QCD

P. Burrows
QCD at SLD

in a

1M \( Z^0 \) Scenario

P. N. Burrows
MIT

• Some basics of QCD

• Outstanding issues

• Where can SLD contribute?
Our Theory of Strong Interactions - QCD

\[ \mathcal{L} = -\frac{1}{4} F^a_{\mu\nu} F^{\mu\nu a} + \bar{q}(i\gamma_\mu D^\mu - m)q \]

⇒ The ‘essential features’ of QCD:

- quarks with spin 1/2 exist as colour triplets
- gluons with spin 1 exist as colour octets
- the coupling q\bar{q}g exists
- the couplings ggg and gggg exist
- the couplings are equal
- the coupling decreases as 1/lnQ^2

"The perfect gauge theory" (Marciano)

⇒ only 1 free parameter, \( \alpha_s \)
\( e^+e^- \) ideal lab. for QCD studies:

- No hadrons in initial state
- Hadronic event selection \( \epsilon \geq 90\% \)
  \( p \sim 99.9\% \)
- Jet observables calc. @ NLO (\( O(\alpha_s^2) \))
- Inclusive " " NNLO (\( O(\alpha_s^3) \))
- Non-pert. calculations "getting going"
- Well understood models of fragmentation
  eg. JETSET, HERWIG
- > 20 years experience

SPEAR: jets
PETRA/PEP: \( q\bar{q}g \)
SLC/LEP: \( b, c, uds, g \)
$Z^0 \rightarrow 3 \gamma + \nu$
SLD's Contributions to $\alpha_s$ Measurements

Jet rates (PNB, Lauber) \hspace{1cm} PRL
Energy-energy correlations (Masuda) \hspace{1cm} 2. PRD
Event shapes (Ohnishi et al) \hspace{1cm} PRD

Theoretical studies

Jet cone energy fraction (Masuda, Ohnishi) \hspace{1cm} PRL
Finite order pQCD calcs... (PNB, Masuda) \hspace{1cm} ZFC
Optimised pert. thy... (PNB, HM, DRM, YO) \hspace{1cm} PLE
Padé approximants... (PNB, TA, MS, ES, HM) \hspace{1cm} PLE
An average of the recent results at the $Z$ resonance from SLD [91], OPAL [100], L3 [101], ALEPH [102], and DELPHI [103], using the combined $\alpha_s^2$ and resummation fitting to a large set of shape variables, gives $\alpha_s(M_Z) = 0.122 \pm 0.007$. The errors in the values of $\alpha_s(M_Z)$ from these shape variables are totally dominated by the theoretical uncertainties associated with the choice of scale, and the effects of hadronization Monte Carlos on the different quantities fitted.

\[ \Rightarrow \text{Need } \mathcal{O}(\alpha_s^3) \text{ calculations for a better measurement of } \alpha_s \]
SUMMARY OF MEASUREMENTS June 1997

\[ \alpha_s(M_Z^2) \]

- \( e^+e^-: \tau \) decays
- DIS: Bjorken SR
- DIS: GLS SR
- DIS: \( F_2 \) (NMC)
- DIS: \( F_2 \) (HERA)
- DIS: \( F_2 \) (SLAC, BCDMS)
- pp: direct \( \gamma \)
- LGT: \( \Psi, \Upsilon \)
- \( \Psi, \Upsilon \) decays
- DIS: \( F_2, xF_3 \) (CCFR)
- DIS: jets
- pp: \( bb \) prod.
- \( e^+e^-: R \)
- pp: \( W+1\)-jet
- \( e^+e^-: \) event shapes
- \( e^+e^-: \) fragment. fns.
- \( e^+e^-: \) \( Z \) lineshape

\[ \chi^2 \approx 6/17 \]

Average value

\[ 0.118 \pm 0.005 \]
Most people agree that:

QCD *is* the correct theory of strong interactions

This does *not* mean that studies of jet physics are passé!

Carefully-crafted studies may be potentially sensitive to new physics processes beyond the standard interaction between quarks + gluons...

May only discover these by making precision tests of QCD, as well as of the EW model
The $\alpha_s$ Crisis (Glasgow 1994)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Year</th>
<th>$\alpha_s(M_Z^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCFR $\nu$: $F_2, F_3$</td>
<td>1993</td>
<td>0.111 ± 0.006</td>
</tr>
<tr>
<td>BCDMS $\mu$, SLAC $e$: $F_2$</td>
<td>1992</td>
<td>0.113 ± 0.005</td>
</tr>
<tr>
<td>LGT $\gamma$ spectra</td>
<td>1994</td>
<td>0.115 ± 0.002</td>
</tr>
<tr>
<td>$\Psi, \Upsilon$ decay widths</td>
<td>1992</td>
<td>0.113$^{+0.007}_{-0.005}$</td>
</tr>
<tr>
<td>CLEO jets</td>
<td>1994</td>
<td>0.113 ± 0.007</td>
</tr>
</tbody>
</table>

$\Delta \Gamma^{EW} (+7 \text{ MeV}) \equiv \Delta \alpha_s (-0.015)$

$+0.4\%$        $147$        $-12\%$
DETERMINING $\alpha_s$ FROM MEASUREMENTS AT $z$
HOW NATURE PROMPTS US ABOUT NEW PHYSICS

M. SHIFMAN
Theoretical Physics Institute, University of Minnesota, Minneapolis, MN 55455, USA

Received 12 Jan.

$R \equiv IC-95-133$

A low $\alpha_s$: hinting new physics at GUT scale?

1) Mar Bastero-Gil and Biswajoy Brahmachari

IC-95-217
UMD-PP-96-14

A low $\alpha_s$ and its consequences for unified model building

Biswaoy Brahmachari

Lowering $\alpha_s$ by flipping SU(5)

John Ellis, 1 Jorge L. Lopez, 2 and D.V. Nanopoulos

$\alpha_s(M_Z^2)$ and $R_4$ discrepancy with nonuniversal interactions

Jae Kwan Kim, Yeong Gyun Kim, Jae Sik Lee and Kang Young Lee

Department of Physics, KAIST, Taejon 305-701, KOREA

(September 19, 1995)
Why Bother Measuring $\alpha_s$?

- single parameter of strong interactions
- important input for EW studies
- constraint on new physics:

$$\alpha_s \sim 1/\beta_0 \ln(Q^2/\Lambda^2_{\overline{MS}}) \quad \beta_0 = 11 - \frac{2}{3} n_f$$

![Diagram of quark interactions](image)

SM: $n_f = 5$ (above $b\bar{b}$ threshold, below $t\bar{t}$ threshold)

*eg. $X = 'light gluino': n_f \rightarrow 5 + 3$ (G. Farrar*
$Q^2$ - Dependence of $\alpha_s$

**OPAL (172 GeV) preliminary**

- OPAL
- L3 (133 GeV)
- ALEPH (133 GeV)

Deep Inelastic Scattering
- $e^+e^-$ Annihilation
- Hadron Collisions
- Heavy Quarkonia
- $ep \rightarrow$ jets

**Lattice**
SLD Precision Tests of QCD
+ (Searches for New Physics)

Clearly, heavy flavours (most) interesting:

- Flavour - independence of strong interaction
- $b\bar{b}g$ events + anomalous moments
- $g \to c\bar{c}$, $g \to b\bar{b}$

and beam polarisation is a good tool:

- $b\bar{b}g$ symmetry tests:
  - $\phi$
  - $CP + T -$ effects + final-state interns.
Flavour Independence of Strong Interactions

Ideally measure separately

couplings

In practice:

uds, c, b

easy anti-tag
difficult tag
easy tag

152
Method

Use 3-jet rate

\[
R_3 = \frac{6 (e^+e^- \rightarrow q\bar{q}g)}{6 (e^+e^- \rightarrow q\bar{q})} \sim \alpha_s
\]

Jet-finding + flavour tagging:

\[
\frac{R_i}{R_j} \quad i, j = \text{flavours}
\]

\[
\Rightarrow \quad \frac{\alpha_s^i}{\alpha_s^j} \quad \text{test FLAVOUR INDEPENDENCE of strong inter}
\]
SLD Study of Flavour Independence

H. Hildreth: N_sig-based flavour-tagging
J. Oishi: Jet-based top. utxing, + N_sig

Comparison of tagging $E + T$:

<table>
<thead>
<tr>
<th>Event type</th>
<th>$E$ (%)</th>
<th>$T$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b\bar{b}$</td>
<td>46</td>
<td>62</td>
</tr>
<tr>
<td>$c\bar{c}$</td>
<td>59</td>
<td>19</td>
</tr>
<tr>
<td>light</td>
<td>77</td>
<td>56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$H$</th>
<th>$O$</th>
<th>$H$</th>
<th>$O$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b\bar{b}$</td>
<td>94</td>
<td>96</td>
<td>94</td>
<td>96</td>
</tr>
<tr>
<td>$c\bar{c}$</td>
<td>38</td>
<td>64</td>
<td>38</td>
<td>64</td>
</tr>
<tr>
<td>light</td>
<td>86</td>
<td>91</td>
<td>86</td>
<td>91</td>
</tr>
</tbody>
</table>
Vertex momentum vs. $p_T$-corr. mass (jet-by-jet)
Light(uds) flavor tag

Events without any secondary vertices

# of significant tracks missed from Interaction Point $\delta/\sigma_\delta \geq 2$

**Diagram Description**

- **x-axis**: $N_{sig}$
- **y-axis**: Events
- **Legend**:
  - Data
  - Light
  - c
  - b
- **Graph Details**:
  - SLD
  - Events range from 0 to 30,000
  - $N_{sig}$ range from 0 to 9

**Notes**:

- 10-97 8358A2
SLD Results on $\alpha_s^b/\alpha_s^{all}$

Hildreth: 93 data (50k)

$$\frac{\alpha_s^b}{\alpha_s^{all}} = 1.03 \pm 0.04 \pm 0.04 \pm 0.03$$

stat. syst. theor.

Dishn: 93-95 data (150k)

$$\frac{\alpha_s^b}{\alpha_s^{all}} = 0.995 \pm 0.015 \pm 0.020 \pm 0.016 \ (\text{NEAR FINAI})$$

Quick look at 96 data (50k)

$$\frac{\alpha_s^b}{\alpha_s^{all}} = 1.017 \pm 0.019$$

stat.

1M $Z^0$ events w. VXD3:

$$\Delta \frac{\alpha_s^b}{\alpha_s^{all}} \approx \pm 0.004$$

stat.
Summary of World Flavour - Independence Test

\[ \frac{\alpha_s^i}{\alpha_s^{\text{all}}} \]

- SLD
- OPAL '93
- SLD
- OPAL '93
- SLD
- OPAL '93
- OPAL '94
- DELPHI '93
- L3 '91

\[ 0.987 \pm 0.041 \]
\[ 1.023 \pm 0.135 \]
\[ 1.012 \pm 0.170 \]
\[ 0.931 \pm 0.095 \]
\[ 1.026 \pm 0.065 \]
\[ 1.013 \pm 0.028 \]
\[ 0.994 \pm 0.013 \]
\[ 1.00 \pm 0.05 \]
\[ 1.00 \pm 0.08 \]
Summary of World Flavour - Independence Tests

- SLD 1993 - 5

\[
\frac{\alpha_s^j}{\alpha_s^{all}}
\]

\begin{array}{c}
\text{SLD} \\
0.987 \pm 0.041 \\
\text{OPAL '93} \\
1.023 \pm 0.135 \\
\text{SLD} \\
1.012 \pm 0.170 \\
\text{OPAL '93} \\
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\text{DELPHI '93} \\
1.00 \pm 0.05 \\
\text{L3 '91} \\
1.00 \pm 0.08
\end{array}
Summary of World Flavour - Independence Test.

- SLD stat. error 1M Z°

\[ \frac{\alpha_s^j}{\alpha_s^{all}} \]

\[ uds \]

\[ 0.987 \pm 0.041 \]

\[ 1.023 \pm 0.135 \]

\[ \pm 0.003 \]

\[ 0.931 \pm 0.095 \]

\[ \pm 0.004 \]

\[ 1.012 \pm 0.170 \]

\[ 1.026 \pm 0.065 \]

\[ 1.013 \pm 0.028 \]

\[ 0.994 \pm 0.013 \]

\[ 1.00 \pm 0.05 \]

\[ 1.00 \pm 0.08 \]
Summary of World Flavour - Independence Test

- SLD stat. error $1M Z^0$
- SLD 1993-5

$\pm 0.003$

0.987 ± 0.041
1.023 ± 0.135

$\pm 0.011$

1.012 ± 0.170
0.931 ± 0.095

$\pm 0.004$

1.026 ± 0.065
1.013 ± 0.028
0.994 ± 0.013
1.00 ± 0.05
1.00 ± 0.08

$\alpha_s^j / \alpha_s^{all}$
Summary of World Flavour - Independence Tests

- SLD stat. error \( IM_{Z^0} \)
- SLD 1993-5

\[
\begin{align*}
\frac{\alpha_s^j}{\alpha_s^{\text{all}}} & \quad \pm 0.003 \\
0.987 \pm 0.041 & \\
1.023 \pm 0.135 & \\
\pm 0.011 & \\
1.012 \pm 0.170 & \\
0.931 \pm 0.095 & \\
\pm 0.004 & \\
1.026 \pm 0.065 & \\
1.013 \pm 0.028 & \\
0.994 \pm 0.013 & \\
1.00 \pm 0.05 & \\
1.00 \pm 0.08 & 
\end{align*}
\]
The Issue of the $b$-mass

Because of the non-zero $b$-mass,

$$R_2^b \neq R_2^{uds} \implies \text{FIG}$$

For our jet algorithms + $y_c$ values:

$O(5\%)$ effect

We assumed $m_b^c (m_{Z^2}) = 3.0 \pm 0.5 \text{ GeV}/c^2$

$\equiv m_b (m_{b}) = 4.3 \pm 0.3 \text{ GeV}/c^2$

$\implies \alpha_s^b/\alpha_s^{uds}$ to test flavour-independence

Alternatively, we can assume flavour-indep. + determine $m_b (m_{Z^2})$ from the data:

Quick look: $m_b (m_b) \simeq 3 \pm 1 \text{ GeV}/c^2$

93-95

c.f. DELPHI: $2.7 \pm 0.5 \text{ GeV}/c^2$
$R_3$ ratios $\rightarrow \alpha_s$ ratios

SLD preliminary

uds

\[ \frac{R_3^i}{R_3^{all}} \]

SLD preliminary

stat. error only

uds

\[ \frac{\alpha_s^i}{\alpha_s^{all}} \]
Quark Mass Effects in QCD Calculations

A, B, C depend on quark mass

Two NEW next-to-leading O results:

Bernreuther et al.

Bilenky et al.

\[ \frac{R_3}{\text{madqg}} \]

\[ 1.3 \quad 1 \]

\( \begin{align*}
\text{LO} \\
\text{NLO} (\overline{\text{W}}_{b5})
\end{align*} \)

\( b) \) DURHAM algorithm

\[ \Rightarrow O (5\%) \text{ correction dep. on jet alg.} \]
Quark Mass Effects in QCD Calculations

A, B, C depend on quark mass

Two NEW next-to-leading 0 results:

Bernreuther et al \{ PRL July 97

Bilenky et al

\[ \frac{R_b}{R_{uds}} \]

\[ \frac{R_3}{R_{uds}} \]

\[ {\text{Bernreuther et al}} \]

\[ {\text{b) DURHAM algorithm}} \]

\[ \Rightarrow O(5\%) \] correction dep. on jet alg.
Gluon Distributions in $b\bar{b}g$ Events

$\tau \rightarrow \tau \rightarrow g \rightarrow 91\%$

Figure 5:
comparison

"anomalous chromomagnetic moment?"

T. Rizzo: PRD50(1994) 4478

\[
L = g_s \bar{b} T_a \left\{ \gamma_\mu + \frac{i \sigma_{\mu\nu} q^\nu}{2m_b} (\kappa - i \bar{\kappa} \gamma_5) \right\} b G_\mu^a
\]

Leading order Calculation (\(\kappa=0\))

SLD preliminary

\[ \frac{1}{N} \frac{dN}{dZ} \]

data

- \(O(\alpha_s)QCD\) (\(\kappa=0\))
- \(\kappa=1/4\)
- \(\kappa=3/4\)

set limit to the anomalous couplings
Limit on Anomalous $b\rightarrow$ Chromomagnetic Moment

\[ F_2 = -0.020^{+0.061}_{-0.062} + 0.012 \]

stat. syst.

\[ \Rightarrow -0.15 < \kappa < 0.09 \ (99\% \ c.l.) \]
b-quark direction in $b\bar{b}q$ events

SLD Preliminary

(T. Maruyama)

$A_p = A_{b}^{\text{EW}} A_{b}^{\text{QCD}}$

Expected $A_{QCD}^{\text{QCD}} = 0.92$ 170-a
'\(T\)-odd' effects in \(Z^0 \to q\bar{q}g\)

\[
\rightarrow S_\pm \rightarrow k_1 \times k_2 \propto \cos \omega
\]

\[(a)\]

\[
\begin{array}{c}
\text{\(e^+\)} \\
\text{\(\gamma, Z\)} \\
\text{\(e^-\)} \\
\end{array}
\quad \text{\(g\)}
\]

\[
\begin{array}{c}
\text{\(q\)} \\
\text{\(\bar{q}\)}
\end{array}
\]

\[(b)\]

\[
\begin{array}{c}
\text{\(e^+\)} \\
\text{\(\gamma, Z\)} \\
\text{\(e^-\)} \\
\end{array}
\quad \text{\(q'\)}
\]

\[
\begin{array}{c}
\text{\(q\)} \\
\text{\(\bar{q}\)}
\end{array}
\]

\[(c)\]

\[
\begin{array}{c}
\text{\(e^+\)} \\
\text{\(\gamma, Z\)} \\
\text{\(e^-\)} \\
\end{array}
\quad \text{\(W, Z\)}
\]

\[
\begin{array}{c}
\text{\(q\)} \\
\text{\(\bar{q}\)}
\end{array}
\]

\[
\frac{d\sigma}{d\cos \omega} \propto 1 - \frac{1}{2} \cos^2 \omega + \beta S_\pm \cos \omega
\]

\[
S.M.: |\beta| \sim 10^{-5} \quad \text{Dixon et al}
\]

SLAC 6725
cos \omega distributions

\[ \frac{1}{N} \frac{dN}{d\cos \omega} \]

SLD: PRL 75 (1995) 4173

Fig. 2

\[ \beta = 0.008 \pm 0.015 \]

\[ -0.022 < \beta < 0.039 \ (95\% \text{ CL}) \]
Sensitivity of b\(\bar{b}\)g Tests

Now SLD1M7

\[ K_{\text{mom. chromag. mom }} \] 0.06* 0.02

\[ K_{\text{chromoelec. }} \] --- 0.03

\( \rho \) at b\(\bar{b}\)g vertex \( A_0^{qcd} \) 0.06# 0.02

Final-state int:

\( CP+ T- \) \( B^+ \) 0.02# 0.00

\( CP- T- \) \( B^- \) 0.03# 0.01

* = 1993-5

# = 1993-7

ALL UNIQUE SLD CONTRIBUTIONS

Note: several anomalous results
4-jet Production

$O(g^2)$

(a) $e^+ e^- \rightarrow q\bar{q} \, g\bar{g}$

(b) $e^+ e^- \rightarrow q\bar{q} \, g\bar{g}$

(c) $e^+ e^- \rightarrow q\bar{q} \, q\bar{q}$
$n$-jet rates ($\sqrt{s} = 35 \text{ GeV}$) "EØ"

TASSO: PLB214 (1988) 286
Electron-Positron Annihilation into Four Jets
at Next-to-Leading Order in $\alpha_s$ $^1$

Adrian Signer and Lance Dixon

Stanford Linear Accelerator Center
Stanford University
Stanford, CA 94309

Abstract

We calculate the rate for $e^+e^-$ annihilation into four jets at next-to-leading order in perturbative QCD, but omitting terms that are suppressed by one or more powers of $1/N_c^2$, where $N_c$ is the number of colors. The $O(\alpha_s^3)$ corrections depend strongly on the jet resolution parameter $y_{cut}$ and on the clustering and recombination schemes, and they substantially improve the agreement between theory and data.

Submitted to Physical Review Letters

"Leading $N_c$" contributions

Full $O(\alpha_s^3)$ now available
(May '97)
Comparison with data:

- tree-level

* leading: N\_N\_e, sub-leading small: \( \leq 0 \ (10\%) \)
Figure 2: Definition of the colour factors in terms of fundamental couplings. The final state colour indices have to be summed.
Sensitivity to "Light Gluinos"

$N_f \rightarrow N_f + 3$

Geneva scheme

Dixon, Signer: SLAC-PUB-7528 May '97
Order jets:

\[ P_1 > P_2 > P_3 > P_4 \]

"primary" "secondary"

Bengtsson - Zerwas

angle:

\[ \chi_{BZ} \]
Nachtmann–Reiter angle:

\[
\cos \theta_{NR}^* \propto (\vec{p}_1 - \vec{p}_2) \cdot (\vec{p}_3 - \vec{p}_4)
\]
New Contribution from ALEPH - CERN-PPE/97-0x

\[ N_c/C_F = 2.20 \pm 0.09 \text{ (stat.)} \pm 0.13 \text{ (syst.)} \]
\[ T_F/C_F = 0.29 \pm 0.05 \text{ (stat.)} \pm 0.06 \text{ (syst.)} \]

\[ \Rightarrow m_\chi > 6.3 \text{ GeV/c}^2 \text{ (95\% c.l.)} \]
\( q \rightarrow Q\bar{Q} \)

Neither well calculated, nor well measured!

\[
\frac{\sigma (q\bar{q}cc)}{\sigma_{\text{tot}}} = \begin{cases} 
2.3 \pm 0.5 \% \ (O) \\
2.7 \pm 0.9 \% \ (A)
\end{cases}
\]

\[
\frac{\sigma (q\bar{q}b\bar{b})}{\sigma_{\text{tot}}} = \begin{cases} 
0.21 \pm 0.15 \% \ (D) \\
0.26 \pm 0.10 \% \ (A)
\end{cases}
\]

QCD

0.6 \ (LO)

1.4 \ (RS)

2.3 \ (MC)

0.1 \ (LO)

0.18 \ (RS)

0.34 \ (MC)
For $R_b$ analyses:

$$\frac{\sigma (q\bar{q} b\bar{b})}{\sigma_{\text{tot}}} = 0.31 \pm 0.10\%$$

used (Blondel, Warsaw 96)

$$\Rightarrow \Delta R_b = \pm 0.00070$$

or

$$\frac{\Delta R_b}{R_b} = \pm 0.33\%$$

ALEPH: largest systematic uncertainty!

$$\Rightarrow \text{NEEDS TO BE MEASURED}$$
Summary of 4-jet Studies

- LEP studies of angular correlations; controversial limits on light gluinos

- Quark-jet tagging $\Rightarrow$ improved $T_F$; only exploited by DELPHI

- Couple of poor LEP meas. of $\sigma (g \rightarrow bb)$
  (See T. Abe tomorrow)

- New NLO QCD calc. (Dixon, Signer); lots of new ideas

SLD 4-jet studies viable w. 1M $\sim^0$

MANPOWER NEEDED!
Jet Fragmentation + Particle Production

Heavy Flavours

B energy distribution (see D. Dong)
D, D* prodn. (T. Akagi, see D. Muller)

No one working on:
B species production rates
Λb polarisation
BB correlations
ditto for charm

ALL VIABLE with 1M Z°!

Whether they realise it or not, people at TeV2 + LHC will NEED TO KNOW the b → B and c → D fragmentation functions accurately.
Light Flavours (see J. Schwiening, D. Muller)

We've measured: $\pi^\pm, K^\pm, \rho, \Lambda, K_s, \phi, K^{*0}$ in:

- inclusive $\pi^0$ decays
- $\oplus$ VXD
- light/heavy $\pi^0$ decays $\oplus$ polarisation.
- quark/antiquark jets $\oplus$ polarisation.

These studies have pushed CRID i.d. to a demanding level.
This ought to be maintained w. new data!

$\Rightarrow$ hadron prod. in $q/g$ jets (H. Kang)

Last opportunity to understand quark fragmentation!

TeV2, LHC - forget it!
NLC - too few events
uds $\rightarrow h$ vs uds $\rightarrow \bar{h}$ Production

Normalized Production Differences $D_h$

$D_h = \frac{R_h - R_{\bar{h}}}{R_h + R_{\bar{h}}}$

SLD

$\Lambda$ (uds)

$\pi^-$ (ud)

$K^-$ ($\bar{u}s$)

$\bar{K}^*$ ($\bar{d}s$)
Hadronic Spectra in Z^0 Decays

SLD

\[ \frac{1}{N} \frac{dN}{dx_p} \]

\[ x_p = \frac{2p}{E_{cm}} \]

\[ \pi^\pm, K^\pm, K^0, K^{*-0}, \phi, p (x 0.04), \Lambda^0 (x 0.04) \]
Spectra in Light-Flavor $Z^0$ Decays

SLD

$\pi^\pm$

$K^\pm$

$K^0$

$K^{*0}$

$\phi$

$\Delta p$ (x 0.04)

$\Lambda^0$ (x 0.04)

$1/N \, dn/dx_p$

$x_p = 2p/E_{cm}$

$0.01$ $0.10$ $1.00$
Ratios of Particle Production in $b$- and Light-Flavor Events

$x_p = 2p/E_{cm}$
Identified Particle Production in Light Quark Jets

SLD

$R_h = \frac{1}{N_{jet}} \frac{dN_h}{dx_p}$

$x_p = p/p_{beam}$
Summary + Outlook

With a 1M Z° VXD3 data sample:

- percent level fundamental symmetry tests in b\bar{b}g sector

- competitive meas. of: QCD Casimir factors
  
  light gluino limits

  g \rightarrow c\bar{c}, g \rightarrow b\bar{b}

rich programme of meas. in b, c + light-quark fragmentation

provided

SLD MANPOWER IS
SENSIBLY DISTRIBUTED