Cross Sections and QCD at 130 − 140 GeV

Wenwen Lu
California Institute of Technology
Pasadena, CA 91125, U. S. A.
The L3 Collaboration

Abstract

I present the LEP 1.5 results with 130 GeV < $\sqrt{s}$ < 140 GeV. With about 5.6pb^{-1} per experiment, cross sections of $e^+e^- \rightarrow f\bar{f}$ have been measured. The results agree with the standard model prediction. The knowledge on the γZ interference term j^{tot}_{had} has been significantly improved from this high energy data. Including TOPAZ's result,

$$j^{tot}_{had} = -0.06 \pm 0.18.$$

The QCD test from the hadronic event structure shows that data and QCD Monte Carlo prediction agree well at $\sqrt{s} \approx 133$ GeV. The LEP average

$$\alpha_s(133) = 0.112 \pm 0.008.$$

Introduction

In Nov 1995, the LEP e^+e^- was upgraded to 130 GeV $< \sqrt{s} <$ 140 GeV. In the run of 27 days, each experiment(Aleph,Delphi,L3,Opal) has accumilated about 5.6pb^{-1}. This is the first time for e^+e^- collider to be at such high energy. It's a great achievement for LEP as the preperation for LEP 200. The LEP machine performance was excellent with expected luminosity and low background condition. This has provided an exciting chance to search for new physics. Besides that, we have also taken advantage of this data sample, even though with small statistics, to check the "standard" processes and search for deviation from Standard Model - this later point is the topic of this report.

I first present the charateristics of these high energy data sample. It follows with the cross section measurements of $e^+e^- \rightarrow f\bar{f}$ and the physics interpretation of these cross section measurements concerning the γZ interference term j^{tot}_{had}. QCD test from the hadronic event structure is shown in the third section. In the end, I give a short summary.

Data sample

The $\sigma_{q\bar{q}}$ at 130−140 GeV is 10^{-2} of the $\sigma_{q\bar{q}}$ at Z peak. The data sample of each experiment ($\approx$ 5.6pb^{-1}) corresponds to about 1600 $q\bar{q}$ events. This leads to the precision of the measurement at LEP 1.5 to be at % level

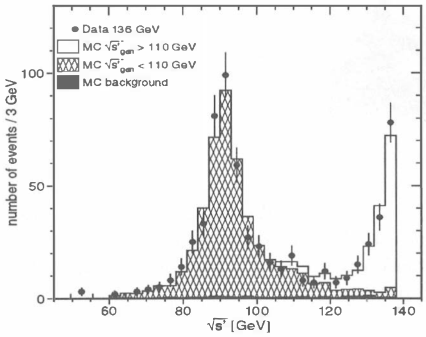

Figure 1: The $\sqrt{s'}$ distribution from L3

The speacial feature for the events of 130 – 140 GeV is that a large fraction of the events (eg. $\approx$ 70% for $q\bar{q}$ events) have hard initial state radiation (ISR) such that the effective-center-mass-of energy $\sqrt{s'}$ is lowed to be at the Z resonance. We define this kind of events as "radiative Z return" events, which should correspond to the same physical processes as the LEP 1 Z events. To study the exclusive feature for "genuine high energy events", a cut on $\sqrt{s'} >> m_Z$ is used to suppress the "radiative Z return" events.

$\sqrt{s'}$ is determined in the following ways: if the ISR γ is detected, $s' = s - 2E_\gamma\sqrt{s}$;otherwise, we use the kinematics constrains to derive $\sqrt{s'}$ with the assumption that the ISR γ is along the beam pipe.

Figure 1 shows distribution of $\sqrt{s'}$ from L3: the double-peak structure is from the "genuine high energy events" and the "radiative Z return events". A cut of $\sqrt{s'} >$ 110 GeV is used to seperate the "genuine high energy events" from the "radiative Z return events"

Cross section measurements and j^{tot}_{had}

The cross section measurements have been applied to two samples: the inclusive total event sample and the exclusive " genuine high energy" event sample. Examples of the results [1] [2] [3] [4] are illustrated in Figure 2 and Figure 3. The cross section measurements of 130 GeV $< \sqrt{s} <$ 140 GeV agree with the Standard Model prediction.

The measurements of center-of-mass energies far away from the Z pole are espeically sensitive to the parameters describing the interference between photon and Z exchange [6]. In the S-

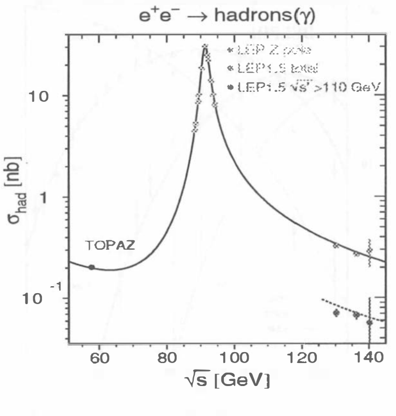

Figure 2: The $q\bar{q}$ cross section measurement

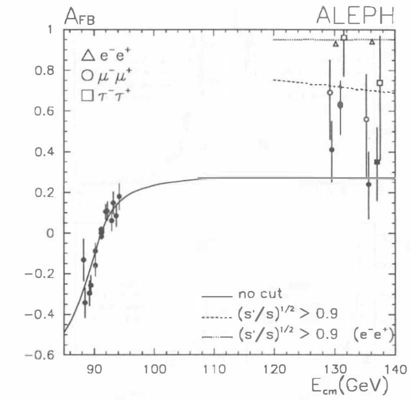

Figure 3: The leptonic charge asymmetry from ALEPH

Matrix formalism [5], the hadronic γZ interference term is scaled by the parameter j^{tot}_{had}, which was fixed to the SM value 0.22 in the lineshape fits to the LEP 1 data[8]. The error on m_Z increase sizeably if j^{tot}_{had} is left free in the fits due to the strong anticorrelation between j^{tot}_{had} and m_Z. Inclusion of LEP 1.5 data allows a simutaneous fit of j^{tot}_{had} and m_Z with much higher precision. To gain more knowledge of j^{tot}_{had}, published result from TOPAZ collaboration [7] is also included. The impact of the measurements of center-of-mass energies far away from the Z pole (LEP 1.5 and TOPAZ) is clearly visible from Figure 4. The results of j^{tot}_{had} and m_Z [9] are :

$$m_Z = 91.1937 \pm 0.0038 \text{ GeV} \quad (1)$$

$$j^{tot}_{had} = -0.06 \pm 0.18 \quad (2)$$

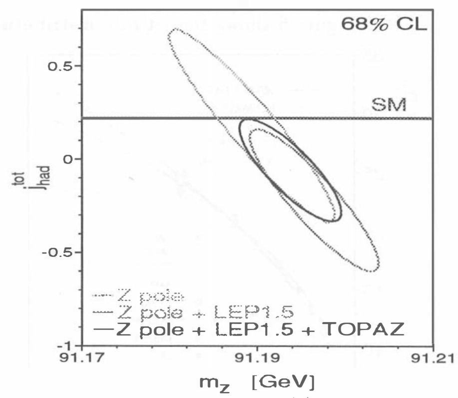

Figure 4: The contour of j^{tot}_{had} and m_Z

QCD test from the hadronic event structure

Hadronic events can be charaterised by event shape distributions (thrust,heavy jet mass,jet broading) and inclusive observables (jet rate,momentumn spectrum,charge multiplicities). Two main effects are expected to influence these QCD observables at the higher energy: the running of the strong coupling α_s and the change of quark flavour composition.

For this analysis of QCD test, the "genuine high engergy" data sample of LEP 1.5 have been used which amounts to about 300 $q\bar{q}$ events per experiment[10][11][12][13]. After detector effects and photon radiation have been corrected ,the event shape distributions are compared with QCD models which have been used extensively at $\sqrt{s} = 91$ GeV and for which parameters

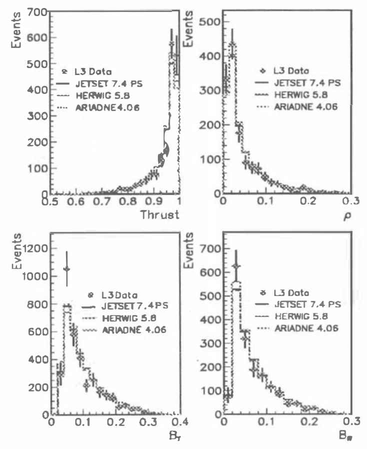

Figure 5: Hadronic event shape distributions from L3

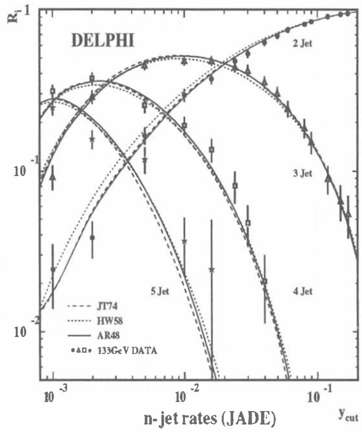

Figure 6: Jet rate distribution from Delphi

have been tuned using the hadronic Z decays. Figure 5 shows the event shape distribution from L3 and Figure 6 shows the jet rate distribution from Delphi.

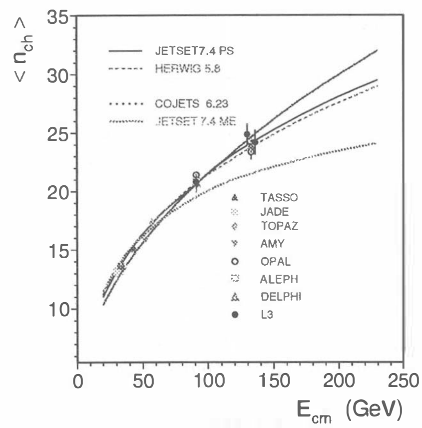

Figure 7: Charge multiplicity $< Nch >$ evolution

Data and QCD MC are shown to be consistent with each other. The energy evolution of the QCD observables have also been checked. As one of the example,the energy evolution of mean value of charge multiplicity $< Nch >$ is shown in Figure 7 along with the results from low energy experiments and LEP 1 results. The JETSET 7.4 ME model fails to describle the energy dependence of $< Nch >$ over a wide energy range due to the low parton multiplicity (maximumn 4) before fragmentation. Apart from that, all the other QCD models decrible the evolution of the quantity very well.

One of the most improtant prediction for QCD is the energy dependence(running) of the strong coupling constant α_s. The determination of α_s was done by fitting to the $\mathcal{O}(\alpha_s^2)$ + resummed QCD calculations with each experiment's favorable event shape variables. DELPHI has a different approach in the sense that they fit the evolution curve of charge multiplicity or of the thrust and heavy jet mass to extract the α_s value. The results and corresponding fitting variable are listed in Table 1. An α_s evolution curve is shown in Figure 8. The $\alpha_s(133)$ is consistent with the QCD prediction of the α_s running.

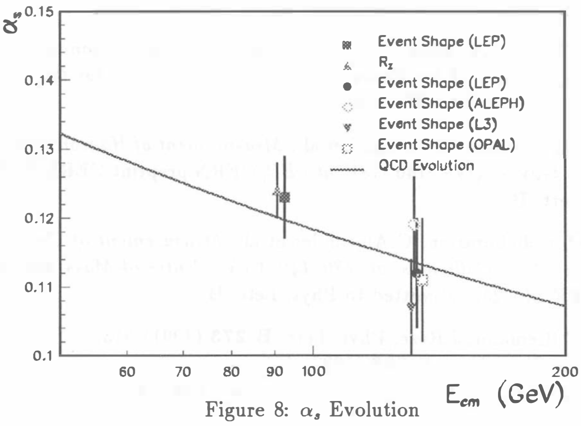

Figure 8: α_s Evolution

α_s(133 GeV)			fit variable
ALEPH	0.119 ± 0.004	± 0.007	$-lny_3$
L3	0.107 ± 0.005	± 0.006	T,ρ,B_w, B_t
OPAL	0.110 ± 0.005	± 0.009	T,ρ,B_w, B_t, D_2
DELPHI	0.105 ± 0.003	± 0.008	$< N_{ch} >$ evolution
DELPHI	0.120 ± 0.006	preliminary	$< 1 - T >, < M_h^2/s >$ evolution

Table 1: α_s results at 133 GeV

Summary

- LEP was very successful for the high energy run
  - very clean background conditions
  - $\mathcal{L} \approx 5.6\text{pb}^{-1}$ per experiment
- Cross sections agree with standard model prediction
  - knowledge about γZ interference term j_{had}^{tot} has been improved
- Hadronic event structure is consistent with QCD model prediction

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