Introduction

$B \to \pi K$ decays have a rich phenomenology:

- Dominant contribution from QCD penguins.
- Colour-allowed tree & electroweak penguin (EWP) at the same level.
- $B^{0}_d \to \pi^0 K_S$: only channel with mixing-induced CP asymmetry.

![Diagram showing mixing-induced CP asymmetry and isospin relation](image1)

**Mixing-induced CP asymmetry and isospin relation**

The mixing-induced CP asymmetry in $B^{0}_d \to \pi^0 K_S$ is given by

$$S_{\text{CP}}^{\pi^0 K_S} = \sin(\phi_d - \phi_0) \sqrt{1 - (A_{\text{SM}})^2},$$

where $A_{\text{SM}}$ is the direct CP asymmetry, $\phi_d$ is the $B^{0}_d - \bar{B}^0_d$ mixing phase and $\phi_0 \equiv \arg(\lambda_6 \lambda_3^*).$

Correlation between $B \to \pi K$ amplitudes:

$$3A_{1/2} \equiv \sqrt{2} A(B^0_d \to \pi^0 K^0) + A(B^0_d \to \pi^- K^+) = \sqrt{2} A(B^+ \to \pi^0 K^0) + A(B^+ \to \pi^- K^+) = - (\bar{T} + \bar{C}) (e_i^0 - q e_i^0 e^{-i \phi_0}).$$

Then $\phi_0$ follows from amplitude triangles. **Very clean relation:** if $q$ and $\phi$ are known, only SU(3) input to determine $|\bar{T} + \bar{C}|$ from $B^+ \to \pi^+ \pi^0.$

**Correlation between CP asymmetries**

Employ $\phi_0$ to obtain a correlation between the CP asymmetries of $B^{0}_d \to \pi^0 K_S.$

![Diagram showing correlation between CP asymmetries](image2)

Determination of $q$ and $\phi$

- Use amplitude triangles in a different way → determine $q$ and $\phi.$
- Can apply for charged and neutral decays separately → for now use charged data as current uncertainty $S_{\text{CP}}^{\pi^+ K^0}$ still large.
- Minimal SU(3) input → only to fix normalization $|\bar{T} + \bar{C}|.$
- No topologies have to be neglected.

![Diagram showing contours in $q$-$\phi$ plane](image3)

Additional contour from $S_{\text{CP}}^{\pi^0 K_S}$

Convert measurement of $S_{\text{CP}}^{\pi^0 K_S}$ into value of $\phi_0.$ Additional contour from $t_0(\delta_1)$ are hadronic parameters determined from $B \to \pi \pi$ decays.

$n_0(\delta_1)$ describes colour-suppressed EWPs → fix through data.

We study 3 scenarios for measurements of $S_{\text{CP}}^{\pi^0 K_S}$ at Belle II.

![Diagram showing contours from $S_{\text{CP}}^{\pi^0 K_S}$](image4)

**Conclusions**

- Data from $B^0_d \to \pi^0 K_S$ have shown puzzling patterns in the past.
- We have performed a state-of-the-art analysis.
- Discrepancy in correlation between CP asymmetries became stronger.
- Will data move to confirm SM or is it NP?
- We have presented a strategy to pin down the EWP parameters $q$ and $\phi.$
- We look forward to data from Belle II and LHCb.