



Heavy Flavor Averaging Group (HFAG)

PDG Collaboration/Advisory Meeting
CERN
October 6, 2012

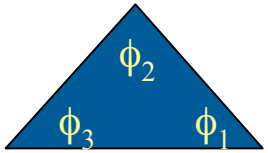
Co-leaders (from 2010): ***Tim Gershon,*** *University of Warwick*
Alan Schwartz, *University of Cincinnati*

2007-2010 *Alan Schwartz, Gianluca Cavoto*
2005-2007: *Soeren Prell, Simon Eidelman*
2002-2005: *David Kirkby, Yoshihide Sakai*

Goal: ***provide up-to-date world averages for measurements of B, D, and τ meson related quantities. Results can be freely quoted by conference speakers, theorists, etc.***

Policy: ***We use the latest conference results in averages; however, if a result is not submitted for publication within 12 months of presentation (or if there are no plans to publish a result), we withdraw it from world averages.***

For averages, we do not inflate errors.



Organization

7 semi-independent subgroups:

- B Lifetimes and Mixing
- Semileptonic B Decays
- Unitarity Triangle
- Rare B Decays
- b to c Decays
- Charm Physics
- Tau Physics

Web pages: subgroups update their websites typically 2-3 times/year, e.g., after Moriond, after ICHEP/LP, sometimes after FPCP/CKM, etc.

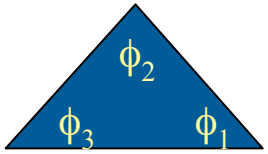
(http://www.slac.stanford.edu/xorg/hfag/)

These provide world averages for conference speakers, theorists, etc.

Preprint: every 1-2 years, all results are collected together in one paper and posted to arXiv (hep-ex). The most recent posting is:

> Y. Amhis et al., "Averages of b-hadron, c-hadron, and τ-lepton Properties as of Early 2012," arXiv:1207.1158

Provide averages for the PDG (next slide)



HFAG and the PDG

HFAG provides numerous averages to the PDG (contact: Weiming Yao)

The provided averages currently include:

A. Lifetimes and Oscillations:

- b lifetimes
- B mixing parameters
- b production fractions
- $\Delta\Gamma_s$, ϕ_s

B. UT Triangle:

- Sin2β ($B^0 \to$ ccbar K^0)
- $|\lambda|$ ($B^0 \to$ ccbar K^0)

C. Charm:

- mixing parameters x, y
- strong phases $\delta_{K\pi}$, $\delta_{K\pi\pi}$
- CPV parameters $|q/p|$, ϕ

D. Semileptonic decays:

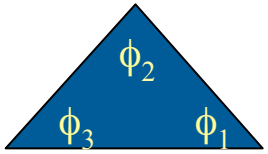
- $|V_{cb}|$ x F(1) for $B^0 \to D^*- l+ \nu$ with ρ^2 and correlation
- $|V_{cb}|$ x F(1) for $B^0 \to D- l+ \nu$ with ρ^2 and correlation

- Exlcusive B($B^0 \to D- l+ \nu$)
- Exclusive B($B^0 \to D^*- l+ \nu$)
- Exclusive B($B^+ \to D0\ l\ \nu$)
- Exclusive B($B^+ \to D^*0\ l\ \nu$)

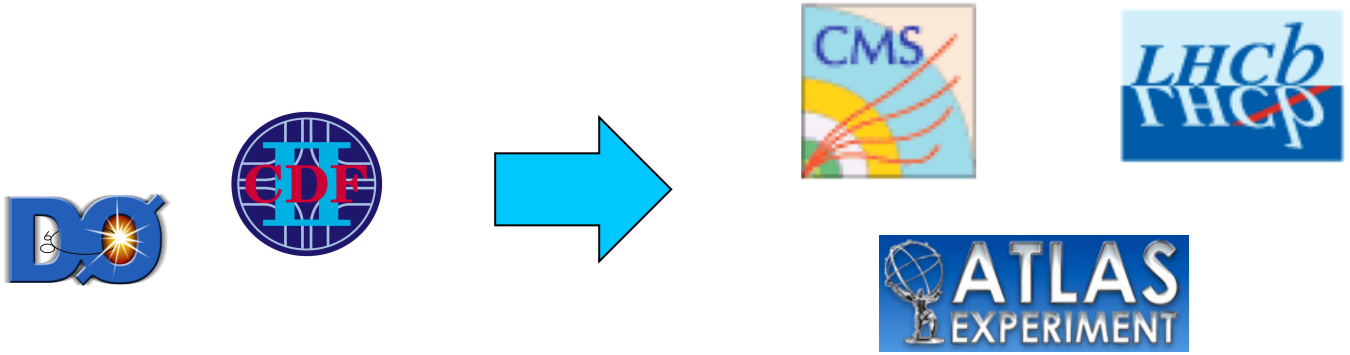
- Exclusive B($B^+ \to D- \pi+\ l\ \nu$)
- Exclusive B($B^+ \to D^*- \pi+\ l\ \nu$)
- Exclusive B($B^0 \to D0\ \pi+\ l\ \nu$)
- Exclusive B($B^0 \to D^*0\ \pi+\ l\ \nu$)

- Inclusive B($B^0/B^+ \to l+\ \nu\ X$)

- V_{ub} for inclusive and exclusive b to u l ν decays
- Exclusive B($B^0 \to \pi- l+\ \nu$)
- Exclusive B($B^0 \to \rho- l+\ \nu$)



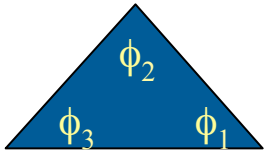
HFAG Transition to the LHC Era



HFAG began as a collaboration between Belle and BaBar, with some input from CLEO and LEP

Over the past five years, CDF and D∅ have played larger roles. For B_s physics, they are playing leading roles.
[Tesarek, Tonelli, Jones, Harr (CDF), Bernhard, Van Kooten (D∅)]

A number of HFAG members collaborate on LHC experiments, so there is already some LHCb, ATLAS, CMS representation. Over the past year, new LHCb representatives have joined most HFAG subgroups
[Leroy, Carbone, Patel, Amhis, Gersabeck; joining Schneider, Gershon, Bozzi]



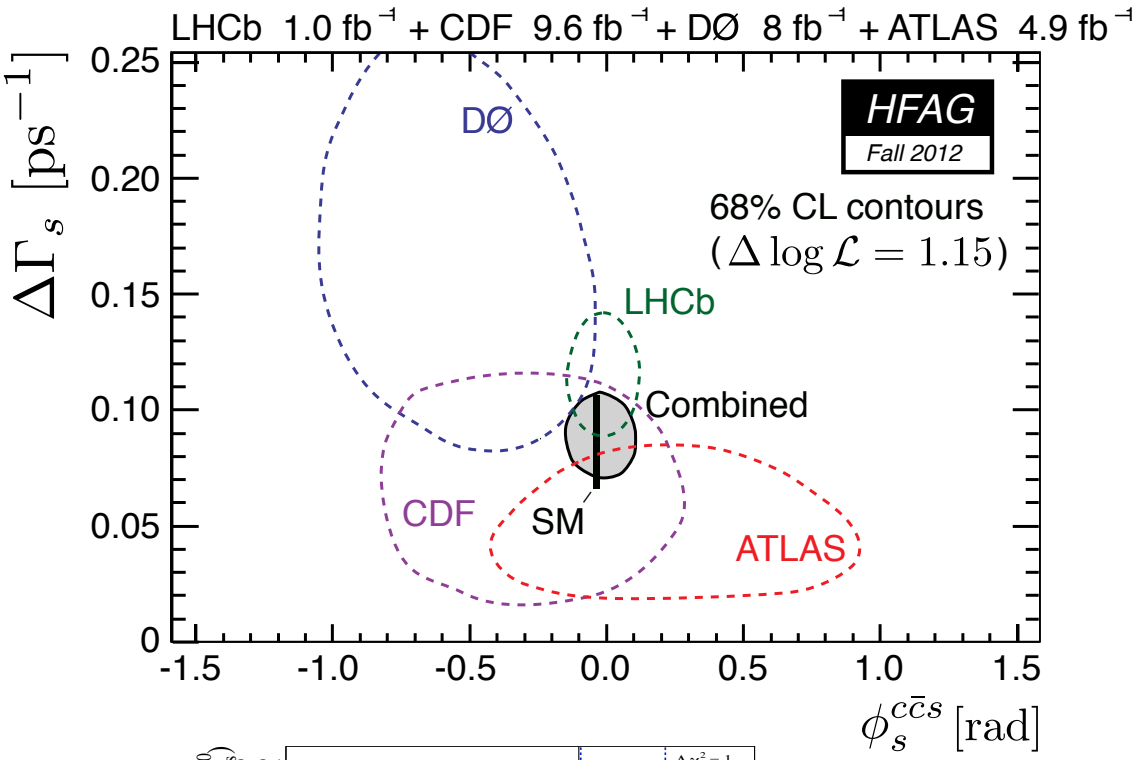
HFAG: Lifetimes and Mixing subgroup

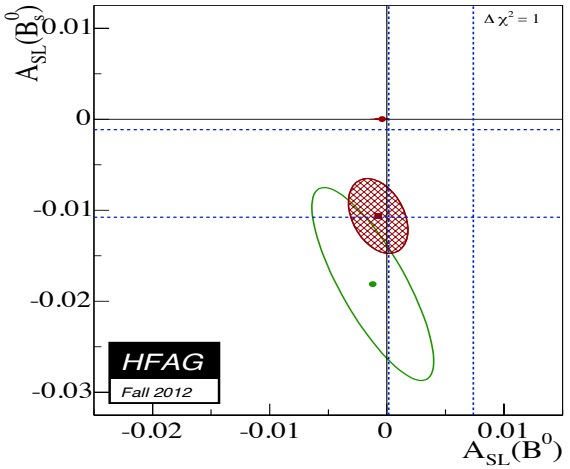
Active Members:

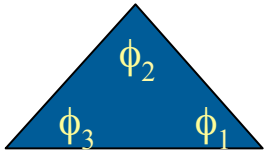
Olivier Leroy (LHCb)
Rick van Kooten (DØ)
Olivier Schneider (Belle/LHCb)
Rick Tesarek (CDF)

Tasks:

b-hadron lifetimes
b-hadron fractions
B_d mixing, CPV
($\Delta\Gamma$, Δm, $|q/p|$)
B_s mixing, CPV
($\Delta\Gamma_s$, Δm_s, $|q/p|$, β_s)

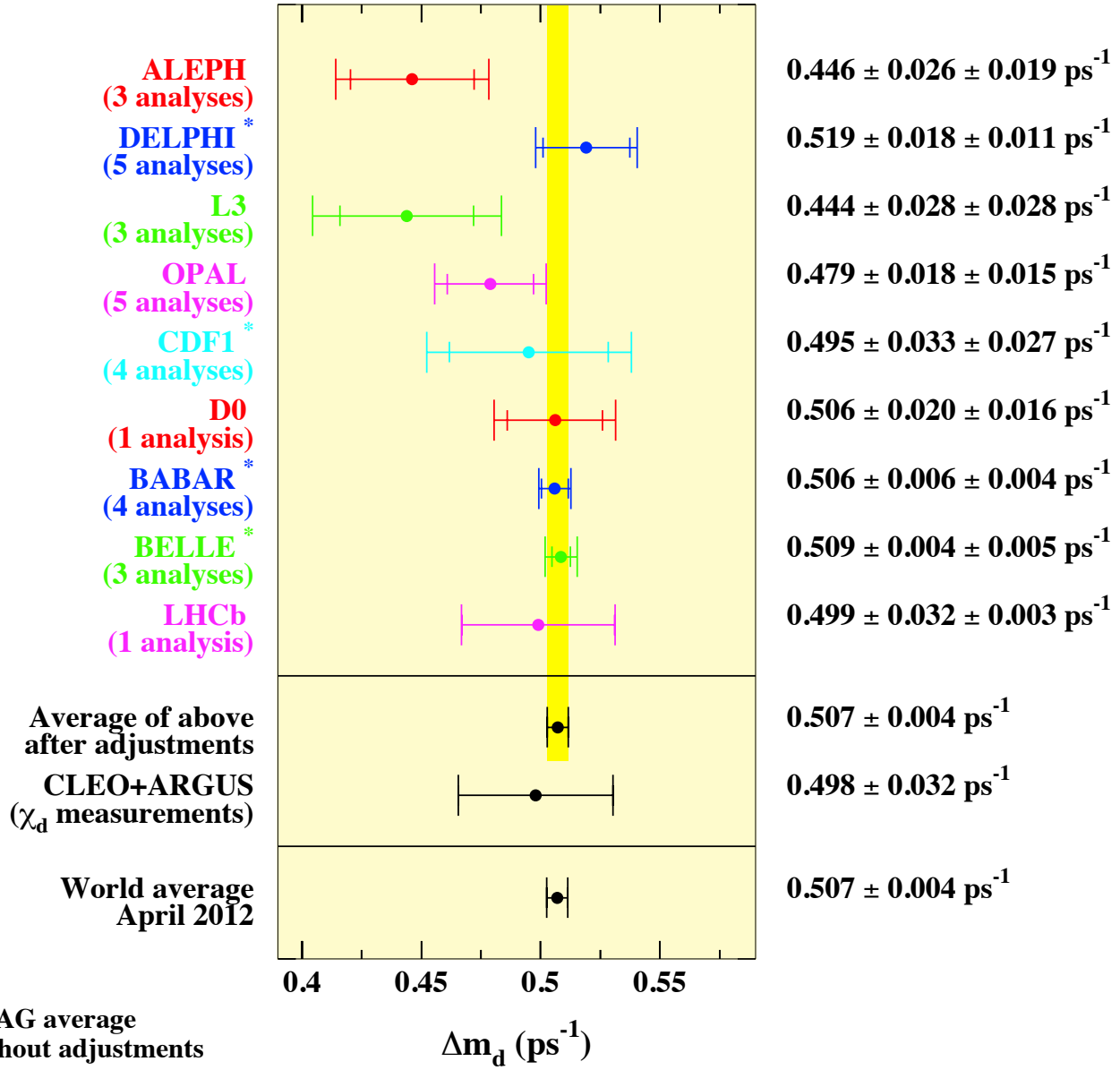




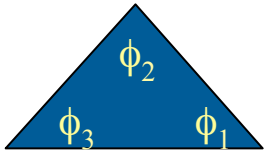


HFAG: Lifetimes and Mixing (cont'd)

Calculated for the PDG 2012:



* HFAG average without adjustments



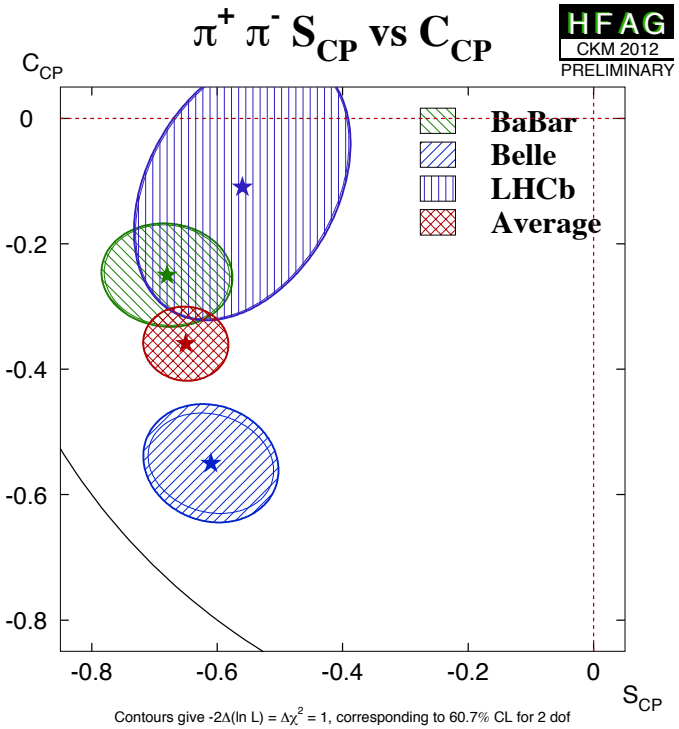
HFAG: UT Triangle subgroup

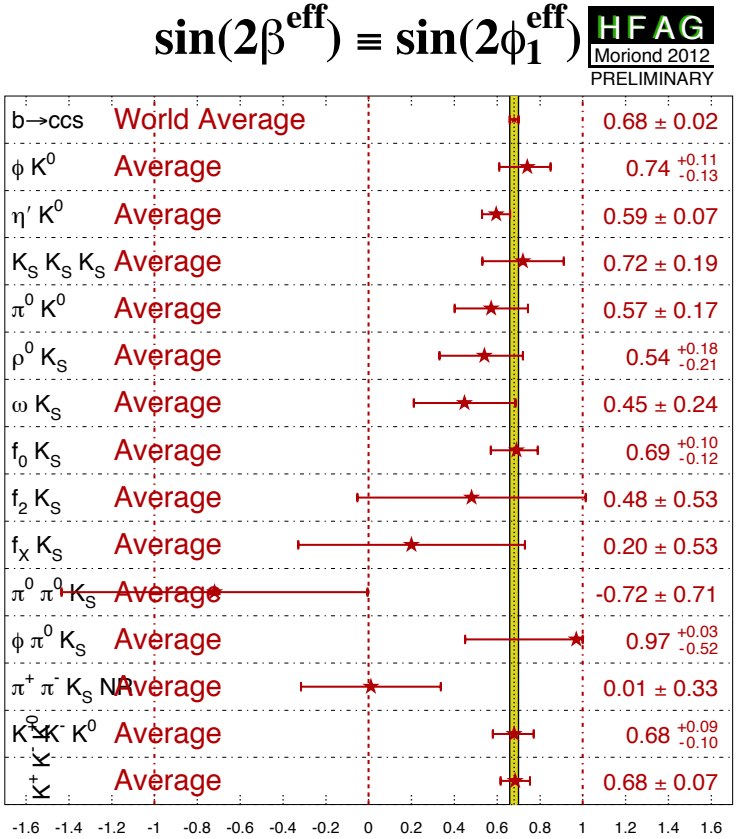
Active Members:

Angelo Carbone (LHCb)
Kenkichi Miyabayashi (Belle)
Tim Gershon (BaBar/LHCb)
Diego Tonelli (CDF)
Karim Trabelsi (Belle)

Tasks:

time-dependent CPV parameters,
ϕ_1 (α)
ϕ_2 (β)
ϕ_3 (γ)





HFAG: Semileptonic subgroup

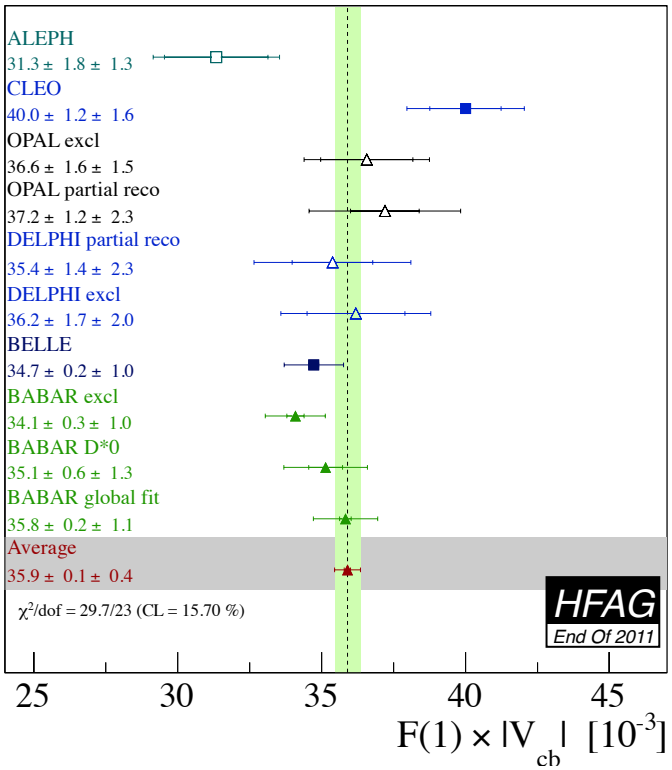
Active Members:

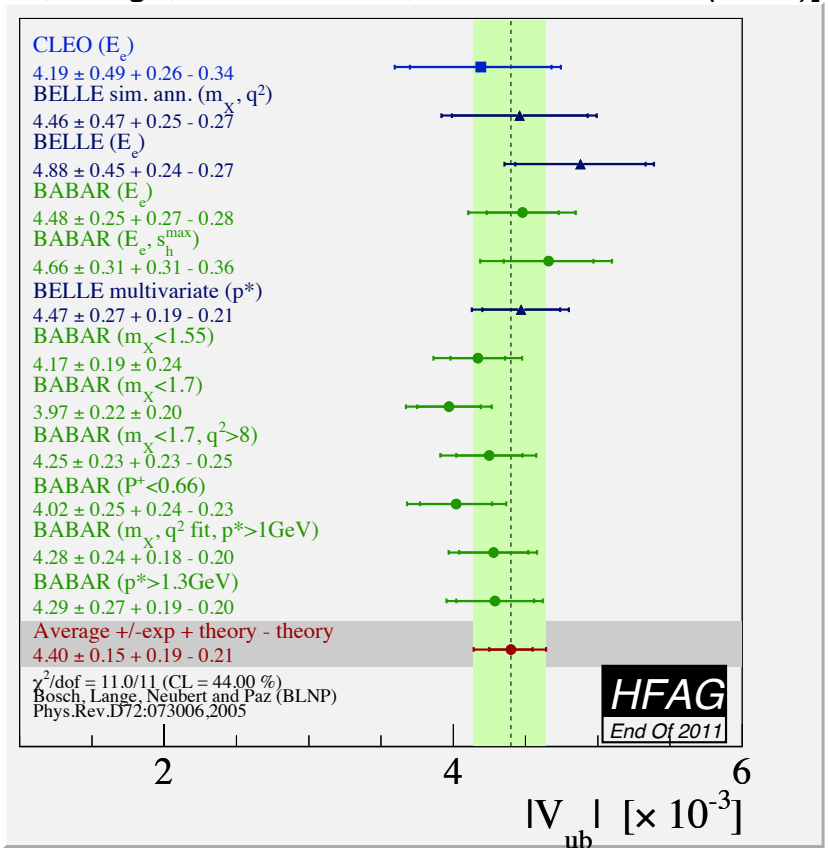
Concezio Bozzi (BaBar/LHCb)
Matthew Jones (CDF)
Vera Lüth (BaBar)
Christoph Schwanda (Belle)
Phillip Urquijo (Belle)
Marcello Rotondo (Babar)
Jochen Dingfelder (Belle)

Tasks:

Branching fractions inclusive
Branching fractions exclusive
$|V_{cb}|$, $|V_{ub}|$
Moments

BLNP Scheme:
[Bosch, Lange, Neubert, Paz, PRD 72:073006 (2005)]





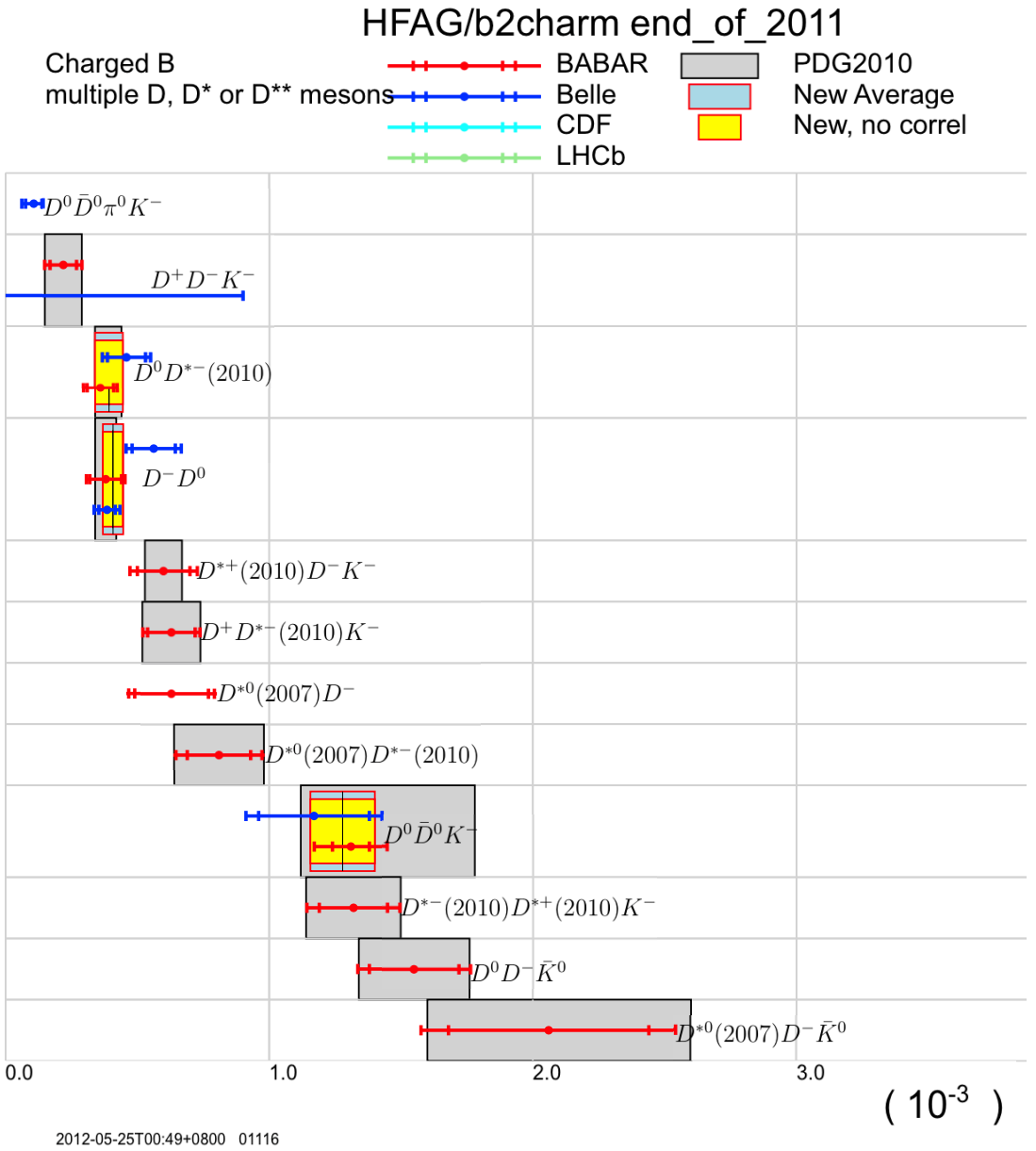
HFAG: b to charm subgroup

Active Members:

Simon Blyth (Belle)
Andrzej Bozek (Belle)
Gianluigi Cibinetto (IBaBar)
Matteo Rama (BaBar)
Yasmine Amhis (LHCb)

Tasks:

Branching fractions (with averages)



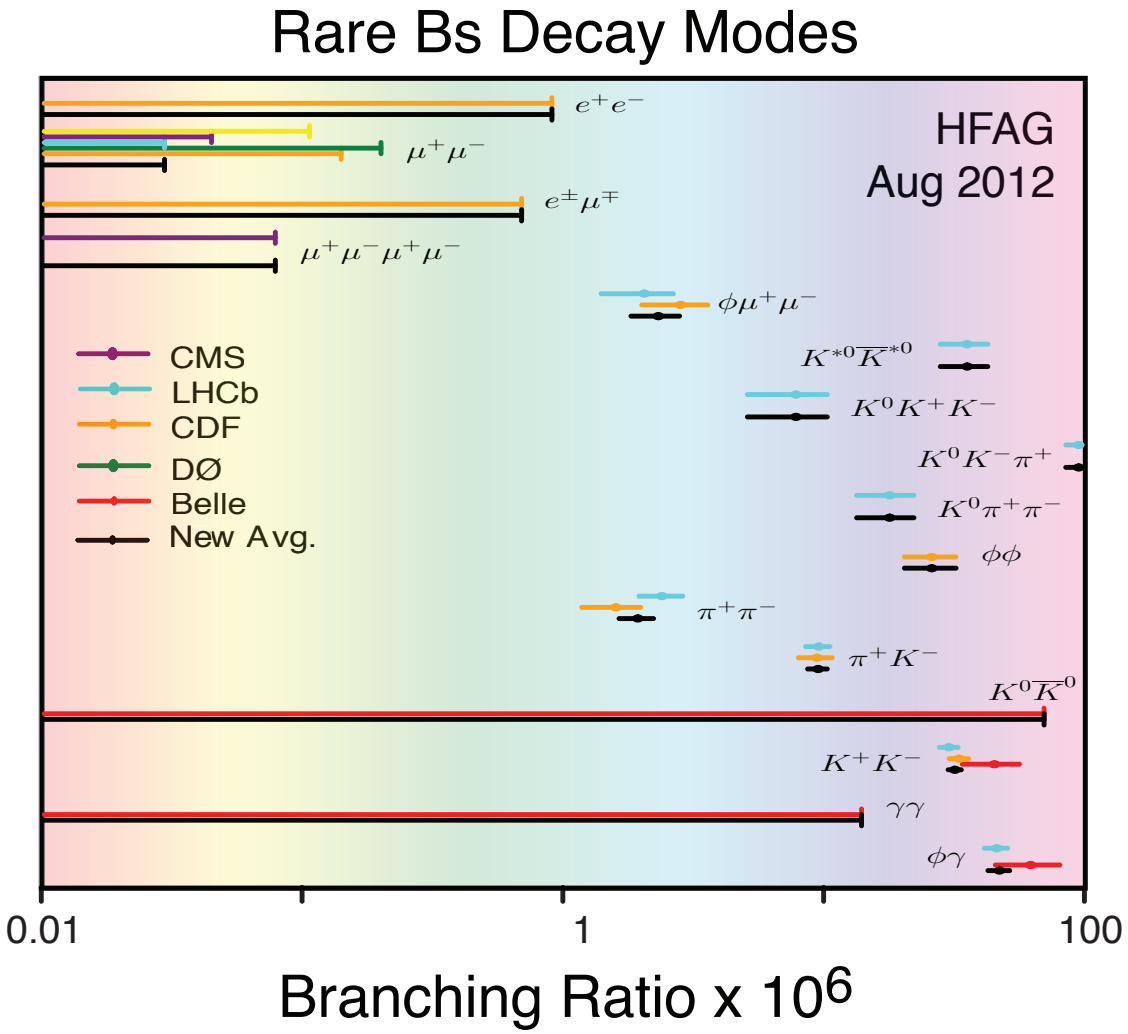
HFAG: Rare subgroup

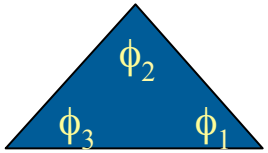
Active Members:

Ralf Bernhard (DØ)
Shohei Nishida (Belle)
Rob Harr (CDF)
Jim Smith (BaBar)
Mitesh Patel (LHCb)

Tasks:

Charmless mesonic decays
Radiative decays
Leptonic decays
Baryonic decays
A_{CP}
Vector-vector polarization
B_s decays
Now providing averages for
$K\mu^+\mu^-$ differential BF, A_{FB}, etc. in bins of q^2





HFAG: Rare subgroup (cont'd)

Forward-backward Asymmetry ($A_{\rm FB}$)

In PDG2012 | New since PDG2012 (preliminary) | New since PDG2012 (published)

RPP#	Mode	q^2 [(GeV/c^2)^2] †	PDG2012 Avg.	BABAR	Belle	CDF ‡	LHCb ‡	New Avg.
124	$K\ell^+\ell^-$	< 2.0	-0.02 ± 0.26		$0.06^{+0.32}_{-0.35} \pm 0.02$	$-0.19^{+0.37}_{-0.45} \pm 0.09$		$-0.03^{+0.18}_{-0.19}$
	$K\ell^+\ell^-$	$[2.0, 4.3]$	0.2 ± 0.6		$-0.43^{+0.38}_{-0.40} \pm 0.09$	$0.32^{+0.17}_{-0.13} \pm 0.10$		$0.20^{+0.15}_{-0.14}$
	$K\ell^+\ell^-$	$[4.3, 8.68]$	$-0.20^{+0.10}_{-0.13}$		$-0.20^{+0.12}_{-0.14} \pm 0.03$	$0.08^{+0.08}_{-0.09} \pm 0.01$		-0.08 ± 0.06
	$K\ell^+\ell^-$	$[10.09, 12.86]$	$-0.15^{+0.13}_{-0.12}$		$-0.21^{+0.17}_{-0.15} \pm 0.06$	$-0.04^{+0.12}_{-0.10} \pm 0.03$		$-0.11^{+0.08}_{-0.07}$
	$K\ell^+\ell^-$	$[14.18, 16.00]$	$0.03^{+0.27}_{-0.14}$		$0.04^{+0.32}_{-0.26} \pm 0.05$	$-0.07^{+0.08}_{-0.08} \pm 0.01$		$-0.04^{+0.07}_{-0.06}$
	$K\ell^+\ell^-$	> 16.00	$0.03^{+0.10}_{-0.08}$		$0.02^{+0.11}_{-0.08} \pm 0.02$	$0.05^{+0.18}_{-0.10} \pm 0.05$		$0.03^{+0.07}_{-0.05}$
	$K\ell^+\ell^-$	$[1.00, 6.00]$			$0.26^{+0.27}_{-0.30} \pm 0.07$	$0.13^{+0.11}_{-0.10} \pm 0.02$		$0.14^{+0.11}_{-0.10}$
125	$K^*\ell^+\ell^-$	< 2.0	$0.45^{+0.26}_{-0.30}$		$0.47^{+0.26}_{-0.32} \pm 0.03$	$0.05^{+0.28}_{-0.27} \pm 0.10$	$-0.15 \pm 0.20 \pm 0.06$	0.12 ± 0.13
	$K^*\ell^+\ell^-$	$[2.0, 4.3]$	0.14 ± 0.27		$0.11^{+0.31}_{-0.36} \pm 0.07$	$-0.11^{+0.34}_{-0.41} \pm 0.16$	$-0.05^{+0.16}_{-0.20} \pm 0.04$	$0.01^{+0.12}_{-0.14}$
	$K^*\ell^+\ell^-$	$[4.3, 8.68]$	0.24 ± 0.24		$0.45^{+0.15}_{-0.21} \pm 0.15$	$0.09^{+0.14}_{-0.14} \pm 0.04$	$0.27^{+0.06}_{-0.08} \pm 0.02$	$0.25^{+0.06}_{-0.07}$
	$K^*\ell^+\ell^-$	$[10.09, 12.86]$	0.53 ± 0.15		$0.43^{+0.18}_{-0.20} \pm 0.03$	$0.44^{+0.12}_{-0.13} \pm 0.08$	$0.27^{+0.11}_{-0.13} \pm 0.02$	0.39 ± 0.07
	$K^*\ell^+\ell^-$	$[14.18, 16.00]$	$0.53^{+0.13}_{-0.15}$		$0.70^{+0.16}_{-0.22} \pm 0.10$	$0.53^{+0.09}_{-0.09} \pm 0.07$	$-0.47^{+0.06}_{-0.08} \pm 0.03$	-0.08 ± 0.05
	$K^*\ell^+\ell^-$	> 16.00	$0.67^{+0.10}_{-0.14}$		$0.66^{+0.11}_{-0.16} \pm 0.04$	$0.35^{+0.17}_{-0.19} \pm 0.06$	$-0.16^{+0.11}_{-0.13} \pm 0.06$	$0.32^{+0.07}_{-0.08}$
	$K^*\ell^+\ell^-$	$[1.00, 6.00]$			$0.26^{+0.27}_{-0.30} \pm 0.07$	$0.19^{+0.17}_{-0.21} \pm 0.05$	$-0.06^{+0.13}_{-0.14} \pm 0.04$	$0.05^{+0.10}_{-0.11}$

† see the original paper for the exact q^2 selection. ‡ muon mode only ($\ell = \mu$).

Heavy Flavor Averaging Group

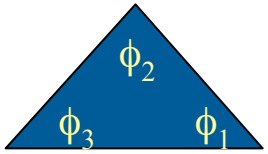
August 2012

Fraction of the Longitudinal Polarization (F_L)

In PDG2012 | New since PDG2012 (preliminary) | New since PDG2012 (published)

RPP#	Mode	q^2 [(GeV/c^2)^2] †	PDG2012 Avg.	BABAR	Belle	CDF ‡	LHCb ‡	New Avg.
125	$K^*\ell^+\ell^-$	< 2.0	0.35 ± 0.17		$0.29^{+0.21}_{-0.18} \pm 0.02$	$0.25^{+0.14}_{-0.13} \pm 0.04$	$0.00^{+0.13}_{-0.00} \pm 0.02$	$0.19^{+0.08}_{-0.07}$
	$K^*\ell^+\ell^-$	$[2.0, 4.3]$	0.60 ± 0.20		$0.71 \pm 0.24 \pm 0.05$	$0.71^{+0.15}_{-0.17} \pm 0.07$	$0.77 \pm 0.15 \pm 0.03$	0.71 ± 0.09
	$K^*\ell^+\ell^-$	$[4.3, 8.68]$	$0.74^{+0.15}_{-0.17}$		$0.64^{+0.23}_{-0.24} \pm 0.07$	$0.72^{+0.12}_{-0.13} \pm 0.05$	$0.60^{+0.06}_{-0.07} \pm 0.01$	0.63 ± 0.05
	$K^*\ell^+\ell^-$	$[10.09, 12.86]$	0.23 ± 0.12		$0.17^{+0.17}_{-0.15} \pm 0.03$	$0.38^{+0.11}_{-0.11} \pm 0.04$	$0.41 \pm 0.11 \pm 0.03$	0.32 ± 0.06
	$K^*\ell^+\ell^-$	$[14.18, 16.00]$	0.34 ± 0.31		$-0.15^{+0.27}_{-0.23} \pm 0.07$	$0.40^{+0.11}_{-0.11} \pm 0.04$	$0.37 \pm 0.09 \pm 0.05$	0.34 ± 0.07
	$K^*\ell^+\ell^-$	> 16.00	$0.11^{+0.12}_{-0.10}$		$0.12^{+0.15}_{-0.13} \pm 0.02$	$0.19^{+0.12}_{-0.11} \pm 0.07$	$0.26^{+0.10}_{-0.08} \pm 0.03$	$0.19^{+0.06}_{-0.05}$
	$K^*\ell^+\ell^-$	$[1.00, 6.00]$			$0.67 \pm 0.23 \pm 0.05$	$0.76^{+0.12}_{-0.14} \pm 0.07$	$0.55 \pm 0.10 \pm 0.03$	0.62 ± 0.08

† see the original paper for the exact q^2 selection. ‡ muon mode only ($\ell = \mu$).



HFAG: Charm subgroup

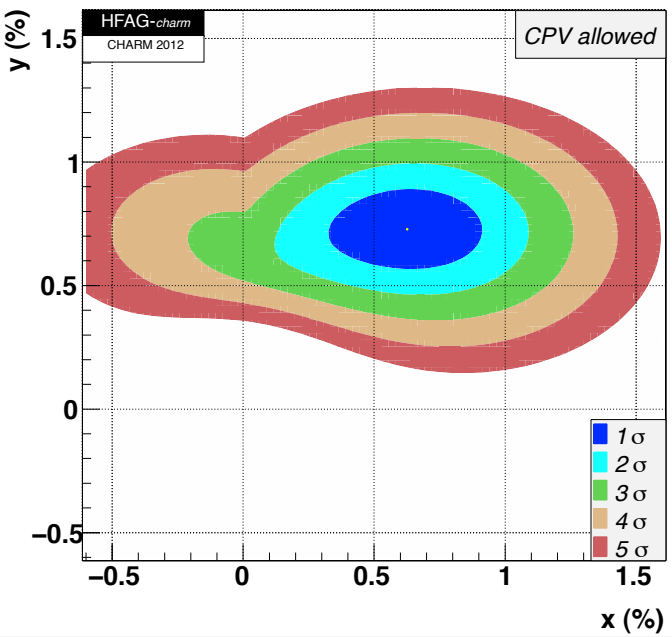
Active Members:

Jonathon Coleman (BaBar)
Lawrence Gibbons (CLEO-c)
Bostjan Golob (Belle)
Ruslan Chistov (Belle)
Daniele Pedrini (FOCUS)
Arantza Oyanguren Campos (BaBar)
Alan Schwartz (Belle)
Marco Gersabeck (LHCb)

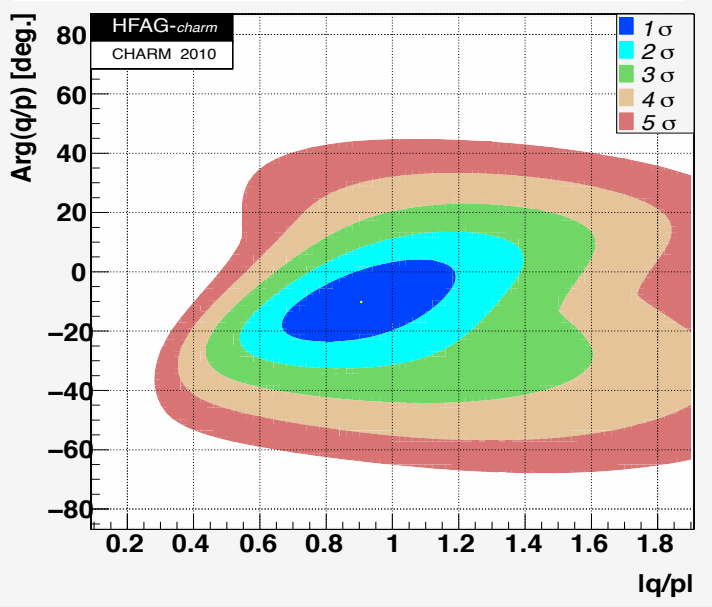
Tasks:

Mixing
CPV in mixing/interference
Direct CPV
Semileptonic (form factors)
Decay constants
Excited D's (D**, D_{sJ})
Rare decays
Charm baryons

Global fit results:



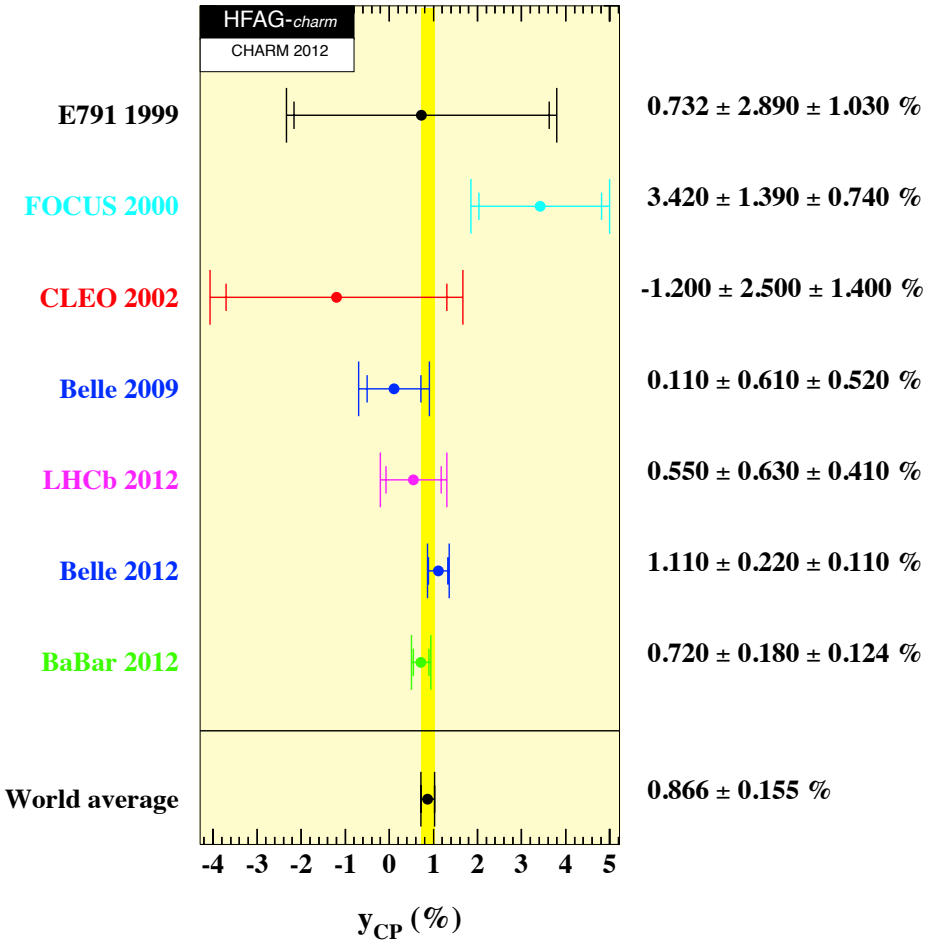
no mixing excluded at >10σ



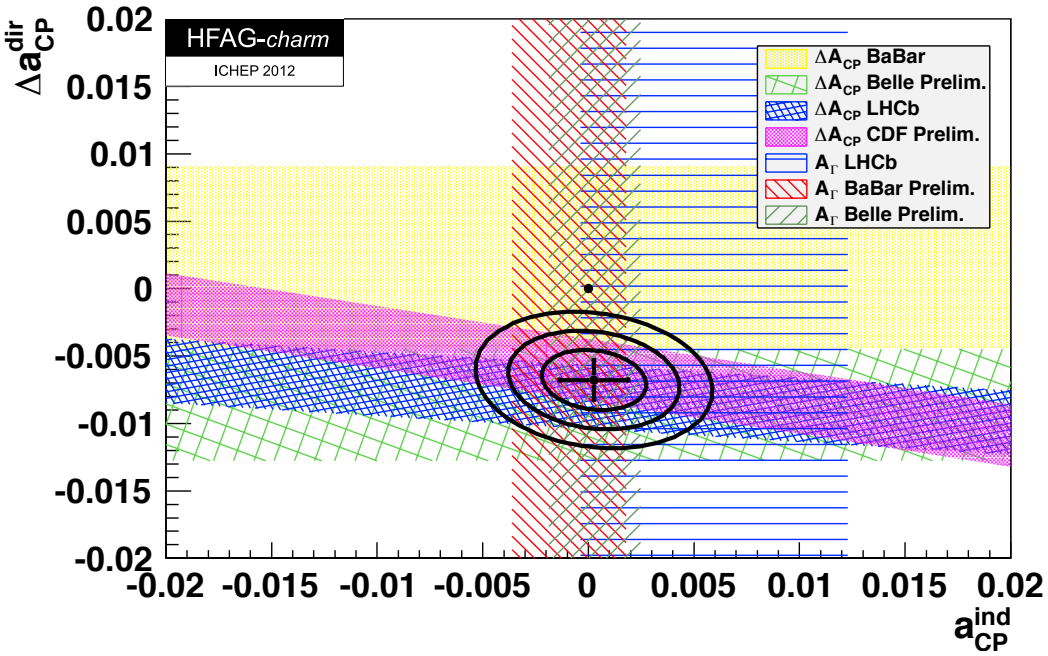
consistent with no CPV

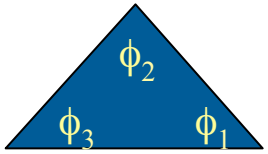
HFAG: Charm subgroup (cont'd)

Mixing parameter y_{CP}:



Evidence (4.1σ) for direct CPV in $A_{CP}(D^0 \to KK) - A_{CP}(D^0 \to \pi\pi)$:





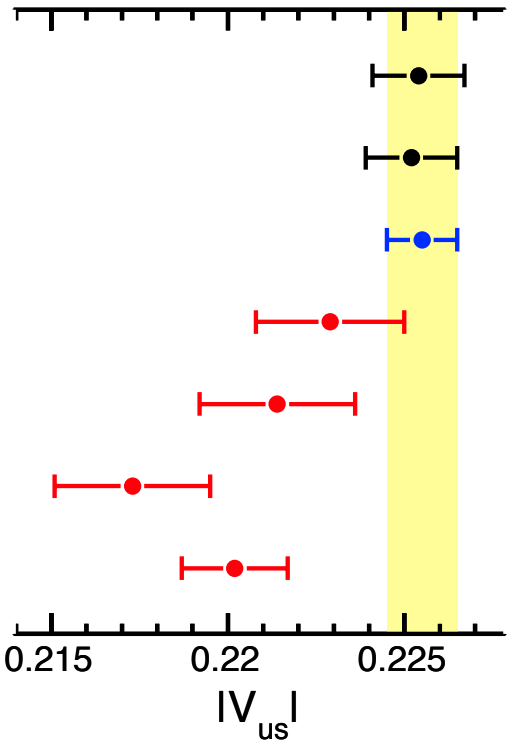
HFAG: Tau subgroup

Active Members:

Kiyoshi Hayasaka (Belle)
Boris Shwartz (Belle)
Hisaki Hayashii (Belle)
Alberto Lusiani (BaBar)
Mike Roney (BaBar)
Swagato Banerjee (BaBar)

Tasks:

Tau mass
Branching fractions
Extraction of $|V_{us}|$
Lepton-flavor-violating limits



K_{l3} decays, FlaviaNet 2010
0.2254 ± 0.0013

K_{l2} decays, FlaviaNet 2010
0.2252 ± 0.0013

CKM unitarity
0.2255 ± 0.0010

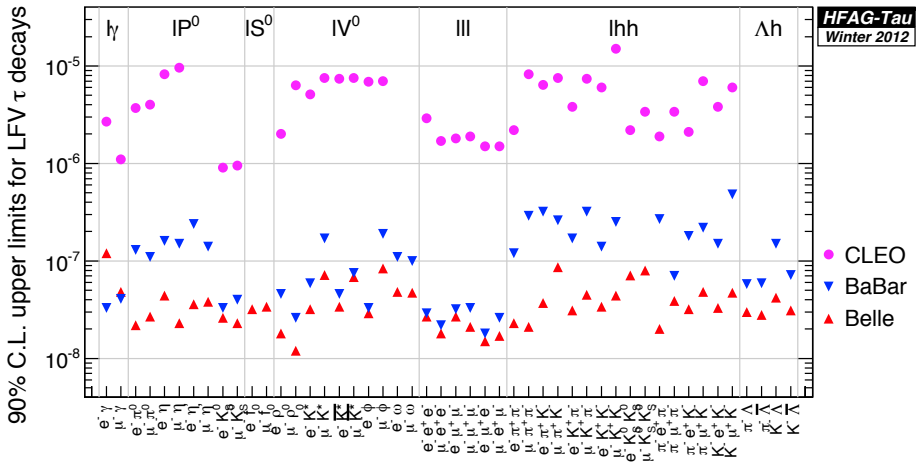
$\tau \to K\nu$ / $\tau \to \pi\nu$, HFAG 2012
0.2229 ± 0.0021

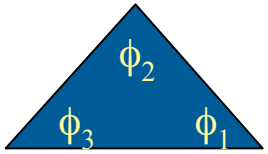
$\tau \to K\nu$, HFAG 2012
0.2214 ± 0.0022

$\tau \to$ s inclusive, HFAG 2012
0.2173 ± 0.0022

τ average, HFAG 2012
0.2202 ± 0.0015

HFAG-Tau
Winter 2012





Summary of activities

- Some new B, D, τ results still coming from full Babar data set
- New B, D, τ results coming from full Belle data set [Υ(4S) and Υ(5S)]
- New D, B_s results coming from full CDF/D$\varnothing$ data sets
- D^0-D^0 mixing and new ϕ_3 (γ) results from B-factories are obtained using strong phase measurements from CLEOc
- Many new B_d, B^+, B_s , D measurements now coming from LHCb

HFAG has evolved to be more LHC-centric, should be busy and relevant for several years to come

- Interaction with PDG is productive

HFAG will remain active in providing averages to the PDG