POWER CORRECTIONS AND EVENT SHAPES AT LEP

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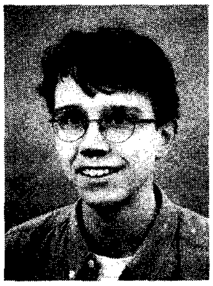

Measurements of event shape variables from hadronic events collected by the LEP experiments, corresponding to hadronic center of mass energies between 30 GeV and 202 GeV are presented. Fits are performed to extract α_s and the effective infrared strong coupling α_0 with the power correction ansatz. Universality is observed for the effective coupling and comparisons are made with fragmentation models.

1 Introduction

The process $e^+e^- \to$ hadrons at the LEP e^+e^- collider provides an ideal environment for QCD studies. Hadronic activity is confined to the final state only, and the initial state is well defined. We can therefore do precise measurements of the strong coupling α_s and its running, and compare this to perturbative QCD predictions. Also, we can measure event shape distributions and study the non-perturbative part of hadron formation.

We present results on event shapes from LEP data collected at center of mass energies up to 202 GeV. We compare distributions to predictions from models based on a perturbative parton shower and phenomenological fragmentation. Using perturbative QCD calculations, we extract a value of the strong coupling from data at high center of mass energies. Also, we compare event shape moments to analytic calculations which predict a power like behaviour of the non-perturbative contribution, and extract α_s and an effective infrared strong coupling α_0.

2 Event Samples

From 1989 until 1995, LEP ran at center of mass energies around M_Z. Since then, beam energies were gradually increased and in 1999, the e^+e^- center of mass energy reached 202 GeV. From hadronic events at $\sqrt{s} \approx M_Z$ with an isolated energetic photon, effective hadronic center of mass energies down to 30 GeV can be reached.

At $\sqrt{s} \approx M_Z$, a high statistics sample was obtained which is almost completely free of non-hadronic background. For $\sqrt{s} < M_Z$, the main background source is given by π^0/η decays, which are misidentified as single isolated photons. At $\sqrt{s} > M_Z$, the dominant source of background is caused by fully hadronic WW and ZZ decays. Also, initial or final state radiation can shift the effective hadronic center of mass energy down to M_Z. In 1999, each experiment collected in total 3-4000 high energy hadronic events at $\sqrt{s} = 192, 196, 200, 202$ GeV.

3 Event Shape Variables

In this report, we consider the following event shape variables: thrust T, scaled heavy jet mass ρ, C-parameter, total and wide jet broadening B_T and B_W, and y_{23}^D, the three jet resolution parameter in the Durham jet algorithm. These infrared and colinear safe observables have been calculated in perturbative QCD to second order in α_s with leading and next to leading logarithms resummed (NLLA). To relate these calculations at parton level to the particles as seen in experiments, we consider phenomenological fragmentation models and power corrections.

3.1 Fragmentation models

Several ways of treating perturbative QCD and fragmentation schemes have been implemented in Monte Carlo models. The programs considered here (JETSET/PYTHIA, HERWIG, ARIADNE, COJETS) are all different in how they treat perturbative QCD and fragmentation.

All measured event shape distributions [1,2,3,4] show good agreement with predictions from these Monte Carlo models. The free parameters in these models were tuned at $\sqrt{s} \approx M_Z$. Also, the evolution of the mean of these distributions with hadronic center of mass energy is well described by the models. In figure 1 the wide jet broadening distribution at $\sqrt{s} = 200 - 202$ GeV and the energy evolution of the mean of $1 - T$ are shown [3,4], together with Monte Carlo predictions.

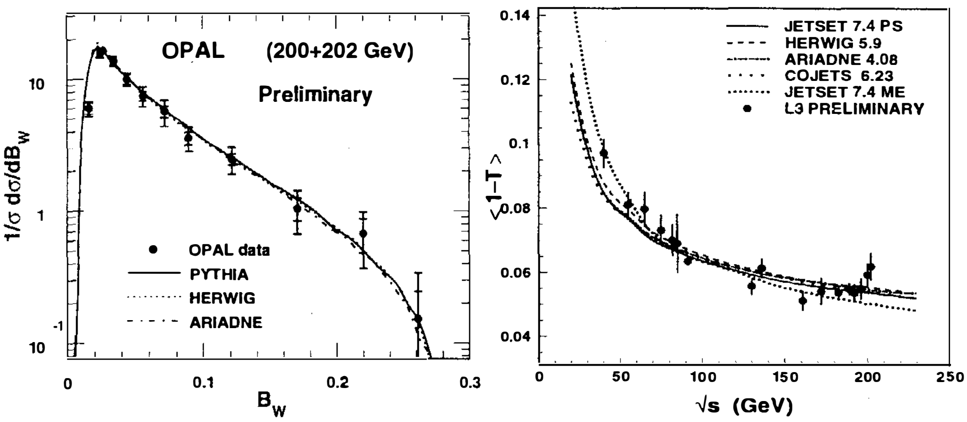

Figure 1: Distribution of B_W at $\sqrt{s} = 200 - 202$ GeV (left) and energy evolution of $< 1 - T >$ at 30 GeV $\leq \sqrt{s} \leq$ 202 GeV (right) compared to MC predictions.

These fragmentation models can also be used to determine α_s. Parton predictions from perturbative QCD are folded with fragmentation and are then compared with data. However, this procedure introduces systematic errors due to uncertainties in the fragmentation process.

As an example, ALEPH fitted $\mathcal{O}(\alpha_s^2)$-NLLA predictions to the event shape distributions at $\sqrt{s} = 196, 200, 202$ GeV. These α_s values were then extrapolated to the scale $Q = M_Z$ and combined to give the final result [1]: $\alpha_s(M_Z) = 0.1212 \pm 0.0024_{\text{stat}} \pm 0.0023_{\text{exp}} \pm 0.0046_{\text{theo}}$, where the experimental error contains uncertainties due to detector effects and background and the theory error is dominated by renormalisation scale uncertainty and includes fragmentation uncertainties. The other experiments performed similar fits [2,3,4]. Results agree with the world average [5] and the energy scale dependence as predicted by perturbative QCD.

3.2 Power Corrections

The non-perturbative contribution to event shape mean $\langle f \rangle$ can be related to infrared divergences in perturbative QCD. Writing $\langle f \rangle = \langle f_{\text{pert}} \rangle + c_f \mathcal{P}$, one finds for the non-perturbative power correction term [6]:

$$\mathcal{P} = \frac{4C_F}{\pi^2} \mathcal{M} \frac{\mu_I}{Q} \left[\alpha_0(\mu_I) - \alpha_s + \mathcal{O}(\alpha_s^2) \right]. \tag{1}$$

$\mathcal{P}$ is supposed to be universal for all shape variables, c_f is a constant depending on the variable f, and for B_T and B_W an extra multiplicative factor [7] depending on the strong coupling is added. A phenomenological effective infrared coupling α_{eff} is introduced as $\alpha_0(\mu_I) = \frac{1}{\mu_I} \int_0^{\mu_I} dq\, \alpha_{\text{eff}}(q)$ where μ_I is an infrared matching scale. We set this scale μ_I to 2 GeV. The 'Milan' factor $\mathcal{M}$ is determined [8] to be 1.49. Note that this value has changed from 1.795 after an error in the calculation was found.

The two free parameters α_s and α_0 can be inferred from fits to data. As shown in figure 2, an excellent fit is found using a $\mathcal{O}(\alpha_s^2)$ perturbative QCD prediction and this power correction term [2]. The values of α_s determined from the various shape variables are consistent and in good agreement with the world average. The values of α_0 agree at the 20 % level, as expected [9].

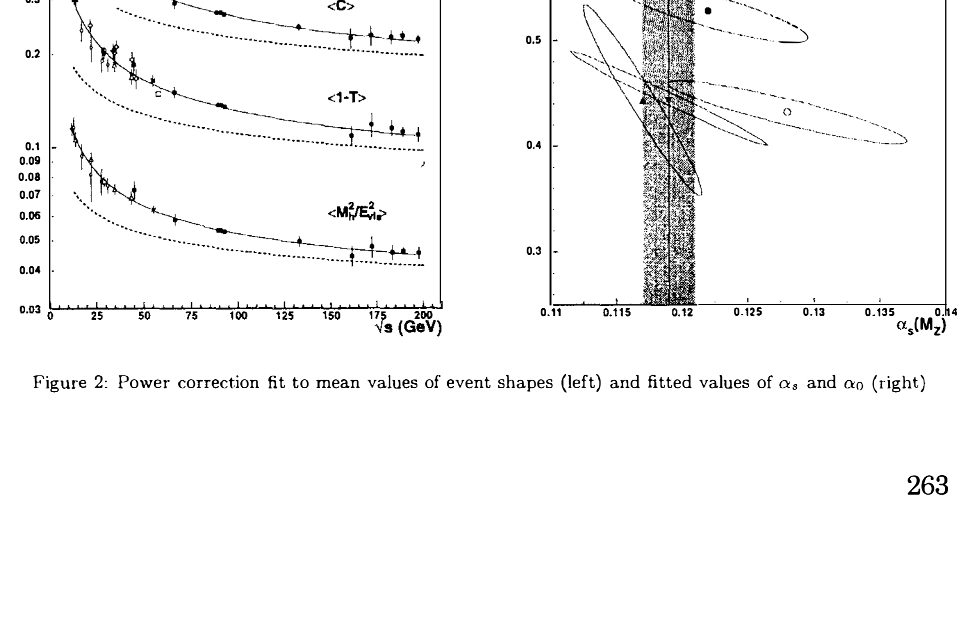

Figure 2: Power correction fit to mean values of event shapes (left) and fitted values of α_s and α_0 (right)

In the same manner, the second moment can be written as $\langle f^2 \rangle = \langle f^2_{\rm pert} \rangle + 2\langle f_{\rm pert} \rangle \cdot c_f \mathcal{P} + \mathcal{O}(1/Q^2)$. Taking α_s and α_0 from a fit to the mean, L3 finds a non-negligible $1/Q^2$ contribution to the second moments [10], as is shown in figure 3 for C and B_T. Note that L3 measures a wide center of mass energy range within the same experiment.

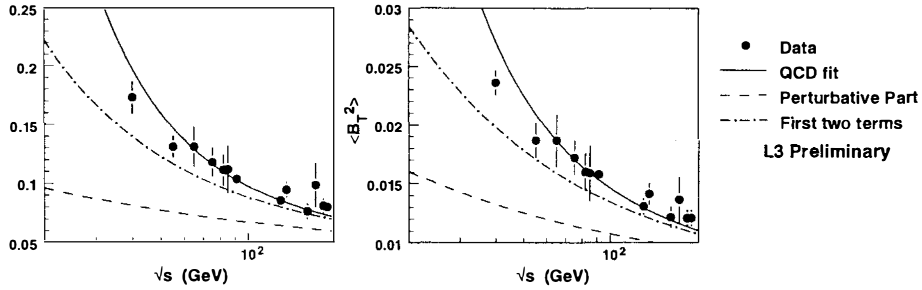

Figure 3: Power correction fit to second moment of event shapes for C (left) and B_T (right)

DELPHI compared power correction fits to $\mathcal{O}(\alpha_s^2)$ fits with optimized scales [11], pure NLLA fits and combined $\mathcal{O}(\alpha_s^2)$-NLLA fits. Values of α_s are in good agreement with each other [2].

4 Conclusions

Hadronic event shape distributions and their moments as obtained from data taken at center of mass energies between 192 and 202 GeV are presented. Fragmentation models tuned at $\sqrt{s} = M_Z$ describe well the distributions and the energy evolution of the means. The strong coupling constant extracted from the high energy data is in agreement with the world average. The non-perturbative component of the event shape means is well described by a universal power correction term over a wide energy range.

References

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