**Physics motivation**

- A rich set of physics processes contribute to the $B^0 \rightarrow h^+h^-$ decays ($h = \pi, K$)
- Tree and penguin decay topologies
- Neutral B-mixing
- Time-dependent (TD) CPV observables are sensitive to the CKM angle $\gamma$ and the mixing phases $\phi_d$ and $\phi_\ell$
- Direct CP asymmetries of $B^0 \rightarrow K\ell\nu$ provide a test of the SM given validity of U-spin symmetry [1,2]
- Presence of loop diagrams makes the CPV observables sensitive to New Physics [3,4]

**Experimental Strategy**

- Event selection
  - Particle identification (PID) requirements:
    - $\pi^+\pi^- K^+K^-$: reduce $B^0 \rightarrow K\pi\pi$ to ~10% of the signal
    - $K^*\pi$: reduce $B^0 \rightarrow \pi\pi$ and $B^0 \rightarrow K^*\pi$ to ~10% of $B^+ \rightarrow \pi\pi$ and $B^0 \rightarrow K^*\pi$ respectively
  - BDT optimisation: $R_{M} = S_1 / S_2 / B_1$ (signal from MC samples)
  - Background from upper mass sideband

**CPV observables and previous measurements**

- Asymmetry of $B^0 \rightarrow K\pi\pi$ and $B^0 \rightarrow \pi\pi$
  - TD CPV asymmetries of $B^0 \rightarrow h^+h^-$ decays
    - $A_{CP} (B^0 \rightarrow K^+K^-) = A_{CP} (B^0 \rightarrow \pi^+\pi^-) = -0.084 \pm 0.004 \pm 0.003$
    - $A_{CP} (B^0 \rightarrow \pi^+K^-) = 0.213 \pm 0.015 \pm 0.007$

**Analysis strategy**

- Favour Tagging plays a crucial role
  - $C_{T}^{s}$ and $S_{T}^{s}$ are diluted by the mistag fraction $\omega$
  - Sensitivity on $C_{T}^{s}$ and $S_{T}^{s}$ is proportional to the tagging power $\varepsilon (1 - 2\omega)^2$
  - $\varepsilon$ is the tagging efficiency

**Conclusions**

- Measurements are very well in agreement with previous results
- Strong evidence of TD CPV in $B_1$ decays: significance $> 4\sigma$
- Most precise measurement of $A_{CP}$ and $C_{T}^{s}$ from single experiment

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**State of the art**

| Observable | Bar$
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>$C_{T}^{s}$</td>
<td>$-0.25 \pm 0.08$</td>
<td>$-0.31 \pm 0.07$</td>
<td>$-0.38 \pm 0.15$</td>
<td>$-0.31 \pm 0.05$</td>
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<tr>
<td>$S_{T}^{s}$</td>
<td>$-0.68 \pm 0.10$</td>
<td>$-0.64 \pm 0.09$</td>
<td>$-0.71 \pm 0.13$</td>
<td>$-0.66 \pm 0.06$</td>
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<tr>
<td>$A_{CP}^{s}$</td>
<td>$0.14 \pm 0.11$</td>
<td>-</td>
<td>$0.30 \pm 0.12$</td>
<td>-</td>
<td></td>
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<tr>
<td>$A_{CP}^{d}$</td>
<td>$-0.107 \pm 0.017$</td>
<td>$-0.069 \pm 0.016$</td>
<td>$-0.831 \pm 0.014$</td>
<td>$-0.803 \pm 0.008$</td>
<td>$-0.802 \pm 0.006$</td>
</tr>
<tr>
<td>$A_{CP}^{u}$</td>
<td>-</td>
<td>-</td>
<td>$0.22 \pm 0.07$</td>
<td>$0.27 \pm 0.04$</td>
<td>$0.26 \pm 0.04$</td>
</tr>
</tbody>
</table>

- $1 \, \text{fb}^{-1}$ LHCb measurements done with $1 \, \text{fb}^{-1}$