PH817 Specialized topics in QFT and Beyond Standard Model physics

Approved syllabus

Pre-midsem: Grand Unified Theories: motivation, construction and constraints Supersymmetry: motivation, construction and constraints. Majorana Neutrinos and challenges in Neutrino mass models. Particle Physics solutions to Dark Matter.

Post-midsem: QFT at finite temperature. Restoration of spontaneously broken symmetry at finite temperature. Topological solutions. Large gauge transformations. Instantons. Theta-vacua. Chiral Lagrangian and Chiral Perturbation Theory. CP violation. Axions. Sphalerons and B+L anomaly.

Proposed plan for Autumn 2022

All lectures are 1.5 hrs. The sub-item are the experimental perspectives to be included within the same lecture duration.

Key prerequisite : Effective Action concept – will be covered on demand as extra lecture

Key message : The hierarchy of mass scales, the puzzle of SSB and the possible inadequacy of traditional QFT. Concept of Effective Field Theory.

- Rapid review of the Standard Model – symmetry breaking, fermion and gauge boson masses, unitarity of scattering amplitudes, the RG for the Higgs K. Huang Chapter VI Weinberg-Salam Model [4 lectures]
    - SLAC, SPS, Tevatron, LEP and the LHC; current status
- Neutrino mass models – three types of BSM contributions to mass [2 lectures]
    - Oscillations, long baselines, DUNE and INO
- SU(5) and SO(10) GUTs. GUT Baryogenesis/Leptogenesis proposals. – Cheng and Li chapter 14 Grand Unification. [4 lectures]
    - SuperKamiokande and limits
- Supersymmetry – the algebra, Chiral and Vector fields, the recipe of the superpotential, Non-renormalisation. R-parity, Dark Matter candidates. Supergravity and the gravitino. SP Martin topics from upto Sec. 6 [6 lectures]
    - LHC status and high scale SUSY
- QFT at finite temperature. Symmetry restoration in SSB gauge theory. Deconfinement in SU(3). Kapusta and Gale [4 lectures]
- Large gauge transformations and topology. Theta vacua, instantons and relation to anomaly. CP violation and the axion proposal. Monopole and vortex solutions for SSB theories. Hunag; Shifman. [4 lectures]

Total 24 lectures of 1.5 hrs = 12 weeks.

Remaining lectures for revision / doubt clearing etc.

Textbooks:

1. K. Huang “Quarks Leptons and Gauge Fields” WSPC 1983
2. T. P. Chang and L. F. Li “Gauge Theory of Elementary Particle Physics”. OUP 1984
3. J. I. Kapusta and C. Gale Finite-temperature Field Theory CUP 2009
4. M. Shifman, “Advanced Topics in Quantum Field Theory: A Lecture Course”, CUP, 2012

References :

1. S. Weinberg, “Quantum Field Theory” vol. II and vol. III, Cambridge University Press, 1998

2. R. N. Mohapatra “Unification and Supersymmetry” 3rd Ed Springer 2003

3. Mark Srednicki, “Quantum Field Theory”, ‎Cambridge University Press, 2007

4. Csaba Csaki, Salvator Lombardo, Ofri Telem, “TASI Lectures on Non-Supersymmetric BSM Models”, https://arxiv.org/abs/1811.04279

5. Anson Hook, “TASI Lectures on the Strong CP Problem and Axions”, https://arxiv.org/abs/1812.02669