# DETERMINATION OF $\alpha_s$ 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 $\alpha_s$ 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 $\text{pb}^{-1}$ of data collected by the L3 detector for measuring five global event shape distributions namely thrust,T, the scaled heavy jet mass, $\rho$, 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:

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

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

- The scaled **heavy jet mass,** $\rho$ : 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 $\rho$ 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, $\lambda_1$, $\lambda_2$ and $\lambda_3$, of $\theta^{ij}$, 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 $\alpha_s$

The value of $\alpha_s$ 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 $\alpha_s$. The mean $\alpha_s$ values are listed in Table 1 together with the experimental and theoretical uncertainties. The fit to $\alpha_s$ versus $\sqrt{s}$ dependence gives a $\chi^2$ of 17.9 for 15 d.o.f corresponding to a confidence level of 0.27 yielding a value of: $\alpha_s(m_Z) = 0.1227 \pm 0.0012 \pm 0.0058$.

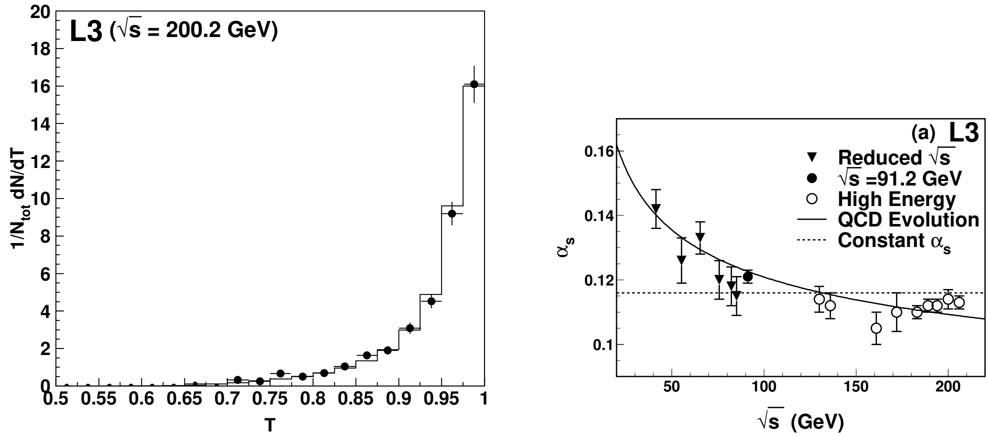


Figure 1: *Thrust distribution at $\sqrt{s}$ = 200.2 GeV (points are data and histogram is the result of fit for QCD predictions) and $\alpha_s$ as a function of center of mass energy, compared to QCD models.*

## References


1. S. Jadach *et al*, Comp. Phys. Comm. **130**, 260(2000).
2. JETSET 7.4 and PYTHIA 5.7 Monte Carlo Programs: T. Sjöstrand, CERN-TH-7112/93 (1993); T. Sjöstrand, Comp. Phys. Comm. **82**, 74(1994).
3. R. Brun *et al*, “GEANT 3”, CERN DD/EE/84-1 (Revised), September 1987.
4. S. Jadach, B. F. L. Ward and Z. Wąs, Comp. Phys. Comm. **79**, 503(1994).
5. J. H. Field, Phys. Lett. **B323** (1994) 432; J. H. Field and T. Riemann, Comp.Phys.Comm. **94**, 53(1996).
6. S. Jadach *et al*, Phys. Lett. **B390**, 298(1997).

Table 1: *Combined $\alpha_s$ values from the five event shape variables.*

| $<\sqrt{s}>$ (GeV) | $\alpha_s$ measurement from $T$, $\rho$, $B_T$, $B_W$, $C$ | | | | |
|---|---|---|---|---|---|
| | $\alpha_s$ | 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 |


7. M. Skrzypek *et al*, Comp. Phys. Comm. **94**, 216(1996); M. Skrzypek *et al*, Phys. Lett. **B372**, 289(1996).

8. S. Catani *et al*, Nucl. Phys. **B407**, 3(1993).

9. Z. Kunszt and P. Nason,"Z Physics at LEP 1", CERN Rep. 89-08,Vol-1, p373.

10. S. Catani *et al*, Phys. Lett. **B263** (1991) 491; S. Catani, G. Turnock and B.R. Webber, Phys. Lett. **B272** (1991) 368; S. Catani and B.R. Webber, Phys. Lett. **B427** (1998) 377.

11. S. Catani, G. Turnock and B.R. Webber, Phys. Lett. **B295** (1992) 269.

12. Yu. L. Dokshitzer *et al*, Journal of High Energy Physics **01** (1998) 11.