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Coplanar emission in gamma ray families, geometrical and dynamical coincidence or new mechanism?

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Abstract. The remarkable event JF2af2 observed near 10^7 GeV in the emulsion chamber embarked on the Concorde shows a perfect alignment of the most energetic gamma's on the X-ray film. To investigate the origin of this phenomenon which indicates a coplanar emission, we have simulated some samples of stratospheric gamma ray families with CORSIKA code and different interaction models. Events with such common features are selected by a simple least square method. The dependance of this phenomenon on favourable geometrical circumstances (a very large transverse momentum for one very energetic secondary near the vertical plane and a large zenith angle) is investigated. The Concorde event (52° of inclination) may enter in this category (with a typical gap between the main clusters). Simulations are also carried out at Pamir altitude where such mechanism would give a probability rising with zenithal angle.

1 Introduction

During the last 20 years, 8 emulsion chambers have been flown on the Concorde for different measurements: very high energy jets, stratospheric γ-ray families, γ-ray flux (Iwai *et al.* 1982, Capdevielle *et al.* 1979, 1987, 1988), hyperstrange baryonic matter (Capdevielle *et al.* 1995) and emulsions for dosimetry. All the detectors, but the last one, were enough thick to measure, at least, the energy of secondary γ-rays up to 1000 TeV, allowing to initiate the collection of informations on multiproduction in the energy range between the limit of the present colliders and the LHC. The present work is devoted to the most energetic event showing a coplanar emission.

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2 Experiments in the low stratosphere

2.1 Exposure of emulsion chambers of high resolution

Regular atlantic flights provide a "plateau exposure" of more than 2 hours. The same X-ray emulsion chamber carried on a hundred times above the atlantic is then exposed during at least 200 hours at an average altitude of 17 km. This corresponds, as indicated by the Concorde flight curve, to an atmospheric depth of 100 g/cm^2. The exceptional event described here was obtained in a such typical run with a classical structure (2 sheets of Sakura N type X-ray film and one emulsion ET7B plate below 0.25 cm lead plate). The X-ray films are used to build the map of the chamber and have a first estimation of the energy. The target diagrammes (in case of contained jets) are constructed with the emulsion plates and the development of each individual cascade is followed by counting the number of electrons tracks within circles of radii from 10 up to 100 μm to measure the shower energy with an accuracy of 17%. Events occuring above the chamber or in the upper part of the chamber are then measured from their e.m. component. The small thickness of the chamber (to limit the weight) doesn't allow the measurement of the energy of the hadrons. Some flights were also performed by Alitalia (to determine the γ-ray energy spectrum) and with the Japan airline for high energy events at 270 g/cm^2 of atmospheric depth.

2.2 The Concorde event near 10^7 GeV

The photography of this event as it appeared to the naked eye from the X-ray is reproduced on figure 1. It shows a clear alignment of the most energetic γ-rays. The 211 γ's (above 200 GeV) of this event were identified with their respective coordinates and energies; the analysis was then focused on the typical multicluster structure and the planarity, ascertained by naked eyes on the X-ray film, was confirmed, suggesting a multijet structure (Capdevielle *et al.* 1988).

The analysis of individual γ-rays revealed that, when taken

Fig. 1. Coplanar emission visible in the event JF2af2

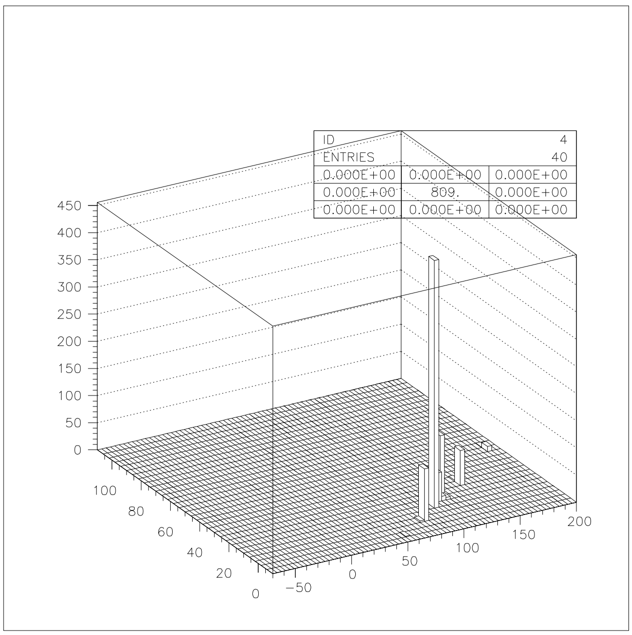

Fig. 2. Central part of the event JF2af2

E_γ (TeV)	x (mm)	y (mm)
300	100.410	11.077
105	117.468	18.109
75	84.240	5.022
53	110.428	15.551

Table 1. The 4 most energetic γ-rays for the JF2af2 event.

in the order of decreasing energies, the most energetic γ's are situated on a perfect geometrical straight line. The general aspect of the event is shown on the lego-plot of figure 2 (central part) where the coordinates are plotted in mm and the visible energy is plotted on the vertical axis in TeV. This lego-plot displays the topology obtained for the 4 most energetic γ-rays (above 50 TeV) listed in table 1 and the 38 γ-ray aligned extracted from the 211 γ's of the event. The regression coefficient of the straight line determined by the coordinates of those 4 γ's is 0.9993 and it remains equal to 0.992 for the 38 γ's aligned containing 808 TeV, i.e. 51% of the visible energy.

The atmospheric layer, the cabin atmosphere and the cabin wall represent less than 30 g/cm^2 at this altitude and the alignment structure has been pointed out without decascading procedure. When compared to the events recorded in the Pamir experiment (Slavatinsky 1997) suggesting more frequent coplanar emission above 10^7 GeV, i.e. $\sqrt{s} \sim 5$ TeV, this event confirms this tendancy (which was not observed for the events at lower energies). The very large multiplicity of this event, for such energy, would imply a larger isotropy for standard multiproduction models: on the opposite, the near perfect alignment observed remains one serious interpellation of the pre-LHC physics in terms of unidimensional properties of hadronic matter at ultra-high energy.

3 Simulations of γ-ray families

We have reproduced the different conditions of registration at mountain and Concorde altitudes to examine here the chances of coplanar emission from pure coincidences or fluctuations of normal interactions described with standard models of multiple production. In a next step the consequences of diquark breaking or phase transition to QGP will be investigated.

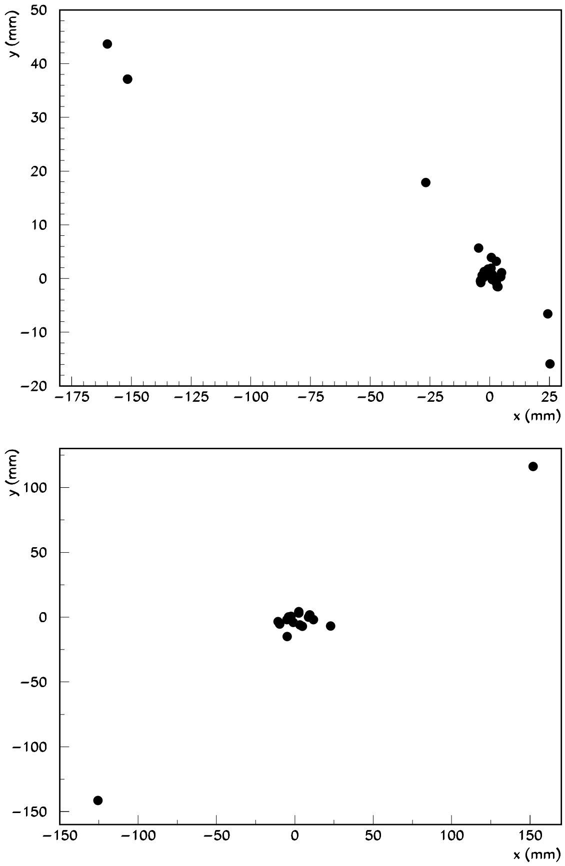

Fig. 3. Examples of aligned γ's in 2 simulated events.

3.1 Simulations in the low stratophere

From some simulations with CORSIKA code (Heck *et al.* 1998), we noticed at first that the energy distribution of the photons for the JF2af2 event is easy to reproduce and that the superposition of 3 successive collisions up to the level of Concorde is a common circumstance. A special set of simulations has been carried out with the same zenithal angle than for JF2af2 of 52° for 100 events. This was done with HDPM2 model (Capdevielle 1989) taking into account recent features from collider physics such as $p_{\rm t}$ versus central rapidity density (UA1-MIMI experiment) and recent results of Fermilab for pseudo-rapidity up to 5.5 (Capdevielle 1999). As it was not possible to scan each individual event, it was requested to calculate the linear regression line from the coordinates of the γ's and to plot only the events with a regression coefficent larger than 0.90. The event n° 47 of this serial selected by this method shows a nice alignment of 32 γ's (figure 3 top). The similarity of the clusters (γ's above 10 TeV are plotted) with those of figure 1 is especially interesting.

Tracing back the genetics of this event, it belongs to the normal NSD multiple production with high multiplicity. The first collision occured at an altitude of 24 km and the regression coefficient of the 32 γ's (above 10 teV) is 0.968 with a total energy deposited of 815 TeV. The main features generating the alignment are here high multiplicity and important zenithal angle. Both circumstances combine as follows: the probability to get a large transverse impulsion is enhanced in high multiplicity events and this large $p_{\rm t}$ can be devoted to a gamma of high energy. This collision can be close, as here, to the vertical plane. The rest of the cluster is displayed in the opposide direction ($p_{\rm t}$ conservation) and the maximal separation between γ's appears in the horizontal plane (the emulsion or X sheets) with a characteristic gap visible in figure 1 and 3 and in some events of Pamir. In our sample of 100 events, we have counted 2% of events with $r \geq 0.95$, 6% events with $r \geq 0.90$, 10% and 18% with r exceeding respectively 0.80 and 0.70. This event also shows a minimal and major displacements corresponding to bremsstrahlung or pair production near the first collision. Figure 3 (bottom) shows another aligned event with similar characteristics to the previous event obtained with a second set of simulated events. In this case the first interaction occured at an altitude of 20 km with a zenithal angle of 30°. The regression coefficient is equal to 0.97.

3.2 Simulations at mountain altitude

The alignement in events recorded in altitude with emulsion chamber have been observed in the two last decades. The X-ray chamber of larger area have increase this probability. However, the experimentalists didn't pay attention to this phenomena and a clear alignemnt of secondaries can be found in a photo reported by J.Nishimura, during London ICRC (1964). In Pamir experiment, coplanar emission has been reported for both gamma'a and hadron families.

We have carried out some simulations at Pamir altitude and scanned, as before, aligned events. We have noticed that the first interaction in the case of alignment occurs in general at high altitude with a large zenithal angle. With a primary proton of 10^7 GeV, we have counted 11.6% of aligned events with $r \geq 0.95$, 14.4% with $r \geq 0.90$, 19.1% with $r \geq 0.80$ and 22.4% with $r \geq 0.70$.

3.3 Energy distributions

As the Concorde event exhibits a remarkable property in energy distribution, i.e. exactly a half of the visible energy is contained in the alignment, we have analysed the part of energy contained in our simulated and aligned events and found that it varies from 20% to 60%. It happens that if commonly a small number of secondaries can carry out a large part of energy, there are few chances to obtain such situation which could be the hint of new processes in the interaction, such as the diquark breaking mechanism. This property may also be a pure coincidence,as shown in several events simulated.

4 Discussion

The combination of a large transverse momentum generated in the vertical plane (or in the neighbourhood) for an energetic secondary at the first collision can be at the origin of the alignments observed in emulsion chambers. In that case the coplanar emission appears near 10^7 GeV where the ratio of the primary energy to the energy threshold of the chamber is the most favourable. More simulations are needed to confirm the increase of the probability of alignment observation at large zenithal angle with a characteristic gap. The zenithal angle distribution of coplanar events, associated to the frequency versus observed energy are probably the best criteria to understand if we have here a pure geometrical-high multilicity fluctuations in NSD component artefact or if this is a footprint of new physics.

References

Capdevielle, J.N. *et al.*, Proc. 16th Int. Cosmic Ray Conf., Kyoto, 6, 324, 1979.

Capdevielle, J.N. *et al.*, Proc. 20th Int. Cosmic Ray Conf., Moscow, 5, 182, 1987.

Capdevielle, J.N. *et al*, J. Phys. G: Nucl. Part. Phys., **14**, 503, 1988.

Capdevielle, J.N., J. Phys. G: Nucl. Part. Phys., **15**, 909, 1989.

Capdevielle, J.N. *et al.*, Proc. 24th Int. Cosmic Ray Conf., Roma, 1, 910, 1995.

Capdevielle, J.N., Proc. 26th Int. Cosmic Ray Conf., Salt Lake City, 1, 111, 1999.

Capdevielle, J.N. *et al*, Astropart. Phys., **13**, 259, 2000.

Heck, D., Knapp, J., Capdevielle, J.N. *et al.*, Report FZKA 6019, 1998.

Iwai, J. *et al*, Nuovo Cimento, **A69**, 295, 1982.

Slavatinsky, S.A., Nucl. Phys., **52B**, 56, 1997.