MEASUREMENT OF α_S AND POWER CORRECTIONS FROM JADE DATA

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Re-analysed JADE data were used to determine $\alpha_{\rm S}$ at $\sqrt{s}$ = 14-44 GeV on the basis of resummed calculations for event shapes and hadronisation models tuned to LEP data. The combined result is $\alpha_{\rm S}(M_{\rm Z^0}) = 0.1194^{+0.0082}_{-0.0068}$ which is consistent with the world average. Event shapes have also been used to test power corrections based on an analytical model and to verify the gauge structure of QCD. Studies of the angular and momentum distributions of charged particles in hadronic final states of e^+e^- annihilation are presented.

1. EVENT SHAPES AND DETERMINATION OF $\alpha_{\rm S}$

The re-analysis of e^+e^- annihilation data collected with the JADE detector at the PETRA collider (1978-1986) has been shown to be a valuable effort [1,2,3,4,5] since the characteristic energy evolution of Quantum Chromodynamics (QCD) becomes more manifest towards decreasing centre-of-mass energies $\sqrt{s}$.

From multihadronic data samples, the distributions of *thrust* $(1-T)$, *heavy jet mass* $(M_{\rm H})$, *total* and *wide jet broadening* ($B_{\rm T}$ and $B_{\rm W}$), *C parameter* and the *differential 2-jet rate* y_{23} in the Durham scheme are calculated [1]. The data are corrected for the limited acceptance and resolution of the detector and for initial state photon radiation.

The determination of $\alpha_{\rm S}$ is based on a combination of an exact QCD matrix element calculation $\mathcal{O}(\alpha_{\rm S}^2)$ [6] intended to describe the 3-jet region of phase space and a next-to-leading-logarithmic approximation (NLLA) [7] valid in the 2-jet region where multiple radiation of soft and collinear gluons from a system of two hard back-to-back partons dominate. We perform χ^2-fits of the theoretical predictions corrected for hadronisation effects. For the main results, we use the $\ln(R)$-scheme [7]. Experimental errors are under control for all data samples. Expectedly, hadronisation uncertainties increase rapidly towards 14 GeV. The individual results agree with each other within 1-2 standard deviations of the fit and experimental errors. The α_S results obtained here and in similar analyses at higher energies based on resummed event shapes agree well with the QCD expectation for the running coupling [8]. A χ^2-fit taking statistical and experimental errors into account yields $\alpha_S(M_{Z^0}) = 0.1213 \pm 0.0006$ with $\chi^2/\text{d.o.f.} = 8.3/11$.

2. TEST OF POWER CORRECTIONS

The DMW model [9] describes non-perturbative effects to event shapes as contributions from gluon radiation at low energy scales, assuming that the physical strong coupling $\alpha_S(\mu)$ remains finite in the energy region around the Landau pole where simple perturbative evolution of α_S breaks down. This leads to the introduction of a parameter $\alpha_0(\mu_I) = 1/\mu_I \int_0^{\mu_I} \mathrm{d}\mu\, \alpha_S(\mu)$ that absorbs all non-perturbative details of $\alpha_S(\mu)$ up to an arbitrary infrared matching scale μ_I. The prediction, in particular the universality of $\alpha_0(\mu_I)$, has been tested by global fits to the hadron level data from this analysis and from other experiments e.g. at LEP/SLC up to $\sqrt{s} = 189\,\text{GeV}$ [2], with $\alpha_S(M_{Z^0})$ and $\alpha_0(2\,\text{GeV})$ as only free parameters.

As shown in Fig. 1, there is a reasonable agreement between the individual results within the total uncertainties. The α_S values from power corrections to the distributions are systematically smaller than the results based on MC corrections. Combining the results for the mean values and the distributions taking correlations between the systematic errors into account yields $\alpha_S(M_{Z^0}) = 0.1175^{+0.0031}_{-0.0021}$ and $\alpha_0(2\,\text{GeV}) = 0.503^{+0.066}_{-0.045}$. The scatter of the α_0 values is mostly covered by the theoretical uncertainty of the Milan factor [9].

3. STUDY OF QCD COLOUR FACTORS

The DMW ansatz has been exploited to extract the QCD colour factors C_A, C_F, and n_f [3]. Various global fits to the event shape spectra trying alternative sets of the free model parameters support the $SU(3)$ symmetry group. Combining the corresponding results for these variables with $\alpha_0(2\,\text{GeV})$ and n_f fixed, and $\alpha_S(M_{Z^0})$, C_F, and C_A free, one finds $C_F = 1.29 \pm 0.18$ and $C_A = 2.84 \pm 0.24$.

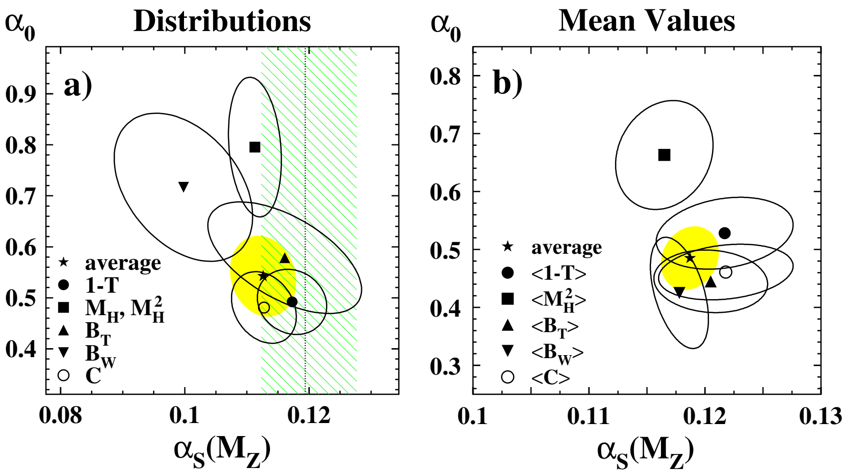

Figure 1. $\alpha_S(M_{Z^0})$ and $\alpha_0(2\,\mathrm{GeV})$ and one standard deviation errors of DMW-fits to distributions a) and means b). The hatched band represents the combined $\alpha_S(M_{Z^0})$ derived from the "conventional" analysis.

4. LONGITUDINAL CROSS SECTION

The distribution of the angles Θ between the charged hadrons and the e^- beam direction can be described as a function of σ_T and σ_L, the transverse and the longitudinal cross sections. A significant contribution to σ_L comes from gluon radiation in the $q\bar{q}$ final state and can be predicted in perturbative QCD in $\mathcal{O}(\alpha_S^2)$ [10] to be $(\sigma_L/\sigma_{tot})_{PT} = 2\hat{\alpha}_S + 33.78\hat{\alpha}_S^2$ with $\hat{\alpha}_S = \alpha_S/(2\pi)$. The fit result of the analysis of JADE data taken at $\sqrt{s} = 35$ and 44 GeV is $\sigma_L/\sigma_{tot} = 0.067 \pm 0.013$ corresponding to $\alpha_S(36.6\mathrm{GeV}) = 0.150 \pm 0.025$ or $\alpha_S(M_{Z^0}) = 0.127 \pm 0.018$.

5. MOMENTUM SPECTRA

The study of momentum spectra of charged particles in hadronic final states of e^+e^- annihilation allows tests NLLA QCD predictions together with Local Parton Hadron Duality (LPHD) [11]. For charged particles with momentum fractions $x = 2p/\sqrt{s}$, where p is their momentum, the distribution of $\xi = \ln(1/x)$ is studied [12]. The NLLA QCD prediction is found to describe the data at 22, 35 and 44 GeV well around the peak region where the predictions are expected to be valid. The evolution of the peak position ξ_0 is seen to be well described by the NLLA prediction.

6. CONCLUSIONS

Resummed QCD theory combined with LEP tuned hadronisation models fits event shape data well down to $\sqrt{s} = 14\,\mathrm{GeV}$ and allow consistent determinations of α_S. The combined result evolved to the Z^0 mass scale is $\alpha_\mathrm{S}(M_{\mathrm{Z}^0}) = 0.1194^{+0.0082}_{-0.0068}$ which is substantially more precise than former PETRA measurements and also in good agreement with the world average value [8]. Power corrections $\propto 1/\sqrt{s}$ generally reproduce the overall event shape spectra, except for the distributions of the less inclusive variables (M_H and B_W) at $\sqrt{s} < M_{\mathrm{Z}^0}$. The results for α_0 support the DMW prediction of universality within 25%. Using power corrections, the gauge structure of QCD has been verified. Potential biases from hadronisation models are reduced within this approach. The measurement of the longitudinal cross section was used, to determine $\alpha_\mathrm{S}(M_{\mathrm{Z}^0}) = 0.127 \pm 0.018$. NLLA QCD predictions describe the momentum spectrum of charged particles well.

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