Measurement of Rc

N. deGroot
Overview Charm Physics

Update Inclusive $R_c$ with mass-tag

Nicolo de Groot

Overview

- Method
- Data and Cuts
- Results
- Systematic Errors
- To Do
Charm Physics Status

- $R_c$: Jun Yashima, Nicolo de Groot
  Using a high efficiency charm tag to get a measurement with small systematic errors. At EPS a preliminary 93-96 result was shown.

- $A_c$: Thomas Wright, Nicolo de Groot Starting from the same tag as $R_c$ and tagging the charge of the charm quark with vertex charge and kaons. Already the most precise measurements in the world. At EPS a preliminary 93-95 result was shown. See Tom's talk next.

- $A_c$ with exclusively reconstructed D: Masako Iwasaki A preliminary result for 93-95 was sent to EPS. Small systematic errors. See Masako's talk later.

- $A_c$ with inclusive slow pions (NEW): Masako Iwasaki New measurement, already very precise. See Masako's talk later.
**A_c Measurements (Summer-97)**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLD K &amp; vtx-Q</td>
<td>0.66 ± 0.07 ± 0.04</td>
</tr>
<tr>
<td>SLD K &amp; vtx-Q 98</td>
<td>0.66 ± 0.03 ± 0.03</td>
</tr>
<tr>
<td>SLD Lepton</td>
<td>0.61 ± 0.10 ± 0.07</td>
</tr>
<tr>
<td>SLD D^*, D^+</td>
<td>0.64 ± 0.11 ± 0.06</td>
</tr>
<tr>
<td>SLD Average</td>
<td>0.647 ± 0.060</td>
</tr>
<tr>
<td>ALEPH Lept</td>
<td>0.86 ± 0.18 ± 0.17</td>
</tr>
<tr>
<td>DELPHI Lept</td>
<td>0.80 ± 0.12 ± 0.11</td>
</tr>
<tr>
<td>L3 Lept</td>
<td>0.76 ± 0.33 ± 0.22</td>
</tr>
<tr>
<td>OPAL Lept</td>
<td>0.58 ± 0.05 ± 0.05</td>
</tr>
<tr>
<td>ALEPH D^*</td>
<td>0.63 ± 0.12 ± 0.03</td>
</tr>
<tr>
<td>DELPHI D^*</td>
<td>0.73 ± 0.11 ± 0.05</td>
</tr>
<tr>
<td>OPAL D^*</td>
<td>0.61 ± 0.11 ± 0.05</td>
</tr>
<tr>
<td>LEP Average</td>
<td>0.656 ± 0.044</td>
</tr>
</tbody>
</table>

**LEP Measurements**: $A_c = 4 A_{cFB}^0 / 3 A_c$

Using $A_c = 0.1505 ± 0.0023$ (Combine SLD $A_{LR}$ and LEP $A_\gamma$)
Counting the number of 3 double tag events and 2 single tag hemispheres

3 types of Double tag events

\[ F_{MM} \quad F_{mm} \quad F_{Mm} \]

2 types of Single tag hemispheres

\[ F_M \quad F_m \]

where \( F_x \) mean event fractions.
Method

Tag event with 1 or 2 events in the high/low mass region, and a mixed tag. This gives us:

\[ F_s = R_b^e_b + R_b^e_b + (1 - R_b - R_c)\epsilon_l \]
\[ F_d = R_b^2 + \lambda_b^h (e_b - e_b^2) + R_c^2 + (1 - R_b - R_c)\epsilon_l^2 \]
\[ G_s = R_b^\eta_b + R_c^\eta_c + (1 - R_b - R_c)\eta_l \]
\[ G_d = R_b^\eta_b^2 + \lambda_b^l (\eta - \eta^2) + R_c^\eta_c^2 + \lambda_c (\eta_c - \eta_c^2) + R_l^\eta_l^2 \]
\[ M = 2[R_b e_b \eta_b + R_c e_c \eta_c + (1 - R_b - R_c)\epsilon_l \eta_l] \]

With \( F \) high mass, \( G \) low mass and \( M \) mixed tag. \( \epsilon \) and \( \eta \) the efficiencies and \( \lambda \) the correlations.

Take \( \epsilon_c, \epsilon_l, \lambda_b^h, \eta_l, \lambda_b^l, \lambda_c \) from Monte Carlo. We have 5 equations with 5 unknown.
Method-2

Solving the equations gives:

\[ R_b = \frac{F_s - R_c(\epsilon_c - \epsilon_l) - \epsilon_l^2)^2}{F_d - R_c(\epsilon_c - \epsilon_l)^2 + \epsilon_l^2 - 2F_s\epsilon_l\lambda_b^h R_b(\epsilon_b - \epsilon_b^2)} \]

\[ \epsilon_b = \frac{F_d R_c \epsilon_c(\epsilon_c - \epsilon_l) - F_s\epsilon_l - \lambda_b^h R_b(\epsilon_b - \epsilon_b^2)}{F_s - R_c(\epsilon_c - \epsilon_l) - \epsilon_l^2)^2} \]

\[ \eta_b = \frac{M/2 - R_c\epsilon_c\eta_c + (1 - R_b - R_c)\epsilon_l\eta_l}{R_b\epsilon_b} \]

\[ \eta_c = \frac{G_d R_b \eta_b(\eta_b - \eta_l) - G_s \eta_l - \lambda_c R_c(\eta_c - \eta_c^2) - \lambda_b^l R_b(\eta_b - \eta_b^2)}{G_s - R_b(\eta_b - \eta_l - \eta_l^2)^2} \]

\[ R_c = \frac{G_s - R_b(\eta_b - \eta_l - \eta_l^2)^2}{G_d - R_b(\eta_b - \eta_l)^2 - 2G_s\eta_l(\lambda_c R_c(\eta_c - \eta_c^2) + \lambda_b^l R_b(\eta_b - \eta_b^2))} \]
solid: MC96
dots: data97
Data

Recon15A, 105k 97 data, using 1996 Monte Carlo, waiting for 97 final numbers. Event selection as for $R_b$, but with $\cos \theta < 0.75$

ZVTOP Parameters:

- **NSIGMA**: Charm - 4.0, B - 5.0 (seed vertex significance)
- **RCUT**: 0.8 (was 0.6)
- **XCAT**: 6.0 (was 10.0) (Max contribution to $\chi^2$ of VTX per track)
- **KIPW**: 0.5 (was 1.0) (Weight of primary IP)
- **LODI**: 0.25 (Ratio of distances to link a track to VTX)
Cuts:

- $0.55 < M_c$ (Corrected mass)
- $M_u < 2$ (Unconstrained corrected mass)
- $p_{vtx} > 5$ (Momentum of the vertex)
- $p_{vtx} - 15 \times M_c > -10$ (2-D cut)

Result:

- Efficiency: $\epsilon_c = 0.113, \epsilon_{uds} = 0.0013$
- Purity: $\pi_c = 0.686$
- Background: $\epsilon_{uds} = 0.0013, pi_u ds = 2.7\%$
- Correlations: $\lambda^h_b = 0.012, \lambda^l_b = 0.006, \lambda_c = 0.001$

$R_c = 0.175 \pm 0.011$
SLD not even Preliminary 1997:

\[ R_c = 0.175 \pm 0.011 \]

Combined Result SLD 1993-1997:

\[ R_c = 0.178 \pm 0.008 \pm 0.008 \]
To Do:

- Include MC97 data
- Fix $\cos \theta$ problem
- Update Systematics.

Conclusions

- Statistically close to single best LEP measurement.
- Systematic already better
- Ready for la Thuile
<table>
<thead>
<tr>
<th>Source</th>
<th>$\delta R_c$ (95)</th>
<th>1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC statistics</td>
<td>0.0022</td>
<td>0.0060</td>
</tr>
<tr>
<td>Detector Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution smearing, 20(\mu m)</td>
<td>0.0025</td>
<td>0.0017</td>
</tr>
<tr>
<td>IP resolution</td>
<td>0.0059</td>
<td>0.0039</td>
</tr>
<tr>
<td>event selection, 100%</td>
<td>0.0004</td>
<td>0.0004</td>
</tr>
<tr>
<td>track efficiency</td>
<td>0.0007</td>
<td>0.0007</td>
</tr>
<tr>
<td>cos $\theta$</td>
<td>0.0019</td>
<td>0.0019</td>
</tr>
<tr>
<td>Physics effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$g \rightarrow bb, cc$</td>
<td>0.0026</td>
<td>0.0021</td>
</tr>
<tr>
<td>gluon radiation</td>
<td>0.0015</td>
<td>0.0015</td>
</tr>
<tr>
<td>uds background, 25%</td>
<td>0.0037</td>
<td>0.0030</td>
</tr>
<tr>
<td>total</td>
<td>0.0085</td>
<td>0.0075</td>
</tr>
</tbody>
</table>

$$R_c = 0.187 \pm 0.019 \pm 0.008 \ (96)$$

$$R_c = 0.179 \pm 0.012 \pm 0.008$$
$R_c$ Measurements (Summer-97)

- **DELPHI $D^*$ incl/incl**
  - Value: $0.171\pm0.013\pm0.015$

- **ALEPH Lepton**
  - Value: $0.165\pm0.007\pm0.011$

- **DELPHI Lepton**
  - Value: $0.164\pm0.009\pm0.020$

- **ALEPH $c$-counting**
  - New
  - Value: $0.176\pm0.005\pm0.011$

- **DELPHI $c$-counting**
  - Value: $0.168\pm0.011\pm0.013$

- **OPAL $c$-counting**
  - Value: $0.167\pm0.011\pm0.011$

- **ALEPH $D^*$ incl/excl**
  - Value: $0.176\pm0.013\pm0.011$

- **DELPHI $D^*$ incl/excl**
  - Value: $0.176\pm0.015\pm0.015$

- **OPAL $D^*$ incl/excl**
  - Update
  - Value: $0.180\pm0.011\pm0.013$

- **ALEPH $D^*$ excl/excl**
  - Value: $0.169\pm0.013\pm0.011$

- **SLD Vtx-mass**
  - New
  - Value: $0.181\pm0.012\pm0.008$

- **SLD Vtx-mass 98**
  - Projection
  - Value: $0.181\pm0.007\pm0.007$

- **World Average**
  - Value: $0.1734\pm0.0048$