Sixth International Workshop on

Tau Lepton Physics

18-21 September 2000 Victoria, Canada

Conference Summary

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Sixth International Workshop on

Tau Lepton Physics

18-21 September 2000 Victoria, Canada

- many interesting results
- can only summarize some highlights
- include a few interesting results not presented here
- apologize to those whose results are not mentioned
- congratulation to organizers for a successful conference!

Outline

- test of lepton universality
- measurement of Michel parameters
- measurement of hadronic decays
- direct evidence of tau neutrino
- status of neutrino oscillations
- search of neutrinoless decays
- conclusion
- Tau2002

Lepton Universality of Charge Current Couplings

- measurements of τ lifetime and leptonic branching ratios:

$$g_\tau / g_e = 1.0000 \pm 0.0023$$

$$g_\tau / g_\mu = 0.9994 \pm 0.0023$$

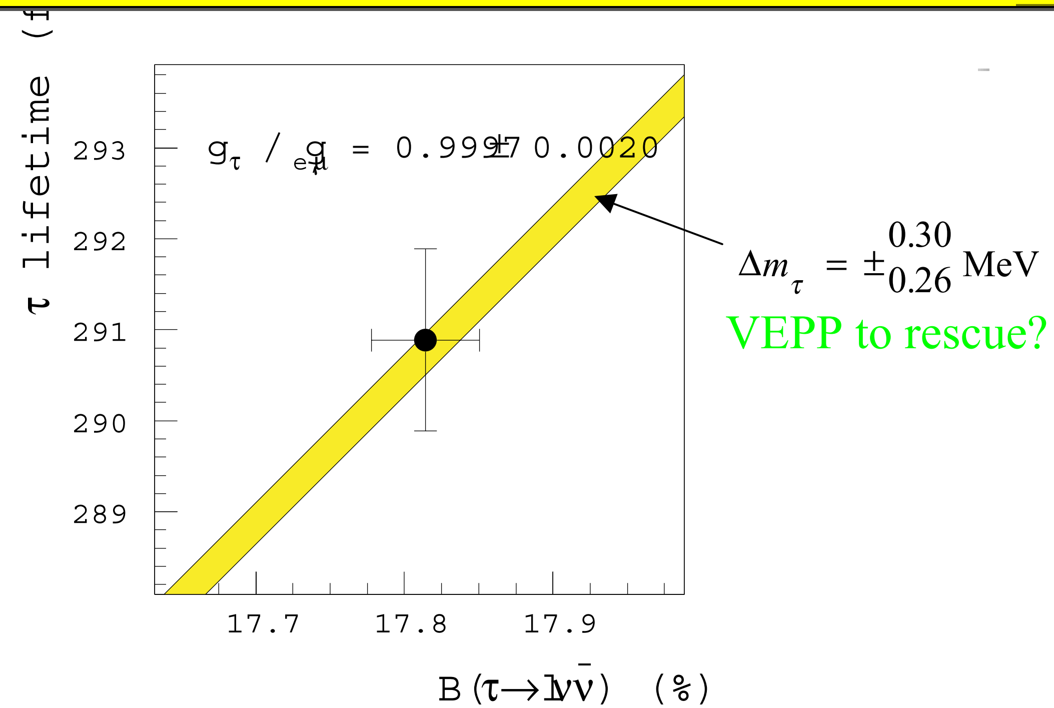
- measurements of W leptonic branching ratios:

$$g_\tau / g_e = 1.021 \pm 0.016$$

$$g_\tau / g_\mu = 1.022 \pm 0.016$$

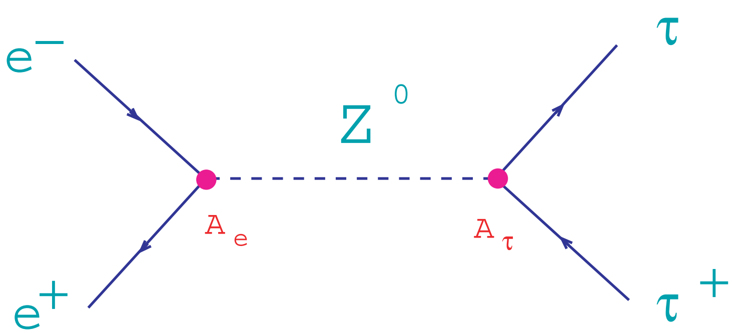
➡ lepton universality is respected from Q^2 of 4 to 6500 GeV^2

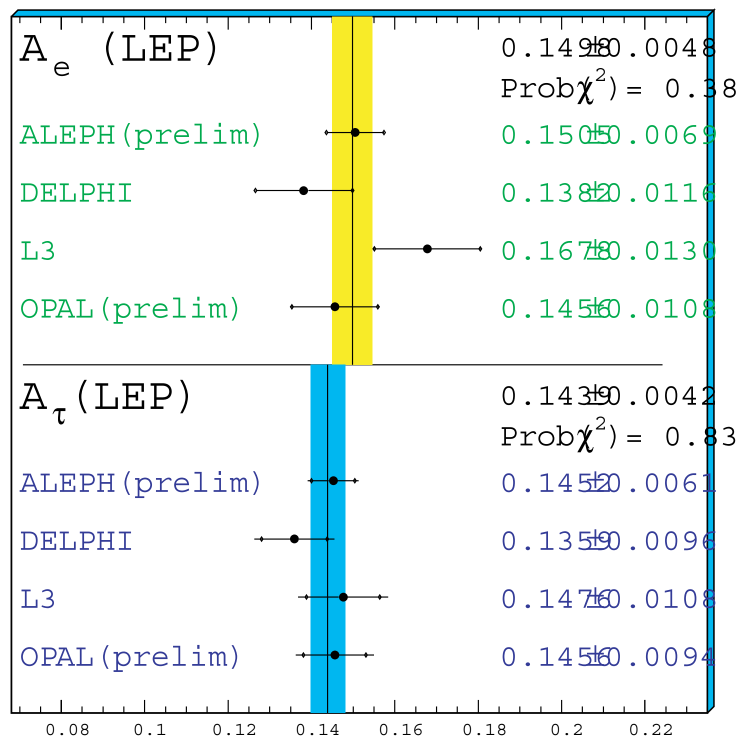
Lepton Universality of Charge Current Couplings



- universality is tested to 0.2% precision

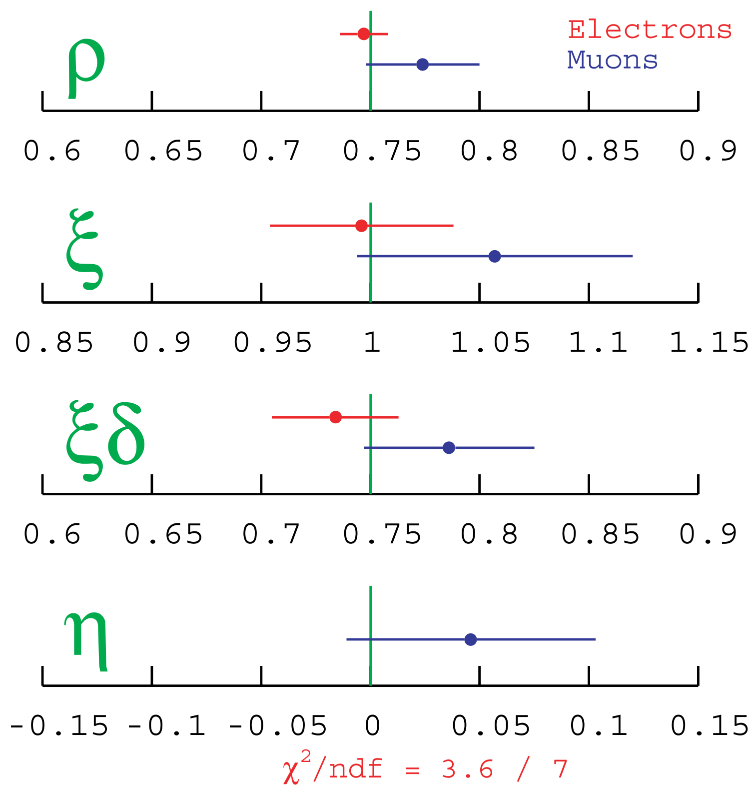
Z^0 couplings: Asymmetry Parameters





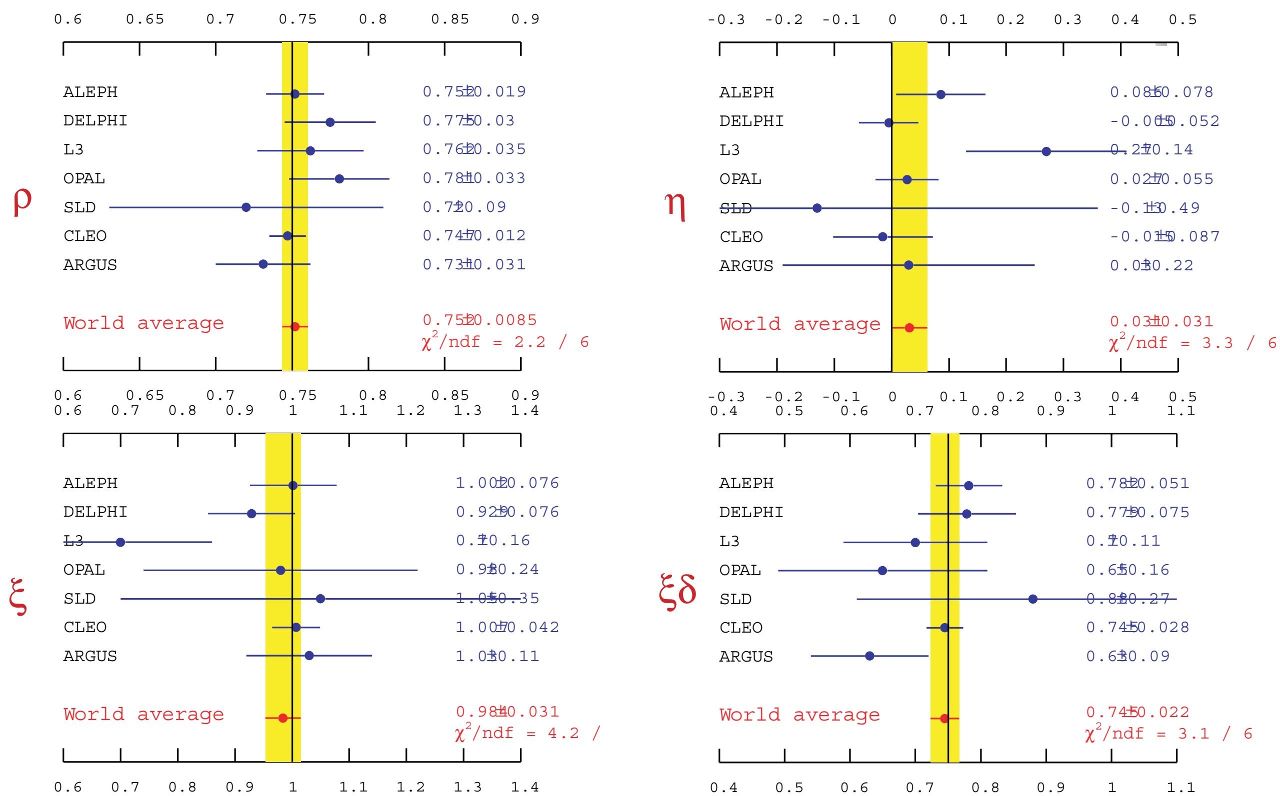
➡ universality of Z^0 couplings

Michel Parameters



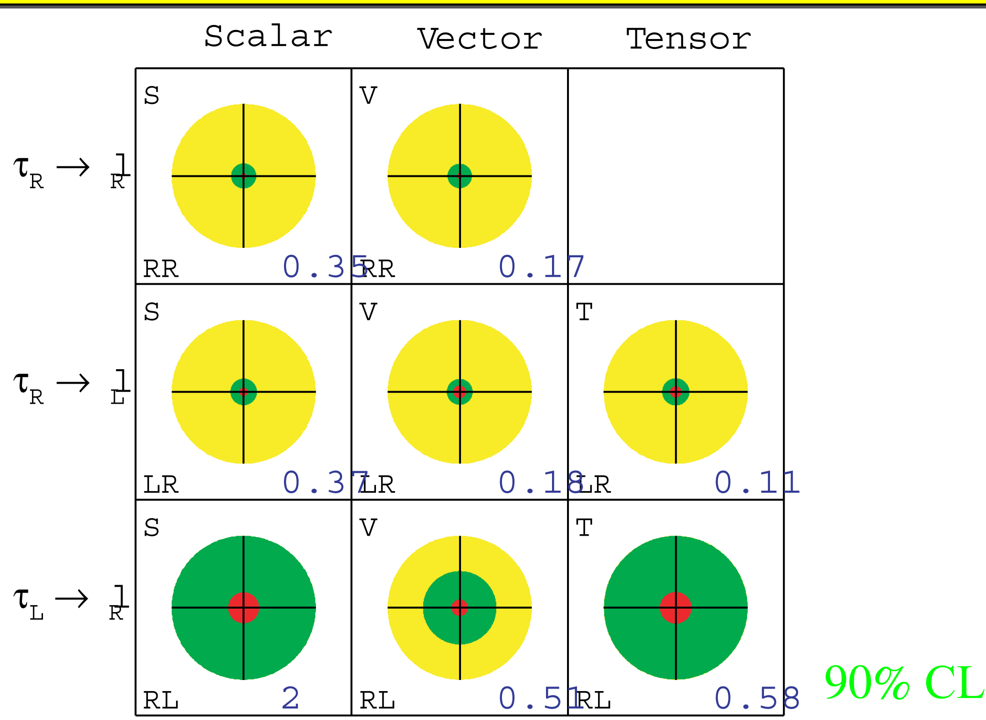
- results are consistent with lepton universality

Michel Parameters (e/μ combined)



- all parameters are consistent with SM expectations
- looking forward to results from b factories

Limits on Coupling Constants



- limits on tau are still less stringent than limits on muon
- no measurement of $\sigma(\nu_\tau e^- \rightarrow \tau^- \nu_e)$
  ➡ no limit on scalar and vector LL couplings

Test of CVC: $B(\tau^- \to \pi^- \pi^0 \nu_\tau)$

- PDG(2000): B = (25.32 ± 0.15)%
- CVC(Tau98): B = (24.52 ± 0.33)%

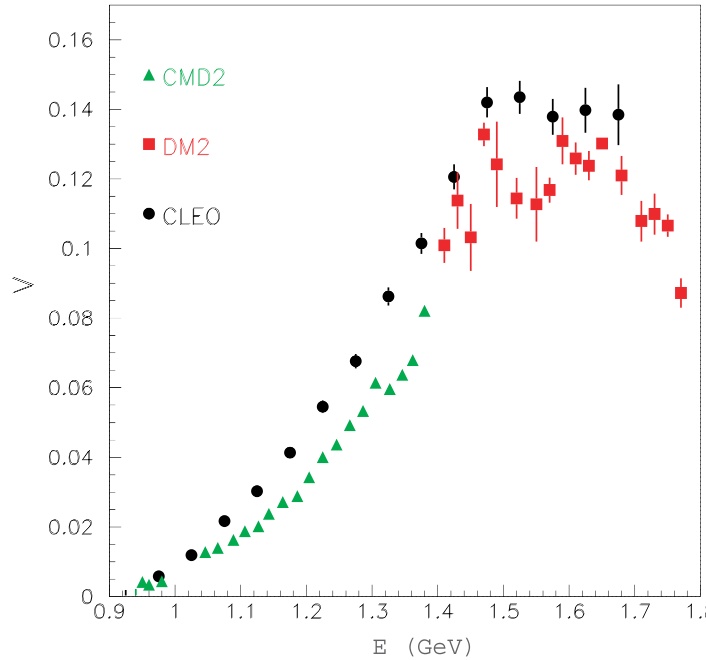
  ➡ Δ = (3.2 ± 1.5)%

- CVC(Tau2000): B = (24.94 ± 0.23)%

  ➡ Δ = (1.5 ± 1.1)%

- L3(Tau2000): B = (25.38 ± 0.18 ± 0.12)% (not included)

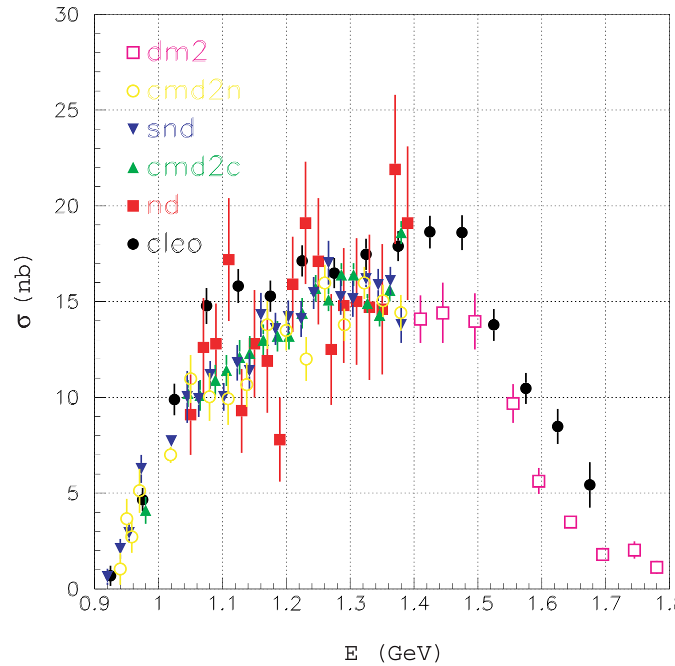
Test of CVC: $B(\tau^- \to 2\pi^-\pi^+\pi^0\nu_\tau)$



- CVC(Tau2000): B = (3.55 ± 0.20)%
- CLEO(Tau2000): B = (4.19 ± 0.10 ± 0.21)%

➡ CVC prediction is somewhat low

Test of CVC: $\tau^- \to \pi^- \omega \nu_\tau$



- CVC(Tau2000): B = (1.73 ± 0.06)%
- PDG: B = (1.92 ± 0. 07)%

➡ CVC prediction is somewhat low

CLEO: $\tau^- \to \pi^- \omega \nu_\tau$

- ρ and ρ' required for good fit:

$$M_{\rho'} = 1523 \pm 10 \text{ MeV}$$

$$\Gamma_{\rho'} = 400 \pm 35 \text{ MeV}$$

- fit from $\tau^- \to \pi^- \pi^0 \nu_\tau$:

$$M_{\rho'} = 1406 \pm 15 \text{ MeV}$$

$$\Gamma_{\rho'} = 455 \pm 41 \text{ MeV}$$

- PDG:

$$M_{\rho'} = 1465 \pm 25 \text{ MeV}$$

$$\Gamma_{\rho'} = 310 \pm 60 \text{ MeV}$$

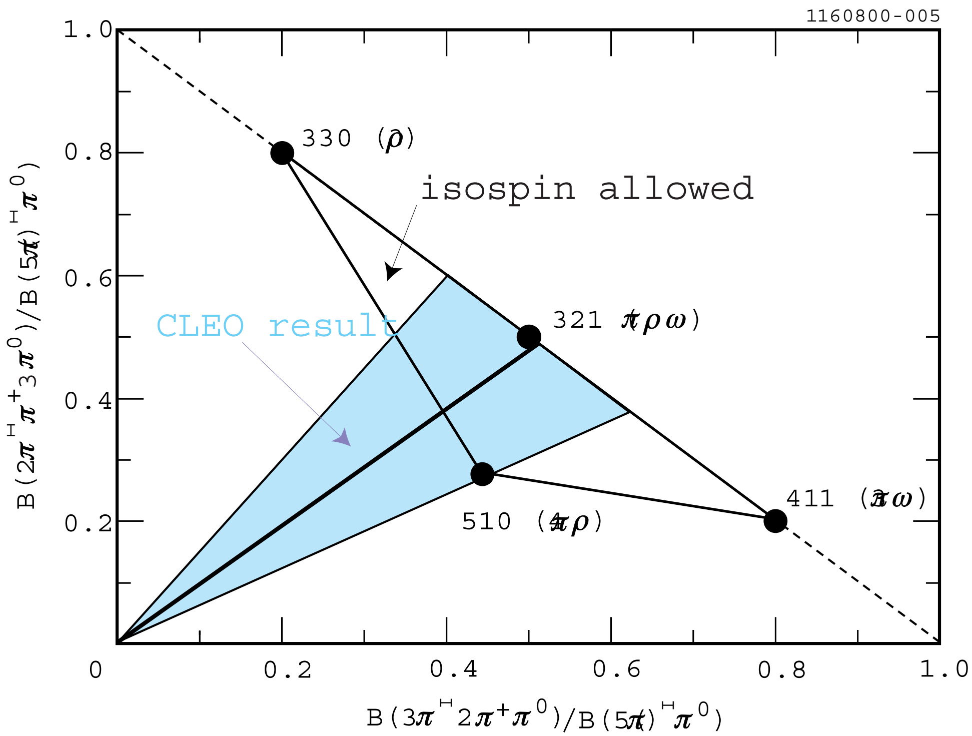
- origin of difference is unresolved

CLEO: $\tau^- \to 2\pi^-\pi^+3\pi^0\nu_\tau$ and $\tau^- \to 3\pi^-2\pi^+\pi^0\nu_\tau$

- decays are saturated by η and ω intermediate states
- $$\begin{cases} B(\tau^- \to \pi^-2\pi^0\omega\nu_\tau) = (1.5 \pm 0.4 \pm 0.3)\times 10^{-4} \\ B(\tau^- \to 2\pi^-\pi^+\omega\nu_\tau) = (1.2 \pm 0.2 \pm 0.1)\times 10^{-4} \end{cases}$$ (1st observation)
- somewhat lower than B.A. Li predictions:

$$\begin{cases} B(\tau^- \to \pi^-2\pi^0\omega\nu_\tau) = 2.16\times 10^{-4} \\ B(\tau^- \to 2\pi^-\pi^+\omega\nu_\tau) = 2.18\times 10^{-4} \end{cases}$$

Test of Isospin Symmetry



- result consistent with isospin symmetry
- looking forward to similar analysis on five-pion decays

Anomalous Magnetic Moment

	$a_\mu^{\pi\pi}(10^{-10})$
$e^+e^- \to \pi^+\pi^-$	498.8 ± 5.0
$\tau^- \to \pi^-\pi^0\nu_\tau$ (ALEPH)	502.2 ± 6.9
$\tau^- \to \pi^-\pi^0\nu_\tau$ (CLEO)	513.1 ± 5.8
combined	504.3 ± 3.3

- τ decays provide measurement of different systematic error
- ALEPH and CLEO are not inconsistent given the errors but the difference is three times the expected precision of the new g-2 experiment at BNL
- need measurements from other LEP and b-factory experiments

Strange Quark Mass

- measurements of strange quark mass (MeV) using ALEPH data:

Scale	Davier	Maltman	Lattice2000
m_τ	112 ± 23		114 ± 16
2 GeV	107 ± 22	$115.1 \pm 13.6 \pm 11.8 \pm 9.7$	110 ± 15

- Lattice 2000 result is quenched, i.e. neglects virtual quark loops:
  - ★ expect 10-15% reduction for unquenched mass

➡ good consistency in estimate of strange quark mass

- need more precise measurement of spectral function to eliminate theoretical uncertainty in de-weighting of high mass region

Direct Measurement of Electric Dipole Moment

- No CP violation in Standard Model
- CP violation interactions contribute to EDM
  - ➡ charge dependent momentum correlation
- Argus (00):

$$\mathrm{Re}(d_\tau) < 4.6 \times 10^{-16}\,\mathrm{e}\cdot\mathrm{cm} \ @\ 95\%\mathrm{CL}$$

$$\mathrm{Im}(d_\tau) < 1.8 \times 10^{-16}\,\mathrm{e}\cdot\mathrm{cm}$$

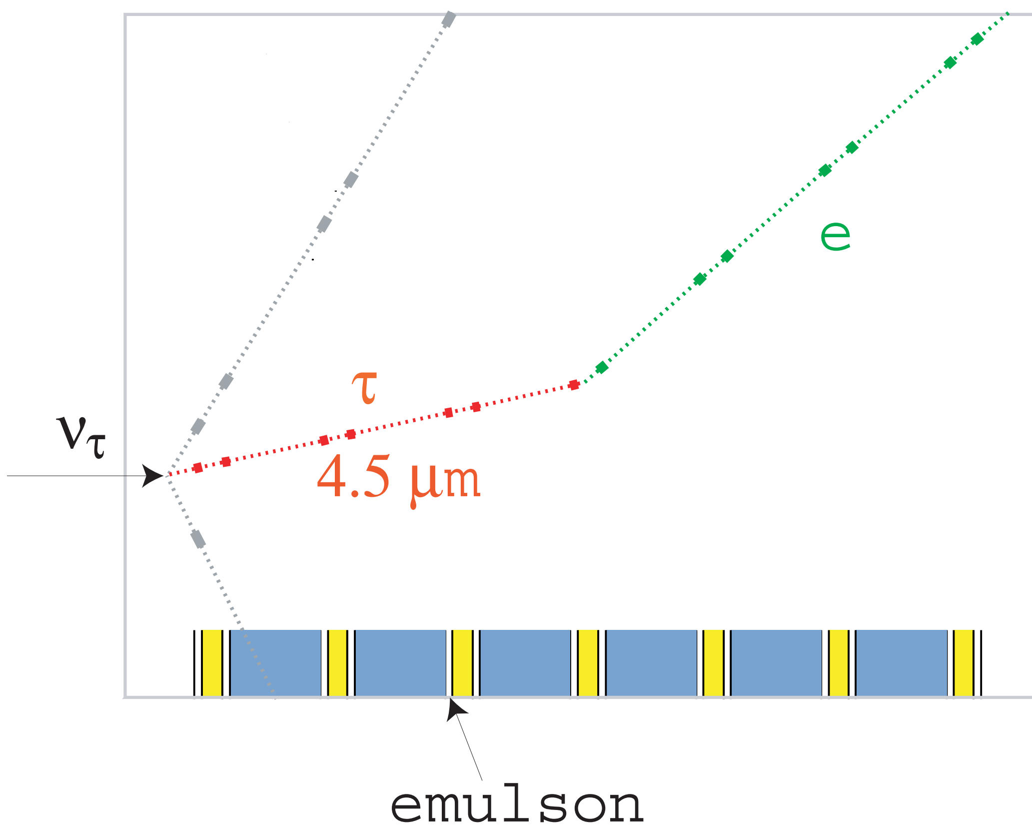
- L3 (98):

$$|d_\tau| < 3.1 \times 10^{-16}\,\mathrm{e}\cdot\mathrm{cm} \qquad @\ 90\%\mathrm{CL}$$

for zero anomalous magnetic dipole moment

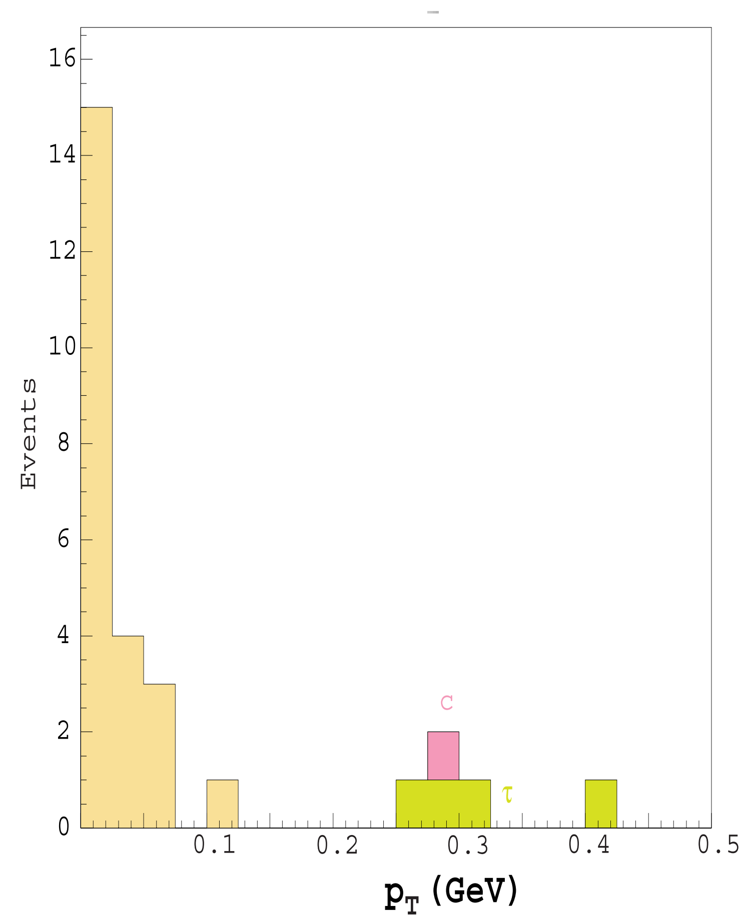
Direct Evidence for ν_τ

- DONUT find the decay $\nu_\tau N \rightarrow \tau X$



Direct Evidence for ν_τ

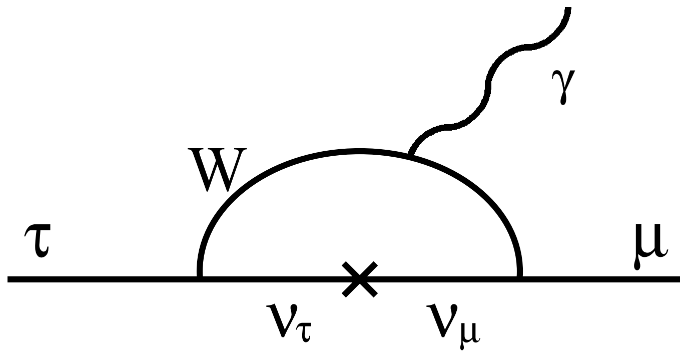
- found 4 events with long decay
- expect: 4.1 ± 1.4 events
- background: 0.41 ± 0.15 events
- background probability: 8×10^{-4}



Neutrino Oscillations

- Super-Kamiokande observed deficit of atomspheric $\bar{\nu}_\mu$
  - ➡ interpreted as $\nu_\mu \rightarrow \nu_\tau$
- MINO (2003): ν_μ disappearance
- OPERA (2005): ν_τ appearance using emulson

Neutrino Oscillations: implication on τ decay



➡ $B(\tau^- \to \mu^- \gamma) \sim 10^{-54}$

- CLEO(Tau2000): $B(\tau^- \to \mu^- \gamma) \sim 1.1 \times 10^{-6}$ @90%CL

Forbidden Decays

- 90% C.L. limits on neutrinoless decays: $\sim 10^{-6}$
- new limits (ICHEP/DPF2000):

	Belle (00)	Mark II (82)
$e^- K^0$	$< 7.7 \times 10^{-6}$	$< 1.1 \times 10^{-3}$
$\mu^- K^0$	$< 8.8 \times 10^{-6}$	$< 1.3 \times 10^{-3}$

Forbidden Decays

- Ilakovac calculated rates for model with heavy neutral leptons:

	Expt.	Theory
$e^- e^+ e^-$	$< 2.9 \times 10^{-6}$	$< 2.7 \times 10^{-6} y_{\tau e}^2$
$e^- \mu^+ \mu^-$	$< 1.8 \times 10^{-6}$	$< 1.4 \times 10^{-6} y_{\tau e}^2$
$e^- \pi^0$	$< 3.7 \times 10^{-6}$	$< 2.8 \times 10^{-6} y_{\tau e}^2$
$e^- \rho$	$< 2.0 \times 10^{-6}$	$< 2.7 \times 10^{-6} y_{\tau e}^2$
$e^- \phi$	$< 6.9 \times 10^{-6}$	$< 2.3 \times 10^{-6} y_{\tau e}^2$
$e^- K^0 \overline{K^0}$		$< 6.6 \times 10^{-7} z_{\tau e}^2$
$\mu^- K^0 \overline{K^0}$		$< 1.3 \times 10^{-7} z_{\tau \mu}^2$

Search for Forbidden Decays at Hadron Colliders

- LHCb expected sensitivity: $\sim 10^{-7}$
- need 10x improvement in sensitivity
  to be competitive with B factories at 2005
- repeat my suggestion at Tau98:
  - ★ CDF and D0 should look for forbidden tau decays

Conclusions

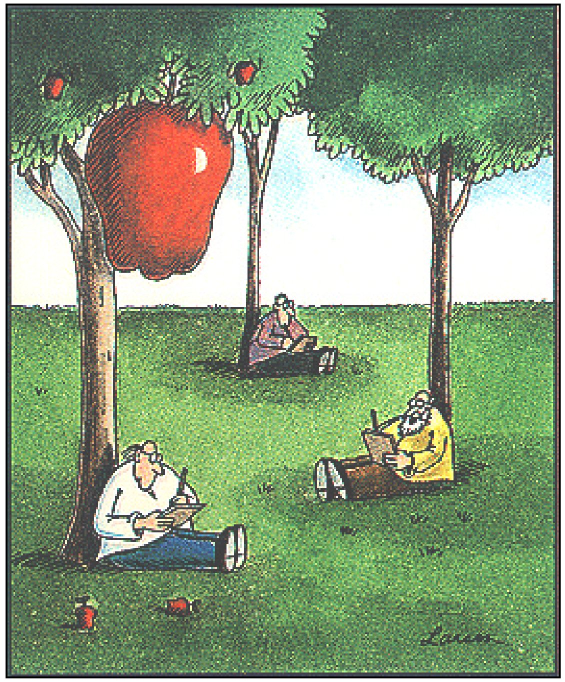
- tremendous progress in the last two years
- no hint of physics beyond the Standard Model other than $\nu_\mu \to \nu_\tau$ oscillation
- challenge of Standard Model continue...

Tau2002

- major advance on Cabibbo-suppressed decays from Babar/Bello/CLEO with kaon identification
- observation of second class current $\tau^- \rightarrow \pi^- \eta \nu_\tau$
- sensitive to $m_{\nu_\tau} \sim 10$ MeV
- surprise...

τ workers busy analyzing data with papers and pens...

This could be you!



Anything new yet, Mr. Tau?