MAX-PLANCK-INSTITUT FÜR PHYSIK
WERNER-HEISENBERG-INSTITUT

MPI-PhE/2000-14
June 15, 2000

Event Shapes and Power Corrections in e^+e^- Annihilation

O. Biebel

Max-Planck-Institut für Physik
80805 Munich, Germany

80805 München • Föhringer Ring 6

MPI-PhE/2000-14
June 15, 2000

EVENT SHAPES AND POWER CORRECTIONS IN e^+e^- ANNIHILATION

O. BIEBEL
Max-Planck-Institut für Physik, Föhringer Ring 6,
80805 München, Germany

The effects of the hadronisation of partons on the distribution of event shape observables are associated with corrections which are suppressed by reciprocal powers of the energy scale of the process. The correction is determined by one non-calculable parameter α_0 for which an universal value of $0.5 \pm 20\%$ is found from the investigation of the distribution of event shape observables and their mean values measured in e^+e^- annihilation.

1 Motivation

When α_S is determined from event shapes in e^+e^- annihilation the effects due to hadronisation need to be corrected. It yields a contribution to the overall error of α_S which is typically as large as the experimental systematics and the uncertainties associated with the choice of the scale. The error contribution might be alleviated by employing power corrections instead of phenomenological hadronisation models which need adjusting many parameters.

2 Power Corrections to Mean Values

Hadronisation is expected to cause corrections to measured observables which are suppressed by reciprocal powers of the energy scale of the process. In [1] power corrections to the mean values of event shape observables are additive terms

$$\langle\mathcal{F}\rangle = \langle\mathcal{F}_{\mathrm{pert}}\rangle + \langle\mathcal{F}_{\mathrm{pow}}\rangle. \tag{1}$$

The correction $\langle\mathcal{F}_{\mathrm{pow}}\rangle \propto a_{\mathcal{F}}\cdot\alpha_0/\sqrt{s}$ depends on a calculable observable-specific parameter $a_{\mathcal{F}}$ and a single non-perturbative parameter α_0 to be measured experimentally which is the mean of the strong coupling α_S between 0 and 2 GeV. This type of correction has been thoroughly investigated for the thrust (T), the heavy jet mass (M_H), the total (B_T) and wide jet broadening (B_W), and the C-parameter (C) observables for $\sqrt{s}$ =14-202 GeV. The results,[2,3,4] updated for the corrected Milan factor,[5] yield on average $\alpha_0(2\ \mathrm{GeV}) = 0.49 \pm 0.03$ (r.m.s. 0.07) supporting the universality of α_0. The r.m.s., which is larger than the combined statistical, systematic and scale uncertainties, is partly due to the neglect of the 20% uncertainty of the Milan factor. The average of $\alpha_S(M_Z)$ is 0.116 ± 0.004 which agrees with the world average.[6]

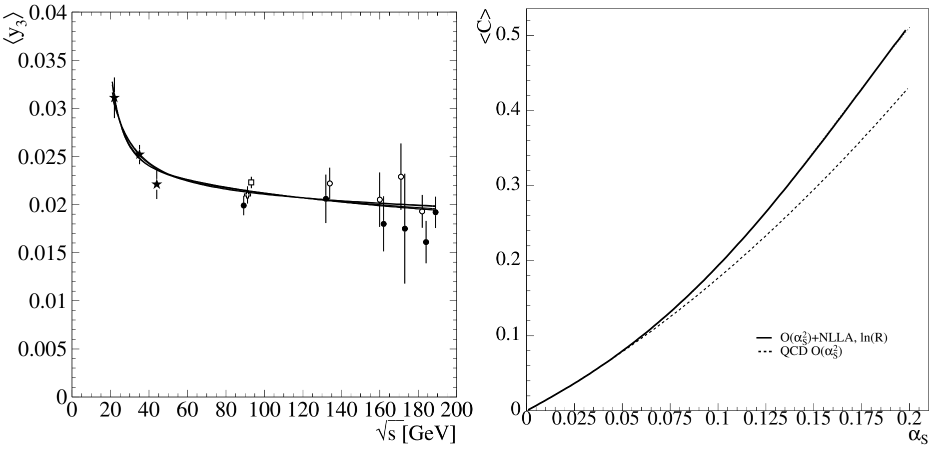

Figure 1: Left: Fits of $1/\sqrt{s}$, $\ln s/\sqrt{s}$, $1/s$, and $\ln s/s$ power corrections to $\langle y_3 \rangle$. Right: Mean values of the C-parameter obtained using second order $\mathcal{O}(\alpha_S^2)$ (dashed) and $\ln R$-matched resummed NLLA plus $\mathcal{O}(\alpha_S^2)$ (solid line) calculations.

2.1 Power Corrections to y_3

Many observables are subject to power corrections of the type $1/\sqrt{s}$ or $1/\sqrt{\ln s}$. One observable which is known to have a leading $1/s$ or $\ln s/s$ correction is the 2-3-jet flip, y_3, for the $k_\perp$ jet finder but the coefficient a_y which determines the size of this correction is not known. Figure 1 shows the fit results of power corrections of the type $1/\sqrt{s}$, $\ln s/\sqrt{s}$, $1/s$, and $\ln s/s$ to the mean of y_3. All fits give $\chi^2/\text{d.o.f.}$ of about 1 but the high values $\alpha_S(M_Z) = 0.144 \pm 0.011_{\text{expt'l}}$ disfavour the $1/\sqrt{s}$-type corrections. The $1/s$ correction yields $a_y = -0.49 \pm 0.37_{\text{expt'l}}$ compatible with zero for $\alpha_S(M_Z) = 0.124 \pm 0.004_{\text{expt'l}}$ and for the first moment of α_S in the range of 0 through 2 GeV, $\alpha_1 = 0.26 \pm 0.02_{\text{expt'l}}$.

2.2 Resummed Predictions of Mean Values

Usually all investigations used the second order calculations for the mean values of the event shape observables but the matched resummed and fixed order calculations for the distributions (see sect. 4). Resummed predictions for the mean values should give a better description of the dominating contribution from the 2-jet region to the mean value. The result of matching the resummed NLLA prediction for the mean value with the fixed order calculation is exemplified in figure 1 for the C-parameter. A comparable change of the $\mathcal{O}(\alpha_S^2)$ result is found for $\langle M_H \rangle$. The difference is about twice as large for the $\langle B_W \rangle$

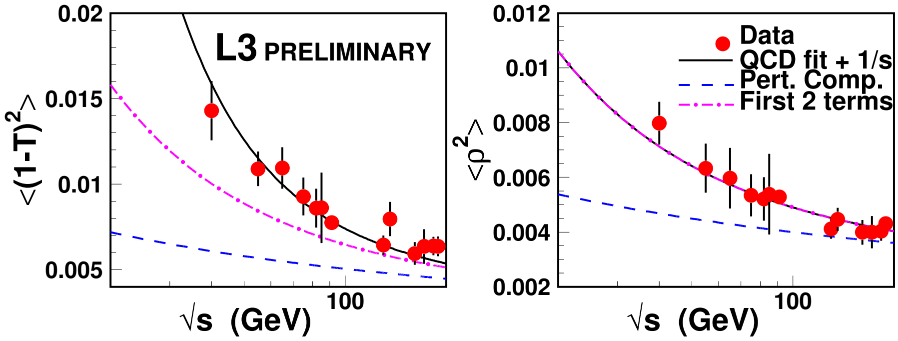

Figure 2: Power corrections to second moment of thrust (left) and heavy jet mass (right).

while it is negligible for $\langle 1-T\rangle$ and $\langle B_T\rangle$. Fitting the data, α_0 turns out to be 5-10% lower (-40% for B_W) and $\alpha_S(M_Z)$ to be 1-10% lower if using the $\ln R$-matched resummed and fixed order calculations.

3 Power Corrections to Higher Moments

An straight forward extension of Eq. (1) to the second moment of the event shapes yields $\langle\mathcal{F}^2\rangle = \langle\mathcal{F}^2_{\rm pert}\rangle + 2\langle\mathcal{F}_{\rm pert}\rangle\cdot\langle\mathcal{F}_{\rm pow}\rangle + \mathcal{O}(1/s)$. For the second moment of the thrust observable, however, a $1/(\sqrt{s})^3$ power correction is expected in the 2-jet region.[7] The investigations [2] exemplified in figure 2 show that $\langle 1-T\rangle$, $\langle B_T\rangle$, and $\langle C\rangle$ require a large $1/s$ term which is not necessary for $\langle\rho^2\rangle \equiv \langle M_H^2/s\rangle$ and $\langle B_W\rangle$.

To suppress the $\langle\mathcal{F}_{\rm pow}\rangle$ term in the formula of the second moment the study of the variance has been proposed.[8] With no other data available the variance of the C-parameter, $\sigma_C^2 \equiv \langle C^2\rangle - \langle C\rangle^2 = 0.034 \pm 0.010$ has been calculated from the distributions measured at 91 GeV using error propagation to assess the total error. Using the second order prediction, $\sigma_C^2 \approx 0.387\alpha_S + 0.0435\alpha_S^2$, and neglecting the $1/s$ correction the variance yields a very low value $\alpha_S(M_Z) = 0.09 \pm 0.03$ which could be due to the C-parameter spectrum which does not vanish at the boundary of the 3-jet phase space.[9] In general, more complete predictions are required to make use of the higher order moments.

4 Power Corrections to Differential Distributions

Power corrections can also be applied to the differential distributions of event shapes by shifting the resummed plus $\mathcal{O}(\alpha_S^2)$ prediction. This has been investigated by several groups using T and M_H. With the reanalysed JADE data at 35 and 44 GeV also power corrections to the C and jet broadening distributions became possible which showed the necessity of squeezing the predicted distributions for the latter in addition to the shift.[4] The fit results from T, B_T, B_W, and C, updated for the corrected Milan factor, yield on average $\alpha_0 = 0.57 \pm 0.09$ (r.m.s. 0.12) and $\alpha_S(M_Z) = 0.107 \pm 0.006$. The χ^2/d.o.f. of the fits is about unity but for B_W which yields $\alpha_0 = 0.79$ too high and $\alpha_S(M_Z) = 0.097$ too low.

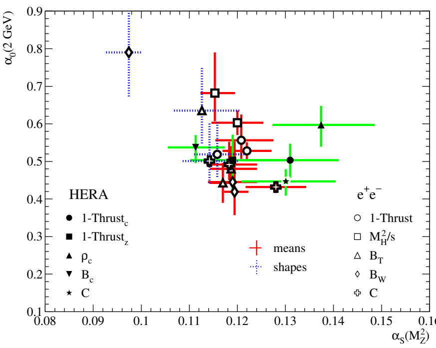

Figure 3: Fit results of α_0 and $\alpha_S(M_Z)$.

These fits of the event shape distributions exclude the extreme 2-jet region. Extending the power corrections with a shape function [10] a fit over the whole distribution is possible.

5 Conclusions

Figure 3 summarises the results of the fits of α_0(2 GeV) and $\alpha_S(M_Z)$ from the mean values and from the distributions of event shapes in e^+e^- annihilation. These results agree with those from studies of event shapes in ep scattering.[11] In all these investigations power corrections prove to be a useful description of the hadronisation effects and the single non-perturbative parameter α_0(2 GeV) assumes an universal value of about $0.5 \pm 20\%$.

References

1. Yu.L. Dokshitzer and B.R. Webber, *Phys. Lett.* B **352**, 451 (1995).
2. L3 Coll.: L3 Note 2504, March 1, 2000.
3. DELPHI Coll.: DELPHI 2000-022 CONF 343, March 1, 2000.
4. O. Biebel et al., *Phys. Lett.* B **459**, 326 (1999).
5. Yu.L. Dokshitzer, *JHEP* **9911**, 025 (1999), `hep-ph/9911316`.
6. S. Bethke: `hep-ex/0004021`.
7. E. Gardi, *JHEP* **0004**, 030 (2000), `hep-ph/0003179`.
8. B.R. Webber, *Nucl. Phys.* (Proc. Suppl.) **71**, 66 (1999).
9. G. Korchemsky, priv. comm.
10. G. Korchemsky: `hep-ph/9806537`.
11. H1 Coll.: C. Adloff et al., *Eur. Phys. J.* C **14**, 255 (2000).