W. Marciano
9/17/04

Tau 2004: Summary / Commentary

Outline

1.) τ Properties (see M. Roney Review)
   - i) QCD Laboratory: α_s, V_{us}, m_s


vac. pol.

2.) Muon Anomalous Magnetic Moment (see D. Hertzog Exp. A. Czarnecki Th. ReV)
   - i) Theory vs Exp. (Status)
   - ii) Future Goals
   - iii) Revenge of the Tau (Red Flag or Red Herring)
   - iv) Supersymmetry Interpretation (Compelling)

3.) Neutrino Oscillations LFV (see J. Shirai + G. Barenboim Reviews)

4.) Charged Lepton Flavor Violation

5.) Collider τ Physics

6.) Future (Concluding Remarks)

1.) Tau Properties (M. Roney)

New Babar Result $\tau_{tau} = 289.4 \pm 0.91 \pm 0.90$ fs (smaller) } A. Lusiani

World Ave 290.11 ± 0.79 fs $\xrightarrow{\text{eventually}}$ ± 0.4 fs

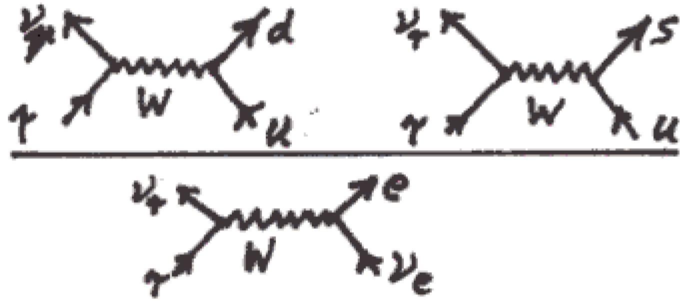
Babar & Belle in the τ business (see also A. Andreazza DELPHI)
$\tau_{tau} = 293.90 \pm 2.3 \pm 2.1$ fs

Old Results: $BR(\tau \to e\nu\bar{\nu}(\gamma)) = 17.824(52)\%$

$BR(\tau \to \mu\nu\bar{\nu}(\gamma)) = 17.331(48)\%$

$m_\tau = 1777.03^{+0.30}_{-0.26}$ MeV BES (Future A. Shamov)

Inclusive: } QCD Laboratory



$$R_\tau \equiv \frac{\Gamma(\tau \to \nu_\tau + \text{hadrons})}{\Gamma(\tau \to e\nu\bar{\nu}(\gamma))} = R_{\tau,V} + R_{\tau,A} + R_{\tau,S}$$

$$R_\tau = 5.6258 \left(\frac{2.9011\,\text{fs}}{\tau_{tau}}\right)\left(\frac{1777\,\text{MeV}}{m_\tau}\right)^5 - 1.9726$$

$$B(\tau \to e\nu\bar{\nu}(\gamma)) = 1.0282\, B(\tau \to \mu\nu\bar{\nu}(\gamma)) = (1.9726 + R_\tau)^{-1}$$

$R_\tau = 3.653 \pm 0.016$; 3.638 ± 0.017; 3.639 ± 0.015 } good agreement

(τ_{tau}, m_τ; $B(\tau \to e)$; $B(\tau \to \mu)$)

Correspond to $\tau_{tau} = 2.909$ fs — better without BaBar 2.906(10) fs WA

$$R_\tau = 3(1+\delta)\left\{1 + \frac{\alpha_s(m_\tau)}{\pi} + 5.2023\left(\frac{\alpha_s(m_\tau)}{\pi}\right)^2 + 26.366\left(\frac{\alpha_s(m_\tau)}{\pi}\right)^3 + \dots\right\}$$

QCD Pert. (see K. Chetyrkin talk)

$R_\tau^{Ave} = 3.643(9) \rightarrow \alpha_s(m_Z) = \underline{0.1202(3)(20)}$ syst.

SUSY SU(5) $\rightarrow m_{susy} \simeq 4$ TeV too high ($\sin^2\theta_W(m_Z)_{\overline{MS}} = 0.231$)

$R_{\tau,V+A}$ vs $R_{\tau,s}$ $\rightarrow$ $|V_{us}| = 0.2196$ $\quad m_s(2\text{GeV}) = 76$ MeV

(Moments)

J. Prades talk

see also K. Maltman, K. Chetyrkin (Issues)
F. Salvatore, D. Dedovich
W. Mader, M. Davier, J. Dubosq
Tauola (Z. Was)

Back in 2002 $\quad m_s(2\text{GeV}) \simeq 116^{+20}_{-25}$ MeV $\quad$ (A. Pich)

Lattice (Aubin 04) $\rightarrow m_s(2\text{GeV}) \simeq 76 \pm 8$ MeV

New Value of $m_s(2\text{GeV})$ from $R_{\tau,s}$ moments better?

However, New K_{e3} Results BNL & FNAL (Revolution)

$|V_{us}| = 0.2259(23)$

$|V_{ud}| = 0.9740(5) \rightarrow |V_{us}| = 0.2265(22)$ (unitarity) $\Big\}$ very good agreement — Old Problem Solved

$|V_{ud}|^2 + |V_{us}|^2 = 0.9997(18)$

Suggests: $m_s(2\,\text{GeV}) \to \sim 120$ MeV (Back Up)

or

$\tau \to \nu_\tau K + X$ will change (likely)

Opportunity for Belle + BaBar K/π separation

Also, $\tau^- \to \nu_\tau K^-$ likely larger than Exp.

Exclusive Hadronic Decays (see J. Portoles) Z. Was Tauola

$\tau \to \nu_\tau \pi^-, \nu_\tau K^- \to f_\pi, f_K, |V_{us}|/|V_{ud}|$

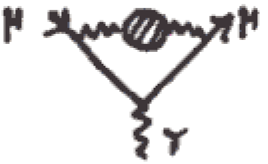
* $\tau \to \nu_\tau \pi^- \pi^0 \to$ spectral function, $m_{\rho^\pm}$, $\Gamma_{\rho^\pm}$, $\rho', \rho'' \ldots$

vs

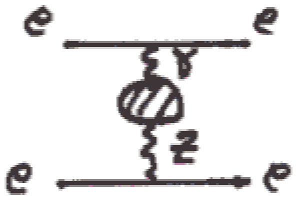
$e^+e^- \to \pi^+\pi^-$ (isospin corrections, QED, $m_d - m_u$)

Dispersion Rel. 

$\alpha = 1/137 \to 1/128 \to m_{Higgs}$



$a_\mu^{hadronic}$



$\sin^2\theta_W(q^2=0) \simeq 1.03 \sin^2\theta_W(m_Z^2)$

$\tau \to \nu_\tau 3\pi \to A_1$ properties, Weinberg sum rules

$\tau \to \nu_\tau 4\pi \to a_\mu^{had.}$ (New Babar: M. Davier)

$\tau \to \nu_\tau K + X \to |V_{us}|, m_s$

⋮

$\tau \to \nu_\tau KK\pi$ WZ term (K. Hayasaka)

Hadronic τ Decays test: χPT, Resonance, Large N_c (J. Prades)

Right now primary focus $\tau \to \nu_\tau \pi^- \pi^0$, $e^+e^- \to \pi^+\pi^-$ $I=1$ } $a_\mu^{hadronic}$

Isospin Violating Effects
$m_{\pi^\pm} - m_{\pi^0}$, $\pi^+\pi^-$ QED , $m_{\rho^\pm} - m_{\rho^0}$, $\Gamma_{\rho^\pm} - \Gamma_{\rho^0}$, $\omega\rho$, $\gamma\rho$..
Pioneered by Davier + Höcker (slides)

Comment: Sum of QED effects ~ 0 (small!)
Spurious effects man made (see $g_\mu - 2$)

2.) Muon Anomalous Magnetic Moment $a_\mu = g_\mu - 2/2$

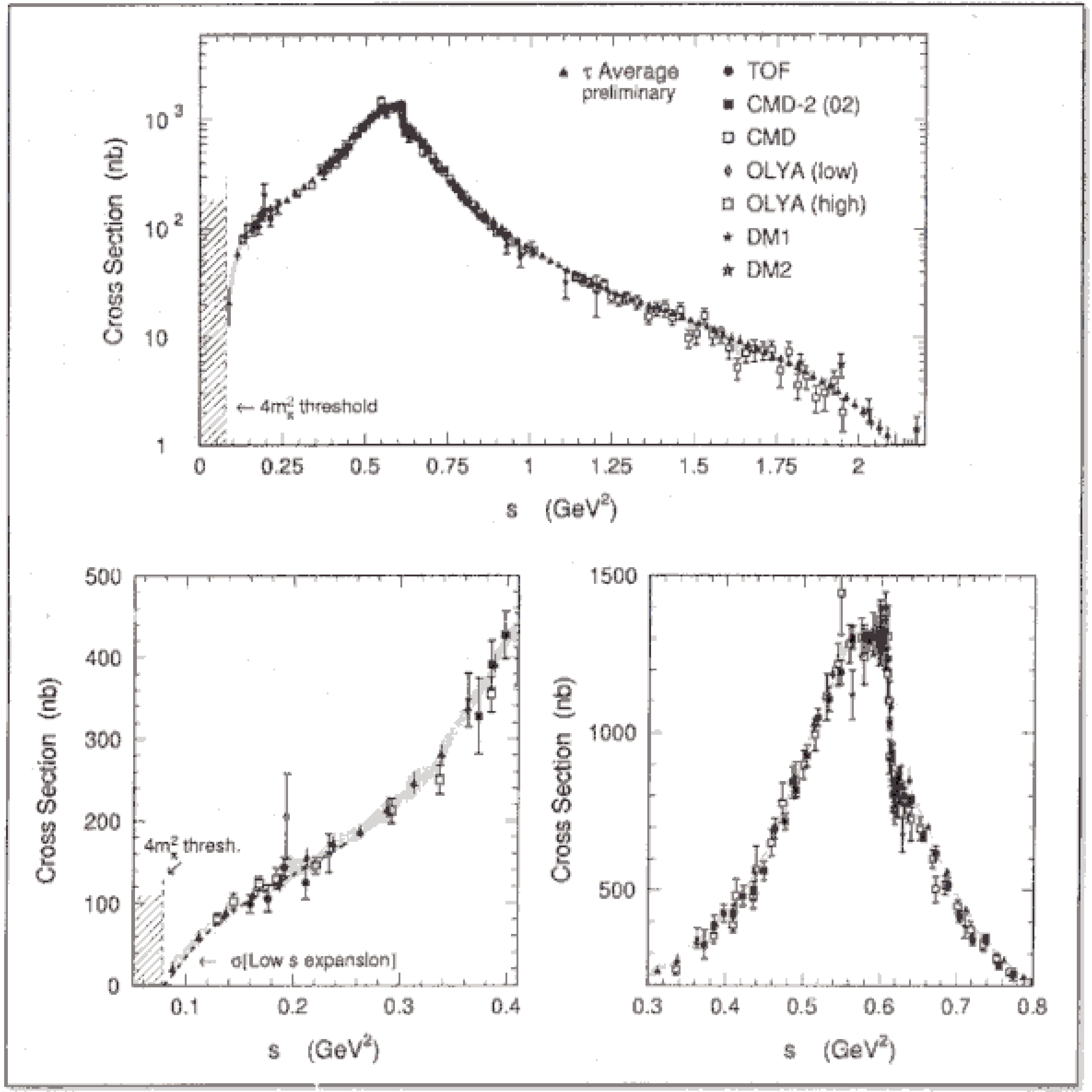
BNL E821 Completed $a_{\mu^+}^{exp} = 116592080(58) \times 10^{-11}$
factor 14 improvement over CERN (1970s) } D. Hertzog

a_τ^{exp} (SM) not observable (Resentment) (W. Lohmann talk)

$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{Had.}$ Much Work by Many

talks A. Czarnecki, T. Kinoshita, J. Kühn, S. Eidelman,
D. Leone, M. Davier, K. Hagiwara

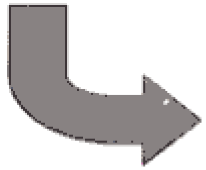
Comparing $e^+e^- \rightarrow \pi^+\pi^-$ and $\tau \rightarrow \pi^-\pi^0\nu_\tau$



Correct τ data for missing ρ-ω mixing (taken from BW fit) and all other SU(2)-breaking sources

Remarkable agreement

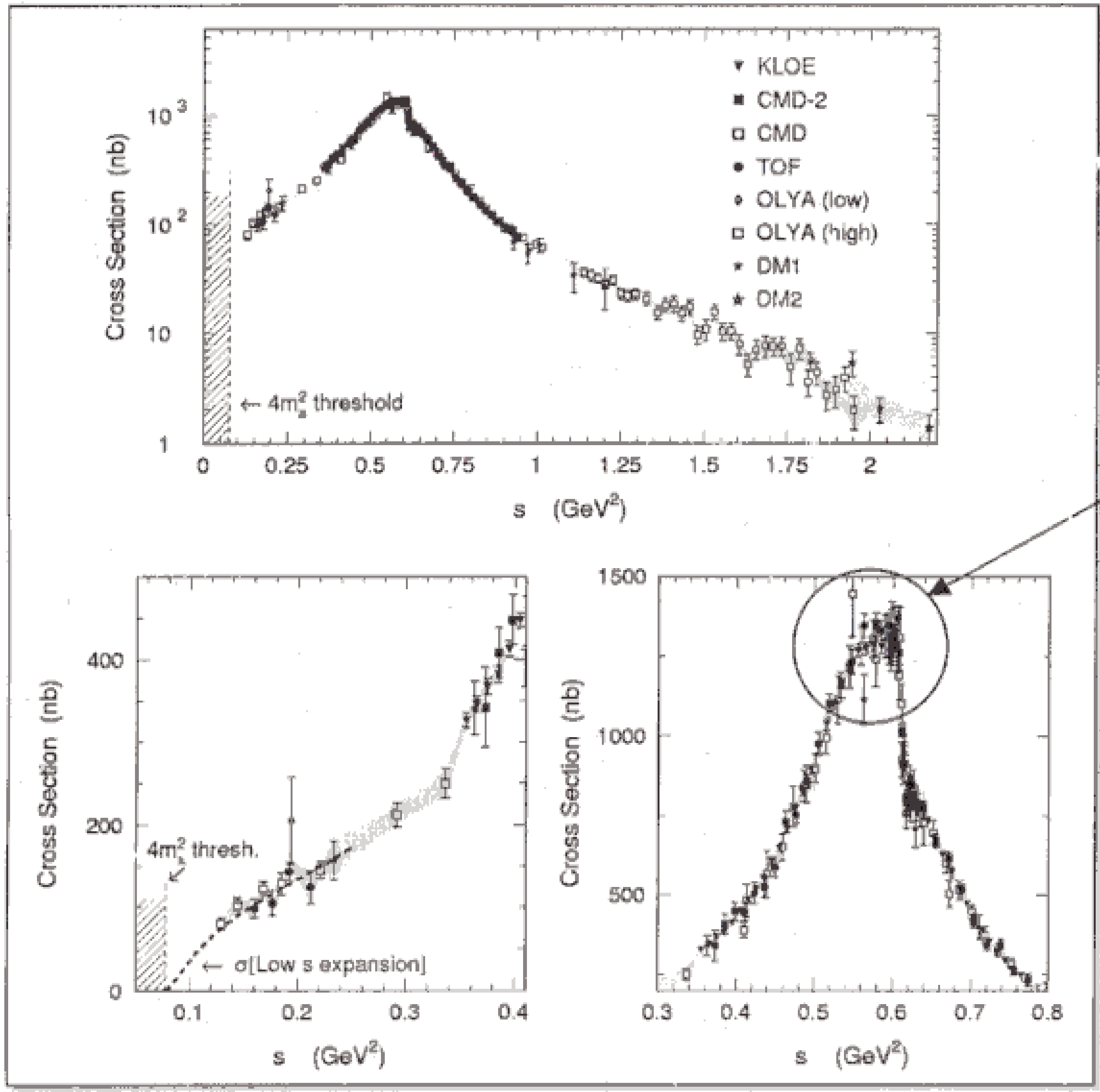
But: not good enough...



...

New Precise $e^+e^- \to \pi^+\pi^-$ Data from KLOE

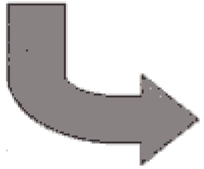
Using the Radiative Return



KLOE Collaboration, hep-ex/0407048

Overall: fair agreement with CMD-2

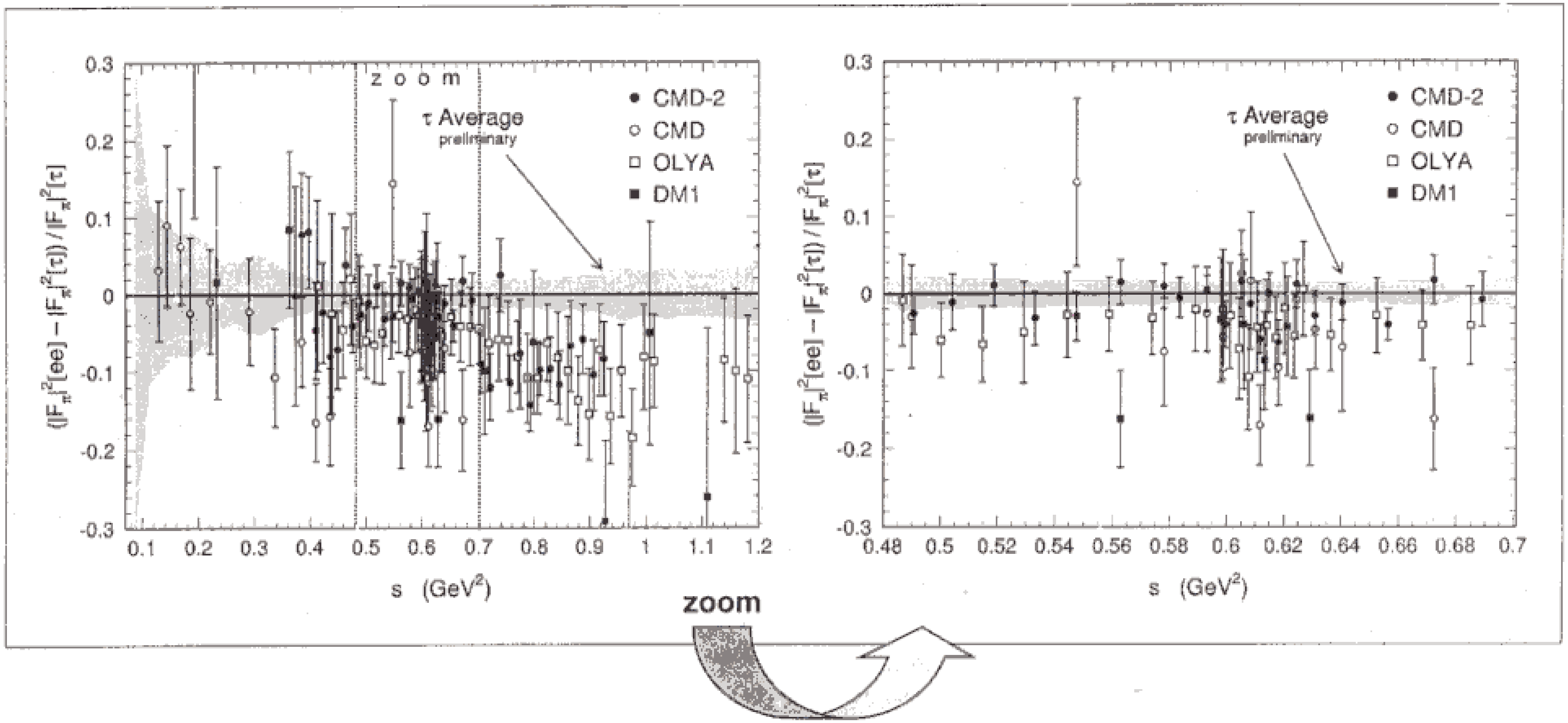
Some discrepancy on ρ peak and above ...



...

The Problem

Relative difference between τ and e^+e^- data:



SU(2) Breaking

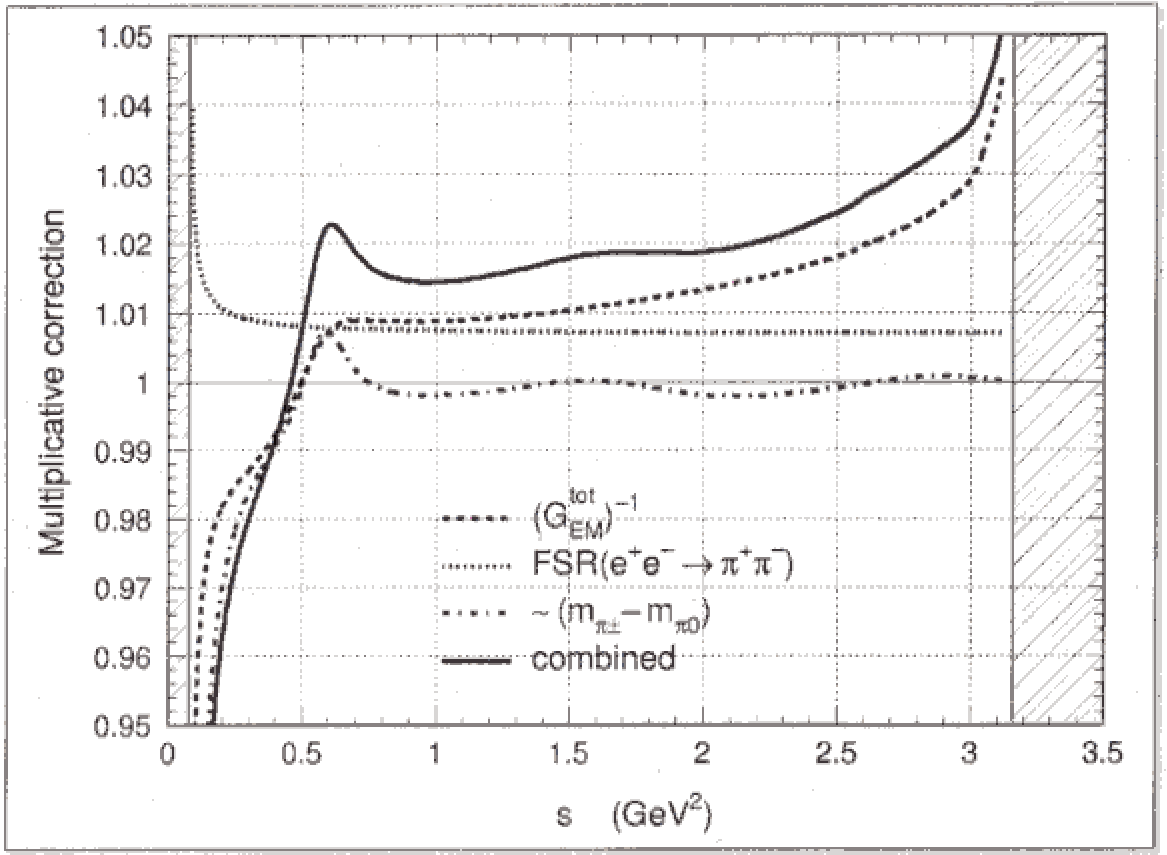
Electromagnetism does not respect isospin and hence we have to consider isospin breaking when dealing with an experimental precision of 0.5%

Corrections for SU(2) breaking applied to τ data for dominant $\pi^+\pi^-$ contribution:

- Electroweak radiative corrections:
  - dominant contribution from short distance correction S_{EW} to effective 4-fermion coupling $\propto (1 + 3\alpha(m_\tau)/4\pi)(1+2\langle Q\rangle)\log(M_Z/m_\tau)$ — Marciano-Sirlin' 88
  - subleading corrections calculated and small — Braaten-Li' 90
  - long distance radiative correction $G_{EM}(s)$ calculated — Cirigliano-Ecker-Neufeld' 02
  [add FSR to the bare cross section in order to obtain $\pi^-\pi^+(\gamma)$]
- Charged/neutral mass splitting: — Alemany-Davier-Höcker' 97, Czyż-Kühn' 01
  - $m_{\pi^-} \neq m_{\pi^0}$ leads to phase space (cross sec.) and width (FF) corrections
  - ρ-ω mixing (EM $\omega \to \pi^-\pi^+$ decay) corrected using FF model
  - ⇒ intrinsic $m_{\rho^-} \neq m_{\rho^0}$ and $\Gamma_{\rho^-} \neq \Gamma_{\rho^0}$ [not corrected so far – can be measured]
- Electromagnetic decays, like: $\rho \to \pi\pi\gamma$, $\rho \to \pi\gamma$, $\rho \to \eta\gamma$, $\rho \to l^+l^-$
- Quark mass difference $m_u \neq m_d$ generating "second class currents" (negligible)

Mass Dependence of SU(2) Breaking

Multiplicative SU(2) corrections applied to $\tau^- \to \pi^- \pi^0 \nu_\tau$ spectral function:



not shown: short distance correction

Only β^3 and EW short-distance corrections applied to 4π spectral functions

$$a_\mu^{QED} = \frac{\alpha}{2\pi} + 0.765857376\left(\frac{\alpha}{\pi}\right)^2 + 24.05050898\left(\frac{\alpha}{\pi}\right)^3 + 131.0\left(\frac{\alpha}{\pi}\right)^4 + \underbrace{677(40)}\left(\frac{\alpha}{\pi}\right)^5 + \cdots$$

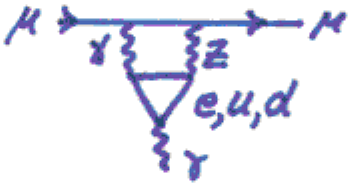
T. Kinoshita (New) was 930(170)

using $\alpha^{-1}(a_e) = 137.035999890(1.5)(3.1)(50)$ New

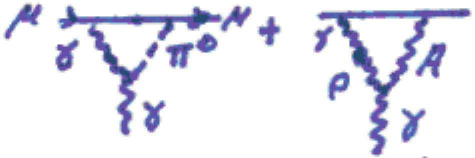
$$\underline{a_\mu^{QED} = 116584719 \times 10^{-11}} \pm 2 \times 10^{-11} \quad (\alpha \text{ value})$$

$$a_\mu^{EW}(2^+\text{loops}) = \underline{154(1)(2) \times 10^{-11}}$$

includes



A. Czarnecki Discussion



Very Precise ±10% } Czarnecki, Vainshtein, W.M.

→

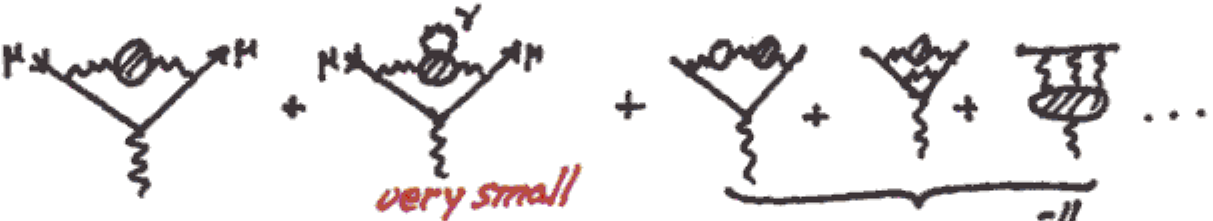
Unc. $\gtrsim 10\%$ at best

very hard to do better than

$\pm 15(25) \times 10^{-11}$

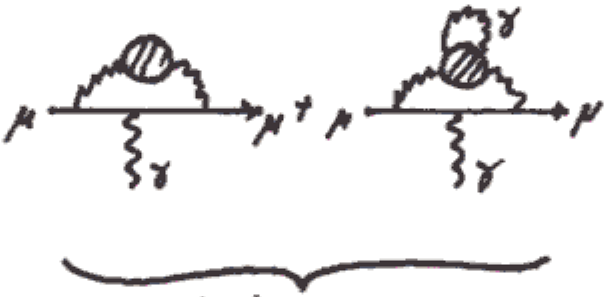
Ultimate Limitation for $a_\mu^{had.}$

a_μ^{had}



$e^+e^- \to$ hadrons

$+ 22(35) \times 10^{-11}$



$e^+e^- \to hadrons + \gamma$ M. Davier talk
CMD II, KLOE ...
see also K. Hagiwara talk

$$a_\mu^{had}(vac.pol) = 6934(53)(35)_{RC} \times 10^{-11}$$ (M. Davier)

↑ large!

$$a_\mu^{SM} = 116591829(53)(35)(35)(3) \times 10^{-11}$$
$$a_\mu^{exp} = 116592080(58) \times 10^{-11}$$
} well matched

$$\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} = \underline{251(93) \times 10^{-11}}$$ 2.7 sigma deviation

if new BaBar $e^+e^- \to 2\pi^+2\pi^-$ used (M. Davier talk)

$$\Delta a_\mu = 265(93) \times 10^{-11} \to 2.85 \text{ sigma}$$

Very large deviation, remember $a_\mu^{EW}(W,Z) = 154 \times 10^{-11}$

<u>What is it?</u>

<u>Can we improve significance?</u>

2) <u>Future Goals</u>

BNL E969 (Funding) $\Delta a_\mu^{exp} \simeq \pm 23 \times 10^{-11}$

Factor 2.5 improvement 21 wk run + upgrades (10× data rate)

Possible SM Improvement:

$$\Delta a_\mu^{SM} = \pm 30 \pm 20 \pm 15 \pm 3 \times 10^{-11} = \pm 39 \times 10^{-11}$$ } well matched

$$a_\mu^{exp} - a_\mu^{SM} \longrightarrow \pm 45 \times 10^{-11}$$

If Central Value unchanged $2.7\sigma \rightarrow 5.6\sigma$ (~2009)

Well Matched to LHC (Physics + Time)

New $e^+e^- \to$ hadrons: CMD II S. Eidelman talk
*Radiative Return J. Kühn talk
KLOE, BaBar, Belle D. Leone, M. Davier
... B. Shwartz
Lattice ?

iii) Revenge of the Tau (Whose Workshop is this?)

$\tau \to \nu_\tau \pi^- \pi^0$ + isospin corr. vs $e^+e^- \to \pi^+\pi^-$

difference $+137 \times 10^{-11}$ (M. Davier)

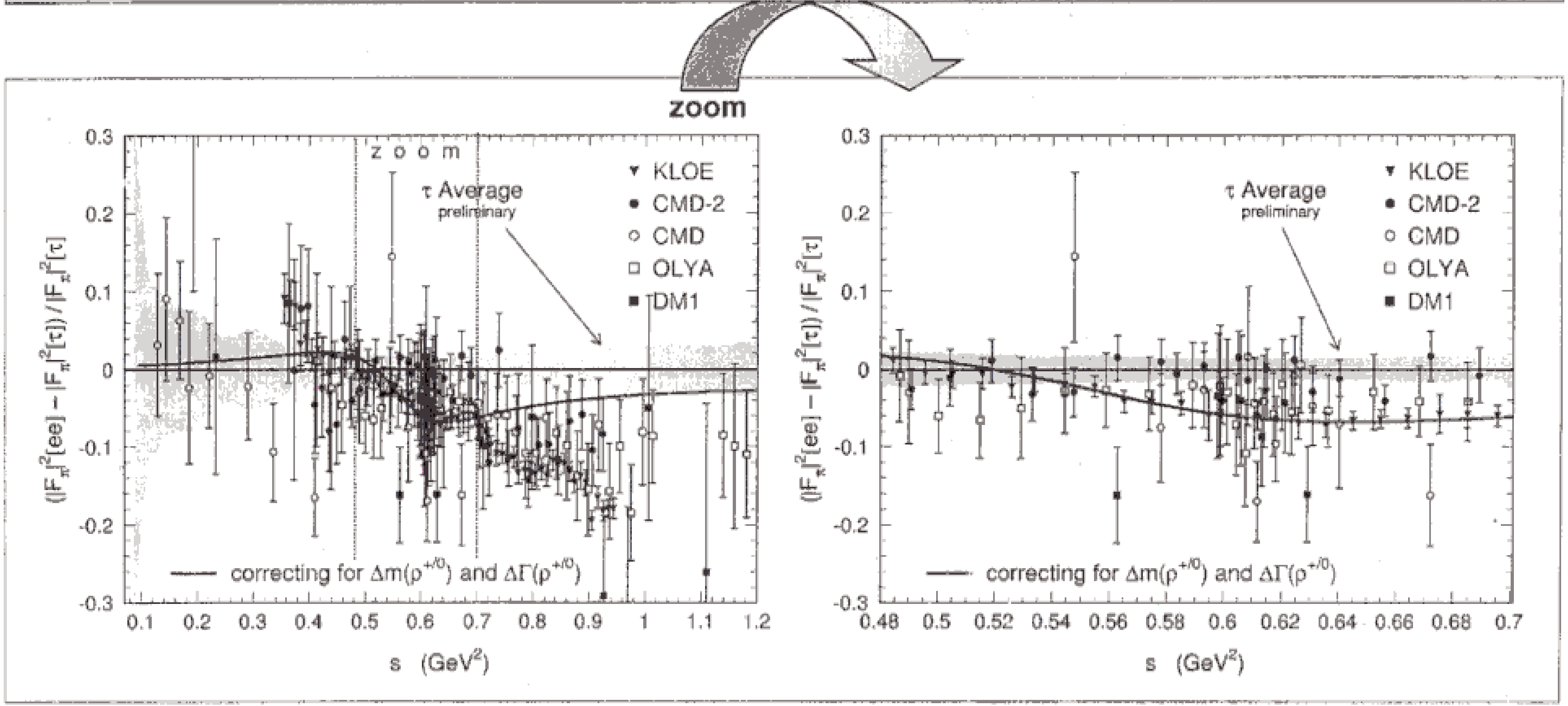
$$a_\mu^{exp} - a_\mu^{SM} = 114(89) \times 10^{-11}$$ Not Very Significant

Isospin Violating Corrections at issue

$m_{\rho^\pm} - m_{\rho^0} = 0$
$\Gamma_{\rho^\pm} - \Gamma_{\rho^0} = 0.8\,\text{MeV}$ } Assumed data $\to$ $m_{\rho^\pm} - m_{\rho^0} \simeq 2.3\,\text{MeV}$
$\Gamma_{\rho^\pm} - \Gamma_{\rho^0} \simeq -2.9\,\text{MeV}$

The Problem (revisited)

Relative difference between τ and e^+e^- data:



Correction for $\rho^{\pm}-\rho^{0}$ mass (~2.3 ± 0.8 MeV) and width (~2.9 MeV) splitting applied

Davier, hep-ex/0312064

Jegerlehner, hep-ph/0312372

Results: the Compilation (including KLOE)

Contributions to a_μ^{had} [in 10^{-10}] from the different energy domains:

Modes	Energy [GeV]	e^+e^-	
Low s expansion	$2m_\pi - 0.5$	$58.0 \pm 1.7 \pm 1.2_{rad}$	$56.0 \pm 1.6 \pm 0.3_{SU(2)}$
[$\pi^+\pi^-$ (DEHZ'03)]	$2m_\pi - 1.8$	[$450.2 \pm 4.9 \pm 1.6_{rad}$]	$464.0 \pm 3.0 \pm 2.3_{SU(2)}$
$\pi^+\pi^-$ (incl. KLOE)	$2m_\pi - 1.8$	$448.3 \pm 4.1 \pm 1.6_{rad}$	–
$\pi^+\pi^- 2\pi^0$	$2m_\pi - 1.8$	$16.8 \pm 1.3 \pm 0.2_{rad}$	$21.4 \pm 1.3 \pm 0.6_{SU(2)}$
$2\pi^+ 2\pi^-$	$2m_\pi - 1.8$	$14.2 \pm 0.9 \pm 0.2_{rad}$	$12.3 \pm 1.0 \pm 0.4_{SU(2)}$
ω (782)	0.3 – 0.81	$38.0 \pm 1.0 \pm 0.3_{rad}$	–
ϕ (1020)	1.0 – 1.055	$35.7 \pm 0.8 \pm 0.2_{rad}$	–
Other exclusive	$2m_\pi - 1.8$	$24.0 \pm 1.5 \pm 0.3_{rad}$	–
J/ψ, ψ(2S)	3.08 – 3.11	$7.4 \pm 0.4 \pm 0.0_{rad}$	–
R [QCD]	1.8 – 3.7	$33.9 \pm 0.5 \pm 0.0_{rad}$	–
R [data]	3.7 – 5.0	$7.2 \pm 0.3 \pm 0.0_{rad}$	–
R [QCD]	5.0 – ∞	$9.9 \pm 0.2_{theo}$	–
Sum (incl. KLOE)	$2m_\pi - \infty$	$693.4 \pm 5.3 \pm 3.5_{rad}$	$711.0 \pm 5.0 \pm 0.8_{rad} \pm 2.8_{SU(2)}$

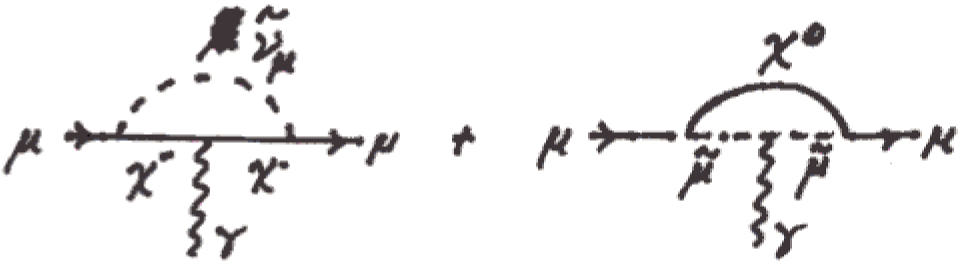
$\rho^{\pm} - \rho^{0}$ mass + width shifts → τ e^+e^- accord in a_μ^{SM}

Some difference remains at HE

Can we make the shifts?

$\Gamma_{\rho^\pm} - \Gamma_{\rho^0}$ being calculated (Result Next Month)

iv) Supersymmetry Interpretation



mixing masses

$$a_\mu^{susy} \simeq (\mathrm{sgn}\,\mu = +/-) \times 130 \times 10^{-11} \tan\beta \left(\frac{100\,\mathrm{GeV}}{m_{susy}}\right)^2$$ Large

Enhanced by $\tan\beta \simeq 3$-40 (Chiral Changing)

$a_\mu^{exp} - a_\mu^{SM} = 251(93) \times 10^{-11} = a_\mu^{susy}$ Natural Explanation

→ $\mathrm{sgn}\,\mu = +$ (Eliminates ~½ Models)

$m_{susy} \simeq 72\sqrt{\tan\beta}$ GeV $\simeq$ 100-500 GeV

Specific Models → Specific Predictions

Dark Matter (Detectable)

LHC (Easy)

edm, LFV $\tan\beta$ enhanced LR transitions

Conclusions and Perspectives

M. Davier

- Hadronic vacuum polarization is dominant systematics for SM prediction of the muon $g-2$
- New data from KLOE in fair agreement with CMD-2 with a (mostly) independent technique
- Discrepancy with τ data (ALEPH & CLEO & OPAL) confirmed
- Until τ/e^+e^- puzzle is solved, we use only e^+e^- data in dispersion integral
- We find that the SM prediction differs by 2.7 σ [e^+e^-] from experiment (BNL 2004)

Future experimental input expected from:

- New CMD-2 results forthcoming, especially at low and large $\pi^+\pi^-$ masses
- BABAR ISR: $\pi^+\pi^-$ spectral function over full mass range, multihadron channels ($2\pi^+2\pi^-$ and $\pi^+\pi^-\pi^0$ already available [see talk by E. Solodov, this session])
- New proposal submitted by E821 Collaboration aiming at precision of 2.4×10^{-10}
- Ambitious muon $g-2$ project at J-PARC, Japan, aiming at $(0.1 - 0.2) \times \sigma$(BNL-E821)

Isospin Corrections to $\tau \to \nu_\tau \pi^- \pi^0$ data:

i) Remove QED from τ decay data
ii) Put in QED corresponding to $e^+e^- \to \pi^+\pi^0$

$m_{\pi^\pm} - m_{\pi^0}$ in cross-section	-70×10^{-11}
" " in Γ_ρ	$+42 \times 10^{-11}$
FSR, $\pi^+\pi^-$ int	$+45 \times 10^{-11}$
$\Gamma_{\rho^\pm}(\gamma) - \Gamma_{\rho^0}(\gamma)$	-14×10^{-11}
ρ-ω int.	$+35 \times 10^{-11}$ unc. K. Maltman warning
	$+38 \times 10^{-11}$

$m_{\rho^\pm} - m_{\rho^0}$ & $\Gamma_{\rho^\pm} - \Gamma_{\rho^0}$ Addition Corrections likely my guess $\simeq -30 \times 10^{-11}$ more?

3. Neutrino Oscillations J. Shirai + G. Barenboim Talks

3 Generation Mixing $\overline{e\,\mu\,\tau} \left(\theta_{12}, \theta_{13}, \theta_{23}, \delta \right) \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$

$\theta_{23} \simeq 45°$ max

$\theta_{12} \simeq 32°$ large

$\theta_{13} \lesssim 13°$ (relatively small) Reactor Exp $\rightarrow \sin^2 2\theta_{13} \simeq 0.01$

$0 \leq \delta < 360°$

$\Delta m^2_{32} = \pm 2.6 \times 10^{-3}\,eV^2$

$\Delta m^2_{21} = 8.2 \times 10^{-5}\,eV^2$

Can only be studied via ν osc.

BNL - Homestake 2540 km $0.5\,GeV < E_{\nu_\mu} < 5\,GeV$

500 kton

1 MW Proton Driver

5×10^7 sec $\nu_\mu \to \nu_\mu$ disappearance

$\nu_\mu \to \nu_e$ appearance

Measure all parameters, δ sgn Δm^2_{32}, "New Physics"

Other New Physics: Sterile ν, Extra dim, Dark Energy?

Long Shots

4.) Charged Lepton Flavor Violation

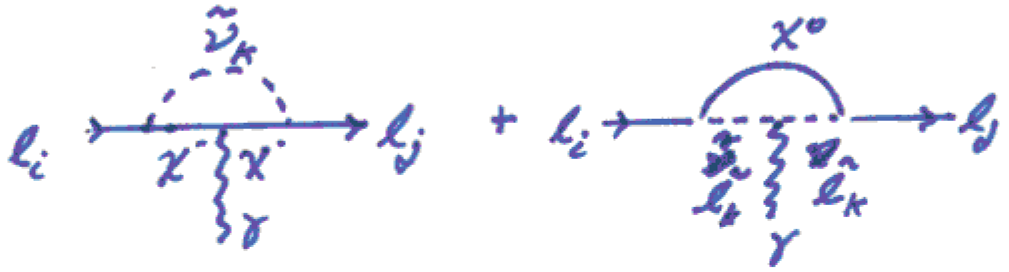
LFV large in ν osc. $\theta_{23} \simeq 45°$, $\theta_{12} \simeq 32°$

sun - earth $\nu_e \to \frac{1}{3}\nu_e + \frac{1}{3}\nu_\mu + \frac{1}{3}\nu_\tau$ (Democratic)

but $\mu \to e\gamma$, $\tau \to \mu\gamma$, $\tau \to e\gamma$, $\mu \to e^- e^- e^+ \ldots$

suppressed by $\left(\frac{\Delta m_{ij}^2}{m_W^2}\right)^2 \simeq 10^{-49} \sim 10^{-52}$!

Only sensitive to "New Physics" eg Supersymmetry



like a_μ^{SUSY}

$$BR(\ell_i \to \ell_j) \sim \left(\frac{\Delta m^2}{m_{SUSY}^2}\right)^2 \tan^2\beta \times \underbrace{\text{mixing}}_{\text{large likely}}$$

Exp $\to$ $\frac{\Delta m^2}{m_{SUSY}^2} \lesssim 10^{-3} \times 10^{-6}$ $\underline{\Delta m \simeq 100 \text{ keV}}$!

Nearly Degenerate Sleptons
But Not Exactly

Expect $BR(\mu \to e\gamma) \sim 10^{-12}$

$BR(\tau \to \mu\gamma) \sim 10^{-9}$

$\vdots$

Currently $B(\mu \to e\gamma) < 1.1 \times 10^{-11} \to 10^{-13} \to 10^{-14}$ MEG at PSI

$B(\mu N \to eN) < 6 \times 10^{-13} \to 10^{-17}$ MECO at BNL

talks by S. Yamada + W. Molzon

GUT Theory J. Hisano + A. Ilakovac

In my opinion a discovery likely → Exploration

$\tau \to \mu\gamma, e\gamma, 3\mu, \mu + X, e + X \ldots$

Also $\mu \to 3e$ } Intense Muon Beams $\mu^- N \to e^- N \to 10^{-19}$ sensitivity

CP Violation }

etc

New Domain To Explore

* New Results $\tau \to \mu\gamma \ldots$ (talks by K. Hayasaka, M. Roney, Y. Enari, M. Hodgkinson, Y. Yusa, N. Sato, G. Tong, J. Dubosca

Starting to approach 10^{-7} sensitivity!

long term goal should be 10^{-9} → Hard (Backgrounds)

Need Lots of τ's + Clean Signal

Bfactories might get 10^{-8} (10^{-9} unlikely)

Need a different approach

5.) <u>Collider τ Physics</u>

Friday talks: F. Matorras, L. Lindfeld, A. Safonov, A. LeBihan, J. Tanaka, R. Chierici

Use τ to search for: $H^{\pm}$, sleptons, LQ ... Higgs ... Zeus (3 τ events)

<u>What about LFV?</u>

Super Z Factory 10^{10} $Z \to \tau^+\tau^-$ $\to 10^{-9}$ Rare Decays

FNAL Tevatron $\to$ LHC $\tau \to 3\mu, \mu\eta$ ... (clean)

use tagged $b \to c\tau\nu_\tau$, $W \to \tau\nu_\tau$

* <u>SUSY FV Decays</u>

<u>S. Kanemura talk</u> 50 GeV μ beam $\mu N \to \tau + X$

Perhaps $eN \to \tau + X$ better (Pol + E_e = 250 GeV)

Fixed Target LC (Beam Dump)

Backgrounds?

Already ideas for $e^-e^- \to e^-e^-$ LR Asy. Moller $\to \sin^2\theta_W (\text{low } q^2)$ to ± 0.00006! } doable

parasitic

better $e^+e^- \to \pi^+\pi^-$ data

6.) Future (Concluding Remarks)

B Factories (Belle + BaBar) τ Players → tau 2006, 2008...

BES τ/Charm (G. Tong talk)

Super B factory, Future Z Factory?

LHC lots of τs

Muons are big part of τ meetings (Also neutrinos)

a_μ, $\mu \to e\gamma$, $\underbrace{\mu^- N \to e^- N}_{\text{Eventually} \to 10^{-19}}$ PSI, BNL → JPARC

$\tau \to \mu\gamma$, $\tau \to 3\ell$ ... Catch up → 10^{-9} sensitivity

Understand isospin viol in $\tau \to \nu_\tau \pi^- \pi^0$ vs $e^+e^- \to \pi^+\pi^-$

Reduce $a_\mu^{exp} - a_\mu^{SM}$ to $\pm 45 \times 10^{-11}$

τ, μ, ν All Complementary

No Feuding