Master 2 NPAC
Plan of the lectures on Neutrino and Dark Matter physics

Lecturers: Davide Franco, APC, CNRS
Asmaa Abada, IJCLAB, Paris Saclay U.
Véronique Van Elewyck, APC, Université de Paris

N.B. The order of lectures among the 3 professors can change

Lecture 1: The history of neutrinos – experimental aspects (V. Van Elewyck)
- Early experiments and historical context
- The discovery of the (anti)neutrino
- Direct measurement of neutrino helicity
- Muon and tau neutrinos, number of families
- Neutrino scattering studies

Lecture 2: The history of neutrinos – theoretical aspects (A. Abada)
- Pauli's hypothesis and Fermi Effective Theory
- Unexpected observations and interpretation
- Oscillation phenomena (in vacuum and in matter) (plane wave and wave packet derivation)
- Parameterization of the leptonic mixing matrix
- CP violation in the leptonic sector
- What is the absolute neutrino mass ?
- Theoretical aspects of beta and neutrino(-less) double beta decays
- Cosmological constraints on neutrinos

Lecture 3: Neutrino mass generation (A. Abada)
- Neutrinos in the Standard Model (chiral and family structure of the weak interaction)
- Dirac and Majorana description of massive neutrinos
- Neutrino masses and Physics Beyond the Standard Model
- Different mechanisms of neutrino mass generation
- Neutrino mass generation at tree-level and basic seesaw mechanisms
- How to disentangle among the different possibilities
- Effective approach

Lecture 4: The sterile fermion (right-handed neutrino) hypothesis (A. Abada)
- The type I seesaw mechanism at different mass scales
- Consequences of the existence of right-handed neutrinos on the leptonic mixing matrix
- How to probe the existence of right-handed neutrinos
- Role of sterile fermions in cosmology

Lecture 5: Neutrino oscillation experiments (V. Van Elewyck)
- Solar neutrino experiments and solving the “solar neutrino problem”
- Discovery of oscillations in the atmospheric sector
- Reactor neutrinos and the quest for θ_{13}
- Neutrino beams and precision oscillation experiments
- Current challenges & future perspectives

Lecture 6: Evidences of dark matter and particle candidates (D. Franco)
- Indirect evidences of dark matter
- Candidate dark matter particles
- WIMP interaction rates

Lecture 7: Experimental techniques in dark matter searches (D. Franco)
- Experimental detection techniques
- Background sources
- Techniques of background rejection

Lecture 8: The neutrino mass and nature; neutrino astronomy(V. Van Elewyck)
- The neutrino mass: direct and indirect experimental searches (single beta decay, neutrinoless double beta decay, constraints from cosmology)
- Neutrino astronomy: motivations and link with other cosmic messengers
- Supernovae neutrinos: observation of SN1987a and future perspectives
- High energy astrophysical neutrinos: sources, first detections and perspectives
- GZK neutrinos

Lecture 9: Experimental techniques in dark matter searches (D. Franco)
- Sensitivities
- Additional dark matter signatures (directionality, annual modulations)
- Neutrino background
- Future detectors

REVIEWS
- A. Abada, *et al.*, "Low energy effects of neutrino masses", JHEP 0712 (2007) 061, https://arxiv.org/pdf/0707.4058.pdf
- C. Giganti, S. Lavignac and M. Zito, "Neutrino oscillations: the rise of the PMNS paradigm", Prog. Part. Nucl. Phys. 98 (2018) 1, https://arxiv.org/pdf/1710.00715.pdf
- Particle Data Group Reviews: http://pdg.lbl.gov/2018/reviews/contents_sports.html
  → K. Nakamura & S. T. Petcov, "Review on Neutrino mass, mixing and oscillations"
  → various authors, "Particle detectors for non-accelerator physics"
  → Particle properties – Neutrinos (several reviews)
- M. C. Gonzalez-Garcia and M. Maltoni, "Phenomenology with massive neutrinos", http://arxiv.org/pdf/0704.1800.pdf
- T. Marrodan Undagoitia and L. Rauch, "Dark matter direct-detection experiments", J. Phys. G43 (2016) no.1, 013001, https://arxiv.org/abs/1509.08767

WEBSITES
- *Neutrino Unbound*, http://www.nu.to.infn.it/
- *History of the Neutrino*, https://neutrino-history.in2p3.fr/