New Data on Semihadronic Decays of the $\tau$ Lepton

CELLO-Collaboration

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Abstract. Branching ratios for the decay $\tau \rightarrow v + (n$ pions) with $n \geq 2$ are presented. The new data include all possible charge configurations of the pion system and, in particular, final states containing one or several neutral pions. The data are compared with predictions from CVC (even number of pions in final state) and current algebra (odd number of pions). They strongly support the standard coupling of the $\tau$ to the weak charged current.

Introduction

$\tau$ leptons from $e^+ e^-$ annihilations have proven a useful tool for testing various aspects of the Standard Model of electroweak interactions [1] through charge asymmetry [2, 3] and polarization measurements [4]. In all these analyses the $\tau$ was assumed to couple to the conventional $V - A$ charged current. Experiments on the $\tau$ decay properties carried out so far have supported this idea: The major branching ratios [4, 5], decay lepton spectra [6], and the $\tau$ life time [7] are consistent with the standard $V - A$ coupling. Very little [8] or not data exist, however, on a large fraction ($\sim 30\%$) of the $\tau$ decay channels, i.e. decays into several pions+$\nu$em. On the other hand rather firm theoretical predictions exist for the width into an even number of pions from $e^+ e^- \rightarrow 2n$ pions using only the CVC hypothesis [9], and, to a lesser extent, on the width into an odd number of...
ions using current algebra and PCAC [9, 10]. The main experimental difficulty which may have delayed an earlier measurement of these channels is connected to the (potential) presence of neutral pions among the final state hadrons. For an even number of pions one always has at least one neutral pion in the final state. Furthermore one has to make sure that a system containing only charged pions is not contaminated by events with undetected π^0's. Thus good neutral detection is mandatory. In this letter we report on measurements of the following decay channels (τ^- is used symbolically for both charge states):

\[ \tau^- \rightarrow \pi^- \pi^0 \nu \]  
\[ \tau^- \rightarrow \pi^- \pi^0 \pi^0 \nu \]  
\[ \tau^- \rightarrow \pi^- \pi^0 \pi^0 \pi^0 \nu \]  
\[ \tau^- \rightarrow \pi^- \pi^+ \pi^- \nu \]  
\[ \tau^- \rightarrow \pi^- \pi^+ \pi^- \pi^+ \nu \]  
\[ \tau^- \rightarrow \pi^- \pi^+ \pi^- \pi^+ \pi^- \nu \]  

The data were recorded by the CELLO detector at PETRA, running at moderate energies (14 and 22 GeV CMS energy). At these energies τ final states containing many pions suffer less from overlap problems (see below) and are thus easier to analyze. We will briefly describe the experiment and then turn to the event selection and the analysis of the multipion final states from the τ decay. The measured branching ratios will be compared to predictions from e^+e^- → hadrons using CVC, and to predictions from current algebra.

**Event Selection**

In order to select τ pairs from the events recorded by CELLO, the event topology is defined using the sphericity axis calculated from all observed charged prongs and neutral particles. Events with energy deposition in the endcaps in excess of 3 GeV were rejected. The particles are divided into two jets by the plane perpendicular to the sphericity axis. For each hemisphere the normalized momentum vector sum \( \mathbf{n}_i \), of all charged particles, the total charge \( Q_i \) and the total invariant mass \( m_i \) (including neutrals and assuming pions for the charged particles) is calculated. The true charged multiplicity in each hemisphere is restored by identifying electron-positron pairs from γ conversions in the beampipe or in the chambers. This has been achieved by reconstructing the true conversion point and forming the invariant mass with the re-evaluated kinematical quantities at the conversion point. A mass cut of 80 MeV was employed to define an e^+e^- pair. The pairs thus found were taken out of the charged multiplicity and counted as photons in the subsequent analysis. Events are accepted with a total charged multiplicity <10 and a minimum energy deposit of 360 MeV in at least one jet. For the 2 prong topology we require the polar angle \( \theta \) to satisfy \(|\cos \theta| < 0.85\) for each of the oppositely charged particles. Electrons were identified via their characteristic shower pattern in the calorimeter (>60% of the energy deposited in the first 2 lead layers of the calorimeter, corresponding to an average of 5X_0) and by comparing the total energy deposited with the measured particle momentum. The efficiency for identifying electrons is around 80% beyond 2 GeV. 2 prongs with 2 positively identified electrons were rejected. A total energy cut of 10(15) GeV for the 14(22) GeV run was applied to reject QED events escaping the above.