

Uncovering Quantum Field Theory and the Standard Model

From Fundamental Concepts to Dynamical Mechanisms

with Uwe-Jens Wiese, University of Bern, Switzerland

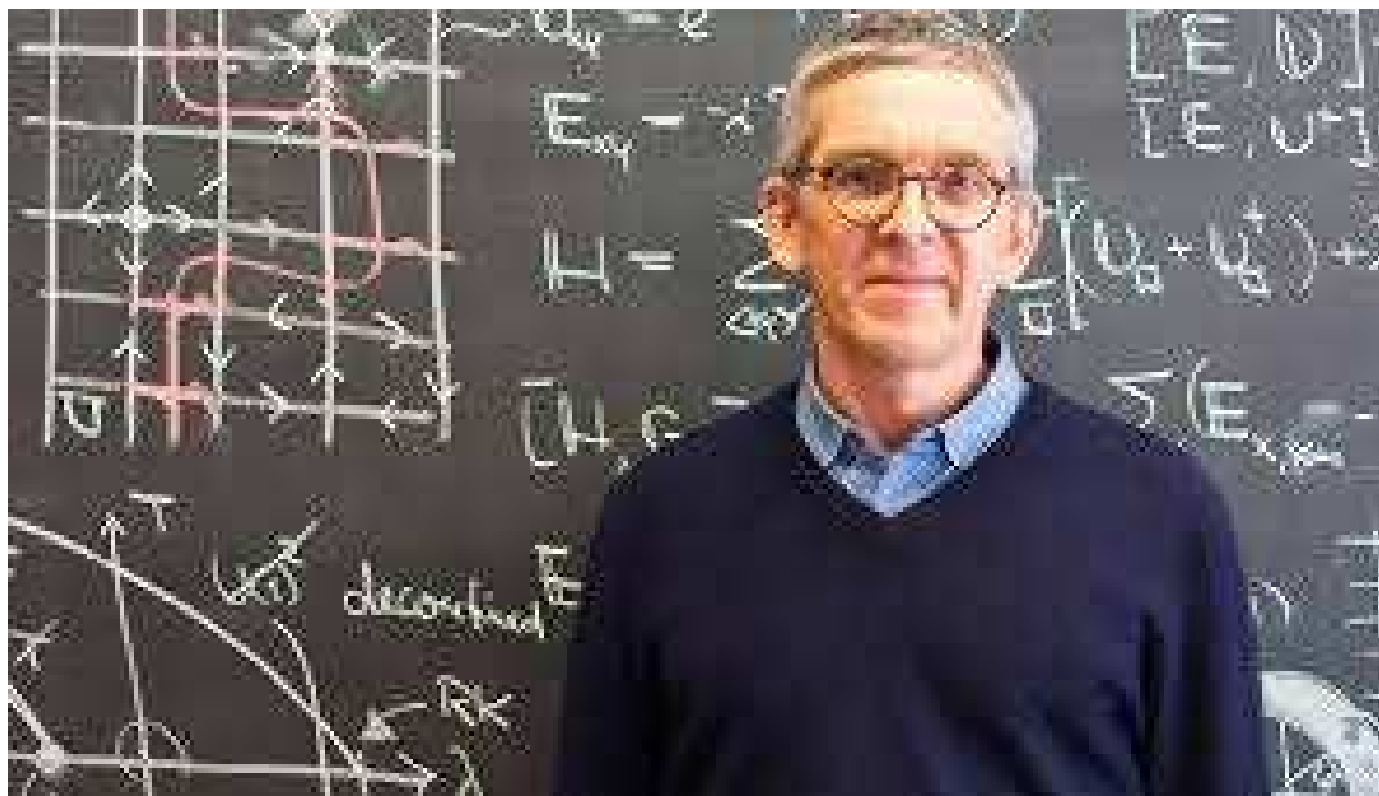
First textbook about particles and fields with an author working in Mexico (second in Latin America)

[H. Nastase (Romanian in São Paulo): “Introduction to QFT”, 2019]

Respect for the Standard Model: Most precise scientific theory!

Origin: Lecture notes by Uwe-Jens from Aachen, 1992

Start for me in Berlin: visit by Uwe-Jens in September 2003, walk near the Brandenburg Gate, agreement to convert it into a joint textbook project.



Uwe-Jens Wiese in his office in Bern

Sporadic progress during > 10 years, in 2009 I moved to Mexico

Sabbatical semester in Bern, 2016/7 (bad luck: stolen laptop).

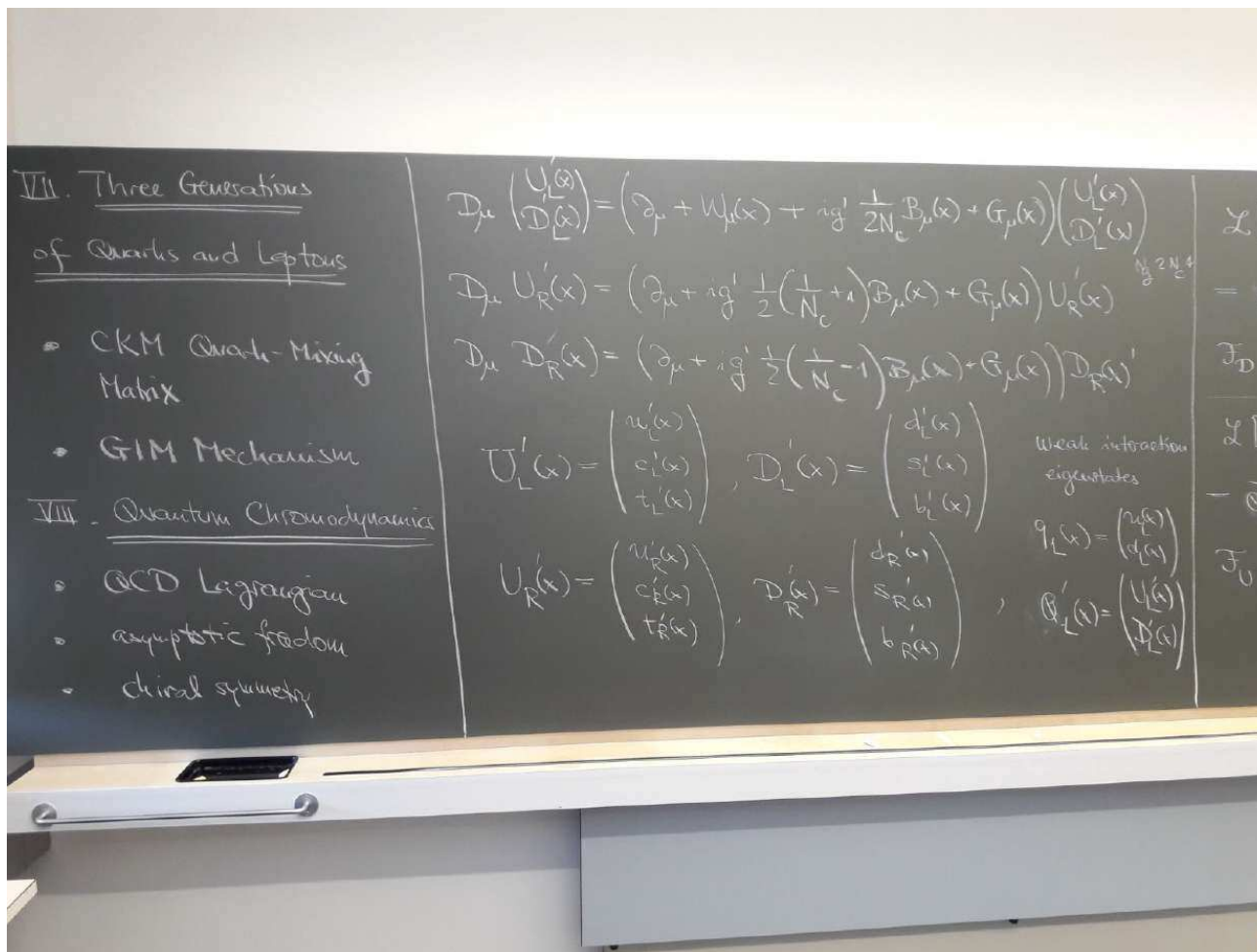
Book proposal sent to *Cambridge University Press*,
5 chapters and one appendix. Approved by 6 referees.
Contract: Maximum of 600 pages, deadline: July 1, 2028.

Another sabbatical semester in Bern, summer 2018

Progress, but distraction with new research projects,
termination still behind the horizon.

More theory and concepts than phenomenology

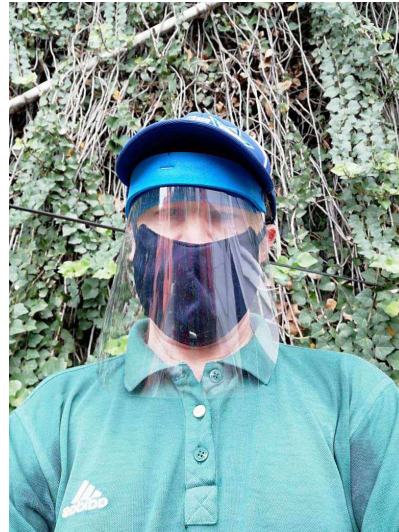
Focus on non-perturbative perspective \neq previous literature



Discussion about fermion generations (Chapter 17).

Upon request, we included gauge fixing, but not SUSY.

Pandemics:



Frequent video calls

Uwe-Jens: Intense work, *e.g.* on canonical fermion fields.

Helpful comments on specific chapters by *Oliver Bär*, Debasish Banerjee, *Detlev Buchholz*, *Wilfried Buchmüller*, Klaus Fredenhagen, *Urs Gerber*, *Carlo Giunti*, Kieran Holland, Gurtej Kanwar, *Martin Lüscher*, Alessandro Mariani, *Colin Morningstar*, *Mike Peardon*, Michele Pepe, João Pinto Barros, *Lilian Prado*, Simona Procacci, Christopher Smith, *Rainer Sommer*, Youssef Tammam, Christiane Tretter, *Christof Wetterich*, *Edward Witten*.

Early version: conceptual introduction of 14 pages. Martin Lüscher: reader who does not know *e.g.* gauge theory gets lost very soon. We only assume previous knowledge of Quantum Mechanics and Special Relativity.

New structure: **Ouverture, Intermezzo, Finale**

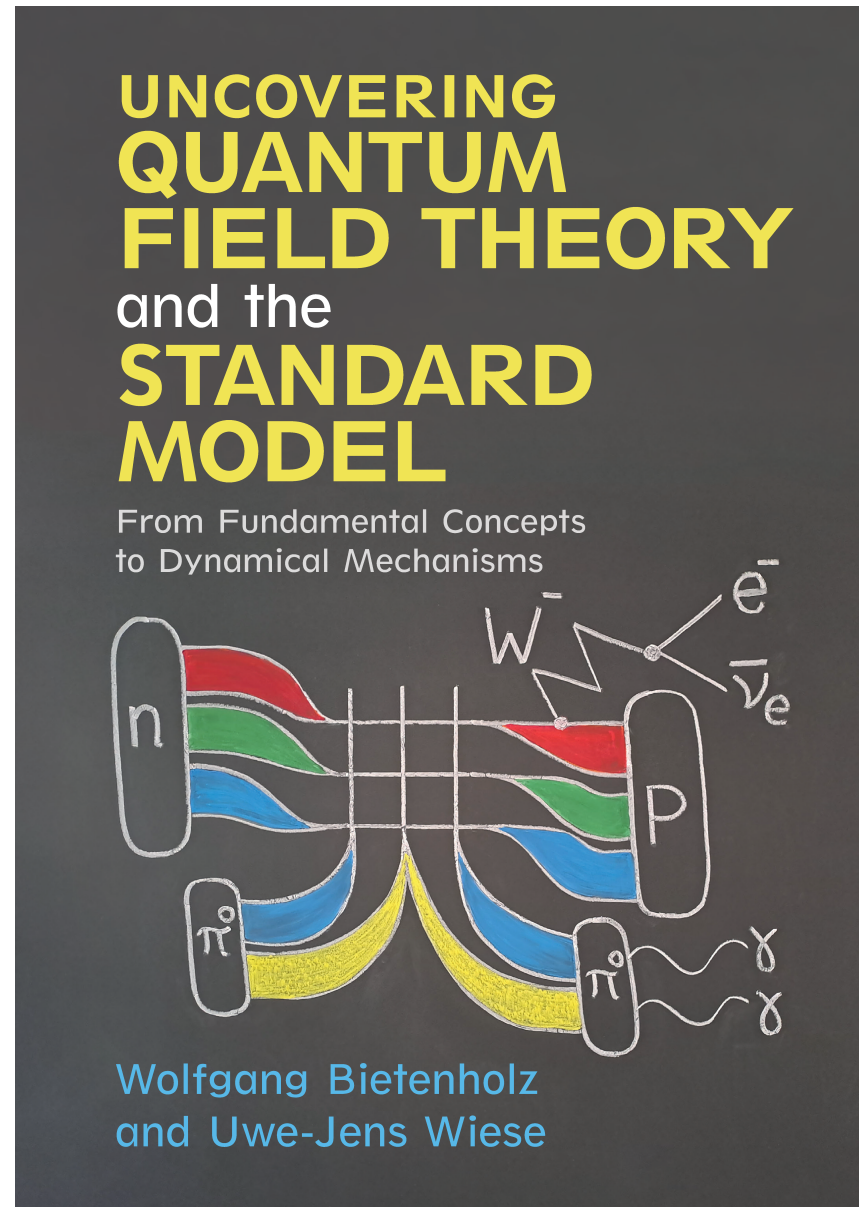
26 Chapters is 4 Parts: Link to “Le quattro stagioni” by Antonio Vivaldi [QFT, SM, Strong Interaction, Beyond SM]. ~ 3 semesters

Finally submitted in December 2022, “takes on average 9 months”, hope for it to be faster, since we used the Cambridge style file throughout.

No way: summer 2023: edited pdf with $O(10^4)$ modifications (lots of commas, some errors, a few corrections: “Klein-Gordon” vs. “Clebsch-Gordan”), convergence after some cycles of revision.

We thank *Sunantha Ramamoorthy*, competent and cooperative, but she could not avoid a strange last-minute change of fonts (exponents, indices etc. displaced). Reduction from 772 to 732 pages.

Cover page: chalk drawing of β^- - and π^0 -decay, by *Nadiia Vlasii*



Ranking of the most frequent names in the authors index:

10 entries: Callen, Lüscher, 't Hooft, Wilczek

9 entries: Weinberg

7 entries: Einstein, Feynman, Wilson

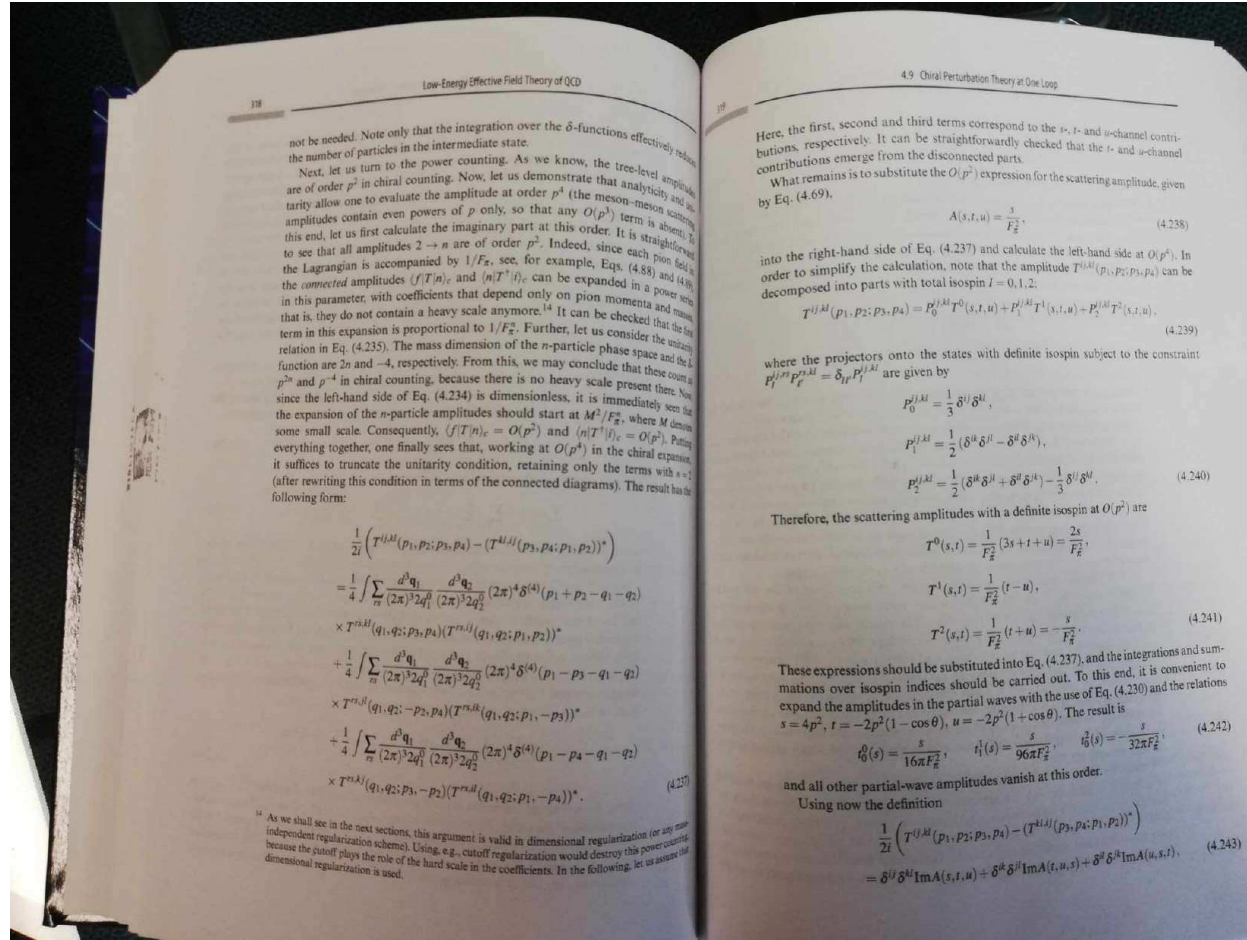
(Referee: “Wilson could have written such a book, but . . .”)

6 entries: Gross, Leutwyler, Witten

5 entries: Hasenfratz, Pauli, Schwinger

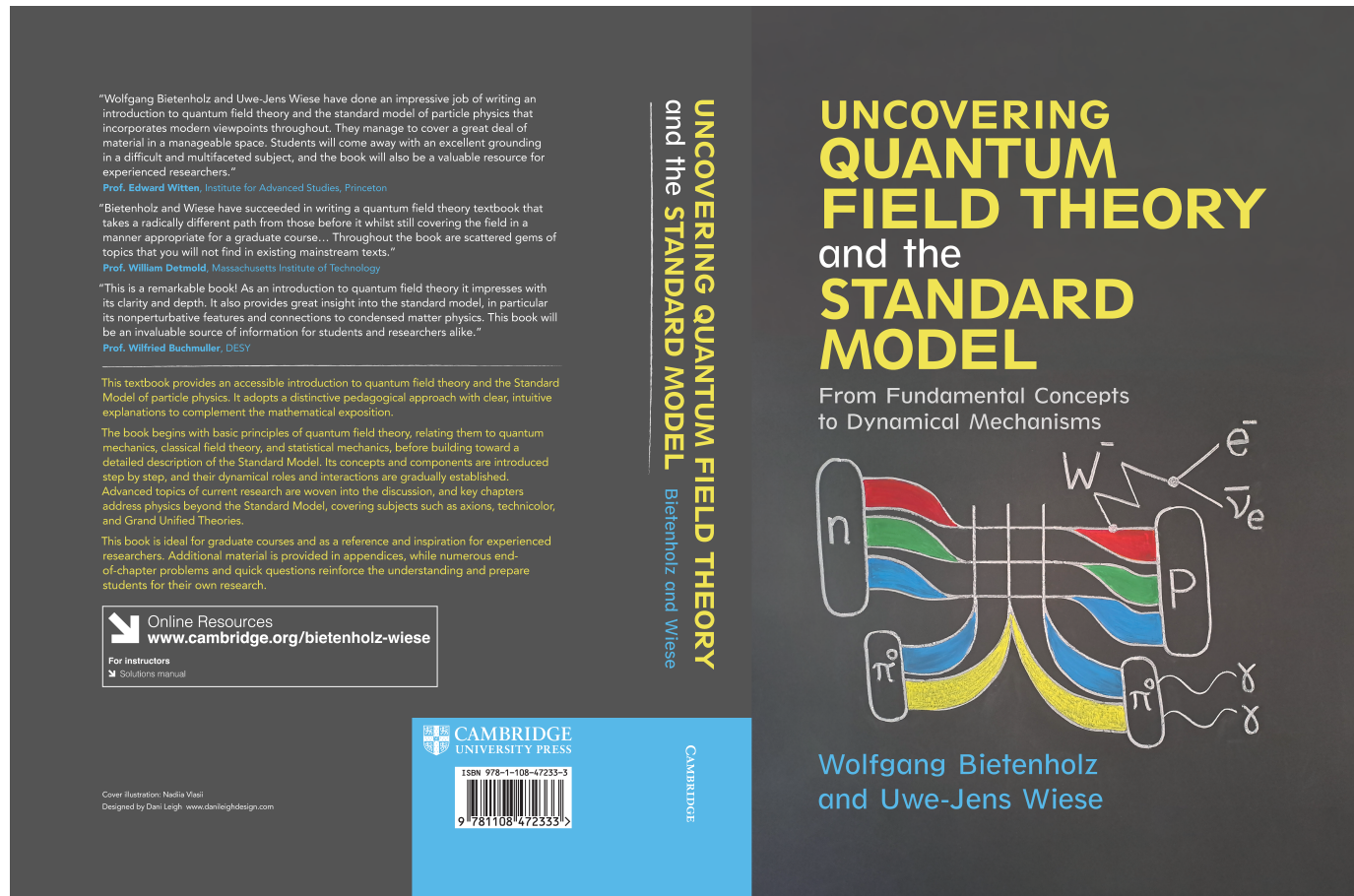
4 entries: Bogoliubov, Coleman, Dashen, Dirac, Gasser, Gell-Mann,
Glashow, Niedermayer, Politzer, Polyakov, Symanzik,
Wess, Yang, Zimmermann, Zinn-Justin, Zumino

Meißner-Rusetsky problem:



U.-G. Meißner, A. Rusetsky, "Effective Field Theories", Cambridge University Press, 2022.
Christian Schubert: Must be related to *Fermat's Last Theorem*.

Confusion about the endorsers, at last 5 very positive statements



Recommendations by Edward Witten (Princeton), William Detmold (MIT), Wilfried Buchmüller (DESY), Poul Damgaard (Niels Bohr Inst.), Tereza Mendes (U. São Paulo)

A gluon string could hold a mass of 20,000 kg, like a steel cable with a diameter of some cm, but $\sim 10^{13}$ times thinner.

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Gluons: From Confinement to Deconfinement

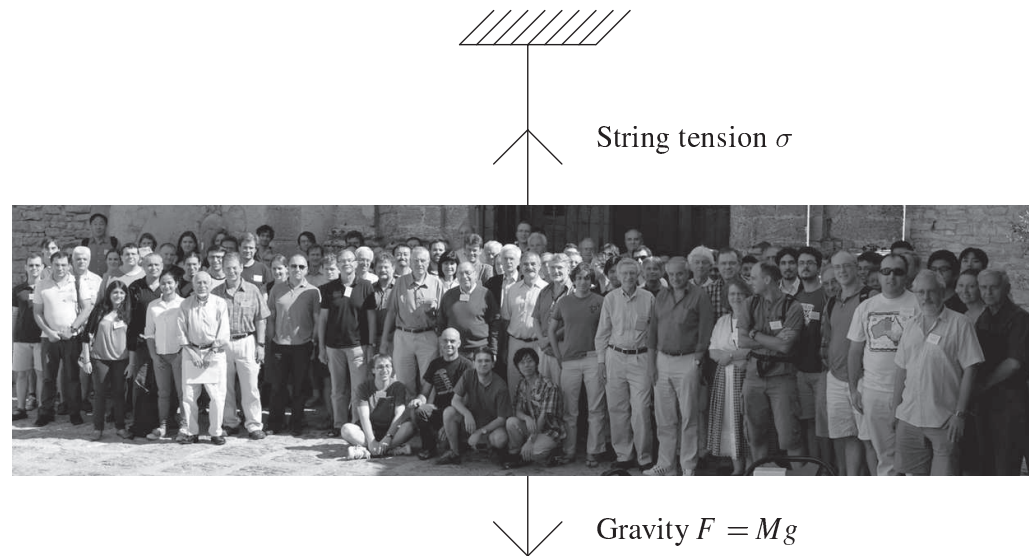


Fig. 14.4 A single Yang–Mills string is strong enough to support more than 100 people. A “Yang–Mills elevator” was installed by one of the authors as a Gedankenexperiment at the Erice workshop “From Quarks and Gluons to Hadrons and Nuclei” in 2011, in order to “elevate” our intuitive understanding for the strength of the strong force (Wiese, 2012).

Quick Question 14.6.1 Overloaded Yang–Mills elevator

What happens when about 1000 (adult) people enter the Yang–Mills elevator?

14.7 Roughening Transition

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The string tension has been computed to high orders of the strong coupling expansion. The resulting contributions are associated with plaquette surfaces that are deformations of the

2024: announced by Cambridge University Press for January, then February ... inductive until June.

Summer 2024: editorial paralyzed by a cyber attack.
Sad news: Sunantha died, substituted by Shanthi Jaganathan.

Promised for November, then December, finally published on January 2, 2025.

Happy ending, once in a lifetime event!

Last chapter about Grand Unified Theories (GUT):

Ende GUT, alles gut!

Up to now (in < 5 months) 638 times sold

Internet: $\langle \text{selling of acad. books} \rangle \approx 500 \dots 1000$

Part I: QUANTUM FIELD THEORY

Overture: Concepts of Quantum Field Theory

Point Particles versus Fields at the Classical Level

Particles versus Waves in Quantum Theory

Classical and Quantum Gauge Fields

Ultraviolet Divergences, Regularization, and Renormalization

Euclidean Quantum Field Theory versus Classical Statistical Mechanics

1 Basics of Quantum Field Theory

1.1 From Point Particle Mechanics to Classical Field Theory

1.2 Quantum Mechanical Path Integral

1.3 Path Integral in Euclidean Time

1.4 Spin Models in Classical Statistical Mechanics

1.5 Quantum Mechanics versus Classical Statistical Mechanics

1.6 **Transfer Matrix**

1.7 **Lattice Field Theory**

2 **Scalar Field Theory and Canonical Quantization**

2.1 Scalar Fields

2.2 Noether Current

2.3 From the Lagrangian to the Hamilton Density

2.4 Commutation Relations for the Scalar Field Operators

2.5 Hamilton Operator in Scalar Field Theory

2.6 Vacuum State and Vacuum Energy

2.7 **Cosmological Constant Problem**

2.8 Particle States and their Energies and Statistics

2.9 Momentum Operator

3 **From Particles to Wavicles and Back**

3.1 **Model for Ions Forming a Crystal**

- 3.2 Phonon Creation and Annihilation Operators
- 3.3 Quantum States of a Vibrating Crystal
- 3.4 Phonons as Wavicles
- 3.5 Explicit Breaking of Continuous Translation Symmetry
- 3.6 Debye Field Theory of the Vibrating Solid
- 3.7 From Wavicles Back to Particles
- 3.8 **What is Space?**

4 Perturbative Scalar Field Functional Integral in Dimensional Regularization

- 4.1 From Minkowski to Euclidean Space–Time
- 4.2 Euclidean Propagator and Contraction Rule
- 4.3 **Perturbative Expansion** of the Functional Integral
- 4.4 **Dimensional Regularization**
- 4.5 2-Point Function to 1 Loop
- 4.6 Mass Renormalization

- 4.7 Connected, Disconnected, and 1-Particle Irreducible Diagrams
- 4.8 Feynman Rules for the $\lambda\phi^4$ Model
- 4.9 4-Point Function to 1 Loop
- 4.10 Dimensional Regularization of $J(p^2)$
- 4.11 Renormalization of the Coupling
- 4.12 Renormalizability of Scalar Field Theories
- 4.13 Condition for Renormalizability

5 Renormalization Group

- 5.1 Locality and Hierarchies of Energy Scales
- 5.2 **Renormalization Group Blocking and Fixed Points**
- 5.3 Gaussian Fixed Points of Lattice Scalar Field Theory
- 5.4 Blocking from the Continuum to the Lattice
- 5.5 **Perfect Lattice Actions** on the Renormalized Trajectory
- 5.6 Wilson–Fisher Fixed Points
- 5.7 Renormalization of Scalar Field Theory in a Cut-off Regularization

5.8 Callan–Symanzik Equation

5.9 β -Function and Anomalous Dimension to 1 Loop

5.10 Running Coupling

5.11 Infrared and Ultraviolet Fixed Points

6 Quantization of the Free Electromagnetic Field

6.1 Vector Potential and Gauge Symmetry

6.2 From the Lagrangian to the Hamilton Density

6.3 Hamilton Operator for the Photon Field

6.4 Gauss Law

6.5 Vacuum and Photon States

6.6 Momentum Operator of the Electromagnetic Field

6.7 Angular Momentum Operator and Helicity of Photons

6.8 **Planck's Formula and the Cosmic Background Radiation**

6.9 Gauge Fixing and Photon Propagator

7 Charged States in Scalar Quantum Electrodynamics

- 7.1 Complex Scalar Field with Global $U(1)$ Symmetry
- 7.2 Scalar Quantum Electrodynamics
- 7.3 Charged Particles as **Infraparticles**
- 7.4 Superselection Sectors
- 7.5 Charged Particles in a Periodic Volume
- 7.6 C-periodic Boundary Conditions

8 Canonical Quantization of Free Weyl, Dirac, and Majorana Fermions

- 8.1 Massless **Weyl Fermions**
- 8.2 Momentum, Angular Momentum, and Helicity of Weyl Fermions
- 8.3 Fermion Number, Parity, and Charge Conjugation
- 8.4 Cosmic Background Radiation of Neutrinos
- 8.5 Massive Dirac Fermions
- 8.6 Massive Majorana Fermions

8.7 Massive Weyl Fermions

8.8 **Redundant Particle Labels** and the Pauli Principle as
a “Gauss Law”

8.9 **Can We Supersede Gauge Symmetry?**

9 Fermionic Functional Integrals

9.1 **Grassmann Algebra**, Pfaffian, and Fermion Determinant

9.2 Dirac Equation

9.3 Weyl and Majorana Equations

9.4 Euclidean Fermionic Functional Integral

9.5 Euclidean Lorentz Group

9.6 Charge Conjugation, Parity, and Time Reversal for Weyl Fermions

9.7 C, P, and T Transformations of Dirac Fermions

9.8 CPT Invariance in Relativistic Quantum Field Theory

9.9 Connections between **Spin and Statistics**

9.10 Euclidean Time Transfer Matrix

10 Chiral Symmetry in the Continuum and on the Lattice

10.1 Chiral Symmetry in the Continuum

10.2 **Lattice Fermion Doubling Problem**

10.3 Nielsen–Ninomiya No-Go Theorem

10.4 Absence of Neutrinos on a Lattice

10.5 Wilson Fermions

10.6 Perfect Lattice Fermions and the **Ginsparg–Wilson Relation**

10.7 Overlap Fermions

11 Non-Abelian Gauge Fields

11.1 Non-Abelian Gauge Fields at the Classical Level

11.2 Gauge Fixing and Faddeev–Popov Ghosts

11.3 Becchi–Rouet–Stora–Tyutin Symmetry

11.4 Nilpotency and BRST Cohomology

11.5 Aharonov–Bohm Effect as an Analogue of BRST Cohomology

11.6 Lattice Gauge Theory

11.7 Canonical Quantization of Compact $U(1)$ Lattice Gauge Theory

11.8 Canonical Quantization of Non-Abelian Lattice Gauge Theory

11.9 Functional Integral for Compact $U(1)$ Lattice Gauge Theory

11.10 Functional Integral for Non-Abelian Lattice Gauge Theory

Part II: CONSTRUCTION OF THE STANDARD MODEL

Intermezzo: Concepts of the Standard Model

The Standard Model: A Non-Abelian Chiral Gauge Theory

Renormalizability of Non-Abelian Gauge Theories

Triviality and Incorporation of Gravity

Fundamental Standard Model Parameters

Hierarchies of Scales and Approximate Global Symmetries

Local and Global Symmetries

Explicit versus Spontaneous Symmetry Breaking

Anomalies in Local and Global Symmetries

Power of Lattice Field Theory

12 Spontaneous Breakdown of Global Symmetries: From Condensed Matter to Higgs Bosons

12.1 Effective Scalar Fields for Cold Condensed Matter

12.2 Vacua in the $\lambda|\Phi|^4$ Model

12.3 Higgs Doublet Model

12.4 Goldstone Theorem

12.5 Mermin–Wagner–Hohenberg–Coleman Theorem

12.6 Low-Energy Effective Field Theory

12.7 Hierarchy Problem

12.8 Solving the Hierarchy Problem with Supersymmetry?

12.9 Is Nature Natural?

12.10 Triviality of the Standard Model

12.11 Electroweak Symmetry Restoration at High Temperature

12.12 Extended Model with **Two Higgs Doublet**

13 Local Symmetry and the Higgs Mechanism: From Superconductivity to Electroweak Gauge Bosons

13.1 Higgs Mechanism in Scalar Electrodynamics

13.2 Higgs Mechanism in the Electroweak Theory

13.3 Identification of the Electric Charge

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13.5 Variants of the Standard Model with Modified Gauge Symmetry

13.6 Scalar Electrodynamics on the Lattice

13.7 $SU(2)_L$ Gauge-Higgs Model on the Lattice

13.8 **Small Electroweak Unification**

13.9 Electroweak Symmetry Breaking in an $SU(3)$ Unified Theory

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- 14.2 Quark Confinement and the Wegner–Wilson Loop
- 14.3 Character Expansion and Group Integration
- 14.4 Strong Coupling Limit of Lattice Yang-Mills Theory
- 14.5 Asymptotic Freedom and Natural Continuum Limit
- 14.6 **How Strong is the Strong Force?**
- 14.7 Roughening Transition
- 14.8 Systematic Low-Energy Effective String Theory
- 14.9 **Lüscher Term as a Casimir Effect**
- 14.10 Cosmological Constant Problem on the String World-Sheet
- 14.11 **Gluon Confinement** and the Fredenhagen–Marcu Operator
- 14.12 **Glueball Spectrum**
- 14.13 Polyakov Loop and Center Symmetry
- 14.14 Deconfinement at High Temperatures
- 14.15 Exceptional Confinement and Deconfinement in
 $G(2)$ Yang-Mills Theory

15 One Generation of Leptons and Quarks

- 15.1 Electron and Left-Handed Neutrino
- 15.2 CP and T Invariance of Gauge Interactions
- 15.3 Fixing the Lepton Weak Hypercharges
- 15.4 Triangle **Gauge Anomalies** in the Lepton Sector
- 15.5 Witten's Global $SU(2)_L$ Gauge Anomaly in the Lepton Sector
- 15.6 Up and Down Quarks
- 15.7 **Anomaly Cancellation between Leptons and Quarks**
- 15.8 Electric Charges of Quarks and Baryons
- 15.9 Anomaly Matching
- 15.10 **Right-Handed Neutrinos**
- 15.11 Lepton and Baryon Number Anomalies
- 15.12 Gauge Anomaly-Free **Technicolor Model**

16 Fermion Masses

16.1 Electron and Down Quark Masses

16.2 Up Quark Mass

16.3 **Neutrino Mass from a Dimension-5 Operator**

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16.9 **Seesaw Mass-by-Mixing Mechanism**

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16.11 Lepton–Baryon Mixing for $N_c = 1$

17 Several Generations and Flavor Physics of Quarks and Leptons

- 17.1 Electroweak versus Mass Eigenstates
- 17.2 Generation-Specific Lepton Numbers and Lepton Universality
- 17.3 **Cabibbo-Kobayashi–Maskawa Quark Mixing Matrix**
- 17.4 Flavor-Changing Neutral Currents and the GIM Mechanism
- 17.5 CP Violation with Neutral Kaons and B -Mesons
- 17.6 **Pontecorvo-Maki-Nakagawa-Sakata Lepton Mixing Matrix**
- 17.7 Neutrino Oscillations
- 17.8 **Overview of Fundamental Standard Model Parameters**
- 17.9 Low-Energy Theory Perspective on the Standard Model Physics

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- 18.2 Asymptotic Freedom

- 18.3 Structure of Chiral Symmetry
- 18.4 Dynamical Realization of Chiral Symmetry
- 18.5 Lattice QCD
- 18.6 Ginsparg-Wilson Relation and **Lüscher's Lattice Chiral Symmetry**
- 18.7 Under-Appreciated **Fermionic Hierarchy Problem**
- 18.8 Domain Wall Fermions and a Fifth Dimension of Space-Time

19 Topology of Gauge Fields

- 19.1 Adler-Bell-Jackiw Anomaly
- 19.2 Topological Charge
- 19.3 Topology of a Gauge Field on a Compact Manifold
- 19.4 **SU(2) Instanton**
- 19.5 **θ -Vacuum States**
- 19.6 Analogy with **Energy Bands in a Periodic Crystal**
- 19.7 Some Questions Related to θ
- 19.8 **Atiyah-Singer Index Theorem**

19.9 Zero-Mode of the $SU(2)$ Instanton

19.10 **Index Theorem on the Lattice**

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20.2 QCD in the Large- N_c Limit

20.3 **Witten–Veneziano Formula for the η' -Meson Mass**

20.4 Topological Susceptibility from Lattice Gauge Theory

21 Spectrum of Light Baryons and Mesons

21.1 Isospin Symmetry

21.2 Nucleon and Δ -Isobar

21.3 Anti-Quarks and Mesons

21.4 Strange Hadrons

21.5 Gell-Mann–Okubo Baryon Mass Formula

- 21.6 Meson Mixing
- 21.7 Hadron Spectrum from Lattice QCD
- 21.8 **Hadrons for $N_c = 5$**

22 Partons and Hard Processes

- 22.1 Electron-Positron Annihilation into Hadrons
- 22.2 **R -Ratio as Evidence for $N_c = 3$**
- 22.3 Deep-Inelastic Electron-Nucleon Scattering
- 22.4 Deep-Inelastic Neutrino-Nucleon Scattering
- 22.5 Sum Rules

23 Chiral Perturbation Theory

- 23.1 **Effective Theory for Pions, Kaons, and the η -Meson**
- 23.2 Masses of Pseudo-Nambu–Goldstone Bosons
- 23.3 Low-Energy Effective Theory for Nambu–Goldstone Bosons and Photons

- 23.4 Electromagnetic Corrections to the Nambu–Goldstone Boson Masses
- 23.5 Effective Theory for Nucleons and Pions
- 23.6 QCD Contributions to the W^- and Z -Boson Masses

24 Topology of Nambu–Goldstone Boson Fields

- 24.1 Skyrmions
- 24.2 Anomaly Matching for $N_f = 2$
- 24.3 G-Parity and its Explicit Breaking
- 24.4 Electromagnetic Decay of the Neutral Pion
- 24.5 **Evidence for $N_c = 3$ from $\pi^0 \rightarrow \gamma\gamma$?**
- 24.6 Wess–Zumino–Novikov–Witten Term
- 24.7 Intrinsic Parity and Its Anomalous Breaking
- 24.8 Electromagnetic Interactions of Pions, Kaons, and η -Mesons
- 24.9 Electromagnetic Interactions of Nambu–Goldstone Bosons
for $N_f \geq 3$

24.10 Can One See the Number of Colors?

24.11 Techni-Baryons, Techni-Skyrmions, and Topological Dark Matter

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25 Strong CP-Problem

25.1 Rotating θ into the Mass Matrix

25.2 θ -Angle in Chiral Perturbation Theory

25.3 θ -Angle at Large N_c

25.4 Peccei–Quinn Symmetry

25.5 $U(1)_{PQ}$ Symmetry Breaking and the Axion

25.6 Astrophysical and Cosmological Axion Effects

25.7 Elimination of the Weak $SU(2)_L$ Vacuum-Angle

25.8 Is there an Electromagnetic CP-Problem?

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- 26.1 Minimal **SU(5) Model**
- 26.2 Fermion Multiplets
- 26.3 Lepton-Quark Transitions and **Proton Decay**
- 26.4 **Baryon Asymmetry in the Universe**
- 26.5 Thermal Baryon Number Violation in the Standard Model
- 26.6 Topological Excitations as Cosmic Relics
- 26.7 't Hooft–Polyakov Monopole and Callan–Rubakov Effect
- 26.8 Dirac–Schwinger–Zwanziger Dyon Quantization Condition
- 26.9 Julia–Zee Dyon and Witten Effect
- 26.10 Fermion Masses and the Hierarchy Problem
- 26.11 Spin(10) Structure
- 26.12 Neutrino Masses in the Spin(10) GUT
- 26.13 Small Unification with SU(3), G(2), Spin(6), or Spin(7)
- 26.14 Grand or not so Grand Unification?

FINALE

A Highlights in the Development of Particle Physics

A.1 **Development** of Experimental High-Energy Physics

A.2 Development of Quantum Field Theory and the Standard Model

B Units, Hierarchies, and Fundamental Parameters

B.1 Man-Made versus Natural **Units**

B.2 Energy **Scales** and Particle Masses

C Structure of Minkowski Space-Time

C.1 Lorentz Transformations

C.2 Gradient as a 4-Vector and d'Alembert Operator

D Relativistic Formulation of Classical Electrodynamics

- D.1 Current and Vector Potential
- D.2 Field Strength Tensor
- D.3 Maxwell Equations
- D.4 Space-Time Scalars from Field Strength Tensors
- D.5 Transformation of Electromagnetic Fields
- D.6 Action and Euler–Lagrange Equation
- D.7 Energy-Momentum Tensor

E From the Galilei to the Poincaré Algebra

- E.1 Galilei Algebra
- E.2 Poincaré and Lorentz Algebras

F Lie Groups and Lie Algebras

- F.1 Definition of a **Lie Algebra**

- F.2 Simple and Semi-Simple Lie Algebras
- F.3 Representations of Lie Algebras
- F.4 Lie Algebra $\mathfrak{so}(3)$ and its Representations
- F.5 Unitary Group $SU(2)$ versus Orthogonal Group $SO(3)$
- F.6 Unitary Group $SU(n)$ and its Algebra $\mathfrak{su}(n)$
- F.7 Group $SU(3)$ and its Algebra $\mathfrak{su}(3)$
- F.8 Permutation Group S_N
- F.9 **$\mathfrak{su}(n)$ Representations and Young Tableaux**
- F.10 Tensor Product of $\mathfrak{su}(n)$ Representations
- F.11 Tensor Product of $\{3\}$ and $\{\bar{3}\}$ in $\mathfrak{su}(3)$
- F.12 Orthogonal Group $SO(n)$ and its Algebra $\mathfrak{so}(n)$
- F.13 Symplectic Group $Sp(n)$ and its Algebra $\mathfrak{sp}(n)$
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- F.15 Graphical Method for Tensor Product Reduction

G Homotopy Groups and Topology

G.1 Maps from S^d to S^n

G.2 Topological Charge in 2-d Abelian Gauge Theory

G.3 Homotopy Groups of Lie Group Manifolds

H Monte Carlo Method

H.1 Concept of a **Markov Chain**

H.2 **Detailed Balance**

H.3 **Ergodicity** and its Implications

H.4 Convergence to the Stationary Distribution

H.5 Metropolis Algorithm

H.6 Error Analysis

H.7 **Critical Slowing Down**

H.8 Supercritical Slowing Down and **Sign Problems**

H.9 Complexity Classes and the Severity of Sign Problems

H.10 **Quantum Computation** and Simulation of Real-Time Evolution

I Phase Transitions and Critical Phenomena

I.1 Phase Transitions and **Critical Points**

I.2 Critical Exponents

I.3 Universal Critical Behavior

I.4 Scaling Hypothesis

I.5 Critical Exponents and Scaling Laws: An Overview

References (15 pages)

Author Index (299 authors)

Subject Index (7 pages, structure with sub-subjects)

“Wolfgang Bietenholz and Uwe-Jens Wiese have done an impressive job of writing an introduction to quantum field theory and the standard model of particle physics that incorporates modern viewpoints throughout. They manage to cover a great deal of material in a manageable space. Students will come away with an excellent grounding in a difficult and multifaceted subject, and the book will also be a valuable resource for experienced researchers.”

Prof. Edward Witten, Institute for Advanced Studies, Princeton

“Bietenholz and Wiese have succeeded in writing a quantum field theory textbook that takes a radically different path from those before it whilst still covering the field in a manner appropriate for a graduate course. The presentation is clear and is interestingly modulated by the authors’ backgrounds in lattice approaches to field theory, explaining difficult concepts in concise and interesting ways. Throughout the book are scattered gems of topics that you will not find in existing mainstream texts, where the authors eloquently delve into these selected topics in deeper detail.”

Prof. William Detmold, Massachusetts Institute of Technology

“This is a remarkable book! As an introduction to quantum field theory it impresses with its clarity and depth. It also provides great insight into the standard model, in particular its nonperturbative features and connections to condensed matter physics. This book will be an invaluable source of information for students and researchers alike.”

Prof. Wilfried Buchmüller, DESY and University of Hamburg

“This is a marvelous book that manages to synthesize the developments over more than fifty years in quantum field theory, statistical mechanics, the Standard Model of particle physics, critical phenomena, and the renormalization group. The authors have a deep understanding of the subject and manage to present the material with explanations and insight rather than heavy use of equations. It serves as an excellent complete textbook for graduate courses but also as a reference book for researchers in the field.”

Prof. Poul H. Damgaard, Niels Bohr Institute

“A modern and empowering text on quantum field theory. The book is very successful in engaging its readers right from the start, with the main relevant topics covered in a solid and motivating way, highlighting open questions, and providing interesting historical remarks and exercises. The authors’ approach is novel and stimulating and the book will be very valuable for students.”

Prof. Tereza Mendes, University of São Paulo