THE USE OF ARGO-YBJ EXPERIMENT FOR SOLAR RELATIVISTIC PARTICLE STUDIES

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ABSTRACT. The ARGO (Astrophysical Radiation with Ground-based Observatory) experiment will be installed at the Yangbajing High Altitude Cosmic Ray Observatory - Tibet (geographic coordinates: 30.11°N - 90.53°E, height: 4300 m a.s.l., atmospheric vertical depth: 606 g/cm^2) to register small size extensive air showers. Using the IGRF95 geomagnetic field model we have studied the charged particle access to the experiment (acronym: ARGO-YBJ). From our knowledge of previous high energy solar particle events we have determined that relativistic charged particles from the Sun could be detected by the ARGO-YBJ experiment.

1. Introduction

Several international experimental programs for cosmic ray physics are under development at Yangbajing in Tibet: geographic coordinates 30.11°N - 90.53°E and altitude 4300 m a.s.l. Among them we recall: (i) a solar neutron telescope of the Nagoya group, which is part of a worldwide network (Katayose et al., 1999); (ii) a super neutron monitor (28-NM-64 type) to record single counts and multiplicities from one to eight for every two adjacent counters (Kohno et al., 1999); and (iii) the air shower array of scintillation detectors (Tibet ASγ Collaboration; Amenomori et al., 1992).

Moreover, an Italian - Chinese joint venture (ARGO-YBJ Collaboration) is under way for the next years with the objective of registering small size extensive air showers. The experiment consists of a $\sim$ 71 x 74 m^2 core detector realised with a single layer of Resistive Plate Counters (RPC's), surrounded by an outer detector for a total size of about 100 x 100 m^2 (Abbrescia et al., 1996).

Among the different aims of the above experiments, solar cosmic ray physics deserves a relevant place because acceleration processes for relativistic particles are still a matter of considerable research. In particular, the energy upper limit for incoming solar particles in the Earth environment has not been established. In this paper we report on charged particle access to the Yangbajing location and the possibility of registering energetic solar cosmic ray events (the so-called Ground-Level Enhancements: GLEs) during the operation of the above experiments.

2. Ground-Level Enhancements

GLE events are transient increases recorded by ground-based detectors for cosmic rays; they are generated by discrete solar particle injections into the interplanetary medium. If conditions are favourable, these particles can penetrate into the Earth's environment. A large variety of time-intensity profiles for GLEs has been observed over the years but the common characteristic of them is their short time duration (normally hours). The intensity rise above the galactic cosmic ray background level can be very fast to a maximum intensity and then followed by a rapid decay. In other cases a complex profile is recorded with a strong dependence on the location of the solar active region on the Sun and the measurement site on Earth. Efforts for archival GLE data were initiated in the U.S.A. several years ago (e.g. Gentile et al., 1990 and references therein). A standard GLE format has been established (Gentile, 1993), and the identified events have been numbered. Presently, data for 58 GLEs, ranging from 1942 to 1998, are collected in an international database currently located at the Air Force Research Laboratory at Hanscom AFB, MA, USA (this database is being duplicated and will continue to be maintained by the Australian Antarctic Division, Kingston, Tasmania, Australia). Of course, looking to the past, scientists need time to complete the international database because local efforts to recover past data are generally not supported by national grant agencies. However, the datasets for events from July 1989 to the present have a good percentage of the available data represented from the world-wide network (gentile@plh.af.mil).

Recently, a study of particle access was made for the ARGO-YBJ collaboration in the rigidity interval 100.00 GV - 4.10 GV, using the IGRF95 model (Storini et al., 2000 and references therein). During quiescent geomagnetic conditions the vertical direction (zenith = 0°) at Yangbajing is characterised by a 0.95 GV penumbra and an effective rigidity cutoff of 13.98 GV. When non-vertical directions are considered the evaluated rigidity cutoffs ranged from 11.23 GV to 18.98 GV depending upon the direction from which the particles were incident at the top of the atmosphere. Evaluations were made for two zenith angles, 15° and 30°, and for eight different azimuthal directions: 0° (North), 45° (North-East), 90° (East), 135° (South-East), 180° (South), 225° (South-West), 270° (West), 315° (North-West) and 360° (North). Hence, it is natural to forward to the scientific community the following question: are there past data records suggesting that solar activity is able to accelerate charged particles above 10-20 GV? From the present database and subsequent studies, the September 29, 1989 event (GLE n. 42) ranks as the third highest particle flux behind the events on February 23, 1956 (GLE n. 5) and November 19, 1949 (GLE n. 4) (Smart and Shea, 1991; Shea and Smart, 1994).

To illustrate the outstanding particle increase during September 29, 1989, Figure 1 shows the percentage of increase at selected neutron monitor locations on an hourly basis. Note that Mt. Norikura is the only one mountain station showed. We add that at Lomnický Štít (49.20°N, 20.22°E - 2632 m - cutoff about 4 GV) the increase was 561%. Of course, on smaller time scales the magnitude of the event is larger than for hourly time intervals. High altitude locations record higher increases because there is less attenuation by the atmospheric mass above the detector. Studies related with the above GLE indicate that solar particles with energies higher than 30 GeV were observed at Earth (see, for instance, Swinson and Shea, 1990; Lovell et al., 1998; Tylka et al.,

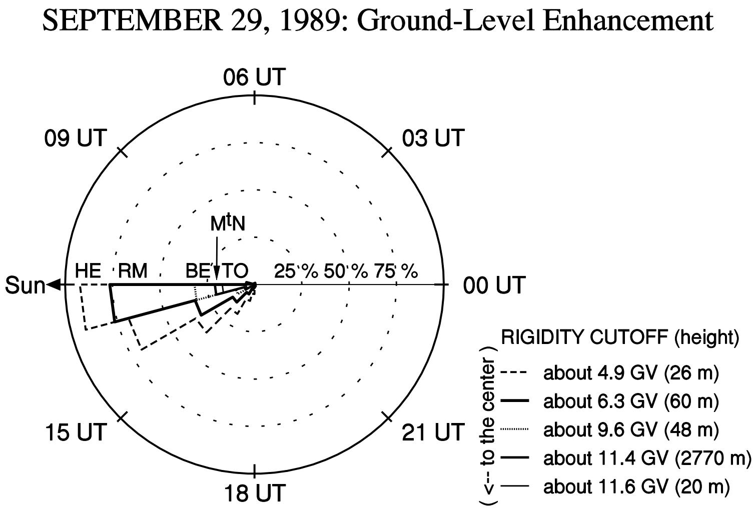

Fig. 1. Intensity increase above the background level (pressure corrected variations) recorded by select neutron monitors (HE: Hermanus - 34.42°S, 19.22°E; RM: Rome - 41.90°N, 12.52°E; BE: Beijing - 40.08°N, 116.26°E; M^{t}N: Mt. Norikura - 36.12°N, 137.55°E; TO: Tokyo - 35.75°N, 139.72°E) during the September 29, 1989 GLE.

1999). Moreover, Chebakova et al. (1999) using data from an underground muon telescope (Baksan MT) inferred that particles with energy up to about 1000 GeV could be generated by the solar activity phenomena related to the solar flare occurrence. Hence, from our knowledge of previous high energy solar particle events we have determined that relativistic charged particles from the Sun could be detected by the Yangbajing experiments.

3. Charged particle access to Yangbajing location and conclusions

Using the same approaching directions considered by Storini et al. (2000) we investigated, by rigidity steps of 2 GV between 20 and 10 GV, the cardinal access of charged particles at Yangbajing location. Figure 2 summarises the obtained results.

We conclude that if GLE events with particle energies greater than 20 GeV occur in the next years the large effective surface of ARGO-YBJ experiment will detect them. Because high energy particles come from the Sun earlier than the main part of middle energy solar cosmic rays (see Figure 1) it is expected that the solar particle flux will have a longer duration in the Western cardinal quadrants (see Figure 2). However, we note that at this stage of our investigation the influence of magnetospheric disturbances on the charged particle access at Yangbajing has not been evaluated, nor have the effects of the atmospheric particle attenuation in the different arrival directions. Anyhow, to our knowledge this is the first attempt to estimate ARGO-YBJ capability for high energy solar particle detection.

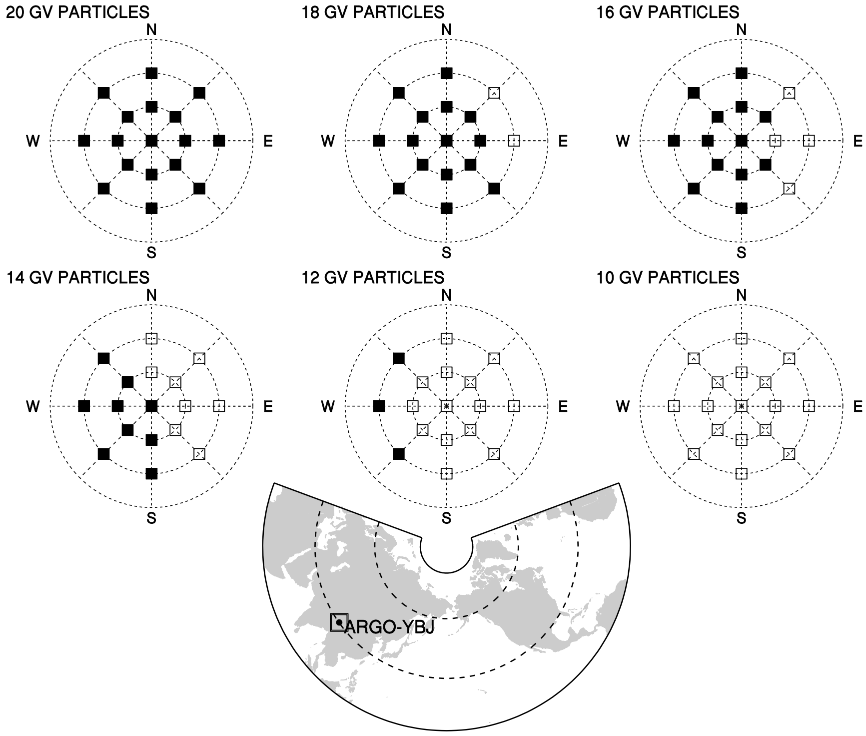

Fig. 2. Illustration of the particle transition from allowed to forbidden access at ARGO-YBJ as determined by cosmic ray trajectory calculations using IGRF95 model (open squares: forbidden access; filled squares: allowed access). The central square corresponds to the vertical direction, while the other squares to the 15° (inner ring) or 30° (outer ring) direction of zenith.

References

Abbrescia, M., et al.: 1996, *Astroparticle Physics with ARGO*, Proposal to INFN.

Amenomori, M., et al.: 1992, *Phys. Rev. Lett.*, **69**, 2468.

Chebakova, E.A., et al.: 1999, *Proc. 26th ICRC*, Salt Lake City (Utah), **6**, 411.

Gentile, L.C.: 1993, *J. Geophys. Res.*, **98**, 21107.

Gentile, L.C., Shea, M.A., and Smart, D.F.: 1990, *Proc. 21st ICRC*, Adelaide, **5**, 148.

Katayose, Y., et al.: 1999, *Proc. 26th ICRC*, Salt Lake City (Utah), **6**, 58.

Kohno, T., et al.: 1999, *Proc. 26th ICRC*, Salt Lake City (Utah), **6**, 62.

Lovell, J.L., Duldig, M.L., and Humble, J.E.: 1998, *J. Geophys. Res.*, **103**, 23733.

Shea, M.A., and Smart, D.F.: 1994, *Adv. Space Res.*, **14**, (10) 631.

Smart, D.F., and Shea, M.A.: 1991, *Proc. 22nd ICRC*, Dublin, **3**, 101.

Storini, M., Smart, D.F., and Shea, M.A.: 2000, A Contribution to the ARGO-YBJ Collaboration, *Proc. IX Convegno GIFCO* (in press).

Swinson, D.B., and Shea, M.A.: 1990, *Geophys. Res. Lett.*, **17**, 1073.

Tylka, A.J., et al.: 1999, *Proc. 26th ICRC*, Salt Lake City (Utah), **6**, 67.