Particle physics: detailed syllabus

1. Elementary particles and interactions

- elementary particles and their quantum numbers; fundamental interactions and their mediators;
- range of interactions and mass of mediators;
- particle decays: lifetime, conservation laws;
- particle scattering: fixed-target and collider experiments, cross sections;
- strength of interactions and typical lifetimes/cross sections;
- detection and identification of particles:
- resonances and Breit-Wigner distribution;
- overview of symmetries and conservation laws of fundamental interactions: Poincaré invariance; P, C, T; accidental symmetries of the SM (baryon and lepton number, flavour symmetries);

2. Relativistic kinematics

- Minkowski spacetime and Lorentz transformations;
- Relativistic particle kinematics:
  - two-particle scattering kinematics, Mandelstam variables and crossing symmetry;
  - invariant phase space; Dalitz plot

3. Scattering theory

- formal theory of scattering:
  - S-matrix and its symmetries;
  - Dyson's formula;
  - cross section from the S-matrix;

4. Interactions as particle exchange

- Relativistic Quantum Mechanics: Klein-Gordon and Dirac equations
- overview of Quantum Field Theory; Feynman diagrams
- basic interaction vertices and basic electromagnetic, strong, and weak processes;
- basic electromagnetic processes: Feynman rules and scattering amplitudes

4. Symmetries of fundamental interactions

- symmetry in Quantum Mechanics;
- discrete symmetries:
  - parity, charge conjugation, and time-reversal;
  - parity conservation and experimental determination of intrinsic parities;
  - CPT invariance and its consequences;
- continuous symmetries - rotations and their representations; spin;

5. Strong interactions

- isospin symmetry:
  - irreducible representations of SU(2) and isospin multiplets;
  - origin of isospin symmetry;
- quark model:
  - hadron multiplets and SU(3) symmetry: meson octet, baryon octet and baryon decuplet; irreducible representations of SU(3) and the "Eightfold way";
  - composition of representations and quark content of hadrons; quark quantum numbers and the Gell-Mann-Nishijima formula;
  - hadron wave functions, problems with Fermi statistics, and colour;
  - SU(3) breaking and the Gell-Mann-Okubo mass formula;

6. Weak interactions and symmetry violations

- P and C violations: Wu's experiment;
- neutrino helicity: Goldhaber's experiment;
- theory overview: from Fermi theory to electroweak unification;
- CP violations in kaon systems; kaon oscillations;
- CKM matrix and precision tests of the Standard Model.