

**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:

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

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 sphericity tensor:

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

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 electromagnetic 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 parallel (E_{\parallel}) and perpendicular (E_{\perp}) to the beam direction. Events are accepted if

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

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: $\alpha_s(m_Z) = 0.1227 \pm 0.0012 \pm 0.0058$.

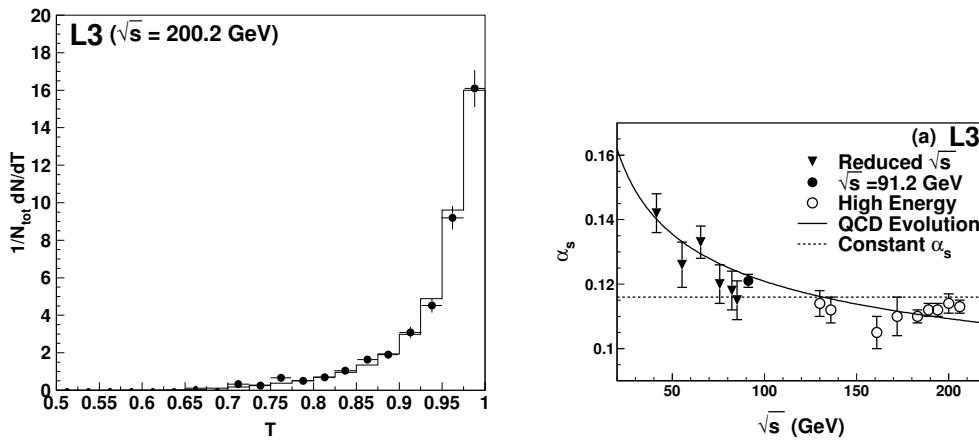


Figure 1: Thrust distribution at $\sqrt{s} = 200.2$ GeV (points are data and histogram is the result of fit for QCD predictions) and α_s as a function of center of mass energy, compared to QCD models.

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

$\langle \sqrt{s} \rangle$ (GeV)	α_s measurement from T, ρ, B_T, B_W, C				
	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

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