LETTERS TO PROGRESS IN PHYSICS

Instability of Protons Beyond 3 GeV Kinetic Energies Explains the Flux Profiles Observed in Cosmic Rays

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We analyze available data for the flux of cosmic rays protons, and find evidence for instability of these particles as their kinetic energy increases beyond about 3 GeV. This is expected from our recent model [1] which proposes the existence of a parent state at 3.7 GeV, from which protons of about 1 GeV mass (as well as the other baryons) would condense in the form of flux-confining vortices. Therefore, this energy difference imposes that beyond 2.7 GeV kinetic energies such vortex states would become unstable compared to the parent, in agreement with the observation that highly energetic protons are rare in cosmic rays. The observation of protons of higher energies is attributed to cohesion provided, e.g. by strong forces, between proton constituents not considered in the vortex model.

We have recently developed a field-theoretical model for baryons in which such particles are modelled as vortices confining magnetic flux, which would "condense" from a parent state at 3.7 GeV, under the effect of electromagnetic instabilities of such a state [1,2]. This model has been shown to reproduce the relation of the masses of baryons with their magnetic moments (through an amount of confined magnetic flux) in a consistent, quantitative way. We here concentrate on the case of protons. Since the particles are assumed to be the result of the creation of states stabilized from a higher energy level, it should be expected that the number of protons will markedly decrease in cosmic rays for excessive kinetic energies. This is what we propose and actually verify in this Letter.

In Fig. 1, we show data for the number flux of protons plotted as $E\,(dN/dE)$ against kinetic energy E in GeV, for cosmic rays below 10 GeV kinetic energy, taken from the upper left corner of figure 1.1 of [3]. Below about 2 GeV kinetic energy there is an approximate plateau. From 2 GeV on, a marked decrease in the flux of protons is observed. The interpretation is that the number N of detected protons is reaching saturation above 2 GeV. To quantify such saturation, we have obtained the actual functional relations in the original double-log plot, to calculate the number N of particles in units of (m^2 sr s)$^{-1}$ for several energy intervals. Assuming from Fig. 2 below that the plateau in $E\,(dN/dE)$ would begin at about 0.1 GeV and goes up to 3 GeV, we obtain N=6800 by integration in this interval. Beyond 3 GeV the ordinate decays as $E^{-3/2}$. Therefore, one obtains by integration N=1100 between 3 and 10 GeV, and at last a very small N=204 between 10 and 100 GeV. That is, well over 80% of the protons in cosmic rays have energies below about 3 GeV, and the numbers beyond 10 GeV are negligible in absolute terms in spite of the great interest on them from the high-energy physics standpoint.

According to our model in [1], protons accelerated beyond 2.7 GeV kinetic energy (which comes from the difference between the parent level at 3.7 GeV and the proton rest mass of about 1 GeV, i.e. the "energy advantage") should become unstable since they lose the energy advantage acquired by settling in the lower energy vortex state. A related effect breaks Cooper pairs in superconductors if the energy associated with current becomes greater than the pairing interaction provided by phonon-intermediated coupling. Fig. 2 shows a plot of the estimated (from collected data) energy distribution for the interstellar flux of protons [3], which peaks exactly at 2.7 GeV. In view of the gigantic values of E beyond the peak one realizes the minute amount of very energetic particles to the right of the peak. That is, once more one concludes that protons are essentially unstable above 2.7 GeV kinetic energy.

In conclusion, this Letter analyzes data collected for the flow of protons in cosmic rays in the light of a recently proposed model in which protons are modelled as vortices in an energy state 2.7 GeV below a parent state from which they would have condensed [1]. We have indeed found evidence for a critical kinetic energy of 2.7 GeV in both the number distribution of protons and in their energy distribution. Although it is clear that 2.7 GeV represents a critical value for the energies of protons in cosmic rays, a very small ("tail") population of particles is detected at high energies. The expected question is: why do these particles still exist? In spite of providing a picture on how baryons condense from instabilities of the vacuum, the vortex model does not go as far as considering the internal structure of the baryons. The survival of some particles to high energies is certainly related to internal short-range strong forces between constituents, not considered in the model. The good results of the vortex model of [1] however suggest that the existence of the proton constituents cannot be neglected when dynamic effects take place at scales shorter than L/π with L the size of the current loop in [1], which is on the order of 10^{-16} m. It must be pointed out

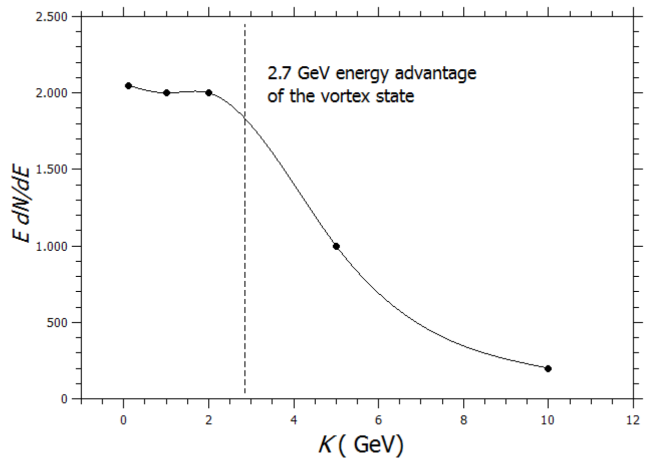

Fig. 1: Reproduction of the upper left part of the double-log plots in figure 1.1 of [3] (linearized scales are adopted here). The number flux of protons in $10^3\,\mathrm{m}^{-2}\,(\mathrm{sr.\ s})^{-1}$ units is plotted against the protons kinetic energy in GeV. The vertical line is placed at the value of K that corresponds to total loss of the vortex energy advantage compared to the vacuum parent state (see [1]). Fast saturation in the detected N of protons is manifest in the drop of dN/dE as the energy increases. Integration shows that beyond 80% of N concentrates below 3 GeV energies. The solid line is a guide.

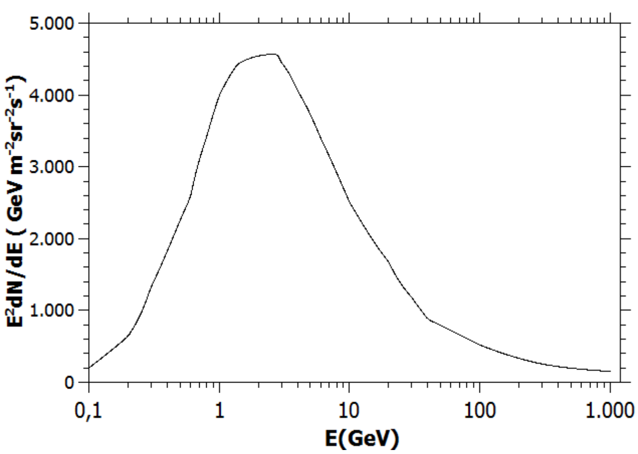

Fig. 2: Estimated energy flux distribution of interstellar protons in cosmic rays, which peaks at exactly K=2.7 GeV [3].

that [3] also displays data for the flux of electrons in cosmic rays in its Fig. 2.1. In this case there are few points in the plot but they peak at the expected range of about 3 GeV, and decay faster than the protons at higher energies. The electron is represented as the very first cross symbol to the left in figure 3 of our paper [1]. If the model applies also to leptons [2], the most energetic electrons might theoretically reach 3.7 GeV kinetic energies (although this requires acceleration to speeds quite close to the light speed). The fact that the electrons data peaks at lower energies and drops faster would be consistent with a greater instability of its structure as compared to the proton. Further investigations on this subject are clearly needed, mainly on the lower range of cosmic rays energies.

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