Die Erste Stunde

Talk title evolved, will explain physics, talk is about Walter

From Johann Rafelski <rafelski@physics.arizona.edu>
Subject **Re: FIAS International Symposion on Discoveries at the Frontiers of Science** 03/18/2017 08:30 PM
To FoS 2017 <fos2017@fias.uni-frankfurt.de>

Dear Colleagues,

Thank you for your kind invitation, which I gladly accept. I intend to participate in the FIAS symposium last week of June 2017. The topic of my lecture dedicated to my academic teacher Walter Greiner could be:
"Spontaneous neutrino production in supercritical fields".

Best regards
Johann Rafelski

On 03/17/2017 07:49 AM, FoS 2017 wrote:
> We would like to invite you, as Walter's friend AND STUDENT, to attend the FIAS Symposion and present your recent scientific work.

From Jan Rafelski <rafelski@gmail.com>
Subject **Re: FoS 2017 - JR-Vortrag** 05/19/2017 06:02 PM
To FoS 2017 <fos2017@fias.uni-frankfurt.de>
Cc Horst Stoecker FIAS <stoecker@FIAS.uni-frankfurt.de>

Liebe
Der Vortragstitel soll unbedingt in Deutsch angezeigt werden:
"Die Erste Stunde"

da ich sowohl die ersten Stunden von Walter
als auch des Universums ansprechen werde.

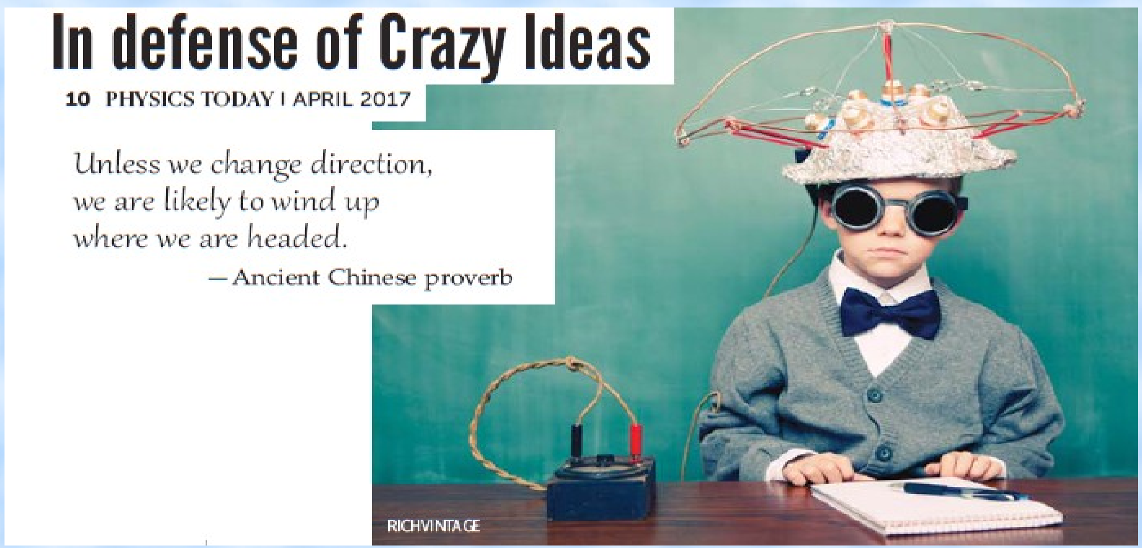
viele Grüße
Johann

On 05/18/2017 05:54 AM, FoS 2017 wrote:
> Lieber Prof. Rafelski,
>
> das Programm habe ich aktualisiert

Die Erste Stunde

This will be an account how a new field of physics was created in Frankfurt beginning in 1968 – coincident with my meeting in classroom of my future thesis adviser and teacher

Walter Greiner



The prehistory

Sometime around 1965-7 Walter Greiner recognizes the need to understand the atomic structure of superheavy element Z=164

PROCEEDINGS
INTERNATIONAL CONFERENCE
ON PROPERTIES
OF NUCLEAR STATES

MONTREAL, CANADA
AUGUST 25-30, 1969

COMPTES RENDUS
CONFÉRENCE INTERNATIONALE
SUR LES PROPRIÉTÉS
DES ÉTATS NUCLÉAIRES

MONTRÉAL, CANADA
25-30 AOÛT 1969

SESSION 11

PANEL DISCUSSION

SEANCE 11

TABLE RONDE

Chairman/Président: D.H. WILKINSON *(Oxford)*

Scientific Secretary/Secrétaire Scientifique: J.C.D. MILTON *(Chalk River)*

EDITORIAL COMMITTEE/COMITÉ DE PUBLICATION
M. Harvey (Chairman/président)
R. Y. Cusson — J. S. Geiger — J. M. Pearson

held on Saturday morning, August 30
tenue le samedi matin 30 août

Greiner: The important thing is that for Z = 80 you have $Z\alpha$ less than unity, but for super-heavy nuclei around Z = 164 it is suddenly larger than unity and you do not know whether the expansion in $Z\alpha$ converges anymore. You really have to start from a completely different point of view and develop new methods.

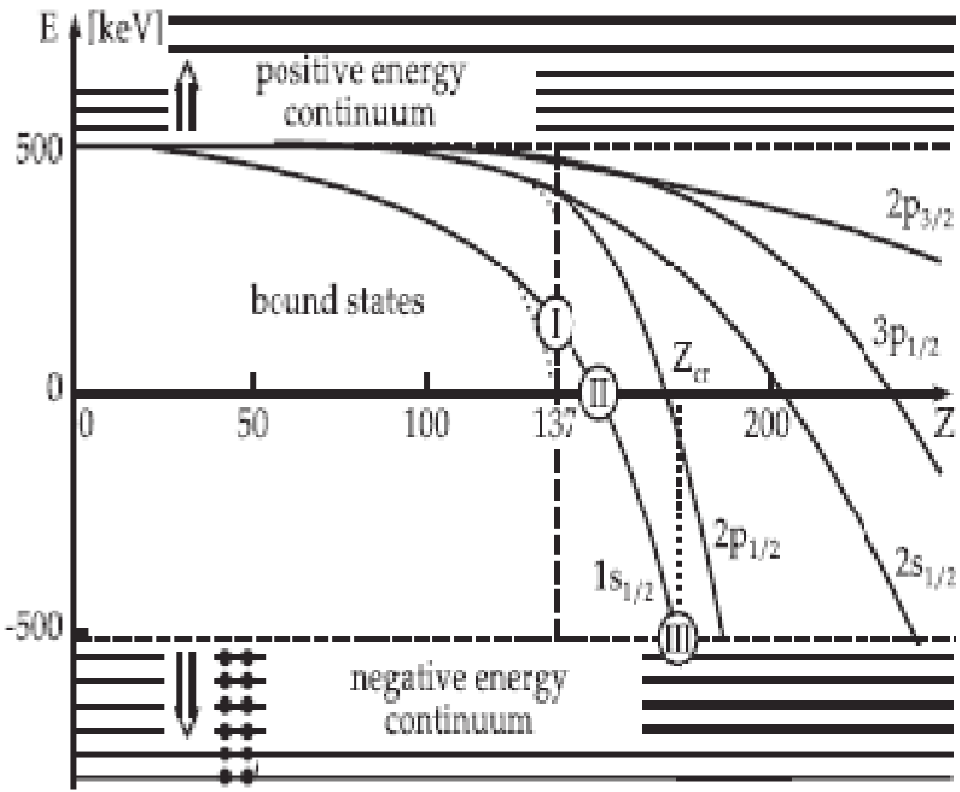
Greiner: I would like to stress that this quantum electrodynamic problem is very interesting from a purely theoretical point of view. I mean no matter whether we can make nuclei with Z = 164 or not, it is interesting in itself to study theoretically what really happens. If however elements around Z = 164 were very unstable the problem would be merely academic.

We may ask ourselves what we may further learn from super-heavy nuclei. Let me mention a few other important aspects. I certainly do not have to convince you that there is nothing to learn about basic nuclear forces - let's forget this completely.

1st step: Dirac relativistic QM Singularity

Interior Electron Shells in Superheavy Nuclei
Pieper-Greiner Z. Physik 218, 327-340 (1969)
submitted August 14 1968

Strong Fields in High Z Atoms



Single Particle Dirac Equation

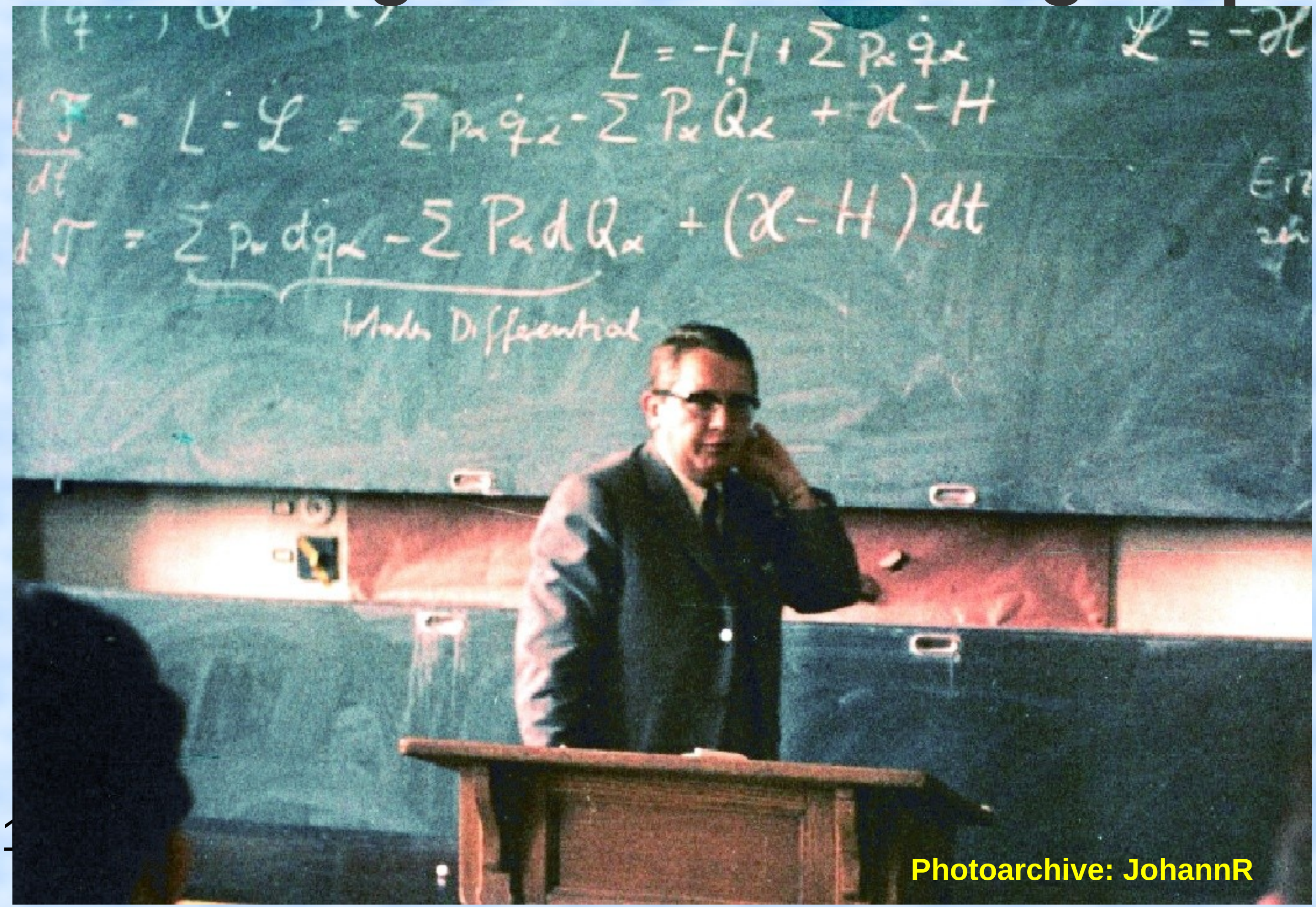
$$(\vec{\alpha}\cdot i\vec{\nabla}+\beta m+V(r))\Psi_n(\vec{r}) = E_n\Psi_n(\vec{r})$$

$$V(r) = \begin{cases} -\frac{Z\alpha}{r} & r > R_N \\ -\frac{3}{2}\frac{Z\alpha}{R_N} + \frac{r^2}{2}\frac{Z\alpha}{R_N^3} & r < R_N \end{cases}$$

Key feature: bound states pulled from one continuum move as function of $Z\alpha$ across into the other continuum.

The 1968 October revolution:

Walter Greiner
teaches theoretical physics in 1st semester,
& starts new strong fields research group with us



2^{nd} step: Walter's great invention

Embedding a super bound electron in positron continuum

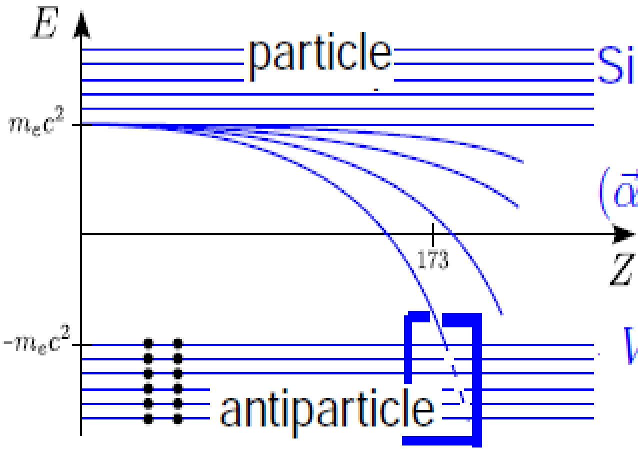
VOLUME 28, NUMBER 19 PHYSICAL REVIEW LETTERS 8 MAY 1972

Solution of the Dirac Equation for Strong External Fields*

Berndt Müller, Heinrich Peitz, Johann Rafelski, and Walter Greiner
Institut für Theoretische Physik der Universität Frankfurt, Frankfurt am Main, Germany
(Received 14 February 1972)

The 1*s* bound state of superheavy atoms and molecules reaches a binding energy of $-2mc^2$ at $Z \approx 169$. It is shown that the *K* shell is still localized in *r* space even beyond this critical proton number and that it has a width Γ (several keV large) which is a positron escape width for ionized *K* shells. The suggestion is made that this effect can be observed in the collision of very heavy ions (superheavy molecules) during the collision.

What is (mostly) this about?



Single Particle Dirac Equation

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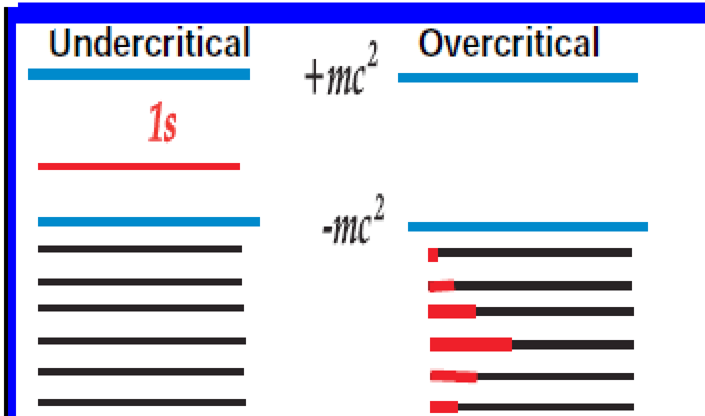
$$V(r) = \begin{cases} -\dfrac{Z\alpha}{r} & r > R_N \\ -\dfrac{3}{2}\dfrac{Z\alpha}{R_N} + \dfrac{r^2}{2}\dfrac{Z\alpha}{R_N^3} & r < R_N \end{cases}$$

Supercritical fields

The bound states drawn from one continuum move as function of Z across into the other continuum. Mix-up of particle/antiparticle states



If diving state 'empty' vacuum decays

$|Q=0\rangle \rightarrow |Q=e\rangle + e^+$ by positron

state occupied by an electron, 'smooth' transition of charge distribution

Reference: W. Greiner, B. Müller and JR ISBN 3-540-13404-2. "Quantum Electrodynamics of Strong Fields," (Springer Texts and Monographs in Physics, 1985),

3^{rd} step: 1972 HI Collisions replace the need for super-super-heavy nuclei

HI collisions: electrons in quasimolecuar fields

LETTERE AL NUOVO CIMENTO VOL. 4, N. 11 15 Luglio 1972

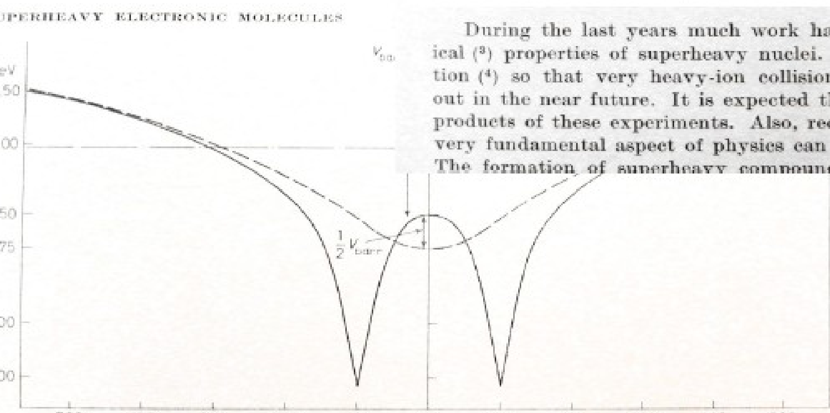
Superheavy Electronic Molecules (*).

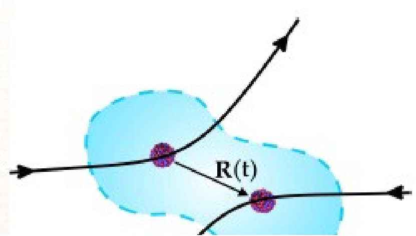
J. Rafelski, B. Müller and W. Greiner

Institut für Theoretische Physik der Universität Frankfurt - Frankfurt/Main

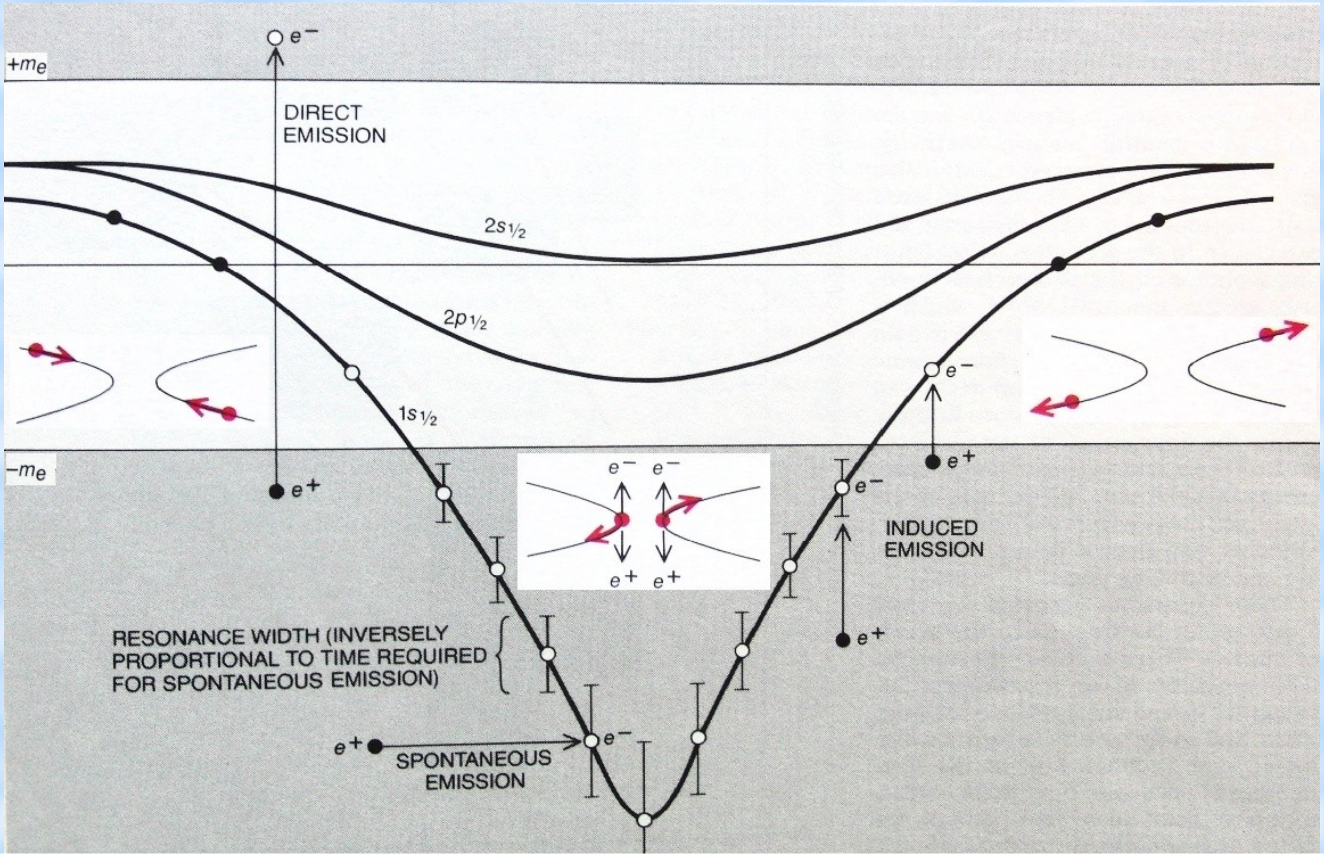
ricevuto il 30 Marzo 1972)

During the last years much work has been done to predict physical (1,2) and chemical (3) properties of superheavy nuclei. Heavy-ion accelerators are under construction (4) so that very heavy-ion collisions above the Coulomb barrier can be carried out in the near future. It is expected that superheavy nuclei will emerge as the end products of these experiments. Also, recently it has been pointed out (5) that another very fundamental aspect of physics can possibly be investigated in these experiments. The formation of superheavy compound nuclei—if existing longer than 10^{-16} s—will





A decade of process computation in heavy ion collisions



Probing QED Vacuum with Heavy Ions

Johann Rafelski, Johannes Kirsch, Berndt Müller, Joachim Reinhardt and Walter Greiner

Abstract We recall how nearly half a century ago the proposal was made to explore the structure of the quantum vacuum using slow heavy-ion collisions. Pursuing this topic we review the foundational concept of spontaneous vacuum decay accompanied by observable positron emission in heavy-ion collisions and describe the related theoretical developments in strong fields QED.

By early 1970 the Strong Fields Frankfurt group was invited by Walter Greiner to a Saturday morning palaver in his office. In the following few years this was the venue where the new ideas that addressed the strong fields physics were born. At first the predominant topic was the search for a mechanism to stabilize the solutions of the Dirac equation, avoiding the "diving" of bound states into the Dirac sea predicted by earlier calculations [3]. However, a forced stability contradicted precision atomic spectroscopy data [6–8]. In consequence the group discussions turned to exploring the opposite, the critical field instability, and the idea of spontaneous positron emission emerged.

S. Schramm and M. Schäfer (eds.), *New Horizons in Fundamental Physics*,
FIAS Interdisciplinary Science Series, DOI 10.1007/978-3-319-44165-8_17

4^{th} step 1973: no stable vacuum, hence vacuum decay in Strong Fields

Nuclear Physics B68 (1974) 585–604. North-Holland Publishing Company

THE CHARGED VACUUM IN OVER-CRITICAL FIELDS*

J. RAFELSKI, B. MÜLLER and W. GREINER

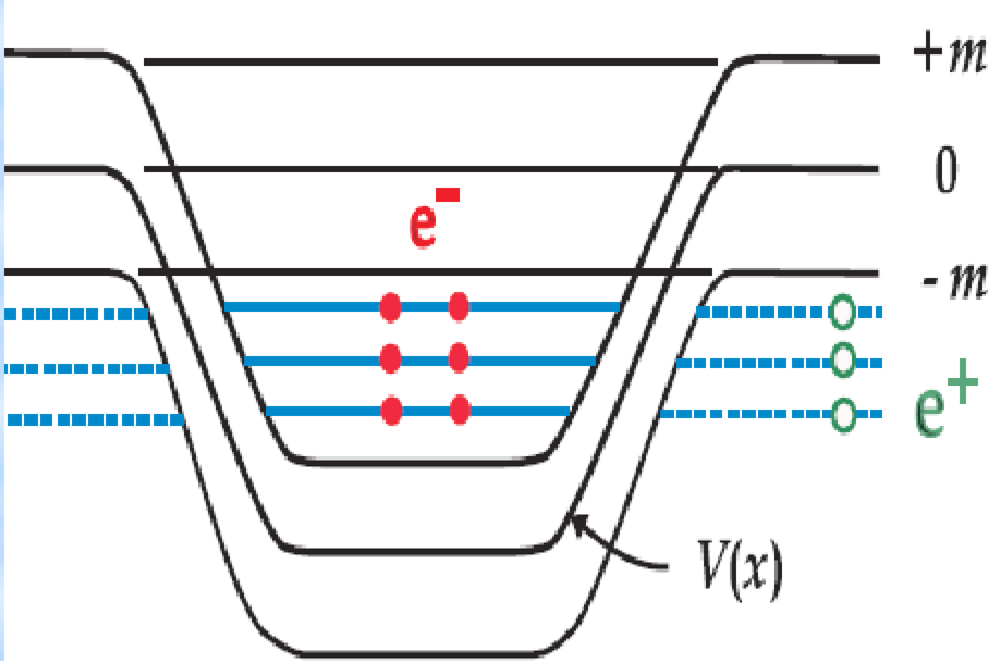
Institut für Theoretische Physik der Universität Frankfurt, Frankfurt am Main, Germany

Received 4 June 1973
(Revised 17 September 1973)

Abstract: The concept of over-critical fields, i.e. fields in which spontaneous, energy-less electron-position pair creation may occur, is discussed. It is shown that only a charged vacuum can be a stable ground state of the overcritical field. The time-dependent treatment confirms previous results for the cross sections for the auto-ionizing positrons. The questions in connection with the classical Dirac wave functions in over-critical fields are extensively discussed in the frame of the self-consistent formulation of QED including the effects of vacuum polarization and self-energy.

New local vacuum state

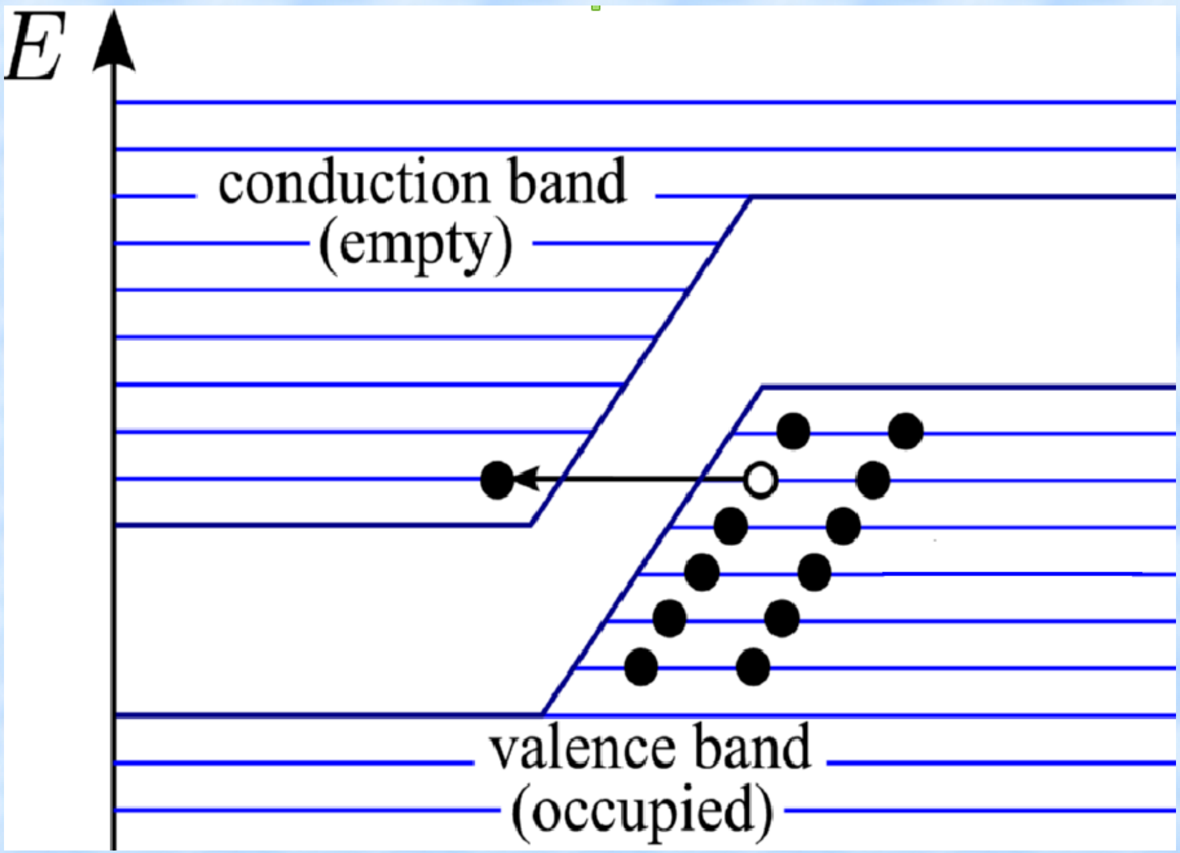
New Stable Ground State: The Charged Vacuum



There is localized charge density in the vacuum, not a particle of sharp energy. Formation of the charged vacuum ground state observable by positron emission: which fills any vacancies among 'dived' states in the localized domain.

Rate of surface pair production

Speed of decay of false vacuum controlled by Heisenberg-Schwinger field strength.



Connection to rate of pair production in constant fields

The sparking of the QED dielectric

Effect large for Field

E_s=1.323 10^{18} V/m

$$P \sim exp\left(-\pi\frac{m^2c^3}{eE\hbar}\right)$$

Probability of vacuum pair production can be evaluated in WKB description of barrier tunneling: All E-fields are unstable and can decay to particles – footnoted by Heisenberg around 1935, added into Schwinger's article as a visible after finish-point invited by referee (Heisenberg?). New idea: strong field = strong acceleration

Supercritical Neutrino Production 2017

Neutrino mass small, but interaction G-small too. Dense nuclear matter will do for $V>2mc^2$.

$$P \sim exp\left(-\pi \frac{m^2 c^3}{eE\hbar}\right)$$

Usefull as energy loss mechanism in presence of critical density fluctuation

Part of Ph.D. Thesis (Cheng Tao Yang) in progress. The other part is about the first hour in the Universe and the role of quantum neutrinos in Universe evolution from QGP era to BBN.

Back to time line: The personal step

August 1973:

Ffm Rathaus

Tucson,
15 years after

June 28, 2017

Back to timeline: 5th Step "Accelerated" Vacuum – compare accelerated observer and BH

Back in Frankfurt Summer 1977 Recognize external fields as a TEMPERATURE

Volume 63A, number 3 PHYSICS LETTERS 14 November 1977

INTERPRETATION OF EXTERNAL FIELDS AS TEMPERATURE★

Berndt MÜLLER and Walter GREINER
Institut für Theoretische Physik, Johann Wolfgang Goethe Universität, 6000 Frankfurt am Main, W.-Germany

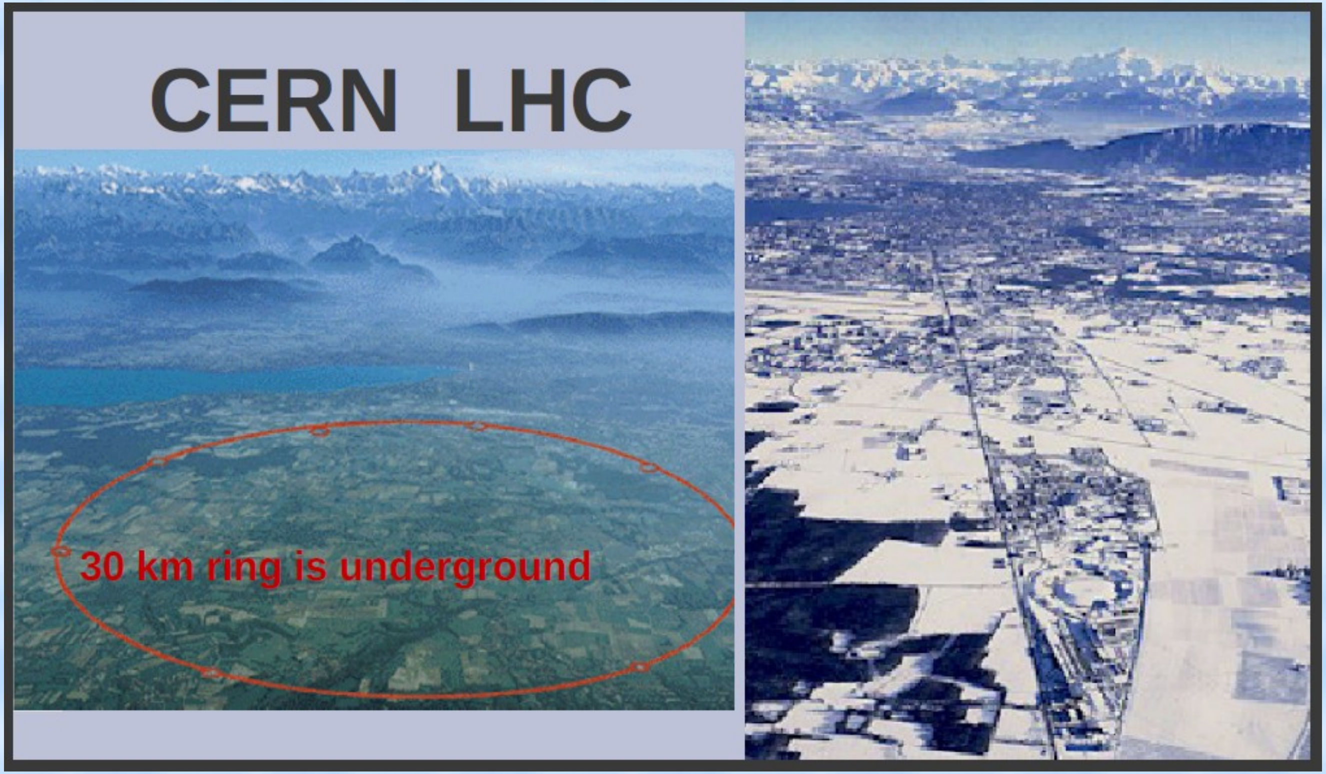
and

Johann RAFELSKI
Gesellschaft für Schwerionenforschung, 6100 Darmstadt, W.-Germany

Received 5 September 1977

We show that average excitation of the vacuum state in the presence of an external electric field can be described by an effective temperature $kT = eE/(2\pi m)$. We present a qualitative generalization of our result to other interactions. Some phenomenological implications concerning matter at low temperatures in strong electric fields (10^5 V/cm) are offered.

Intermezzo: **Walter bridged for a few months with a GSI job before on Sept 1, 1977 I started CERN fellowship; I was at CERN for start of RHI-PS/SPS project, the decision to build LEP/LHC etc.came back to Frankfurt November 1979 bringing with me QCD, confining vacuum and QGP**



Return to Frankfurt: Introduction of Quark-Gluon Plasma:

QCD vacuum and strangeness arrive

QUARKMATTER--NUCLEAR MATTER

The fusion of constituents of protons and neutrons -- quarks -
to quarkmatter is expected to form a new phase of nuclear matt
Based on our recent theoretical work this is expected to occu
temperature and density accessible to experimental study.

Fachbereich Physik
der Johann Wolfgang Goethe-Universität Frankfurt am Main

Einladung

zu der öffentlichen Antrittsvorlesung des Herrn

Prof. Dr. Johann Rafelski

über das Thema

„Quarkmaterie – Kernmaterie"

Das Verschmelzen der Bestandteile der Protonen und Neutronen – der Quarks – zur Quarkmaterie, einer neuen Phase der Kernmaterie wird aufgrund von neuesten theoretischen Ar[illegible]ten in einem experimentell zugänglichen Druck und Temperaturbereich erwartet.

am Mittwoch, dem 18. Juni 1980, 17 Uhr c. t.
im Hörsaal des Instituts für Angewandte Physik
Frankfurt am Main, Robert-Mayer-Straße 2–4

Die Vorlesung findet im Rahmen des Physikalischen Kolloquiums statt.

Der Dekan: Prof. Dr. Werner Martienssen

IM NAMEN DES LANDES HESSEN

ERNENNE ICH

Herrn

Dr. Johann Rafelski
geb.am 19.5.1950

UNTER BERUFUNG IN DAS BEAMTENVERHÄLTNIS

AUF LEBENSZEIT

zum

Professor

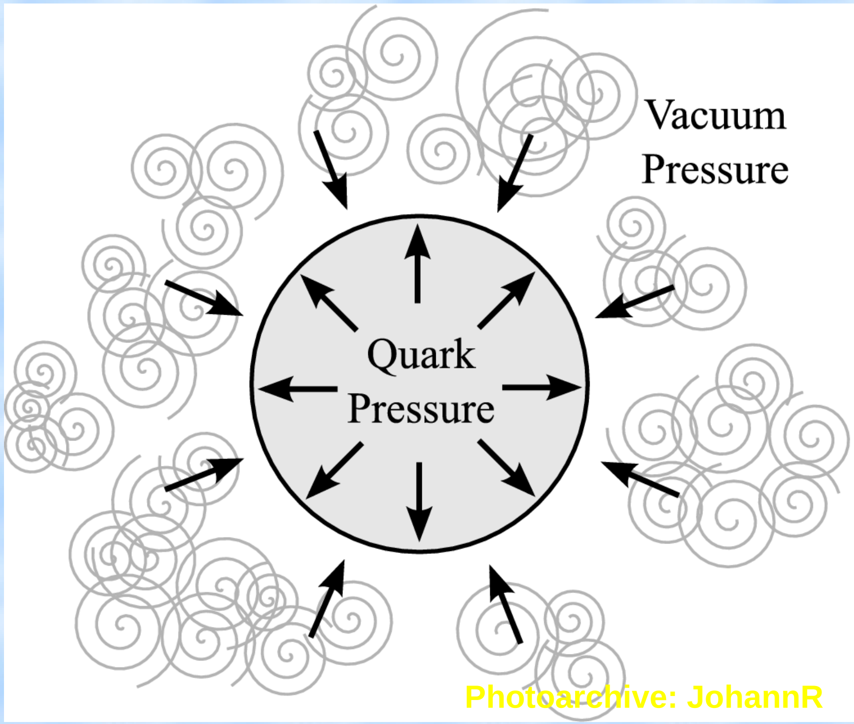
WIESBADEN, DEN 19. November 1979

DER HESSISCHE MINISTERPRÄSIDENT

Börner

Photoarchive: JohannR

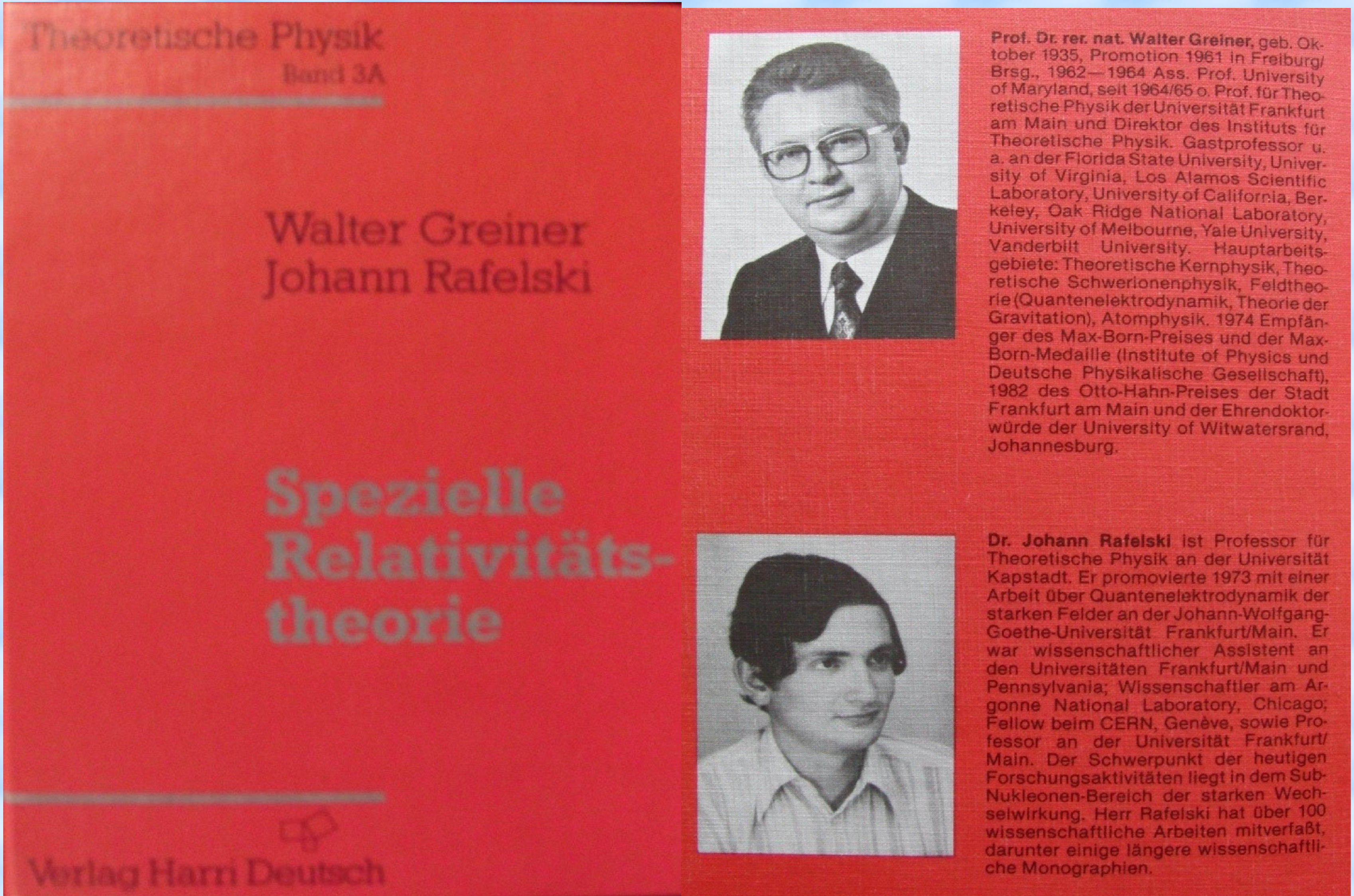
Vacuum structure model of quark confinement in hadrons: simulacrum of the charged vacuum in strong field



Quarks live inside a domain where the (perturbative) vacuum is without gluon fluctuations. This outside structure wants to enter, but is kept away by quarks trying to escape.

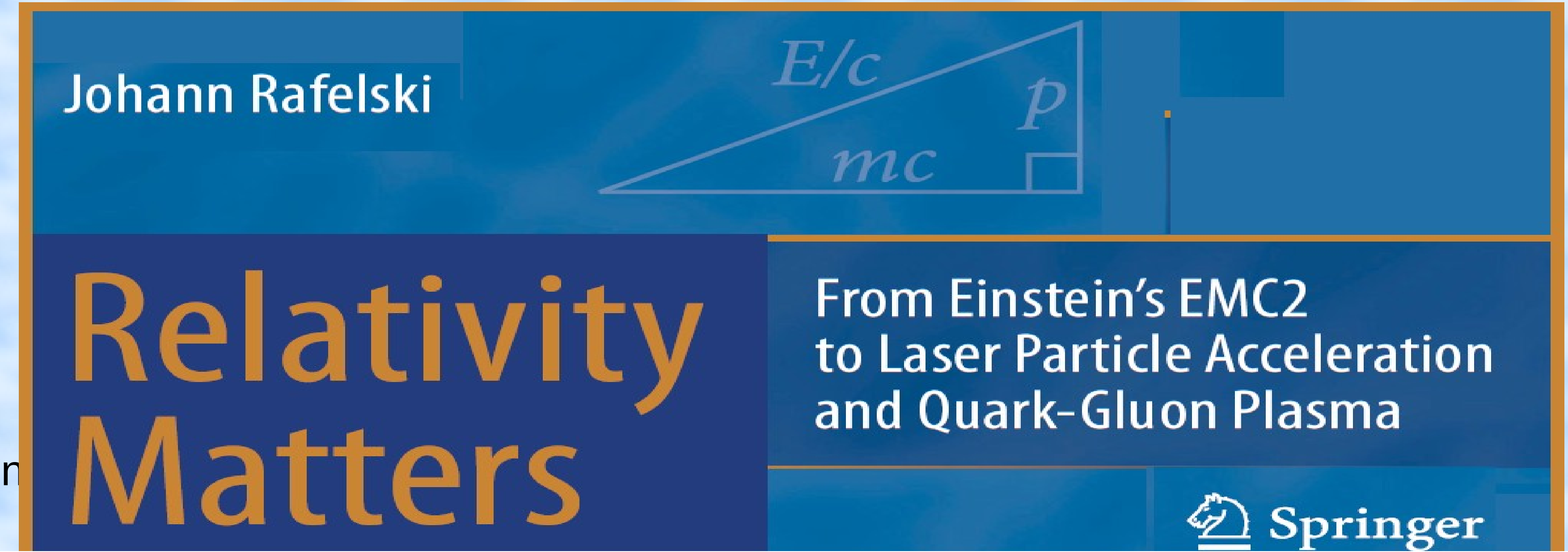
- The model assumes that the energy density E/V=0 of the true vacuum is lower than the inside of a hadron.

Book on Special Relativity 1982-2017

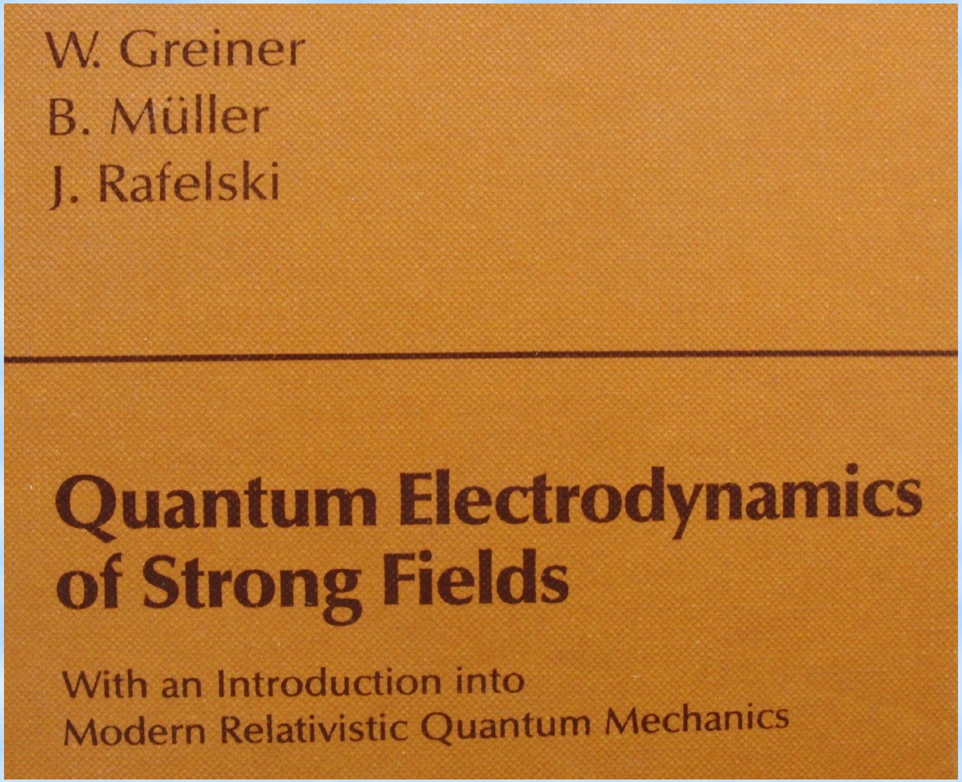


Relativity was both part of Strong Fields and QGP physics and very misunderstood back then and now

How did we write the book? I taught a class; Walter heavily edited my notes and made me invent examples and exercises so the class would be practical. Tradition continues.



Strong Field book followed 1983-86



This time we wrote independently three parts,
Berndt and Joachim R corrected my errors and omissions;
In Cape Town I was busy with finishing the big review on strangeness in QGP
(P.Koch, BM, JR)

QED of Strong Fields Book: 1986

W. Greiner B. Müller J. Rafelski

Quantum Electrodynamics of Strong Fields

With an Introduction into
Modern Relativistic Quantum Mechanics

With 258 Figures

Springer-Verlag
Berlin Heidelberg New York Tokyo

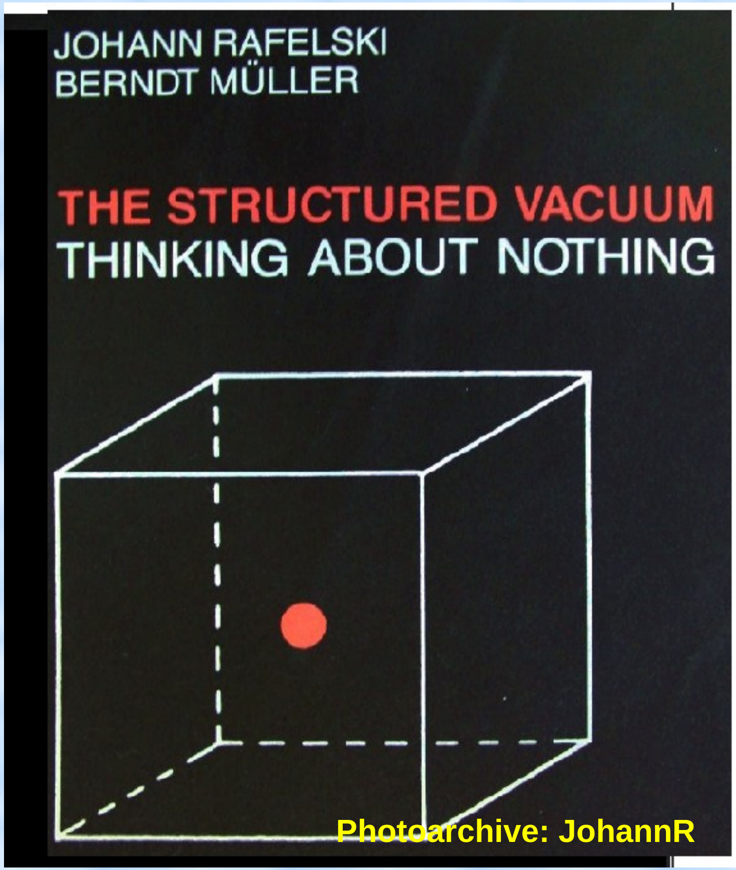
1. Introduction

The structure of the vacuum is one of the most important topics in modern theoretical physics. In the best understood field theory, Quantum Electrodynamics (QED), a transition from the neutral to a charged vacuum in the presence of strong external electromagnetic fields is predicted. This transition is signalled by the occurrence of spontaneous e^+e^- pair creation. The theoretical implications of this process as well as recent successful attempts to verify it experimentally using heavy ion collisions are discussed. A short account of the history of the vacuum concept is given. The role of the vacuum in various areas of physics, like gravitation theory and strong interaction physics is reviewed.

1.1 The Charged Vacuum

Our ability to calculate and predict the behaviour of charged particles in weak electromagnetic fields is primarily due to the relative smallness of the fine-structure constant $\alpha \approx 1/137$. However, physical situations exist in which the coupling constant becomes large, e.g. an atomic nucleus with Z protons can exercise a much stronger electromagnetic force on the surrounding electrons than could be described in perturbation theory, and hence it is foreseeable that the new expansion parameter $(Z\alpha)$ can quite easily be of the order of unity. In such cases non-perturbative methods have to be used to describe the resultant new phenomena, of which the most outstanding is the massive change of the ground-state structure, i.e. of the vacuum of quantum electrodynamics.

Another book followed 1984-85 with Berndt



JOHANN RAFELSKI
BERNDT MÜLLER

IL VACUUM STRUTTURATO
PENSANDO AL NULLA

Contenuti

Tradotto in Italiano da Riccardo Viola

English, German, Italian,..

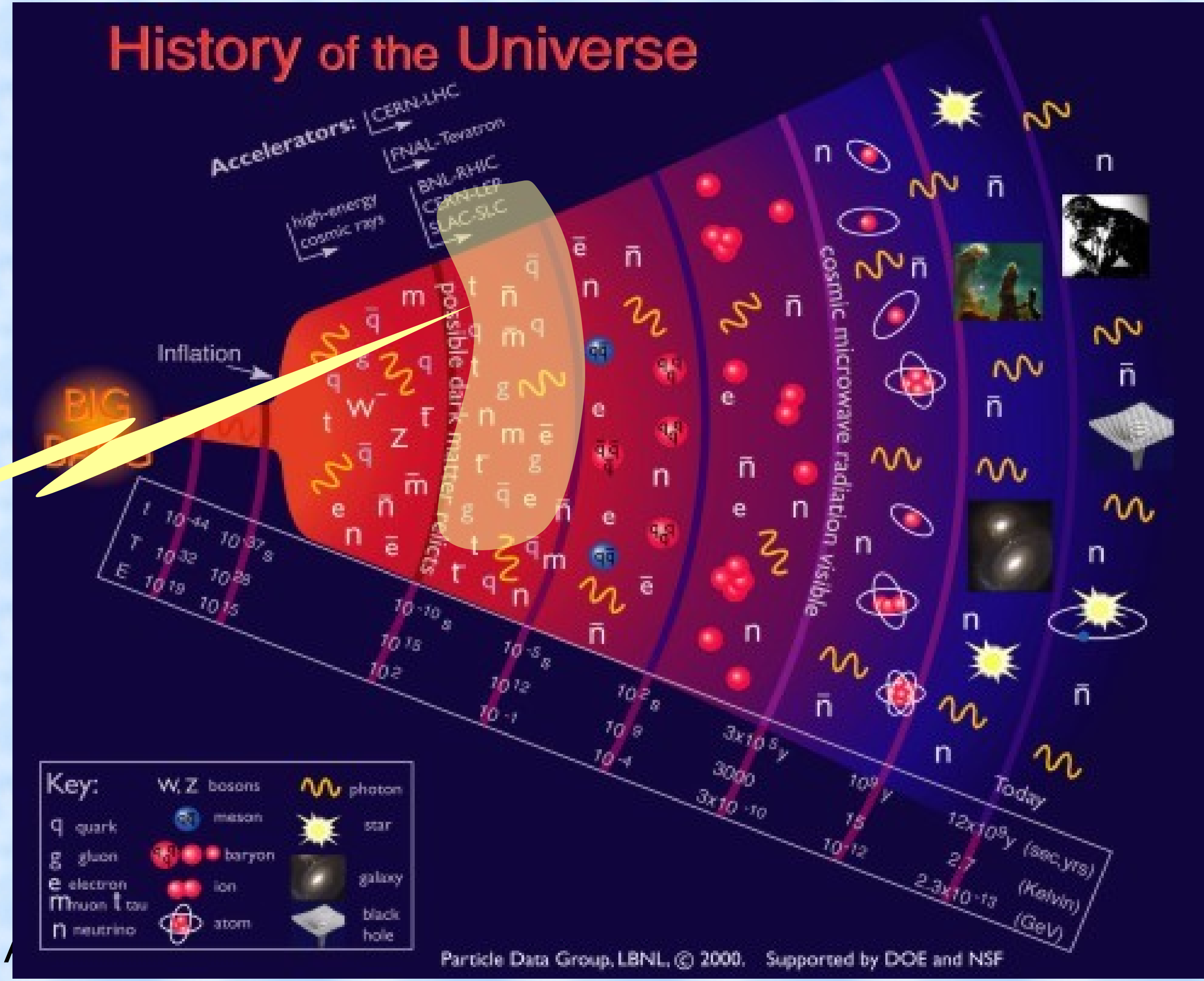
Jobs accomplished: Visby 1986

Next 30 years work to understand the first hour: picture for pedestrians.....

Matter emerges from quark-gluon plasma

After the Big-Bang the "vacuum" was different till about at 20 μs – expansion cooled the temperature T to a value near 150 MeV that is ~ $2\text{x}10^{12}$K at which point vacuum changed and our matter "froze out".

Most of other things blah-blah



Freeze-out of hadrons T=150 MeV (hadrochemistry) and after?

Radiation Dominated Era

Neutrinos freeze-out at T 1MeV.

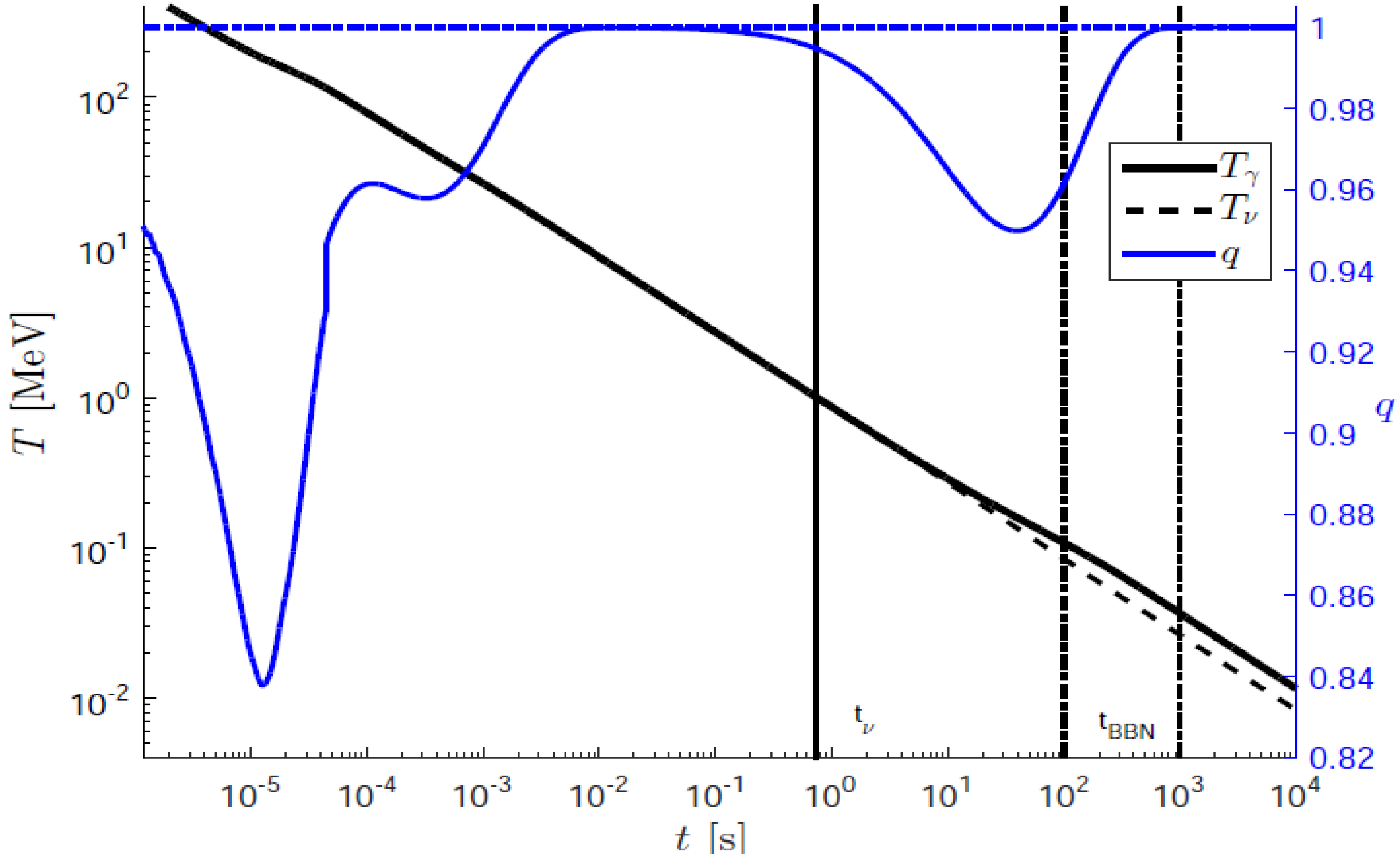
Energy density dominated by neutrinos, photons down through BBN (T = 40 -70keV) until T = O(1eV)

Dark energy and Matter Dominated Eras

Present day on left of plot: 69% dark energy, 26% dark matter, 5% baryons, < 1% photons and neutrinos.

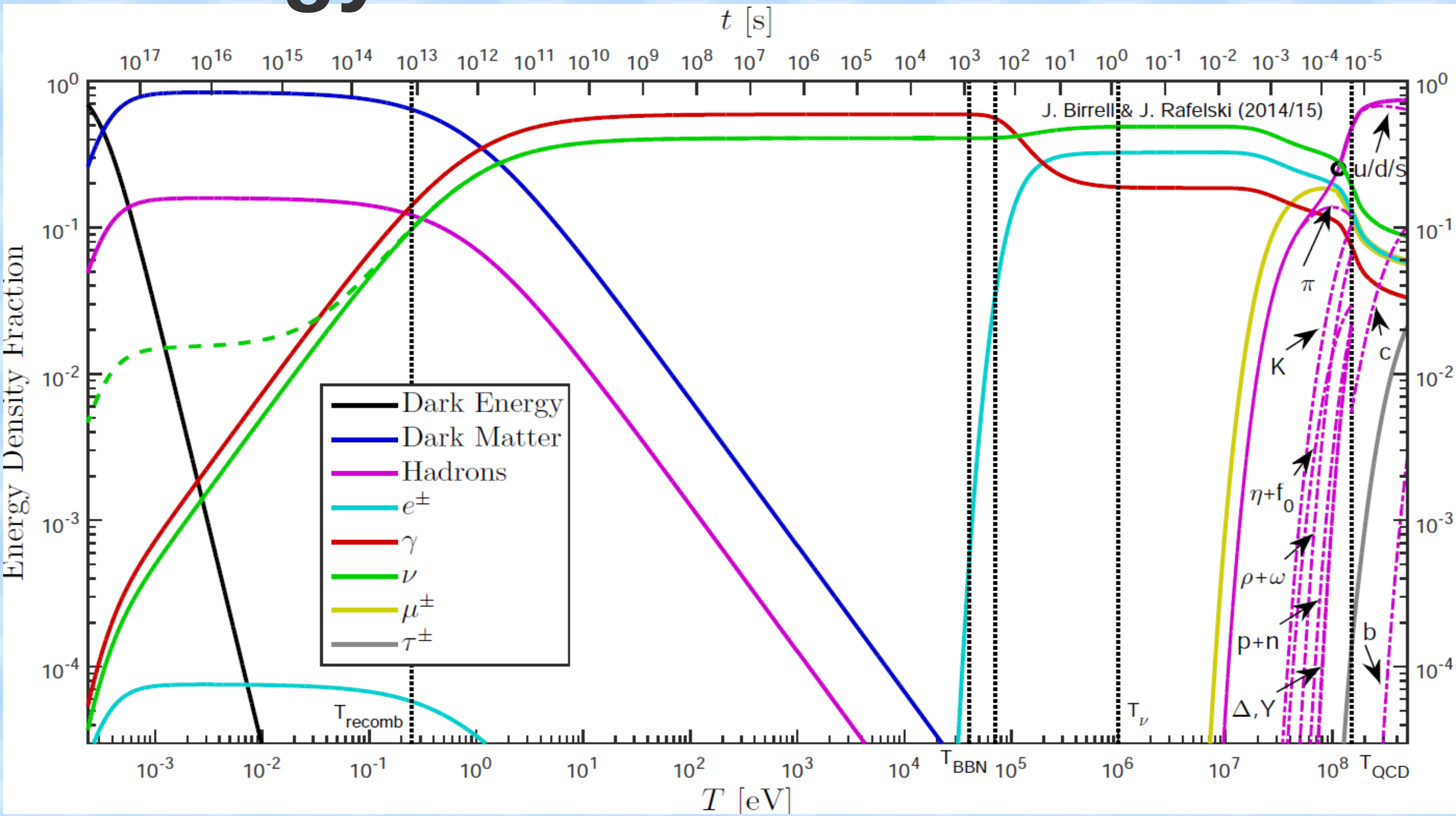
First vertical line on the left shows recombination at T 0:25eV.

For experts: The First Hour of the Universe

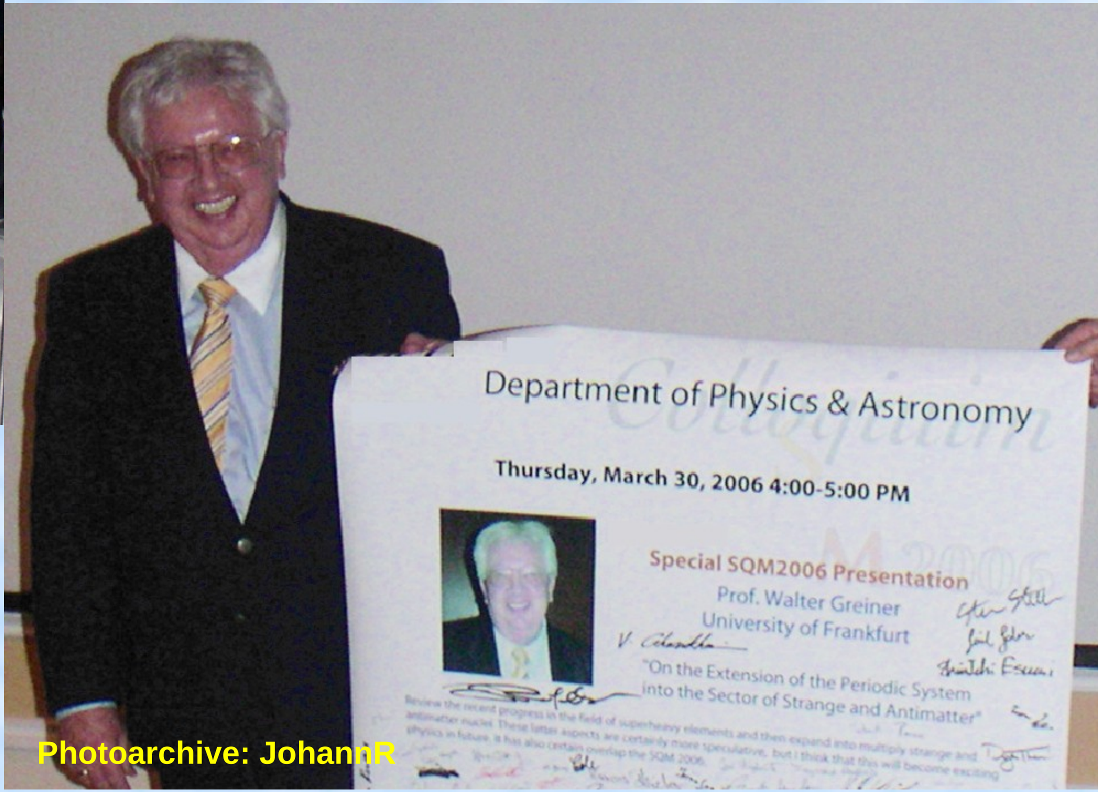


Evolution of temperature T and deceleration parameter q from QGP era until near BBN.

Energy evolution in Universe

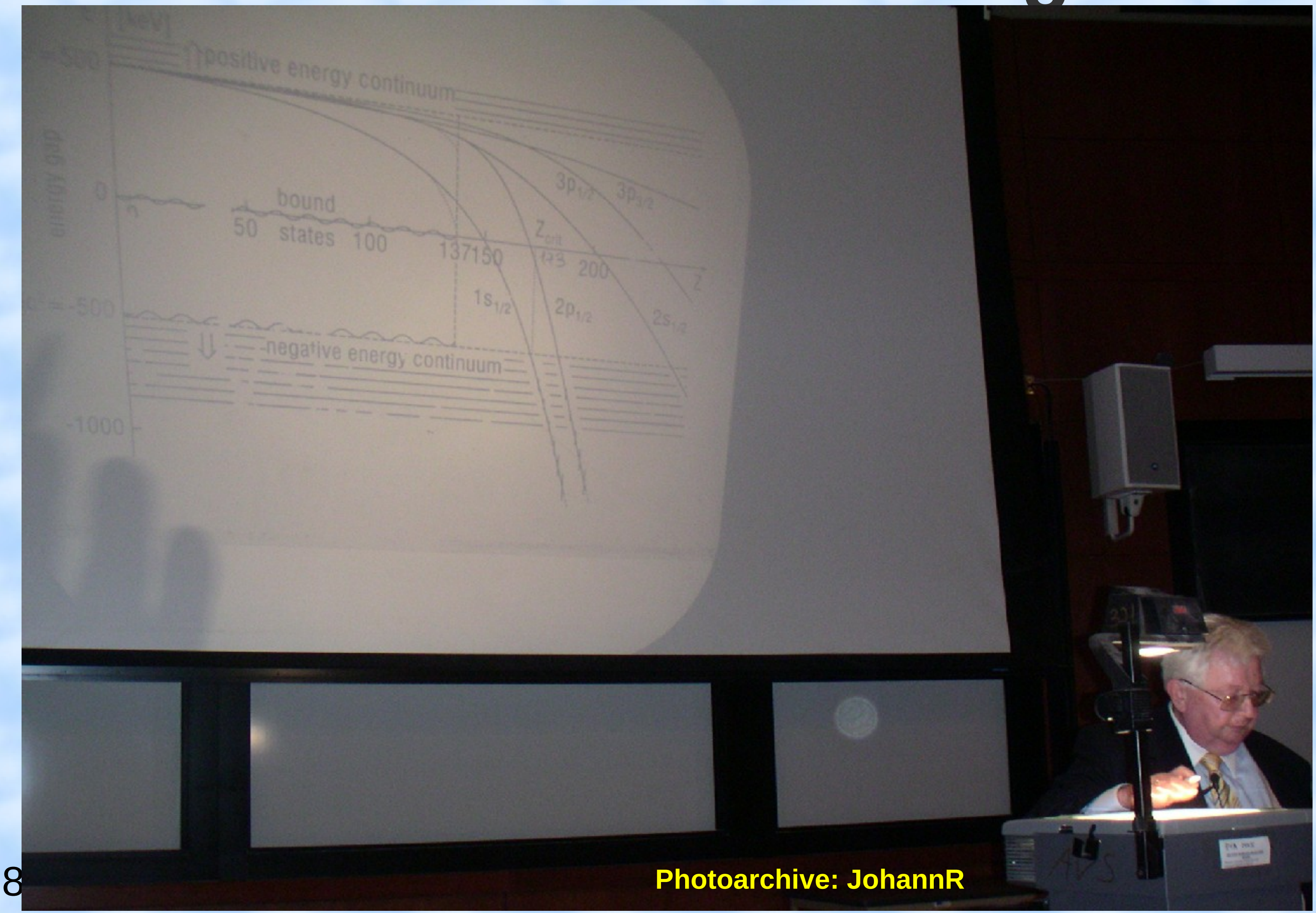


30 years after: 2006: Walter at SQM



Conclusions:

Walter is the man of strong fields



Photoarchive: JohannR