

Measuring the γ angle of the CKM matrix with the decay $B^\pm \rightarrow D^0(\rightarrow K_s^0 \pi^+ \pi^- \pi^0)h$.

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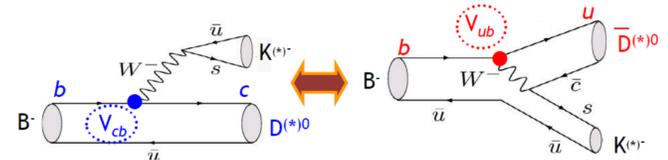
LHCC - November 18th, 2021

1. Introduction

We can measure γ by amplitude modulation in the interference between the processes $b \rightarrow c\bar{u}s$ and $b \rightarrow u\bar{c}s$. That is the case in the following Feynman diagrams where both decay have the same final state $D^0 \equiv [D^0/\bar{D}^0]$.

As no analysis currently dominates the measurement, each mode helps to increase the precision on γ .

The GGSZ method [3] with the three-body decay $D^0 \rightarrow K_s^0 \pi^+ \pi^-$ currently is the more precise studied mode in LHCb. That's why, in this analysis, we study the corresponding four-body decay with an additional π^0 $D^0 \rightarrow K_s^0 \pi^+ \pi^- \pi^0$ which has been studied in Belle but still not in LHCb, where we already have twice more statistics.



Direct measurement : $\gamma = (65.4^{+3.8}_{-4.2})^\circ$ [1]
Indirect measurement : $\gamma = (65.7^{+0.9}_{-2.6})^\circ$ [2]

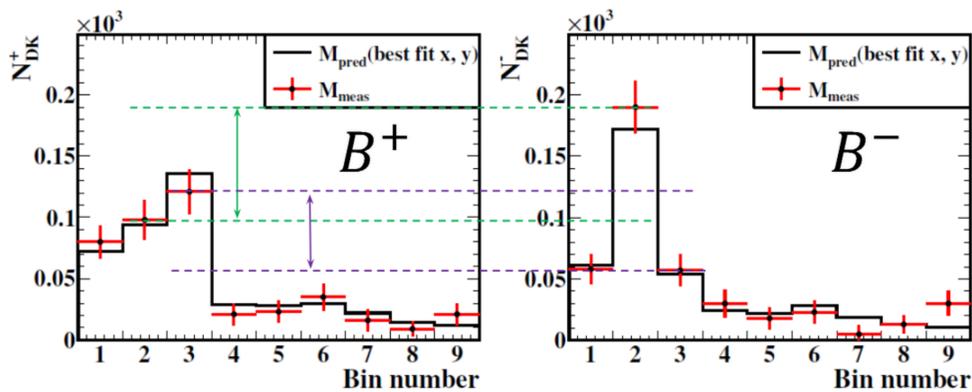
The goal is to increase the precision in the measurement of γ in tree diagrams decays, that is to say in the case of the standard model in order to compare it with loop-level measurements that could be sensible to new physics phenomenons. The CKMfitter group has notably proved that with a 1° precision, one may test the Standard Model up to at least 17 TeV [4].

2. The Strong phase δ_D mapping

The γ measurement is dependent on the $\Delta\delta_D$ difference between the strong phases for $D^0 \rightarrow f(\delta_D)$ and $\bar{D}^0 \rightarrow f(\delta_D)$, which varies itself on the phase space of the four-body decay of D^0 .

Then, one need a mapping of this strong phase.

In the Belle analysis [5], a binned map of the Phase Space has been used, using results from the Cleo-c experiment [6]. In a first approach, I will use the same binned scheme. The goal is to see some CP violation in those bins as we can see in the next figure from the Belle paper:

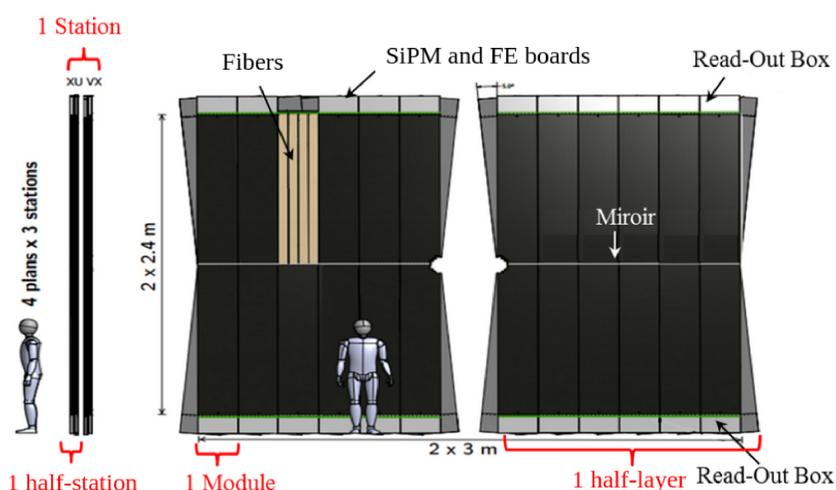


Next, we will perform an Amplitude Analysis with the LHCb 2011-2018 data, to obtain a continuous map of the strong phase to have a more precise result.

4. Prospects

With their analysis, the Belle group obtained a precision of 12° on the γ measurement. With our statistics from Runs 1 and 2 (2011-2018 LHCb data $9fb^{-1}$), we then expect a 8.5° precision with the binning method.

This measure will be improved in Run 3 ($23fb^{-1}$ in 2025). An important upgrade of the LHCb detector is in progress before Run 3. In particular, the trigger is changed from a 1 MHz frequency to 40 MHz and the tracking system is improved, notably with the new SciFi subdetector (see picture below), which is very interesting for this analysis which studies 5 charged tracks. In the best case, we could double the precision on this study.

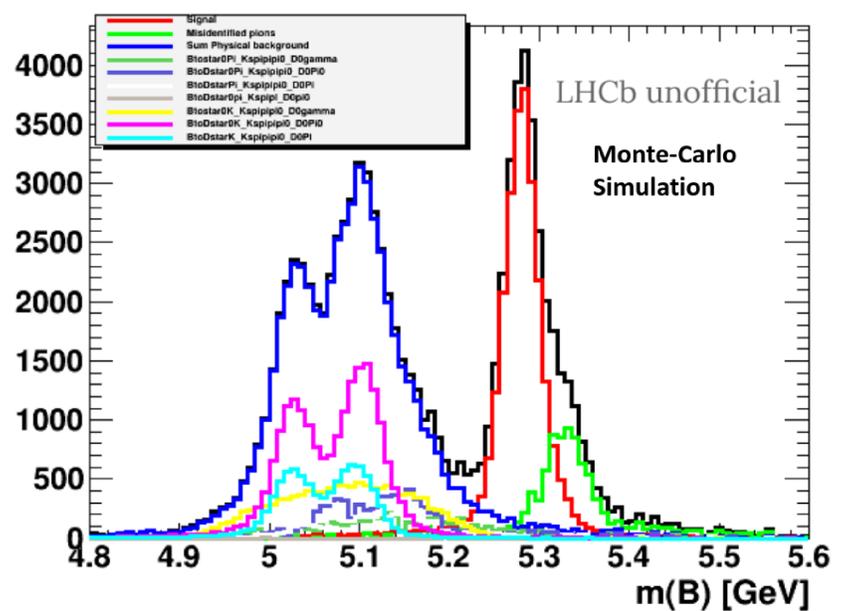


3. Selection and background characterisation

The signal selection is performed with the reference channel $B^\pm \rightarrow D^0 \pi^\pm$ which is 13 times larger than $B^\pm \rightarrow D^0 K^\pm$. The selection is based on two MVA, the first one with topological variables of D^0 and its daughters, the second being related to the B meson and the $B \rightarrow D^0 h$ decay. There are also one-dimensional cuts on the mass distributions of the π^0 , K_s^0 and D^0 mesons.

Once those selections are done, we discriminate K and π using the DDL method based on a likelihood difference.

In addition to residual combinatorial background, different decay channel may interfere with the signal and we have simulated each of them to study this effect. The largest effect is due to the cross-feed when a K or a π is miss-identified. The following picture shows a Monte-Carlo simulation of the mass distribution of the B meson, considering the signal, the crossfeed and the physical background.



We finally obtain, in the mode DK , which is the interested one, 1608 ± 49 signal events at 2σ with a purity of 68.8%, which is twice the Belle experiment statistics which had 815 ± 51 events with a purity of only 60%. Thus, it is clear that there is interest in re-doing this measurement with LHCb data.

5. References

- [1] LHCb collaboration. Simultaneous determination of CKM angle γ and charm mixing parameters. *Submitted to JHEP*, 2021. arXiv 2110.02350.
- [2] CKMfitter group. CKMfitter global fit results as of Summer 19. http://ckmfitter.in2p3.fr/www/results/plots_summer19/num/ckmEval_results_summer19.html.
- [3] A. Soffer A. Giri, Yu. Grossman and J. Zupan. Determining γ using $B^\pm \rightarrow DK^\pm$ with multibody d decays. *Phys. Rev. D*, 68, 2003. arxiv 0210433 [hep-ph].
- [4] Jerome Charles *et al.* Future sensitivity to new physics in B_d , B_s and K mixings. *Phys. Rev. D*, 89, 2014. arXiv 1309.2293.
- [5] J. Libby P.K Resmi and K. Trabelsi. First measurement of the CKM matrix angle ϕ_3 with $B^\pm \rightarrow D(K_s^0 \pi^+ \pi^- \pi^0)K^\pm$ decays. *JHEP*, 2019. arXiv 1908.09499.
- [6] S. Malde P.K Resmi, J. Libby and G. Wilkinson. Quantum-correlated measurements of $D^0 \rightarrow K_s^0 \pi^+ \pi^- \pi^0$ decays and consequences for the determination of the CKM angle γ . *JHEP*, 2018. arXiv 1710.10086.