A Test of the Flavour Independence of α_s

presented by

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- Introduction
- Flavour tagging methods
- Correction procedure
- Fit procedure
- Results and Summary

Introduction

- Flavour independence of the strong coupling is a fundamental assumption in QCD.

  $\Rightarrow$ Required for gauge invariance of QCD Lagrangian.

- Previous tests at LEP and SLC: $\frac{\alpha_s^f}{\alpha_s^{incl}}$ or $\frac{\alpha_s^f}{\alpha_s^{comp}}$

  $\Rightarrow$ All confirm flavour independence of α_s

- Previous tests used QCD Calculations assuming massless quarks or leading order calculations with massive quarks.

- Complete NLO calculations for 3-jet observables including important mass effects now available:

  – G. Rodrigo, A. Santamaria and M. Bilenky

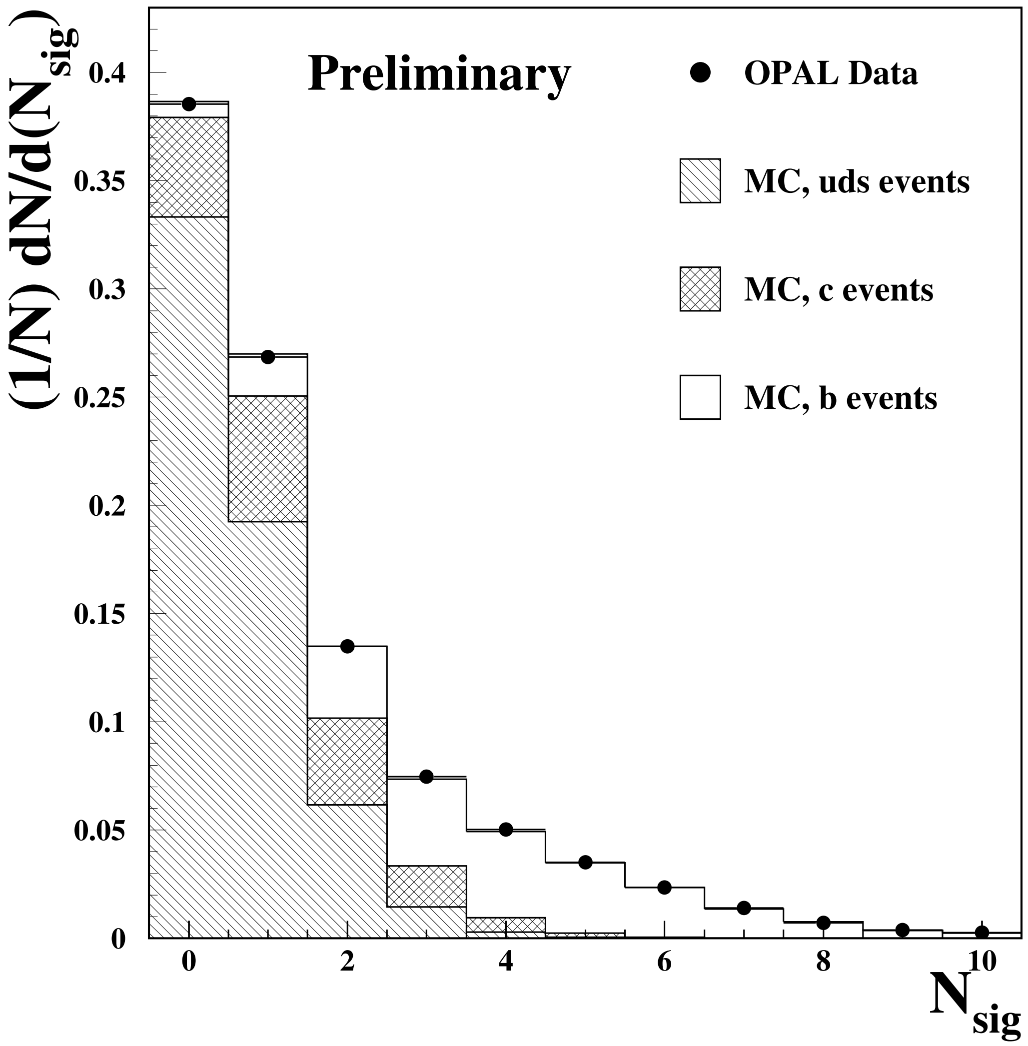
  – W. Bernreuther, A. Brandenburg and P. Uwer

  – P. Nason and C. Oleari (used here)

Introduction

- Improvements possible:
  - NLO calculations including mass effects.
  - Much higher event statistics over previous OPAL studies. ($2.5\times$ b sample, $33\times$ c sample)
  - Improved b and uds event tagging methods.
- NLO calculations used in fits to distributions of global event shapes:
  D_2, $1-T$, M_H, B_T, B_W and C .
- Each distribution determined in three flavour tagged event samples:
  uds-tag , c-tag and b-tag.
- Perform fits to determine ratios $\frac{\alpha_s^c}{\alpha_s^{uds}}$ and $\frac{\alpha_s^b}{\alpha_s^{uds}}$.

uds and b event tagging



where N_{sig} is the number of tracks per event with large impact parameter significance: $b/\sigma_b > 2.5$

Large mass and lifetime of B hadrons $\Rightarrow$ large impact parameters.

c event tagging

Charm tag based on reconstruction of D^{*+} mesons in five different decay channels.

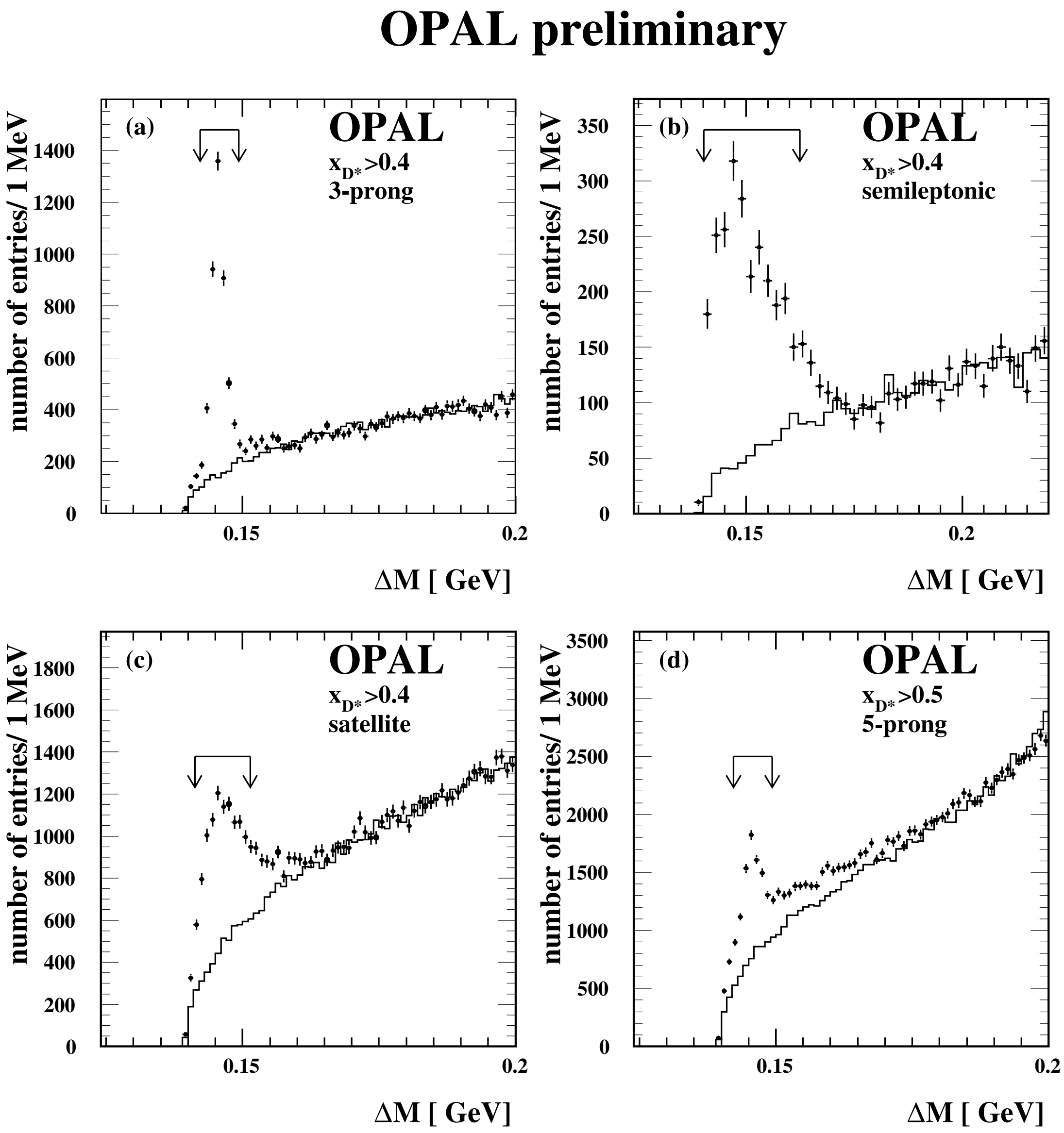
$$
\begin{array}{lll}
\mathrm{D}^{*+} \to \mathrm{D}^0\pi^+ & & \\
& \hookrightarrow \mathrm{K}^-\pi^+ & \text{“3 prong”}, \\
& \hookrightarrow \mathrm{K}^-\pi^+\pi^0 & \text{“satellite”}, \\
& \hookrightarrow \mathrm{K}^-\pi^+\pi^-\pi^+ & \text{“5 prong”}, \\
& \hookrightarrow \mathrm{K}^-\mathrm{e}^+\nu_\mathrm{e} & \text{“electron”}, \\
& \hookrightarrow \mathrm{K}^-\mu^+\nu_\mu & \text{“muon”}.
\end{array}
$$

- Require that $x_{D^{*+}} = E_{D^{*+}}/E_{beam} > 0.4$.
- Reduces low momentum background due to:

  ⇒ Cascade decays of b meson.

  ⇒ Gluon splitting to c$\bar{c}$.

D^* reconstruction



$$\Delta M = M_{D^{*+}} - M_{D^0}$$

Flavour composition

	uds fraction	charm fraction	bottom fraction
uds-tag	0.862 ± 0.010	0.119 ± 0.003	0.019 ± 0.011
c-tag	0.246 ± 0.005	0.548 ± 0.018	0.206 ± 0.017
b-tag	0.008 ± 0.002	0.028 ± 0.004	0.964 ± 0.019

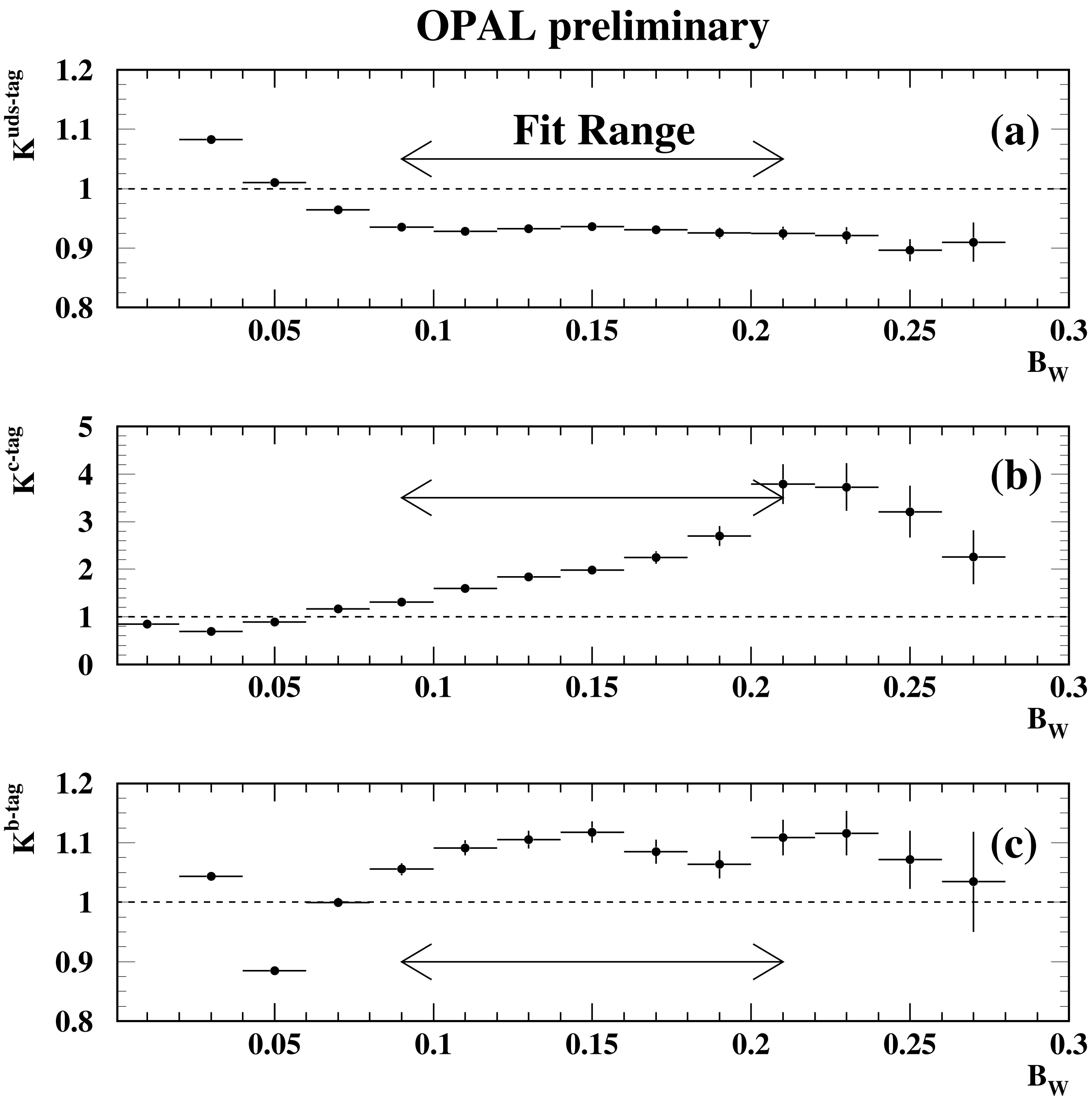
uds-tag : 325 111 events

c-tag : 27 005 events

b-tag : 71 521 events

The event shapes D_2, $1-T$, M_H, B_T, B_W and C determined in each flavour tagged event sample.

bin-by-bin corrections



- Matrix correction method: Detector resolution.
- Bin-by-bin correction: Detector acceptance, Initial state radiation, Flavour tagging bias.
- Distributions corrected to the hadron level.

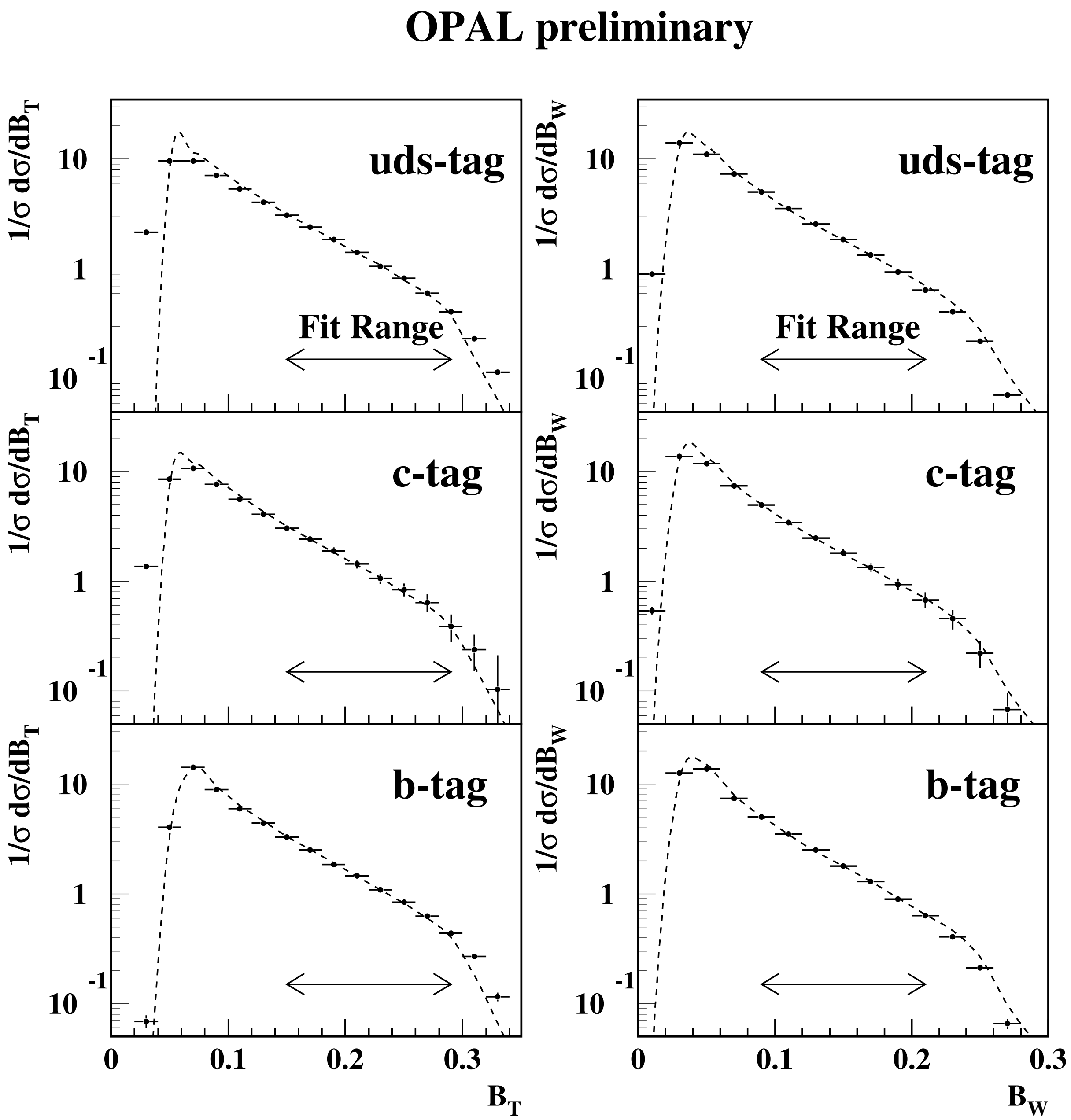
Fit procedure

$$\left(\frac{1}{\sigma_{tot}}\frac{\mathrm{d}\sigma}{\mathrm{dy}}\right)^{q-tag} = f_{\mathrm{uds}}^{q-tag} R(y)^{\mathrm{uds}} \left(\frac{1}{\sigma_{tot}}\frac{\mathrm{d}\sigma}{\mathrm{dy}}\right)^{\mathrm{uds},th} + f_{\mathrm{c}}^{q-tag} R(y)^{\mathrm{c}} \left(\frac{1}{\sigma_{tot}}\frac{\mathrm{d}\sigma}{\mathrm{dy}}\right)^{\mathrm{c},th} + f_{\mathrm{b}}^{q-tag} R(y)^{\mathrm{b}} \left(\frac{1}{\sigma_{tot}}\frac{\mathrm{d}\sigma}{\mathrm{dy}}\right)^{\mathrm{b},th}$$

where f_{q}^{q-tag} are flavour fractions and $R(y)^{\mathrm{q}}$ hadronization corrections ($\sim$10%).

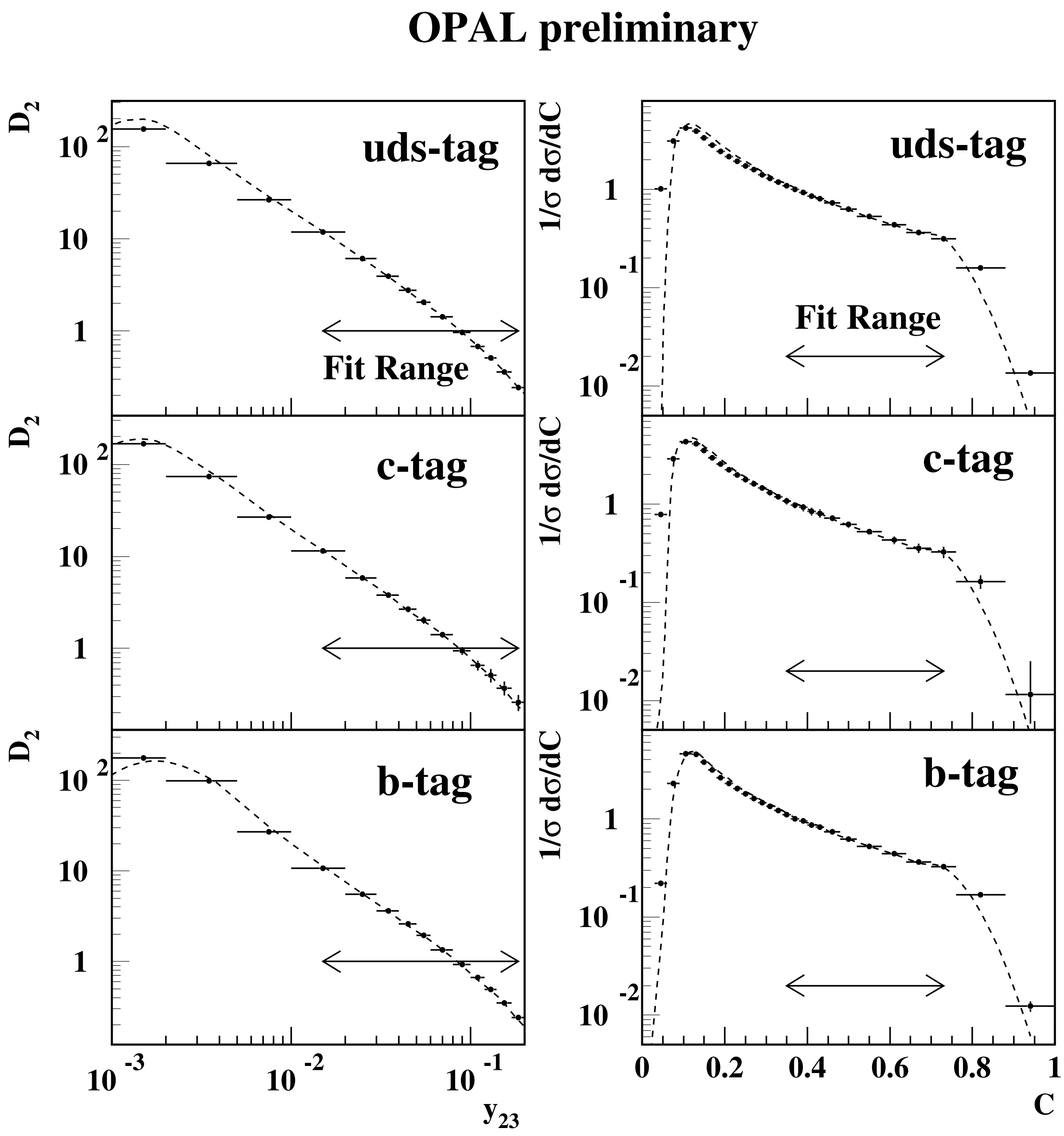
- uds,th: Ellis, Ross and Terrano
  (massless approximation)
- c,th and b,th: P. Nason and C. Oleari
  (hep-ph/9709360)
  $m_{\mathrm{c}} = 1.35$ GeV and $m_{\mathrm{b}} = 5.0$ GeV
  (pole mass scheme)
- Three free parameters: α_s^{uds}, $\frac{\alpha_s^c}{\alpha_s^{uds}}$ and $\frac{\alpha_s^b}{\alpha_s^{uds}}$.

Fit Results

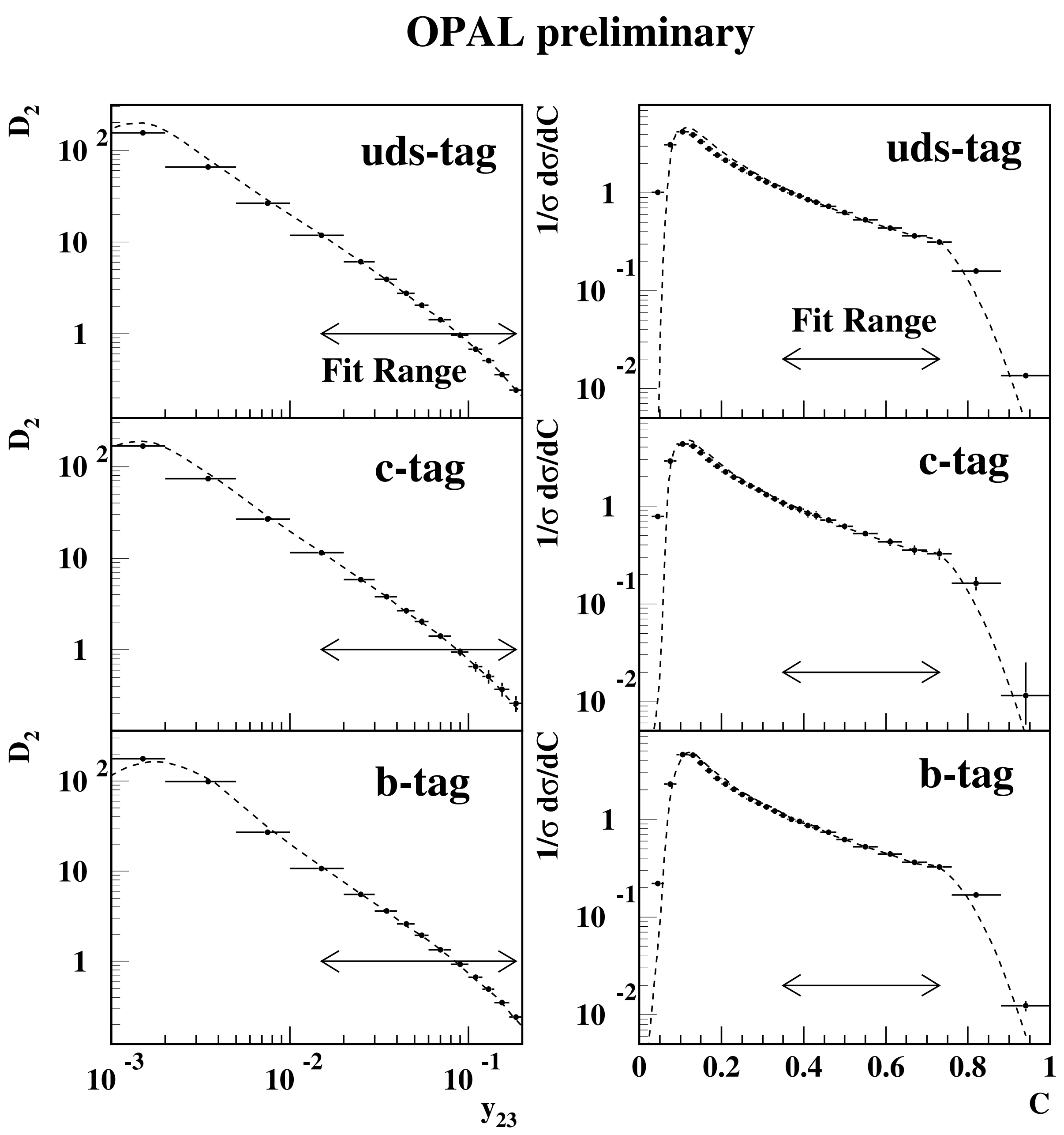


Fit results and data agree well within the fit range.

Fit Results


OPAL preliminary
uds-tag
c-tag
b-tag
Fit Range
D_2
$1/\sigma\, d\sigma/dC$
y_{23}
C

Fit Results


OPAL preliminary
uds-tag
c-tag
b-tag
Fit Range
D_2
$1/\sigma\ d\sigma/dC$
y_{23}
C
10^{-3}
10^{-2}
10^{-1}
10^{2}
10
1
10^{-1}
10^{-2}
0
0.2
0.4
0.6
0.8
1

Systematic Errors

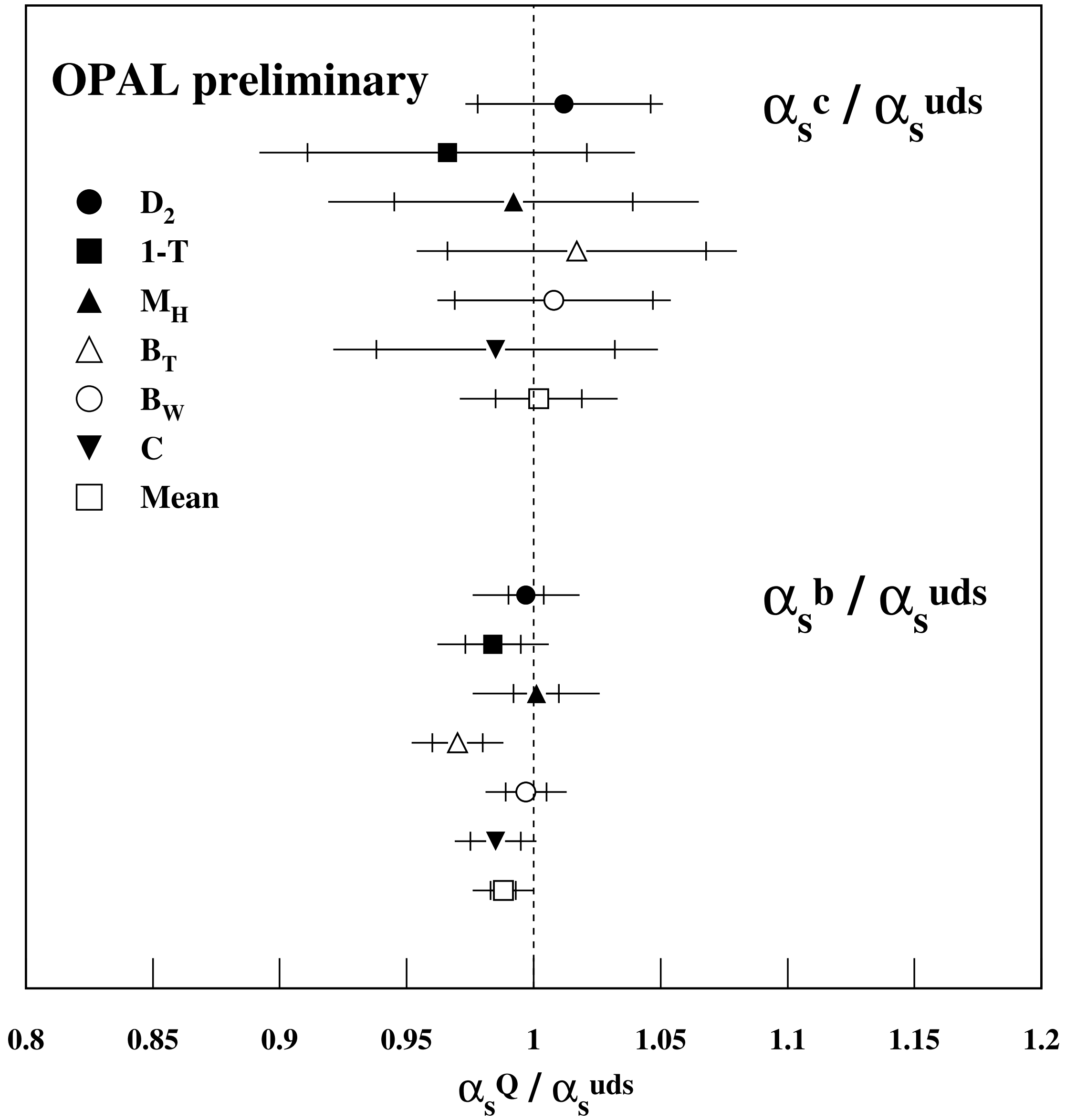
→Experimental←

- Flavour composition
- Charged tracks only
- Fit range
- $x_{D^*} > 0.3$, $x_{D^*} > 0.5$

→Theoretical←

- Virtuality cutoff: $Q_0 = (1.90 \pm 0.50)$ GeV
- Fragmentation: Lund frag. for light quarks, Peterson frag. for heavy quarks. σ_q transverse momentum of $q\overline{q}$ pairs.
- Renormalization scale: Fits with $x_\mu = 1.0$ and x_μ as free parameter.
- Quark masses: $m_{\mathrm{b}} = (5.0 \pm 0.5)$ GeV and $m_{\mathrm{c}} = 1.35$ GeV vary between 1.2 and 1.9 GeV.

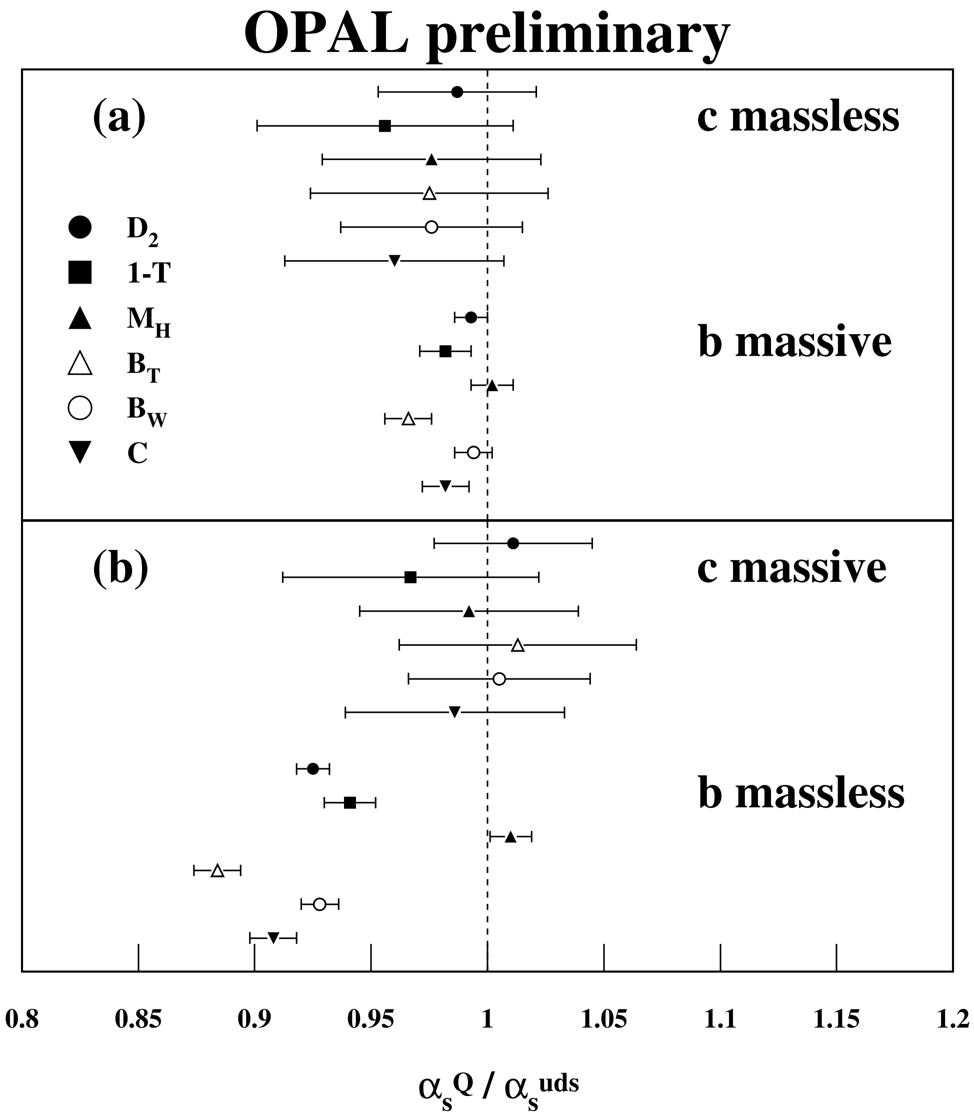
Results



$$\frac{\alpha_s^c}{\alpha_s^{uds}} = 1.002 \pm 0.017\,(stat.) \pm 0.025\,(syst.) \pm 0.009\,(theory)$$

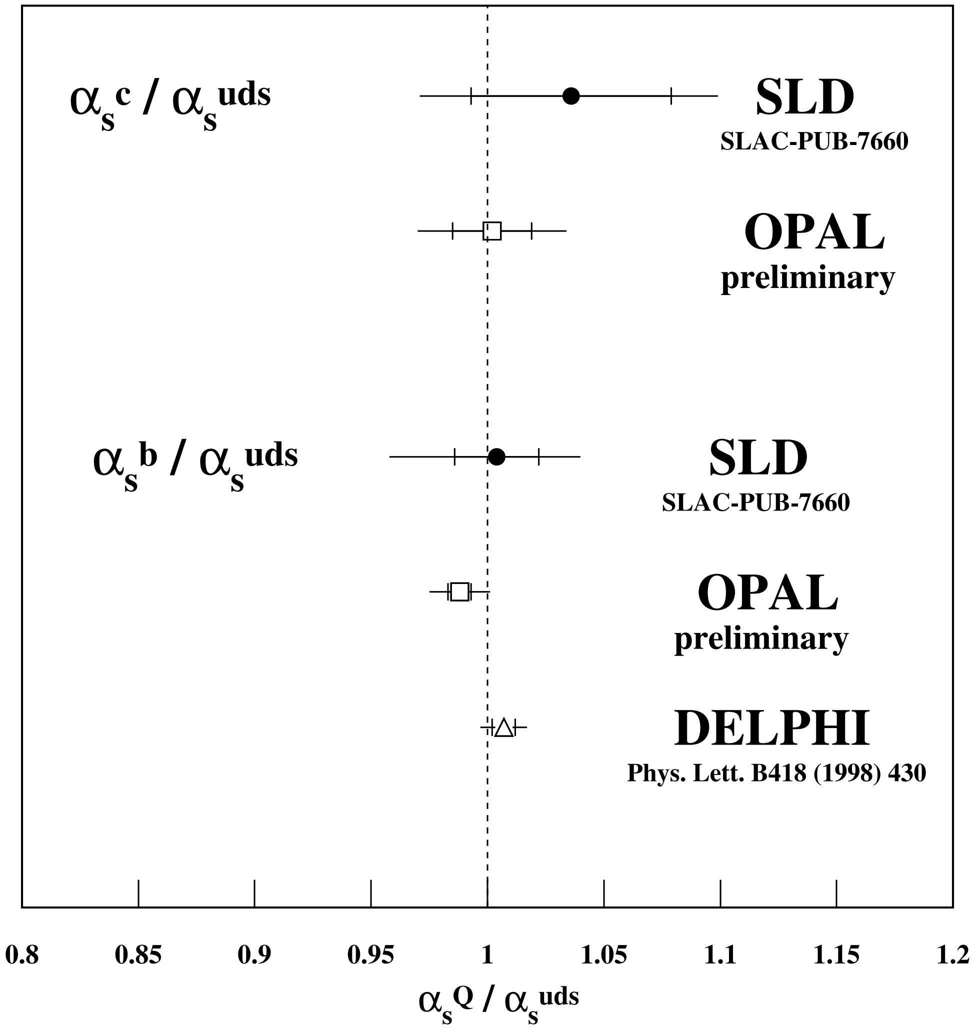
$$\frac{\alpha_s^b}{\alpha_s^{uds}} = 0.988 \pm 0.005\,(stat.) \pm 0.004\,(syst.) \pm 0.011\,(theory)$$

Mass Effect



- Mass effect for charm small, within statistical error.
- Mass effect for bottom large: systematic shift $\sim$ 8% and spread of points increases.

Summary



- Each collaboration used different NLO calculations and different observables.
- All ratios consistent with unity, indicating flavour independence of α_s.