MEASUREMENT OF $\tau$ BRANCHING FRACTIONS

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On behalf of the

DELPHI COLLABORATION
$Z^0 \rightarrow \tau^+ \tau^- \text{ SELECTION}$

At LEP1 energies, the signature of a $\tau^+ \tau^-$ event consists of 2 collimated low multiplicity jets in opposite direction

- the plane perpendicular to the thrust axis defines 2 hemispheres
- 1 of the leading particles $|\cos(\Theta)| < 0.732$
- $q\bar{q}$ was reduced: charged track multiplicity $\leq 6$ and $\theta_{iso} > 160^\circ$
- Cosmic rays and beam gas were reduced: $Imp_{\rho\phi} < 1.5 \text{ cm}$ and $Imp_z < 4.5 \text{ cm}$
- Two photon events were removed: $E_{tot} > 8 \text{ GeV}$ and $P_t > 0.4 \text{ GeV}/c$
- $e^+e^-$ and $\mu^+\mu^-$ was reduced: $\theta_{uncol} > 0.5^\circ$
  
  $P_{rad} = \sqrt{(P_1^2 + P_2^2)} < P_{beam}$ and
  
  $E_{rad} = \sqrt{(E_1^2 + E_2^2)} < E_{beam}$
$Z^0 \rightarrow \tau^+ \tau^-$ SELECTION (Cont.)

Data Sample

This analysis was done on 47000 $\tau^+ \tau^-$ selected events from 1993 (15.7 pb$^{-1}$ at $E_{cm} = 91.2$GeV, 9.4 pb$^{-1}$ at $E_{cm} = 89.2$GeV and 4.5 pb$^{-1}$ at $E_{cm} = 93.2$GeV) and 1994 (47.4 pb$^{-1}$ at $E_{cm} = 91.2$GeV) data.
The $K_y$ analysis was also done on 25000 additional $\tau^+ \tau^-$ from 1992 and 1995 data.

MonteCarlo Sample

Events simulated through the detector and reconstructed with the same program as the real data were used, produced with the generators:

- KORALZ for $e^+ e^- \rightarrow \tau^+ \tau^-$
- DIMU3 for $e^+ e^- \rightarrow \mu^+ \mu^-$
- BABAMC for $e^+ e^- \rightarrow e^+ e^-$
$Z^0 \rightarrow \tau^+\tau^-$ SELECTION (Cont.)

• JETSET7.3 for $e^+e^- \rightarrow q\bar{q}$

• Berends-Dasheveldt-Kleiss for $e^+e^- \rightarrow e^+e^-e^+e^-$

• TWOGRAM for $e^+e^- \rightarrow e^+e^-\tau^+\tau^-$
  and $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$

  $c = 80\%$ and $b = 2\%$
PARTICLE ID IN $\tau$ DECAYS

- ELECTRONS
  - just 1 part. in the hem. with $p > 0.1p_{beam}$
  - $dE/dx$ in TPC compatible with $e$
  - associated $E/p$ compatible with $e$
  - no $E_{CAL}$ beyond the 1st. layer
  - no neutral $E_{EM} > 4$GeV in a cone of $18^\circ$
  - track in the opposite hemisphere inconsistent with $e$ ID
MUONS

- Just 1 particle in the hemisphere with \( p > 0.05p_{beam} \)
- \( E_{HCAL} \) compatible with MIP (<2GeV per layer)
- At least 2 hits in MUCH
- Associated EM energy <3GeV
- No neutral energy with \( E > 2\text{GeV} \) in a cone of 18°
- \( E_{tot} < 0.7E_{CM} \) if muons in both hemispheres
DELPHI (prelim)
• PIONS
  • \( \frac{dE}{dx} \) in TPC compatible with \( \pi \)
  • \( \langle E \rangle_{\text{HICAL}} \) 3GeV
  • associated \( E_{EM} \) compatible with MIP
  • no neutral \( E'_{EM} \) in a cone of 18°
  • no hits in MUCH
• **KAONS**

$K^+$ ID in RICH for $p > 8.5 \text{GeV/c}$

- at least 1 track with $p > 6 \text{ GeV/c}$

- Ring ID if $p > 10.5 \text{ GeV/c} : \theta_c$ compatible with $\theta_K$ AND non compatible with $\theta_\pi$ or $\theta_\mu$

- Veto ID if $p < 8.5 \text{ GeV/c} :$ no photons for the $K$ candidate

- Veto ID and Ring ID if $8.5 < p < 10.5 \text{ GeV/c}$
KAONS (Cont.)

- fit the ring independently for each track
- simultaneous fit for 2 tracks if ambiguous photons

Resonances

For 3 particles in the hemisphere, the $K^* \rightarrow K^{\pm} \pi^+$ signal was recognised

- identify a 2nd. track as $K^-$ or $\pi^-$
- classify as $KK\pi$ or $K\pi\pi$
Invariant mass (GeV/c²) of opposite charged K−π pair from
(a) $\tau \rightarrow K^+ \pi^- \nu$, and (b) $\tau \rightarrow K^- \pi^+ \nu$. 
- $\pi^0$

- Achieve an efficient recognition of several $\pi^0$ in a decay
- Minimise the number of faked $\pi^0$

- Pairs of $\gamma$ compatible with $\pi^0$ mass

- For $E_\gamma > 8\text{GeV}$ the transverse development of the shower was studied to identify 'merged' $\pi^0$. When it was compatible with 2 $\gamma$, the $\pi^0$ axis was searched and the photons resolved
$K_s^0$

- $V^o$ far from primary vertex
- $V^o$ comes from primary vertex
- none of these tracks have VD hits
- $V^o < R_{1st\ point} < V^o + 30\ cm$
- $0.457 < M_{V^o} < 0.537\ \text{GeV}/c^2$

**Resonances**

- just 1 charged track and the $V^o$
- $M_{V^o\pi^\pm}$ fitted to a linear combination of $M_{K^\pm\pi^\pm}$ and background
EXCLUSIVE AND SEMI-EXCLUSIVE DECAYS : Standard selection

The following channels were studied:

- $\tau^{-} \rightarrow c^{-} \bar{\nu} \nu$, $\epsilon = 35\%$ (in $4\pi$) and $b = 5\%$
- $\tau^{-} \rightarrow \mu^{-} \bar{\nu} \nu$, $\epsilon = 44\%$ (in $4\pi$) and $b = 3\%$
- $\tau^{-} \rightarrow \pi^{-} \nu$, $\epsilon = 60\%$ and $b = 10\%$
- $\tau^{-} \rightarrow \rho^{-} \nu$, $\epsilon = 45\%$ and $b = 16\%$
- $\tau^{-} \rightarrow K^{0}_{\pi} h^{-} \nu$, $\epsilon = 10\%$ and $b = 2\%$
- $\tau^{-} \rightarrow K^{*0} h^{-} \nu$, $\epsilon = 7.5\%$ and $b = 0.5\%$
- $\tau^{-} \rightarrow 3h \geq 0 \gamma \nu$, $\epsilon = 70\%$ and $b = 5\%$
- $\tau^{-} \rightarrow 3h \nu$, $\epsilon = 60\%$ and $b = 15\%$
- $\tau^{-} \rightarrow a_{1} \nu$, $\epsilon = 57\%$ and $b = 15\%$
- $\tau^{-} \rightarrow K^{0} h^{+} h^{-} \nu$, $\epsilon = 19\%$ and $b = 1\%$
Neural Nets

A neural net with 19 input variables, 2 hidden layers of 40 and 10 neurons was trained, optimising the network parameters to identify

- $\gamma \rightarrow e^- \bar{\nu} \nu$, $\epsilon = 95\%$ and $b = 5\%$
- $\tau^- \rightarrow \mu^- \nu \nu$, $\epsilon = 97\%$ and $b = 3\%$
- $\tau^- \rightarrow \pi^- \nu$, $\epsilon = 85\%$ and $b = 25\%$
- $\tau^- \rightarrow \rho^- \nu$, $\epsilon = 80\%$ and $b = 20\%$
- $\tau^- \rightarrow \pi^- \geq 2\pi^- \nu$, $\epsilon = 70\%$ and $b = 45\%$
- $\gamma \rightarrow a_1^- \nu$, $\epsilon = 55\%$ and $b = 45\%$
- $\tau^- \rightarrow \pi^- \geq 3\pi^- \nu$, $\epsilon = 22\%$ and $b = 50\%$
<table>
<thead>
<tr>
<th>mode</th>
<th>$BR(%)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau \rightarrow e^+\nu\nu$</td>
<td>$18.22 \pm 0.15 \pm 0.20$</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^- \bar{\nu}$</td>
<td>$17.29 \pm 0.13 \pm 0.16$</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \pi^- \nu$</td>
<td>$11.29 \pm 0.14 \pm 0.20$</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \rho^- \nu$</td>
<td>$74.90 \pm 0.24 \pm 0.22$</td>
</tr>
<tr>
<td>$\gamma^- \rightarrow \pi^- \geq 2\pi^\circ \nu$</td>
<td>$10.87 \pm 0.21 \pm 0.15$</td>
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<tr>
<td>$\tau^- \rightarrow a_1^- \nu(\pi^- - 2\pi^\circ)$</td>
<td>$9.14 \pm 0.43 \pm 0.20$</td>
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<td>$\tau^- \rightarrow \pi^- \geq 3\pi^\circ \nu$</td>
<td>$1.39 \pm 0.27 \pm 0.20$</td>
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<td>$\tau \rightarrow K^- h^- \nu$</td>
<td>$0.97 \pm 0.10 \pm 0.05$</td>
</tr>
<tr>
<td>$\tau \rightarrow K^{*-} \geq 0 \gamma \nu(K^{0}\pi^-)$</td>
<td>$1.50 \pm 0.33 \pm 0.06$</td>
</tr>
<tr>
<td>$\tau \rightarrow 2h^- h^+ \geq 0 \gamma \nu$</td>
<td>$14.54 \pm 0.14 \pm 0.30$</td>
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<td>$\tau \rightarrow 2h^- h^+ \nu$</td>
<td>$8.73 \pm 0.12 \pm 0.16$</td>
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<td>$\tau \rightarrow a_1^- \nu(2\pi^- - \pi^+)$</td>
<td>$8.31 \pm 0.11 \pm 0.16$</td>
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<td>$\tau \rightarrow K^- K^+ \pi^- \nu$</td>
<td>$0.18 \pm 0.04$</td>
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<tr>
<td>$\tau \rightarrow K^- K^{+1} \pi^- \geq 1\pi^\circ \nu$</td>
<td>$0.04 \pm 0.02$</td>
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<td>$\tau^- \rightarrow K^- \pi^{+1} \pi^- \nu$</td>
<td>$0.49 \pm 0.08$</td>
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CONCLUSIONS

DELPHI has measured inclusive and exclusive $\tau$ Branching Fractions, with special emphasis in channels containing $K^0_S$ and $K^+$, using the RICH for kaon identification.

Our results for leptonic Braching Fractions yield the ratio

$$g_\mu/g_e = 0.988 \pm 0.007$$

between the muon and electron couplings to the weak charged currents. Combining our result with recent measurements from ALEPH and our previous results,

$$g_\mu/g_\pi = 0.991 \pm 0.006$$
### CONCLUSIONS (Cont.)

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<th>PDG96(%)</th>
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<td>$\tau^- \rightarrow \pi^- \nu$</td>
<td>11.79±0.14±0.20</td>
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<td>$\tau^- \rightarrow \rho^- \nu$</td>
<td>24.90±0.24±0.22</td>
<td>25.24±0.16</td>
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<td>$\tau^- \rightarrow \pi^- \geq 2\pi^0\nu$</td>
<td>10.82±0.21±0.15</td>
<td>10.95±0.16</td>
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<td>$\tau^- \rightarrow \alpha^- \nu (\pi^0 2\pi^0$)</td>
<td>9.14±0.43±0.20</td>
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<td>$\eta^- \rightarrow \pi^- \geq 3\pi^0\nu$</td>
<td>1.39±0.27±0.20</td>
<td>1.28±0.10</td>
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