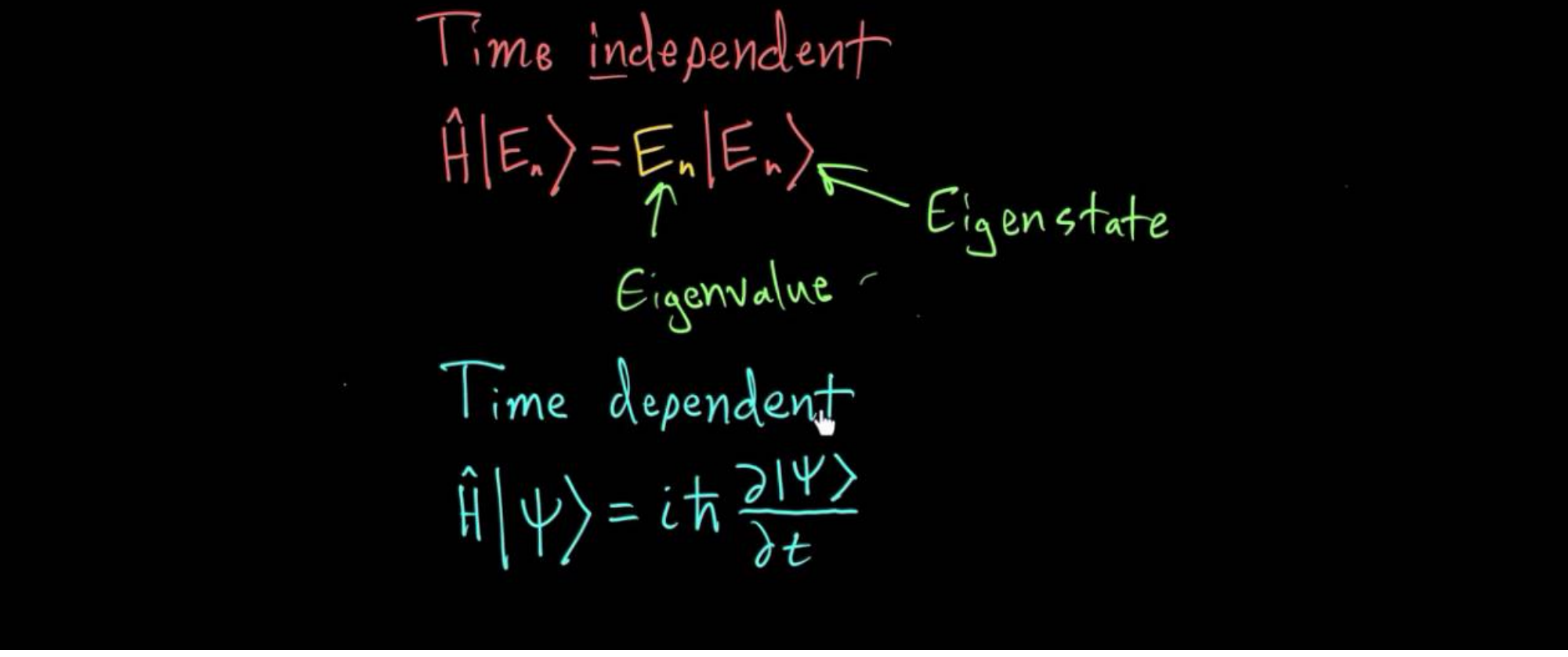


Time-integrated and time-dependent CP-violation measurements

Sevda Esen

Nikhef

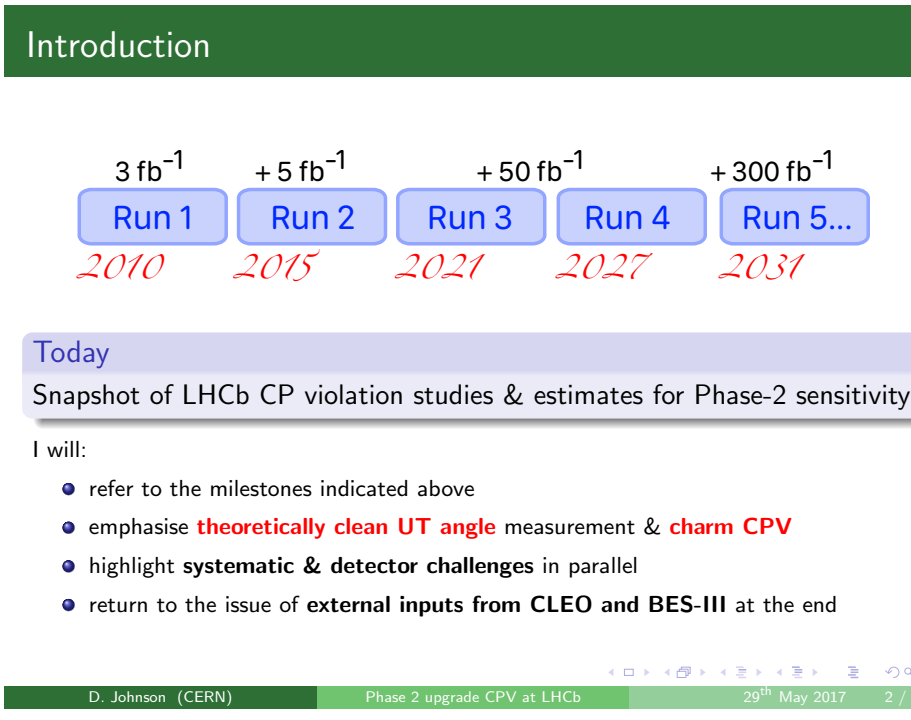
NWO

3rd Workshop on LHCb Upgrade II
21-23 March 2018, Annecy

Introduction

- a very comprehensive summary last year by Dan Johnson
- Today

  A less comprehensive summary
- Selected measurements toward new physics searches involving CPV in B decays
- Technical chalenges, especially for time dependent measurements



How do we measure CPV?

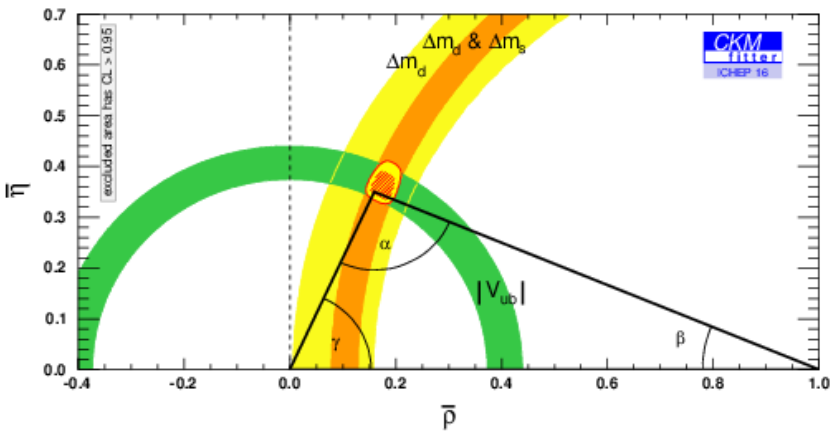
Time independent measurements:

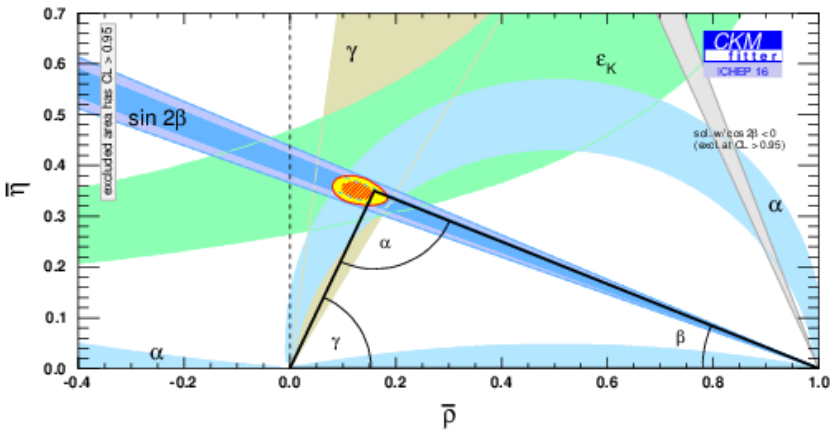
- Charge specific final states
- For B decays: direct CPV
- Measure raw A_{CP}
- Subtract asymmetries from
  - production
  - detection
- Main systematics:
  - Mass modeling
  - Uncertainties on control channel

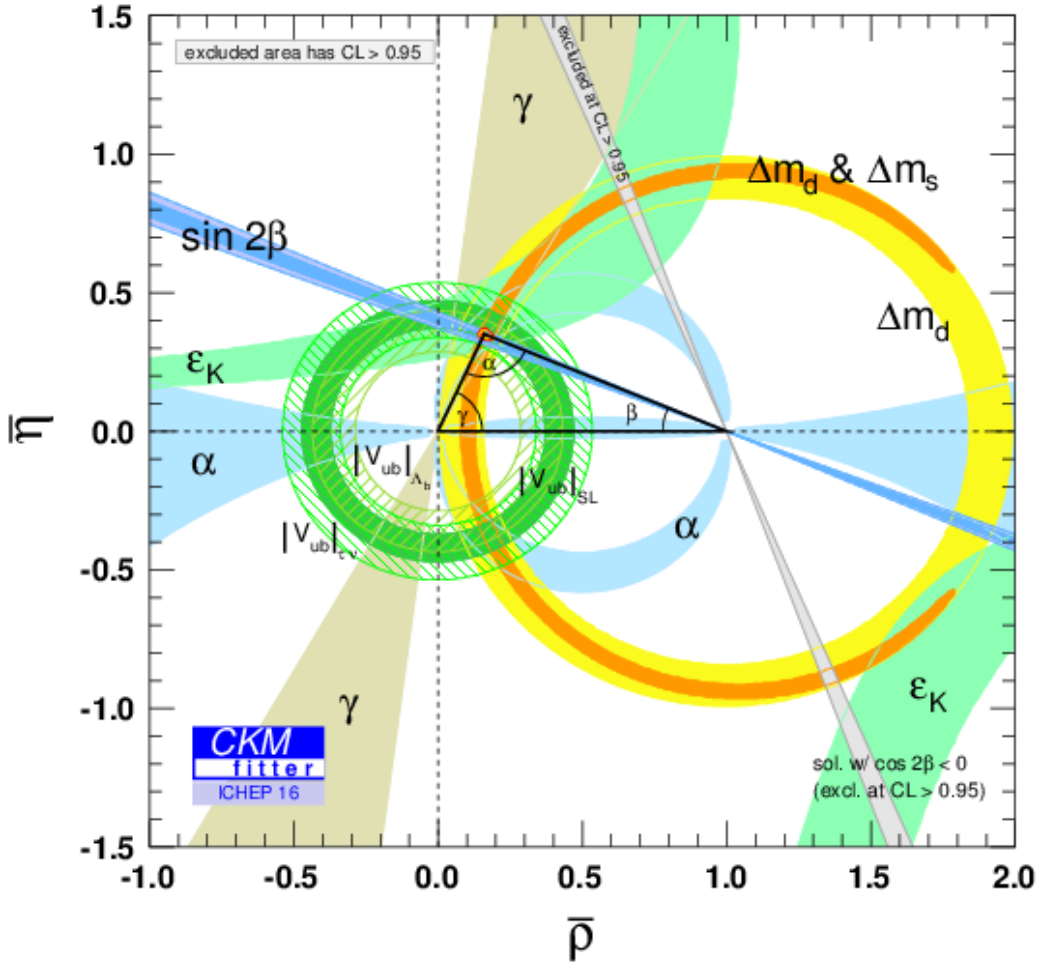
Time dependent measurements:

- Fit to decay time if CP final state
  - Time resolution
  - Time acceptance
  - PV association
  - Flavor tagging
- Angular analysis if not CP specific state
  - Angular acceptance
  - Angular resolution

What have we measured so far?

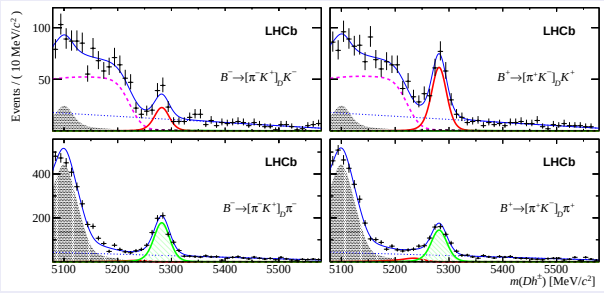






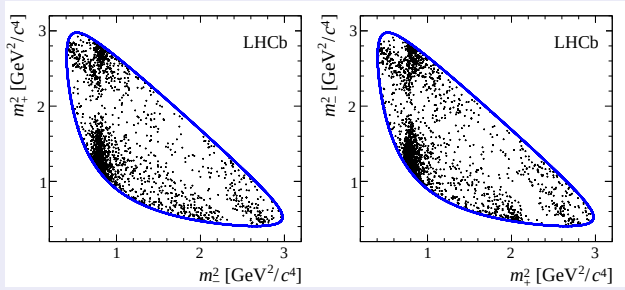
The angle γ

2-body 'ADS' : $B^{\pm} \to [\pi^{\pm}K^{\mp}]h^{\pm}$



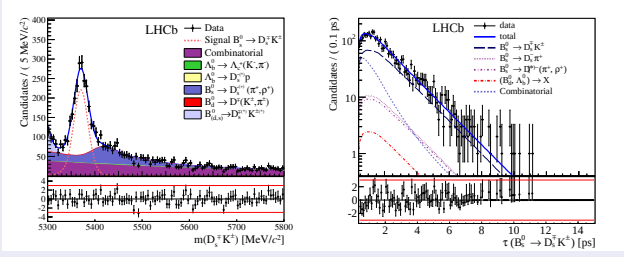
- Suppressed: 550 candidates in Run 1
- Large interference; 8σ CPV (PLB 760 117)

'GGSZ' : $B^{\pm} \to [K^0_S h^+ h^-]h^{\pm}$



- Mod. indep.; 2,600 candidates in Run 1
- Reduced γ ambiguity (JHEP 1410 097)

TD : $B^0_s \to D^{\pm}_s K^{\mp}$



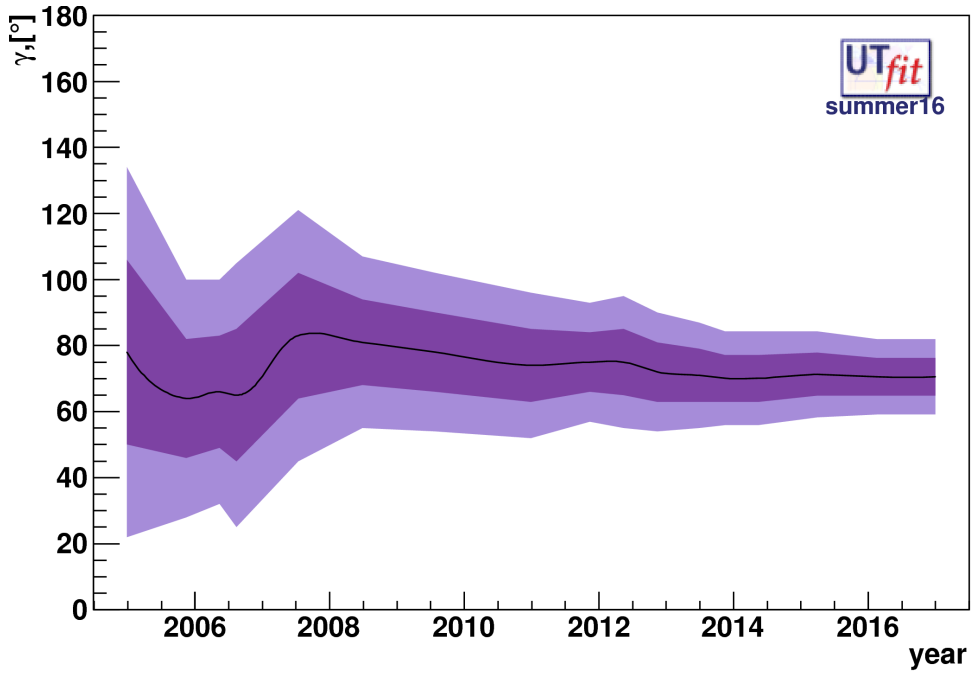
- 1,800 candidates in $1\,\text{fb}^{-1}$ (JHEP 1411 060)
- Measures $\gamma - 2\beta_s$; $B^0_s \to J/\psi\, hh$ input

Many more

- ADS/(pseudo-)GLW 2/4 body (PLB 760 117)
- GLS $B \to (K^0_S K^{\mp}\pi^{\pm})K$ (PLB 733 36)
- ADS $B^0 \to DK^{*0}$ (PRD 90 112002)
- Dalitz $B^0 \to [hh]_D K\pi$ (PRD 93 112018)
- ADS $B^0 \to [hh\pi^0]_D K$ (PRD 91 112014)
- GGSZ $B^0 \to DK^{*0}$ (JHEP 06 131)
- ADS/GLW $B^{\pm} \to DK^{*\pm}$ (LHCb-CONF 2016 014)

The angle γ

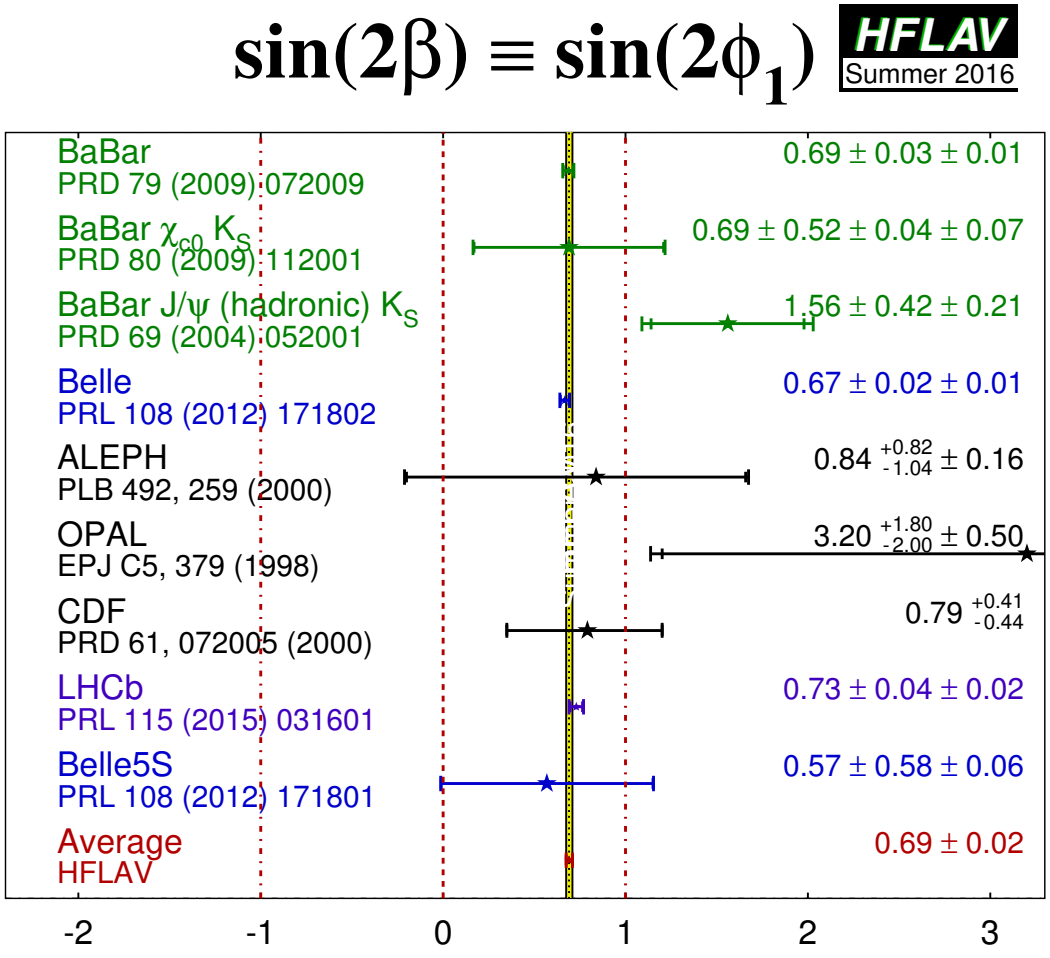
$\gamma[^\circ]$	-109.5 ± 5.7 and 70.5 ± 5.7
$\delta_B(DK)[^\circ]$	-42.9 ± 6.2 and 137.0 ± 6.2
$r_B(DK)$	0.1025 ± 0.0049
$\delta_B(DK^*)[^\circ]$	-52 ± 33 and 128 ± 33
$r_B(DK^*)$	0.126 ± 0.056
$\delta_B(D^*K)[^\circ]$	-48 ± 12 and 132 ± 12
$r_B(D^*K)$	0.119 ± 0.017
$\delta_{B0}(DK^{*0})[^\circ]$	-168 ± 21 and 12 ± 21
$r_{B0}(DK^{*0})$	0.226 ± 0.034

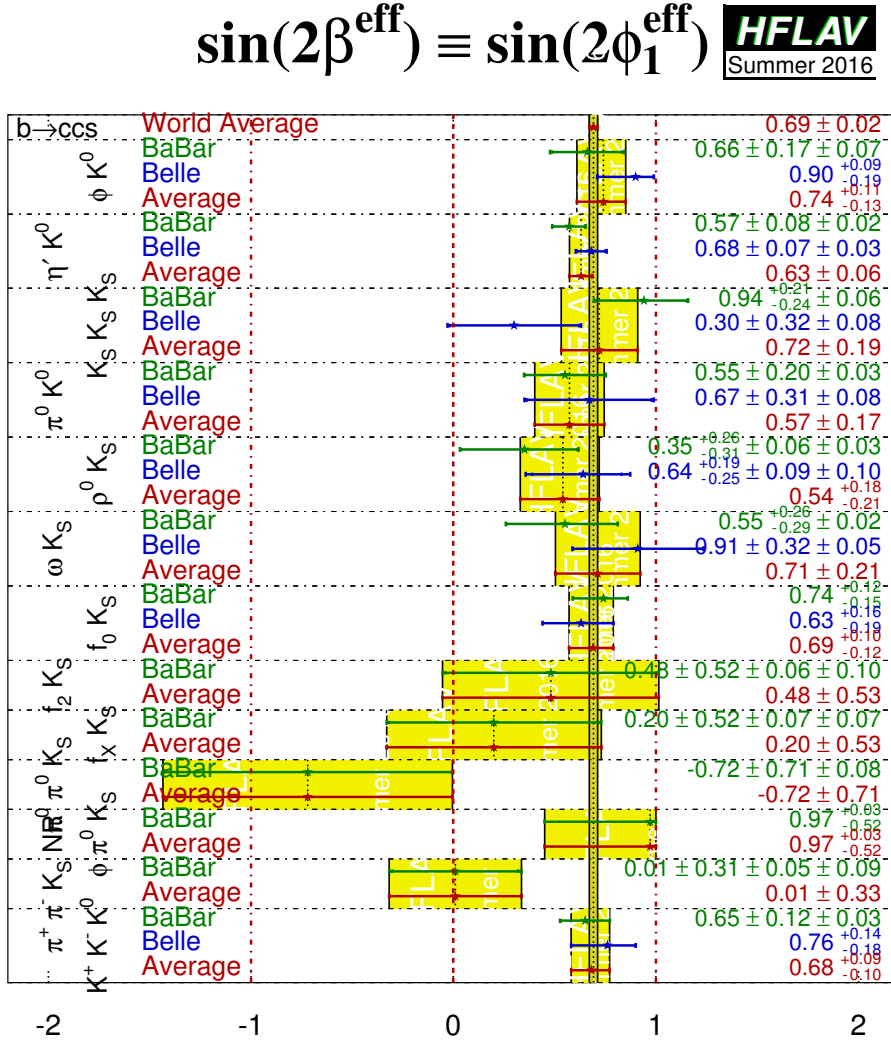


Run 1	8°	
Run 2	4°	increased cross section
Run3+4	$\sim 1^\circ$	assuming double efficiency for hadronic triggers
Run5++	$< 0.5^\circ$	

sin 2β

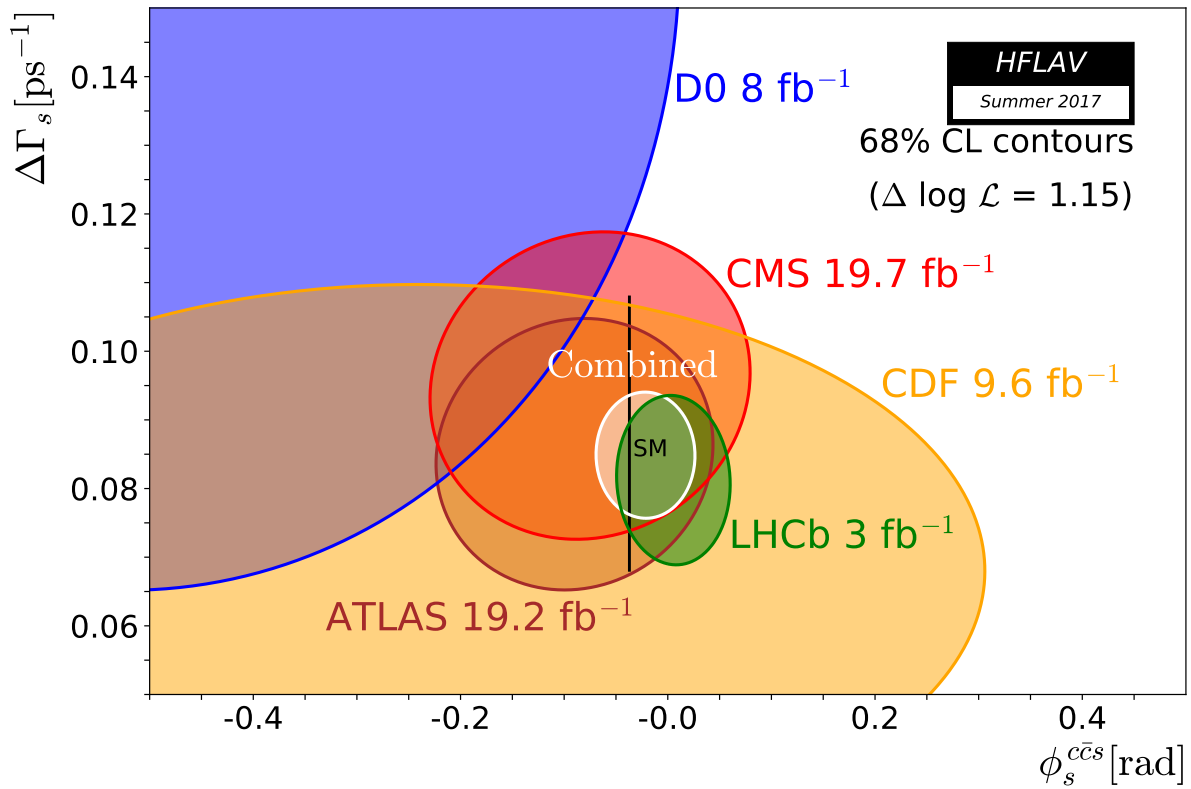
- How about neutrals?
- CKMfitter: $\sin(2\beta) = 0.7094^{+0.0098}_{-0.0094}$





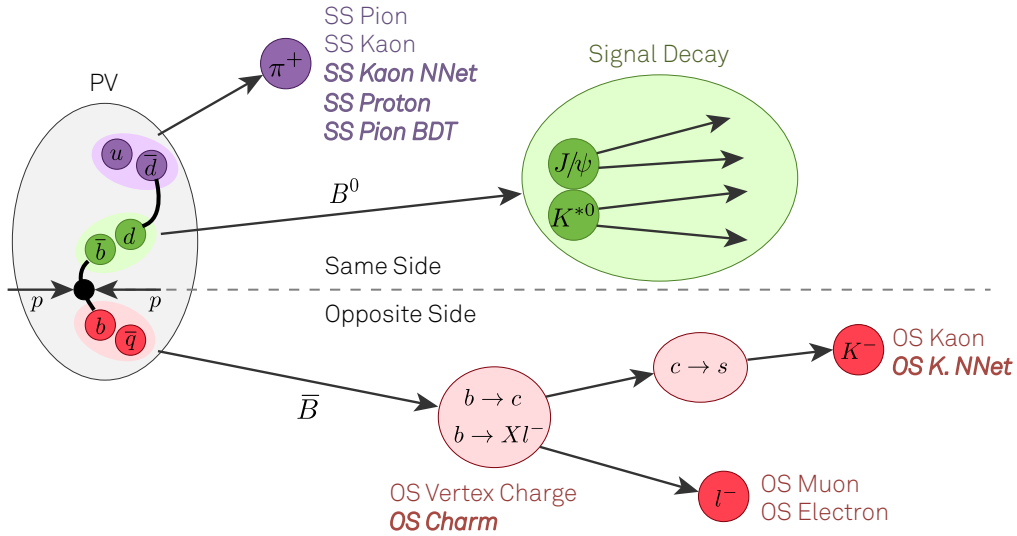
Measurement of ϕ_s

- Several channels: $B_s \to J/\psi KK$,$J/\psi\pi\pi$, D_sD_s...
- So far no significant polarization dependence seen
- By 2030 we expect $\sigma(\phi_s) \sim 0.01 \Rightarrow$ compare to 0.006 from CKMfitter



Tagging

- Tagging has been a great success in run I and II
- Tagging powers of 3-5% depending on channel
- On going studies with upgrade simulation
- And more taggers being developed
- Chalenges for upgrade:
  - not having full event information ⇒ offline calibration?
  - controlling tagging asymetries ⇒ largest uncertanty for sin(2β) in runI
  - optimization with data

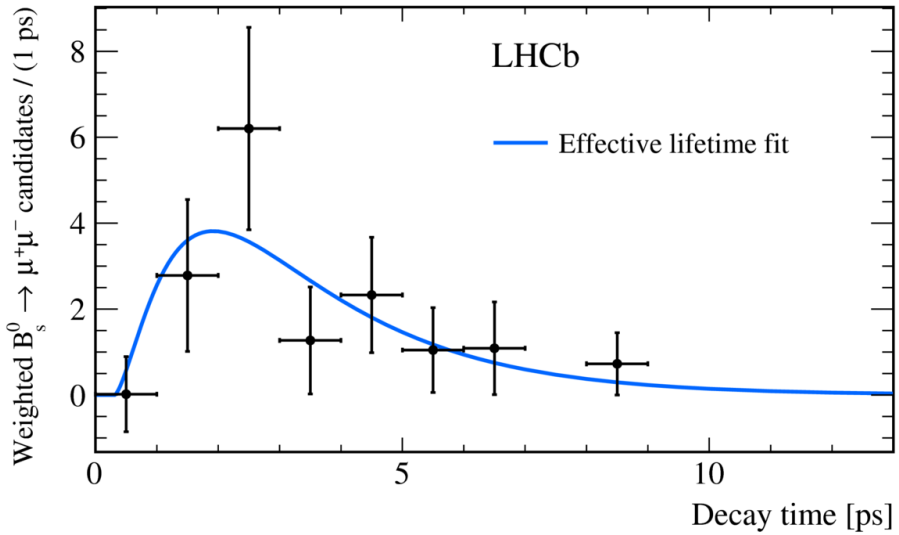


Decay time resolution

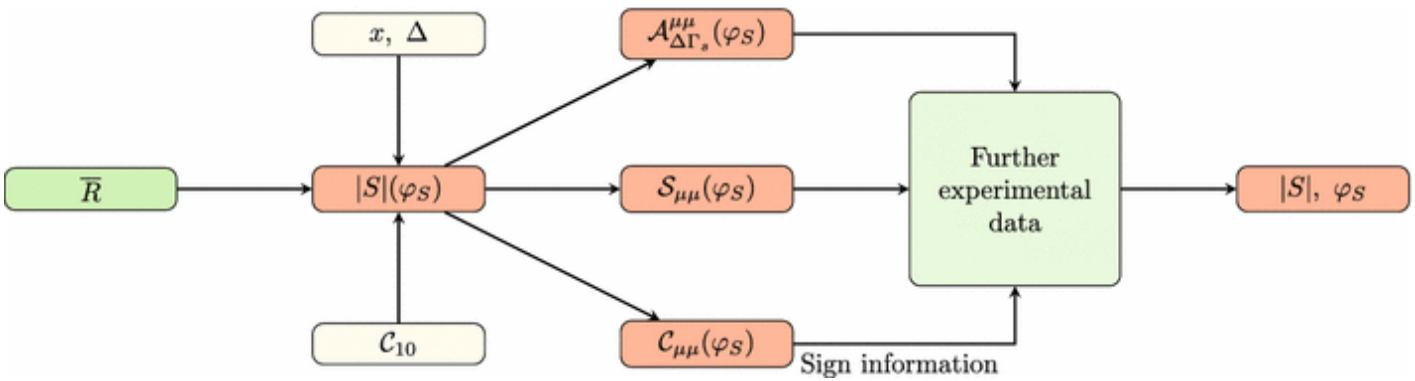
- In run I-II: $\sim 45 - 50$fs $\Rightarrow$ dilution of 70% for B_s
- Estimated per event error calibrated with usually prompt events
  - need to check portability $\Rightarrow$ any difference becomes systematic uncertainty
  - often linear or quadratic calibration
- wrong PV association $\Rightarrow$ 1-2% in run I
  - usually only included in decay time fit for calibration
  - will be a problem for higher sensitivities or with larger wrong PV fractions
- For upgrade:
  - better estimated per event error
  - true PV association in MC

CPV IN RARE DECAYS

- $\tau(B_s \to \mu\mu) = 2.04 \pm 0.44 \pm 0.05$ ps with 4.4/fb



"We urge the LHC collaborations to add studies of CP violation in rare $B_s^0 \to \ell\ell$ decays to their physics agenda for the long-term future and super-high-precision era of B physics."



Fleischer, R., Espinosa, D.G., Jaarsma, R. et al. Eur. Phys. J. C (2018) 78: 1.

Summary

- No sign of new Physics in CPV measurements yet
  $\Rightarrow$ up to 10% still allowed
- Phase2 Upgrade will get us closer to undirect CPV measurements
  $\Rightarrow$ better care for systematics and penguin pollution
- CPV with rare decays is going to be fun!