

**A few things that matter  
after one turns 70 years old**

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**BTSLXX Symposium  
Budapest, June 11, 2026**

## Looking at Myself: 70 was a few years back; use personal experience

- 1. Supporting Family and Friends**
- 2. Completing open research projects**  
(seems an endless enterprize)
  - A Nuclear Fusion and Plasma Physics
  - B Primordial QGP and related topics
  - C QED Strong Fields, Spin
  - D Special Relativity and Electromagnetism
- 3. Books completion**
- 4. Mentoring Students**
- 5. Academic & Institutional Responsibilities**
  - A Institutional Collaborations
  - B Representing Faculty Interests, Improving University Management
- 6. Travel, Lecture, Remember and Meet old, make new friends**

# 1. Supporting Family and Friends

## Example: Birthday Poems (now 30 and counting)

Break out the glitter and all things that shine  
Our dear boy Eddie is turning nine!

In the dojo, you spar and you kick,  
Earning new belts, mastering each trick.

With numbers and puzzles, you're quick as can be,  
Solving math mysteries fills you with glee.

And in your rare moments of leisure

You enjoy your cars and counting treasure

You write well too, filled with creative joy

Gosh, you are a talented boy!

Much love and kisses ~ Happy, happy birthday,  
Eddie



**Simple Math:** When you turn 9 you are also 469.6 weeks or 3,287 days, or 78,892 hours or 284,012,568



Guys, it's time to  
celebrate!

Katie Rafelski is turning  
eight!

Dear Katie,



With dreams as bright as the morning sun,  
Your journey has only just begun.

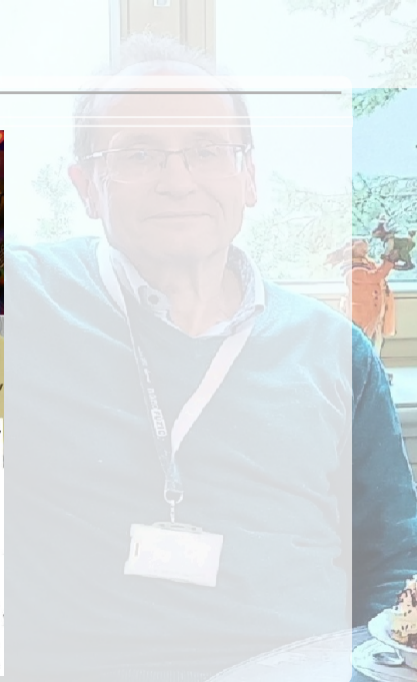
You're growing wiser, brave, and kind,  
Worlds of wonders within your mind.

Dancing, laughing, spreading cheer,  
Like moonbeams lighting up this sphere.

For you, sweet girl, this wish we send,  
That happiness and love never end.

May your eighth birthday be pure delight,  
A trove of memories, shining bright!

We hope this next year is like you, just fine  
And you enjoy the journey from eight to nine.



## 2. Completing Open Research Projects

### A – Nuclear Fusion and Plasma Physics

- Current-conserving relativistic linear plasma response (2021)
- Electron-positron plasma in BBN (2023)
- Superheavy elements and ultradense matter (2023)
- Self-consistent strong screening (2024)
- Nuclear fusion by heavy nuclear catalysts (2025)
- Molecular  ${}^9\text{Be}+p$  fusion reaction (2025)
- Weinberg angle, neutron abundance in BBN (2026)
- (finalizing) Advances in Science of Nuclear Fusion: A few novel ideas and approaches (2026)

### B – Primordial QGP and related

- Reactions governing strangeness in the primordial Universe(2020)
- Muon abundance in primordial Universe (2021)
- Cosmological strangeness abundance (2022)
- Dynamic magnetic response of QGP (2022)
- Short survey: matter-antimatter evolution in the Universe (2023)
- Matter-antimatter origin of cosmic magnetism (2023)
- Spin magnetization in Primordial QGP (2025)
- Quarks to Cosmos (review) (2025)
- Fermi-Dirac integrals in degenerate regimes (2024)
- Higgs thermal nonequilibrium in QGP (2025)

## Research Overview – Groups C and D

### C – QED Strong Fields

- Particle production at finite potential step (2021)
- Singular QED vacuum response (2022)
- Emergence of periodic effective QED action (2022)
- Improving Euler-Heisenberg with dressed photons (2023)
- QED singular properties, variable  $g \simeq 2$  (2023)
- Dynamic fermion flavor mixing (2023)
- Everlasting interaction / Landau pole (2023)
- Comment on Heisenberg-Euler effective Lagrangian (2024)

### D – SpecialRelativity amd Electromagnetism

- Radiation reaction friction (2020)
- Motion of charged particles in plane-wave EM (2021)
- Radiation reaction and limiting acceleration (2022)
- Born-Infeld EM in heavy-ion collisions (2023)
- Covariant Cherenkov radiation (2026)

### 3. Books + Completion

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1. *Hadrons and QGP* (book, reissue 2022)
2. *Modern Special Relativity* (textbook, 2022)
3. *Discovery of QGP* (book in preparation)
4. Particle Dynamics and Radiation in Strong Fields: Classical and Quantum Physics (Review Bookstyle 230+ large pages, nearing completion)
5. Other projects ?????

## 4. Mentoring Students

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### Collaborating, and Doctoral students since 2020

#### Collaborating

1. Lance Labun
2. Jeremiah Birrell

#### Since 70th BD graduated

3. Martin Formanek
4. Andrew Steinmetz
5. Cheng Tao Yang
6. Chris Grayson
7. Stefan Evans
8. Will Price

## 5. Academic & Institutional Responsibilities

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### A: Institutional Collaborations

1. Wigner–Arizona fusion collaboration agreement (2024)
2. TVLBAI: (Terrestrial Very Long Base Atomic Interferometry (2022 to CERN prop 2026)
3. Isospin-symmetry violation ISO-BREAK 25 (2026)

### B: Representing Faculty Interests, Improving University Management

1. Multiple time elected Senator at large by all faculty (direct election)
2. Elected to strategic University committees by all faculty (direct election)

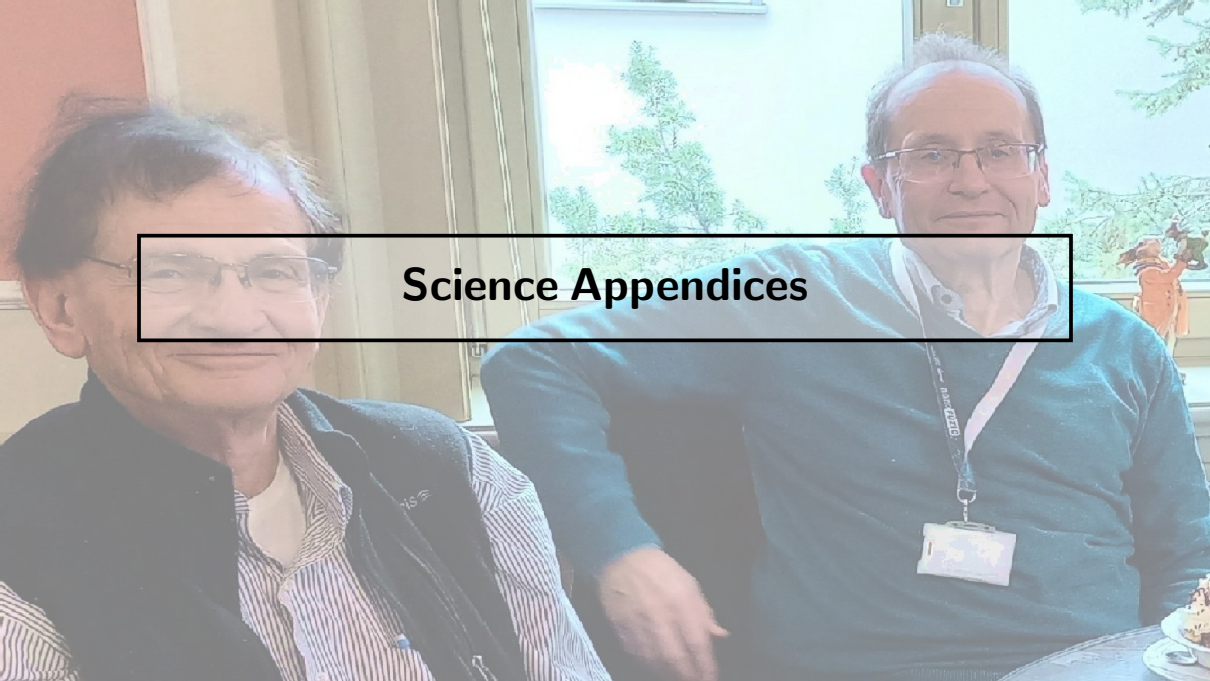
## 6. Travel, Lecture, Remember and Meet old, make new friends

1. **Norbert Kroo** (2021)
2. Homage to Harald Fritzsch (2024)
3. Serbia and Maribor meetings (2025)
4. Contributing to memorials in person (2025, Hans Specht)
5. Contributing to Birthdays in person (2026, Tamas Biro)

A photograph of two men sitting at a table. The man on the left is older, with glasses, wearing a dark jacket over a striped shirt. The man on the right is younger, with glasses, wearing a blue sweater and a lanyard with a badge. They are in a room with a window in the background showing trees. A text box is overlaid on the image.

**Wishing Tamas all the best in  
coming hard working decade**

**BTSLXX Symposium  
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A photograph of two men sitting at a table in front of a window. The man on the left is older, with glasses, wearing a dark jacket over a striped shirt. The man on the right is younger, also with glasses, wearing a blue sweater and a lanyard with an ID badge. A black-bordered white box is superimposed over the center of the image, containing the text "Science Appendices".

**Science Appendices**

# Reactions Governing Strangeness Abundance in Primordial Universe

## Publication Details

J. Rafelski, C.T. Yang arXiv:2009.05661 [hep-ph]

*EPJ Web Conf.* **259** (2022) 13001 doi:10.1051/epjconf/202225913001

## Abstract

Strangeness production processes can balance natural strangeness decay in the early hadronic Universe. Comparing to the characteristic Hubble time  $1/H$ , the reaction rates for  $\mu^\pm + \nu_\mu \rightarrow K^\pm$ ,  $I^- I^+ \rightarrow \phi$ , and  $\pi\pi \rightarrow K$  become slower than expansion at  $T = 33.9$ , 25, and 20 MeV respectively. In the antibaryon-annihilation epoch near  $T \simeq 40$  MeV, strangeness is in chemical equilibrium.

# The Muon Abundance in the Primordial Universe

## Publication Details

J. Rafelski, C.T. Yang arXiv:2103.07812 [hep-ph]

*Acta Phys. Polon. B* **52** (2021) 277 doi:10.5506/APhysPolB.52.277

## Abstract

Muon abundance is required for understanding properties of the primordial Universe. We evaluate production and decay rates of muons in the cosmic plasma as a function of temperature, determining exactly when the muon abundance disappears. When the Universe cools below  $kT_{\text{disappear}} \approx 4.135$  MeV muons vanish quasi-instantaneously. At  $T_{\text{disappear}}$  the muon number is nearly equal to baryon abundance.

# Current-Conserving Relativistic Linear Response for Collisional Plasmas

## Publication Details

M. Formanek, C. Grayson, J. Rafelski, B. Müller    arXiv:2105.07897 [physics.plasm-ph]  
*Annals Phys.* **434** (2021) 168605    doi:10.1016/j.aop.2021.168605

## Abstract

A current-conserving relativistic linear response framework is developed for collisional plasmas applicable to the hot early Universe and to quark-gluon plasma in heavy-ion collisions. The approach satisfies the Ward identity exactly and incorporates collision damping, enabling self-consistent treatment of electromagnetic response in finite-temperature, finite-density relativistic matter.

# Cosmological Strangeness Abundance

## Publication Details

C.T. Yang, J. Rafelski arXiv:2108.01752 [hep-ph]

*Phys. Lett. B* **827** (2022) 136944 doi:10.1016/j.physletb.2022.136944

## Abstract

We investigate the strange particle composition of the expanding early Universe and examine freeze-out temperatures. The abundance of strange hadrons as a function of temperature is evaluated, and we follow the strangeness freeze-out processes as the Universe cools. The cosmological strangeness freeze-out is sensitive to strangeness-changing reactions and hadronic resonances.

# A Short Survey of Matter-Antimatter Evolution in the Primordial Universe

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## Publication Details

J. Rafelski, J. Birrell, A. Steinmetz, C.T. Yang    arXiv:2305.09055 [hep-th]  
*Universe* **9** (2023) no.7, 309    doi:10.3390/universe9070309

## Abstract

A 50-page review with novel results describing the role of antimatter in the early Universe. We characterize the epochs between the electroweak scale and Big Bang Nucleosynthesis, detailing antimatter annihilation, neutrino decoupling, and the impact on the cosmic microwave background and large-scale structure.

# Electron-Positron Plasma in BBN: Damped-Dynamic Screening

## Publication Details

C. Grayson, C.T. Yang, M. Formanek, J. Rafelski    arXiv:2307.11264 [astro-ph.CO]  
*Annals Phys.* **458** (2023) 169453    doi:10.1016/j.aop.2023.169453

## Abstract

We apply linear response theory to describe the inter-nuclear potential in the electron-positron plasma during Big Bang Nucleosynthesis. The damped-dynamic dielectric function is computed relativistically. Chemical potential and plasma damping rate affect the Coulomb interaction; results are incorporated into the relativistic Boltzmann equation to explore consequences for primordial light element synthesis.

# Matter-Antimatter Origin of Cosmic Magnetism

## Publication Details

A. Steinmetz, C.T. Yang, J. Rafelski    arXiv:2308.14818 [hep-ph]  
*Phys. Rev. D* **108** (2023) no.12, 123522    doi:10.1103/PhysRevD.108.123522

## Abstract

We propose a model of para-magnetization driven by the large matter-antimatter content of the early Universe. A fully spin-polarized single-flavor up-quark gas could generate cosmic magnetic fields in excess of  $10^{15}$  T. The required polarization to explain large-scale cosmic magnetic fields scales as  $1/T$  at high temperature and could be at the pico-scale.

# Quarks to Cosmos: Particles and Plasma in Cosmological Evolution

## Publication Details

J. Rafelski, J. Birrell, C. Grayson, A. Steinmetz, C.T. Yang arXiv:2409.19031

[hep-ph]

*Eur. Phys. J. ST* **234** (2025) no.7, 1125–1329

doi:10.1140/epjs/s11734-025-01470-w

## Abstract

We describe primordial properties and composition of the Universe in the temperature range  $130 \text{ GeV} > T > 20 \text{ keV}$  using the particle physics standard model and FLRW cosmology. A global view on particle content across time is presented via the deceleration parameter  $q$ . Quarks and gluons hadronize at  $T \simeq 150 \text{ MeV}$ ; baryonic antimatter disappears at  $T_B = 38.2 \text{ MeV}$ .

# Fermi-Dirac Integrals in Degenerate Regimes: Novel Asymptotic Expansion

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## Publication Details

J. Birrell, M. Formanek, A. Steinmetz, C.T. Yang, J. Rafelski arXiv:2405.05287  
*Int. J. Theor. Phys.* **63** (2024) no.7, 163 doi:10.1007/s10773-024-05695-8

## Abstract

We characterize the physical properties of the low-temperature Fermi gas in the degenerate domain. For the first time, results are obtained in the regime where several fermions occupy one de Broglie spatial cell, where the usual Sommerfeld expansion fails. A novel asymptotic expansion is derived; relative errors of all three approximate methods are quantified.

# Higgs Thermal Nonequilibrium in Primordial QGP

## Publication Details

C.T. Yang, S. Foster, J. Rafelski arXiv:2502.03598 [hep-ph]  
*Eur. Phys. J. ST* **234** (2025) no.10, 2907–2917  
doi:10.1140/epjs/s11734-025-01624-w

## Abstract

We investigate conditions under which the Higgs field departs from thermal equilibrium during the primordial quark-gluon plasma epoch. Higgs interaction rates are evaluated in the hot dense plasma; we identify the temperature window where Higgs boson number is no longer maintained by equilibrium processes. Implications for electroweak symmetry restoration and cosmological phase transitions are discussed.

# Weinberg Angle, Neutron Abundance in BBN, and Lifetime

## Publication Details

C.T. Yang, J. Rafelski    arXiv:2603.02652 [hep-ph] (2026)

## Abstract

We study the sensitivity of Big Bang Nucleosynthesis neutron abundance to the electroweak mixing angle (Weinberg angle). The weak interaction rates that govern the neutron-to-proton ratio at freeze-out depend on the Weinberg angle through both vector and axial-vector couplings. We evaluate how a variation from the standard-model value modifies the relic neutron abundance, and consequently the primordial helium-4 yield. The neutron lifetime and its current experimental status are also discussed.

# Radiation Reaction Friction: Resistive Material Medium

## Publication Details

M. Formanek, A. Steinmetz, J. Rafelski  
*Phys. Rev. D* **102** (2020) no.5, 056015

arXiv:2004.09634 [hep-ph]  
doi:10.1103/PhysRevD.102.056015

## Abstract

We derive radiation-reaction friction for a classical charged particle moving through a resistive material medium. Starting from microscopic Maxwell equations with finite conductivity, we obtain the modified Abraham-Lorentz-Dirac equation including medium-induced dissipation. The interplay between radiation reaction and material resistivity leads to novel dynamical regimes with implications for laser-driven particle acceleration.

# Motion of Classical Charged Particles with Magnetic Moment in Plane-Wave EM Fields

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## Publication Details

M. Formanek, A. Steinmetz, J. Rafelski    arXiv:2103.02594 [physics.class-ph]  
*Phys. Rev. A* **103** (2021) no.5, 052218    doi:10.1103/PhysRevA.103.052218

## Abstract

We study the classical dynamics of a charged particle with anomalous magnetic moment in an external plane-wave electromagnetic field. The Bargmann-Michel-Telegdi equation is solved alongside the Lorentz force equations. Parameter regimes are identified where the anomalous moment significantly modifies trajectory and spin evolution, with implications for precision measurements of electron and muon anomalous magnetic moments.

# Particle Production at a Finite Potential Step: From Euler-Heisenberg to Klein Paradox

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## Publication Details

S. Evans, J. Rafelski    arXiv:2108.12959 [hep-ph]

*Eur. Phys. J. A* **57** (2021) no.12, 341    doi:10.1140/epja/s10050-021-00654-x

## Abstract

We study particle production at a finite electrostatic potential step, interpolating between the Euler-Heisenberg Schwinger pair-production regime and the Klein paradox. The transition from perturbative to over-barrier behaviour is analysed as a function of step height and width. We identify a universal crossover scale and compare pair-production rates, providing a unified picture of strong-field particle creation.

# Emergence of Periodic-in-Magnetic-Moment Effective QED Action

## Publication Details

S. Evans, J. Rafelski arXiv:2203.13145 [hep-ph]

*Phys. Lett. B* **831** (2022) 137190 doi:10.1016/j.physletb.2022.137190

## Abstract

We study the non-perturbative effective action of QED in a constant background magnetic field when the gyromagnetic ratio  $g$  is a free parameter. A periodic structure in the magnetic moment emerges from the Euler-Heisenberg Lagrangian, opening new possibilities for probing QED beyond the standard perturbative expansion and providing insight into the vacuum structure in strong external fields.

# Dynamic Magnetic Response of the Quark-Gluon Plasma to Electromagnetic Fields

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## Publication Details

C. Grayson, M. Formanek, J. Rafelski, B. Mueller    arXiv:2204.14186 [hep-ph]  
*Phys. Rev. D* **106** (2022) no.1, 014011    doi:10.1103/PhysRevD.106.014011

## Abstract

We compute the dynamic magnetic response of the QGP to external electromagnetic fields using the current-conserving relativistic linear response framework. The frequency- and momentum-dependent magnetic permeability is evaluated as a function of temperature and quark chemical potential. Strong time-varying magnetic fields in peripheral heavy-ion collisions drive non-trivial magnetization dynamics observable in soft-photon and dilepton spectra.

# Singular Properties of QED Vacuum Response to Applied Quasi-Constant EM Fields

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## Publication Details

S. Evans, J. Rafelski    arXiv:2207.04033 [hep-ph] (2022)

## Abstract

We investigate singular properties of the QED effective action (Euler-Heisenberg-Schwinger) for quasi-static background electromagnetic fields, extending the analysis to regimes where the usual perturbative expansion breaks down. The structure of the singularities is mapped as a function of field strength. Physical consequences for pair production in near-critical fields and strong-field laser experiments are discussed.

# Study of QED Singular Properties for Variable Gyromagnetic Ratio $g \simeq 2$

## Publication Details

J. Rafelski, S. Evans, L. Labun arXiv:2212.13165 [hep-th]

*Phys. Rev. D* **107** (2023) 076002 doi:10.1103/PhysRevD.107.076002

## Abstract

We investigate singular properties of the QED effective action when the gyromagnetic ratio deviates from the Dirac value  $g = 2$ . For  $g \simeq 2$  we examine how quantum corrections modify the vacuum persistence amplitude and Schwinger pair-production rate. Analytic expressions for the perturbative expansion around  $g = 2$  are provided, with implications for precision QED tests and beyond-standard-model magnetic moments.

# Dynamic Fermion Flavor Mixing Through Transition Dipole Moments

## Publication Details

J. Rafelski, A. Steinmetz, C.T. Yang    arXiv:2309.15797 [hep-ph]  
*Int. J. Mod. Phys. A* **38** (2023) no.31, 2350163    doi:10.1142/S0217751X23501634

## Abstract

We show that Majorana neutrino flavor mixing can be driven by transition dipole moments in the presence of external electromagnetic fields. The sensitivity of the rotation mixing matrix to strong fields is demonstrated in the two-flavor model. The three-flavor case and extensions to the quark sector are introduced, opening a new framework for flavor oscillations in astrophysical environments with intense magnetic fields.

# Everlasting Interaction: Polarization Summation Without a Landau Pole

## Publication Details

S. Evans, J. Rafelski arXiv:2311.00891 [hep-ph]

*Phys. Rev. D* **110** (2024) no.3, 036012 doi:10.1103/PhysRevD.110.036012

## Abstract

We demonstrate that a careful all-orders resummation of photon self-energy insertions in QED is free of the Landau pole plaguing fixed-order perturbation theory. The dressed photon propagator remains finite at all energy scales when polarization contributions are properly summed, suggesting QED may be self-consistent to arbitrarily high energies.

# Comment on the Strong Magnetic Field Limit of the Heisenberg-Euler Effective Lagrangian

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## Publication Details

S. Evans, J. Rafelski    arXiv:2403.09745 [hep-ph] (2024)

## Abstract

We provide a critical comment on a recently claimed all-loop result for the strong-field limit of the Heisenberg-Euler effective Lagrangian. Issues in the derivation are identified and the correct asymptotic behaviour of the QED effective action in intense magnetic fields is discussed. Implications for the non-perturbative structure of the Euler-Heisenberg Lagrangian at large field strengths are clarified.

## Short Note on Spin Magnetization in QGP

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### Publication Details

A. Steinmetz, J. Rafelski arXiv:2502.05052 [hep-ph]

*Eur. Phys. J. ST* **234** (2025) no.10, 2919–2929

doi:10.1140/epjs/s11734-025-01625-9

### Abstract

We outline the theory of spin magnetization applicable to the QGP epoch of the Universe. A fully spin-polarized single-flavor up-quark gas could generate cosmic magnetic fields in excess of  $10^{15}$  T. The complete multi-component ferro-magnetized primordial fermion gas consists of five nearly free charged quarks and leptons. Results at 150–500 MeV are also relevant to laboratory QGP experiments.

# Covariant Cherenkov Radiation and Its Friction Force

## Publication Details

W. Price, M.S. Formanek, J. Rafelski    arXiv:2603.01636 [hep-ph] (2026)  
doi:10.1103/x81q-1b3v

## Abstract

We develop a manifestly covariant treatment of Cherenkov radiation emitted by a charged particle moving through a dispersive medium at superluminal phase velocity. The friction force arising from the emission is derived in a Lorentz-covariant manner. The formalism is applied to charged particles in dense plasmas and dielectric media, with implications for radiation-reaction dynamics and energy loss in relativistic collisions.

# Radiation Reaction and Limiting Acceleration

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## Publication Details

W. Price, M. Formanek, J. Rafelski    arXiv:2112.04444 [hep-ph]  
*Phys. Rev. D* **105** (2022) no.1, 016024    doi:10.1103/PhysRevD.105.016024

## Abstract

We investigate radiation reaction in the context of a maximal (limiting) acceleration principle. The Abraham-Lorentz-Dirac equation is analysed to determine whether self-force effects can enforce an upper bound on the acceleration of a classical charged particle. The interplay between external forces and radiation reaction friction sets limits on achievable accelerations, with implications for laser-driven acceleration and strong-field QED.

# Born-Infeld Nonlinear Electromagnetism in Relativistic Heavy Ion Collisions

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## Publication Details

W. Price, M. Formanek, J. Rafelski    arXiv:2306.07704 [nucl-th]  
*Acta Phys. Polon. A* **143** (2023) S87    doi:10.12693/APhysPolA.143.S87

## Abstract

We study the role of Born-Infeld nonlinear electrodynamics in the extreme electromagnetic fields of peripheral relativistic heavy-ion collisions. The Born-Infeld modification introduces a maximum field strength and changes the field distribution around fast-moving ions. The impact on dilepton and photon production, and on the initial-state magnetic field relevant for chiral magnetic effects, is evaluated.

# Superheavy Elements and Ultradense Matter

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## Publication Details

E. LaForge, W. Price, J. Rafelski arXiv:2306.11989 [nucl-th]

*Eur. Phys. J. Plus* **138** (2023) no.9, 812 doi:10.1140/epjp/s13360-023-04454-8

## Abstract

We explore the nuclear and electronic structure of superheavy elements ( $Z \gg 100$ ) and their relation to ultradense matter. In extreme nuclear environments electron orbitals dive into the Dirac sea, producing spontaneous positron emission – originally predicted by Rafelski, Müller, and Greiner. We revisit this physics with modern nuclear structure input and discuss observational prospects at current and planned heavy-ion facilities.

# Self-Consistent Strong Screening Applied to Thermonuclear Reactions

## Publication Details

C. Grayson, C.T. Yang, M. Formanek, J. Rafelski    arXiv:2406.13055 [nucl-th]  
*Astrophys. J.* **976** (2024) no.1, 31    doi:10.3847/1538-4357/ad7dee

## Abstract

We apply damped-dynamic dielectric screening to thermonuclear reactions in stellar interiors and in Big Bang Nucleosynthesis. Self-consistent treatment of Coulomb screening modifies the effective Gamow peak and fusion cross sections. Medium screening corrections have a measurable effect on primordial light-element abundances and on hydrogen burning rates in main-sequence stars.

# Nuclear Fusion Enhancement by Heavy Nuclear Catalysts

## Publication Details

C. Grayson, J. Rafelski arXiv:2502.07804 [physics.plasm-ph]  
*Eur. Phys. J. ST* **234** (2025) no.10, 2967–2977  
doi:10.1140/epjs/s11734-025-01623-x

## Abstract

We investigate enhancement of thermonuclear fusion reactions through catalysis by heavy nuclei embedded in a dense plasma. The presence of a heavy nuclear charge modifies the screening environment and the effective Coulomb barrier seen by reacting light nuclei. Enhancement factors are computed as a function of plasma temperature and density, with implications for laboratory fusion devices and stellar nucleosynthesis.

# Molecular ${}^9\text{Be} + p$ Fusion Reaction

## Publication Details

J. Rafelski, B. Müller arXiv:2503.00023 [physics.app-ph]

*Eur. Phys. J. ST* **234** (2025) no.10, 2957–2966

doi:10.1140/epjs/s11734-025-01626-8

## Abstract

We study the molecular-assisted fusion reaction  ${}^9\text{Be} + p$  in the context of table-top nuclear fusion using optoelectronic targets. Molecular binding modifies the effective nuclear interaction distance and tunnelling probability through the Coulomb barrier. Enhanced fusion cross sections are evaluated as a function of molecular configuration and collision energy.

# Cold Atoms in Space: Community Workshop Summary and Proposed Road-Map

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## Publication Details

I. Alonso, C. Alpigiani, . . . , J. Rafelski    arXiv:2201.07789 [astro-ph.IM]  
*EPJ Quantum Technol.* **9** (2022) no.1, 30    doi:10.1140/epjqt/s40507-022-00147-w

## Abstract

This community paper summarises a workshop on cold-atom physics in space, covering matter-wave interferometry for gravitational-wave detection, dark-matter searches, equivalence principle tests, and measurement of fundamental constants. A road-map for future space missions exploiting ultra-cold atom technology is proposed.

# Improving Euler-Heisenberg-Schwinger Effective Action with Dressed Photons

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## Publication Details

S. Evans, J. Rafelski arXiv:2306.07887 [hep-ph]

*Acta Phys. Polon. A* **143** (2023) S13 doi:10.12693/APhysPolA.143.S13

## Abstract

We propose an improvement to the Euler-Heisenberg-Schwinger effective action by dressing the photon propagator with self-energy insertions. The dressed photon resums an infinite class of loop diagrams and modifies the pair-production threshold and rate in strong background fields, providing a more physical description of QED in near-critical fields.

# Homage to Harald Fritzsch

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## Publication Details

J. Rafelski

*Int. J. Mod. Phys. A* **39** (2024) no.09n10, 2441018

doi:10.1142/S0217751X24410185

## Abstract

This contribution pays homage to Harald Fritzsch (1943–2022), one of the founding fathers of quantum chromodynamics. We recall Fritzsch's seminal work with Gell-Mann on the quark model and the development of QCD, and reflect on his contributions to our understanding of hadronic matter, quark masses, and the strong interaction, with personal recollections from a long-time colleague.

# Terrestrial Very-Long-Baseline Atom Interferometry: Workshop Summary

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## Publication Details

S. Abend, B. Allard, . . . , J. Rafelski    arXiv:2310.08183 [hep-ex]  
*AVS Quantum Sci.* **6** (2024) no.2, 024701    doi:10.1116/5.0185291

## Abstract

This paper summarises the first TVLBAI workshop. Proposals for multi-km baseline atom interferometers are reviewed, targeting detection of mid-frequency gravitational waves, searches for ultralight dark matter, and precision tests of general relativity. Scientific case, experimental design, and required technology development are assessed.

# Terrestrial Very-Long-Baseline Atom Interferometry: Second Workshop Summary

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## Publication Details

A. Abdalla, M. Abe, . . . , J. Rafelski    arXiv:2412.14960 [hep-ex]  
*EPJ Quantum Technol.* **12** (2025) no.1, 42    doi:10.1140/epjqt/s40507-025-00344-3

## Abstract

The second TVLBAI workshop further developed the scientific programme and technical specifications for terrestrial very-long-baseline atom interferometers. Progress on prototype experiments, systematic error mitigation, and site selection is reported. Updated sensitivity projections for gravitational-wave detection in the 0.1–10 Hz band and for dark-matter searches are presented.

# Higgs in the Cosmos

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## Publication Details

J. Rafelski, C.T. Yang arXiv:2503.03224 [hep-ph]  
*PoS QCHSC24* (2025) 246 doi:10.22323/1.483.0246

## Abstract

We examine the role of the Higgs field in cosmological evolution, focusing on the primordial epoch when the Higgs boson was thermally abundant. The Higgs contribution to energy density, pressure, and equation of state is evaluated as a function of temperature. Implications for the electroweak phase transition, baryogenesis, and the thermal history from the Higgs scale down to Big Bang Nucleosynthesis are discussed.

# Long-Baseline Atom Interferometry

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## Publication Details

A. Balaž *et al.* [TVLBAI Proto]    arXiv:2503.21366 [hep-ex] (2026)

## Abstract

This paper presents the status and scientific prospects of long-baseline atom interferometry projects. Scientific targets include gravitational-wave astronomy in the mid-frequency band, searches for dark-matter candidates, and fundamental tests of quantum mechanics and general relativity. Prototype detector design, sensitivity projections, and complementarity with other gravitational-wave observatories are discussed.

# Isospin-Symmetry Violation – Kaons and Beyond (ISO-BREAK 25)

## Publication Details

M. Gazdzicki, F. Giacosa, . . . , J. Rafelski    arXiv:2604.16005 [nucl-ex] (2026)

## Abstract

This contribution summarises the ISO-BREAK 25 symposium on isospin-symmetry violation in hadronic systems. The focus is kaon production anomalies in proton-nucleus and nucleus-nucleus collisions. The role of isospin-breaking in QCD, signatures in strangeness observables, and prospects for future measurements at NA61/SHINE are reviewed. Connections to strangeness as a signature of quark-gluon plasma are highlighted.

## **Books Published in This Period**

### **Hadrons and Quark-Gluon Plasma (Open Online Republication)**

J. Letessier, J. Rafelski

Cambridge University Press, 2022    doi:10.1017/9781009290753

ISBN 978-1-009-29075-3

Open-access republication of the year-2000 text, making the foundational treatment of statistical hadronization and quark-gluon plasma freely available to the community.

### **Modern Special Relativity: A Student's Guide with Discussions and Examples**

J. Rafelski

Springer, 2022    doi:10.1007/978-3-030-54352-5

ISBN 978-3-030-54351-8

A pedagogical textbook introducing special relativity with discussions and worked examples, aimed at upper-division undergraduates and beginning graduate students.

A photograph of two men sitting at a table. The man on the left is older, with glasses, wearing a dark jacket over a striped shirt. The man on the right is younger, also with glasses, wearing a blue sweater and a lanyard with a badge. They are in a room with a window in the background showing trees. A text box is overlaid on the image.

**Wishing Tamas all the best in  
coming hard working decade**

**BTSLXX Symposium  
Budapest, June 11, 2026**