Future Constraints on, and from Lepton Universality

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Collaborators

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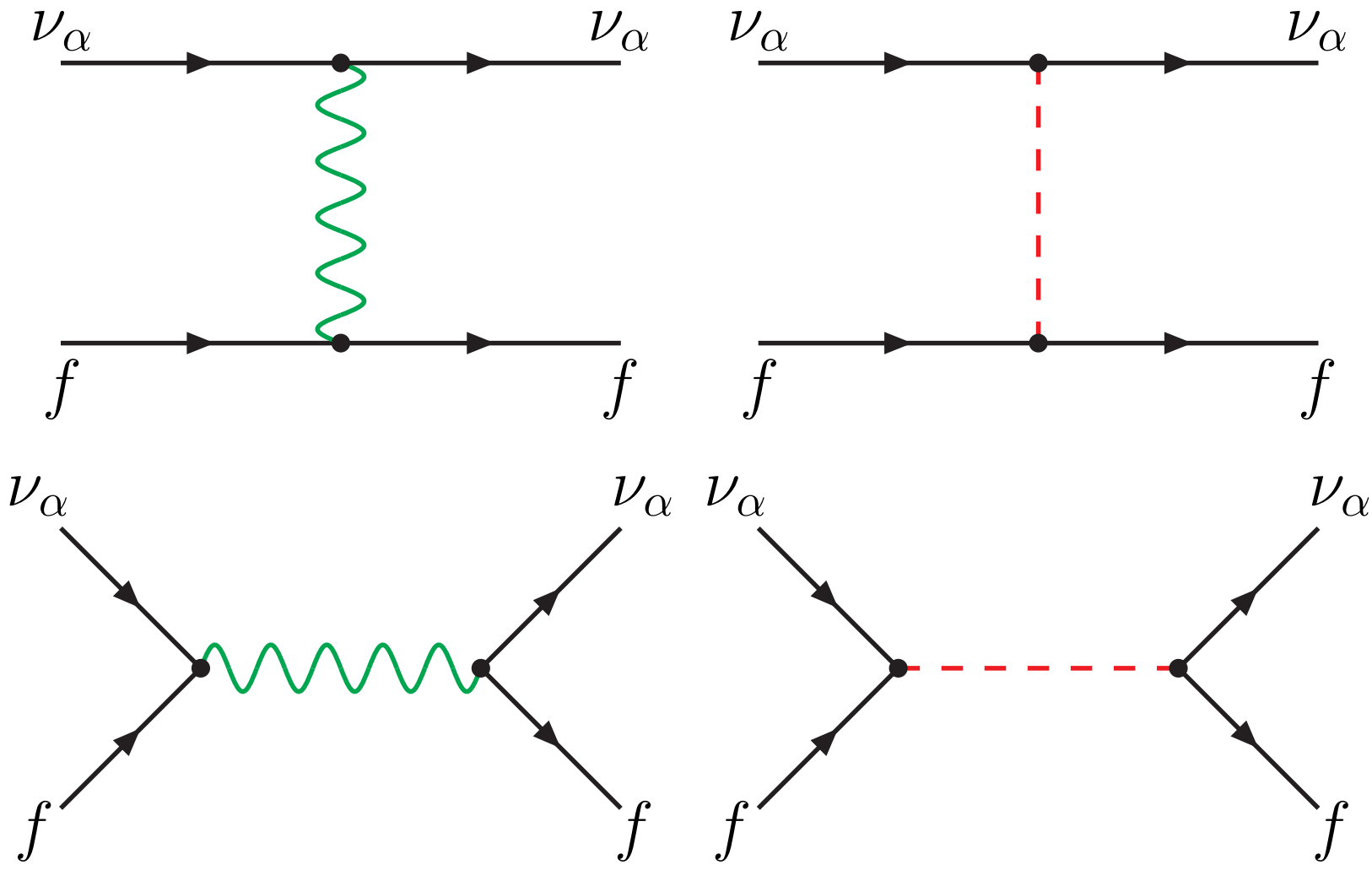
Potential of Future ν Experiments

- Future high statistics neutrino experiments can probe new physics at the TeV scale.
  - Fixed target ν-scattering experiments, *e.g.* NuSOnG.
    $\Rightarrow$ talks by Janet Conrad, Georgia Karagiorgi, Will Loinaz (2008)
  - Long baseline ν-oscillation experiments, *e.g.* Fermilab$\rightarrow$Hyper-Kamiokande.
    $\Rightarrow$ talks by Yee Kao, Alexey Pronin (2007)

New Physics Contributions



Example: R-parity Violation

$$W_{\not R} = \frac{1}{2}\lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}_k + \frac{1}{2}\lambda''_{ijk}\hat{U}_i\hat{D}_j\hat{D}_k \ ,$$

	NuSOnG 95%	current 95%
$\lvert\lambda_{231}\rvert$	$0.05\left(\frac{M_{\tilde{\tau}_L}}{100\,\mathrm{GeV}}\right)$	$0.07\left(\frac{M_{\tilde{e}_R}}{100\,\mathrm{GeV}}\right)$
$\lvert\lambda'_{211}\rvert$	$0.05\left(\frac{M_{\tilde{d}}}{100\,\mathrm{GeV}}\right)$	$0.06\left(\frac{M_{\tilde{d}_R}}{100\,\mathrm{GeV}}\right)$

Current Bounds

Current bounds on RPV come from CC lepton universality measurements:

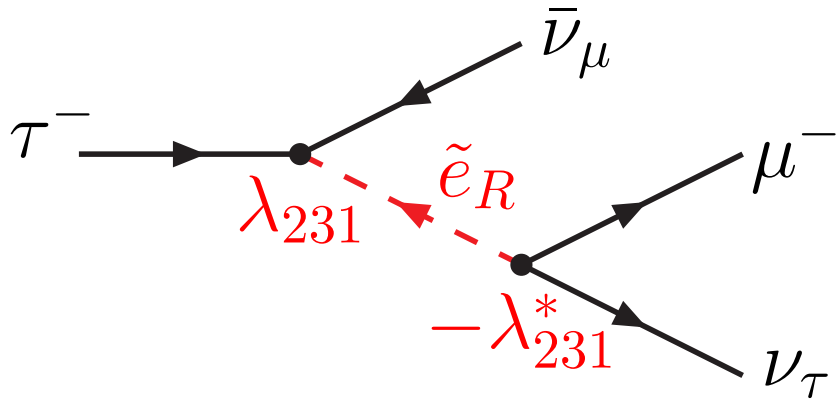
$$R_\tau = \frac{B(\tau \to e\nu_e\nu_\tau)}{B(\tau \to \mu\nu_\mu\nu_\tau)} = 1.028 \pm 0.004$$

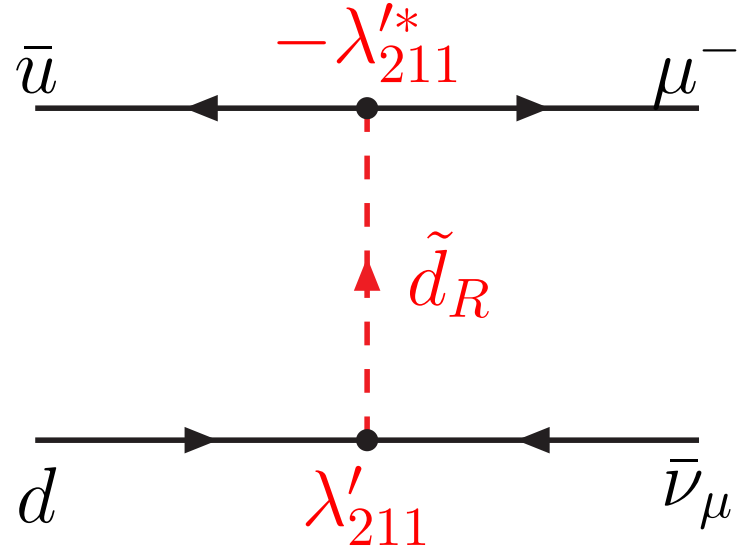
$$\to \quad g_\mu/g_e = 1.0021 \pm 0.0016$$

$$R_\pi = \frac{B(\pi \to e\nu_e)}{B(\pi \to \mu\nu_\mu)} = (1.231 \pm 0.004) \times 10^{-4}$$

$$\to \quad g_\mu/g_e = 1.0003 \pm 0.0021$$

RPV contribution to τ and π decays





In the Near Future:

Current bounds on CC lepton universality can be expected to be improved dramatically in the near future.

- PIENU aims to reduce the error on R_π by a factor of 5.
- Babar aims to reduce the errors on ALL one-prong τ branching fractions by factors of 3.
- τ-decay data from Belle?
- W-decay data from Tevatron Run 2?

Potential Impact on RPV limits

- Babar

$$|\lambda_{231}| < 0.07 \left(\frac{M_{\tilde{e}_R}}{100\,\mathrm{GeV}} \right) \Rightarrow 0.03 \left(\frac{M_{\tilde{e}_R}}{100\,\mathrm{GeV}} \right)$$

- PIENU

$$|\lambda'_{211}| < 0.06 \left(\frac{M_{\tilde{d}_R}}{100\,\mathrm{GeV}} \right) \Rightarrow 0.02 \left(\frac{M_{\tilde{d}_R}}{100\,\mathrm{GeV}} \right)$$

Actual bounds could be stronger or weaker depending on whether the measured values are higher or lower than the SM.

Global Analysis of CC Lepton Universality

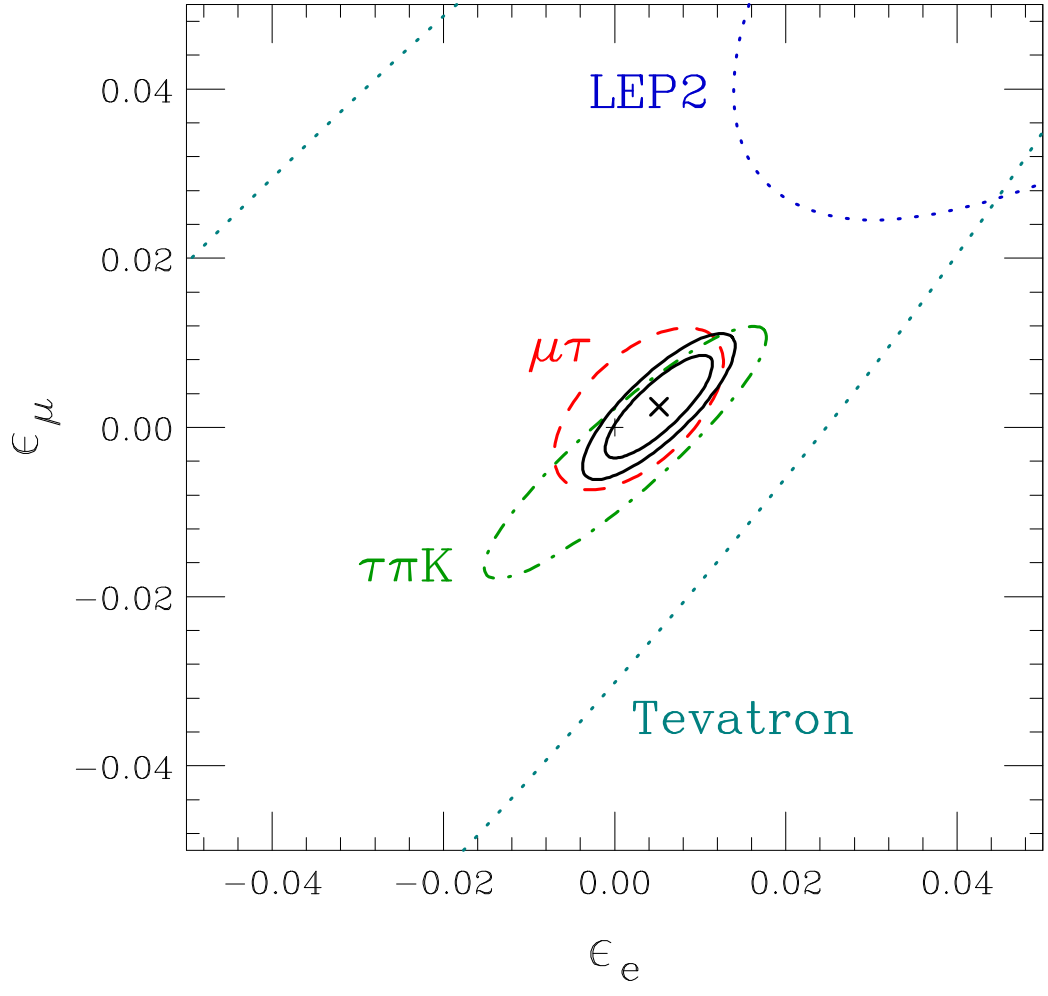
Allow the CC couplings to depend on lepton flavor:

$$\mathcal{L} = \sum_{\ell=e,\mu,\tau} \frac{g_\ell}{\sqrt{2}} W^+_\mu \, \bar{\nu}_\ell \, \gamma^\mu \left(\frac{1-\gamma_5}{2} \right) \ell^- + \text{h.c.} \; .$$

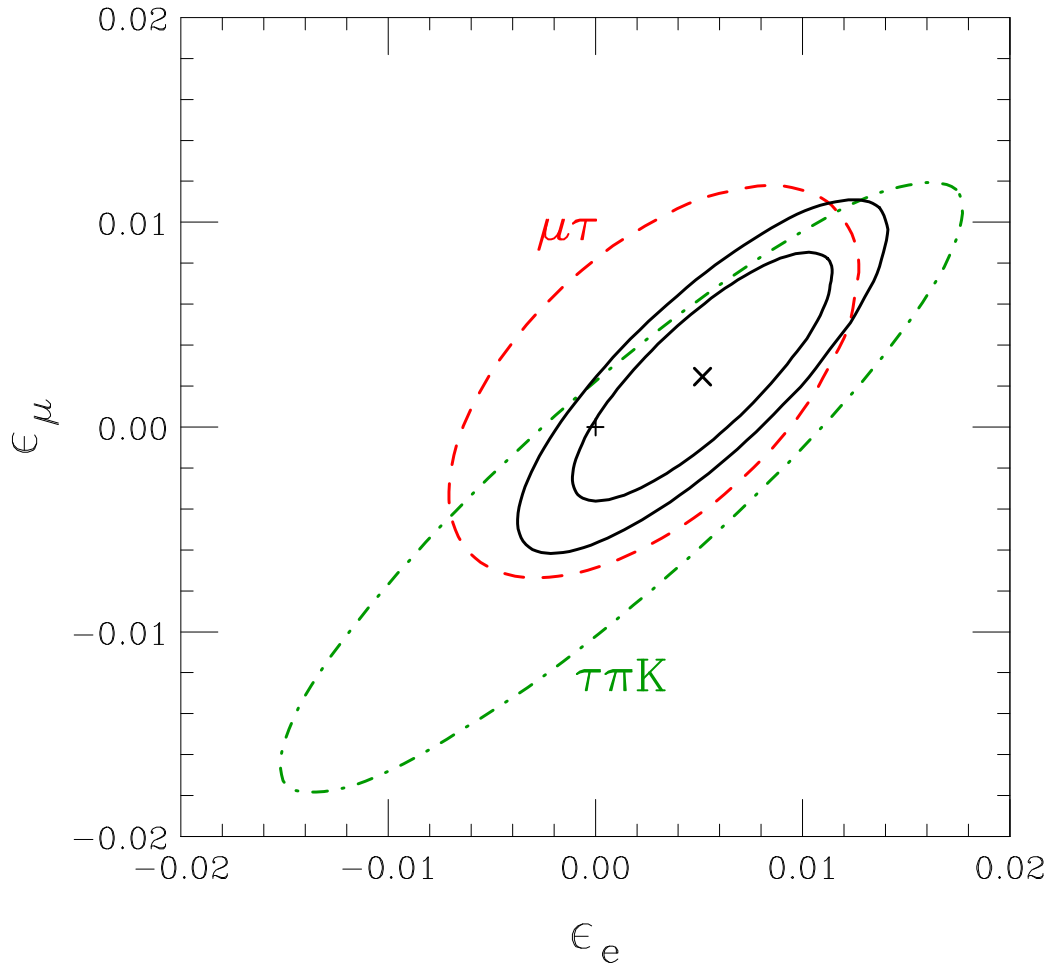
Fit all CC particle decay data with the parameters ϵ_ℓ, $\ell = e, \mu, \tau$.

$$g_\ell \; = \; g \left(1 - \frac{\epsilon_\ell}{2} \right)$$

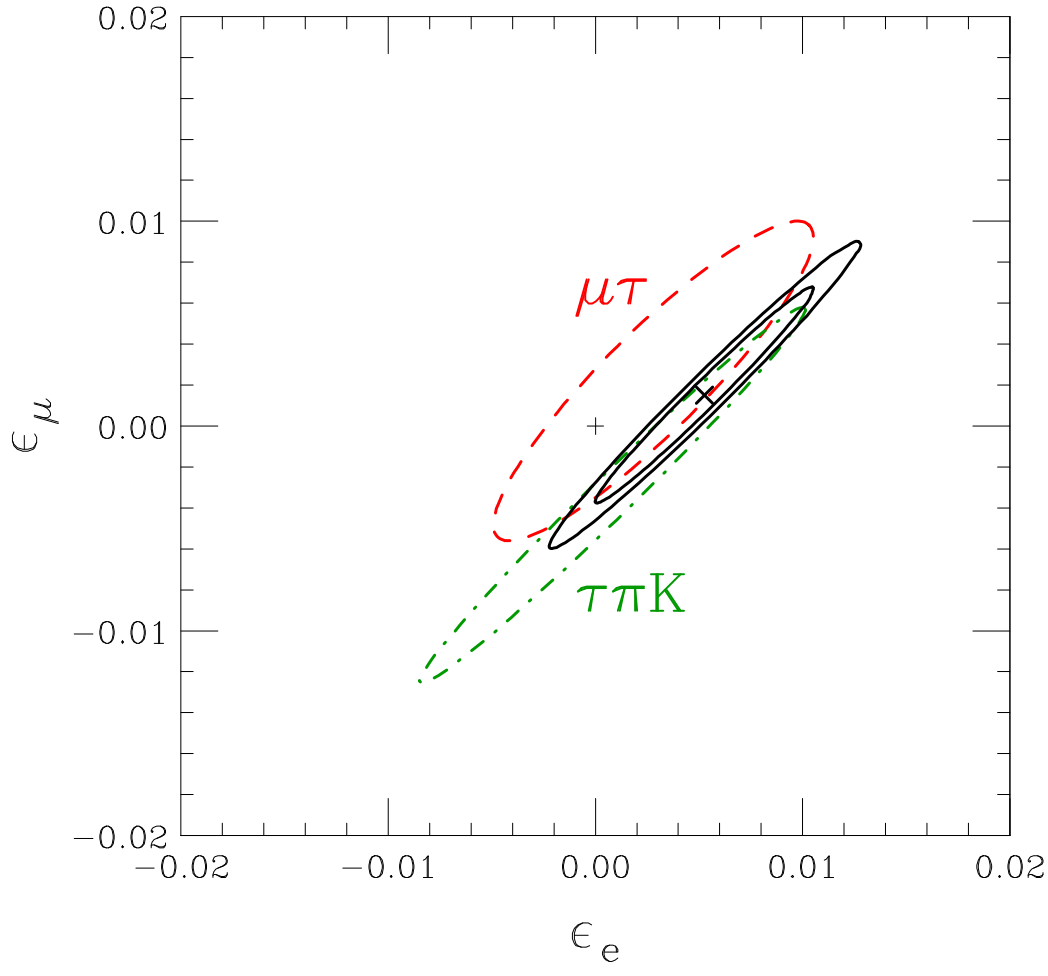
Current Status:



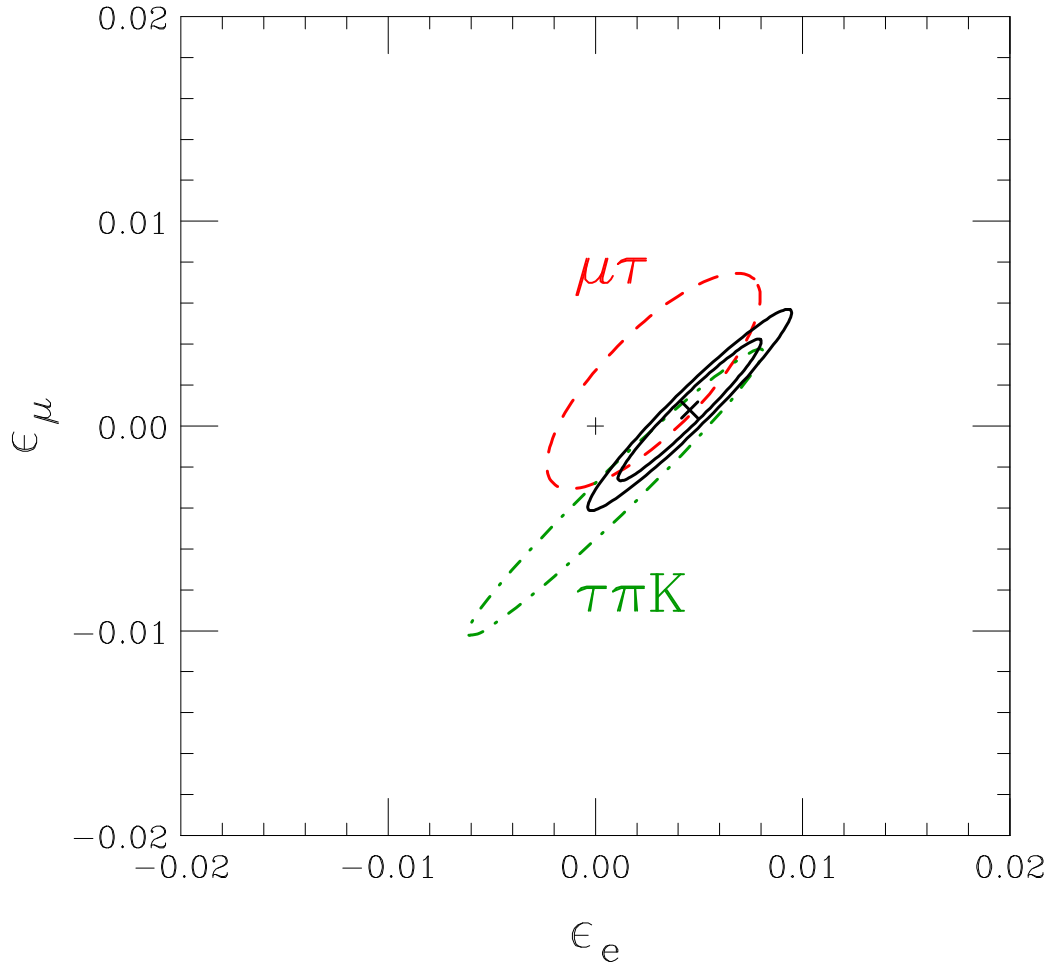
Blowup of Current Status:



With improved π and τ branching fractions:



With improved τ lifetime:



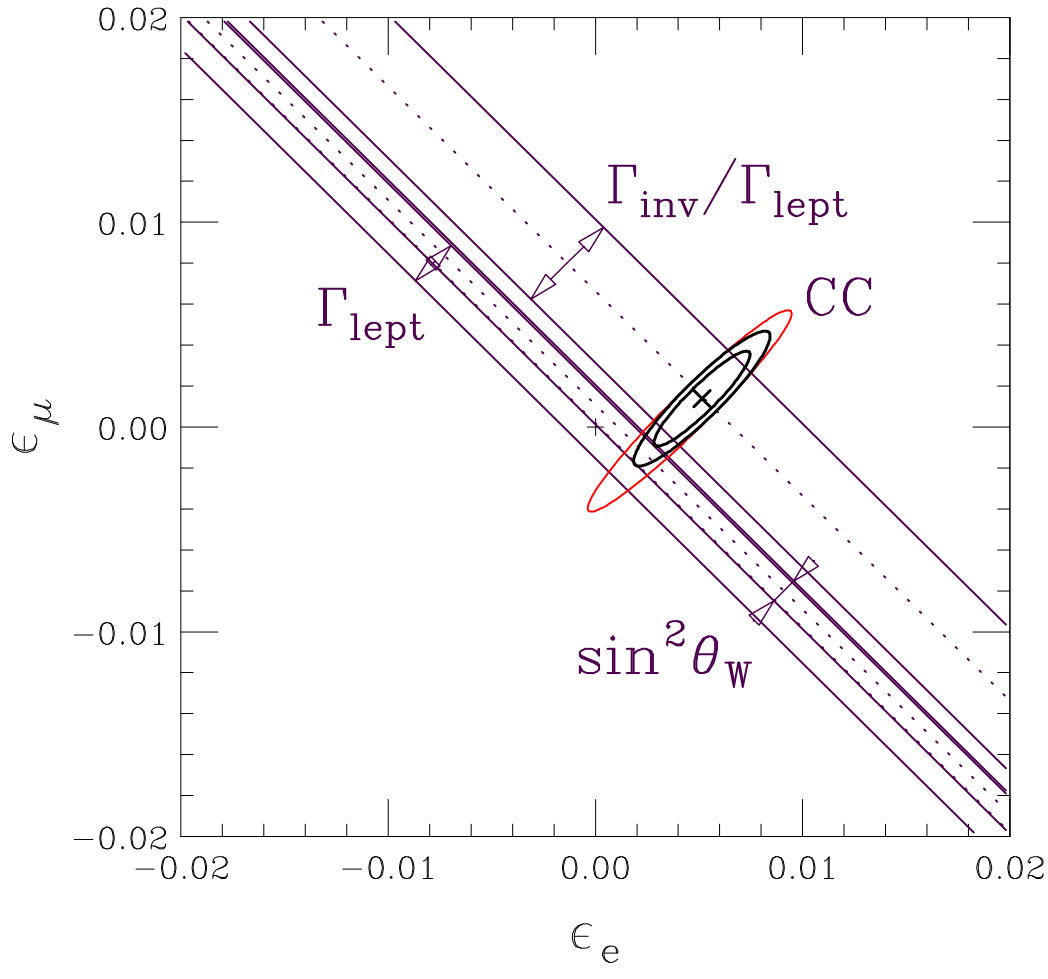
Neutrino Mixing with Gauge Singlet States

$$
\begin{aligned}
\nu &= \nu_{\rm light}\cos\theta + \nu_{\rm heavy}\sin\theta \\
\chi &= -\nu_{\rm light}\sin\theta + \nu_{\rm heavy}\cos\theta
\end{aligned}
$$

$$
\begin{aligned}
Z\nu\nu &= Z\nu_{\rm light}\nu_{\rm light}\cos^2\theta \\
&\quad + 2Z\nu_{\rm light}\nu_{\rm heavy}\sin\theta\cos\theta \\
&\quad + Z\nu_{\rm heavy}\nu_{\rm heavy}\sin^2\theta \\
W\ell\nu &= W\ell\nu_{\rm light}\cos\theta + W\ell\nu_{\rm heavy}\sin\theta
\end{aligned}
$$

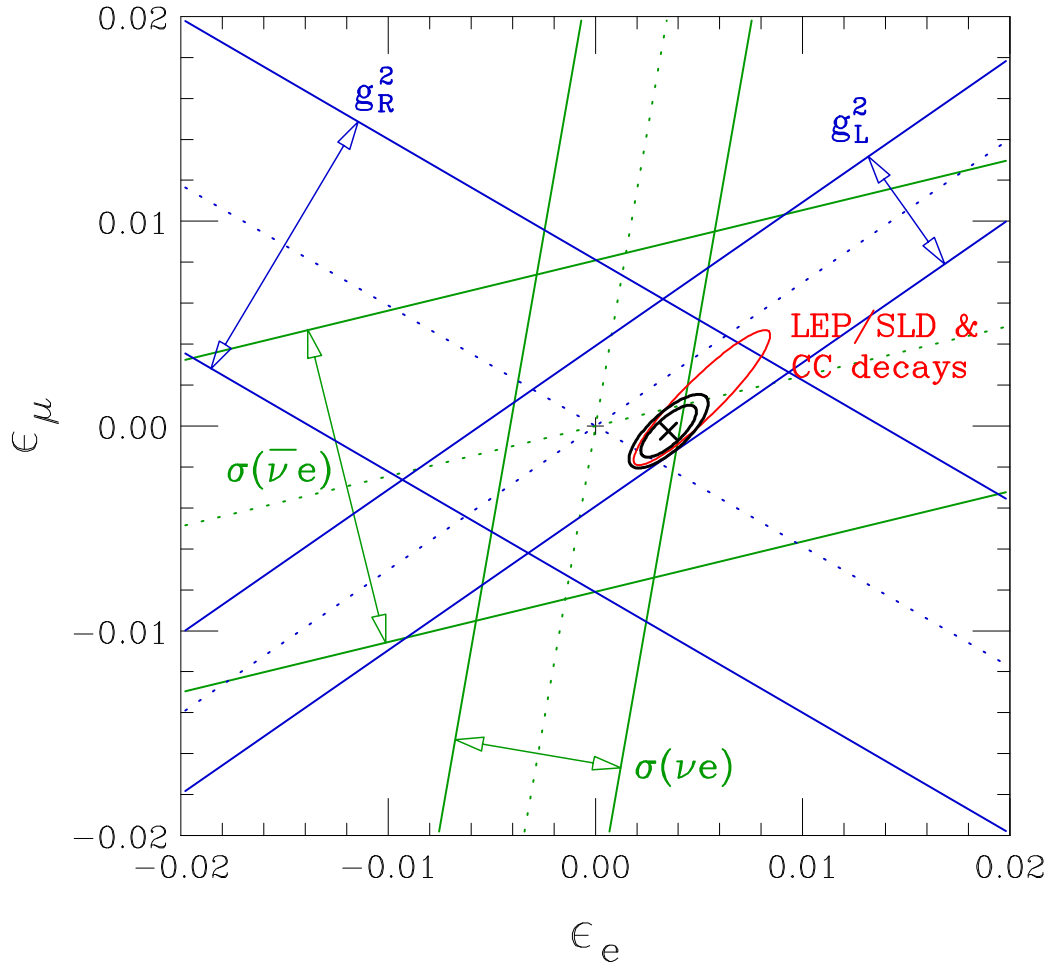
$$
Z\nu_\ell\nu_\ell\,(1-\epsilon_\ell) \qquad W\ell\nu_\ell\left(1-\frac{\epsilon_\ell}{2}\right)
$$

With LEP/SLD data:



Fit with S, T, ε_e, and ε_μ.

Potential Impact of NuSOnG:



Fit with S, T, ε_e, and ε_μ.

Conclusions:

- Bounds on CC Lepton Universality can be expected to be improved dramatically in the near future by new data (PIENU) and the analysis of already existing ones (Babar, Belle, Tevatron).
- Such improvements will place strong constraints on certain types of New Physics which will be difficult to beat even with future high statistics ν experiments. (e.g. certain R-parity violating couplings)

Conclusions continued:

- When combined with future high statistics ν experiments, they can yield very stringent bounds on other types of New Physics. (e.g. neutrino mixing with heavy gauge singlet states)
- When are the Belle and Tevatron Run 2 analyses coming out?