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 and Belle 2
    - 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/2020/reviews/rpp2020-rev-b-bar-mixing.pdf

- *D*-mixing
  http://pdg.lbl.gov/2020/reviews/rpp2020-rev-d-dbar-mixing.pdf

- Quark model
  http://pdg.lbl.gov/2020/reviews/rpp2020-rev-quark-model.pdf

- CKM matrix
  http://pdg.lbl.gov/2020/reviews/rpp2020-rev-ckm-matrix.pdf

- CP-violation
  http://pdg.lbl.gov/2020/reviews/rpp2020-rev-cp-violation.pdf

- V_{ub}, V_{cb}
  http://pdg.lbl.gov/2020/reviews/rpp2020-rev-vcb-vub.pdf

- CKM angles
  http://pdg.lbl.gov/2020/reviews/rpp2020-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