ICTP DIPLOMA PROGRAMME IN HIGH ENERGY, COSMOLOGY AND ASTROPARTICLE PHYSICS 2015-2016

SYLLABUS

The Standard Model - {20 Lectures = 30 hours} G. Senjanovic

1. Introduction
Overview of the Standard Model, heuristic principles for construction of Standard Model. Symmetry. Electromagnetic interactions, the Lagrangian of electrodynamics, P and C symmetry QED Lagrangian, gauge symmetry of the EM interactions.

2. Unification of Weak and Electromagnetic Interactions
Similarity of the weak and EM interactions. Intermediate bosons. Unification and symmetry.

3. Symmetry of the Standard Model
The rise and fall of SU(2) Schwinger model. SU(2) x U(1) model of Glashow.

4. γ **and** Z_0 **boson.** Weak mixing angle. Weak isospin and weak hypercharge.

5. Gauge Invariance of the Standard Model
W-bosons as gauge bosons. Gauging the symmetry, U(1) case. SU(2) gauge symmetry. Properties of Yang-Mills Lagrangian. Covariant derivative. Gauge invariant interaction of fermions. SU(2) x U(1) gauge theory. How to construct gauge invariant theory? Mass terms and symmetry breaking. Non-renormalizability due to explicit mass terms in the Lagrangian. High energy behaviour of theory.

6. Spontaneous Symmetry Breaking
Higgs mechanism. Higgs potential, two field example. U(1) invariance. Continuous set of degenerate ground states. Choice of ground state breaks symmetry. Wrong sign of mass term for scalar field. Flat direction and appearance of massless scalar field. Spontaneous violation of discrete symmetry. More scalar fields.

7. Goldstone Theorem
Spontaneous violation of symmetry and Goldstone theorem at quantum level. Vacuum and symmetry. Vacuum expectation value (VEV). On the translation invariance of the vacuum Spontaneous violation of symmetry and masses of particles.

8. Higgs mechanism
Gauge interactions of the scalar boson. Spontaneous violation of symmetry. Effects of gauge interactions: two important terms, mass
term for gauge field, gauge condition. Gauge fixing, radiation gauge, gauge fixing Lagrangian. Unitary gauge. Summary.

9. Patterns of Symmetry Breaking
O(3) gauge symmetry breaking. Examples of symmetry breaking in SU(2) and beyond. Field counting.

Higgs mechanism in the Standard Model. Spontaneous violation of SU(2) x U(1). Masses of vector bosons. Masses, VEV, mixing, weak mixing angle. Masses of fermions. Concluding remarks about Higg's mechanism in SM. Summary of SM.

11. Generations of Fermions. Fermion Mixing
Generations of fermions. Charge currents and weak mixing. GIM cancellation. How to get mixing, mixing matrices. Quark mixing matrix. Mixing matrix and CP violation. Determination of the elements of the CKM-matrix.Semileptonic decay of hadrons. Properties of CKM-matrix, unitarity, hierarchy of mixing. Mixing in Leptonic Sector**:** non-zero neutrino masses and mixing in leptonic sector. Lepton universality.

12. Phenomenology of Neutral Currents
Neutral currents in the SM. Another representation. Properties of NC couplings. 4-fermion interactions due to neutral currents. Processes stipulated by neutral currents, neutrino-electron scattering, neutrino nucleon scattering.

13. Physics of W and Z Bosons
Masses of W and Z. Decays and production of W and Z. Production of W and Z in proton-antiproton colliders. LEP and the physics of Z: Invisible width, number of generations, asymmetries and parity violation

14. Higgs Boson Physics
Properties of the Higgs boson, mass, couplings and decays. Searches for Higgs boson, bounds on Higgs mass. Searches of Higgs at LEP. Higgs mass and precision tests of the SM. Future searches of Higgs, LHC and Higgs.

15. Neutrino mass and neutrino oscillations SM and massless neutrinos. Neutrino mass and the physics beyond the SM. Seesaw mechanism and the Majorna nature of neutrino. Violation of lepton number and neutrino – less double beta decay. Basics of neutrino oscillations. Solar and atmospheric neutrinos, present and future experiments. Why neutrinos oscillate and why charged fermions do not oscillate. Analogy with kaons.