Consequences of the LHC Results in the Interpretation of γ ray families and Giant EAS Data

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The earliest results of CMS exhibit central pseudo rapidity densities larger than the predictions of the different models. Introducing on this basis new guidelines with larger multiplicities of secondaries in the models implemented in the simulations, we examine the consequences in γ ray families (spikes in rapidity distribution, coplanar emission) and very large EAS (penetration power in the atmosphere).

1. INTRODUCTION

The collection of high energy cosmic ray events performed with X ray emulsion chambers (XREC) in the energy range covered by the LHC has been the origin of questions for high energy physics. Conversely, the experience of the colliders and the earliest results of the LHC help considerably the interpretation of those events by sophisticated simulations ; the separation of genuine hints of new physics among complex effects of natural fluctuations becomes more reliable. Usually, the gamma ray families recorded with XREC at very high altitudes are not contained events ; the origin of the collision can be only approached by the invariant mass of the π_0's and sometimes by the geometry of the most energetic subcascades.

Aside those events more or less depending on the primary composition, the extensive air shower data, through the characteristic properties of the different components is also correlated with the important features of the primary collisions up to energies larger by 3 orders of magnitude (in laboratory system) than the present limit of the LHC. Additive uncertainties come from the cosmic ray particles interaction with the air nuclei (N, O, Ar) instead of nucleons, the lower energy limits of the experiments in p-A collisions and a lack of observation in the fragmentation region in colliders.

Figure 1: γ's pseudo rapidity distribution in Laboratory System for 149 γ's recorded in the event JF1af1 at CONCORDE flight altitude of 17km ; typical spikes may be observed near 7.6, 10.3 and 11.4 units of rapidity.

2. REMARKABLE COSMIC RAY EVENTS

The Centauro's have been widely studied in the previous ISVHECRI's and measurements are done in colliders in relation with $N_\gamma - N_{ch}$ relation. Hence, this section is concentrated on other striking features such as the abnormal fluctuations in pseudo rapidity distribution and the coplanar emission. The observation of the pseudo rapidity distribution near an energy above 10^6 GeV is rare ; we may quote the Texas Lone Star, a dozen of A-A collisions recorded in balloons by the JACEE and an event recorded in the Concorde experiment [1] exhibiting spikes in the pseudo rapidity distribution (fig.1). The localisation of the vertex in the cabin wall of the Concorde airliner by both trian-
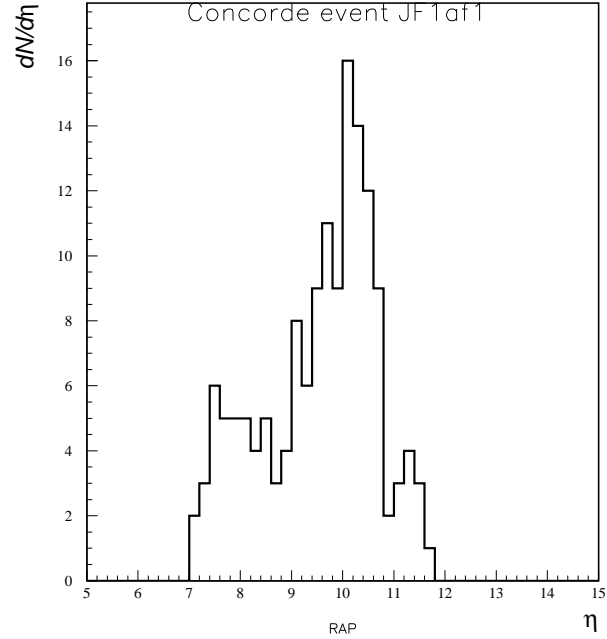
gulation and invariant mass method allowed the reconstruction of this distribution, also plotted in the Centre of Mass System (CMS) on fig.2 assuming a primary energy of 10^6 GeV. The forward cone (142 γ's over 149) is compared here with the charged inclusive and semi inclusive NSD pseudo rapidity distributions for $Z_{kno} = 2$ and $Z_{kno} = 3$ ($Z_{kno} = N_{ch}/ < N_{ch} >$ is the Koba-Nielsen-Olesen parameter) averaged other 3000 events generated with our Monte Carlo generator (see section 3).

The question occurred how those spikes could arise of simple random fluctuations or might indicate the formation of hot spots of quark-gluon plasma[2], the peaks of fig.1 being considered as the drops of hadronic
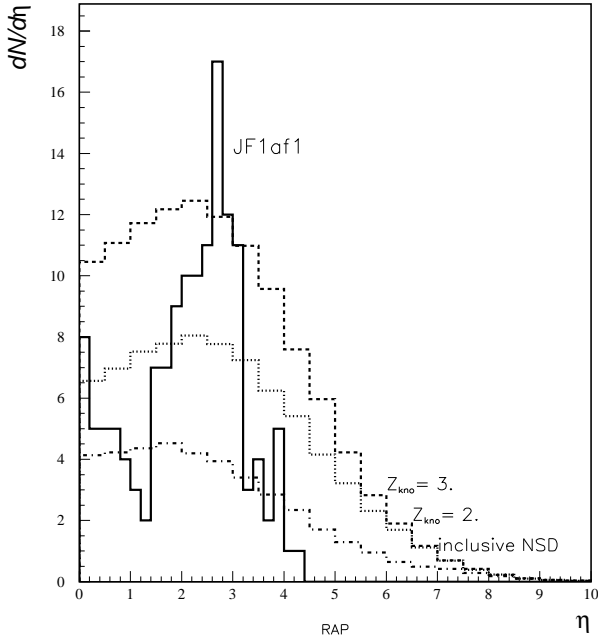
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Figure 2: γ's pseudo rapidity distribution in CMS for 142 γ's (solid line) recorded in the event JF1af1 ; the spikes are shifted near 2.8 and 3.9 units of rapidity. Simulated NSD distributions are superimposed for the inclusive component (dotted-dashed)and for semi inclusive data with $Z_{kno} = 2$ (dotted) and $Z_{kno} = 3$ (dashed)

Figure 3: Most energetic secondaries among the 211 γ's recorded in the event JF2af2. 50% of the visible energy $\sum E_\gamma$ (1586 TeV) is contained in the alignment.

matter into which the quark-gluon-plasma condensates.

Such events have been also searched in UA5 CERN experiment [3] : the random grouping of clusters in Monte Carlo simulated events suggest that there could be no need to include here new phenomenon. In the case of JF1af1 which is a p-Al collision, a similar investigation might progress by the analysis of individual γ's distributions between $Z_{kno} = 2$ and $Z_{kno} = 3$ for events corresponding to fig.2.

At energies around 10 PeV, alignments of γ's and hadrons have been observed, suggesting a coplanar emission of the most energetic secondaries. One pair of events in addition to a dozen of clear events recorded at mountain altitude have been collected under a minimal cascading in the low stratosphere, JF2af2, the most energetic event during the exposures on the Concorde and Strana during siberian balloon flights. JF2af2 is characterised by a near perfect alignment of all the cascades with energy exceeding 50 TeV (fig.3). After extensive simulations, we have shown that alignments may appear in emulsion chamber and result from rare fluctuations of standard collisions [4]. However, both events JF2af2 and STRANA with a primary energy near $\sqrt{(s)} = 5\text{TeV}$ exhibit a simi-
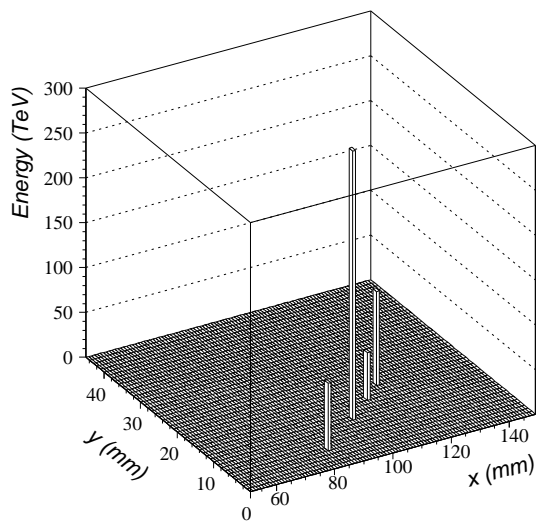
lar visible energy, large multiplicities and require very large transverse momenta (around 10GeV/c).

The very modest exposure of the chambers (500 hours with an area of 0.2m^2 combined with the important reduction of the primary flux after the knee) objects the hypothesis on standard fluctuations. Therefore, a mechanism involving the valence quarks and diquarks, based on relativistic string fragmentation has been proposed [4]: one pair $q - \bar{q}$ or $qq - \bar{q}q$ is created when the distance L separating both valence quarks exceeds a threshold value. The string fragmentation tension 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:

$$\sqrt{\langle p_{\mathrm{t}}\rangle^2} = \sqrt{\frac{\kappa}{\pi}} \qquad (1)$$

The fragmentation of the new strings stretched between valence quarks and diquarks and also between the partners of the valence diquarks (assumed to be strongly bounded) is the origin of the large p_t's : a strong tension of those last strings (κ multiplied by $10 - 15$)provides large p_t's after a violent diquark breaking as in fig.4 for example where $< p_t >= 11$ GeV/c>, able to reproduce JF2af2. We have here applied the Schwinger mechanism [5].

The fragmentation of such strings would occur above an energy threshold of 200 GeV in CMS per valence quark. Near this threshold the most energetic secondaries are aligned (minimal energy required for maximal tension of the string when 3 valence quarks are aligned) ; this could explain why the coplanar
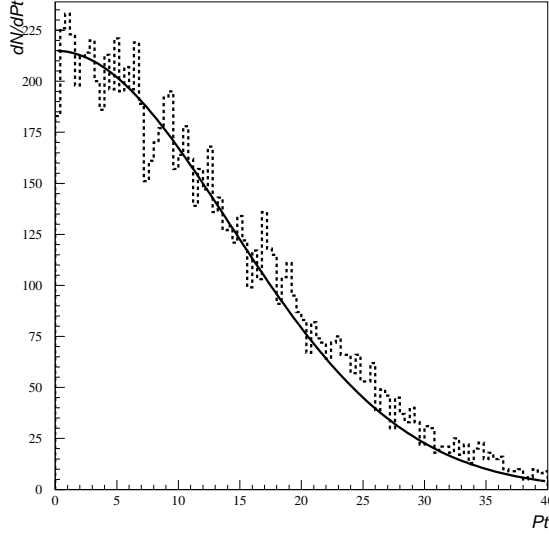
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Figure 4: p_t distribution of valence quarks assuming valence diquark breaking and Schwinger mechanism.
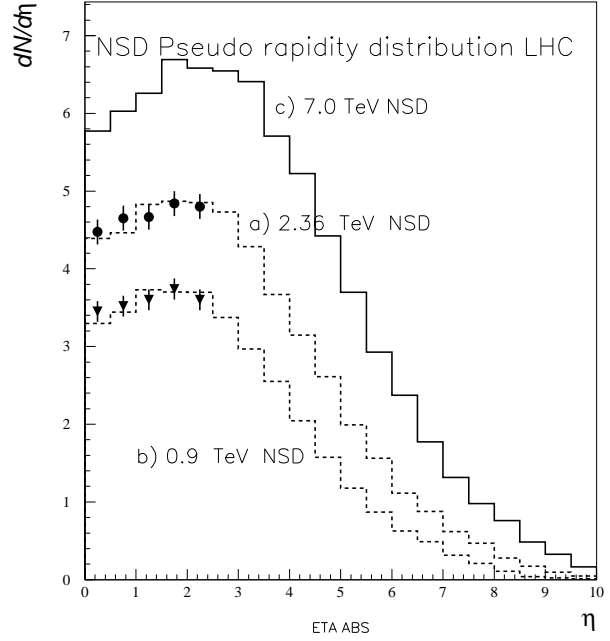

Figure 5: Charged pseudo rapidity distributions for the inclusive NSD component averaged over 3000 collisions

emission is more likely observed close to 10^7 GeV. Such configuration is no more necessary at energies exceeding this threshold, the excitation energy being widely sufficient to generate the valence diquark breaking.

There are some super families at energies above the energy of the LHC (Andromeda, Tadjikistan, Fianit...). Those events present halo's, multiple clustering, large multiplicities and large p_t, but up to now no coplanar emission.

3. SIMULATION AND EAS DATA

3.1. New Model Guide Lines

Taking the opportunity of the earliest results of the LHC given by CMS [6], we begin to update and improve the collision generator HDPM implemented in CORSIKA and report here the preliminary results obtained with the non diffractive code. The parameters of the main guidelines such as the average central pseudo rapidity density $< dN_{ch}/d\eta >$, the average multiplicity $< N_{ch} >$ have been tuned on the experimental data as follows for $\sqrt{(s)} > 0.9$ TeV:

$$< dN_{ch}/d\eta >= 0.595 s^{0.13} \quad < N_{ch} >= 2.257 s^{0.195}$$
$$(2)$$

instead of the previous adjustment to UA5 data:

$$< dN_{ch}/d\eta >= 0.74 s^{0.105} \quad < N_{ch} >= 7.2 s^{0.127} - 7$$
$$(3)$$

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Those asympotic tendancies turn to be an intermediate between the behaviour predicted by the Landau hydrodynamical model (having overestimated the conversion in an $s^{0.25}$ multiplicity of the major part of the CM'S available energy) and the prediction of Feynman's scaling in favour of $s^{0.13}$.

Our collision Monte Carlo generator has provided in those conditions the pseudo rapidity distributions $dN_/d\eta$ for charged and neutral particles, as shown for charged hadrons on fig.5. The central pseudo rapidity's are in agreement with CMS, ATLAS and ALICE measurements. Other characteristics of the p-p collisions are shown on Table I. The inclusive and semi-inclusive data are compared on fig.2 at $\sqrt{(s)} = 1.37$ TeV (comparison with JF1aF1). The discrepancy with earliest extrapolations based on UA5 data are not visible at this energy, but according to Table I we can expect clear asymptotic tendencies such as larger multiplicities, larger violation of KNO scaling, larger central rapidity densities and a larger energy flow transferred to secondaries (as suggested by the inelasticity K_{tot} in Table I) . The microscopic models with intrinsic parameters tuned to involve those effects will produce for proton initiated showers more muons and a maximum depth of the e.m. component at higher altitude. Consequently, the present values proposed for the primary mass are overestimated in the knee region and beyond.

Table I Characteristics of NSD inclusive data

$\sqrt{(s)}$	0.9**TeV**	2.6**TeV**	7.0**TeV**
$< dN_{ch}/d\eta >$	3.48	4.47	5.95
$< N_{ch} >$	33.6	49.27	73.86
$< K_{tot} >$	0.59	0.64	0.65
$< p_t >$	0.46	0.49	0.54

3.2. Extensive air showers at UHE

At ultra high energy, the maximum depth X_{max} is also an indicator of the characteristics of the primary interaction in reason of the relation of the individual maximum of the main subcascade with two factors ; the vertex of the earliest collisions dependent on the inelastic cross section on one hand, the individual energy given to the most energetic γ's according to the profile of the fragmentation region on the other hand. The situation is compared on fig.5 with the different models [7] together with the data collected by HIRES and AUGER. In contrast with HIRES, above an energy of $2 - 3$ EeV, AUGER suggests that the penetration power of cosmic particle in atmosphere levels off with an asymptotic tendency pointing to the alone event and most energetic event of the Fly's Eye. Is here a hint of a phase transition to QGP (an energy density larger than 30 GeV/Fm^3 can be expected for 100 EeV collisions)? Is it the signature of a transition to a heavy primary composition? We observe that the last bins of energy in fig.6 for AUGER contains hardly 20 primaries and the hybrid showers selected by the surface detector might no reflect the actual situation of the primary flux in those bins.

4. CONCLUSION

The preliminary data coming from the LHC implies at least an incremental revision of the models used in EAS simulation. The interpretation of the simulations will turn consequently to lower the primary mass composition at the knee level and above. The modest changes expected up to 10^8 GeV could be more important at AUGER level and would favour the interpretation of HIRES (GZK behaviour and pure proton component).
In the LHC energy range, the conjecture is similar to the situation preceding the discovery of the charm, proposed in cosmic rays, rejected in a first accelerator experiment and finally discovered in further measurements. Furthermore LHC data will help to clarify the role of complex fluctuations in XREC data: updated XREC experiments (for instance with emulsion bricks)could also be performed in parallel with the LHC in order to determine the behaviour of the most energetic secondaries in fragmentation region.
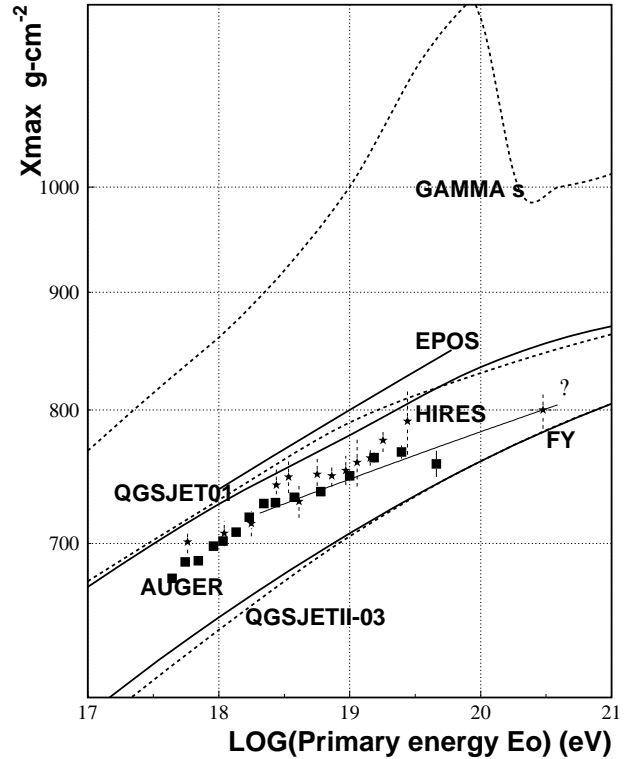

Figure 6: Penetration power of the UHE cosmic ray particles in the atmosphere. The solid line with a question mark corresponds to the tendency suggested by AUGER data

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