THE ALEPH FOUR-JET STORY

B. Pietrzyk
Laboratoire de Physique des Particules LAPP, IN2P3–CNRS,
F-74941 Annecy-le-Vieux, France

Abstract

The ALEPH search for the production of pairs of exotic particles in e^+e^- annihilation is described. Each of these particles decays into two jets, giving rise to four-jet events.

After very successful data-taking at the Z resonance, in autumn 1995 LEP experiments started collecting data at higher e^+e^- c.m.s. energies. The following luminosities were used in the ALEPH experiment: 5.5 pb^{-1} at 130–136 GeV, 11.1 pb^{-1} at 161 GeV and 10.7 pb^{-1} at 172 GeV e^+e^- c.m.s. energy. The ALEPH search in e^+e^- annihilation for the production of pairs of exotic particles is described in this talk; each of these particles decays into two jets, giving rise to four-jet events. hA Monte Carlo (MC) is used as the model for the production of these two exotic particles without the last step $\Rightarrow$ the b identification. The following selection criteria were chosen in order to minimize the expected Standard Model backgrounds whilst preserving a high efficiency for an $e^+e^- \rightarrow hA \rightarrow$ 4-jet signal:

- select hadronic events ($N_{ch} \geq 8$; $E_{ch} \geq 10\% \sqrt{s}$)
- reject ISR $e^+e^- \rightarrow Z\gamma$ (γ not seen) [$|P_z| < 0.75(m_{vis}\text{-}90)$]
- force events to form 4 jets (Durham algorithm, $y_{cut} > 0.008$)
- reject radiative returns $Z\gamma$; (γ seen in the apparatus)
  - no jet with more than 80% e.m. energy
  - no jet with mass < 1 GeV
- rescale energy to p,E conservation (the same v, $E_i \geq 0$)
- reject $q\bar{q}$ events ($Min(m_{ij}) > 25$ GeV $\Rightarrow 19.2\% \sqrt{s}$)
- reject $Z\gamma^*$ events
  - $Min(n^i_{ch} + n^j_{ch}) \geq 10$
  - $Min(m_i + m_j) \geq 10$ GeV
- take the smallest ΔM combination
- plot the di-jet mass sum ΣM.

The following conclusions are drawn from the MC studies (see Fig. 1 in Ref. [1]):

- the selection efficiency is 42%
- about 60% of the events coming from $e^+e^- \rightarrow hA$ are expected to be found within $\pm 2\sigma$ (3.2 GeV at c.m.s. 133 GeV) around the peak in the di-jet mass sum
- tails contain 40% of the sample; the second-smallest di-jet mass spectrum is similar to the smallest ΔM distribution
- the better resolution in the di-jet mass sum distribution (compared to the di-jet mass difference) is a purely kinematical effect induced by rescaling (without rescaling, the resolution is 9 GeV in the sum)

The di-jet mass sum distribution ΣM for the smallest ΔM distribution is shown in Fig. 1a for the data taken at 130–136 GeV. The following conclusions can be drawn from the analysis of these data:

- 16 events were observed in a search for hadronic decays of pair-produced heavy particles (8 were expected) $\Rightarrow$ probability $\sim$ 1%, 9 of them show an accumulation around 105 GeV in a mass interval corresponding to $\pm 2\sigma$ of the detector resolution (0.7 expected) $\Rightarrow$ probability $\sim$ 0.01% (3 in the second-smallest mass difference)
- the observed excess corresponds to a cross-section of 3.1 $\pm$ 1.7 pb (compared to the expected 0.49 pb for $e^+e^- \rightarrow hA$ and the point-like cross-section of 5.6 pb)
- the distribution of the QCD matrix element squared, the smallest jet charge (Fig. 1c), and the charge separation (Fig. 1d) of these 12 events show little compatibility with those predicted by standard processes (each probability $\sim$ 1%)

- among the 12 peak events only one has two jets tagged as b with lifetime tag; no leptons with high transverse momenta were found; no event satisfies the four b criterion, whilst 8.4 ± 1.6 are expected for 12 $b\bar{b}b\bar{b}$ events $\Rightarrow$ no hA production

More data were taken in 1996 at c.m.s. energies of 161 and 172 GeV. Figure 1b shows the corresponding di-jet mass sum distribution ΣM for the smallest ΔM. In addition to an accumulation aroud 105 GeV an accumulation around 160 GeV is also observed, corresponding to the W-pair production signal. The cuts:

- smallest ΔM combination: $|\ \Sigma M-160\ | > 10$ IF $\Delta M < 15$
- 2^{nd} smallest ΔM combin. : $|\ \Sigma M-160\ | > 10$ IF $\Delta M < 30$
- largest ΔM combination : $|\ \Sigma M-160\ | > 5$ IF $\Delta M < 60$ (only at 161 GeV)

strongly reduce the W-pair contamination, giving rise to the distribution presented in Fig. 1e. The full statistics distribution for the data taken between 130 and 172 GeV is shown in Fig. 1f. There are 34 events in this plot whilst 24.5 were expected. In a mass window of 106 ± 5 GeV there are 18 events whilst 3.1 were expected (probability 10^{-6}). Side-bands are well predicted by the MC. Results of a fit made with a slightly looser selection give the ΣM peak at 106.1 ± 0.8 GeV and σ of 2.1 ± 0.4 GeV, consistent with the detector resolution. The production cross-section is 2.2 ± 0.5 pb. The mass difference of two exotic particles is small. The smallest jet charge and the charge separation distributions still show exotic behaviour, but additional events collected at 161 and 172 GeV are less exotic.

There are two probable scenarios:

- huge statistical fluctuation;
  the results of DELPHI, L3 and OPAL presented in the next talk [2] support this hypothesis
- production of two exotic particles (C,D) in e^+e^- annihilations, each of them decaying into two jets, with the following properties:
  - $m_C + m_D \approx 106$ GeV
  - jets look more like jets of quarks – not b quarks, not gluons
  - production cross-section $\approx 2.2 \pm 0.5$ pb, perhaps decreasing with c.m.s. energy
  - small $m_C - m_D$, perhaps ≈ 10 GeV

More data will be taken in 1997 at the c.m.s. energy of about 184 GeV.

I would like to thank P. Janot and D. Schlatter for their contribution to this talk.

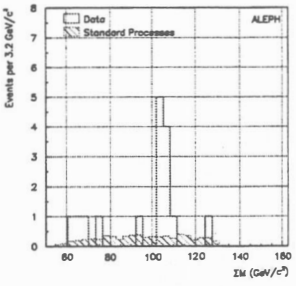
References

[1] The ALEPH Collaboration, D. Buskulic *et al.*, Zeit. Phys. C71 (1996) 179.

[2] M.A. Bizouard, these proceedings.

The ALEPH four-jet story

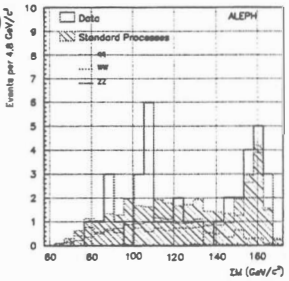
130-136



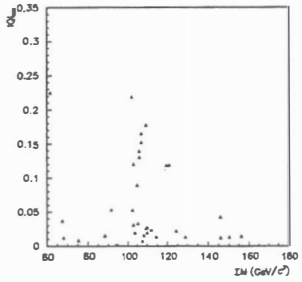
(a)

(b)

161-172



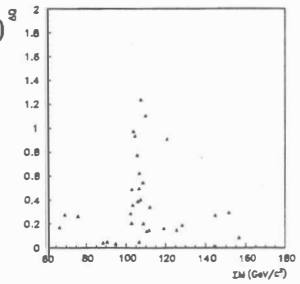
$|Q|_{MIN}$



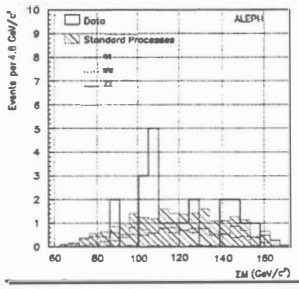
(c)

(d)

ΔQ



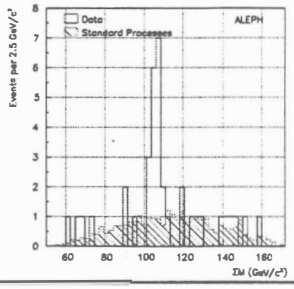
161-172 with M_W rejection



(e)

(f)

130-172



March 22, 1997 Figure 1: The ALEPH four-jet story Bolek Pietrzyk