Particle Physics and Quantum Field Theory

1. Relativistic quantum mechanics
   - Klein-Gordon equation. Interpretation problems, Klein paradox.
   - Dirac equation. Clifford algebra, gamma matrices. Relativistic invariance in the Dirac equation.
   - Plane wave solutions of the Dirac equation. The Dirac sea.
   - Majorana and Weyl fermions.
2. Weak interactions
   - Beta decays, neutrino. Parity and CP violation.
   - Charged current Lagrangian. Lepton number conservation.
   - Flavour changing neutral current processes, the GIM mechanism. Flavour mixing, origin of CP violation. Neutral kaon and neutrino oscillations.
   - Weak vector bosons. Elements of the gauge theory of weak interactions. Higgs mechanism, vector boson and fermion masses.
3. Strong interactions
   - Mesons and baryons. Classification of hadrons.
   - Baryon number, isospin, strangeness and hypercharge.
   - SU(3) quark model. Hadron multiplets.
   - Experimental evidence for quarks. Discovery of colour.
   - Basics of quantum chromodynamics. Confinement and asymptotic freedom.
4. Relativistic fields
   - Poincaré symmetry. Locality principle. Lagrangian formalism. Interacting scalar field, relativistic electrodynamics with scalar and Dirac fields.
   - Noether's theorem. Energy momentum tensor. Global symmetry currents.
   - C, P and T symmetries. CPT theorem.
   - Gauge invariance in electrodynamics. Elements of non-Abelian gauge theory.
5. Canonical quantisation
   - Quantised Klein-Gordon and Dirac fields.
   - Quantisation of the electromagnetic field. Role of gauge invariance.
   - Feynman propagators.
   - Spin-statistics theorem.
6. Interacting fields
   - Scattering theory and the S-matrix. Unitarity and microcausality.
   - Covariant perturbation theory. Wick's theorem. Feynman rules for correlation functions.
   - Asymptotic states. Feynman rules for the S matrix. Cross sections and decay rates.
7. Functional methods
   - Feynman path integral in Hamiltonian and Lagrangian formalism.
   - Functional formalism, generator functionals.
   - Wick theorem and Feynman rules from functional integral.
   - Grassmann variables and path integrals for fermions.
8. Renormalisation
   - Classification of divergences, counter term formalism. Physical interpretation.
   - Renormalisation of scalar theory and quantum electrodynamics at one loop.
   - Renormalisation group, Callan-Symanzik equation, running coupling. Connection with theory of critical phenomena.

Recommended MSc courses

BMETE11MF43 Particle Physics
BMETE15MF46 Quantum Field Theory

Recommended literature

- G. Takács: Lecture notes for Particle Physics MSc course
  (available from http://physics.bme.hu/BMETE15MF43_kov?language=en)
- D. Griffiths: Introduction to Elementary Particles (2008, Wiley-VCH)
- M.E. Peskin and D.V. Schroeder: An Introduction to Quantum Field Theory (1995, Addison-Wesley)
- C. Itzykson and J-B. Zuber: Quantum Field Theory (2006, Dover Publications)