An analysis of high energy cosmic ray gamma-hadron families

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Abstract

An extensive Monte Carlo simulations of high energy cosmic ray families detected at high mountain altitudes by X-ray emulsion chambers have been performed. The hadron interactions are described on the basis of collider data (UA5 model) and QCD calculations (VENUS model). Several observables are presented and their dependence on models are compared with experimental data. There is an agreement between simulation and experiment for basic observables. However, it is found that experimental neutral pion fraction distribution can hardly be explained within framework of both models.

1 Introduction:

We analyze cosmic ray families observed by means of emulsion chambers exposed at mountain altitudes (the Pamirs, 4300 m) (Baradzei et al., 1992). The energy region of the families detected in our experiment (100 $TeV < \Sigma E_{vis} < 900\ TeV$) is overlapped with the one of present collider accelerators. The family is initiated by a cosmic ray particle (for instance a proton) which penetrates deep in the atmosphere. The atmospheric cascade is considered to be the chain of successive interactions with production of mainly pions as can be seen in the study of C-jets in cosmic ray experiment (Lattes et. al., 1980) and in the collider minimum bias events (Abe et. al., 1992). Recently there has been a growing interest to the possibility of production of disoriented chiral condensate (DCC) in a high energy collisions (Bjorken, 1992). This hypothesis gives one of explanation for peculiar events with large isospin fluctuations known as Centauro (Lattes et. al., 1980).

2 Experiment and Simulation:

We use experimental data from thick lead chambers of homogeneous structure exposed at the Pamirs in 1988-1991 (Arisawa et. al., 1994). The present analysis is based on 59 families found in $\sim 57\ m^2 year$ of exposure[1].

For comparison with experiment we have used two simulation codes for calculation of atmospheric families: phenomenological UA5 algorithm (Alner et. al., 1987) (10000 events) VENUS (Knapp et. al., 1997) (5000 events).

3 Jet Picture:

To construct the energy flow pattern representing main stream of energy in a family we make the following steps (Augusto et. al., 1999): 1) decascading of γ showers to clusters with parameter $D_{dec} = 12$ TeVmm; 2) jet-clustering of all showers ,clusters, hadrons and γ with parameter $K_{jet} = 200$ TeVmm ; 3) normalizing jet energy by setting threshold $f_{min} = 0.04$ for their fractional energy

$$f = E_j/\Sigma E_{vis}.$$

[1]This database is part of the project MSU-Waseda on joint study of cosmic ray families of $100 m^2 year$ exposure. The rest of data is currently under analysis

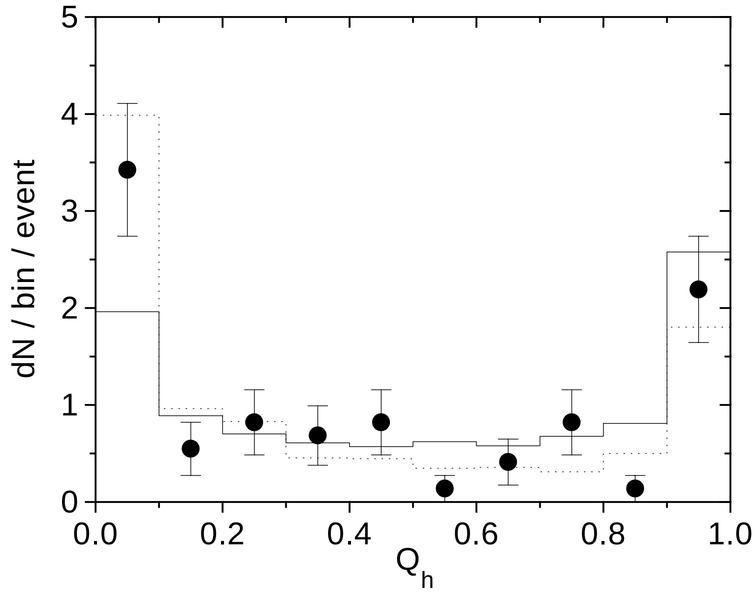

Fig. 1. Distribution of the energy fraction occupied by hadron component in forward leading jets. The marks are: experiment - circles, solid line - UA5 model, dotted line - VENUS model.

By this way number of jets $n^{'}$ $(> f_{min})$ will have some of the original features of the parent nuclear interaction. In our analysis to trace family back the leading jet is close to the initial stage of family development.

4 Fraction of Hadron Energy Inside of Leading Jet:

Fig.1 shows the distribution of the energy fraction occupied by hadron component (individual hadron showers) in leading jet. This fraction Q_H is defined as

$$Q_h = \frac{\sum E_h^\gamma}{\sum E_h^\gamma + \sum E_\gamma}.$$

These distributions are similar to the usual correlation between number of hadrons in a family N_h, and the energy fraction which hadron component occupies in family energy Q_h (Baradzei et al., 1992). We can see agreement between simulation (solid line is for the UA5 model and dashed line for the VENUS) and experiment (circles).

5 Neutral Fraction Pion Distribution Inside of Family and Leading Jet:

The neutral pion fraction defined as

$$f = \frac{N_{\pi^0}}{N_{\pi^0} + N_{\pi^\pm}}$$

is shown in Fig.2. The expected distribution of f, under the assumption of isospin conservation in pion multiple production follows to binomial distribution and has a maximum at f=1/3. We can see that even after degradation by cascade processes, both experiment and simulation are still consistent with a binomial distribution represented by a solid line.

6 Robust Observables:

The robust observables (Brooks et. al., 1997) 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

$$F_{i,j} = \frac{< n_{ch}(n_{ch}-1)...(n_{ch}-i+1)n_\gamma(n_\gamma-1)...(n_\gamma-j+1) >}{< n_{ch} >^i < n_\gamma >^j}.$$

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

$$r_{i,1}(DCC) = \frac{1}{i+1}.$$

Experimental values of $r_{i,1} \ll 1$ can be an indication of events with DCC formation overlaying generic events. Fig.3 shows the robust observables $r_{3,1}$ as a function of E_{lead}. Such behavior of robust observables indicates that there could be a transformation of far-forward reaction products, formed in the beam fragmentation region into a very high mass system, with subsequent evolution to a DCC.

7 Acknowledgments:

We would like to express our deep gratitude to all members of the Pamir collaboration. This research was supported partly by FAPERJ (Rio de Janeiro State Agency).

References

Abe, F. et al. 1992, (CDF Collab), Phys. Rev. D45, 2249
Alner, G. L. et al. 1987, (UA5 Collab),., Nucl. Phys. B291, 445
Arisawa, T. et al. 1994, Nucl. Phys. B 424, 241
Augusto, C.R.A. et al. 1999, Phys. Rev. D 59, 054001
Baradzei, L. T. et al., 1992, Nucl. Phys. B 370, 365
Bjorken, J.D. 1992, Acta Phys. Pol. B 23, 561
Brooks, T.C. et al. 1997, Phys. Rev. D 55, 5667
Knapp, J. et al. 1997, Nucl. Phys. B52 (Proc. Suppl.), 136
Lattes, C. M. G. et al. 1980, Phys. Rep. 65, 151

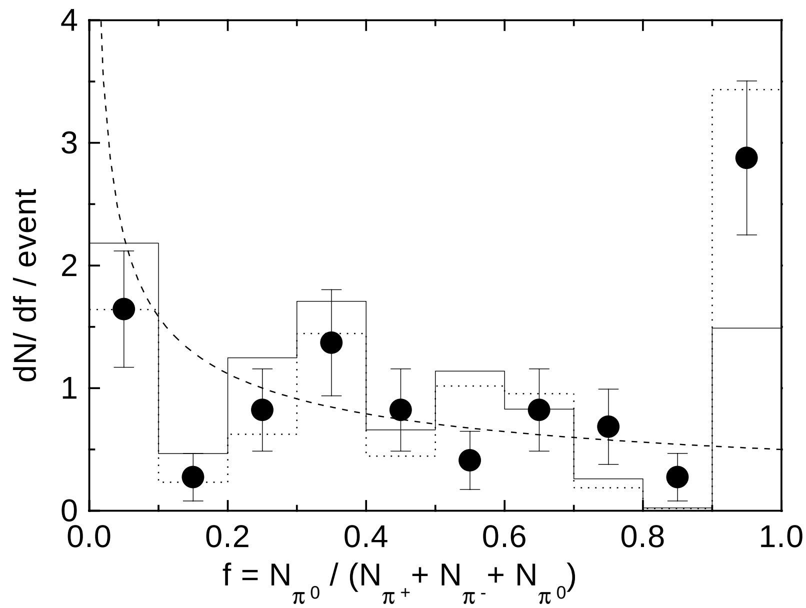

Fig. 2. Distribution of the neutral pion fraction inside of forward leading jet. The dashed line shows the f distribution expected under the assumption of DCC domain formation. The marks are the same as Fig.1.

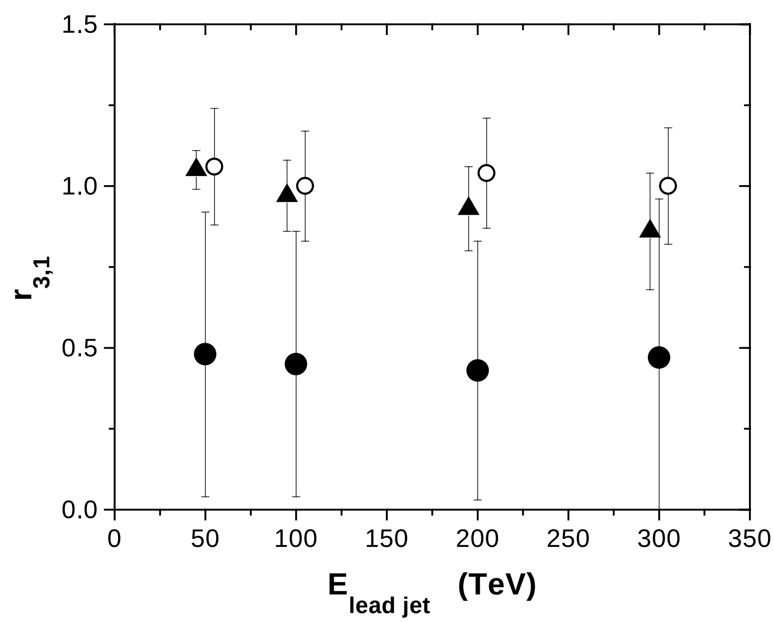

Fig. 3. The robust observable, $r_{3,1}$, as a function of the visible leading jet energy. The marks are: solid circles - experiment, triangles - UA5, open circles - VENUS.