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Physikalisches Institut
Universität Bonn

Elementary Particle Physics I

Course Nr. 6780

Summer Semester 2000

Course Outline

I. **General Introduction**

   A. Lectures and questions
   B. The role of the exercise sets
   C. Literature
   D. Remarks on the nature of particle physics research
   E. Historical review of a Century of Particle Physics
      1. Natural units
      2. Scales of energy, length, and time

II. **The Structure of Matter**

   A. Quarks and leptons
   B. Baryons and mesons
   C. Nuclei
   D. Forces: coupling strengths and symmetries

III. **Scattering Experiments**

   A. Scattering cross sections
      1. Hard-sphere scattering
      2. Classical Rutherford scattering
   B. Relativistic kinematics
      1. Lorentz transformations
      2. Four-vectors
      3. The energy-momentum four-vector

C. Feynman diagrams
   1. Fermi's golden rule
   2. Feynman rules for spin 0
   3. Anti-particles
   4. Electron-muon scattering
   5. Higher-order diagrams

D. Contemporary scattering experiments at accelerator laboratories
   1. Accelerator centers
   2. Examples of large multi-purpose detectors
   3. Particle detection techniques

IV. Spin Statistics and Wave Functions

A. Fermions and bosons

B. Elastic scattering of identical particles

C. Decay of the ρ^0 vector meson to two neutral pions

D. The quark model and color

E. The quark model and magnetic moments

V. Symmetries and Conservation Laws

A. Noether's theorem

B. Rotational symmetry
   1. Orbital angular momentum
   2. Spin angular momentum
   3. Addition of angular momenta

C. Isospin symmetry
   1. Two-nucleon states
   2. Nucleon-nucleon scattering

D. Gauge symmetry

E. Parity

F. Charge conjugation

G. CP symmetry
   1. Neutral kaon decays
   2. Kaon oscillations
   3. CP violation

H. Time reversal symmetry

I. CPT symmetry

VI. Quantum Chromodynamics

A. Introduction

B. Counting quark colors

1. $R = \frac{\sigma(e^+e^- \to hadrons)}{\sigma(e^+e^- \to \mu^+\mu^-)}$
2. π^0 decay
3. τ decay

C. Non-abelian gauge theory

1. Gauge invariance
2. Covariant derivative
3. Gauge boson couplings
4. Running coupling constant

D. Examples of phenomenological successes

1. Mesons and baryons
2. Deep inelastic scattering
3. Gluon jets
4. Running α_{s}

E. Open problems

1. Non-perturbative calculations
2. Deconfinement
3. Unification

VII. Electroweak Unification

A. Introduction

B. Charged-current weak interactions

1. Muon decay
2. $\nu_\mu + e \to \mu + \nu_e$ scattering

C. Neutral-current weak interactions

D. Weak interactions of quarks

1. Cabibbo mixing
2. The Cabibbo-Kobayashi-Maskawa matrix
3. $K^0 \to \mu^+\mu^-$

E. Weak isospin and hypercharge

F. Gauge-boson mixing, the Weinberg angle

G. Spontaneous symmetry breaking and the Higgs mechanism

VIII. Recent Developments and Open Questions

A. Neutrino masses and mixing

B. CP violation

C. Review of Standard Model parameters

D. The origin of mass

E. Grand unification