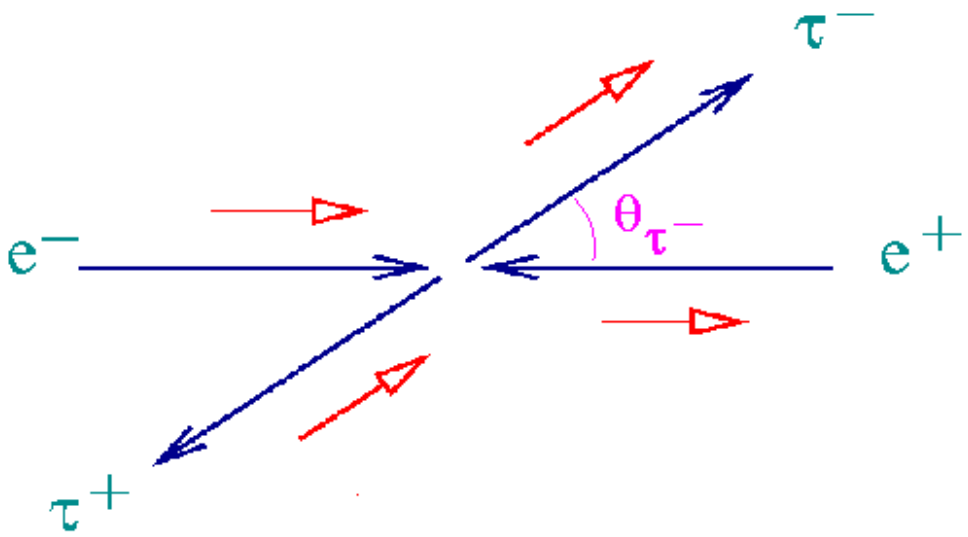
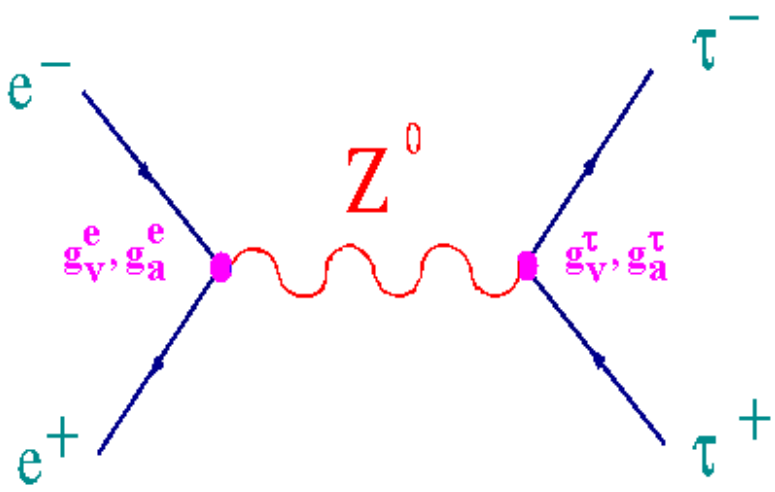
τ Polarization @ LEP

DELPHI ALEPH L3 OPAL

J.M. Roney
University of Victoria
for the LEP Collaborations

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





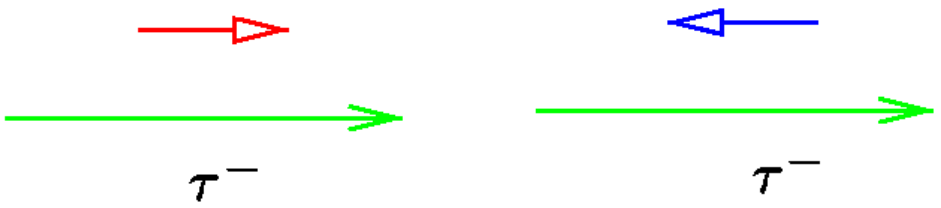
$$A_\ell = \frac{\hat{g}_L^{\ell\,2} - \hat{g}_R^{\ell\,2}}{\hat{g}_L^{\ell\,2} + \hat{g}_R^{\ell\,2}} = \frac{2\hat{g}_v^{\ell}\hat{g}_a^{\ell}}{\hat{g}_v^{\ell\,2} + \hat{g}_a^{\ell\,2}} = \frac{2\left(\hat{g}_v^{\ell}/\hat{g}_a^{\ell}\right)}{1+\left(\hat{g}_v^{\ell}/\hat{g}_a^{\ell}\right)^2}$$

- $\left(\hat{g}_v^{\ell}/\hat{g}_a^{\ell}\right) = 1 - 4\sin^2\theta_{\text{eff}}^{\text{lept}}$
- Lepton universality: A_e and A_τ

Measure the Polarization

$$P_\tau = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{\sigma_+ - \sigma_-}{\sigma_{\text{total}}}$$

+ helicity ~ right-handed **- helicity ~ left-handed**



$$P_\tau \equiv P_{\tau^-} = -P_{\tau^+}$$

$$\frac{1}{\sigma_{\text{total}}}\frac{d\sigma_+}{d\cos\theta_{\tau^-}} = \frac{3}{16}\left[\left(1+\langle P_\tau\rangle\right)\left(1+\cos^2\theta_{\tau^-}\right)+\frac{8}{3}\left(A_{FB}+A_{pol}^{FB}\right)\cos\theta_{\tau^-}\right]$$

$$\frac{1}{\sigma_{\text{total}}}\frac{d\sigma_-}{d\cos\theta_{\tau^-}} = \frac{3}{16}\left[\left(1-\langle P_\tau\rangle\right)\left(1+\cos^2\theta_{\tau^-}\right)+\frac{8}{3}\left(A_{FB}-A_{pol}^{FB}\right)\cos\theta_{\tau^-}\right]$$

$$\langle P_\tau\rangle = \frac{\sigma_+ - \sigma_-}{\sigma_{\text{total}}} \quad \text{averaged over } \cos\theta_{\tau^-}$$

$$A_{pol}^{FB} = \frac{\left[\sigma_+ - \sigma_-\right]_{\cos\theta_{\tau^-}>0} - \left[\sigma_+ - \sigma_-\right]_{\cos\theta_{\tau^-}<0}}{\sigma_{\text{total}}}$$

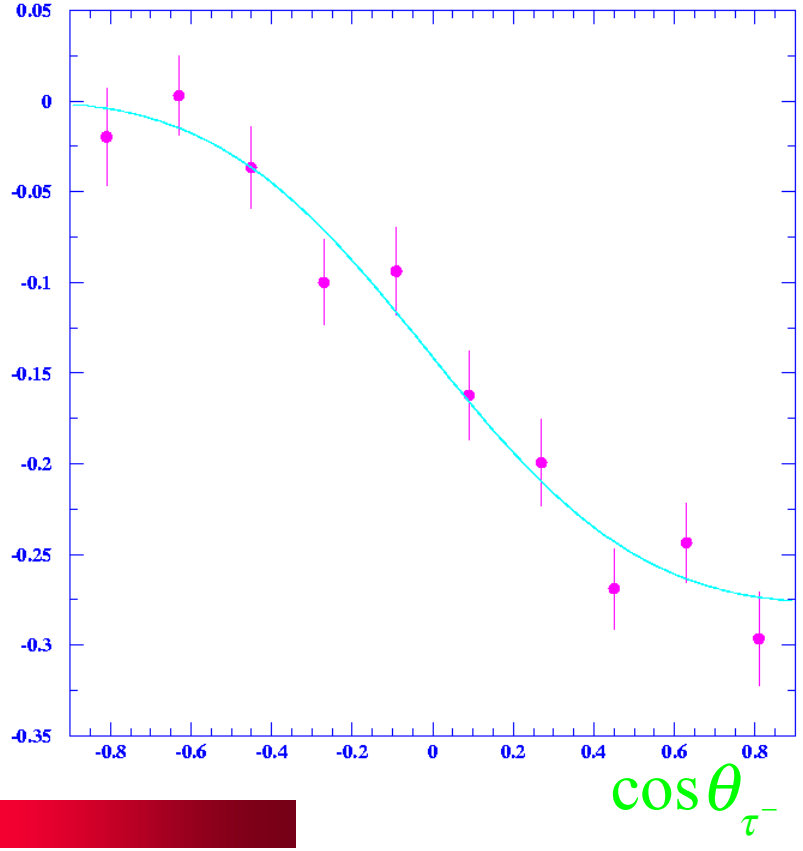
$$A_{FB} = \frac{\left[\sigma\right]_{\cos\theta_{\tau^-}>0} - \left[\sigma\right]_{\cos\theta_{\tau^-}<0}}{\sigma_{\text{total}}}$$

$$\langle P_\tau \rangle = -A_\tau \qquad A_{pol}^{FB} = -\frac{3}{4} A_e \qquad A_{FB} = \frac{3}{4} A_e A_\tau$$

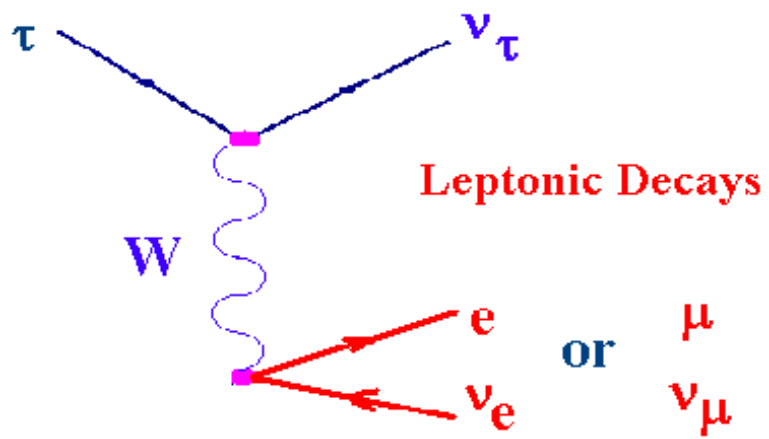
pure Z^0 exchange at the pole

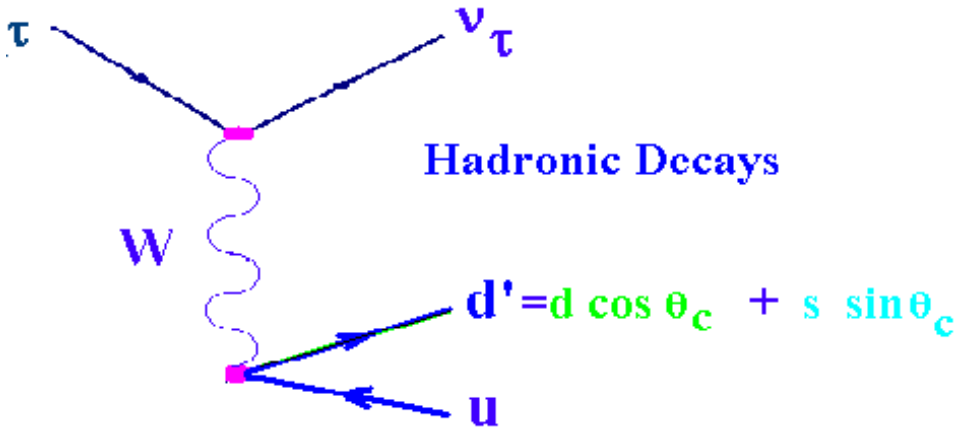
$$P_\tau(\cos\theta_{\tau^-}) = \frac{\langle P_\tau \rangle \left(1+\cos^2\theta_{\tau^-}\right) + \frac{8}{3} A_{pol}^{FB} \cos\theta_{\tau^-}}{\left(1+\cos^2\theta_{\tau^-}\right) + \frac{8}{3} A_{FB} \cos\theta_{\tau^-}} = -\frac{A_\tau \left(1+\cos^2\theta_{\tau^-}\right) + 2A_e \cos\theta_{\tau^-}}{\left(1+\cos^2\theta_{\tau^-}\right) + 2A_e A_\tau \cos\theta_{\tau^-}}$$

$P_\tau(\cos\theta_{\tau^-})$

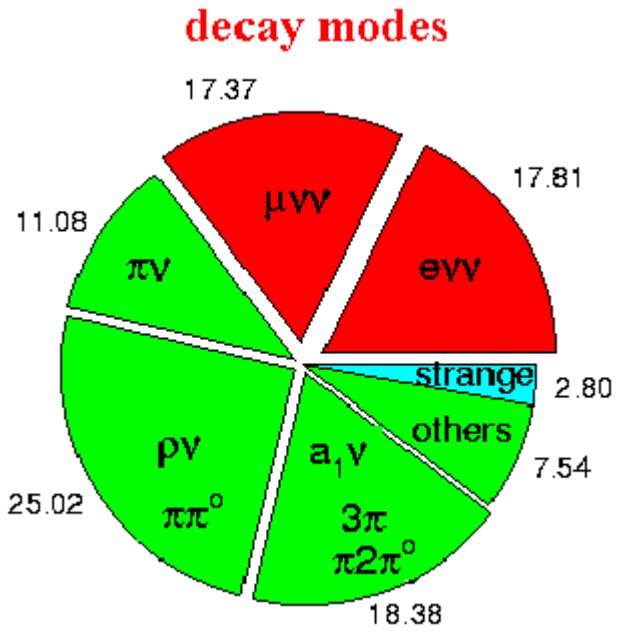


Measure τ Decay Kinematics





Assume V-A τ decays



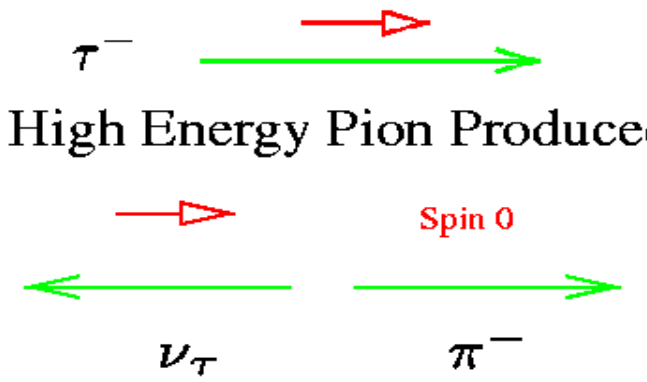
Kinematic spectra of visible decay products

Fit linear combinations of + and - helicity distributions for each decay mode

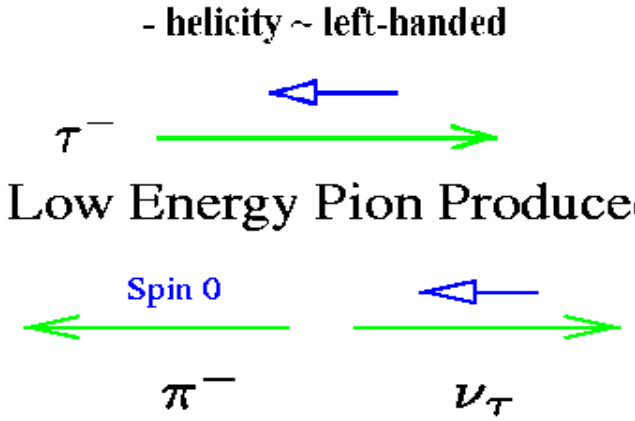
$$\frac{1}{\Gamma}\frac{d\Gamma}{dx} = f(x) + P_\tau g(x)$$

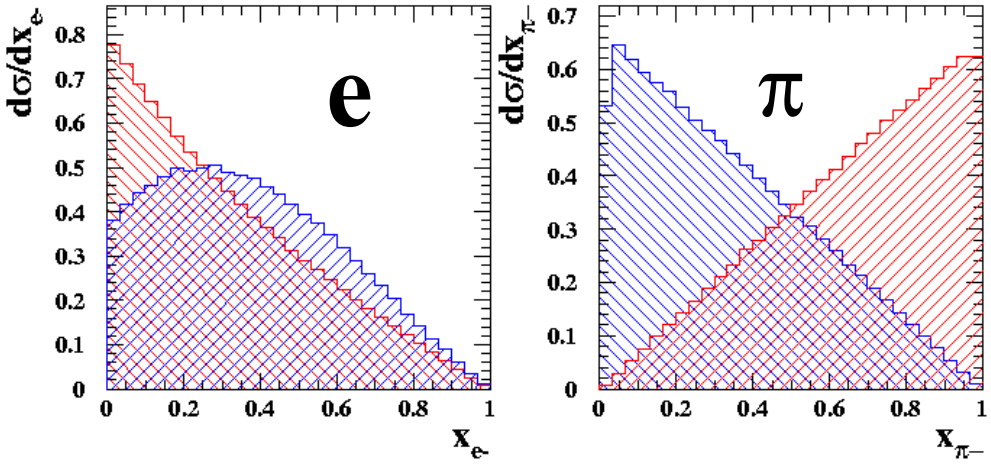
optimal variable $\omega = \dfrac{g(x)}{f(x)} = \dfrac{R_+ - R_-}{R_+ + R_-}$

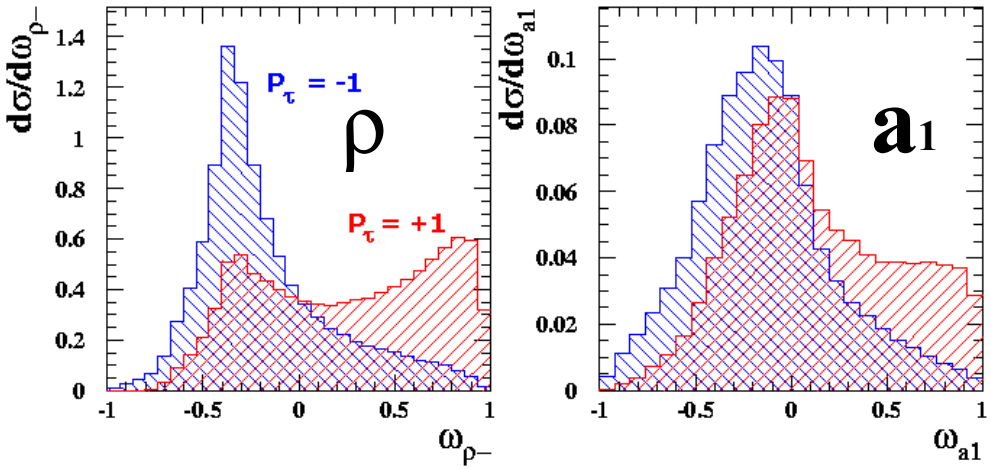
+ helicity ~ right-handed



- helicity ~ left-handed







Status of LEP Results

L3

complete LEP analysis finalized in 1998

(Phys.Lett.B429:387-398,1998) Same as Vancouver ICHEP

DELPHI

complete LEP analysis finalized in 1999

(Eur.Phys.J.C14:585-611,2000) Finalized since Vancouver

ALEPH

complete LEP analysis preliminary in 1998

(J.-C. Brient, Proceedings of ICHEP 98, Astbury et al Ed.)

Same as Vancouver

OPAL

complete LEP analysis, full acceptance

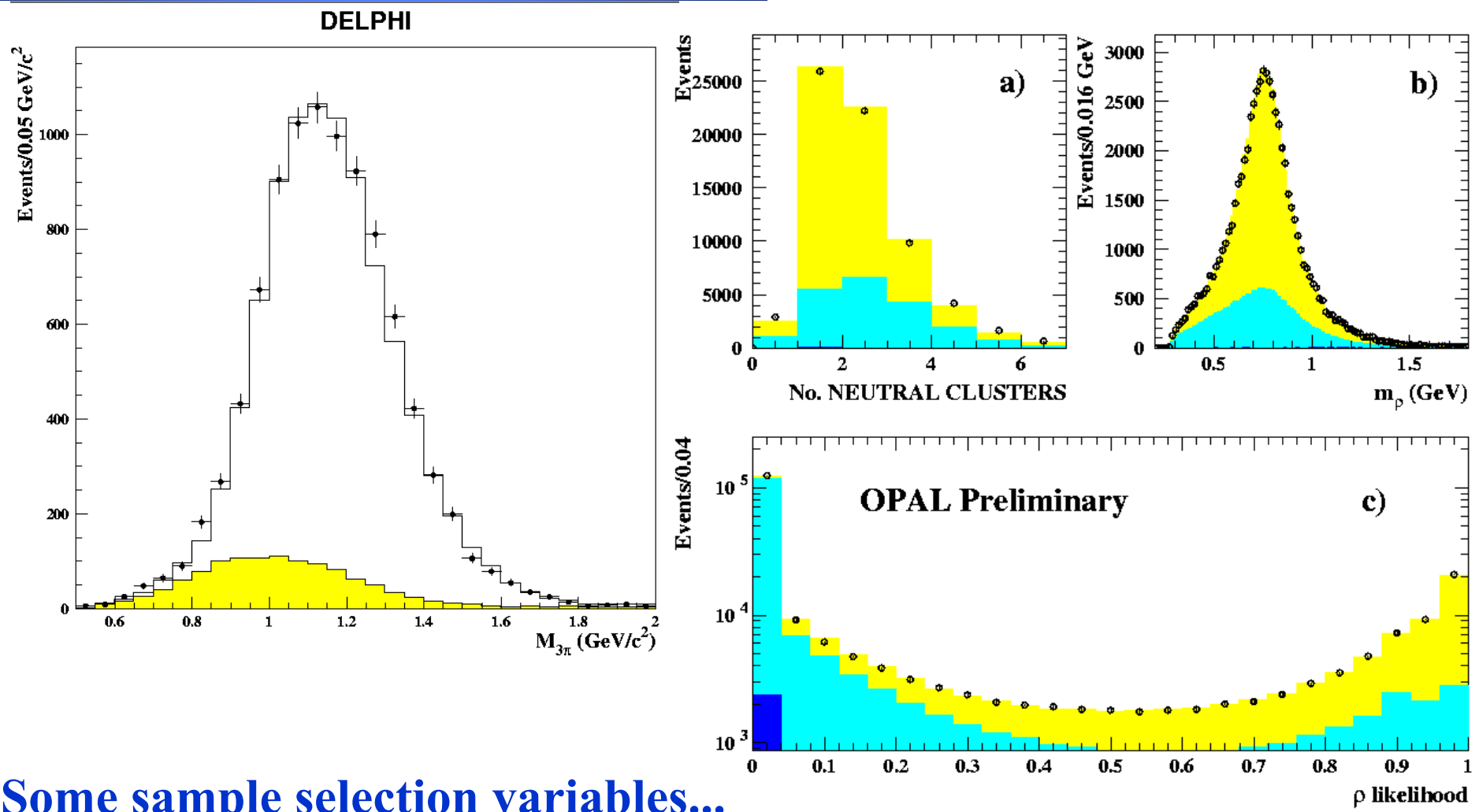
NEW preliminary results for ICHEP 2000

Methods employed...

- All use e, μ, π, $\pi^{\pm}\pi^{0}(\rho)$, $\pi^{\pm}\pi^{\pm}\pi^{\pm}(a_1)$ modes (and strange analogs)
- ALEPH also uses $\pi^{\pm}2\pi^{0}$ and info from τ flight direction
- L3 and ALEPH augment analysis with event acollinearity
- DELPHI and L3 add 1-prong semi-leptonic inclusive channel
- DELPHI 93-95 1-prong data separately analysed with NN
- OPAL employs global analysis of complete events

ALEPH L3 OPAL DELPHI

τ Selection and Decay Identification



Some sample selection variables...

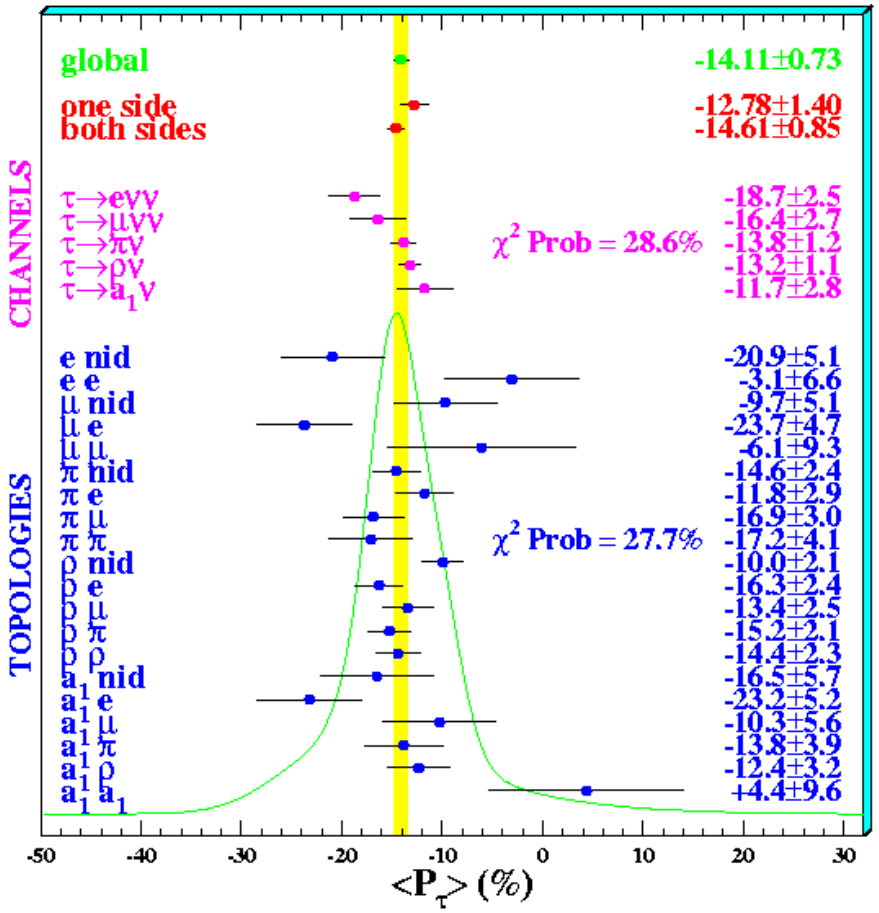
OPAL (new preliminary)

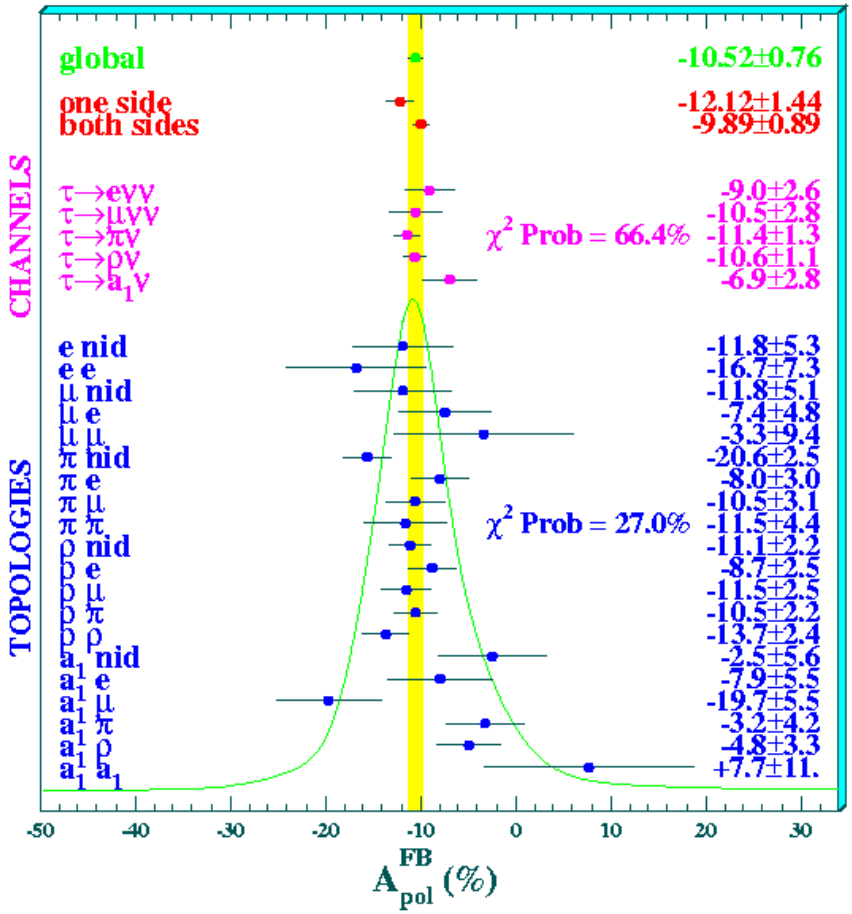
Analysis of complete events in global simultaneous fit of all decay modes.

All helicity and systematic correlations accounted for

$$\frac{d^3\sigma_{ij}}{d\cos\theta_{\tau^-}\,dx_i\,dx_j} = \frac{3}{16}\sigma_{ij}\sum_{\lambda=\pm1}\left[\left(1+\cos^2\theta_{\tau^-}\right)+\frac{8}{3}A_{FB}\cos\theta_{\tau^-}+\lambda\left(\langle P_\tau\rangle\left(1+\cos^2\theta_{\tau^-}\right)+\frac{8}{3}A_{pol}^{FB}\cos\theta_{\tau^-}\right)\right]\times$$

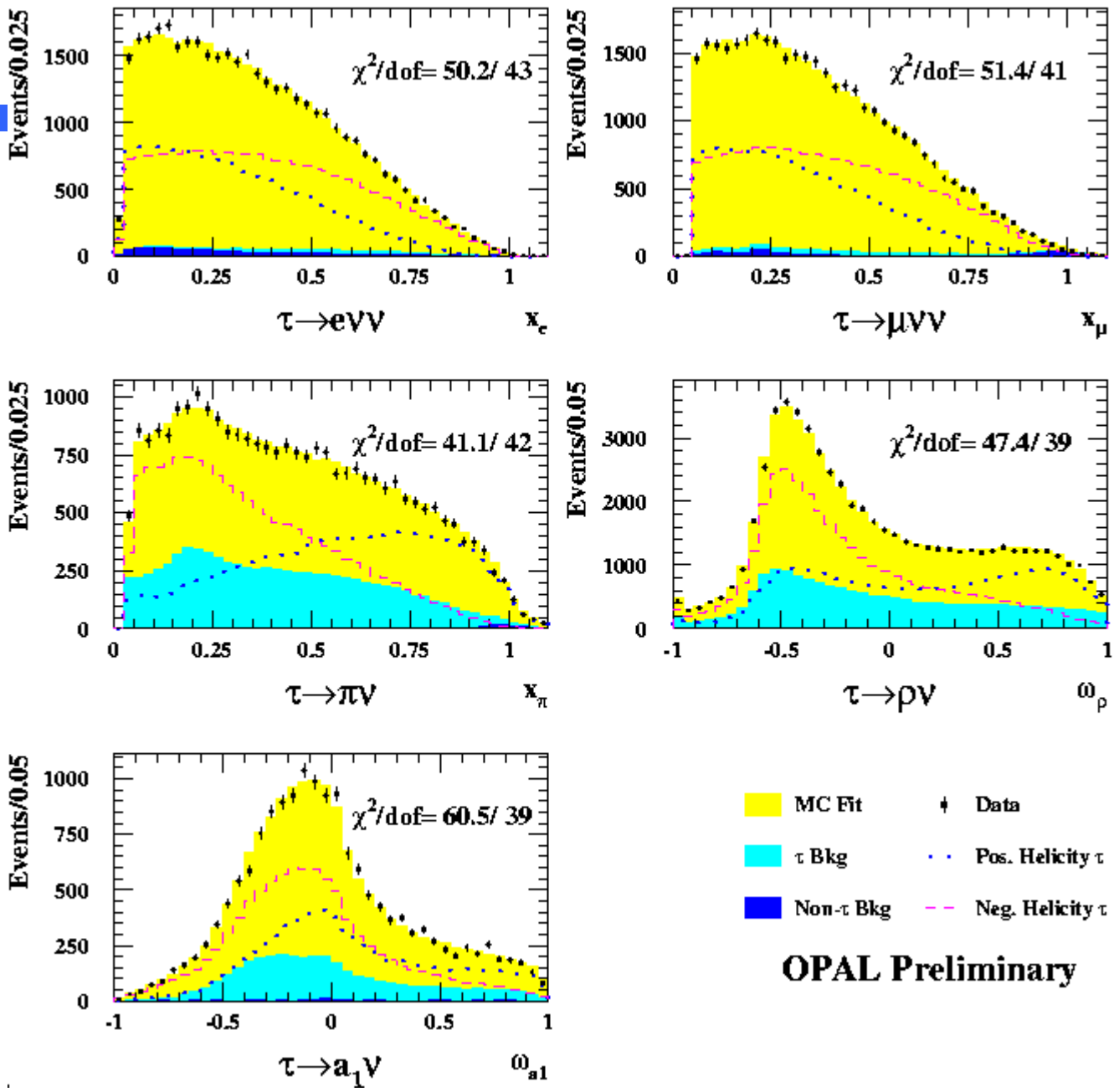
$$\left[F_i+\lambda G_i\right]\left[F_j+\lambda G_j\right]$$





OPAL

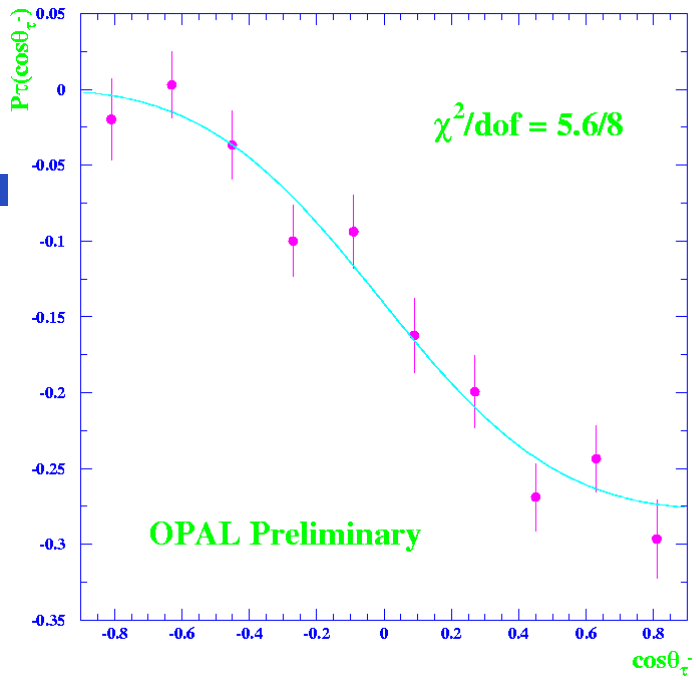
Kinematic Distributions

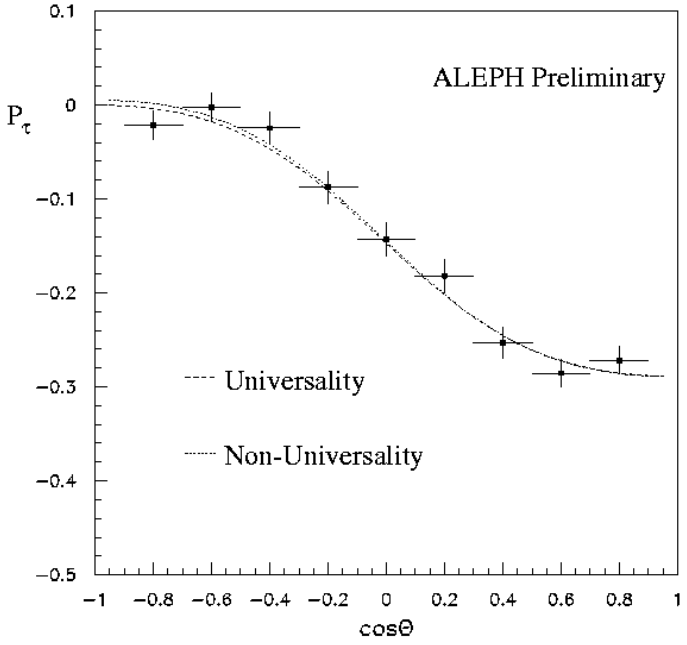


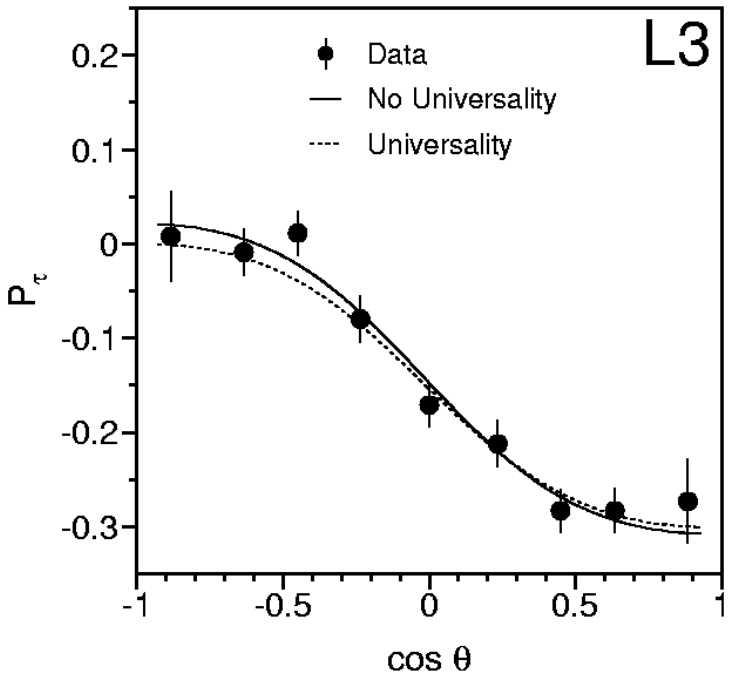
OPAL (new preliminary)

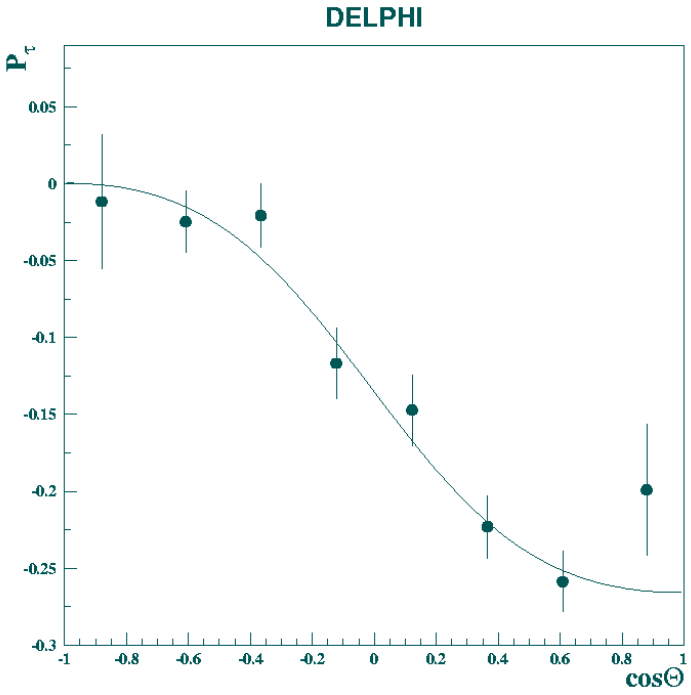
SYSTEMATIC ERRORS: $\Delta\langle P_\tau \rangle = 0.0056$ $\Delta A_{pol}^{FB} = 0.0025$

	$\Delta\langle P_\tau\rangle$ and ΔA_{pol}^{FB} (%)											
	e		μ		π(K)		ρ		a_1		Global fit	
Momentum scale/resolution	0.5	0.2	2.1	0.2	0.8	0.1	0.3	0.1	0.4	0.2	0.27	0.14
ECAL scale/resolution	3.0	0.1	0.2	0.2	0.2	–	1.1	0.2	0.3	0.1	0.22	0.12
HCAL/MUON modelling	0.1	–	1.1	0.5	0.5	0.1	–	–	–	–	0.13	0.05
dE/dx errors	0.4	0.1	0.1	0.2	0.1	0.1	0.1	–	0.2	–	0.05	0.06
Shower modelling in ECAL	0.6	0.2	0.2	0.2	0.3	0.1	0.5	0.2	0.4	0.1	0.25	0.09
Branching ratios	0.1	–	0.1	–	0.1	–	0.2	–	0.2	0.1	0.10	0.02
$\tau \to a_1 \nu_\tau$ modelling	–	–	–	–	–	–	0.4	–	0.5	0.1	0.22	0.01
$\tau \to 3h \geq 1\pi^0 \nu_\tau$ modelling	–	–	–	–	–	–	–	–	0.2	0.1	0.11	0.04
A_{FB}	–	0.2	–	–	–	–	–	–	–	–	0.03	0.02
Decay radiation	–	–	0.1	–	–	–	–	–	0.1	–	0.01	–
Monte Carlo statistics	0.7	0.2	0.8	0.3	0.3	0.1	0.3	0.1	0.8	0.2	0.22	0.10
total	3.2	0.4	2.4	0.6	1.1	0.2	1.4	0.3	0.8	0.3	0.56	0.25


$P\tau(\cos\theta_{\tau^-})$
χ^2/dof = 5.6/8
OPAL Preliminary
$\cos\theta_{\tau^-}$

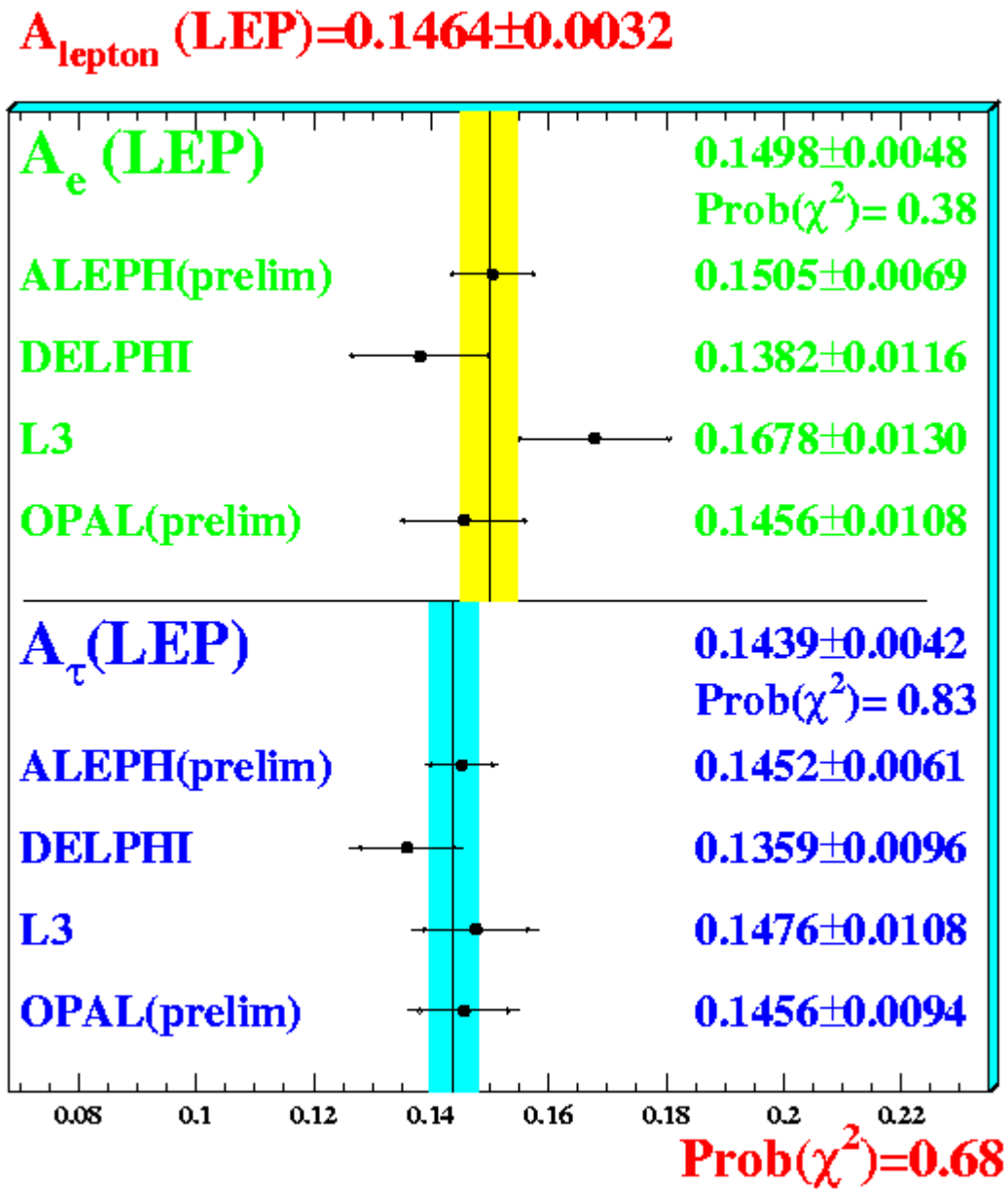

ALEPH Preliminary
P_τ
Universality
Non-Universality
cosΘ


L3
Data
No Universality
Universality
P_τ
cos θ


DELPHI
P_τ
cosΘ

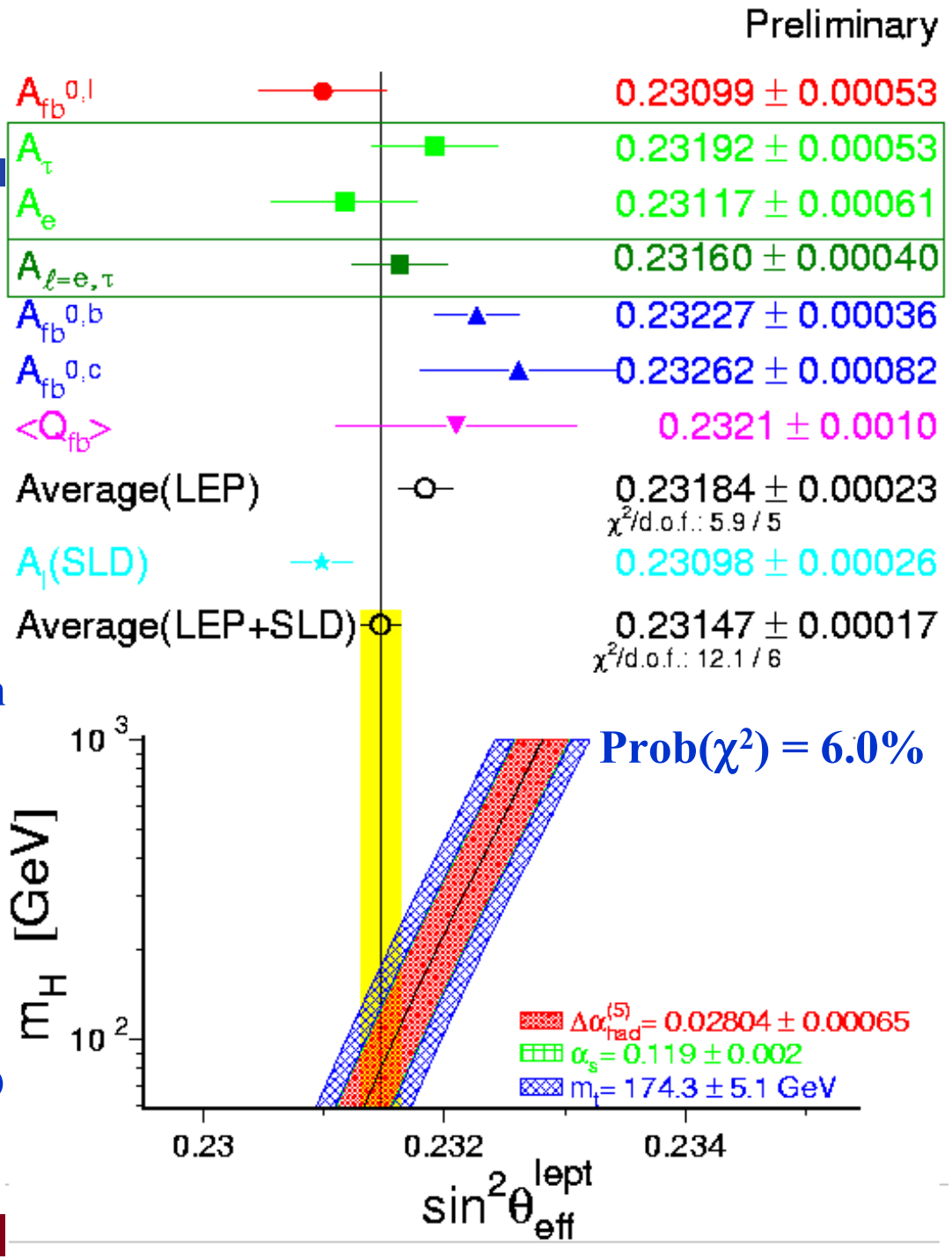
Potential systematic error correlations between experiments: small

Systematics dominated by detector response modelling uncertainties and Monte Carlo statistics



SUMMARY

- Complete analysis of all LEP Z^0 data by all four LEP experiments
- New preliminary results from OPAL for ICHEP 2000
- DELPHI and L3 have published
- OPAL and ALEPH still to publish
- All data consistent with lepton universality
- Assuming lepton universality, τ polarization result consistent with other LEP measurements and SLD



SUMMARY

- Direct limit: $m_{\nu\tau}<18.2 MeV/c^2$ @95%CL from ALEPH
- New limit from CLEO $m_{\nu\tau}<28 MeV/c^2$ with new higher statistics channel
- Some improvement in limit when likelihoods combined, but loophole remains
- Reasonable prospects for reaching $3 MeV/c^2$ at BABAR and BELLE