Updating Monte Carlo collision generators with LHC data up to √s = 8 TeV

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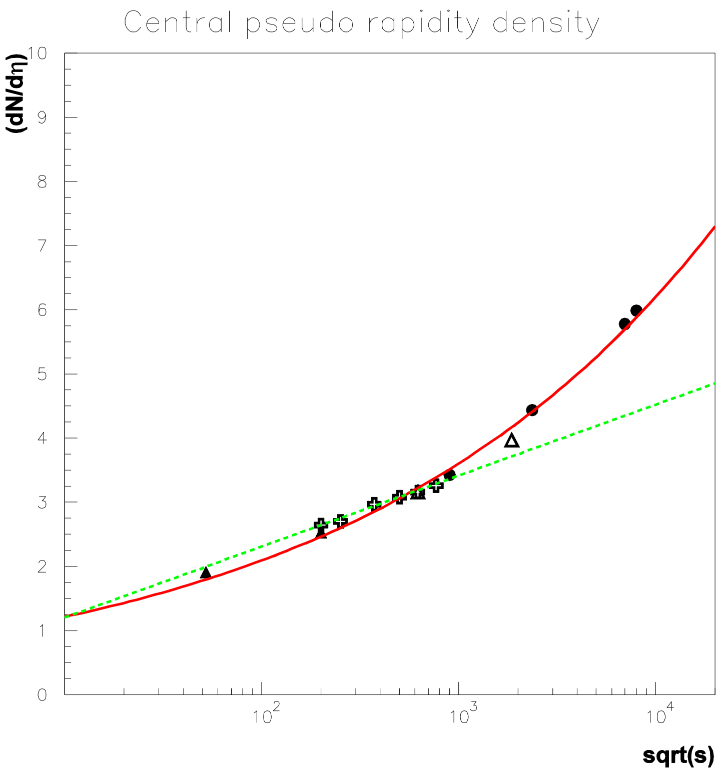
Outlook

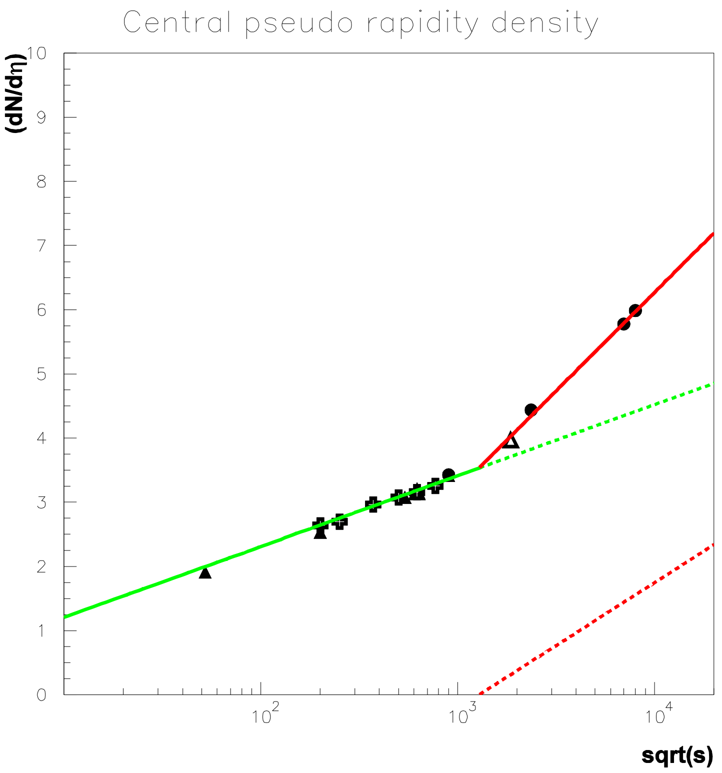
- **Central pseudo-rapidity density at LHC**
- **Difficulties of hadronic models with NSD pseudo-rapidity distributions measured by CMS and TOTEM at $\sqrt{s}$ = 7-8TeV**
- **One phenomenological model with 4 centers of hadronic multiprodution to solve the discontinuities in those distributions.**
- **A few questions from cosmic ray data in γ ray families and EAS at high altitude**

$\rho_o = 0.70835\ s^{0.11775}$

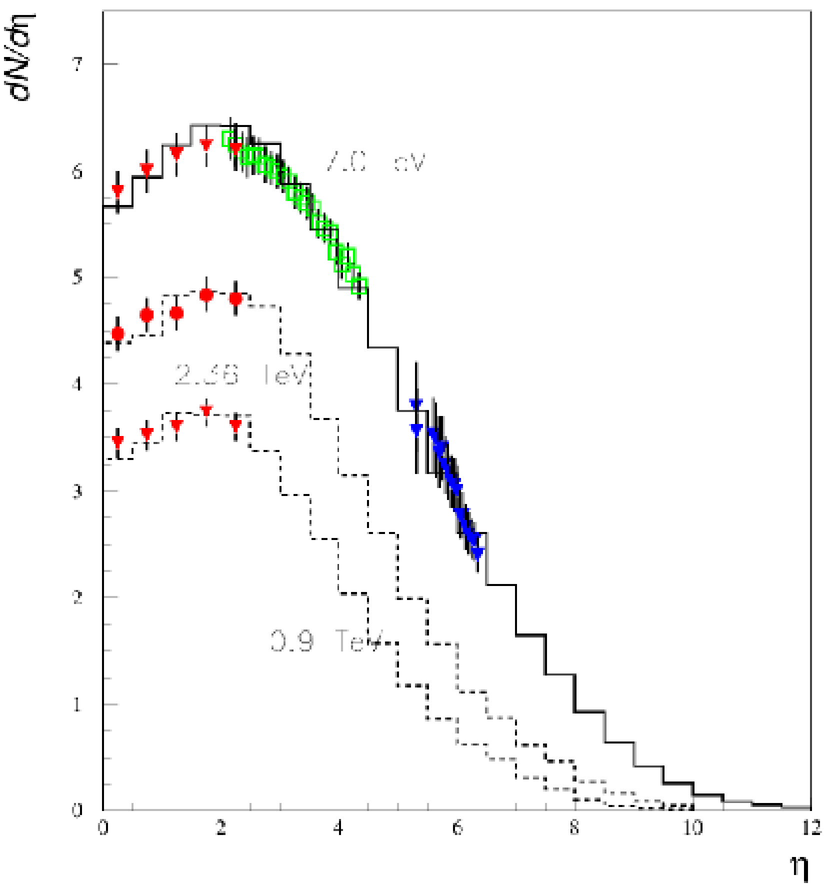
or

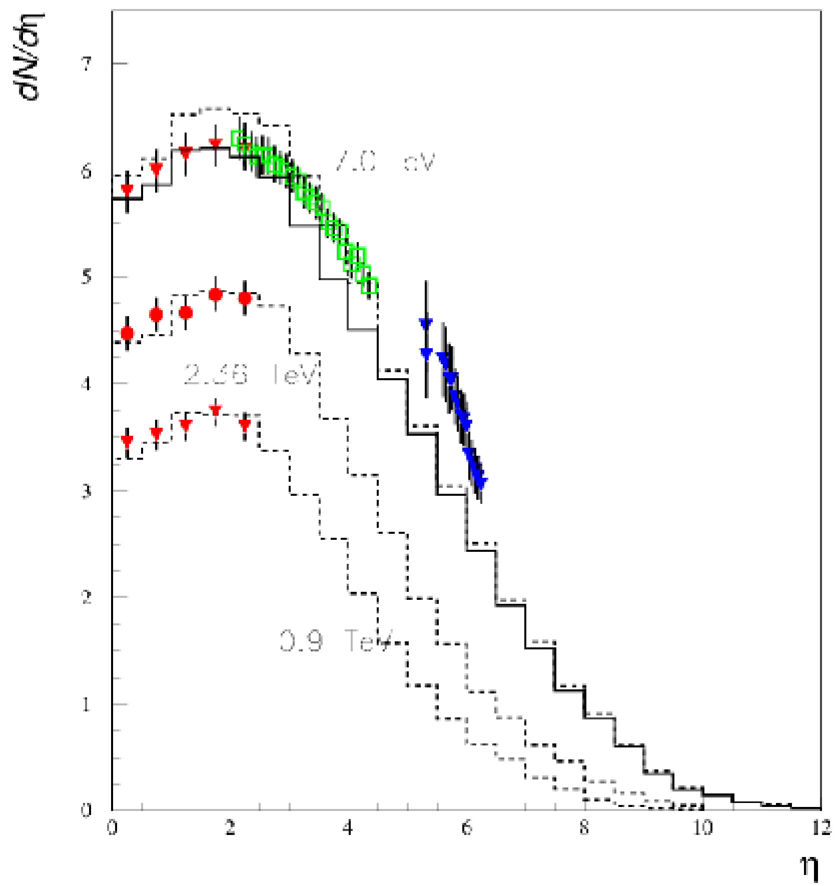
0.24Ln(s) +0.1 + 0.426Ln(s)-6.1 ?



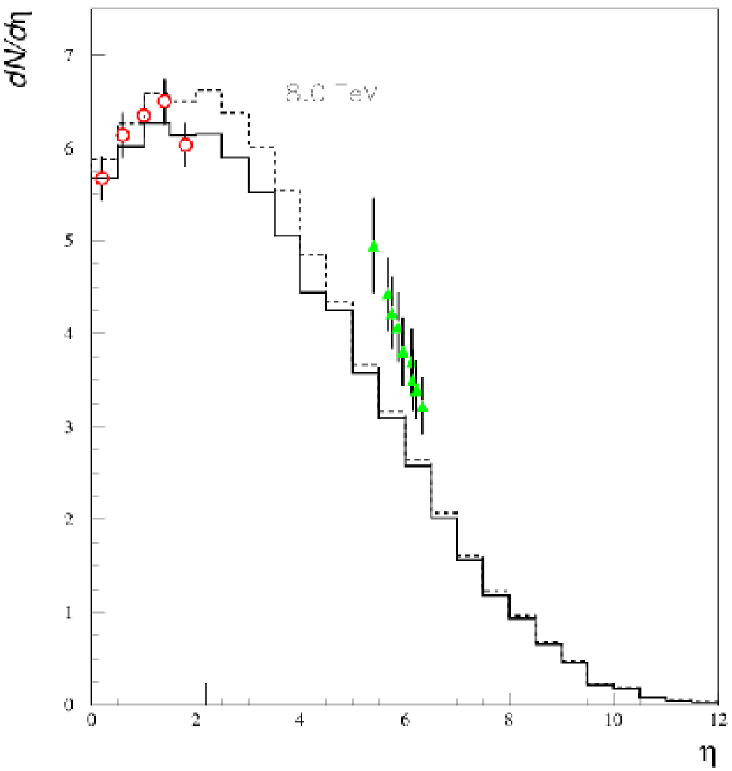


Pseudo-rapidity distributions (NSD) √s = 7 TeV
left wrong (blue points Totem inelastic others NSD)
right estimated blue points NSD, all NSD



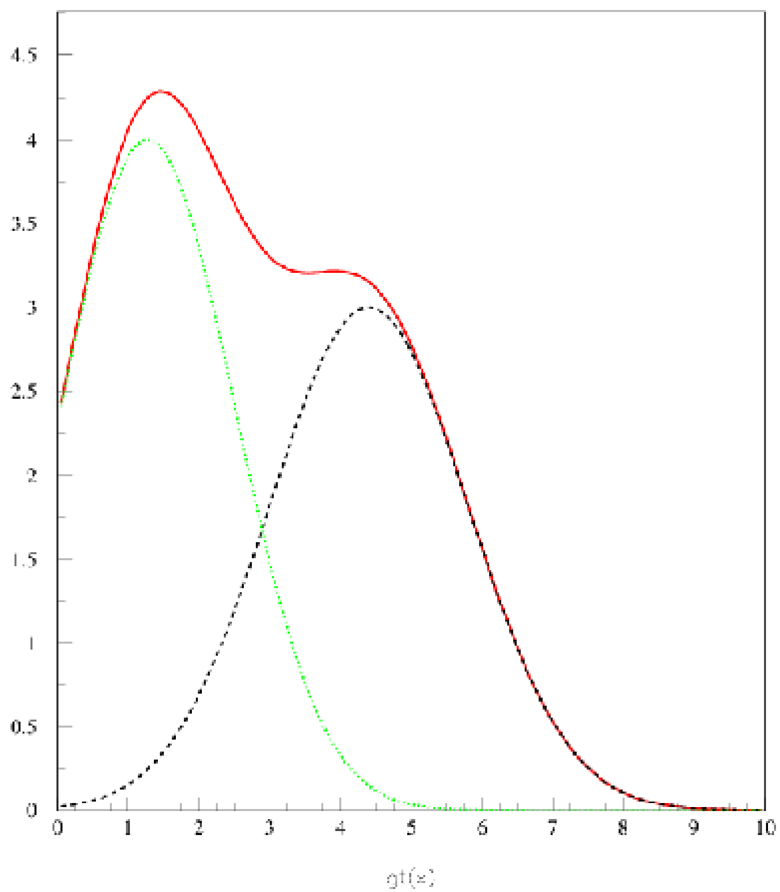


Pseudo-rapidity distributions (NSD) √s = 8 TeV (charged secondaries)



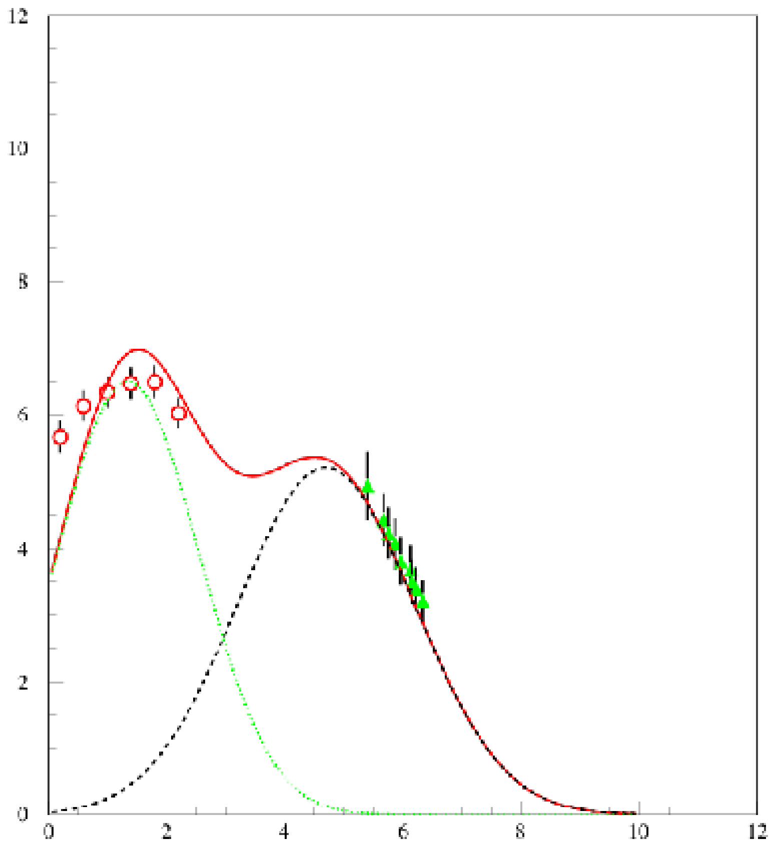
- Original rapidity is **no more a simple plateau with gaussian wings**
- Changes between √s = 2 TeV and √s =7 TeV in the cosmic ray knee energy region
- Usual models from phenomenology are unadapted at **√s =7 and 8 TeV**

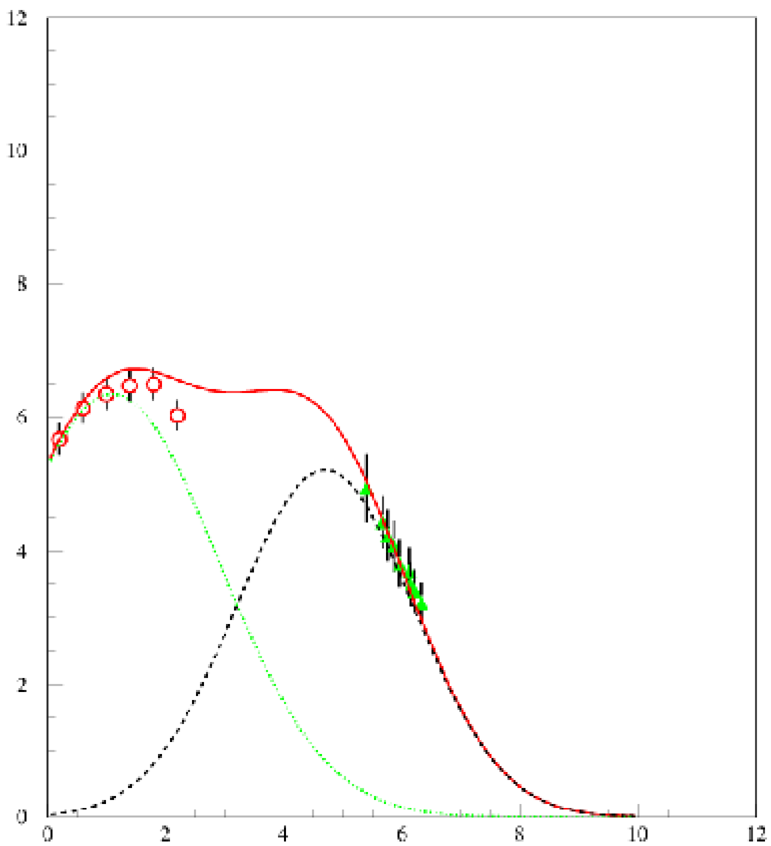
4 component rapidity generator



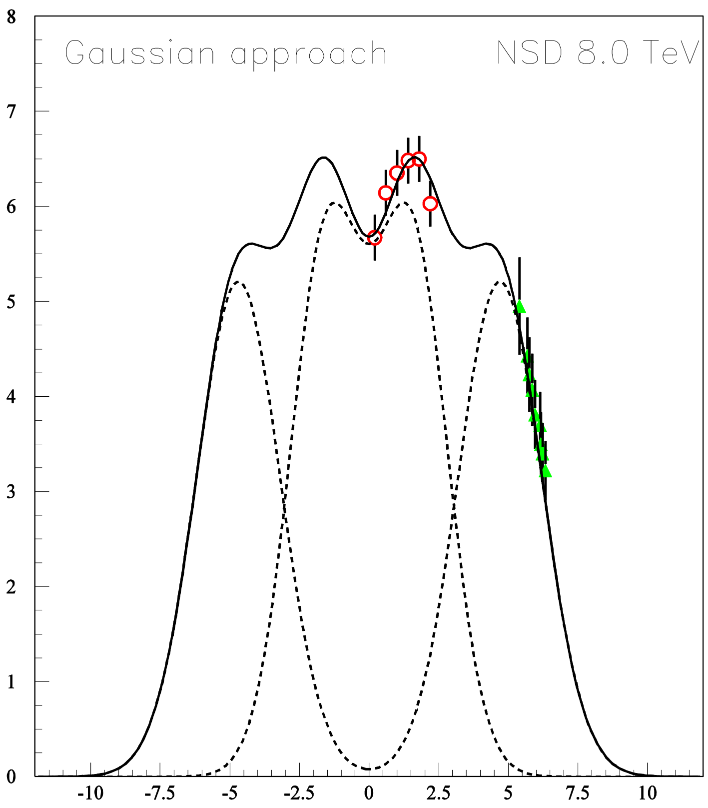
- From HDPM (hybrid dual parton model) to GHOST (Generator of hadrons for simulation treatment)
- Symmetry forward backward hemispheres
- 4 sources of multiparticle production

Approach of the **rapidity** source





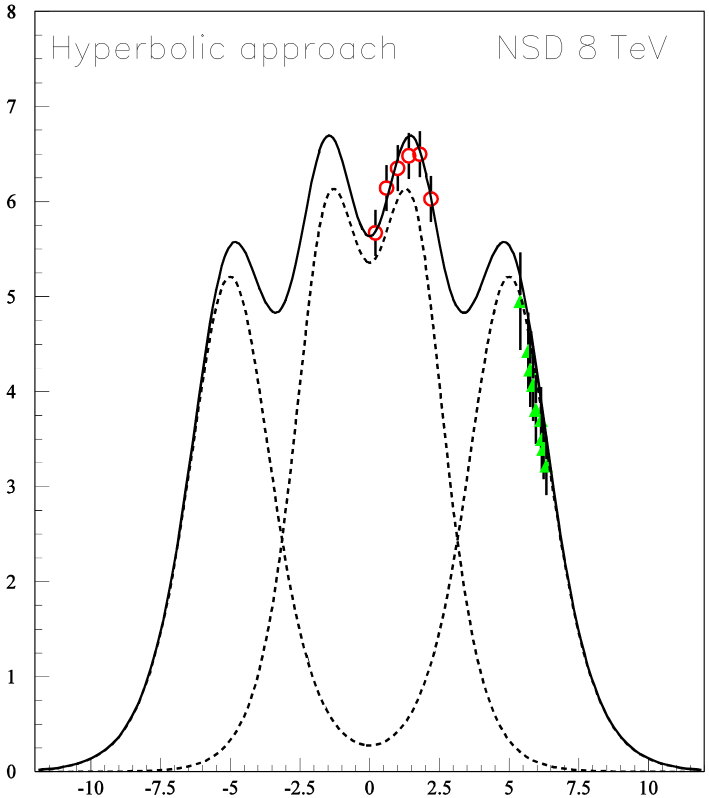
Approach with Gaussian deviates



- **4 gaussian functions**
- **$A_i \{\exp(-0.5u_i) + \exp(-0.5v_i)\}$**
- **$u_i = \{(y-y_i)/\sigma_i\}^2$**
- **$v_i = \{(y+y_i)/\sigma_i\}^2$**

A_i = 5.21, 5.6
Y_i = 4.7, 1.53
σ_I = 1.5, 1.3

Hyperbolic approach



Dependance $1/\cosh^2 y$

$A_i\{1/\cosh^2 u_i + 1/\cosh^2 v_i\}$

- $u_i = \{a_i(y-y_i)\}$
- $v_i = \{a_i(y+y_i)\}$

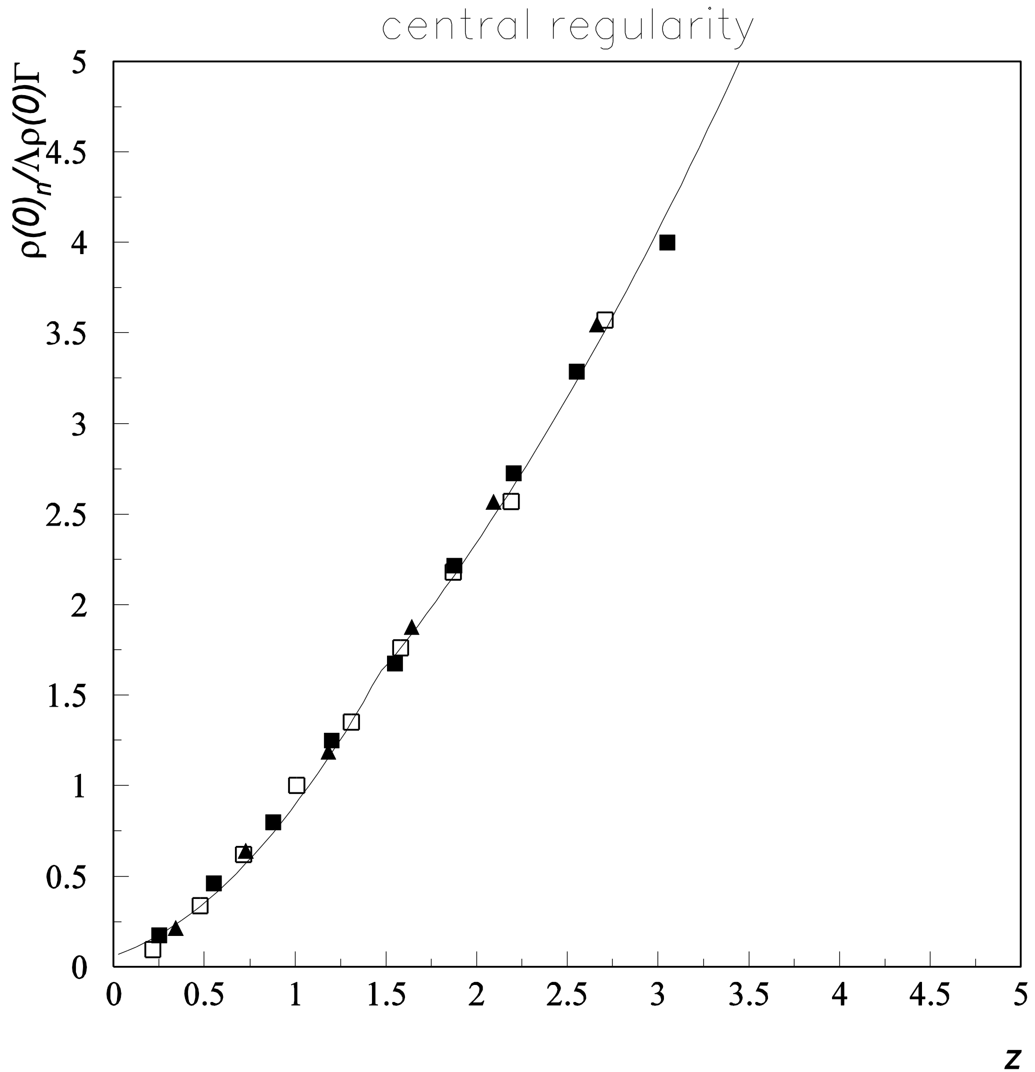
A_i = 5.21, 5.5
Y_i = 5.0, 1.5
a_l = 1.5, 1.3

Gaussian hadronic generation

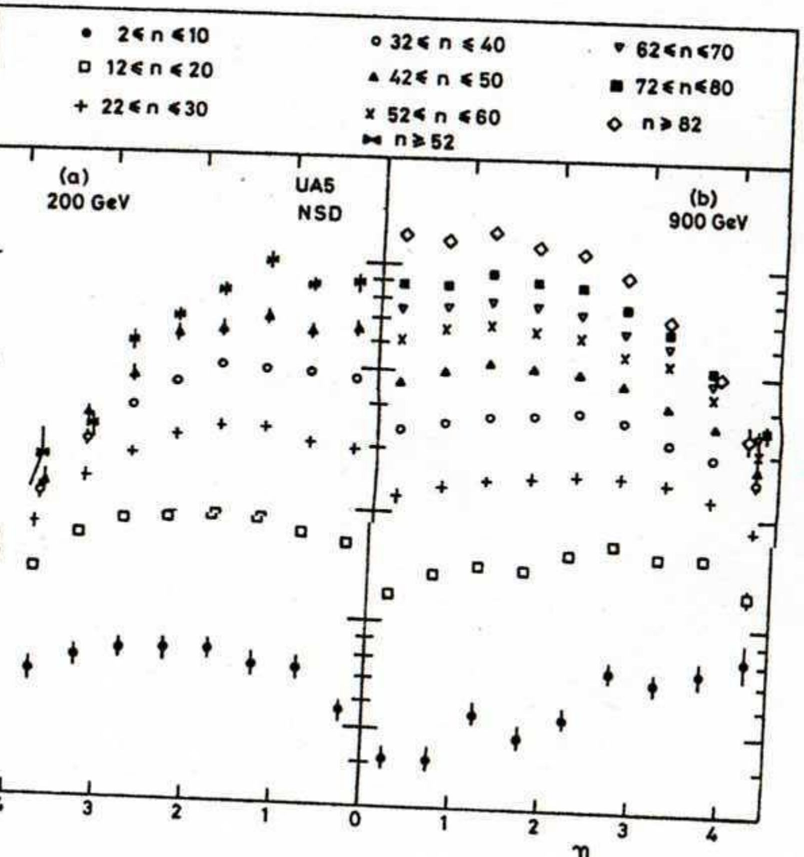
- **Multiplicity N via negative binomial function $\Psi(z)$ with KNO scaling violation ($z=N/\langle N\rangle$)**
- **Central regularity vs z, parameters for semi-inclusive data**
- **couples (y_i, $p_{t\ i}$) via gaussian generation of rapidity and p_t**
- **Validity of the set of secondaries for a single collision, conservation laws, rejections…**
- **Treatment of SD and DD**
- **Respective cross sections for SD, DD, NSD and inelastic data**

New central regularity

$f(z) = 0.11499z^2 + 1.0231z - 0.13198$



Semi-inclusive data

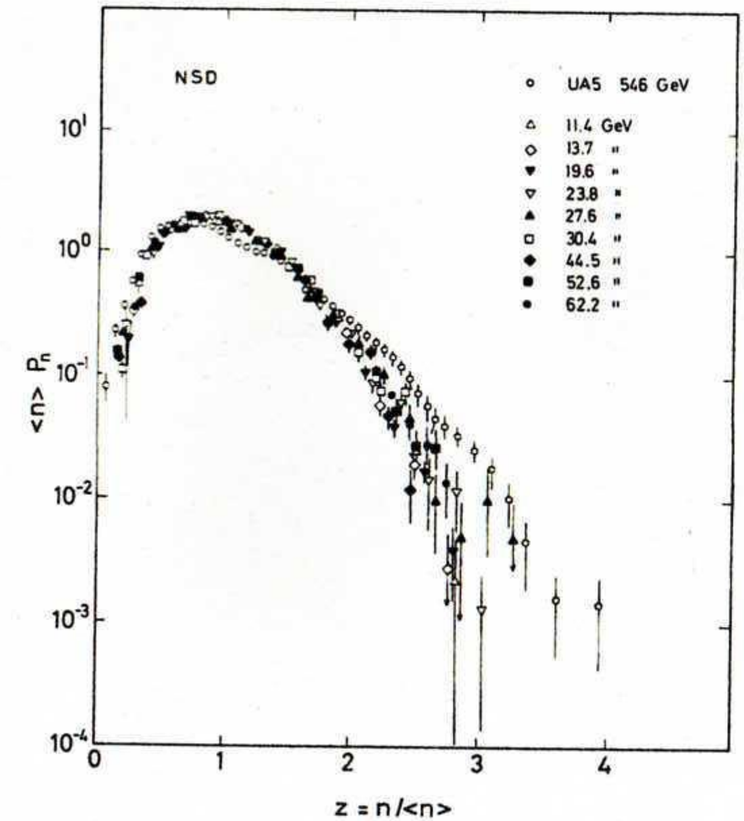


UA
Semi
incl
dat

i-inclusive pseudorapidity distributions for charged particles (NSD events)
ervals of charged multiplicity n at $\sqrt{s} = 200$ and 900 GeV [176].

KNO scaling violation !

UA5 Collaboration. UA5: A general study of proton–antiproton physics at $\sqrt{s} = 546$ G



Charged multiplicity distribution in NSD events plotted as a function of z for UA5 data at $\sqrt{s} = 546$ GeV, co
ISR [138], and from Serpukhov and FNAL [139–144].

Treatment of the semi inclusive data

$z = n/\langle n\rangle$, the KNO variable, $\langle n\rangle$ being t erage multiplicity (z is generated from the negative binomial distribution). This can b marized [7] as

$$\frac{\rho_n}{\langle\rho_0\rangle} = (az+b)^2$$

(The values of a and b can be found in ref.

Observing that the integro-differential sy

$$\begin{cases} \frac{dN}{dy}\Big|_{y\simeq 0} = & m\frac{dN}{d\eta}\Big|_{\eta\simeq 0} = m(az+b)^2\langle\rho_0\rangle \\ \int \frac{dN}{dy}\,dy = & z\langle n\rangle \end{cases}$$

(m ratio of rapidity to pseudorapidity in c has to be satisfied, we can obtain, before g ating a collision, the best position s_1 to ger a given number η of secondaries, as

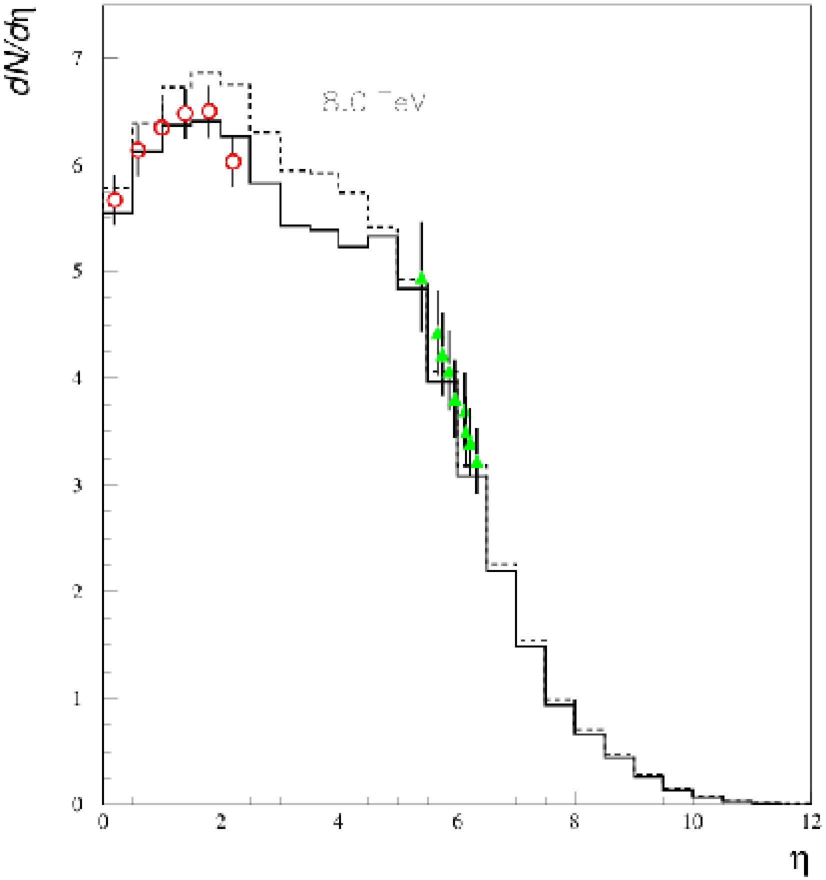
$$\begin{cases} s_1 & = & \sigma_1\sqrt{2\ln\left\{\dfrac{z\langle n\rangle}{\sqrt{2\pi}\sigma_1(az+b)^2}\right\}} \\ s_1 & = & \dfrac{1}{\alpha}\mathrm{Argch}\left\{\dfrac{1}{az+b}\sqrt{\dfrac{\alpha}{2}\dfrac{z\langle n\rangle}{m\langle\rho_0\rangle}}\right\} \end{cases}$$

(respectively for Gaussian and hyperbolic

NSD pseudo-rapidity distribution $\sqrt{s}$ = 8 TeV

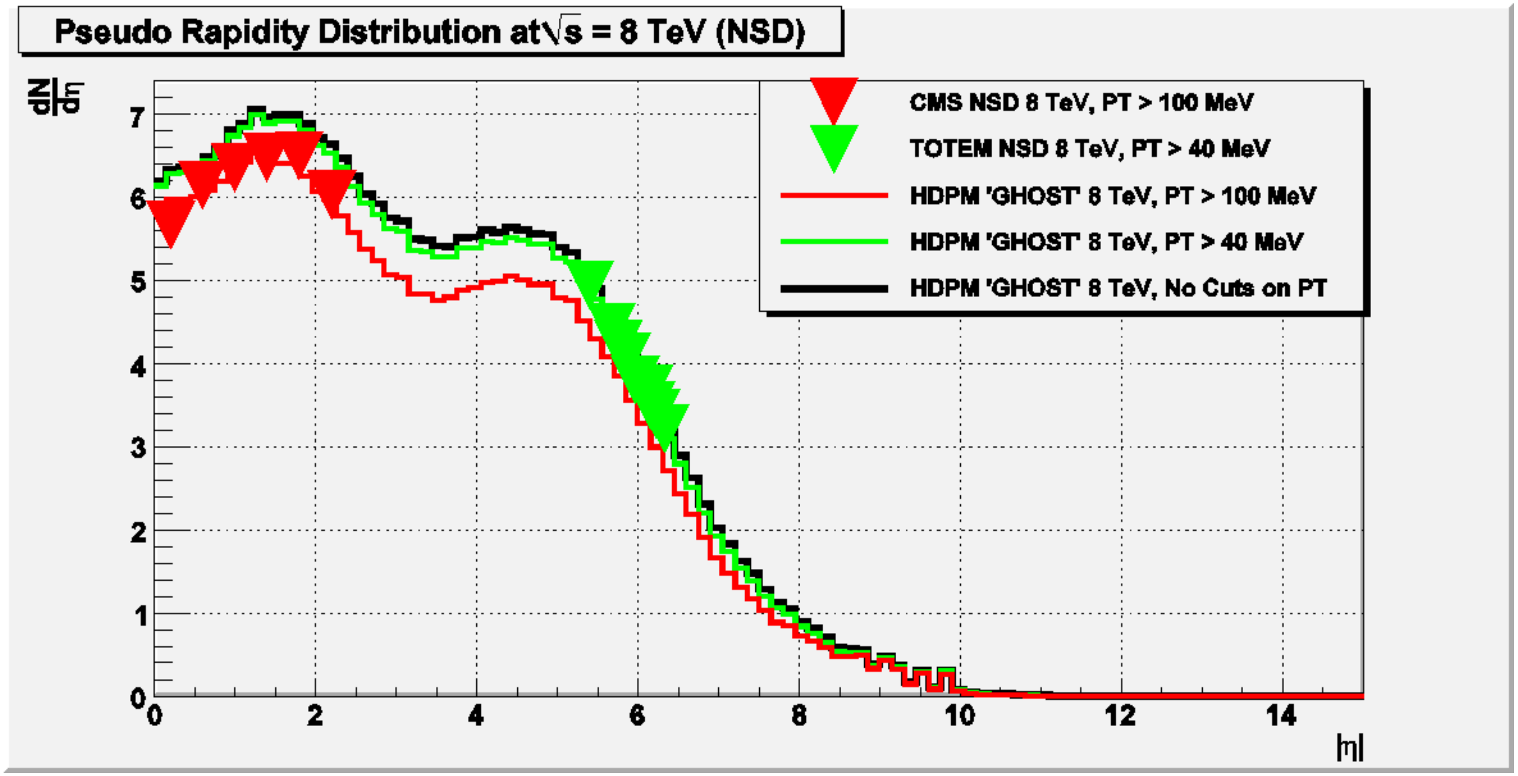
(… all secondaries, __ corrected for Pt<100 MeV red CMS Pt<40 MeV TOTEM) balance g1 52% N, g2 48% N

$y_1 = 1.28, \sigma_1 = 1.22 \quad y_2 = 4.4 , \sigma_2 = 1.4$



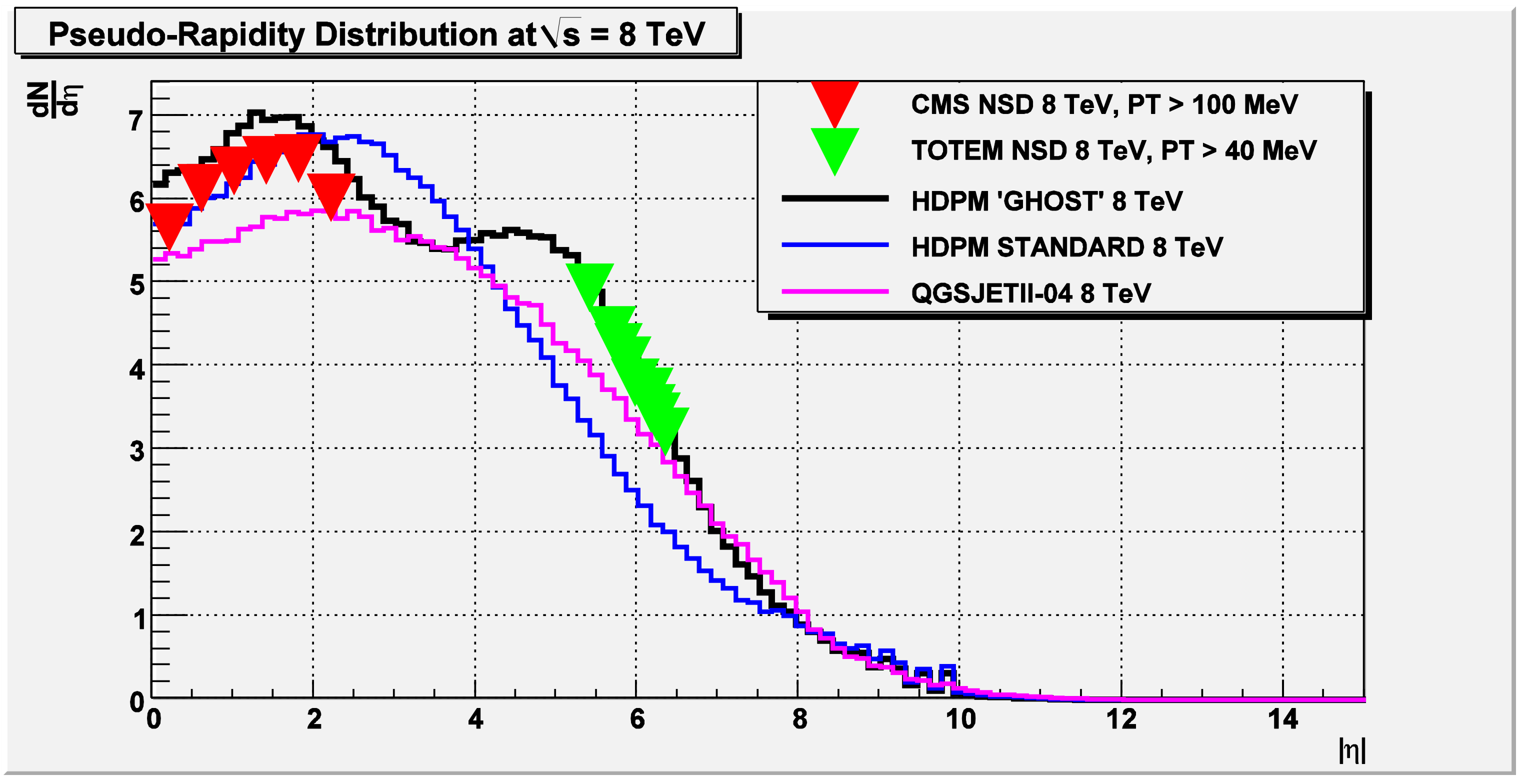
INTEST option of CORSIKA

(with Z. Plebaniak and J. Szabelski)



INTEST Option of CORSIKA

with Z.Plebaniak and J. Zsabelski (no cuts on Pt)



Hadron experiment in Tian Shan

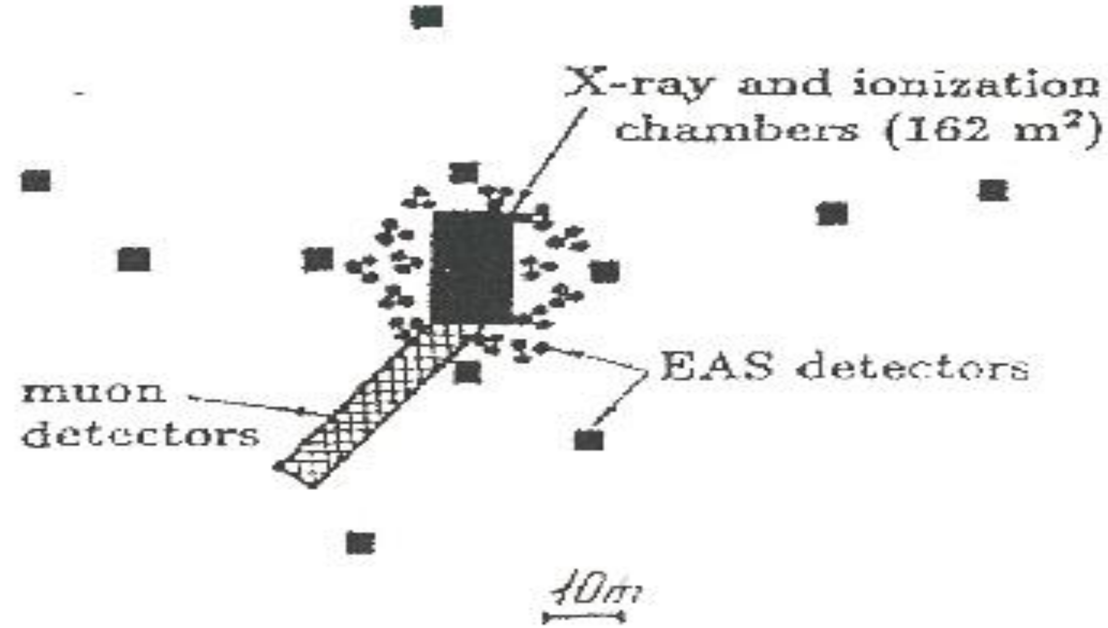


Figure 1. The HADRON array.

Hadron experiment in Tian Shan

- Results 1995
- S.I.Nikolski Nucl.Phys. B, 39A, 228-234

trons are divided by the number of EAS in which

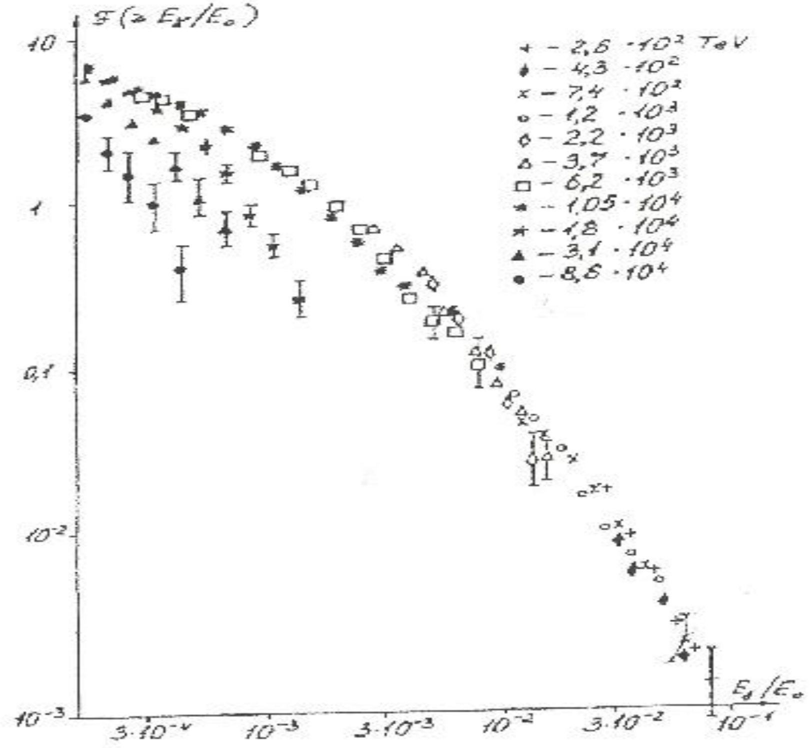
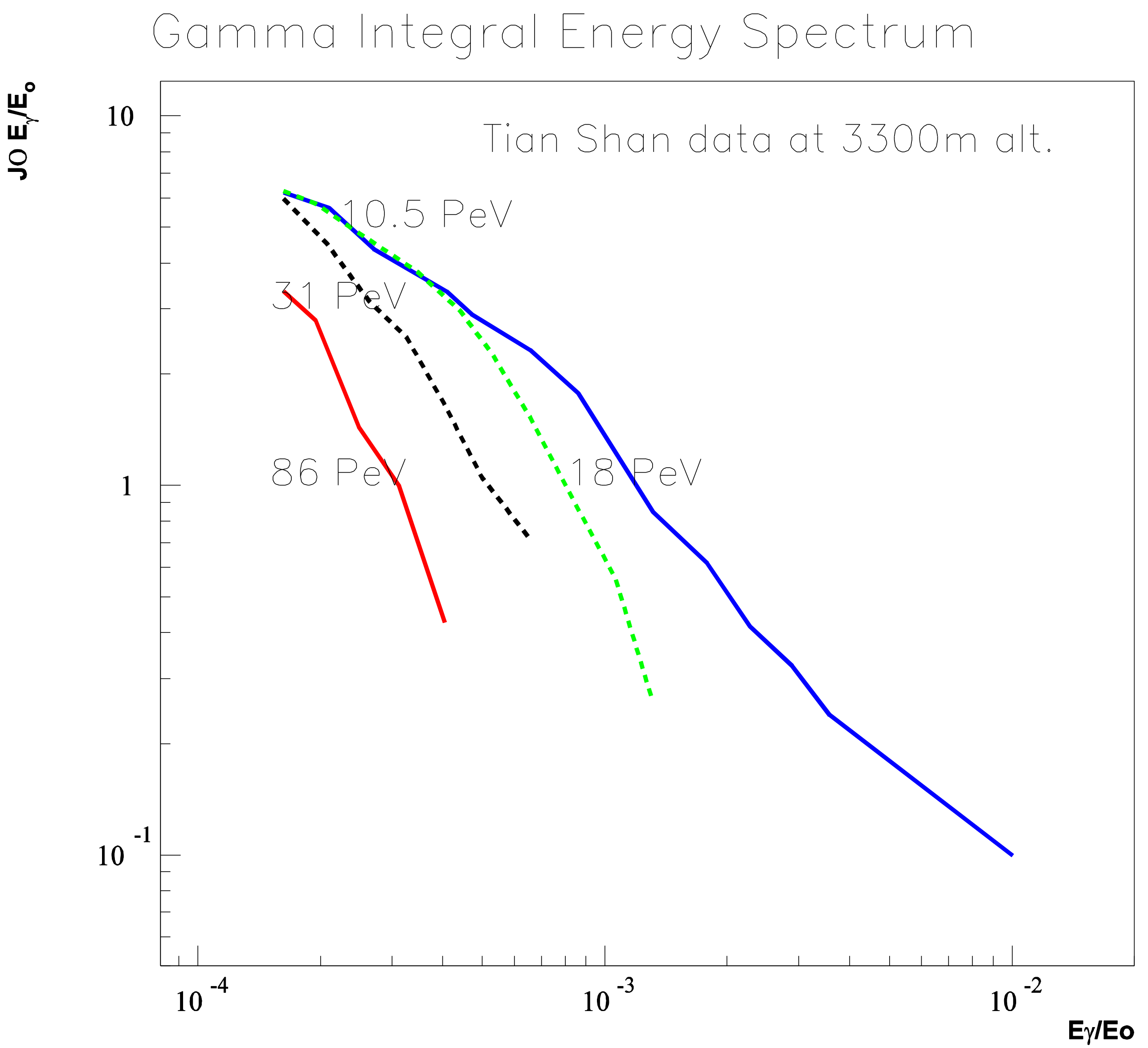
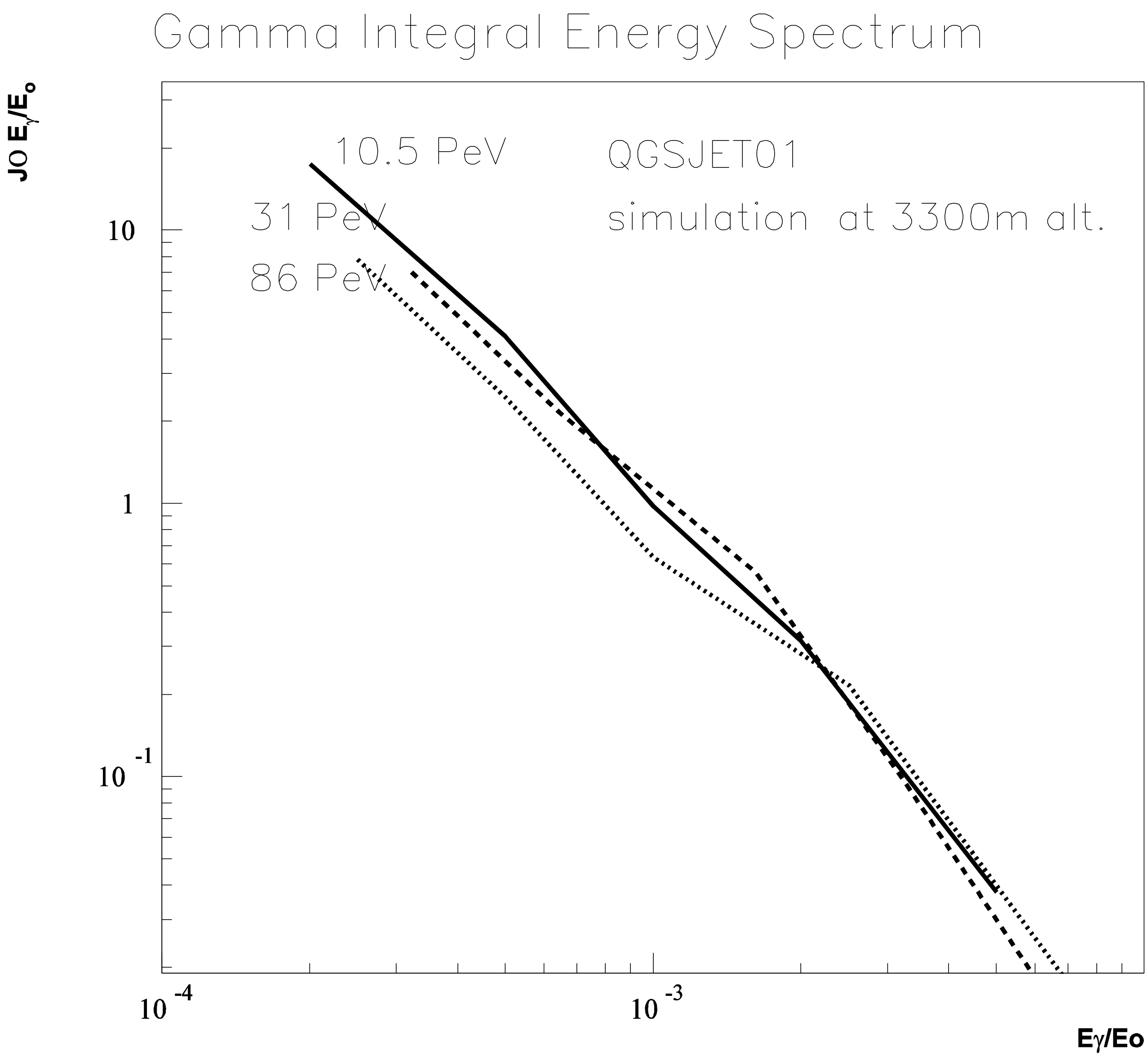


Figure 2. Energy spectra of electrons and γ-quanta in EAS cores for different energies of the primary particles.


Gamma Integral Energy Spectrum
JO E_γ/E_o
Tian Shan data at 3300m alt.
10.5 PeV
31 PeV
86 PeV
18 PeV
10
1
10 -1
10 -4
10 -3
10 -2
Eγ/Eo



Gamma Integral Energy Spectrum
JO E_γ/E_o
10.5 PeV
QGSJET01
31 PeV
simulation at 3300m alt.
86 PeV
10
1
10 -1
10 -4
10 -3
Eγ/Eo

COSMIC RAYS

Concorde hits the fan

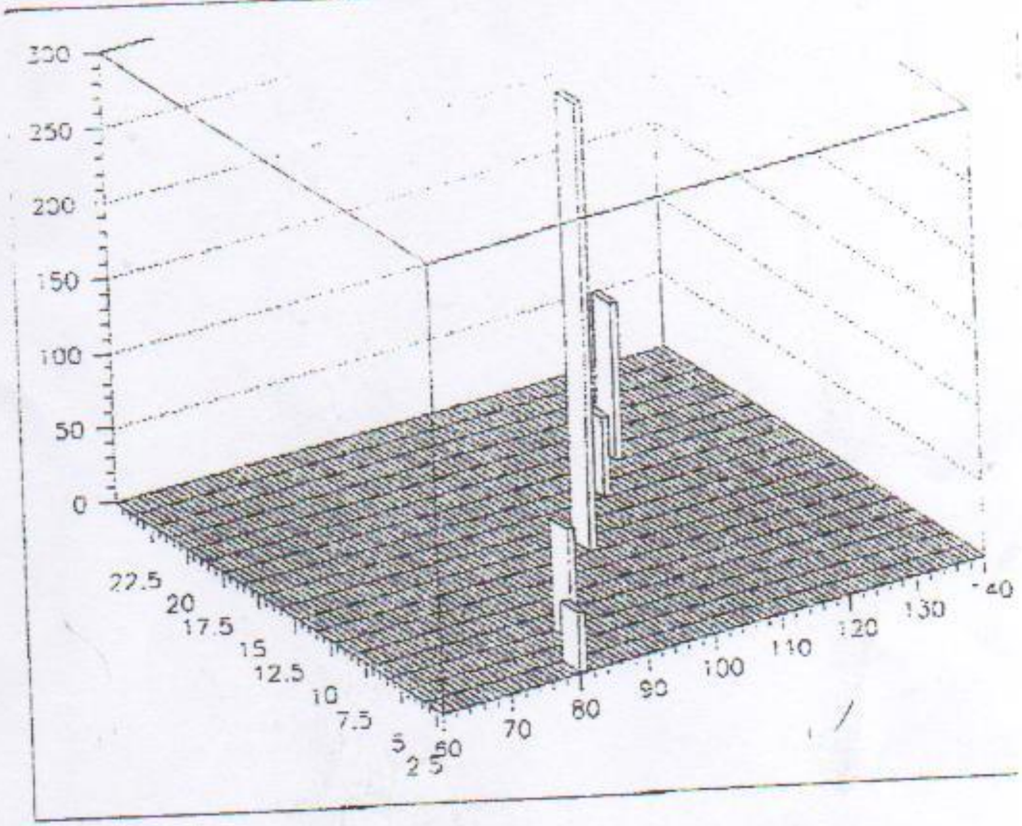
CERN Courier april 97

For the past 15 years, a Paris/Tokyo cosmic ray collaboration has been flying emulsion chambers on Concorde, typically exposing for 200 hours at altitudes of 17 kilometres.

While the event harvest has enabled the researchers to cover a wide range of physics - gamma ray flux, nucleon-nucleus collisions, fragmentation of heavy primaries, hyperstrange baryonic matter,....... one particularly intriguing event, corresponded to a stratospheric gamma ray shower at 10^7 GeV, containing over 200 gammas above 200 GeV (higher energy events, up to 10^{11} GeV, have been seen elsewhere).

At first, this high energy event, dating from 1982, was neglected. Only later did physicists notice the tendency for its gammas to slot together in a plane, or sheet, following suggestions reported from cosmic ray exposures at 4360 m in the Pamir mountains in Central Asia.

Taking another look at the high energy Concorde event last year, Jean-Noël Capdevielle of the Collège de France started to plot the gammas by hand, starting with the most energetic, and was startled to find they were on an almost perfect straight line.



Near 10^7GeV, 211 γ's

Fan-like array of high energy gamma rays (photons) seen in a cosmic ray event recorded by a Paris/Tokyo collaboration flying emulsion chambers on Concorde at altitudes of 17 kilometres. The photon energies (vertical axis) are in TeV, while the horizontal pixels are 1 mm square.

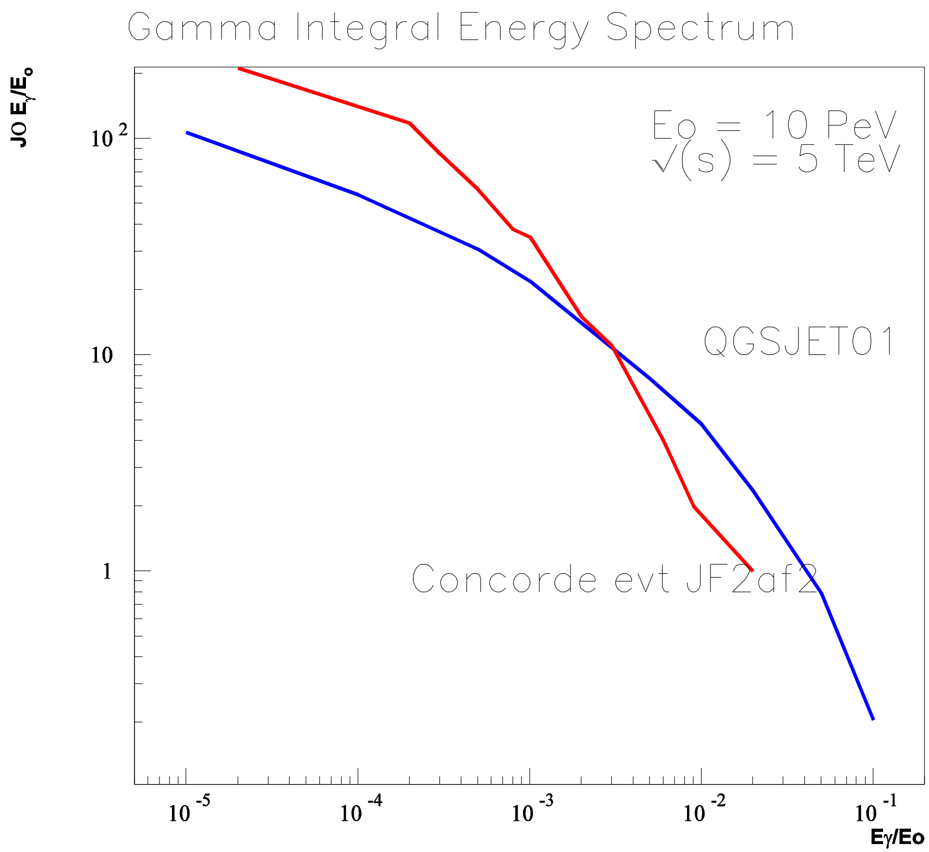
Such sheet-like alignments are also seen in a dozen or so events by the large Pamir chambers (several hundred tonnes), which also see the emergent hadrons but are degraded

Linear collision course

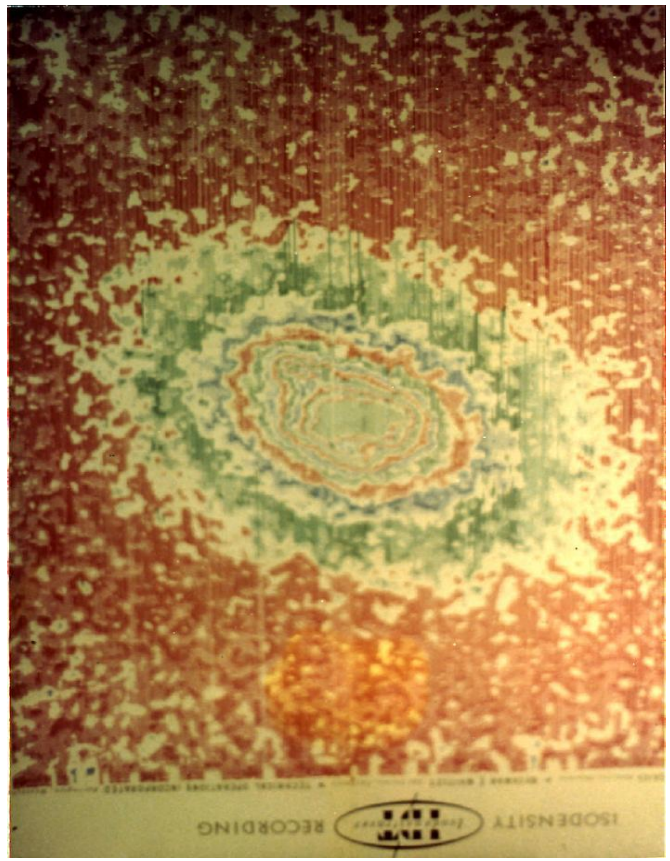
While attention is focused on CERN's LHC proton collider the next major step for particle physics, the parallel electron-positr collider route is acknowledged as providing a complementary approa to many outstanding physics questions.

With CERN's 27-kilometre LEP electron-positron ring defining a feasibility limit for circular electron machines, research and

Concorde Evt JF2aF2 alt. 17 km $\theta = 52°$



One γ ray of 200 TeV…



Conclusion and Questions

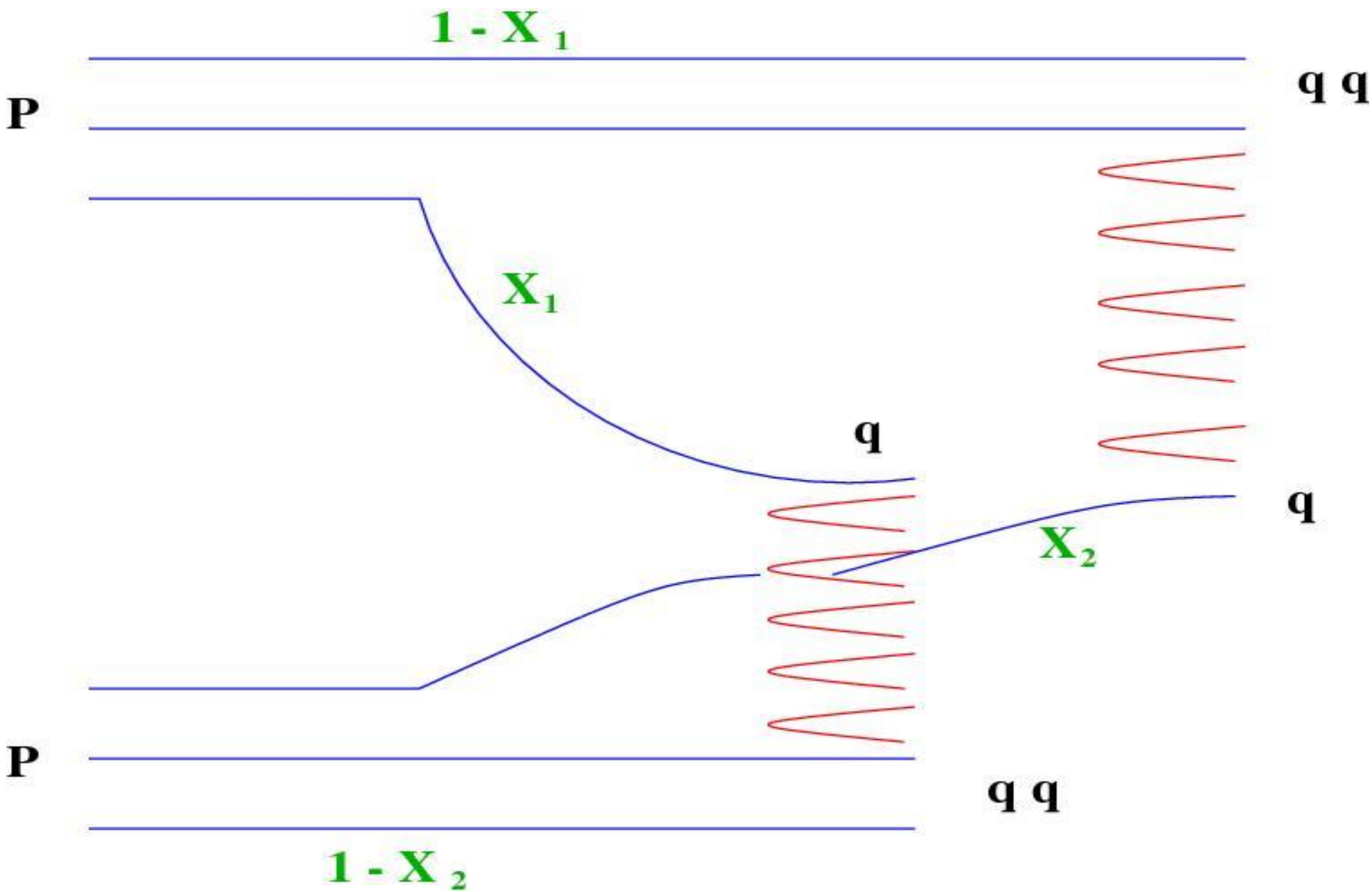
- 4 sources of multiple particle production in CMS **located symmetrically** at rapidity distances **+/- 1.3-1.5** in **central region** and **+/-4.4-4.7** in **mid rapidity region** can reproduce the charged pseudo-rapidity observed at **√s = 8 TeV.**
  Respective distribution width are 1.22 , 1.4
- Both central and mid-rapidity components can be described by gaussian distributions, the mid rapidity emission **near 4.5 units** being similar to the decay of the diffractive mass of a **W boson**.

conclusion

- **Break of scaling of the gamma integral energy spectrum up to Eo =10 PeV (*but divided by 2 at xlab = 4.10-4 in simulation against by10 in Tian Shan measurement when Eo rises from 10 to 86 PeV)***
- **Energy in leading cluster not available for normal leading particle effect (connected with the steepness of the pseudo rapidity in Totem?)**
- **Breaking of the valence diquark? Coplanar emission above 10 PeV ? *Pamir experiment and on Concorde (J.N.C. ISVHECRI 2006)***

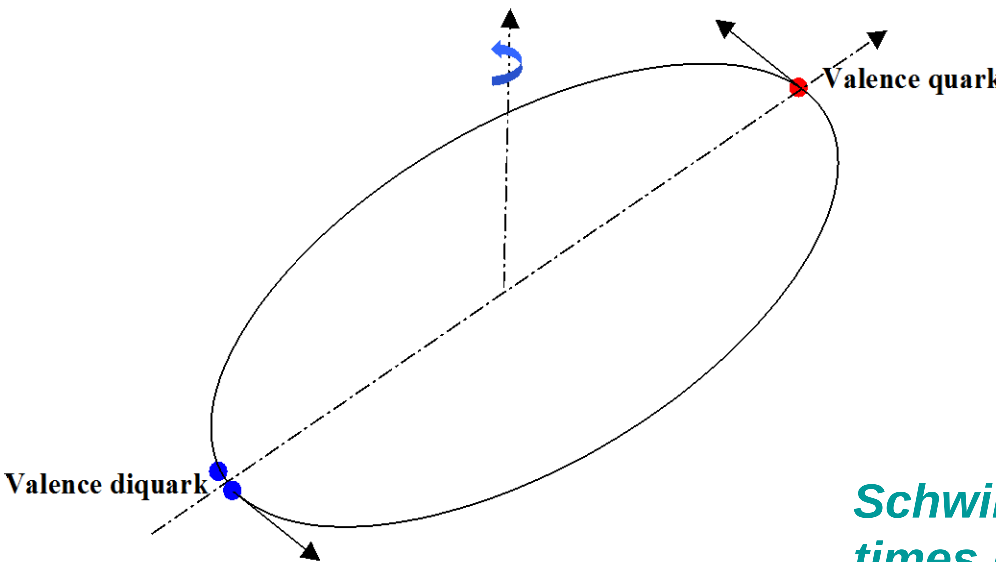
Conclusion

- **Does we underestimate the primary energy of EAS above 10 PeV, more and more as the energy is rising?**
- ***In 1963, 5 years after the observation of the knee, the fixed index near $\gamma \sim -2.5$ was proposed by Ginzburg assuming an equal contribution from the 3 energy sources , kinetic energy of the gas turbulent motion, the magnetic field energy and the cosmic ray energy.***
- **The tendancy in LHC when reaching $\sqrt{s}$ =14 TeV (100 PeV in cosmic rays) might provide a new interpretation of cosmic rays above the knee.**



1 - X 1
P
q q
X1
q
q
X2
P
q q
1 - X 2

String Model and di-quark breaking

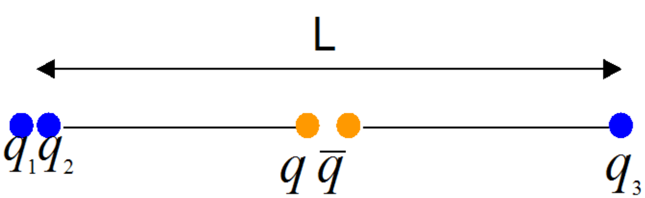


Tension $\kappa = \frac{1}{2\pi\,\alpha'} \cong 1\,\mathrm{GeV}\ /\mathrm{fm}$

α' : Regge Slope

$$\sqrt{\langle p_T \rangle^2} = \sqrt{\frac{\kappa}{\pi}}$$

Schwinger theory, tension 10 times larger for partners of valence diquark?



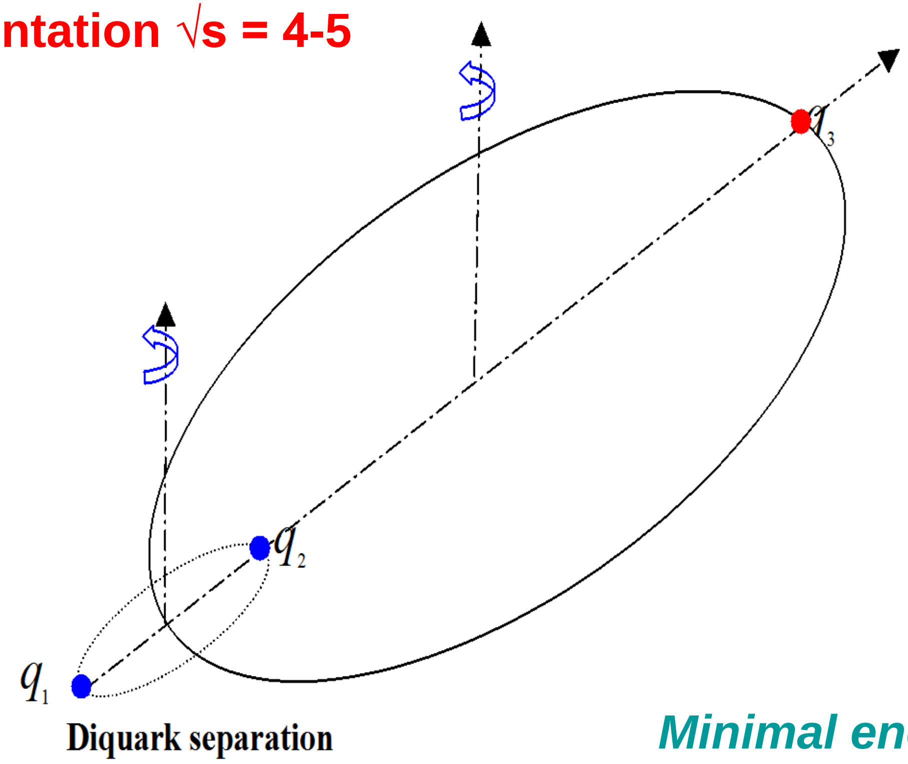
The pair $q\bar{q}$ is created when the distance L exceeds a threshold value.

Above a threshold energy, the di-quark is broken excluding recombination of the leading cluster.

Most energetic gamma's aligned in realtion with valence quarks?

Very large tension for the diquark partners ?

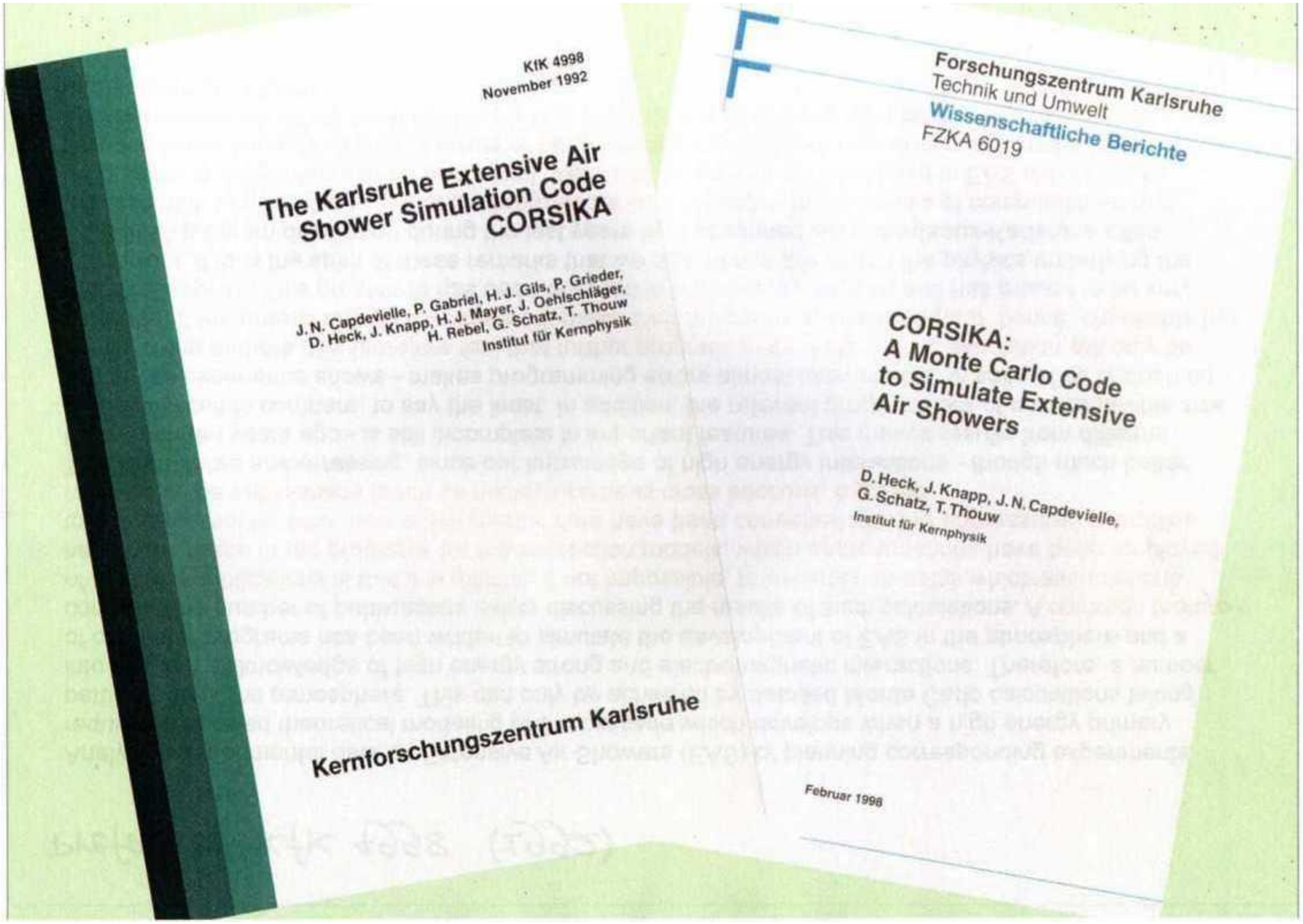
Energy threshold for valence diquark fragmentation √s = 4-5 TeV ?



Maximal tension when the 3 valence quarks are at the largest distance from each other, then aligned.

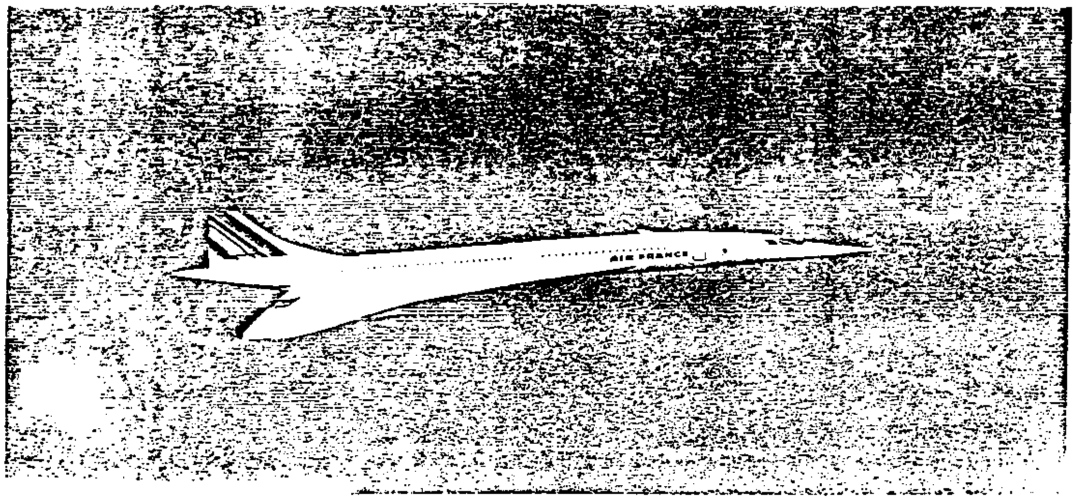
Minimal energy consumed at threshold and maximal probability of observation in cosmic rays

CORSIKA is 2 solar cycles old!
(Curved option in present work)



CERN Courier
October 1981

- Experiences ECHOS started in October 1978
- 0ne collision of 10^6 GeV (high multiplicity, spikes in the distribution of pseudo-rapidité) at first exposure



Concorde — adding to the repertoire of cosmic ray experiments.

(Photo Air France)

High flying physics

Cosmic ray physicists have always had to aim high. In the constant search for interactions produced as close as possible to the immensely high primary particles entering the earth's atmosphere from outer space, they have installed experiments on high mountain peaks and flown detectors aloft in balloons.

In these studies, there have been periodic sightings of remarkable configurations of secondary particles. These events, many of which bear exotic names like Centauro, Andromeda, Texas Lone Star, etc., frequently defy explanation in terms of conventional physics ideas and give a glimpse of what may lie beyond the behaviour seen so far under laboratory conditions.

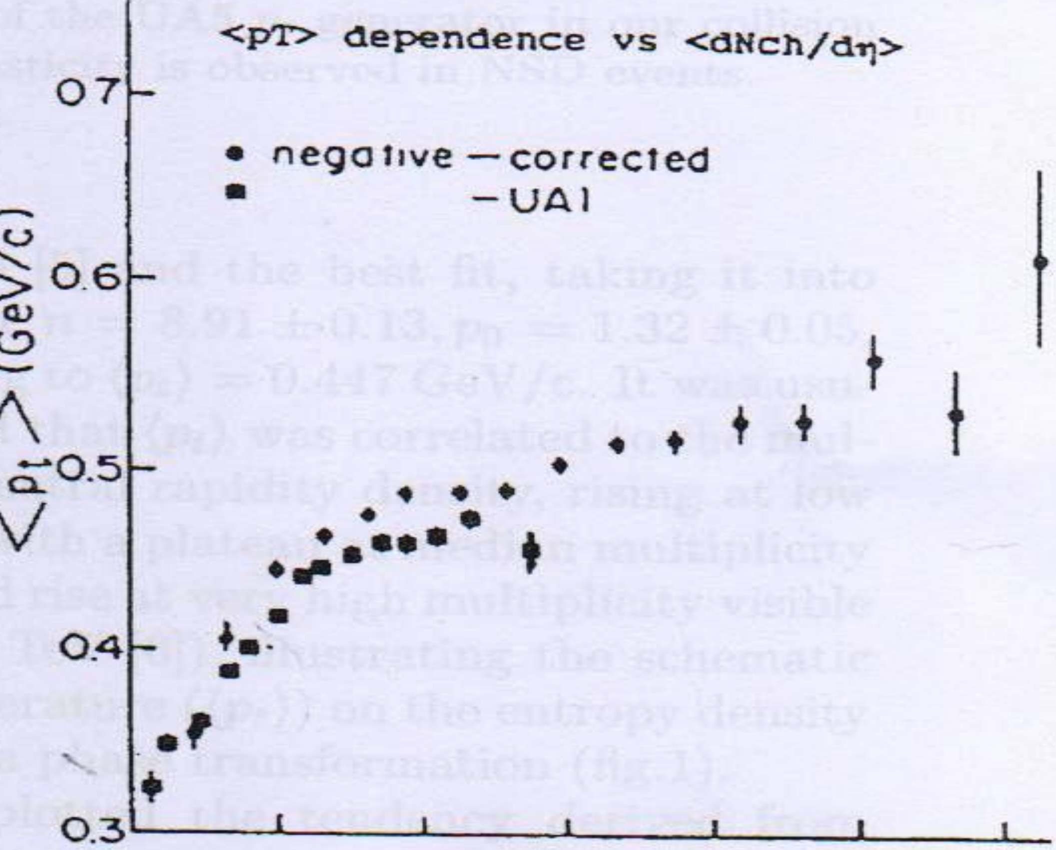
The 540 GeV collisions at the CERN proton-antiproton collider (equivalent to a 155 TeV proton beam hitting a stationary target) will for the first time provide man-made energies which approach the region where these exotic events might turn up. This search is perhaps second only on the experimental agenda to the quest for the intermediate weak interaction bosons.

But cosmic ray studies continue to produce interesting results. In 1978, the ECHOS experiment began by a France/Japan collaboration using emulsion chambers mounted in the baggage compartment of an Air France Concorde supersonic airliner. This has too produced its exotic event, tamely referred to as JF1af1.

Two emulsion chambers were packed in the Concorde baggage hold, one being specifically designed for the detailed observation of high energy events. This 35 kg JF1a chamber contained three sections, an upper one with different types of nuclear emulsion plates to enable charge determinations to be made, a central target layer, and an emulsion calorimeter at the bottom. The second Concorde detector was more concerned with measuring particle fluxes.

The exposure was planned to cover 200 hours of level flight some 16 km above sea level, requiring a total of some two months in the aircraft. Because of the high altitude and relatively long exposure, a good crop of high energy interactions was obtained. In particular, the very first flight produced the JF1af1 event, estimated as containing about 150 gamma rays and a total radiated energy of 260 TeV. As well as its large energy and high multiplicity, the event is remarkably well collimated. The presence of a certain level of hadrons implies that the event was due to a nuclear interaction and analysis suggests that it occurred somewhere on or inside the Concorde, rather than in the outer atmosphere. Its closest counterpart so far observed is the Texas Lone Star interaction picked up by balloon-borne emulsion stacks.

er replacement of the UA5 ... generator in one collision
10 % of the inelasticity is observed in NSD events.
ect are discussed



by Hagedorn [1] and the best fit, taking it into account, gave $n = 8.91 \pm 0.13$, $p_0 = 1.32 \pm 0.05$, corresponding to $\langle p_t \rangle = 0.447$ GeV/c. It was usually admitted that $\langle p_t \rangle$ was correlated to the multiplicity or central rapidity density, rising at low multiplicity with a plateau at medium multiplicity (and a second rise at very high multiplicity visible at $\sqrt{s} = 1.8$ TeV [8]) illustrating the schematic picture temperature ($\langle p_t \rangle$) on the entropy density (dN/dy) for a phase transformation (fig.1).

We have plotted the tendency derived from UA1/MI results

$$\langle p_t \rangle = 0.0109 \left\langle \frac{dN_c}{d\eta} \right\rangle + 0.383 \qquad (2)$$

for $\langle \frac{dN_c}{d\eta} \rangle \geq 3.4$,

$$\langle p_t \rangle = 0.0033 \left(\left\langle \frac{dN_c}{d\eta} \right\rangle - 1.56 \right)^2 + 0.406 \qquad (3)$$