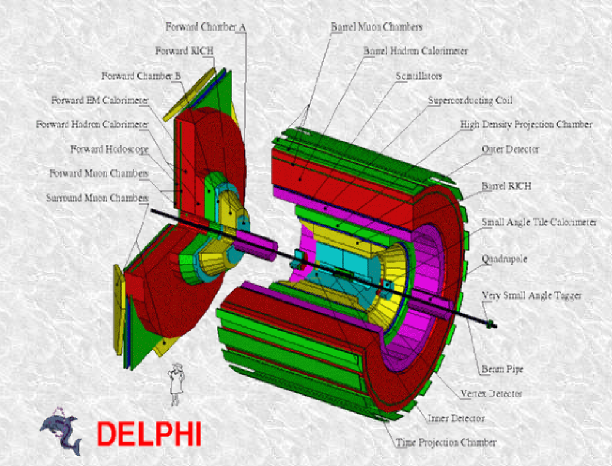
Measurement of $e^+e^- \to Z^0(\gamma^*) \to \tau^+\tau^-(\gamma)$ cross section and determination of the branching fraction $\tau \to \mu \bar{\nu}_\mu \nu_\tau$ at $\sqrt{s}$ =189 GeV in DELPHI

L. M. Mundim Filho and M. A. A. Pacheco,
UERJ – Rio de Janeiro - Brazil
M. E. Pol
CBPF – Rio de Janeiro - Brazil



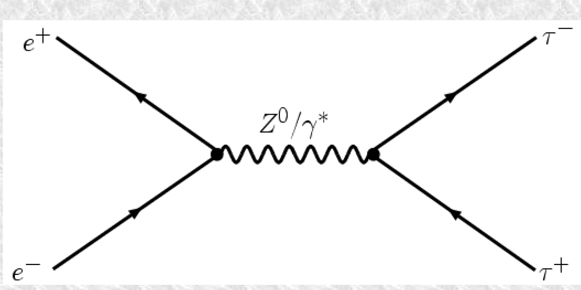
Introduction

We study the $\tau^+\tau^-$ production from e^+e^- collisions at the DELPHI detector at LEP for data acquired during the data taking period of 1998, which amounted to an integrated luminosity of 158 pb^{-1}. We compare the real data with Monte Carlo simulations of all foreseen Standard Model processes for e^+e^- and find a good agreement.

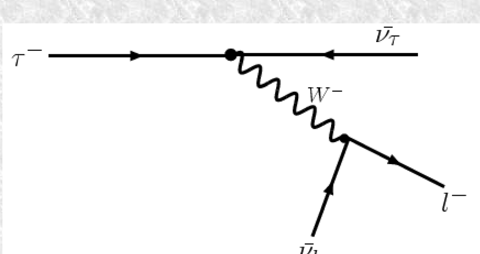
We study the behaviour of several kinematics variables in signal and background Monte Carlo SM samples, with that it was possible to establish selection criteria in order to maximize the rejection of background and minimize the rejection of signal. We apply these same selection criteria to real data in order to obtain a $\tau^+\tau^-(\gamma)$ sample, used to measure the cross section of the process $e^+e^- \to Z^0(\gamma^*) \to \tau^+\tau^-(\gamma)$. Our result is $\sigma = 8.62 \pm 0.86 \pm 0.79$ pb, where the first error is the statistical one and the second is the systematic error.

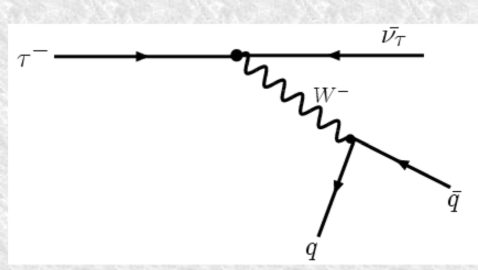
The muon identification was done studying the hits in the muon chambers and the characteristic energy losses in the electromagnetic and hadronic calorimeters. It was used to select the decay $\tau \to \mu \bar{\nu}_\mu \nu_\tau$ from the $\tau^+\tau^-(\gamma)$ sample and perform the measurement of the branching fraction, which we found to be BR = $0.173 \pm 0.045 \pm 0.025$.

The signature



The tau lepton final state decays can be leptons or hadrons:





Each tau lepton can decay in 1 (85.3%), 3 (15.2%) or 5 (0.1%) visible particles. In this study we only consider the 1 prong decays.

Monte Carlo Samples

- KK2F signal sample $\tau^+\tau^-$;
- WPHACT four-fermion neutral and charged current processes;
- KK2F for $q\bar{q}(\gamma), \mu^+\mu^-$;
- BHWIDE for $e^+e^-(\gamma)$;
- TWOGAM for $\gamma\gamma \to q\bar{q}$;
- BDK for $\gamma\gamma \to \ell^+\ell^-$;
- TEGG7.1 for Compton Scattering ;
- QEDBK for $e^+e^- \to \gamma\gamma$.

$\tau^+\tau^-(\gamma)$ Event selection

To extract the $\tau^+\tau^-(\gamma)$ final state we require:

- 2 well reconstructed charged particles with $p > 3$ GeV/c each,
  - +up to 5 additional charged particles were allowed, provided that $p < 0.5$ GeV/c
- total charge equal to 0;
- coordinate R where the particle was first detected less than 7 cm ;
- track length of the two lepton candidates > 30 cm;
- events are in the barrel region, $0.8 < \theta < 2.37$ rad;
- impact parameters $|R| < 0.6$ cm and -2.0 cm $< z < 1.0$ cm.
- visible energy greater than 20% of $\sqrt{s}$;
- $prad = \sqrt{\left(\frac{p_1}{m_1}\right)^2 + \left(\frac{p_2}{m_2}\right)^2} < 0.9$, where $m_i = \frac{\sqrt{s}\sin\theta_j}{|\sin(\theta_1+\theta_2)| + \sin\theta_1 + \sin\theta_2}$;
- no more than one identified muon per event;
- No more than one identified electron per event;
- acoplanarity between main tracks less than 20 degrees;

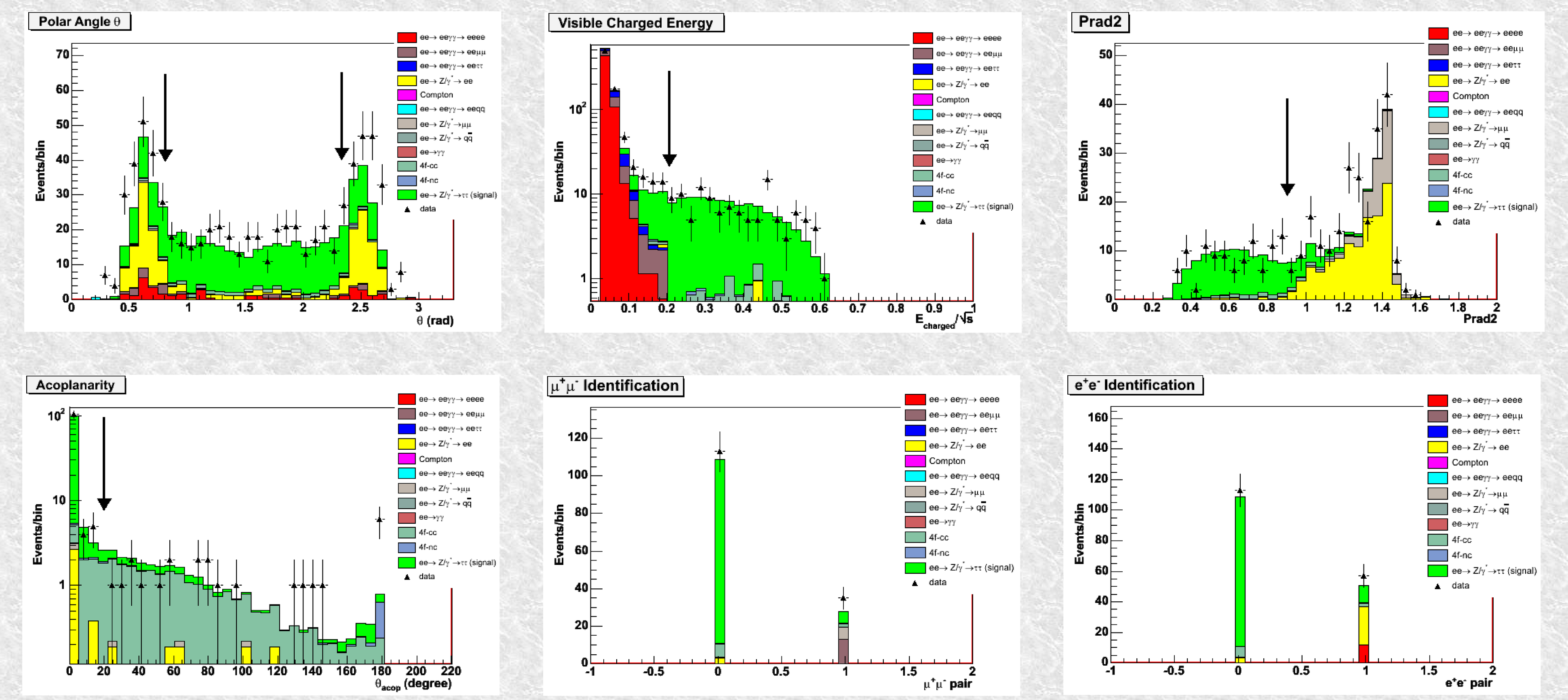
Muon Selection

Muons are identified by the hits registered in the Muon Chambers, the associated electromagnetic and hadronic energies, and using the fact that the hadronic energy should be evenly distributed in the four layers of the calorimeter $\left(RH = \frac{E_{Layer3} + E_{Layer4}}{E_{Layer1} + E_{Layer2}}\right)$.

A charged particle is identified as a μ if it satisfies one of the following conditions:

- signals in the Mch, Eelm < 2 GeV, Ehad <15 GeV and RH < 5;
- very good signals in the Mch, Eelm > 2 GeV, Ehad < 15 GeV and RH < 5;
- no hits in the Mch, Eelm < 2 GeV, Ehad < 15 GeV and 0.2 < RH < 3.0.

The plots below, which correspond to the $\tau^+\tau^-(\gamma)$ selection, show the effect of the main cuts: all cuts are applied except for the displayed variable.



Selection Efficiencies

The selection efficiency for $\tau^+\tau^-(\gamma)$ selection is ε = 7.5 % in the solid angle 4 π.
We selected 113 events in the real data sample, while we expected 97.9 from the signal Monte Carlo simulations and 10.8 from the background.

From the selected $\tau^+\tau^-(\gamma)$ data and Monte Carlo samples, the $\tau \to \mu \bar{\nu}_\mu \nu_\tau$ decays were identified with efficiency ε = 8.4 % in the solid angle 4 π. 47 τ decays into μ were found in the data, while 38.6 were expected from the signal MC and 7.3 from the background (1.7 from other τ–channels and 5.6 from non-τ channels).

Cross-section

The cross-section for this process is,

$$\sigma_{\tau\tau} = \frac{N_{data} - N_{background}}{\epsilon_{\tau\tau} L} = \frac{113 - 10.84}{0.075 \times 158\, pb^{-1}} = 8.62 \pm 0.86\,(stat) \pm 0.79\,(sist)\, pb$$

where N_{data} is the number of $e^+e^- \to Z^0(\gamma^*) \to \tau^+\tau^-(\gamma)$ events selected in the data, $N_{background}$ is the expected background in the $\tau^+\tau^-(\gamma)$ sample, $\varepsilon_{\tau\tau}$ is the $\tau^+\tau^-(\gamma)$ selection efficiency and L is the integrated luminosity.
This result is in good agreement with the Standard Model cross-section at 189 GeV, which is 8.235 ± 0.009 pb.

Branching Fraction

The branching fraction for $\tau \to \mu \bar{\nu}_\mu \nu_\tau$ decay is:

$$BR(\tau \to \mu \bar{\nu}_\mu \nu) = \frac{N_{\tau\to\mu}}{N_\tau} \frac{1 - b_{\tau\to\mu}}{1 - b_\tau} \frac{\epsilon_{\tau\tau}}{\epsilon_{\tau\to\mu}} = 0.173 \pm 0.045\,(stat) \pm 0.025\,(sist)$$

where N_τ is the number of selected τ in the data, b_τ is the fraction of the τ background, $\varepsilon_{\tau\tau}$ is the $\tau\tau$ selection efficiency, $N_{\tau\to\mu}$ is the number of selected μ in the $\tau\tau$ data sample, $b_{\tau\to\mu}$ is the fraction of background for the μ selection within the $\tau\tau$ sample and $\varepsilon_{\tau\to\mu}$ is the efficiency for selecting μ inside the $\tau\tau$ sample.
This result is in good agreement with the world average (PDG) branching fraction, which is 0.1736 ± 0.0006.

References

- DELPHI Coll.; P. Aarnio et al., Nucl. Instr. and Meth. **A303** (1991) 233.
- DELPHI Coll.; P. Abreu et al., Nucl. Instr. and Meth. **A378** (1996) 57.
- DELPHI Coll.; P. Abreu et al., Eur. Phys. J. **C10** (1999) 201.

Acknowledgments:

We acknowledge the financial support of Capes and CNPq.