HOW REAL IS THE TOKYO AIR SHOWER EVENT OF ENERGY 4 × 10^{21} eV ?

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ABSTRACT

It is pointed out that the recently reported extensive air shower (EAS) event by the Tokyo group need not necessarily be assigned as energy of 4×10^{21} eV. An alternate interpretation leads to an estimate as low as 10^{18} eV. It is suggested that all the other reported EAS of energy $\sim 10^{20}$ eV could be scaled down to a limit of this order.

SUGA *et al.*[1] have reported an extensive air shower (EAS) observed by them which they interpret as having been caused by the incidence of a cosmic ray primary of energy 4×10^{21} eV. The interpretation needs critical examination[2] before one can believe that particles of such enormous energy exist in Nature.

Basically the information about the event consists of the recording of the incidence of a high density of particles ranging from 3860 to $1170/m^2$ (mostly electrons and positrons) in 22 scintillation counters in the so-called INS-AS array, all confined within a circle of radius 50 m. In addition, there is a recording of 80 ± 6 particles/m^2 and 36 ± 9 particles/m^2 in the INS-LAS array at distances of about 1 km from the above array of 22 scintillators. The authors have not explicitly stated the density at a distance of 300 m from the INS-AS in station I of the INS-LAS array. Apparently this can be deduced as $> 270/m^2$ from Fig. 2 of their paper.

The total number of particles recorded in this event is roughly 45,000. From this sampling, the authors argue that the shower contained 10^{12} particles leading to an energy estimate of 4×10^{21} eV. This enormous extrapolation is based on considerable faith in a hypothetical lateral particle density distribution which it is quoted holds good for lower energy events observed : for example the event observed by Linsley[3] of estimated energy 10^{20} eV is compared. The observed event cannot rule out discontinuities in the density distribution nor can it vouch for a steep distribution of particles at distances less than 600 m from the assigned core position. The arguments leading to the assignment of core position are not clear and no errors are given for the uncertainty in the location of the core position. Even if we assume that the assignment of core position as done by the authors is correct, one is confronted with the question why the densities of particles in the 22 scintillators, all of them at distances of about 700 m from the shower core, show fluctuations by a factor of three. Thus the assumed smoothness of the lateral density distribution is in doubt. Information on the densities of particles in this shower within 700 m from the shower core is vital for an independent check on the lateral distribution of particles within this region since the assumed steep lateral distribution here contributes 99% of the calculated shower size.

In the absence of a reliable estimate of the core position, I have assumed that the core struck at a distance of 1 m from the scintillator which recorded the highest density of particles ($3860/m^2$) in the INS-AS. This hypothesis would lead to the lowest estimate of the shower size.

In Fig. 1 is shown a plot of the lateral distribution of density which results from this hypothesis. If we admit of fluctuations in the densities of shower particles well outside statistical limits as exhibited by INS-AS, one need not bother about fluctuations at the two INS-LAS points close to 1 km. In the same figure is shown the original plot of densities of Suga, *et al.*[1] and also some points taken from the next two highest energy EAS events[3,4]. In all the three showers, there are no data below 400 m from the core. One can conclude from the figure that all the three showers claimed to have energy $\gtrsim 10^{20}$ eV show comparable densities at about 1 km and this fact is insensitive to inaccuracies in the locations of their cores. Since at these distances, muons constitute at least as much as 30% of the shower particles,[5] there is little to choose in the relative order of magnitude of size of these showers. If all these events are about the same in size, the suggested core location of the INS event gives the density distribution of particles near the core and obviously this is very flat. The area under the curve drawn for the INS events is 10^9 particles. If we use the usual energy conversion factor of 1–2 BeV/ particle, the primary energy in all these events could have been only $(1-2) \times 10^{18}$ eV.

The question which arises is whether there is any evidence to show that as the shower size

increases to the largest ones observed, the density of particles near the core is held approximately constant. One can quote here the observations of Reid *et al*[5] who found that the exponent in the differential density spectrum of EAS is -4.0 ± 0.5 in the density region 1000–5000 particle/m² whereas it is expected to reproduce the exponent of the size spectrum (≈ 2.6) if the lateral distribution is independent of shower size. Further, recent observations[7] on the density distributions of very large air showers do seem to show flat cores compared to expectations from smaller size showers.
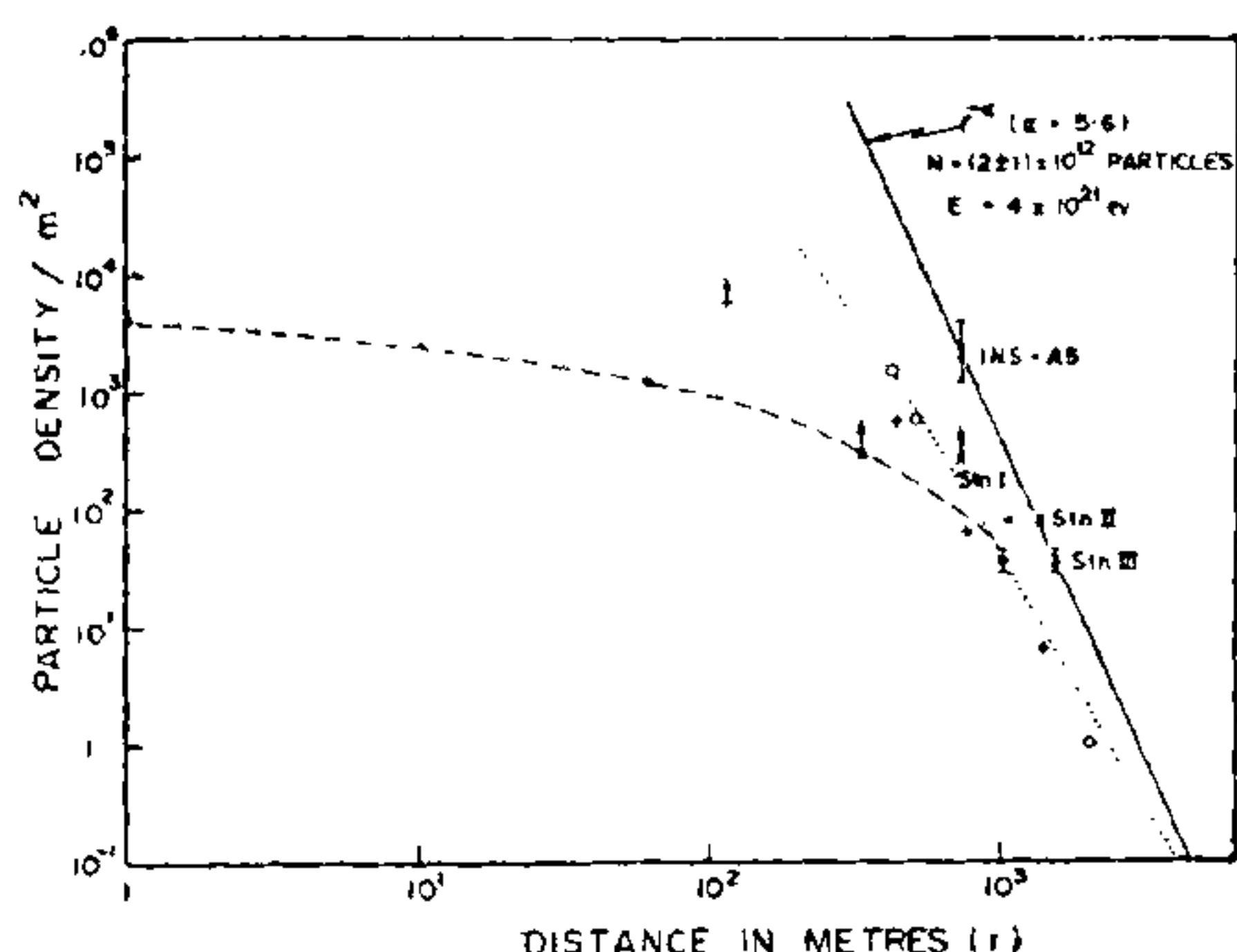

FIG. 1. A plot of the lateral density distribution of particles observed in the Tokyo event[1] and other two events[3,4] of energy claimed to be $\sim 10^{20}$ eV. Full circles represent the Tokyo event if core is assumed to have struck 1 m from the detector which recorded the highest density of particles. Crosses represent the same shower according to the choice of core location by the authors of ref. (1) and the full line is the extrapolation of the resulting lateral distribution. The open circles represent some points taken from the paper of Linsley[3] and the dotted line represents the lateral structure used by him to estimate the energy as 10^{20} eV. The plus marks represent the shower recorded at Havarah Park[4]. The dashed line is a guide to the lateral structure for the Tokyo event on repositioning the core as suggested here. Only the nearest (1·0 m) and the farthest (60 m) scintillator density recordings among the twenty-one detectors excluding the one which recorded the highest density have beeen plotted.

Thus one can conclude that in order to prove conclusively the existence of cosmic ray particles of energy $\geq 10^{18}$ eV, one has to have an array of large number of detectors (~ 100) spread evenly over distances of ~ 1 km. It is interesting to speculate on the origin of flat cores of very large EAS. They could arise if the primaries at these energies are predominantly heavy nuclei ($Z \geq 26$) and these

are photo-disintegrated by sunlight as was first suggested by Zatsepin[8]. A more detailed discussion on this point is hoped to be published in the *Proceedings of the Indian Academy of Sciences* in the near future.

I wish to thank Prof. B. V. Sreekantan, Shri R. H. Vatcha and Dr. S. C. Tonwar for stimulating discussions and guidance to the literature on EAS.

Since writing this note, the author came to know the work of Garmston and Watson[9] in which it is pointed out that the estimate of primary energy of the Tokyo event could be in the range 4×10^{19} to 1.4×10^{20} eV from more detailed considerations of data including those on muon densities observed near the INS-AS array. These authors however use a lateral structure function for particle densities based on measurements of smaller size showers ; the main question to be answered is : how far is it justified to use average characteristics observed at lower shower sizes to explain an unusual event ? The author feels that the energy estimates suggested here in this paper would be real if we admit of change of characteristic features of showers at these energies[7] (not necessarily a change in the characteristics of nuclear interactions at these energies).

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