Mini-Course (August 8-16 2013, CINVESTAV, Mexico):

Higgs Bosons in the SM and beyond:
Implications for Particle Physics and Cosmology

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1. Review of the Standard Model of strong and electroweak interactions

1.1 Basics of the Standard Model (SM) of the Elementary Particles. Gauge symmetries and conservation laws.

1.2 The structure of the SM Lagrangian: the fundamental interactions of gauge bosons, Higgs bosons and fermions.

1.3 Higgs potential and Higgs mechanism at the tree level: vacuum energy and cosmological constant.

1.4 Renormalization of the gauge boson masses: $\delta\rho$ and Δr parameters. Custodial symmetry.

2. Higgs bosons beyond the Standard Model

2.1 Introduction to Grand Unified Theories. Spontaneous symmetry breaking from high energy to low energies.

2.2 Cosmological Implications: Baryogenesis and Higgs bosons.

2.3 Extension of the Higgs sector at low energies: the general Two-Higgs-Doublet Model (2HDM).

2.4 Renormalization aspects of the 2HDM. More on $\delta\rho$ and Δr.

3. Higgs bosons in Supersymmetric Theories

3.1 Motivation for Supersymmetry (SUSY). Graded Lie Algebra and vacuum energy.

3.2 Global Supersymmetry. Superspace and superfields. Supersymmetric theories without gauge interactions. F and D terms. Superpotential.

3.3 Cancelation of quadratic divergences in SUSY.

3.4 Supersymmetric theories with Abelian gauge interactions. The Lagrangian of Supersymmetric QED.

3.5 Extension of SUSY to non-Abelian gauge interactions.

3.6 Spontaneous SUSY breaking versus soft SUSY-breaking.

3.7 The structure of the Minimal Supersymmetric Standard Model (MSSM) and beyond.

3.8 R-parity and LSP. Proton decay.

3.9 The Higgs sector in the MSSM at tree-level and at one-loop. Upper bound on the lightest CP-even mass.

3.10 Introduction to Supergravity (SUGRA). Superpotential and Kähler potential. Vacuum energy in SUGRA.

4. The effective potential and the effective action in Quantum Field Theory

4.1 Path integral representation and Green's functions.

4.2 Mean field and effective action

4.3 Effective potential. Higgs potential at higher orders.

4.4 Computing the one-loop effective potential

4.5 Vacuum energy and the cosmological constant problem beyond tree level.

5. Higgs boson production and decay in the colliders

5.1 Higgs boson production in the SM

5.2 Higgs boson production in the 2HDM and MSSM

5.3 Higgs boson decays

5.4 Present status

6. Aspects of Higgs boson physics in Cosmology

6.1 Brief thermal history of the Universe.

6.2 Thermodynamics of the early Universe. Equilibrium distributions.

6.3 Out of the equilibrium: Boltzmann equation. Thermal relics in the early universe. Computing the matter density parameter.

6.4 WIMPS, Neutralinos, Higgs bosons, axions and dark matter.

6.5 Dark energy and quintessence.

Some bibliography

This short course is based essentially on my notes on courses I give in the Univ. de Barcelona. However some complementary references can be helpful:

1. *An Introduction to Quantum Field Theory*, **M. Peskin & D. Schroeder** (Addison-Wesley,1995)

2. *Dynamics of the Standard Model*, **J. Donoghue, E. Golowich& B. Holstein** (Cambridge, 1992)

3. *Aspects of Symmetry*, **S. Coleman** (Cambridge, 1985)

4. *A Supersymmetry Primer*, **S. Martin** (Perspectives on Supersymmetry, World Scientific, 2010)

5. *The Higgs Hunter's Guide*, **J. F. Gunion, H. E. Haber, G. L. Kane & S. Dawson** (Addison-Wesley, Menlo-Park, 1990)

6. **W. Hollik**, *Renormalization of the Standard Model, in: Precision tests of the Standard Electroweak Model*, Ed. P. Langacker, Advanced Series on Directions in High Energy Physics, Vol. 14 (World Scientific, 1995)

7. **D. López-Val and J. Solà**, Phys. Rev. **D 81** (2010) [arXiv:0908.2898].

8. **J. Solà**, *Cosmological constant and vacuum energy: old and new ideas* [arXiv:1306.1527] (to appear in J.Phys.Conf.Ser. 2013)

9. **A. Djouadi**, Phys. Rept. **459** (2008) 1 [arXiv:hep-ph/0503173].

10. *Physical foundations of Cosmology*, **Mukhanov** (Cambridge, 2005)

11. *The Early Universe*, **E. Kolb & M. Turner** (Addison-Wesley, 1990)