PROCEEDINGS OF SCIENCE

Determinations of α_S and tests of analytic hadronisation models using e^+e^- annihilation data

C. Pahl*
Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 Munich, Germany
Excellence Cluster Universe, Technische Universität München, Boltzmannstr. 2, D-85748 Garching, Germany
E-mail: Pahl@mppmu.mpg.de

S. Bethke
Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 Munich, Germany
E-mail: Bethke@mppmu.mpg.de

O. Biebel
LMU München, Fakultät für Physik, Am Coulombwall 1, D-85748 Garching, Germany
E-mail: Otmar.Biebel@physik.uni-muenchen.de

S. Kluth
Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 Munich, Germany
E-mail: SKluth@mppmu.mpg.de

J. Schieck
Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 Munich, Germany
E-mail: Schieck@mppmu.mpg.de

and the JADE Collaboration

We report results on measurements of the strong coupling α_S from event shape data at PETRA and LEP. Their distributions are analysed employing the new NLLO+NLLA calculations and hadronisation correction by Monte Carlo models using JADE data. This results in a very precise measurement of the strong coupling, $\alpha_S(m_{Z^0}) = 0.1172 \pm 0.0051$. The running of the strong coupling is confirmed significantly. Analyses of their moments using next to leading order calculations and hadronisation correction by analytical power corrections show shortcomings of the calculations, which can be expected to be alleviated by the NNLO calculations.

The 2009 Europhysics Conference on High Energy Physics,
July 16 - 22 2009
Krakow, Poland

*Speaker.

 http://pos.sissa.it/

PoS(EPS-HEP 2009)292

1. Introduction

The JADE Experiment was operated 1978–1986 at the PETRA collider at DESY, at low c.m. energies $Q = 12$–44 GeV where QCD effects are strong. The analysis and detector simulation software has been reactivated and the data have been saved from tapes and printouts to use them for analyses employing new Monte Carlo models and very recent calculations.

Event shapes measure properties of an hadronic event. We employ the variables Thrust $1-T$, C-parameter C and Total Jet Boadening B_T, which are sensitive to the whole event; further Wide Jet Broadening B_W, Durham two-jet flip parameter y_{23}^D and Heavy Jet Mass M_H, which are sensitive to only one suitable chosen hemisphere of the event. They all vanish for an ideal two jet event, and have an upper limit, e.g. $1-T = 1/2$, for a spherical event. The nth moment of an event shape variable y is defined as $\langle y^n \rangle \equiv \frac{1}{\sigma}\int y^n \frac{d\sigma}{dy} dy$, so higher order moments probe the multi-jet region.

2. Fits of the moments

Fits of event shape moments aim at specific tests of QCD calculations. The moments $\langle y^m \rangle$, m=1...5 have been measured by JADE [1] and OPAL [2]. In these tests [3], perturbative predictions are employed in Next to Leading Order (NLO), $\langle y^n \rangle = A_n \cdot \alpha_S(Q^2) + B_n \cdot \alpha_S^2(Q^2)$. The hadronisation correction is performed by analytical "non perturbative" power correction models.

The dispersive model predicts non perturbative corrections supressed with Q and parametrised by a quantity α_0, which is universal for all event shapes. The predictions for the moments of the distributions fit the data well. Fits of the NLO predictions reveal several non-universalities of the fit parameters. Fig. 1 (left) shows that the α_0 values from one-hemisphere moments $\langle B_W^1 \rangle$, $\langle M_H^2 \rangle$ and $\langle M_H^4 \rangle$ are rather high. The steeper rise of inverse powers of Q compared to any power of α_S compensates for the uncompletenes of the NLO description of the one-hemisphere variables which is explained in [4].

The $\alpha_S(m_{Z^0})$ values from higher order two-hemisphere moments steeply rise with moment order as already observed in fits of JADE or OPAL data when using hadronisation corrections by Monte Carlo models [1, 2]. The predictions of these moments receive large corrections in α_S^2, see [2] and Fig. 1 (right, dashed lines). The fit results indicate that this trend continues, i.e. for the higher moments of the two-hemisphere variables large contributions in higher orders of α_S are missing [6]. This has recently been confirmed in Next to Next to Leading Order (NNLO): The α_S^3 contributions [5] increase strongly with moment order for the moments of the two-hemisphere variables, while they are moderate for the one-hemisphere variables. This is shown in Fig. 1 (right, solid lines) for $1-T$ and y_{23}^D.

Moment analyses of the shape function model, which predicts more detailed power corrections, give similar results. The single dressed gluon approximation is an approximate calculation available up to α_S^6, and results in a precise measurement, $\alpha_S(m_{Z^0}) = 0.1172 \pm 0.0036$.

3. Fits of the distributions

Fits of event shape distributions aim at precise measurement of α_S. In these measurements [7], perturbative predictions are employed in NNLO [8]. These calculations are also combined with

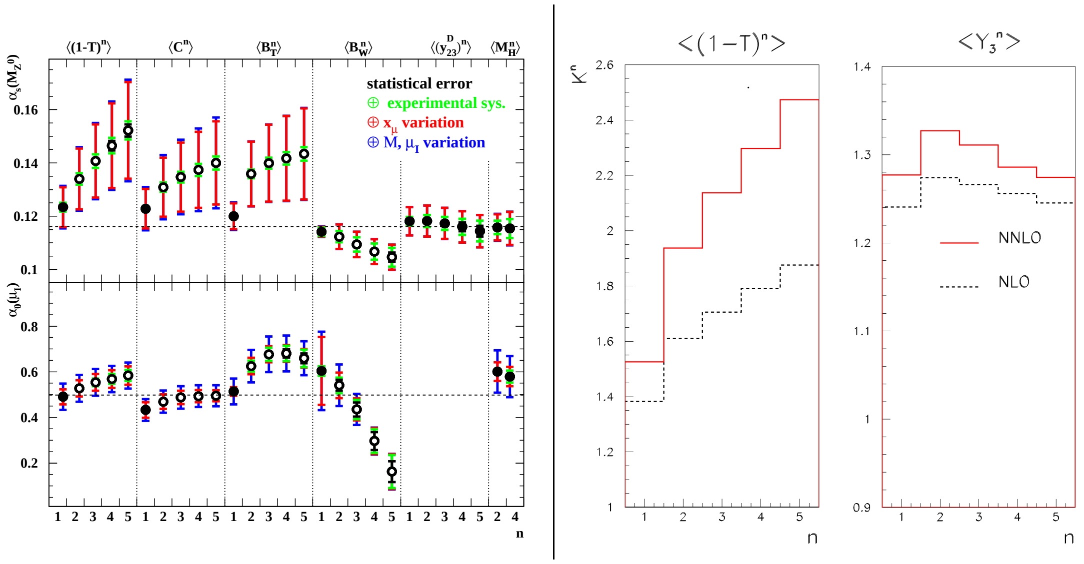

Figure 1: The left figure shows measurements of $\alpha_S(m_{Z^0})$ and α_0 in the dispersive model (no power corrections were employed for $\langle(y_{23}^D)^n\rangle$. The right figure [5] shows the the ratios of the first five thrust and Durham flip parameter moments in NLO over leading order (dashed) and in NNLO over leading order (solid) at 91 GeV with $\alpha_S(m_{Z^0})$=0.124.

resummed logarithms in the Next to Leading Logarithmic Approximation (NNLO+NLLA). The effects of hadronisation are corrected for by Monte Carlo models.

For comparison studies, the analysis has been performed using NLO, NLO+NLLA and NNLO predictions only. Several effects show that the NNLO predictions are more complete than the respective NLO predictions: The data are described by NNLO+NLLA well over virtually all phase space. The renormalisation scale uncertainty, wich is the largest contribution to the total error, is reduced. This can be seen from Fig. 2 (left), which also shows that the scatter from the different variables is reduced. Using NNLO predictions, combined over events shape variables and JADE energy points, yields $\alpha_S(m_{Z^0}) = 0.1210 \pm 0.0061$. Using the NNLO+NLLA predictions results in $\alpha_S(m_{Z^0}) = 0.1172 \pm 0.0051$, its 4% precision puts it among the best $\alpha_S(m_{Z^0})$ measurements. Fig. 2 (right) shows that the running of $\alpha_S(Q)$ as predicted from the renormalisation group is confirmed strongly in the JADE range 14–44 GeV.

4. Conclusion and outlook

The strong coupling has been measured from six event shape variables using NNLO+NLLA calculations at 14-44 GeV very precisely, $\alpha_S(m_{Z^0}) = 0.1172 \pm 0.0051$. The running of $\alpha_S(Q)$ has been confirmed strongly in this JADE energy range. Event shape moments reveal shortcomings of the NLO calculations, which are expected to be alleviated by the NNLO calculations.

An OPAL NNLO analysis is in progress, and a NNLO analysis of event shape moments would be interesting. Re-analyses of data taken at the JADE and OPAL experiment have a huge potential, as new calculations and new models are available. As everyone is now looking at the LHC, still precise QCD studies in e^+e^- physics are also important to the understanding of LHC physics.

PoS(EPS-HEP 2009)292

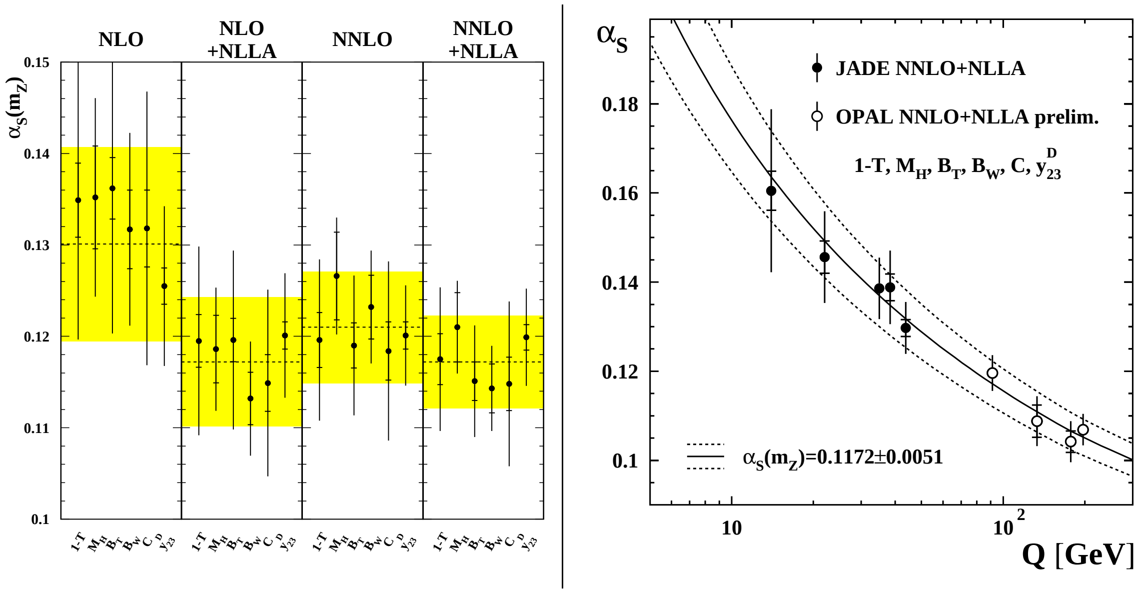

Figure 2: The left figure shows the $\alpha_S(m_{Z^0})$ results from six event shape variables from fits of NLO or NNLO predictions without or with inclusion of resummed logarithms. The dashed lines show the values, combined over the variables, and the shaded bands show their total errors. The right plot shows the running $\alpha_S(Q)$ results from event shape combinations using NNLO+NLLA predictions. The solid line shows the combined value, evolved over c.m. energy, and the dashed lines show its total error. In both plots, the inner error bars show the statistical errors and the outer error bars show the total errors including the experimental, hadronisation and scale uncertainties.

References

[1] C. Pahl, S. Bethke, S. Kluth, J. Schieck, *Study of moments of event shapes and a determination of α_S using* e^+e^- *annihilation data from* JADE, Eur. Phys. J. **C60** 181 [arXiv:0810.2933].

[2] OPAL Collaboration (G. Abbiendi et al), *Measurement of event shape distributions and moments in $e^+ e^- \rightarrow$ hadrons at 91 GeV - 209 GeV and a determination of α_S*, Eur. Phys. J. **C40** 287 [hep-ex/0503051].

[3] C. Pahl, S. Bethke, O. Biebel, S. Kluth, and J. Schieck, *Tests of analytical hadronisation models using event shape moments in* e^+e^- *annihilation*, accepted by Eur. Phys. J. **C** arXiv:0904.0786.

[4] C. Pahl, *Measurement of event shapes and α_s in e^+e^-*, to appear in High Energy Physics ICHEP 2008, Proceedings of the 34th International Conference arXiv:0810.3326.

[5] A. Gehrmann-De Ridder, T. Gehrmann, E. W. N. Glover, G. Heinrich, *NNLO moments of event shapes in e^+e^- annihilation*, JHEP **05** 106 [arXiv:0903.4658].

[6] C. Pahl, *Untersuchung perturbativer und nichtperturbativer Struktur der Momente hadronischer Ereignisformvariablen mit den Experimenten JADE und OPAL*, http://nbn-resolving.de/urn:nbn:de:bvb:91-diss-20070906-627360-1-2.

[7] S. Bethke, S. Kluth, C. Pahl, J. Schieck, *Determination of the strong coupling α_S from hadronic event shapes and NNLO QCD predictions using* JADE *data*, accepted by Eur. Phys. J. **C** arXiv:0810.1389.

[8] A. Gehrmann-De Ridder, T. Gehrmann, E. W. N. Glover, G. Heinrich, *NNLO corrections to event shapes in e^+e^- annihilation*, JHEP **12** 094 [arXiv:0711.4711].