Search for tachyons associated with extensive air showers in the ground level cosmic radiation

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Abstract

Events detected in a shielded plastic scintillation counter occurring in the 260μs preceding the arrival of an extensive air shower at ground level with local electron density $\gtrsim 20m^{-2}$ and the 240μs after its arrival have been studied. No significant excess of events (tachyons) arriving in the early time domain have been observed in a sample of 11,585 air shower triggers.

Introduction. According to the special theory of relativity a particle of rest mass m and moving with velocity $\nu=\beta c$ has total energy $E=\gamma mc^2$ where $\gamma=1/\sqrt{1-\beta^2}$ so that velocities greater than the velocity of light c are forbidden. To accommodate velocities >c in the formalism Recami and Mignami (1974, pg 263) suggest that for such objects (tachyons) $E=imc^2/\sqrt{\beta^2-1}$ where the complex number i is associated with the superluminal Lorentz transformation and not the 'rest mass' of the tachyon. For such objects their total energy would decrease as their velocity increases tending to zero as $\beta\to\infty$. Thus if tachyons are produced in the collision of high energy primary cosmic ray protons in the atmosphere via $P+N\to N+N+t+\bar{t}$+pions etc. then one would expect that they are produced with high velocities ($\to\infty$) at their production energy threshold. If produced, tachyons would arrive at sea level before the air shower front (comprising mainly electrons moving with velocity $\simeq c$) and for a primary proton incident in the zenith direction and making its first interaction at 17.7km above sea level the relevant time for infinite velocity tachyons is 59μs. For showers incident at a zenith angle of 60° the relevant time is 150μs. To cover all possibilities ionising events occurring in a $1.05m^2$ area plastic scintillator (shielded by 15cm of lead and 15cm of iron) occurring in the 260μs time domain preceding the arrival of air showers with local electron density $\gtrsim 20m^{-2}$ have been recorded. Events occurring in the 240μs after the arrival of showers have also been recorded for comparison purposes. Some details of the experimental arrangement were described by Darjazi et al (1983).

Results. The occurrence time distribution of events recorded in the tachyon detector relative to the arrival time of the extensive air shower are shown in figure 1. Events occurring in the tachyon detector were continuously injected into a 265μs delay line system and its outout was recorded on a dual beam oscilloscope which was triggered by the arrival of an air shower at the detector. Particles and photons penetrating the shielding above the tachyon detector and interacting with it thus occur at the time of 265μs in figure 1. It is seen from figure 1 that there is no evidence for an excess of events occurring in the 150μs preceeding the arrival of an air shower as expected if there is a significant flux of tachyons associated with air showers at ground level.

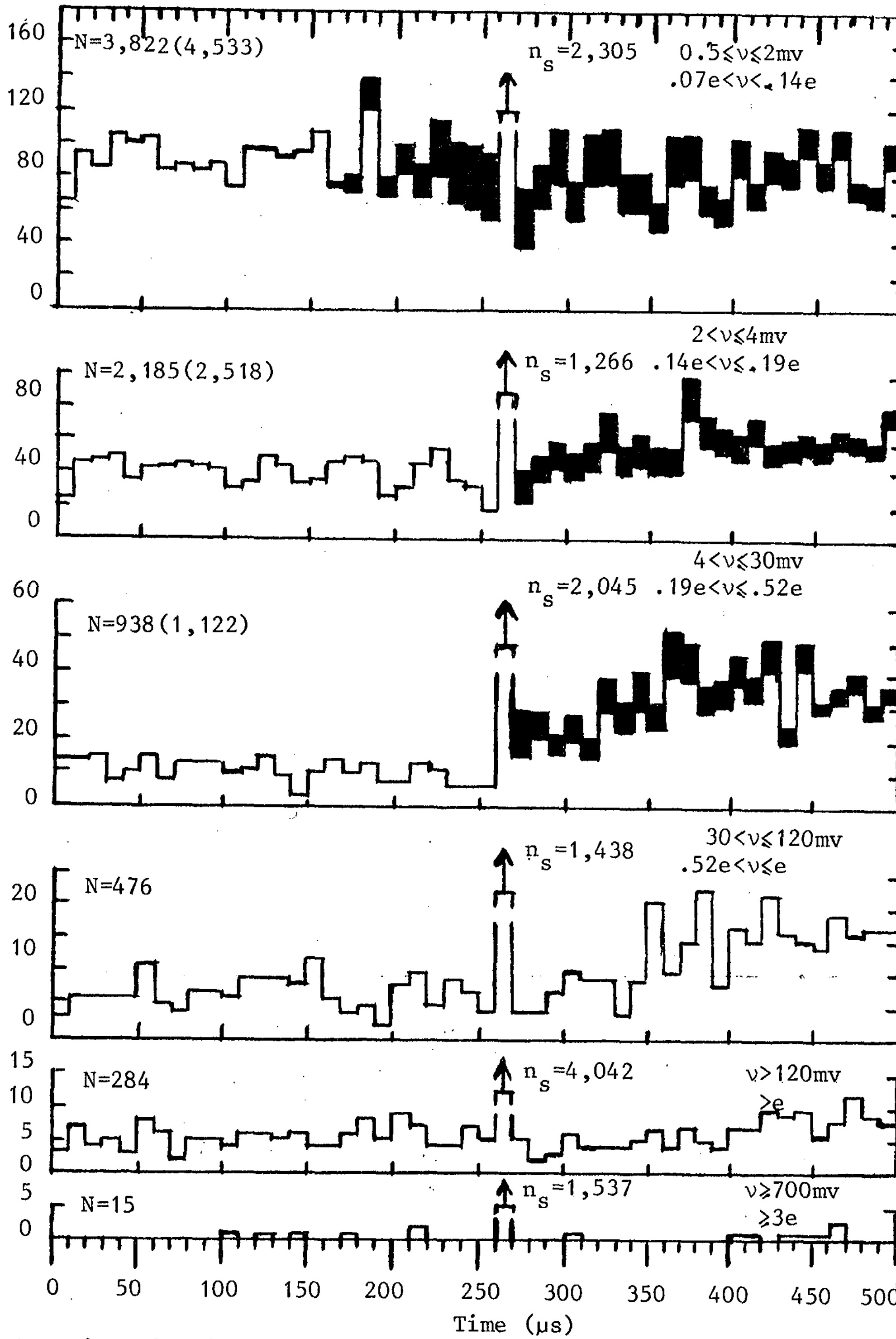

Figure 1. Time distribution of pulses occurring in different ranges of pulse height from a sample of 11,585 shower triggers. Time is measured from the start of the oscilloscope time base and the shower front occurs at the well defined time of 265 μs. The number of pulses in the 260-270μs time bin (which contains shower front pulses with

Caption to Figure 1 continued

pulse heights in the stated range of energy deposition) are too large to be plotted and are indicated by n_s. N is the total number of measured events in the 0-500μs time range but excluding the events in the 260-270us time bin and the figure in brackets is the number obtained after correction for experimental bias. The range of pulse height ν is as measured on the recording oscilloscope. Also shown is the corresponding range of energy deposition in the scintillator in terms of e where e is the energy loss (10MeV) produced by a relativistic muon traversing the scintillator at normal incidence. The amplifiers used in conjunction with the delay lines had a non linear response so the range of pulse height is not linearly related to the range of energy loss. The shaded portions of the histograms represent the effect of experimental bias produced by large shower front pulses that saturate the recording electronics and cause pulses occurring after the shower front pulse to be unmeasureable. Large shower front pulses are preceeded by an oscillation which causes a loss of measureable pulses at small pulse height (<2mv) before the occurrence of the shower front pulse.

It is apparent from figure 1 that there is evidence for more events being observed to occur in the tachyon detector at times after the arrival of the air shower than before it for energy deposits in the detector of .19e - .52e and .52e - e. e = 10MeV is the energy deposited in the detector when a relativistic muon traverses it at normal incidence. Table 1 gives quantitative data on this effect.

Conclusion. No evidence is found for a significant flux of tachyons in regions of showers with electron density $\geq 20m^{-2}$ in a sample of 11,585 air showcr triggers. The excess of events found to trail the arrival of the air shower front could be due to either photons in the air shower electromagnetic cascade which have undergone diffusive scattering, to low energy evaporation neutrons from air nuclei produced in the air shower hadron cascade which subsequently interact in the detection scintillator or low energy nuons from π-μ decay.

Pulse height range	N(0-260μs)	N(270-500μs)	$\frac{N(0-260\mu s)}{N(270-500\mu s)}$
$0.5 \leq \nu \leq 2$mv $0.07e \leq \nu \leq 0.14e$	2,225 (2,459)	1,597 (2,074)	1.39±0.05 (1.19±0.04)
$2 \leq \nu \leq 4$mv $0.14e < \nu \leq 0.19e$	1,048	1,137 (1,470)	0.92±0.04 (0.71±0.03)
$4 < \nu \leq 30$mv $0.19e < \nu \leq 0.52e$	273	665 (849)	0.41±0.03 (0.32±0.02)
$30 < \nu \leq 120$mv $0.52e < \nu \leq e$	175	301	0.58±0.06
$\nu > 120$mv $\nu > e$	138	146	0.95±0.11
$\nu \geq 700$mv $\nu \geq 3e$	6	9	0.67±0.35

Table 1. The ratio of the number of events $\frac{N(0-260\mu s)}{N(270-500\mu s)}$ occurring in the time regions 0-260μs and 270-500μs with times measured from the start of the oscilloscope time base. The shower front pulse occurs at 265μs from the start of the oscilloscope time base. The numbers in brackets are the results obtained after correcting the observed number of events for experimental bias. Assuming all pre shower front and post shower front pulses are random coincidences the expected value of the ratio $\frac{N(0-260\mu s)}{N(270-500\mu s)} = 1.13$.

References.

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