Search for Lepton Flavor Violation in Tau Decays at *BABAR*

Olga Igonkina

University of Oregon

August 30, 2004

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- Search for $\tau \to \mu\gamma$

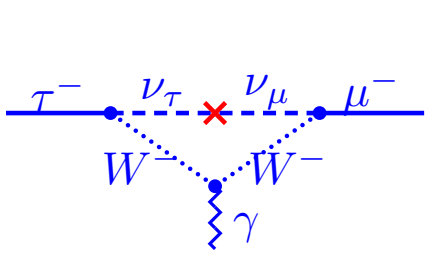
Introduction

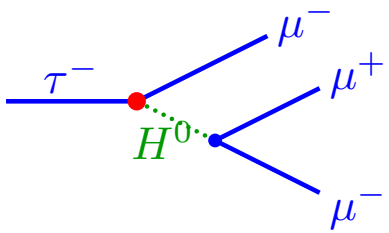
Lepton Flavor Violating (LFV) tau decays

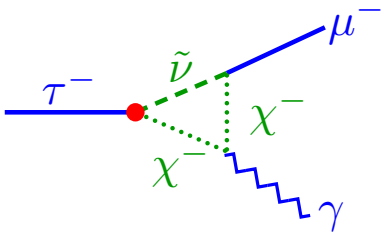
are forbidden in the classical Standard Model;

are allowed but very small in SM with neutrino mixing;

are very sensitive to non-SM physics.







The limits on LFV before *BABAR*/Belle :

- $\mathcal{B}(\tau \to \mu\gamma\ ) < 1.1 \times 10^{-6}$ at 90% CL [CLEO, 13.8 fb^{-1}]
- $\mathcal{B}(\tau \to \mu\mu\mu) < 1.9 \times 10^{-6}$ at 90% CL [CLEO, 4.8 fb^{-1}]

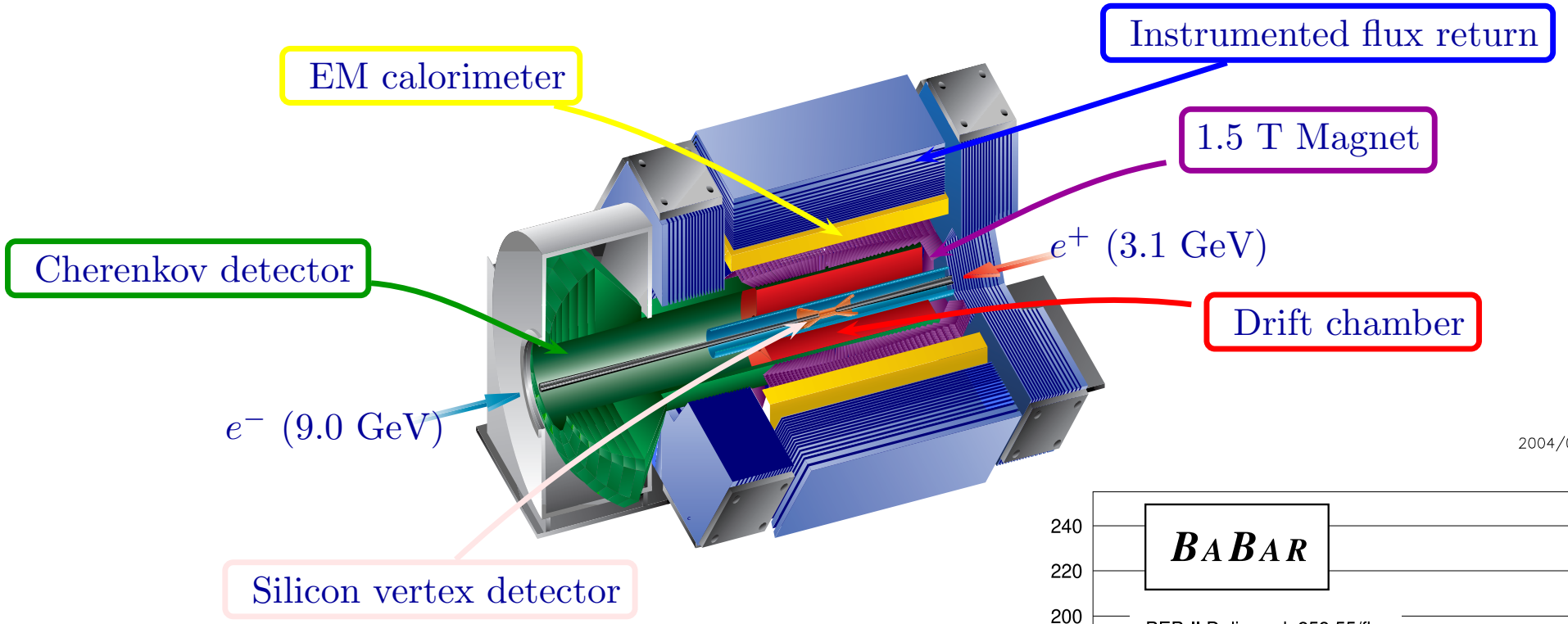
Theory Grab-bag

Model	$\tau \to \ell\gamma$	$\tau \to \ell\ell\ell$	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}	$10^{-10} - 10^{-7}$	hep-ph/0304081)
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 on given publication. For precise information, please, consult the reference)

BABAR Experiment



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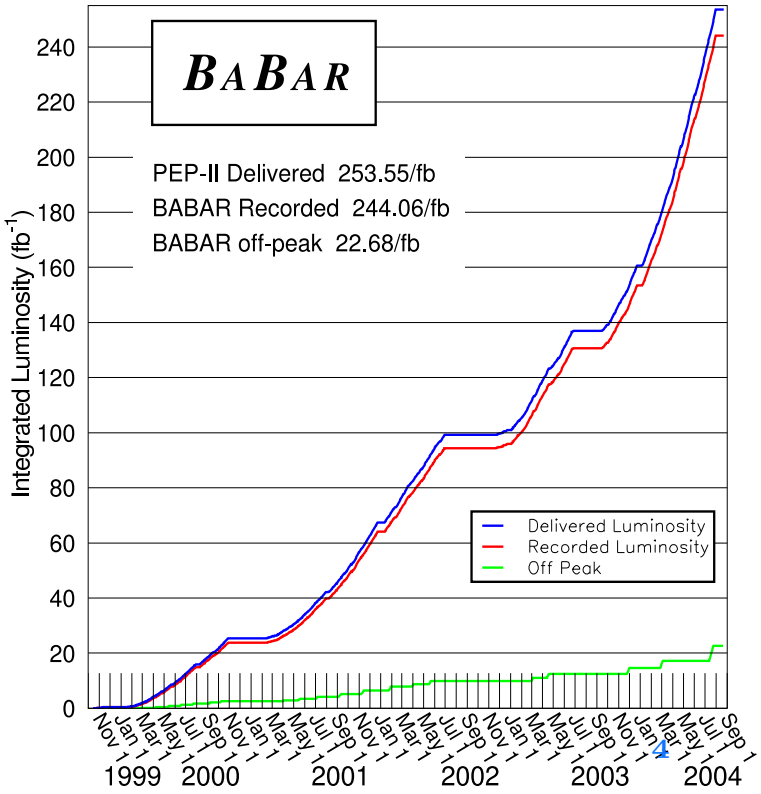


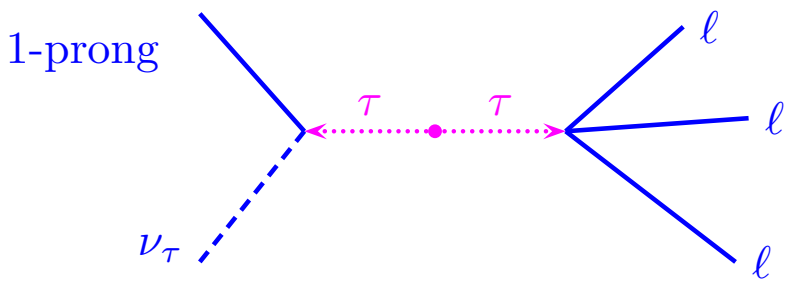
244 fb^{-1} recorded, more data on its way

$\sigma(e^+e^- \to \tau^+\tau^-) = 0.89$ nb

Almost 220 millions $\tau^+\tau^-$ events!

Results shown today use ~ 90 fb^{-1}

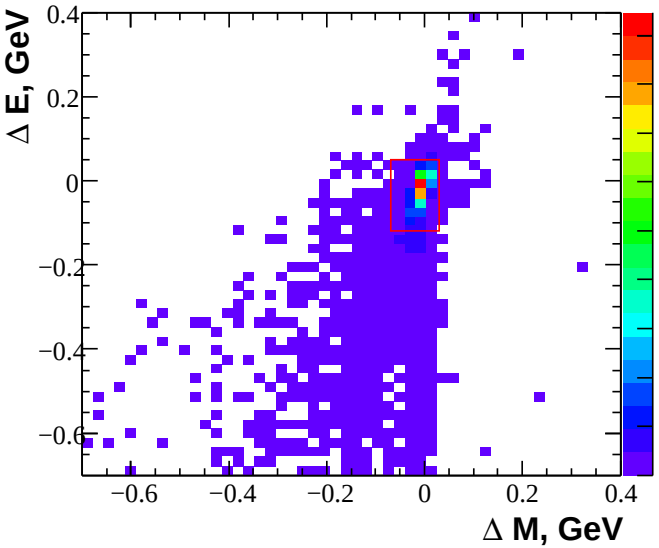
Search for $\tau \to \ell\ell\ell$ decay



- One prong on the *tag* side ($\pi\nu_\tau$, $\rho\nu_\tau$, $e\nu_e\nu_\tau$, $\mu\nu_\mu\nu_\tau$, ..) $\sim 85\%$
- Three well identified leptons on the signal side
- No missing momentum on the signal side

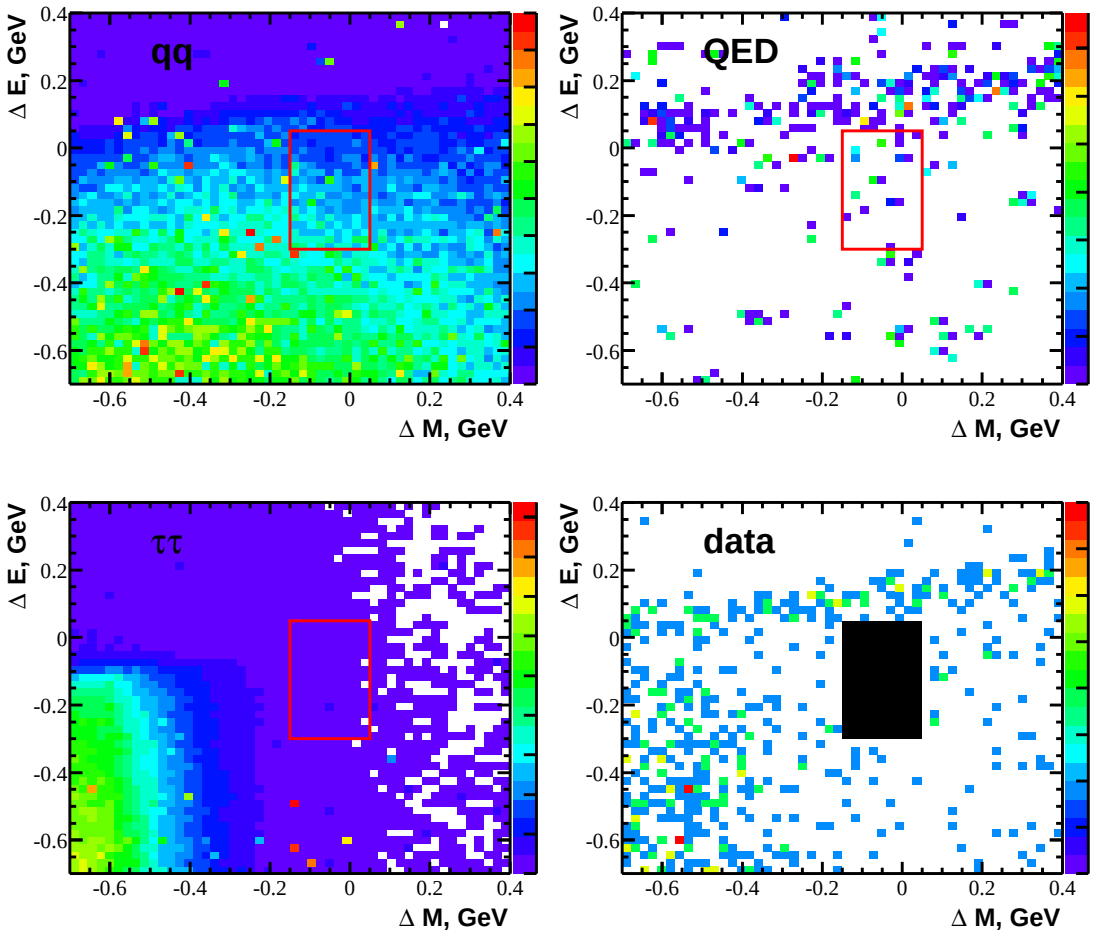
Neutrinoless Decay
$\Delta M = M_{rec} - M_\tau \sim 0$
$\Delta E = E^{CM}_{rec} - E_{CM}/2 \sim 0$
Smeared by resolution and radiative effects

MC: $\tau^- \to \mu^- e^+ e^-$



Backgrounds for $\tau \to \ell\ell\ell$ decay

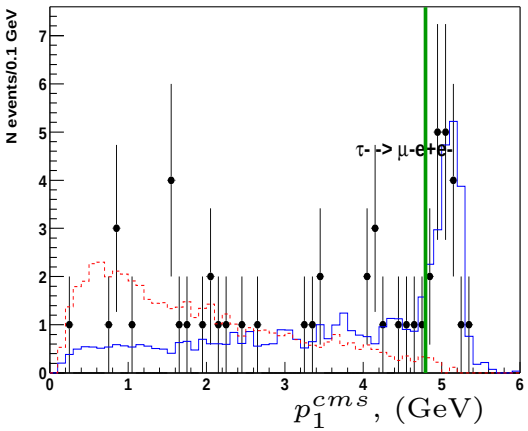
Require 1-3 topology, reject conversions; apply lepton identification and selection cuts. Selection cuts and signal box borders are optimized for each channel separately.

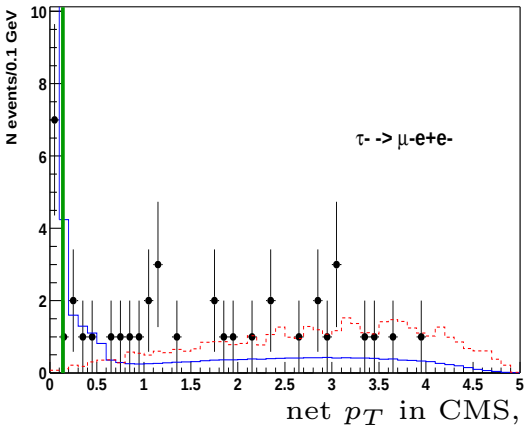


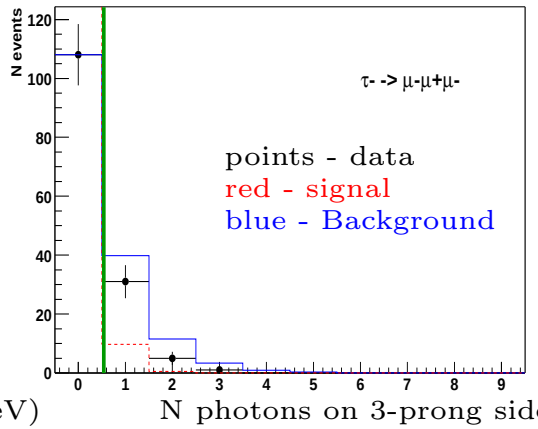
Selection criteria for $\tau \to \ell\ell\ell$

Different channels are contaminated with different backgrounds:

- $\tau^- \to e^-e^+e^-$, $\tau^- \to e^-\mu^+\mu^-$ - Bhabha, $q\overline{q}$, $\tau\tau$
- $\tau^- \to e^-\mu^+\mu^-$, $\tau^- \to \mu^-\mu^+\mu^-$ - Di-muon, $q\overline{q}$, $\tau\tau$
- $\tau^- \to \mu^+e^-e^-$, $\tau^- \to e^+\mu^-\mu^-$ - $q\overline{q}$, $\tau\tau$







All cuts except the one shown are applied

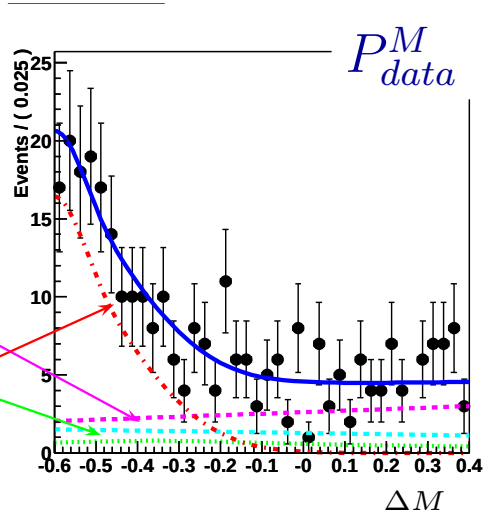
Suppress Bhabha and di-muon events with $p_T^{cms} > 100$ MeV/c;
On 1-prong side - $p_1^{cms} < 4.8$ GeV/c and lepton veto for Bhabha and di-muon contaminated channels;
On 3-prong side - kaon veto and no photon candidates with $E > 100$ MeV

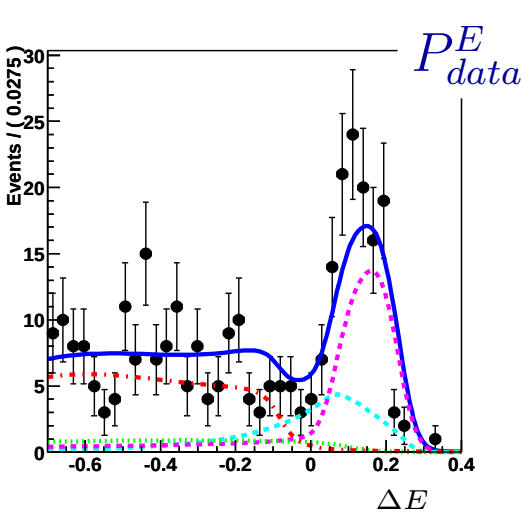
Backgrounds estimates

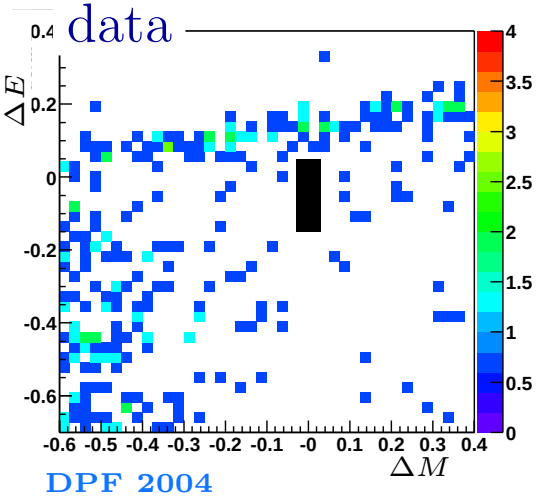
Each background shape (P_i) is fitted on MC or data control sample. Data are fitted with sum of 3 PDFs. The contribution of backgrounds in signal box is estimated using sideband region.

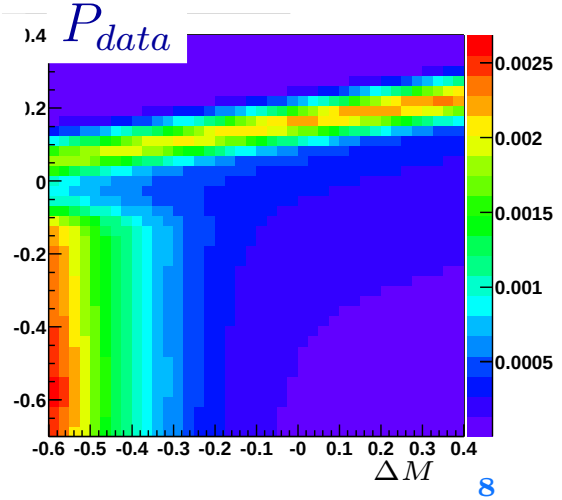
$$\underline{P_{data}} =$$
$$f_{QED} \cdot P_{QED} +$$
$$f_{q\bar{q}} \cdot (1 - f_{QED}) \cdot P_{q\bar{q}} +$$
$$(1 - f_{QED} - f_{q\bar{q}} \cdot (1 - f_{QED})) \cdot P_{\tau\tau}$$

$$N_{bkgr} = N_{GS} \frac{\int_{SB} P_{data} dM dE}{\int_{GS} P_{data} dM dE}$$



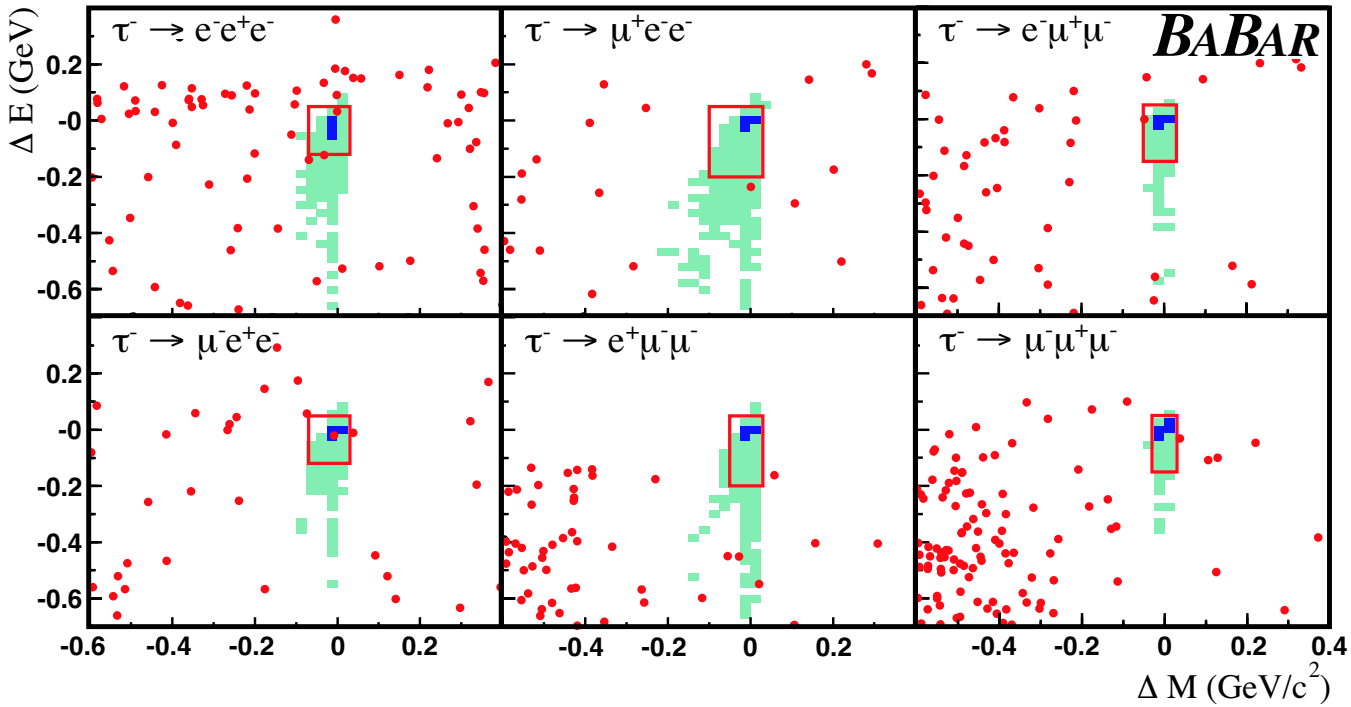






BABAR $\tau \to \ell\ell\ell$ LFV limits

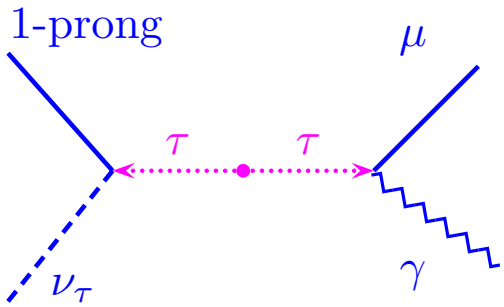
PRL 92, 121801 (2004)



	$e^-e^+e^-$	$\mu^+e^-e^-$	$\mu^-e^+e^-$	$e^+\mu^-\mu^-$	$e^-\mu^+\mu^-$	$\mu^-\mu^+\mu^-$
ε [%]	7.3 ± 0.2	11.6 ± 0.2	7.7 ± 0.1	9.8 ± 0.1	6.8 ± 0.1	6.7 ± 0.1
$N_{\rm bgd}$	1.51 ± 0.11	0.37 ± 0.08	0.62 ± 0.10	0.21 ± 0.07	0.39 ± 0.08	0.31 ± 0.09
$N_{\rm obs}$	1	0	1	0	1	0
$\mathcal{B}^{90}_{\rm UL}$	2.0×10^{-7}	1.1×10^{-7}	2.7×10^{-7}	1.3×10^{-7}	3.3×10^{-7}	1.9×10^{-7}

No excess found in $\mathcal{L} = 91.6$ fb^{-1}; $\mathcal{B}(\tau \to \ell\ell\ell) < (1-3) \times 10^{-7}$ at 90% CL

Old Preliminary *BABAR* $\tau \to \mu\gamma$ Limit



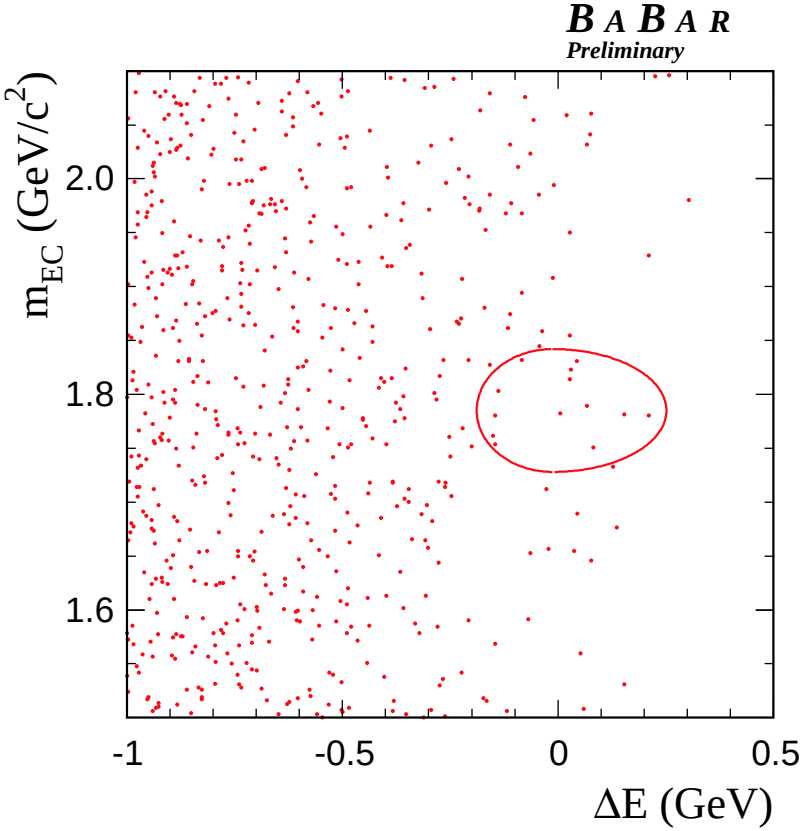
Select 1-1 topology; e or ρ tag; only μ and γ on signal side; cuts on missing momentum and net p_T in the event. Significant background from $e^+e^- \to \mu^+\mu^-\gamma$ and $\tau \to \mu\bar{\nu}_\mu\nu_\tau\gamma$

$\mathcal{L} = 63$ fb^{-1}
$\varepsilon = (5.2 \pm 0.5)\%$
Expected $N_{bkgr} = 7.8 \pm 1.4$

Data observed : 13

$\mathcal{B}(\tau \to \mu\gamma) < 2.0 \times 10^{-6}$ at 90% CL

Update with 220 fb^{-1} is expected for Tau2004



BABAR/Belle era

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

Mode	*BABAR* PRL 92, 121801 (2004)	Belle PLB 589, 103 (2004)
$\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-)$	1.9	2.0
$\mathcal{B}(\tau^- \to e^-\mu^+\mu^-)$	3.3	2.0
$\mathcal{B}(\tau^- \to e^+\mu^-\mu^-)$	1.3	2.0
$\mathcal{B}(\tau^- \to \mu^-e^+e^-)$	2.7	1.9
$\mathcal{B}(\tau^- \to \mu^+e^-e^-)$	1.1	2.0
$\mathcal{B}(\tau^- \to e^-e^+e^-)$	2.0	3.5

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

B-factories have lowered limits on LFV in tau decays to 10^{-7}

Over 500 fb^{-1} expected in next few years; $\tau \to \ell\ell\ell$ limits should approach $\mathcal{O}(10^{-8})$ soon : many predictions are above this level!

Many more channels to study $\tau \to \ell hh$, $\tau \to \mu\eta'$, $\tau \to p\gamma$, etc.

Conclusions

- New *BABAR* results on search of $\tau \to \ell\ell\ell$ are presented for $\mathcal{L} = 91.6$ fb^{-1}. $\mathcal{B}(\tau \to \ell\ell\ell) < (1-3) \times 10^{-7}$ at 90% CL, where $\ell = e$ or μ.

- *BABAR* preliminary result for $\tau \to \mu\gamma$ on $\mathcal{L} = 63$ fb^{-1} is $\mathcal{B}(\tau \to \mu\gamma) < 2.0 \times 10^{-6}$ at 90% CL - will be updated soon

- Current experimental sensitivity to LFV tau decays approaches theoretical predictions

- Run 4 was very successful for *BABAR*, the total integrated luminosity is over 220 fb^{-1} $\Rightarrow$

  expect many more new results on tau physics and LFV processes soon!