A Measurement of Tau Polarization Using L3 Detector at LEP

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Contents

From Tau Polarization to $\sin^2\theta_w^{eff}$

At LEP, τ's from the process $e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$ are polarized. In the Born approximation, $\mathcal{P}_\tau(\cos\theta)$ is a simple function of the vector and axial vector current constants.

$$\mathcal{P}_\tau \equiv \frac{\sigma(h_\tau = 1/2) - \sigma(h_\tau = -1/2)}{\sigma(h_\tau = 1/2) + \sigma(h_\tau = -1/2)}$$

$$\mathcal{P}_\tau(\cos\theta) = -\frac{\mathcal{A}_\tau + 2\mathcal{A}_e \cos\theta/(1+\cos^2\theta)}{1 + 2\mathcal{A}_\tau\mathcal{A}_e \cos\theta/(1+\cos^2\theta)}$$

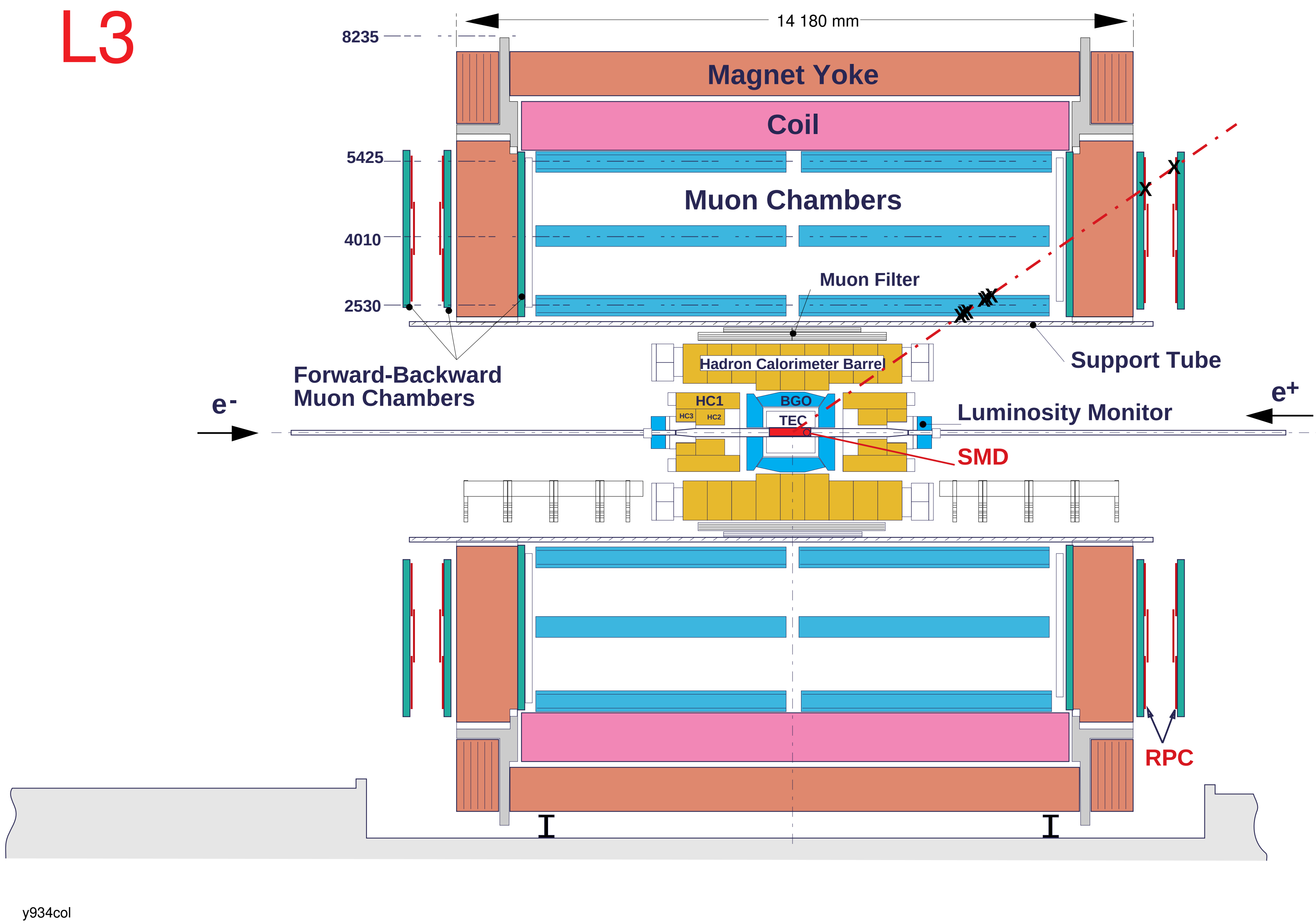
where

$$\mathcal{A}_l \equiv 2g_{Vl}g_{Al}/(g_{Vl}^2 g_{Al}^2).$$

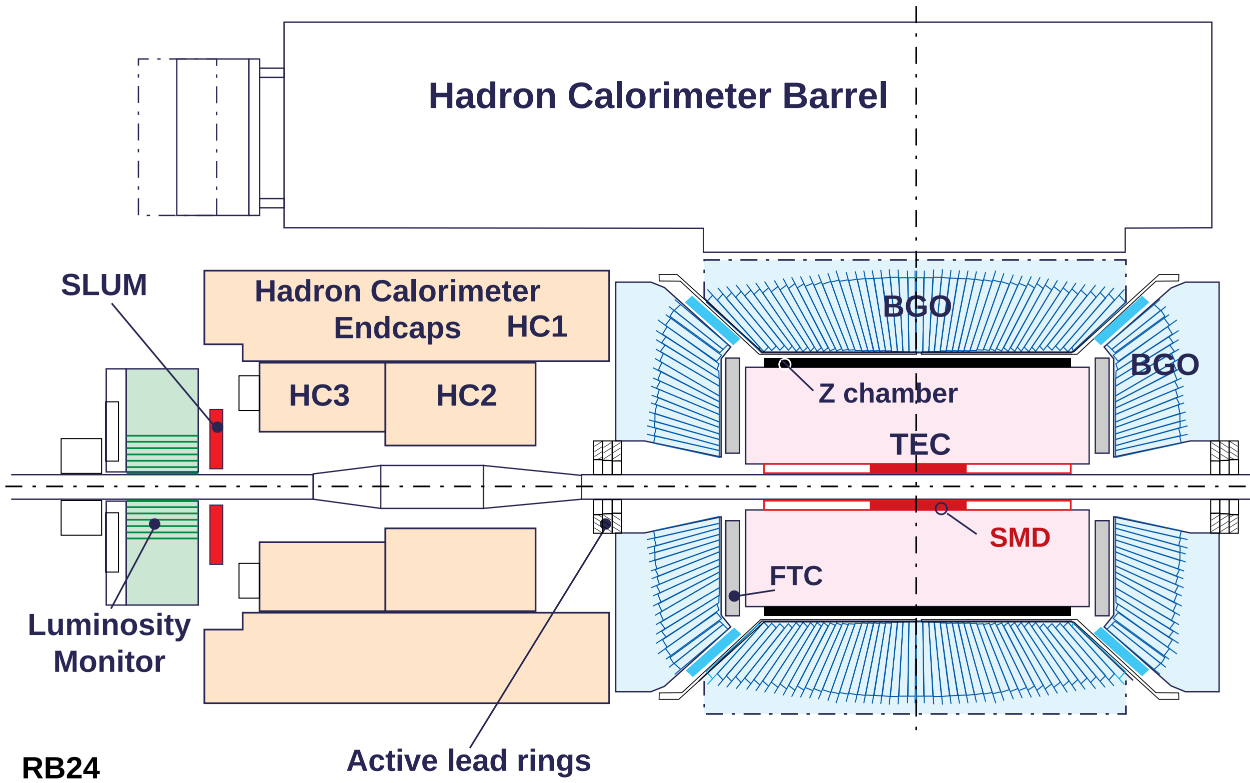
In the Standard Model,

- $\mathcal{A}_\tau = \mathcal{A}_e$
- $g_{Vl}/g_{Al} = 1 - 4\sin^2\theta_w^{eff}$

L3

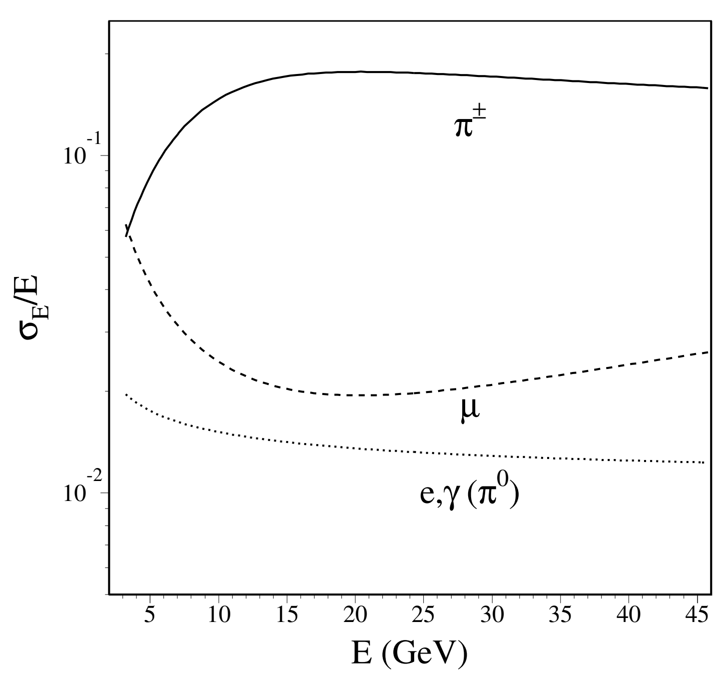

14 180 mm
8235
5425
4010
2530
Magnet Yoke
Coil
Muon Chambers
Muon Filter
Support Tube
Hadron Calorimeter Barrel
Forward-Backward
Muon Chambers
e-
e+
HC1
HC3
HC2
BGO
TEC
Luminosity Monitor
SMD
RPC
y934col

Inner view of L3 Detector



Energy Resolution

- π^- determined by TEC, ECAL, HCAL
- μ by the muon spectrometer
- $e, \gamma(\pi^0)$ by ECAL



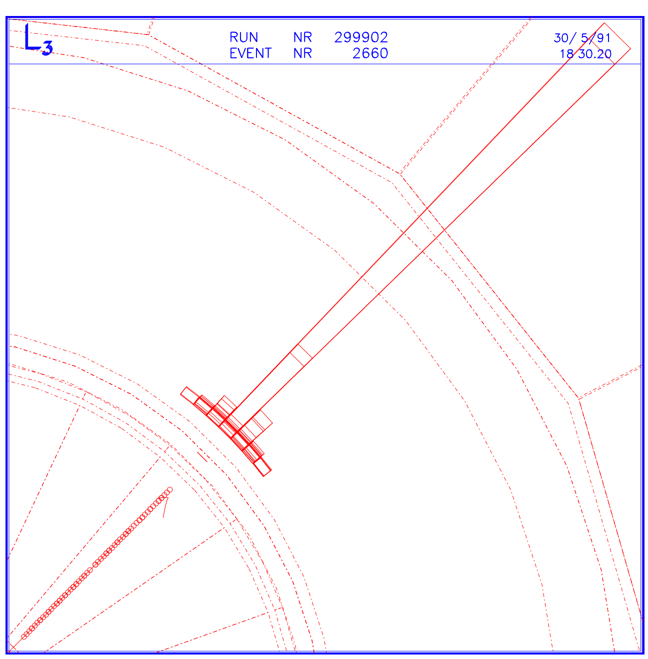
Preselection from Dilepton Samples

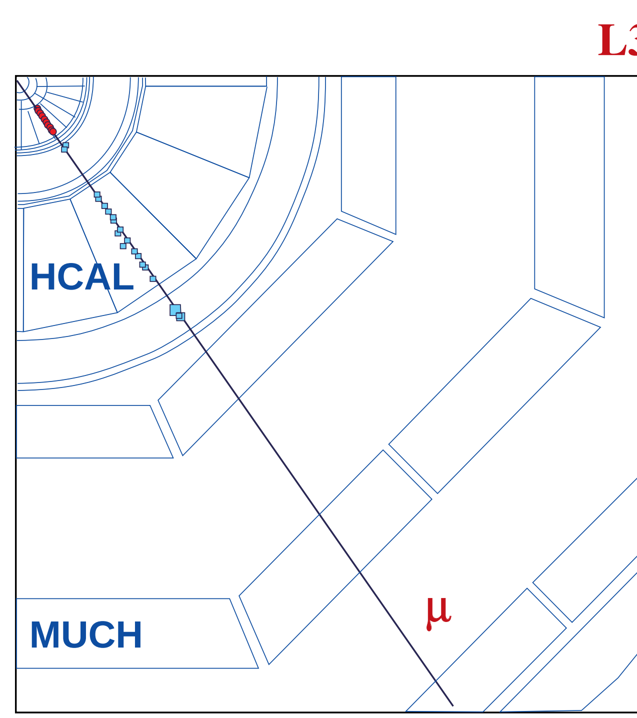
- Selection cuts are imposed to reject $Z \rightarrow hadrons$, cosmic muons, and $e^+e^- \rightarrow f^+f^-e^+e^-$

Particle Identification

$\boxed{\text{The leptonic 1-prong } \tau \text{ decays}}$

- The electron signature A sharp narrow shower in ECAL with a matching TEC track. Little HCAL deposit.
- The muon signature A minimum ionizing track in HCAL with a matching TEC track or hits in the muon spectrometer.

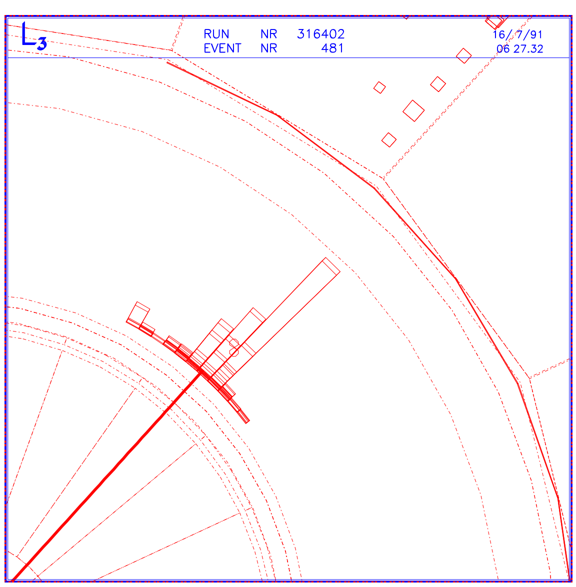


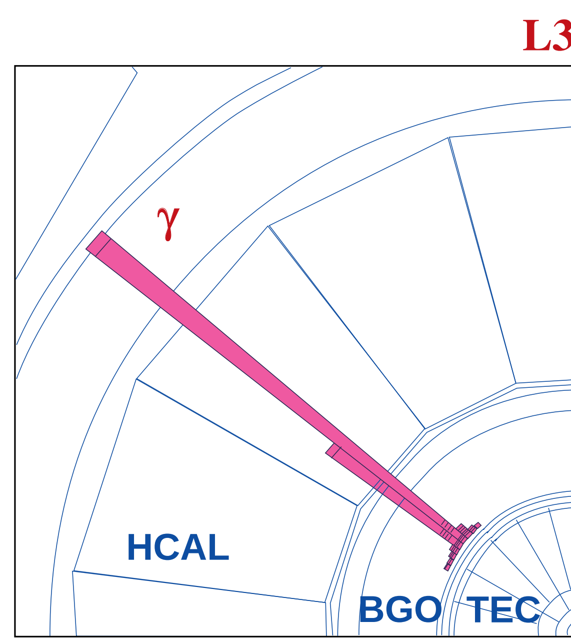


e candidate μ candidate

The hadronic 1-prong τ decays

- The charged pion signature A wide asymmetrical shower in ECAL with a matching TEC track. visible HCAL clusters.
- The photon signature A sharp narrow shower in ECAL only.
- π^0 is determined by the invariant mass of the two photon clusters in ECAL.
- ρ requires one π^- and one π^0 candidate while a_1 requires one π^- and two π^0 candidates.
- Since π^- and π^0 from τ are boosted together, it is necessary to separate the energies in ECAL.

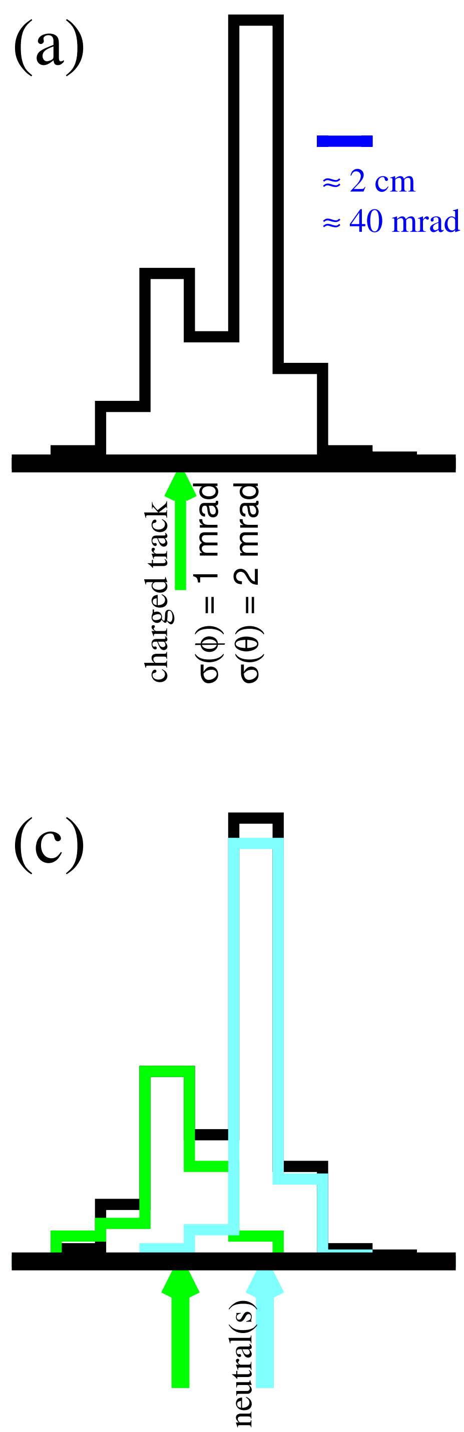


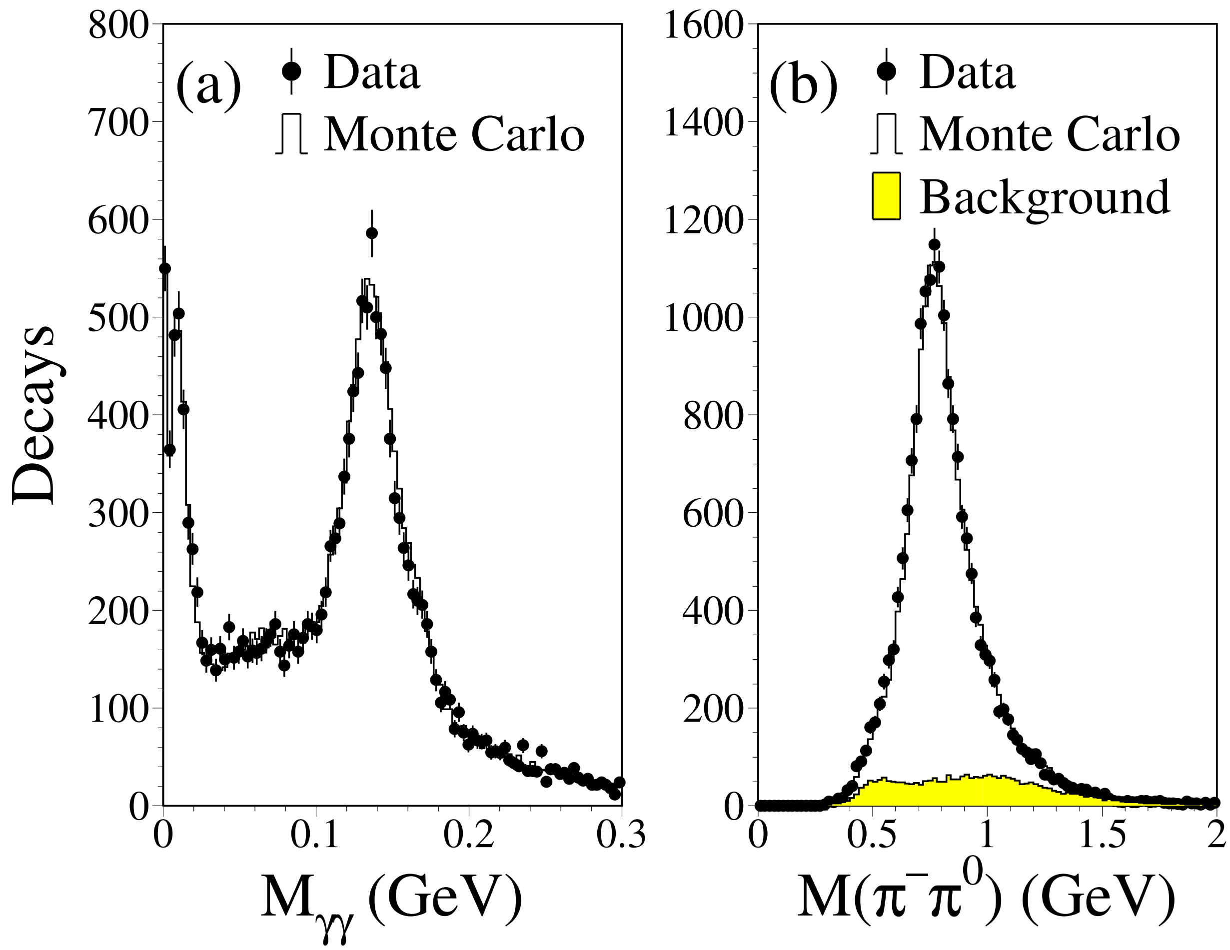


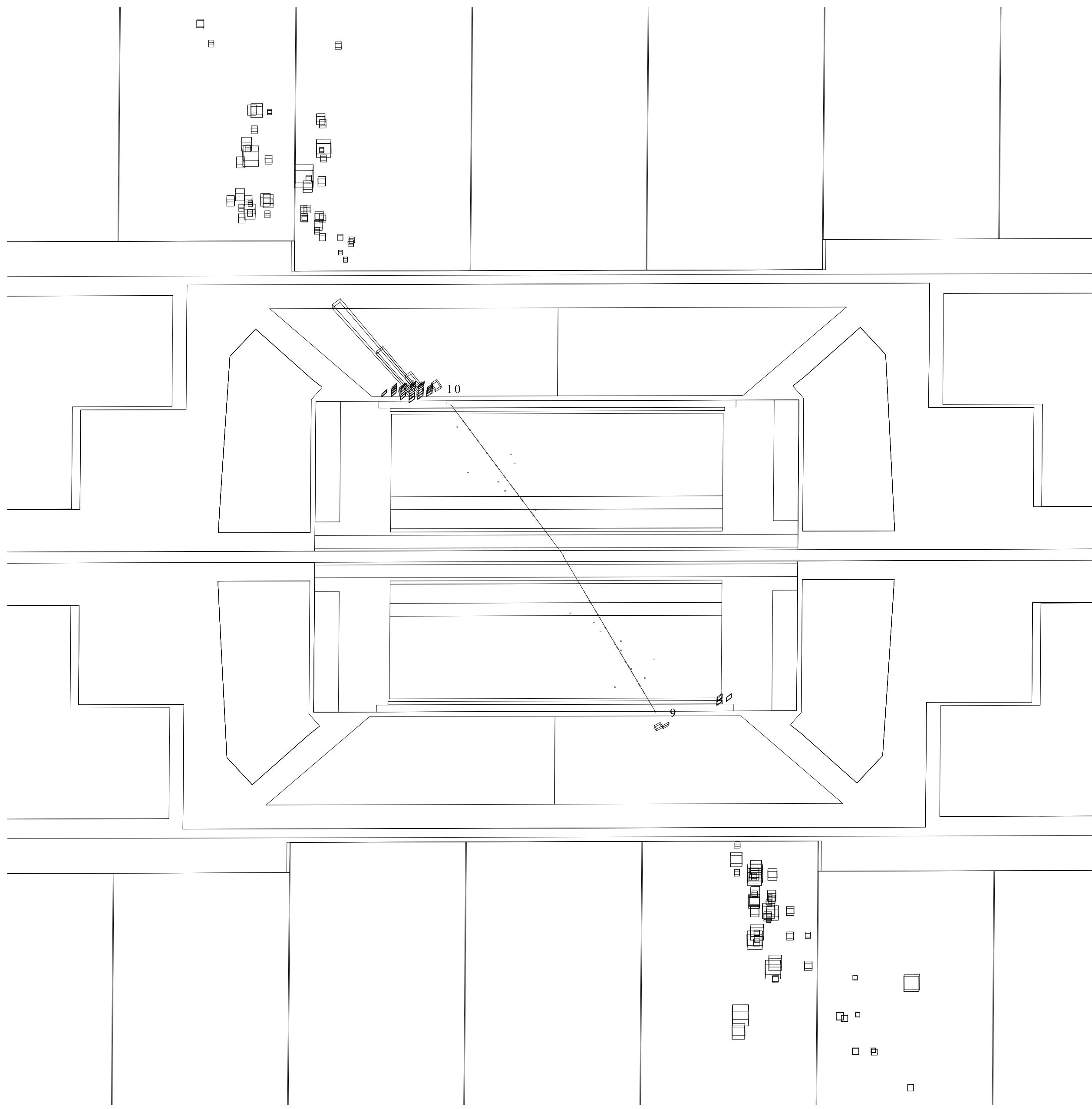
Background Rejection

- After the particle identification, the opposite hemisphere is checked to reject bhabha and dimuon events.

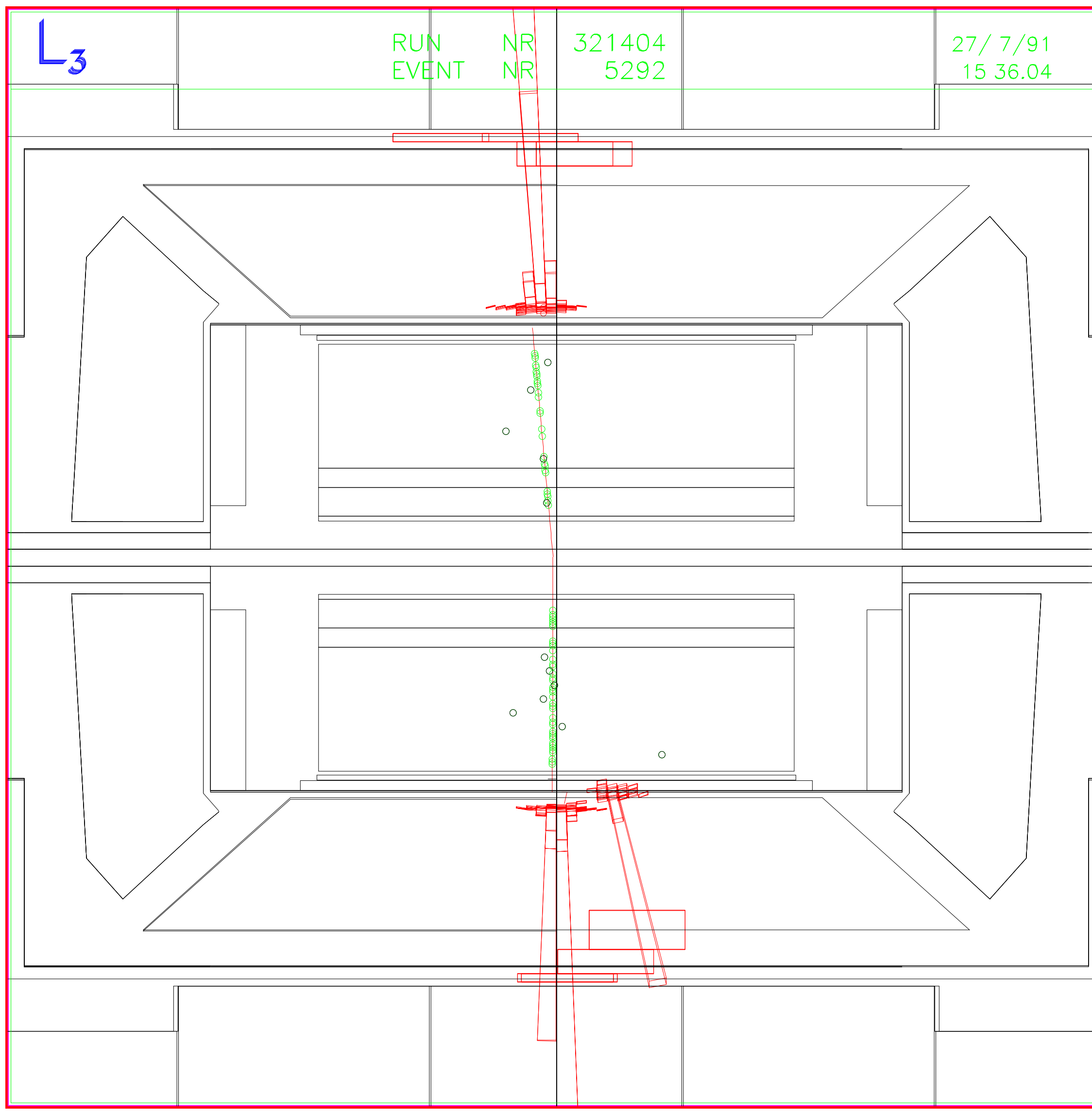
Charged/Neutral Cluster Reconstruction
(BGO Calorimeter, TEC, Z-Chamber)




Decays
(a)
Data
Monte Carlo
$M_{\gamma\gamma}$ (GeV)
(b)
Data
Monte Carlo
Background
$M(\pi^-\pi^0)$ (GeV)



$$\tau^+\tau^- \longrightarrow \rho^+\pi^-\nu_\tau\nu_\tau \qquad \text{candidate}$$
$$\hookrightarrow \pi^+\pi^0$$



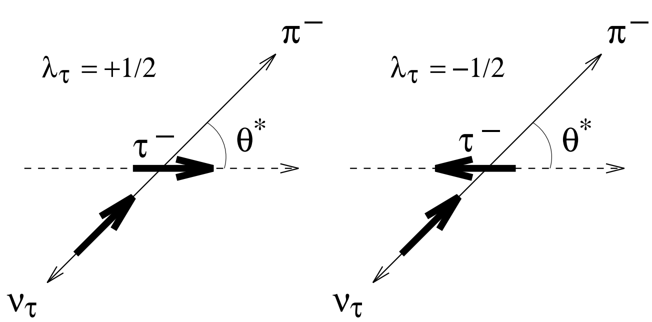
non-τ event $e^+e^-\gamma$

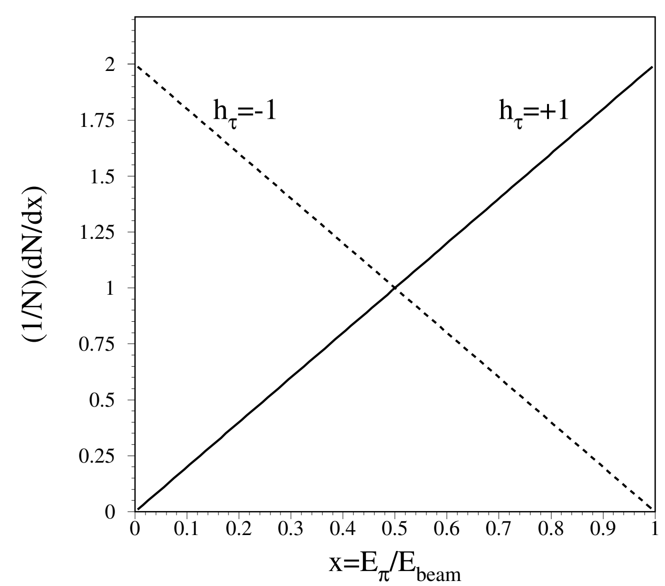
Fitting Method

The kinematical distribution of the decay particles from τ depends on $\mathcal{P}_\tau$. In each τ decay channel, the combination of the positive and negative helicity MC histograms is fitted with the data histogram with the variables sensitive to τ polarization.

$$\frac{1}{N}\frac{dN}{dx} \simeq f(x) + \mathcal{P}_\tau g(x)$$

Example: τ to $\pi\nu$

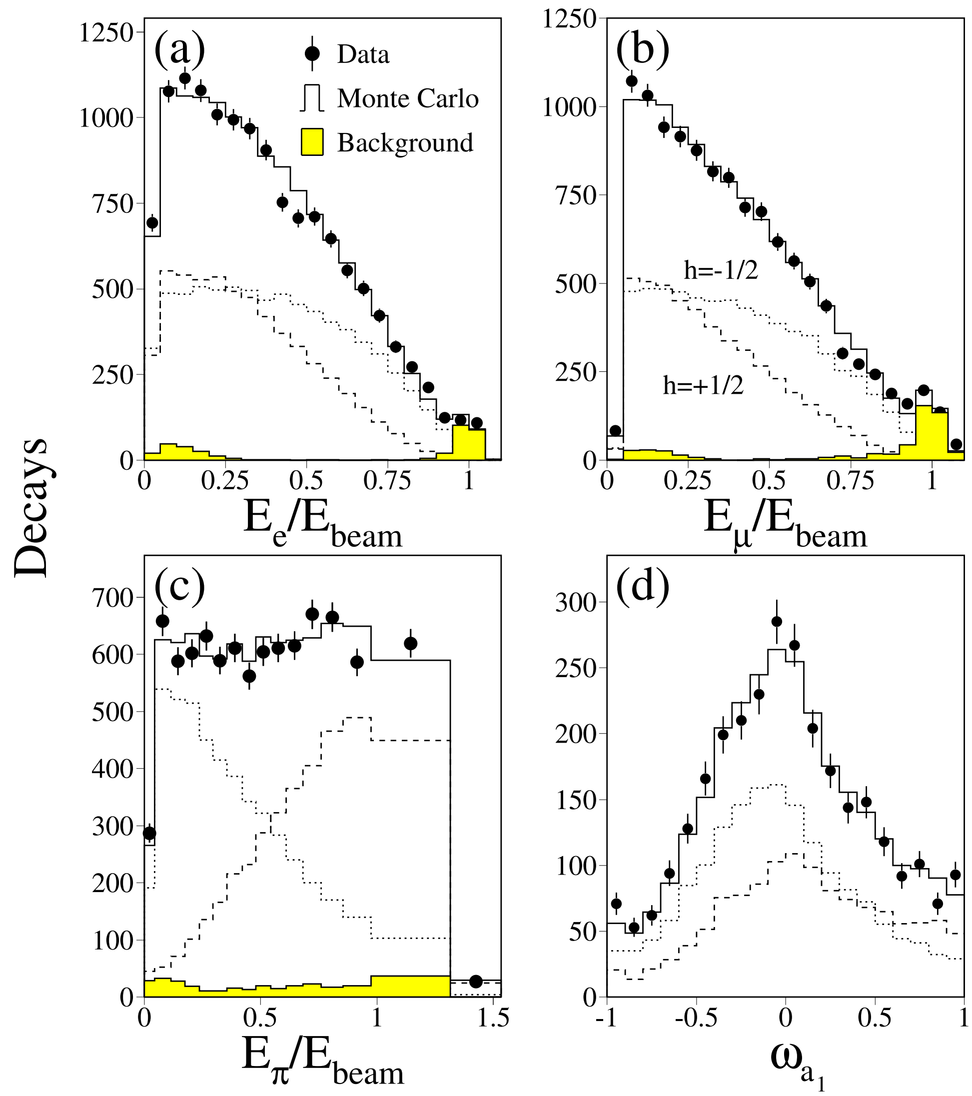




Sensitivity

Decay Channel	Variables	Sensitivity
$e\nu\nu$, $\mu\nu\nu$	E_l/E_{beam}	0.22
$\pi\nu$	E_π/E_{beam}	0.58
$\rho(\pi^-\pi^0)\nu$	$\cos\theta^*$, $\cos\psi^*$	0.49
$a_1(\pi^-\pi^0\pi^0)\nu$	ω_a	0.44

Fitted Result



(a) $\tau \to e\nu\nu$ (b) $\tau \to \mu\nu\nu$

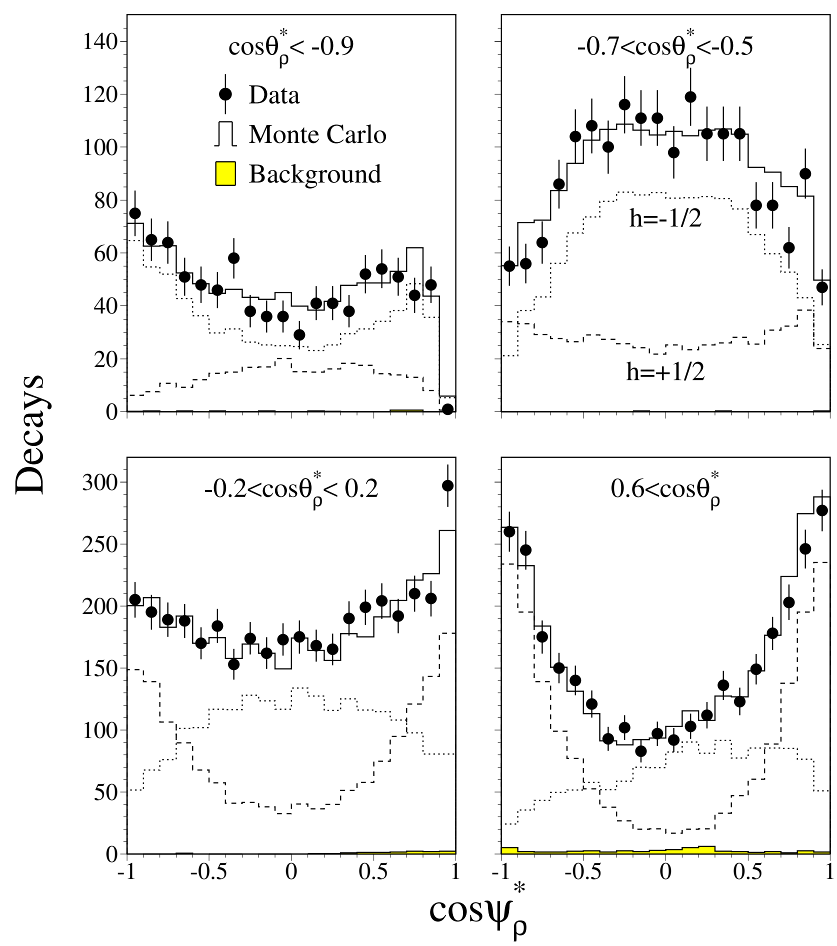
(c) $\tau \to \pi\nu$ (d) $\tau \to a_1\nu$

Result for $\tau \rightarrow \rho\nu$

The ρ channel decay is described by two angles, the ρ direction at the τ rest frame and the π^- direction angle at the ρ rest frame.

$$\cos\theta^* = \frac{4m_\tau^2}{m_\tau^2 - m_\rho^2}\frac{E_{\pi^0}+E_{\pi^-}}{E_{beam}} - \frac{m_\tau^2+m_\rho^2}{m_\tau^2-m_\rho^2} \sim \frac{E_\rho}{E_{beam}}$$

$$\cos\psi^* = \frac{m_\rho}{\sqrt{m_\rho^2-4m_\pi^2}}\frac{E_{\pi^-}-E_{\pi^0}}{\left|\vec{P}_{\pi^-}+\vec{P}_{\pi^0}\right|} \sim \frac{E_{\pi^-}-E_{\pi^0}}{E_\rho}$$



L3 Result

From 86 000 τ pairs with $88.2 < \sqrt{s} < 94.3$ GeV collected during 1990-1993,

- $\mathcal{A}_\tau = 0.150 \pm 0.013 \pm 0.009$
- $\mathcal{A}_e = 0.157 \pm 0.020 \pm 0.005$
- $\sin^2\theta_w^{eff} = 0.2309 \pm 0.0016$.

Systematic errors in $\mathcal{P}_\tau$ are coming from the selection procedure, background estimation, calibration, charge confusion and theoretical uncertainties.

Other LEP Results

Group	Aleph	Delphi	Opal
$\mathcal{A}_\tau$	$0.136 \pm 0.012 \pm 0.009$	$0.148 \pm 0.017 \pm 0.014$	$0.134 \pm 0.010 \pm 0.009$
$\mathcal{A}_e$	$0.129 \pm 0.016 \pm 0.005$	$0.136 \pm 0.027 \pm 0.003$	$0.134 \pm 0.015 \pm 0.004$
$\sin^2\theta_w^{eff}$	0.2332 ± 0.0014	0.2320 ± 0.0021	0.2331 ± 0.0013
Year	1990-1992	1990-1992	1990-1994
Ref	Published	Published	Preliminary

SLAC SLD Results

Based on 1993 data,

- $\mathcal{A}_e = 0.1656 \pm 0.0071 \pm 0.0028$
- $\sin^2\theta_w^{eff} = 0.2292 \pm 0.0009 \pm 0.0004$