XII Polish Workshop on Relativistic Heavy-Ion Collisions

From Instabilities to Fluctuations

Institute of Physics, Jan Kochanowski University

Kielce, November 4-6, 2016

Decelerating Partons: Accelerating Science with SM

Jan Rafelski

Department of Physics, University of Arizona, Tucson, AZ

SPONSORED by Springer, November 5, 2016

Celebrating of Stanisław Mrówczynski contributions to the study of quark-gluon plasma phase of matter, on occasion of his 60th birthday.

First things First: Springer Publishers

The Organizers and especially the Speaker thank Springer Publishers for their kind support and the interesting publicity material; as Wojtek believes participants can carry away on first-come first-served basis what they need to remember topics such as “Hagedorn”, “NICA”, “Strangeness”. I am missing: “Fluctuations and correlations”! With a due deference to APP-B, Someone should notice, if you want to publish, Springer is the place (I am betting my book that this is true!)

Springer Publishers, 2017, ca 500

Relativity Matters
From Einstein's EMC2 to
Laser Particle Acceleration and Quark-Gluon Plasma
With Exercises, Examples and Discussions
Johann Rafelski November 1, 2016

Dedicated to the memory of my academic teacher
Prof. Dr. Dr. h. c. mult. Walter Greiner
(29 October 1935 – 5 October 2016)

29.1 Can there be acceleration in SR?
29.2 Evidence for acceleration
29.3 Strong acceleration

pages

The dedication: Picture taken 30 years ago, Visby, Sweden

. . . to the memory of my academic teacher, Prof. Dr. Dr. h.c. mult. Walter Greiner (October 1935-October 2016)

Many ideas what to speak about

Long before first relativistic CERN-SPS heavy ion collision experiments we have seen models of what may happen to colliding nuclei, with theorists arguing different extreme scenarios: parton transparency, and parton stopping. Similarly we argued about the related mechanism of entropy formation. Today 30 years have passed and these questions continue to be discussed with the same fervor. What this means is that we lack in understanding of how it happens that we generate a fireball of hot and dense parton matter where many had expected two "cooked" nuclei to emerge. Across several science frontiers of the SM I see that the process of Bremsstrahlung and radiation reaction that was invoked by SM remains an interesting functional simple idea which may help characterize parton deceleration and fireball formation.

1. Why am I speaking?

28 years of Friendship

THE UNIVERSITY OF ARIZONA
TUCSON
OFFICE OF THE PRESIDENT

NOTICE OF APPOINTMENT

Dr. Stanislaw Mrowczynski
% Physics
University of Arizona
CAMPUS

October 13, 1988
(Date)

Your appointment has been approved as

Visiting Scientist in Physics (year-to-year)

for the fiscal year 1988-89, effective October 1, 1988

at an annual salary rate of $31,100. Your appointment is dependent on the availability of funds from a source other than state appropriations, and is subject to termination if the non-state funds are not available

A picture to remember: Hadrons in Collision, Tucson 1988 - A first meeting with Heavy Ion Data

who can spot in this picture a few people with us here today?

And a publication

PHYSICAL REVIEW C VOLUME 40, NUMBER 2 AUGUST 1989

Parton bremsstrahlung as a mechanism of energy deposition in high-energy hadron-nucleus and nucleus-nucleus collisions

Stanisław Mrówczyński* and Johann Rafelski
Department of Physics, University of Arizona, Tucson, Arizona 85721
(Received 1 March 1989)

On the basis of perturbative quantum chromodynamics, we consider the bremsstrahlung energy losses of partons traversing *parton matter* using the well-known quantum electrodynamical formulas. We find the transport equation describing the energy distribution of partons as a function of thickness of a target. The equation is solved numerically and we briefly discuss the relevance of our results for hadron-nucleus and nucleus-nucleus collisions at high energies.

The mechanism of energy deposition in soft hadronic collisions at high energy is not well understood at present.

And habilitation

Stanisław Mrówczyński
Institute for Nuclear Studies
ul. Hoża 69
PL - 00-681 WARSZAWA
Poland

9 listopada 1990 rok

Professor
Johann Rafelski
Department of Physics
University of Arizona
TUCSON, ARIZONA 85721
U S A

Drogi Janku,

Od sierpnia jestem z powrotem w Warszawie, na stałe i właśnie przygotowuję habilitację zatytułowaną *Metody teorii transportu w fizyce plazmy kwarkowo-gluonowej*.

Zgodnie z tym o czym mówiliśmy w Menton bardzo bym chciał przyjechać do Ciebie do Tucson na miesiąc lub dwa. Ponieważ chciałbym ten wyjazd połączyć z uczestnictwem w konferencji Quark Matter'91, najbardziej by mi odpowiadała wczesna jesień - wrzesień, październik.

Department of Physics
College of Arts & Sciences
Faculty of Science

ARIZONA
TUCSON ARIZONA

1118 E. 4th Street
Tucson, Arizona 85721
(602) 621-6820

November 29, 1990

Prof. J. Wdowczyka
Przewodniczacy Rady Naukowej
Institute of Nuclear Studies
Swierk-Otwock

REF: Habilitation of Dr. S. Mrowczynski

Dear Prof. Wdowczyka:
I would like to confirm to you that Dr. S. Mrowczynski contributed in most essential and decisive way in the research that lead to our joint publication entitled "Parton bremsstrahlung as a mechanism of energy deposition in high-energy hadron-nucleus and nucleus-nucleus collisions" (Phys. Rev. C40 (1989) 1077).

Yours Sincerely

Johann Rafelski
Professor of Physics

2. What is the matter with stopping?

PHYSICAL REVIEW D VOLUME 22, NUMBER 11 1 DECEMBER 1980

Central collisions between heavy nuclei at extremely high energies: The fragmentation region

R. Anishetty*
Physics Department, University of Washington, Seattle, Washington 98195

P. Koehler and L. McLerran†
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

(Received 11 August 1980)

We discuss central collisions between heavy nuclei of equal baryon number at extremely high energies. We make a crude estimation of the energy deposited in the fragmentation regions of the nuclei. We argue that the fragmentation-region fragments thermalize, and two hot fireballs are formed. These fireballs would have rapidities close to the rapidities of the original nuclei. We discuss the possible formation of hot, dense quark plasmas in the fireballs.

The collisions of very-high-energy nuclei are likely to be the subject of intense experimental investigation in the next few years.

We shall discuss the theory of such collisions in this paper. We shall concentrate on describing central collisions between nuclei of equal baryon number.

The fragmentation regions of the nuclei represent an area of phase space where new phenomena might occur. "Fragmentation region" refers to the region of phase space of particles where the particles have longitudinal momentum close to that of the original nucleus projectile or target. In the fragmentation region, the nucleus fragments and inelastically produced particles might form a hot, dense fireball. We shall soon see that this forma-

Volume 97B, number 1 PHYSICS LETTERS 17 November 1980

HOT HADRONIC MATTER AND NUCLEAR COLLISIONS ☆

R. HAGEDORN
CERN, Geneva, Switzerland

and

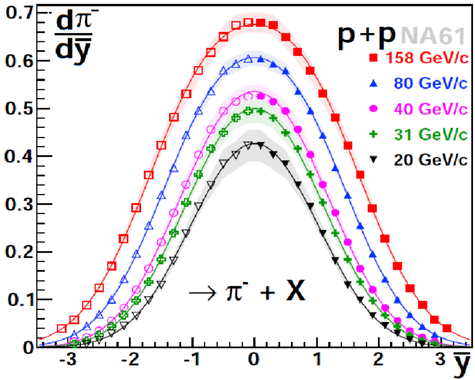
J. RAFELSKI [1]
CERN, Geneva, Switzerland
and Institut für Theoretische Physik der Universität, D-6000 Frankfurt a/M, Fed. Rep. Germany

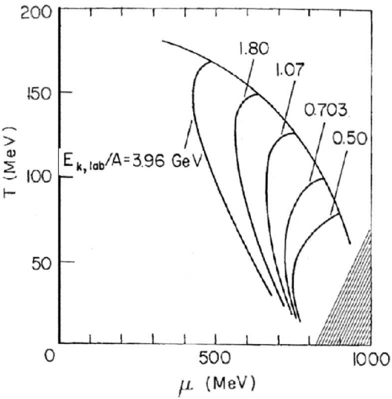
Received 22 August 1980

we develop a description of hadronic matter with particular emphasis on hot nuclear matter as created in relativistic heavy ion collisions. We apply our theory to calculate temperatures and of hadronic fireballs.

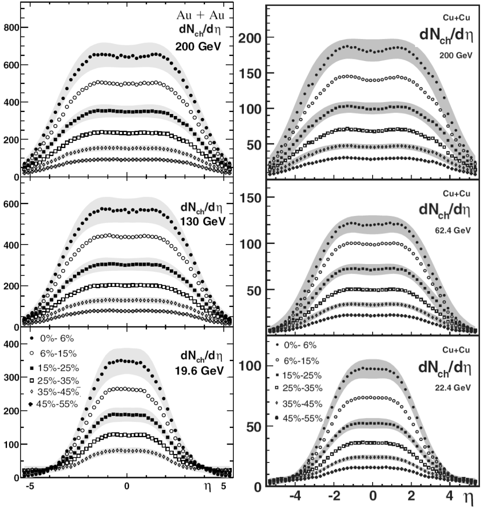
Two opposite views: SPIRES 253 and 221 citations today.

Two views of full stopping (Fig 2a HR reflected)





“Fragmentation” stopping experiment (no part. ID)



3. Parton transport model stopping and QGP

Michael Danos and JR develop idea that fluctuations and instability in pile-up of partons create a high density seed that grows. Publication impossible in 1982-1987. Written in some reviews and long paper published after Danos passed away in memorial volume.

APH N.S., Heavy Ion Physics **14** (2001) 97–120

HEAVY ION PHYSICS
©Akadémiai Kiadó

Baryon-Rich Quark–Gluon Plasma in Nuclear Collisions[a]

Michael Danos[1,b,c] and Johann Rafelski[2,d]

[1] National Bureau of Standards, Washington, D.C. 20234, USA

[2] Institute of Theoretical Physics and Astrophysics, Department of Physics University of Cape Town, Rondebosch 7700, Cape, South Africa

Received 12 November 2000

Abstract. The maximum achievable temperature (energy density) and minimum kinetic energy required for the formation of a baryon-rich quark–gluon plasma formed at central rapidity in small impact parameter nuclear collisions is estimated. A possible mechanism leading to the pile-up of matter is introduced. Plasma formation is expected to appear at about 15 GeV/Nucleon uranium beam energy on a stationary target or 2.7 GeV/Nucleon in colliding beams.

Notes

a. This manuscript has never been published. It was widely circulated was University of Cape Town preprint UCT-TP 7/84 in November 1984. It comprises material of an earlier shorter manuscript by M. Danos and J. Rafelski, *Formation of quark-gluon plasma at central rapidity*, a Frankfurt University preprint UFTP-82/94, (December 1982), 10pp. In order to preserve the historic accuracy only corrections of a few equation typos seen in UCT-TP 7/84, and update of footnotes and references, were made.

b. Deceased, August 30, 1999, see: http://physics.arizona.edu/~rafelski/MDOB.htm

c. Visiting Scientist, Institute of Theoretical Physics and Astrophysics, University of Cape Town, Rondebosch 7700, Cape, South Africa.

d. Permanent address since 1987: Department of Physics, University of Arizona, Tucson, AZ 85721, E-mail: Rafelski@Physics.Arizona.EDU

This backdrop leads on to SM and JR collaboration

PHYSICAL REVIEW C VOLUME 40, NUMBER 2 AUGUST 1989

Parton bremsstrahlung as a mechanism of energy deposition in high-energy hadron-nucleus and nucleus-nucleus collisions

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Physics Letters B 269 (1991) 383–388
North-Holland

PHYSICS LETTERS B

Energy loss of a high-energy parton in the quark–gluon plasma

Stanisław Mrówczyński [1]
High-Energy Department, Soltan Institute for Nuclear Studies, ul. Hoża 69, PL-00 681 Warsaw, Poland

A screen-shot from the book soon in print

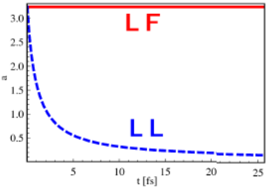


Figure 29-5: Electron invariant acceleration $a = \sqrt{-a_\mu a^\mu}$ in natural units of critical acceleration, see Eq. (22.5), is shown as a function of time measured in fs (10^{-15}s) for the case of an electron with an initial energy E_e=511 MeV, *i.e.* $\gamma = 1000$ hitting a circular polarized laser plane wave with amplitude $a_0 = 100$ and wavelength $\lambda = 942\,\mathrm{nm}$. The solid red line is for electron motion subject to the LF (Lorentz force) case, while the dashed (blue) line gives the deceleration according to the LL (Landau-Lifshitz force). Adopted from Ref. [31].

Table 29-1: Models of radiation-reaction extensions of the Lorentz force.

Maxwell-Lorentz	$m\dot{u}^\mu = \mathbf{e}\mathbf{F}^{\mu\nu}\mathbf{u}_\nu$
LAD[35]	$m\dot{u}^\mu = \mathbf{e}\mathbf{F}^{\mu\nu}\mathbf{u}_\nu + m\tau_0\left[g^{\mu\nu} - \frac{u^\mu u^\nu}{c^2}\right]\ddot{u}_\nu\ ,\ \tau_0 = \frac{2}{3}\frac{e^2}{4\pi\epsilon_0 mc^3}$
Landau-Lifshitz[37]	$m\dot{u}^\mu = \mathbf{e}\mathbf{F}^{\mu\nu}\mathbf{u}_\nu + e\tau_0\left\{u^\gamma\partial_\gamma F^{\mu\delta}u_\delta + \frac{e}{m}\left(g^{\mu\gamma} - \frac{u^\mu u^\gamma}{c^2}\right)F_{\gamma\beta}F^\beta{}_\delta u^\delta\right\}$
Caldirola[38]	$0 = \mathbf{e}\mathbf{F}^{\mu\nu}(\tau)\,\mathbf{u}_\nu(\tau) - m\left[g^{\mu\nu} - \frac{u^\mu(\tau)u^\nu(\tau)}{c^2}\right]\frac{u_\nu(\tau) - u_\nu(\tau - 2\tau_0)}{2\tau_0}$

29.7 Caldirola radiation recation model

The radiation-reaction force is obtained under the assumption of radiation emission by a locally accelerated particle. Since the radiation-reaction force in-

Runaway stopping instability cause of QGP formation

Work with Staś on radiation of partons triggers my interest in radiation-reaction (RR) which I understand today: for the case of a charged particle stopped by EM wave the more you radiate, the more you apply "radiation breaks", the more you radiate again. A phenomenal runaway effect. Acceleration frontier unites HI and EM-Strong Field Physics. I will describe that story in Warsaw on Monday. All welcome!

Wydział Fizyki Uniwersytetu Warszawskiego

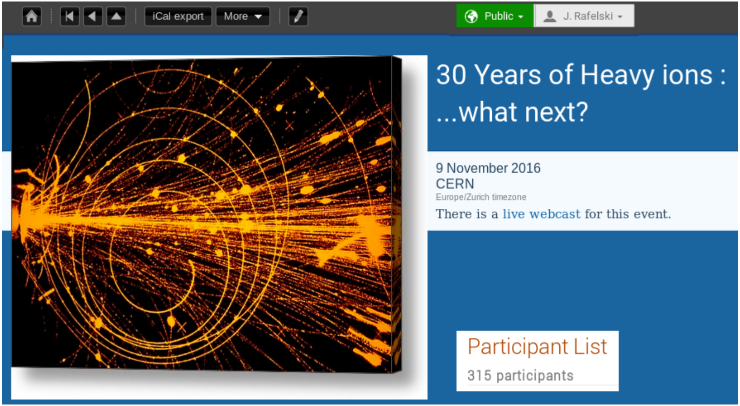
*Ankieta praco

Aktualności

www.fuw.edu.pl/home.html

Uprzejmie zapraszamy na Sympozjum poświęcone planowanym badaniom naukowym przy użyciu Extreme Light Infrastructue (ELI), które odbędzie się 7 listopada 2016 (poniedziałek) w godzinach 10-13 w sali 1.40. ELI to duża europejska infrastruktura badawcza wykorzystująca lasery o mocy rzędu 10 PW w wielu zagadnieniach. Szczególnie zapraszamy na godzinę 10.15 na wykład prof. Johanna Rafelskiego (University of Arizona, Tucson, USA) pt. "Fundamental Physics Acceleration Frontier"

“Acceleration Frontier” = the answer CERN is looking for:



Summary

1. The cards are on the table: the big mystery of RHI collisions is how and why QGP forms. Fluctuations can help unravel the question providing observables, the RR provides the instability mechanism.
2. The discovery viscosity time scale is $\tau = 10^9$ s . The increase of life expectancy in Poland gives everyone a chance to contribute (I defer any discussion on this point).
3. The origin of 30y+30y celebration is to be looked for in the ancient Egypt: a long lived Pharaoh was re-certified as capable. That is how Staś situation looks. Admiring his good looks and well fitted dress, I am certifying Staś is ready to lead the Physics army for another 30y.

My sincere wishes for much success in coming three decades, you deserve it!

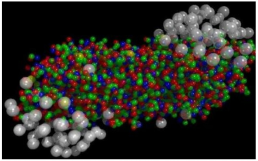
PS: Yes, we all heard, quark-gluon plasma has been discovered. . .

When and how did we discover QGP?

CERN press office

New State of Matter created at CERN

10 Feb 2000



At the April 2005 meeting of the American Physical Society, held in Tampa, Florida a press conference took place on Monday, April 18, 9:00 local time. The public announcement of this event was made April 4, 2005:

EVIDENCE FOR A NEW TYPE OF NUCLEAR MATTER At the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab (BNL), two beams of gold atoms are smashed together, the goal being to recreate the conditions thought to have prevailed in the universe only a few microseconds after the big bang, so that novel forms of nuclear matter can be studied. At this press conference, RHIC scientists will sum up all they have learned from several years of observing the worlds most energetic collisions of atomic nuclei. The four experimental groups operating at RHIC will present a consolidated, surprising, exciting new interpretation of their data. Speakers will include: Dennis Kovar, Associate Director, Office of Nuclear Physics, U.S. Department of Energy's Office of Science; Sam Aronson, Associate Laboratory Director for High Energy and Nuclear Physics, Brookhaven National Laboratory. Also on hand to discuss RHIC results and implications will be: Praveen Chaudhari, Director, Brookhaven National Laboratory; representatives of the four experimental collaborations at the Relativistic Heavy Ion Collider; and several theoretical physicists.