PHY304 Particle Physics

Dr. Chris Booth

17:00 Tuesday

11:00 Wednesday*

(Hicks LT1)

* except week 2

→ overview

Recommended Books

Text Book

- Introduction to Elementary Particles – David Griffiths

Background reading

- Ideas of Particle Physics – G D Coughlan, J E Dodd & B M Gripaios

Start with chapters 1 to 4.3 (of 46)

Web page: http://www.cbooth.staff.shef.ac.uk/phy304

(and MOLE page)

Syllabus (21 lectures)

Introduction

Units – energy, momentum and mass.

Cross-Sections

Total and partial cross-sections. Differential cross-sections $d\sigma/d\Omega$. Elastic scattering. Form factor $F(q)$. Born approximation. Fourier relationship between $\rho(r)$ and $F(q)$.

Kinematics

4-vectors; $P = (\underline{p}, iE)$. 4-momentum transfer, q.

Classification of Particles

Fermions and bosons; constituents of matter and fields. The Standard Model. Leptons and quarks.

Interactions and Fields

Exchange bosons. The 4 fundamental forces; their ranges and relative strengths. Feynman diagrams. Virtual particles. Yukawa potential.

Invariance Principles and Conservation Laws

Origin of conservation laws, properties of space-time. Conservation of $\underline{p}$, E and $\underline{L}$. Global phase or gauge transformations; multiplicative conservation laws; charge conjugation (C), parity (P) and time-reversal (T) symmetries; CPT theorem.

Fundamental Interactions

a) Electromagnetic – QED, electron self-energy, vacuum polarisation, renormalisation. Magnetic moments, g–2 experiment and theory.

b) Weak – Low energies, beta decay, W^+,W^-. High energy divergences and electroweak unification, Z^0. e^+e^- annihilation experiments; number of fermion generations.

c) Strong – QCD, quarks and gluons, colour, α_s (running). Allowed hadrons, hadronisation and jets.

Properties of Quarks

Isospin & strangeness, charm, beauty (bottom), top.
Quark content of hadrons. Symmetries.
CKM matrix & weak eigenstates. Strangeness regeneration.

Evidence in support of the Quark Model

e^+e^- scattering & annihilation; time-like & space-like virtual photons, *R* and colour factor.
Deep inelastic scattering, scaling.
Jets and gluon bremsstrahlung.

Summary

→ 2 strands, units

Cross Sections

The idea of cross-section arises from the simplest model of a nucleus (or some other particle) as a completely absorbing sphere of cross-sectional area σ.

This simple model in which the probability of absorption, or some other interaction, is unity within a certain radius of the centre of a nucleus and zero elsewhere does not correspond with physical reality, but nevertheless the cross-section σ is a very useful way of expressing the overall probability per nucleus (or other target particle) that a given interaction will occur.

→ In most cases there are several possible reactions between the incident and target particles, and the cross-section for each will be different. These individual cross-sections are known as partial cross-sections, and their overall sum is the total cross-section.

After a reaction or scattering has occurred the outgoing particles often have an anisotropic distribution, with different energies at different directions. Then the number of particles scattered per second into solid angle dΩ at (θ, φ) is given by the differential cross-section for the process,

$$\frac{d\sigma(\theta,\varphi)}{d\Omega}$$

The partial cross-section for the process can be obtained by integrating the differential cross-section over all solid angles,

$$\sigma = \int_0^{2\pi}\int_0^{\pi} \frac{d\sigma}{d\Omega} \sin\theta \, d\theta \, d\varphi \qquad \text{(see notes).}$$

→ Momentum transfer