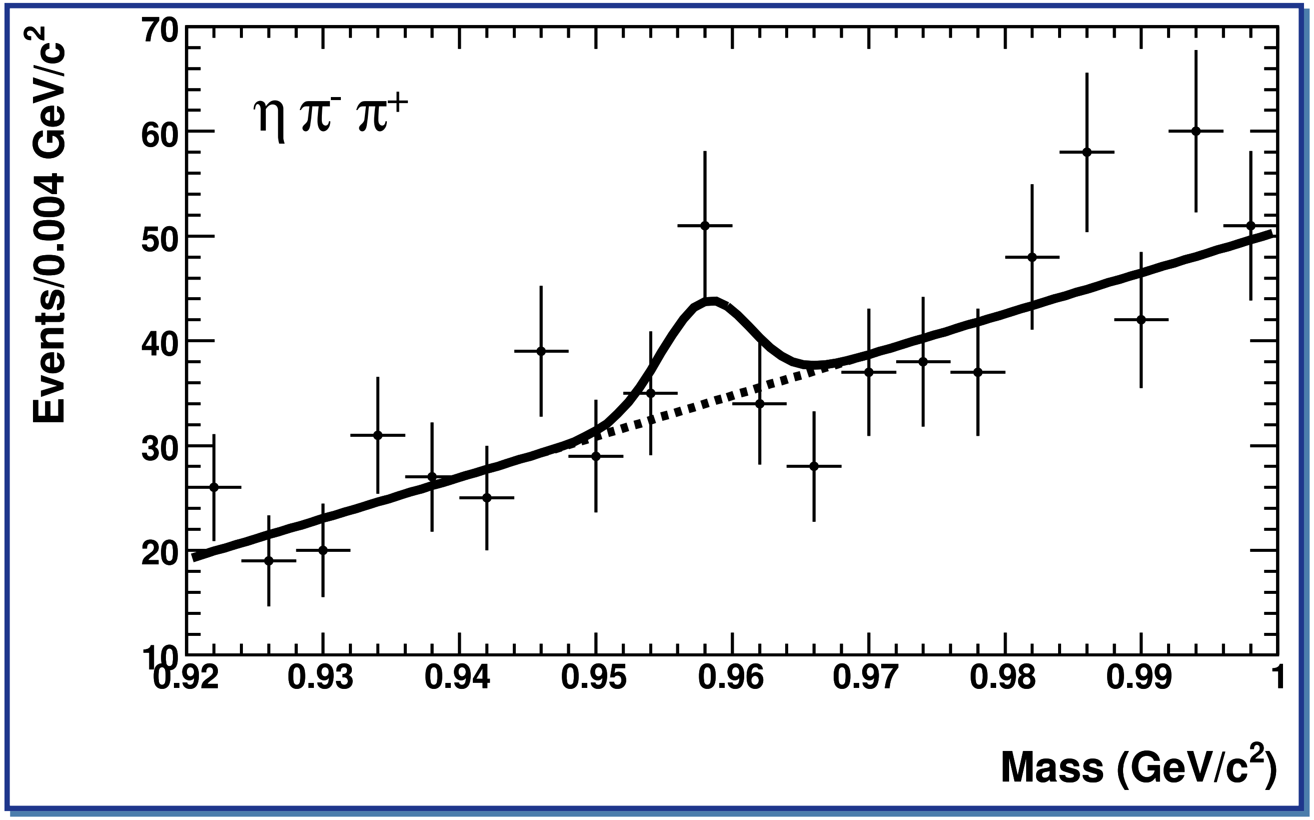
    dedicated study for BABAR ISR events → **Δ muon-efficiency = 0.34%** (M.Davier, priv.comm.)

$\tau \to 3\pi\eta\nu$ and $\tau \to \pi\eta'\nu$ 2nd class current search

BABAR 384 fb^{-1}

- $\tau \to \eta'(958)\pi\nu < 7.3 \cdot 10^{-6}$ (90%CL)

no tau 2nd class current seen yet, updated since Tau06



- update of remaining Tau06 results in progress

(semi-)Hadronic tau decays *BABAR* measurements

$\tau \rightarrow 5\pi\nu$ | BABAR | $232\ \text{fb}^{-1}$ | Phys.Rev. D72 (2005) 072001

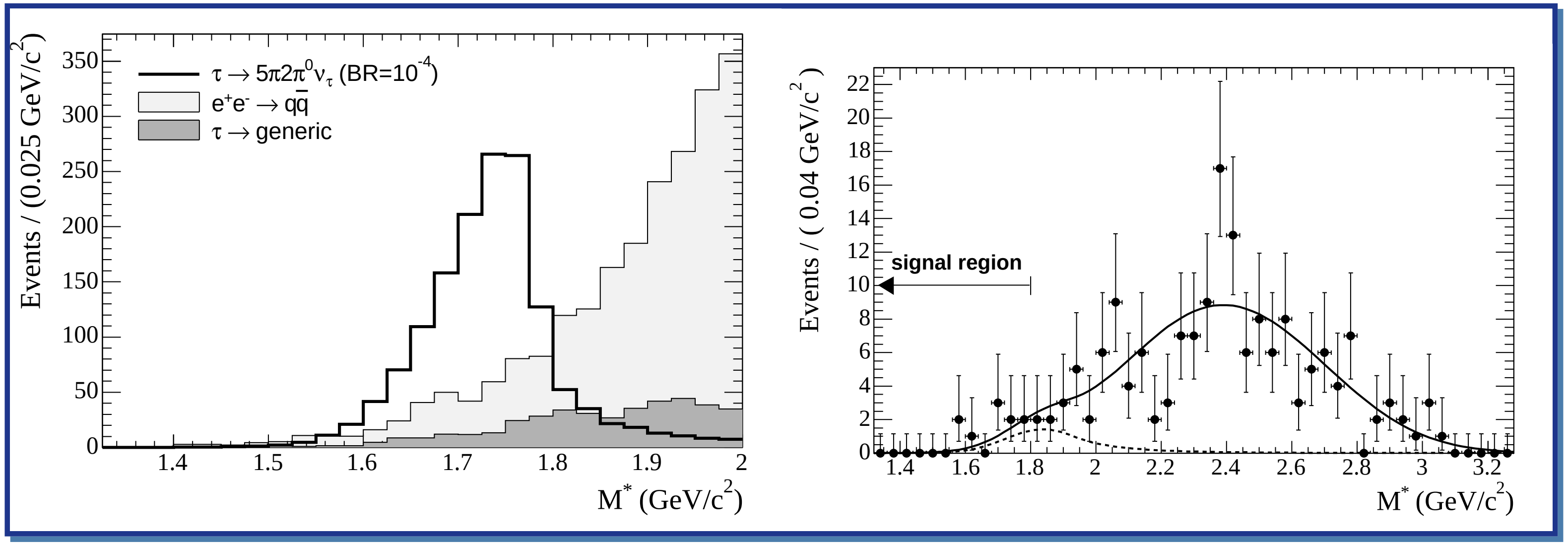
$\tau \rightarrow 5\pi\nu$	$(8.56 \pm 0.05 \pm 0.42)\cdot 10^{-4}$
$\tau \rightarrow f_1(1285)\pi\nu$	$(3.9 \pm 0.7 \pm 0.5)\cdot 10^{-4}$

$\tau \rightarrow 3\pi\pi^0\nu$ | BABAR | $210\ \text{fb}^{-1}$ | Nucl.Phys. B (Proc.Suppl.) 169 (2007) 44 preliminary

$\tau \rightarrow 3\pi\pi^0\nu$	$(4.39 \pm 0.01 \pm 0.21)\cdot 10^{-2}$
$\tau \rightarrow \pi\omega\nu$	$(1.97 \pm 0.01 \pm 0.10)\cdot 10^{-2}$

$\tau \rightarrow$ 7 pions ν_τ

BABAR 232 fb^{-1}



Theory predicts BFs $< 6{\cdot}10^{-11}$
(phase space suppression)
PRD 65 (2002) 034018

BABAR publications
PRD 72 (2005) 012003 7π
PRD 74 (2006) 011103 $5\pi 2\pi^0$

decay mode	previous	BABAR
$\tau \rightarrow 7\pi(\pi^0)\nu$	$< 2.4{\cdot}10^{-6}$ (CLEO, 1997)	**$< 3.0{\cdot}10^{-7}$**
$\tau \rightarrow 7\pi)\nu$		**$< 4.3{\cdot}10^{-7}$**
$\tau \rightarrow 7\pi\pi^0\nu$		**$< 2.5{\cdot}10^{-7}$**
$\tau \rightarrow 5\pi 2\pi^0\nu$	$< 1.1{\cdot}10^{-4}$ (CLEO, 1994)	**$< 3.4{\cdot}10^{-6}$**
$\tau \rightarrow 2\omega\pi\nu$		**$< 5.4{\cdot}10^{-7}$**

Conclusions

LFV Searches
- good experimental coverage
- $\tau \to \ell\omega$ submitted to PRL 06-Nov-2007
- $\tau \to \ell\ell\ell$ accepted by PRL 02-Nov-2007
- expect further improvements
- Super Flavour Factory golden channels

(semi-)hadronic decays
- results on several small BF
- close to update Tau06 results on $\tau \to 3\pi\eta\nu$

2nd class current searches
- updated Tau06 UL on $\tau \to \eta'\pi\nu$

non-LFV rare decays
- $\tau \to$ 7-pions upper limits

V_{us} from $\tau \to s$ inclusive
- results on several BF, V_{us} updated
- 3.4σ discrepancy w.r.t. kaons and unitarity

Lepton Universality
- tau lifetime: not yet systematics limited
- not easy to improve mass and leptonic BF

Future prospects
- KEDR, BES-III
  - Tau Mass
- Tau Physics at Super B-Factories
  - complement LHC in identifying NP
  - LFV: improve ULs by factor 10-100
  - Tau EDM / T-violation