Tau id and polarization – role of photons

R. Frey, University of Oregon

- A potential criterion for ILC electromagnetic calorimeters (ECal) is the ability to reconstruct photons in a densely populated environment.
- Identifying and measuring photons (from π° s) in jets is already an important/crucial requirement.
- The full reconstruction of tau's may be yet more challenging and the physics opportunities are potentially crucial.
- Tau's appear in many New Physics signatures:
  - $h \to \tau^+\tau^-$
  - $H^+ \to \tau^+\nu$
  - $e^+e^- \to \tilde{\tau}_1^+\tilde{\tau}_1^- \ , \ \tilde{\tau}_1^\pm \to \tilde{\chi}_1^0\tau^\pm$
  - etc

tau polarization in SUSY

- Analysis of tau final states can provide crucial information on new physics
- Important & broad example $e^+e^- \rightarrow \tilde{\tau}_1^+\tilde{\tau}_1^- \ , \ \tilde{\tau}_1^\pm \rightarrow \tilde{\chi}_1^0\tau^\pm$
- The SUSY model leaves fingerprint on tau polarization:

$$\tilde{\chi}_1 = N_{11}\widetilde{\mathrm{B}} + N_{12}\widetilde{\mathrm{W}} + N_{13}\widetilde{\mathrm{H}}_1 + N_{14}\widetilde{\mathrm{H}}_2$$

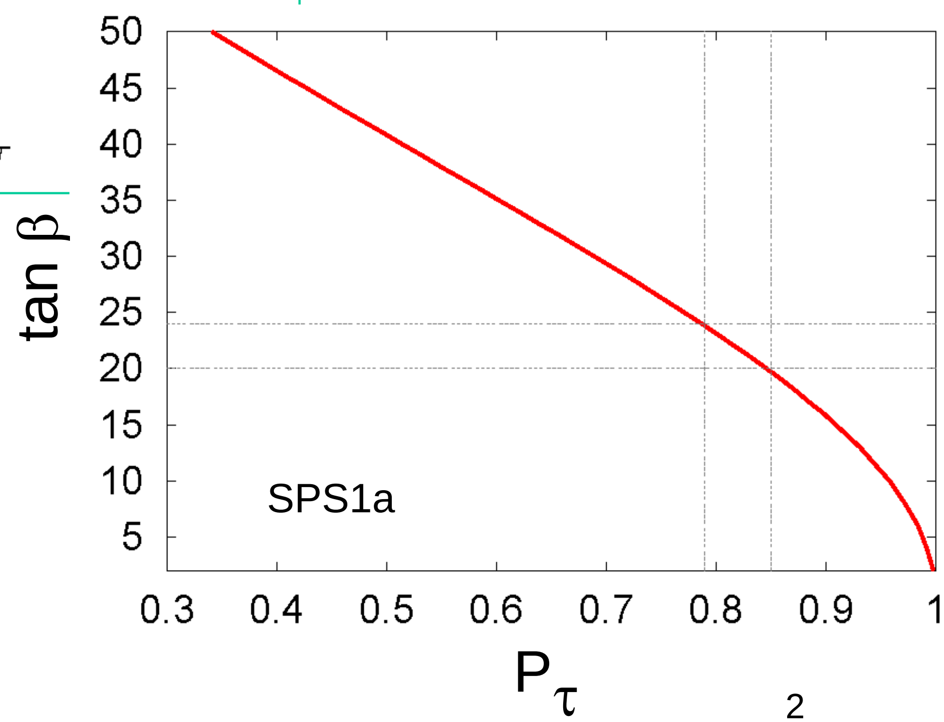
- mSUGRA: $\tilde{\chi}_1 \sim \widetilde{\mathrm{B}} \Rightarrow P_\tau \approx +1$
- non-universal SUGRA: $\tilde{\chi}_1 \sim \tilde{\mathrm{H}} \Rightarrow P_\tau \approx \cos^2\theta_\tau - \sin^2\theta_\tau$
- AMSB: $\tilde{\chi}_1 \sim \widetilde{\mathrm{W}} \Rightarrow P_\tau \approx -1$
- GMSB: $\tilde{\tau}_1^\pm \rightarrow \widetilde{\mathrm{G}}\tau^\pm \Rightarrow P_\tau \approx \sin^2\theta_\tau - \cos^2\theta_\tau$

References:

M. Nojiri, PRD 51 (1995)

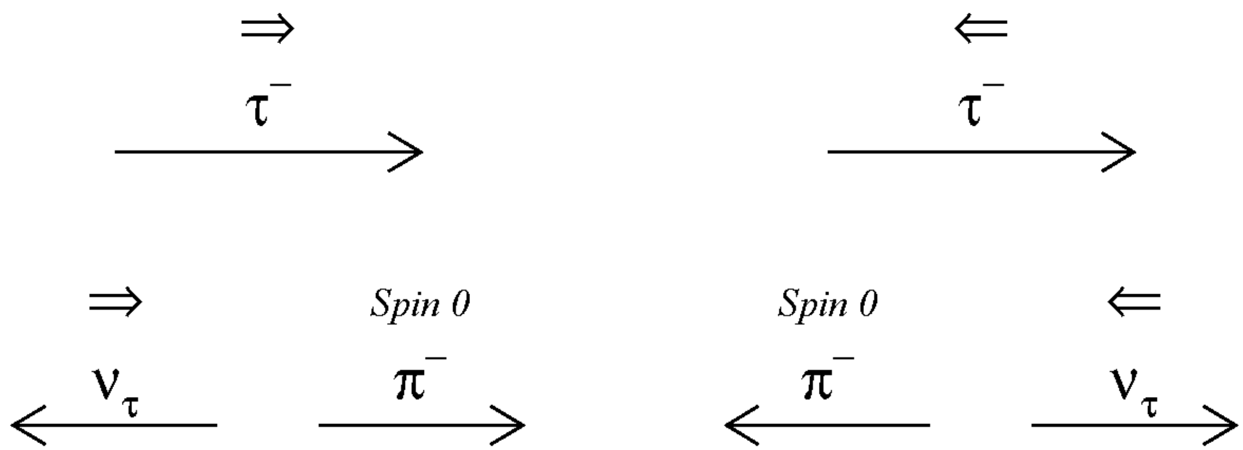
E. Boos, et al, EPJC 30 (1993)

Godbole, Guchait, Roy, Phys Lett B (2005)



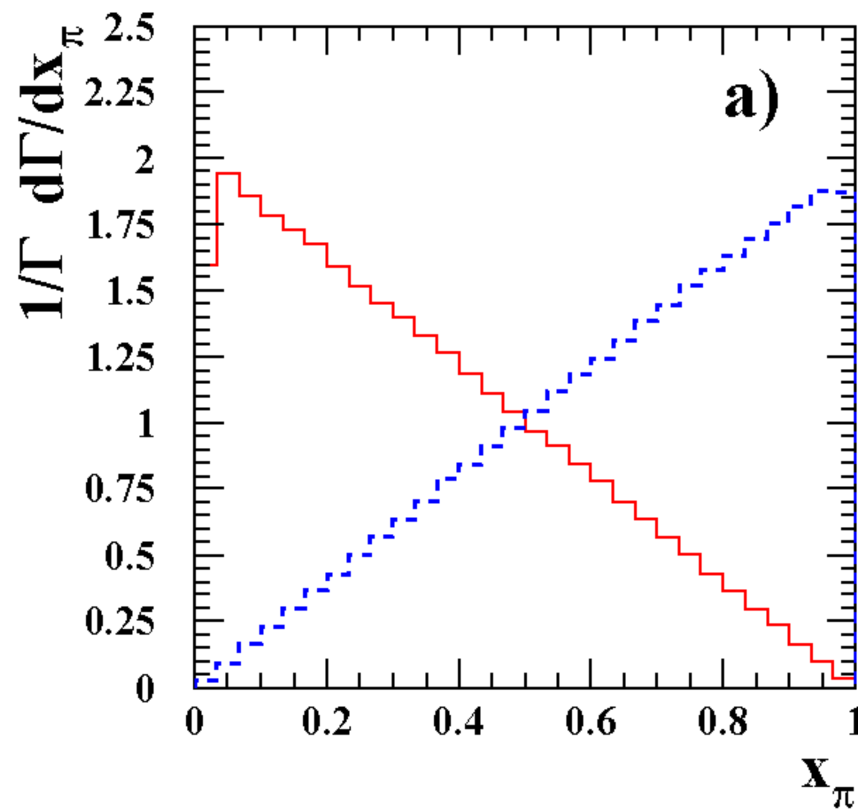
tau polarization

Example: $\tau \rightarrow \pi \nu$



$$\frac{1}{\Gamma}\frac{d\Gamma}{dx_\pi} = 1 + \mathcal{P}_\tau(2x_\pi - 1)$$

$$x_\pi = E_\pi / E_\tau$$



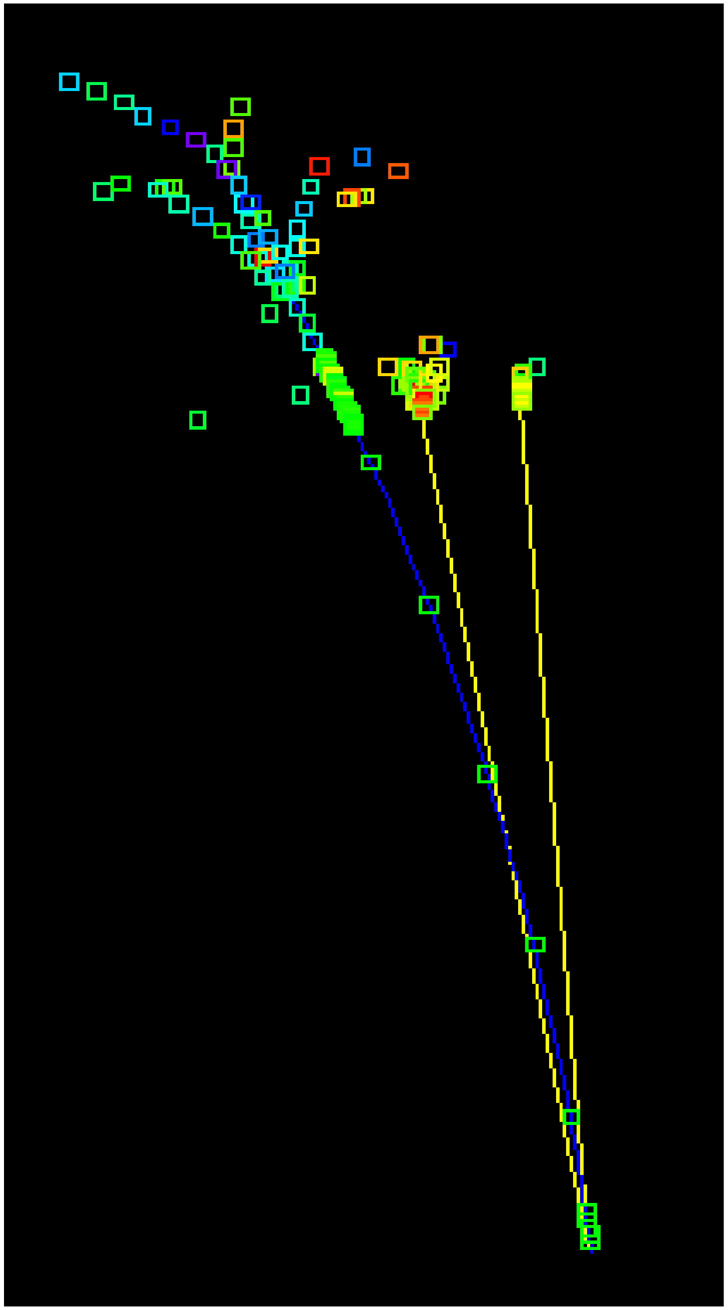
lessons from LEP

Precision electroweak measurements on the Z resonance. Phys.Rept.427:257,2006.

	$\tau \to \rho\nu$	$\tau \to \pi\nu$	$\tau \to e\nu\overline{\nu}$	$\tau \to \mu\nu\overline{\nu}$	$\tau \to a_1\nu$ $a_1 \to \pi^{\pm}\pi^{+}\pi^{-}$
Branching fraction	0.25	0.12	0.18	0.17	0.09
Maximum sensitivity:					
no 3D τ direction	0.49	0.58	0.22	0.22	0.45
with 3D τ direction	0.58	0.58	0.27	0.27	0.58
Normalised ideal weight:					
no 3D τ direction	0.44	0.30	0.06	0.06	0.13
with 3D τ direction	0.47	0.22	0.07	0.07	0.17

$\tau \to \rho\nu$ is most powerful

tau polarization - measurement



Separate and analyze decay modes:

- $\tau^+ \rightarrow \rho^+\nu \quad (\pi^+\pi^o\nu)$
- $\tau^+ \rightarrow \pi^+\nu \quad (\pi^+\nu)$
- $\tau^+ \rightarrow a_1^+\nu \quad (\pi^+\pi^+\pi^-\nu,\ \ \pi^+\pi^o\pi^o\,\nu)$

Analyzing the $\tau \to \rho\nu$ decay

$$\omega_\rho = \frac{W_+(\theta^*, \psi) - W_-(\theta^*, \psi)}{W_+(\theta^*, \psi) + W_-(\theta^*, \psi)}$$

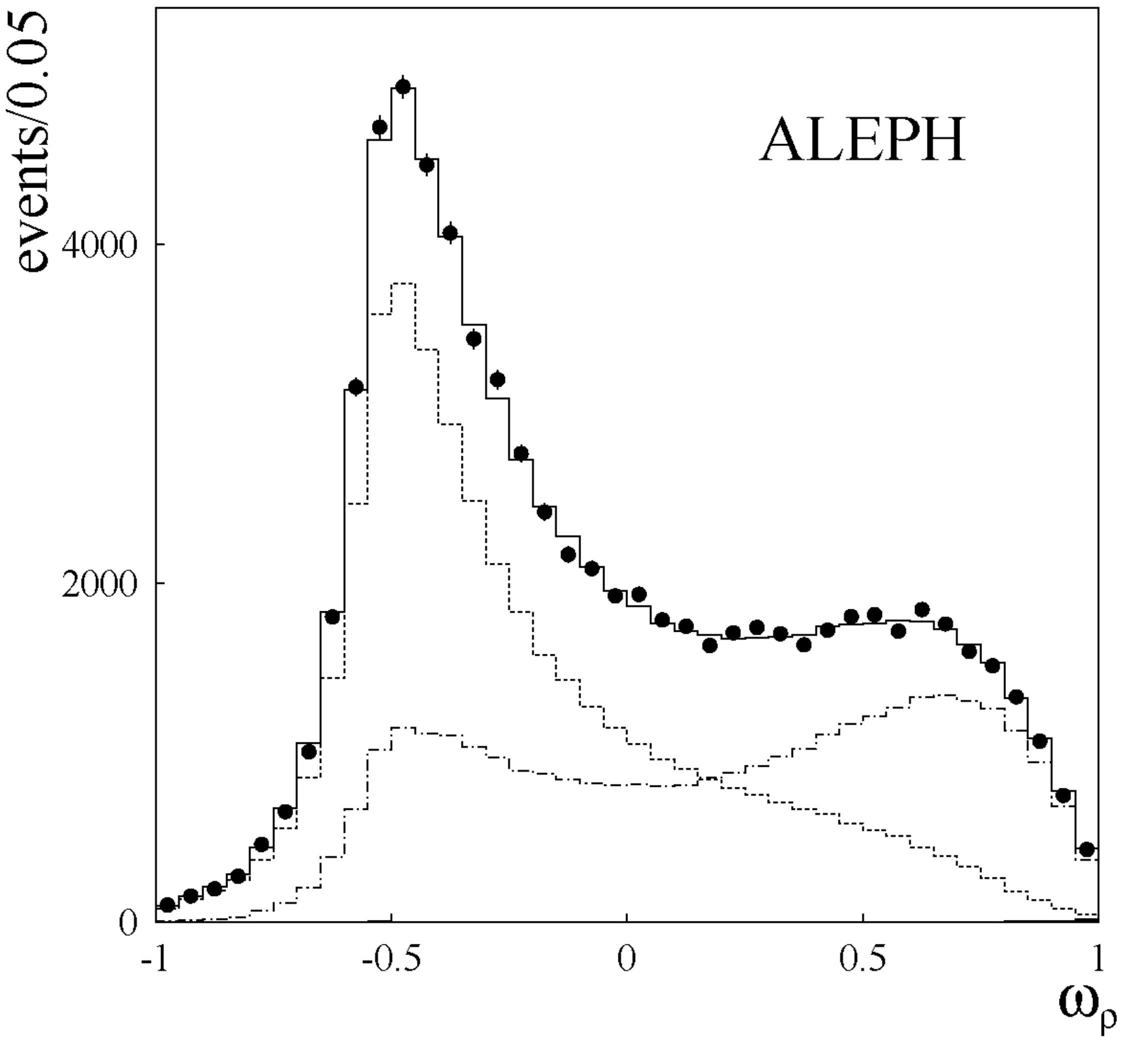


Figure 4.4: The measured spectrum of the polarisation-sensitive variable ω_ρ, described in the text, for the $\tau \to \rho\nu$ decays in the ALEPH experiment. The dashed and dashed-dotted lines correspond to the contributions of negative and positive helicity τ's, respectively. The small shaded area near ω=1 is the non-τ background contribution.

Summary

- Tau final states show up in New Physics signatures.
- Tau polarization is a potentially powerful analyzer of the underlying physics.
- To make best use of the information, need to separate and analyze tau decay modes involving charged and neutral pions.
  - $\tau \rightarrow \rho\nu$ is most powerful
- This requires a segmented ECal
  - ALEPH was about 2$\times$ better than others (best segmentation)
- This would appear to be a useful (crucial?) detector benchmark.