



Remarkable events from X ray emulsion chambers and multiple production at LHC energy

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Abstract: The interpretation of X-ray emulsion chambers data on super gamma ray families at mountain altitude and in the stratosphere is carried with CORSIKA and specific collision generators. The violent rupture of the string under very high tension between the partners of the valence diquark might explain the intriguing alignments registered in the energy band between colliders and LHC.

Introduction

Among several remarkable features of the cosmic ray data collected in the energy range between present colliders and LHC (Centrauro's, clusters, halos, large P_t 's, spikes in rapidities...), the coplanar emission appearing around 10^{16} eV merits a special attention. Our simulations have demonstrated [1] that such phenomena can be explained by fluctuations with standard physics. However, in the case of two events observed in the stratosphere, several features contradicts such explanation. According to the properties of those events with a minimal cascading, we explore the hints of new physics which could explain the alignment in terms of relativistic strings and diquark breaking. The asymmetry of the events is characterized by the linear correlation coefficient r from the coordinates of the γ 's or by the parameter λ_n used in Pamir [2].

Coplanar events in the stratosphere (Concorde and Siberian balloon flights)

The most energetic event of Concorde data arrived under a zenith angle of 52° with a deposited energy of 1600 TeV by 211 γ -rays (above 200 GeV), suggesting a primary energy of 10 PeV [3]. When

sorted in order of decreasing energy, it comes out that the 4 most energetic γ -rays (above 50 TeV) stand along a perfect geometrical straight line ($r = 0.9993$ and $\lambda_4 = 0.9972$). The topology of JF2af2 is displayed as a *lego-plot* on fig. 1 for the 34 γ -rays aligned containing 808 TeV, i.e. 51% of all the visible energy.

Tracing back inside our CORSIKA data bank the genetics of events exhibiting a very clear alignment, we ascertained the source in normal NSD primary interaction with a high multiplicity combined with a large distance between the chamber and the first collision (10km): the probability to get a large p_t is enhanced in high multiplicity events and this p_t can be assigned to a high energy γ -ray. The rest of the cluster is displayed in the opposite direction (p_t conservation) and the maximal separation between γ -rays appears in the horizontal plane with a characteristic gap visible on X-ray films.

For the earliest Siberian balloon flight (SBF), the calorimeter was deep enough to collect the energy deposited also by the secondary hadrons with one energy threshold for γ 's and hadrons of 2 TeV. In the case of the XREC of Concorde, it was not possible to follow the hadronic contribution, but the energy threshold for γ 's of 0.2 TeV provided a better resolution. Taking into account the differ-

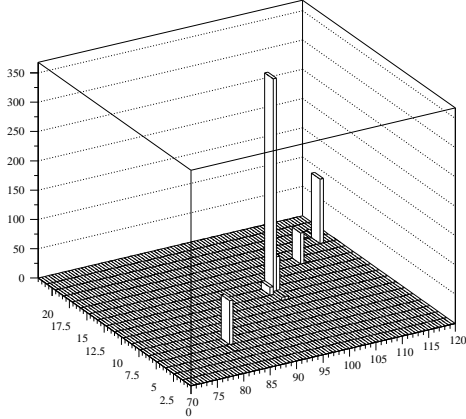


Figure 1: Lego-plot of the central part of the event JF2af2 (34 γ -rays).

	$\sum(E_\gamma)$	N_γ	E_{th}
JF2AF2	1586.	211	0.2
STRANA	1400.	76	2.

Table 1: Total energy deposited for JF2AF2 and STRANA (e.m. component)

ent energy thresholds of the XREC's used for both events, respectively 200 GeV for JF2af2 and 2 TeV for STRANA [4], we observe first that the visible energy deposited in γ rays is very similar, as shown in table 1.

In the case of STRANA, the hadronic accompaniment is observed for the central jet with 30 hadrons depositing a total energy of 2500 TeV.

Vertex localization, invariant mass method, $\langle ER \rangle$ factor

For non contained events, the tracks appears parallel as far as the distance to the vertex exceeds more than 50 m and the geometrical convergence measurements are no more valid. The height of the primary collision can be approached by the invariant mass method, assuming that the γ 's originates

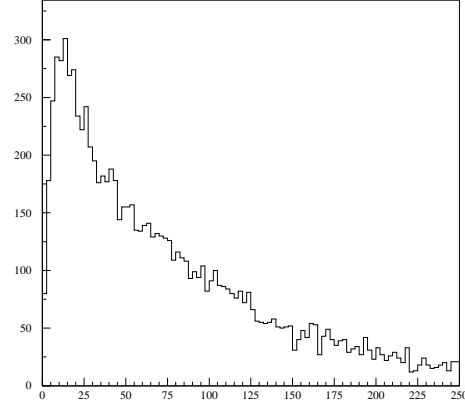


Figure 2: Invariant mass histogram for the 77 γ -rays of cluster B (invariant masses in TeV-mm).

Jet	$\sum(E_\gamma)$	X	Y	N_γ	R	$\langle ER \rangle$
A	331.	81.3	7.1	60	8.6	35.8
Ap	455.4	100.5	11.2	10	0.5	13.1
B	610.6	114.	22.	77	10.3	75.6

Table 2: 3 main clusters in JF2AF2.

mainly from neutral pion decay, by the $\langle ER \rangle$ factor assuming an average transverse momentum of $0.2 GeV/c$ for γ 's and by the best fit of pseudo-rapidity distribution for a given height.

The histograms of invariant mass have been constructed for JF2af2 for the total event as well as for the individual jets A, Ap, B and we derive from the maxima of the histograms the respective heights around 80 m (for total), 65 m, 75 m (as for total). The histogram of Jet B is shown for example (fig 2). Those histograms are taken directly from the emulsion chamber scanning diagram with possible pairs of γ 's mixing $\gamma+e^\pm$ and incorporating γ 's of multiple generation.

Those values are however submitted to large uncertainties (η and K mesons production), an error of 10 – 20% on coordinates and energy measurements, proportion of γ 's of 1st generation, but they suggest that the γ 's of the 3 major jets of JF2AF2 (characteristics plotted on table 2 are generated at less than 300 m above the chamber.

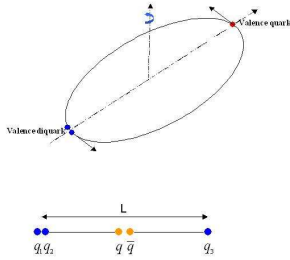


Figure 3: valence quarks and diquarks, string tension.

The $\langle ER \rangle$ factors (table 2) that indicates an origin of 325 m for Jet B, instead of an origin of 175 m for Jet A and 65 m for Jet Ap. The effect simulated of the XREC energy threshold explains the discrepancy in the number of γ 's observed in Concorde and STRANA. The close production of the photons does not enter in the fluctuation background produced with standard multiple production and suggest to go further in the theoretical investigations (reviewed in [3]).

Strings between valence quarks, valence diquark breaking and coplanarity

According to the simplified presentation of Wong [5], one pair $q - \bar{q}$ is created when the distance L separating both valence quarks exceeds a threshold value (fig.3). The string fragmentation corresponds to a tension $\kappa = 1/2\pi\alpha'$ of about 1 GeV/fm, α' being the Regge slope. The transverse momentum of the quarks emitted is related to the tension by the relation (1).

$$\sqrt{\langle p_t \rangle^2} = \sqrt{\frac{\kappa}{\pi}} \quad (1)$$

Such relation provides the classical values of $p_t = 0.25$ GeV/c for quarks and 0.35 GeV/c for the pions where the pairs $q - \bar{q}$ are recombined. Above an energy threshold of about 200 GeV (in CMS) per valence quarks (corresponding to a proton pro-

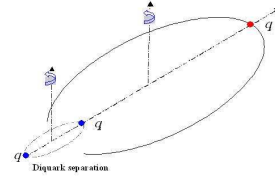


Figure 4: Maximal tension for a threshold excitation energy, stretching of a high tension string between valence quarks of the diquark, diquark breaking.

jectile of 10 PeV in the Laboratory system, a new string appears between the partners of the valence diquark (figure 4).

The tension increases with the distance and the breakdown happens as soon as the minimal energy of excitation required is available; the maximal distance between the valence quarks associated to this minimal energy is obtained when the 3 quarks are aligned. Such circumstance excludes the classic recombination of the leading cluster (one valence diquark with one quark of the sea giving a pilot proton, a neutron or a Δ resonance); this could explain why the penetrating power of the cosmic air showers appears to level off in the "knee" energy range. At energies more close to the LHC, the fragmentation of 3 separated valence quarks will still be observed, but the alignment will be smeared out, the energy required for the rupture being available for all geometrical configurations. The most simple recombination for the 3 valence quarks of the projectile will happen with antiquarks of the sea giving the emission of 3 energetic hadrons for instance as a collimated trident of 3 charged pions, (or charged pions and K_0) on fig. 5.

In the case of JF2af2, the external jets ($\langle ER \rangle$) factor and some secondary peak at the largest values of the invariant mass indicate a maximal distance of the primary collision at 2.2km above the chamber. We notice that 3 coplanar charged pi-

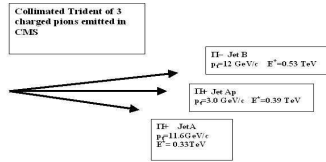


Figure 5: Trident emission expected in colliders as suggested by JF2af2.

ons carrying the e.m. energy deposited in A, Ap and B interacting respectively at about 175, 60 and 320 m above the chamber are able to reproduce the structure observed and require a primary energy of about 5 PeV (reduced by 50% when compared to normal hadronic collision); this energy is very close of the "knee" of the primary energy spectrum and in better agreement with the number of high energy events expected with the modest exposures on Concorde and on SBF. The transverse momenta required for those pions at the emission are 10.0, 3.3 and 6.5 GeV/c (comparable to the values required for STRANA) suggesting a maximal tension of the string concerning the diquark of 20-30 GeV/fm instead of 1 GeV/fm. The transformation of JF2af2 characteristics in the CMS gives a crude description of a possible coplanar emission in colliders.

- characteristics coplanar tridents collimated (emitted inside $0.3-1.5^\circ$);
- pseudo-rapidities between 4.3 and 5.8, energies between 0.4 and 0.7 TeV;
- p_t 's around 3-10 GeV/c;
- energy threshold $\sqrt{s} = 3000 \text{ GeV}$, (reachable by Fermi collider in pulse mode for valence quarks with energies above 200 GeV).

Discussion

Among the new ideas to explain the coplanar emission, the diquark breaking mechanism combined with relativistic strings fragmentation leads to a reduction by about a factor 2 of the primary energy when converted from the visible energy, which results in an enhancement of the frequency of occurrence of coplanar emission; it may also explain the reduction of the penetrating power of the cosmic ray cascades near the energies of the cosmic ray knee and the decrease of high energy secondaries in the fragmentation region suggested by hybrid EAS- γ families experiment. The collimated coplanar tridents could be a simple signature to recognize with collider experiments. An experiment at low luminosity in the LHC, measuring the secondaries in the very forward region could probably clarify the question of coplanar emission, as well as the extension of the present emulsion chamber experiments with an arrangement of emulsion bricks (like in the Opera neutrino experiment). The easier access now on Tibet or to test flights of the Airbus A380 (on both decks of the airliner) would improve considerably the efficiency.

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