NEW MATSUSHIRO UNDERGROUND COSMIC RAY STATION (220 M.W.E. IN DEPTH)

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ABSTRACT

A new underground cosmic ray station has been opened at Matsushiro, Japan and multi-directional (17 directional channels) muon telescope has been installed at an effective vertical depth of 220 m.w.e. The counting-rates are; 8.7×10^4/hr for the wide-vertical component and 2.0×10^4/hr for the vertical component. The continuous observation has been performed since March 22, 1984. Some details of the telescope and preliminary analyzed results of the data are presented.

1. Introduction

More than a dozen of the underground cosmic ray stations have been actively operated, and invaluable data have been accumulated. Based on those data, a great deal of investigation has been performed on the cosmic ray modulation in the heliosphere, cooperated with small air shower measurements (e.g., Nagashima and Mori, 1976). Complete pictures of the modulation have not yet been established in the rigidity range of $10^{11}\sim10^{14}$ eV, therefore more accumulation of the data of high counting-rates with multi-directional channels would be mostly acknowledged.

2. Underground Site and Muon Telescope

Matsushiro is located in Nagano-city, Nagano Pref., Japan and $\sim$40 km northeast of our Cosmic-Ray Lab. of Shinshu University in Matsumoto-city. A new station is very close to our elder one ($\sim$4 km in distance) (Yasue et al., 1981; also in this issue). Locality of the present station is; 36.53°N and 138.02°E in geographic coordinate and 360 m in altitude. Fig. 1(a) shows the contour map of the underground site and Fig. 1(b) illustrates one of the cross-sections along the line AB in Fig. 1(a).

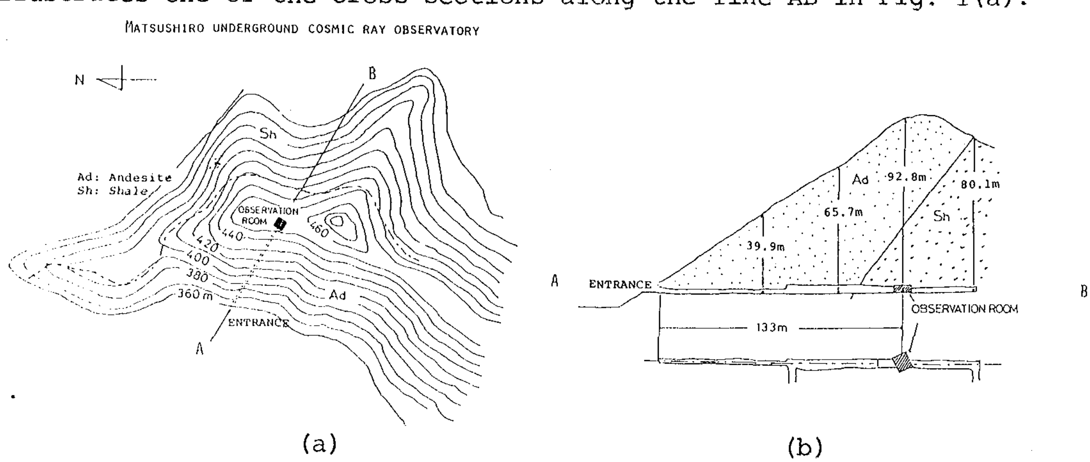

Fig. 1 (a) Contour map of tunnel area and (b) Cross-section along AB

The vertical rock depth is 92.8 m, and the rocks overburden are mostly andesite (Ad) and shale (Sh), its average density ≅2.65 g/cm^3, therefore ≅240 m.w.e. The depth is somewhat different in each direction, and the effective vertical depth is estimated at ∿220 m.w.e.

The temperature inside the tunnel is 14∿15°C, almost constant throughout the year (precise temperature variations on the daily and seasonal bases have not yet been measured). Both observation room (10×10 m^2 in area) and recording room have been heated up to ∿19°C, and the humidity has been kept as $\lesssim$50%.

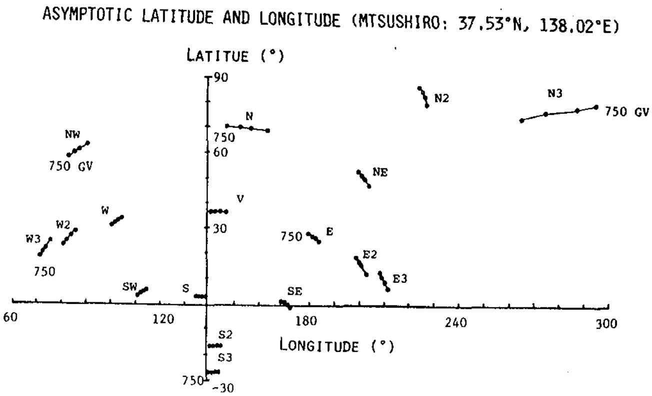

Fig. 2 Asymptotic orbit for 13 comp.'s.

Fig. 2 shows the asymptotic directions for 17 component telescopes calculated for the rigidities of 750, 450, 350 and 250 GV (Inoue, personal communication).

The median primary rigidity is estimated at ∿600 GV, using the response function given by Murakami et al. (1981). The corresponding Lamore radius for 6 nT of the IMF strength is ∿2 AU.

The muon telescope consists of 50 plastic scintillation detectors in all, as shown in Fig. 3, arranged in two layers spaced by 150 cm. The detectors are exactly the same as those of our elder Matsushiro station (Yasue et al., 1981); each having 1×1 m^2 in area, 4 plastic scintillators (50×50×10 cm^3), and viewed with double photomultipliers (5" in diameter), as shown in Fig. 4, to obtain good S/N ratio and high detection efficiency.

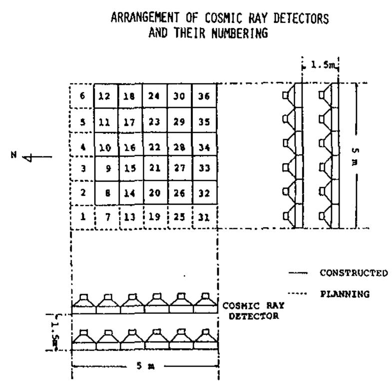

Fig. 3 Arrangement of detectors

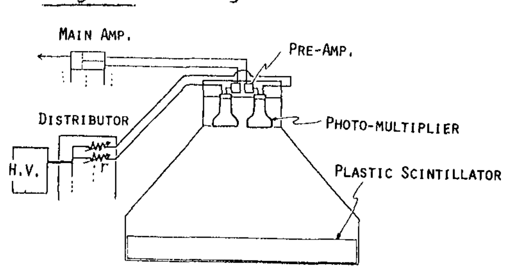

Fig. 4 Cosmic ray detector

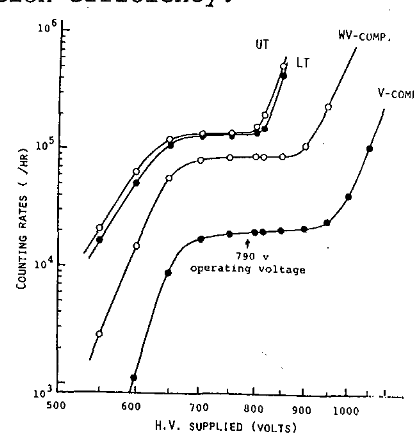

Fig. 5 High-voltage characteristic

Based on this arrangement, 17 component telescopes are constructed by taking an appropriate 2-fold coincidence between the detectors in upper and lower trays. In Fig. 5, high-voltage characteristics of some telescopes are plotted of real counts vs. high-voltage supplied for the upper (US) and the lower (LS) trays, the wide-vertical component (WT; 2-fold coincidence between US and LS) and the vertical component (V). The continuous observation has been performed since March 22, 1984 and the hourly counts have been recorded. In the followings, some preliminary analyzed results of the data are presented.

3. Data and Their Analysis

3.1 Atmospheric effect

Barometric pressure effect was examined; one for a short time-period of 6 days when transient large atmospheric pressure change was observed in a range of ∿30 mb and the other for a long time-period of abour 6 months (Mar.~Oct., 1984). Single correlation between the pressure and the counting-rate was taken. Barometric coefficients were obtained as; $\beta \cong -0.01$%/mb for the former short-period and $\infty \cong -0.04$%/mb for the latter long-period. These are in good agreement with our previous results and can be well explained by taking accounts of the upper atmospheric temperature effect (Sagisaka et al., 1983).

3.2 Cosmic ray north-south asymmetry (N-S asymmetry)

Among 17 component telescopes, some telescopes (e.g., N, N2, ...) view rather northern latitude, while some (e.g., S, S2, ...) view rather southern latitude or equatorial plane, as shown in Fig. 2. Using the daily mean values of these directional intensities (∿60×10^4/day), N-S asymmetry was evaluated daily as

$$\Delta=(N+N2+N3+NE+NW)-(S+S2S3+SE+SW)^*$$

where * indicates the normalized counts between these two groups (Mori and Nagashima, 1979). Also IMF-sense dependence of this N-S asymmetry was examined by referring to Toward (T)- and Away (A)-sense given by Stanford group (Solar-Geophysical Data, NOAA, 1985). Fig. 6 shows the correlation between derived N-S asymmetries of the present station and Misato (34 m.w.e. in depth). Table 1 gives the numerical values on T and A of these two stations for the period Mar.22∿Oct. 31, 1984. From this result, some indication may be noted that even such high rigidity particles (∿600 GV) observed at 220 m.w.e. underground station, are influenced by the IMF-sense.

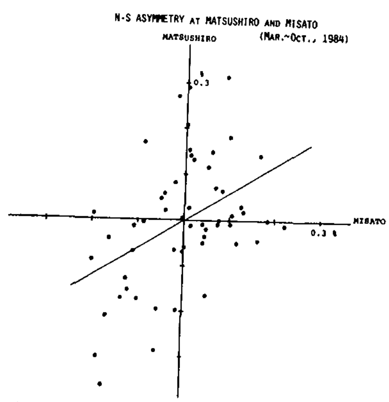

Fig. 6 Correlation between Matsushiro and Misato.

Station	T(%)	A(%)
Matsushiro	0.02	-0.05
Misato	0.066	-0.060

Table 1 N-S asymmetries on T and A

3.3 Daily intensity variation

The hourly data (without corrected for barometric effect) were harmonically analyzed in solar (SO), sidereal (SI) and anti-sidereal (AS) time for full one-year (Apr. 1984 Mar. 1985). Fig. 7 shows one of month-to-month variations of SO(1st) for V-comp. The monthly vectors move counterclockwise systematically, indicating the at deep undergrouns station SI(1st) may be more significant in the 1st harmonics. Fig. 8 illustrates some of the harmonics for 13 component telescopes (V, N, S, E, W, NE, NW, SE, SW, N2, S2, E2 and W2); Si(1st) in (a), AS(1st) in (b) and SO(2nd) in (c). In the figure, errors are derived from counting-rates. We may note that from their directional dependence, almost of them are significant.

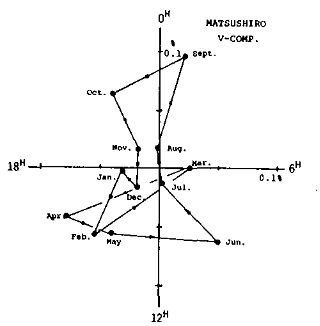

Fig. 7 Monthly movement of SO(1st) for V-comp.

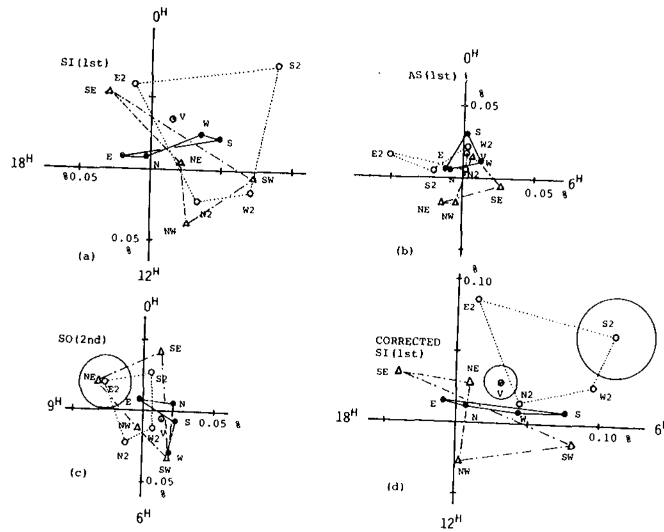

Fig. 8 Harmonics of; (a) SI(1st), (b) AS(1st), (c) SO(2nd) and (d) corrected SI(1st)

In a case, where SO(2nd) is observed significantly, as developed by Nagashima et al. (1983), space anisotropy of 2nd order responsible for the observed SO(2nd) produces the spurious SI(1st) and AS(1st) having equal amplitude and due phase. As in Fig. 8 (b), AS(1st) may be significant. Based on Nagashima correction (1983), the observed SI(1st) should be, at least, corrected for the above spurious SI(1st) by utilizing the observed AS(1st). Fig. 8 (d) shows the corrected SI(1st) thus derived. We may summarize that 1) these results are consistent with those so far reported; almost of them lie in the direction 3~5 hr LST. And 2) some of SI(1st)'s, e.g., S2-comp. is rather larger (~0.13% in ampltude) than others, which is consistent with that of Ueno et al. (1984) at Sakashita.

4. Acknowledgement

The authors express their aapreciation to Prof. K. Nagashima for his kind discussion.

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