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Search for Pair Production of Heavy Objects in 4-Jet Events at $\sqrt{s} = 130 - 136$ GeV[1]

N. Kjær
NIKHEF
P.O. Box 41882
1009 DB Amsterdam
The Netherlands

Abstract

Results are presented of a search for pair production of heavy objects decaying into four hadronic jets, like the production of MSSM Higgs bosons, hA or H^+H^-, using a data sample of 5.9 pb^{-1} of e^+e^- collisions at $\sqrt{s} = 130 - 136$ GeV collected with the DELPHI detector at LEP in 1995. The data and expectations from standard processes agree after four-jet selections. An analysis based on b-tagging finds no hA candidate with high mass. A study optimized to search for H^+H^- events with mass in the 40–50 GeV/c^2 range also finds no candidate. Finally a comparison is made with a recent ALEPH analysis which found an excess of four-jet events with high multiplicity and high mass. No evidence for such a signal is observed, although a slight excess in the mass region around 105 GeV/c^2 is seen.

[1] Presented at the Annual Divisional Meeting of the Division of Particles and Fields of the American Physical Society 10-15 August 1996, Minnesota, USA.

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Niels Jørgen Kjær for the DELPHI Collaboration
NIKHEF-H, Postbus 41882, NL-1009 DB Amsterdam, The Netherlands

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1 Event selection and analysis

A detailed description of the DELPHI detector and its performance can be found in references [1,2]. The reconstruction of four-jet events relies on the tracking detectors and calorimeters. The data sample was collected by DELPHI at LEP during November 1995. The integrated luminosities accumulated were 2.92 pb^{-1} and 3.01 pb^{-1} at energies of 130.4 GeV and 136.3 GeV respectively. Detector effects on the analysis were studied using fully simulated events, both for the signal and for the background, mainly QCD events.

The selection procedure is based on the expected signature: non radiative hadronic events with no missing energy and giving four hadronic jets. A total of 672 events are selected in the data after preliminary cuts, while 653 ± 5 are expected from the background simulation. The efficiency of this selection for a four-jet signal is 94%. The DURHAM clusterizing algorithm is then employed leading to a total of 95 four-jet events selected in the data, while 98 ± 3 are expected from standard processes. The efficiency for the four-jet signal at this level is 81%.

The most direct signature for pair production of new heavy objects is the measurement of their masses, which relies on the jet reconstruction. A simple rescaling method is used based on total energy and momentum conservation. This improves the mass measurements and after requiring positive rescaling, 64 events are found in the data, to be compared to a total of 62 ± 2 expected. The efficiency for the hA signal is maintained at a high value of 75%.

2 Searches for new heavy objects

2.1 Search for hA events using b−tag

The MSSM predicts the associated production of the neutral Higgs bosons, hA, both predominantly decaying into a pair of b quarks, with a cross section depending on the model parameters ($\tan\beta$ and m_A).

At these centre-of-mass energies, this cross section is significant for the newly accessible mass range only if $\tan\beta$ is high: for example for $\tan\beta = 20$ and $m_A = 55\ GeV/c^2$, $\sigma = 0.4$ pb at $E_{cms} = 136\ GeV$. In this case both Higgs masses would be practically equal.

The search relies on b-tagging techniques to eliminate the backgrounds. This b-tagging is based on the measurement of the impact parameters of charged particles provided by the DELPHI microvertex detector. The method counts offsets in $r\phi$ and z, defined as charged particles with a positive lifetime-signed impact parameter in $r\phi$ or z larger than 2.5 times its error.

After requirering three or more jets with at least two offsets only one event is left in the data and 1.3 are expected from the background simulation. The signal efficiency obtained is 46%. This event has a sum of di-jet masses equal to 66 GeV/c^2 and a difference of di-jet masses of 22 GeV/c^2. So the interesting region ($m_A > 40\ GeV/c^2$) contains no candidate in the data. This result can be translated into a 95% confidence level (CL) exclusion limit of 1.3 pb which gives no improvement with respect to LEP1 [3].

2.2 Search for H^+H^-

In e^+e^- interactions, charged Higgs bosons are pair-produced via s-channel γ and Z exchanges. The total cross-section is 1.03 pb for $m_{H+} = 44\,GeV/c^2$, decreasing to 0.32 pb for $m_{H+} = 55\,GeV/c^2$. For low values of $\tan\beta$, $H^+ \to c\bar{s}$ is dominant. In order to optimize the search, a linear function F of measured shape and jet variables was built and a cut was chosen to optimize the ratio of signal to background. After applying this cut, 11 events were selected in the real data, while 13.2 ± 0.8 were expected from simulated $f\bar{f}(n\gamma)$. The efficiency of the signal was found to be 37%.

An equal mass constrained fit was then applied. After a cut on the goodness of fit, 7 events were selected while expecting 10.6 ± 0.8 from the simulated background. Further cuts optimized for a 45 Gev/c^2 signal were applied on the value of the jet pair mass and on the value of the minimal angle between the fitted jets. No events were selected, while 2.4 ± 0.4 were expected from the simulated $f\bar{f}(n\gamma)$sample. The final efficiency of the signal was found to be 29%. The exclusion limit gives no improvement with respect to LEP1 [4].

2.3 *Analysis motivated by the* ALEPH *excess*

The ALEPH Collaboration has reported [5] an excess of four-jet events with respect to the standard model predictions.

This analysis has been adapted to DELPHI, taking into account the differences in tracking efficiency and in detector coverage. 12 events are selected in the data while 9.8 ± 0.6 are expected from standard processes. Using the 44% estimated efficiency for the hA-like signal, a 95% CL upper limit of 4.1 pb on the cross section of a new channel is derived. No statistically significant peak structure is seen in the corresponding mass plot of figure 1.

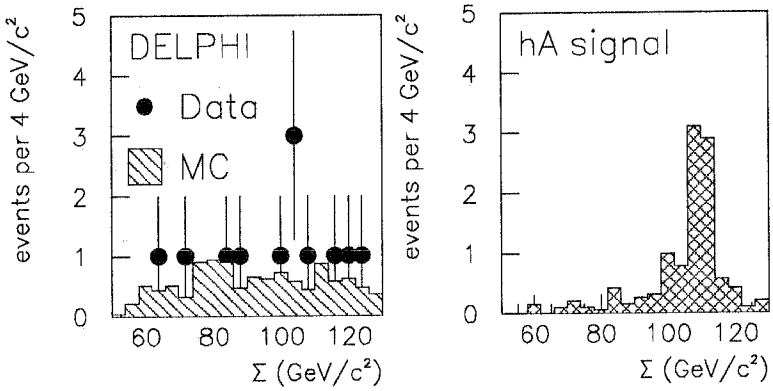

Figure 1: Distribution of reconstructed sum of di-jet masses.

3 Conclusions

The results have been presented of a search for pair production of heavy objects decaying into four hadronic jets, using a data sample of 5.9 pb^{-1} of e^+e^- collisions at $\sqrt{s} = 130 - 136$ GeV collected with the DELPHI detector at LEP in November 1995. Good agreement between data and the expectation from standard processes is found at the four-jet selection level. No significant signal was found in three different 4-jet searches.

1. DELPHI Collaboration, P.Aarnio et al., *Nucl. Instrum. Methods* A30391233.
2. DELPHI Collaboration, P.Abreu et al., "Performance of the DELPHI detector", CERN PPE/95-194, to appear in Nucl. Inst and Meth. A.
3. DELPHI Collaboration, P. Abreu et al., *Z. Phys.* C679569.
4. DELPHI Collaboration, P. Abreu et al., *Z. Phys.* C6494183.
5. ALEPH Collaboration, Contribution to this conference A05370