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Search of Centauro like events

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Abstract. Since 1971, Brazil-Japan Chacaltaya Emulsion Chamber Experiment is observing unusual events interpreted as Multiple Hadron Production without π^0 events. As previously reported, these events are characterized by high hadron content and no π^0 production at the interaction. Two of the five Centauro events have their interaction point determined through microscope measurements in the films of the emulsion chamber exposed at Mount Chacaltaya (5,220 m of altitude). In spite of the fact that exists other Centauro candidates, in this paper we present analysis on the beforehand mentioned 5 events because all have showers observed at both upper and lower chamber exposed at Chacaltaya and the total showers energy in the range (200-300)TeV. The comparison was done with 285 events through acceptance analysis of similar to the 5 selected Centauro events, using their physical quantities like: total energy ($\Sigma E_{showers}$), multiplicity ($n_{showers}$), emission angle related quantity ($r_{showers}$) and so on. It results that only 3 other events are comparable with Centauro events but neither of them has high hadron content. Sideways we compared with 9,360 computer simulated events and the result is only 1 compatible, in terms of the same used observables, with the 5 Centauro events.

1 Introduction

Brazil-Japan Collaboration on Emulsion Chamber Experiment (B-J Collaboration) observed unusual events with high percentage of hadrons in comparison with γ's. They are nicknamed Centauro events due to different aspects between upper and lower parts of the detector. Normal events have more showers in upper but this is not the case of the event Centauro I found in 1971. Other events with high content of hadrons were observed so far but neither of them has this remarkable characteristics. However others events have characteristics that justifies the classification as exotic events. In Table I it is written their characteristics and some of the events have other stricking features as presented below.

Centauro number	$\Sigma E_\gamma + \Sigma E_h^{(\gamma)}$ (TeV)	$n_\gamma + n_h$	*Height* (m)	*Remarks*
I	$9.0 + 221.5$	$1 + 49$	50^*	*most reliable*
II	$24.4 + 179.0$	$5 + 32$	80	*block corner*
III	$101.3 + 168.5$	$26 + 37$	230	*two blocks*
IV	$139.3 + 147.7$	$68 + 39$	500	*without central core*
V	$79.4 + 270.6$	$25 + 40^{**}$	500^*	*'Leading particle'*

Table 1. Main characterists of 5 Centauro events. The marks (*) indicates events with height determined directly, whereas the mark (**) corresponds to the highest energy hadron

2 Experimental description

A series of detectors named Emulsion Chambers have been exposed to Cosmic Radiation incident at mountain altitudes by B-J Collaboration, since 1962. This paper concerns to the observation of the secondaries produced by Hadronic Interactions induced by Cosmic Ray Particles incident on Mt.Chacaltaya (5220m above sea level and 20 km far from La Paz City, Bolivia). This Cosmic Rays Observatory (geomagnetic coordinates $4^0 50' 40''$ South and $0^0 50' 20''$ East) was inaugurated in scientific activities in the year 1947 with the π-μ events and since then are showing some remarkable scientific informations, maybe due to its privileged location in a direction of the center of Galaxy. Since 1969 the Emulsion Chambers settled there have area size comparable to the summed area of previous 13 previous detectors. Also an improvement of the experiments was the inclusion of a fixed target of asphalt pitch, nowadays blocks of compacted and amalgamated plastic sheets. Between the target and the floor of the room there is an air gap of 170 cm thick. Over the tar-

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get and also over the floor are settled envelopes with photosensitive material inside them, constituting a kind of carpet. Inserted between the envelopes, there are lead plates working as a converter of electromagnetic particles in the electron/positron showers. The lead plates that are the converter would act also as a target material for hadronic particles. So, the photosensitive material (X-ray films and Nuclear Emulsion plates) registers showers of electron/positron converted from γ's coming mainly from π^0 decay. Other hadrons ($\pi^{\pm}$, p, n, etc.) could interact with the atmosphere molecules, carbon and lead, then obviously named A-jet, C-jets and Pb-jet, respectively. So, the spots seen in the films are always from γ's showers, these produced mainly by π^0's. By obvious reasons the upper and lower parts of the detector are called Upper and Lower Chamber. The event named Centauro I is unusual because it mimics an event coming from the botton and leaving to the atmosphere above the detector. That is not the case, because the measurements of shower spots results in an increasing distance between pairs of them as we go downstream inside the detector. So, the simplest and naive interpretation is to assume a Multiple Production of Hadrons without π^0's, as this behaviour is not usual for γ's. Since this event observation, other events with high content of hadrons were found. In spite of their similitude with the first one in this aspect, they present more showers in Upper than in Lower Chamber, as usually. An exception is the event named Centauro VIII which has recocgnizable showers only in the Lower Chamber. Besides the absence of signal in the upper part of the detector, this event has total energy very different from the selected Centauro candidates and by these reasons it was not included in the present analysis. Another remarkable Centauro event presenting stricking features is Centauro V(C16S086I037). This event has a peculiar characteristic of a very high energy shower (around 20% of total energy of showers) and 2 successive interactions in the Lower Chamber, without observable signal in the Upper Chamber. Moreover this Centauro candidate has a direct estimation of height (500 $^{+206}_{-113}$ m), through measurement on a distance of one pair of showers in both, Upper and Lower Chambers. Detailed analysis of Centauro V will be presented in (Improved analysis of one centauro candidate event. C.R.A.Augusto et al. (2001)).

3 Acceptance analysis

Measurements of $e^{\pm}$ in both X-ray films and/or Nuclear Emulsion plates, yields energy and multiplicity of showers, directly. Then, to look for Centauro similar events, we first did unsuccessful search for usual events with same parameters of Centauro ones.

From the informations on energy and multiplicity we estimate the energy weigthed center. So, all the following physical quantities (azimuthal and zenital angles, transverse momentum, etc.) depends on the energy. Even the multiplicity, that is one observable quantity, depends on the energy, through threshold energy effect. So, the next procedure to

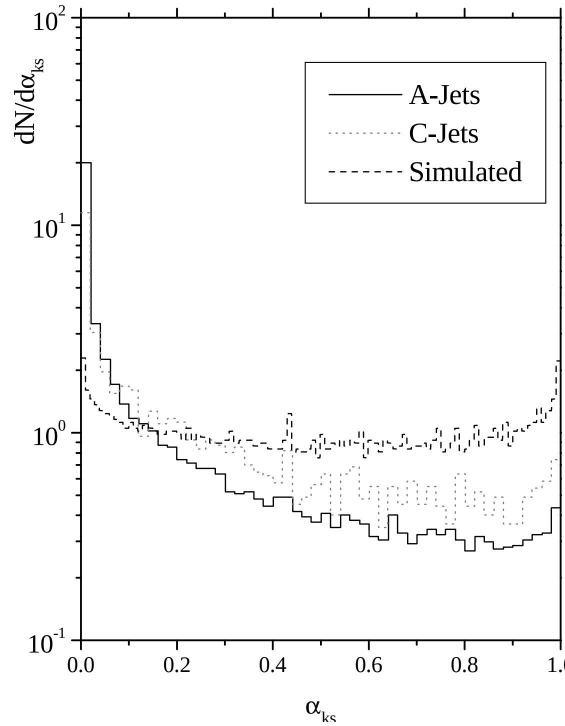

Fig. 1. Kolmogorov Smirnov parameter of pairs of events

look for Centauro similar events was the total energy, using the Kolmogorov-Smirnov statistical analysis (Numerical Recipes in Fortran. W.H.Press et al. (1992)). The results are seen in figure 1, with separate plots for experimental events (87 C-Jets and 288 A-jets, including 5 Centauro events) and 9,360 simulated A-jets events (M.Tamada used CORSIKA/QGSJET and a simulation of the detector.Part of the results gotten, was used in the reference M.Tamada & A.Ohsawa (2000)) under CORSIKA5.20 code (Knapp et al. (1997)), employing QGSJET model (Kalmykov et al. (1994)). It is clear that both experimental events distributions looks similar, but they differ from simulated ones. Due to this and to the difference between experimental and uniform distribution, our conclusion is that the experimental distribution already is showing various types of interactions. Unfortunatelly, this analysis could not inform how much and which usual events are similar to the 5 Centauro ones.

Following the acceptance criteria we used other physical quantities (total energy, multiplicity, mean zenital angle, mean transverse momentum, azimutal angle, 'sphericity') and ad hoc statistical quantities ('dqm' and 'relm'). The quantity 'relm' is defined as a relationship between quantity of showers emitted forward, compared with the total multiplicity. We adopted for 'relm' ≥ 0.5. The quantity 'dqm' is defined as,

$$dqm = \frac{\sum_{i=1}^{N} \left(R_i - R(\bar{r}, r_i)\right)^2}{N} \qquad (1)$$

where N is the multiplicity and R is defined in the reference

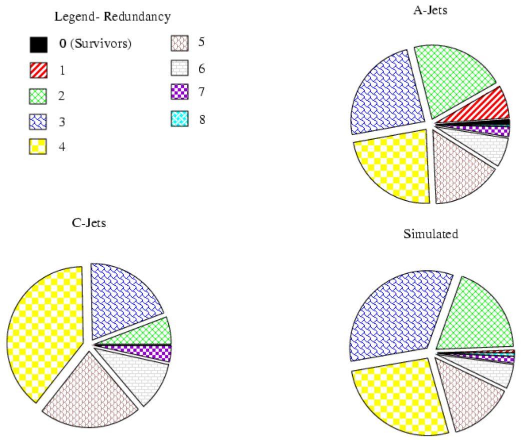

Fig. 2. Plots of 'surviving' events

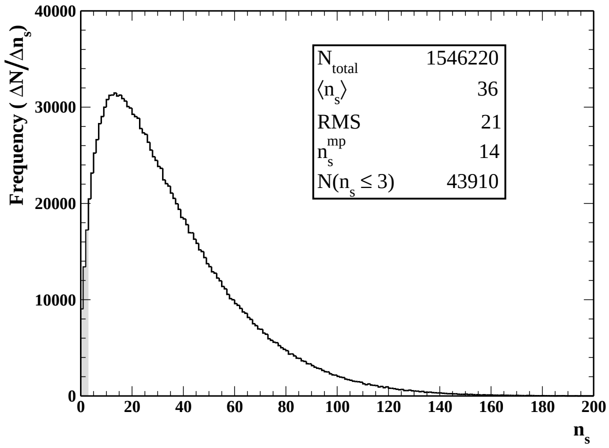

Fig. 3. 'Confidence' analysis

(Algorithms based on isotropic azimuthal angle distribution of interaction secondaries. C.R.A.Augusto et al. (2001)). There it is shown that the algorithm R is a function of Lorentz factor and zenital angle. When it is not possible to know the height of the interaction we could use a quantity proporcional to the zenital angle. In particular the algorithm R is convenient due to the opposite effects of height in both, Lorentz factor and zenital angle.

In this reference also there is the definition of 'sphericity'. As this quantity is obtained from an algorithm named mDW, the same favourable condition, mentioned above, is used to their estimation. These criteria are used to establish the acceptable range of the quantities of 5 Centauro events. Throwing out the usual events that are out of the ranges, we constructed a 'redundancy' figures, condensated in the figure 2. To each slice corresponds a number of criteria (see legend). The size of a slice is proportional to the number of families rejected by the correspondent number of criteria. The idea is to show that the major part of 'non-surviving' events are rejected by two or more criteria.

In the figure 3 it is presented an analysis about the independency of the results with the particular choice of 5 events. It is observed that in the sub-sample of 1.5×10^6 combination of any 5 events, the probability of getting 3 'survivors' is small ($\sim$ 3%).

4 Conclusions and discussions

Figure 4 presents results of C-jets and Centauro events of B-J Collaboration compared with acelerator data (Transverse momentum spectra for charged particles at the Cern Proton-Antiproton Collider.UA1 Collaboration (1992)) and (Multiplicity Dependence of the Transverse-Momentum Spectrum for Centrally Produced Hadrons in Antiproton-Proton Collisions at $\sqrt{s}$ = 1.8 TeV. T.Alexopoulos et al. (1988)). It is necessary to say that the C-jets data is for γ's and so, its P_T value must be multiplied by 2, approximately. This figure shows that Centauro events secondary particles, supposing as γ's, fits with C-jets events. However, from figure 2 we did not found any C-jet compatible with Centauro events. Then, only the Centauro secondaries, properly identified as hadrons, must be corrected by a factor of inelasticity, because in C-jets there are not predominancy of hadrons. Here, we used its mean value, $\bar{k}_\gamma = 0.3$ and the Centauro events occupaies a region of (0.8 - 1.8) GeV/c and (10 - 17) for mean transverse momentum and rapidity density, respectively. Even using $\bar{k}_\gamma = 0.4$, the mean transverse momentum region decreases to (0.6 - 1.4), somehow greater than acelerator data.

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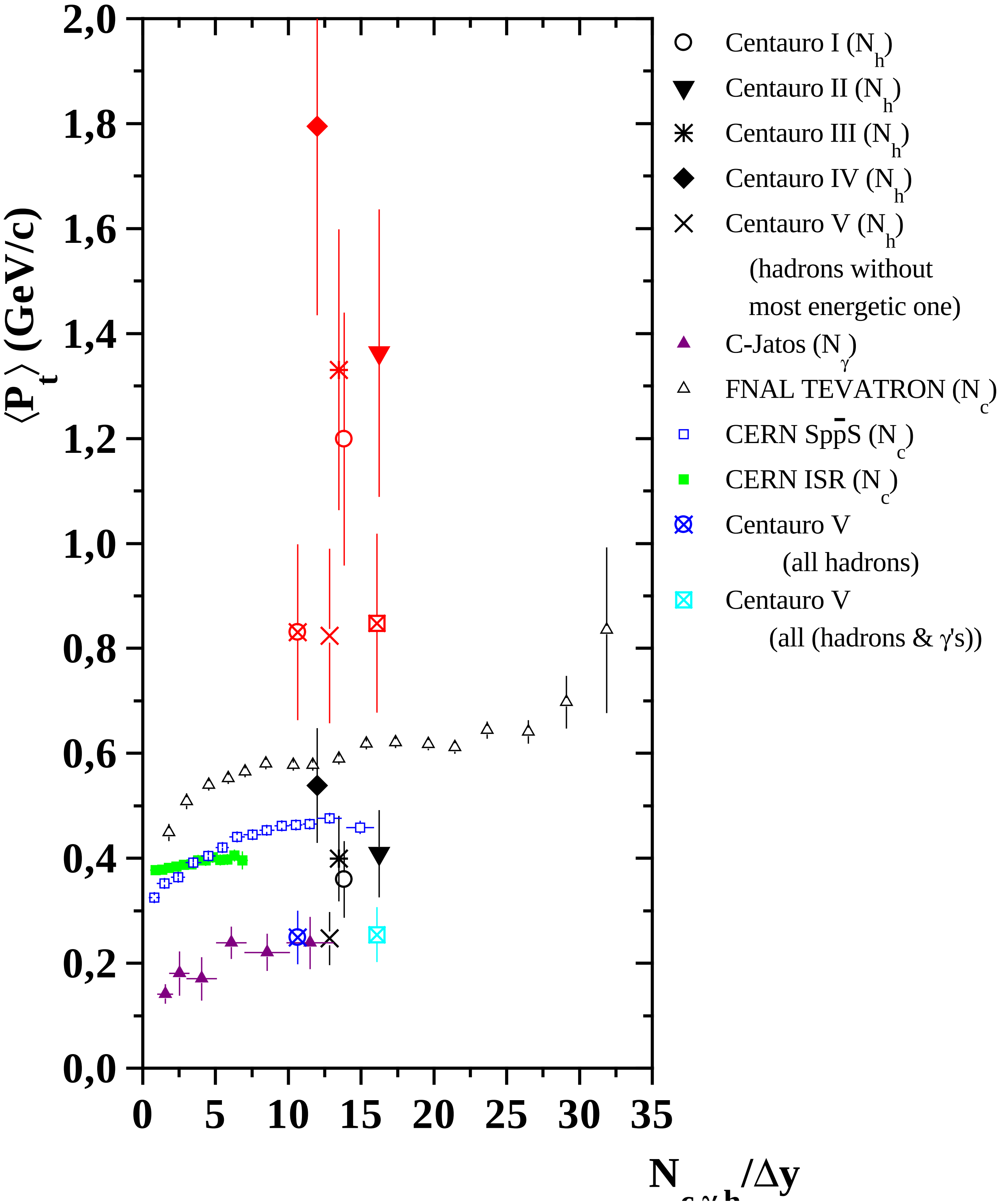

Fig. 4. P_T - rapidity density correlation