3C24 Nuclear and Particle Physics: Aims and Objectives

March 19, 1999

Aims

To provide introductory coverage of modern particle physics. Complete coverage of nuclear physics principals relevant to modern day nuclear physics usage. Comprehensive coverage of principals of particle detection and measurement.

Objectives

After completeing the particle physics section, the students should

- Understand the concept of natural units
- Know the names and masses of the fundamental particles
- Understand the process of fundamental particles interacting via a gauge boson
- Be able to derive the expression for the invariant amplitude of an interaction starting from the wave equation for the gauge boson
- Understand the importance of the cross section and lifetime as measurables
- Understand what goes into calculating cross sections and lifetimes
- Calculate kinematics of scattering and annihilation
- Calculate the centre of mass energy and understand its significance
- Be able to draw any first order Feynman diagram
- Know the composition of baryons and mesons
- Understand the Breit Wigner formula for width
- Understand the concepts of helicity, chirality and parity violation in the weak interaction
- Explain the observations of muon decay and pion decay

- Know the process of neutrino production in cosmic rays

After completing the accelerator and detector section, the students should

- Understand the differences between linear and circular accelerators and their limits
- Understand the main principals of a synchrotron
- Understand the concepts of deep inelastic scttering for fixed target and colliding beams
- Know the main processes by which charged particles lose energy in matter
- Know the main processes by which photons lose energy in matter
- Understand the concepts of operation of a tracking detector, a calorimeter and a Cerenkov counter and the physics processes involved.
- Explain how these detectors are used together and what they properties of the particles they measure

After completing the nuclear physics section, the students should

- Understand the complexities of the nuclear force
- Understand the Liquid drop model and its parametrization (SEMF)
- Understand the various aspects of stability of nuclei
- Be able to explain the underlying physics processes in radioactivity
- Explain what happens in fission
- Understand the beta-stability valley
- Be able to explain why ^{238}U is safe
- Understand the concept of critical mass
- Understand the complexity of information available in photon spectra from radioactive devices
- Be able to explain the workings of Thermal and Fast Breeder Reactors
- Be able to explain what happens in Fusion in the Sun
- Be able to explain what happens in Fusion in the laboratory and why the reactions studied are different from those in the sun

- Understand the cycle of Nucleosynthesis in general terms
- Be able to discuss the possibility of treatment of radiaoactive waste using neutrons from an accelerator
- Understand the nuclear shell model and the magic numbers

1 Particle Physics (12 Lectures)

Overview of the course; Historical perspective; Natural Units; Four Vectors and Lorentz Invariance Revisited; Introduction to the fundamental particles and forces; Quarks and Leptons; The Force Carriers: Gauge Bosons; Introduction to Feynman Diagrams; The Klein Gordon Equation; Virtual Particles; Interactions between two particles; Perturbation Theory; The Invariant Amplitude; The relationship between the theory and the measurables; Interaction Kinematics; The Search for New particles; The Center of Mass System; The Cross Section: a measurable; Fermi's Golden Rule; Phase Space or Density of States; First and Second Order Feynman Diagrams; Fermion Production in e^+e^-annihilation; Introduction to Hadrons; Baryons and Mesons; Nucleons; Pions; Kaons; The Lifetime: another measurable; Conservation Laws; The Spectator Model; Kaon Decay; Muon Decay; Resonances; The Breit-Wigner Formula; The Δ^{++}; The Weak Interaction : some important topics; Helicity; Parity Violation in the Weak Interaction; Muon Decay; Pion Decay; The thing about neutrinos; The MINOS proposed experiment; Cosmic Rays; Evidence for neutrino oscillations from Cosmic Rays; Summary of fundamental particles and their interactions;

2 Accelerators and Detectors (6 Lectures)

Linear vs Circular Accelerators; Synchrotrons; Colliding Beams; Synchrotron Radiation; Advancing the Technology; Deep Inelastic Scattering; Detectors; The interaction of charged particles with matter; The Bethe-Bloch Formula; Coulomb Scattering; Bremsstrahlung : braking radiation; The interaction of photons with matter; Tracking Detectors; Wire Chambers; Multi-Wire Proportional Chambers; Calorimeters; Hadron Calorimeters; Scintillator; Electromagnetic (EM) Calorimeters; Cerenkov Counters; A Generic High Energy Physics Experiment.

3 Nuclear Physics (12 lectures)

Terminology of Nuclear Physics; The Nucleons; The Deuteron; The Nuclear Force; Heavier Nuclei; The Measurables; Liquid drop model; The Semi Empirical Mass Formula of Weizsaecker; The Volume Term; The Surface Term; The Coulomb Term; The Asymmetry Term; The Pairing Term; Stability conditions of nuclei; Spontaneous Activity: Radioactivity and Fission; Radioactivity; Energy considerations for stability against α and β Fission; Why ^{238}U is safe; Critical Mass in ^{235}U ; Thermonuclear Devices; Measurements of γ rays from cruise missiles; Reactors; Fusion in the Sun; Fusion in the Lab; Nucleosynthesis in Stars; Resonance Enhanced Neutron Capture for Waste Transmutation; The Nuclear Shell Model.

Course Books

Introduction to High Energy Physics - Perkins (Addison Wesley) An Introduction to Nuclear Physics - Cottingham and Greenwood (Cambridge) Nuclear and Particle Physics - WSC Williams (Oxford)

Assessment Unseen written Examination Paper 90% Assessed course work 10%

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