The role of hadron formation time: from particle-nuclei to relativistic ion collisions

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A short review of some problems of the role of zone formation effect in multiproduction which are under active investigation nowadays is given.

The formation length of hadron from particle-nuclei collision is derived and compared with those from relativistic ion collisions.

In this Report, I want to draw too much attention to the problem of formation time.

It is necessary to take into account the time needed for the formation of particles produced at high energy.

Why?

Firstly....because of:

In analysis of data on multiparticle production in proton – nucleus interactions it has turned out that the cascading of secondaries is considerably lower than expected under the assumption that a secondary pion is able to interact **immediatelly** after it has been produced in a nucleon – nucleon collision. And this has been ascribed to the formation time of secondary particles.

PHYSICAL REVIEW VOLUME 110, NUMBER 1 APRIL 1, 1958

1958

Monte Carlo Calculations on Intranuclear Cascades. I. Low-Energy Studies*†

N. METROPOLIS,‡ R. BIVINS, AND M. STORM,§ *Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico*
ANTHONY TURKEVICH, *Enrico Fermi Institute for Nuclear Studies, University of Chicago, Chicago, Illinois*
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(Received November 26, 1957)

82 ÷ 350 Mev

Protons

PHYSICAL REVIEW VOLUME 110, NUMBER 1 APRIL 1, 1958

1958

Monte Carlo Calculations on Intranuclear Cascades. II. High-Energy Studies and Pion Processes*†

0.45 ÷ 1.8 Bev

Protons

N. METROPOLIS,‡ R. BIVINS, AND M. STORM,§ *Los Alamos Scientific Laboratory, Los Alamos, New Mexico*
J. M. MILLER, *Columbia University, New York, New York*
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(Received December 9, 1957)

Nuclear Physics 87 (1966) 241—255;

INELASTIC INTERACTIONS OF COSMIC RAY PARTICLES WITH ATOMIC NUCLEI AT VERY HIGH ENERGIES

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Received 18 February 1966

Abstract

The nucleon-nucleus interactions in the energy range **T = 100 -1000 GeV** are analysed from the point of view of the mechanism of intranuclear cascades in its generally accepted form (as a series of independent two-particle interactions). .. The result… the cascade calculation **is strongly contradictory with the experimental data…etc.**

Nuclear Physics B59 (1973) 128-140 ;

INTERACTIONS OF PIONS WITH HEAVY EMULSION NUCLEI

S.M. ELISEEV and J.M. KOHLI
Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna
Received 4 October 1972

Abstract

An analysis of the basic characteristics of secondary particles created in the interaction of pions with heavy emulsion nuclei **at the highest accelerator energies available** is presented. Calculations were performed with an intranuclear cascade model using the Monte-Carlo method, taking into account the "trailing effect". The theoretical results were compared with experimental results at 17.2 and 60 GeV interactions.

From Few-Body:

M.A. Braun, C. Ciofi degli Atti, L.P. Kaptari, H.Morita, "***Finite Formation Time in Electro-Disintegration of Few-Body Nuclei*** ", arXiv:nucl-th/0308069.

To Heavy Nuclei:

1.) Peter Filip, Jan Pisut,***"Hadron Formation Time and Dilepton Mass Spectra in Heavy Ion Collisions",*** arXiv:nucl-th/9705051.

2.) Sa Ben-Hao, *et al.*, ***"Formation time effect on J\Ψ Dynamical Nuclear Suppression",*** arXiv:nucl-th/9803033.

3.) Jörg Hüfner, Pengfei Zhuang, “***The Time Structure of Anomalous J\Ψ Suppression in Nuclear Collisions***”
in “*Proc. of XIIth International Conference on Selected Problems of Modern Physics Dedicated to the 95th anniversary of the birth of D.I. Blokhintsev (1908-1979)*”,
Dubna, June 8 - 11, 2003, D1,2-2003-219, p.282

In a high energy collision between two hadrons it takes a finite amount of time for the reaction products to evolve to physical particles. The time cannot be calculated within perturbative QCD because the hadronization process involves small Momentum transfers.

The question of fundamental importance in QCD is the fragmentation and hadronization-mechanism which converts quark and gluon quanta into integrally-charged final state hadrons. Hadronization is a large distance process for which we only have models at resent.

Zone formation (L.Stodolsky),
Finite Time Formation,
Landay-Pomeranchuk-Migdal Effect
(at high energy the electron become more “penetrating”).

The programme of the first day of Conf.
(The set of things that exist at our time and place.)

<ins>Chairman</ins> V. Kadyshevsky

10.00 *Malakhov A., Burov V.*
Opening
10.20 *Sissakian A.*
M.A. Markov and JINR

Quantum Chromodynamics at the Large Distances

10.40 *Prokhorov L.* (SPbSU, Russia)
On Fractioning of Quanta: Electrons and Neutrons

Coffee break 11.00 – 11.30

<ins>Chairman</ins> V. Burov

11.30 *Musakhanov M.* (Tashkent, Uzbekistan)
Low energy constants of ChPT from the instanton vacuum model
12.10 *Dorokhov A.* (BLTP, JINR)
Rare decay π^0 to *ee* as a filter for low mass dark matter
12.30 *Konopleva N.* (BLTP, JINR)
Physics and Geometry

Prof. R. Hagedorn outlined the genuine situation with the investigation of QGP and highlighted the current problem:

"*If you ask me now why it took 27 years to arrive at the present (still problematic) state, (QM), let me answer with Shakespear*:

There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy."

W. Shakespear, Hamlet (1601).

See:

R. Hagedorn, "*How we got to QCD matter from hadron side by trial and error*", QM 1984, June 17-21, 1984,Helsinki.

1.) D.I. Blokhintsev, "***Some remarks on the validity of the hydrodynamic description of quantum systems***", Zh. Eksp. Teor. Fiz., **32**, 350 (1957).

Abstract

It is shown that the hydrodynamic description of quantum system imposes some serious restrictions on the dimensions of the investigated system. A result of this is that this description is invalid for atomic nuclei or multiple creation of mesons at the initial stages of expation of the meson liquid.

2.) R.Ya. Zulkarneev, ***Does the fireball found in AuAu collisions at RHIC resemble plasma***? arXiv:nucl-th/0706.1007.

(LPM effect)

QED

1.) The radiation of a photon by electron of momentum ***p*** and mass ***m***, $k=(1-m)p$ and $q_{min}=m^2(1-x)/2xp$.

$l_f \sim 1/q$ - the formation length.

At high energy and soft photon $(1-x)p<<1$ and $l_f > l_{m.f.p.}$

The coherence is lost - suppression of the radiation,

Bethe-Heitler spectrum $dN \sim dk/k$ is modified:

L.D. Landau, I.J. Pomeranchuk, Dok. Ak. Nauk. SSSR **92**, 535 (1953),

A.B. Migdal, Phys. Rev. **103**, 1811 (1956).

2a.) E.L. Feinberg: "***the electron "shake off" his field after the first collision. The scattering take place without radiation***".

2b.) The hadronic analogy of LPM effect?

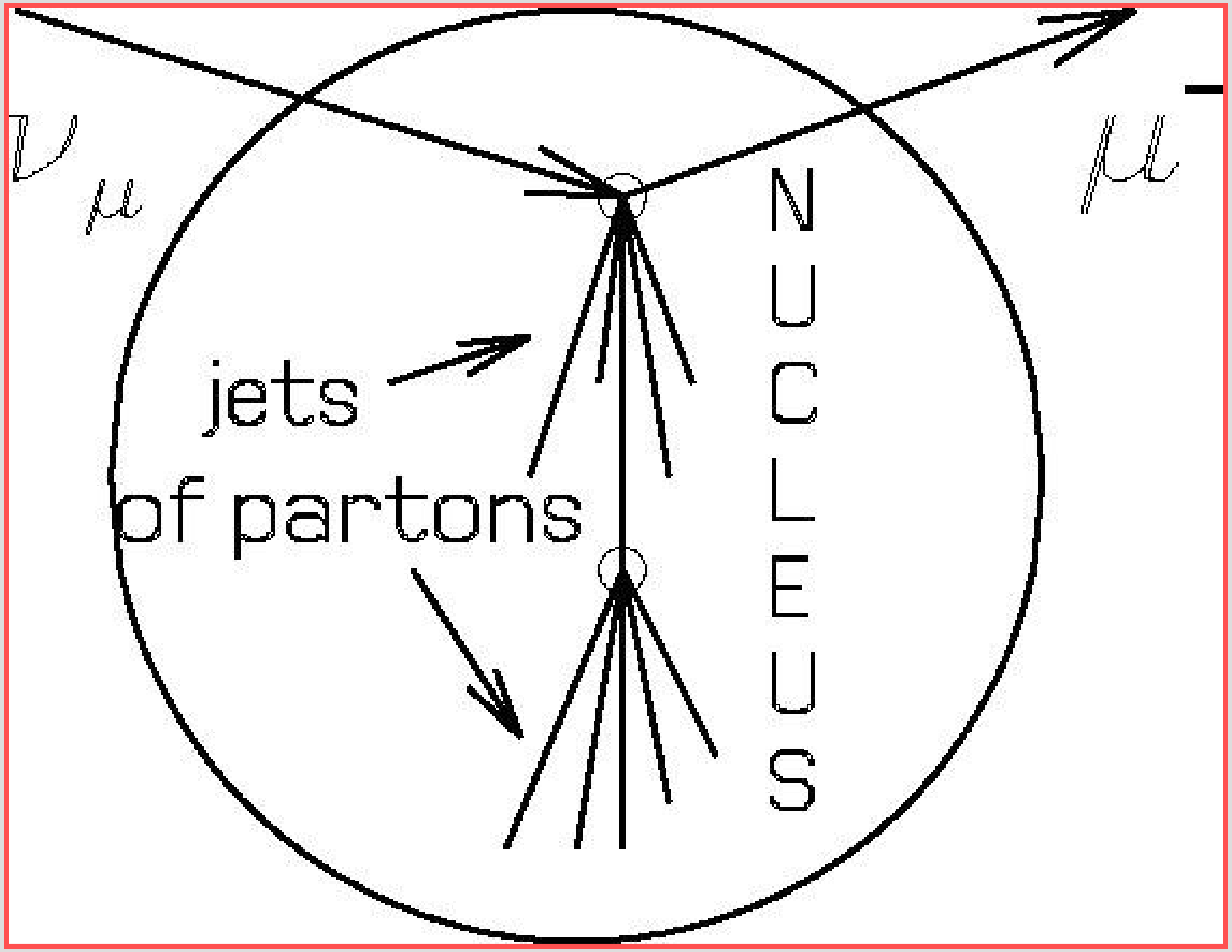
I.) E.L. Feinberg, in "*Problems of theoretical physics*", Moscow: Science, 1972, pp. 248.

II.) L.Stodolsky, Phys.Rev.Letters, **28**, 60 (1972)

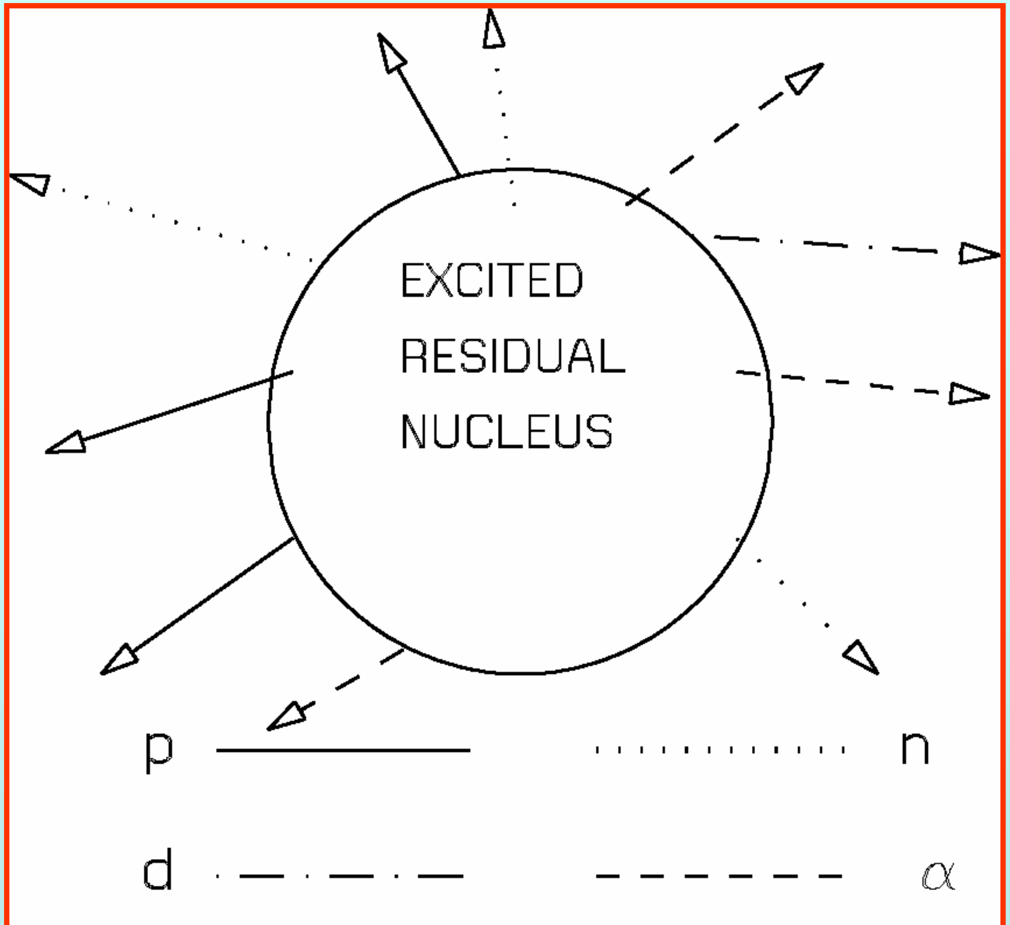
In Deep Inelastic Scattering on nuclear targets (nDIS) one observes a suppression of hadron production analogous to hadron quenching in heavy-ion collision at the Relativistic Heavy-Ion Collider (RHIC).
Moreover, the nucleons act as femtometer-scale detectors allowing to experimentally study the propagation of a parton in this ``cold nuclear matter'', and its space-time evolution into the observed hadron. In the case of heavy ion collisions, one wants to use hadron suppression as a tool to extract the properties of the hot and dense system created in the collision, also called ``hot nuclear matter''.

According to the parton model, a high energy lepton interacts with a nucleon transferred a considerable amount of the momentum to one of the quarks of the nucleon. Lepton–nucleon scattering allows us to investigate the hadronisation of quark-diquark jets (or strings) in vacuum. In the course of the evolution between the hard scale Q_{hard} and the cut-off scale Q_0 that results in the formation of a perturbative parton shower, the quarks and gluons become organized in colour-singlet 'clusters', whose mass is of order Q_0 and is independent of Q_{hard}. This is a theorem of colour preconfinement, which follows from perturbative QCD: A.M. Polyakov *et al.*, D. Amati, G. Veneziano *et al.*, Y.L. Dokshitzer, V.A. Khoze *et al.*). The parton evolution in QCD can (in the LLA) be described in term of probability distribution as a Markovian branching process. Lepton-nucleus scattering provides a nontrivial possibility to analyze space-time evolution and hadronisation of jets inside a nuclear matter.

A model for parton's jets hadronisation (as Markovian branching process) in semi-inclusive DIS of nuclear targets will be presented. All calculations were performed by Monte Carlo method. Landau-Pomeranchuk-Migdal (LPM) effect was introduced. The formation length parameter L_f (in the system of a moving parton) was found to be $\approx 0.5 fm$. In our approach, the evolution of quark–gluon jets in nuclei is accompanied by a nucleon emission at backward angles and momentum ≥ 300 MeV/c (cumulative nucleons). The chance of the observing of Blokhintsev's fluctons from the generation of more energetic cumulative nucleons will be discussed. Also, the new data from NOMAD detector will be presented. In addition, our estimation of zone formation is in agreement with the other finding for different particle-nucleus reactions. In conclusion, role of the effect of particle formation in many high energy phenomenon, e.g., in the study of signatures for QGP formation: "jet quenching", the structure of anomalous J/ψ suppression in nuclear collisions, will be discussed.

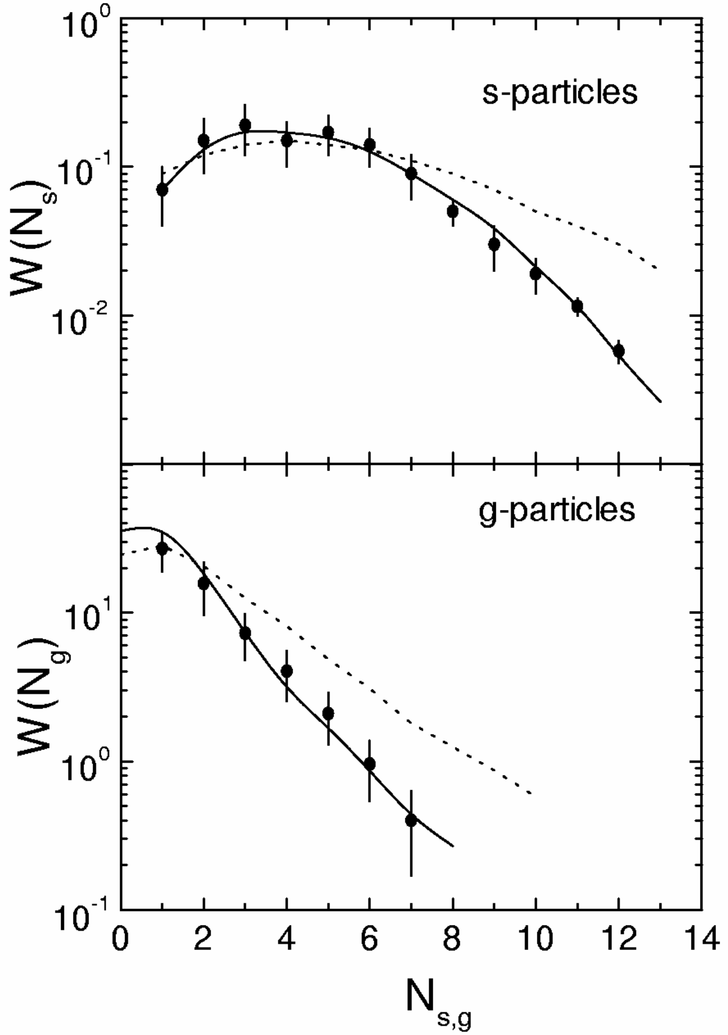


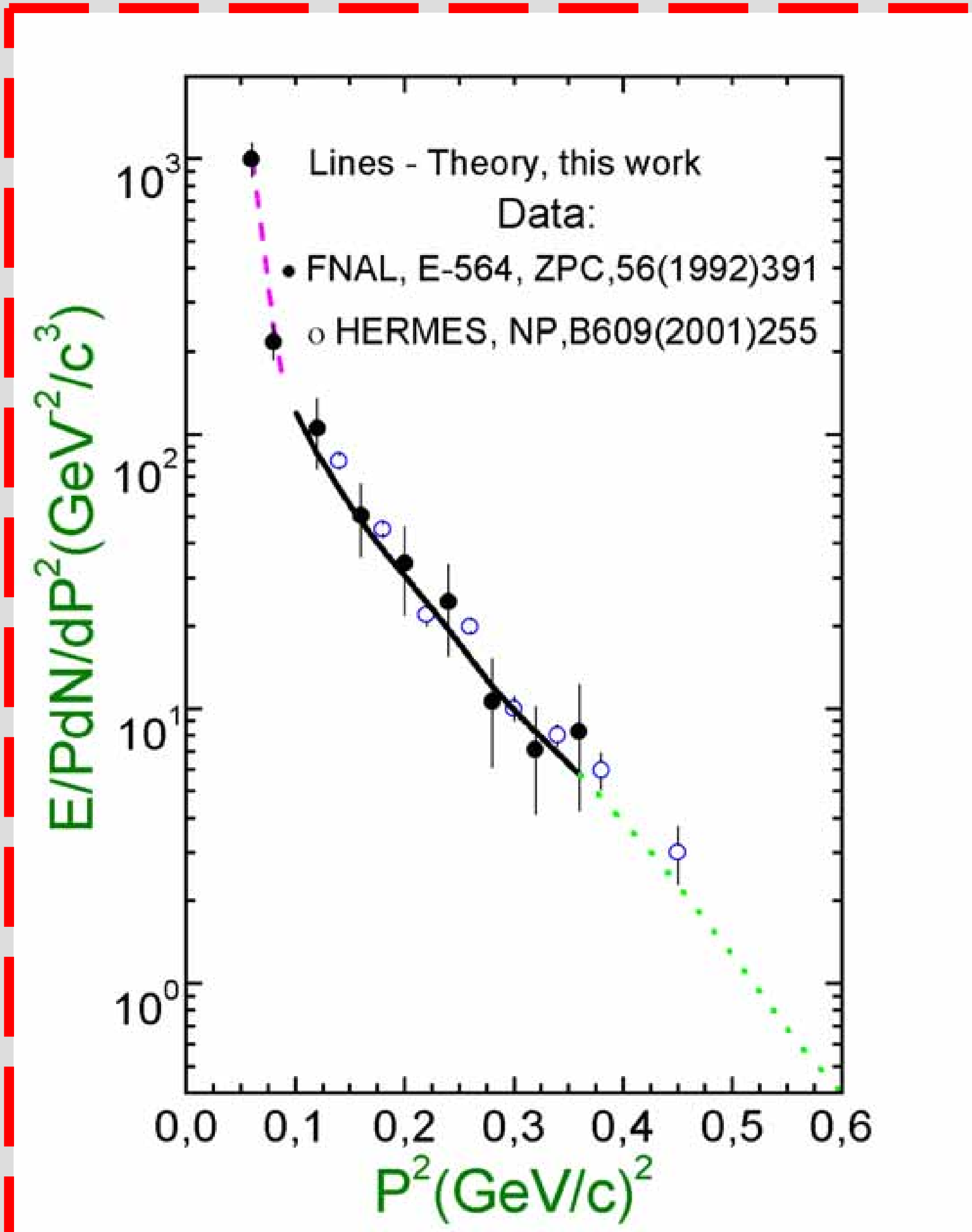
ν_μ
μ^-
jets
of partons
NUCLEUS



EVAPORATION OF THE PARTICLES FROM A RESIDUAL NUCLEUS

L_f=0.5 fm


s-particles
g-particles
W(N_s)
W(N_g)
N_s,g
10^0
10^-1
10^-2
10^1
10^0
10^-1
0
2
4
6
8
10
12
14



Lines - Theory, this work
Data:
• FNAL, E-564, ZPC,56(1992)391
o HERMES, NP,B609(2001)255
10^3
10^2
10^1
10^0
E/PdN/dP^2(GeV^2/c^3)
0,0
0,1
0,2
0,3
0,4
0,5
0,6
P^2(GeV/c)^2

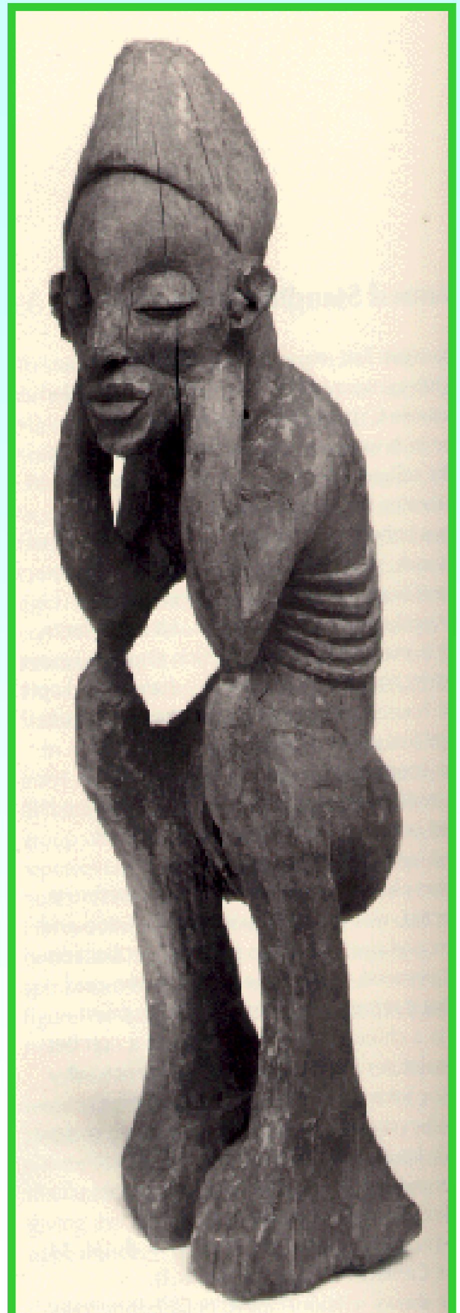
Conclusion

The discovery of QGP:

To be or not to be?

To be, but not in parameter free approach!

END



END

the set of things that are happening and the conditions that exist at a particular time and place

А.П. Чехов, ”*Ну, публика*”(1885), **3**, 525(1957).

A.P. Chekhov, “*O! Public*”(1985), **3**, 525(1957). (in Russian).