29th International Cosmic Ray Conference Pune (2005) **1**, 383-386

The Forbush Decreases of October-November 2003 as Measured with Milagro

J.M. Ryan and the Milagro Collaboration
University of New Hampshire, Durham, NH, 03824, USA
Presenter: J.M. Ryan (james.ryan@unh.edu), usa-ryan-J-abs1-sh26-poster

Milagro, a ground-level TeV gamma-ray telescope, is sensitive to solar energetic particles and Forbush decreases. Milagro sits in the Jemez mountains at an altitude of 2630 m in northern New Mexico and has detected and measured SEPs in GLEs. By measuring count rates due to secondary muons and electromagnetic showers, Milagro can be used to investigate SEPs and galactic-CR modulations. On 2003 October 29 Milagro registered a major Forbush decrease at various thresholds beyond 5 GV. The data reveal a Forbush decrease in at least three independent channels coinciding with the decrease registered at several neutron-monitor stations. Since the count rates are primarily those from secondary muons, significant barometric and diurnal corrections are necessary. A preliminary correction for these effects has been performed revealing a Forbush decrease greater than 10% at 5 GV. Different detection modes possess different energy thresholds. The analysis of some of these channels addresses the rigidity dependence of the decrease and subsequent recovery. We will present data and preliminary analyses of the Forbush decrease and recovery.

1. Introduction

Milagro is a TeV ground-level g-ray telescope[1]. It operates by detecting electromagnetic (or hadronic) showers as they enter a 1-acre pond of water, outfitted with photomultiplier tubes. As the shower passes over the pond the differential timing signal reveals the incident direction in elevation and azimuth and allows one to identify TeV sources. Shown in Figure 1 is the instrument. Figure 2 is the TeV g-ray image of the Crab nebula[1].

Figure 1. The Milagro instrument.

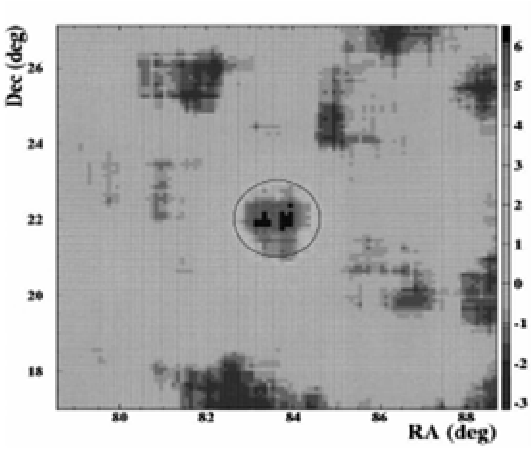

Figure 2. The Crab Nebula

Shown in Figure 3 is a cross sectional schematic of the instrument. The two layers of photomultiplier tubes serve to identify muons-associated showers that would contaminate the g-ray signal in TeV astronomy studies.

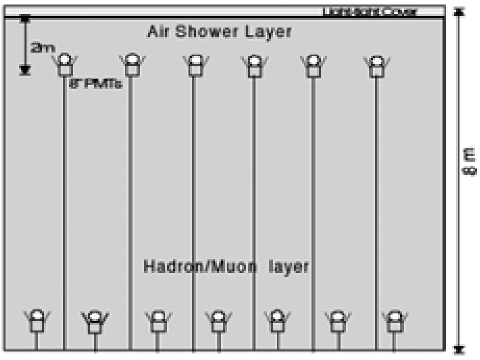

Fig. 3. Cross sectional schematic of Milagro.

The *Milagro* instrument detects muons generated by solar and galactic protons with two layers of photomultipliers submerged in an 8-m deep water pond. The Çerenkov light from the relativistic muon illuminates one or several PMTs triggering them if the light intensity is sufficient. The basic data channel for recording the effect of modulated galactic cosmic-ray protons is the High Threshold (HT) scaler, in which only a single PMT need trigger in a sub-μs resolving time. Other scaler data are available, including those of external particle detectors and higher levels of PMT multiplicity. These were not used in this analysis.

When enough PMTs are triggered the instrument records the individual event. Presently, such events are interpreted as potential g-ray showers, but with software under construction, they can also be interpreted as muon-related hadronic showers. For either case the incident direction, both in azimuth and elevation can be determined.

2. Discussion

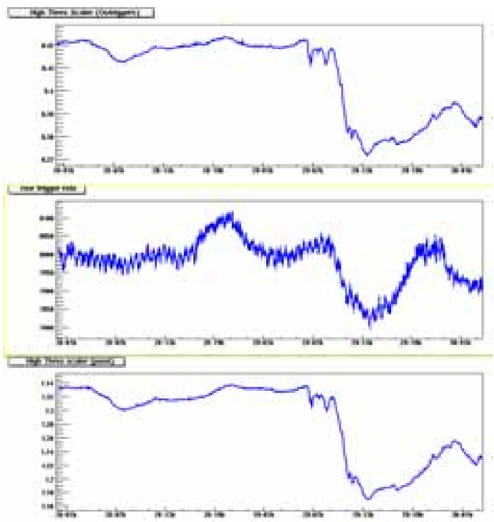

Fig. 4. Milagro rates October 28-30 2003.

Raw Milagro rates for the period of 28-30 October 2003 are shown in Fig. 4. The upper panel and the lower panel show the rates in the outrigger Çerenkov detectors and the HT scaler in the pond, respectively. The two behaviors are similar in all respects. The middle panel shows the raw trigger rate in the pond. The threshold for an event trigger is of order 50 GeV. During this time barometric variations are small. It shows that the Forbush decrease is registered in all data channels. The recovery in the raw trigger rate may be corrupted by barometric changes, but the decrease occurs when the pressure is almost constant. In Fig. 5 we show how the HT rate compares to that of Climax over a three-week period around this time. One can see that Climax (~280 km from Milagro) registers an initial decrease on 22 October 2003 larger than that with Milagro by 4×. The large decrease on 29 October 2003 was twice as large for Climax as for Milagro (26% vs. 13%). The smaller decreases for Milagro is to be expected since its effective cutoff is ~5 GV, so we would expect the modulation to be relatively smaller for Milagro. We would also expect the Milagro recovery to be quicker. This is not what is seen in the rates, although all meteorological corrections have not been made on the Milagro data.

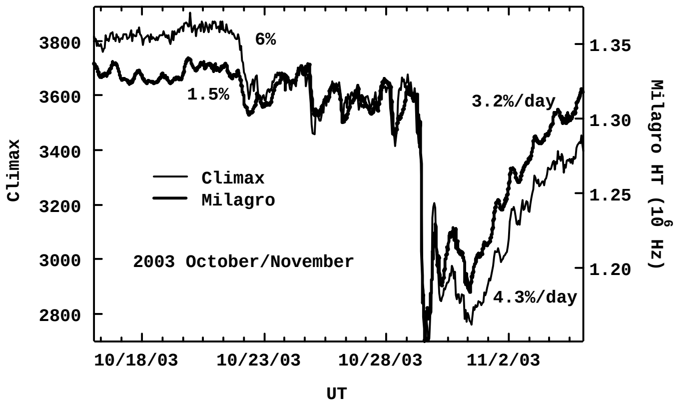

Fig. 5. Milagro and Climax rates.

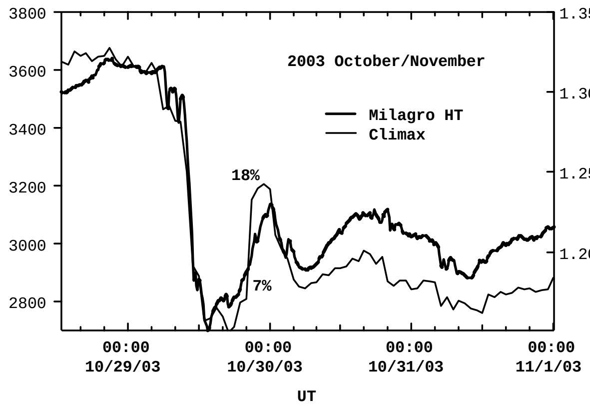

Fig. 6. Expanded Milagro and Climax rates.

Expanding the time scale, we see that in Fig. 6 that the intermediate 'recovery' at the bottom of the Forbush decrease is similarly more than twice as large for Climax as for *Milagro*. Some small differences in the behavior of the two instruments prior to the main decrease may be seen in the plot. The first drop comes earlier at Climax, but the main decrease is simultaneous for both instruments.

Looking at the higher-energy data in the triggered rates in Fig. 4, one sees that the large decrease is seen in the *Milagro* data. This indicates that the Forbush decrease is affecting galactic cosmic rays at least up to ~50 GeV.

Although the pressure is steady during the large decrease, giving it credibility, the pressure falls after October 30, changing the count rate in a manner that would be interpreted as a slow recovery. An accurate and precise correction for meteorological effects is necessary to ascertain the rate of recovery in the long term. The slow recovery of the Milagro HT data (compared to Climax) may result from only a small error in the barometric correction or the neglect of other effects such as temperature in the stratosphere, affecting the production of muons. Without such instrumental effects, the slower Milagro recovery is a surprise since the higher energy cosmic rays should repopulate the Earth's environment more quickly.

3. Conclusions

1. Milagro registers the heliospheric modulation caused by the solar activity in October/November 2003 at energies in the range up to 50 GeV.

2. All temporal features show less modulation at Milagro rigidities.

3. The slow long-term recovery of the Milagro count rate is suspicious probably being affected by meteorological corrections. We expect a faster Milagro recovery.

New work includes:

1. More precise and accurate met corrections are necessary to re-evaluate the hi-*E* recovery.

2. Simulations must be completed to establish the atmospheric energy cutoff of the instrument for various modes.

3. The triggered-event data will be analyzed to search for azimuthal distributions revealing anisotropies in the decrease onsets and recoveries.

4. Different detection modes will be inspected for evidence of modulation at the highest possible energies.

4. Acknowledgements

This work has been supported by the National Science Foundation (under grants PHY-0075326, -0096256, -0097315, -0206656,-0245143, -0245234, -0302000, and ATM-0002744, -0411651) the US Department of Energy (Office of High-Energy Physics and Office of Nuclear Physics), Los Alamos National Laboratory, the University of California, and the Institute of Geophysics and Planetary Physics. We also thank Dr. Cliff Lopate for Climax data and useful discussions.

References

[1] R. Atkins *et al.*, Astrophys. J., 595, 803 (2003).