Update on $B^\pm \to Dh^\pm$, $D \to K^+K^-\pi^+\pi^-$ analysis at LHCb and BESIII

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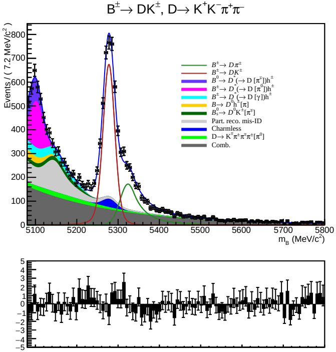
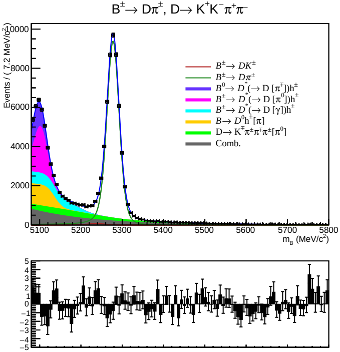
Outline

1. LHCb
   - Summary of current LHCb analysis progression
2. BESIII
   - Strong-phase determination in quantum correlated $D^0\bar{D}^0$ decays
   - First look at binned fits: Measurement of fractional bin yields K_i
   - Measurement of CP-even fraction F_+
3. Summary

LHCb analysis summary

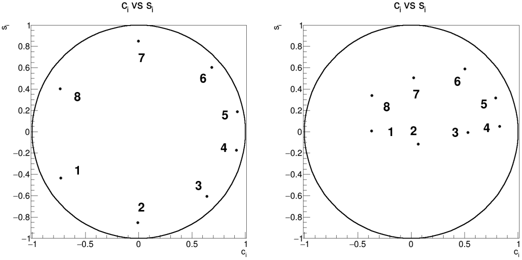
- Previous report on $B^{\pm} \to Dh^{\pm}$, $D \to K^{+}K^{-}\pi^{+}\pi^{-}$:
  1. Global mass fit $\implies$ Obtain mass shape
  2. Binned CP fit $\implies$ Obtain CP observables
  3. Backgrounds: Charmless, $D \to K\pi\pi\pi^{0}$, $D \to K\pi\pi\pi$, $D \to K(X)l\nu$





LHCb analysis summary

- Current analysis progress:
  1. Finished ANA note draft, currently in 1st circulation in B2OC WG
  2. Received comments from 2/3 reviewers, replies ready this week
     - Will request $B \to (K\pi\pi\pi\pi^0)_D h^\pm$ MC
     - Fit with c_i, s_i floated?
  3. Need to finish off systematics for:
     - Charmless and $K\pi\pi\pi\pi^0$ backgrounds
     - c_i, s_i model-dependent uncertainties

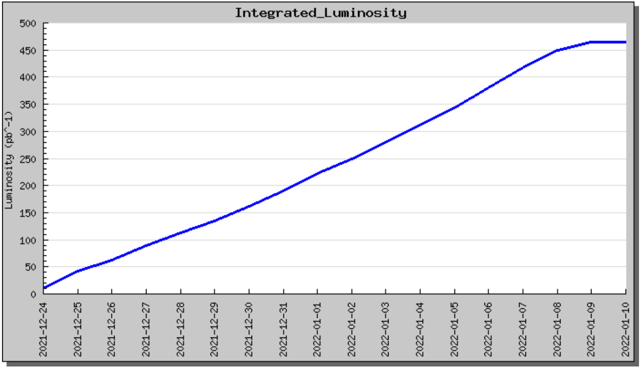


(a) LHCb model

(b) CLEO model

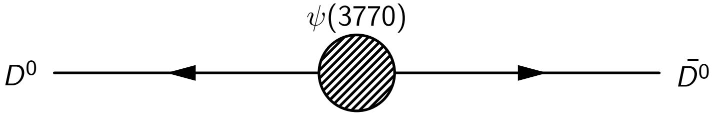
Strong-phase in quantum correlated $D^0\bar{D}^0$ decays

- BESIII: e^+e^- collider at $\psi(3770) \to D^0\bar{D}^0$ threshold
  - 2010-2011: $2.93\,\mathrm{fb}^{-1}$
  - Since 23rd December: $0.46\,\mathrm{fb}^{-1}$
  - Expect $20\,\mathrm{fb}^{-1}$ by end of 2023

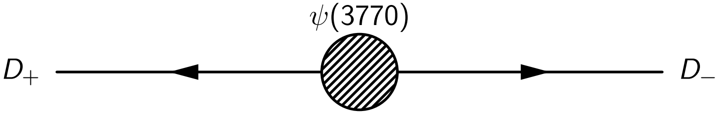


Strong-phase in quantum correlated $D^0\bar{D}^0$ decays

- Double-tag analysis: Reconstruct signal mode ($KK\pi\pi$) and known tag mode
- $D^0\bar{D}^0$ pair is quantum correlated

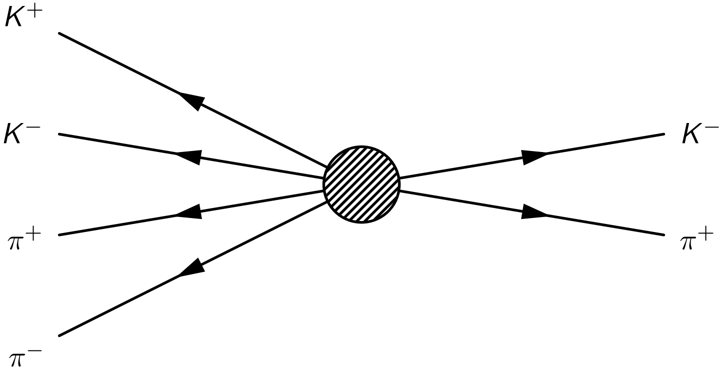


- Equivalently, we can consider D_+D_-
  - $D_\pm = \frac{1}{\sqrt{2}}(D^0 \pm \bar{D}^0)$ are CP eigenstates



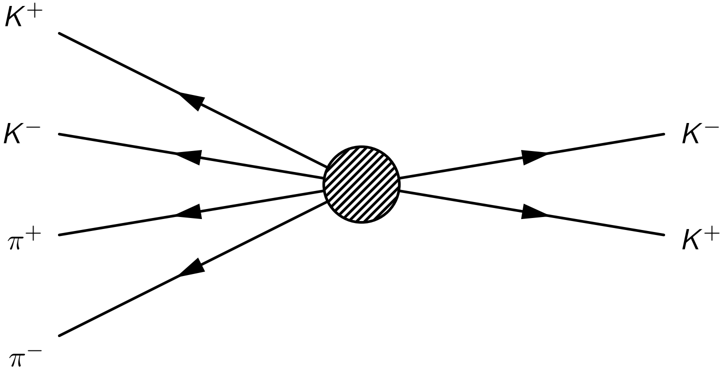
Strong-phase in quantum correlated $D^0\bar{D}^0$ decays

- Tag mode can be a flavour tag
  - $K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^-\pi^+$, $K^-e^+\nu_e$



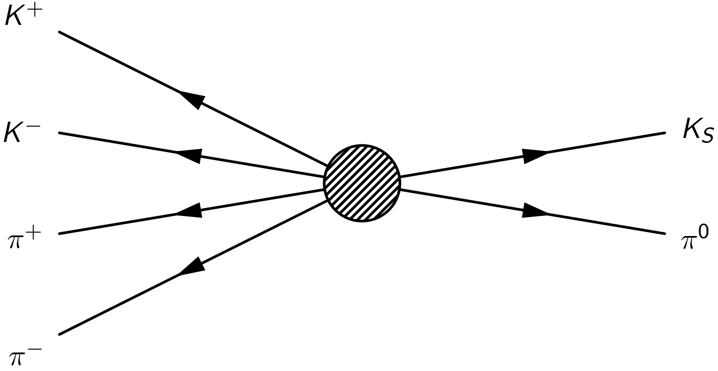
Strong-phases in quantum correlated $D^0\bar{D}^0$ decays

- Tag mode can be a CP even tag
  - KK, $\pi\pi$, $\pi\pi\pi^0$, $K_S\pi^0\pi^0$, $K_L\pi^0$, $K_L\omega$



Strong-phase in quantum correlated $D^0 \bar{D}^0$ decays

- Tag mode can be a CP odd tag
  - $K_S\pi^0$, $K_S\omega$, $K_S\eta$, $K_S\eta'$, $K_L\pi^0\pi^0$



Strong-phase in quantum correlated $D^0\bar{D}^0$ decays

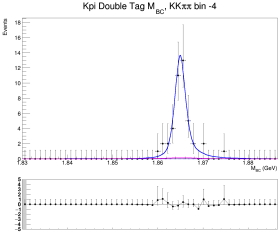
The yield in bin i depends on the tag mode:

- Flavour tag:
  - $N_i \propto K_i$
- CP even tag:
  - $N_i \propto K_i + \bar{K}_i - 2\sqrt{K_i\bar{K}_i}c_i$
- CP odd tag:
  - $N_i \propto K_i + \bar{K}_i + 2\sqrt{K_i\bar{K}_i}c_i$

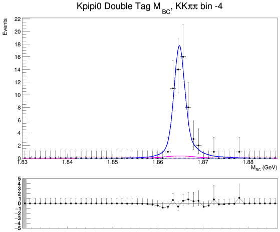
Strategy for obtaining c_i (and s_i):

1. Measure K_i using flavour tags
2. Determine yields of CP even/odd tags
3. Fit for c_i

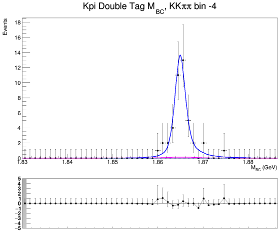
Measurement of fractional bin yields K_i



(a) $K\pi$

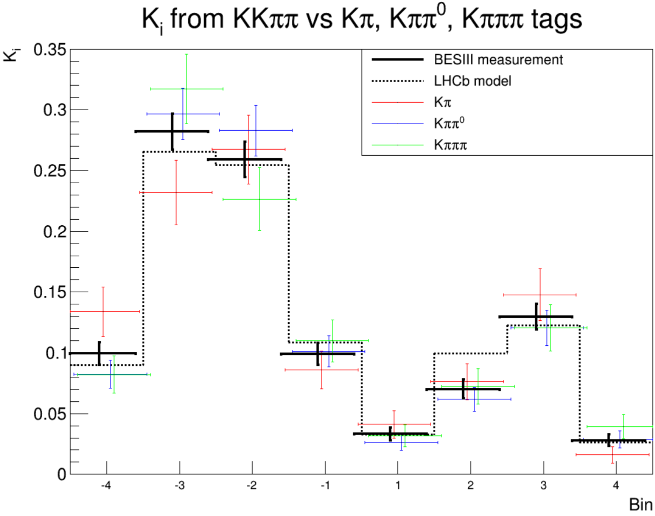


(b) $K\pi\pi^0$



(c) $K\pi\pi\pi$

Measurement of fractional bin yields K_i



Model agrees well with data so far!

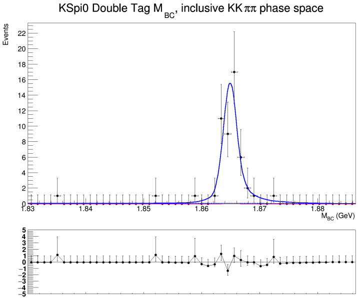
Measurement of CP-even fraction F_+

- CP tag yields too small for strong-phase analysis...
- Measure CP-even fraction F_+ instead
  - $F_+ = 1$ for CP even tags, $F_+ = 0$ for CP odd tags
  - $2F_+ - 1$ is the average cosine of the strong-phase
- F_+ is an input to GLW analyses of γ
- Good cross check of data-model agreement
- $KK\pi\pi$ model prediction: $F_+ = 0.74$ $(2F_+ - 1 = 0.47)$

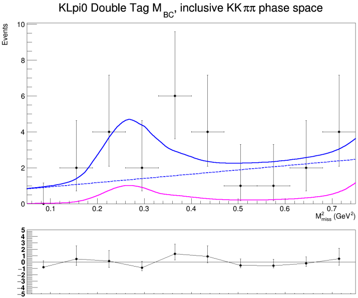
Measurement of CP-even fraction F_+

Strategy for measuring F_+:

- Measure double tag yield of CP tags *without* binning
- Normalize double tag yields with single tag yields
- $\frac{N^{\mathrm{DT}}}{N^{\mathrm{ST}}} = \mathrm{BF}(\mathrm{D}^0 \to \mathrm{KK}\pi\pi) \times \left(1 \pm (2\mathrm{F}_+ - 1)\right)$

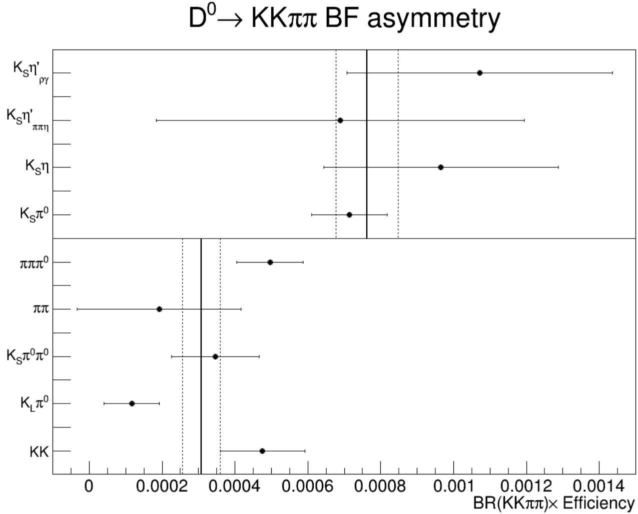


(a) $K_S\pi^0$



(b) $K_L\pi^0$

Measurement of CP-even fraction F_+



Fit result: $F_+ = 0.71 \pm 0.04$

Model prediction: $F_+ = 0.74$

Summary

- LHCb:
  - $B^{\pm} \to (K^+K^-\pi^+\pi^-)_D h^{\pm}$ analysis in B2OC WG review
  - Very encouraging feedback so far
- BESIII:
  - Fractional bin yields K_i agree well with model
  - CP-even fraction F_+ shows good agreement with model, but low yields
  - Will include $K_{S,L}\pi\pi$ tags

Thank you!