DPhil thesis outline

1 Introduction

- Introduction to *CP*-violation and measurement of γ using $b \to c$ transitions
- Introduction to strong-phase measurements at charm factories

2 Theoretical background

- Introduction to *CP*-violation

2.1 The Standard Model and the CKM matrix

- Basic description of the Standard Model
- Explanation of how *CP*-violation arises from the CKM matrix

2.2 Measuring γ using $B^\pm \to Dh^\pm$ decays

- Theory of γ measurements using $B^\pm \to Dh^\pm$ decays

2.2.1 Measuring γ using self-conjugate multibody D final states

- Description of BPGGSZ and GLW methods
- Motivation for model-independent measurement
- Present yield equations and fit strategy

2.2.2 Binning scheme of $D^0 \to K^+K^-\pi^+\pi^-$

- Strategy for binning of phase space

2.3 Strong phases from quantum-correlated $D^0\bar{D}^0$ decays

- Theory of quantum-correlated $D^0\bar{D}^0$ processes
- Present the double tag method and tag types
- Derive yield equations for the strong-phase fits

Sections 3-5 describe the BESIII analysis. Currently, a paper on the inclusive phase space measurement has been published in PRD. The binned phase space analysis is ongoing and expected to finish at the end of TT23.

3 The BESIII experiment

- Description of the BESIII experiment and the available data sets
- Focus on MDC, TOF system and EMC

4 Selection of single- and double-tagged $D^0 \to K^+K^-\pi^+\pi^-$

4.1 Event selection

- Overview of all the selection requirements

4.1.1 Particle selection

- Charged pion and kaon track requirements
- Photon shower requirements
- Neutral composite particles

4.1.2 Tag selection

* Reconstruction of fully and partially reconstructed D-mesons
* Novel technique for partially reconstruction of $D \to K^+K^-\pi^+\pi^-$
* Final selection of single- and double-tag events
* Quantum correlated phase space reweighting

5 Analysis of $D^0 \to K^+K^-\pi^+\pi^-$ strong phases

5.1 Yield determinations using mass fits

- Overview of strategy for determining event yields

5.1.1 Single tag yields

* Description of mass shapes
* Extraction of single tag yields

5.1.2 Double tag yields

* Description of mass shapes and fit strategy
* Simultaneous fit of double tag yields

5.1.3 Peaking backgrounds

* Determination of background yield and mass shapes from simulation
* Quantum correlation corrections in double tag yields

5.2 Systematic uncertainties

- Very brief description of each systematic uncertainty considered

5.2.1 External parameters

5.2.2 Model dependence

5.2.3 Peaking backgrounds

5.2.4 Single tag yields of K_L^0X tags

5.2.5 Efficiency factorisation

5.2.6 K_S^0 veto

5.2.7 Summary of systematic uncertainties

5.3 Maximum likelihood fit of strong phases

- Description of likelihood function and fitter

5.3.1 Inclusive phase space measurement

* Present measurement of F_+

5.3.2 Binned phase space measurement

* Present fit results for c_i and s_i
* Comparison with model prediction
* Evaluation of binning scheme performance and impact on γ measurement

Sections 6-8 describe the LHCb analysis. The analysis has been completed and a paper on the measurement of γ has been submitted to EPJC.

6 The LHCb experiment

- Description of the LHCb experiment during Run 1 and 2
- Focus on VELO, tracking system and RICH

7 Selection of $B^{\pm} \to [K^+K^-\pi^+\pi^-]_D h^{\pm}$ candidates

7.1 Data selection

- Overview of all the selection requirements

7.1.1 Initial selection requirements

  * Simple requirements on triggers, mass windows, momentum and RICH

7.1.2 Boosted Decision Tree

  * Training and test samples
  * Training variables
  * Optimisation of working point

7.1.3 Final selection requirements

  * Flight significance requirement
  * PID requirements
  * K^0_S mass veto
  * Semileptonic $B^{\pm}$ decay veto
  * Ghost track rejection

7.2 Background studies

- For each background, describe the origin, mass shape and yield

7.2.1 Charmless background

  * Rejection with flight significance requirements
  * Residual background estimate using sidebands

7.2.2 Semileptonic D background

  * Overview of all possible decay modes
  * RapidSim studies of shape and yield

7.2.3 Background from $D^0 \to K^-\pi^+\pi^-\pi^+\pi^0$ decays

  * Explanation of combined mis-ID and missing particle background
  * RapidSim studies of mass shape and PID requirements in data

7.2.4 Background from $D^0 \to K^-\pi^+\pi^-\pi^+$ decays

  * Present full study of single and triple mis-ID

8 Analysis of $B^{\pm} \to [K^+K^-\pi^+\pi^-]_D h^{\pm}$

8.1 Invariant mass fits

- Outline the fit strategy

8.1.1 Global invariant mass fit

  * Present and describe global mass fit
  * Show the same fit, split by charge

8.1.2 Binned invariant mass fit

  * Describe binned mass fit
  * Show the fitted CP-violating parameters

8.2 Systematic uncertainties

- Very brief description of each systematic uncertainty considered

8.2.1 Strong-phase uncertainties

8.2.2 Bin-dependent mass shapes

8.2.3 Fixed signal shape

8.2.4 PID efficiencies

8.2.5 Fixed yield fractions

8.2.6 Low mass physics effects

8.2.7 Small backgrounds not included in the fit

8.2.8 Fit bias

8.2.9 $D \to K\pi\pi\pi\pi^0$ phase space distribution and mass shape

8.2.10 Charmless backgrounds

8.2.11 Checks of negligible systematic effects

8.2.12 Summary of systematic uncertainties

8.3 Interpretation of in terms of γ

- Combination and interpretation of *CP*-violating observables in terms of γ
- Highlight the difference between model-dependent and independent results
- Compare with latest LHCb combination

Section 9 contains the PID study with TORCH testbeam data. The PID likelihood algorithm has already been tested on 2018 testbeam data. The analysis of PID performance using 2022 testbeam data is ongoing and expected to finish at the end of 2023.

9 Analysis of TORCH testbeam PID performance

9.1 The TORCH detector

- Describe the design, physics and strategy of TORCH

9.1.1 Physics behind TORCH

- Motivate the need for low momentum PID at LHCb
- Explain how TORCH combines timing and Cherenkov information
- Show the design of TORCH

9.2 PID likelihood calculation

- Describe analytical likelihood calculation

9.3 November 2022 testbeam

- Briefly mention the motivation and goals of this testbeam campaign

9.3.1 Testbeam setup

9.3.2 PID study of testbeam

- Calibration of timing information
- Cable length measurement
- PID separation power at different momenta
- PID separation power in different beam positions
- Comparison of PID seperation power with and witout knowledge of t_0
- Overall improvement in PID performance at LHCb

10 Summary and conclusion

- Summarise LHCb, BESIII and TORCH analyses
- Outlook on future improvements and measurements