Preprint FÚ SAV, Aug. 31, 2003

ANOMALOUS PHENOMENA
in terms of
QUANTUM STATISTICS

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- ♣ Normal vs. Anomalous Phenomena
- ♣ Quantum Statistics
- ♣ Applications

Normal Phenomena (Distributions, ...)

... described either by simple functions (like NBD, Gaussians, ...)

$$P(n) = \binom{n+M-1}{n}\left(1+\frac{\langle n\rangle}{M}\right)^{-M}\left(1+\frac{M}{\langle n\rangle}\right)^{-n}$$

... production of bosons from vacuum, they are produced by stochastic way ("thermally")

... $\langle n\rangle$ ... average...

... M ... number of bins (cells, modes...)

OR

by reasonable number of (superposed, convoluted; combined...)

continuous functions with smooth derivatives,

involving acceptably many free parameters.

... in general, there should be achieved some consensus: to what extent such a procedure is still sufficiently reliable ...

... in the past, **NBD** (+ corresp. factorial moments) were applied quite often

["the NBD was found to describe reasonably well all the measured multiplicity distributions" ... Tihány]

$$F^{(NBD)}(q;M) = \frac{(M+q-1)!}{M^q \cdot (M-1)!} .$$

... Looking for fractality/intermittancy :

$$F_q \sim M^{a_q}$$ ... scaling indices if $a_q \neq f(M)$!!

Now, $\ln F \sim a_q \cdot \ln M$.

or $a_q \sim \dfrac{\ln F}{\ln M}$ |

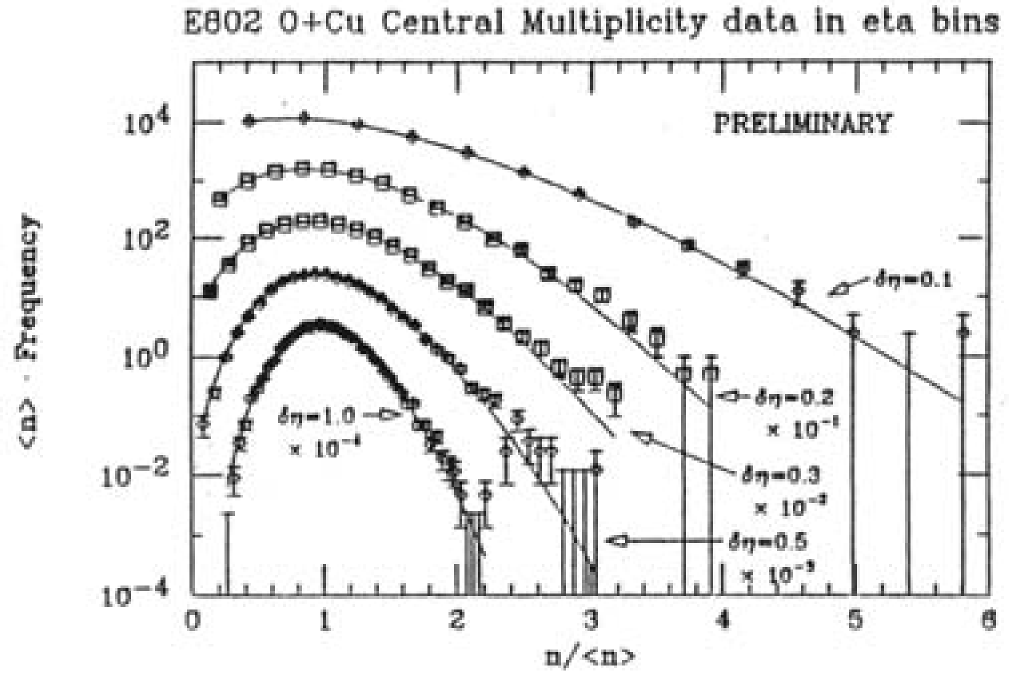
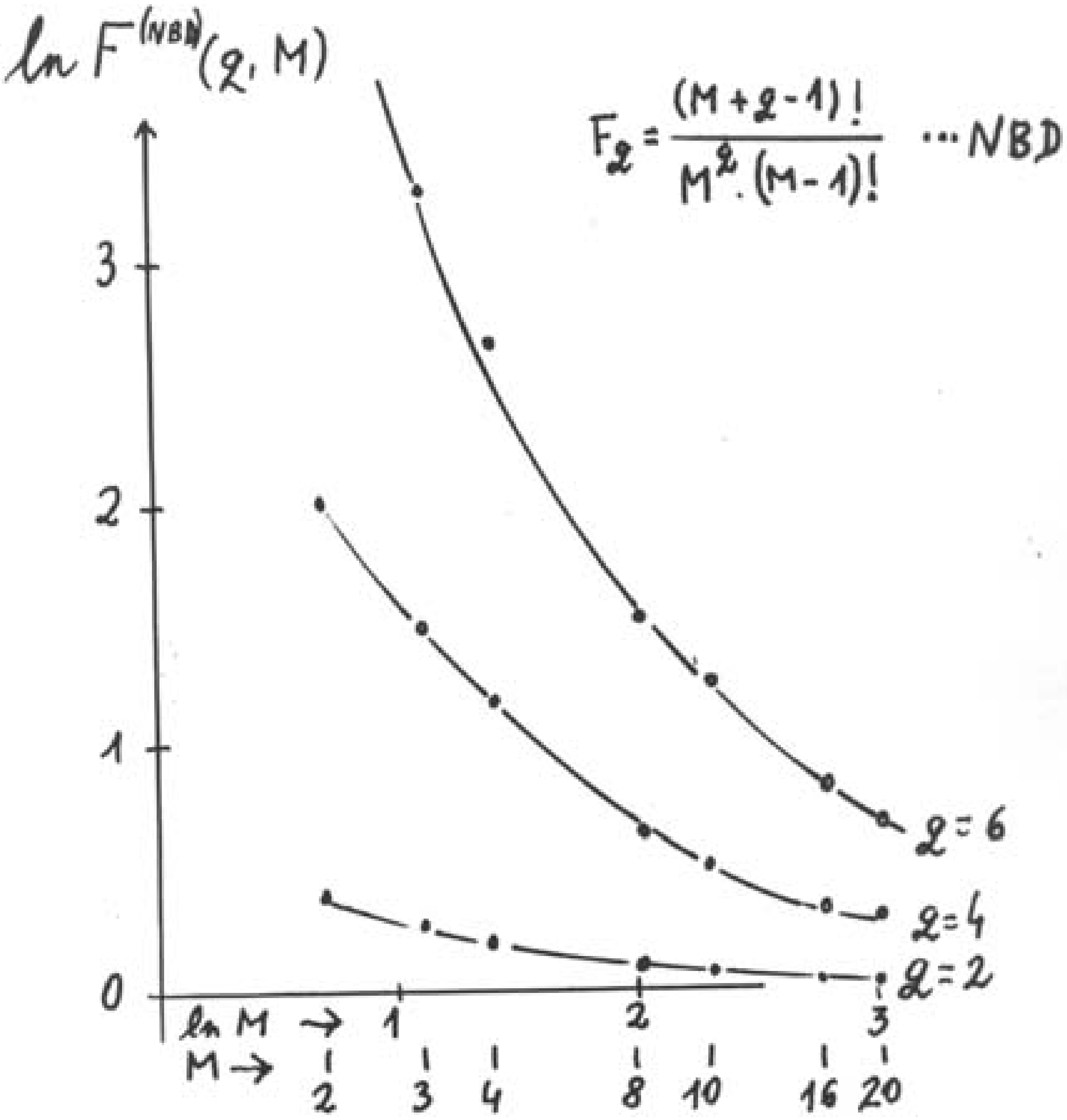


Fig. 1. E802 multiplicity distributions for O + Cu central collisions in individual $\delta\eta$ bins as indicated. The data are plotted scaled in multiplicity by the mean $\langle n \rangle$ in each bin. The solid lines are NBD fits.

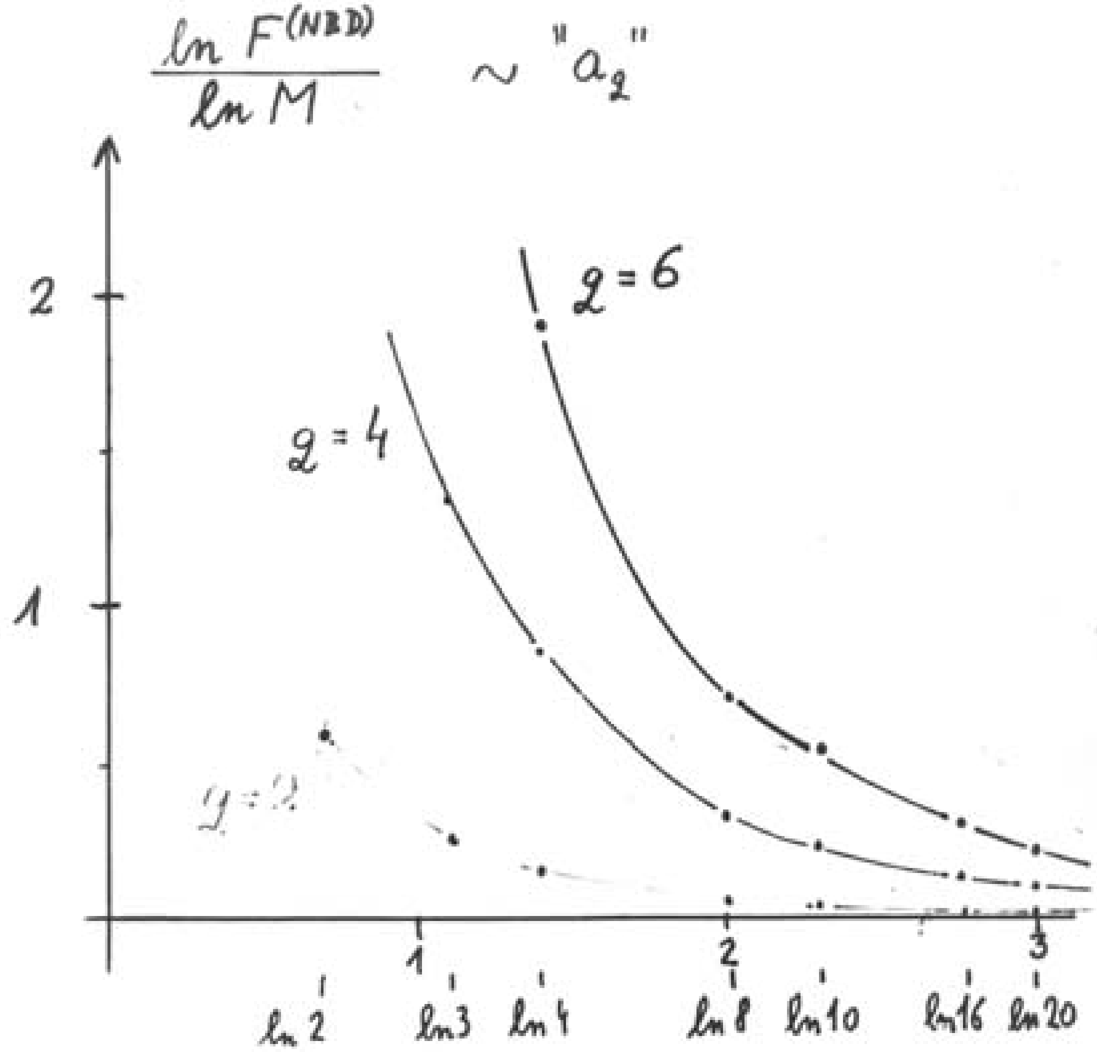
... at 14·6 A GeV/c

M. J. Tannenbaum, Mod. Phys. Lett's, A, Vol. 9, No. 2 (1994) 89-100



$$F_q \sim M^{a_q} \quad , \ldots \quad a_q \neq f(M)$$

$$\ln F_q \sim a_q \ln M$$



$\Rightarrow$

$$\frac{\ln F^{(NBD)}(q, M)}{\ln M} \sim \xi, \text{ with } \xi = \xi(M, q \text{ fixed})$$

$$\ldots F^{(NBD)} \sim M^{\xi}$$

$\Rightarrow$ NBD ... does not lead to genuine scaling,
... inappropriate for investigating (the presence ...)
the fractality or intermittency ...

Anomalous Phenomena

... JACEE with two calculations ...

... preceding approach ?

... when we shall conclude that there is a reasonable agreement between experimental results and theor. model ?

... extention of the case considered as normal is badly needed ...

... representing exper. data by (appropriate) statistical moments ... (if the distr's ...) ... unusual

... JACEE ... one event; ... factorial moments (experimental):

$$F^{(H)}(q,M) = \left[\sum_{m=1}^{M} n_m\right]^{-q} \left[\sum_{m=1}^{M} n_m \cdot (n_m-1)\ldots(n_m-q+1)\right]$$

n_m ... number of particles in the m-th bin

... $m = 1, 2, \ldots M$

(H) ... ; correl. moments ...

n_m from experiment

... $\ln F$ vs. $\ln M$ ...

PHYSICAL REVIEW LETTERS

VOLUME 50, NUMBER 26 , p. 2063, 1983

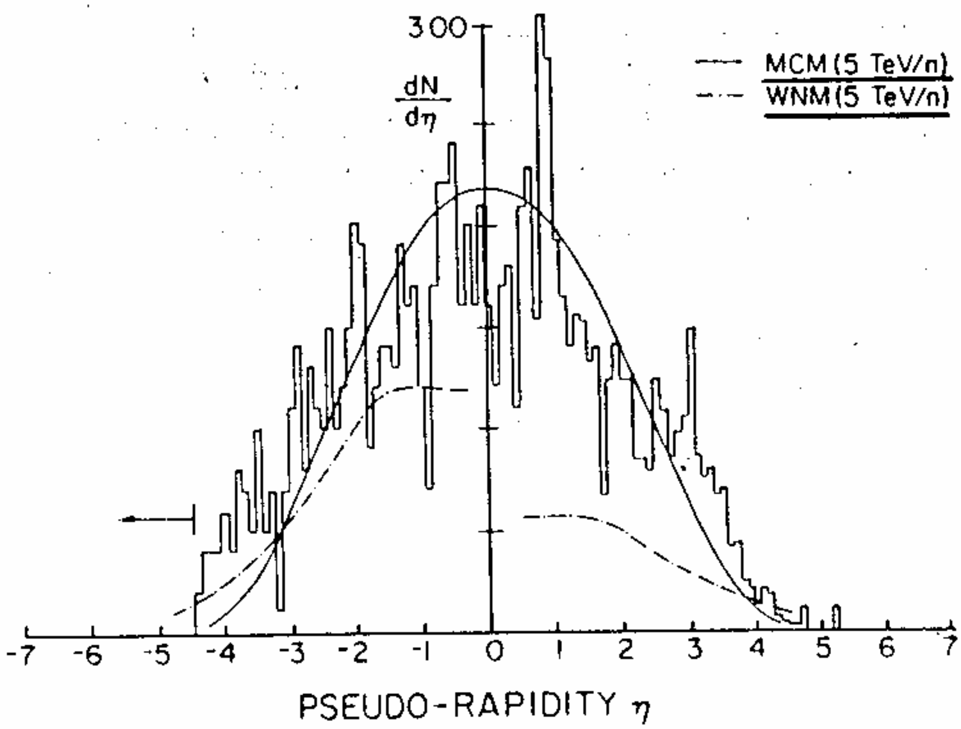


FIG. 1. The CMS pseudorapidity distribution of charged particles in the Si + AgBr event. Solid curve, multichain-model calculation; dashed curve, wounded-nucleon-model calculation; both for $\langle P_{T\pi} \rangle = 0.4$ GeV/c. The arrow indicates the unobserved region.

Japanese American Cooperative
Emulsion Experiment

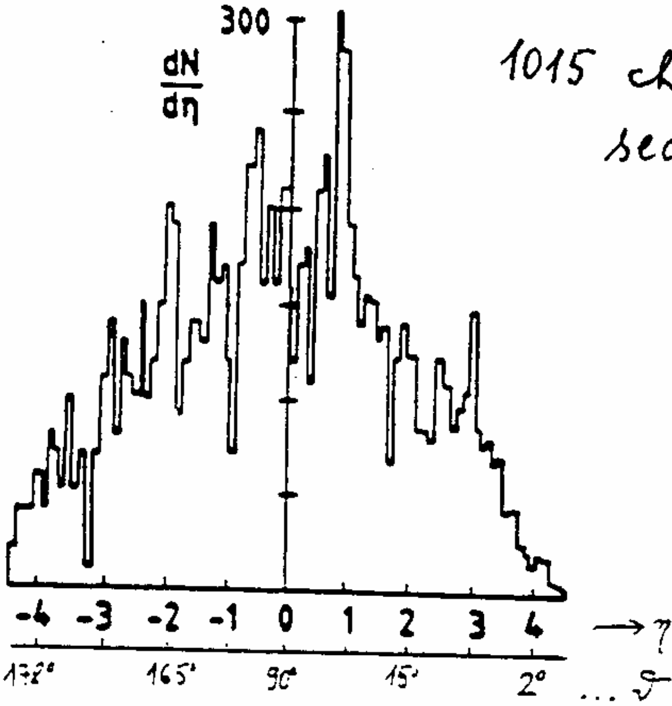
VOLUME 50, NUMBER 26 PHYSICAL REVIEW LETTERS 27 JUNE 1983

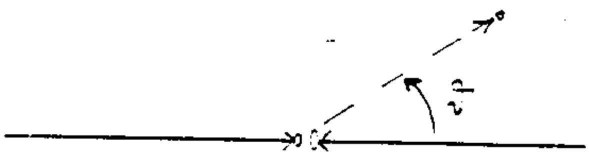
Extremely High Multiplicities in High-Energy Nucleus-Nucleus Collisions

T. H. Burnett, S. Dake, M. Fuki, J. C. Gregory, T. Hayashi, R. Holynski, J. Iwai, W. V. Jones, A. Jurak, J. J. Lord, O. Miyamura, H. Oda, T. Ogata, T. A. Parnell, T. Saito, T. Tabuki, Y. Takahashi,[a] T. Tominaga, B. Wilczynska, R. J. Wilkes, W. Wolter, and B. Wosiek

JACEE Collab.

1015 charged secondaries

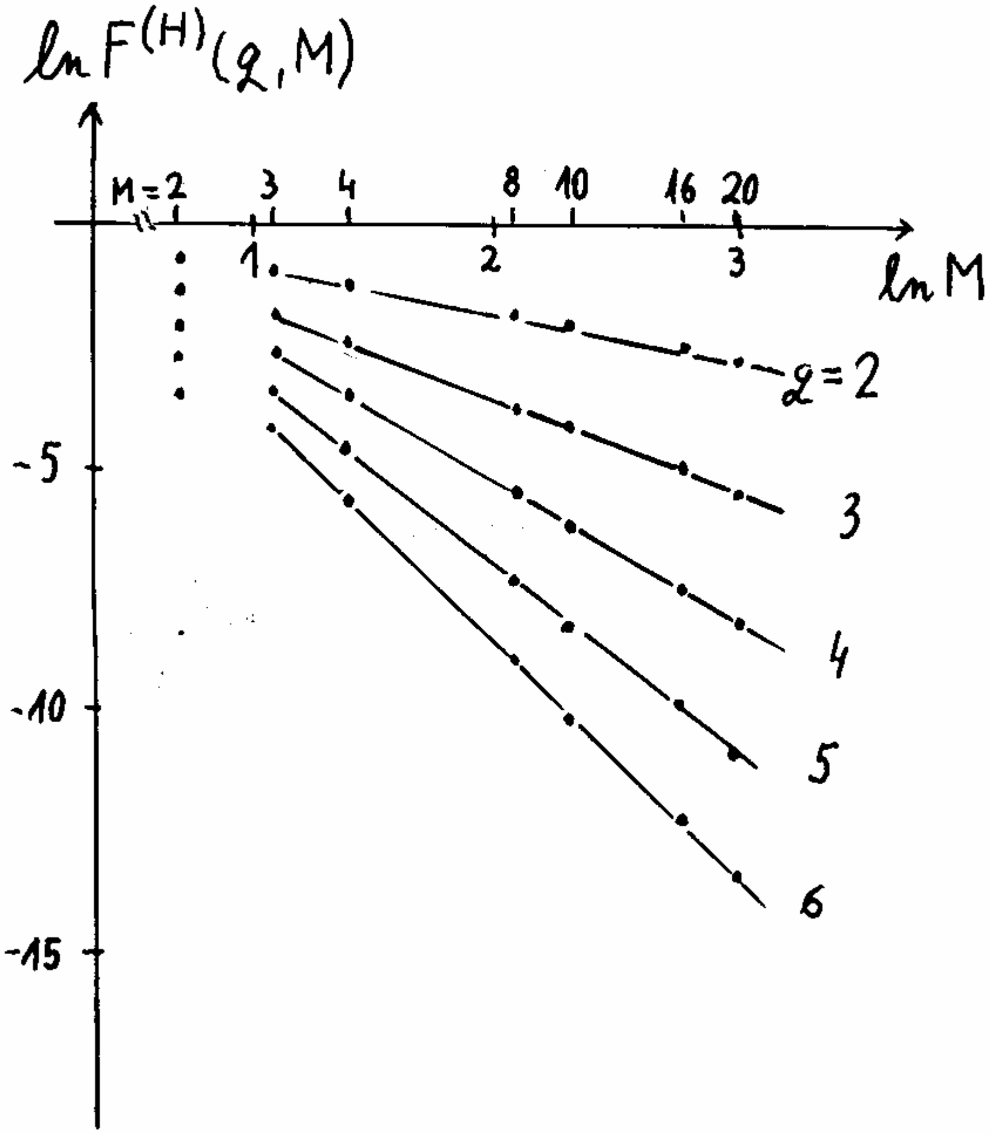




$$\eta = -\ln \operatorname{tg} \frac{\vartheta}{2}$$

$Z = {}^{14}Si_{A=28} + {}^{47}Ag_{108} / {}^{35}Br_{80}$

... 4 TeV/nucleon , ... baloon exper.



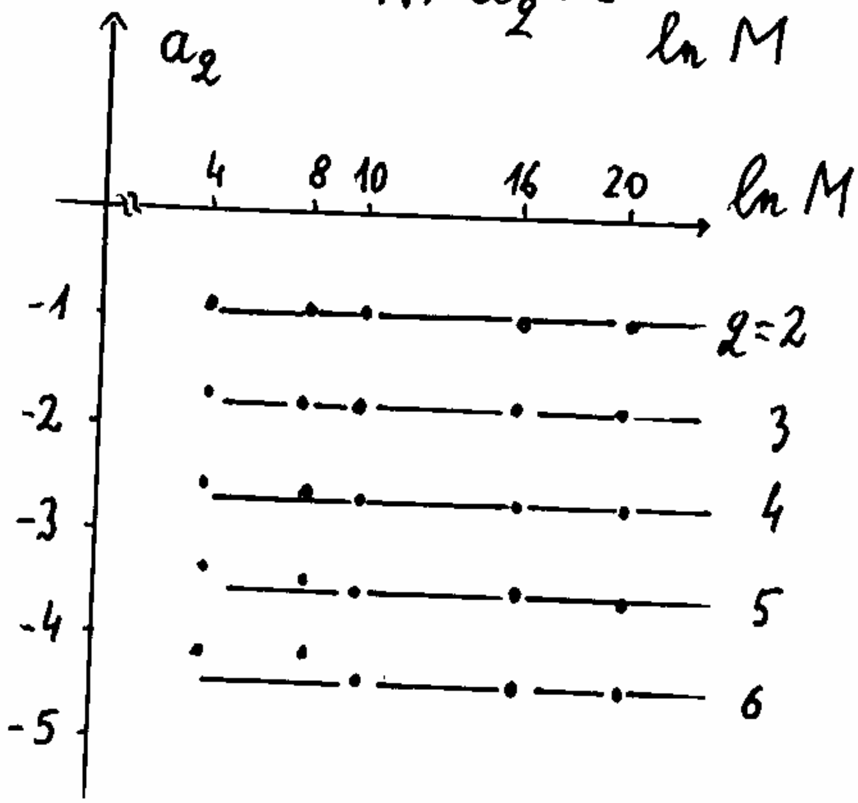
(points ... <u>data</u> from experiment)

(data suggest: $F \sim M^{a_q}$

(NBD fails to reproduce the data)

$$F^{(H)}(q, M) \sim M^{a_q}$$

$$\ldots\ a_q \sim \frac{\ln F}{\ln M} \neq f(M)\ ..$$



WHAT TO DO ¿

... generalize NBD in frame of the Quant. Stat.:

in every restricted region of (pseudo) rapidity, particles are produced also coherently (not only stochastically);

... $a^{-}|\alpha\rangle = \alpha|\alpha\rangle$

... $e^{-\alpha^2}$ ...

... M-bins; in every bin there are produced

$(n_T)_m$ (<u>m = 1, 2, ..., M</u>) particles stochastically

and

$(n_c \cdot \varkappa^2)_m$ particles coherently;

MOREOVER, there are M-bins where

$(n_c)_m - (n_c \cdot \varkappa^2)_m \equiv B_m$ particles are produced only coherently;

... Quantum Statistics gives:

$$F^{(H)}(q,M) = \Big[\sum_{m=1}^{M} B_m +$$

$$+ \sum_{m=1}^{M} (n_T)_m \cdot L_{(\omega_m)}\left(-\frac{(n_C)_m \cdot \mathcal{H}_m^2}{(n_T)_m} \right) \Big]^q \times$$

$$\times \left[\frac{1}{\sum_{m'=1}^{M} (n_T + n_C)_{m'}} \right]^q$$

... L ... Laguerre Polynomials

... with all $n_c = 0 \Rightarrow$ NBD F_q

! :

... i.e. theory gives:

$$F^{(H)}(q,M) \approx (X)^q$$

...... indep. of q

or $\ln F \sim q \cdot \ln X$

... we met already:

$$\ln F \sim a_q \ln M$$

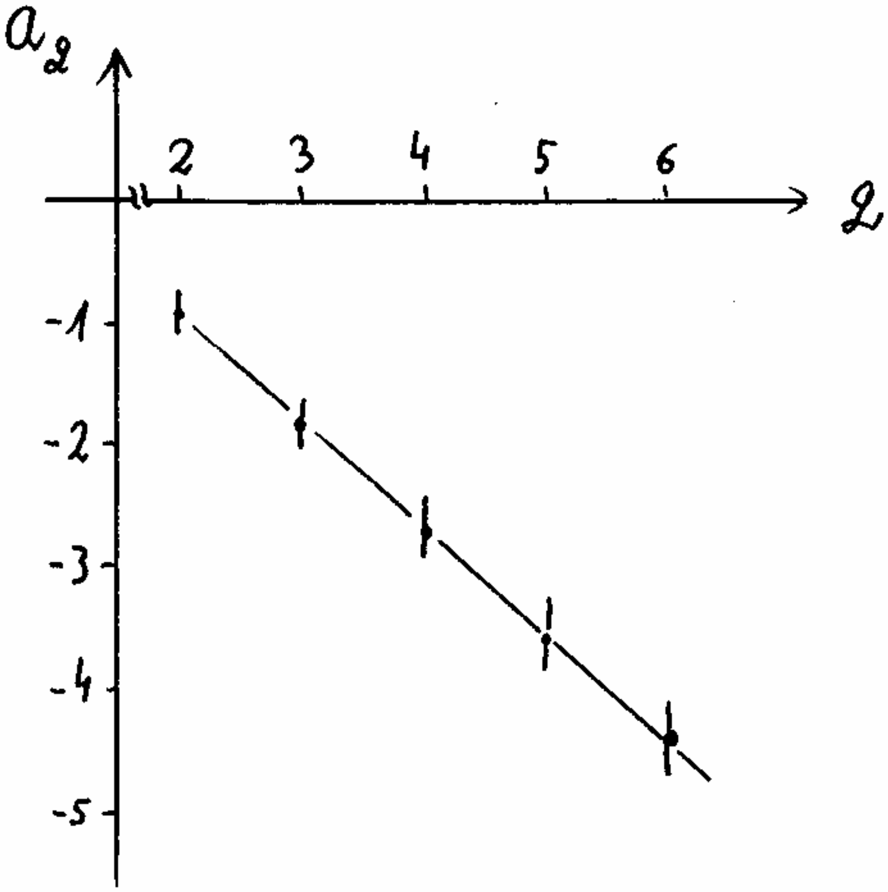
...... indep. of q

$\Rightarrow \quad a_q \sim q$ ... prediction

... and exper. data :

JACEE data:

$$F^{(H)}(q, M) \sim M^{a_q}$$



$$a_q \doteq 0{\cdot}814 - 0{\cdot}875\, q$$

CONCLUSIONS

- normal vs anomalous phenomena,
- some experimental results cannot be understood in frame of the NBD,
- to describe some data correctly also coherent production of secondaries is to be introduced,
- if the case when the genuin scaling indices

$$a_2 \not\equiv 0$$

is interpreted in terms of fractality/intermittency, then the JACEE data represent a clear evidence of their presence also at very high energies,
- it is not correct to conclude (or to decide) about the pesence or absence of the multifractality or intermittency on the basic properties of the factorial moments obtained by means of the NBD.
- scaling indices in terms of the quantum statistics ... model.

□

... it is very nice to formulate those conclusions at the 20-th aniversary since publication of that JACEE paper – and to show that "there is something" in the JACEE result...