Comments on the paper 'High transverse momenta observed in air shower cores'

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Thirdly, we note that if $\gamma_+(\omega)$ is in any sense an effective one-particle polarizability in a many-particle system then both (13) and (18) imply exponential growth, with an exponent proportional to the intensity, in an amplifying medium (for which $\rho_{ss}-\rho_{00} = 1$).

The theory will be published in detail elsewhere.

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Comments on the paper *High transverse momenta observed in air shower cores*

Abstract. The recent findings of the Sydney air shower group concerning the existence of high-transverse-momentum events in air shower cores are disputed. It is shown that the multiple cores which are interpreted as large-transverse-momentum events are likely to be simulated by the detection fluctuations quoted by the Sydney group itself.

The Sydney air shower group (McCusker *et al.* 1969, Bakich *et al.* 1969, Bakich *et al.* 1970 to be referred to as I, II, and III respectively) have claimed that they have found evidence for the existence of large-transverse-momentum events in air shower cores. The transverse momenta (p_t) reported range up to more than 100 GeV/c and it was these findings which lead them to their widely known quark search. The Sydney evidence for large p_t is based primarily on the observation of multiple cores in the electron distribution of showers recorded by means of a 16 m^2 scintillation counter hodoscope consisting of 64 quadratic elements. Shower cores with well separated peaks have been observed and, using electromagnetic cascade theory, the transverse momenta necessary to explain the observed separation of peaks have been estimated.

Since 1965 we have recorded shower cores in the same region of primary energy (10^{14} to 10^{17} eV) employing a 32 m^2 neon hodoscope. This detector has an excellent stability and uniformity of response and we are able to measure particle densities up to the order of 100 000 particles/m^2. Using an integration area of 0·2 m^2, which roughly corresponds to the Sydney counter area, our measuring errors are smaller than 10% up to particle densities of 50 000/m^2. In total about 5000 showers falling with their cores on the neon hodoscope have been recorded and already a rough inspection of the photographs shows that in our case the particle densities near the core are much less fluctuating than at Sydney. In fact, a quantitative analysis shows that at showers sizes above approximately 2×10^5 our lateral distributions are essentially consistent with more or less steep *single cores* having only Poissonian density fluctuations. (Samorski *et al.* 1970a, Samorski *et al.* 1970b). It is just in this shower size region above 2×10^5 where the large p_t multicore events have been found by the Sydney group. In previous papers (Samorski *et al.* 1970a,b) we have discussed various background effects which might simulate separated cores in the electron distribution and consequently lead to large transverse momenta.

Now, in a recent publication in this journal (III) the Sydney group have attempted to show that their large p_t events are not due to such background effects. However, the arguments used in that paper are very indirect and qualitative in nature. Evidently, it would be necessary to prove that the observed *separated cores* leading to the large p_t shown in figure 18 of I, figure 5 of II and figure 3 of III cannot be produced by Poissonian and detection fluctuations, and this has not been done. In the following we shall show that the detection fluctuations reported by the Sydney group are just of the right order to explain the large p_t found.

According to paper III the scintillation counters measure particle densities with an error distribution having a fractional standard deviation of 0·4, and this error is nearly independent of density. Now, a shower with $N = 3\times10^6$ contains typically 4000 particles/m^2 within 2·5 m from the core, which corresponds to 675 particles in one of the Sydney counters ($0{\cdot}41\times0{\cdot}41$ m^2). Assuming a Gaussian error distribution there is typically one of the 64 counters which has a positive excess of twice the standard deviation, corresponding to $675\times0{\cdot}8 = 540$ particles. If this excess occurs at a core distance of 2 m and is misinterpreted as real peak in the electron distribution, application of cascade theory leads to a simulated p_t of 30 GeV/c. At $N = 3\times10^6$ the reported Sydney p_t values scatter around 10 GeV/c (I), 30 GeV/c (II), and 15 GeV/c (III). Leaving out the obvious differences between the reported p_t distributions it becomes clear from the above example that they are close to the noise level set by the detection fluctuations or even below that level. As a consequence of the constant fractional standard deviations of the detection fluctuations, a linear increase of the simulated p_t values with shower size is to be expected and we note that this is just the behaviour of the reported Sydney p_t–N diagrams (I figure 18, II figure 5, III figure 3).

Summarizing, we conclude that the p_t values reported by the Sydney group are likely to be produced by detection fluctuations. In order to prove their real existence it would be necessary to demonstrate, by a quantitative discussion of the individual events contributing to the published p_t–N distributions, that they stand out significantly above the background. We are not able to do this since sufficient details of the events claimed for large p_t have not been published.

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The possibility of measuring spatial velocity correlation functions in a turbulent fluid by means of light scattering†

Abstract. The aim of this letter is to show in which way the conditional probability of light diffused by particles suspended in a turbulent fluid can yield direct information on spatial velocity correlation functions.

The relation between the conditional probability of light scattered by particles suspended in a turbulent fluid and velocity correlation functions has been already considered, both from an experimental (Bourke *et al.* 1969) and a theoretical (Di Porto *et al.* 1969) point of view. It has been shown that the probability density that a photon is registered at time τ by means of a counter with 'quantum efficiency' α, provided one has occurred at time $t = 0$ (Mandel and Wolf 1965), is

$$p_{\mathrm{c}}(\tau) = \alpha \frac{\langle |\boldsymbol{E}(t)|^2 |\boldsymbol{E}(0)|^2 \rangle}{\langle |\boldsymbol{E}(t)|^2 \rangle} \tag{1}$$

where $\boldsymbol{E}$ represents the diffused electric field and the angular brackets stand for ensemble averages. Further, p_{c} obeys the relation (Di Porto *et al.* 1969)

$$p_{\mathrm{c}}(\tau) = \alpha \langle I \rangle \left[1 + \exp\left\{ -k^2 \overline{U_1{}^2} \int_0^\tau \int_0^\tau R_{\mathrm{L}}(t'' - t')\, \mathrm{d}t'\, \mathrm{d}t'' \right\} \times \left\langle \exp\left\{ k^2 \overline{U_1{}^2} \int_0^\tau \int_0^\tau \tilde{R}_{\mathrm{L}}(t'' - t'; \boldsymbol{r}_{i,0} - \boldsymbol{r}_{j,0})\, \mathrm{d}t'\, \mathrm{d}t'' \right\} \right\rangle_{\mathrm{P}} \right] \tag{2}$$

where $\langle I \rangle$ is the average intensity scattered at an angle ν and $k = 2k_0 \sin(\nu/2)$, k_0 being the wavenumber of the incident radiation. The right hand side of equation (2) depends on the dynamics of the fluid through the mean square value of velocity fluctuations $\overline{U_1{}^2}$ along an arbitrary direction (if one conside isotrrsopic turbulence), the normalized Lagrangian velocity correlation function $R_{\mathrm{L}}(t'' - t')$ (Hinze 1959) and the normalized Lagrangian correlation function $\tilde{R}_{\mathrm{L}}(t'' - t'; \boldsymbol{r}_{i,0} - \boldsymbol{r}_{j,0})$ generalized to different fluid elements. The symbol $\langle \ldots \rangle_{\mathrm{P}}$ labels an ensemble averaging operation over the initial positions $\boldsymbol{r}_{i,0}$, $\boldsymbol{r}_{j,0}$ of two different particles. It is worthwhile to remember that the validity of equation (2) rests on the assumption of joint Gaussian probability density distribution for the velocity of turbulence. This hypothesis is somewhat questionable, but it has recently received experimental confirmation for weak turbulent fields (Long and Huang 1970).

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