Leading Cluster Approach to Simulation of Hadron collisions with Ghost Generator

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Outlook

. VHE Interactions in the LHC

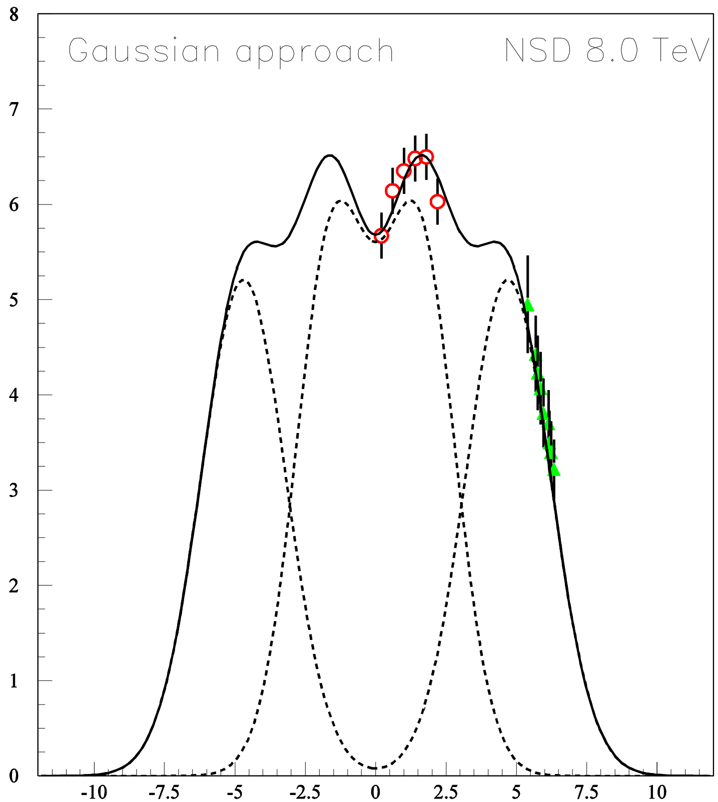
- 4 gaussians or multiple clusters, charged multiplicity, central pseudorapidity density, energy dependence of the mean central charged particle density
- pseudorapidity distribution normalized by the mean multiplicity

- Semi inclusive data
  - KNO scaling in central region, Empirical scaling
  - Semi-inclusive data

Leading clusters

- leaders distributed randomly
- leaders confined among 10% of most energetic secondaries

Approach with Gaussian deviates



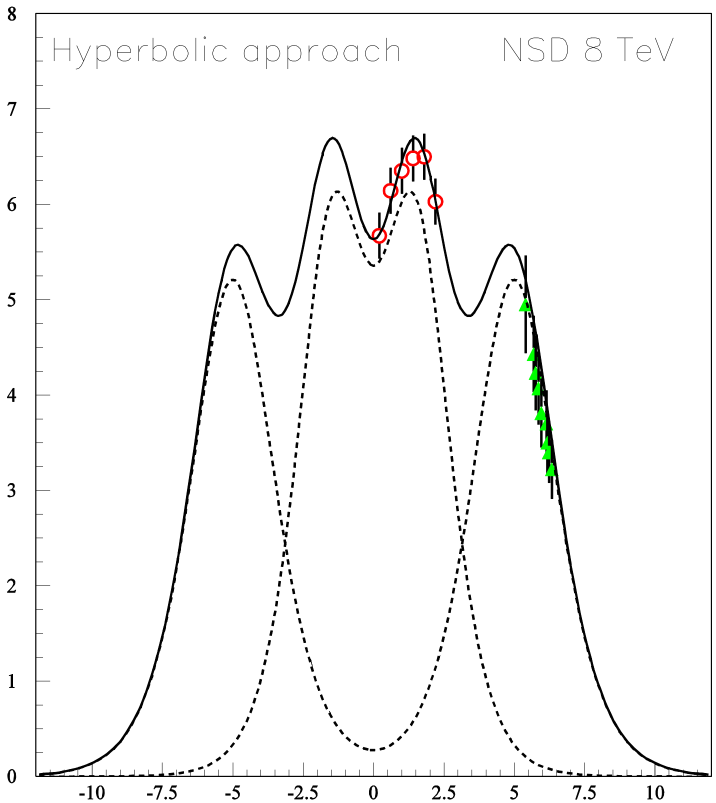
- 4 gaussian functions
- $A_i \{\exp(-0.5u_i) + \exp(-0.5v_i)\}$
- $u_i = \{(y-y_i)/\sigma_i\}^2$
- $v_i = \{(y+y_i)/\sigma_i\}^2$

$A_i = 5.21, 5.6$

$Y_i = 4.7, 1.53$

$\sigma_I = 1.5, 1.3$

Hyperbolic approach



Dependance $1/\cosh^2 y$

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

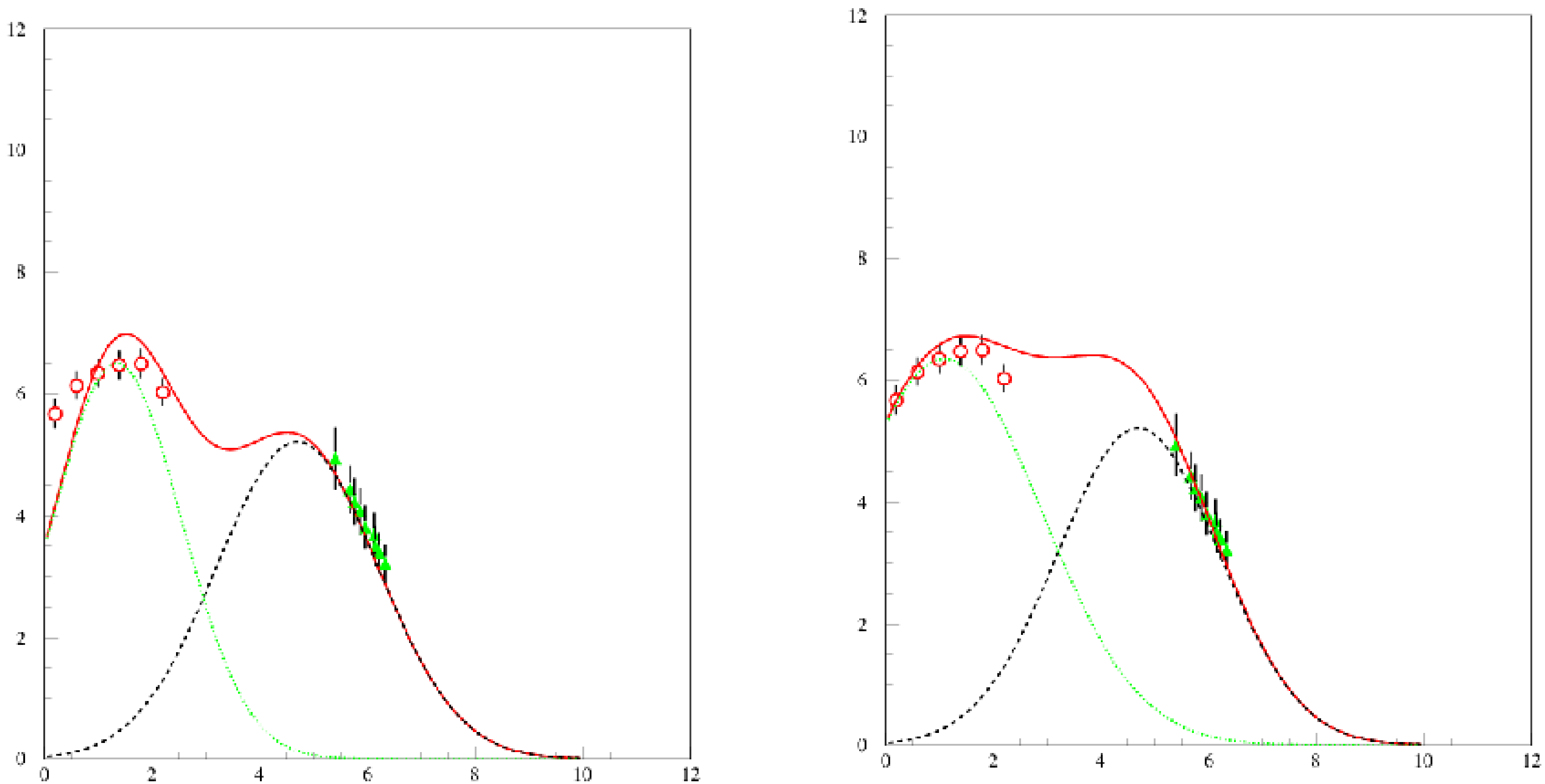
- $u_i = \{a_i(y-y_i)\}$
- $v_i = \{a_i\ (y+y_i)\}$

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

Gaussian hadronic generation

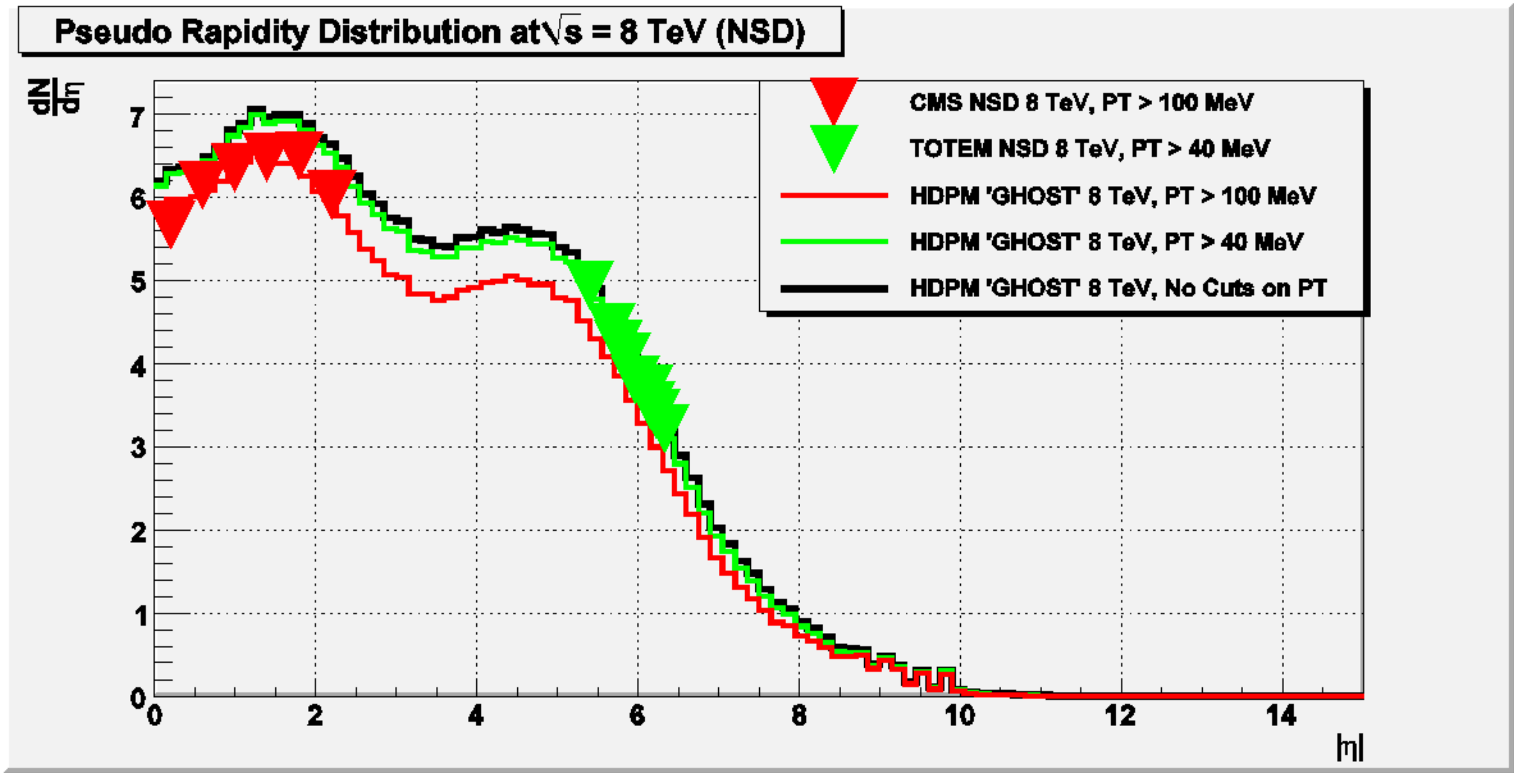
- **Multiplicity N via negative binomial function $\Psi(z)$ with KNO scaling violation (z=N/<N>)**
- **Central regularity vs z, parameters for semi-inclusive data**
- **couples (y_i, $p_{t\,i}$) via gaussian generation of rapidity and p_t**
- **Validity of the set of secondaries for a single collision,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

Approach of the pseudo**rapidity** source (no more plateau of Feynman?)



INTEST option of CORSIKA

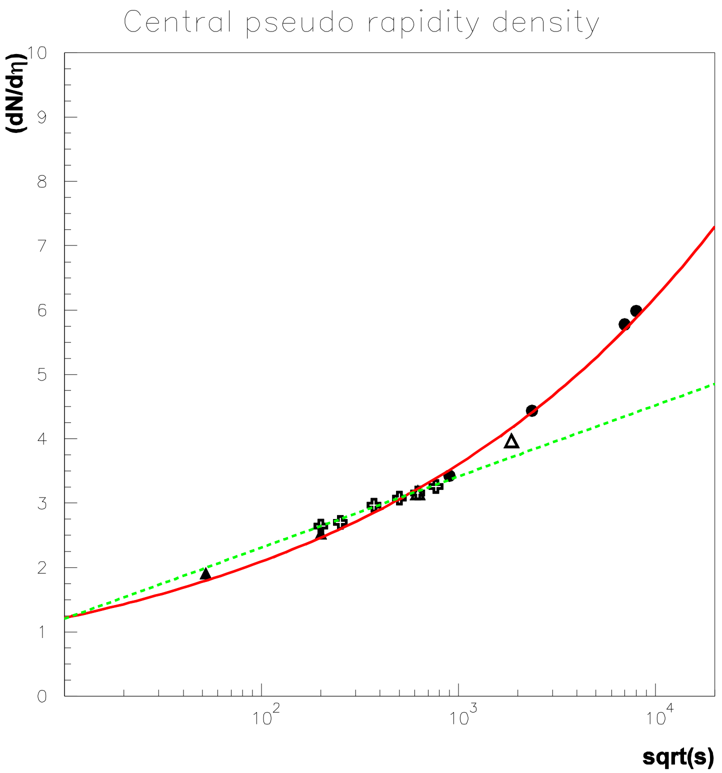
(with Z. Plebaniak and J. Szabelski)

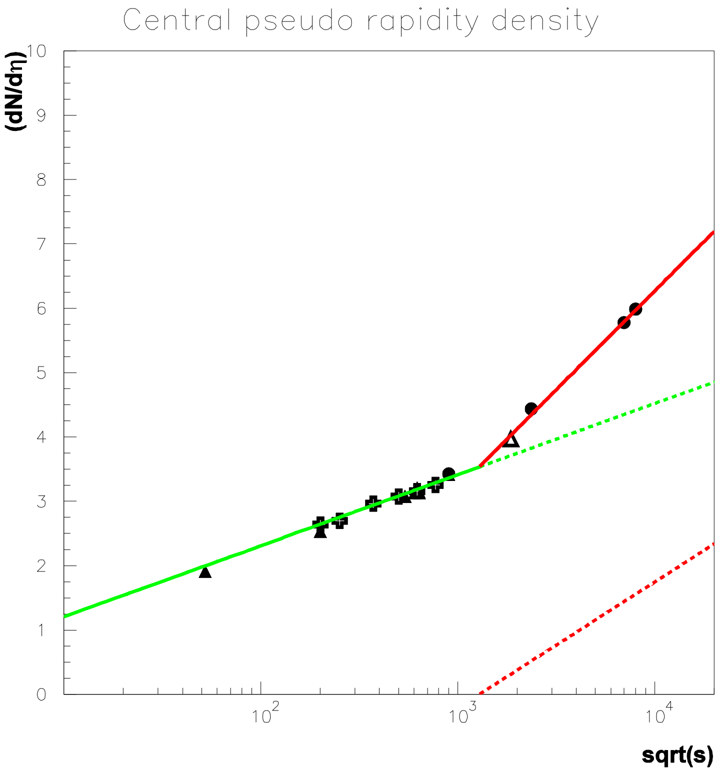


$$\rho_o = 0.70835\ s^{0.11775}$$

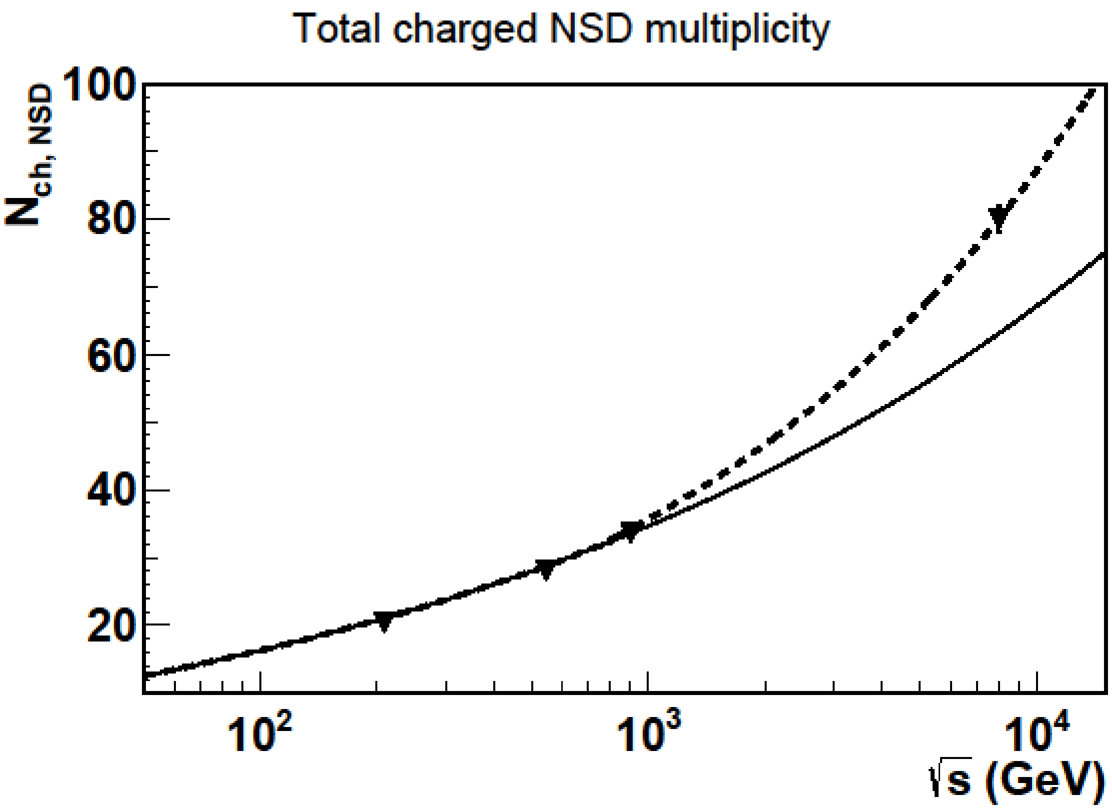
or

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





Charged NSD Multiplicity



$< N_{\_ch\text{-}ua5} > = \mathbf{-7.0\ +7.2\ s^{0.127}}$

$\mathbf{< Nch > = -0.74 + 2.59\ s^{0.191}}$

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

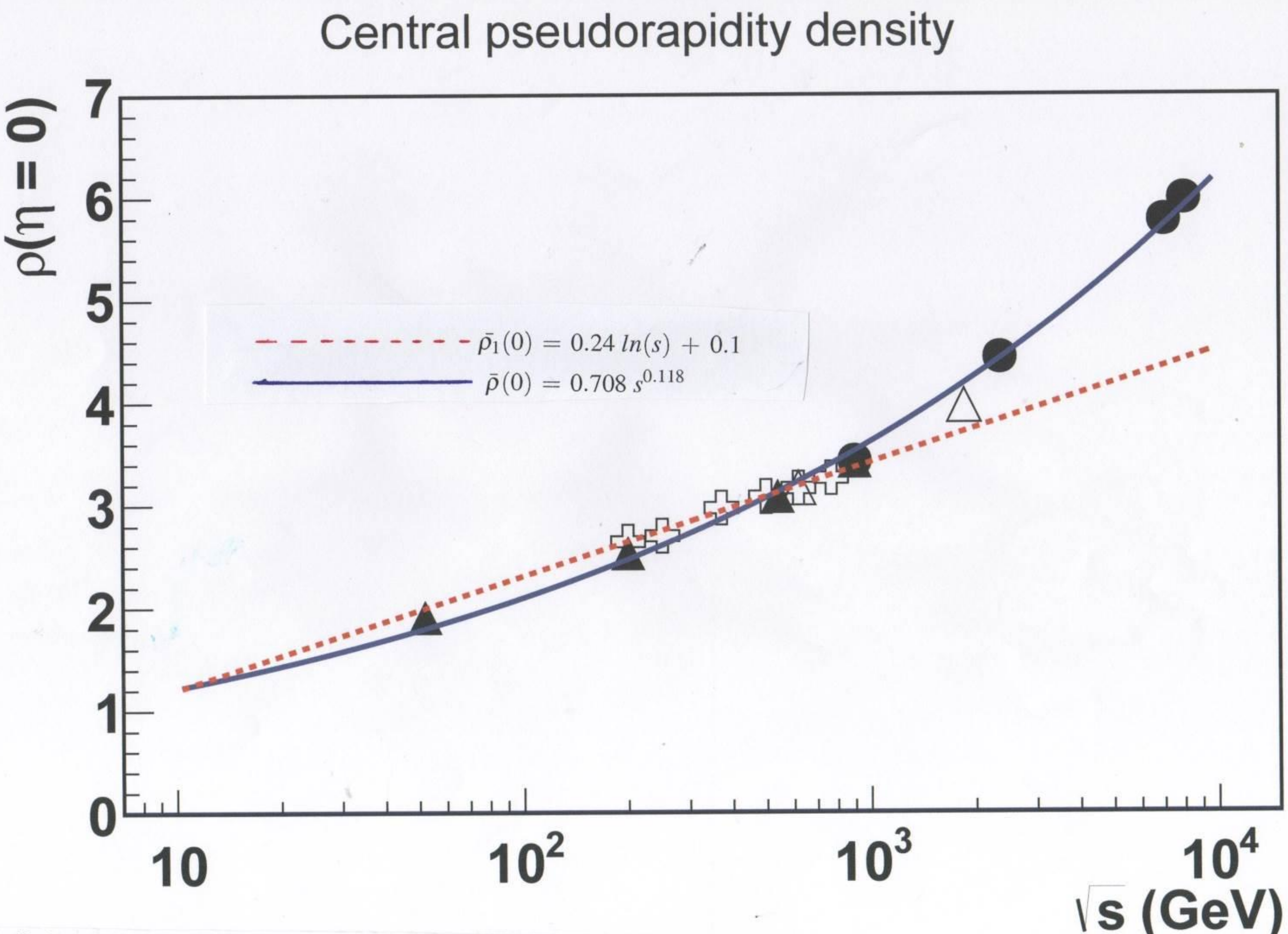
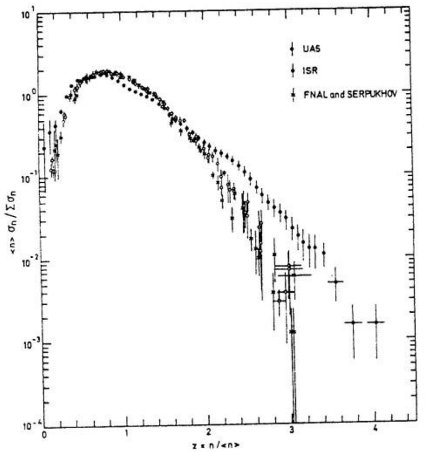


Fig.1b (right): Central pseudorapidity density dependence on s for $E_0 = 10^{13}$-10^{17} eV.

KNO scaling violation

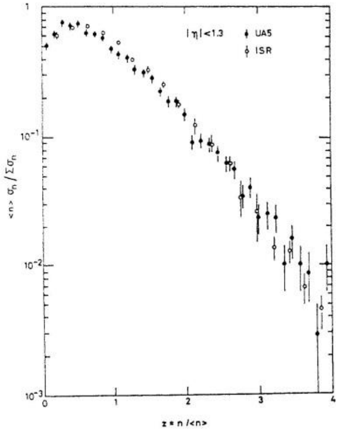
Fluctuations of NSD total multiplicity

Violation between ISR ($\sqrt{s}$ = 53 GeV)and UA5 ($\sqrt{s}$ = 540 GeV) established in 1983



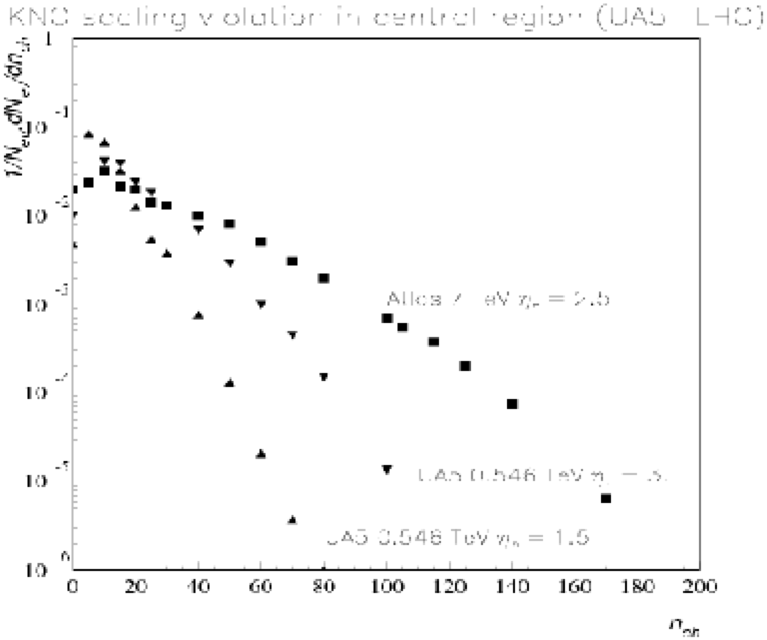
UA5, Alner et al.,Phys. Lett. B 180 (1986), 415

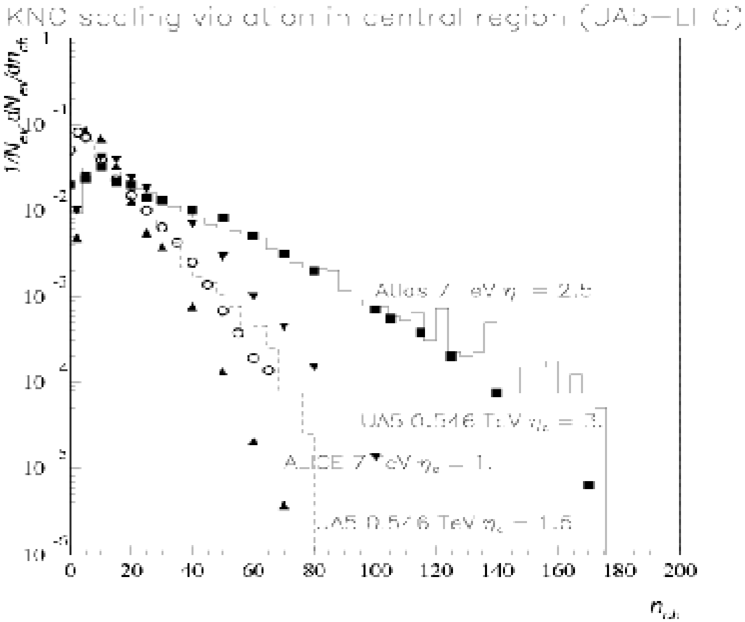
Scaling in central region $\sqrt{s}$ = 53 GeV and $\sqrt{s}$ = 540 GeV ?? for $|\eta| < 1.3$



UA5, Alner et al., Phys. Lett. B 138 (1984), 304

KNO scaling violation in central region

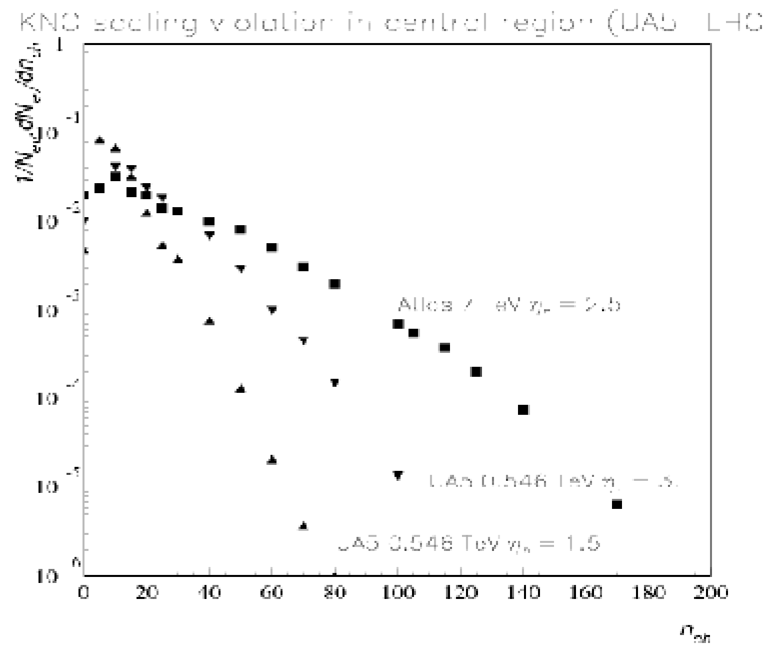




Violation of KNO scaling at Vs = 8 TeV

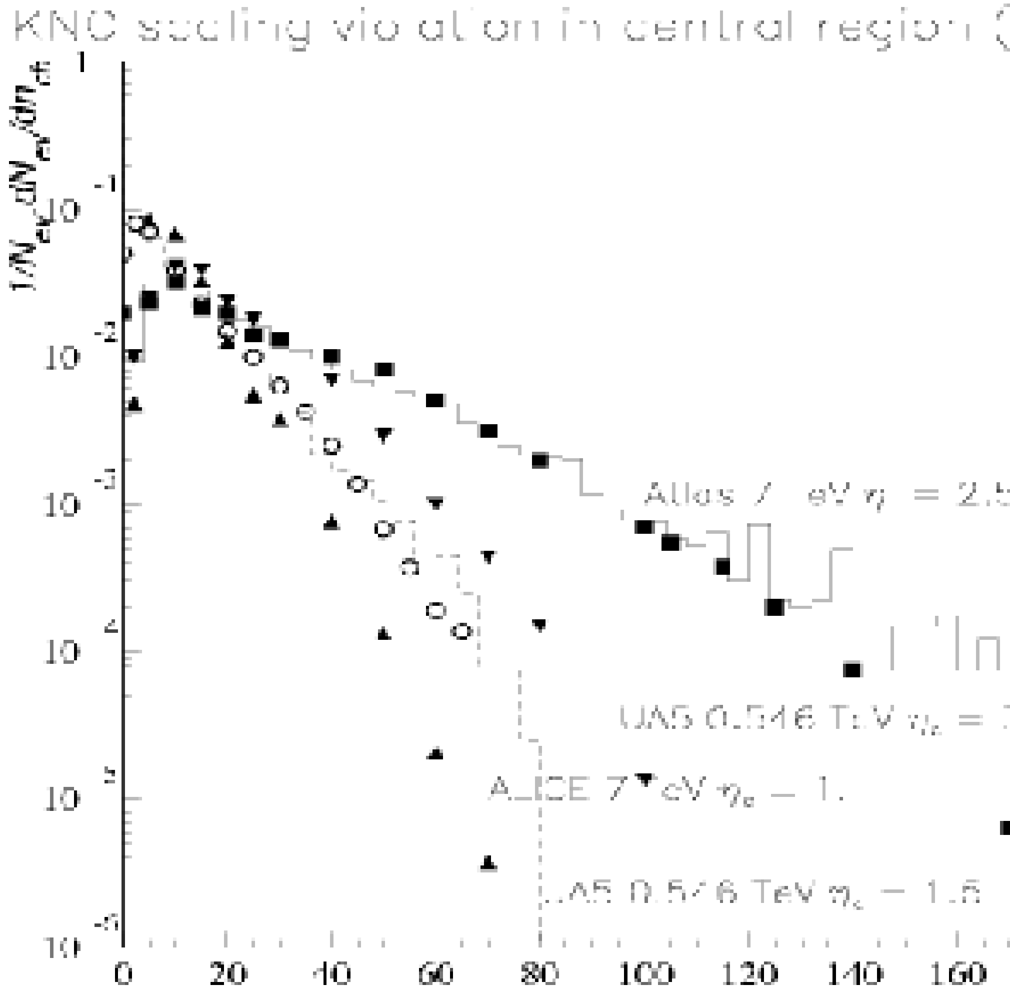
Measurements of Alice and UA5

KNO scaling in central region of pseudorapidity is no more conserved for Vs> 1 TeV



Violation of KNO scaling in central region

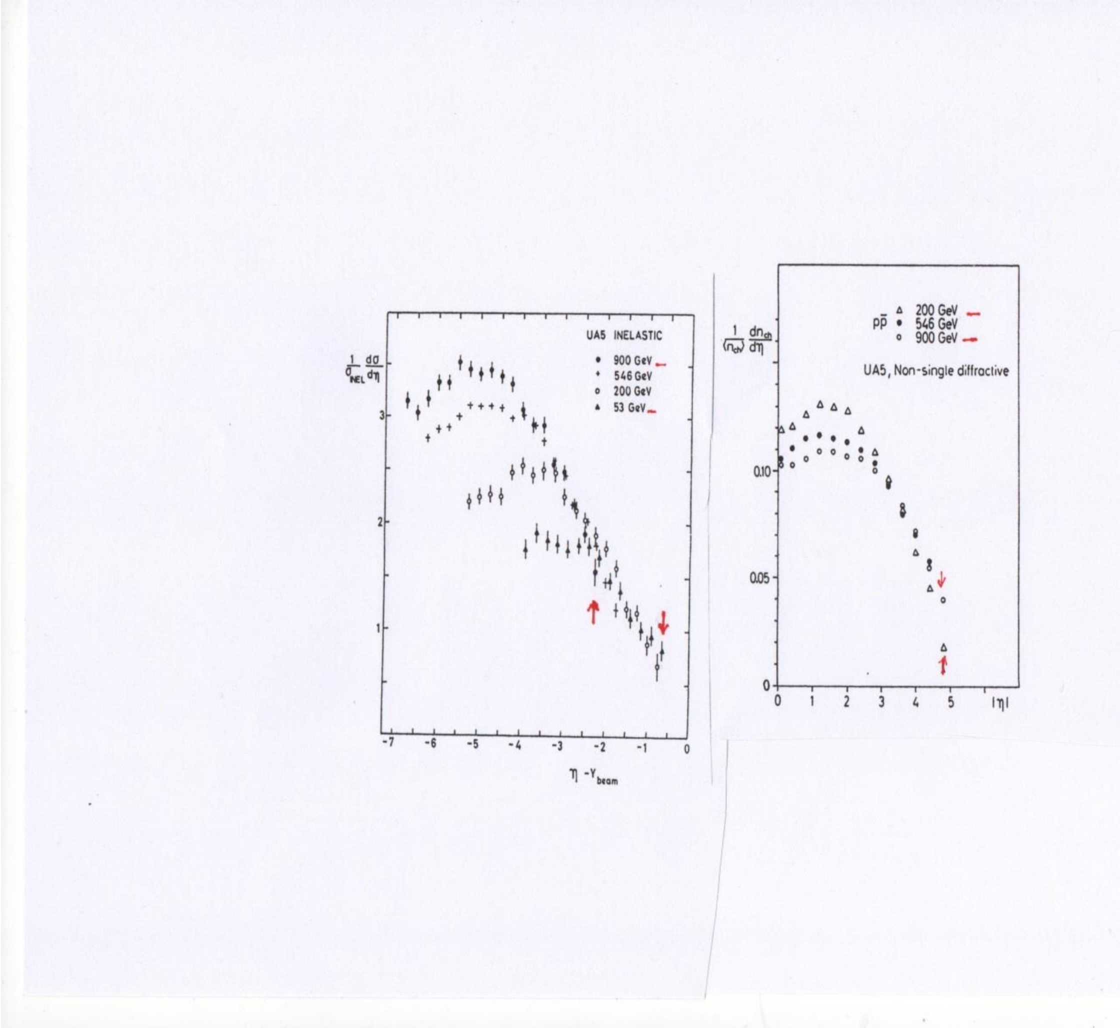
Comparison of GHOST results (histograms) with Alice and Atlas data at Vs = 8 teV



Test of scaling in fragmentation region

Right: UA5 NSD pseudorapidity distribution at Vs= 200, 546, 900 GeV

Left: Inelastic pseudorapidty distribution in the beam rest frame for Vs=53, 200, 546, 900 GeV



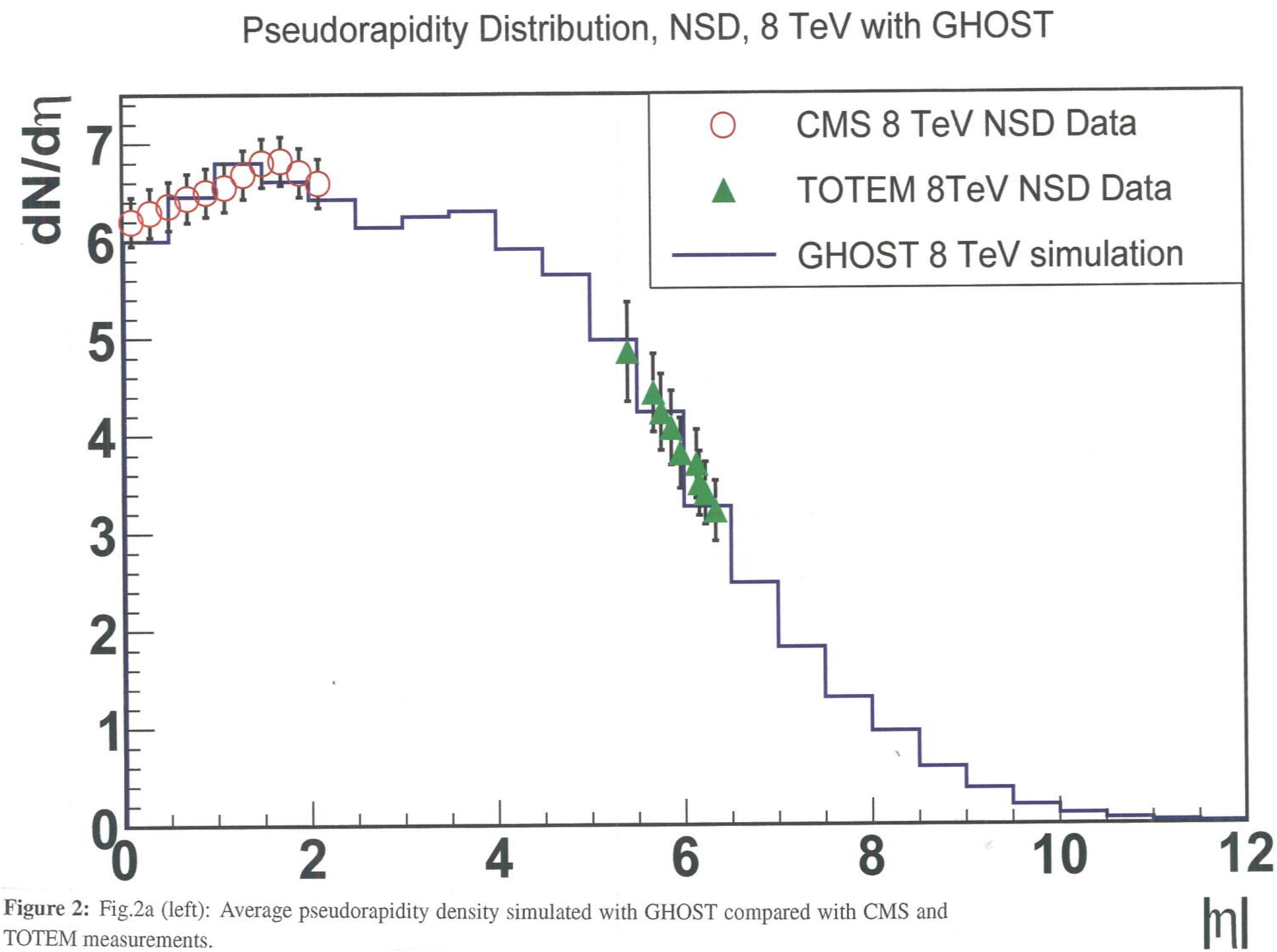


Figure 2: Fig.2a (left): Average pseudorapidity density simulated with GHOST compared with CMS and TOTEM measurements.

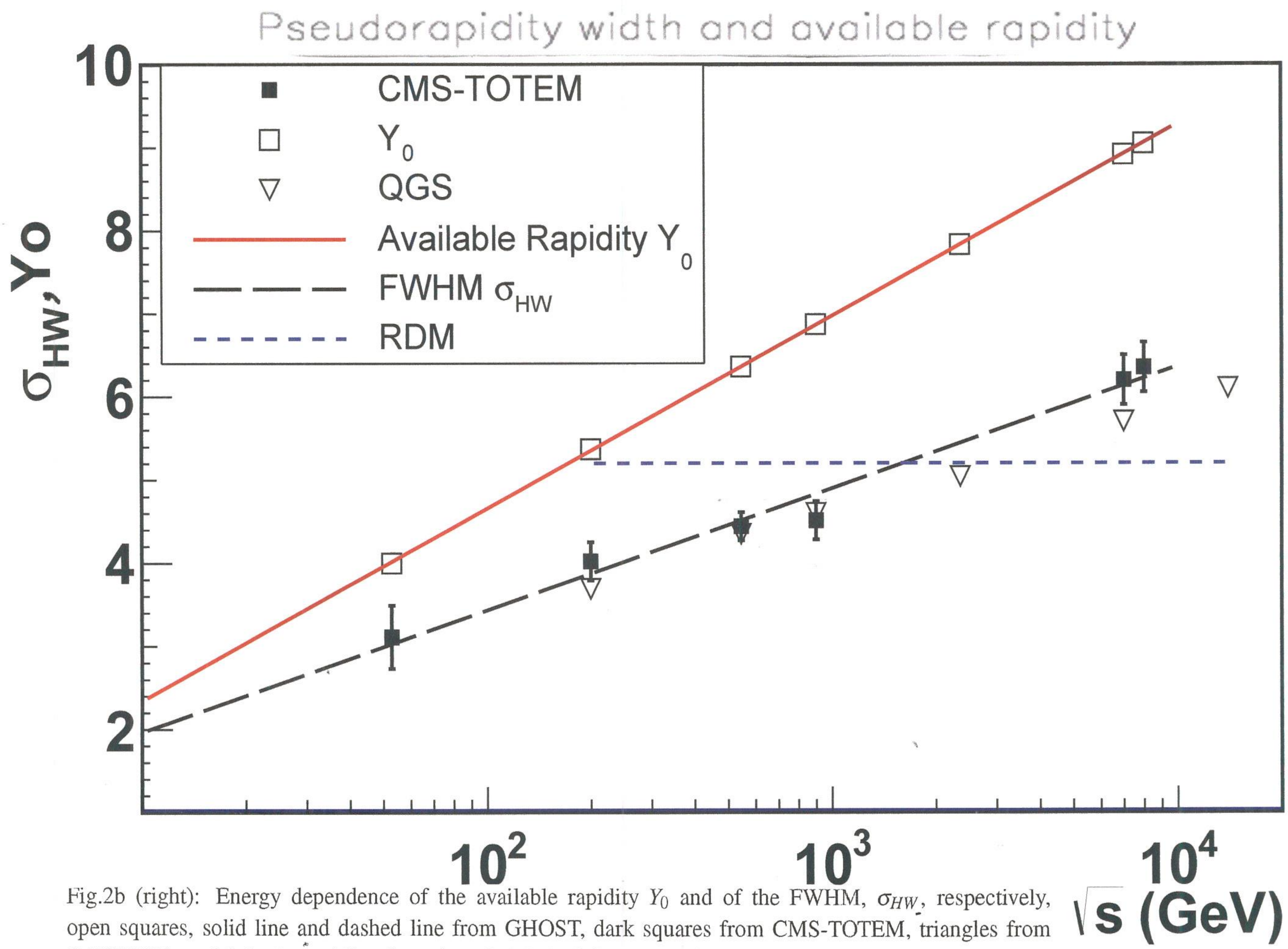
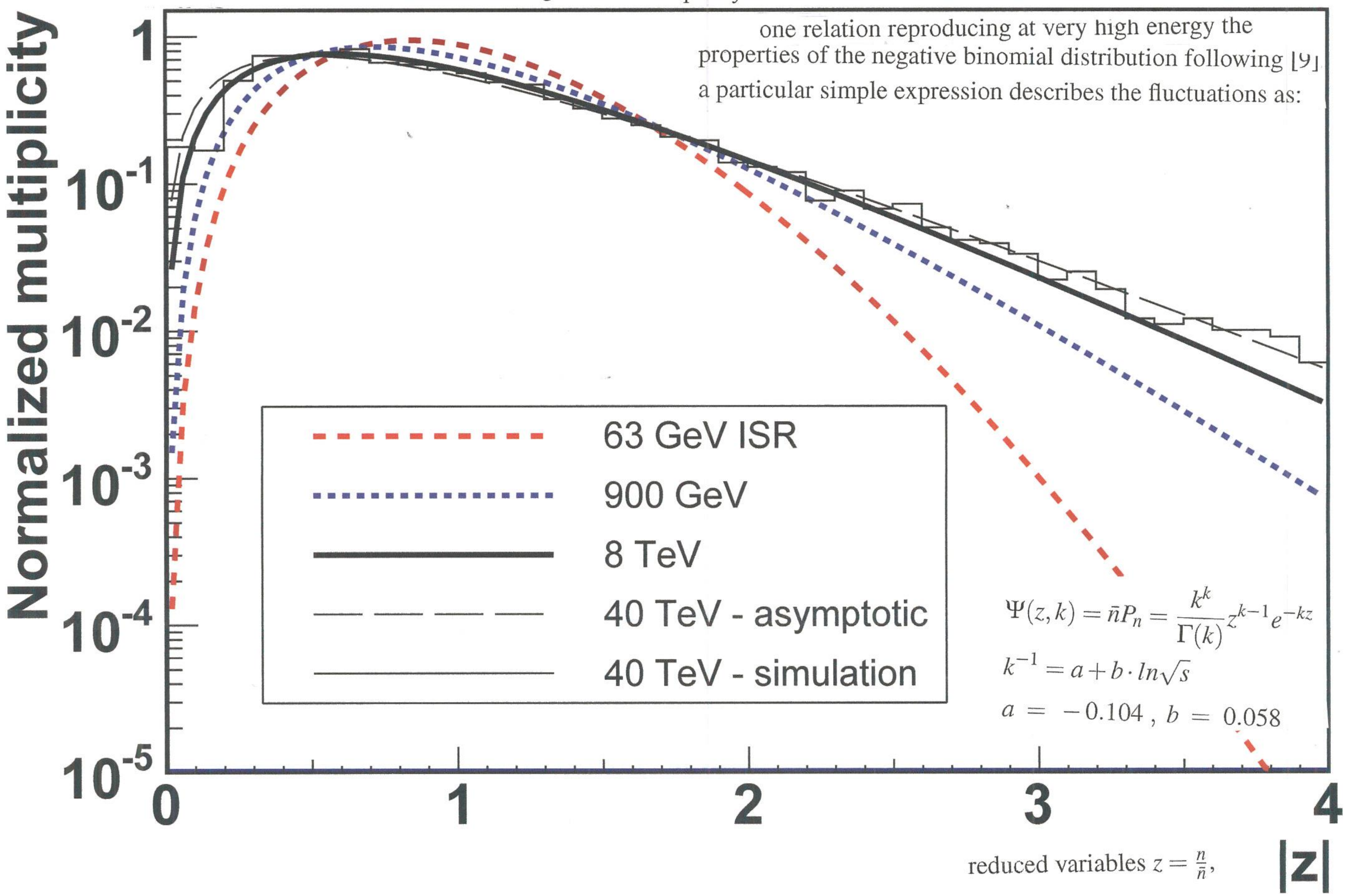


Fig.2b (right): Energy dependence of the available rapidity Y_0 and of the FWHM, σ_{HW}, respectively, open squares, solid line and dashed line from GHOST, dark squares from CMS-TOTEM, triangles from QGSJET01 model, horizontal line from the relativistic diffusion model RDM [7].

(Violation of) KNO scaling

Figure 3: Fig.3a. Fluctuations of total charged NSD multiplicity.



Central regularity

3.2 Empirical scaling

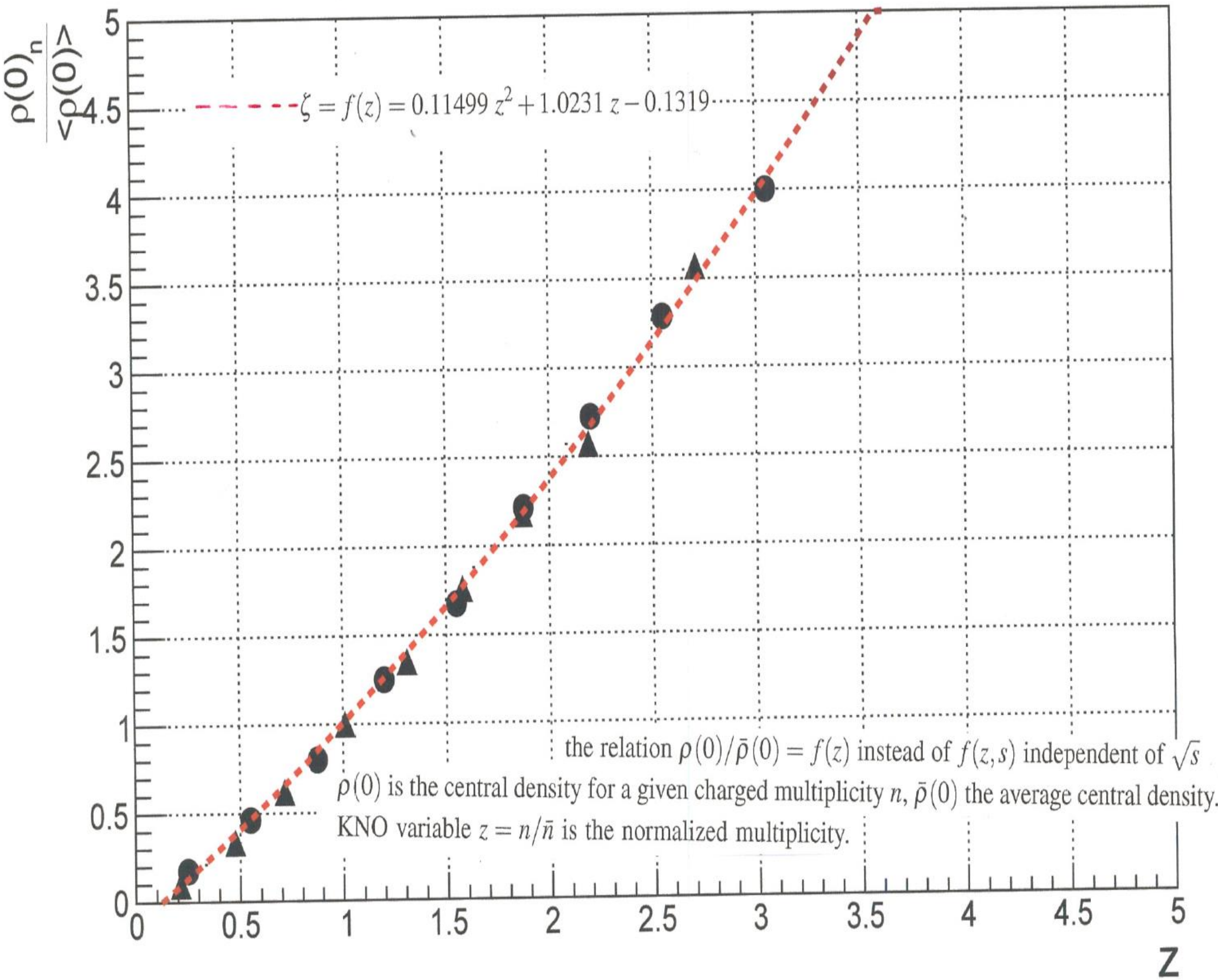


Fig.3b. Empirical scaling function $\zeta = f(z)$ for $\sqrt{s} = 200$, 546 and 900 GeV for NSD collisions.

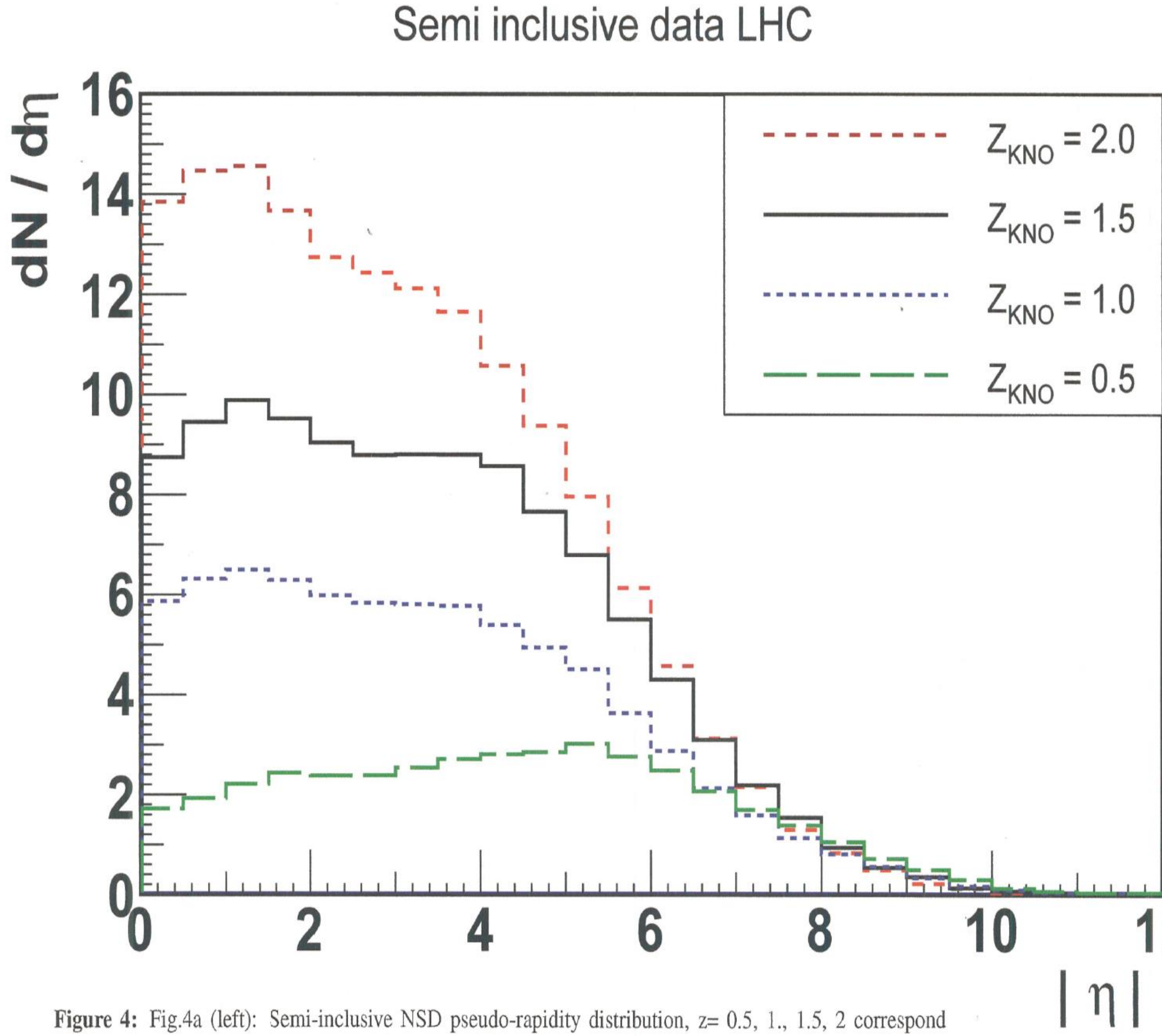


Figure 4: Fig.4a (left): Semi-inclusive NSD pseudo-rapidity distribution, z= 0.5, 1., 1.5, 2 correspond respectively to relative intervals of N_{ch} $[0.25 - 0.75]$, $[0.75 - 1.25]$, $[1.25 - 1.75]$, $[1.75 - 2.25]$.

3.3 Semi-inclusive data

The semi-inclusive data is governed by the integro-differential system:

$$\frac{dN}{dy}_{y=0} = m_r \frac{dN}{d\eta}_{\eta=0} = m_r \, \zeta \, \bar{\rho}(0) \tag{3.3}$$

$$\int \frac{dN}{dy} dy = z < n > \tag{3.4}$$

m_r is the ratio of central mean rapidity density and mean central pseudo rapidity density derived from the "dip" existing in the centre of the pseudorapidity distribution, resulting from the mass m and the transverse mass m_T of the secondaries as $m_r = \sqrt{1 - \frac{m^2}{m_T^2}}$. In the case of the 4 gaussian generation (one pair of functions in each hemisphere, symmetrics around the center of mass,

$$\frac{dN}{dy} = \sum_{i=1}^{i=2} a_i (e^{-0.5u_i} + e^{-0.5v_i}) \tag{3.5}$$

$$u_i = (\frac{(y-y_i)}{\sigma_i})^2, \; v_i = (\frac{(y+y_i)}{\sigma_i})^2$$

it is possible to use the opportunity of the scaling $3-2$ in the relation between the center y_i and the width σ_i of each gaussian function as

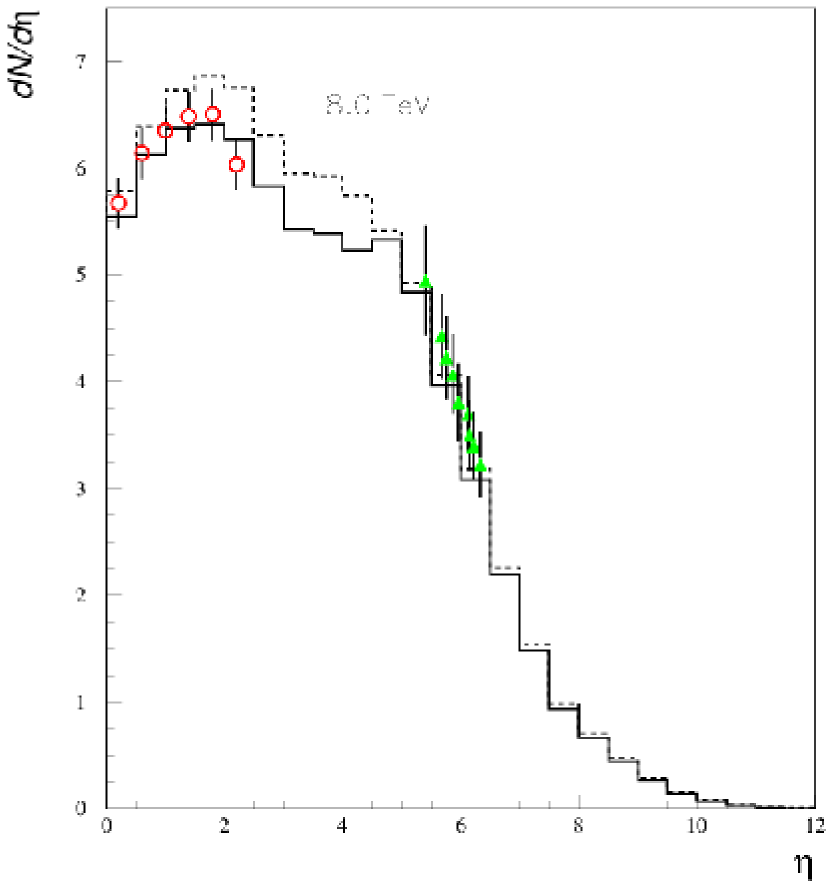
$$y_i = \sigma_i \, (2ln(\frac{z < n >}{\sqrt{(2\pi)} \, \zeta \, \sigma_i}))^{0.5} \tag{3.6}$$

After introducing one proportion χ of the multiplicity distributed to the pair of gaussian centered in central region and in mid-rapidity region, it is possible to obtain with a minimal Monte Carlo generation of random deviates the total original rapidity distribution source of the distribution of

INELASTIC 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

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



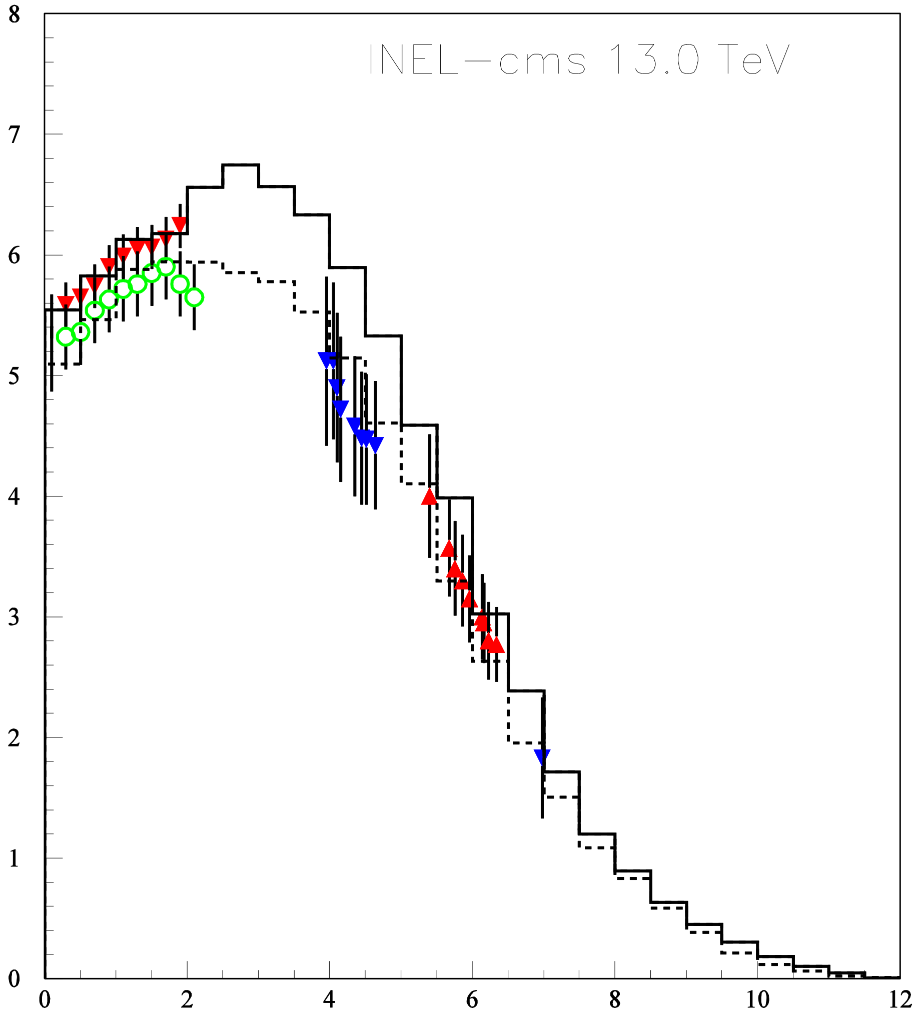
Inelastic pseudorapidity

CMS and Totem data.

Calculation with the generator GHOST

at $\sqrt{s}$ = 8 TeV and

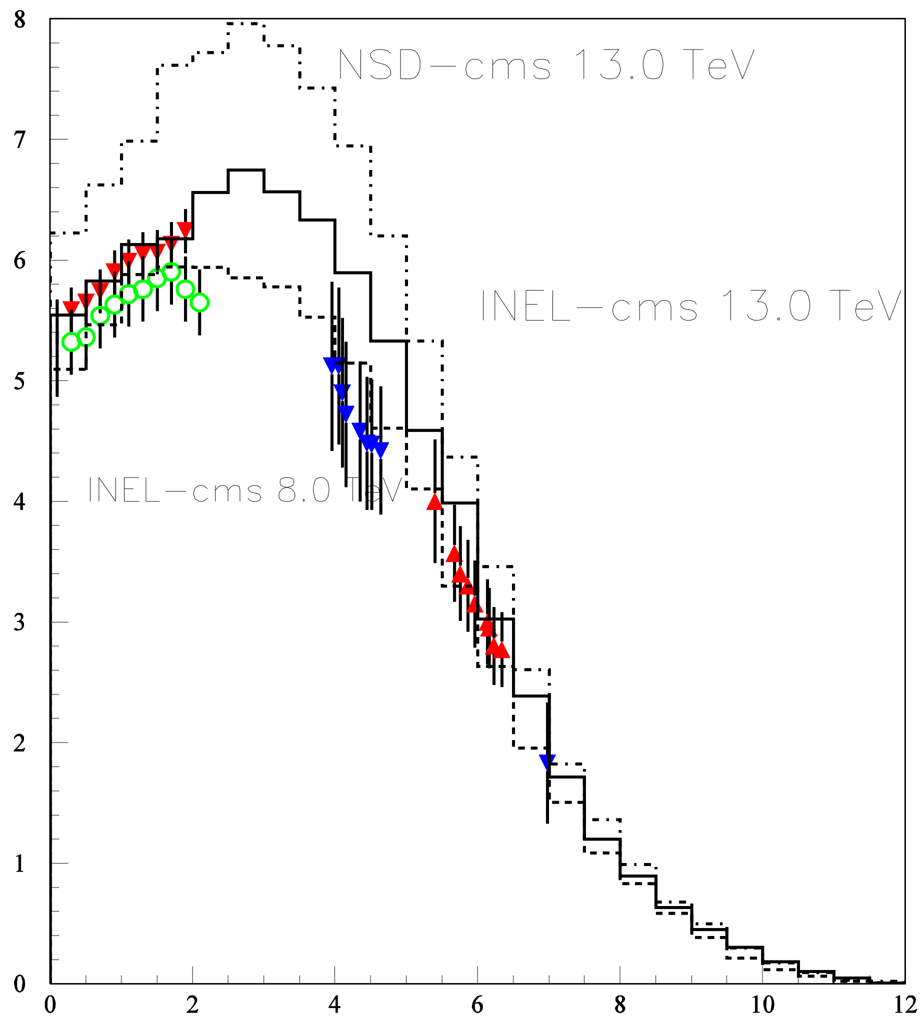
$\sqrt{s}$ = 13 TeV.



NSD and INELASTIC distributions

Simulation with Ghost

Data from CMS (only inelastic for points)



NSD distribution

Case of leading cluster used inside 10% of most energetic secondaries

```
 HBOOK      ID =          9                                                DATE
01/07/2018            NO =      9

        6.6         --
        6.4        -II-
        6.2       -I  I-
        6         I    I-
        5.8       I     I-
        5.6       I      I
        5.4       I      I-
        5.2       I       I
        5         I       I
        4.8       I       I
        4.6       I       I-
        4.4       I        I
        4.2       I        I
        4         I        I-
        3.8       I         I
        3.6       I         I
        3.4       I         I
        3.2       I         I-
        3         I          I
        2.8       I          I
        2.6       I          I
        2.4       I          I-
        2.2       I           I
        2         I           I
        1.8       I           I-
        1.6       I            I
        1.4       I            I
        1.2       I            I-
        1         I             I
         .8       I             I-
         .6       I              I-
         .4       I               I-
         .2       I                I------

CHANNELS    10    0        1         2
             1    123456789012345678901234

CONTENTS     1.   666666555433211
             0    024431962581371742100000
             0    546668986980828577463100
             0    492322182175128553280041
             0    972922861780277506764828

LOW-EDGE    10                        1111
             1.     1122334455667788990011
             0    050505050505050505050505

* ENTRIES =      733534      *
```

This is not the previous calculations where the leading particles have been taken randomly at the end of the generation of all charged secondaries

CHARGED MULTIPLICITY DISTRIBUTION AT Vs = 8 TeV

Multiplicity compared in the case of

1/ most energetic leaders confined among secondaries inside 10% of charged multiplicity

2/ Leaders are distributed randomly

3/ convergence at

Vs=40 TeV (as suggested by « SSC » central design group in 1986 ?

- **Multiplicity I Lead. 10% most energetics I Lead. at random**
- **10 83. -------- 170.**
- **20 229. -------- 384.**
- **40 ------- 456. 419.**
- **60 ------- 443. 380.**
- **80 ------- 381. 333.**
- **100 ------- 276. 269.**
- **120 -------- 219. 203.**
- **140 ------- 144. 133.**
- **160 89. --------- 108.**
- **200 39. ---------- 43.**
- **250 27. ---------- 12.**
- **300 3. 3.**

CHARGED PSEUDORAPIDITY DISTRIBUTION AT Vs = 8 TeV

Pseudorapidity distribution compared in the case of

1/ most energetic leaders confined among secondaries inside 10% of charged multiplicity

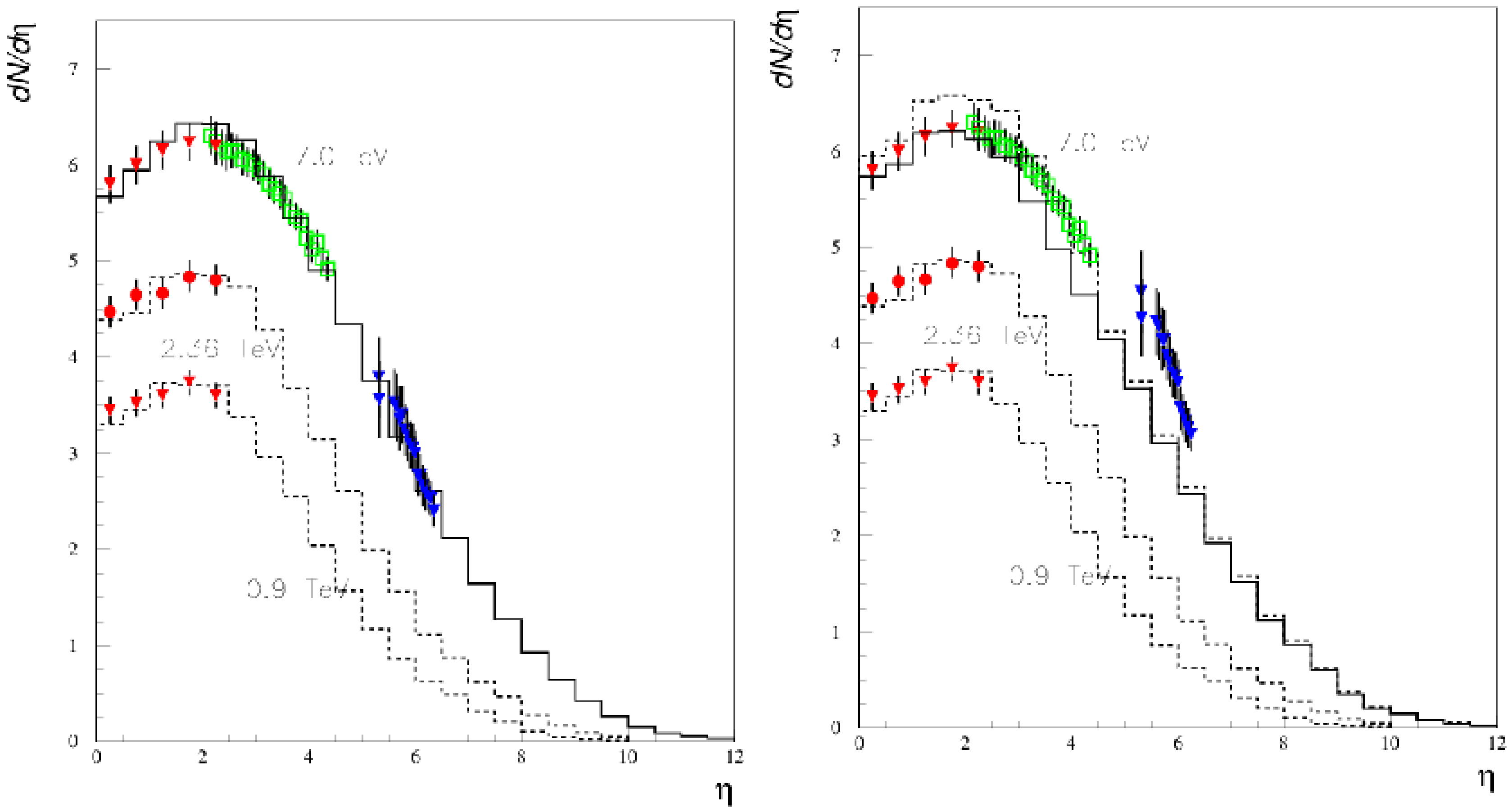
2/ Leaders are distributed randomly (2nd column)

Pseudorapidity	Lead. 10% most energetics	Lead. at random
0.	6.05	6.2
5.	6.24	6.4
10.	6.46	6.6
20.	6.31	6.7
30.	5.99	6.7
40.	5.26	6.27
50.	3.88	5.01
60.	2.38	3.3
70.	1.19	1.9
80.	0.47	0.94
90.	0.14	0.4
100.	0.03	0.12

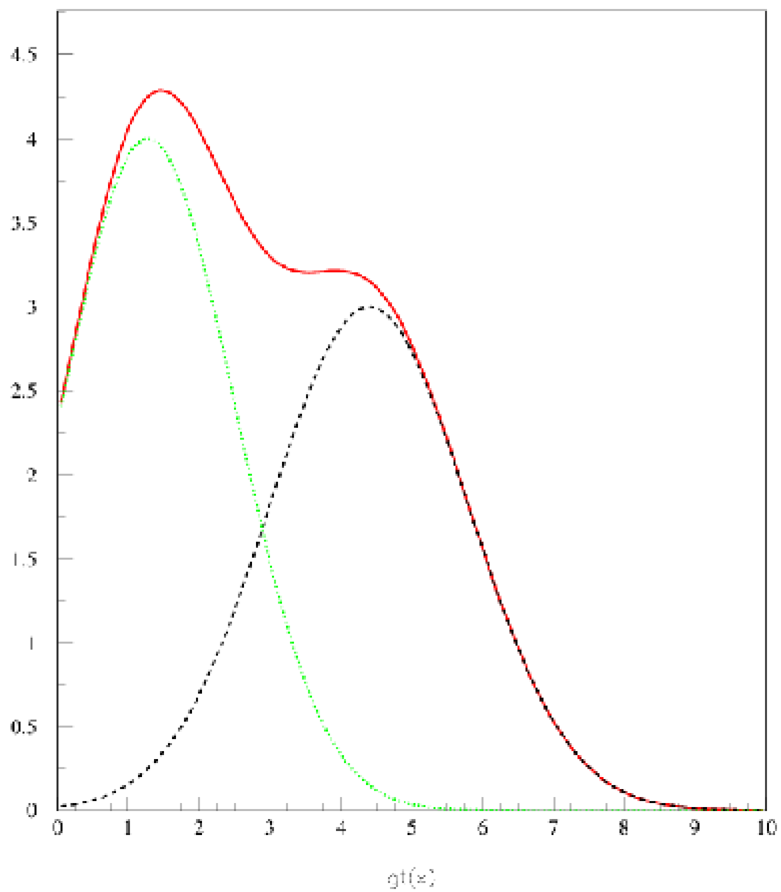
Conclusion

- **The multi-source Generator GHOST can reproduce the inclusive as well as the semi-inclusive data.**
- **The guidelines derived from LHC data at Vs = 8, 13 TeV allow better simulations and extrapolations up to 100TeV.**
- **The enhancement of the inelasticity indicates also a weaker participation of the leading cluster at UHE.**
- **Attempts are proceeded to insert GHOST in CORSIKA.**

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



4 component rapidity generator

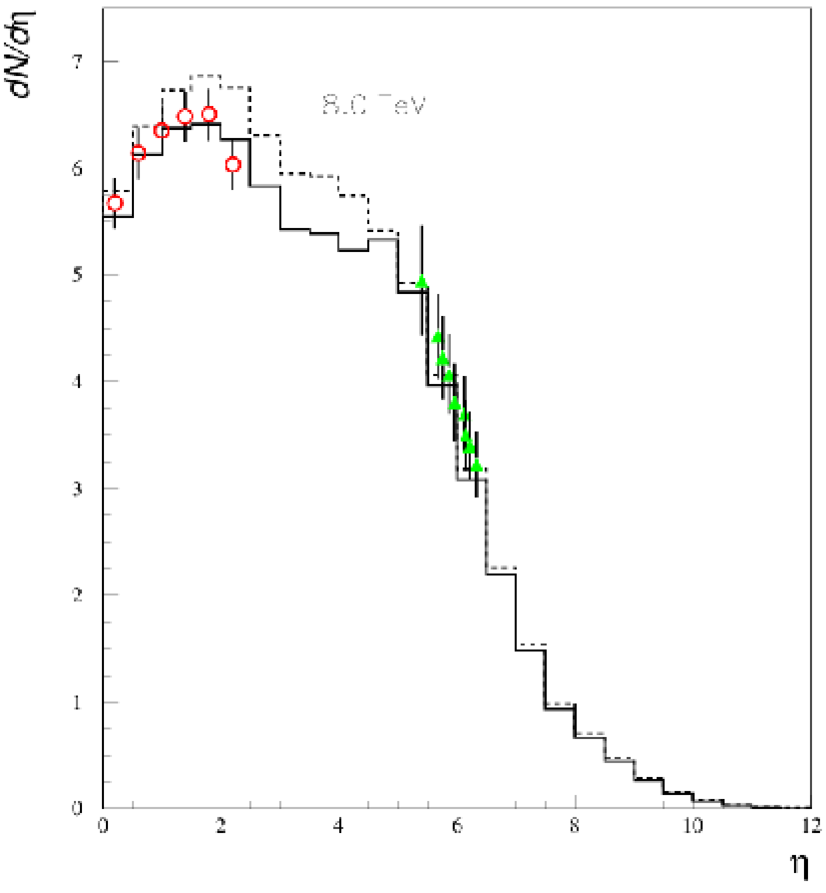


- From HDPM (hybrid dual parton model) to GHOST (Generator of hadrons for simulation treatment)
- Symmetry forward backward hemispheres
- 4 sources of multiparticle production

INELASTIC 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

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



COSMIC RAYS
Concorde hits the fan

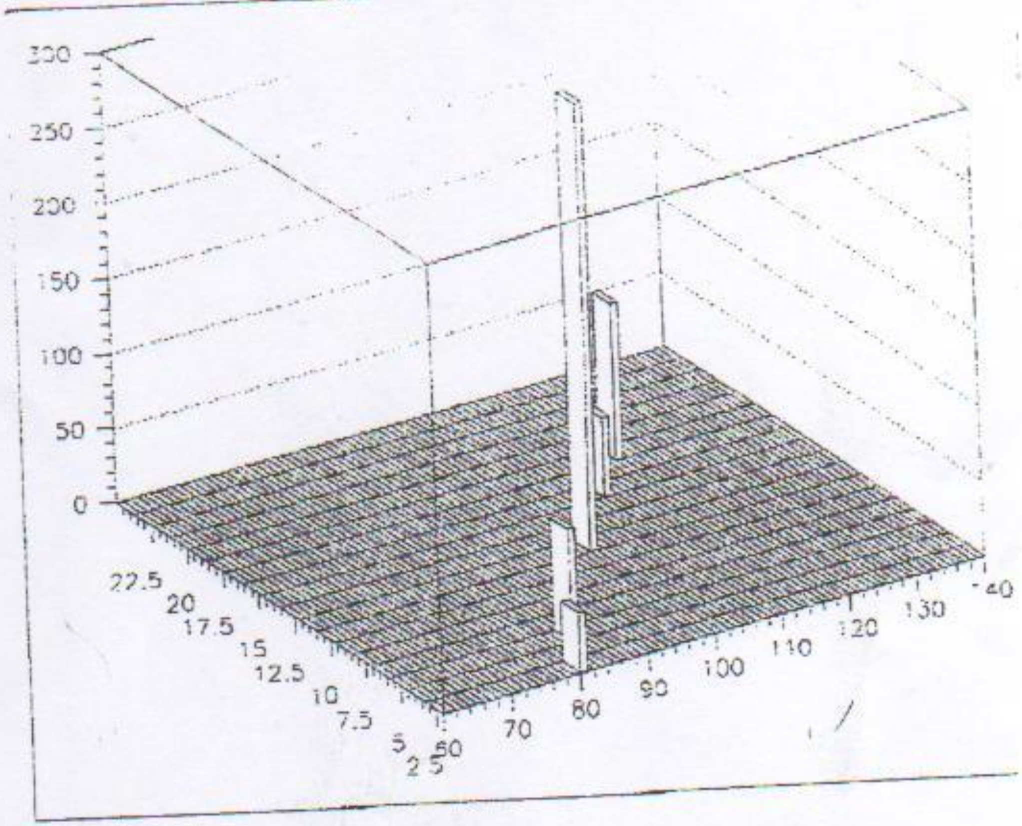
CERN Courier april 97

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.

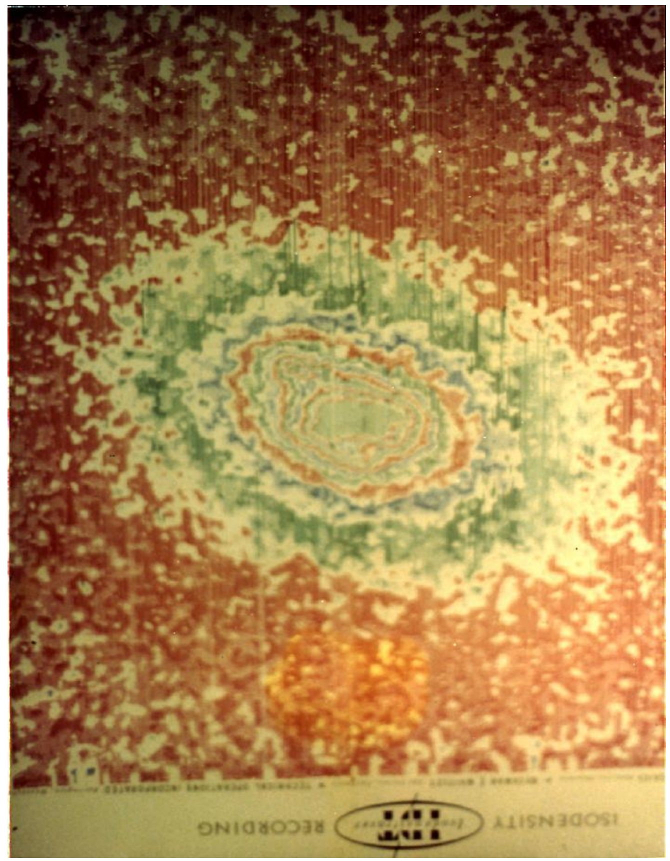
Such sheet-like alignments are also seen in a dozen or so events by the large Pamir chambers (several hundred tonnes), which also see the emergent hadrons but are degraded

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.

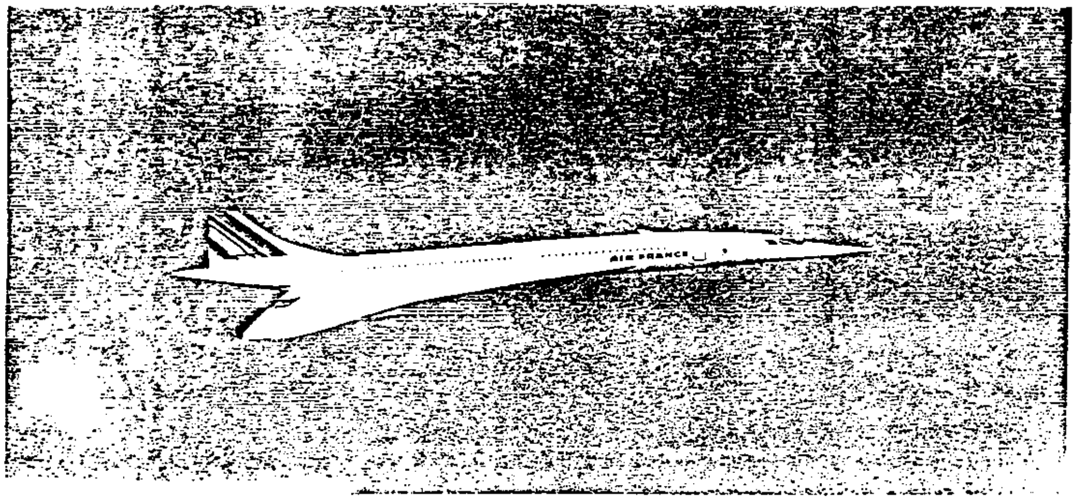
With CERN's 27-kilometre LEP electron-positron ring defining a feasibility limit for circular electron machines, research and

One γ ray of 200 TeV…



CERN Courier
October 1981

- Experiences ECHOS started in October 1978
- One 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.