QCD AND FSI AT LEP

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Significant progress has recently been made in measurement of the strong coupling constant, α_S, and studies of colour reconnection (CR) in W^+W^- decays at LEP. The results presented combine all LEP data and are preliminary.

1. Introduction

Experiments accumulated data in two distinct phases during the 12 years of LEP operation. At LEP1, each experiment recorded several million hadronic $Z \to q\overline{q}$ events, with effectively no backgrounds (below 0.5%) or initial state radiation (ISR). In contrast, at LEP2 energies above $\sqrt{s}=m_Z$, each collaboration recorded a mere $\sim 15k$ such events at seven nominal points in $\sqrt{s}$, with large contamination from 4-fermion processes such as $e^+e^- \to W^+W^-$ of 10–15% and significant ISR effects. The main effort in studies of α_S of late has therefore been divided between the more difficult analysis of the LEP2 data and use of improved theoretical calculations. For $e^+e^- \to W^+W^-$ where the precise measurement of m_W is compromised by possible QCD effects such as colour reconnection, a first combined result using data from the four LEP collaborations has been made[1].

2. α_S Measurements

Measurements first select hadronic final states and then reject 4-fermion-like events and events with hard ISR photons. Distributions of event shape observables, $\frac{1}{\sigma}d\sigma dy$, such as thrust, T, differential 2-jet rate, y_3, heavy jet mass, M_H, wide and total jet broadenings, B_W and B_T, and the C-parameter, are formed using charged particles, calorimeter clusters or energy flow objects. Backgrounds are subtracted and bin-by-bin corrections account for finite acceptance, resolution and residual ISR contamination.

The data are described relatively well by Monte Carlo simulations.

Fits are performed using a combination of next-to-leading order calculations (all terms to $O(\alpha_S^2)$) and NLLA resummed QCD calculations (leading and sub-leading log terms to all orders in α_S). So-called modified $\log R$ or R matching schemes avoid double counting of common terms and also ensure necessary boundary conditions for the calculations are satisfied within the restricted, experimentally accessible range of observables. The perturbative QCD calculations are corrected for hadronisation using Monte Carlo simulations. The data are described well by this combined fit. Systematics may

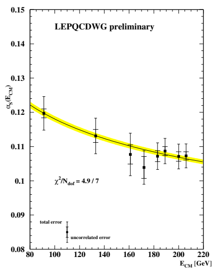

Figure 1. Combined α_S measurements from LEP vs. $\sqrt{s}$.

be classified into three categories. Firstly, experimental sources (e.g. event selection, background subtraction, ISR corrections) which have little inter-experiment correlation and for which full covariance matrix is used. These are typically $\sim 1\%$ relative error. Secondly, hadronisation uncertainties are assumed to be moderately correlated, and the on-diagonal covariance terms are used. These are typically 0.7-1.5% in size, and estimated by comparing different hadronisation models or by varying parameters within a single model. Finally, theoretical uncertainties which are highly correlated between experiments and for which a new prescription is proposed by the LEP QCD WG[2]: the theoretical uncertainty is estimated by varying different aspects of the theoretical calculation (e.g. renormalisation scale, kinematic limit in y, rescaling factor, modification degree) for a fixed, best fit value of α_S. These are large, typically 3.5–5%.

The combined results obtained from using six observables, eight centre-of-mass energies from the four LEP experiments, are presented in Table 1 and in Figure 1. Note that the "all LEP" average is a separate fit rather than a weighted average of the two subsets of data.

Table 1. LEP combined α_S measurements.

Prelim.	LEP1	LEP2	All LEP
$\alpha_S(m_Z^2)$	0.1197	0.1196	0.1198
Δ statistical	0.0002	0.0005	0.0003
Δ experimental	0.0008	0.0010	0.0009
Δ hadronisation	0.0010	0.0007	0.0003
Δ theoretical	0.0048	0.0044	0.0046
Δ total	0.0049	0.0046	0.0048

3. Colour Reconnection

ALEPH have recently updated their measurement of inclusive charged particle multiplicity, $\langle n_c h \rangle$, searching for differences in $\langle n_c h \rangle$ between $W^+W^- \to q\bar{q}q\bar{q}$ and twice $\langle n_c h \rangle$ in $W^+W^- \to q\bar{q}\ell\nu_\ell$. Using their entire data set, they observe no evidence for CR, and find limited sensitivity with this method.

Thus far the most sensitive analysis using W^+W^- data is that of particle flow. This has been performed by all collaborations and for the first time, the results were combined in summer 2002[1]. The analysis compares the particle density in regions between jets which have a common W parent and jets which originate from different W's. The ratio of the integrated particle density in these regions, R_N, predicted by CR models differs from conventional, no-CR models. As the experiments have different event selection criteria, and do not correct to the hadron level, the only meaningful comparison is performed relative to a shared, common sample of simulated W^+W^- events, processed by each experiment's detector simulation program. Analysing these correlated samples allows a direct combination of the results. The results are quantified by r, the ratio of R_N measured in data to that in a shared no-CR MC sample, as shown in Figure 2. The data are found between the CR and no-CR scenarios. In the context of the SK-I model, the best agreement with the data are found for a reconnection probability of approx. 49%, see Figure 3. Further details are given in[1].

4. Summary

A first combination of CR results from particle flow and a precise measurements of α_S were presented using all LEP data. Further improvements in the former are still expected.

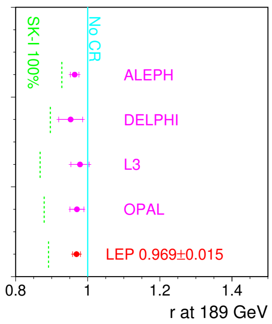

Figure 2. Comparison of normalised R_N results, extreme scenario of SK-I model.

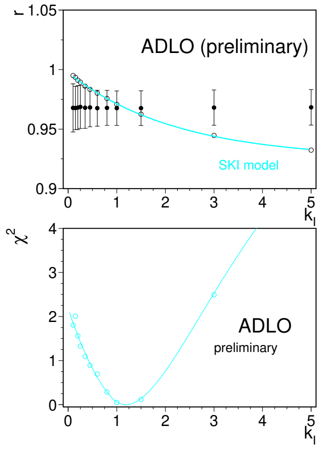

Figure 3. LEP average r vs. SK-I CR parameter, k_I, minimum corresponds to 49% reconnection probability.

Acknowledgments

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References

1. LEP WW Working Group, LEPEWWG/FSI/2002-01, July 2002, and Chapter 12 in `http://arxiv.org/abs/hep-ex/0212036`
2. LEP QCD Working Group, note in preparation, see `http://lepqcd.web.cern.ch/LEPQCD/annihilations/Welcome.html`,