Laboratoire de Physique Corpusculaire de Clermont-Ferrand

CP violation(s) and CKM angles in B^0, B^+ and B_s beautiful mesons systems

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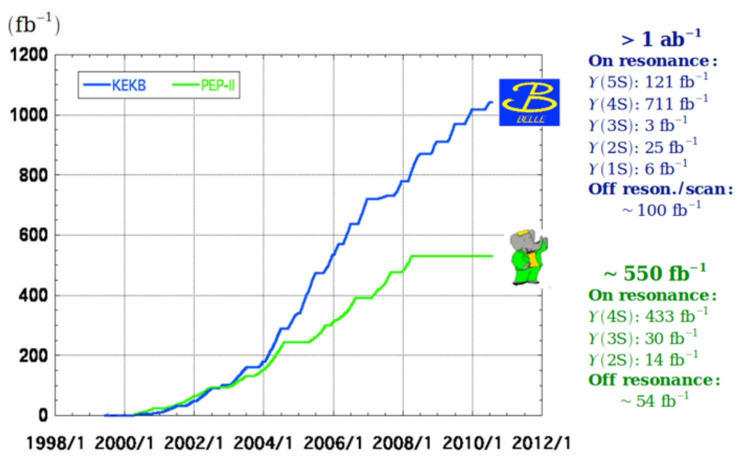
on behalf of the LHCb collaboration,
including results from Babar, Belle, CDF, D0 and LHC collaborations

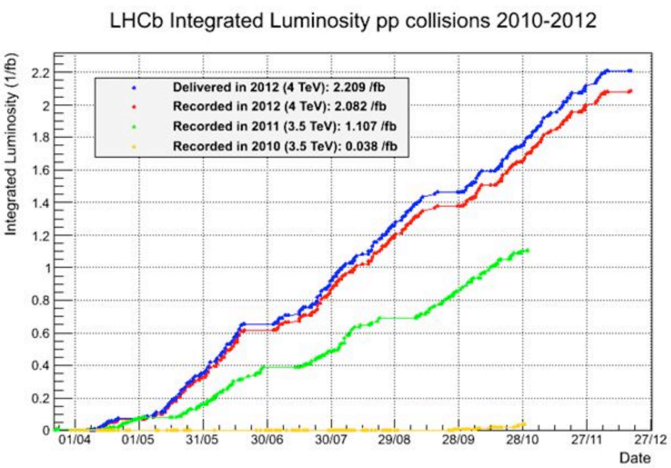
Disclaimer and presentation of the experiments

- The measurements reviewed in this presentation are published by the experiments BaBar (PEP II - SLAC), Belle (KEKB - KEK), D0 and CDF (TeVatron - FNAL) and ATLAS, CMS and LHCb (LHC - CERN). See C. Bozzi's talk in this session for a presentation of them.

- Mostly report on B-factories and LHCb results.

Integrated luminosity of B factories





- Inclined to present most recent measurements, there is an imbalance towards LHCb results.

Outline of the presentation

1. Historical measurements of CP violation (CPV) as an introduction.

2. Recent first observations of direct CPV.

3. Electroweak (Standard Model) interpretation of CPV: the CKM paradigm .

4. Overview of CKM angles measurements (and related quantities).

5. The CKM profile as a summary.

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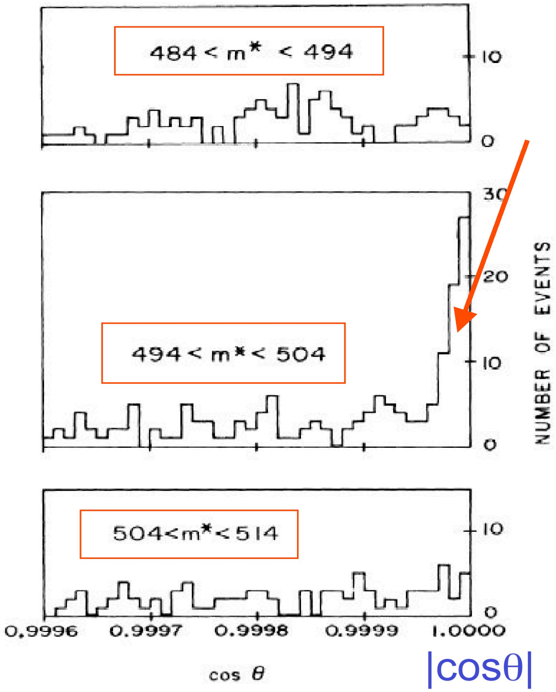
1. CPV observations in history as an introduction

- CPV in neutral kaons mixing (1964)(where it all started):



Cronin et al. Phys. Rev. Lett. 13 (1964): far after the target, only K long survive. They measured decays in the wrong CP eigenstate:

$$|\eta_{+-}| = \frac{A(K_L^0 \to \pi\pi)}{A(K_S^0 \to \pi\pi)}$$

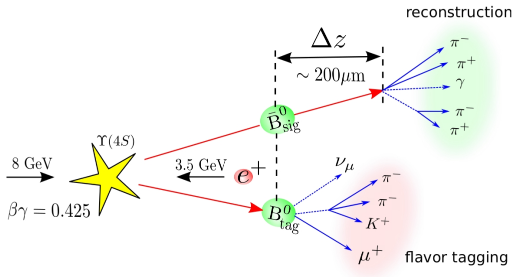
$$|\eta_{+-}| = \frac{A(K_L^0 \to \pi\pi)}{A(K_S^0 \to \pi\pi)} = (2.271 \pm 0.017)10^{-3}.$$

- The next new observation of (direct) CPV came 40 years later in kaon decays (2001) by NA48 Eur.Phys.J. C22 (2001) (and KTeV) collaborations.

1. CPV observations in *B* as an introduction

• In the very same year (2001), CPV was observed in an entirely different system. One of the most beautiful measurement in Physics: mixing-induced CPV in B^0 mixing.

• The quantum coherence of B pair production ensures that the reconstruction of the flavour of one B (flavour specific) tags the flavour of the other at the very same decay time.

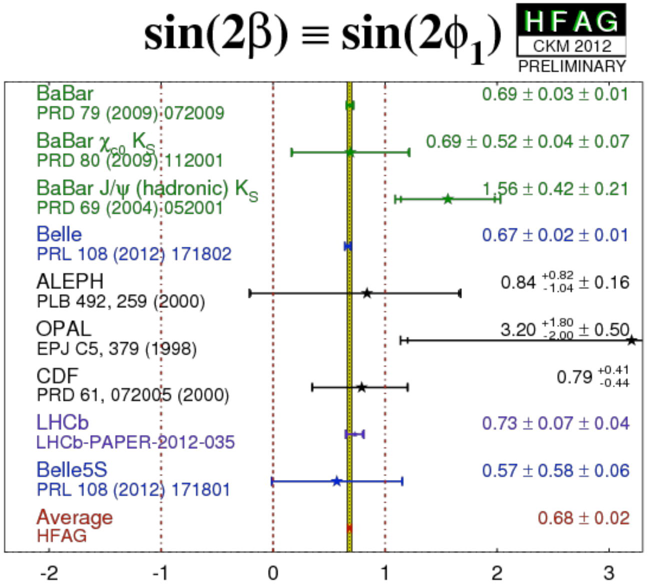


• Make asymmetric beams to measure the decay time → B-factories.

• Measure the time-dependent asymmetry brings constraint on the CP-violating phase in B^0 mixing.

$$A_f(t) = \frac{\Gamma(B^0(t)\to f) - \Gamma(\bar{B}^0(t)\to f)}{\Gamma(B^0(t)\to f) - \Gamma(\bar{B}^0(t)\to f)}$$

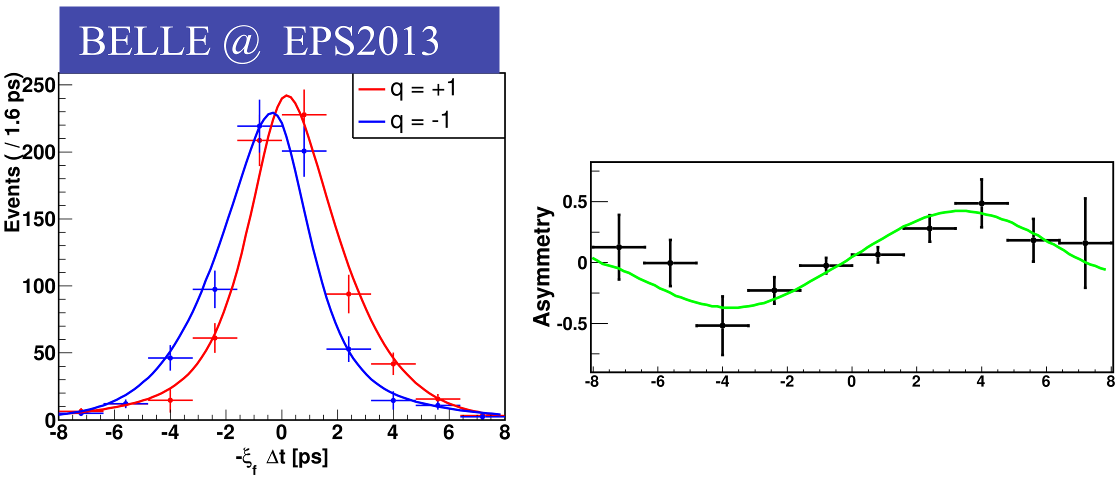
$$A_f(t) = S_f \sin(\Delta m_d t) + C_f \cos(\Delta m_d t)$$

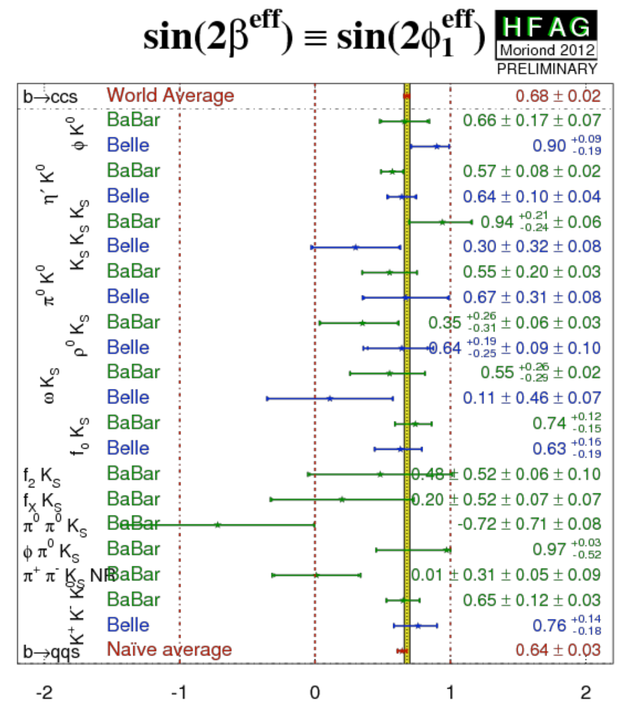


1. CPV observations in *B* as an introduction

- The B-factories scrutinized beyond-SM CPV phases in loop-dominated decays

- As an illustration, a recent analysis from Belle experiment with one of the charmless decay mode with the cleanest theoretical prediction $B^0 \to \eta' K_S$



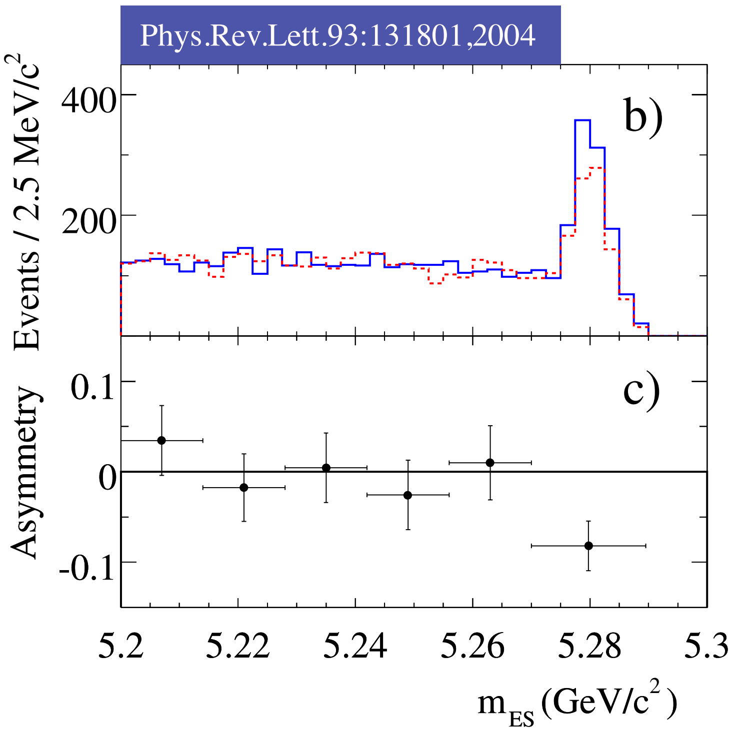


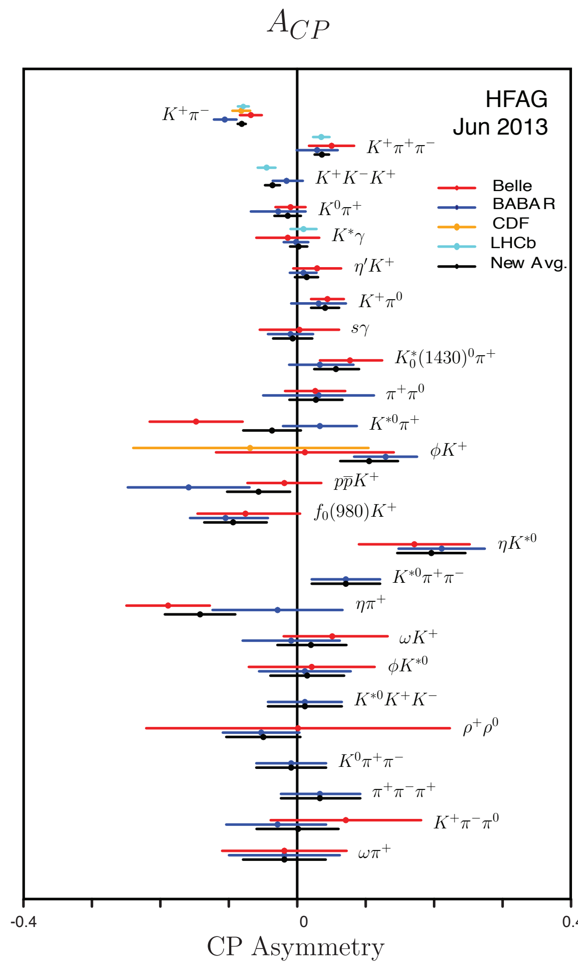
$$S_{\eta' K_S^0} \quad = \quad 0.68 \pm 0.07\ (\text{stat.})\ \pm 0.03\ (\text{syst.}),$$

- The naive average of $b \to qqs$ transitions is in fair agreement w/ $b \to ccs$.

1. CPV observations in history as an introduction

- The B-factories observed direct CP-violation (2004) in the $B^0 \to K\pi$ decays:
- BaBar's first observation.





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2.1 Direct CP violation in 2-body *B* decays

- Compare the decay rates of self-tagged modes $K\pi$

$$A_{CP}(B^0 \to K\pi) = \frac{\Gamma(\bar{B}^0 \to K^-\pi^+) - \Gamma(B^0 \to K^+\pi^-)}{\Gamma(\bar{B}^0 \to K^-\pi^+) + \Gamma(B^0 \to K^+\pi^-)}$$

$$A_{CP}(B_s^0 \to \pi K) = \frac{\Gamma(\bar{B}_s^0 \to \pi^- K^+) - \Gamma(B_s^0 \to \pi^+ K^-)}{\Gamma(\bar{B}_s^0 \to \pi^- K^+) + \Gamma(B_s^0 \to \pi^+ K^-)}.$$

- These raw asymmetries must be corrected from detection asymmetry and B production asymmetry:

$$A_\Delta(B^0_{(s)} \to K\pi) = \zeta_{d(s)} A_D(K\pi) + \kappa_{d(s)} A_P(B^0_{(s)} \to K\pi)$$

- Ingredients: these analyses are heavily relying on Particle Identification performance. It is also necessary to master the *B* production asymmetry and the differences of charged particle detection efficiencies (data-driven estimates).

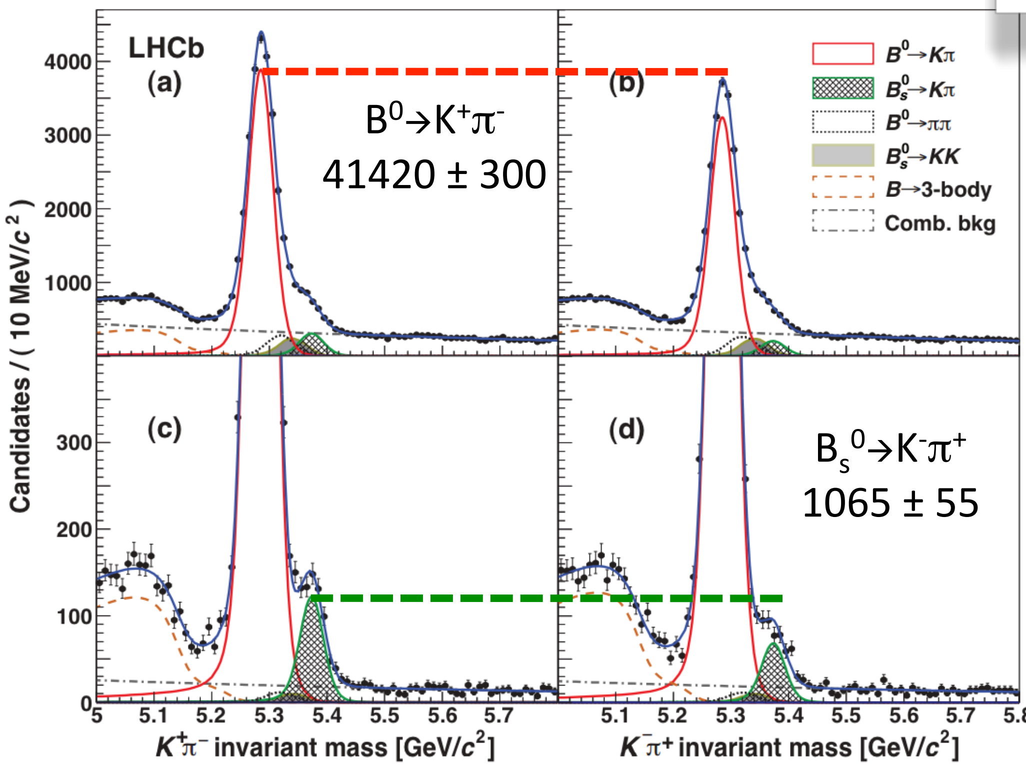
2.1 Direct CP violation in 2-body B decays

LHCB-PAPER-2013-018

- Compare the decay rates of self-tagged modes $K\pi$

$$A_{\mathrm{raw}}(B^0 \to K^-\pi^+) = -0.091 \pm 0.006,$$
$$A_{\mathrm{raw}}(B_s \to K^+\pi^-) = 0.28 \pm 0.04,$$

$\mathcal{L}$ = (1/fb @ √s = 7 TeV)



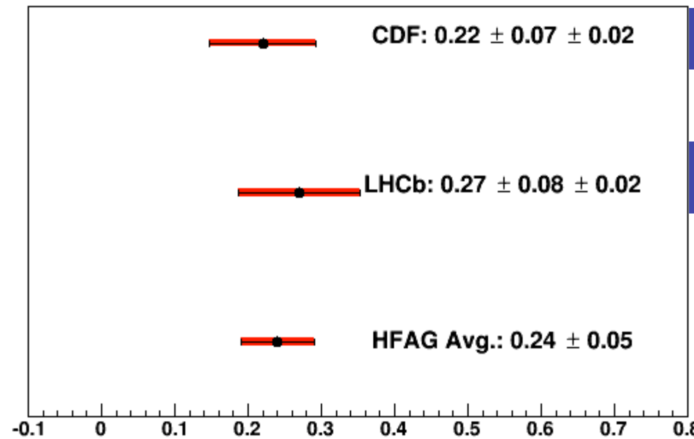
- Data-driven control of PID efficiencies thanks to the self-tagged mode $D^{*+} \to D^0 (K^-\pi^+)\, \pi^+$
- Raw asymmetries corrected from detection asymmetry (also D^{*+} control sample.
- B production asymmetry simultaneously measured from decay time distribution.

2.1 Direct CP violation in 2-body B decays

LHCB-PAPER-2013-018

$$A_{\mathrm{CP}}(B^0 \to K^-\pi^+) = -0.080 \pm 0.007\,(\mathrm{stat.}) \pm 0.003\,(\mathrm{syst.}),$$
$$A_{\mathrm{CP}}(B_s \to K^+\pi^-) = 0.27 \pm 0.04\,(\mathrm{stat.}) \pm 0.01\,(\mathrm{syst.}).$$

- World best measurement for the B^0
- Former results for B_s



CDF-PUBLIC-10726

Phys. Rev. Lett. 108 (2012)

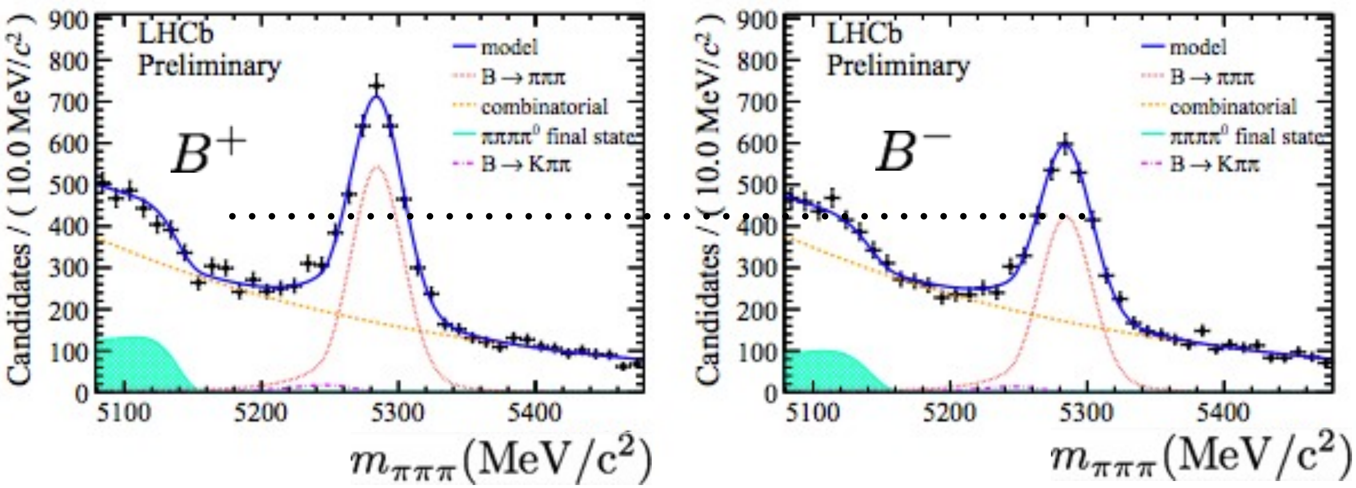
- **First observation of CPV in the *Bs* system.**

2.1 Direct CP violation in 3-body B decays

LHCb-CONF-2012-028
LHCB-PAPER-2013-027

- Compare the decay rates of B^+ vs $B^- \to K\pi\pi, KKK, KK\pi, \pi\pi\pi$

- The same comment as in 2-body case is in order to go from raw asymmetries to CP asymmetries as in 2-body case. One illustration $\pi\pi\pi$:



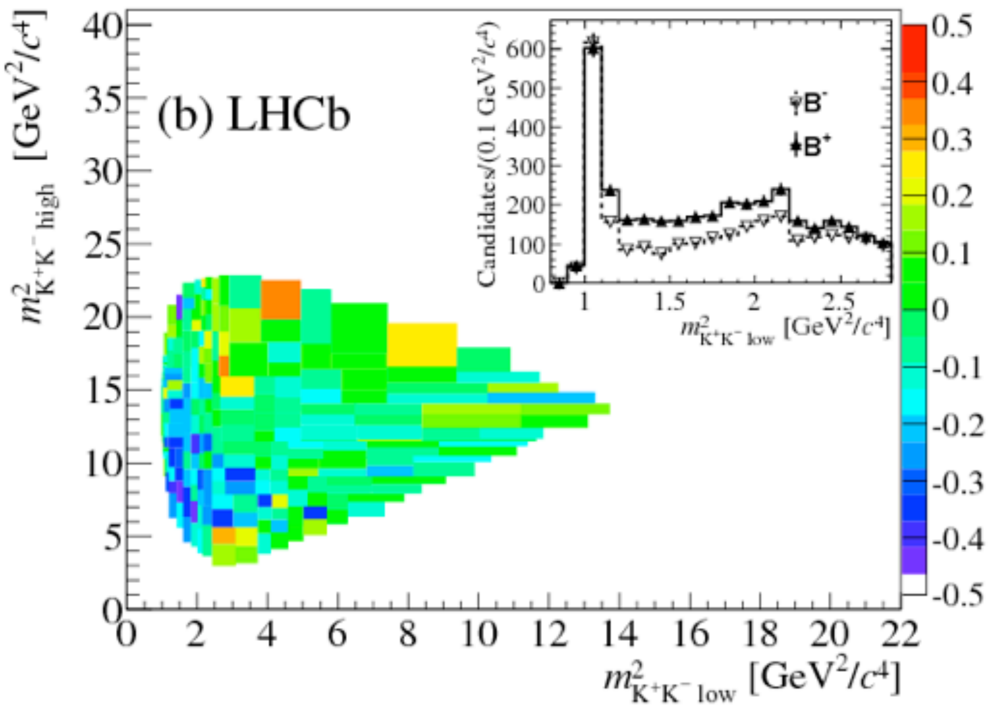
$$A_{CP}(B^\pm \to \pi^\pm\pi^+\pi^-) = +0.120 \pm 0.020(\text{stat}) \pm 0.019(\text{syst}) \pm 0.007(J/\psi K^\pm)$$

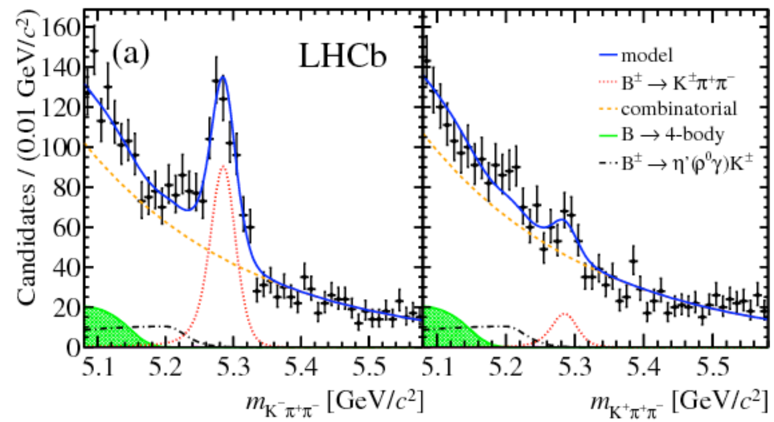
- **First observation of CP violation in the three-body charged B system.**

2.1 Direct CP violation in 3-body *B* decays

LHCB-PAPER-2013-027

- More interestingly one can scrutinize where the CP asymmetry lies in the Dalitz Plane of the decay: illustration with $B \rightarrow KKK$ (left).





- **Very large CP asymmetries are observed**. Not likely connected to the resonant structures in the Dalitz projections. Full Dalitz analysis is the next step.

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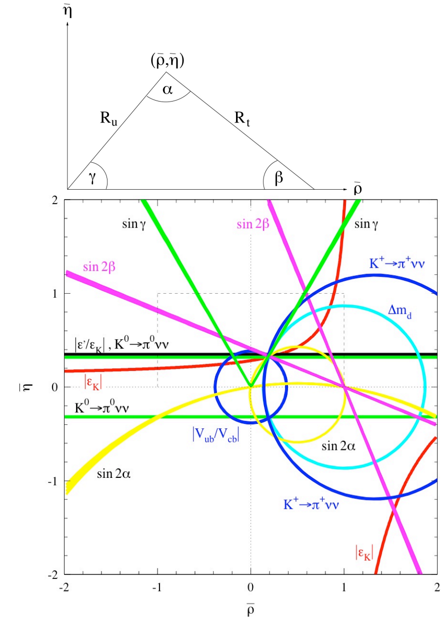
3. CPV in SM and angles definitions

3.1 CPV in SM hand CKM parametrization.

$$\mathcal{L}_{cc}^{\text{quarks}} = \frac{g}{2\sqrt{2}} W_\mu^\dagger [\sum_{ij} \bar{u}_i(q_2)\gamma^\mu(1-\gamma^5) V_{ij} d_j] + \text{h.c} \qquad V_{\text{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Consider the Wolfenstein parametrization as in EPJ C41:1-131,2005 : unitary-exact and phase convention independent:

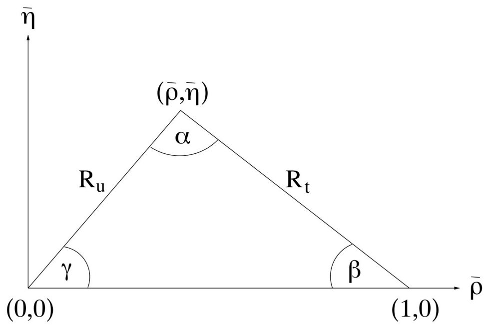
$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2}, \quad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2} \quad \text{and} \quad \bar{\rho} + i\bar{\eta} = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$



An elegant way to represent the unitarity relations is to display them in the complex plane.

$$\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} + \frac{V_{cd}V_{cb}^*}{V_{cd}V_{cb}^*} + \frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*} = 0.$$

3.2 The CKM angles and related quantities.



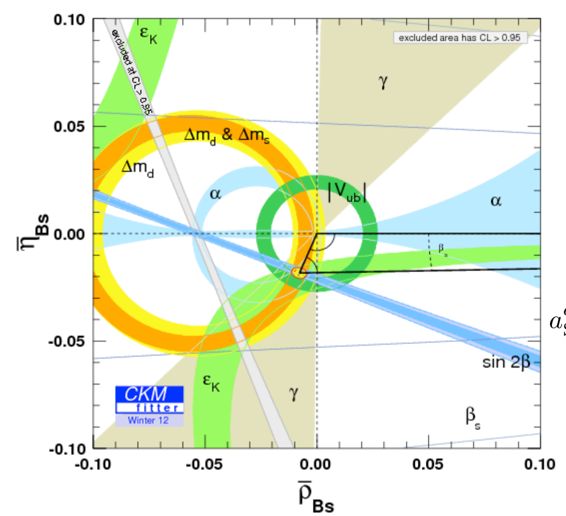
$$\alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right),$$
$$\beta = \pi - \arg\left(\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}\right),$$
$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$

- The angle β is the weak mixing phase of the of B^0 mixing.

- The angle γ is the weak phase at work in the $b \rightarrow u$ transitions. Need of an interfering amplitude to probe the phase.

- The angle α is nothing else than (π–β–γ) and can be exhibited in processes where both charmless decays and mixing are present.

- Additionally the weak mixing phase of the B_s mixing in the SM is expressed as β_s and is accurately (at the degree level) predicted in the global consistency test.



$$\beta_s = -\arg\left(-\frac{V_{cs}V_{cb}^*}{V_{ts}V_{tb}^*}\right)$$

$$\phi_q = \arg\left(\frac{-M_{12}^q}{\Gamma_{12}^q}\right)$$

$$a_{SL}^q = 2\left(1 - \left|\frac{q}{p}\right|\right) = \mathcal{I}m\left(\frac{\Gamma_{12}^q}{M_{12}^q}\right)$$

$$\sin 2\beta_s = 0.0367 \pm 0.0014.$$

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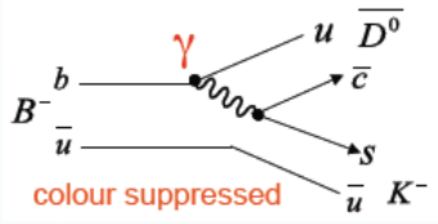
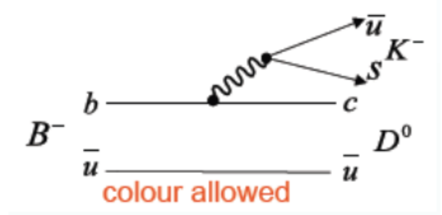
4.1 CKM angles - γ angle in tree-dominated decays.

- The γ angle can be measured in interferences between $b \to u$ and $b \to c$ transitions in charged B decays to a final state $(D^0 K)_{cc}$ where the kaon tags the B flavour and the D^0 and $\bar{D}^0$ share the same decay:

  - $D^0 \to K^+K^-$, $\pi^+\pi^-$ *[GLW]*
  - $D^0 \to K^-\pi^+$, $D^0 \to K^+\pi^-$ *[ADS]*
  - $D^0 \to K_s^0\pi^+\pi^-$, $K_s^0K^+K^-$ *[GGSZ]*





- The level of interference is controlled by the quantity $r_B \approx \left| \dfrac{\mathcal{A}(b \to u)}{\mathcal{A}(b \to c)} \right|$

- It can also be measured at LHCb in the *Bs* decay [$B_s \to D_sK$] through a time-dependent analysis, exhibiting both the mixing-induced CP phase Φ_s and the CP-violating phase in the $b \to u$ transition.

- The three former methods have been pioneered at B-factories but used at LHCb as well (one example w/ GGSZ method in the following slides).

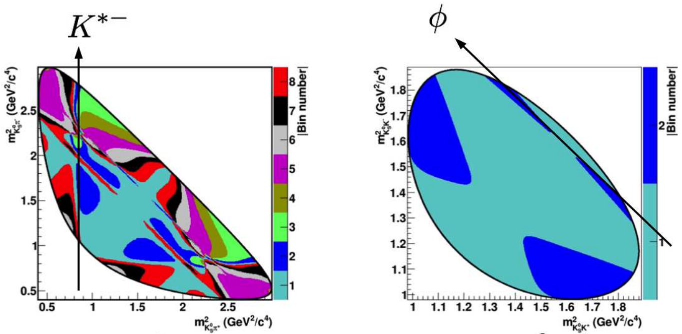
4.1 CKM angles - γ angle in tree-dominated decays. GGSZ

LHCB-CONF-2013-004

- The comparison of the Dalitz planes (DP) of the decays $D^0 \to K_s^0\pi^+\pi^-$ or $K_s^0K^+K^-$ for the transitions $B^+ \to DK^+$ and $B^- \to DK^-$ contains information on γ angle.

- Constrain from CLEO-c measurements the strong phase variation in DP. (Phys. Rev. D 82 (2010) 112006)

- DP binned in regions of similar strong phase:



$D \to K_S^0\pi^+\pi^-$ $D \to K_S^0K^+K^-$

- Defining:

$$
\begin{aligned}
x_\pm &= r_B \cos(\delta_B \pm \gamma), \\
y_\pm &= r_B \sin(\delta_B \pm \gamma).
\end{aligned}
$$

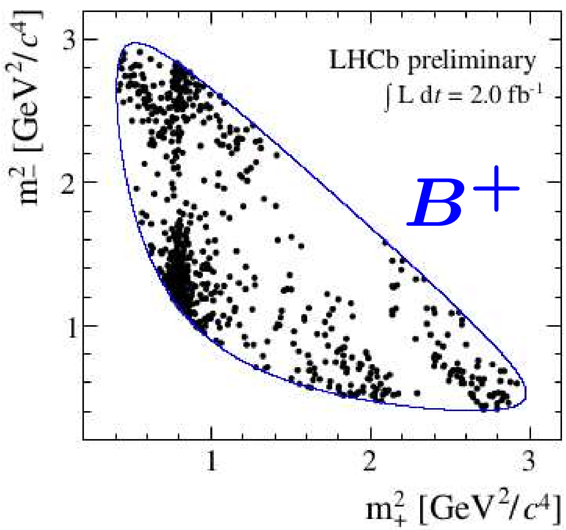
- One counts the number of events in each bins *i* for B^+ and B^-:

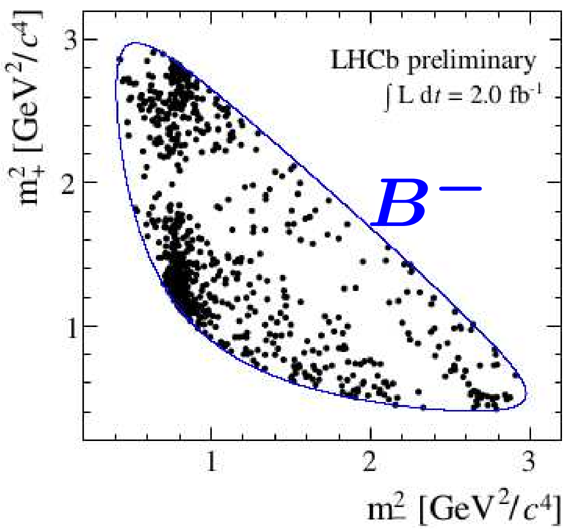
$$
\begin{aligned}
N^+_{\pm i} &\propto K_{\mp i} + (x_+^2 + y_+^2)K_{\pm i} + 2\sqrt{K_i K_{-i}}[x_+ \cos\delta_D(\pm i) \mp y_+ \sin\delta_D(\pm i)], \\
N^-_{\pm i} &\propto K_{\pm i} + (x_-^2 + y_-^2)K_{\mp i} + 2\sqrt{K_i K_{-i}}[x_- \cos\delta_D(\pm i) \mp y_- \sin\delta_D(\pm i)].
\end{aligned}
$$

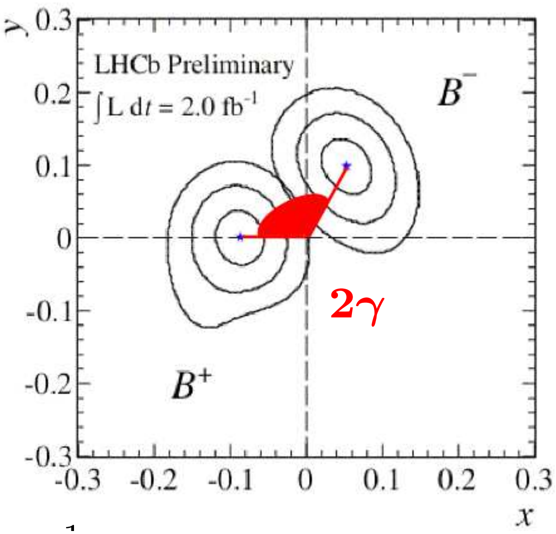
- And solve for the four unknowns *x* and *y*.

LHCB-CONF-2013-004

- The γ angle with GGSZ method: LHCb data.



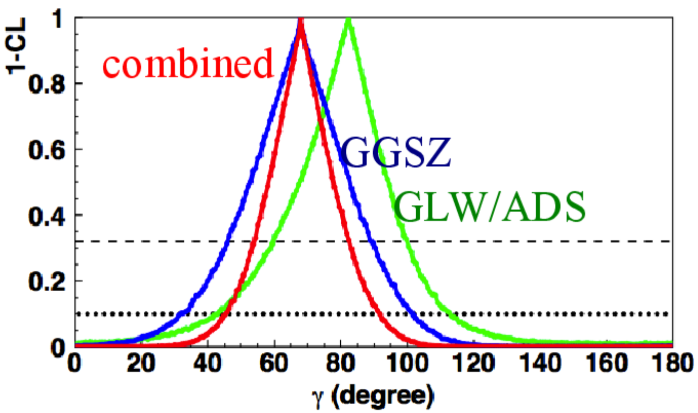




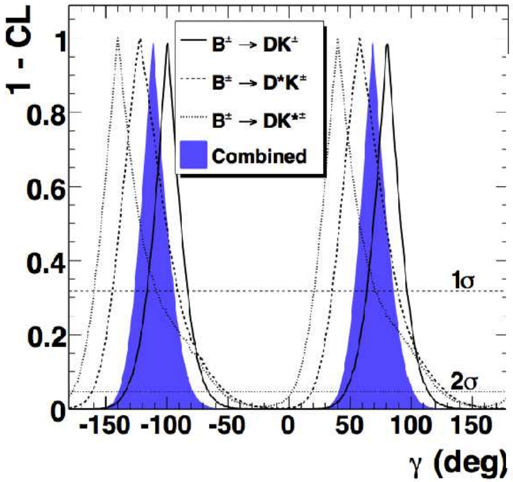
$$r_B = (8.8^{+2.3}_{-2.4})10^{-2},$$
$$\gamma = (57 \pm 16)^\circ$$

(2+1 /fb)

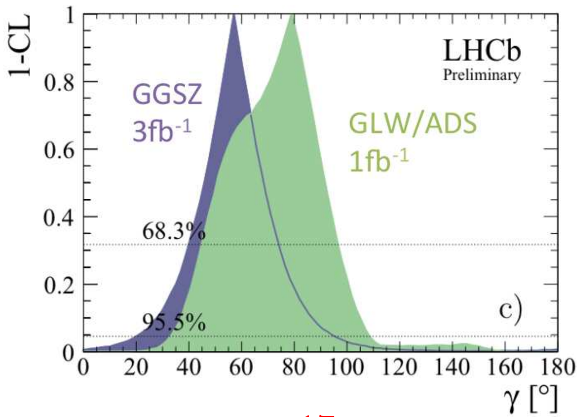
- γ angle combinations:



arXiv:1301.2033



Phys Rev D 87, 052015 (2013)



LHCB-CONF-2013-006

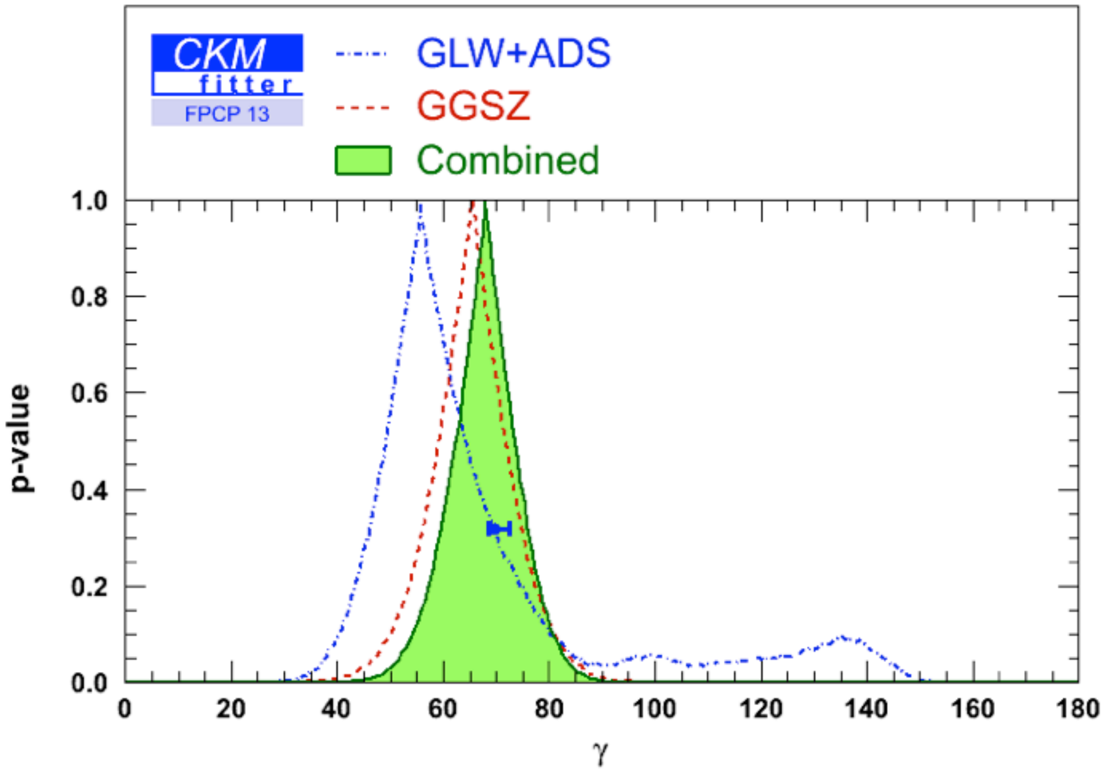
$$\begin{aligned}\gamma(\text{Belle}) &= (68^{+15}_{-14})^\circ \\ \gamma(\text{BaBar}) &= (69^{+17}_{-16})^\circ \\ \gamma(\text{LHC}b) &= (67 \pm 12)^\circ\end{aligned}$$

- LHCb already in the playground of B-factories (precision-wise). More to come w/ 3/fb for ADS and GLW.

4.1 CKM angles - γ angle in tree-dominated decays.

Phys.Rev.D85 (2011)
ckmfitter.in2p3.fr

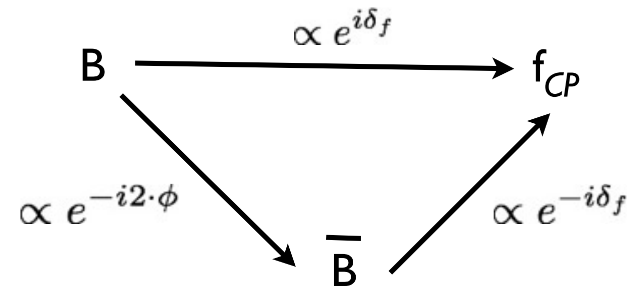
- The γ angle grand combination BaBar/Belle/LHCb (CKMfitter):



$$\gamma(\mathrm{WA}) = \left(68.0^{+8.0}_{-8.5}\right)^\circ .$$

4.2 CKM angles - α w/ charmless hadronic *B* decays.

- The α angle is exhibited in the interference of the direct (tree) and mixed decays of charmless hadronic decays and hence requires time-dependent measurement of CP asymmetries.



- The penguin contributions (not necessarily small) to the decays must be corrected for.

- So far constrained w/ time-dependent tagged analyses of:

  - $B^0 \to \pi^+\pi^-$ *and* B^+, B^0 isospin companions constraints
  - $B^0 \to \rho\rho$ *and* B^+, B^0 isospin companions constraints.
  - $B^0 \to \rho\pi$ [SQ] *Phys.Rev. D 48,2139 (1993).*

- One example of ingredients for each method entering in the global α determination are given in the following.

4.2 CKM angles - α (and γ) w/ charmless hadronic B decays.

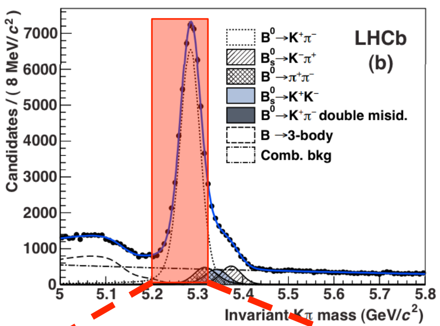
Phys. Rev. Lett.110 (2013)

- Two-body (charged) charmless hadronic B decays at LHCb.

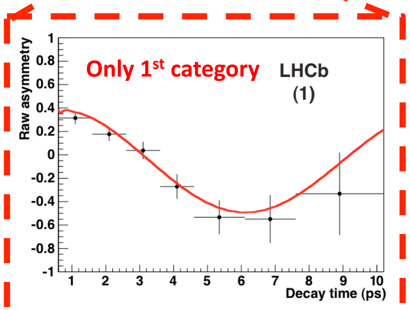
$$\mathcal{A}(t) = \frac{-C_f \cos(\Delta m_s t) + S_f \sin(\Delta m_s t)}{\cosh(\Delta\Gamma_s t/2) - \mathcal{A}_f^{\Delta\Gamma} \sinh(\Delta\Gamma_s t/2)}.$$

$$\mathcal{A}(t) = -C_f \cos(\Delta m_d t) + S_f \sin(\Delta m_d t).$$

$\mathcal{L}$ = (1/fb @ √s = 7 TeV)



LHCB-PAPER-2013-040
Preliminary



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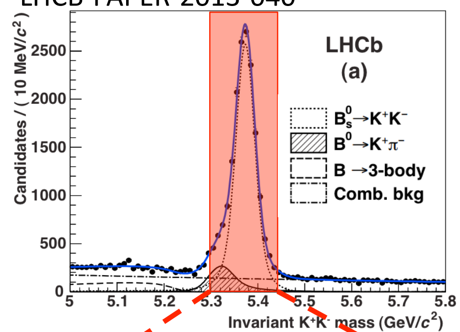
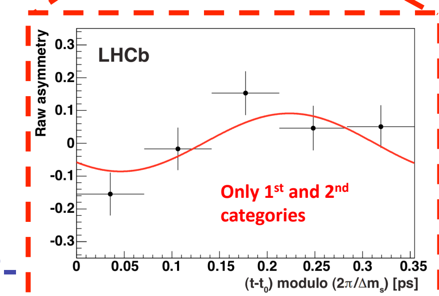
Preliminary
LHCB-PAPER-2013-040

$\mathcal{L}$ = (1/fb @ √s =



$$C_{\pi\pi} = -0.38 \pm 0.15\,(\text{stat}) \pm 0.02\,(\text{syst})$$
$$S_{\pi\pi} = -0.71 \pm 0.13\,(\text{stat}) \pm 0.02\,(\text{syst})$$
$$C_{KK} = 0.14 \pm 0.11\,(\text{stat}) \pm 0.03\,(\text{syst})$$
$$S_{KK} = 0.30 \pm 0.12\,(\text{stat}) \pm 0.04\,(\text{syst})$$

- Consistent w/ B-factories for B^0. (input for α)
- First evidence for mixing-induced CP-violation in B_s (input for ($\gamma + \Phi_s$) assuming U-spin symmetry).



4.2 CKM angles - α w/ charmless hadronic B decays.

ArXiv:1304.3503

- Three-body $B^0 \to \rho\pi$ decays at BaBar:

- Competition in between tree and penguin diagrams.

- Time-dependent analysis in the Dalitz Plane of the $(\pi\pi\pi)0$ decay.

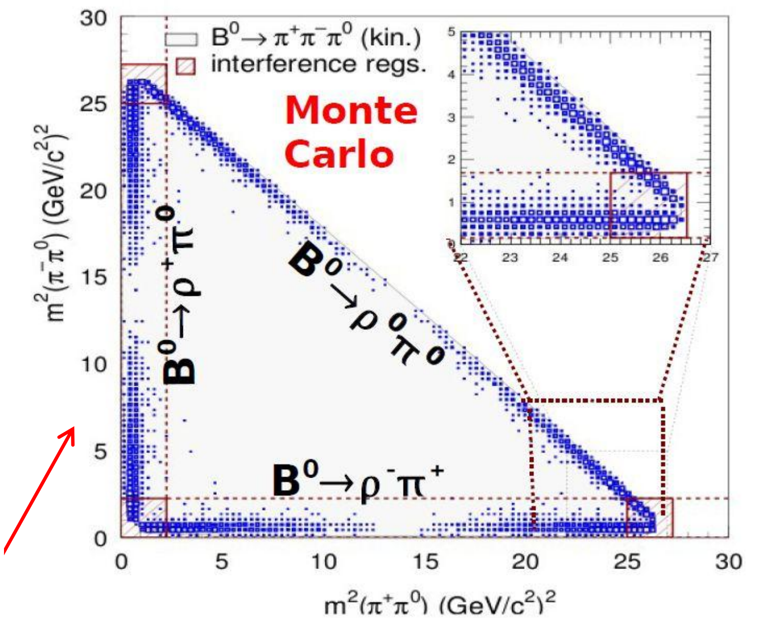
- Assume isospin symmetry to solve unambiguously for α.

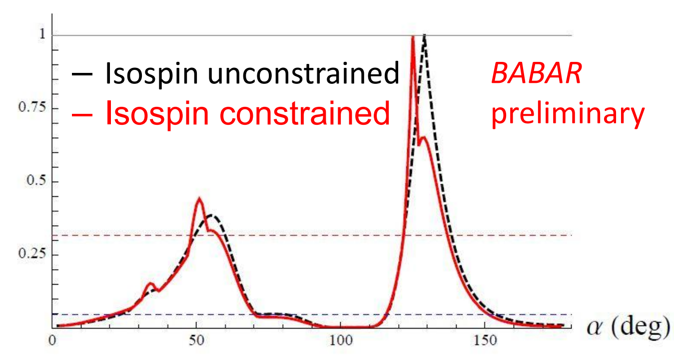
$$\mathcal{A}_{\rho\pi}^{+-} \equiv \frac{\Gamma(\bar{B}^0 \to \rho^-\pi^+) - \Gamma(B^0 \to \rho^+\pi^-)}{\Gamma(\bar{B}^0 \to \rho^-\pi^+) + \Gamma(B^0 \to \rho^+\pi^-)} = 0.09^{+0.05}_{-0.06} \pm 0.04$$

$$\mathcal{A}_{\rho\pi}^{-+} \equiv \frac{\Gamma(\bar{B}^0 \to \rho^+\pi^-) - \Gamma(B^0 \to \rho^-\pi^+)}{\Gamma(\bar{B}^0 \to \rho^+\pi^-) - \Gamma(B^0 \to \rho^-\pi^+)} = -0.12 \pm 0.08^{+0.05}_{-0.06}$$

- Direct CP symmetry found consistent w/ zero.

- α scan checked not robust w/ this statistics and illustrates the complexity of the approach.





4.2 CKM angles - α w/ charmless hadronic *B* decays.

ArXiv:1202.6251

- Three-body $B \to \rho\rho$ charmless decays at Belle:

- Similar technique as $B^0 \to \pi^+\pi^-$ with the advantage that penguins modes are suppressed.

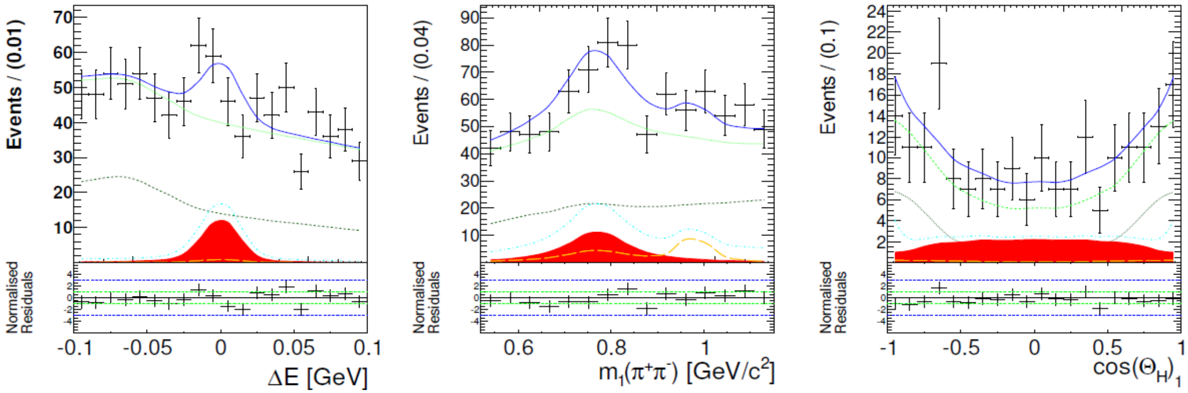
- Controlled by the size of $B^0 \to \rho^0\rho^0$

$$\boxed{\mathcal{B}(B^0 \to \rho^0\rho^0) = (1.02 \pm 0.3(stat) \pm 0.22(syst)) \times 10^{-6}}$$

$\boxed{2.9\sigma \text{ significance}}$

$$f_L = 0.21^{+0.18}_{-0.22} \pm 0.11$$

$B^0 \to \rho^0\rho^0$, $B^0 \to f^0\rho^0$, all $B^0 \to 4\pi$, non-peaking $B\bar{B}$, all non-peaking



- The correction to α for the penguin pollution is found to be: $\Delta\alpha = (0.0 \pm 5.4)^\circ$.

- BaBar prefers f_L closer to unity...

4.2 CKM angles - α (and γ) w/ charmless 2-body B decays.

Phys.Rev.D85 (2011)
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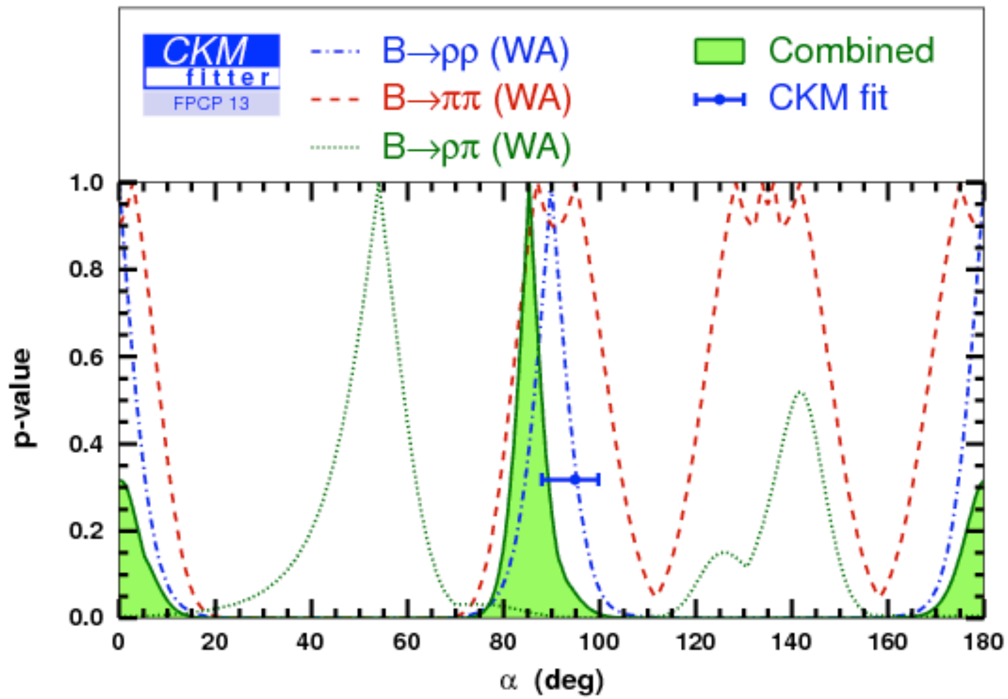
- Grand combination for α angle:



$$\alpha(\mathrm{WA}) = (85.4^{+4.0}_{-3.8})^\circ.$$

4.3 CKM angles - weak phase of Bs mixing (mixing-induced).

- As seen in section 3, the mixing-induced CP violation in Bs system is nicely predicted to be close to vanish in the SM.

- Search for new CP violating phases in that system as null test of the SM hypothesis. A golden-mode for this purpose is $B_s \to J/\psi\ (\mu^+\mu^-)\ \phi\ (K^+K^-)$

$$
\begin{tikzcd}
B_s^0 \arrow[rr, "\phi_D"] \arrow[dr, bend right, "\phi_M"'] & & f_{CP} \\
& \overline{B}_s^0 \arrow[ur, bend right, "-\phi_D"'] &
\end{tikzcd}
$$

- Introducing the notation for CP violating phase $\phi_S = \phi_M - 2\phi_D$

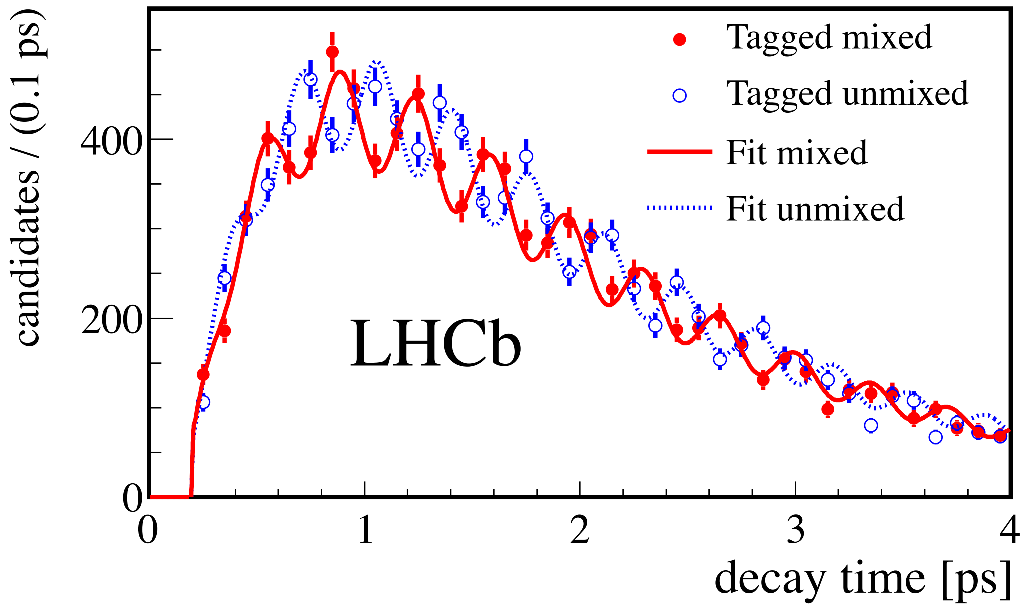
- The mixing phase, $\phi_M \approx 0$ in Standard Model can be modified by New Physics and hence measured by ϕ_S.

- Since the decay is P → VV, the final state is superposition of states with different CP value: the measurement requires a tagged, time-dependent angular analysis.

4.3 CKM angles - weak phase of Bs mixing (mixing-induced).

- A CP-conserving APARTE:

- decay time resolution is of utmost importance for such measurements. A textbook illustration of the LHCb performance can be found in the frequency of the B_s mixing, resolved here in the decay $B_s \to D_s\pi$:

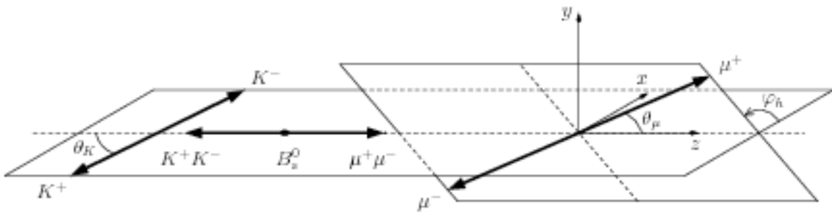


New J. Phys. 15 (2013) 053021 (1 fb^{-1})

4.3 CKM angles - weak phase of Bs mixing (mixing-induced).

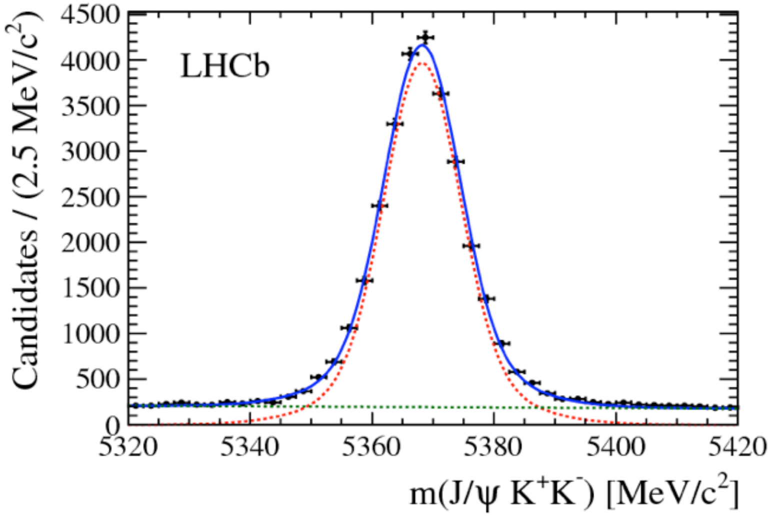
LHCB-PAPER-2013-002

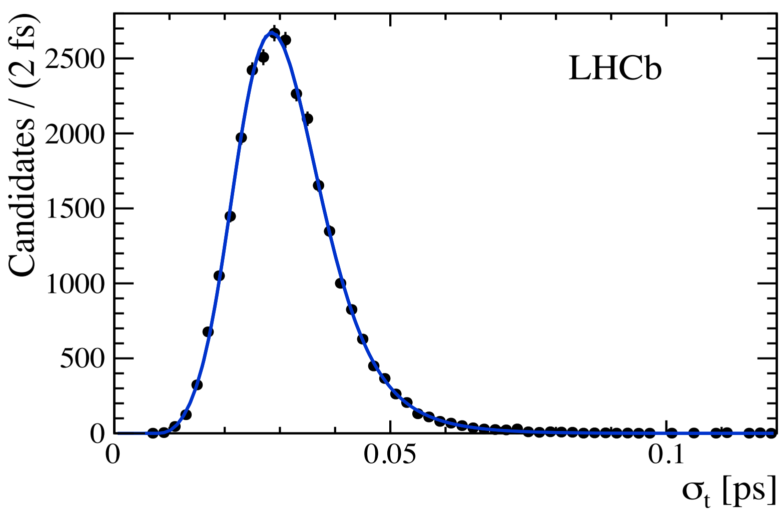
- It requires a simultaneous fit to *m, t and 3* helicity angles.



- Let's start with mass and propertime (resolutions of 7 MeV and 45 fs, resp.)

- Out of the dimuon trigger stream with a mild kinematical selection:



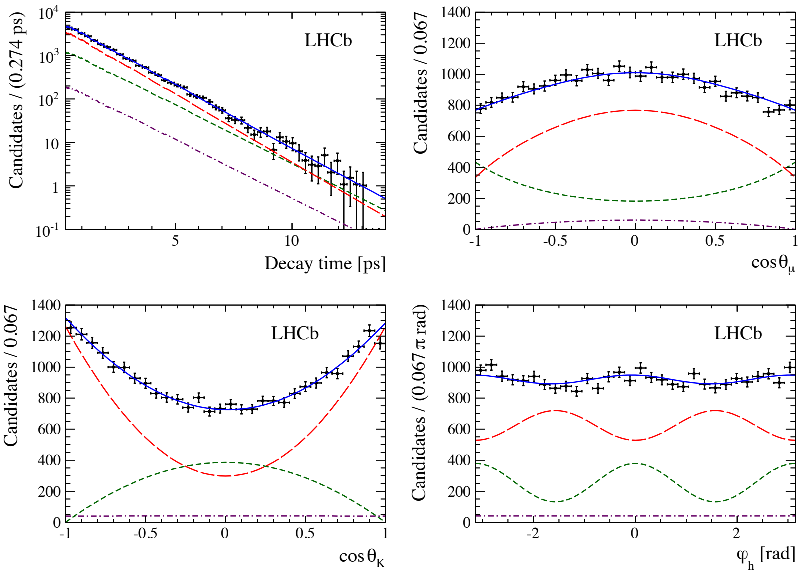


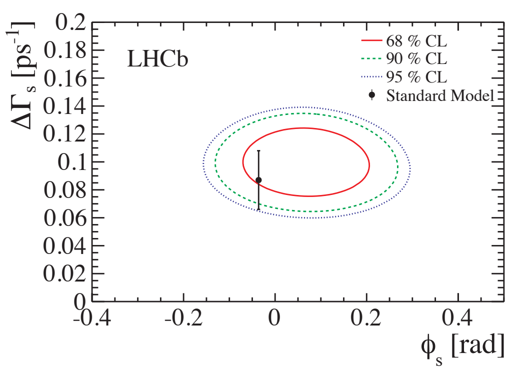
4.3 CKM angles - weak phase of Bs mixing (mixing-induced).

LHCB-PAPER-2013-002

- Amplitude analysis:

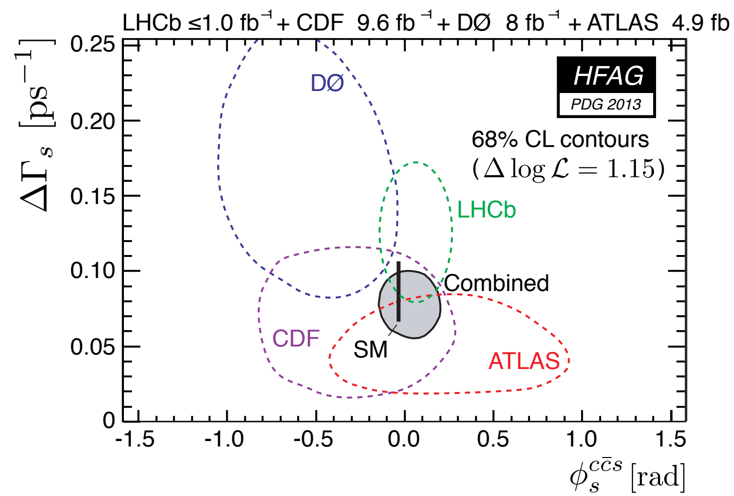
CP odd
CP even
S-wawe
Sum





- Results (including the VS mode $B_s \to J/\psi(\pi^+\pi^-)$):

$$
\begin{aligned}
\phi_s &= 0.01 \pm 0.07\ (\mathrm{stat}) \pm 0.01\ (\mathrm{syst})\ \mathrm{rad}, \\
\Gamma_s &= 0.661 \pm 0.004\ (\mathrm{stat}) \pm 0.006\ (\mathrm{syst})\ \mathrm{ps}^{-1}, \\
\Delta\Gamma_s &= 0.106 \pm 0.011\ (\mathrm{stat}) \pm 0.007\ (\mathrm{syst})\ \mathrm{ps}^{-1}.
\end{aligned}
$$



4.3 CKM angles - weak phase of Bs mixing (mixing-induced).

Phys.Rev.D83 (2011)
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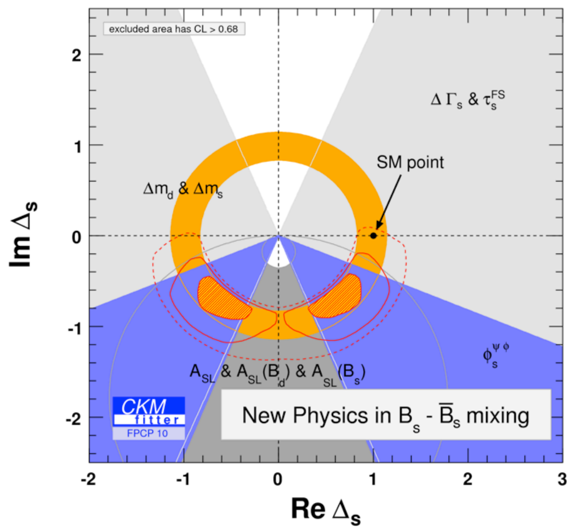
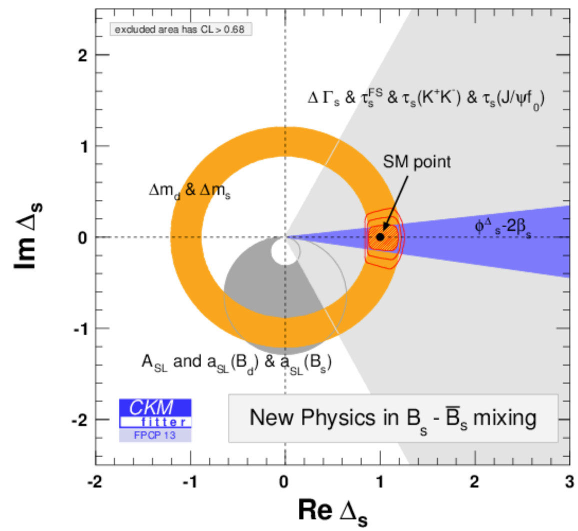
- Implications of LHCb result:

- Generic (minimal assumptions) NP in B_d and B_s mixing: 1 complex number for each multiplying the SM matrix element.





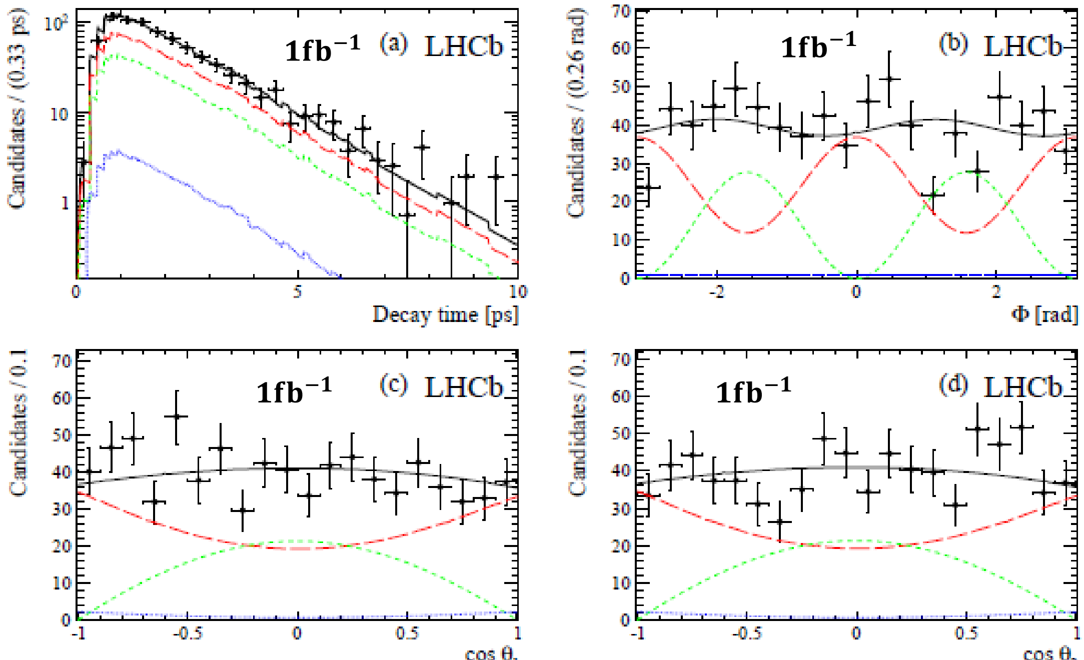
- The 2D SM hypothesis is: 0.2 σ (used to be ~ 3 σ)

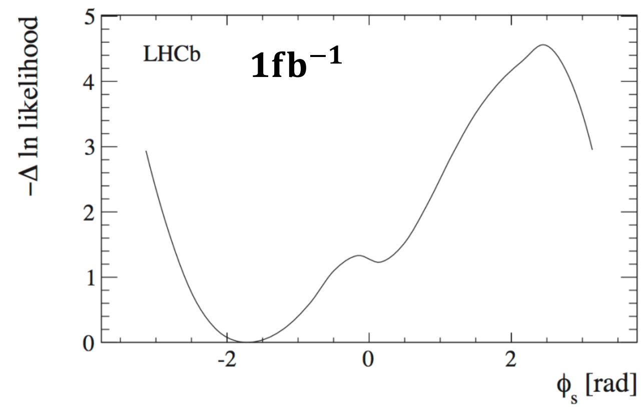
- But don't infer a wrong statement: sizeable NP is still allowed by the LHCb constraint in both Bd and Bs mixing.

4.3 CKM angles - weak phase of Bs mixing (mixing-induced).

LHCB-PAPER-2013-007

- Search for new CP-violating phases in loop-dominated diagrams: $B_s \rightarrow \phi\,\phi$





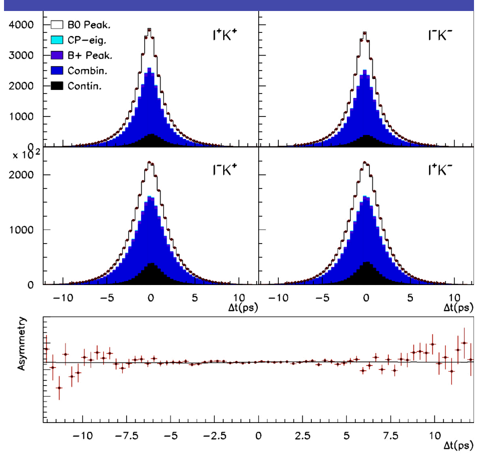
$$\phi_s(b \to s\bar{s}s) \in [-2.46, -0.76] \text{ at } 68\% \text{ C.L.}$$

- First constraint from loop processes. The sensitivity is so far modest but a certain amount of times the current statistics is to come.

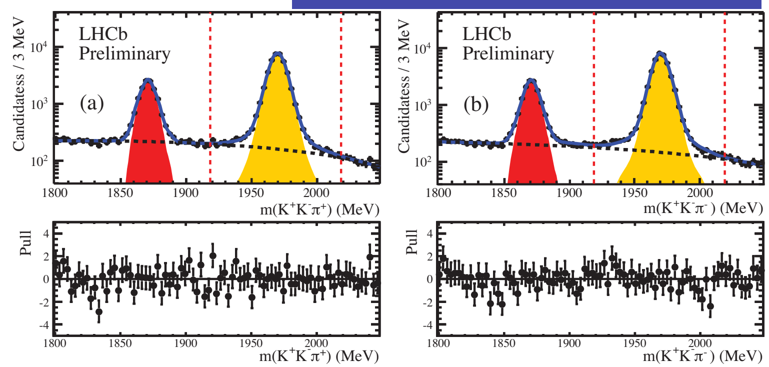
- Flavour specific asymmetries are a measure of CP violation in the mixing, not observed so far in *B* mesons systems.

- $a_{sl}(d)$ measured at B-factories and D0 experiments. $a_{sl}(s)$ measured D0 and LHCb experiments. Additionally, D0 exp. measures a like-sign dimuon asymmetry A_{sl} - average CPV in the mixings of B_d and B_s mesons.

BaBar-arXiv:1305.1575



LHCb-PAPER-2013-033



$$a_{\rm sl}^d = (0.06 \pm 0.16^{+0.36}_{-0.32})\%.$$

$$a_{\rm sl}^s = (-0.06 \pm 0.50 \pm 0.36)\%.$$

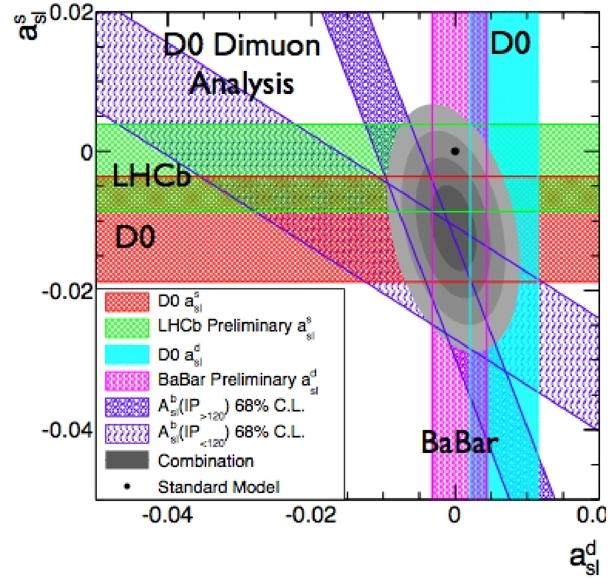
single most precise measurement on $a_{sl}(d)$.

4.4 CKM angles - flavour specific $B_{d,s}$ mixing asymmetries $a_{sl}(d,s)$

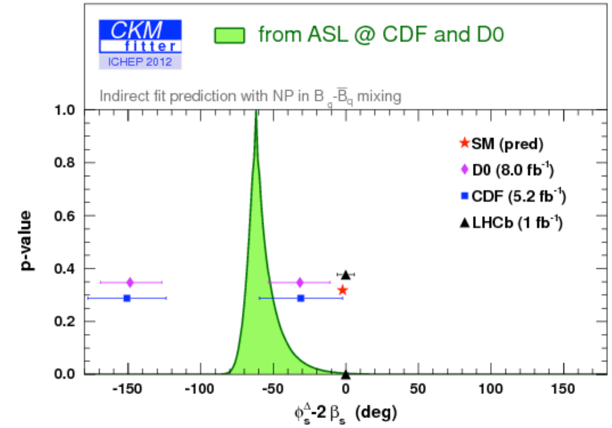
- Consistent results on individual flavour specific asymmetries.

- D0 average asymmetry discrepant from the SM prediction. Marginal agreement with individual $a_{sl}(d,s)$.

- BaBar experiment: single most precise measurement on $a_{sl}(d)$. Measurements at LHCb in preparation.



- The D0 dimuon asymmetry and LHCb ϕ_s ($J/\Psi\ \Phi$) are currently ~ 3 σ discrepant in generic NP models as in Phys.Rev.D83 (2011). Difficult to accommodate both results even in a generic NP scenario.



- Strong physics case for improving precision. Measurements at LHCb in preparation on $a_{sl}(d)$.

Outline of the presentation

1. Historical measurements of CP violation as an introduction.

2. Recent first observations of direct CP violation.

3. Electroweak (Standard Model) interpretation of CP violation: the CKM paradigm .

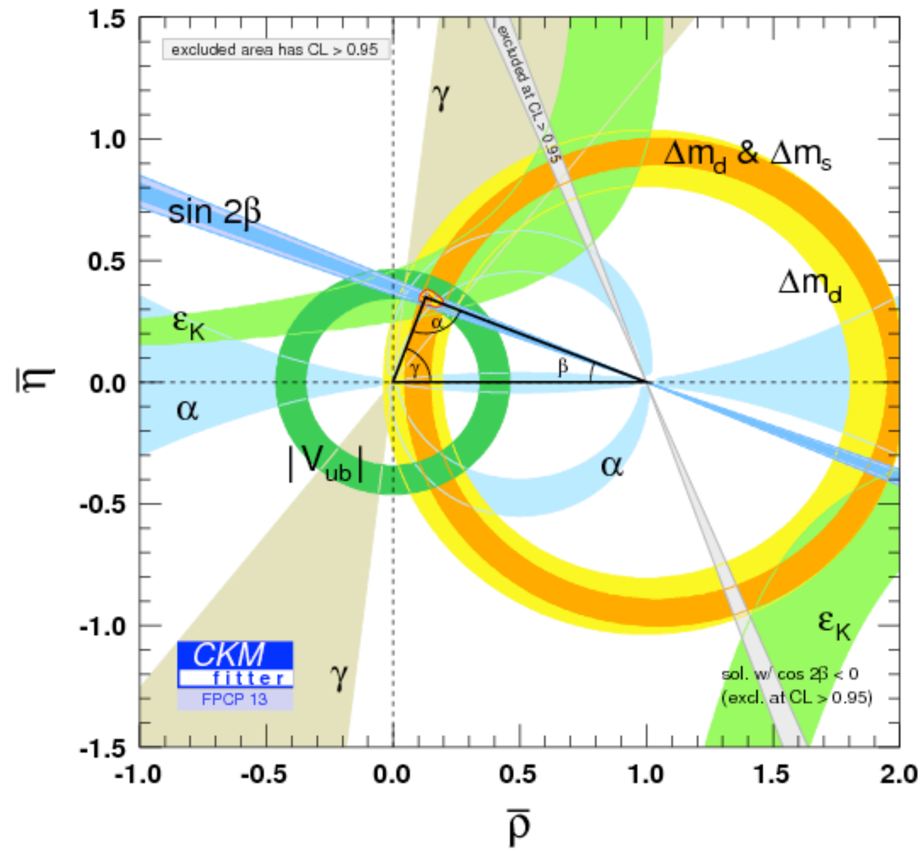
4. Overview of CKM angles measurements (and related quantities).

5. The CKM profile as a summary.

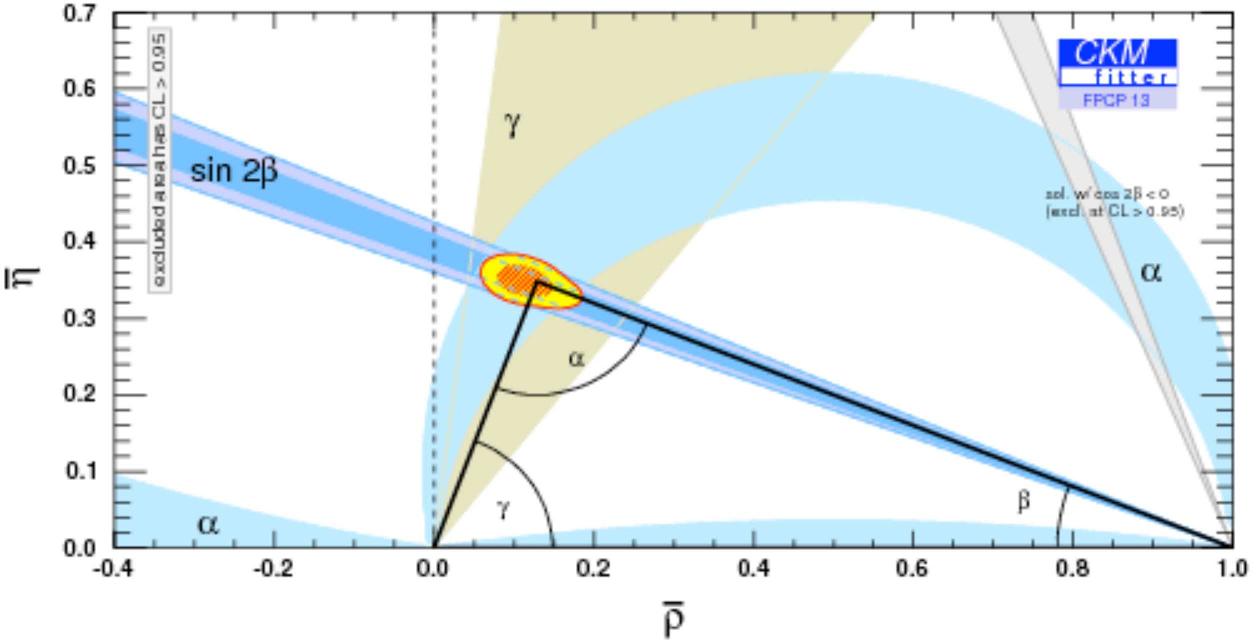
5. Summary: the CKM profile.

5.1 The global fit : CKM profile

- This is a tremendous success of the Standard Model and especially the Kobayashi-Maskawa mechanism. This is simultaneously an outstanding experimental achievement by the B factories (at first).
- CKM is at work in weak charged current.
- The KM phase IS the dominant source of CP violation in K and B system.
- The second pillar of the SM.



5. Summary: the CKM profile w/ angles only.



- No theoretical uncertainties there. Let me point out that the γ constraint is not yet accurate enough to participate valuably to the global consistency check of SM.

$$\alpha + \beta + \gamma = (174.8 \pm 9.4)^\circ.$$

- Fair agreement though. Breakthrough: LHCb γ update w/ 3/fb.

5. Concluding remarks

- B-factories were an outstanding experimental success. The experiments are still providing these days world class measurements.

- The LHCb experiment is a sound success. An harvest of results significantly explores its core physics case already with the first 1/fb recorded in 2011. Much more to come with the 3 /fb recorded so far.

- The SM passed successfully all tests so far.

- Some tensions though (not only in CP-violating observables).

- The first message is that sizeable NP contributions are allowed by the current experimental constraints in both B_d and B_s mixings, which both the LHCb upgrade and the SuperKEKB program will study.

- The second message is that LHCb is well suited to provide a decisive breakthrough by a complete characterization of the Bs mixing properties.