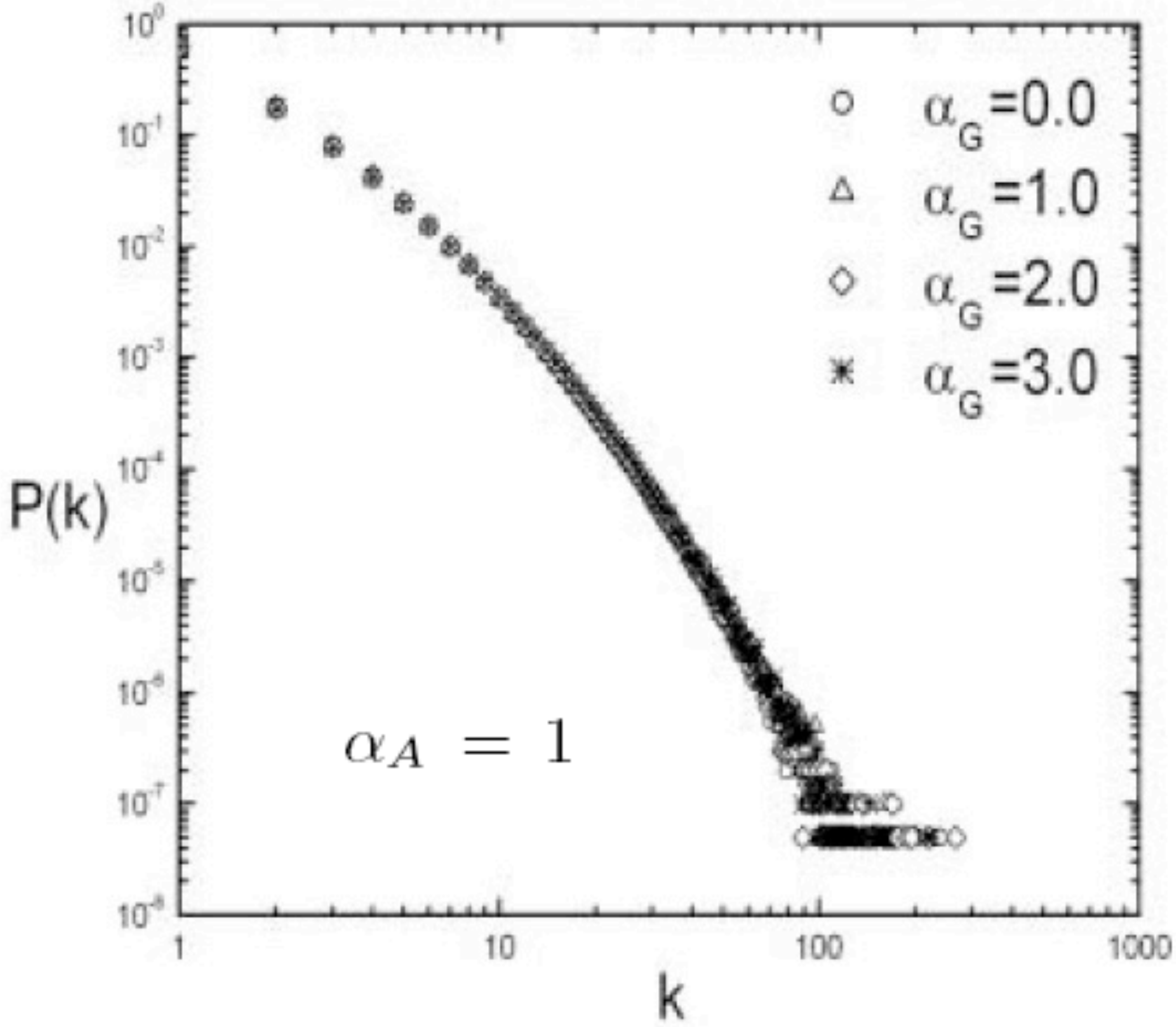
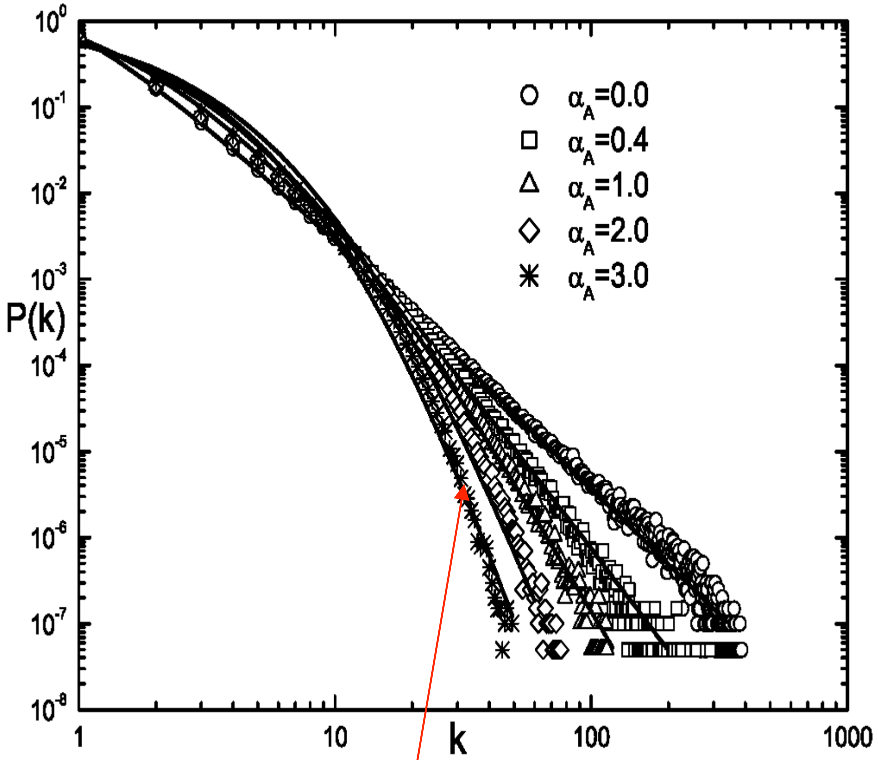
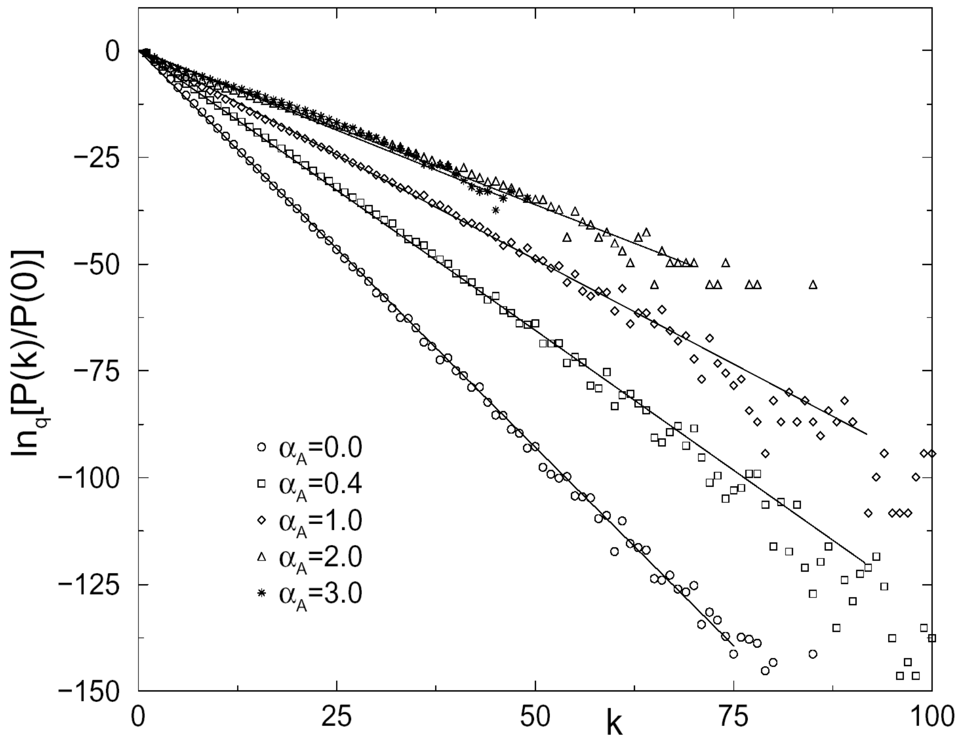


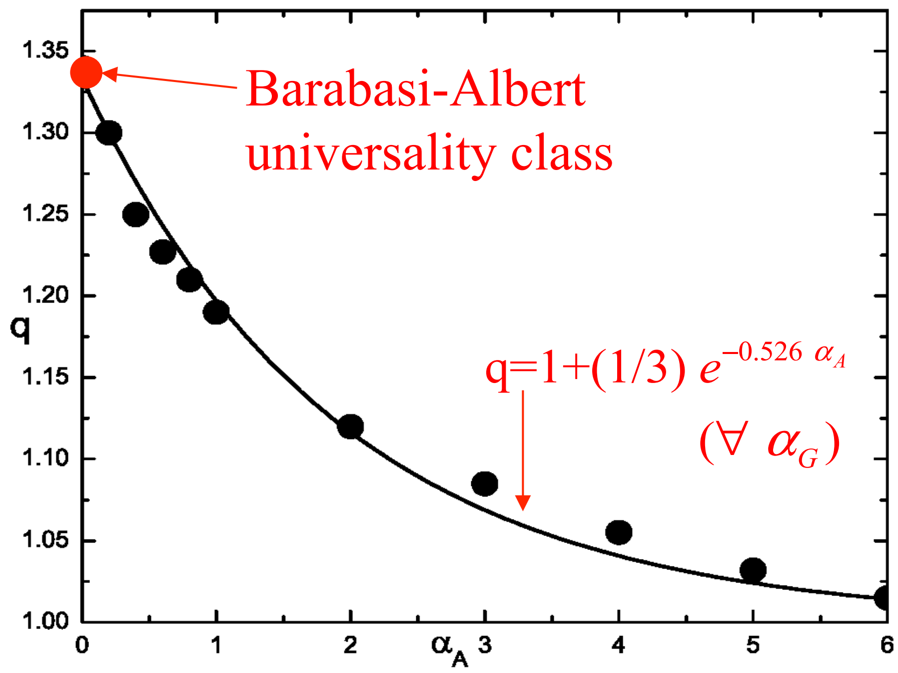
2000 realizations of $N = 10000$ networks

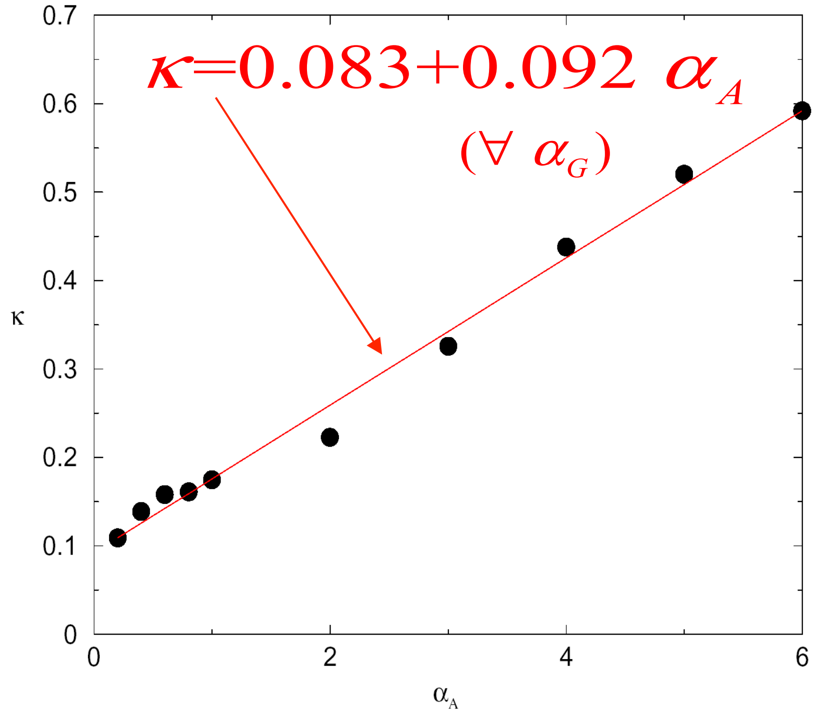


$$P(k)/P(0) = e_q^{-k/\kappa}$$
$$\equiv 1/[1+(q-1)k/\kappa]^{1/(q-1)}$$



D.J.B. Soares, C. T. , A.M. Mariz and L.R. Silva
Europhys Lett **70**, 70 (2005)

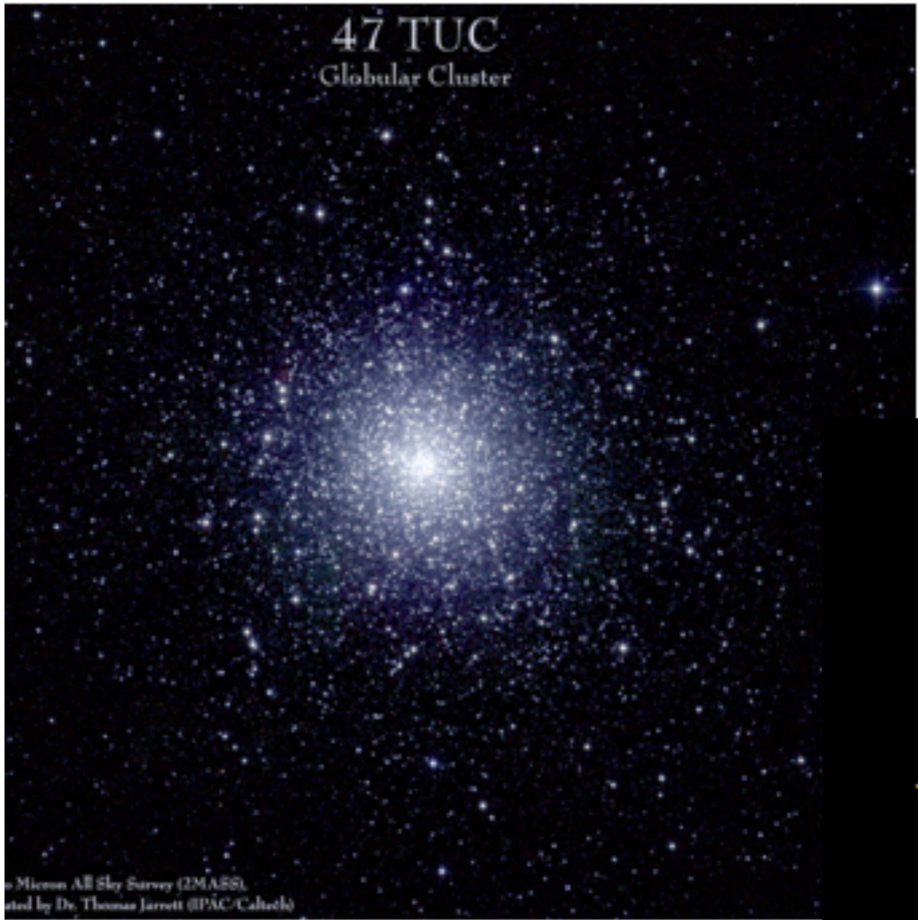


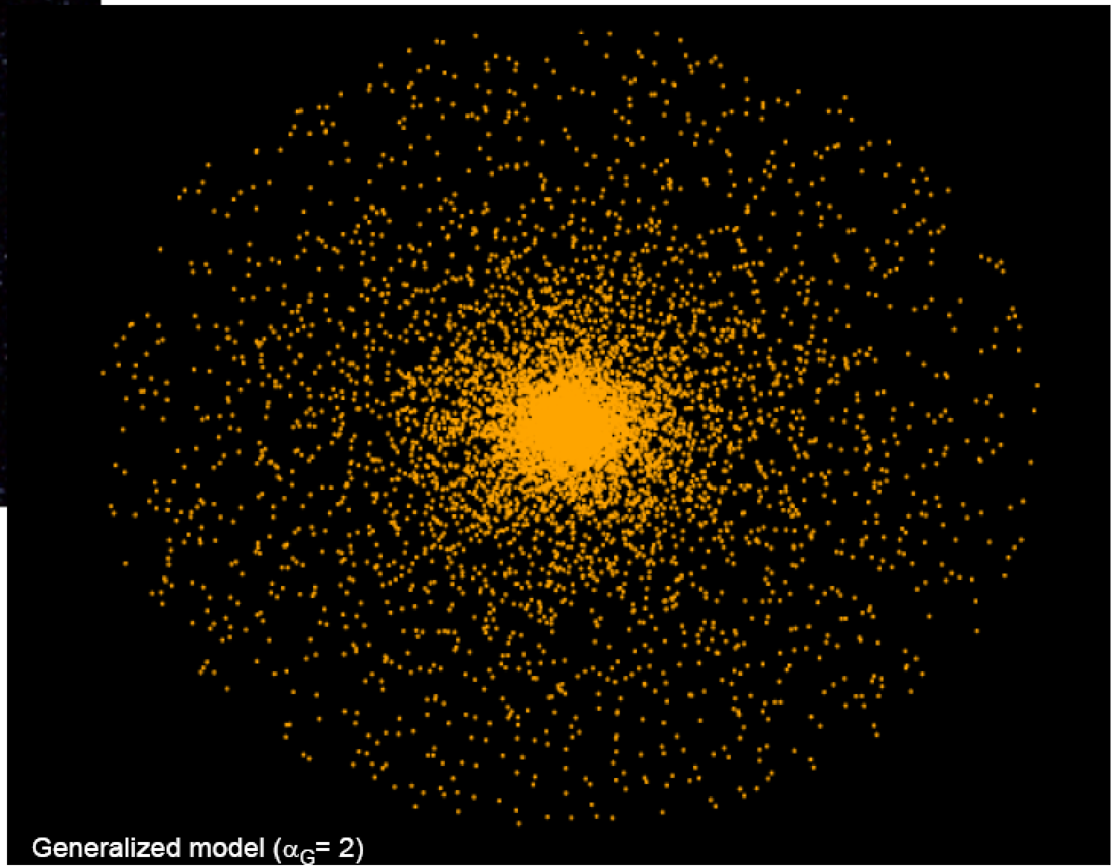


D.J.B. Soares, C. T. , A.M. Mariz and L.R. Silva
Europhys Lett **70**, 70 (2005)

SCALE-FREE NETWORKS:

D.J.B. Soares, C. T., A.M. Mariz and L.R. da Silva
Europhys. Lett. **70**, 70 (2005)





GAS-LIKE (NODE COLLAPSING) NETWORK:

S. Thurner and C. T., Europhys Lett **72**, 197 (2005)

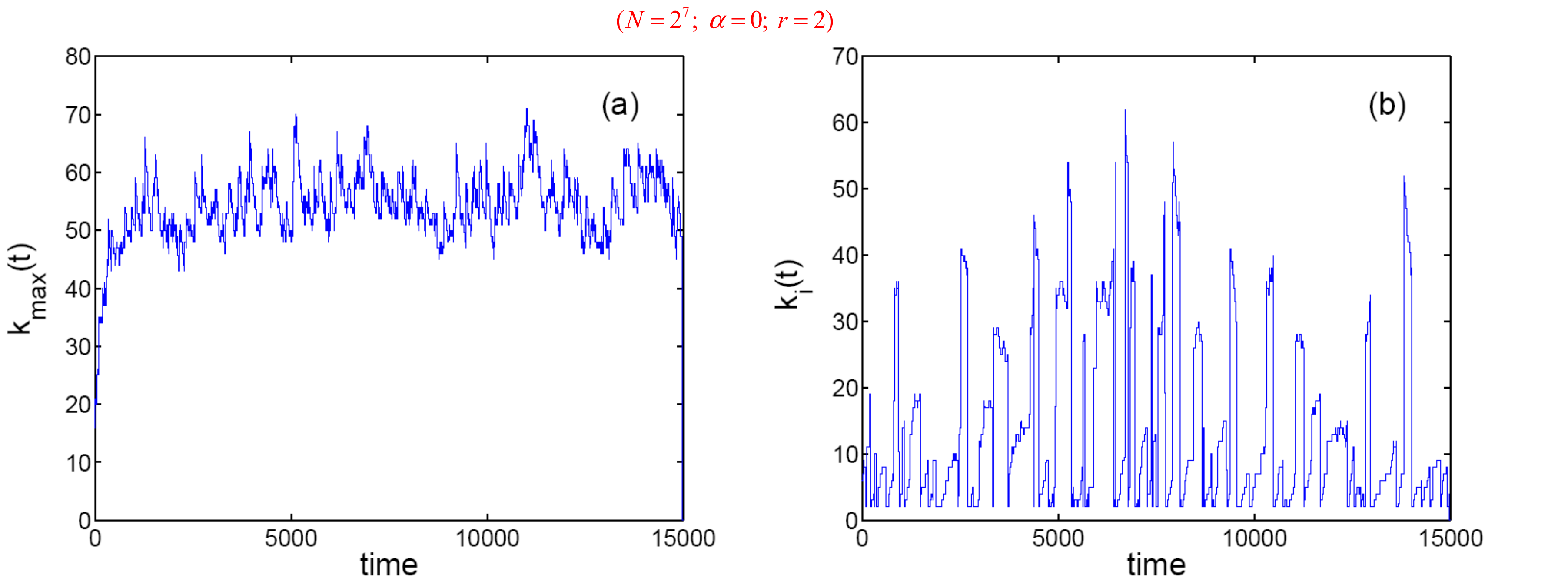
Number *N* of nodes fixed (*chemostat*); i=1, 2, …, *N*

Merging probability $p_{ij} \propto \frac{1}{d_{ij}{}^{\alpha}} \quad (\alpha \geq 0)$

$d_{ij} \equiv$ *shortest path (chemical distance) connecting nodes i and j on the network*

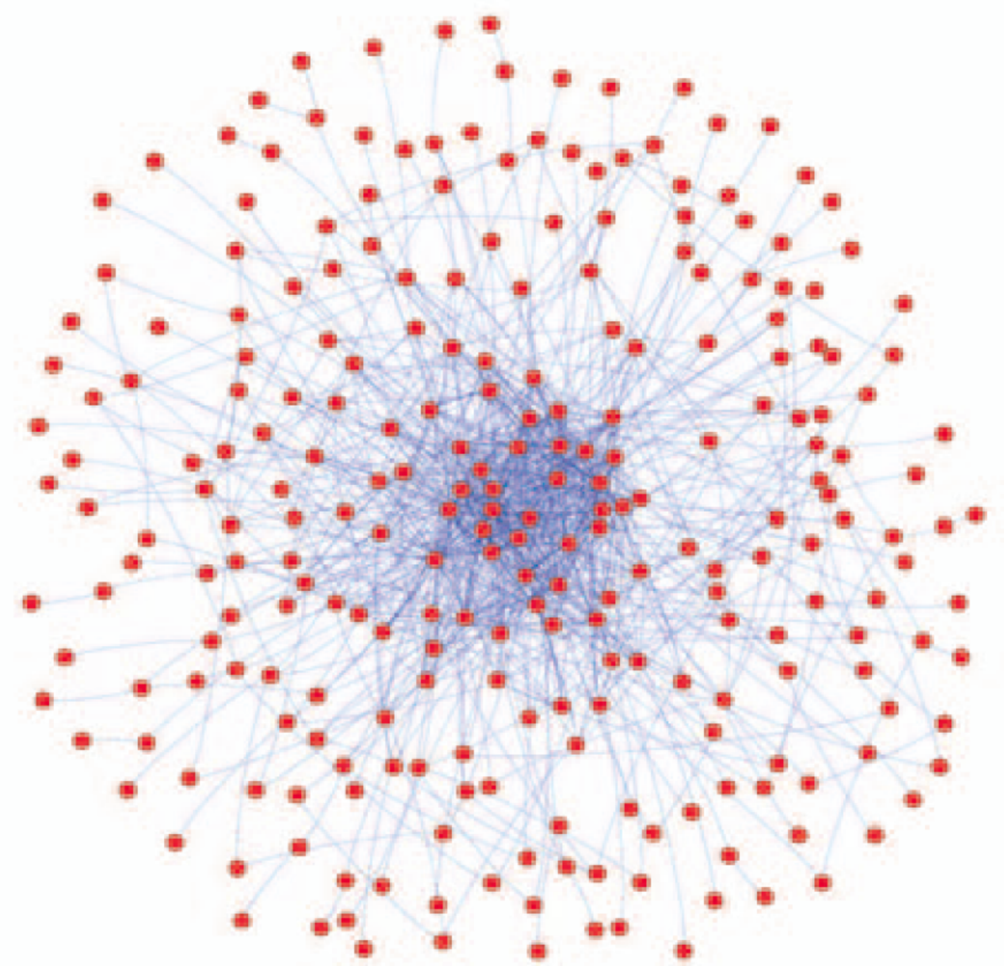
$\alpha = 0$ *and* $\alpha \to \infty$ *recover the random and the neighbor schemes respectively*

(Kim, Trusina, Minnhagen and Sneppen, *Eur. Phys. J. B* 43 (2005) 369)



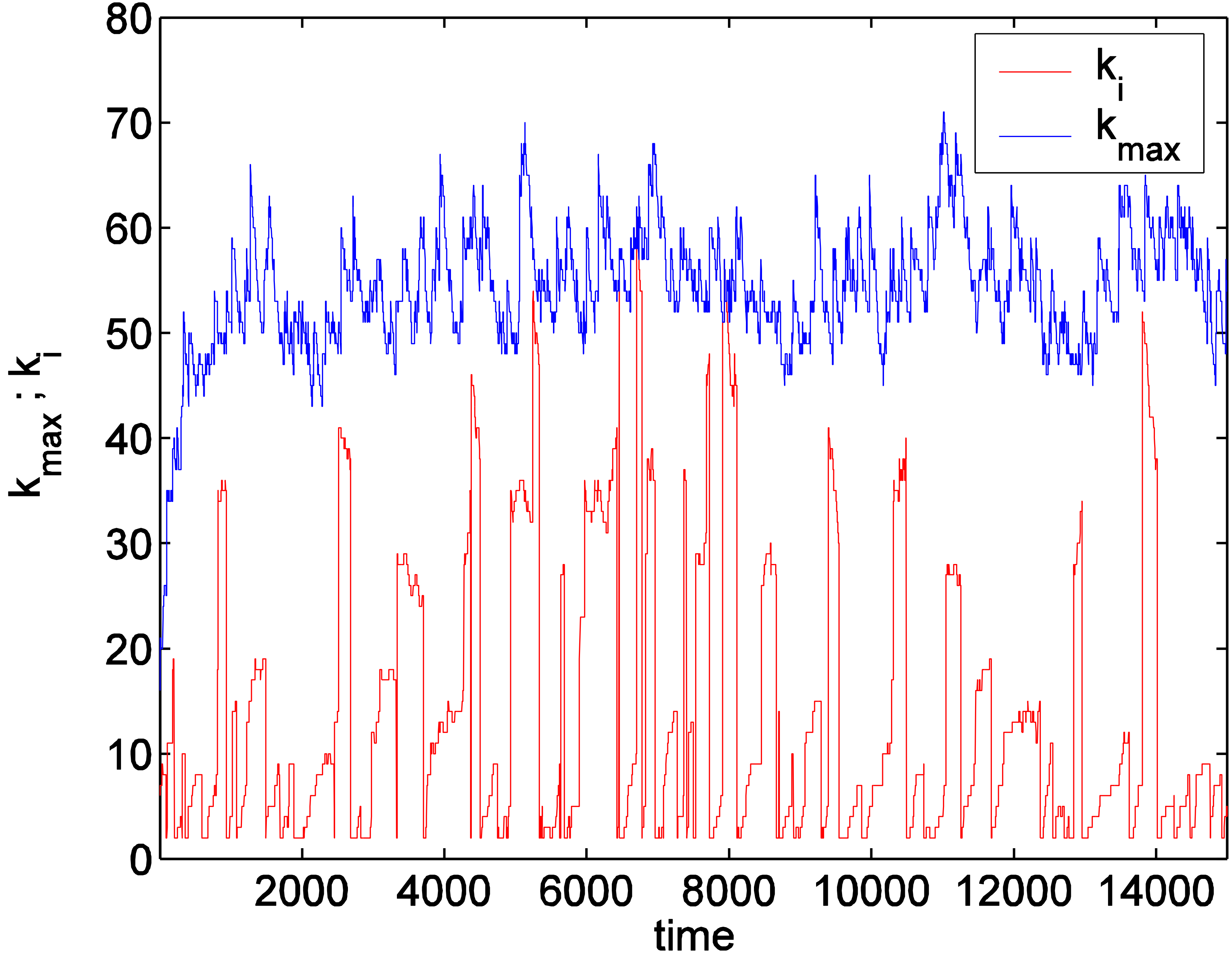
Degree of the most connected node

Degree of a randomly chosen node



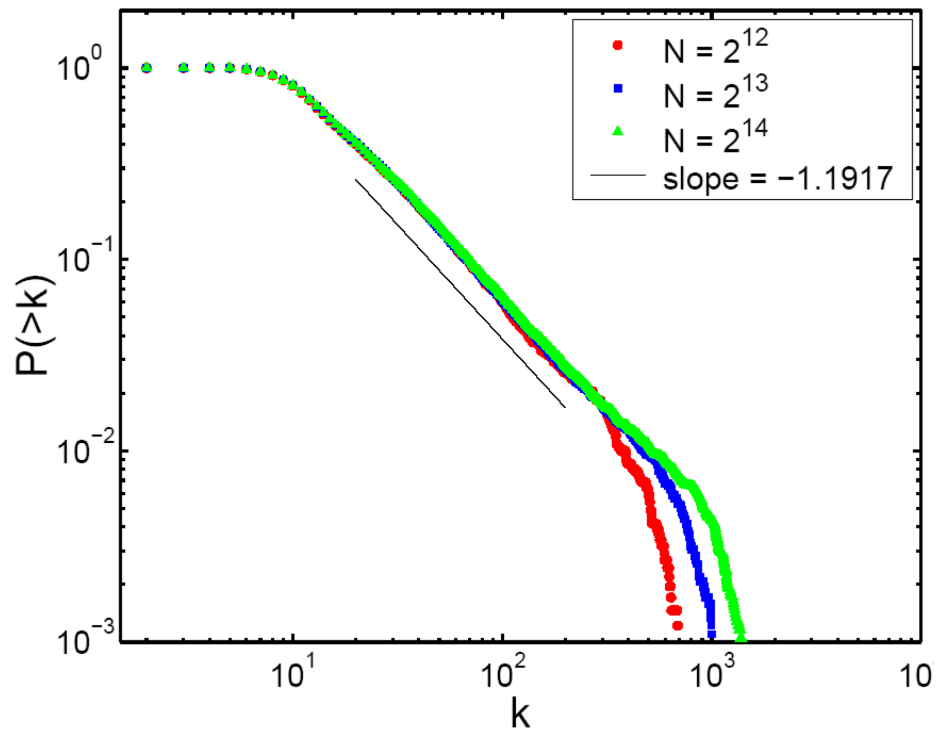
▲ **Fig. 1:** Snapshot of a non-growing dynamic network with q-exponential degree distribution for $N = 256$ nodes and a linking rate of $\bar{r} = 1$, for details see [8, 9]. The shown network is small to make connection patterns visible.

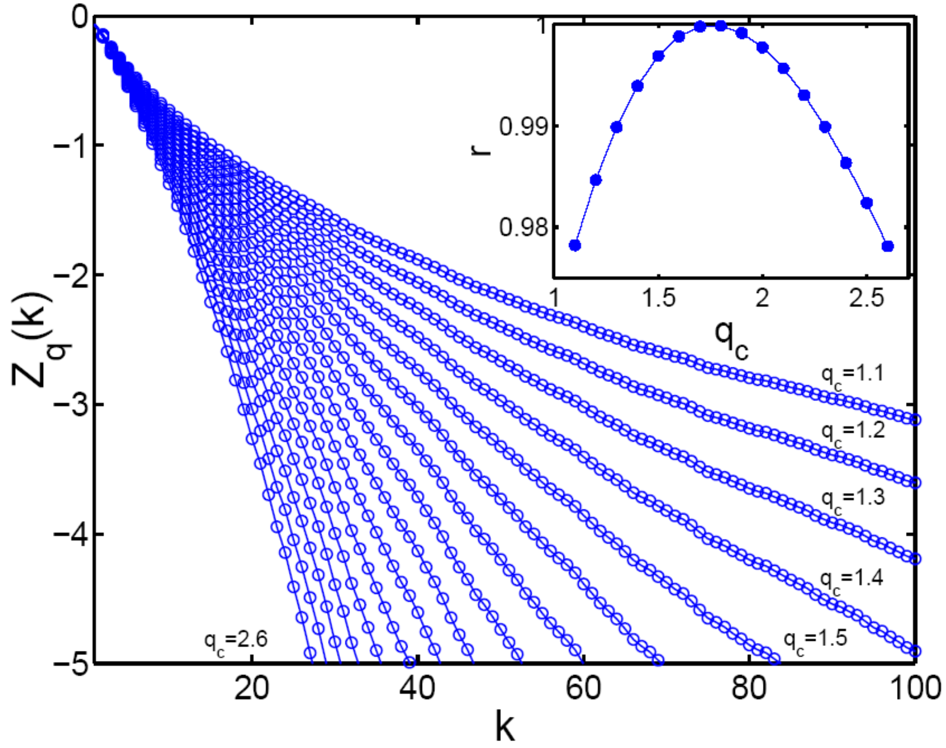
S. Thurner, Europhys News **36**, 218 (2005)



80
70
60
50
40
30
20
10
0
2000
4000
6000
8000
10000
12000
14000
time
k_{max} ; k_i
k_i
k_{max}

$$(\alpha \to \infty\ ;\ \ < r >= 8)$$



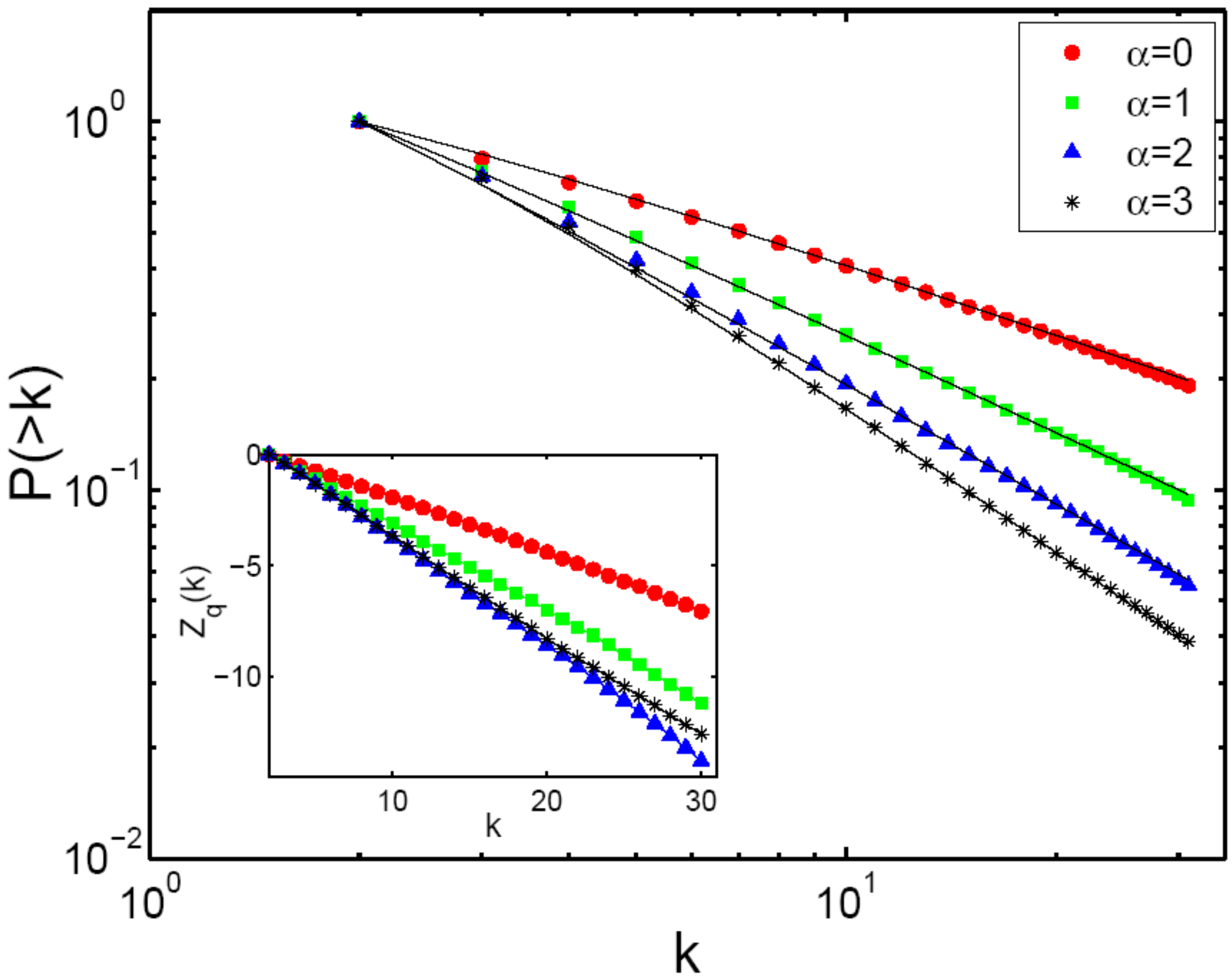


$$Z_q(k) \equiv \ln_q\left[P(>k)\right] \equiv \frac{\left[P(>k)\right]^{1-q} - 1}{1-q}$$

$(optimal\ q_c = 1.84)$

S. Thurner and C. T., Europhys Lett **72**, 197 (2005)

$$(N = 2^9;\ r = 2)$$

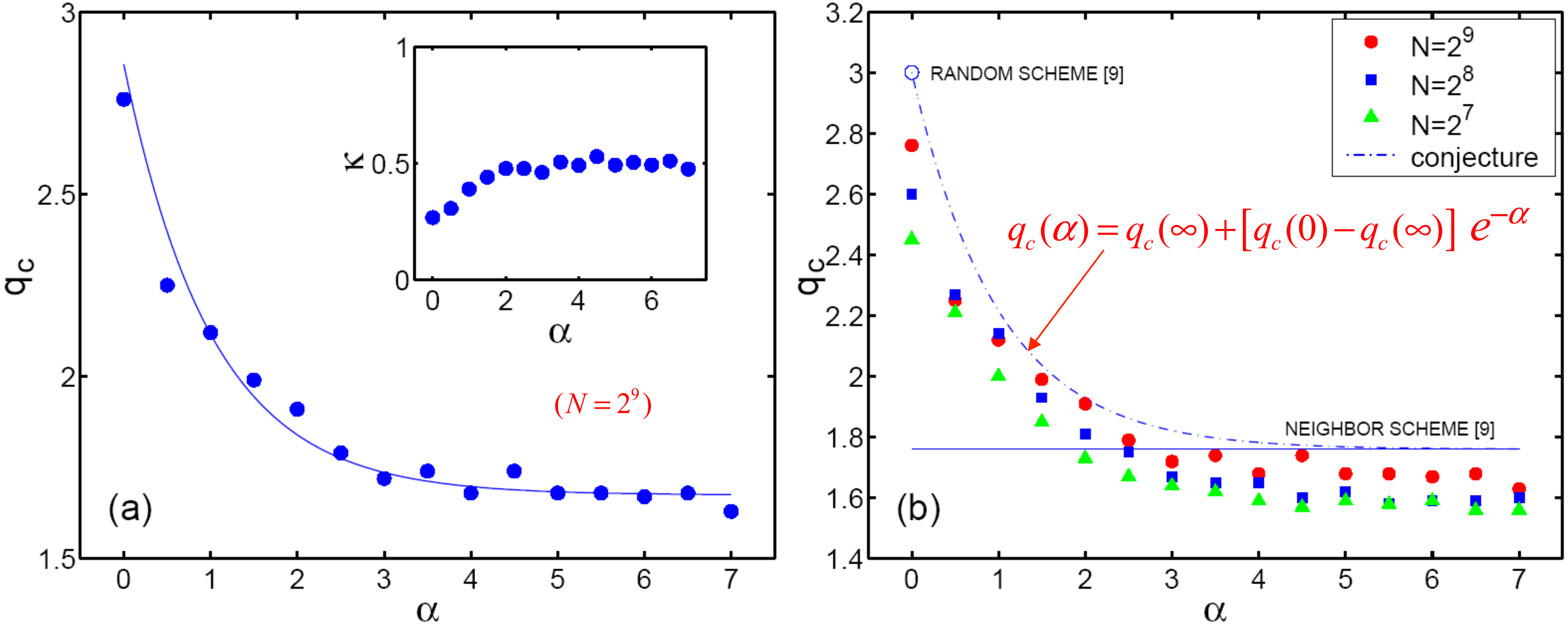


$$P(\geq k) = e_{q_c}^{-(k-2)/\kappa}\ (k = 2,\ 3,\ 4, \ldots)$$

$$linear\ correlation \in [0.999901, 0.999976]$$

S. Thurner and C. T., Europhys Lett **72**, 197 (2005)

$$(r = 2)$$



S. Thurner and C. T., Europhys Lett **72**, 197 (2005)

HOW COME THE DEGREE DISTRIBUTION COINCIDES WITH THAT MAXIMIZING Sq ?

If we associate with each bond an "energy" ε,
we may associate with each node $(i = 1, 2, \ldots, N)$ *the energy* $k_i \varepsilon / 2$.

Therefore the degree distribution coincides with the energy distribution!

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SCIENTIFIC REPORTS

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Role of dimensionality in complex networks

Samuraí Brito[1], L. R. da Silva[1,2] & Constantino Tsallis[2,3]

Received: 04 April 2016
Accepted: 25 May 2016
Published: 20 June 2016

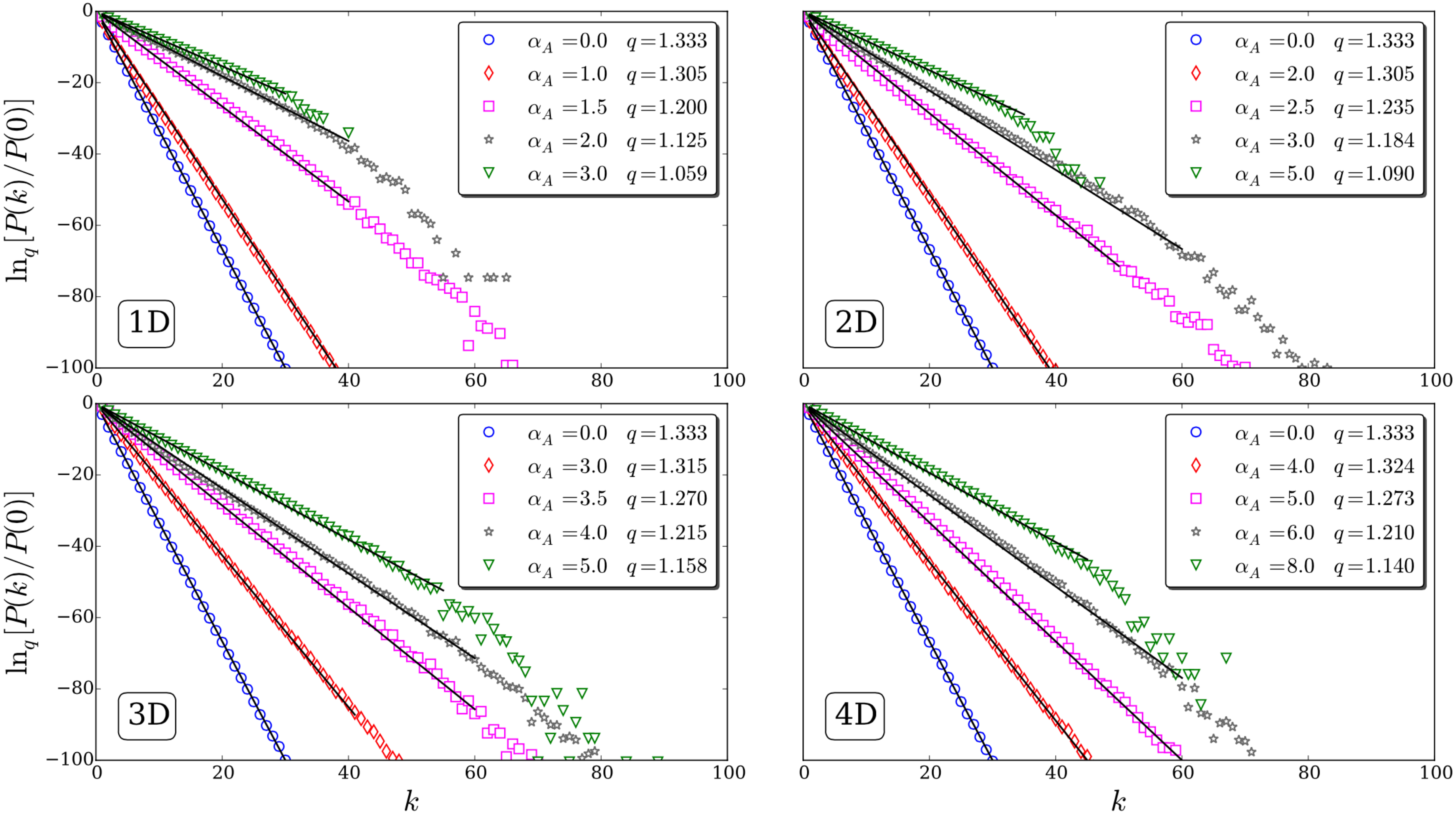
Deep connections are known to exist between scale-free networks and non-Gibbsian statistics. For example, typical degree distributions at the thermodynamical limit are of the form $P(k) \propto e_q^{-k/\kappa}$, where the q-exponential form $e_q^z \equiv [1 + (1-q)z]^{\frac{1}{1-q}}$ optimizes the nonadditive entropy S_q (which, for $q \to 1$, recovers the Boltzmann-Gibbs entropy). We introduce and study here d-dimensional geographically-located networks which grow with preferential attachment involving Euclidean distances through $r_{ij}^{-\alpha}$ ($\alpha_A \geq 0$). Revealing the connection with q-statistics, we numerically verify (for $d = 1, 2, 3$ and 4) that the q-exponential degree distributions exhibit, for both q and k, universal dependences on the ratio α_A/d. Moreover, the $q = 1$ limit is rapidly achieved by increasing α_A/d to infinity.

$$p(r)\begin{cases} = 0 & \text{if} \quad 0 \leq r < 1 \\ \propto \dfrac{1}{r^{d+\alpha_G}} & \text{otherwise} \end{cases}$$

$$(\alpha_G > 0)$$

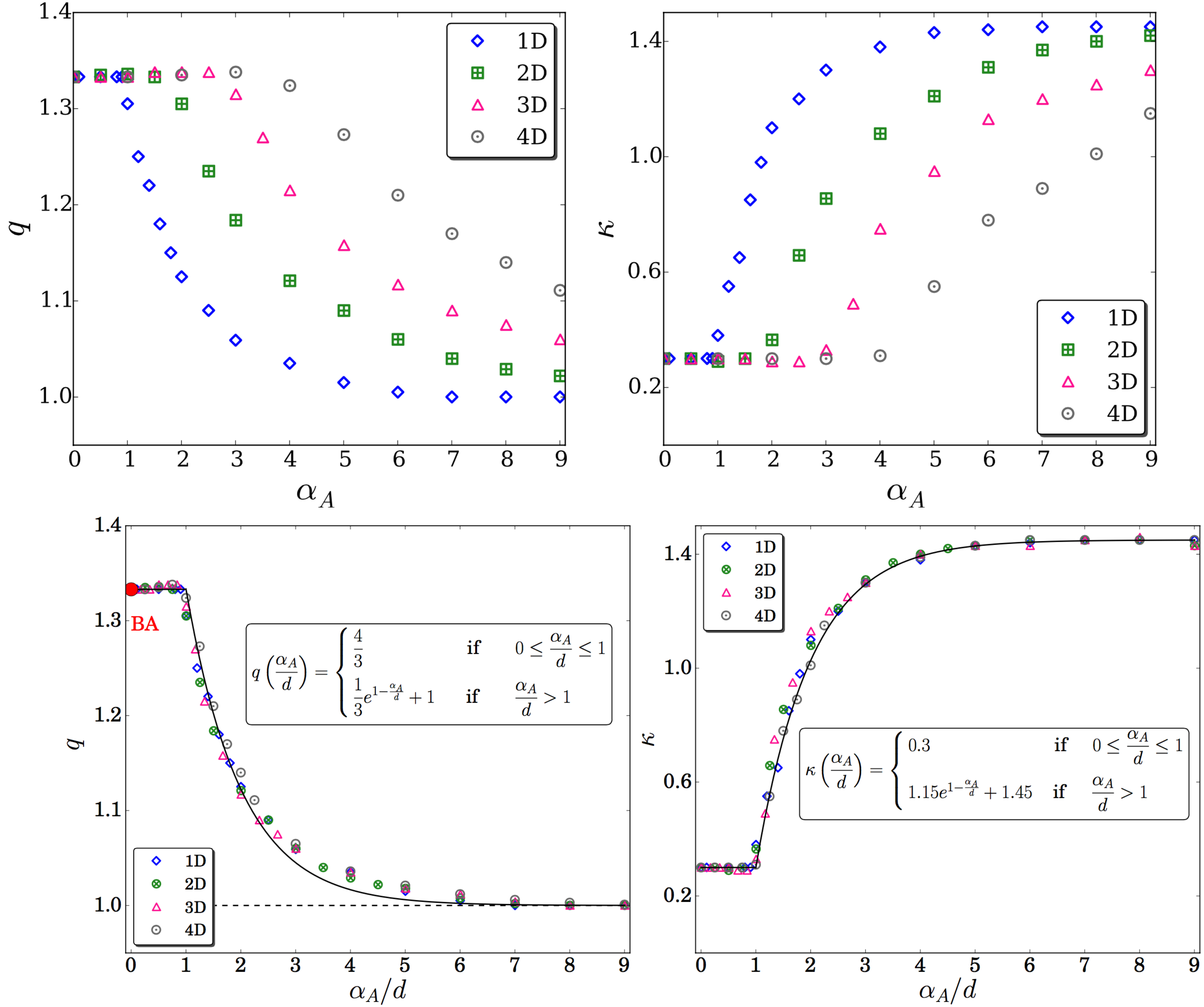
$$\Pi_{ij}(k_i) \propto \frac{k_i}{r_{ij}^{\alpha_A}}$$

$$(\alpha_A \geq 0)$$



$$P(k) = P(0)\, e_q^{-k/\kappa} = \frac{P(0)}{\left[1+(q-1)k/\kappa\right]^{\frac{1}{q-1}}}$$

S.G.A. Brito, L.R. da Silva and C. T., Nature/Scientific Reports **6**, 27992 (2016)

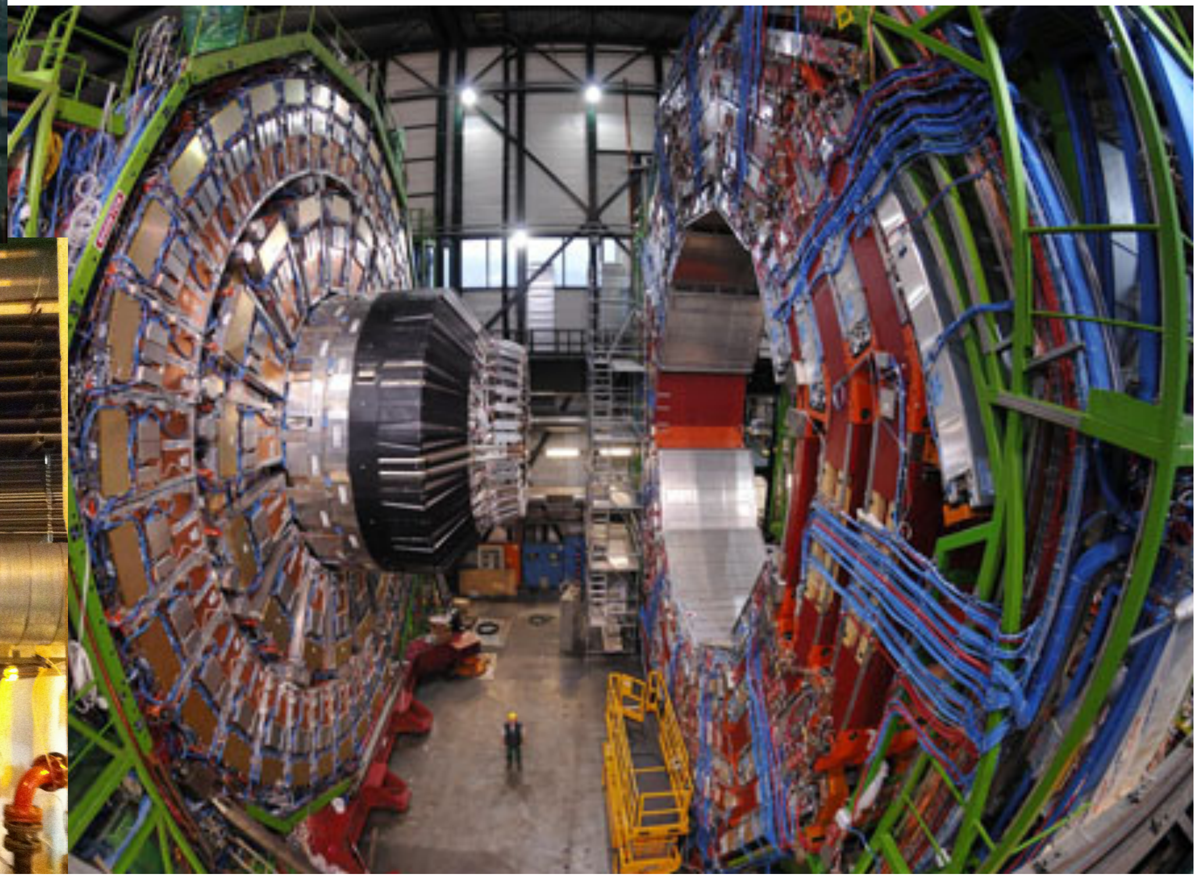


S.G.A. Brito, L.R. da Silva and C. T.
Nature/Scientific Reports **6**, 27992 (2016)

LHC (Large Hadron Collider)

CMS, ALICE, ATLAS and LHCb detectors

~ 4000 scientists/engineers from ~ 200 institutions of ~ 50 countries



PHYSICAL REVIEW D **87,** 114007 (2013)

Tsallis fits to p_T spectra and multiple hard scattering in pp collisions at the LHC

Cheuk-Yin Wong
Oak Ridge National Laboratory, Physics Division, Oak Ridge, Tennessee 37831, USA

Grzegorz Wilk
National Centre for Nuclear Research, Warsaw 00-681, Poland
(Received 12 May 2013; published 5 June 2013)

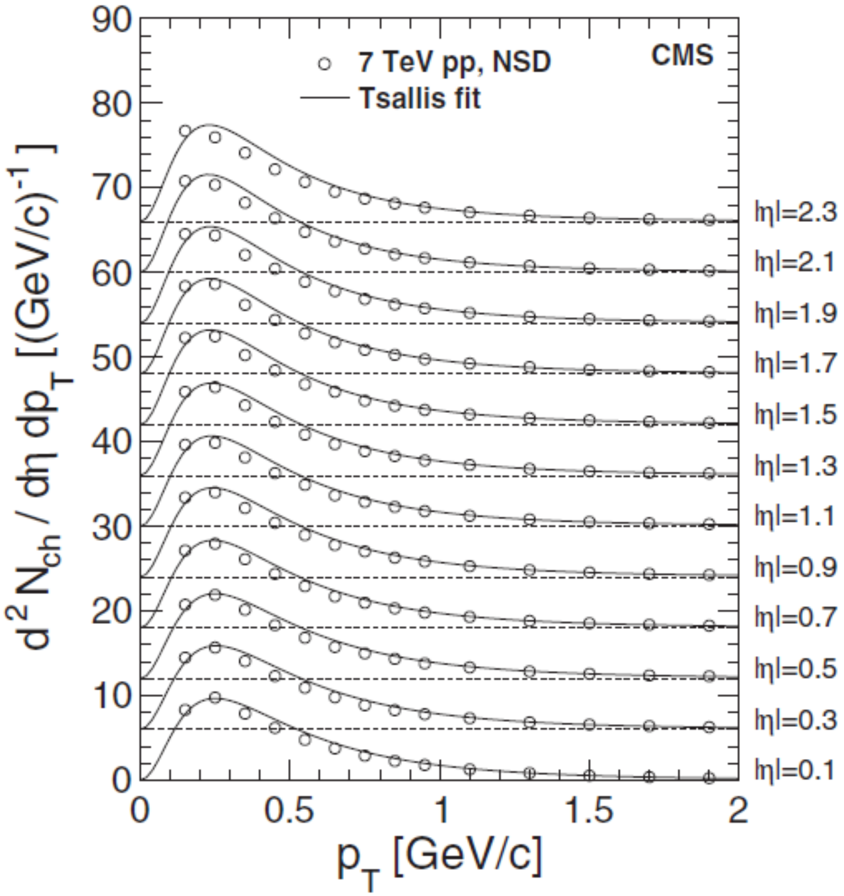
Phenomenological Tsallis fits to the CMS, ATLAS, and ALICE transverse momentum spectra of hadrons for pp collisions at LHC were recently found to extend over a large range of the transverse momentum. We investigate whether the few degrees of freedom in the Tsallis parametrization may arise from the relativistic parton-parton hard-scattering and related processes. The effects of the multiple hard-scattering and parton showering processes on the power law are discussed. We find empirically that whereas the transverse spectra of both hadrons and jets exhibit power-law behavior of $1/p_T^n$ at high p_T, the power indices n for hadrons are systematically greater than those for jets, for which $n \sim 4$–5.

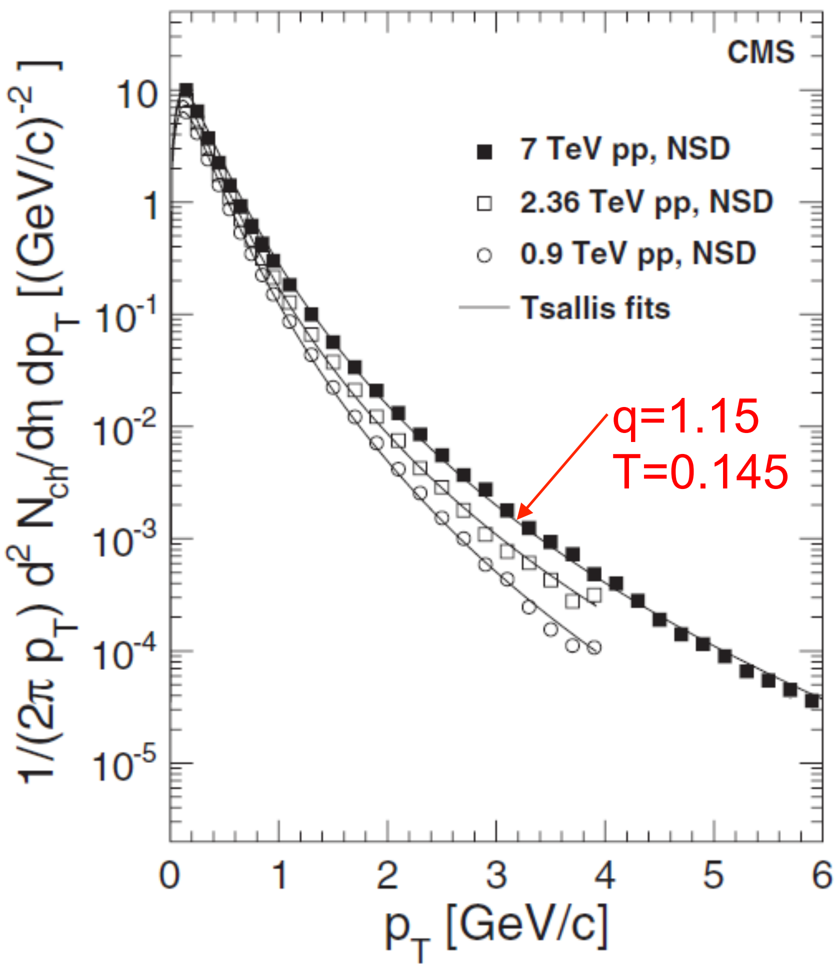
Transverse-Momentum and Pseudorapidity Distributions of Charged Hadrons in pp Collisions at $\sqrt{s} = 7$ TeV

V. Khachatryan *et al.**

(CMS Collaboration)

(Received 18 May 2010; published 6 July 2010)





PHYSICAL REVIEW D **87,** 114007 (2013)

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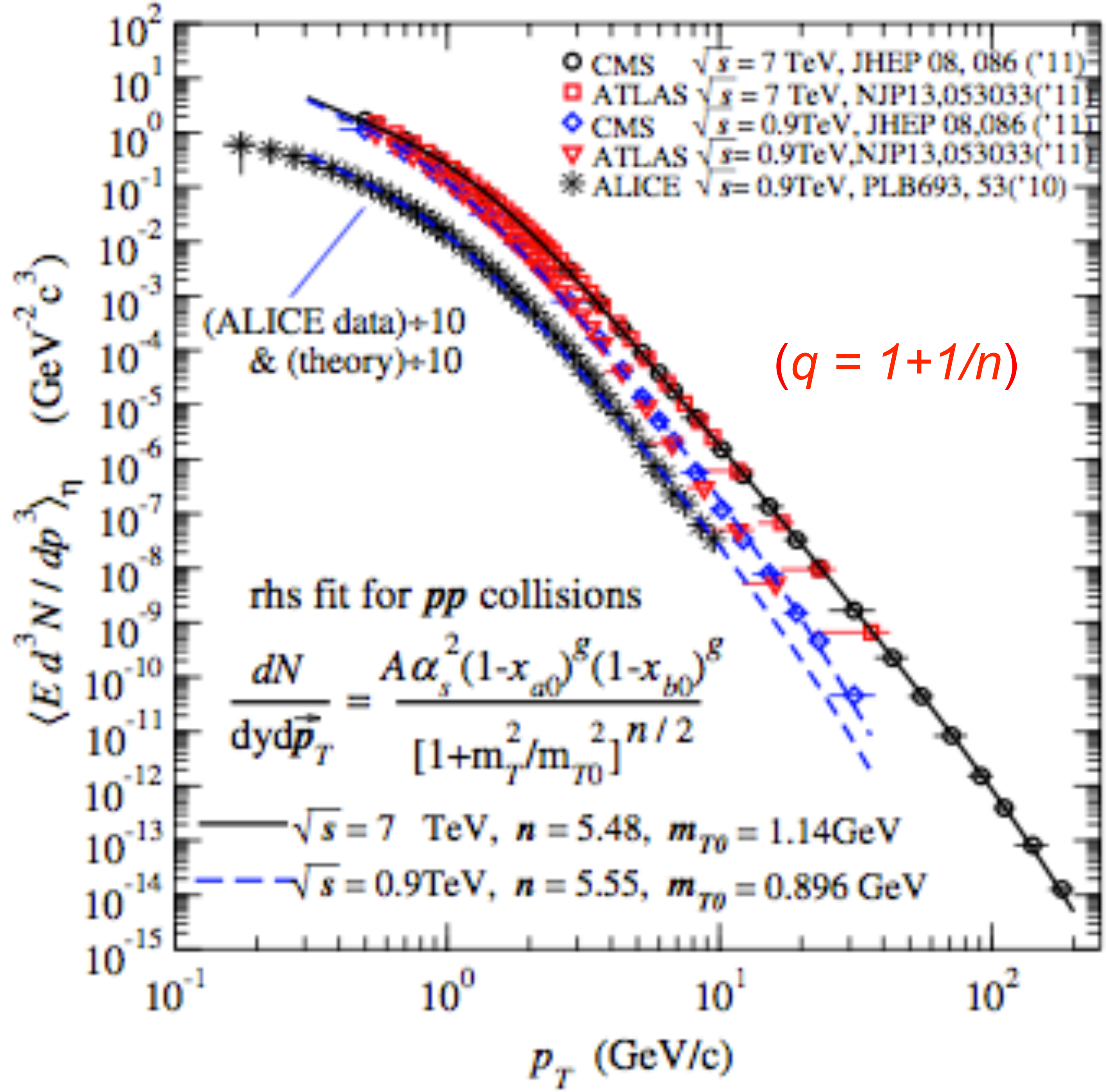
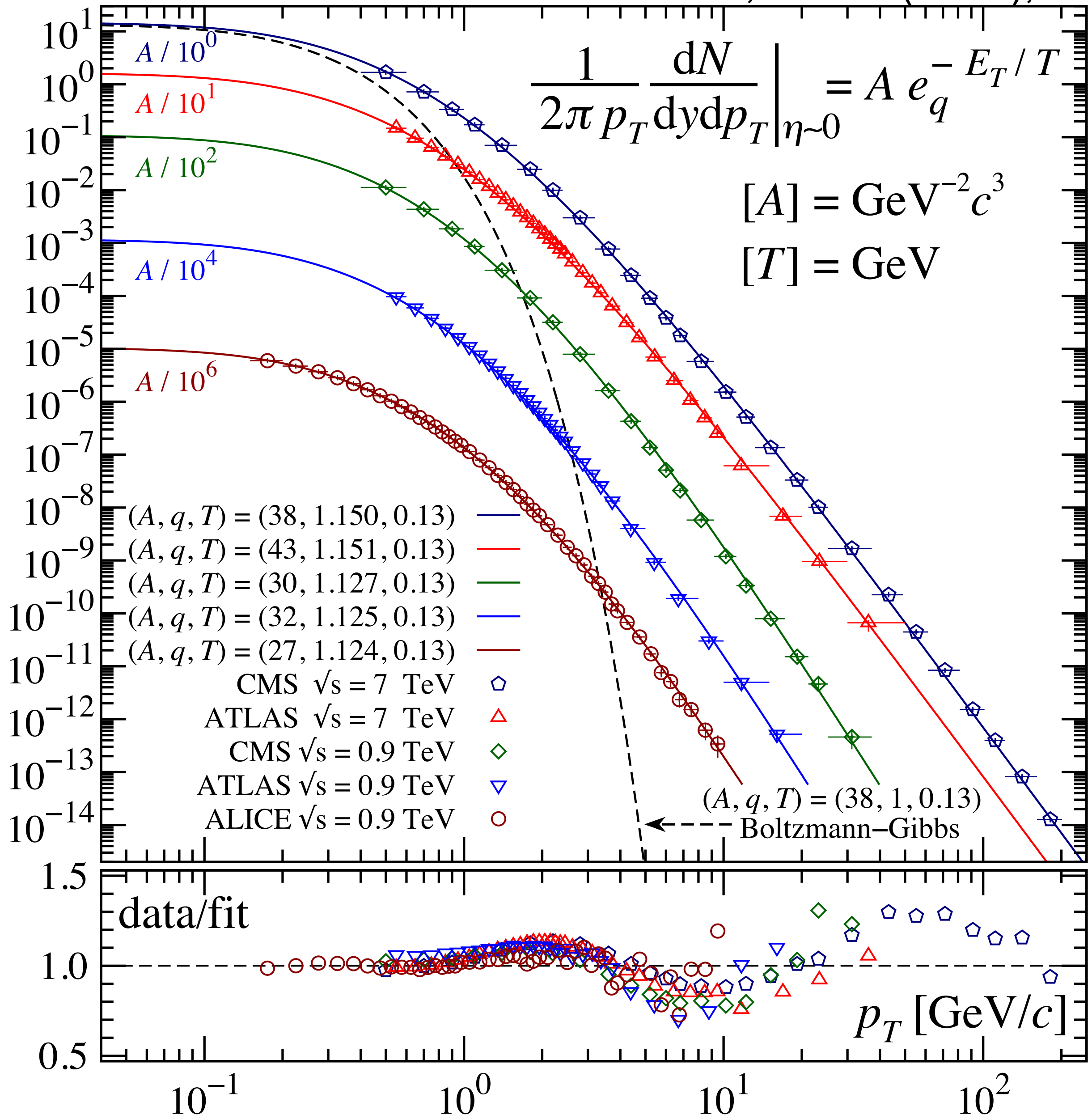
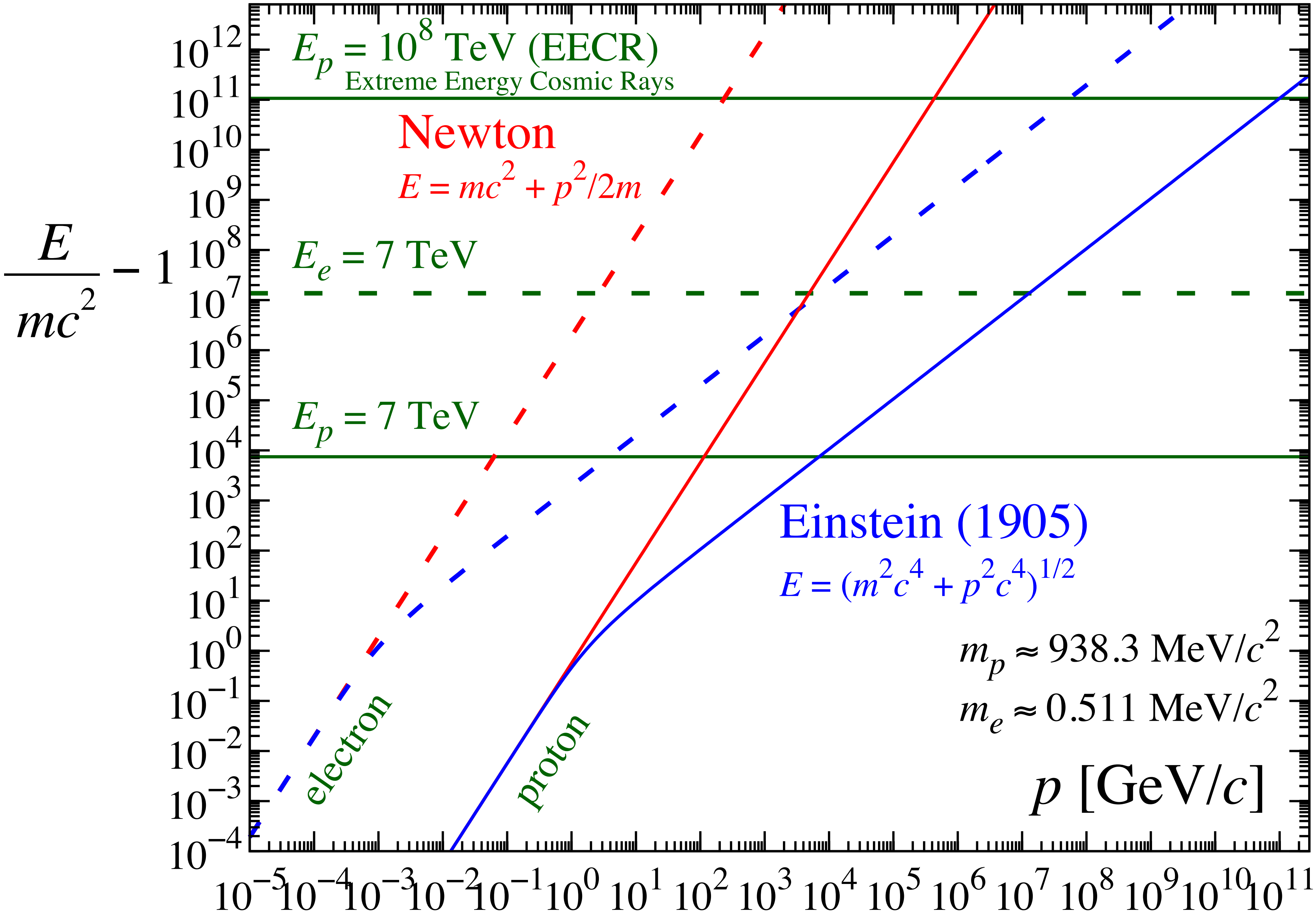

CMS √s = 7 TeV, JHEP 08, 086 ('11)
ATLAS √s = 7 TeV, NJP13,053033('11)
CMS √s = 0.9TeV, JHEP 08,086 ('11)
ATLAS √s= 0.9TeV,NJP13,053033('11)
ALICE √s= 0.9TeV, PLB693, 53('10)
(ALICE data)÷10
& (theory)÷10
(q = 1+1/n)
rhs fit for pp collisions
dN/dyd$\vec{p}_T$ = $A\alpha_s^2(1-x_{a0})^g(1-x_{b0})^g$ / $[1+m_T^2/m_{T0}^2]^{n/2}$
√s = 7 TeV, n = 5.48, m_{T0} = 1.14GeV
√s = 0.9TeV, n = 5.55, m_{T0} = 0.896 GeV
⟨E d³N / dp³⟩η (GeV⁻²c³)
p_T (GeV/c)

SIMPLE APROACH: TWO-DIMENSIONAL SINGLE RELATIVISTIC FREE PARTICLE

C.Y. Wong, G. Wilk, L.J.L. Cirto and C. T.,
EPJ Web of Conferences **90**, 04002 (2015), and PRD **91**, 114027 (2015)



$$E_T = \sqrt{m^2c^4 + p_T^2c^2}$$



$E_p = 10^8$ TeV (EECR)
Extreme Energy Cosmic Rays
Newton
$E = mc^2 + p^2/2m$
$E_e = 7$ TeV
$E_p = 7$ TeV
Einstein (1905)
$E = (m^2c^4 + p^2c^4)^{1/2}$
$m_p \approx 938.3$ MeV/c^2
$m_e \approx 0.511$ MeV/c^2
electron
proton
p [GeV/c]
$\frac{E}{mc^2} - 1$
10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12}
10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11}

Entropy **2015**, *17*, 384-400; doi:10.3390/e17010384

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ISSN 1099-4300

www.mdpi.com/journal/entropy

Article

Tsallis Distribution Decorated with Log-Periodic Oscillation

Grzegorz Wilk [1,*] and Zbigniew Włodarczyk [2]

[1] Department of Fundamental Research, National Centre for Nuclear Research, Hoża 69, 00-681 Warsaw, Poland

[2] Institute of Physics, Jan Kochanowski University, Świętokrzyska 15, 25-406 Kielce, Poland; E-Mail:zbigniew.wlodarczyk@ujk.edu.pl

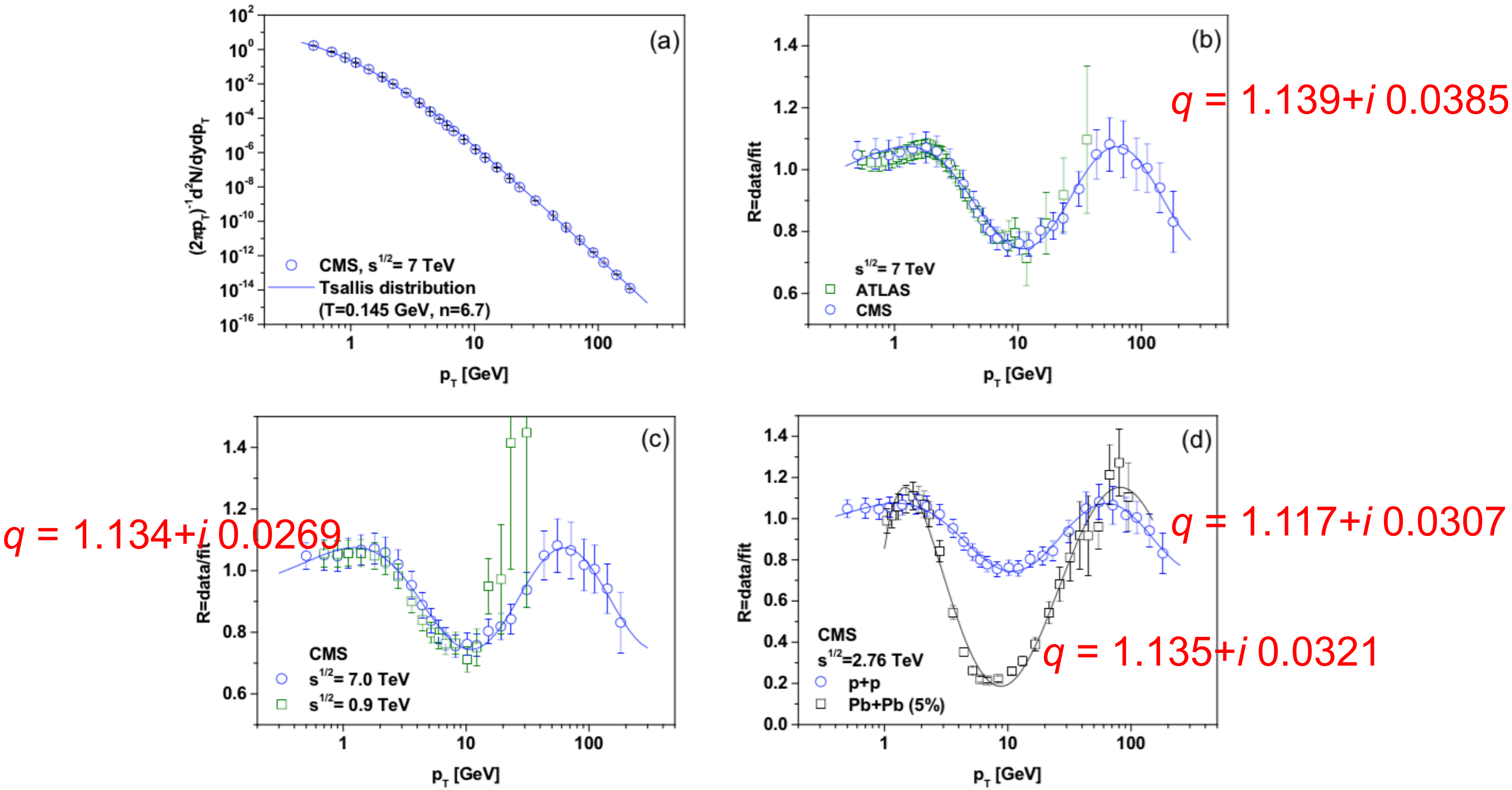

Figure 1. Examples of log-periodic oscillations. (**a**) dN/dp_T for the highest energy 7 TeV; the Tsallis behavior is evident. Only data from CMS experiment are shown [12]; others behave essentially in an identical manner. (**b**) Log-periodic oscillations showing up in different experimental data, like CMS [12] or ATLAS[15], taken at 7 TeV. (**c**) Results from CMS [12] for different energies. (**d**) Results for different systems ($p+p$ collisions compared with $Pb+Pb$ taken for 5% centrality [54]. Results from ALICE[55] are very similar. Fits for $p+p$ collision at 7, 2.76 and 0.9 TeV are performed with $q = 1.139 + i \cdot 0.0385$, $1.134 + i \cdot 0.0269$ and $1.117 + i \cdot 0.0307$, respectively. The fit for central $Pb+Pb$ collisions at 2.76 TeV is done with $q = 1.135 + i \cdot 0.0321$. See the text for more details.

Tout le monde savait que c’ était impossible.

Il y avait un qui ne le savait pas.

Alors il est allé et il l’a fait.

Jean Cocteau (Marcel Pagnol, Winston Churchill, Mark Twain ...)

Si l’action n’a quelque splendeur de liberté, elle n’a point de grâce ni d’honneur.

Montaigne

Sofia e la scoperta delle fragole (Marco Bersanelli)

A Gutenberg, tra le verdissime colline austriache, una mattina saliamo per il sentiero che attraversa il bosco scuro e profumato alle spalle del paese. Dopo mezz'ora di cammino troviamo sulla destra una sorgente presso una radura e ci fermiamo a bere. Con una grande espressione di felicità ad un tratto Sofia, la piccola di tre anni, esclama: «Mamma, mamma!! una fragola!!». Gli altri due accorrono e, constatato che la sorellina ha prontamente raccolto e inghiottito il frutto della sua scoperta, si mettono a cercare, presto seguiti dai genitori. «Un'altra!» e dopo un po': «Guarda qui, ce ne sono altre tre, quattro...». La caccia è aperta. Cercando in quel prato abbiamo presto riempito un bicchiere di fragole di bosco. Poi al ritorno, con mia sincera sorpresa, ripercorrendo lo stesso sentiero dalla sorgente in giù ne abbiamo trovate altrettante! Zero fragole all'andata, forse un centinaio al ritorno: un effetto statisticamente schiacciante. Cos'era cambiato?

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Eravamo cambiati noi.