Introduction to strong field physics

A new Foundational Physics Frontier

Strong Fields - Acceleration

Johann Rafelski with Chris Grayson

- Aether=Structured quantum vacuum
- (Super)Critical Fields=Positron Production=Local Structured Vacuum
- Critical Fields=Critical Acceleration and Radiation-Reaction

Relativistic Aether= Structured quantum vacuum

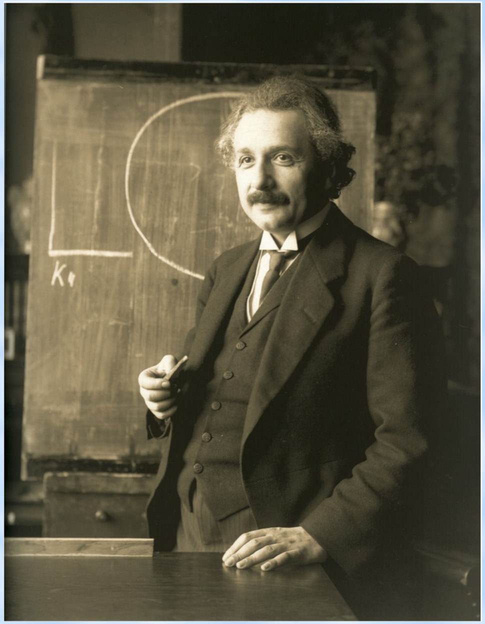
Like dark energy, this is something filling the Universe and compatible with the principle of relativity, the concept of velocity cannot be associated with it, parts cannot be tracked in time. For now!

Four elements and the aether

- The word aether in Homeric Greek means “pure, fresh air" or “clear sky", pure essence where the gods lived and which they breathed. The aether was believed in ancient and medieval science to be the substance that filled the region of the universe above the terrestrial sphere.

Fire:=energy; Air:=gas phase;
Water:=liquid phase; Earth:=solid phase; Aether=vacuum

How can the laws of physics be known in all Universe?



"Recapitulating, we may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an aether"

Albert Einstein, 1920

"According to the general theory of relativity space without aether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense."

"But this aether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it."

Albert Einstein, *Ather und die Relativitaetstheorie* (Berlin, 1920):

TODAY: The laws of physics are encoded in quantum vacuum structure

Inertia & Mach’s Principle

Ernst Mach
1838-1916

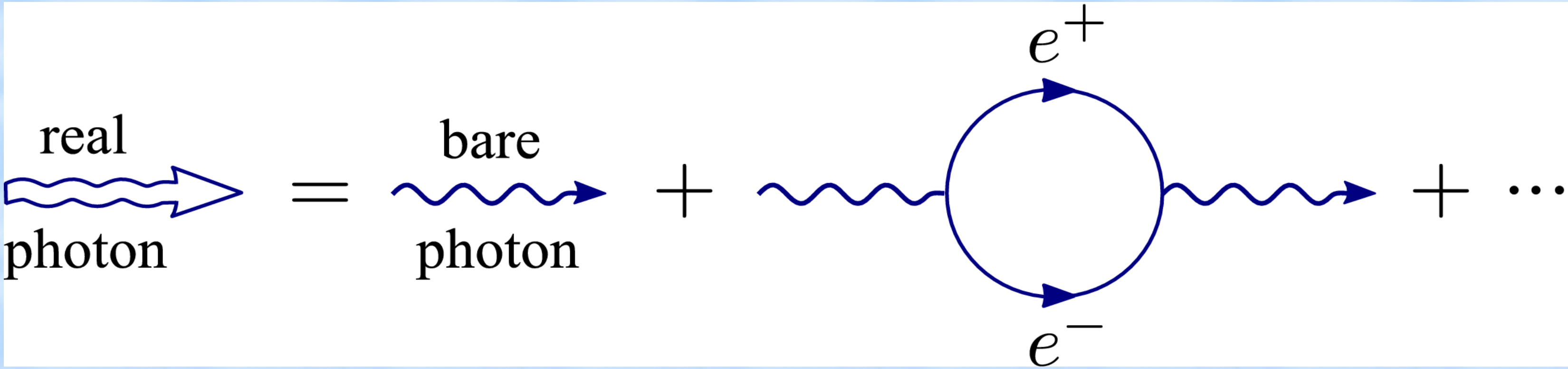
Measurement of **(strong)** accleration requires a Reference frame: what was once the set of fixed stars in the sky is today CMB photon freeze-out reference frame.
To be consistent with special relativity: all inertial observers with respect to CMB form an equivalence class,
we measure acceleration with reference to the CMB inertial frame.
It is rather clear that the information about who is accelerating must be provided locally.

... with the new theory of electrodynamics we are rather forced to have an aether. **– P.A.M. Dirac, ‘Is There an Aether?,’ *Nature*, v.168, 1951, p.906.**

In Einstein’s gravity reference frame provided by metric.
In Gravity Relativity there is no “acceleration”. GR alone is a theory of a dust of gravitating particles is in free fall.

Relativity enters the quantum world: Paul Dirac – memorial in St Maurice, VS

Virtual Pairs:
The quantum vacuum is a dielectric



The vacuum is a dielectric medium: a charge is screened by particle-hole (pair) excitations. In Feynman language the real photon is decomposed into a bare photon and a photon turning into a "virtual" pair. The result: renormalized electron charge smaller than bare, Observable Coulomb interaction stronger (0.4%) at distance 1/m

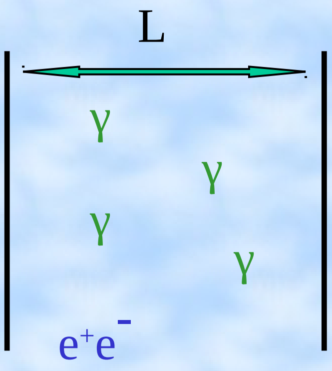
This effect has been studied in depth in atomic physics, is of particular relevance for exotic atoms where a heavy (muon) charged particle replaces an electron.

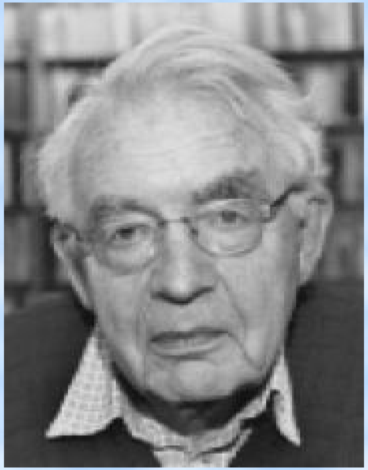
Matter influences quantum vacuum

Photons fluctuations altered by matter, Casimir effect can be measured:

Attractive force between two adjacent metal plates
(Casimir force, 1948)

$$F = \frac{\pi^2}{240} \frac{\hbar c}{L^4} A$$





Hendrik B.G. Casimir

More fluctuations outside the plates compared to the space between: outside pressure, plates attract

NOTE: Each ‘elementary’ particle, each interaction adds a new “fluctuation” to vacuum structure.

Origin of Forces and Nature of Mass, Stability of Matter

- “Elementary” masses are generated by the vacuum. Two dominant mechanisms:

- ➔ Higgs vacuum: $\langle H \rangle = h = 246$ GeV;
- ➔ $m_{higgs} = h/2$ (?); defines mass for W, Z; top, bottom, charm(?), contributes to lighter particle mass

- QCD vacuum latent heat at the level of $\langle EV_p \rangle = 0.3$ GeV =: nuclear mass scale, quarks get constituent mass and are confined. QCD vacuum structure provides +95% of mass of matter

$m_e c^2 = 0.511$MeV	$m_N c^2 = 0.940$GeV
(EM mass!)	(QCD mass)

Units are G=giga, M=mega e=electron charge, V=Volt, Supercritical fields in all space:

quantum vacuum instability

(Heisenberg-Euler, Schwinger)

Local strong fields:

Local change (particle prpduction) in the quantum structured Vacuum

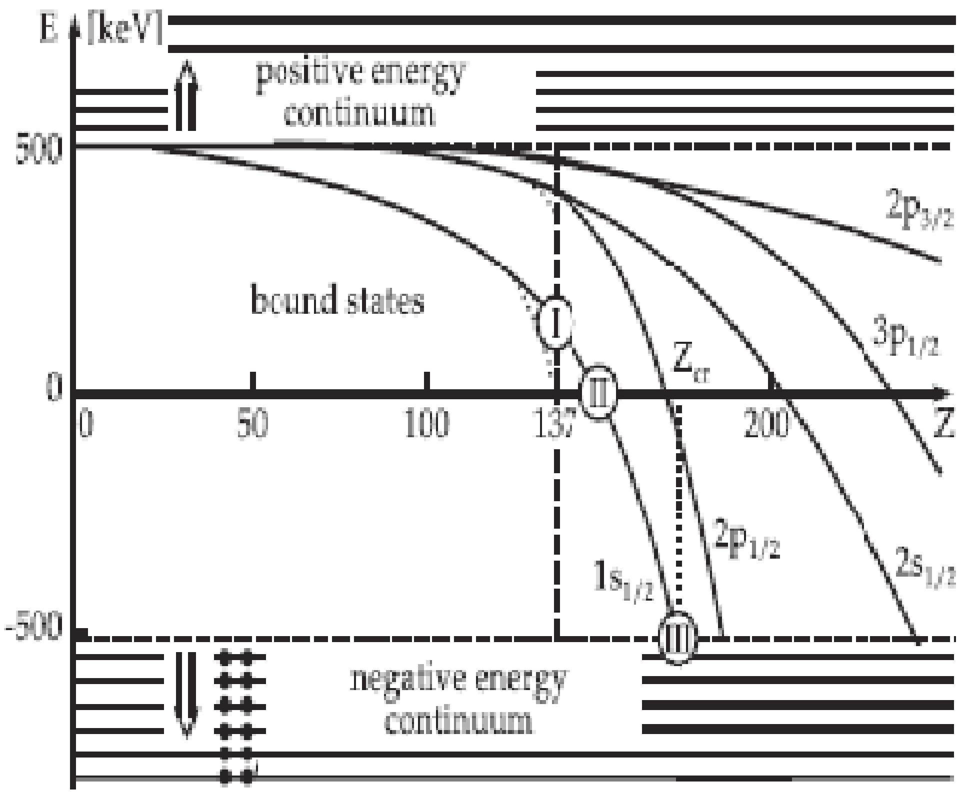
PRESET DAY PARADIGM CREATED

in Frankfurt 1970-80

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



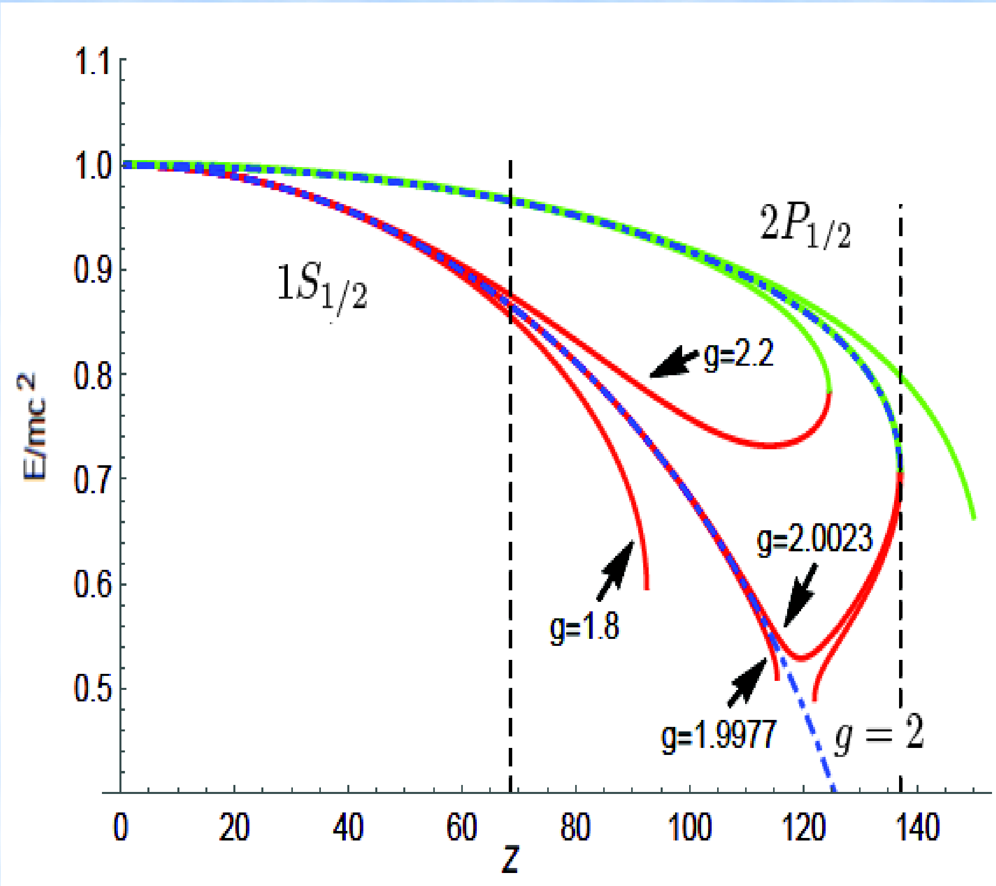
Single Particle Dirac Equation

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

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

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

Return to 1/r-Coulomb problem with gyromagnetic ratio as a variable: Eur.Phys.J. A55 (2019) no.3, 40



The energy levels of the KGP-Coulomb equation are

$$E_{\pm\lambda}^{n_r,j} = \frac{mc^2}{\sqrt{1+\dfrac{Z^2\alpha^2}{(n_r+1/2+\nu)^2}}}\,, \qquad \text{(a)}$$

$$\nu = \sqrt{(\lambda \pm 1/2)^2 + \left(\frac{g^2}{4}-1\right) Z^2\alpha^2}\,, \qquad \text{(b)}$$

$$\lambda = \sqrt{(j+1/2)^2 - \frac{g^2}{4} Z^2\alpha^2}\,. \qquad \text{(c)}$$

Using Eq. ($\boxed{\text{c}}$) in Eq. ($\boxed{\text{b}}$) we can also write

$$\nu = \sqrt{(j+1/2)^2 + (1/2)^2 - Z^2\alpha^2 \pm \lambda} \qquad \text{(d)}$$

This clarifies that eigenvalues Eq. ($\boxed{\text{a}}$) are analytic functions of the two independent couplings $Z\alpha$ and $gZ\alpha$ seen in the original form of the KGD equation, and, $gZ\alpha$ is now only appearing in λ.

2nd step: Walter's great invention

Embedding a super bound electron in positron continuum

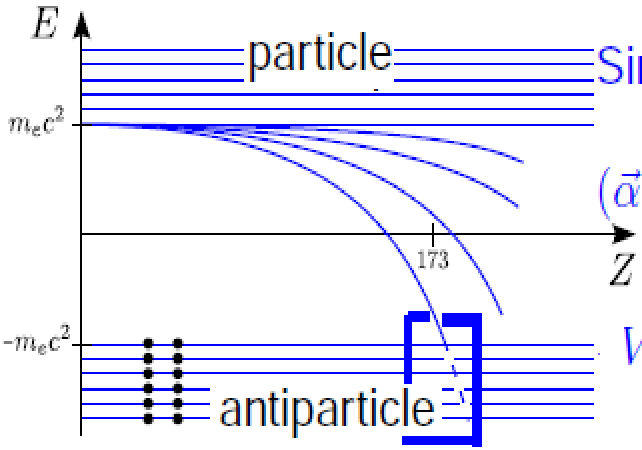
VOLUME 28, NUMBER 19 PHYSICAL REVIEW LETTERS 8 MAY 1972

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 $1s$ 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?



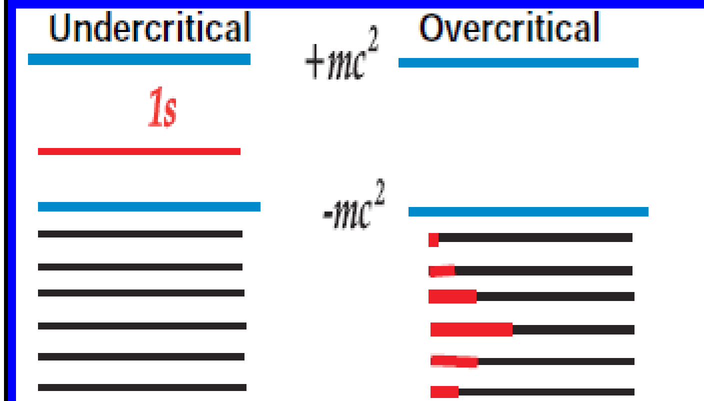
Supercritical fields

Single Particle Dirac Equation

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

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

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



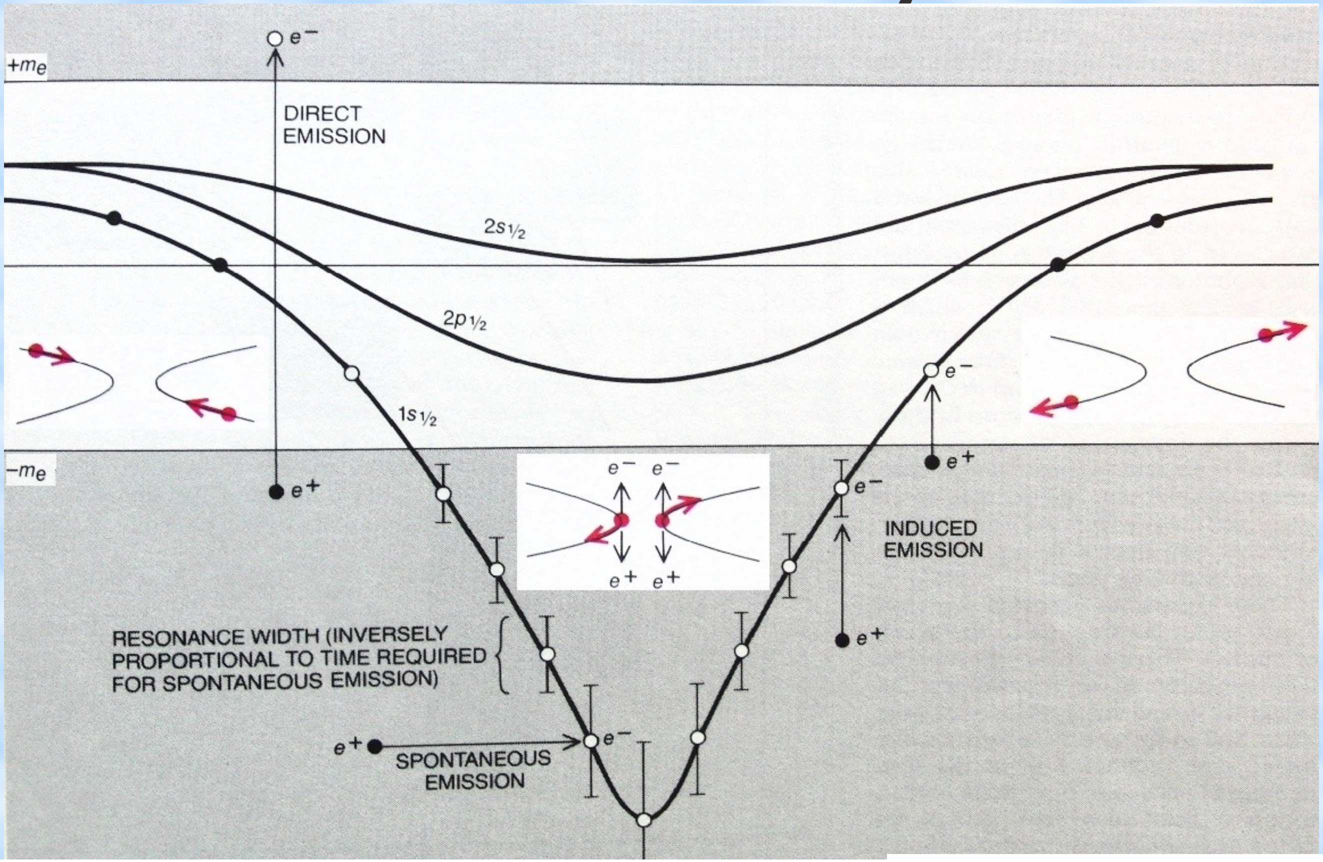
If diving state 'empty' vacuum decays

$|Q=0\rangle \rightarrow |Q=e\rangle + e^+$ 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. Step: Experimental Realization: Quasi-Molecules in Heavy Ion collision



Physica Scripta, Vol. 17, 417–419, 1978

Systematic Investigations of Binding Energies of Inner-Shell Electrons in Superheavy Quasimolecules

Gerhard Soff, Joachim Reinhardt and Wilfried Betz
Institut für Theoretische Physik der Johann Wolfgang Goethe Universität, 6000 Frankfurt am Main, W. Germany
Johann Rafelski
Gesellschaft für Schwerionenforschung (GSI), Darmstadt,
Received October 24, 1977; revised December 9, 1977

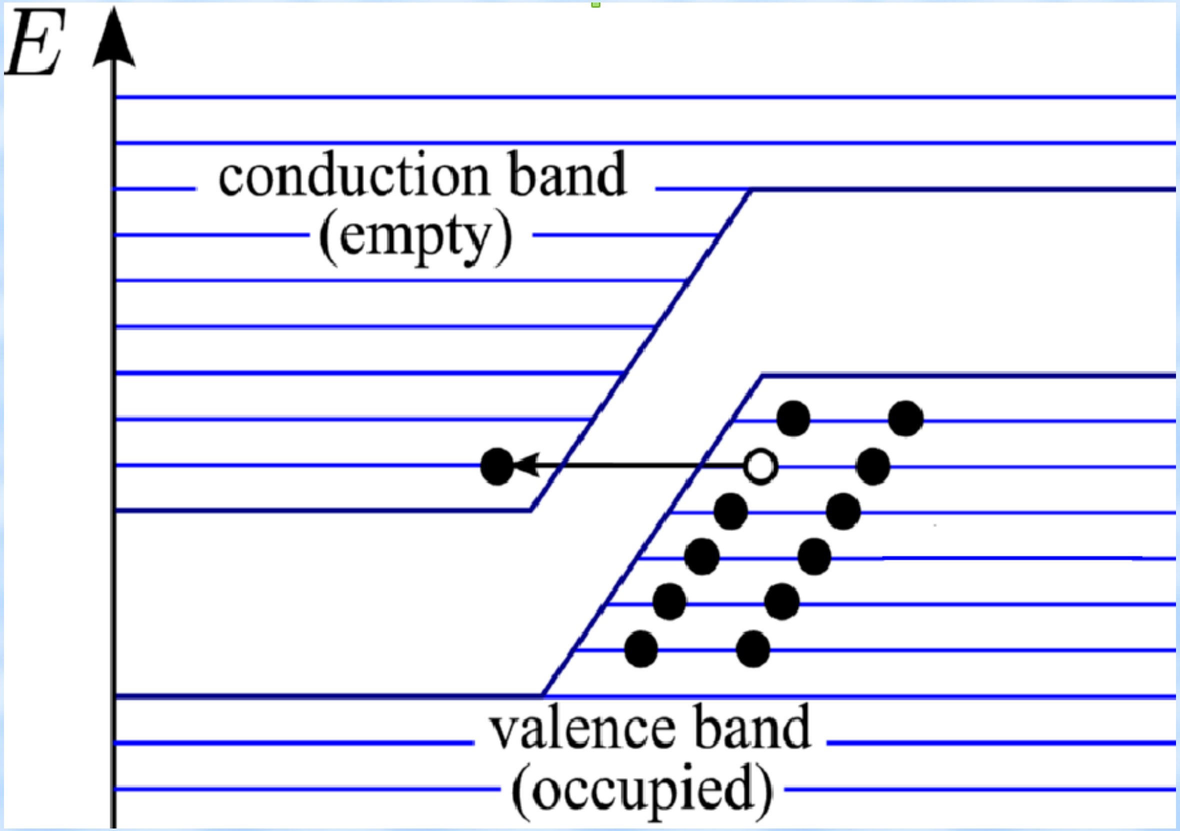
Electronic binding energies in superheavy quasimolecules are calculated using the monopole approximation, finite size and screening effects are included. The validity of the monopole approximation is discussed. A phenomenological description of the binding energy as a function of the total charge $(Z_1 + Z_2)$ and the two-center separation R is given. It is shown, that the $1s\sigma$-ionization rate does not depend on the projectile or target charge, but only on the total charge of the superheavy quasimolecule.

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
ricevuto il 30 Marzo 1972)

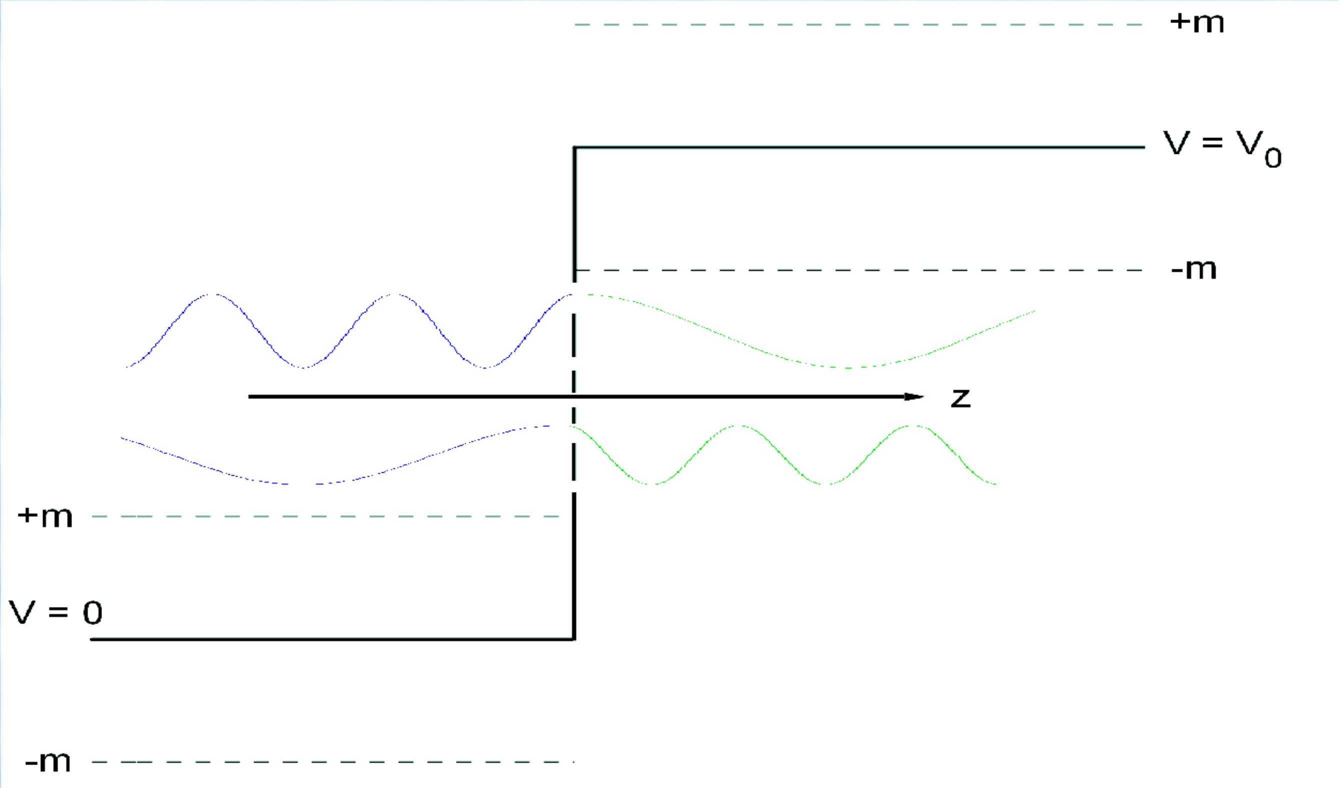
Tunneling pair production instability: Explanation of Klein's paradox



Relativistic Dirac quantum physics predicts antimatter and allows formation of pairs of particles and antiparticles.

The relativistic gap in energy reminiscent of insulators, where conductive band is above the valance (occupied) electron band

Klein's "Paradox": pair production in strong fields



The Dirac equation uses energy, mass and momentum of special relativity $\boldsymbol{E^2 = p^2c^2 + m^2c^4}$, taking root we find in quantum physics two energy (particle) bands. A potential mixes these states!

4th 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*

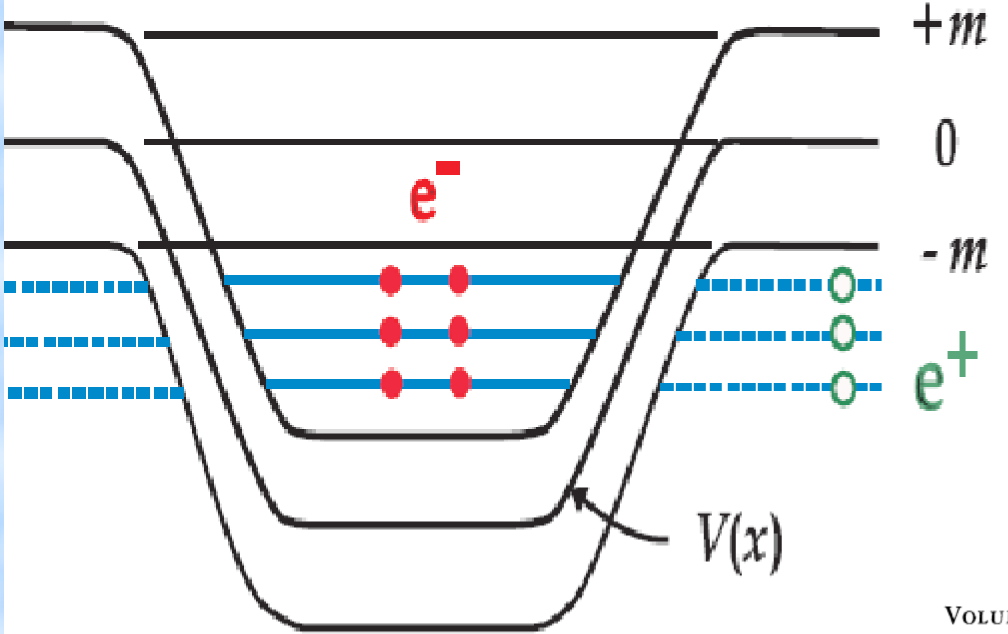
J. RAFELSKI, B. MÜLLER and W. GREINER
Institut für Theoretische Physik der Universität Frankfurt, Frankfurt am Main, Germany

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.

Stabilization of local vacuum state

Speed of decay of false vacuum controlled by (Heisenberg-Schwinger mechanism) E-field strength



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.

SCIENTIFIC AMERICAN
DECEMBER 1979
VOL. 241, NO. 6 PP. 150–159

The Decay of the Vacuum

by Lewis P. Fulcher, Johann Rafelski and Abraham Klein

Near a superheavy atomic nucleus empty space may become unstable, with the result that matter and antimatter can be created without any input of energy. The process might soon be observed experimentally

VOLUME 34, NUMBER 6 PHYSICAL REVIEW LETTERS 10 FEBRUARY 1975

Stabilization of the Charged Vacuum Created by Very Strong Electrical Fields in Nuclear Matter*

Berndt Müller and Johann Rafelski

(Received 2 December 1974)

The expectation value of electrical charge in charged vacuum is calculated utilizing the Thomas-Fermi model. We find almost complete screening of the nuclear charge. For any given nuclear density there is an upper bound for the electrical potential. For normal nuclear densities this value is − 250 MeV. This suggests that the vacuum is stable against spontaneous formation of heavy, charged particles.

5th Step "Accelerated" Vacuum

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

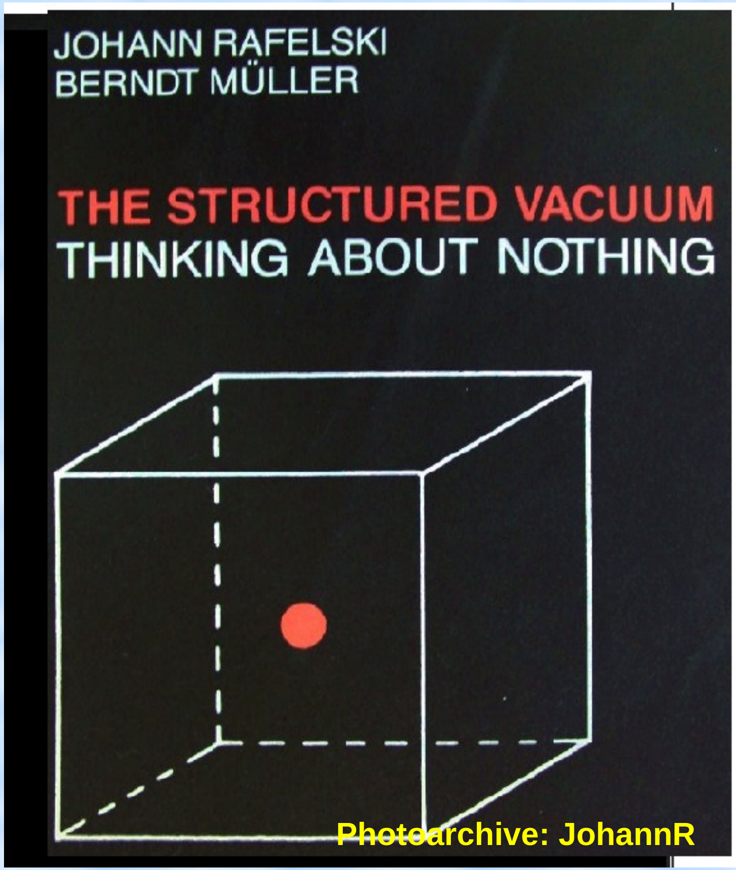
Johann RAFELSKI

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.

All of this and more in....



JOHANN RAFELSKI
BERNDT MÜLLER

IL VACUUM STRUTTURATO
PENSANDO AL NULLA

Contenuti

Tradotto in Italiano da Riccardo Viola

English, German, Italian,..

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

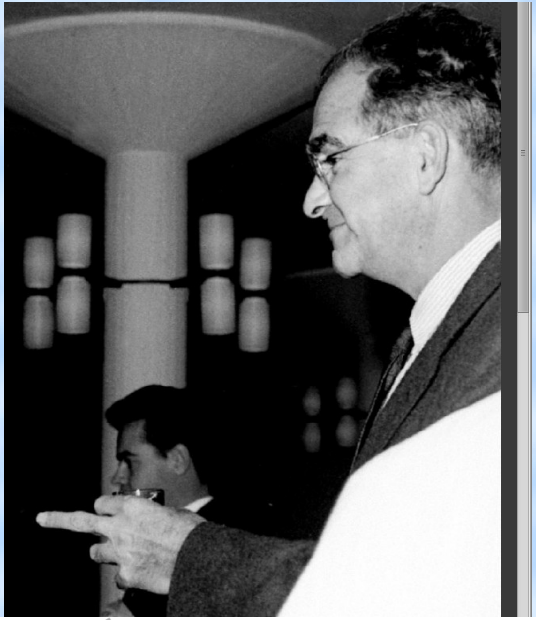
1. Introduction

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.

1974 first local vacuum structure model of quark confinement inside hadrons



New extended model of hadrons

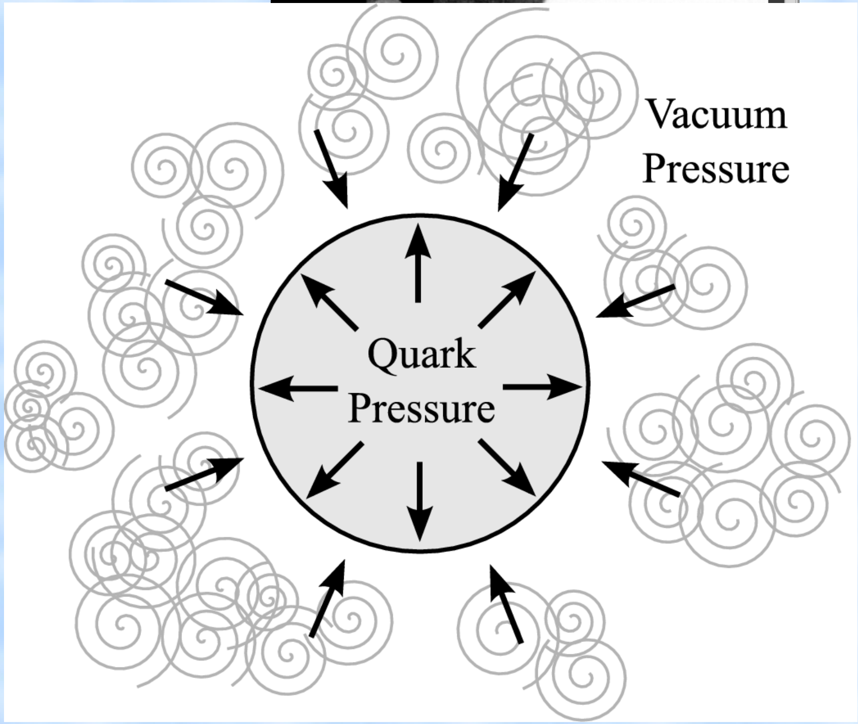
A. Chodos, R. L. Jaffe, K. Johnson, C. B. Thorn, and V. F. Weisskopf
Phys. Rev. D **9**, 3471 – Published 15 June 1974 Received 25 March 1974

DOI: https://doi.org/10.1103/PhysRevD.9.3471

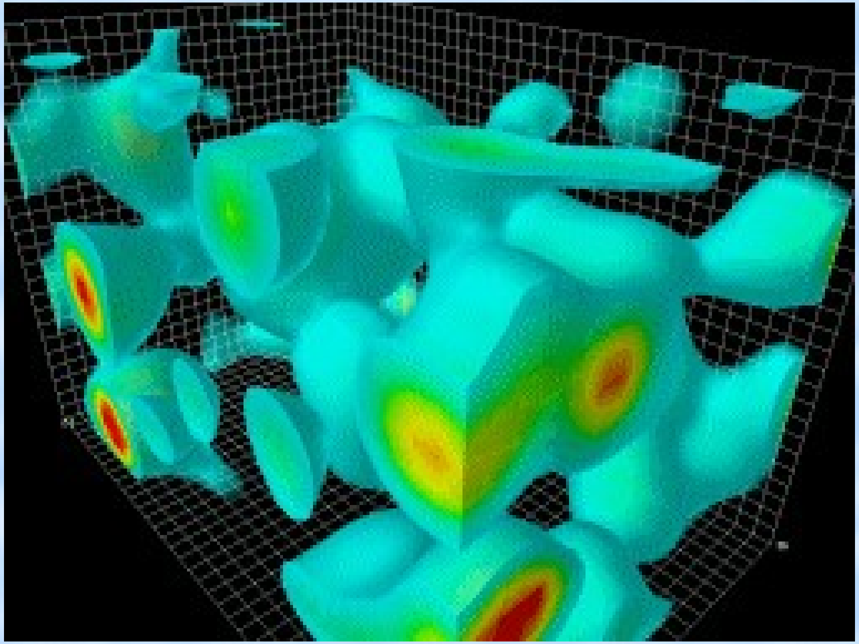
ABSTRACT

» endowing the finite region with a constant energy per unit volume »

- 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 that inside of a hadron.



Color confinement due to gluon fluctuations



- QCD induces chromo-electric and chromo-magnetic fields throughout space-time – the vacuum is in its lowest energy state, yet it is strongly structured. Fields must vanish exactly everywhere $\langle H \rangle = 0$
- This is an actual computation of the four-d (time +3-dimensions) structure of the gluon-field configuration. The volume of the box is 2.4 by 2.4 by 3.6 fm, big enough to hold a couple of protons.
- Derek B. Leinweber's group (U Adelaide)

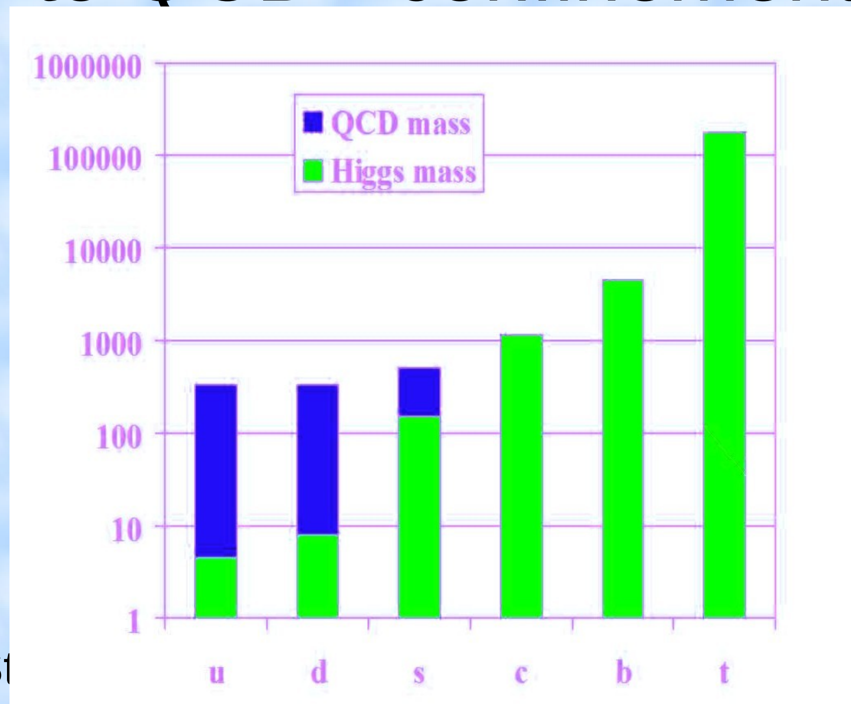
Numerical Method used: lattice in space time

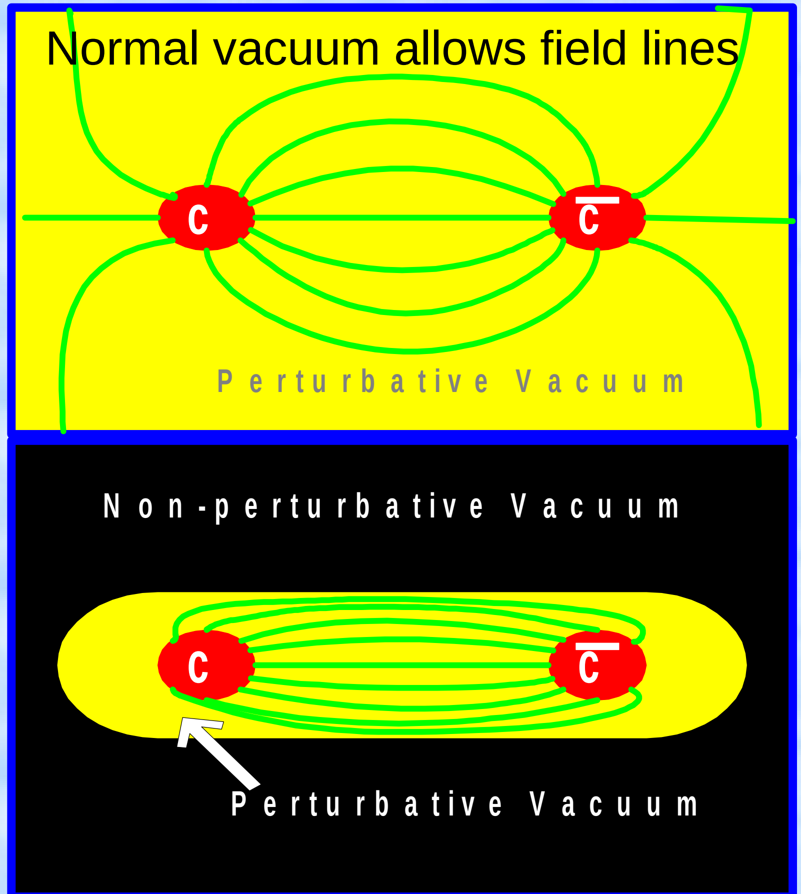
Square of fields does not average out: "condensates

$$\langle \bar{q}q \rangle = (235\ \mathrm{MeV})^3, \left\langle \frac{\alpha_s}{\pi} G_{\mu\nu} G^{\mu\nu} \right\rangle = (335\ \mathrm{MeV})^4$$

Quantum Chromo-Dynamics(QCD): Quark colour field lines confined

Most of the mass of visible matter is due to QCD - confinement





Return 30 years after:
Magnetic anomalies motivate

LHC RHI collisions with extreme B-fields

Magnetic stars (magnetars) with common extreme magnetic properties

Obtain classical and QM description of neutral particles with magnetic moment

Summary:

By 1973 we predicted local (charged) quantum vacuum structure.

This quantum vacuum feature extends the classical paradigm of Einstein's relativistic aether which can only change globally.

The idea of local vacuum change adapted to explain quark confinement as of about a year later.

Local strong field=strong force=strong acceleration= instability of the QED ground state given good foundational basis

Lienard Wiechert field of a moving charge

- Each point particle in the ion contributes a Lienard Wiechert field to the overall field.

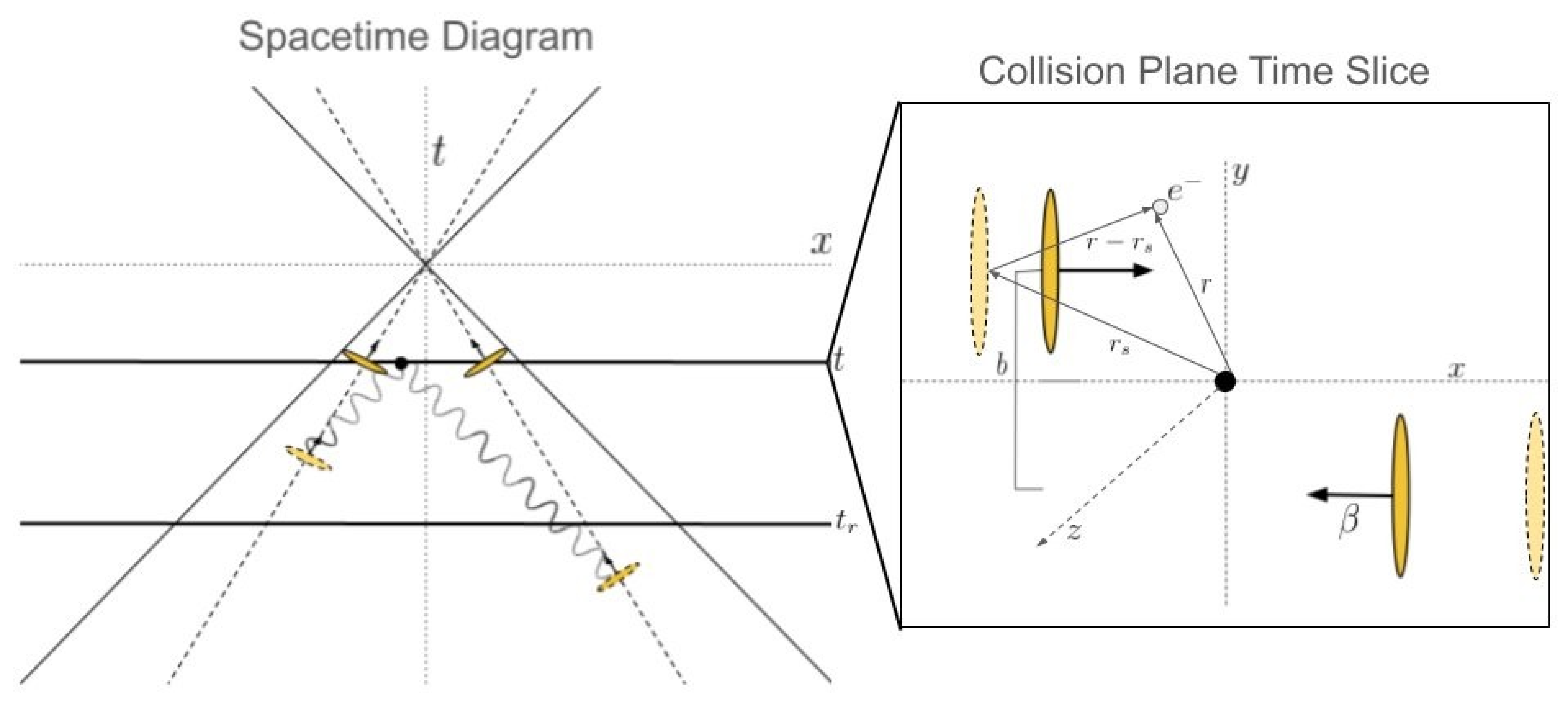
$$e\mathbf{E}(\mathbf{r},t) = Z\alpha\hbar c\left(\frac{(\mathbf{n}-\beta)}{\gamma^2(1-\mathbf{n}\cdot\beta)^3|\mathbf{r}-\mathbf{r}_s|^2} + \frac{\mathbf{n}\times((\mathbf{n}-\beta)\times\dot{\beta})}{c(1-\mathbf{n}\cdot\beta)^3|\mathbf{r}-\mathbf{r}_s|}\right)_{t_r}$$

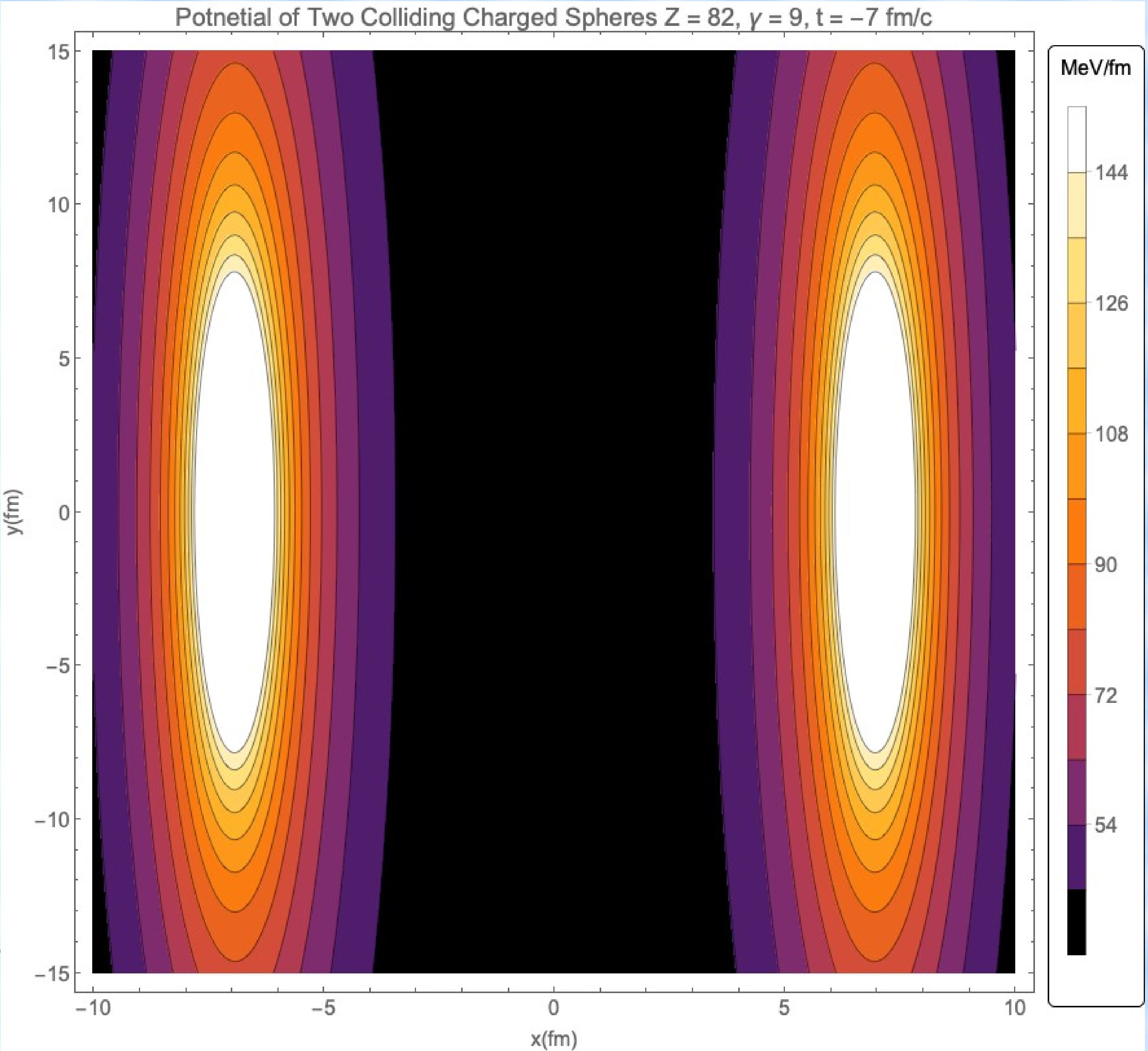
$$ec\mathbf{B}(\mathbf{r},t) = \frac{\mathbf{n}(t_r)}{c}\times\mathbf{E}(\mathbf{r},t)$$

Where, $t_r + \frac{1}{c}|\mathbf{r}-\mathbf{r_s}(t_r)| = t$

  - **Lienard-Wiechert field: Fields of an arbitrarily moving relativistic point particle derived by assuming a current density,**
  - **Often it is assumed that the ions travel in straight line motion, or that $\dot{\beta} = 0$ *which is not always a good argument to neglect* the acceleration term in the Lienard wiechert field**
  - **When acceleration is strong, radiation field dominated the velocity field and it radiates energy**

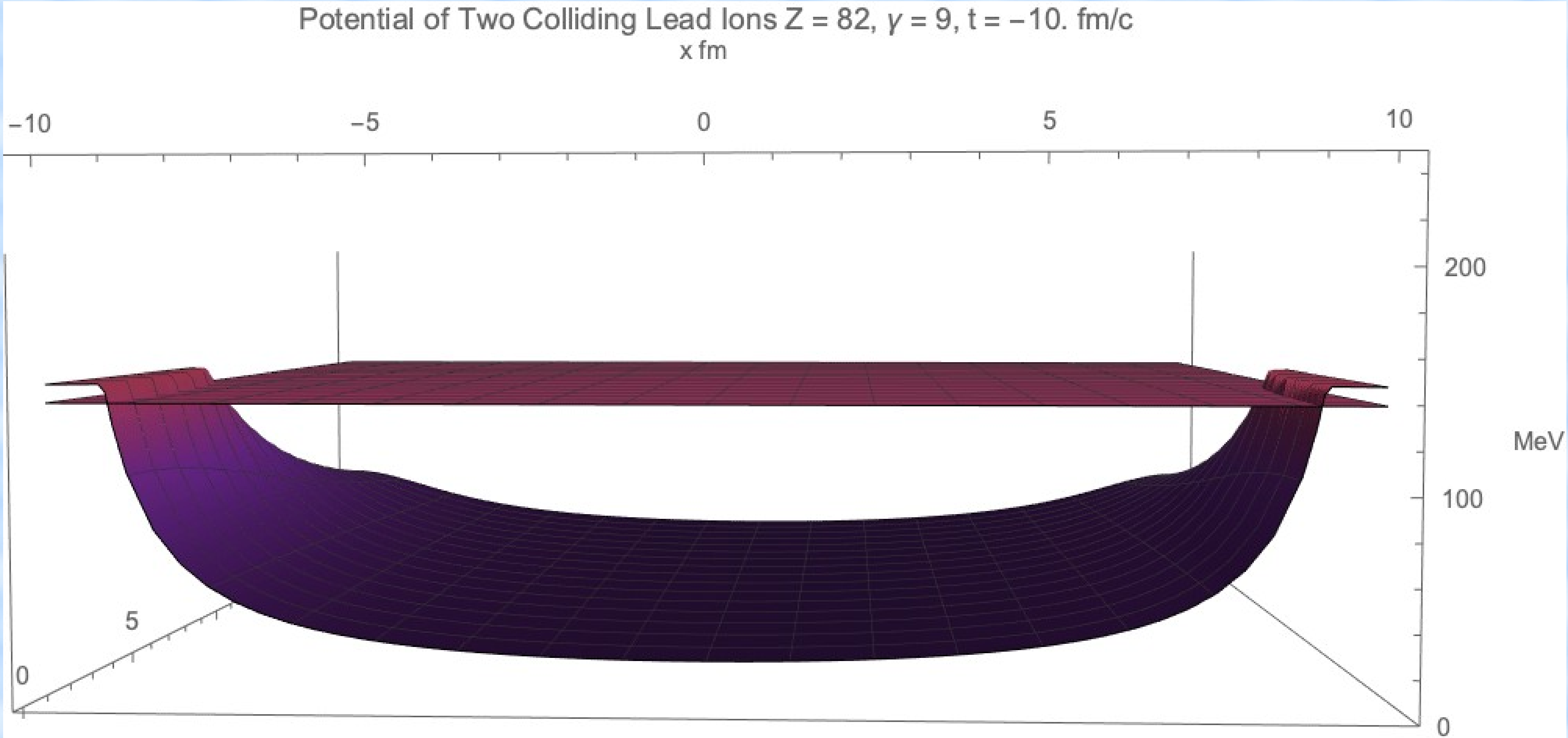
Retarded EM-Field in RHI collisions



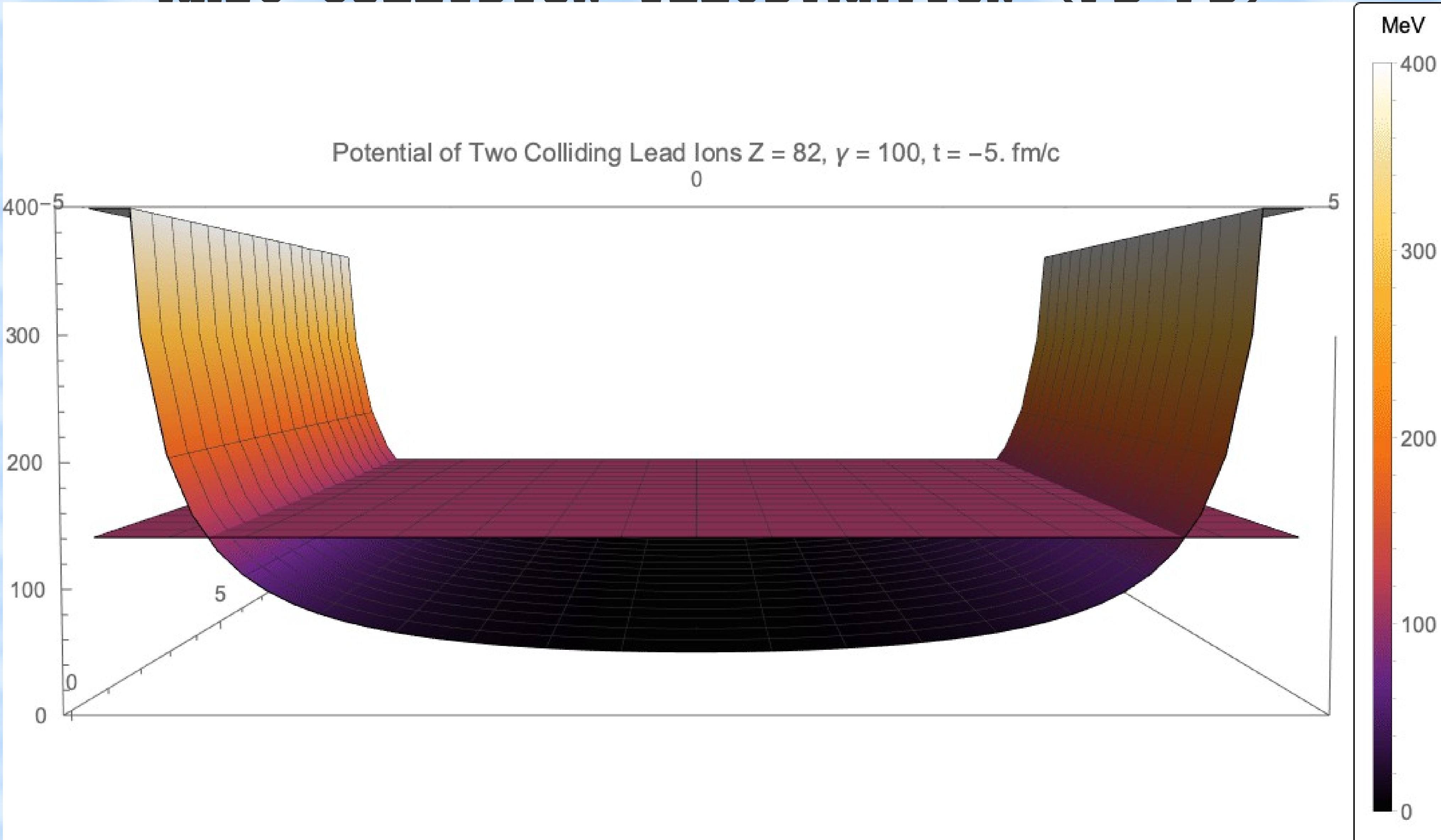

Potnetial of Two Colliding Charged Spheres Z = 82, γ = 9, t = −7 fm/c
y(fm)
15
10
5
0
−5
−10
−15
x(fm)
−10
−5
0
5
10
MeV/fm
144
126
108
90
72
54

Strong F

SPS collision illustration Pb-Pb



RHIC collision illustration (Pb-Pb)



Strong Field Unsolved Problem Radiation-Acceleration-Reaction

Conventional Lorentz-Electromagnetic force is incomplete: accelerated charged particles can radiate: “radiation friction” instability – some acceleration produces friction slowdown, produces more slowdown etc. Need acceleration that is not negligible to explore the physics of radiation friction. Problem known for 115 years.

Microscopic justification in current theory (LAD)

1) **Inertial Force = Lorentz-force with friction**- > get world line of particles=source of fields
2) **Source of Fields = Maxwell fields** - > get fields, and omit radiated fields
3) **Fields fix Lorentz force with friction -> go to 1**.

So long as the radiated fields are small, we can modify the Lorentz Force to account for radiated field back reaction. The “Lorentz-Abraham-Dirac (LAD)” patch is fundamentally inconsistent, and does not follow from an action principle. Many other patches exist, some modifying inertia, others field part of Lorentz force - it introduces a nonlinear and partially nonlocal Lorentz-type force. **No action principle is known**

Radiation-Acceleration Trouble

Conventional SR+Electromagnetic theory is incomplete: radiation emitted needs to be incorporated as a back-reaction “patch”:

1) **Inertial Force = Lorentz-force**-->get world line of particles=source of fields
2) **Source of Fields = Maxwell fields** --> get fields, and omit radiated fields
3) **Fields fix Lorentz force --> go to 1**.

So long as radiated fields are small, we can modify the Lorentz Force to account for radiated field back reaction approximately

458 29 Afterword: Acceleration

Table 29.1 Models of radiation reaction extensions of the Lorentz force

Maxwell-Lorentz	$\mathbf{m\dot u}^{\mu} = \mathbf{eF}^{\mu\nu}\mathbf{u}_{\nu}$
LAD[33]	$\mathbf{m\dot u}^{\mu} = \mathbf{eF}^{\mu\nu}\mathbf{u}_{\nu} + m\tau_0\left[g^{\mu\nu} - \frac{u^{\mu}u^{\nu}}{c^2}\right]\ddot u_{\nu}\,,\quad \tau_0 = \frac{2}{3}\frac{e^2}{4\pi\epsilon_0 m c^3}$
Landau-Lifshitz[35]	$\mathbf{m\dot u}^{\mu} = \mathbf{eF}^{\mu\nu}\mathbf{u}_{\nu} + e\tau_0\left\{u^{\gamma}\partial_{\gamma}F^{\mu\delta}u_{\delta} + \frac{e}{m}\left(g^{\mu\gamma} - \frac{u^{\mu}u^{\gamma}}{c^2}\right)F_{\gamma\beta}F^{\beta}_{\delta}u^{\delta}\right\}$
Caldirola[36]	$0 = \mathbf{eF}^{\mu\nu}(\tau)\mathbf{u}_{\nu}(\tau) - m\left[g^{\mu\nu} - \frac{u^{\mu}(\tau)u^{\nu}(\tau)}{c^2}\right]\frac{u_{\nu}(\tau) - u_{\nu}(\tau - 2\tau_0)}{2\tau_0}$

Critical Fields=

Critical Acceleration

An electron in presence of the critical 'Schwinger' (Vacuum Instability) field strength of magnitude:

$$E_s = \frac{m_e^2 c^3}{e\hbar} = 1.323 \times 10^{18} V/m$$

is subject to critical natural unit =1 acceleration:

$$a_c = \frac{m_e c^3}{\hbar} \to 2.331 \times 10^{29} \mathrm{m/s}^2$$

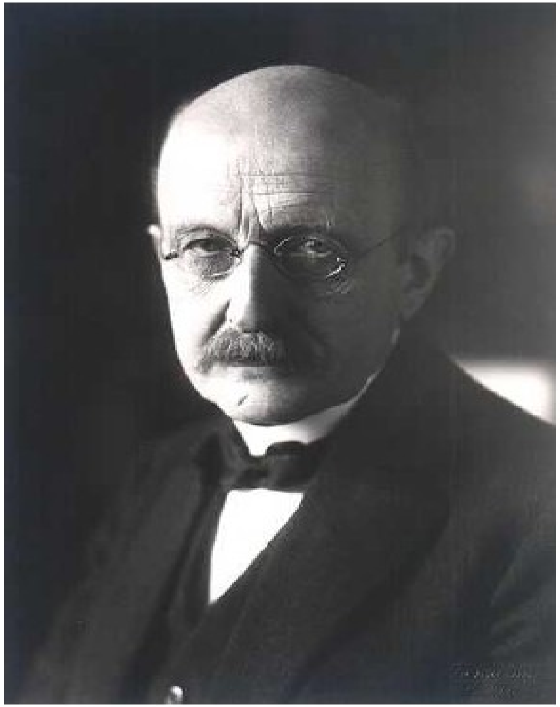
Truly dimensionless unit acceleration arises when we introduce specific acceleration

$$\aleph = \frac{a_c}{mc^2} = \frac{c}{\hbar}$$

Specific unit acceleration arises in Newton gravity at Planck length distance: $\aleph_G \equiv G/L_p^2 = c/\hbar$ at $L_p = \sqrt{\hbar G/c}$.

In the presence of sufficiently strong electric field E_s by virtue of the equivalence principle, electrons are subject to Planck 'critical' force.

Planck units



$$h/k_B = a = 0.4818 \cdot 10^{-10} [\text{sec} \times \text{Celsiusgrad}]$$
$$h = b = 6.885 \cdot 10^{-27} \left[\frac{\text{cm}^2\text{gr}}{\text{sec}}\right]$$
$$c = c = 3.00 \cdot 10^{10} \left[\frac{\text{cm}}{\text{sec}}\right]$$
$$G = f = 6.685 \cdot 10^{-8} \left[\frac{\text{cm}^3}{\text{gr. sec}^2}\right]^1.$$

Wählt man nun die »natürlichen Einheiten« so, dass in dem neuen Maasssystem jede der vorstehenden vier Constanten den Werth 1 annimmt, so erhält man als Einheit der Länge die Grösse:

$$\sqrt{2\pi}\, L_{Pl} = \sqrt{\frac{bf}{c^3}} = 4.13 \cdot 10^{-33} \text{cm}, \mapsto \sqrt{2\pi}\, 1.62 \times 10^{-33}\ \text{cm}$$

als Einheit der Masse:

$$\sqrt{2\pi}\, M_{Pl} = \sqrt{\frac{bc}{f}} = 5.56 \cdot 10^{-5} \text{gr}, \mapsto \sqrt{2\pi}\, 2.18 \times 10^{-5}\ \text{g}$$

als Einheit der Zeit:

$$\sqrt{2\pi}\, t_{Pl} = \sqrt{\frac{bf}{c^5}} = 1.38 \cdot 10^{-43} \text{sec}, \mapsto \sqrt{2\pi}\, 5.40 \times 10^{-44}\ \text{s}$$

als Einheit der Temperatur:

$$\sqrt{2\pi}\, T_{Pl} = a\sqrt{\frac{c^5}{bf}} = 3.50 \cdot 10^{32}\,{}^\circ \text{Cels.} \mapsto \sqrt{2\pi}\, 1.42 \times 10^{32}\ \text{K}$$

Diese Grössen behalten ihre natürliche Bedeutung so lange bei, als die Gesetze der Gravitation, der Lichtfortpflanzung im Vacuum und die beiden Hauptsätze der Wärmetheorie in Gültigkeit bleiben, sie müssen also, von den verschiedensten Intelligenzen nach den verschiedensten Methoden gemessen, sich immer wieder als die nämlichen ergeben.

"These scales retain their natural meaning as long as the law of gravitation, the velocity of light in vacuum and the central equations of thermodynamics remain valid, and therefore they must always arise, among different intelligences employing different means of measuring." *M. Planck, "Über irreversible Strahlungsvorgänge." Sitzungsberichte der Königlich Preußischen Akademie der Wissenschaften zu Berlin* **5**, *440-480 (1899), (last page)*

Insight:

To resolve inconsistencies: we need to formulate a NEW "large accelaration" theory of electro-magnetism, comprising Mach's principle, and challenging understanding of inertia.

THEORY Question: How to achieve that charged particles when accelerated radiate in self-consistent field – and we need EM theory with Mach principle accounted for (gravity, quantum physics=zero acceleration theories)!

EXPERIMENT: strong acceleration required. What is strong: unit acceleration=Heisenberg-Schwinger Field

Is there a limit to how fast we can accelerate (electrons, heavy ions) to ultra high energy? Example of early Model: Born-Infeld electromagnetism