

# Advanced Particle Physics 2

(Spring semester 2024)

In addition to the **Lecture Notes** the following textbooks should be consulted

F. Halzen and A. D. Martin (H&M)

Quarks and Leptons

M. Thomson

Modern Particle Physics (Thomson)

There are many textbooks at the same level that you can consult and that complement the course, but **you should not get lost in the literature:**

Experimental:

R. N. Cahn and G. Goldhaber (2<sup>nd</sup> Ed.)

The Experimental Foundations of Particle Physics

W. S. C. Williams

Nuclear and Particle Physics

Introduction to particle physics:

D. Griffiths

Introduction to Elementary Particles (2<sup>nd</sup> Ed.)

G. Kane

Modern Elementary Particle Physics (2<sup>nd</sup> Ed.)

D. Perkins

High Energy Physics (careful, Perkins uses  $x_4 = ict$ ) (4<sup>th</sup> Ed.)

Quantum Field Theory:

C. Quigg

Gauge Theories of the Strong, Weak, and Electromagnetic Interactions (2<sup>nd</sup> Ed.)

M. Maggiore

A Modern Introduction to Quantum Field Theory

I. J. R. Aitchinson and A. J. Hey

Gauge Theories in Particle Physics (4<sup>th</sup> Ed.)

**Do as many exercises as you can!!!**

## INTRODUCTION

**Lecture 1:** Introduction to the Standard Model

H&M ch. 1, ch. 3

Thomson ch. 1, ch. 2 sect.s 1, 3.6, ch. 3 sect.s 1, 2, 4, 5

## STRONG INTERACTIONS

**Lecture 2:** The Quark Model and the Hadron Spectrum

H&M ch. 2 sect.s 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

Thomson ch. 9 sect.s 2, 3, 4, 5, 6, 7, ch. 10 sect. 8

**Lecture 3:** Introduction to QCD (QCD lagrangian, running of  $\alpha_s$ , qq scattering)

H&M ch. 14 sect. 3, 4, ch. 2 sect. 15, ch. 7 sect.s 9, 10

Thomson ch. 10 sect.s 1, 2, 3, 4, 5, 7, app. F

**Lecture 4:** QCD Parton Model (scaling violations and QCD evolution equations)

H&M ch. 8 sect. 4, 5, ch. 10 sect.s 1, 2, 3, 4, 5, 6, 7, 8

Thomson ch. 8

**Lecture 5:**  $e^+e^- \rightarrow \text{hadrons}$  ( $e^+e^- \rightarrow q\bar{q}$ ,  $e^+e^- \rightarrow q\bar{q} + g$ , hadronization)

H&M ch. 11 sect.s 1, 2, 3, 4, 5, 6, 7

Thomson ch. 10 sect. 6

**Lecture 6:** Hadron – Hadron Interactions (low energy, Drell-Yan  $q\bar{q} \rightarrow l\bar{l}$ , jet production, HF)

H&M ch. 11 sect.s 8, 9

Thomson ch. 10 sect. 9

## WEAK INTERACTIONS

**Lecture 7:** Phenomenology of Weak Interactions

H&M ch. 12 sect.s 1, 2

Thomson ch. 11 sect.s 1, 2, 3, 4, 5, 7

**Lecture 8:** Weak Decays (beta,  $\mu$ ,  $\pi$ , n)

H&M ch. 12 sect.s 3, 5, 6

Thomson ch. 11 sect. 6, ch. 12 sect. 1

**Lecture 9:** Quark Mixing, CKM Matrix,  $K^0 - \bar{K}^0$  and  $B^0 - \bar{B}^0$  oscillations, CP violation

H&M ch. 12 sect.s 11, 12, 13, 14

Thomson ch. 14

**Lecture 10:**  $\nu$ -e Scattering and  $\nu$ -q Scattering (Charged and Neutral Currents)

H&M ch. 12 sect. 7, ch. 13 sect. 5, ch. 12 sect.s 8, 9, 10

Thomson ch. 12 sect.s 2, 3, 4, 5

## ELECTROWEAK INTERACTIONS AND THE HIGGS BOSON

**Lecture 11:** Electroweak Unification

H&M ch. 13 sect.s 1, 2, 3, 4, 5, 6, 7

Thomson ch. 15, ch. 16, app. D

**Lecture 12:** Spontaneous Electroweak Symmetry Breaking and the Higgs Mechanism

H&M ch. 14 sect.s 5, 6, 7, 8, 9, ch. 15 sect.s 1, 2, 3, 4, 5, 6

Thomson ch. 17

## NEUTRINOS

**Lecture 13:** Neutrino Oscillations

Thomson ch. 13