Lecture topics

School length 32 hours

1. Electroweak interactions on the nucleon 3 hours

Electromagnetic interactions; V-A and current-current theories of weak interactions; CVC and PCAC; single-nucleon matrix elements of the electroweak current and associated form factors; parametrizations and sources of experimental information about electromagnetic and weak form factors.

2. Strong and electroweak interactions in nuclei 4 hours

Two- and three-nucleon pion exchange interactions; realistic models of two- and three-nucleon interactions; short-range structure of nuclei and nuclear correlations; momentum distributions of nucleons and nucleon pairs in nuclei; spectral functions; two- and many-body components in the nuclear electroweak current.

3. The nuclear physics of electron and neutrino scattering in nuclei in the quasielastic regime and beyond 9 hours

3.1 Approximate methods for nuclei (I) 3 hours

Shell model; relativistic Fermi gas model (success and limitations); relativistic mean field. Phenomenological description of inclusive neutrino scattering based on scaling and super-scaling.

3.2 Approximate methods for nuclei (II) 3 hours

The polarization propagator; RPA approach; RPA equations; many-body diagrams; meson exchange currents and 2p2h terms in general.

3.3 Ab initio methods for nuclei 3 hours

A selection from: variational and Green's function Monte Carlo methods, no-core shell model, coupled-cluster method, auxiliary-field Monte Carlo methods. Ab initio descriptions of inclusive scattering: i) integral transform methods (Euclidean and Lorentz transform techniques), ii) self-consistent Green's function methods.

4. Pion production 3 hours

QCD (chiral symmetry) constraints to pion pion production at threshold. The role of the Delta(1232) resonance in pion photon and electroproduction. Electroweak excitation of baryon resonances. Transition form factors. Unitarization. Watson theorem. Single pion production, diffractive off a nucleon and coherent off a nucleus. Other meson production channels (kaon, 2 pions, associated strangeness, etc).

5. Description of exclusive channels and final state interactions 3 hours

Transport and cascade approaches to the description of the exclusive final state; pions in nuclei: propagation and absorption; formation time; baryon resonances in the nuclear medium. Nucleon propagation in nuclei. Entanglement between quasielastic and inelastic processes.

6. Inclusive electron and neutrino scattering in the deep inelastic regime 3 hours

General analysis of deep inelastic scattering (DIS); Bjorken scaling; quark-parton model; DGLAP equations; nuclear effects in DIS; shadowing; extraction of parton distribution functions; duality.

7. Impact of uncertainties in neutrino cross sections 3 hours

Impact of uncertainties in neutrino cross sections on the determination of oscillation parameters; potential for CP violation discovery; role of the near detector. Experimental example: the T2K analysis.

8. Selected experimental illustrations 4 hours

Experimental overviews complementing and supporting the theory lectures.