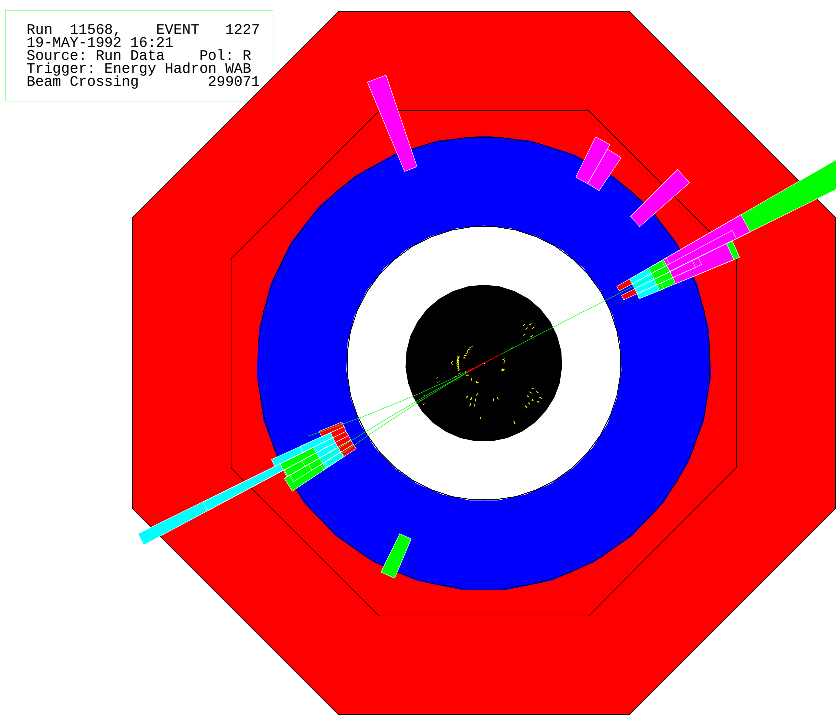
Measurement of $h(\nu_\tau)$ and τ Michel Parameters in Polarized e+e- Collisions



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representing

The SLD Collaboration

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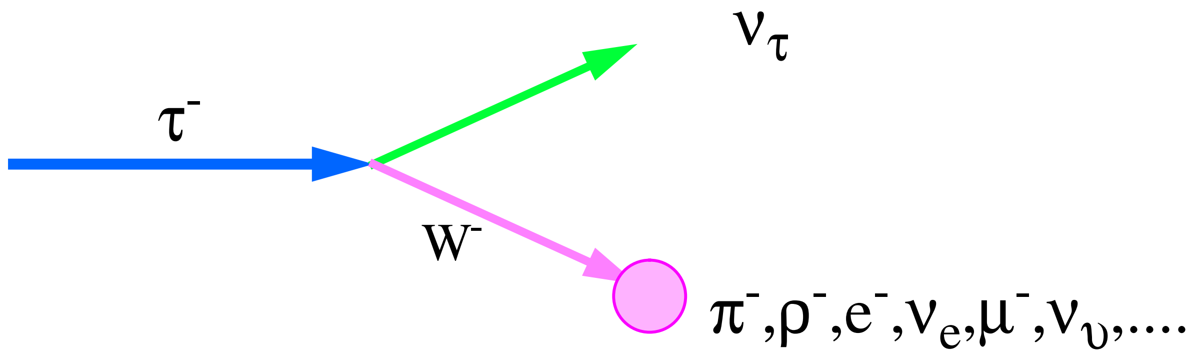
Introduction

Taus decay by W exchange.



SM predicts this to be a V-A interaction.

Spin dependendent.

By studying the spectra of spin-polarized taus,
we can study the W couplings.

or hadronic decay characterize this by the
helicity of the tau neutrino. Expect h_ν=-1.

For leptonic decays use Michel parametrization
Expect:

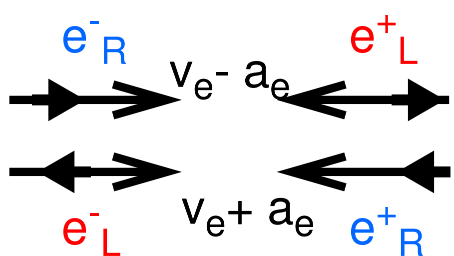
$$\rho = 0.75, \xi = 1, \xi\delta = 0.75, \eta = 0$$

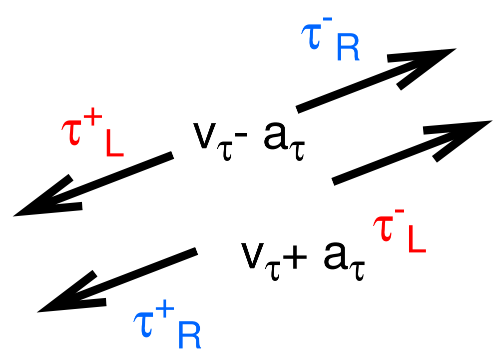
Tau Production at the Z

Taus are produced longitudinally polarized due to:

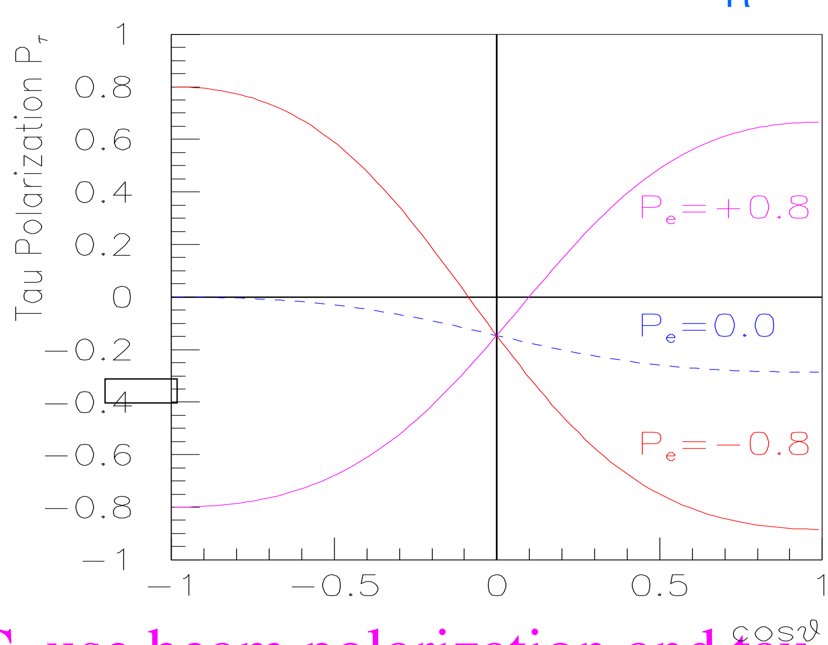
- Z parity violation.

  The two allowed helicity config. of e+e- couple differently to the Z0 results in Pz
  In an anlogous way the differece in the Z0 coupling to the right and left handed t produces Pt





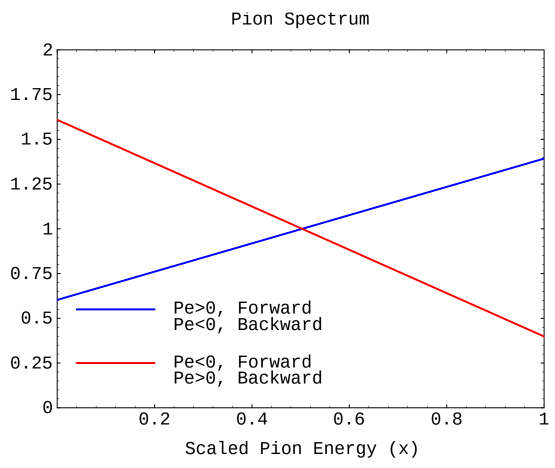
- Beam polarization

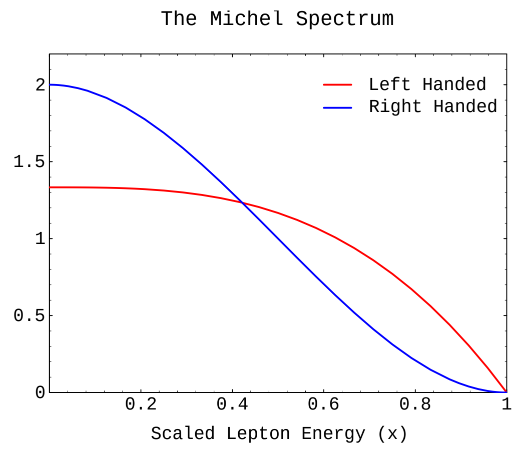


At SLC, use beam polarization and tau-production direction to tag the tau spin.

Tau Decay at the Z.

- Taus are produced highly boosted.
- Decay products are collimated in the tau direction.
- Measurable spectrum is the energy spectrum of the decay products.

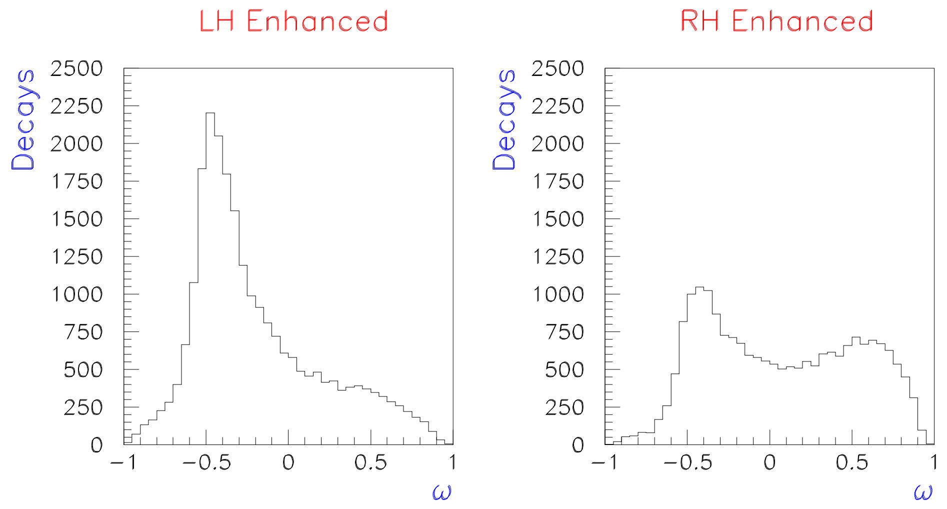




- Can write this as:
  $n(x) = f(x) + P_\tau\, g(x)$.
- For pions(kaons) h_ν characterizes $g(x)$:
  $n_\pi(x) = f(x) + P_\tau\, h_\nu\, g(x)$
- For leptons we get:
  $n_l(x) = f_c(x) + \rho\, f_\rho(x) + P_\tau\, \xi\, \left[g_\xi(x) + \delta\, g_{\xi\delta}(x)\right]$

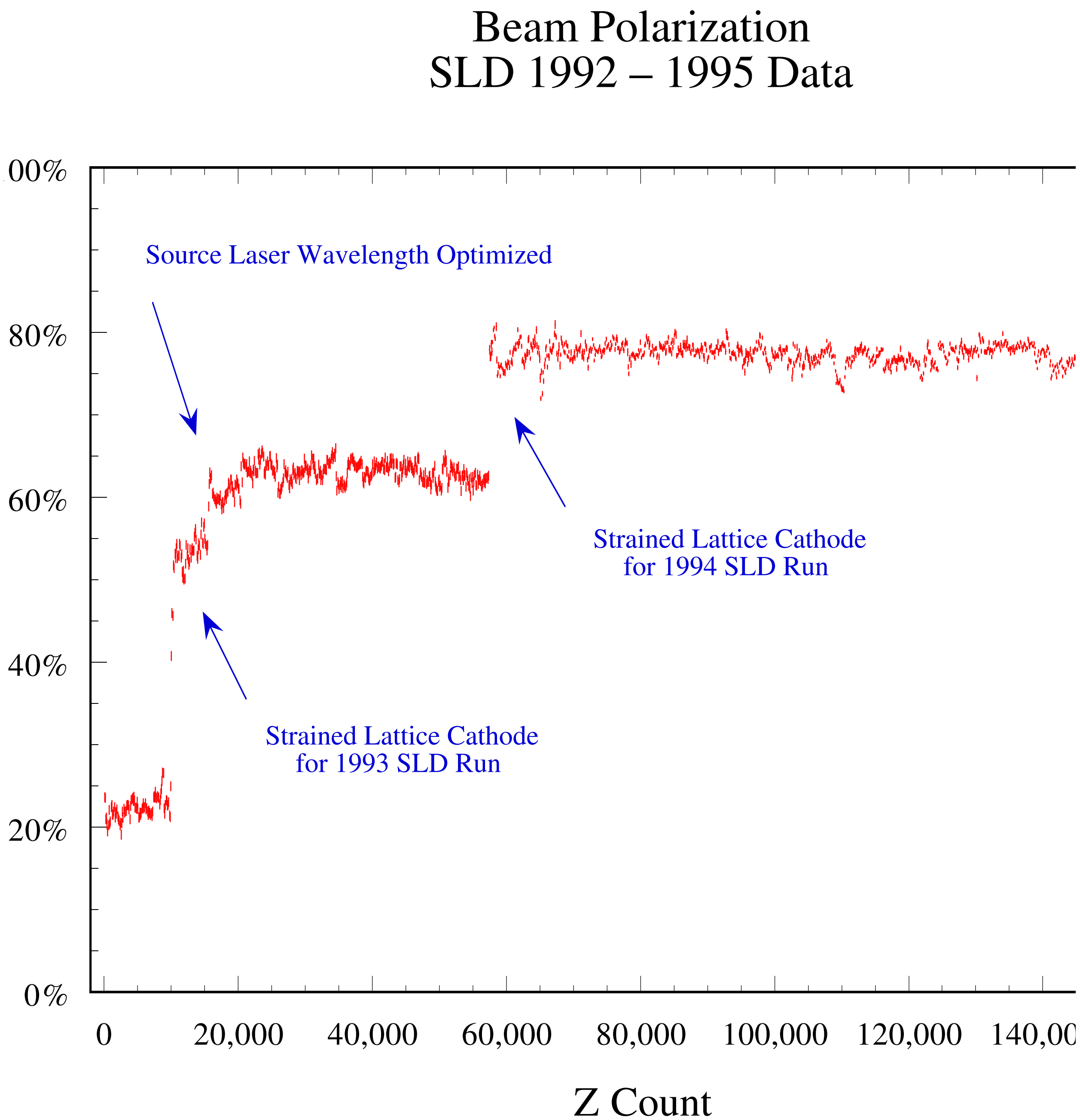
Tau Decays to Rhos.

- Spin of ρ carries some information.
- Rhos decay to $\pi\,\pi^\circ$, measure the momenta of both pions.
- Can still write as:
  $n_\rho(z_i) = f_\rho(z_i) + P_\tau\, h_\nu\, g_\rho(z_i)$
  where z_i are the observables.
- Define $\omega = g(z_i)/f(z_i)$.
- Rewrite spectrum with one parameter:
  $n_\rho(\omega) = (1/2)(1 + h_\nu\, \omega)$



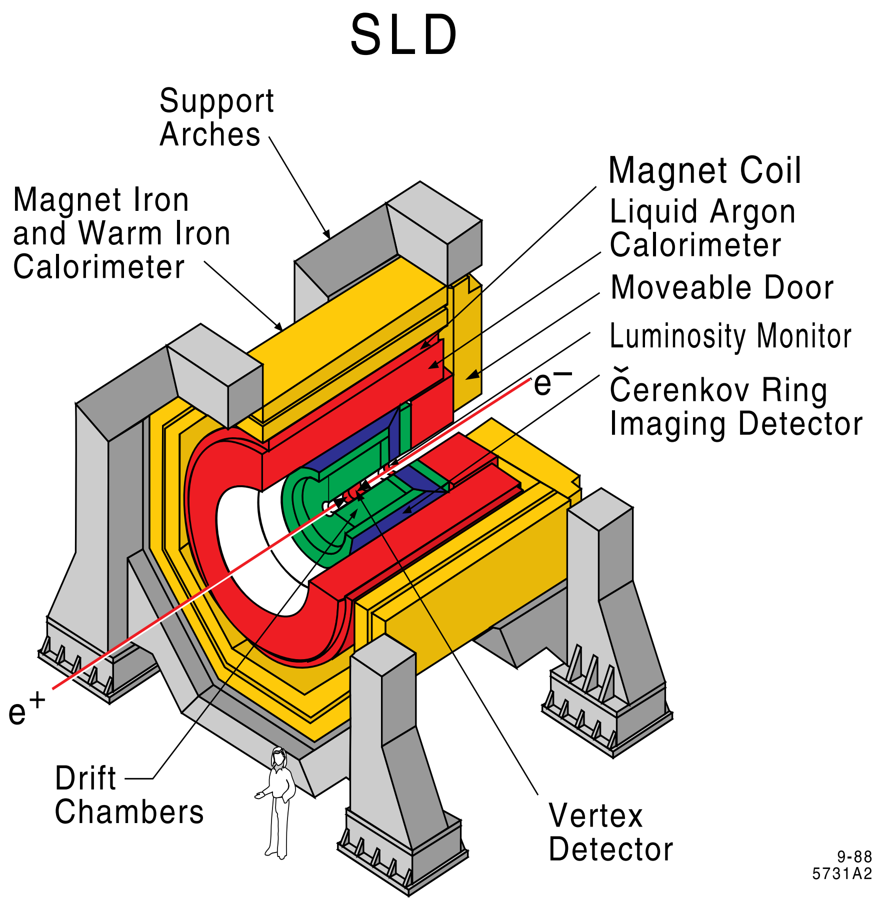
- This optimally uses the information in the ρ spin and momentum.

The SLC$_T$



* Colliding e-e+ beams at 91.28 GeV.
* 50k Zs at 63% polarization in 1993.
* 100k Zs at 77% polarization in 1994-5.

The SLD detector



Impact parameter resolution $\sigma_{\rho\phi}=11+70/p\sin^{3/2}\theta$

Momentum resolution $\sigma_{pt}/p_t=0.01+0.0026p_t$

Energy resolution $\sigma_E/E=0.15/E^{1/2}$(EM)
$\sigma_E/E=0.60/E^{1/2}$(HAD)

Event Selection.

Tau Pairs.

- Low Track Multiplicity.
- Two Back-to-Back Collimated Jets.
- Missing Momentum.

Results: 4316 taus. 62.7% eff. 97.5% pur.

From these select one-prong final states:

Electrons.

- Electron-like shower (large e/p) and
- Mass inconsistent with a rho.

Select: 932 electrons. 61.7% eff. 96.0% pur.

Muons.

- Muon counter hits or
- Muon-like shower.

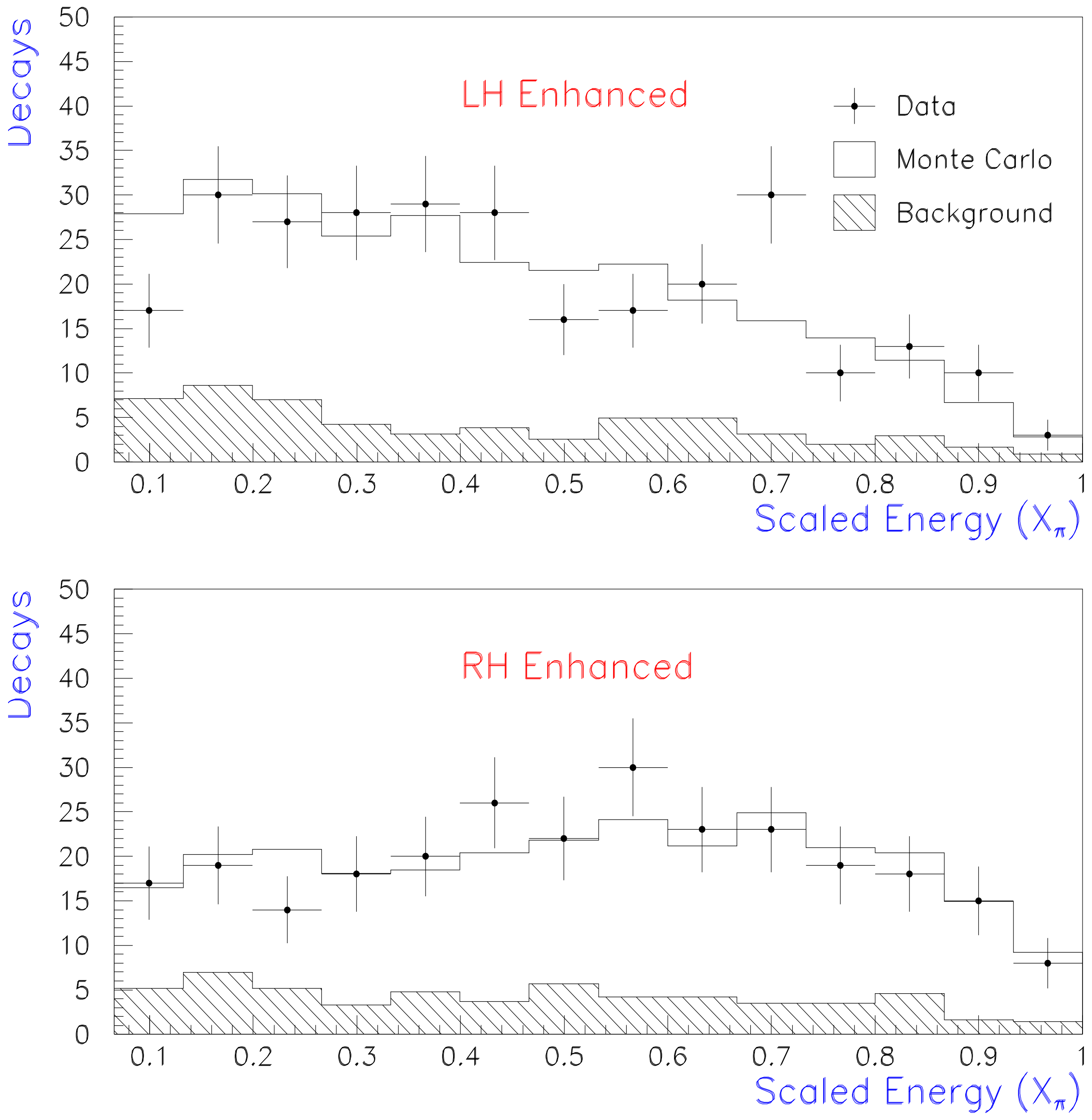
Select: 1123 muons. 69.0% eff. 93.6% pur.

Pions (Kaons).

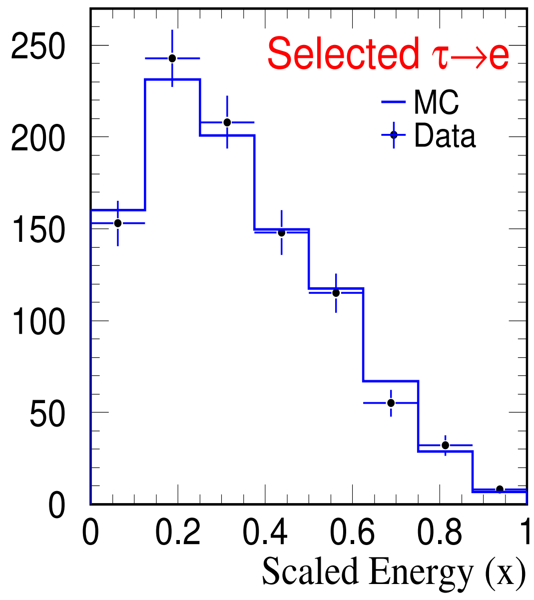
- Reject electrons and muons.
- Pion-like shower.

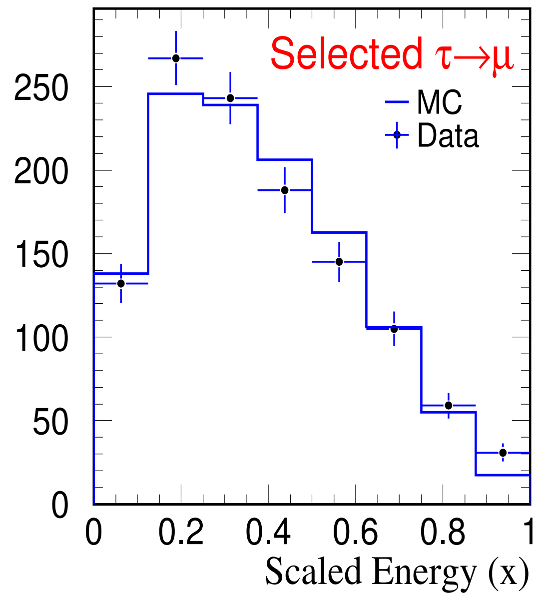
Select: 558 pions. 57% eff. 79% pur.

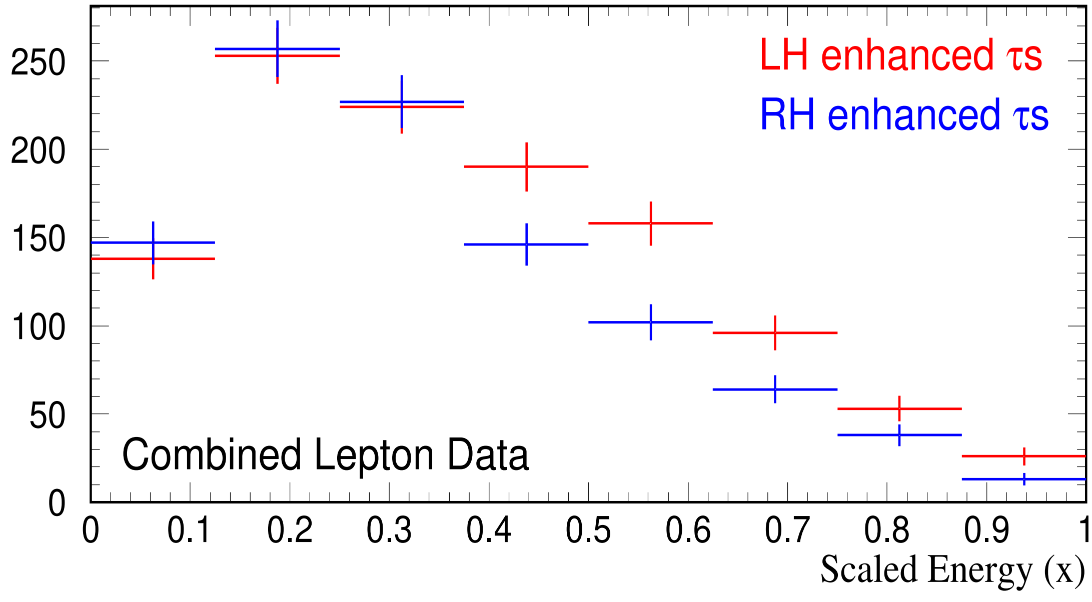
$\tau \rightarrow \pi(K)\nu_\tau$ Decay Energy Spectra 93–95



Lepton Data and MC

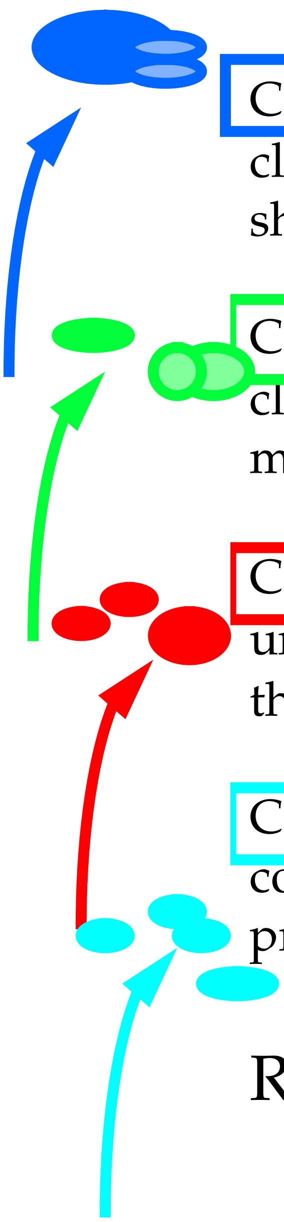






Rho Selection.

Reject e, μ and π events. Categorize by clusters within 20° of thrust axis:



Category 1 1 cluster. Use track energy and scaled cluster energy to compute a ρ mass taking shower shape into consideration.

Category 2: 2 clusters. Use scaled unassociated cluster energy and track momentum to compute a ρ mass.

Category 3: 3 clusters. Reconstruct the π° from the 2 unassociated clusters and calculate the ρ mass from the π° energy and the track momentum.

Category 4: 4+ clusters. Try various cat. 2 and cat. 3 combos, accept if only one works. Cat. 2 takes precedence.

Require $0.44 < m_\rho < 1.2$ GeV.

Select: 1295 rhos. 60% eff. 76% pur.

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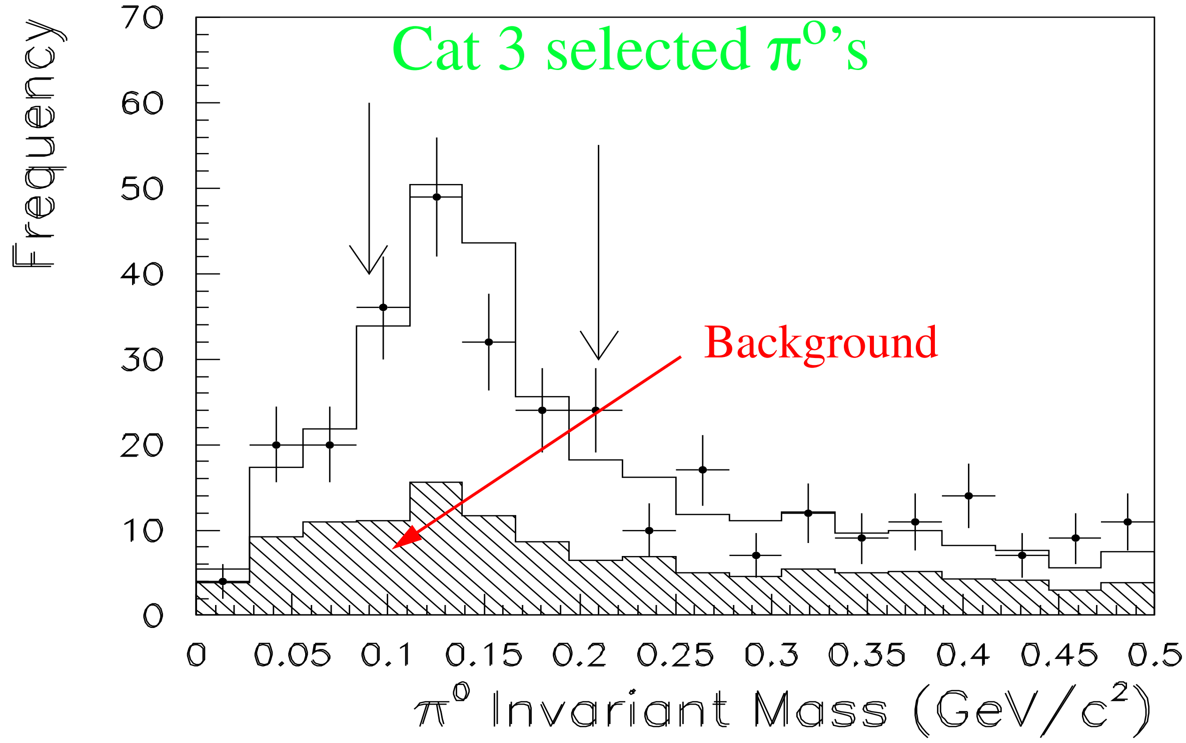
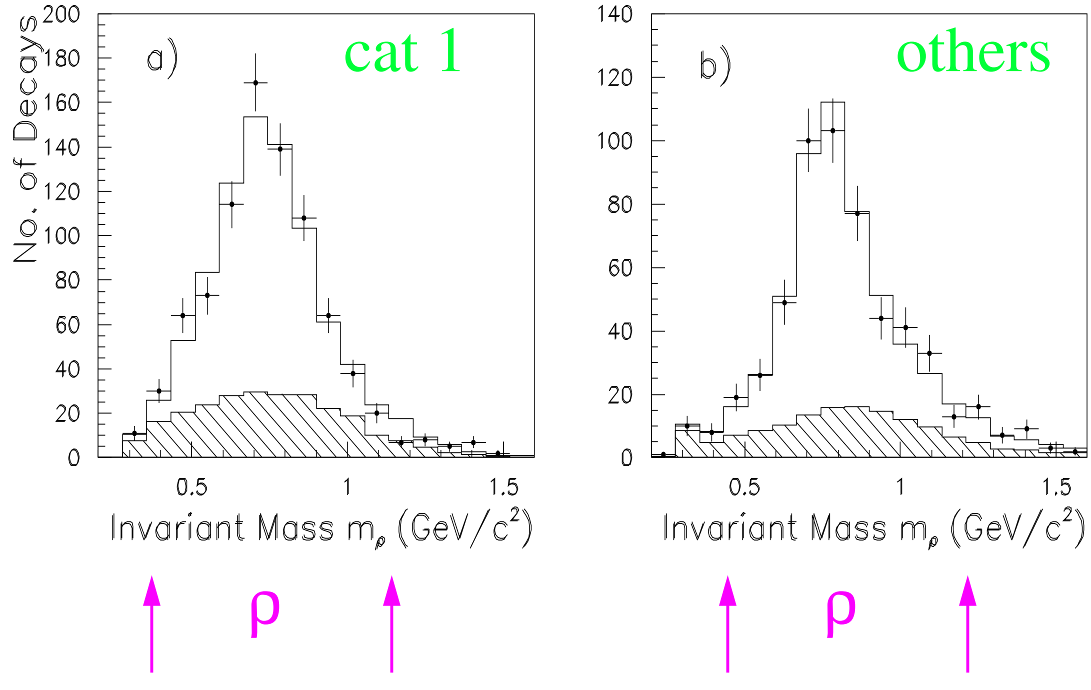
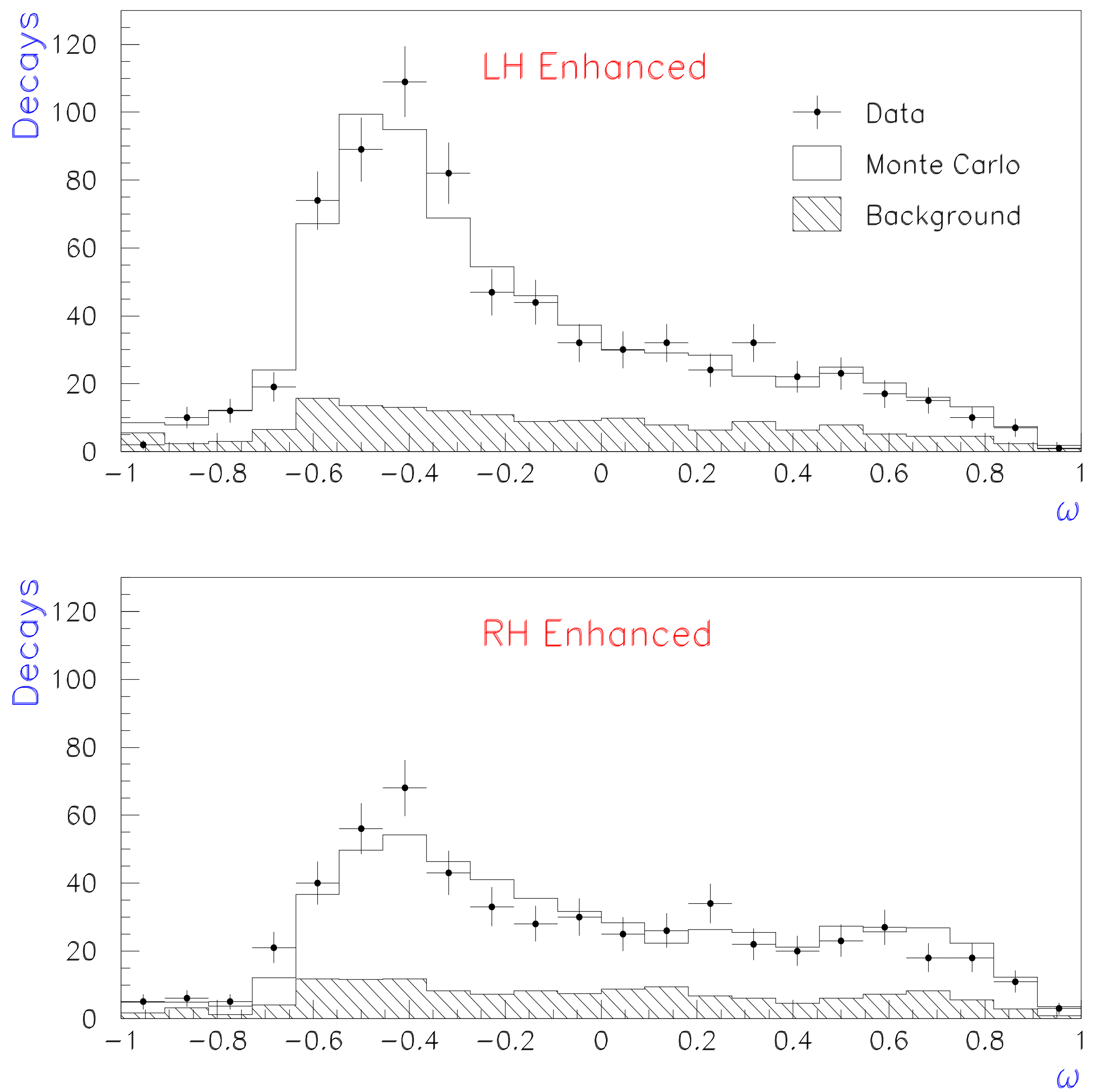
$\tau \longrightarrow \rho\nu_\tau$ SELECTION



m_ρ reconstruction



$\tau \longrightarrow \rho\nu_\tau$ Decay ω Spectra 93–95



Fit Technique

Perform an event by event maximum likelihood fit to the combined theoretical production and decay cross section, corrected for radiation, resolution, event selection, and background.

$$l(x,c,p) = BG_{non-\tau}(x,c) + BG_{\tau}(x,c,p) + \varepsilon_{\tau-sel}(x,c,p)$$

$$\times\, \varepsilon_{decay-id}(x,c,p) \int xres(x,x',c) \times rad(x',c,p)\, n(x')\, dx'$$

$$\times \int cres(c,c',x) \frac{d\sigma}{dC}(c',p)\, dc'$$

x,x'- measured and theoretical scaled energy
c,c' - measured and theoretical $\cos\theta$
p - measured electron beam polarization
x->ω for rho and combined hadron fits.

Corrections are determined from MC.
The likelihood function is normalized to 1 over the relevant phase space.

Tau Neutrino Helicity.

SLD

Fit Results

Combined	$\tau \to \pi(k)\nu$	$\tau \to \rho\nu$
-0.93+0.10+0.04	**-0.81+0.17+0.02**	**-0.99+0.12+0.04**

Systematics	π	ρ
Final State Selection	0.7	2.7
Background	1.1	1.3
Radiative Corrections	0.5	0.4
Resolution	1.3	1.5
Beam Polarization	0.9	0.6
A_e, A_τ	0.7	0.8
Total	2.4	3.5

Tau Michel Parameters.

Fit Results

	Combined	$\tau \to e\nu\nu$	$\tau \to \mu\nu\nu$
ρ	0.72+0.09+0.03	0.71+0.14+0.05	0.54+0.28+0.14
η			–0.59+0.82+0.45
ξ	1.05+0.35+0.04	1.16+0.52+0.06	0.75+0.50+0.14
$\xi\delta$	0.88+0.27+0.04	0.85+0.43+0.08	0.82+0.32+0.07

Systematics	$\Delta\rho$	$\Delta\xi$	$\Delta(\xi\delta)$	η^{μ}
Final State Selection	0.008	0.032	0.015	0.14
τ Background	0.023	0.024	0.033	0.42
Non-τ Background	0.020	0.017	0.007	
Radiative Corrections	0.012	0.004	0.005	0.008
Resolution	0.023	0.015	0.023	0.05
Beam Energy	0.013	0.013	0.008	
Beam Polarization	0	0.008	0.005	0.045
A_e, A_τ	0.004	0.004	0.008	0.014
Total	0.03	0.04	0.04	0.45

Systematics and cross checks.

- Evaluate systematics by varying MC parameterizations within their statistical errors and varying input physics parameters by their errors.
- Check fitting procedure on fully reconstructed MC samples.
- Test robustness of fit using numerous "toy" MC samples.
- Check consistency by fitting for different run periods, tau charges, etc.
- Vary selection cuts and refit.

Summary

The results are consistent with the V-A prediction and are in good agreement with other experimental results.

A first measurement using beam polarization to tag the spin of the tau.
Relatively small number of events, however unique systematics.

Measured not only the magnitude but also the sign of all pseudoscalar and parity violation quantities.

Expecting more data in the next couple of years which can be reduce th errors by factor of ~ 2.