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Comparison of Centauro and usual γ's events

Brasil-Japan Collaboration on Emulsion Chamber (B-J Collaboration)
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B-J Collaboration experiments discovered a high transverse momenta in hadronic interaction, through cosmic ray events. Among then, mean transverse momenta $< P_{T_h} >$ of the order of 1 GeV/c events were found and such events were nicknamed Centauro events. As the high transverse momenta are of hadronic particles, naturally it is connected with the criteria of identification of secondaries. To have more confidence on the abnormal features of Centauro events, we used the Kolmogorov-Smirnov non parametric test, aiming to show the discrepancy with normal events.

1. Introduction

Since 1962, B-J Collaboration is doing experiments on high energy hadronic interactions (E > 10 TeV), by exposing detectors to the cosmic rays. These detectors, called emulsion chambers, are settled at Mt. Chacaltaya (5220m. above sea level, geographic coordinates $16^0$20'45" South, $68^0$07'31" West, corresponding to geomagnetic coordinates $4^0$50'40" South and $0^0$50'20" East). Details of emulsion chambers composed by photosensitive materials inserted between lead plates can be found, for instance in [1].

One of the features of Centauro events is the high mean transverse momenta, around 1 GeV/c, but this high value is a consequence of proper identification of particles (i.e. dependent on the criteria for hadronic and electromagnetic components identification). The main purpose of this paper is to show that some events observed by B-J Collaboration have small probability to be classified as an usual γ-event, despite of previous identification of particles.

2. Analysis

We concentrate our analysis only on 3 candidates for Centauro events. They have common features, such as small signal on the upper part of the detector and/or vertex determined through direct measurements. They were denominated Centauro I, V and VIII. Centauro I and V have estimations of the respective point of divergence, whereas Centauro I and VIII have greater signal (more particles) in lower part compared with upper one.

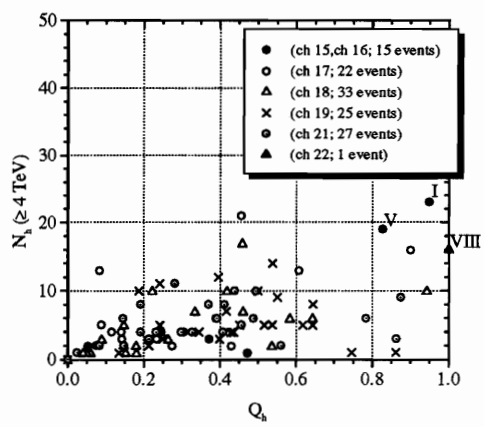

Figure 1. N_h - q_h correlation showing Centauro events concentrated on the right

Previous papers concerned on Centauro events, presented results for hadronic and electromagnetic components, separately. They show that Centauros are hadron-rich events, as in figure 1,

correlating N_h (number of hadrons) with $q_h = \frac{\Sigma E_h^{(\gamma)}}{\Sigma E_h^{(\gamma)} + \Sigma E_\gamma}$. In this figure the restriction of $N_h (\geq$ 4 TeV) is not valid for Centauro VIII, plotted with its total multiplicity. Also shows, in figure 2, that they have hadrons distributed isotropically as it are near to the analytical curve $R = \frac{\Sigma E \Sigma E \Theta^2}{[\frac{4}{\pi}\Sigma E \Theta]^2} \times \Theta$, calculated under a hypothesis of isotropic decay of secondary hadrons. Confirmation of quasi-isotropic behaviour was found in figure 3, correlating $mDW = \frac{1}{4\Sigma E}[\Sigma E + \Sigma E(\Gamma\Theta) + \Sigma E(\Gamma\Theta)^2 + \Sigma E(\Gamma\Theta)^3]$ with Θ, where the slope is $\approx$ 2, characterizing quasi-isotropic distribution of hadrons. In the case of Centauro I and V, transverse momenta distributions result in a mean value, $< P_{T_h}^{(\gamma)} >= 366 \pm 56$ MeV/c and 267 ± 43 MeV/c, respectively (figure 4), giving a $< P_{T_h} > \approx 1$ GeV/c if we use $k_\gamma = 0.3$. As all are dependent of proper discrimination between hadronic and electromagnetic components, we are trying to look for a feature characterizing Centauro as an unusual event.

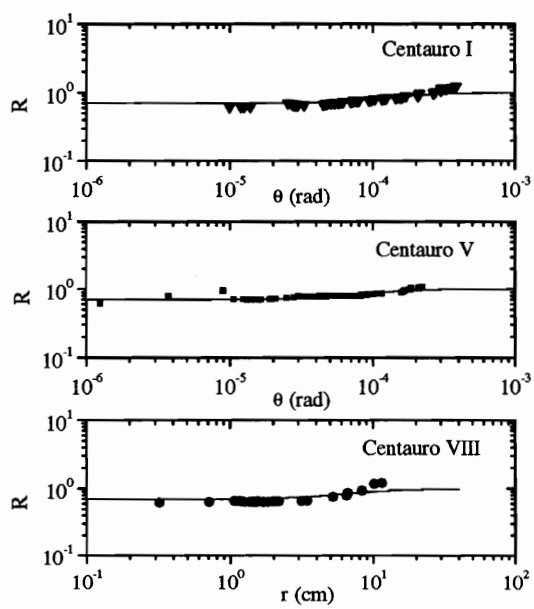

Figure 2. Plots showing a quasi-isotropic distribution of hadrons

For that purpose, distribution of fractional energy $f = \frac{E}{\Sigma E}$ (quantity similar to Feynman X parameter), of Centauro events were compared with the ones of usual γ-events with comparable multiplicity and observed total energy. Comparison of Centauro distribution shapes with joint distribution shape of 5 Guaçú events (all normalized to have the same f_{peak}, to allow comparison of shapes), shows that they are similar, but with small probability (figure 5). Figure 6 shows the same f distributions as before, but now without the f_{peak} normalization, and the probabilities are much smaller.

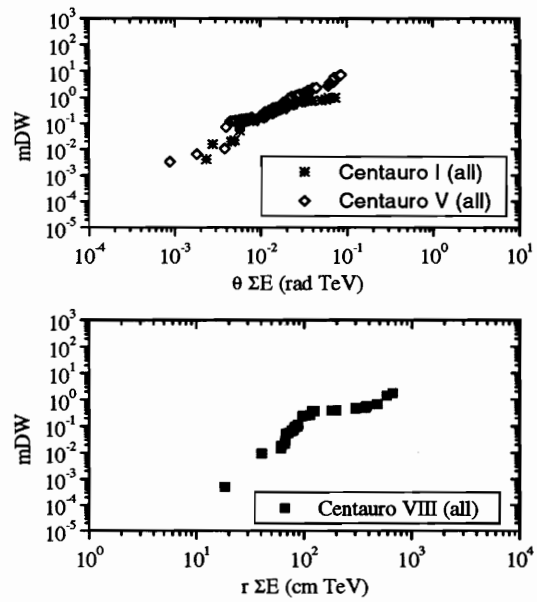

Figure 3. Distribution showing slope $\approx$ 2

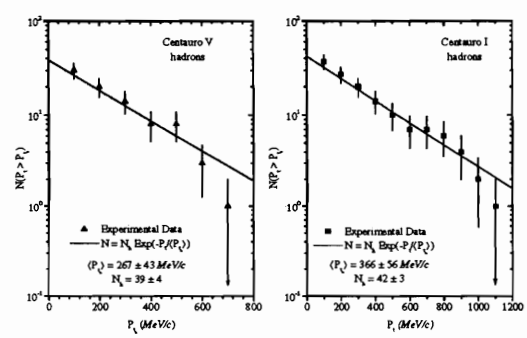

Figure 4. Distribution of $P_{T_h}^{(\gamma)}$

3. Conclusion

These analyses show comparison among Centauro and usual γ-events, having comparable multiplicity and total observed energy of particles. The analysis was made irrespectively from particles identification and shows small probabilities that Centauros and usual γ-events come from the same f distribution (Figure 6) and have rather similar shapes (figure 5).

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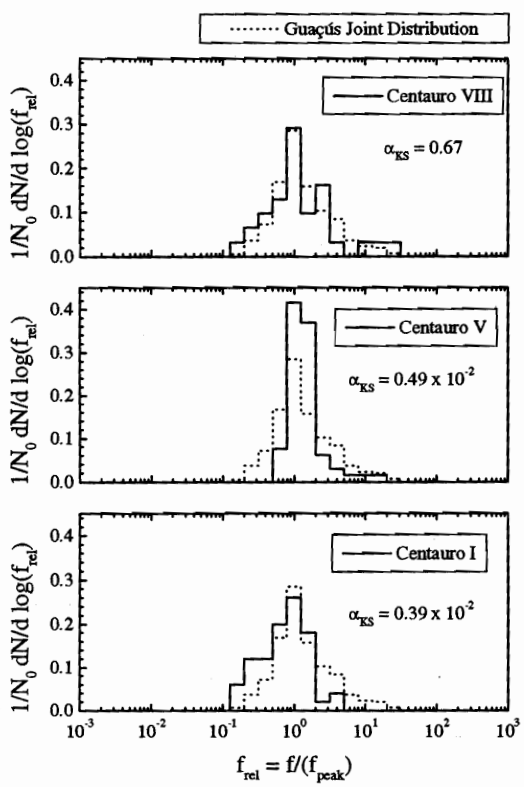

Figure 5. Comparison of Centauro and usual γ's events showing similitude of shapes

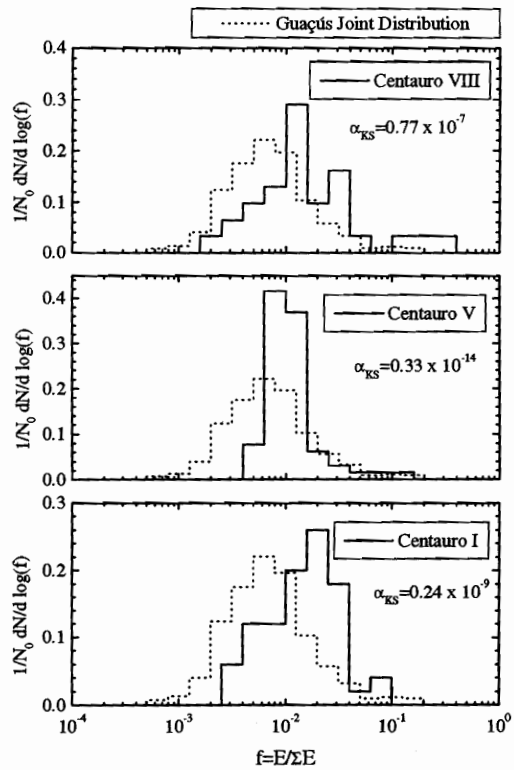

Figure 6. Comparison of Centauro and usual γ's events with very small Kolmogorov-Smirnov probability estimation

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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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