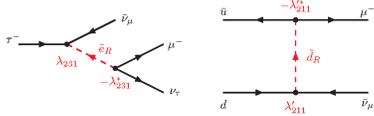


Future Constrains on and from Lepton Universality

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Various types of New Physics lead to the violation of charged current lepton universality. Example: R-parity violation

$$W_R = \frac{1}{2} \lambda_{ijk} \hat{L}_i \hat{L}_j \hat{E}_k + \lambda'_{ijk} \hat{L}_i \hat{Q}_j \hat{D}_k + \frac{1}{2} \lambda''_{ijk} \hat{U}_i \hat{D}_j \hat{D}_k$$



These contributions are constrained by:

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

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

Current 95% bounds:

$$|\lambda_{231}| < 0.07 \left(\frac{M_{\tilde{E}_R}}{100 \text{ GeV}} \right), \quad |\lambda'_{211}| < 0.06 \left(\frac{M_{\tilde{d}_R}}{100 \text{ GeV}} \right).$$

Experimental bounds on CC lepton universality are expected to improve dramatically in the near future:

- PIENU@TRIUMF aims to reduce the error on R_π by a factor of 5.
- PEN@PSI aims to reduce the error on R_π by a factor of 6.
- Combined, they will reduce the error on R_π by a factor of 8.

$$|\lambda'_{211}| < 0.06 \left(\frac{M_{\tilde{d}_R}}{100 \text{ GeV}} \right) \rightarrow 0.01 \left(\frac{M_{\tilde{d}_R}}{100 \text{ GeV}} \right)$$

- Babar is analyzing its τ data (~500 million $\tau^+\tau^-$ pairs) and aims to reduce the errors on all the one-prong branching fractions of the tau by a factor of 3.

$$|\lambda_{231}| < 0.07 \left(\frac{M_{\tilde{E}_R}}{100 \text{ GeV}} \right) \rightarrow 0.03 \left(\frac{M_{\tilde{E}_R}}{100 \text{ GeV}} \right)$$

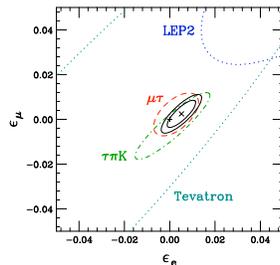
- Belle also has a large τ data set (>700 million $\tau^+\tau^-$ pairs and growing) the analysis of which can improve the limit further.

- The Tevatron Run 2 has accumulated about 4000 pb⁻¹ of data, of which only a fraction has been analyzed for lepton universality in W decays. → May confirm the 2 sigma difference between the tau and mu/e branching fractions seen by LEP2.

To quantify how the constraints will improve, allow CC couplings to be flavor dependent and perform global fit.

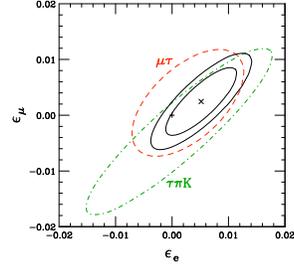
$$\mathcal{L} = \sum_{\ell=e,\mu,\tau} \frac{g_\ell}{\sqrt{2}} W_\mu^+ \bar{\nu}_\ell \gamma^\mu \left(\frac{1-\gamma_5}{2} \right) \ell^- + \text{h.c.} .$$

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

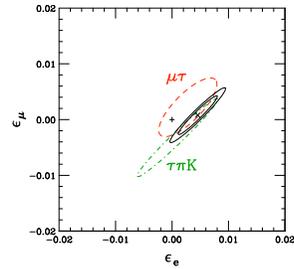


Current bounds:

Blowup of current bounds:



With expected improvement from PIENU and Belle:

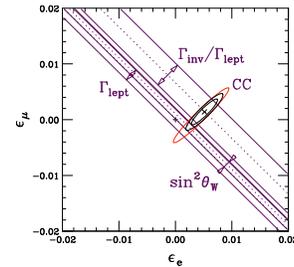


With PEN and Belle, the ellipse will shrink even further. If the ellipse shrinks off the origin as shown, it will be a clear signature of new physics.

If CC lepton universality violation is due to the mixing of neutrinos with heavy gauge singlet states, then NC observables from LEP/SLD can also be used to constrain epsilon's:

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

Fit with the epsilons and the oblique correction parameters yield:



Future high statistics neutrino scattering experiments such as NuSONG can potentially improve the limits further:

