Cosmic muon events coincident in two LEP detectors

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Abstract

A search for time- and direction-correlated cosmic muon events has been made using data collected during the period May to November 2000 by the CosmoALEPH and L3+C underground experiments being 6 km apart. Four threefold-coincidence events between L3+C, ALEPH's hadron calorimeter, and one CosmoALEPH scintillator station have been found.

1. Introduction

The proposal to search for cosmic ray induced Extensive Air Showers (EAS) underground in the 27 km long tunnel of the Large Electron-Positron collider (LEP) at CERN (CosmoLEP [2,9]) was motivated by the question: Are there cosmic events spreading over all four LEP detectors? For known EAS, extremely low rates of coincidences over such large distances are predicted [5,6]. The observation of time correlations in cosmic rays over distances as large as a few 100 km [4,7], however, hints at the possibility to observe muon showers over LEP distances ($\sim$ 8 km) at measurable rates.

2. Experimental set-up

Two of the large sophisticated LEP detectors, L3 and ALEPH, had muon identifying subdetectors with beam-independent trigger possibility, being required for a 100% duty-cycle data taking: L3's cosmic ray experiment, L3+C [1], used L3's muon chambers (MUCH) together with 202 m^2 timing scintillators, and a scintillator array at the surface, and ALEPH's cosmic ray experiment, CosmoALEPH [3,8], used ALEPH's hadron calorimeter (HCAL) together with five scintillator stations (Trolley, BypassA, BypassB, BypassC, and Alcove) (see figure 1). MUCH can measure muon arrival directions with an angular resolution better than 0.4°. In CosmoALEPH only HCAL has direction information. HCAL can measure angles projected onto a plane perpendicular to its axis and only if less than 3 or 4 muons traverse HCAL. The direction resolution is 3° for single muons and, due to HCAL's modular structure, 4.2° for multiple muons.

Due to the molasse and rock overburden, the threshold energy of vertically

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incident muons is 70 GeV at CosmoALEPH and 15 GeV at L3+C (7 GeV in direction of a major shaft). Both experiments use the Global Positioning System (GPS) to search offline for time coincident events.

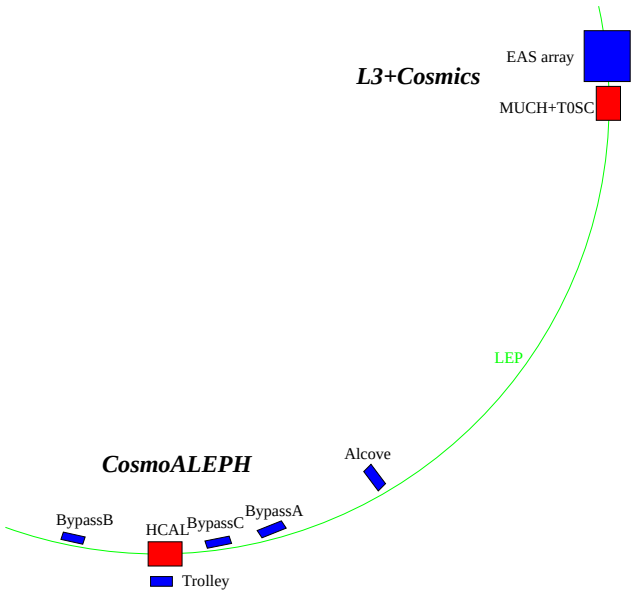

Fig. 1. L3+C and CosmoALEPH layout.

3. Data selection and results

A search for twofold coincident events between L3+C and CosmoALEPH did not yield a positive signal. To suppress the background from accidentals, the data selection was restricted to events having approximately the same projected direction in L3+C and CosmoALEPH. The muon direction from L3+C, projected onto the same plane as in HCAL, was used to define an acceptance window of 11°. In addition the search was restricted to triple coincidences between L3+C, HCAL and one of the scintillator stations. The common data taking time was 110 days.

The event arrival time difference between L3+C and HCAL is defined as Δt_1, and Δt_2 is the event arrival time difference between L3+C and a scintillator station. To allow for large zenith angle incidence, the event selection sets an arrival time window of ± 30 μs between L3+C and HCAL and of ± 5 μs between CosmoALEPH stations. 168 events have been found in L3+C and HCAL with Trolley (figure 2a1), 7 events with BypassC (figure 2a2), 6 with BypassA, 6 with Alcove and 2 with BypassB. After the projection angle cut has been applied, 15 events remain with Trolley (figure 2b1) and two events with BypassC (figure 2b2). After correcting for the flight time delay (t_d) two events remain with Trolley

(figure 2c1) and two with BypassC (figure 2c2) in an arrival time window of ± 4 μs. One of the two events with Trolley has 2 muons in L3+C and 3 muons in HCAL (figure 3), the other one and the two events with BypassC have single muons in L3+C and HCAL. Table 1 shows details about the 4 events.

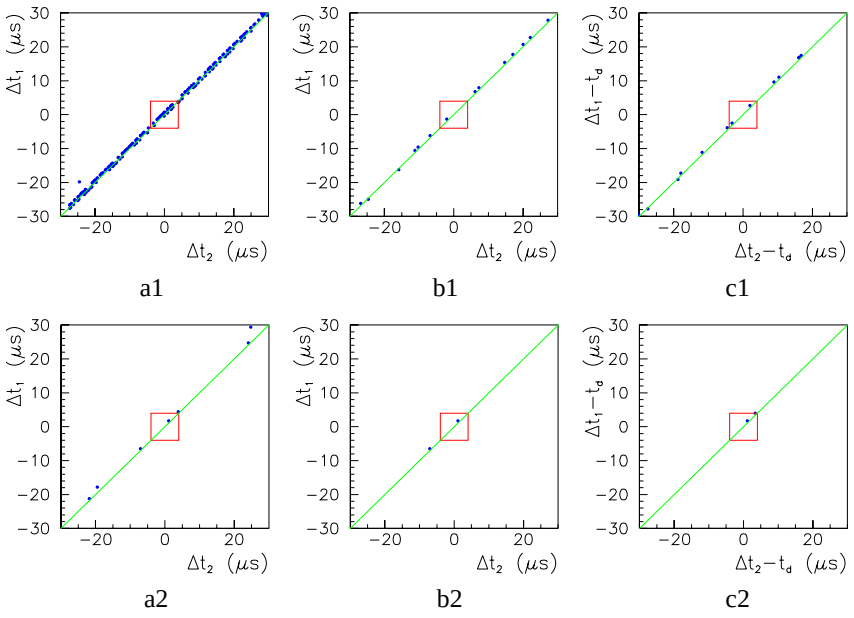

Fig. 2. Selection procedure shown for L3+C and HCAL with Trolley (upper plots), and BypassC (lower plots), see text.

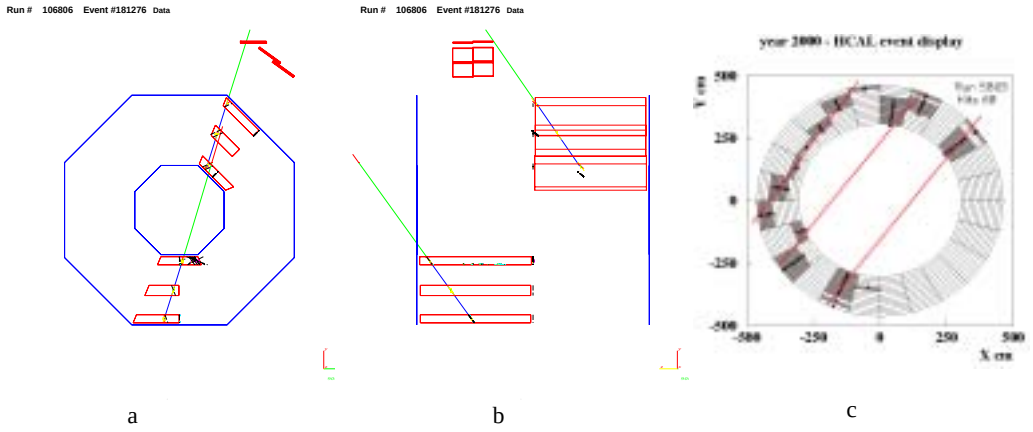

Fig. 3. Event display of one of the two events L3+C-HCAL-Trolley in MUCH (a,b) and HCAL (c).

The background estimate from accidentals, including the direction cut, is 3 events for the combination L3+C-HCAL-Trolley and 0.09 events for L3+C-

Table 1. Details of the four events

stations	L3+C-HCAL-BypassC		L3+C-HCAL-Trolley	
event number	1	2	3	4
date (YYYYMMDD)	20000706	20001025	20000520	20000704
time (hh:mm:ss, UTC)	17:17:35	02:55:42	16:48:34	16:06:30
number of muons at L3+C	1	1	2	1
number of muons at HCAL	1	1	3	1
muon signal in the sicntillator station	1	1	1	1
zenith angle (°) at L3+C	20.9	39.2	37.9, 38.8	37.8
azimuthal angle (°) at L3+C	282.7	40.4	122.1, 124.3	330.3
projection angle (°) at HCAL	104.8	98.1	52.0	128.0
right ascension (h) at L3+C	10.659	9.942	11.363, 11.331	7.254
declination (°) at L3+C	46.8	63.2	20.1, 18.6	69.9
momentum (GeV) at L3+C	-30.5	48.9	589.5, 58.7	33.8

HCAL-BypassC. The high background level for the former is due to the small distance between HCAL-Trolley (39 m), which gives a dominant contribution from accidentals between L3+C and real HCAL-Trolley coincidences. The estimated background level is consistent with the observed number of events in figures 2a1 to 2c1. The combination L3+C-HCAL-BypassC, shown in figures 2a2-2c2 has a higher sensitivity due to the larger distance between the BypassC and HCAL (167 m). The Poisson probability to observe 2 events for which the expected background is 0.09 events is 0.004.

4. Conclusion and outlook

Four events concident in time and in a projected direction have been found in a data sample collected during the L3+C - CosmoALEPH common running time of 110 days. Further studies are required to decide whether these events are originating from extensive air showers, or from other phenomena.

5. References

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