

# Rare decays overview

Eli Ben Haim, on behalf of the Rare Decays working group

# The working group

- ▶ **Scope:** branching fractions, direct CP asymmetry ( $A_{CP}$ ), polarization fractions and other observables in b-hadron decays to final states that do not contain charm hadrons or charmonia mesons

- ▶ **Tables (from the web page)**

- Branching fractions of **charmless mesonic**  $B^0$  and  $B^\pm$  meson decays
- Branching fractions and other observables of **radiative and leptonic**  $B^0$  and  $B^\pm$  meson decays, including LFV and LNV modes
- Branching fractions of charmless **baryonic**  $B^0$  and  $B^\pm$  meson decays
- Direct  $A_{CP}$  in b-hadron decays
- **Polarization** measurements in b-hadron decays
- Branching fractions of charmless mesonic  $B_s^0$  meson decays
- Branching fractions of charmless decays of **b-baryons**
- Branching fractions of charmless mesonic  $B_c$  meson decays

At the end of some of these sections we give a list of results that were not included in the tables.

*Typical cases are the measurements of distributions, such as differential branching fractions or longitudinal polarizations, which are measured in different binning schemes by the different collaborations, and thus cannot be directly used to obtain averages.*

- ▶ We deal with ~1000 averages (>1500 inputs from ~400 papers)

- ▶ Positive interaction with the PDG

Comparison with PDG averages allows to spot (unavoidable) mistakes on both sides

- ▶ **Group members:**

- ▶ EB (convener), LPNHE-Paris BABAR and LHCb
- ▶ Emilie Bertholet, Tel Aviv University Belle 2
- ▶ Pablo Goldenzweig, Karlsruhe Belle, Belle 2
- ▶ Justine Serrano, CPPM Marseille Belle 2
  
- ▶ Arantza Oyanguren Campos, Valencia, LHCb, was member until the last summer

# Current status

- ▶ We continue working with the **new framework** (common with the B to Charm Working Group).  
→ Things remain stable compared to last year's report, with only a few minor modifications and improvements.
- ▶ Regular updates of the tables and plots. 2 updates in the last 12 months: HFLAV paper, May 2024
- ▶ We are now preparing another update, with results put on the arXiv until the end of 2024
- ▶ As part of these regular updates, we ensure our chapter of the HFLAV paper is up to date. The chapter is published on the website, providing users with method explanations and tables in PDF format.  
→ The chapter can be uploaded to Overleaf for the next publication at any time
- ▶ All updates include a list of results added since the previous version
- ▶ we have included an interactive interface (similar to that of the B to Charm WG, developed by a Google Summer student). This interface allows users to: find decay modes by selecting initial- and final-state particles, choose several modes, generate personalized HFLAV plots (it does not appear for the latest update due to a technical problem)
- ▶ B(s) →  $\mu\mu$  average has been removed our tables. We quote the LHC HF WG average instead
- ▶ Personnel Update: Arantza recently left the group. We are asking for a suitable replacement aligned with our future plans.

# Short and medium term plans

- ▶ Continue updating the web pages regularly
  - ▶ Maintain and further develop the framework in collaboration with the B to Charm WG
  - ▶ Continue discussions with the PDG about how to enhance the interface allowing automatic updates
    - Regularly report and discuss any issues we identify in their averages
  - ▶ Wherever possible, use HFLAV inputs from other groups rather than the PDG's when external values are needed for our fits.
  - ▶ Explore the possibility of averaging distributions of observables when provided in different binnings by various collaborations (ideas?)
  - ▶ Broaden the scope of our working group by including a section comparing Wilson-coefficient fits from different collaborations
    - ▶ As a starting point, the aim is to compare results, not to perform the fits ourselves
    - ▶ Engage with collaborations performing these fits and seek, wherever possible, results using consistent inputs (preferably HFLAV averages) for our comparative study
    - ▶ Discuss the differences in approaches, input variations, and result discrepancies in the new section
- A new team member with appropriate experience is needed to assist with this work

# Backup

# Current status (web page)

## Averages

As from the update corresponding to the HFLAV 2021 publication, we have been using a new framework, with improvements both in the averaging method and the presentation of the results.

## End of April 2023 (latest)

The End of January 2022 pages contain tables and plots that include results put on the arXiv and InspireHEP until the end of January 2023. The PDG averages correspond to PDG 2022 [R.L. Workman et al. (Particle Data Group), to be published in *Prog. Theor. Exp. Phys.* 2022, 083C01 (2022)].

**The rare-decays averages are available [here](#).**

Details about the input and average of each observable are accessible via clickable links.

Averages  
(see next slide)

**All the results that have been added or modified in the present update are listed [here](#).**

This page groups all types of observables (BFs,  $A_{CP}$ , ratios of BFs...).

Delta since the last update

The pdf version of the rare-decays tables and plots, including an introduction with further details about the averaging method and conventions used in the tables, is available [here](#).

Full set of tables and plots, along with explanations  
(very similar to our chapter in the HFLAV paper)

**\*New\*** The rare-decays average in an alternative presentation is available [here](#).

The user may find decay modes by choosing initial- and final-state particles. It is also possible to select several modes and present them in the same plot.

New interface

## End of January 2023

The End of January 2022 pages contain tables and plots that include results put on the arXiv and InspireHEP until the end of January 2023. The PDG averages correspond to PDG 2022 [R.L. Workman et al. (Particle Data Group), to be published in *Prog. Theor. Exp. Phys.* 2022, 083C01 (2022)].

# Averages in the web page

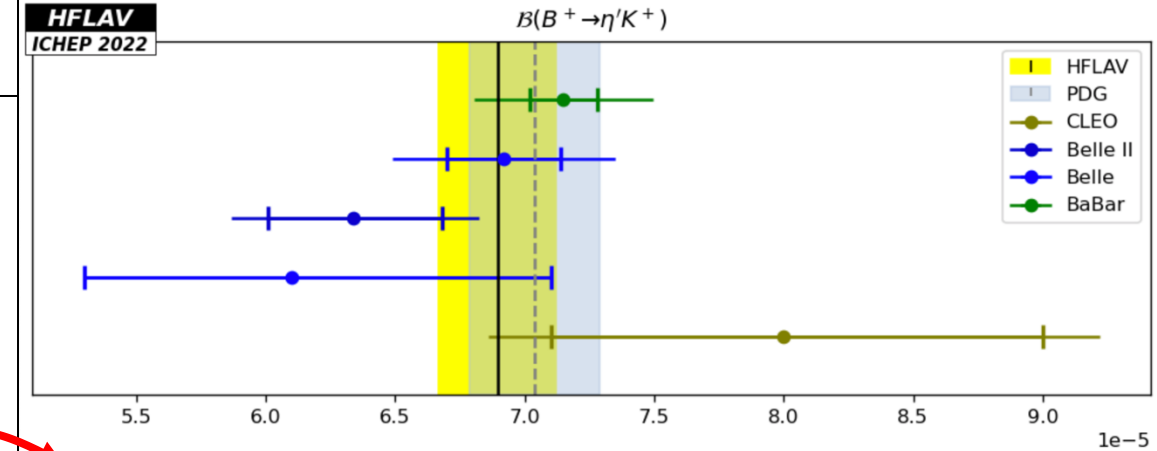
## Rare Decays

- Charmless  $B$  meson decays
- Baryonic  $B$  meson decays
- $b$  baryon decays
- Charmless  $B_s^0$  decays
- $B_c^+$  Decays
- Electroweak radiative  $B$  decays
- $CP$  asymmetries
- Polarisation in  $B$  decays

## Charmless $B$ meson decays

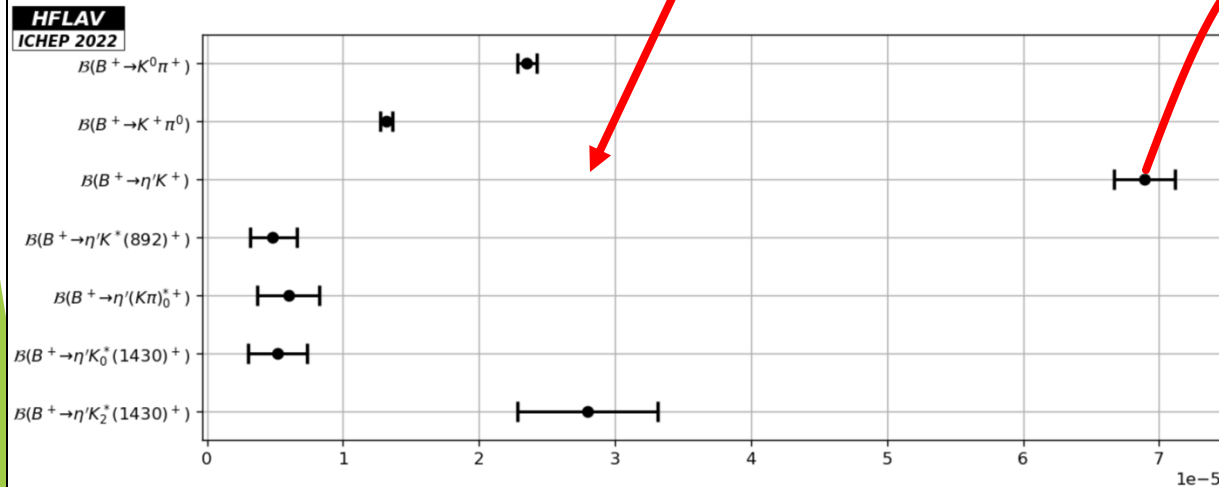
- $B^\pm$  decays
- $B^0$  decays

## $\mathcal{B}(B^+ \rightarrow \eta' K^+)$



## $B^\pm$ decays

### Branching fractions of charmless mesonic $B^+$ decays with strange mesons (part 1)



Experiment	Measurement [ $10^{-5}$ ]	$\Delta\chi^2$ Reference	Comments
<b>Average</b>	$6.89 \pm 0.23$	3.47 $p = 0.48$ (ndf=4)	
PDG	$7.04 \pm 0.25$	pdgLive	
BaBar	$7.15 \pm 0.13 \pm 0.32$	0.55 <a href="#">Phys.Rev.D 80,112002 (2009)</a>	
Belle	$6.92 \pm 0.22 \pm 0.37$	0.00 <a href="#">Phys.Rev.Lett. 97,061802 (2006)</a>	
Belle II	$6.34^{+0.34}_{-0.33} \pm 0.34$	1.33 <a href="#">arXiv:2104.06224</a>	
Belle	$6.1^{+1.0}_{-0.8} \pm 0.1$	0.65 <a href="#">Phys.Lett.B 662,323 (2008)</a>	
CLEO	$8.0^{+1.0}_{-0.9} \pm 0.7$	0.94 <a href="#">Phys.Rev.Lett. 85,520 (2000)</a>	
LHCb	$\mathcal{B}(B_s^0 \rightarrow \eta' \eta') / \mathcal{B}(B^+ \rightarrow \eta' K^+)$	0.00 <a href="#">Phys.Rev.Lett. 115,051801 (2015)</a>	

Input values that appear in red are not included in the PDG average.

Input values in blue correspond to yet unpublished results.

### Further parameters used in the fit and their correlation with the average

Source	Parameter	Correlation [%]	Value	$\Delta\chi^2$
fit	$\mathcal{B}(B_s^0 \rightarrow \eta' \eta')$	15.4	$3.24 \pm 0.69 \times 10^{-5}$	

Parameters of interest whose average is determined from individual measurements are called *fit* parameters.