

# Challenges in Averaging Branching Fraction Measurements

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# Averaging of Heavy Flavor Measurements

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- Want to have best estimates of physics parameters  
→ as input for measurements or theoretical calculations
- ➔ Combine measurements
- Task of HFLAV, working groups with representatives from LHCb, Belle (II), BaBar, ...
  - B lifetimes and oscillation parameters
  - Semi-leptonic B decays
  - Rare B decays
  - Unitarity triangle angles
  - B decays to charm final states
  - Charm Physics
  - Tau Physics

# Heavy Flavor Averaging Group (HFLAV)

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- Web page: <https://hflav.web.cern.ch/>
- Preprints and publications, e.g. [arXiv:1909.12524](https://arxiv.org/abs/1909.12524), *Eur. Phys. J. C* **77** (2017) 895 (826 citations on inspire)
- Some HFLAV averages taken by PDG

- Averaging methodology described in chapter 3 (COMBOS)

## **HFLAV** Heavy Flavor Averaging Group

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### The Heavy Flavor Averaging Group

The Heavy Flavor Averaging Group (HFLAV) was established at the May 2002 Flavor Physics and CP Violation Conference (Philadelphia) and continues the LEP Heavy Flavor Steering Group's tradition of providing regular updates to the world averages of heavy flavor quantities.

The latest averages can be found at Y. Amhis et al., *Averages of b-hadron, c-hadron, and tau-lepton properties as of summer 2018*, [arXiv:1909.12524](https://arxiv.org/abs/1909.12524) and online updates here.

The activities of HFLAV are currently divided up into seven sub-groups that focus on individual measurements.

- B lifetimes and oscillation parameters
- Semi-leptonic B decays

# B to charm

- Decays of b-hadrons into open or hidden charm hadrons
- ~600 parameters (mainly branching fractions),  
~900 measurements,  
~300 publications
- ➔ Automated procedures required

## B to charm

### $B^0$ decays to

- [Single open charm mesons](#)
- [Double open charm mesons](#)
- [Charmonium](#)
- [Charm baryons](#)
- [Other states](#)

### $B^-$ decays to

- [Single open charm mesons](#)
- [Double open charm mesons](#)
- [Charmonium](#)
- [Charm baryons](#)
- [Other states](#)

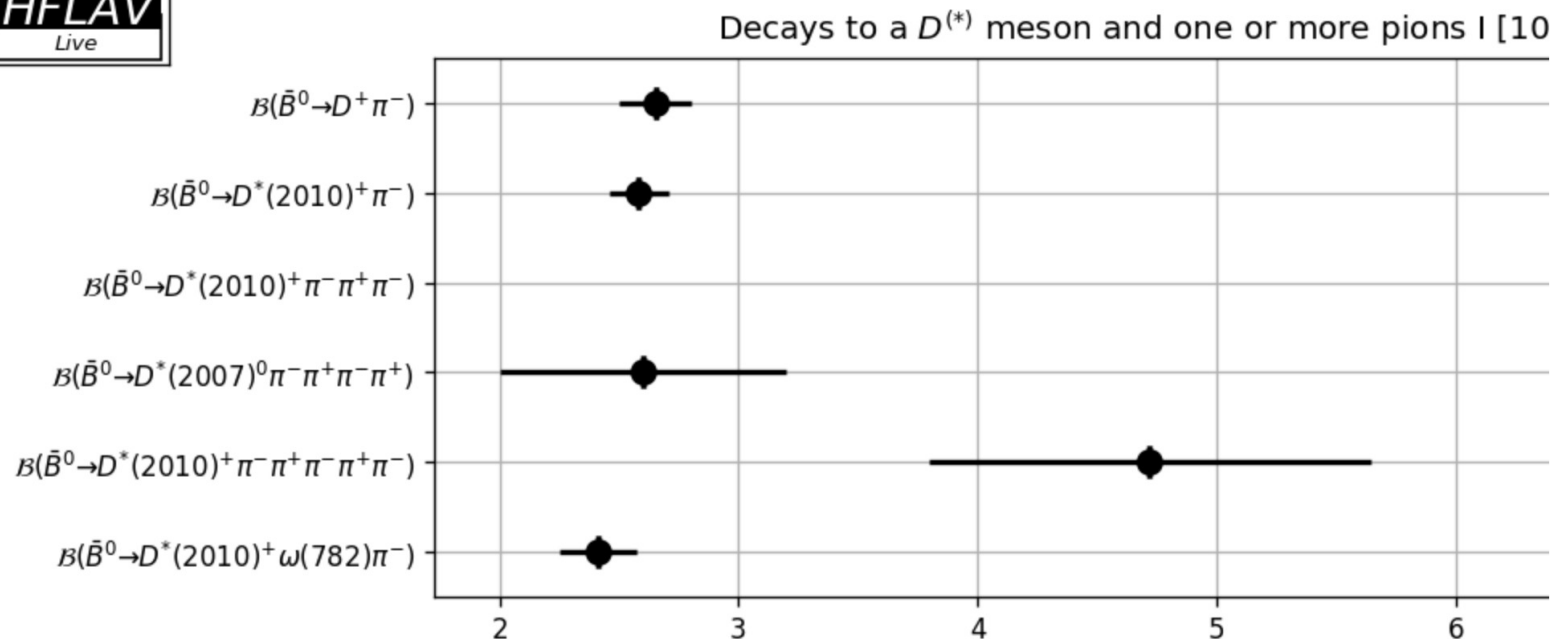
### $B^{0/-}$ decays to

- [Double open charm mesons](#)
- [Charmonium](#)
- [Other states](#)

### $B_s$ decays to

- [Single open charm mesons](#)
- [Double open charm mesons](#)

## $B^0$ decays to single charm mesons



# b2charm framework

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- Data in xml format and averaging code in python stored in git repository
- $\chi^2$  minimization with iminuit
- Output: html pages and latex code with plots and numbers

- Parameters identified by name, xml contains latex code

```
parameters > Bu > cc >  BR_B-KS-_Jpsi.xml
```

```
You, 3 years ago | 1 author (You)
```

```
1 <parameter>  
2 | <latex>{\cal{B}} ( B^{\{-}\ \to J/\psi K^{\{*}}(892)^{\{-}\ } )</latex>  
3 </parameter>
```

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- Publications with measurements / limits
- Grouping in tables/plots defined in xml files

# Example

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```
<publication>
  <reference>PRL 97, 162003 (2006)</reference>
  <preprint>hep-ex/0606022</preprint>
  <inspire>718970</inspire>
  <bibtex>
@article{Wu:2006vx,
  author      = "Wu, C.-H. and others",
  title       = "{Study of J/psi to p anti-p, Lambda anti-Lambda and
  | | | | | | | | | | observation of eta(c) to Lambda anti-Lambda at Belle}",
  collaboration = "Belle",
  journal     = "Phys. Rev. Lett.",
  volume      = "97",
  pages       = "162003",
  doi         = "10.1103/PhysRevLett.97.162003",
  year        = "2006",
  eprint      = "hep-ex/0606022",
  archivePrefix = "arXiv",
  primaryClass = "hep-ex",
  reportNumber = "BELLE-PREPRINT-2006-18, KEK-PREPRINT-2006-15",
  SLACcitation = "%%CITATION = HEP-EX/0606022;%%",
}
```

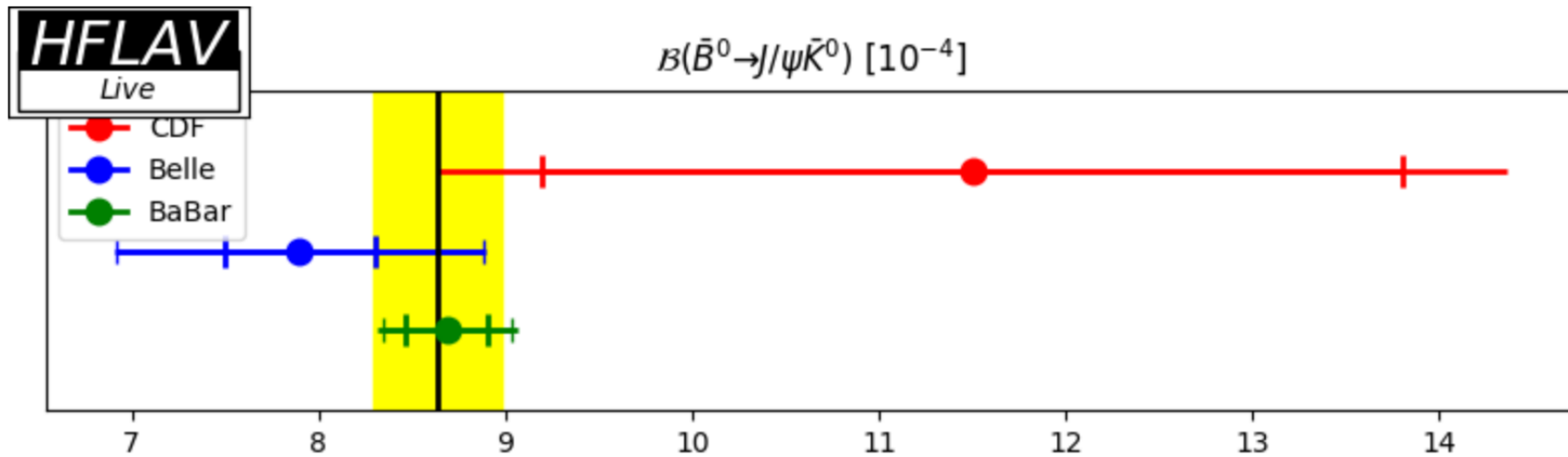
```
</bibtex>
<comment>an update of hep-ex/0509020 for journal submission</comment>
<measurement>
  <param>Bu/cc/BR_B-K_etic.BR_etic_pbar_p</param>
  <value>1.42</value>
  <unit>0.000001</unit>
  <error type="stat">0.11</error>
  <error type="syst">0.16, -0.20</error>
</measurement>
<measurement>
  <param>Bu/cc/BR_B-K_etic.BR_etic_Lambda0bar_Lambda0</param>
```

Script to  
get metadata  
from arxiv or  
inspire

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# Results

- See <https://hflav-eos.web.cern.ch/hflav-eos/b2charm/live/>



Experiment	Measurement	Reference
CDF	$[11.5 \pm 2.3 \text{ (stat)} \pm 1.7 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRL 76 2015 (1996)</a>
Belle	$[7.9 \pm 0.4 \text{ (stat)} \pm 0.9 \text{ (syst)} \pm 0.1 \text{ (psi br (correlated))}] \times 10^{-4}$	<a href="#">PRD 67, 032003(2003)</a>
BaBar	$[8.69 \pm 0.22 \text{ (stat)} \pm 0.26 \text{ (syst)} \pm 0.15 \text{ (jpsi br (correlated))}] \times 10^{-4}$	<a href="#">PRL 94 141801 (2005)</a>
<b>Average</b>	<b><math>[8.63 \pm 0.35 \text{ (combined)}] \times 10^{-4}</math></b>	CL=0.2093

# Statistical Issues

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- Treatment of limits  
→ most stringent or ignored
- Inconsistent measurements  
→ no scaling, quote CL
- Correlated systematic uncertainties among measurements of the same parameter  
→ common nuisance parameter
- Asymmetric uncertainties  
→ asymmetric Gaussian function with variable width  
linear in variance, fixed above  $\pm\sigma$

# Further Statistical Issues

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- Ideally would like to know/use likelihood
- Dependence on input parameters, update on change of input parameters
- Correlations among different parameters
- Missing information about inputs or systematic uncertainties
- Constraint on sum of BRs
- Averaging of decay amplitudes and phases (of multi-body decays)
- Technical issues: reference to PDG averages, use HEPData?, xml → json, better layout
- Open source?