Updated measurement of decay-time-dependent CP asymmetries in $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays

Daniel Unverzagt*, Physikalisches Institut, Heidelberg University

*on behalf of the LHCb Collaboration

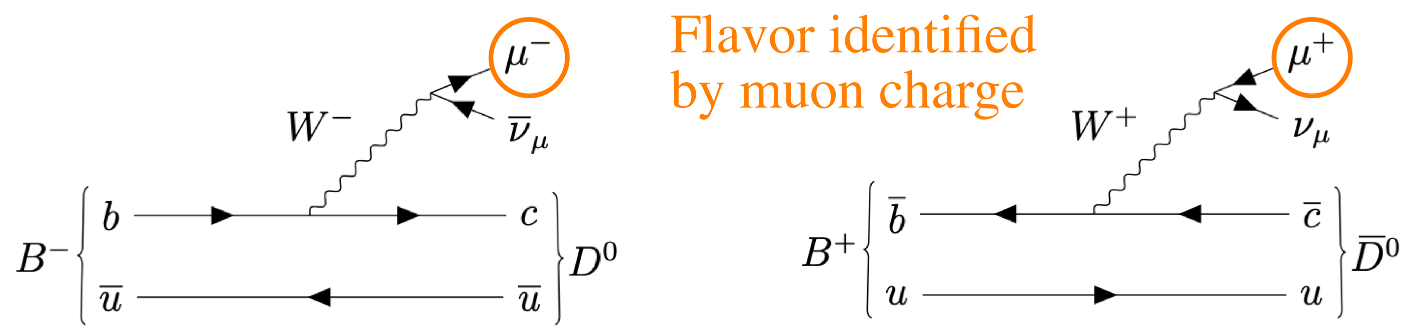
1. Motivation

- CP violation in charm decays very small
- Significant enhancements due to new physics possible
- Charm hadrons: unique opportunity to measure CPV in systems containing up-type quark
- Discovery of direct CPV in charm decays
  - $(\sim 10^{-3})$[1]
- No evidence of indirect CPV
  - Expected scale $(10^{-4} - 10^{-5})$[2, 3]
- A_Γ highest precision probe of CPV in charm mixing

$$A_\Gamma(f) = \frac{\hat{\tau}(\bar{D}^0 \to f) - \hat{\tau}(D^0 \to f)}{\hat{\tau}(\bar{D}^0 \to f) + \hat{\tau}(D^0 \to f)}$$

2. How to measure A_Γ?

- Identifying flavor of the D-meson:



Semileptonic $B \to D\mu$ decays are used to tag the flavor of the D-meson.

- Estimating time-dependent asymmetry:

$$A_{CP}^{RAW}(t) = \frac{N(\bar{D}^0(t) \to f_{CP}) - N(D^0(t) \to f_{CP})}{N(\bar{D}^0(t) \to f_{CP}) + N(D^0(t) \to f_{CP})} = A_{CP}(t) + \overbrace{A_\mu + A_{prod}}^{time-independent} + O(A^3)$$

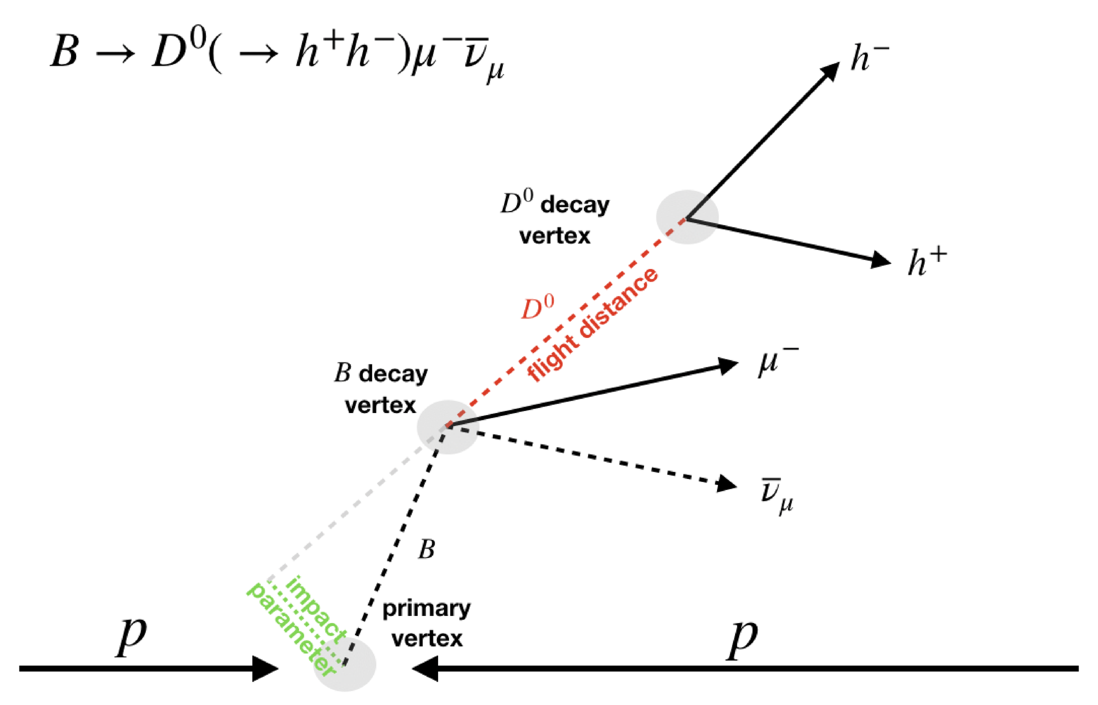
$$A_{CP}(t) = \frac{\Gamma(\bar{D}^0(t) \to f_{CP}) - \Gamma(D^0(t) \to f_{CP})}{\Gamma(\bar{D}^0(t) \to f_{CP}) + \Gamma(D^0(t) \to f_{CP})} \approx A_{CP}^{dir} - \frac{t}{\tau} A_\Gamma$$

3. Analysis strategy

1. Select a clean $B \to \bar{D}^0 \mu X$ sample
2. Split data in approximate equi-populated decay-time bins
3. Simultaneous fit to the D^0 and $\bar{D}^0$ mass distribution to determine the asymmetry between signal yields
4. Fit the yield asymmetry vs decay-time

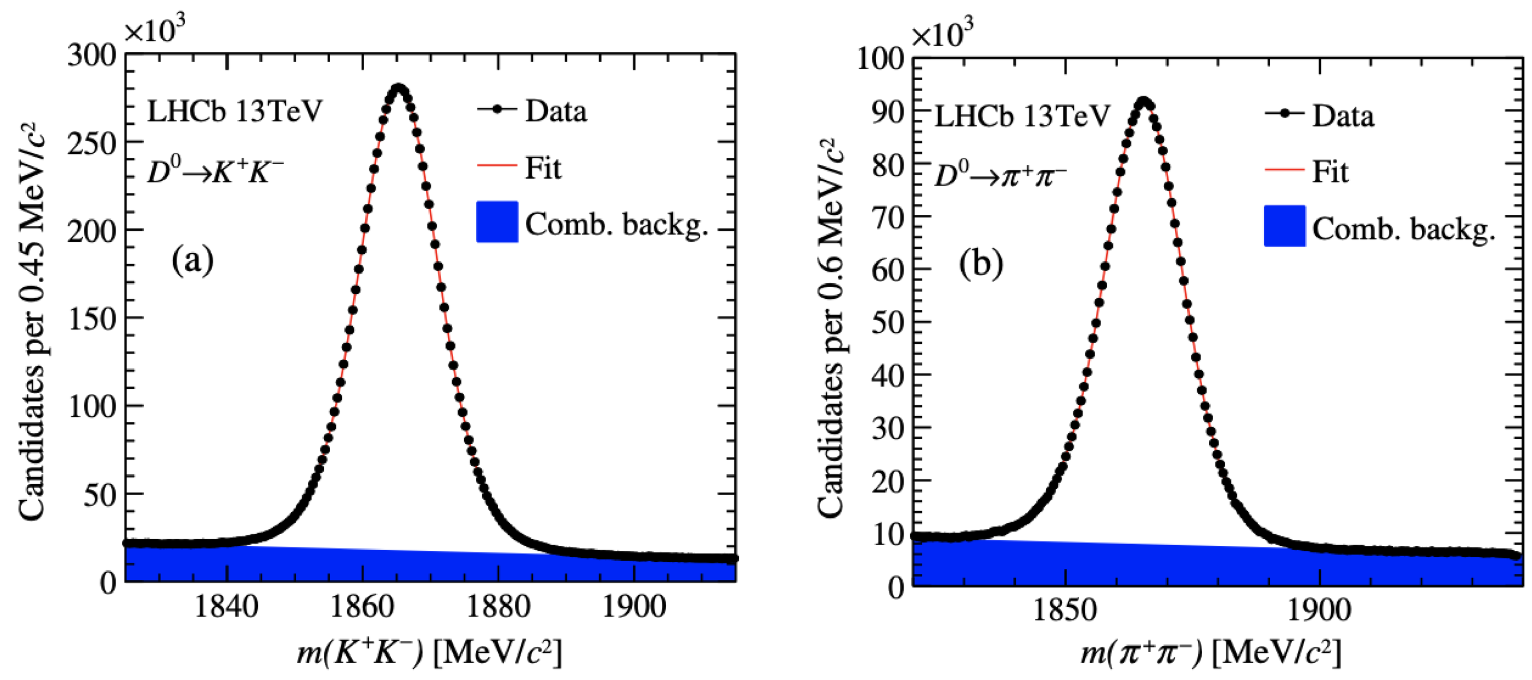
- Validate analysis strategy on $D^0 \to K\pi$ (no CPV, $A_\Gamma = 0$)

4. Selection



Around 9×10^6 KK, 3×10^6 $\pi\pi$ and 76×10^6 $K\pi$ (control channel) events after selection.

5. Mass Fit



KK: $\sim 4.5 \times 10^5$ events per decay-time bin

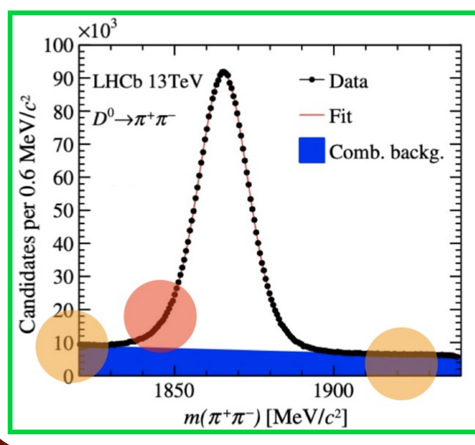
$\pi\pi$: $\sim 1.5 \times 10^5$ events per decay-time bin

1. Create D^0 and $\bar{D}^0$ sub-samples by muon tag
2. Divide data in 20 decay-time bins
3. Estimate asymmetry by simultaneous fit to D^0 and $\bar{D}^0$ mass spectrum in each decay-time bin

6. Systematics

Mistag: probability to wrongly associate unrelated muons with the D^0 candidates lies between 1% and 3%.

Generate PE with realistic mistag fraction and assess impact on fit parameters.



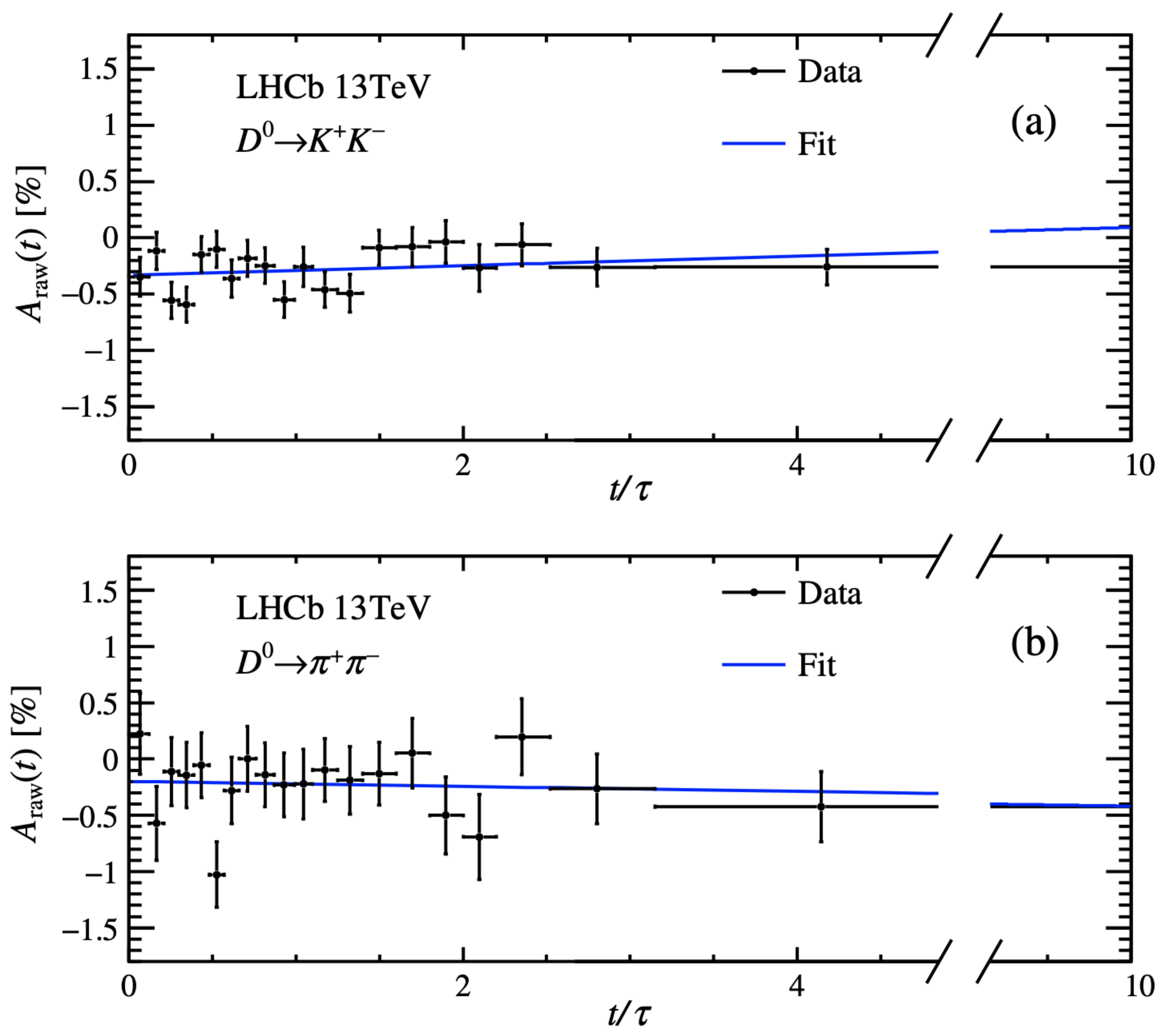
Alternative signal and background models are tested.

Systematics are studied by large samples of pseudoexperiments (PE).

Source of uncertainty	$A_\Gamma(K^+K^-)$ $[10^{-4}]$	$A_\Gamma(\pi^+\pi^-)$ $[10^{-4}]$
Decay-time resolution and acceptance	0.3	0.4
Mistag probability	0.3	0.6
Mass-fit model	0.3	0.3
Total	0.5	0.8

Several crosschecks performed → No additional systematics were observed

7. Final result



This analysis[4]:

$$A_\Gamma(K^+K^-) = (-4.3 \pm 3.6 \pm 0.5) \times 10^{-4}$$
$$A_\Gamma(\pi^+\pi^-) = (2.2 \pm 7.0 \pm 0.8) \times 10^{-4}$$

Combination with previous LHCb measurements:

$$A_\Gamma(K^+K^-) = (-4.4 \pm 2.3 \pm 0.6) \times 10^{-4}$$
$$A_\Gamma(\pi^+\pi^-) = (2.5 \pm 4.3 \pm 0.7) \times 10^{-4}$$

No indication of CP violation in mixing or in the interference between mixing and decay in neutral D-decays.

References

[1] LHCb Collaboration. *Observation of CP violation in charm decays*, Phys. Rev. Lett. 122, 211803

[2] M. Bobrowski, A. Lenz, J. Riedl, and J. Rohrwild. *How large can the SM contribution to CP violation in $D^0 - \bar{D}^0$ mixing be?*, J. High Energ. Phys. 2010, 9 (2010)

[3] Grossman, Yuval and Kagan, Alexander L. and Nir, Yosef. *New physics and CP violation in singly Cabibbo suppressed D decays*, Phys. Rev. D **75**, (2007) 036008.

[4] LHCb Collaboration. *Updated measurement of decay-time-dependent CP asymmetries in $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays*, Phys. Rev. D **101** (2020) no.1, 012005