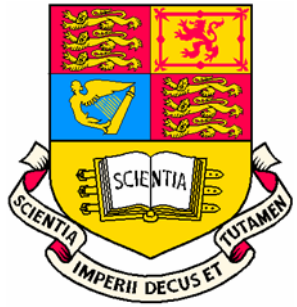
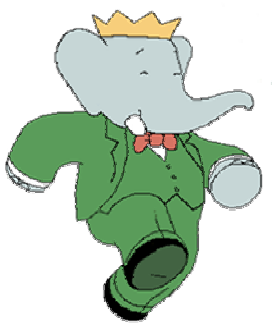
Imperial College London



Lepton Flavour Violation in τ-decays

Robert L. Flack

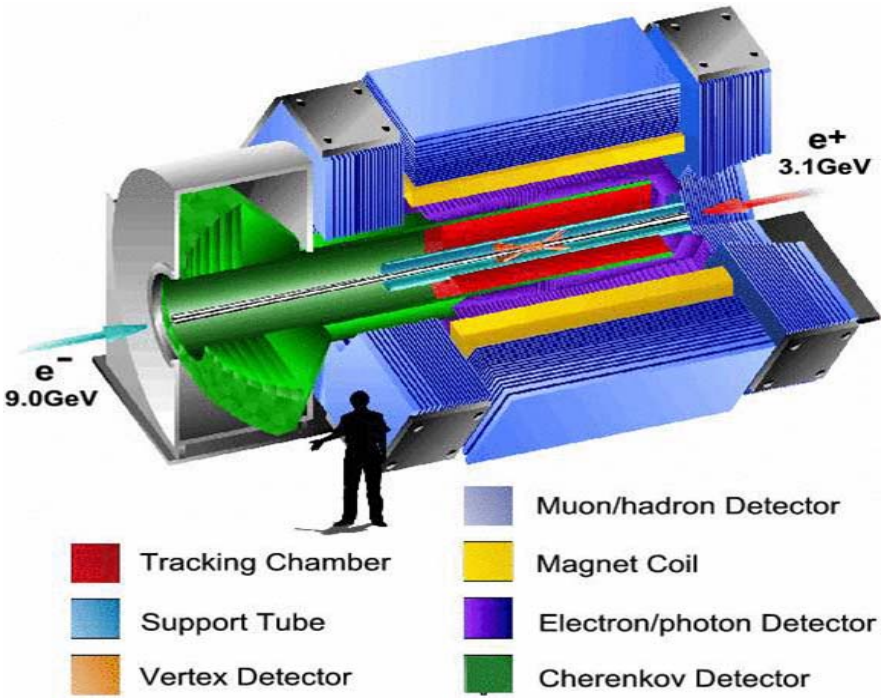
On behalf of the BABAR collaboration



Contents

- The BABAR detector
- Definition of lepton flavour violation (LFV)
- LFV decays in the Standard Model (SM)
- LFV processes as probes for new physics
- Results on LFV in τ-decays at BABAR
- Exclusion of SUSY parameter space
- Conclusion

BABAR Detector



Asymmetric energy collider:

$\sqrt{s} = 10.58\,\text{GeV}$ at $\Upsilon(4s)$ peak

Current integrated luminosity

$$\int L dt \approx 350\,\text{fb}^{-1}$$

$$\sigma(B\bar{B}) \approx 1.1\text{nb}$$

$$\sigma(\tau^+\tau^-) \approx 0.9\text{nb}$$

3.15×10^8 τ-pairs

More than just a B-Factory!

Lepton Flavour Violation

The conservation of baryon and Individual lepton number is considered to be an “accidental global symmetry” within the Standard Model.

LFV is defined as the violation of individual lepton numbers whilst preserving the overall lepton number:

$$L = L_e + L_\mu + L_\tau$$

Lepton number violating processes have also been proposed

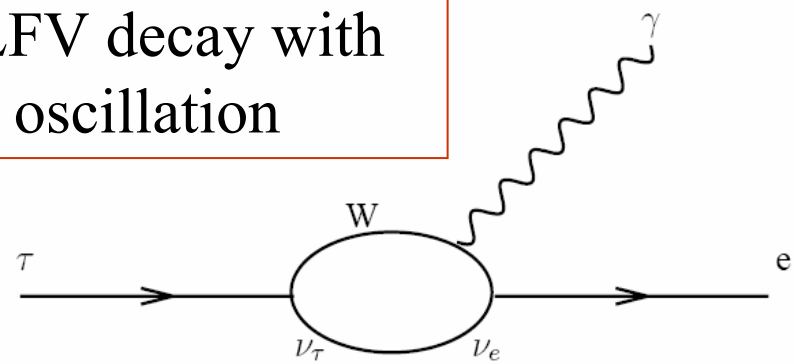
LFV in the SM

Minimal SM: zero neutrino mass

LFV is forbidden

Confirmation of neutrino oscillations and the realisation that neutrinos have mass LFV is allowed but highly suppressed

LFV decay with ν oscillation



The small BF for the decay with ν oscillation is dominated by the term $|M_\nu / M_W|^4$

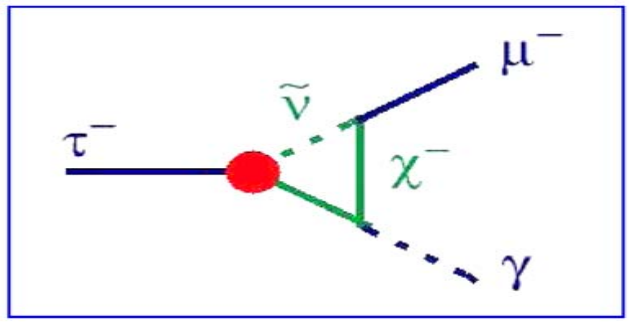
BF for this process is $<10^{-40}$

LFV Beyond the SM(1)

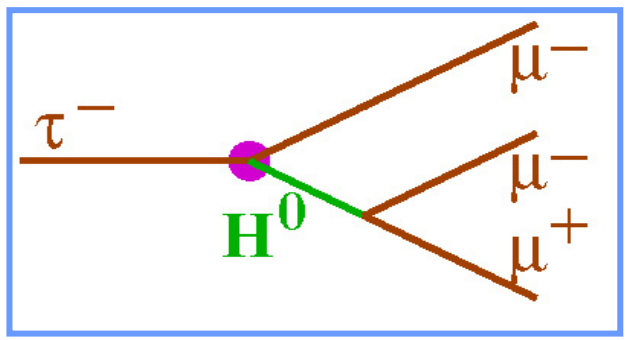
Many extensions to the SM greatly increase the BF for LFV decays

Probe for new physics

Supersymmetry, for example, can give much higher BFs for neutrinoless decays $\tau \to l\gamma$ and $\tau \to lll$



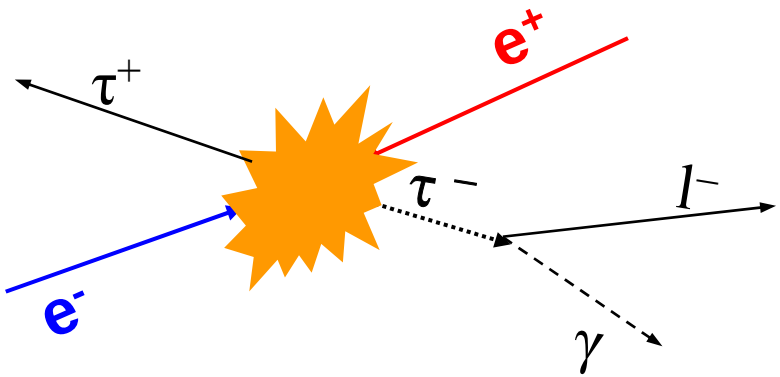
Some of these BFs are possibly within reach with the present size of the BABAR data set

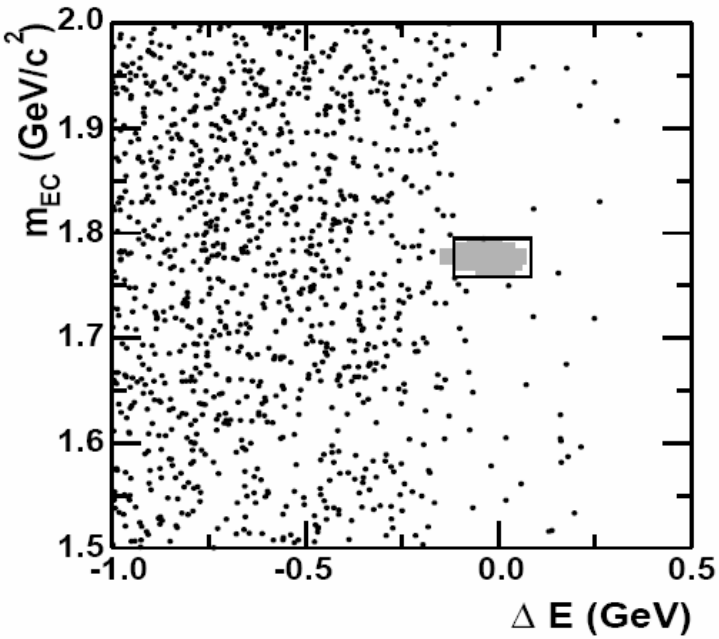


LFV Beyond the SM(2)

Model	$\tau \to l\gamma$	$\tau \to lll$	Reference
SM+lepton mixing	$<10^{-40}$	$<10^{-14}$	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/right handed neutral singlets	$<10^{-8}$	$<10^{-9}$	PRD66(2002)034008
mSUGRA+seesaw	$<10^{-7}$	$<10^{-9}$	hep-ph/0206110
SUSY *SU(5)*	$<10^{-4}$		hep-ph/0303071
SUSY flipped *SU(5)*	$<10^{-7}$		hep-ph/0304130
SUSY *SO(10)*	$<10^{-8}$	$<10^{-10}$	hep-ph/0209303
SUSY anomoulous *U(1)*	$<10^{-7}$		hep-ph/0308093
Neutral SUSY Higgs	$<10^{-10}$	$<10^{-7}$	hep-ph/0304081
Charged SUSY Higgs triplet		$<10^{-7}$	hep-ph/0209170
MSSM+nonuniversal soft SUSY breaking	$<10^{-10}$	$<10^{-6}$	hep-ph/0305290
Non universal Z′ (technicolour)	$<10^{-9}$	$<10^{-8}$	PLB547(2002)252
Two Higgs doublet III	$<10^{-15}$	$<10^{-17}$	hep-ph/0208117
Extra dimensions	$<10^{-11}$		hep-ph/0210021

Neutrinoless decay $\tau \rightarrow \mu/e\nu$





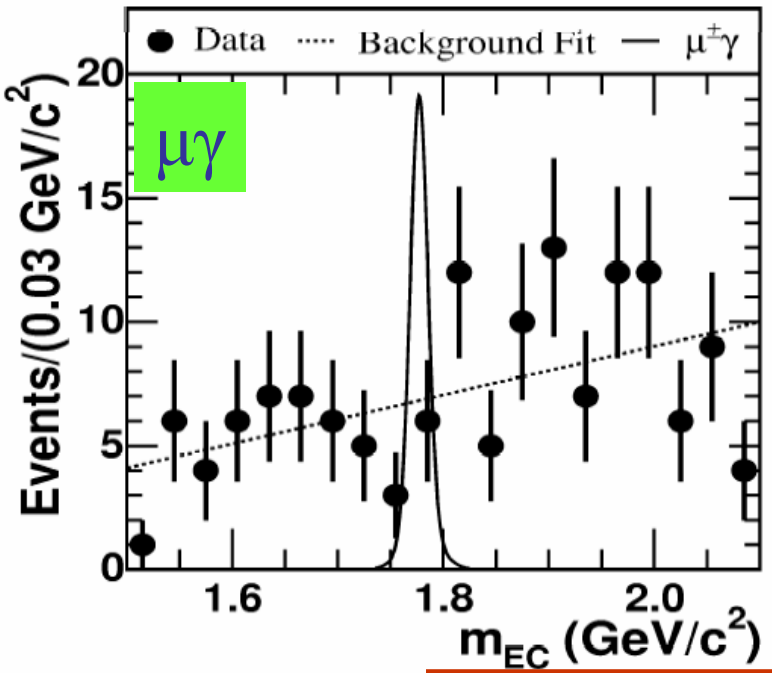
The non-signal τ decays to any standard decay mode that has one or three charged tracks

The signal τ is fully reconstructed and its mass, m_{EC}, is constrained to the τ-mass; 1.8 GeV/c^2

The energy of the signal τ is equal to the beam energy, within resolution; 5.28 GeV in the centre of mass

Neutrinoless decay $\tau \to \mu/e\gamma$

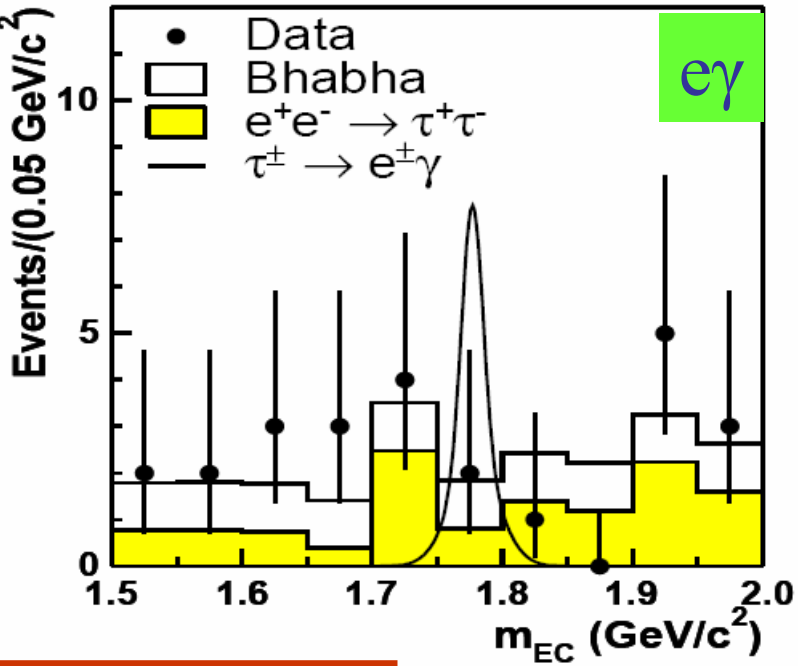
Data sample: 232 fb^{-1}



BF < 6.8 x 10^{-8} @ 90% CL

PRL 95 (2005) 041802

Data sample: 232 fb^{-1}



BF < 1.1 x 10^{-7} @ 90% CL

PRL 96 (2006) 041801

No evidence of signal

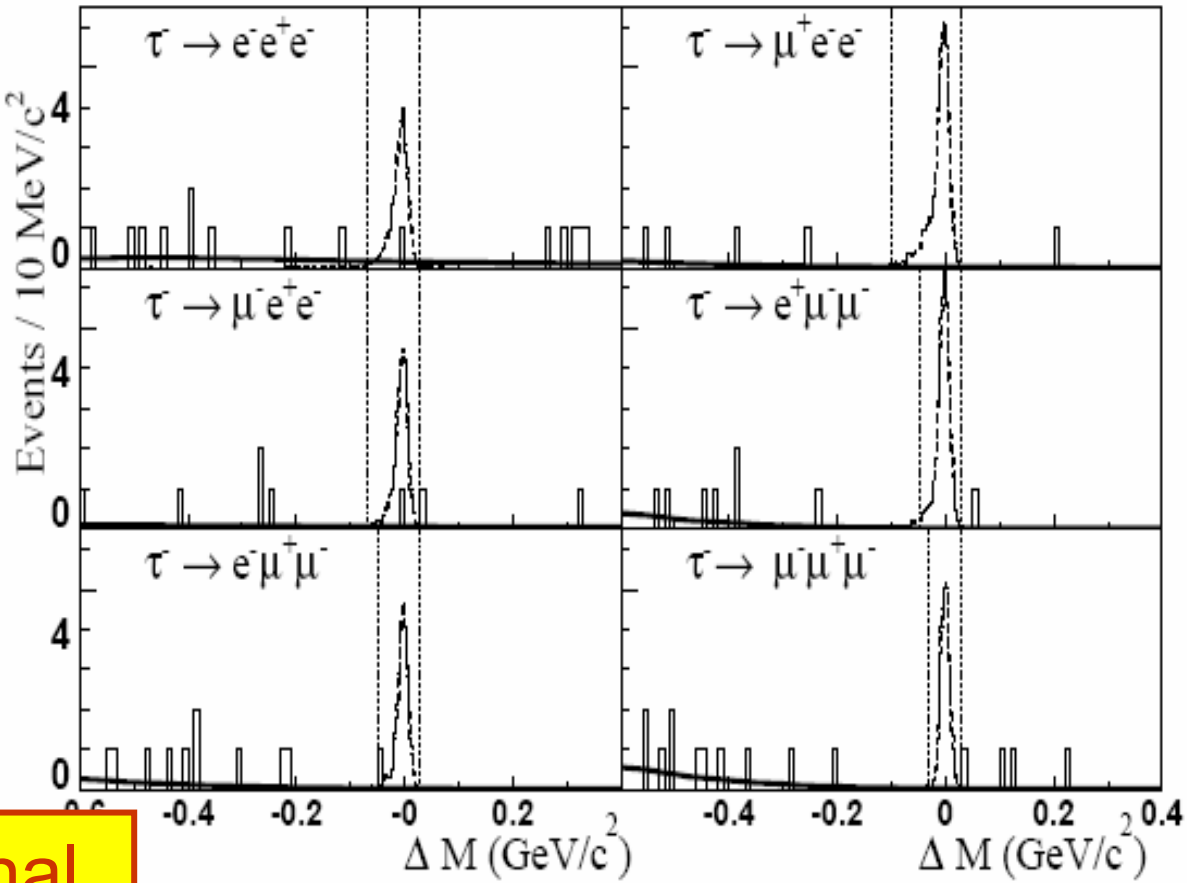
LFV decay $\tau \to lll$

Data sample 91.5 fb^{-1}

All 6 decay modes considered

The signal events are selected in the ΔM, ΔE plane

$\Delta M = m_\tau - m_{lll}$,
$\Delta E = E_{beam} - E_{lll}$



No evidence of signal

BF < 1 - 3 x 10^{-7} @ 90% CL

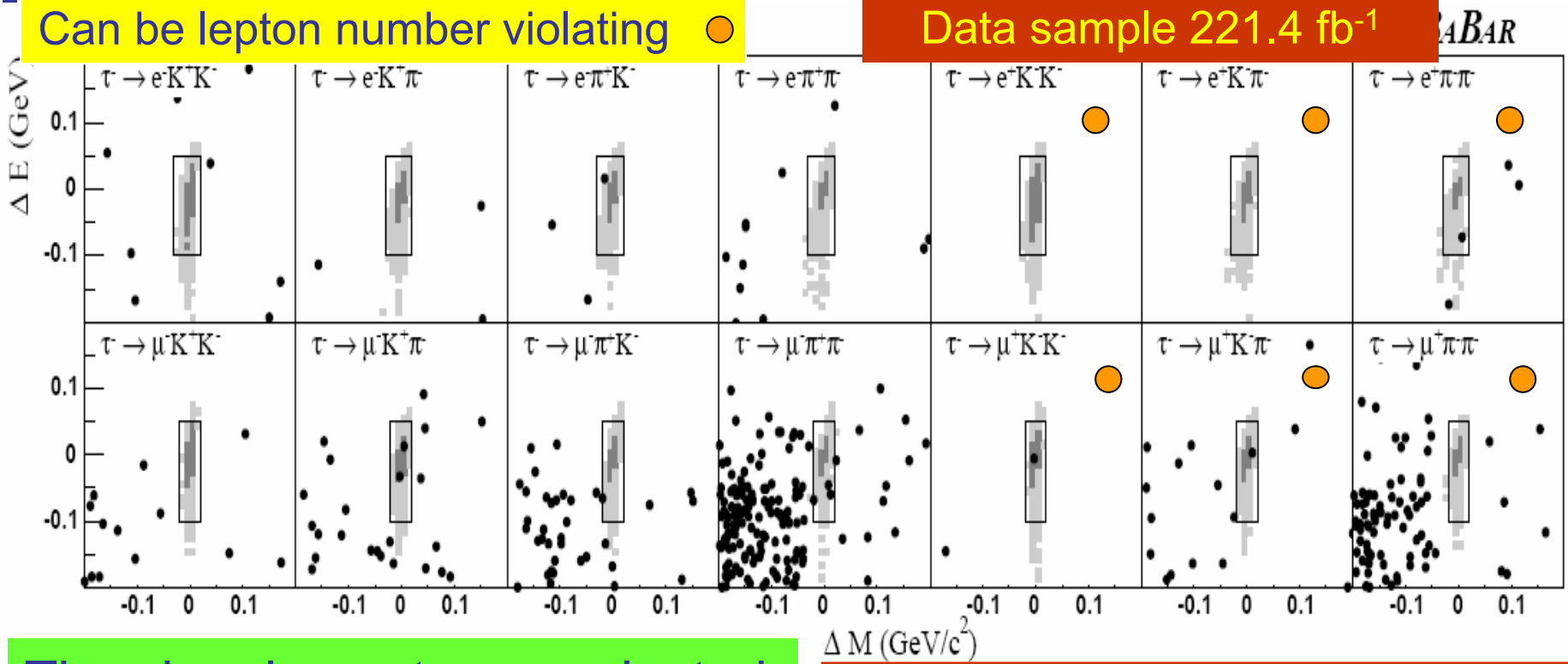
PRL 92 (2004) 121801

LFV decay $\tau \to lhh'$

l = e/μ, h = π/K

Can be lepton number violating

Data sample 221.4 fb^{-1}



The signal events are selected in the ΔM, ΔE plane

No evidence of signal

$\Delta M = m_\tau - m_{lhh'}$

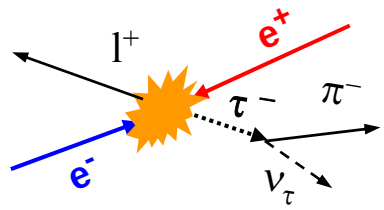
$\Delta E = E_{beam} - E_{lhh'}$

BF < 1 - 5 x 10^{-7} @ 90% CL

PRL 95 (2005) 191801

$e^+e^- \to l^+\tau^-$ (preliminary result)

Signature of the process



Select signal events in (m_τ, p*(l)) plane

m_τ is the τ mass

p*(l) is the momentum of the lepton, * indicates CM

Unbinned ML fit to extract signal and background

No signal observed

Mode	σ UL(95%)	$\sigma/\sigma_{\mu\mu}$ UL(95%)
$e^+e^- \to \mu^-\tau^+(\tau^+ \to \pi^+\pi^-\pi^+\upsilon_\tau)$	$5.91 fb$	5.2×10^{-6}
$e^+e^- \to \mu^-\tau^+(\tau^+ \to \pi^+\upsilon_\tau)$	$11.4 fb$	10.1×10^{-6}
$e^+e^- \to e^-\tau^+(\tau^+ \to \pi^+\pi^-\pi^+\upsilon_\tau)$	$14.8 fb$	13.1×10^{-6}
$e^+e^- \to e^-\tau^+(\tau^+ \to \pi^+\upsilon_\tau)$	$11.1 fb$	9.8×10^{-6}

Combined	σ	$\sigma / \sigma_{\mu\mu}$
$e^+e^- \to \mu^-\tau^+$	4.6fb	4.0×10^{-6}
$e^+e^- \to e^-\tau^+$	10.1fb	8.9×10^{-6}

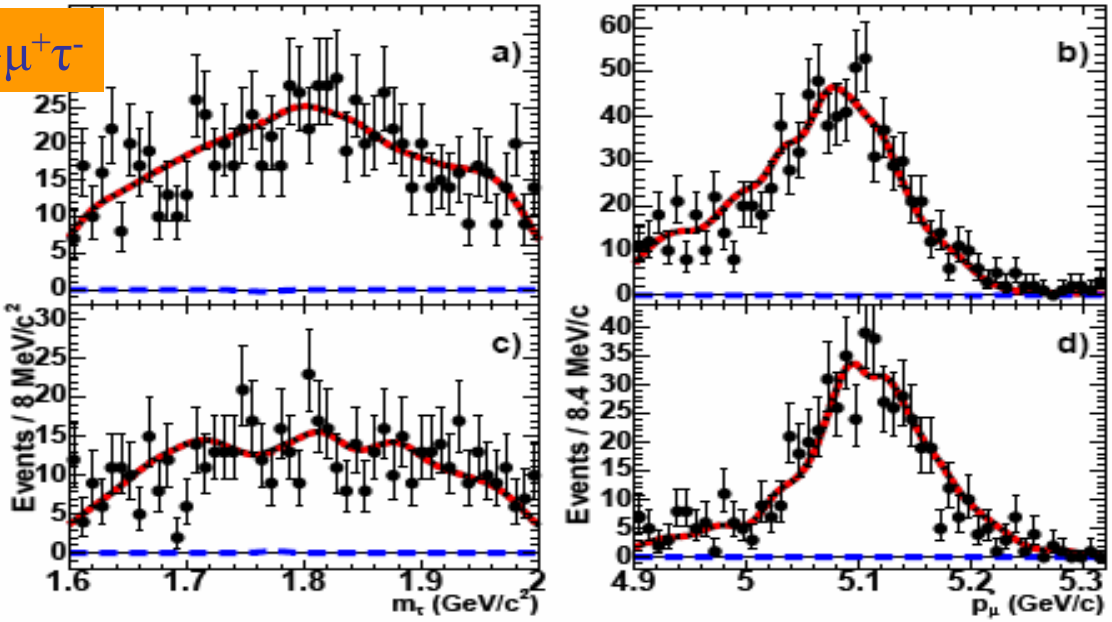
$e^+e^- \to \mu^+\tau^-$

3π

Black lines are the projections of the ML fit

Single π

Red dashed line is the background

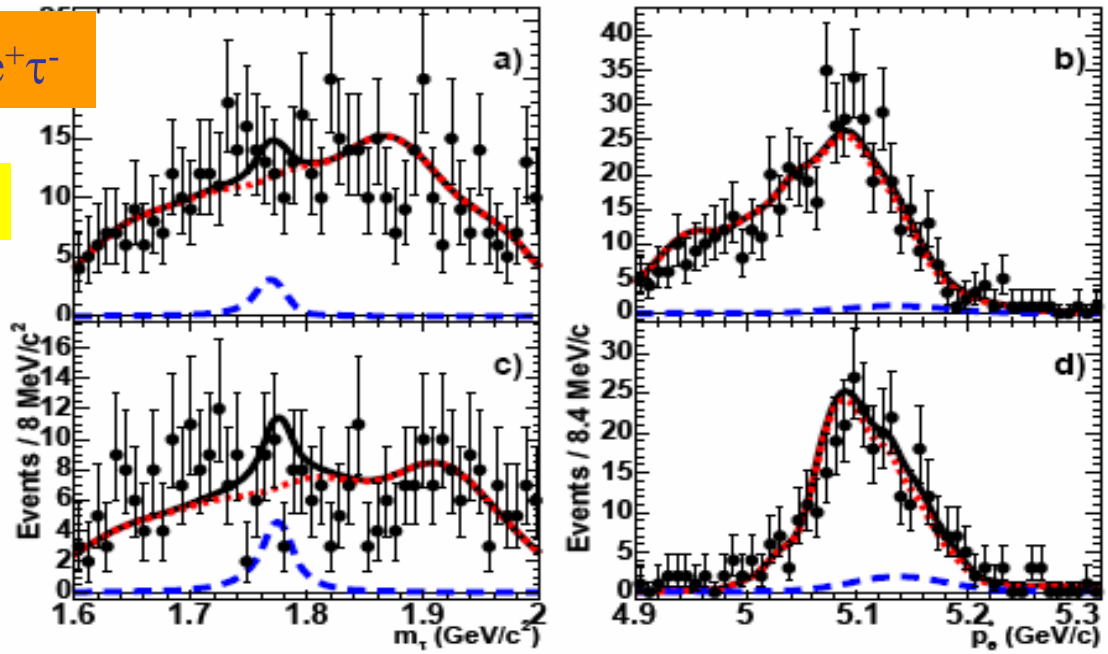


$e^+e^- \to e^+\tau^-$

3π

The blue dashed line are signal events

Single π

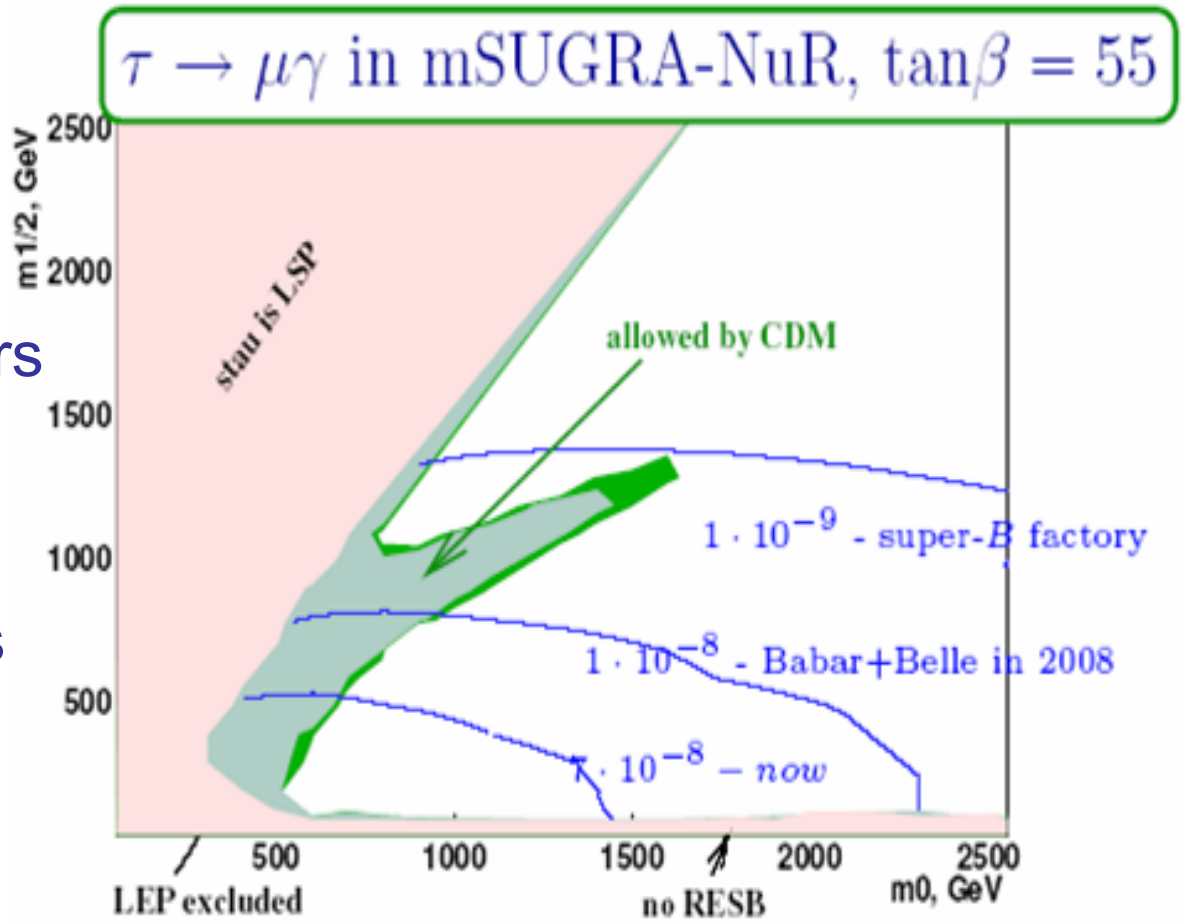


Preliminary: Novisibirsk06

LFV constraints on SUSY parameter space

Exclusion plot constructed using a specific set of parameters

$m_{½}$ is the gaugino mass
m_0 is the scalar mass



Ref: O. Igonkina at SUSY05

Conclusion

The size of the samples collected has allowed high precision measurements to be made.

The sensitivity is limited to BFs of 10^{-8}.

LFV decays have not been observed.

$\tau \to \mu\gamma$	BR < 0.68×10^{-7} (PRL 95 (2005) 041802)
$\tau \to e\gamma$	BR < 1.10×10^{-7} (PRL 96 (2006) 041801)
$\tau \to lll$	BR < $(1.1\text{-}3.3) \times 10^{-7}$ (PRL 92 (2004) 121801)
$\tau \to lhh'$	BR < $(0.7\text{-}4.8) \times 10^{-7}$ (PRL 95 (2005) 191801)
$e^+ e^- \to \mu^+\tau^-$ $e^+ e^- \to e^+\tau^-$	$\sigma_{\mu\tau}$ <4.6 fb $\sigma_{e\tau}$ <10.1 fb (Preliminary: Novisibirsk06)

Looking forward to increasing the data set and challenging the limits of LFV processes.