ISSN 1330–0016
CODEN FIZBE7

LETTER TO THE EDITOR

FALSE VACUUM AND ITS DETECTION AT THE CERN LARGE HADRON COLLIDER (LHC)

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Dedicated to Professor Mladen Paić on the occasion of his 90th birthday

Received 1 August 1995

UDC 539.1.01

PACS 13.85.Hd

The posibility to detect the false vacuum, so-called disoriented chiral condensate (DCC), in ultra-high energy proton-proton collisions, was studied. It is shown that using the intermittency method one can, even in the presence of a large background, identify the possible DCC candidates.

In hadron collissions at very high energies one has the advantage of huge multiplicities, so that one can regard each collision as an experiment similar to the observation of a stellar object.

Cosmic ray experiments [1] have observed some peculiar phenomena in high multiplicity events: centauro events, showers of only charged hadrons and chiron events where low $p_\perp$ (< 0.1 GeV/c transverse momenta) dominate. Many theoretical papers have tried to explain these events as coherent effects of the so-called the false vacuum [2].

The Lorentz invariant vacuum could be a coherent mixture of states of different quantum numbers and so the vacuum expectation value of the spin-0 field carrying quantum numbers could be different from zero. Today it is well known that the vacuum expectation value of the Higgs field plays a crucial role in the reduction of SU(2) × U(1) symmetry to U(1). In general it is of fundamental interest to study the vacuum because it is filled with most profound physical content.

F. Wilczek [3] pointed out that among the most interesting speculations regarding ultra-high energy at LHC is the idea of possible production of the false vacuum so-called disoriented chiral condensate (DCC). In the framework of the low energy sigma model [3,4], the following phenomenological picture is developed: In very high-energy collisions, the hadronic debris, which are expanding outwardly, at the speed of light, build the relativistic outer hot shell core and leave the interior cool. The quenching mechanism [3] when the temperature suddenly drops produces a phase transition to the broken semiclassical system, DCC, whose chiral orientation differs from that of the normal vacuum. Eventually, the relativistic outer hot shell cools to the hadronisation temperature and the interior re-establishes contact with the rest of the universe. At this point, DCC realigns with the exterior through the coherent radiation of non-relativistic pions. It is a most striking effect that the disorientation in iso-space produces clusters of pions bunched in rapidity with highly non-Gaussian charge distributions. Under the assumption that all initial values on the cartesian isospin 3-sphere are equally probable the relative probability distribution $P(r)$, is given by

$$P(r) = \frac{1}{2} r^{-1/2}\,,\text{where}\;\; r = \frac{n_{\pi^\pm}}{n_{\pi^0} + n_{\pi^\pm}}\,.$$

Thus a misaligned vacuum region starting with the field in $\pi_1 - \pi_2$ plane would emit only charged pions, as was observed in centauro events.

From the epxerimental point of view the most crucial questions are:

a) Can DCC be produced with reasonable cross-section and volume?

b) If produced, how can it be detected and how can its properties be analysed?

As experimentalists we can try to answer only question b). In order to answer we construct a two-component Monte Carlo model [6]. One component was the Bjorken BAKED ALASKA [4] model, where the nickname orginated in condensed-matter physics of the ^{3}He suprafluid [7]. The second component was just the standard Lund model. The experimental strategies to pick up the DCC signal should be to select the events with higher than average ratio of charged to neutral pion multiplicities and with a somewhat smaller average $p_\perp$ of the particles. That should be done with the on-line trigger for central collision events. For these events we will off-line apply the intermittency analysis inside restricted p_T, ϕ (azimuthal angle around the collision line) and y (rapidity) region. In order to test the efficiency of the method for the search of DCC signals we applied the method on the events of our Monte Carlo model.

In the intermittency method [8] we calculated first the number of all possible order q-tuples for each "measured" n-multiplicity event (we use positive and negative particles in order to suppress Bose-Einstein correlations): $(n(n-1)\dots(n-q+1))$ in some part of the phase space. We constructed new events by mixing the tracks of different events, that is the background where DCC correlations are washed out. With these constructed events we calculated again the q-tuples. We divided the average q-tuples over all measured events (signal) by average q-tuples with constructed events (background). The normalization is such that for full phase space, e.g. for $q = 2$ F-moment is: $F_2 = \langle n(n-1)\rangle/\langle n\rangle^2$. Now we investigate the F_q dependence on the always smaller parts of the phase space. In Fig. 1, we show on the log-log plot the normalized factorial moment F_2 versus M^3, the number of divisions of the considered phase space for Monte Carlo events with DCC and without DCC.

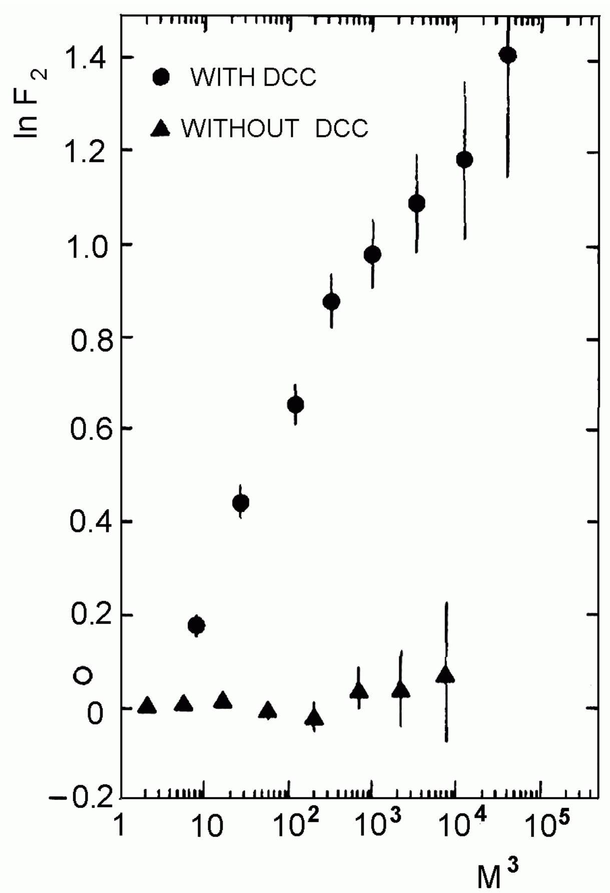

Fig. 1. Log-log plot of the normalized factorial moment F_2 vs. M^3 (number of the divisions).

In this restricted phase-space region ($p_\perp < 0.2$ GeV/c, $y < 0.1$) the contribution of DCC is smaller than 0.04 percent. In a previous investigation [9] with experimental data we have shown that this analysis of F_2 moments was sensitive to the addition of 0.07 percent of correlated background tracks. For events without DCC we do not see any correlations (flat dependence on M^3). But for events with DCC we observe strong signal. Thus we can very easy pick up the events which contribute to the exponential increase of F_2. These events are candidates for DCC studies. The structure of these events could be compared with non-candidate events in order to get some experimental guidance for theoretical hypotheses.

In conclusion, using adequate on-line and off-line selection of events and the appropriate momentum and rapidity cuts on the tracks with the intermittency analysis we hope at LHC to pick up from the huge background the interesting DCC candidates.

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KRIVI VAKUUM I NJEGOVA DETEKCIJA U VELIKOM HADRONSKOM SUDARALU (LHC) U CERNU

Raspravlja se mogućnost otkrića “krivog vakuuma”, tzv. neorijentiranog kiralnog kondezata (DCC), u visoko energetskom sudaru protona s protonom. Pokazuje se da je pomoću tzv. intermitentne metode moguće odabrati DCC dogadaje i u prisutnosti jakih smetnji (šuma).