

## Search for Kolar-like Events from L3+C Data

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Some exotic events were published by a joint team of Indian and Japanese researchers with detectors operating deep underground in the Kolar Gold Mines (KGF) in south India, which were so called Kolar events. We have made an effort to search the Kolar-like events within the data set of the L3+C experiment. No reliable Kolar-like event is observed from a total  $0.89 \times 10^{10}$  trigger events. The corresponding event flux upper limit at 90% c.l. is  $7.1 \times 10^{-13} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$ .

### 1. Introduction

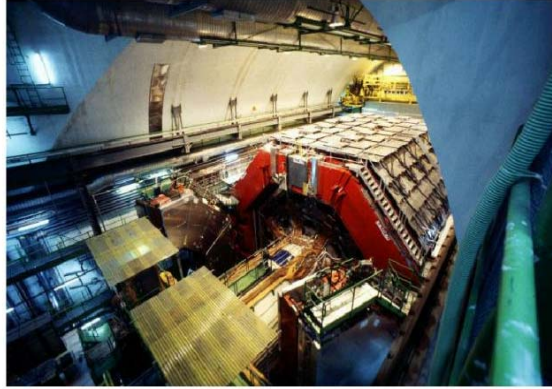
Some cosmic ray experiments observed some exotic events, which have not been well explained and need a further confirmation. Examples include a possible charged heavy mass particle observed in the Yunnan Mountain Station<sup>[1]</sup> and Kolar events observed by the India-Japan collaboration deep underground<sup>[2]</sup>. In the former case the mass of the particle was estimated by the momentum and  $dE/dx$  measurement using a magnetic cloud chamber. The event consists of three collimated tracks with a common vertex at the target on the top of the cloud chamber, which looks like an interacting one. The heavy particle track is characterized by a larger momentum and a lower velocity ( $\gamma \approx 3.5$ ). In the latter case, each of five reported events has a vertex in the air near the detector and contains two or three tracks. The common features of Kolar events are larger momenta (only seen from larger range) of observed particles and a larger opening angle between them. Therefore, they are likely decay events induced by some kind of unstable particles, indicating a lower speed ( $\gamma \approx 2-3$ ) and a larger invariant mass of the decaying particle. In the work [3], a further analysis on those two types of events showed that the secondary heavy particle of the Yunnan event or the decaying parents of Kolar events, can not be produced by normal cosmic ray particles such as protons (in the Yunnan event case), muons or neutrinos (in Yunnan and Kolar cases), due to their heavier mass and lower velocity, but can only be produced by some unknown particles with heavy (heavier than known normal cosmic ray particles) mass. It is also mentioned in [3] that the experimental searching of such heavy mass particles might be related to the searching of lightest and stable SUSY particles, or of the candidates of cold dark matter particles. Therefore, a further experimental exploration of the Yunnan-like or Kolar-like events will have obvious implication in particle physics, astrophysics and cosmology.

The L3+C experiment [4] used the L3 muon chamber to detect underground cosmic ray muons. An additional trigger was applied to enable the recording of cosmic ray muons as well as Kolar-like events. Its precise measurement of particle tracks may provide a clearer picture of the event pattern and more precise momentum information of each particle than found in the Kolar experiment. Thus it is very suitable to search of Kolar-like events. However, since it does not measure  $dE/dx$  or TOF, L3+C does not suit for the search of Yunnan-like events. In this paper the search of Kolar-like events using the L3+C data set is reported.

### 2. The L3+C experiment

The L3+C detector system consists of the high precision muon drift chambers, the magnet of the L3 spectrometer, and additional scintillator tiles on the top of the magnet, as well as of an air shower array on

the surface. A drawing of the spectrometer is shown in Figure 1. The detector is located near Geneva (6.02°E, 46.25°N) at an altitude of 450m above sea level.



**Figure 1.** The L3 spectrometer. Only the muon detectors, the magnet and additional scintillator tiles were used in this experiment.

The muon drift chamber system, with an octant shape in the plane perpendicular to the beam (11m in width and 11m in height) and a square shape in the plane along the beam (11m in length), was installed in a 1000m<sup>3</sup> magnetic field of 0.5 T and used to record cosmic ray muons and to measure their momenta. In order to independently (of L3) observe cosmic ray events, a timing detector, composed of 202m<sup>2</sup> of plastic scintillators, was installed on the top of the magnet, and a separate trigger and DAQ system were used for the data taking of cosmic ray events.

The dedicated data taking started in 1999 with a trigger rate of about 450Hz. Up to November 2000; nearly  $1.2 \times 10^{10}$  trigger events have been recorded within an effective live-time of 312 days. About 75% of the data were used to search for Kolar-like events.

### 3. Search of Kolar-like events

Firstly, we rule out single muon events, parallel double muon events and multi-muon events. Secondly, we rule out the following events with two tracks:

1. two tracks which have no intersection point;
2. two tracks intersect, but the crossing point is at the edge of the muon chamber, or even outside the chamber system;
3. intersecting event having an opening angle less than 10°;
4. events, in which one of the two tracks has a momentum smaller than 5 GeV/c;
5. events, in which one of the two tracks has a low quality.

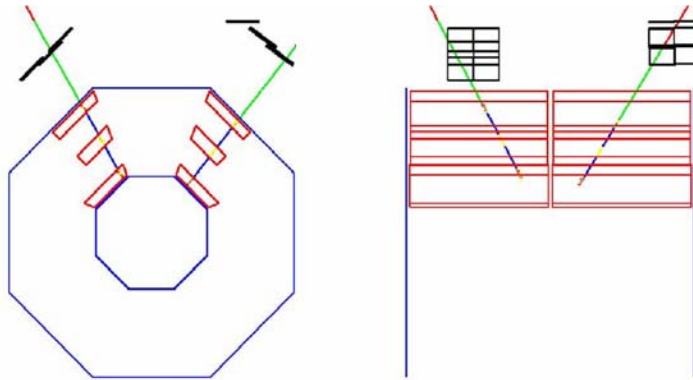
After the application of these cuts, about 27000 events were left for eye scanning. In order to reproduce the topology of Kolar-like events, we further requested:

1. The two tracks should correspond to two different electrical charges;
2. At least one track should have a correct time signal, meaning that the track has passed through the scintillator tiles;
3. Both tracks should arrive within 20ns. This could be checked in the case where each track crossed a wire plane or a mesh plane in the drift chamber.

## 4. Result

After the eye scanning 19 events were found satisfying all conditions. But their crossing points were very close to the center of the detector, i.e. in the colliding beam region. All these events were recognized as double muon final states of  $e^+e^-$  collisions via  $W^+W^-$  production (L3+C was taking data at the same time as L3 during the LEP operation). One such event is shown in Figure 2 for an example. 14 of 19 events have correct triggers on the scintillator tiles, and other five events were regarded as accidental coincidences with un-related noise signals of the scintillator tiles. Based on the cross section of  $W^+W^-$  production at  $e^+e^-$  collisions and the live time of L3+C detector, the number of double muon events could be estimated, which was found consistent with the observed one.

The conclusion is that no reliable Kolar-like events are observed in the L3+C data sample according to the selection criteria described above.



**Figure 2.** An example of an event with two muons, recognized as an  $e^+e^-$  collision event.

## 4. Discussion

The parent heavy particles of the Kolar-like events may either be charged or neutral. They may be produced from a collision of a unknown, stable, neutral and weakly interacting cosmic ray heavy particle with a nucleus of Earth's like material. The unknown interaction cross section, the unknown mass of the heavy particle produced in the collision, and the unknown momentum spectrum of these particles, make it difficult to estimate the upper limit of the flux of the unknown particles from the L3+C data sample. The upper limit of the flux of Kolar-like events seen in the L3+C detector may be estimated via a Monte Carlo simulation. It may be reasonable to assume that the decaying points of Kolar-like events are distributed uniformly underground, and that the directions of the parent particles are isotropic. Under these assumptions a Monte Carlo Kolar event sample was produced and was used to estimate an upper flux limit.

Assumed was also that a neutral decaying particle has a mass of  $200 \text{ GeV}/c^2$ , a momentum of  $800 \text{ GeV}/c$ , and decays into three particles consisting of a neutral heavy particle, a  $\mu^+$  and a  $\mu^-$ . 76489 Monte Carlo Kolar-like events with a decay vertex in the corresponding volume were produced.

The secondary particles were traced and reconstructed by the L3+C reconstruction program. 19448 events with at least one track were found. Using the same filter conditions as for the data set, 704 events were selected, and 697 events were left for the eye scanning.

The calculated geometrical acceptance was found to be:

$$(S\Omega)_{\text{box}} = 1.68 \times 10^7 \text{ cm}^2 \text{sr}, \quad (1)$$

the effective acceptance for Kolar-like events able to trigger the L3+C system:

$$(S\Omega)_{\text{eff}} = (S\Omega)_{\text{box}} \times 19448/76489 = 4.28 \times 10^6 \text{ cm}^2 \text{sr}, \quad (2)$$

and the efficiency for Kolar-like events triggering the L3+C system and being observed was

$$\eta = 704 / 19448 = 0.036 \quad (3)$$

The number  $\kappa$  of really observed Kolar-like events within  $N$  incident events, with at least one track follows the binomial distribution

$$P(\kappa) = C_N^\kappa \eta^\kappa (1-\eta)^{N-\kappa} \quad (4)$$

The probability that at least one event was observed is

$$1 - P(0) = 1 - (1-\eta)^N \quad (5)$$

and in the case of no event observed, the event upper limit at 90% c.l.,  $N_{0.9}$ , can be evaluated from

$$1 - (1-\eta)^{N_{0.9}} = 0.9 \quad (6)$$

Thus

$$N_{0.9} = 63.1 \quad (7)$$

The total live-time of the searched event sample amounts to

$$T = 2.07 \times 10^7 \text{ sec}. \quad (8)$$

Therefore, the corresponding upper limit of the event flux at 90% c.l. is

$$I_{0.9} = N_{0.9} / (S\Omega)_{\text{eff}} T = 7.1 \times 10^{-13} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}. \quad (9)$$

## References

- [1] Yunnan Cosmic Ray Station, *Scientia Sinica*, **16**, 1233 (1972).
- [2] M. R. Krishnawamy et al., *Phys. Lett.*, **B57**, 105(1975).
- [3] T. H. Ho et al., *Scientia Sinica*, **38**, 954 (1995).  
L. K. Ding et al., *Science in China A*, **39**, 1077 (1996).  
H. S. Chen et al., *Phys. Rep.* **282**, 1(1997).
- [4] L3 Collaboration, *NIM*, **A488**, 209(2002).