RIGIDITY SPECTRUM OF FORBUSH DECREASE

S. Sakakibara, K. Munakata and K. Nagashima
Cosmic Ray Research Laboratory, Faculty of Science,
Nagoya University, Nagoya 464 Japan

ABSTRACT

Using data from neutron monitors and muon telescopes at surface and underground stations(Nagoya, 0 m.w.e.; Misato, 34 m.w.e.; Sakashita, 80 m.w.e.), we obtain the average rigidity spectrum of Forbush decreases(Fds) during the period of 1978-1982. Thirty eight Fd-events are classified into two groups "Hard Fd" and "Soft Fd" according to size of Fd at Sakashita station. It is found that a spectral form of fractional-power type($P^{-\gamma_1}(P+P_c)^{-\gamma_2}$) is more suitable for the present purpose than that of power-exponential type or of power type with an upper limiting rigidity. The best fitted spectrum of fractional-power type is expressed by γ_1=0.37, γ_2=0.89 and P_c=10GV for Hard Fd and γ_1=0.77, γ_2=1.02 and P_c=14GV for Soft Fd.

1. Introduction.

Rigidity spectrum of Forbush decrease(Fd) has been studied by many authors, using neutron monitor data(e.g. Lockwood, 1971; Iucci et al., 1979; Lumme et al., 1983; Fenton et al., 1983), or by adding a small amount of underground muon data to those in the above(e.g. Thambyahpillai et al., 1965; Andreis-Sandrucci et al., 1968; Mishima et al., 1973; Suda et al., 1977; Krymsky et al., 1979; Wada et al., 1979; Sakakibara et al., 1979; Wada and Suda, 1980). These studies have been made by assuming apriori a definite form of the spectrum and have tried to determine parameters involved in the spectral form. In the present paper, we make a comparative study of the spectral forms of Fd, using plenty of data in wide range of primary cosmic ray rigidity. For the muon telescope data, we use the response function given by Murakami et al.(1979,1981). For the neutron monitor data, we choose the response function given by Nagashima(1980) for the maximum solar activity out of three functions(Lockwood and Webber,1967; Aleksanyan et al.,1981; Mori and Nagashima,1984), based on a comparative study of response functions(S.Sakakibara et al.,1984; S.Mori and K.Nagashima,1984).

2. Rigidity spectrum of Forbush decrease.

Data used for the present analysis are those of 8 neutron monitors(median primary rigidity P_m=21 ∿ 35GV), 17 muon telescopes at Nagoya(P_m=60 ∿ 119GV), 9 underground muon telescopes at Misato(P_m=145 ∿ 209GV) and 3 underground muon telescopes at Sakashita(P_m=330 ∿ 567GV) during the period of Feb. 1978 - Feb. 1983. Fourty five Fds greater than 2% in depression for neutron intensity at Alert station were selected, but because of missing data of muon components, 38 Fds were finally adopted.

Fig.1 shows the rigidity dependence of the development of Fd on daily basis, obtained by superposing those 38 Fds at the epoch which 0-day includes the occurence time of SC. As can be seen in this figure, the depression at Sakashita is about 0.15% on the average and statiscally significant, but individual Fd at the station is not always statiscally significant and, in some cases, shows some increase. Taking this fact into account, we classify the Fds into two groups "Hard"(23 events) and "Soft"(15 events) according to size of Fd of Sakashita vertical component.

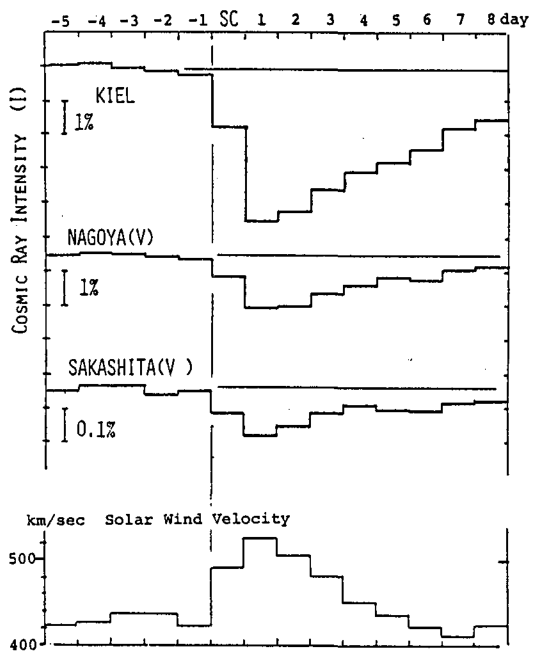

Fig.1 Averaged daily development of 38 Forbush decreases, superposed at the epoch day including SC, and that of the corresponding solar wind velocities.

The magnitude(ΔI) of each Fd is defined by the difference between daily mean intensities on +1 day and -3 day(cf. Fig.1). The boundary of two groups is set at the magnitude(ΔI=0.05%) of Sakashita vertical component, which corresponds to the statistical error for the component.

We made a comparative study of the rigidity spectrum of Fd, using the following three types of the spectrum.

PW : Power type

$$\Delta I \propto \begin{cases} P^{-\gamma} & \text{for } P \leqslant P_u \\ 0 & \text{for } P > P_u \end{cases}$$

PE : Power-Exponential type

$$\Delta I \propto P^{-\gamma} \exp(-P/P_o)$$

FP : Fractional-Power type

$$\Delta I \propto P^{-\gamma_1}(P+P_c)^{-\gamma_2}$$

..... (1)

Corresponding to the parameters involved in Eq.(1), the expected values ΔI_{exp}'s for muon components and neutron monitors are calculated, respectively, from the differential coupling coefficients by Fujimoto et al. (1984) and from those by Mori and Nagashima(1984). By the least squares method, we found that FP-type spectrum in Eq.(1) can produce the expected values ΔI_{exp}'s most compatible with the observations. To demonstrate the coincidence between the observation and ΔI_{exp}'s, we use a diagram whose ordinate represents the observed magnitude of Fd and whose abscissa expresses the corresponding magnitude ΔI_{exp} calculated by using a rigidity spectrum of Fd. We call this the correlation diagram of Fd. If ΔI_{exp} is calculated by using the spectrum determined from the observed data by the least squares method, we call the diagram the best fitted correlation diagram of Fd. In this case, all points on the graph must lie on a line inclined by 45° from the abscissa. Such diagrams of Hard and Soft Fd's are shown in Fig.2, for the FP-type spectrum. It is noted that, in case of Soft Fd, the least squares method was applied to those data excluding those of Sakashita station.

The rigidity dependence of Fd's can be expressed more plainly if we use an effective primary rigidity(P_E) for Fd, which is defined as the median rigidity of a function obtained by multiplying the response function by the best fitted rigidity spectrum of the Fd. Fig.3 shows the P_E-dependence of Hard and Soft Fd's. The average magnitudes <ΔI>'s can line up systematically on this graph.

In Table I, we show the best fitted parameters of three types of the rigidity spectrum.

Table I. The best fitted parameters for three types of the rigidity spectrum.

Spectral type / Group	FP: $P^{-\gamma_1}(P+P_c)^{\gamma_2}$ γ_1	γ_2	P_c(GV)	PE: $P^{-\gamma}\exp(-P/P_o)$ γ	P_o(GV)	PW: $P^{-\gamma}$, $(P \leqslant P_u)$ γ	P_u(GV)
Hard Fd	0.37	0.89	10	0.90	471	0.98	400
Soft Fd	0.77	1.02	14	1.17	145	1.26	100

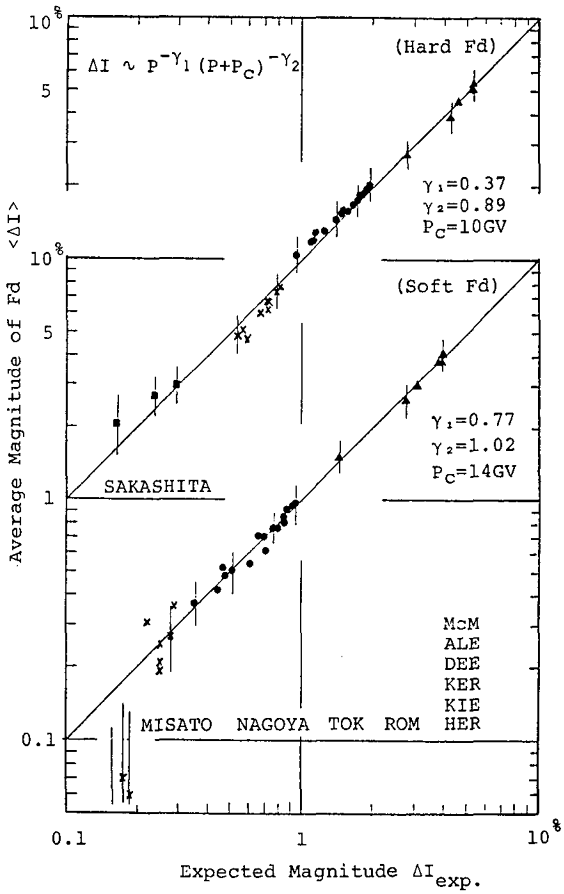

Fig.2 The best fitted correlation diagram of Hard and Soft Fds. ΔI_{exp} is calculated by using the fractional-power type spectrum with parameter shown in the figure, and in case of neutron monitors the NAGASHIMA-response function is selected for the calculation.

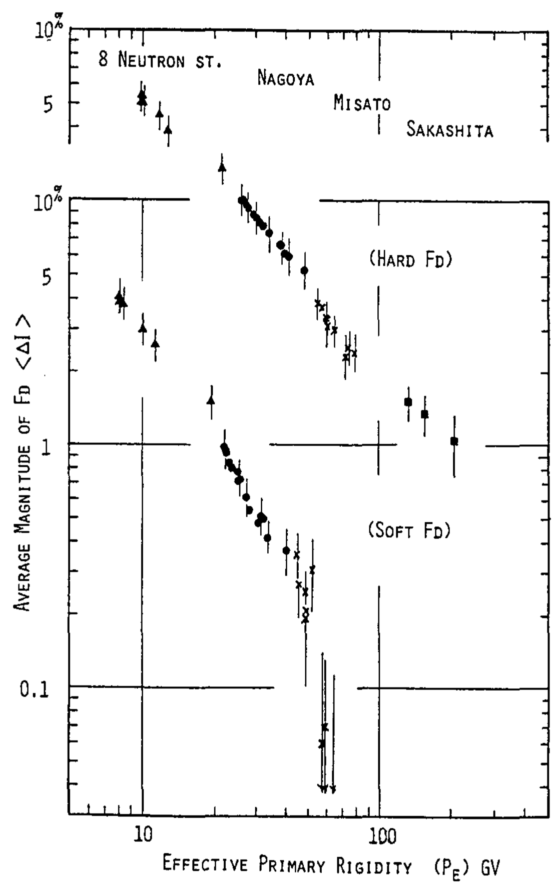

Fig.3 P_E -dependence of average magnitude <ΔI> of Hard and Soft Fds. The effective primary rigidity P_E for Fd defined in the text is calculated under the same conditions as in Fig.2. Errors are derived from the dispersion of individual Fds.

3. Conclusion. It is concluded that the FP-type spectrum is more suitable than PE-type or PW-type to express the observed rigidity dependence of Forbush decrease. However, in case of the Soft Fd, one cannot select the best spectral form out of the three types, by reason of the insufficient accuracy of the observed data in the higher rigidity range.

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