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GLAS-PPE/1999–19
November 1999

Mass Measurement of the W-boson using the ALEPH Detector at LEP

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Abstract

The W-boson mass has been measured using the ALEPH detector at LEP. Preliminary results from data taken in 1998 are added to previous measurements to give $m_W = 80.411 \pm 0.064(\mathrm{stat.}) \pm 0.037(\mathrm{syst.}) \pm 0.022(\mathrm{BE\text{-}CR}) \pm 0.018(\mathrm{LEP})$ GeV/c^2.

Presented at the
8th International Conference on Hadron Spectroscopy, IHEP, Beijing,
August 24-28 1999

1 INTRODUCTION

In this paper we discuss the measurement of the W mass from direct reconstruction of the invariant mass of the decay products in the channels WW→$q\bar{q}q\bar{q}$ (4q) and WW→ $\ell\nu q\bar{q}$. Preliminary results are presented for data collected in ALEPH[1] during 1998 with an integrated luminosity of $174.2pb^{-1}$ at 188.63GeV.

2 EVENT SELECTIONS

2.1 WW → $q\bar{q}q\bar{q}$ events

Events are preselected to remove radiative returns to the Z and clustered into four jets using the `DURHAM-PE` algorithm, defining $y_{cut} > 0.001$. Events are vetoed if a charged track in a jet carries more than 90% of the jet energy or if there is more than 95% of electromagnetic energy in a 1° cone around any particle.

A Neural Network with fourteen input variables (NN14) is used to perform the final selection. Training is performed with an independent sample of the standard Monte-Carlo (`KORALW`[2] hadronised with `JETSET`[3]) and comparable samples of $q\bar{q}(\gamma)$ and ZZ events, both generated using `PYTHIA`[3], to simulate the background. Events with NN14 > 0.3 are used to extract the W mass[4].

2.2 WW → $e\nu q\bar{q}$ and WW → $\mu\nu q\bar{q}$ events

The total charged energy and multiplicity are used to preselect events with a further cut on the total longitudinal momentum and visible energy to remove radiative returns to the Z. The lepton candidates are chosen to be more energetic and isolated than the other charged tracks and are identified as an electron or muon in the detector. The energy of electron candidates are corrected for possible bremsstrahlung photons detected in the electromagnetic calorimeter.

The `DURHAM-PE` algorithm is used to force two jets from objects not used to reconstruct the lepton defining $y_{cut} > 0.0003$. A probability for an event to come from a signal process is determined from Monte Carlo reference samples using the lepton energy and isolation and the event total transverse momentum. Selected events are required to have a probability greater than 0.4.

2.3 WW → $\tau\nu q\bar{q}$ events

A similar preselection to that used for electron and muon events is applied with additional constraints to remove events with i) energy around the beam line, ii) isolated, energetic photons and iii) those already selected as electron or muon candidate events.

A tau jet is constructed from one or three charged tracks and two other jets are forced using the `JADE` algorithm. The tau jet must be that jet most anti-parallel to the missing momentum vector and isolated from the other jets. As with electron and muon candidate events, a probability is calculated and the same cut applied.

3 EXTRACTION OF THE W-MASS

3.1 WW → $q\bar{q}q\bar{q}$ events

To improve the invariant mass resolution a four constraint kinematic fit is applied to the four jets to conserve energy (as provided by LEP) and momention. Corrections are applied to the jets to take into account particle losses in the detector. The masses from the three combinations of di-jets formed from the fitted jets are rescaled according to $m_{ij}^{resc}/m_{ij} = E_{beam}/(E_i + E_j)$, where E_i and E_j are the measured jet energies.

A pairing algorithm is applied to the di-jet combinations to select that which most closely corresponds to a WW pair. The combination with the smallest mass difference between rescaled masses is chosen provided one mass lies in the window 60 to 86 GeV/c^2 and the other 74 to 86 GeV/c^2.

A binned Monte-Carlo reweighting procedure is employed to find the value of m_W which best fits the mass distributions. Events from a `KORALW`[2] sample with equivalent background are reweighted with a CC03 matrix element to provide a two-dimensional probability density function for the minimisation using a single parameter, m_W. Variable binning controlled by the density of Monte-Carlo is employed optimised to produce a stable result. The W-width is allowed to vary with m_W according to the Standard Model.

In order to check that the procedure does not introduce any biases, Monte Carlo samples are generated with m_W in the range 79.35 and 81.35 GeV/c^2. Treating these samples as data, no significant offsets in the masses measured are found.

3.2 WW → $\ell\nu q\bar{q}$ events

A two constraint fit[6] is applied to each event by minimising a χ^2 constructed from the deviations of selected parameters of the jets and leptons from their true values and demanding that the hadron and lepton invariant masses are equal. The single fitted mass obtained for each event must lie in the window 74 to 94.5 GeV/c^2.

A reweighting procedure similar to that employed in the four quark channel is used to fit the mass distribution. Fixed binning is used for the electron and muon channels and variable binning is retained for the tau channel.

Table 1: Summary of Systematic Errors on the measurement of the W-mass (MeV/c^2)

Source	4q	e	μ	τ
Errors correlated between channels				
Calorimeter calibrations	30	27	14	19
Charged particle tracking		7	3	3
Jet corrections	8	14	4	7
Parton fragmentation	35	25	25	30
Initial State radiation	10	5	5	5
LEP energy	17	17	17	17
Uncorrelated Errors				
Reference MC statistics	10	16	15	23
Background contamination	10	8	1	25
Colour reconnection	25			
Bose-Einstein effects	50			
Total	77	47	37	53

4 SYSTEMATIC UNCERTAINTIES

The systematic errors summarised in Table 1. Uncertainties due to the detector are determined using data taken at the Z at intervals during the high energy running. Particles not seen by the detector cause discrepancies in the jet finding, the effect is estimated by matching jets built from Monte Carlo tracks before and after passing them through the detector simulation.

The error due to parton fragmentation effects is measured by determining the mass shift when `HERWIG`[7] rather than `JETSET` is used for hadronisation. The effect of initial state radiation is estimated by comparing the use of 1st and second order matrix elements. The LEP energy error is that given by LEP.

Colour reconnection between parton pairs in the $q\bar{q}q\bar{q}$ channel is studied using variants on `JETSET` or `HERWIG`. The Bose-Einstein effect has been studied using Z-peak data[9], the systematic error is determined from the shift in the mass measured when the parameters obtained at the Z peak are applied to Monte Carlo events using a modified `JETSET`. This effect is applied between to W decay products in the $q\bar{q}q\bar{q}$ channel.

Table 2: W mass measurement results at 189 GeV

	m_W GeV/c^2	stat.	stat.	BE-CR
Hadronic (4q)	80.561	0.116	0.053	0.056
WW $\rightarrow e\nu q\bar{q}$	80.524	0.180	0.047	
WW $\rightarrow \mu\nu q\bar{q}$	80.297	0.164	0.037	
WW $\rightarrow \tau\nu q\bar{q}$	80.461	0.332	0.053	
Semileptonic	80.406	0.114	0.033	
Weighted Mean	80.472	0.081	0.043	0.025

5 MASS MEASUREMENT RESULTS

The mass distributions obtained are shown in figure 1. The preliminary results for 189 GeV are given in Table 2 for each channel where the BE-CR error is that for the Bose-Einstein and Colour reconnection systematics added in quadrature.

Results for data taken at 172 and 183 GeV have been published [5, 6], combining these and the results above gives

$m_W^{hadronic} = 80.561 \pm 0.095(\text{stat.}) \pm 0.050(\text{syst.}) \pm 0.056(\text{BE-CR})\ \text{GeV}/c^2$

$m_W^{leptonic} = 80.343 \pm 0.089(\text{stat.}) \pm 0.041(\text{syst.})\ \text{GeV}/c^2$.

The current weighted average of all ALEPH results is obtained by including measurements from W pair cross sections at 161 and 172 GeV [8], giving

$m_W = 80.411 \pm 0.064(\text{stat.}) \pm 0.037(\text{syst.}) \pm 0.022(\text{BE-CR}) \pm 0.018(\text{LEP})\ \text{GeV}/c^2$

References

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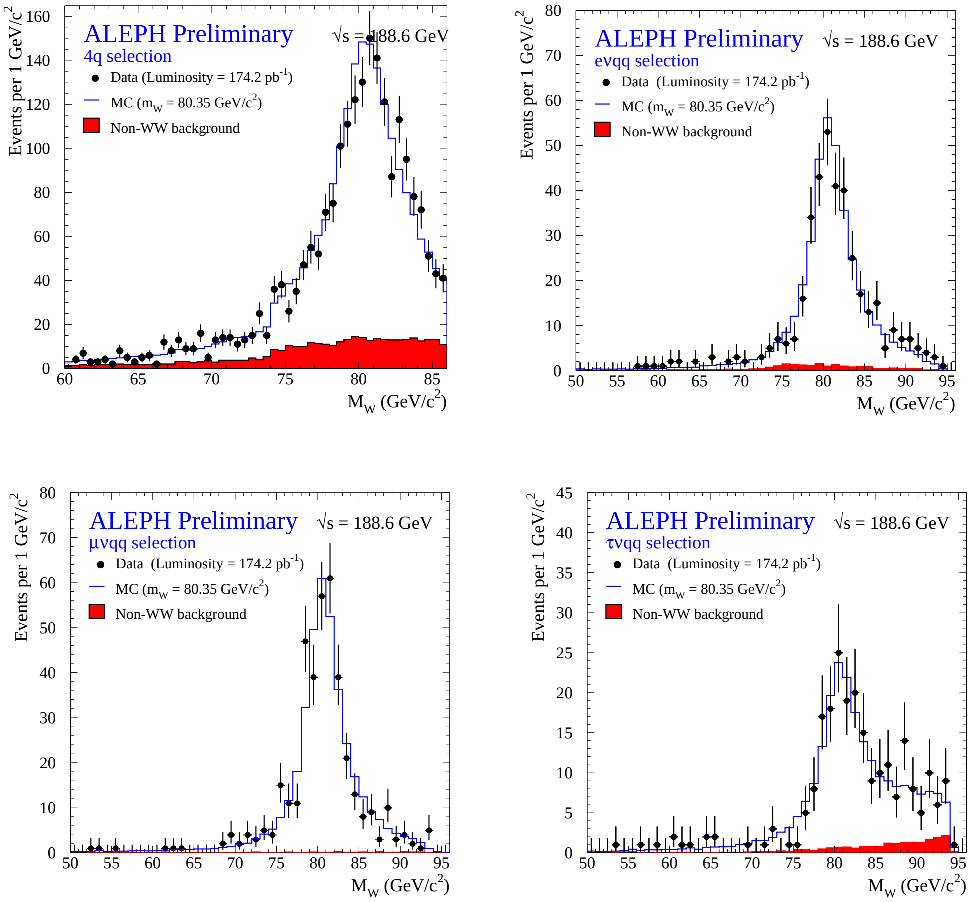

Figure 1: Mass distributions for the 4q (rescaled, two entries per event), e, μ and τ channels. The Monte Carlo prediction is for $m_W = 80.35$ GeV/c^2.

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