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Study of Multi-muon Events from EAS with the L3 Detector at Shallow Depth Underground

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We present first preliminary data from the L3+Cosmics experiment and results from Monte Carlo simulations of multi-muon events as observed 30 m underground.

1. THE L3+COSMICS EXPERIMENT

The muon component of extensive air showers (EAS), due to the long muon range in the Earth's atmosphere, carries a wealth of information about the shower development. Study of multi-muon events gives an insight into the primary cosmic ray composition and the physics of high energy hadronic interactions. The L3 detector, situated 30 m underground, offers interesting possibilities to detect and study such events [1], which are complementary to the data collected in traditional cosmic ray experiments. The hadron component of EAS is absorbed, while the muon component is detected with low threshold (typically, if we exclude access shafts, 15 GeV) and high momentum and spatial resolution by the sophisticated tracking system of the L3 detector. The muon spectrum can be measured up to 2 TeV with high precision. The multi-muon event rate is high enough to make studies of the knee region possible with one year of data taking.

This year, 5 billion triggers were collected with the full L3+Cosmics setup. The independent readout and data acquisition system allows us to take data in parallel with L3. The acceptance of the setup is 200 m^2sr. The angular resolution is better than 3.5 mrad for muons above 100 GeV and zenith angles from 0 to 50°. The momentum resolution is 5.0 % at 45 GeV. It is calibrated with $Z \rightarrow \mu^+\mu^-$ events from the LEP calibration runs, where the muon momentum is known exactly.

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2. MONTE CARLO SIMULATIONS

The simulation program ARROW [2,3] is used to calculate the hadron, muon and neutrino flux at the detector level. The method combines simulations for fixed energies and different primary nuclei with a parametrization of the energy dependence and allows to do fast calculations for different geometries and energy thresholds. Results for the L3+C setup with sensitive area 200 m^2sr are

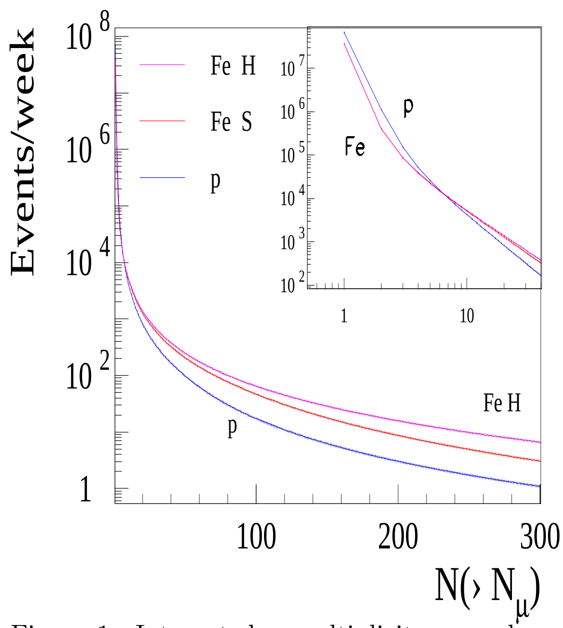

Figure 1. Integrated μ multiplicity - number of expected events with $N(> N_\mu)$ for a week of data taking. Lower curve - protons, middle curve - iron S, upper curve - iron H (see text). The predicted rate agrees well with the experimental one.

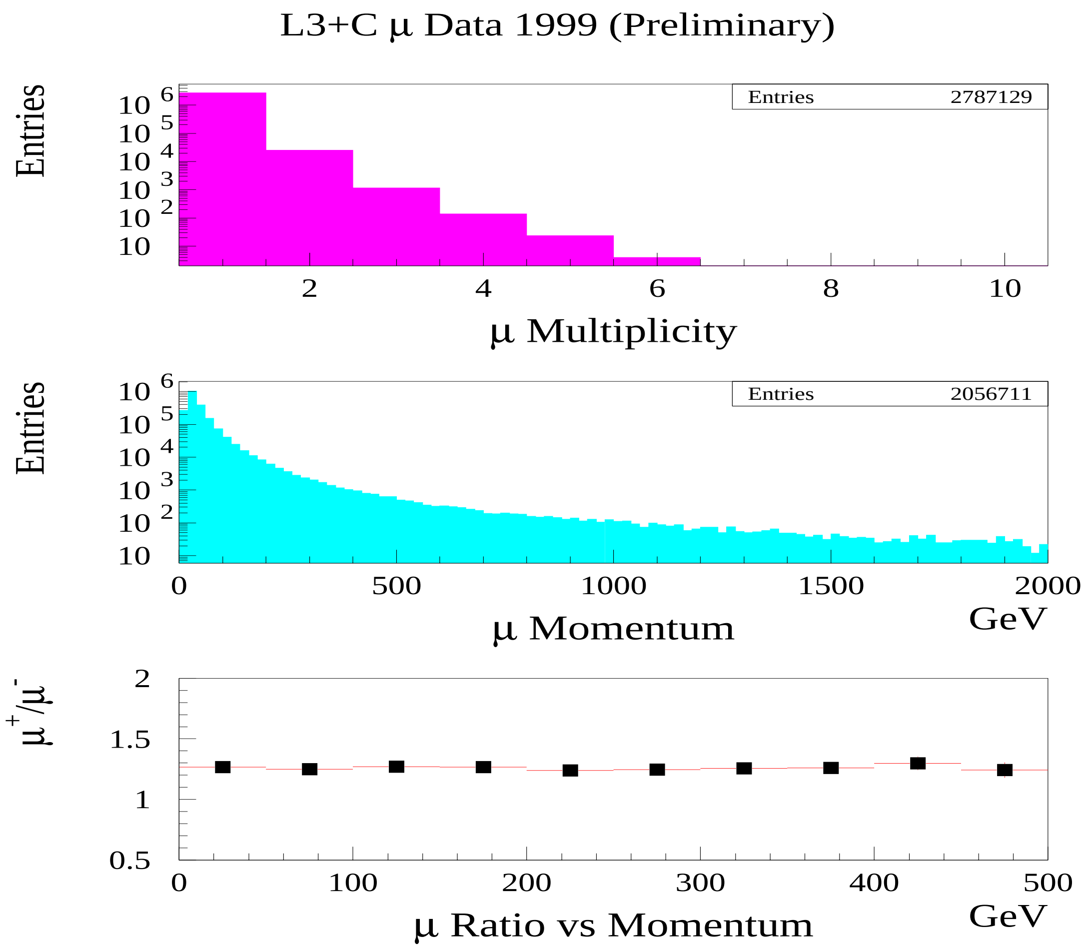

Figure 2. Preliminary data from the 1999 run. No corrections for acceptance or efficiency are applied.

shown in Figure 1. The primary composition is divided in heavy (Fe) and light (p) components in two limiting hypotheses: Fe S for constant heavy contribution $\sim$ 30% and Fe H for heavy contribution rising from 30% below to 70% above the knee. The events with up to 6 muons are dominated by proton induced showers and above 10 muons the iron takes over. To distinguish between the two hypotheses with this method we need to detect events with $\sim$ 50 muons and more.

3. DATA AND OUTLOOK

A first small subset of our data is shown in Figure 2. Only part of the events with up to 6 muons are reconstructed currently. The observed charge ratio μ^+/μ^- from the raw data is flat in the region between 50 and 500 GeV.

In the year 2000 an EAS array will be mounted above L3+C in order to detect the primary energy and core position. The experimental program includes studies of muon families and the primary composition, sidereal anisotropies, high multiplicity events in coincidences with other experiments, the moon shadow, searches for point sources, gamma ray bursts and exotic events.

REFERENCES

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