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DETERMINATION OF α_s FROM HADRONIC EVENT SHAPES IN e^+e^- ANNIHILATION AT 192 $\leq\sqrt{s}\leq$ 208 GeV

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ABSTRACT

Results are presented from a study of the structure of high energy hadronic events recorded by the L3 detector at $\sqrt{s} \geq 192$ GeV. The distributions of several event shape variables are compared to resummed $\mathcal{O}(\alpha_s^2)$ QCD calculations to determine the strong coupling constant at average centre-of-mass energies: 194.4, 200.2 and 206.2 GeV. These measurements, combined with previous L3 measurements at lower energies, demonstrate the running of α_s as expected in QCD and yield $\alpha_s(m_Z) = 0.1227 \pm 0.0012 \pm 0.0058$, where the first uncertainty is experimental and the second is theoretical.

1 Introduction

We have used 436.8 pb^{-1} of data collected by the L3 detector for measuring five global event shape distributions namely thrust,T, the scaled heavy jet mass, ρ, the total B_T, and wide, B_W, jet broadening variables and the C-parameter at average centre-of-mass energies 194.4, 200.2, and 206.2 GeV. The shape variables are defined as ;

- **Thrust**: $T = \max \frac{\sum |\vec{p}_i \cdot \vec{n}_T|}{\sum |\vec{p}_i|}$,

  where $\vec{p_i}$ is the momentum vector of the particle i. The thrust axis $\vec{n}_T$ is the unit vector which maximizes the above expression. The value of the thrust can vary between 0.5 and 1.

- The total, $\mathbf{B_T}$, and wide, $\mathbf{B_W}$ **jet broadening variables** defined by computing in each hemisphere the quantity:

$$B_\pm = \frac{\sum_{i\in S_\pm} |\vec{p}_i \times \vec{n}_T|}{2\sum_i |\vec{p}_i|} \quad where \quad B_T = B_+ + B_- \quad \text{and} \quad B_W = \max(B_+, B_-)$$

  referred to as 'total jet broadening' and 'wide jet broadening', respectively.

- The scaled **heavy jet mass,** ρ : The heavy jet mass M_H defined as ;

$$M_H = \max[M_+(\vec{n}_T), M_-(\vec{n}_T)] ,$$

  where $M_\pm$ are the invariant masses in the two hemispheres, $S_\pm$, defined by the plane normal to the thrust axis: $M_\pm^2 = \left(\sum_{i\in S_\pm} p_i\right)^2$ and where p_i is the four momentum of particle i. The scaled heavy jet mass ρ is defined as $\rho = M_H^2/s$

- The C**-parameter** is derived from the spherocity tensor:

$$\theta^{ij} = \frac{\sum_a p_a^i p_a^j / \mid \vec{p_a} \mid}{\sum_a \mid \vec{p_a} \mid} \quad i,j = 1,2,3 ,$$

  where the sums run over all particles and $\vec{p}_a$ is the momentum vector of the particle a. The C-parameter is defined in terms of the eigenvalues, λ_1, λ_2 and λ_3, of θ^{ij}, as, C = $3(\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1)$.

2 Event Selection

The selection of $e^+e^- \rightarrow$ hadrons is based on the energy measured in the elctromagnetic calorimeter and hadron calorimeter. We use energy clusters in the calorimeter with a minimum energy of 100 MeV, measure the total visible energy (E_{vis}) and the energy imbalances parellel ($E_\parallel$) and perpendicular ($E_\perp$) to the beam direction. Events are accepted if

$$0.6 \leq \frac{E_{vis}}{\sqrt{s}} \leq 1.4 \quad , \quad \frac{\mid E_\parallel \mid}{E_{vis}} \leq 0.40 \quad , \quad \frac{\mid E_\perp \mid}{E_{vis}} \leq 0.40 \quad , \quad N_{\text{cluster}} > 12$$

The efficiency of the selection criteria and the purity of the data sample are estimated using Monte Carlo events for the process $e^+e^- \rightarrow qq\ (\gamma\ )$ generated by the KK2F [1] program, interfaced with JETSET PS [2] routines to describe the QCD parton shower evolution and hadronisation. The events are then passed through the L3 detector simulation [3]. Background events are simulated with PYTHIA [2] for two-photon events and Z-pair production, KORALZ [4] for the $\tau^+\tau^-(\gamma)$ final state, BHAGENE [5] and BHWIDE [6] for Bhabha events and KORALW [7] for W-pair production. Hadronic events with hard ISR photons, where the mass of the hadronic system is close to m_Z, are considered as background if the photon energy exceeds $0.18\sqrt{s}$.

3 Determination of α_s

The value of α_s is extracted in each energy range given in Table 1. by comparing the event shape distributions measured from data with predictions of second order QCD calculations [9] supplemented by resummed leading and next-to-leading order terms [10, 11, 8, 12]. These values are used, together with previous L3 measurements at lower effective centre-of-mass energies, from 30 GeV to 189 GeV, to study the energy evolution of α_s. The mean α_s values are listed in Table 1 together with the experimental and theoretical uncertainties. The fit to α_s versus $\sqrt{s}$ dependence gives a χ^2 of 17.9 for 15 d.o.f corresponding to a confidence level of 0.27 yielding a value of: $\alpha_s(m_Z) = 0.1227 \pm 0.0012 \pm 0.0058$.

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Table 1: *Combined α_s values from the five event shape variables.*

$<\sqrt{s}>$	α_s measurement from T, ρ, B_T, B_W, C				
(GeV)	α_s	stat	syst	hadr.	hi. order
41.4	0.1418	±0.0053	±0.0030	±0.0055	±0.0085
55.3	0.1260	±0.0047	±0.0056	±0.0066	±0.0062
65.4	0.1331	±0.0032	±0.0042	±0.0059	±0.0064
75.7	0.1204	±0.0024	±0.0059	±0.0060	±0.0053
82.3	0.1184	±0.0028	±0.0053	±0.0060	±0.0051
85.1	0.1152	±0.0037	±0.0051	±0.0060	±0.0055
91.2	0.1210	±0.0008	±0.0017	±0.0040	±0.0052
130.1	0.1138	±0.0033	±0.0021	±0.0031	±0.0046
136.1	0.1121	±0.0039	±0.0019	±0.0038	±0.0045
161.3	0.1051	±0.0048	±0.0026	±0.0026	±0.0044
172.3	0.1099	±0.0052	±0.0026	±0.0024	±0.0048
182.8	0.1096	±0.0022	±0.0010	±0.0023	±0.0044
188.6	0.1122	±0.0014	±0.0012	±0.0022	±0.0045
194.4	0.1123	±0.0018	±0.0016	±0.0020	±0.0047
200.2	0.1138	±0.0018	±0.0021	±0.0020	±0.0046
206.2	0.1132	±0.0014	±0.0016	±0.0019	±0.0047

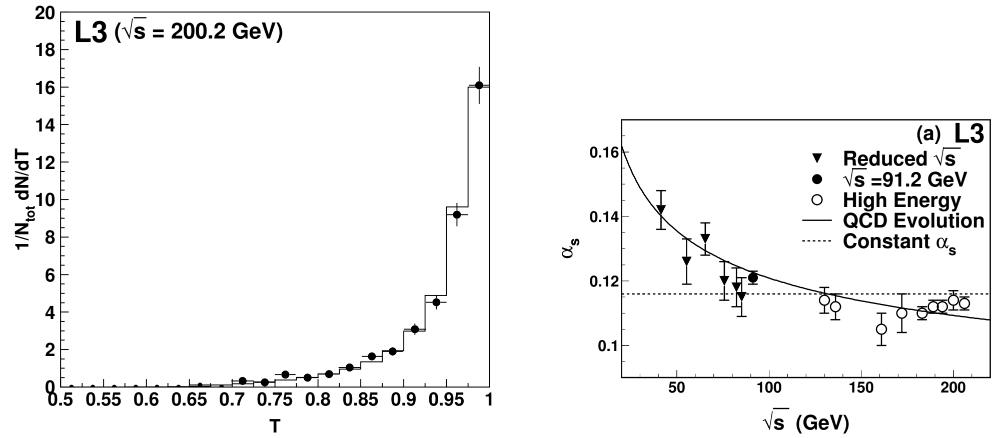

Figure 1: *Thrust distribution at $\sqrt{s}$ = 200.2 GeV (points are data and histogram is the result of fit for QCD predictions) and α_s as a function of center of mass energy, compared to QCD models.*