

Flavour Physics

Warwick Week Graduate Lectures

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Lecture 1: Flavour in the SM

- Introduction
- Flavour in the Standard Model
- Quark Model History
 - Isospin
 - Strangeness
 - GIM mechanism and charm
 - P and CP violation
- The CKM mechanism
 - CKM parametrisation and hierarchy
 - Unitarity Triangles
 - The Jarlskog Invariant and matter-antimatter asymmetry

Lecture 2: Mixing and CP violation

- Neutral Meson Mixing
 - Time-evolution of coupled systems
 - Differences in mixing parameters between neutral meson states
- B -meson production, experiments and techniques
 - B -factories: BaBar, Belle and Belle-II
 - LHCb
 - Flavour Tagging
 - Dalitz analysis

- CP violation
 - Types of CP violation
 - The “master” equations for generalised meson decays

Lecture 3: Measuring the CKM parameters

- Measurements of CKM matrix element magnitudes
 - $V_{ud}, V_{us}, V_{cd}, V_{cs}, V_{tb}$
 - Measurements of Unitarity Triangle sides ($V_{ub}, V_{cb}, V_{td}, V_{ts}$)
 - Tensions in $R(D^{(*)})$
- Measurements of CKM matrix angles
 - The angles α, β, γ and ϕ_s
- CP violation in the kaon system
- Global constraints on the CKM matrix and the unitarity triangle(s)
- T violation and CPT
- Electric and magnetic dipole moments

Lecture 4: Flavour Changing Neutral Currents

- Effective Theories
- Flavour Changing Neutral Current (FCNC) processes
- Experimental constraints from FCNCs
 - Constraints from B -mixing ($\Delta F = 2$ FCNCs)
 - Constraints from $b \rightarrow s$ transitions ($\Delta F = 1$ FCNCs)
- Minimal Flavour Violation
- Lepton Flavour Violation
- Future Flavour Violation Experiments

Reading Material

This course has been taught previously by Tom Blake (material [here](#)) and Tim Gershon (material [here](#)). There is another excellent set of similar lectures given by Niels Tuning (material [here](#)). Many thanks to all three of them (particularly Tom) for inspiration (and occasional downright plagiarism) from their material.

Lecture Notes (from other sources)

- Nikhef lecture notes (mostly experimental point of view)
<https://www.nikhef.nl/h71/Lectures/2015/ppII-cpviolaFon-29012015.pdf>
- ESHEP lecture notes (more theoretical)
<https://arxiv.org/abs/1704.03753>
- Zurich lecture course (a bit of both)
<https://www.physik.uzh.ch/en/teaching/PHY568/FS2016.html>
- A. J. Buras, “Weak Hamiltonian, CP violation and rare decays,”
<https://arxiv.org/abs/hep-ph/9806471>
- A. J. Buras, “Flavor physics and CP violation,”
<https://arxiv.org/abs/hep-ph/0505175>
- G. Isidori, “Flavor physics and CP violation,”
<https://arxiv.org/abs/1302.0661>
- Y. Grossman, “Introduction to flavor physics,”
<https://arxiv.org/abs/1006.3534>
- Y. Nir, “Flavour physics and CP violation,”
<https://arxiv.org/abs/1010.2666>
- M. Neubert, “Effective field theory and heavy quark physics,”
<https://arxiv.org/abs/hep-ph/0512222>

PDG reviews

The Particle Data Group (PDG) provide a host of useful material (particularly values of branching-fractions, cross-sections and pretty much every particle physics related observable you can think of). They also have some really great reviews, aimed at the level of a typical PhD student.

- *B*-mixing
<http://pdg.lbl.gov/2021/reviews/rpp2021-rev-b-bar-mixing.pdf>

- *D*-mixing
<http://pdg.lbl.gov/2021/reviews/rpp2021-rev-d-dbar-mixing.pdf>
- Quark model
<http://pdg.lbl.gov/2021/reviews/rpp2021-rev-quark-model.pdf>
- CKM matrix
<http://pdg.lbl.gov/2021/reviews/rpp2021-rev-ckm-matrix.pdf>
- CP-violation
<http://pdg.lbl.gov/2021/reviews/rpp2021-rev-cp-violation.pdf>
- V_{ub} , V_{cb}
<http://pdg.lbl.gov/2021/reviews/rpp2021-rev-vcb-vub.pdf>
- CKM angles
<http://pdg.lbl.gov/2021/reviews/rpp2021-rev-ckm-angles.pdf>

Other reviews

- G. Isidori, “Flavor physics and CP violation”
<https://arxiv.org/abs/1302.0661>
- T. Blake, T. Gershon and G. Hiller, “Rare b hadron decays at the LHC”
<https://arxiv.org/abs/1501.03309>
- T. Gershon and V. Gligorov, “ CP violation in the B system”
<https://arxiv.org/abs/1607.06746>

Books

Most introductory particle physics books will contain chapters on flavour physics. There are also a few specialist books available

- “CP violation”, I. I. Bigi and A. I. Sanda
- “CP violation”, G. C. Branco, L. Lavoura and J. P. Silva
- “Effective Field Theories in Flavour Physics”, T. Mannel

Other useful resources

- Particle Data Group (PDG)
<http://pdg.lbl.gov>
<http://pdglive.lbl.gov> (Particle Listings)

- Heavy Flavour Averaging Group
<https://hflav.web.cern.ch>
<https://arxiv.org/abs/1909.12524>
- CKMfitter
<http://ckmfitter.in2p3.fr>
- UTfit
<http://www.utfit.org/UTfit>
- LHCb Public Results page
http://lhcbproject.web.cern.ch/lhcbproject/Publications/LHCbProjectPublic/Summary_all.html
- Belle II Document Server
<https://docs.belle2.org>