Possible DCC signature in γ-hadron families seen through robust observables

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We have found by using robust observables in experimental cosmic ray gamma-hadron families ($100\ TeV < E_{vis} < 700\ TeV$) detected at mountain altitudes that there are peculiar clusters with large asymmetries in the neutral pion fraction distribution, absent in the artificial generic families. A qualitative explanation of this result can be associated with assuming copious production of pions in the far-forward angular region from a channel of DCC generation in nuclear collisions.

1. Introduction

Recently there has been a growing interest to the possibility of production of disoriented chiral condensate (DCC) in a high energy collisions [1]. This hypothesis gives one of explanation for peculiar events with large isospin fluctuations known as Centauro and anti-Centauro type events in cosmic ray experiments [2]. To analyze DCC admixture in pion multiple production processes robust observables have been proposed [3]. In this work we use Pamir experimental data on 139 families with visible energy $100 \leq$ TeV $\Sigma E_{vis} = \Sigma E_\gamma + \Sigma E_h(\gamma) \leq 700$ TeV found in $\sim 780\ m^2 year$ exposition [4] [5,6] and (~ 1000 simulated families based on UA5 model Monte Carlo code described in [7–9].

2. Semi-classic interpretation of DCC formation

Basically, the formation of a DCC in one hadronic collision can be explained within semi-classic frame and σ model [1,10] using a fire-ball shell production mechanism. In a hadron collision the fire ball with a mass M_X can be formed in the leading particle region. Initially small in size, it can expand to the big macroscopic volume ($R \leq 5$fm). The interior of the fire ball cools quickly before the hadronization starts. The fire ball interior region can be characterized by the chiral orientation of the vacuum that leans from the original direction to the new one (DCC formation). This vacuum relaxes to the original direction again emitting pions governed by distribution $\frac{dN}{df} = \frac{1}{2\sqrt{f}}$ where $f = N_{\pi^0}/(N_{\pi^0} + N_{\pi^\pm})$. At the Tevatron energy ($\sqrt{s} = 1800$GeV) overlapping with the energy of cosmic ray families the spontaneous production rate of a DCC is estimated as 24 % in average for the leading particle region [10] and for the whole inelastic channel this value is less than 5%.

3. Robust observables and DCC formation

The robust observables [3] are constructed through the ratio of factorial momenta sensitive to the distribution $p(f)$, where f is the fraction of produced π^0 . The robust observables can be expressed as $r_{i,1} = \frac{F_{i,1}}{F_{i+1,0}}$ with

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$F_{i,j} = \frac{<n_{ch}(n_{ch}-1)...(n_{ch}-i+1)n_\gamma(n_\gamma-1)...(n_\gamma-j+1)>}{<n_{ch}>^i<n_\gamma>^j}$.
In case of standard pion multiple production $r_{i,1}(generic) = 1$. If $p(f) = 1/(2\sqrt{f})$, then it is connected to DCC formation in the semi-classical limit and the robust observables are expressed as $r_{i,1}(DCC) = \frac{1}{i+1}$.

4. Robust observables in γ-hadron families

4.1. Main characteristics of γ-hadron families

To detect family the main interaction that is the one contributing most for observed family energy should happen not far above the chamber level. We can see from simulation in Fig.1 that $\sim 40\%$ of families have a main interaction height under 1.0 Km.

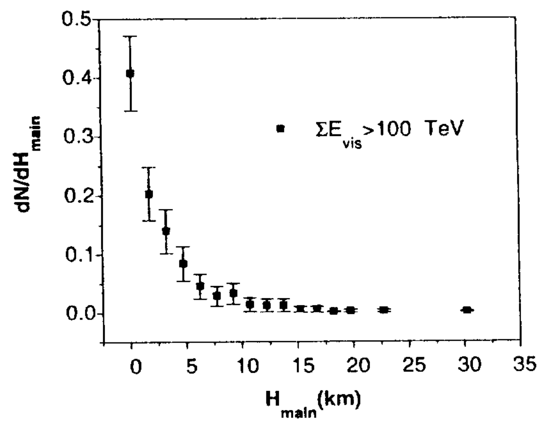

Figure 1. Main interaction-height distribution at Pamir level, for families with visible energies above 100 TeV.

Besides, $\sim$ 70% of families have H_{main} under 2.0 Km. In spite of the large fluctuations in family development in the atmosphere, majority of families is produced at low height of their main interaction. Fig.2 shows the distribution of chemical composition of the nuclei in the primary cosmic radiation (input) and in the families $\sum E_{vis} > 100$TeV (output). The atmosphere plays the role of filter for heavy component, so particles detected in the form of families mainly come from proton primaries, almost irrespectively to the primary particle abundance.

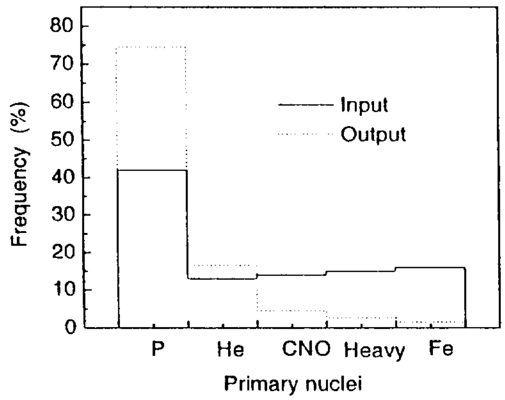

Figure 2. Distribution of the chemical primary cosmic ray composition in the simulation at Pamir level. Marks are: solid line - input and dash line - output.

4.2. Robust observables in leading jets

We examine the pattern of energy flow in individual family through the picture of jets. Jets in experiment and simulated families are constructed in a similar way, from the level of individual showers observed in the X-ray film as gamma and hadron showers, to gamma clusters constructed through decascading with parameter $Z_{dec} = 11.0$ TeVmm and then jet clusters after jet-clustering of all showers, clusters, hadrons and gamma with parameter $Z_{jet} = 200$ TeVmm and normalization of jet energy by $f_{min} = 0.04$ for $f = E_j/E_{tot}$ [11,12]. In our analysis the leading jet is close to the initial stage of family development, its main interaction. Energy fraction carried by leading jet shows signature of primary particle origin and surviving nucleon in interaction. Fig.3 gives distribution of leading jet fractional energy $f' = E_{lead}/E_{tot}$.

5. Summary and conclusions

Fig.4 shows the robust observables $r_{3,1}$ as a function of E_{lead}. Experimental values of $r_{i,1} \ll 1$

can be an indication of events with DCC formation overlaying generic events. Such behavior of robust observables indicates that there are peculiar clusters with large asymmetries in the neutral pion fraction distribution. This result shows that there could be a transformation of far-forward reaction products, formed in the beam fragmentation region into a very high mass system and its subsequent evolution to a Disoriented Chiral Condensate.

We would like to express our deep gratitude to all members of Pamir collaboration. One of us (C.E.N.) gratefully acknowledges to Prof. M. Tamada and Y. Fujimoto for the useful discussions. Also we express our gratitude to Prof. C.M.G. Lattes for his encouragement. This research was supported partly by FINEP (Federal Brazilian agency for research) and FAPERJ (Rio de Janeiro State Agency).

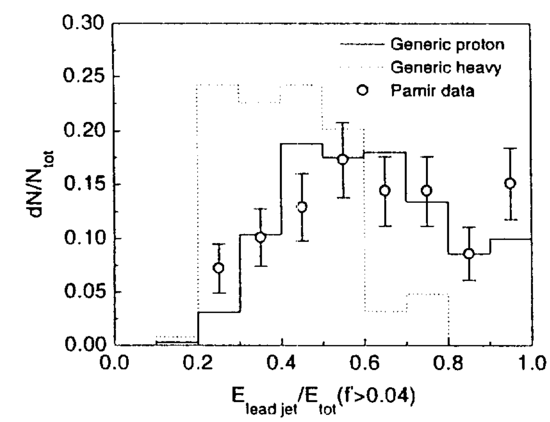

Figure 3. Distribution of the leading jet energy fraction $f = E_{jet}/E_{tot}$. Marks are: open circles - experiment; solid line - proton simulation, dash line - heavy simulation.

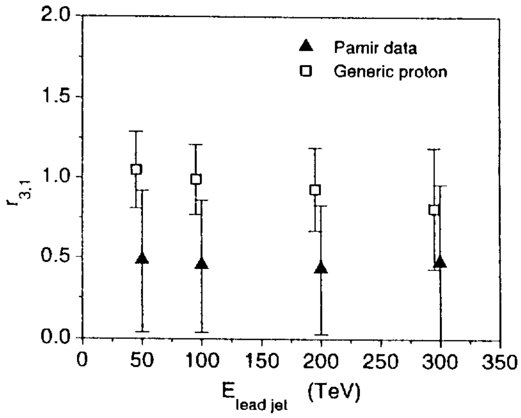

Figure 4. The robust observable, $r_{3,1}$, as a function of the visible leading jet energy.Marks are: triangles-experiment;squares-simulation.

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