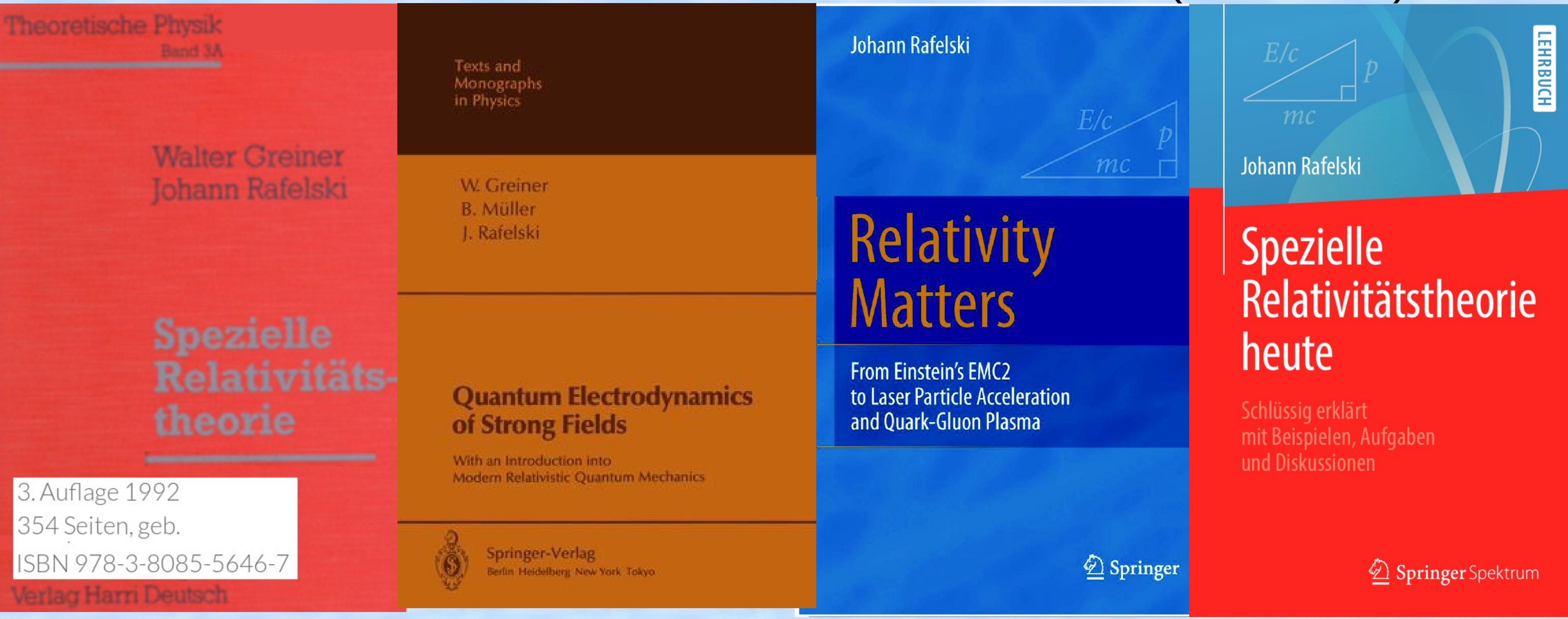
Special Relativity and Strong Fields

Johann Rafelski
Department of Physics, The University of Arizona

Special Relativity (SR), the foundation of modern physics, experiences a renaissance as a discipline and is rapidly evolving: We are probing the acceleration/strong electromagnetic field frontier in relativistic heavy ion experiments, and thinking ahead to the very high intensity laser-particle interaction. We are facing a challenge: Teaching of SR to future researchers in these field. SR remains poorly represented in many introductory text books. Non-expert lecturers do not correctly understand SR and related elementary physics phenomena. The unfinished formulation of SR when forces are not gravity will be explained. Strong EM fields will be introduced.

My QUALIFICATION: Long Interest in SR and StrongFields & illustrous teacher (Greiner)



Einstein 1905 extended the relativity principle to electromagnetism (only inertial motion) and light

Time recognized as a 4th coordinate

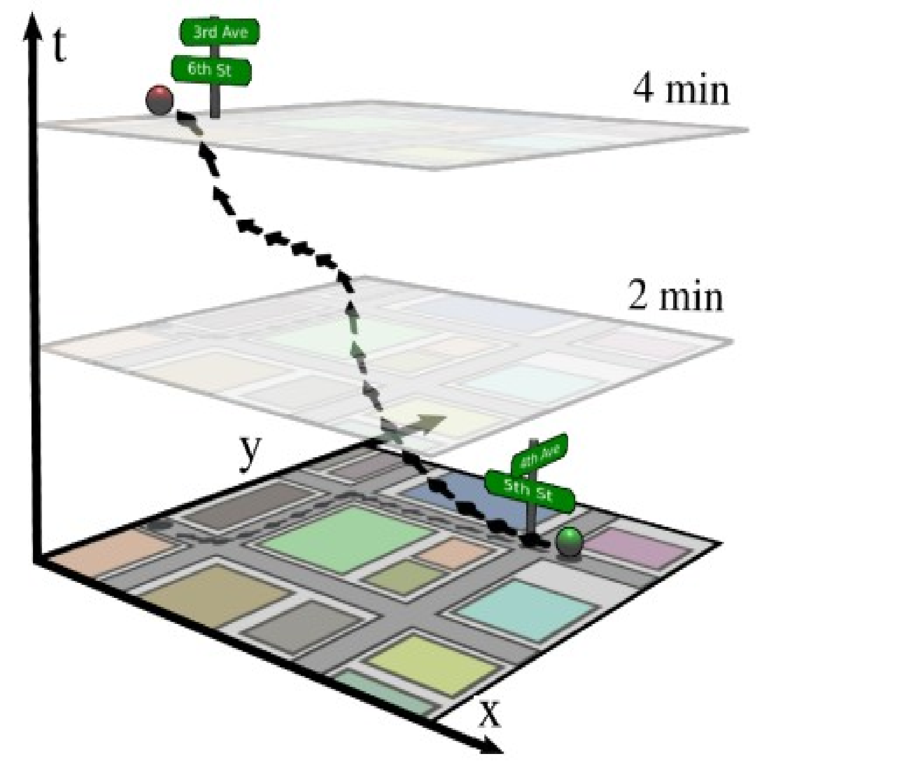


Fig. 1.2 A world line, shown here, of a four-minute walk from the corner of 4th Ave and 5th St to the corner of 3rd Ave and 6th St. Motion in the x, y, and time t dimensions is shown, with the z dimension suppressed (except for the street signs)

$$x' = \frac{x - vt}{\sqrt{1-(v/c)^2}}, \quad t' = \frac{t-(v/c^2)x}{\sqrt{1-(v/c)^2}}.$$

Lorentz Coordnate Transformation

Set t=0: $$x = \sqrt{1-(v/c)^2}\, x'$$ x<x'

Observer measuring at their equal time report event separation consistent with 'contraction'

$$x' = x\sqrt{1-(v/c)^2} - t'v, \quad t' = t\sqrt{1-(v/c)^2} - \frac{x'v}{c^2}.$$

Larmor's form of the Lorentz transformation

Set x'=0: $$t' = t\sqrt{1-(v/c)^2}$$ t'<t

A clock sticking to a body measures shorter time: time dilation

Each body has its proper time

Teaching SR I begin asking students

What is "Lorentz contraction"?

Some say space is contracted. NO

Before Gravity Relativity (GR=ART) nobody would confound properties of a material body with space-time. Since GravityR changes space-time, this confounds thinking about Special=inertialR

Other say this is distance contraction. What is this?

A coordinate transformation (allowing for a specific measurement process) must be consistent with the behavior of material bodies. Coordinate transformation of the two body ends, considered at equal time in observer's frame, is consistent with the Lorentz-FitzGerald body contraction.

A few claim this is apparent body contraction. ???

Einstein wrote a "response" in 1911 explaining that his and Lorentz views in this matter agree: body contraction is real: JR: in the same way kinetic energy and momentum of a car is real even if it is zero for the driver

LETTERS TO THE EDITOR.

*** Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

The editor will be glad to publish any queries consonant with the character of the journal.

Twenty copies of the number containing his communication will be furnished free to any correspondent on request.

The Ether and the Earth's Atmosphere.

I HAVE read with much interest Messrs. Michelson and Morley's wonderfully delicate experiment attempting to decide the important question as to how far the ether is carried along by the earth. Their result seems opposed to other experiments showing that the ether in the air can be carried along only to an inappreciable extent. I would suggest that almost the only hypothesis that can reconcile this opposition is that the length of material bodies changes, according as they are moving through the ether or across it, by an amount depending on the square of the ratio of their velocity to that of light. We know that electric forces are affected by the motion of the electrified bodies relative to the ether, and it seems a not improbable supposition that the molecular forces are affected by the motion, and that the size of a body alters consequently. It would be very important if secular experiments on electrical attractions between permanently electrified bodies, such as in a very delicate quadrant electrometer, were instituted in some of the equatorial parts of the earth to observe whether there is any diurnal and annual variation of attraction, — diurnal due to the rotation of the earth being added and subtracted from its orbital velocity; and annual similarly for its orbital velocity and the motion of the solar system. GEO. FRAS. FITZ GERALD.

Dublin, May 2.

A body contracts in direction of motion: First was FitzGerald

Considering that practically all attribute body contraction to Lorentz I keep Lorentz name but factually FitzGerald was first in 1889. **Lorentz** once aware, named the body contraction to be **FitzGerald body contraction**. FitzGerald passed away before SR and all world wanted to please Lorentz.... Lorentz also gets unwanted credit for the relativistic coordinate transformation he never derived -- it was independently obtained by Larmor, Einstein, Poincare, …. *Live long and prosper*

Symptoms of Issues in teaching & learning Special Relativity

»

A claim <u>today</u> of a "paradox", or "not real", *means book or lecturer do not understand SR*

»

Students: choose SR sources carefully, *lots of bad stuff around (many false internet prophets)*

»

Remember: "S" R is a **bigger unfinished theory** compared to "Gravity"R; *GR=ART does not supersede but extends SR for gravity only*

SR in 1905 format "incomplete": *allows inertial motion only*

Beware of qualitative arguments: **SR is very subtle. SR explained on internet is ….**

SR is evolving: we use it daily in situations where *strong forces are relevant and are trying fix-ups.*

Common challenges

1: What is contracted?

A: There is a real contraction of a moving body

space is NOT contracted: *SR does not address the properties of the space-time in which we live.* The fact that one inertial observer (IO) measures event coordinates that are different from those measured by another IO does not mean that there is a change of the space-time manifold.

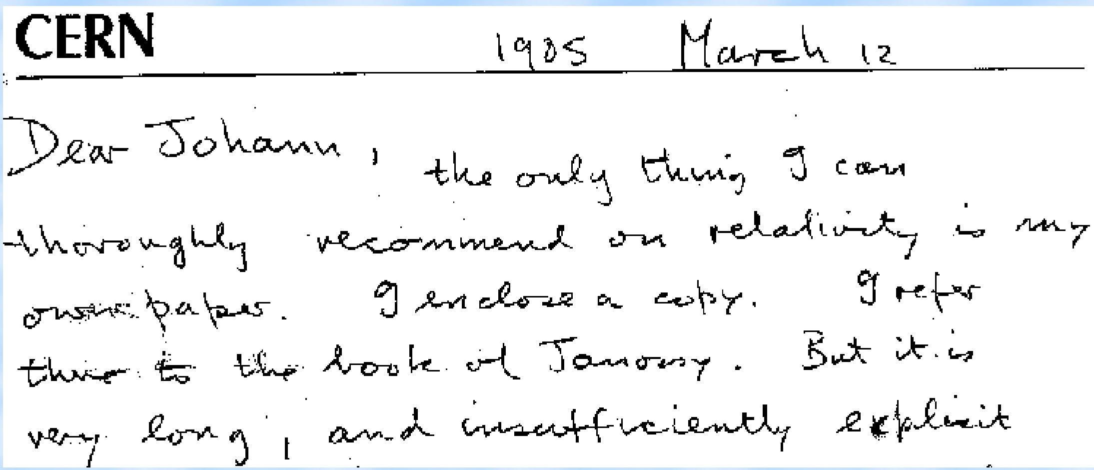
unwise to be "diplomatic" *speaking of "distance" contraction: since this creates need for complicated explanations.* Always remember: space and time are not impacted in any way in SR; in particular, SPACE AND TIME are not impacted by the inertial motion of particles or extended material bodies.

best always to say "**body contraction**," rather than simply "contraction" and to include **Lorentz-FitzGerald (LFG) to avoid confusion with "Lorentz... this .. that"**

2. Is a passenger on a relativistic train aware s/he is "body contracted"?

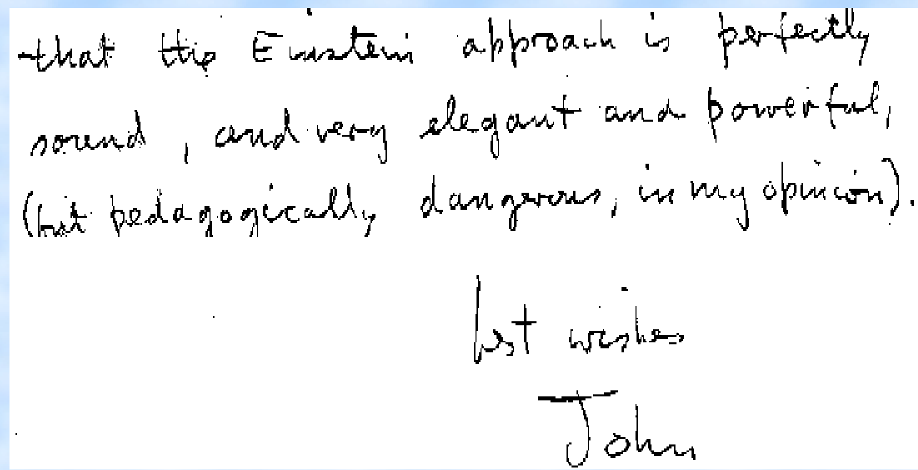
A. Einststein 1911: *No - there is no absolute reference frame in the Universe, s/he cannot know against what she contracts.*

J. S. Bell 1976 of "Bell inequality fame": *adapts Lorentz-Janossy* ***reality*** *point of view: using acceleration he transports IO from one to another reference frame. This allows to know and measure relative contraction.*



CERN 1985 March 12

Dear Johann, the only thing I can thoroughly recommend on relativity is my own paper. I enclose a copy. I refer there to the book of Janossy. But it is very long, and insufficiently explicit



that the Einstein approach is perfectly sound, and very elegant and powerful, (but pedagogically dangerous, in my opinion).

best wishes

John

Eur. Phys. J. A (2018) 54: 29
DOI 10.1140/epja/i2018-12370-4

Letter

THE EUROPEAN PHYSICAL JOURNAL A

Measurement of the Lorentz-FitzGerald body contraction

Dedicated to Walter Greiner; October 1935 – October 2016.

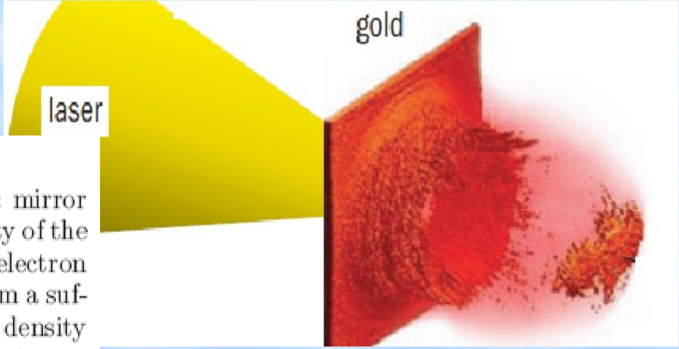
Johann Rafelski[a]

Published online: 20 February 2018

Department of Physics, The University of Arizona, Tucson, AZ, 85721, USA

Abstract. A complete foundational discussion of acceleration in the context of Special Relativity (SR) is presented. Acceleration allows the measurement of a Lorentz-FitzGerald body contraction created. It is argued that in the back scattering of a probing laser beam from a relativistic flying electron cloud mirror generated by an ultra-intense laser pulse, a first measurement of a Lorentz-FitzGerald body contraction is feasible.

The "moving electron cloud mirror" is body compressed.



Body contraction experiment. — To accomplish our goal to build a laboratory-sized experiment we consider an ultra-intense ultra-short laser pulse shot at a thin (micron) foil. Such a pulse in its focal point can act as a micron-sized hammer pushing out of the foil an electron cloud accelerated to ultrarelativistic motion with a high value of Lorentz-factor γ_e. The emerging electron cloud compared to the original foil thickness will be Lorentz-FitzGerald compressed by γ_e.

A moving electron cloud acts as a relativistic mirror for a low intensity laser light bounce. The capability of the ultrarelativistic mirror to function depends on the electron cloud density; laser light can scatter coherently from a sufficiently high density cloud – what is low and high density is determined by comparing mean electron separation to the light wavelength.

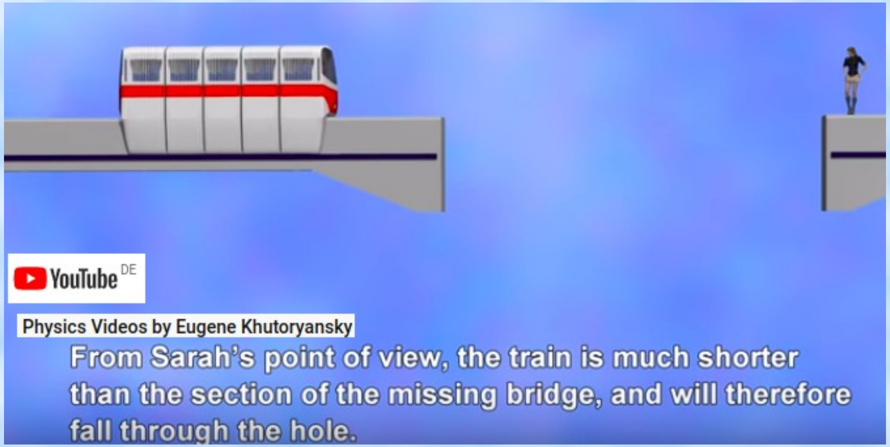
two Lorentz transforms, first into the rest-frame of the mirror and upon reversal of the propagation direction of the light motion, transform back to the laboratory frame.

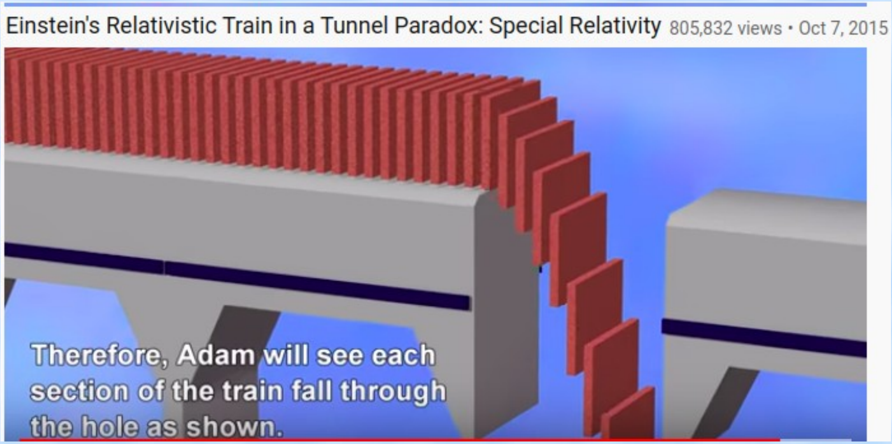
3: I SEE YOU CONTRACTED, YOU SEE ME CONTRACTED??

A measurement of body length is always carried out at observer's equal time. A mountain tunnel and a train (at rest or moving) are measured from a station in this way. The long train departs station, moving train is contacted in the direction of motion and will fit in full in the tunnel (or fall into a break in the bridge).

A "Contraction reversal paradox (??)" does not exist. A passenger on the train observes at her equal time the mountain. Whatever she measures at her equal time, which is not the same as station time does not change the fact that the train seen by the station observer will fit the mountain. Everything is perfectly consistent allowing for DIFFERENCE IN TIME.

Internet Physics needs to account for "space contraction" DO NOT TRUST INTERNET…..





4: Time dilation is NOT reversible (no twin paradox)

Lorentz invariant (invariant under coordinate transformations) quantities such as **the proper time** of a body, are measured to be the same by all IO:

$$c^2\tau^2 = c^2t^2 - x^2 = c^2t'^2 - x'^2 .$$

Proper time is a meaningful measure of body time flow. A returning space traveler has the age τ and is younger compared to her twin on Earth aged t since she traveled a distance x.

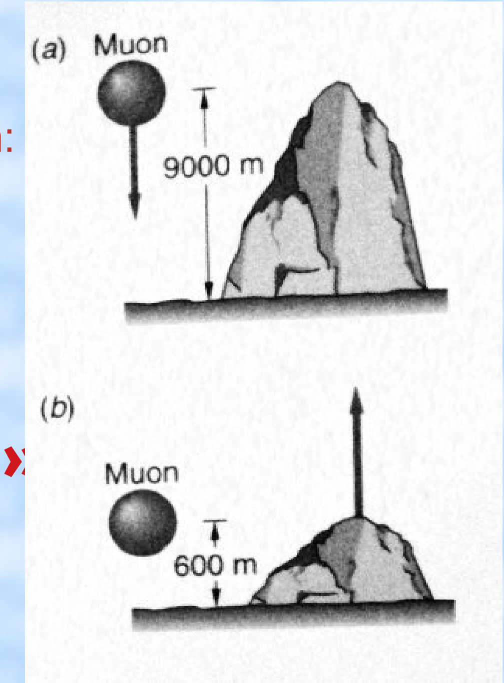
The twin paradox is created by claims that the relativity principle allows "exchange" of the argument. Such exchange is not possible since only the laboratory twin was inertial, not the traveler (Langevin 1911). Langevin argues that unlike velocity, acceleration has absolute meaning: one cannot find an observer for whom the traveler is not accelerated. More in 2nd part of talk.

5: The LFG body contraction and time dilation confirm each other??

In SR both the Lorentz-FitzGerald (LFG) body contraction, and time dilation are **unrelated body property phenomena** (unlike energy and momentum which are related). That they are unrelated is easily recognized by remembering that an **elementary point particle** can experience time dilation but **cannot experience a LFG body contraction.**

Footnote remarks: A finite size body is often introduced in a discussion of time dilation to claim presence of an unrelated LFG body contraction: However, an unstable particle (e.g. muon) experiences time dilation irrespective of another finite size material body being present.
This book picture is drawn to illustrate the FALSE CLAIM that body contraction and time dilation confirm each other. This is a logically incorrect line of argument: this claim requires presence of a material body, so what happens without a mountain???

NO»NO»



(UNSTABLE) PARTICLE TRAVEL RANGE

Imagine you perform muon range measurement in intergalactic empty space so there is no LFG body contraction of anything. Using time dilation:

$$c^2\tau^2 = (1 - v^2/c^2)\ c^2 t^2$$

AND LORENTZ-INVARIANCE OF PROPER TIME:

$$c^2\tau^2 = c^2t^2 - x^2$$

$$x^2 = c^2t^2 - c^2\tau^2$$

$$x^2 = \tau^2\ v^2/(1 - v^2/c^2)$$

The muon travels the Lorentz extended distance **x** during its lifespan τ.

6: Relativistic Doppler effect (RDE): HAS NOTHING TO DO WITH TIME DILATION

Time dilation of the source cannot be part of the RDE effect since the relative speed with respect to the yet undetermined observer cannot be known at the time of light emission.

Einsteins 1905 paper works in the following way: the light wave carries to the observer the information about the source allowing the determination of the RDE shift in frequency and wavelength and position aberration at the time of actual observation of the light signal. Einstein presents all results without detailed derivation (next page) and the argument is very terse, leading to numerous misreads, von Laue SR book discussing RDE can also be easily misunderstood.

[redacted] — Durch Anwendung der in § 6 gefundenen Transformationsgleichungen für die elektrischen und magnetischen Kräfte und der in § 3 gefundenen Transformationsgleichungen für die Koordinaten und die Zeit erhalten wir unmittelbar:

$$X' = X_0 \sin \Phi', \qquad L' = L_0 \sin \Phi',$$
$$Y' = \beta\left(Y_0 - \frac{v}{V} N_0\right) \sin \Phi', \qquad M' = \beta\left(M_0 + \frac{v}{V} Z_0\right) \sin \Phi',$$
$$Z' = \beta\left(Z_0 + \frac{v}{V} M_0\right) \sin \Phi', \qquad N' = \beta\left(N_0 - \frac{v}{V} Y_0\right) \sin \Phi',$$
$$\Phi' = \omega'\left(\tau - \frac{a'\xi + b'\eta + c'\zeta}{V}\right),$$

wobei

$$\omega' = \omega\beta\left(1 - a\frac{v}{V}\right), \qquad a' = \frac{a - \frac{v}{V}}{1 - a\frac{v}{V}},$$
$$b' = \frac{b}{\beta\left(1 - a\frac{v}{V}\right)}, \qquad c' = \frac{c}{\beta\left(1 - a\frac{v}{V}\right)}$$

gesetzt ist.

Aus der Gleichung für ω' folgt: Ist ein Beobachter relativ zu einer unendlich fernen Lichtquelle von der Frequenz ν mit der Geschwindigkeit v derart bewegt, daß die Verbindungslinie „Lichtquelle—Beobachter" mit der auf ein relativ zur Lichtquelle ruhendes Koordinatensystem bezogenen Geschwindigkeit des Beobachters den Winkel φ bildet, so ist die von dem Beobachter wahrgenommene Frequenz ν' des Lichtes durch die Gleichung gegeben:

$$\nu' = \nu \frac{1 - \cos\varphi \frac{v}{V}}{\sqrt{1 - \left(\frac{v}{V}\right)^2}}.$$

Dies ist das Doppelersche Prinzip für beliebige Geschwindig-

In our language: Einstein postulates the Lorentz-invariance of the phase of light wave

$$\Phi = \omega t - \boldsymbol{x}\cdot\boldsymbol{k} = \omega t - \boldsymbol{x}\cdot\boldsymbol{n}|\boldsymbol{k}| = \omega/c(ct - \boldsymbol{x}\cdot\boldsymbol{n})$$

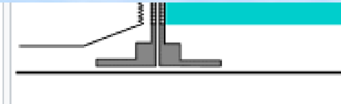
- Ives and Stilwell 1938 experiment measuring (transverse)Doppler shift, claim they measure time dilation

Ives–Stilwell experiment

From Wikipedia, the free encyclopedia

https://en.wikipedia.org/wiki/Ives–Stilwell_experiment

The **Ives–Stilwell experiment** tested the contribution of relativistic time dilation to the Doppler shift of light.[1][2] The result was in agreement with the formula for the transverse Doppler effect and was the first direct, quantitative confirmation of the time dilation factor.



Ives–Stilwell experiment (1938). mostly H_2^+ and H_3^+ ions) were a

- Resnick around 1960 leans on text of von Laue SR without knowing German, so relies on language of Ives-Stilwell. **This is copied in most English language books and is today found all over the Internet.**

Dark (middle)age of special relativity

JOURNAL OF SYNCHROTRON RADIATION

ISSN 1600-5775

Received 4 April 2017
Accepted 24 May 2017

Edited by M. Eriksson, Lund University, Sweden

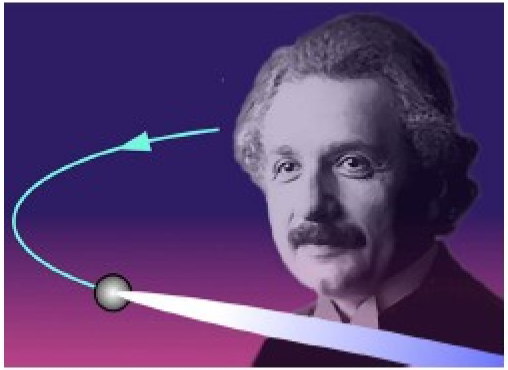
Keywords: special relativity; Doppler; time dilation; Lorentz transformation.

The relativistic foundations of synchrotron radiation

Giorgio Margaritondo[a]* and Johann Rafelski[b]

[a]Faculté des Sciences de Base, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne 1015, Switzerland, and [b]Department of Physics, The University of Arizona, Tucson, AZ, USA. *Correspondence e-mail: giorgio.margaritondo@epfl.ch

Special relativity (SR) determines the properties of synchrotron radiation, but the corresponding mechanisms are frequently misunderstood. Time dilation is often invoked among the causes, whereas its role would violate the principles of SR. Here it is shown that the correct explanation of the synchrotron radiation properties is provided by a combination of the Doppler shift, not dependent on time dilation effects, contrary to a common belief, and of the Lorentz transformation into the particle reference frame of the electromagnetic field of the emission-inducing device, also with no contribution from time dilation. Concluding, the reader is reminded that much, if not all, of our argument has been available since the inception of SR, a research discipline of its own standing.



7: Extended bodies in SR

In SR we strive to comprehend what happens to extended material bodies. LFG body contraction emerges as a pivotal concept.

A cohesive extended body is naturally different from a cloud of non-interacting particles. Since space does not contract, a free particle cloud does not either (assuming a density well below some interaction range).

All cohesive material bodies are contracted.

Between a non-interacting cloud and a rigid stick are many other complicated structures. This does not mean that SR is somehow not applicable to such objects or that it could not with success be used in their study. REMINDER: „BELL ROCKETS“

Bell rockets: Spatial distance vs body length

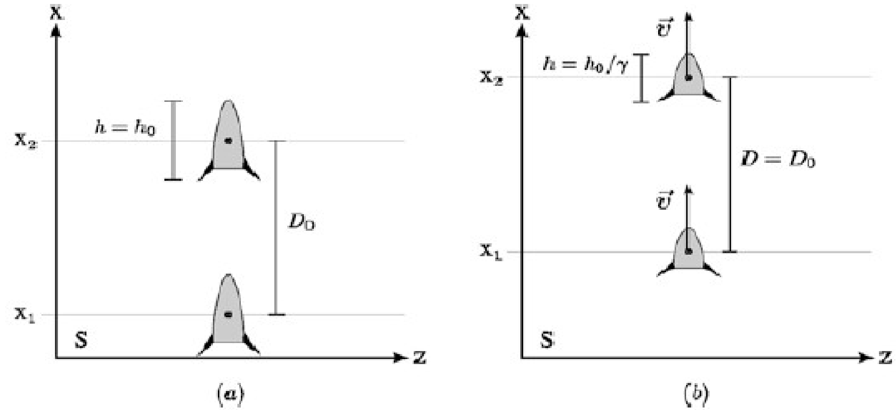


Fig. 10.2 Two rockets of length h separated by distance $D = x_2 - x_1 = D_0$. (**a**) at rest, and in case (b) moving at velocity $\vec{v}$ acquired at a later time

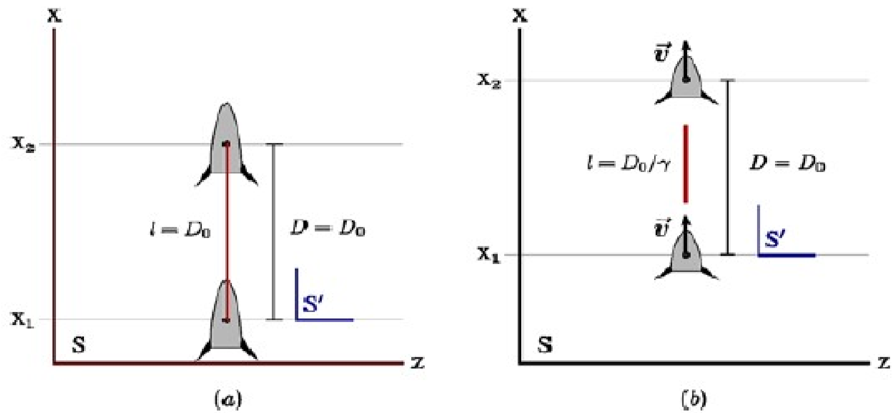


Fig. 10.3 Two rockets separated by distance $D = x_2 - x_1 = D_0$ and connected by a thin thread of (a) at rest, and in case (b) moving at velocity $\vec{v}$ acquired at a later time

Part II: Strong field = strong acceleration Frontier

Objective: to learn how to incorporate accelerated motion in SR: observers always inertial, the observed body maybe non-inertial; for example: a self-propelled rocket, a charged particle in an EM applied field. „Small acceleration does not matter“ is not an option as acceleration effect cumulates in time.

How big can we make "a" in laboratory?

REFERENCE value: Natural "unit-1" acceleration

$a_{cr}=M_e c^2\, c/(h/2\pi)=9.11\ 10^{-31}\ 27\ 10^{24}/1.05\ 10^{-34}=\mathbf{2.33\ 10^{29} m/s^2}$

This is also the acceleration generated by "critical" or Schwinger EM fields": $E_{cr}=(M_e c^2)^2/(ehc/2\pi)=1.323\ 10^{18}$ V/m

$B_{cr}=(M_e c^2)^2/(ehc^2/2\pi)=4.414\ 10^{9}$ T

Ultra-relativistic electron in a magnet of 4.41Tesla at CERN

$a_{MAX}=(e/M_e)\ \mathbf{v x B}$

$=1.6\ 10^{-19}\ 3\ 10^{8}\ 4.41/(9.11\ 10^{-31})=\mathbf{2.33x10^{20} m/s^2}$=**<u>nano a_{cr}</u>**

Classical Electromagnetism is incomplete!

We have two separate theories:

•One which, from given sources of charges and currents, calculates the EM fields

•The other which from prescribed fields calculates the motion of charged particles.

J.D. Jackson, *Classical Electrodynamics 3rd edition*, John Wiley & Sons, (1999).

There is a disconnect – accelerated charges **radiate** and loose energy and momentum which should reflect on their motion! Radiation reaction / friction force term is needed.

We don’t have (but we work on this) an action principle which would describe this process!

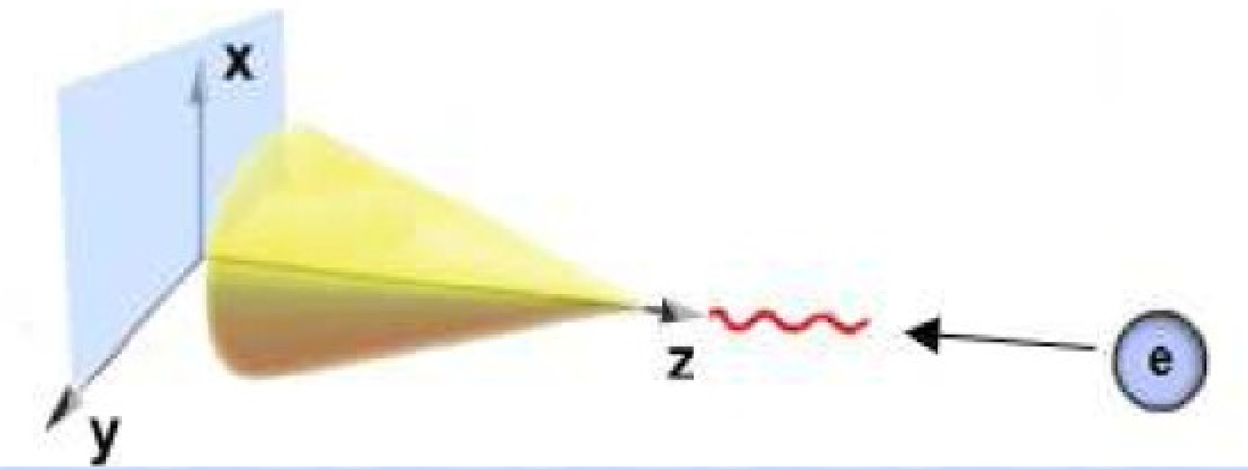
- So far experimental ways of probing such situations are limited: Relativistic heavy ion collisions are a promising today.
- Another future way forward: UHE short pulse laser systems in collision with individual particles.

Probing super-critical (Planck) acceleration

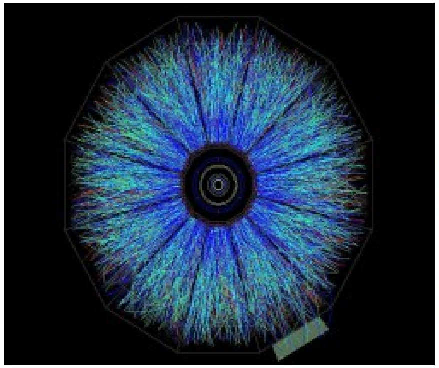
$$a_c = 1(\rightarrow m_e c^3/\hbar = 2.331 \times 10^{29} \mathrm{m/s}^2)$$

Plan A: Directly laser accelerate electrons from rest, requires Schwinger scale field and may not be realizable – backreaction and far beyond today's laser pulse intensity technology.

Plan B: Ultra-relativistic Lorentz-boost: we collide counter-propagating electron and laser pulse.



Unit Acceleration in Strong Interactions



Two nuclei smashed into each other at highest achievable energy: components can be stopped in CM frame within $\Delta\tau \simeq 1$ fm/c. Tracks show multitude of particles produced, as seen at RHIC (BNL) and at CERN.

- The acceleration *a* required to stop some/any of the components of the colliding nuclei in CM: $a \simeq \frac{\Delta y}{M_i \Delta\tau}$. Full stopping: $\Delta y_{\rm SPS} = 2.9$, $\Delta y_{\rm RHIC} = 5.4$, larger at CERN. Considering constituent quark masses $M_i \simeq M_N/3 \simeq 310$ MeV we need $\Delta\tau_{\rm SPS} < 1.8$ fm/c and longer times at colliders to exceed critical *a*.

- The soft electromagnetic radiation in hadron reactions (*A. Belognni et al. [WA91 Collaboration], "Confirmation of a soft photon signal in excess of QED expectations in π–p interactions at 280-GeV/c," Phys. Lett. B* **408**, *487 (1997) [arXiv:hep-ex/9710006].*) and heavy ion reactions exceeds the perturbative QED predictions significantly

Proposed radiation friction force

(We do not belive is right)

Framework: Lorentz-Abraham-Dirac (LAD):

see *e.g.* P. A. M. Dirac, *Classical theory of radiating electrons*, Proc. Roy. Soc. A **167**, 148 (1938).

$$m\dot{u}^\mu = eF^{\mu\nu}u_\nu + m\tau_0\left(g^{\mu\nu} - \frac{u^\mu u^\nu}{c^2}\right)\ddot{u}_\nu$$

So called "Schott term"added ad-hoc to ensure

$$u^2 = c^2$$

- Introduces intrinsic higher order (beyond acceleration) derivative
- Creating issues with initial condition
- And "runaway" solutions
- Causality issues for small times

Provides the radiated power from Liénard-Wiechert solution of Maxwell equations

$$P = m\tau_0\dot{u}^2$$

The time scale τ_0 is

$$\tau_0 = \frac{2}{3}\frac{e^2}{4\pi\varepsilon_0 mc^3} = 6.3\times10^{-24}\mathrm{s}$$

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

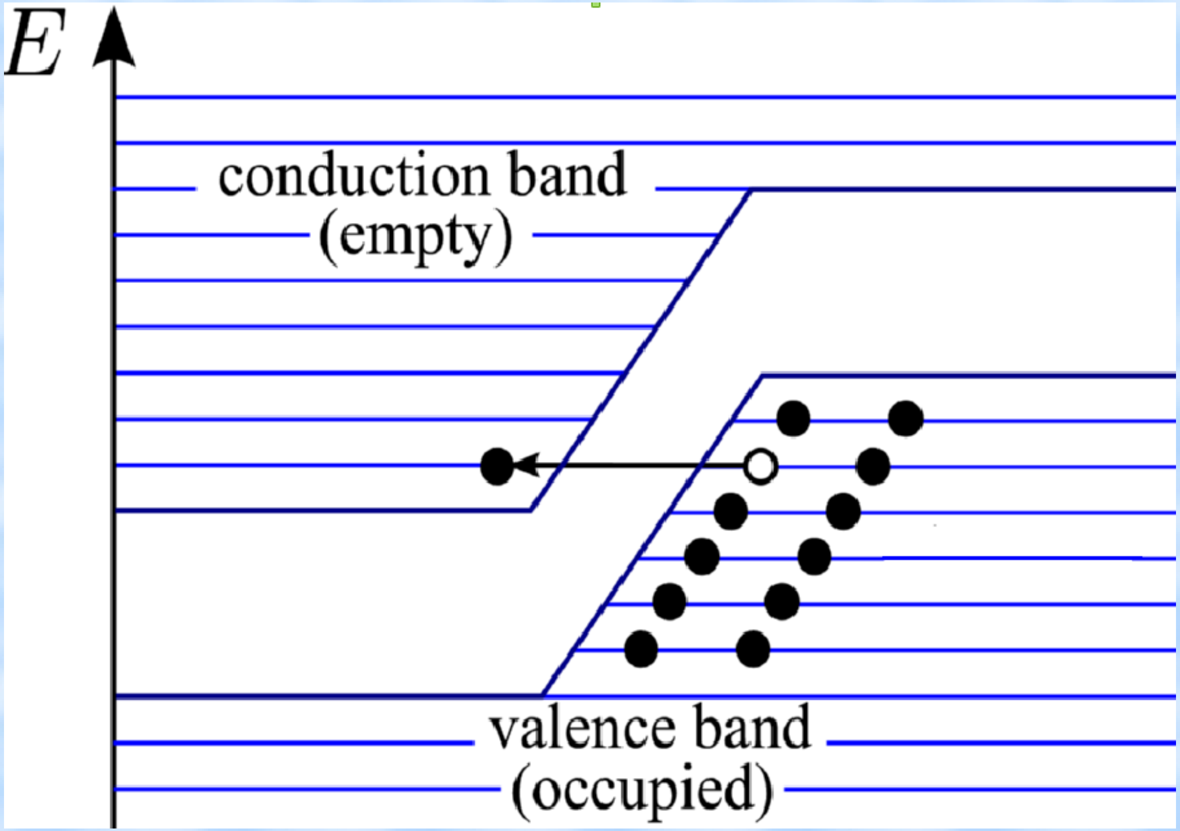
  - **Lienard-Wiechert field: Fields of an arbitrarily moving relativistic point particle derived by assuming a current density,**
  - **Often it is assumed that the ions travel in straight line motion, or that $\dot{\beta}=0$ *which is not always a good argument to neglect* the acceleration term in the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

„Absolute" Acceleration (Langevin)

Only relative velocity in SR, but not everything is „relative“
Can body acceleration have „absolute“ meaning? How does a body "know" that it is accelerated? *Charged particles in general respond emitting radiation, so they know!*

Beyond radiation there is electron-positron pair production: Electric fields at critical value cannot be sustained due to back-reaction. IS there a maximum acceleration for EM processes?? What happens to particles in such fields?

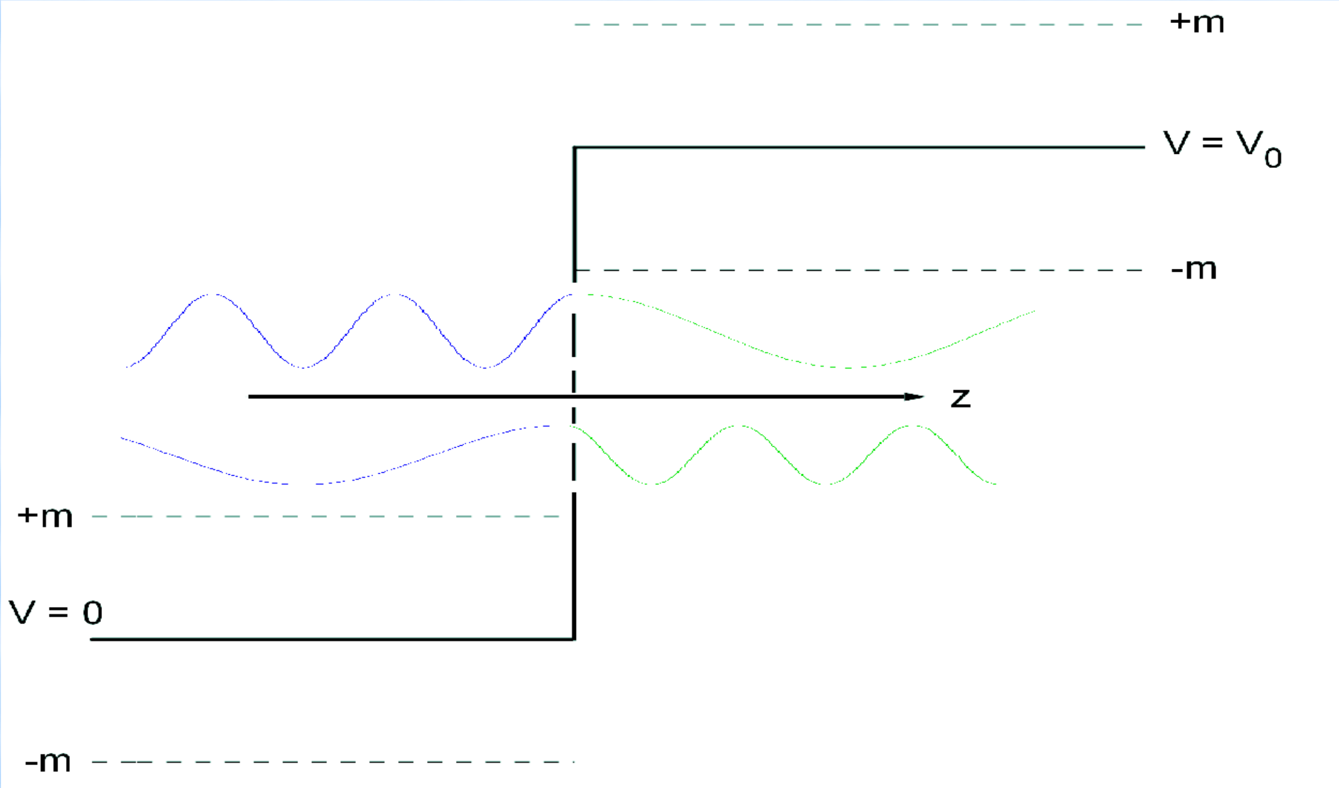
Tunneling pair production instability: Explanation of Klein's paradox



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

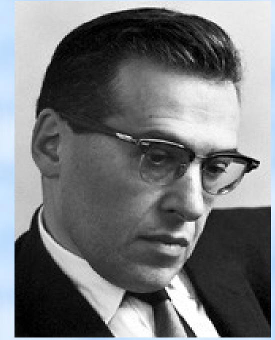
Klein's "Paradox": pair production in strong fields



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

W Heisenberg

Rate of **pair production** in “constant” fields



J Schwinger

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 pair production evaluated in WKB description of barrier tunnelling: All E-fields are unstable and can decay to particles if energy is available and rate is large enough – noted by Heisenberg 1935, in 1950 Schwinger's article as an visibly after finish-point (*my idea how this happened: request by referee=Heisenberg*?).

Pair production limits the field to the critical acceleration value. What happens to an electron in presence of critical fields?

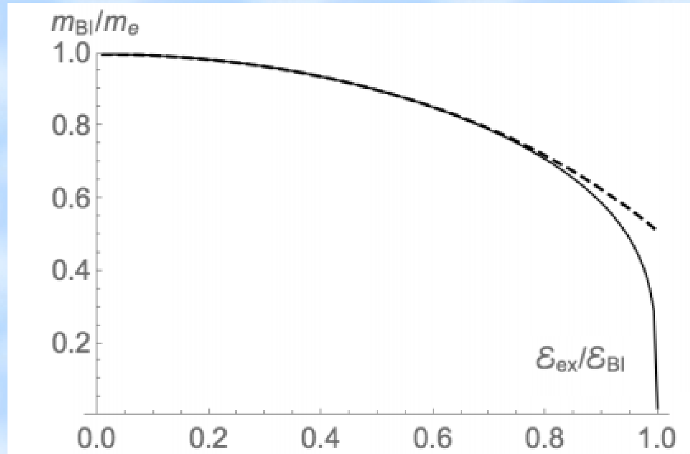
arXiv.org > hep-ph > arXiv:1911.08714

Mass melting and pair production in strong fields

Stefan Evans, Johann Rafelski

(Submitted on 20 Nov 2019)

The electron's electromagnetic (EM) and Higgs mass contents respond differently to strong external fields. The EM mass melts entirely in the presence of a critical external electric field, as we show explicitly using a model. For strong quasi-constant electromagnetic fields we apply this effect to compute an enhancement of pair production rates allowing direct measurement of mass melting. Virtual electron mass melting using the perturbative loop QED insert narrows the muon anomalous magnetic moment discrepancy.



Mass melting in a purely electromagnetic mass model: solid line: exact result

Vanishing mass enhances pair production. Small effect for nano fields.

Final Words

After many years of SR neglect return to the acceleration/strong field frontier. Challenge: Teaching of relativity in the “dark” ages to the future researchers in this vibrant new field.

EXTRA SLIDES about group and deeper look

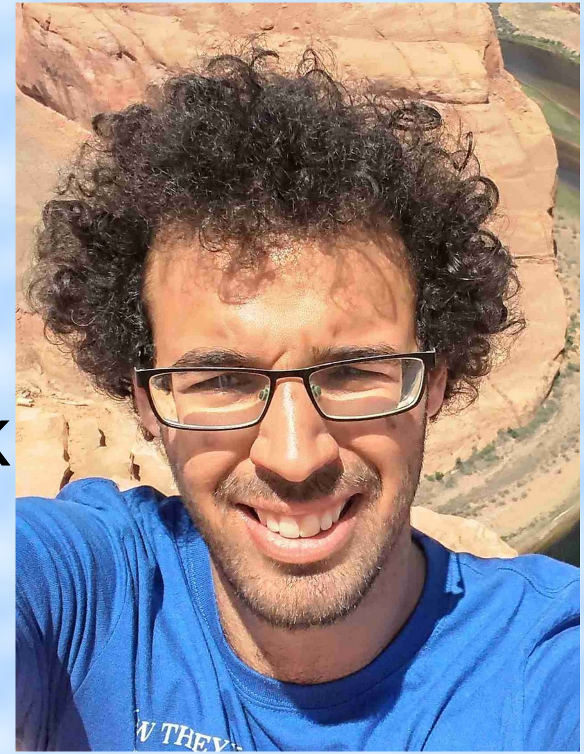
We are the Arizona Acceleration-Team

In S-Relativity we want to figure out what to do with acceleration in general and all non-G forces (EM overdue!). S-Relativity is still incomplete. We are here to rescue it.

The A-Team

Stefan Evans

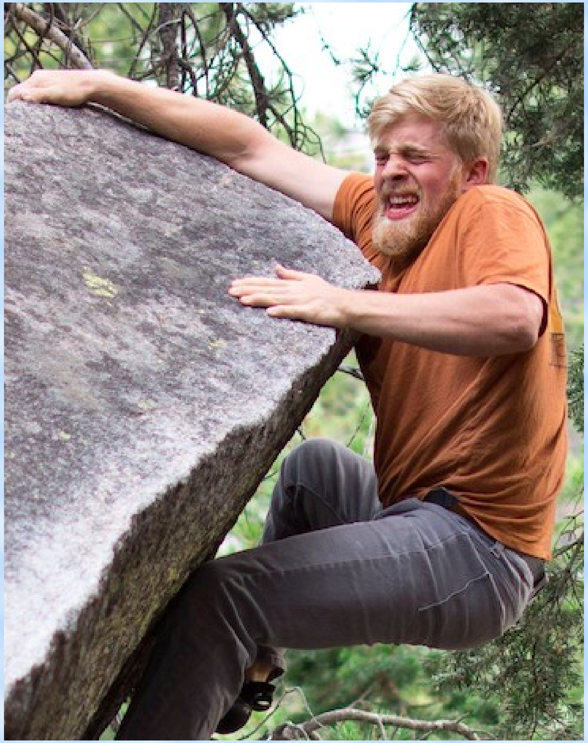
Martin Formanek



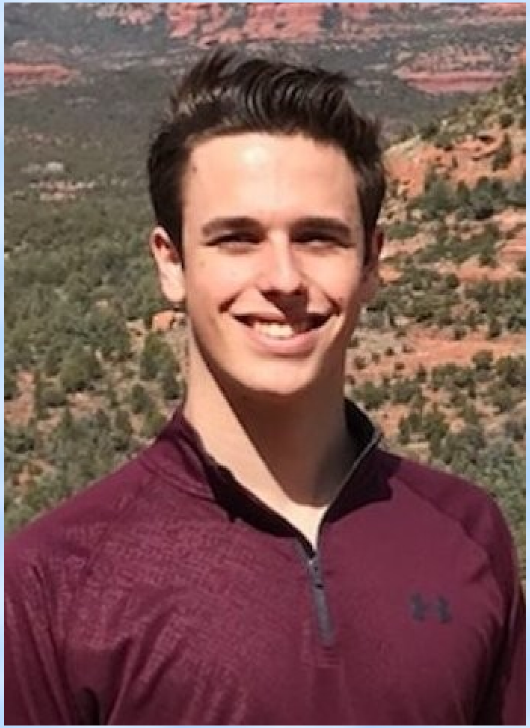
How EM strong fields modify vacuum structure and stability: fields turning into particles. Continues work of Lance Labun (PhD Dec. 2011)

How forces influence dynamical relation between proper time and laboratory time

Chris Grayson



Blake Lee



Relativistic Electro-magnetic Field Dynamics of Particle Collisions: ripping up the vacuum with relativistic strong fields.

Motion/radiation in periodic and random wiggled systems. *Undergraduate student*

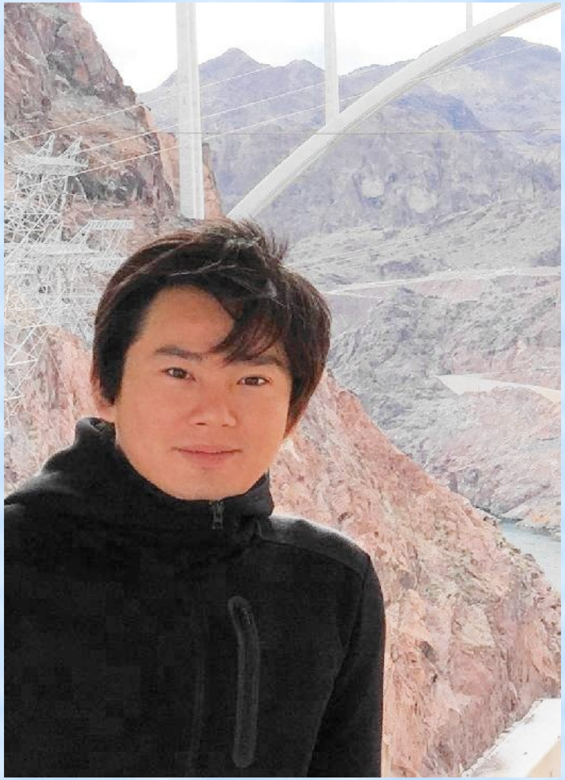
Will Price

Andrew Steinmetz

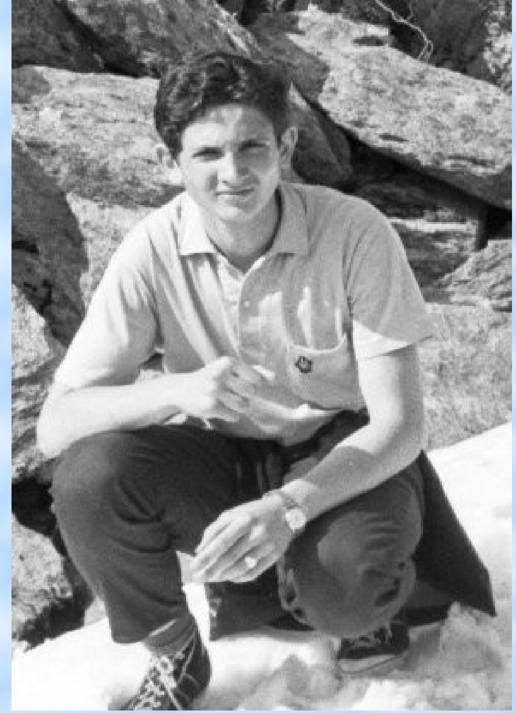
Classical dynamics of relativistic charged particle collisions, including radiation reaction in strong fields. Started in the group as an undergrad

Relativistic dynamics of particles with anomalous magnetic moment and connection with quantum dynamics

Cheng
Tao
Yang



Dt. R:



48 years of work in relativistic everything. Current passion: SR, Strong/critical acceleration phenomena.

Relativistic Thermodynamics in expanding primordial Universe: from quarks to BBN. Continues work of Jeremey Birrell, PhD May,2014

VOLUME 27, NUMBER 14 PHYSICAL REVIEW LETTERS 4 OCTOBER 1971

Superheavy Elements and an Upper Limit to the Electric Field Strength

Johann Rafelski, Lewis P. Fulcher,† and Walter Greiner
Institut für Theoretische Physik der Universität Frankfurt, Frankfurt am Main, Germany
(Received 9 August 1971)

An upper limit to the electric field strength, such as that of the nonlinear electrodynamics of Born and Infeld, leads to dramatic differences in the energy eigenvalues and wave functions of atomic electrons bound to superheavy nuclei. For example, the $1s_{1/2}$ energy level joins the lower continuum at $Z = 215$ instead of $Z = 174$, the value obtained when Maxwell's equations are used to determine the electric field.