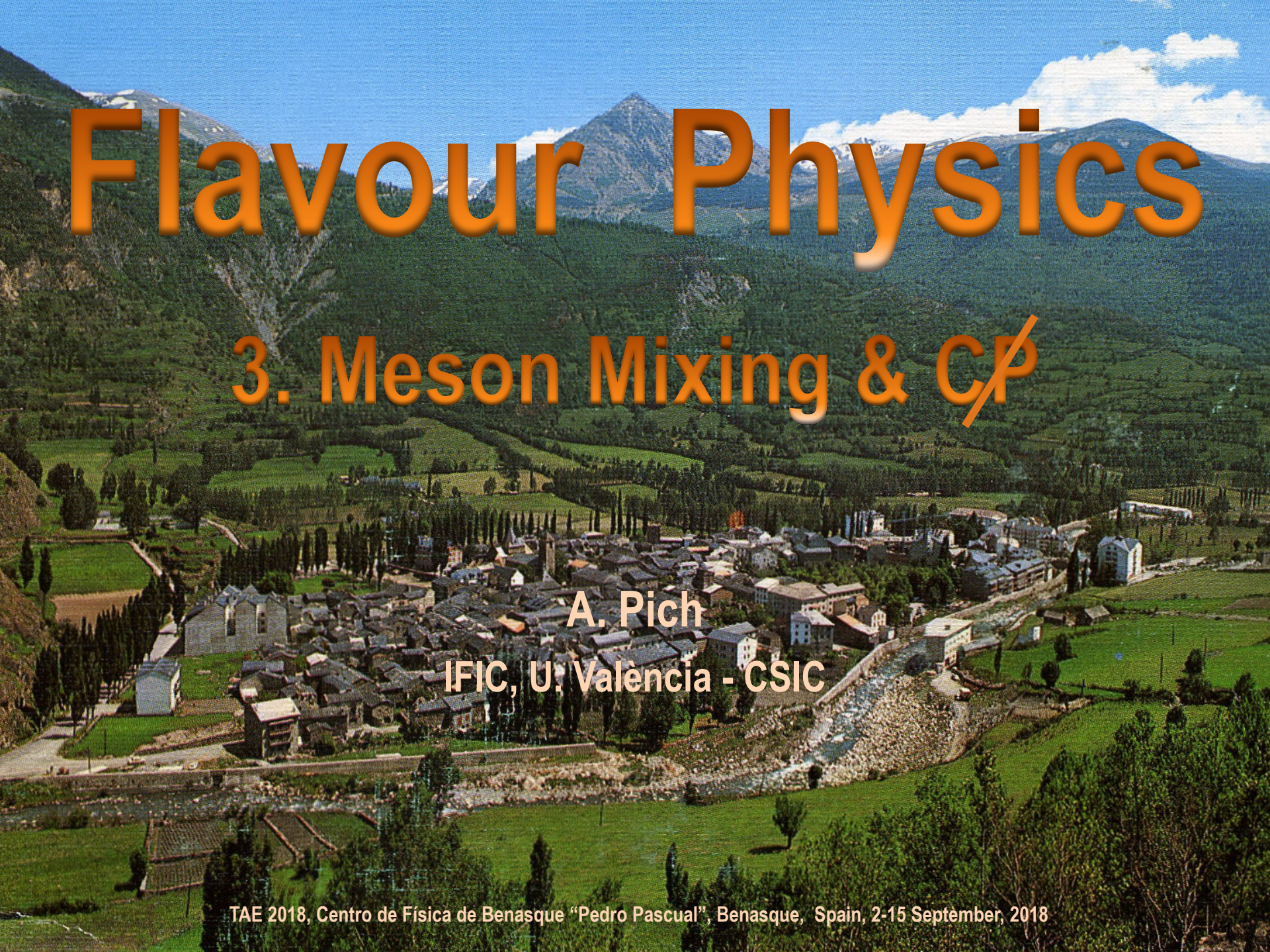


Flavour Physics

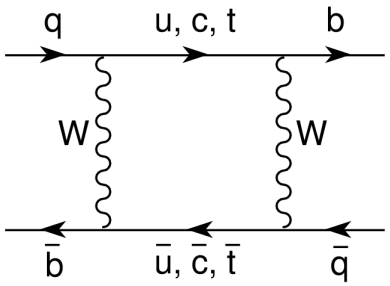
3. Meson Mixing & $\not{CP}$

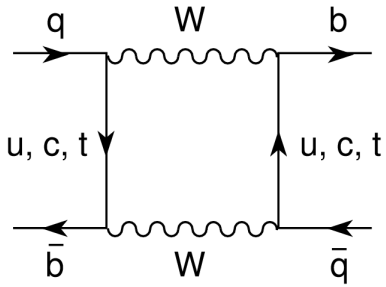
A. Pich

IFIC, U. València - CSIC

TAE 2018, Centro de Física de Benasque "Pedro Pascual", Benasque, Spain, 2-15 September, 2018

$B^0 - \bar{B}^0$ MIXING





$$V_{ud}\,V_{ub}^* \sim V_{cd}\,V_{cb}^* \sim V_{td}\,V_{tb}^* \sim A\lambda^3$$

$$\left\langle \bar{B}^0 \left| \mathrm{H} \right| B^0 \right\rangle \sim \left| V_{td} \right|^2 S(r_t, r_t) \left(\frac{4}{3} M_B^2 f_B^2 \right) \hat{B}_B$$

$$\Delta M_{B_d^0} = (0.5064 \pm 0.0019)\ \mathrm{ps}^{-1} \quad \Rightarrow \quad \left| V_{td} \right|$$

- $\Delta M_{B_d^0} / \Gamma_{B_d^0} = 0.770 \pm 0.004$
- $\Delta M_{B_s^0} = (17.757 \pm 0.021)\ \mathrm{ps}^{-1}$
- $\Delta\Gamma_{B^0} / \Delta M_{B^0} \sim m_b^2 / m_t^2 \ll 1$
- $\mathrm{Re}\left(\bar{\varepsilon}_{B_d^0} \right) = -0.0005 \pm 0.0004$

$\not{CP}$ very small

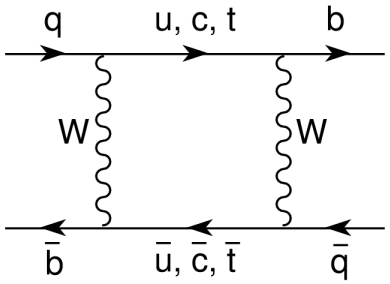
$$\Delta M_{B_s^0} / \Gamma_{B_s^0} = 26.72 \pm 0.09$$

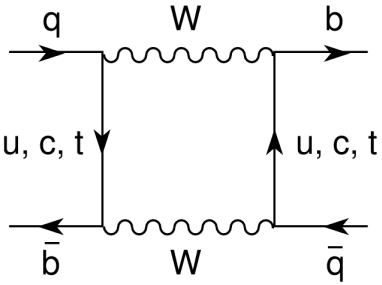
$$\left| V_{ts} \right|^2 \gg \left| V_{td} \right|^2$$

$$\Delta\Gamma_{B_s^0} / \Gamma_{B_s^0} = -0.130 \pm 0.009$$

$$\mathrm{Re}\left(\bar{\varepsilon}_{B_s^0} \right) = -0.0002 \pm 0.0007$$

$$|q/p| - 1 \sim m_c^2 / m_t^2$$





$$\mathbf{M} = \begin{pmatrix} M & M_{12} \\ M_{12}^* & M \end{pmatrix} - \frac{i}{2} \begin{pmatrix} \Gamma & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma \end{pmatrix}$$

$$\left| B_\mp^0 \right\rangle = \frac{1}{\sqrt{|p|^2 + |q|^2}} \left(p \left| B^0 \right\rangle \mp q \left| \bar{B}^0 \right\rangle \right) \quad , \quad \frac{q}{p} \equiv \frac{1-\bar{\varepsilon}_B}{1+\bar{\varepsilon}_B} = \left(\frac{M_{12}^* - \frac{i}{2}\Gamma_{12}^*}{M_{12} - \frac{i}{2}\Gamma_{12}} \right)^{1/2}$$

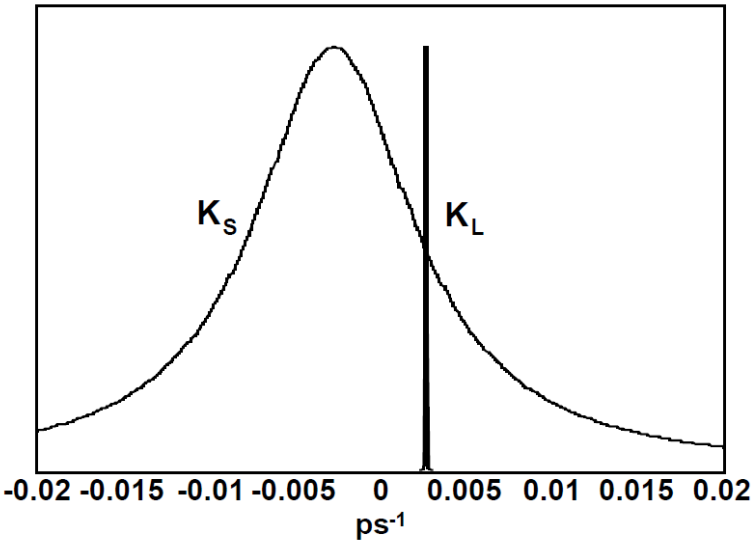
$$(\Delta M)^2 - \frac{1}{4}(\Delta\Gamma)^2 = 4\left|M_{12}\right|^2 - \left|\Gamma_{12}\right|^2 \quad , \quad \Delta M\, \Delta\Gamma = 4\,\mathrm{Re}(M_{12}\Gamma_{12}^*)$$

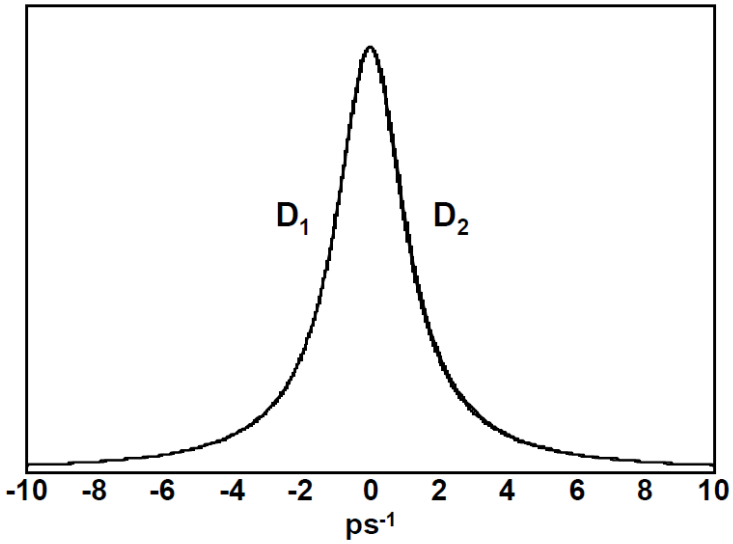
$$\Delta\Gamma/\Delta M \approx \Gamma_{12}/M_{12} \sim m_b^2/m_t^2 \ll 1 \quad \Rightarrow \quad \left|\frac{q}{p}\right| \approx 1 + \frac{1}{2}\left|\frac{\Gamma_{12}}{M_{12}}\right| \sin\phi_{\Delta B=2} \quad , \quad \phi_{\Delta B=2} \equiv \arg\left(M_{12}/\Gamma_{12}\right)$$

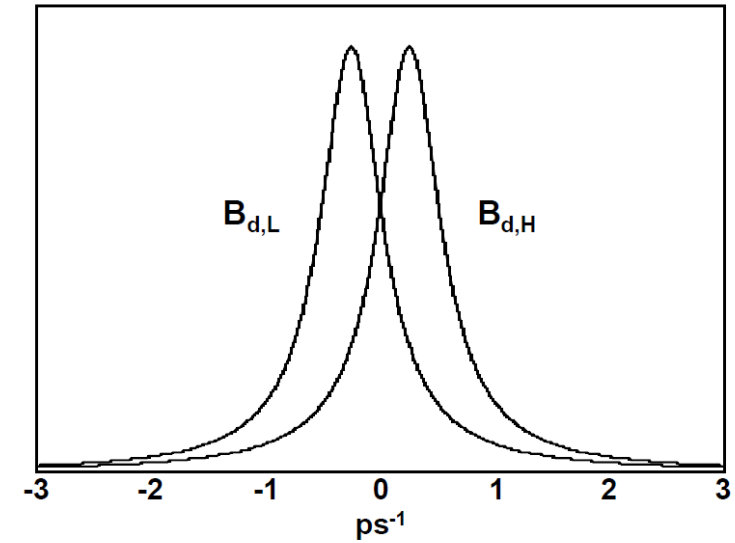
$$\Delta M \equiv M_{B_+} - M_{B_-} \quad , \quad \Delta\Gamma \equiv \Gamma_{B_+} - \Gamma_{B_-}$$

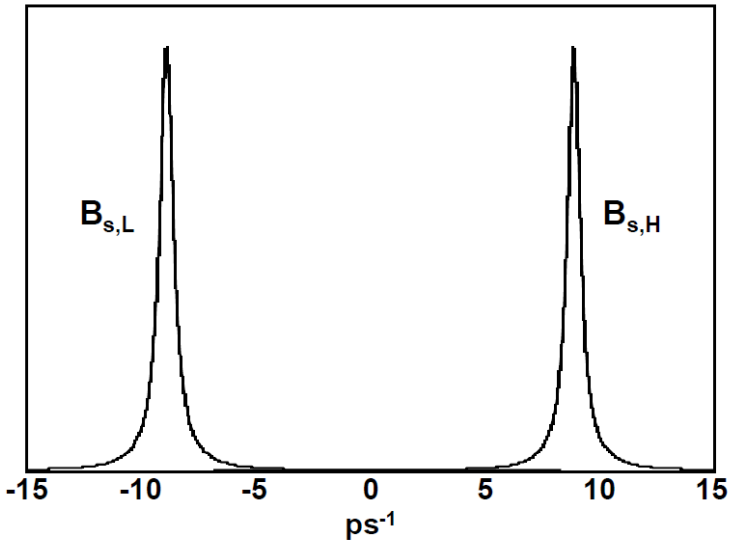
$$\begin{pmatrix} \left|B^0(t)\right\rangle \\ \left|\bar{B}^0(t)\right\rangle \end{pmatrix} = \begin{pmatrix} g_1(t) & \frac{q}{p} g_2(t) \\ \frac{p}{q} g_2(t) & g_1(t) \end{pmatrix} \begin{pmatrix} \left|B^0\right\rangle \\ \left|\bar{B}^0\right\rangle \end{pmatrix} \quad , \quad \begin{pmatrix} g_1(t) \\ g_2(t) \end{pmatrix} = e^{-iMt}\, e^{-\Gamma t/2} \begin{pmatrix} \cos\left[\left(\Delta M - \frac{i}{2}\Delta\Gamma\right)\frac{t}{2}\right] \\ -i\sin\left[\left(\Delta M - \frac{i}{2}\Delta\Gamma\right)\frac{t}{2}\right] \end{pmatrix}$$

Widths & Mass Differences







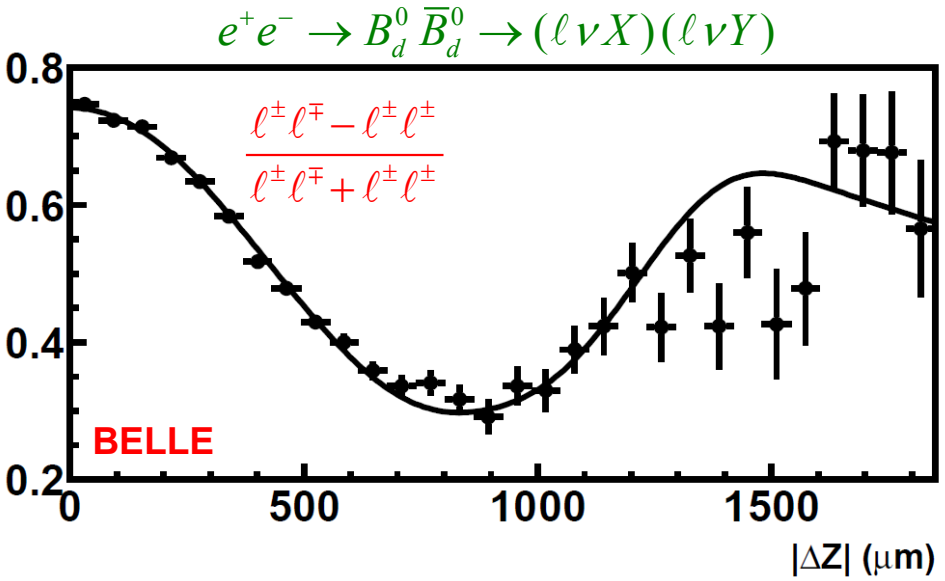


M. Gersabeck

Time Scales:

Oscillation ~ $\sin\left[\left(x-iy\right)\Gamma\, t/2\right]$

$$x \equiv \frac{\Delta M}{\Gamma} \quad , \quad y \equiv \frac{\Delta\Gamma}{2\Gamma}$$



- **K^0 :** x ~ y ~ 1
- **D^0 :** x ~ y ~ 0.01 Slow oscillation (decays faster)
- **B_d :** x ~ 1 , y ~ 0.01
- **B_s :** x ~ 25 , y ~ 0.05 Fast oscillation (averages out to 0)

Time Scales:

Oscillation ~ $\sin\left[\left(x-iy\right)\Gamma t/2\right]$

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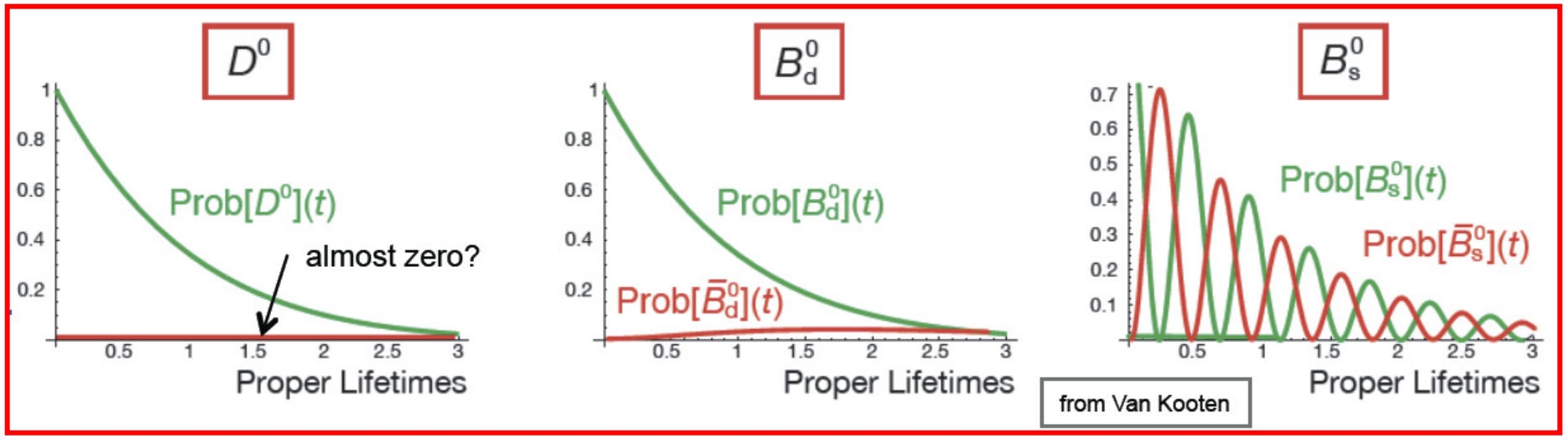

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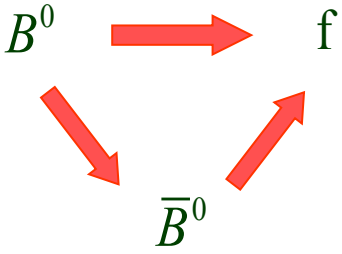
$B^0 - \bar{B}^0$ MIXING AND DIRECT $\not{CP}$



$$T_f \equiv T[B^0 \to f] \;\; ; \;\; \bar{T}_f \equiv -T[\bar{B}^0 \to f] \;\; ; \;\; \bar{\rho}_f \equiv \bar{T}_f / T_f$$
$$T_{\bar{f}} \equiv T[B^0 \to \bar{f}] \;\; ; \;\; \bar{T}_{\bar{f}} \equiv -T[\bar{B}^0 \to \bar{f}] \;\; ; \;\; \rho_{\bar{f}} \equiv T_{\bar{f}} / \bar{T}_{\bar{f}}$$

$$\mathcal{CP}\ B^0 = -\bar{B}^0 \qquad ; \qquad \mathcal{CP}\ f = \bar{f}$$

$$\Gamma[B^0(t) \to f] \sim \frac{1}{2}\, e^{-\Gamma t} \left(|T_f|^2 + |\bar{T}_f|^2 \right) \left\{ 1 + \mathbf{C_f} \cos(\Delta M\, t) - \mathbf{S_f} \sin(\Delta M\, t) \right\}$$

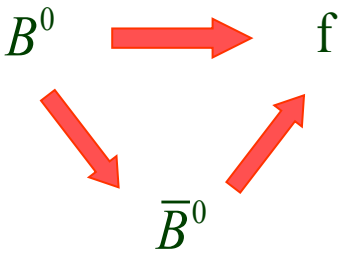
$$\Gamma[\bar{B}^0(t) \to \bar{f}] \sim \frac{1}{2}\, e^{-\Gamma t} \left(|\bar{T}_{\bar{f}}|^2 + |T_{\bar{f}}|^2 \right) \left\{ 1 - \mathbf{C_{\bar{f}}} \cos(\Delta M\, t) + \mathbf{S_{\bar{f}}} \sin(\Delta M\, t) \right\}$$

$$\mathbf{C_f} \equiv \frac{1 - |\bar{\rho}_f|^2}{1 + |\bar{\rho}_f|^2} \qquad ; \qquad \mathbf{S_f} \equiv \frac{2\,\mathrm{Im}\left(\frac{q}{p}\, \bar{\rho}_f \right)}{1 + |\bar{\rho}_f|^2} \qquad ; \qquad \mathbf{C_{\bar{f}}} \equiv -\frac{1 - |\rho_{\bar{f}}|^2}{1 + |\rho_{\bar{f}}|^2} \qquad ; \qquad \mathbf{S_{\bar{f}}} \equiv \frac{-2\,\mathrm{Im}\left(\frac{p}{q}\, \rho_{\bar{f}} \right)}{1 + |\rho_{\bar{f}}|^2}$$

$\Delta\Gamma \ll \Delta M$ ⇒

$$\frac{q}{p} \approx \sqrt{\frac{M_{12}^*}{M_{12}}} \approx \frac{\mathbf{V}_{tb}^*\, \mathbf{V}_{tq}}{\mathbf{V}_{tb}\, \mathbf{V}_{tq}^*} = e^{-2i\phi_M} \qquad ; \qquad \phi_M \approx \begin{cases} \beta & \left(B_d^0\right) \\ -\beta_s \approx -\lambda^2 \eta & \left(B_s^0\right) \end{cases}$$

$B^0 - \bar{B}^0$ MIXING AND DIRECT $\not{CP}$



$$T_f \equiv T[B^0 \to f] \;\; ; \;\; \bar{T}_f \equiv -T[\bar{B}^0 \to f] \;\; ; \;\; \bar{\rho}_f \equiv \bar{T}_f / T_f$$
$$T_{\bar{f}} \equiv T[B^0 \to \bar{f}] \;\; ; \;\; \bar{T}_{\bar{f}} \equiv -T[\bar{B}^0 \to \bar{f}] \;\; ; \;\; \rho_{\bar{f}} \equiv T_{\bar{f}} / \bar{T}_{\bar{f}}$$

$$\mathcal{CP}\ B^0 = -\bar{B}^0 \qquad ; \qquad \mathcal{CP}\ f = \bar{f}$$

$$\Gamma[B^0(t) \to f] \sim \frac{1}{2}\, e^{-\Gamma t} \left(|T_f|^2 + |\bar{T}_f|^2 \right) \left\{ 1 + \mathbf{C_f} \cos(\Delta M\, t) - \mathbf{S_f} \sin(\Delta M\, t) \right\}$$

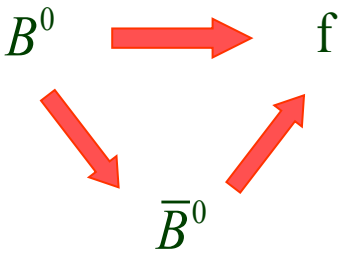
$$\Gamma[\bar{B}^0(t) \to \bar{f}] \sim \frac{1}{2}\, e^{-\Gamma t} \left(|\bar{T}_{\bar{f}}|^2 + |T_{\bar{f}}|^2 \right) \left\{ 1 - \mathbf{C_{\bar{f}}} \cos(\Delta M\, t) + \mathbf{S_{\bar{f}}} \sin(\Delta M\, t) \right\}$$

$$\mathbf{C_f} \equiv \frac{1 - |\bar{\rho}_f|^2}{1 + |\bar{\rho}_f|^2} \quad ; \quad \mathbf{S_f} \equiv \frac{2\,\mathrm{Im}\left(\frac{q}{p}\,\bar{\rho}_f \right)}{1 + |\bar{\rho}_f|^2} \quad ; \quad \mathbf{C_{\bar{f}}} \equiv -\frac{1 - |\rho_{\bar{f}}|^2}{1 + |\rho_{\bar{f}}|^2} \quad ; \quad \mathbf{S_{\bar{f}}} \equiv \frac{-2\,\mathrm{Im}\left(\frac{p}{q}\,\rho_{\bar{f}} \right)}{1 + |\rho_{\bar{f}}|^2}$$

CP self-conjugate: $\bar{f} = \eta_f\, f$ ⟹

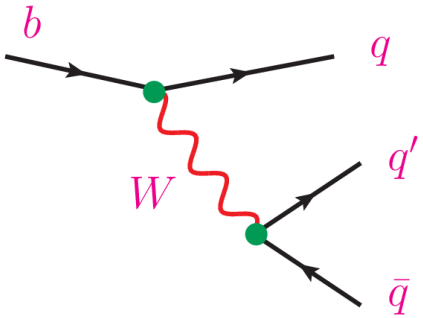
$$T_{\bar{f}} = \eta_f\, T_f \;\; ; \;\; \bar{T}_{\bar{f}} = \eta_f\, \bar{T}_f \;\; ; \;\; \rho_{\bar{f}} \equiv 1/\bar{\rho}_f$$
$$\mathbf{C_{\bar{f}}} = \mathbf{C_f} \qquad ; \qquad \mathbf{S_{\bar{f}}} = \mathbf{S_f}$$

$B^0 - \bar{B}^0$ MIXING AND DIRECT $\not{CP}$



CP self-conjugate: $\bar{f} = \eta_f \, f$

$$\frac{q}{p} \approx \frac{V_{tb}^* \, V_{tq}}{V_{tb} \, V_{tq}^*} = e^{-2i\phi_M} \quad ; \quad \phi_M \approx \begin{cases} \beta & (B_d^0) \\ -\beta_s \approx -\lambda^2 \eta & (B_s^0) \end{cases}$$



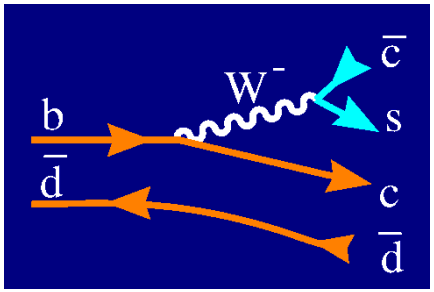
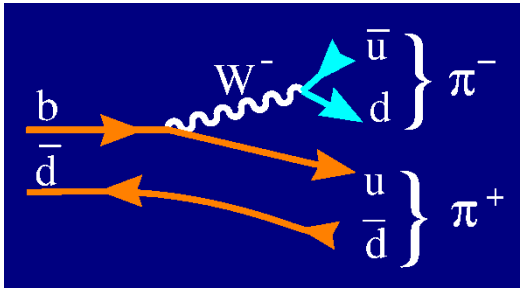
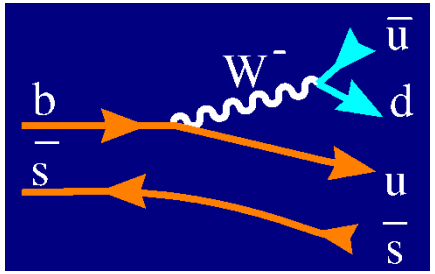
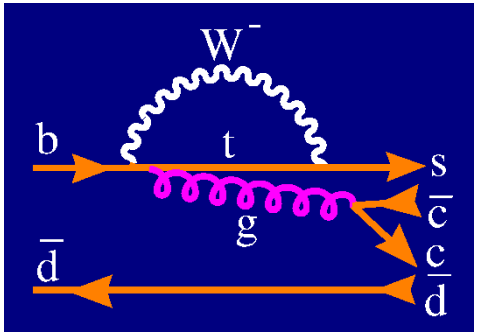
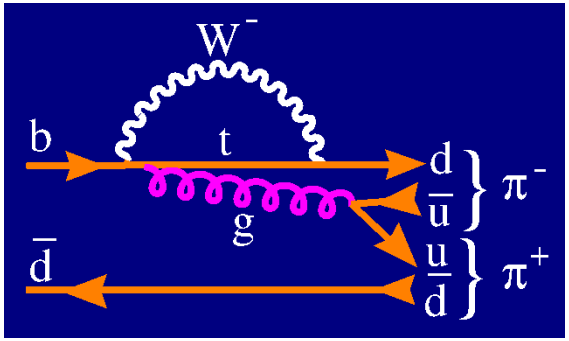
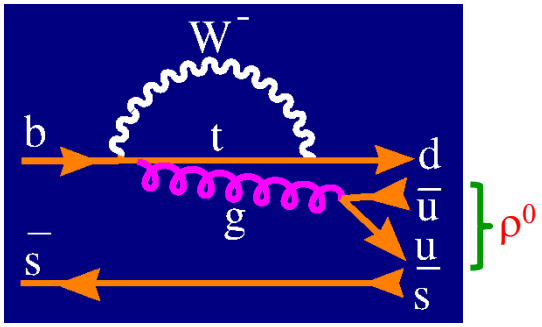
Assumption: **Only 1 decay amplitude**

$$\frac{A_{b\to q\bar{q}q'}}{A_{\bar{b}\to\bar{q}q\bar{q}'}} = \frac{V_{qb} \, V_{qq'}^*}{V_{qb}^* \, V_{qq'}} = e^{-2i\phi_D} \quad \Rightarrow \quad \rho_{\bar{f}} = \bar{\rho}_f^* = \eta_f \, e^{2i\phi_D}$$

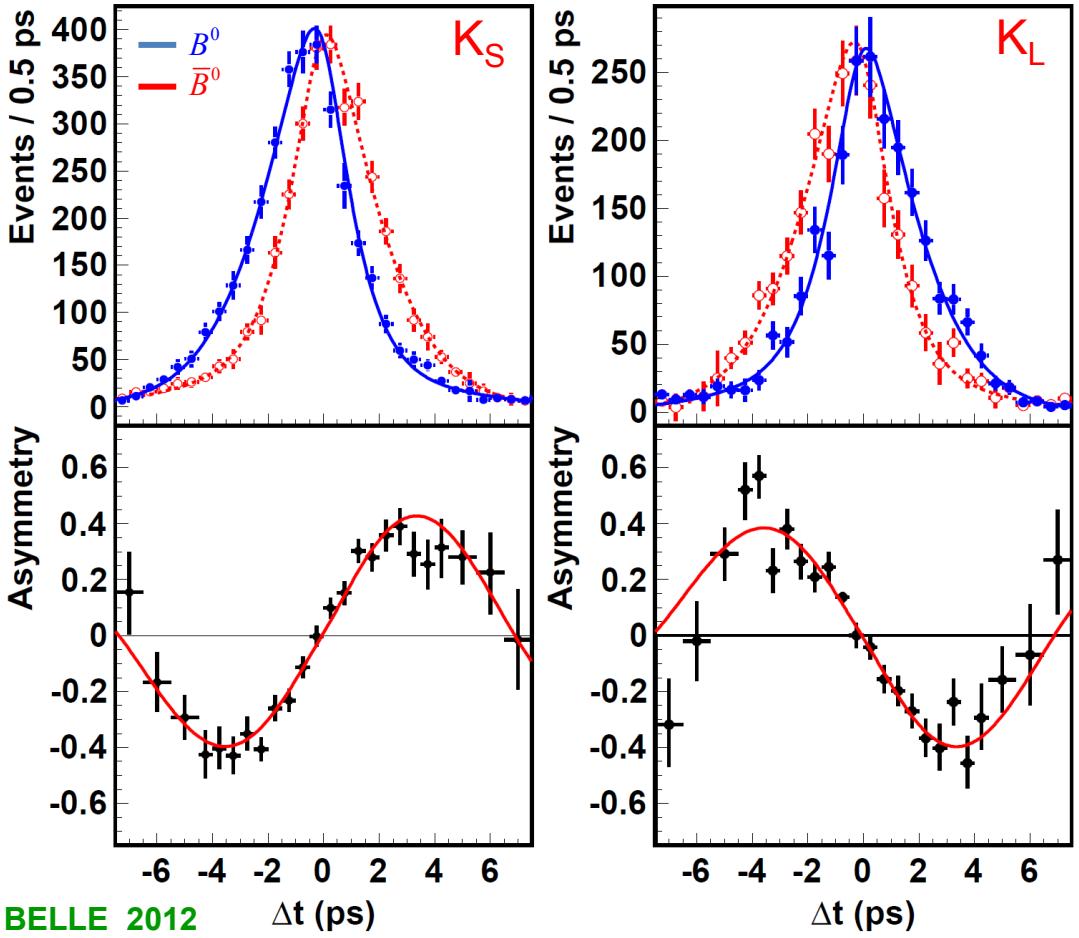
$$C_f = 0$$

$$\Rightarrow \quad \frac{\Gamma(\bar{B}^0 \to \bar{f}) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to \bar{f}) + \Gamma(B^0 \to f)} = -\eta_f \, \sin(2\phi) \, \sin(\Delta M \, t) \quad ; \quad \phi = \phi_M + \phi_D$$

Direct information on the CKM matrix

$\bar{B}^0_d \to J/\Psi\, K^0_S$	$\bar{B}^0_d \to \pi^+\pi^-$	$\bar{B}^0_s \to \rho^0 K^0_S$
$\phi \simeq \beta$	$\phi \simeq \beta + \gamma = \pi - \alpha$	$\phi \neq \gamma$
		
$V_{cb}\, V^*_{cs} \sim A\lambda^2$	$V_{ub}\, V^*_{ud} \sim A\lambda^3(\rho - i\eta)$	$V_{ub}\, V^*_{ud} \sim A\lambda^3(\rho - i\eta)$
		
$V_{tb}\, V^*_{ts} \sim -A\lambda^2$	$V_{tb}\, V^*_{td} \sim A\lambda^3(1 - \rho + i\eta)$	$V_{tb}\, V^*_{td} \sim A\lambda^3(1 - \rho + i\eta)$
***	**	**BAD**

$$\frac{\Gamma(\bar{B}^0 \to J/\psi\, K_S) - \Gamma(B^0 \to J/\psi\, K_S)}{\Gamma(\bar{B}^0 \to J/\psi\, K_S) + \Gamma(B^0 \to J/\psi\, K_S)} = -\eta_f \sin(2\beta) \sin(\Delta M\, t)$$

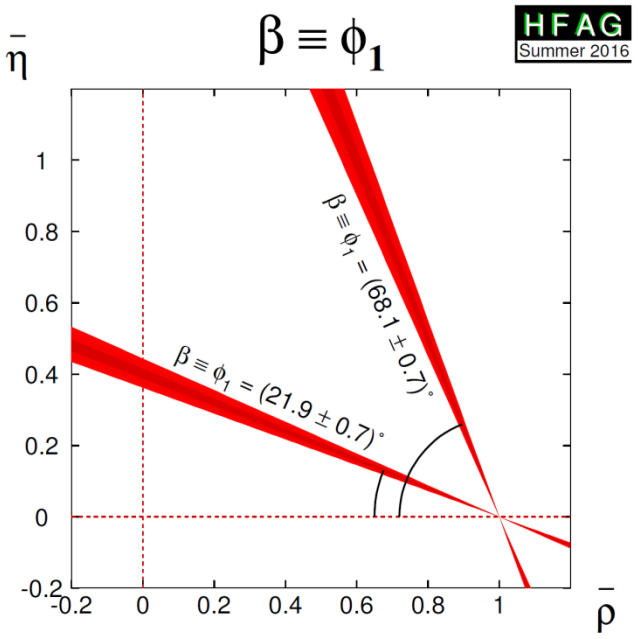


CP Signal

HFAG:

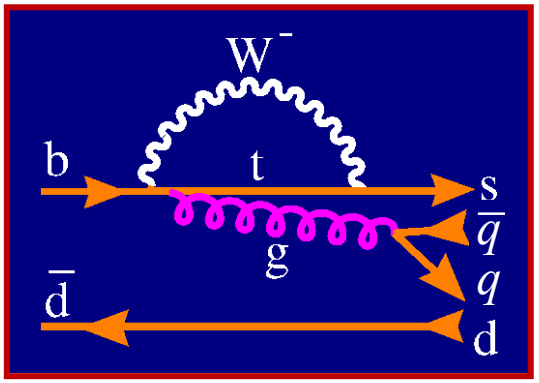
$\sin(2\beta) = 0.691 \pm 0.017$

$B^0 \to J/\psi\, K_{S,L}\,,\ \psi(2S)\, K_S\,,\ \chi_c\, K_S\,,\ \eta_c\, K_S$



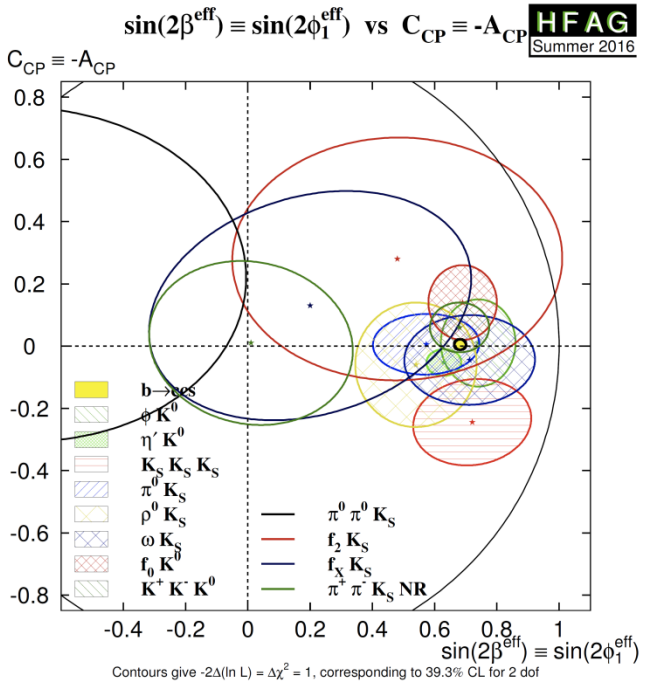
$b \to q\bar{q}s$

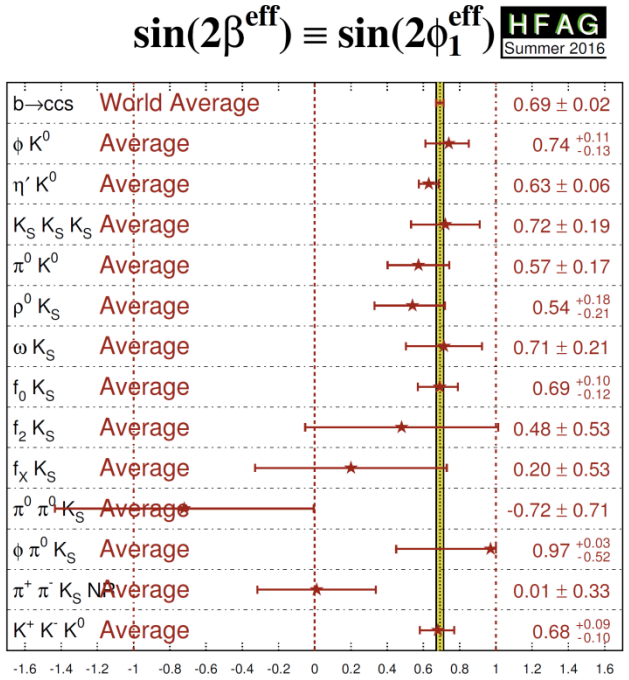
$q = d, s$

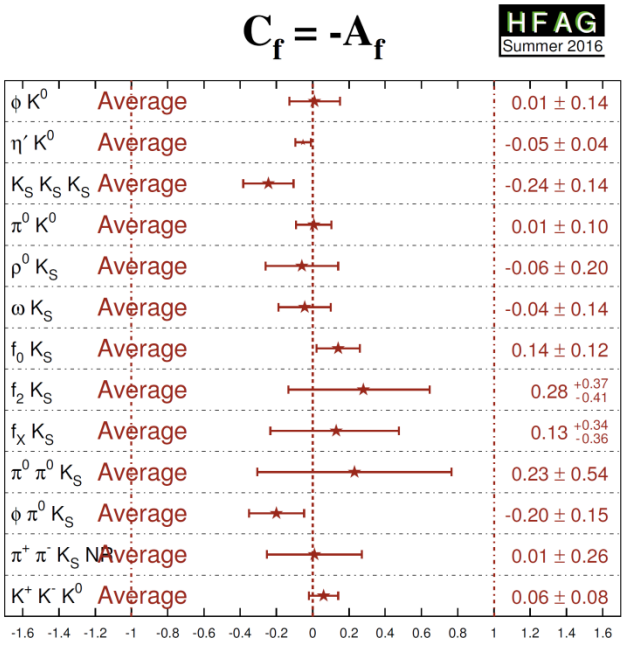


$V_{tb} V_{ts}^* \sim -A\lambda^2$

Sensitive to New Physics in Penguin diagram







Agreement with

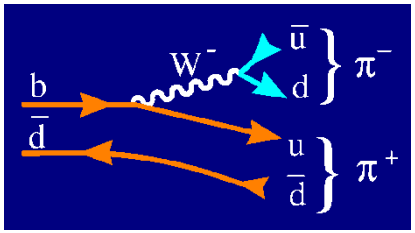
$B^0 \to J/\Psi\, K_S \quad (b \to c\bar{c}s)$

No signal of direct $\not{CP}$

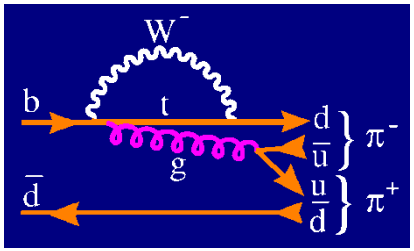
$B^0 \to \pi\pi$

$$\frac{\Gamma\left(\bar{B}^0 \to \bar{f}\right) - \Gamma\left(B^0 \to f\right)}{\Gamma\left(\bar{B}^0 \to \bar{f}\right) + \Gamma\left(B^0 \to f\right)} = -C_f \cos(\Delta M\, t) + S_f \sin(\Delta M\, t)$$

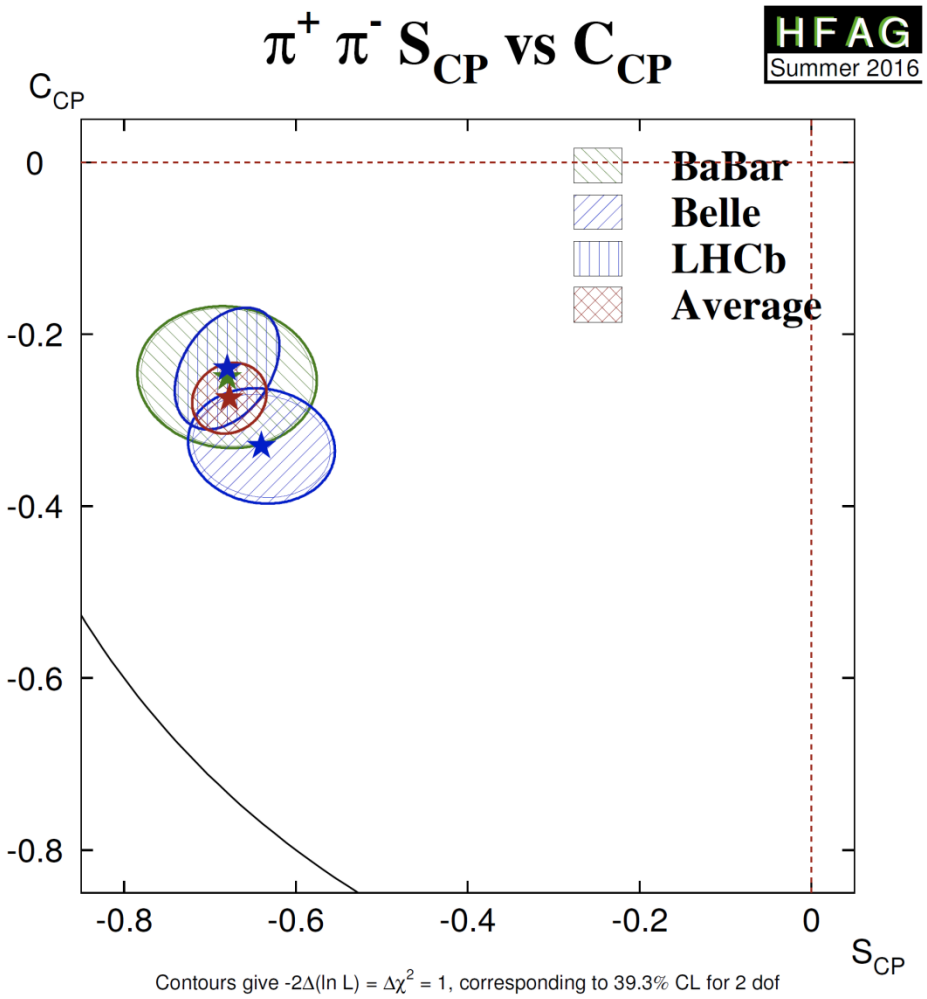
$$\alpha \equiv \arg\left[-\frac{V_{td}\, V_{tb}^*}{V_{ud}\, V_{ub}^*}\right]$$



$$V_{ub}\, V_{ud}^* \sim A\lambda^3(\rho - i\eta)$$



$$V_{tb}\, V_{td}^* \sim A\lambda^3(1 - \rho + i\eta)$$



$$C_f \equiv \frac{1 - |\bar{\rho}_f|^2}{1 + |\bar{\rho}_f|^2} \neq 0$$

Direct $\not{CP}$

Penguins

$$\frac{\Gamma(B^0 \to \pi^0\pi^0)}{\Gamma(B^0 \to \pi^+\pi^-)} = 0.37\,(5)$$

$$S_f \approx -\sin(2\alpha) \quad ?$$

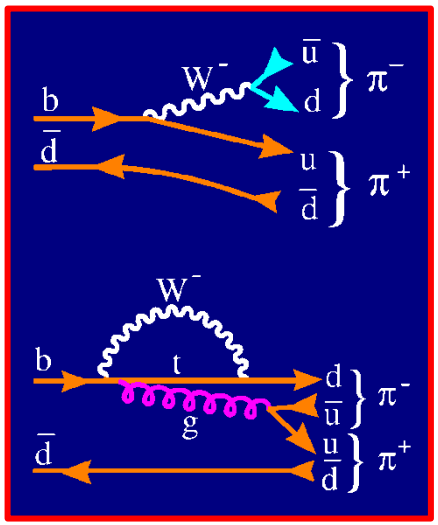
$B^0 \to \pi\pi, \rho\rho, \rho\pi$

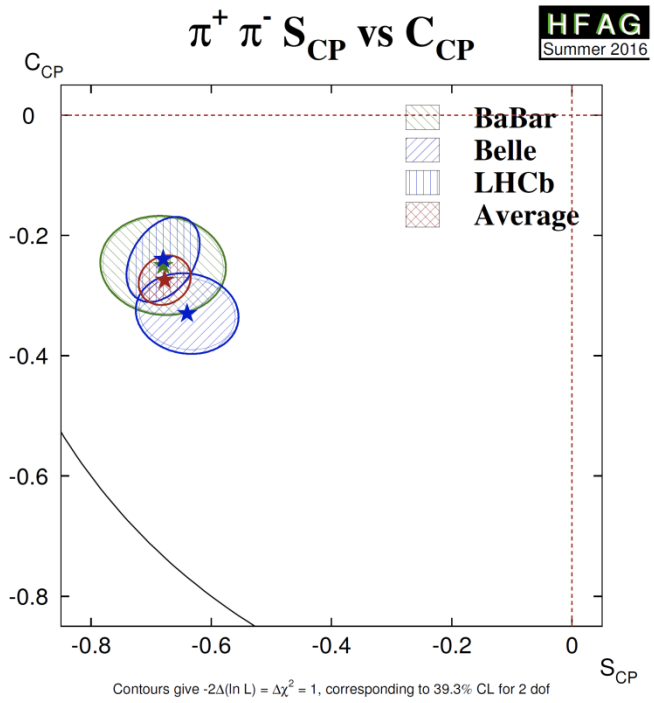
$$C_f \equiv \frac{1-|\bar{\rho}_f|^2}{1+|\bar{\rho}_f|^2} \neq 0$$

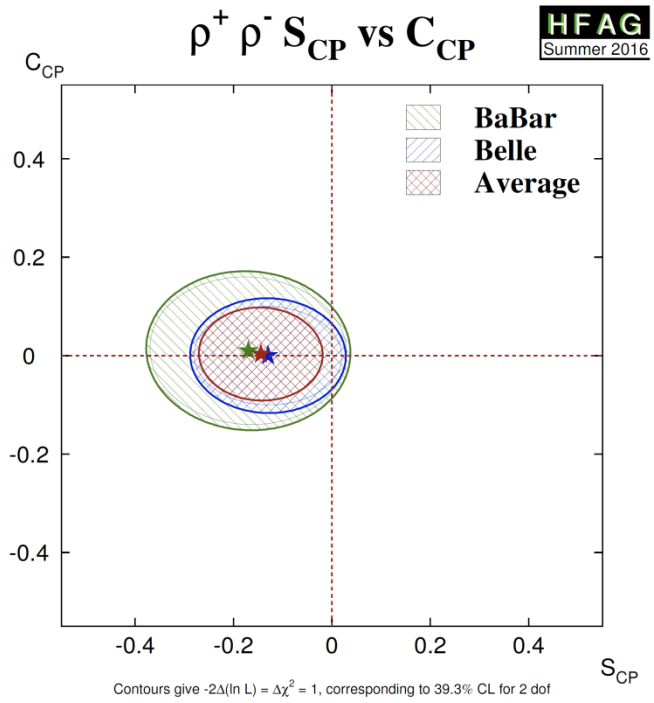
Direct $\not{CP}$

Penguins

$$\frac{\Gamma(B^0 \to \rho^0\rho^0)}{\Gamma(B^0 \to \rho^+\rho^-)} = 0.035 \ (6)$$

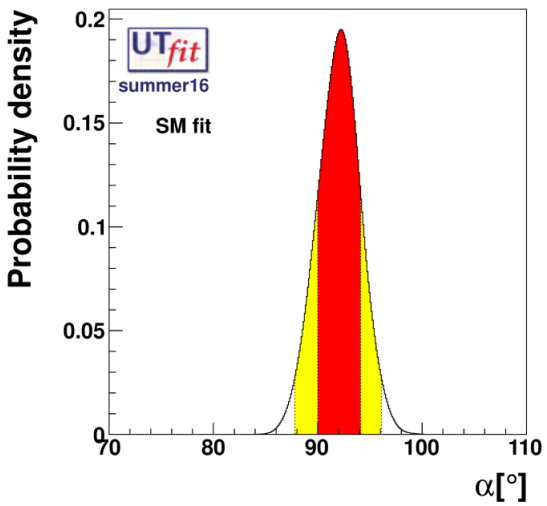


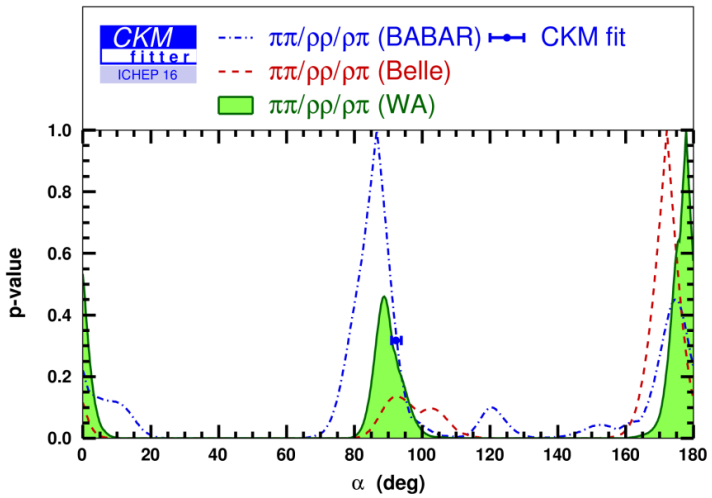




HFAG 2017:

$$\alpha \equiv \arg\left[-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right] = (88 \pm 5)^\circ$$





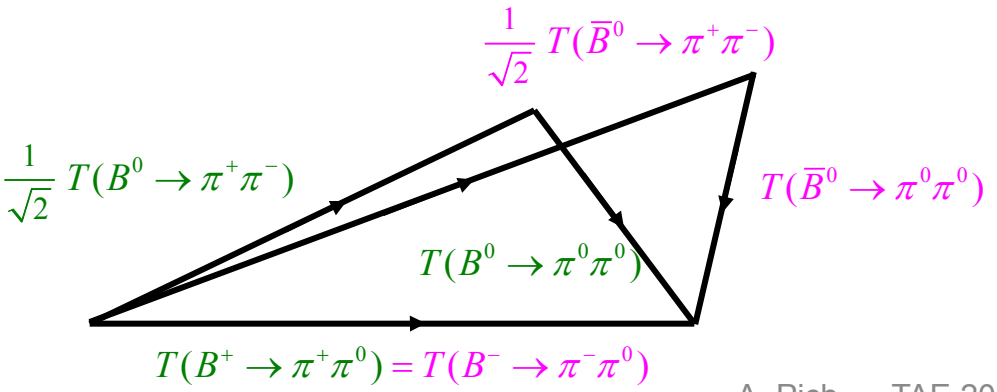
MEASURING HADRONIC CONTAMINATIONS

- **Time Evolution**
- **Transversity Analysis: $B \to V\,V$**
- **Isospin Relations** (Gronau-London)
- **D^0-$\bar{D}^0$ Mixing** (Gronau-London-Wyler, Atwood-Dunietz-Soni)

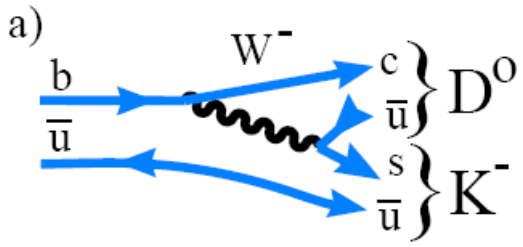
$$\sqrt{2}\,\mathrm{T}(B^+ \to D_+^0 K^+) = \mathrm{T}(B^+ \to D^0 K^+) + \mathrm{T}(B^+ \to \bar{D}^0 K^+)$$

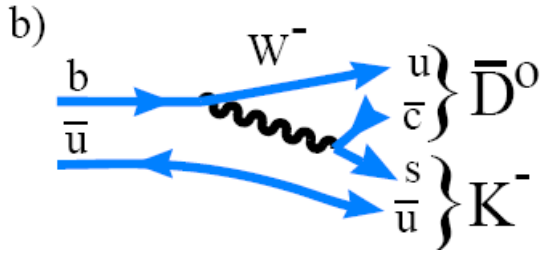
$$\sqrt{2}\,\mathrm{T}(B_d^0 \to D_+^0 K_S) = \mathrm{T}(B_d^0 \to D^0 K_S) + \mathrm{T}(B_d^0 \to \bar{D}^0 K_S)$$

- **Dalitz Analysis**
- **SU(3) Relations: $B \to \pi K$, $\pi\,\pi$, ...**
- ...



D^0-$\bar{D}^0$ Mixing

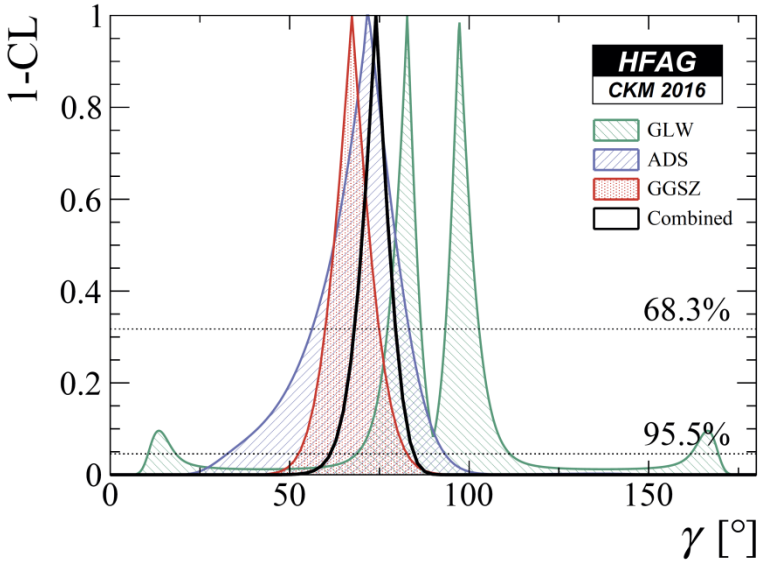


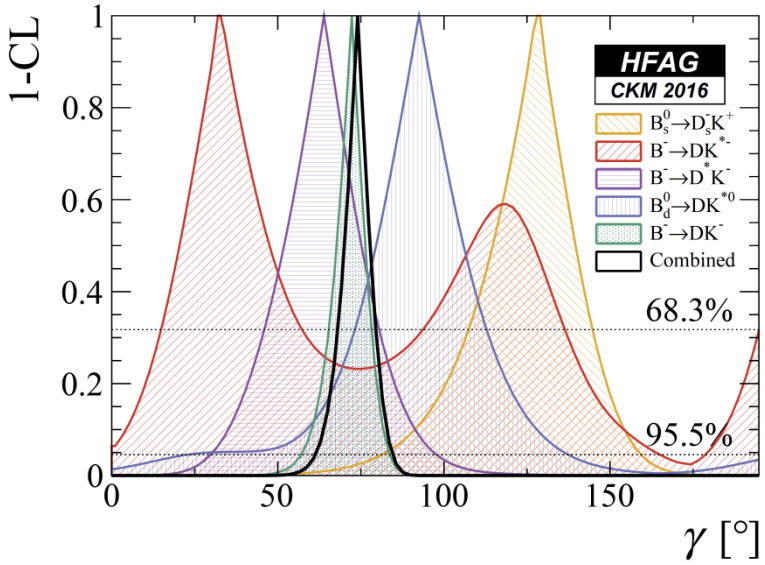


Gronau-London-Wyler
Atwood-Dunietz-Soni
Giri-Grossman-Soffer-Zupan

$$\sqrt{2}\,\mathrm{T}(B^+ \to D_+^0 K^+) = \mathrm{T}(B^+ \to D^0 K^+) + \mathrm{T}(B^+ \to \bar{D}^0 K^+)$$

$$\sqrt{2}\,\mathrm{T}(B_d^0 \to D_+^0 K_S) = \mathrm{T}(B_d^0 \to D^0 K_S) + \mathrm{T}(B_d^0 \to \bar{D}^0 K_S)$$



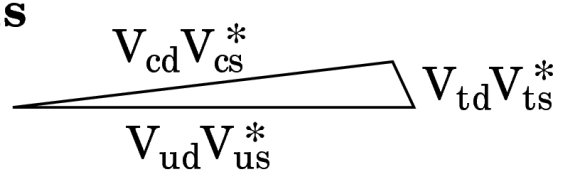


$$\gamma \equiv \arg\left[-\frac{V_{ud}\,V_{ub}^*}{V_{cd}\,V_{cb}^*}\right] = \left(74.0\,^{+5.8}_{-6.4}\right)^\circ$$

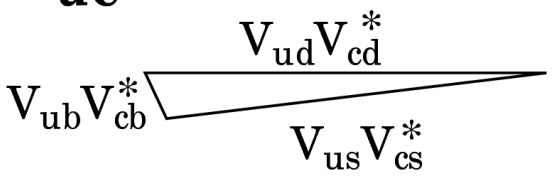
UNITARITY TRIANGLES

$$\mathbf{V_{ui}\, V_{uj}^{*} + V_{ci}\, V_{cj}^{*} + V_{ti}\, V_{tj}^{*} = 0} \qquad (i \neq j)$$

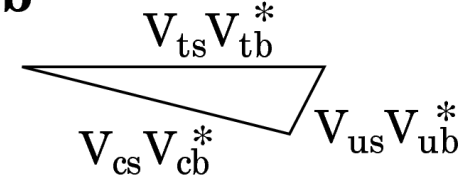
ds



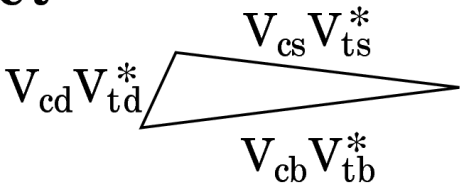
uc



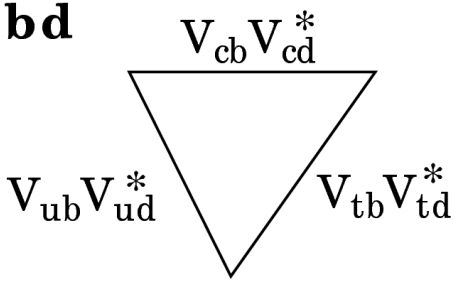
sb



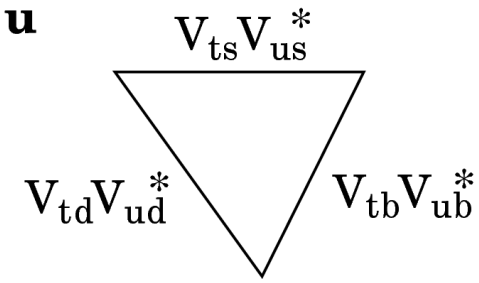
ct



bd

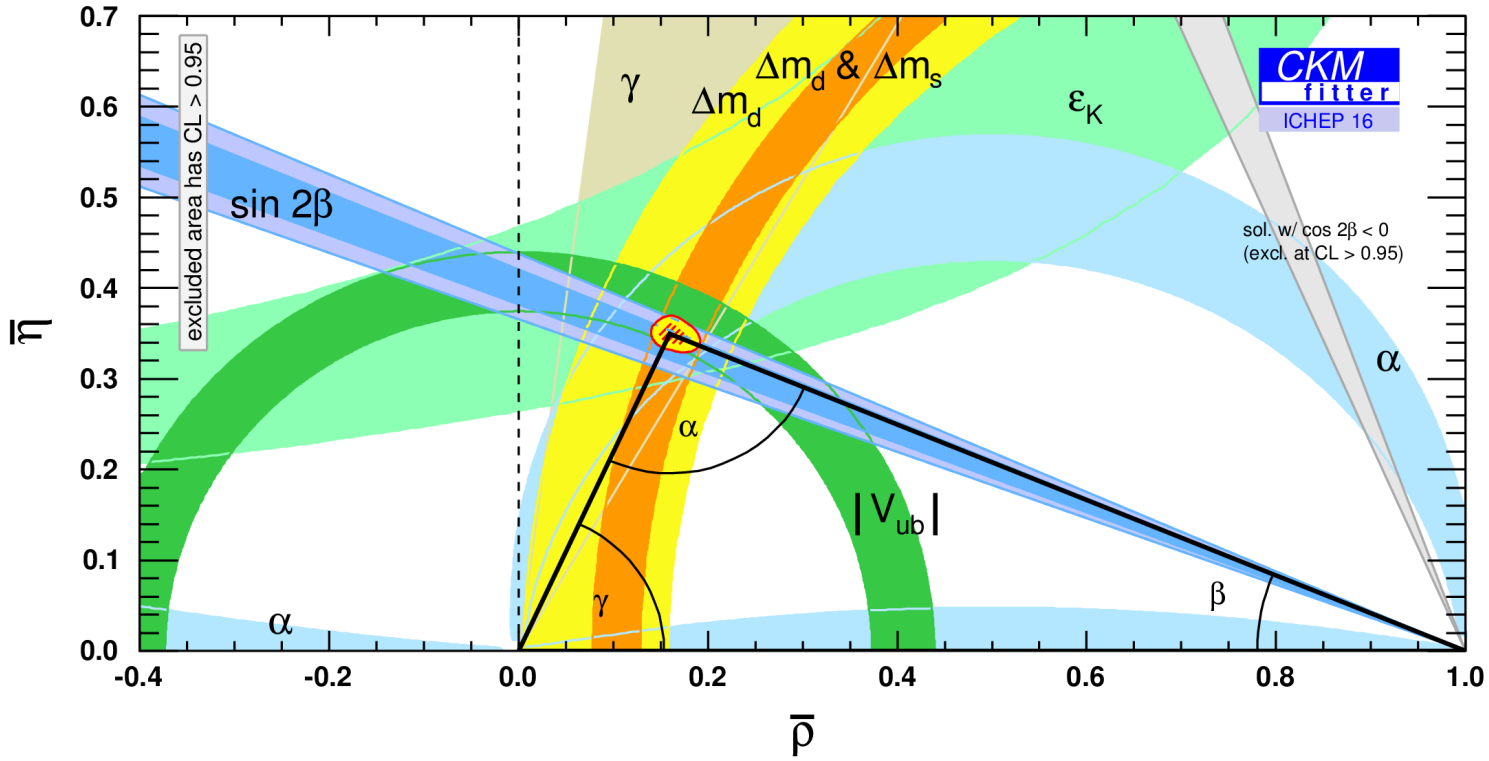


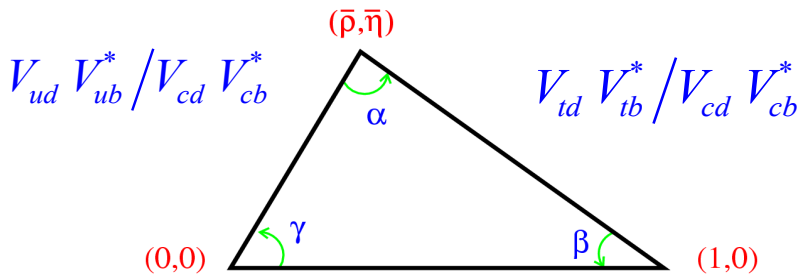
tu



$$\mathbf{V} \approx \begin{bmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{bmatrix} + \mathcal{O}\left(\lambda^4\right)$$

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





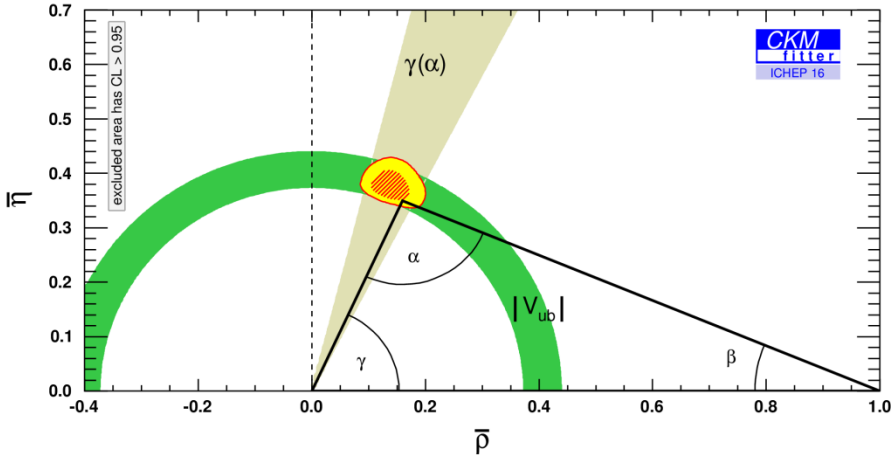
UT*fit*

$$\bar{\eta} \equiv \eta\left(1-\frac{1}{2}\lambda^2\right) = 0.343 \pm 0.011$$

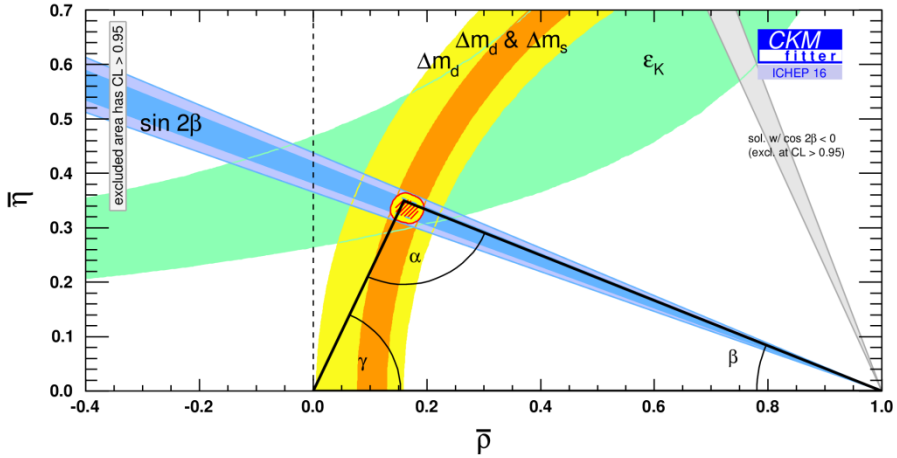
$$\bar{\rho} \equiv \rho\left(1-\frac{1}{2}\lambda^2\right) = 0.153 \pm 0.013$$

$$\alpha = 91.0 \pm 2.5^\circ \;;\; \beta = 23.2 \pm 1.2^\circ \;;\; \gamma = 65.3 \pm 2.0^\circ$$

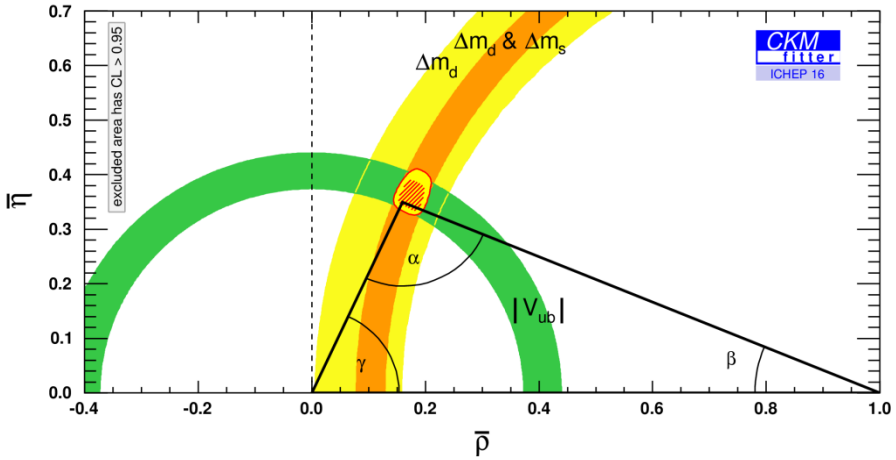
Tree-level determinations



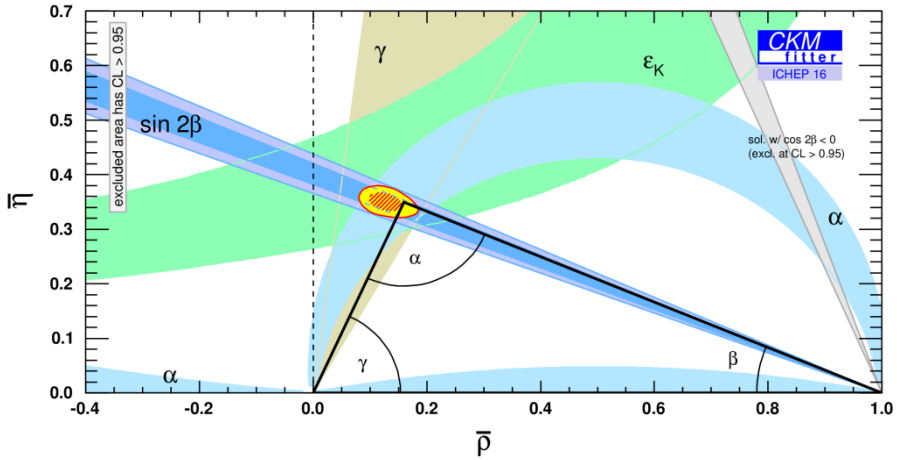
Loop processes



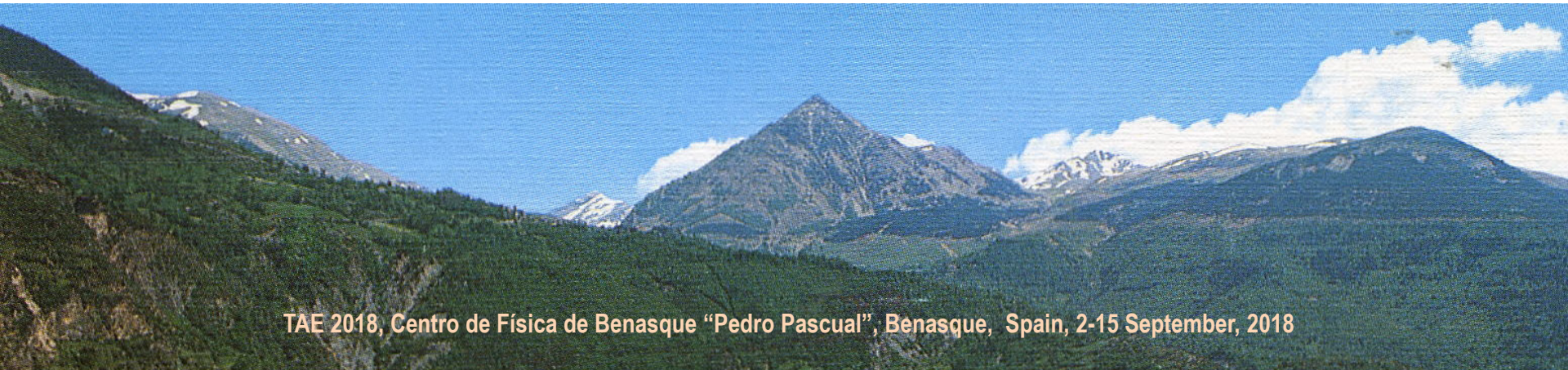
CP Conserving



CP Violating



Backup


TAE 2018, Centro de Física de Benasque “Pedro Pascual”, Benasque, Spain, 2-15 September, 2018

P^0 — $\bar{P}^0$ MIXING

Phase convention: $\mathcal{CP}\,\left|P^0\right\rangle = -\left|\bar{P}^0\right\rangle$

$$\left|\psi(t)\right\rangle = a(t)\left|P^0\right\rangle + b(t)\left|\bar{P}^0\right\rangle \qquad i\frac{d}{dt}\left|\psi(t)\right\rangle = \mathbf{M}\left|\psi(t)\right\rangle$$

$\mathcal{CPT}$: $\mathbf{M} = \begin{pmatrix} M & M_{12} \\ M_{12}^* & M \end{pmatrix} - \frac{i}{2}\begin{pmatrix} \Gamma & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma \end{pmatrix}$ $\qquad$ $\mathcal{CP}$: $M_{12} = M_{12}^*$, $\Gamma_{12} = \Gamma_{12}^*$

- **Dispersive:** $M_{12} = \frac{1}{2M}\left\{\left\langle P^0\left|H_{\Delta P=2}\right|\bar{P}^0\right\rangle + PP\int \frac{ds}{M^2-s}\sum_X dQ_X \left\langle P^0\left|H_{\Delta P=1}\right|X\right\rangle\left\langle X\left|H_{\Delta P=1}\right|\bar{P}^0\right\rangle\right\}$

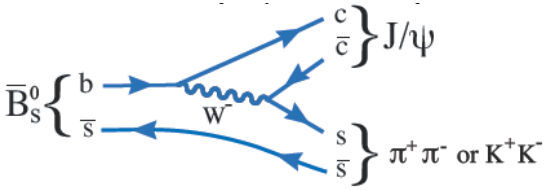
- **Absorptive:** $\Gamma_{12} = \frac{\pi}{M}\int ds \sum_X dQ_X\ \delta(s-M^2)\left\langle P^0\left|H_{\Delta P=1}\right|X\right\rangle\left\langle X\left|H_{\Delta P=1}\right|\bar{P}^0\right\rangle$

- **Eigenvalues:** $\left|P_\mp^0\right\rangle = \frac{p\left|P^0\right\rangle \mp q\left|\bar{P}^0\right\rangle}{\sqrt{|p|^2+|q|^2}}$, $\frac{q}{p} \equiv \frac{1-\bar{\varepsilon}}{1+\bar{\varepsilon}} = \left(\frac{M_{12}^* - \frac{i}{2}\Gamma_{12}^*}{M_{12} - \frac{i}{2}\Gamma_{12}}\right)^{1/2}$

$$\langle P_- | P_+\rangle = \frac{|p|^2-|q|^2}{|p|^2+|q|^2} = \frac{2\,\mathrm{Re}(\bar{\varepsilon})}{1+|\bar{\varepsilon}|^2}$$

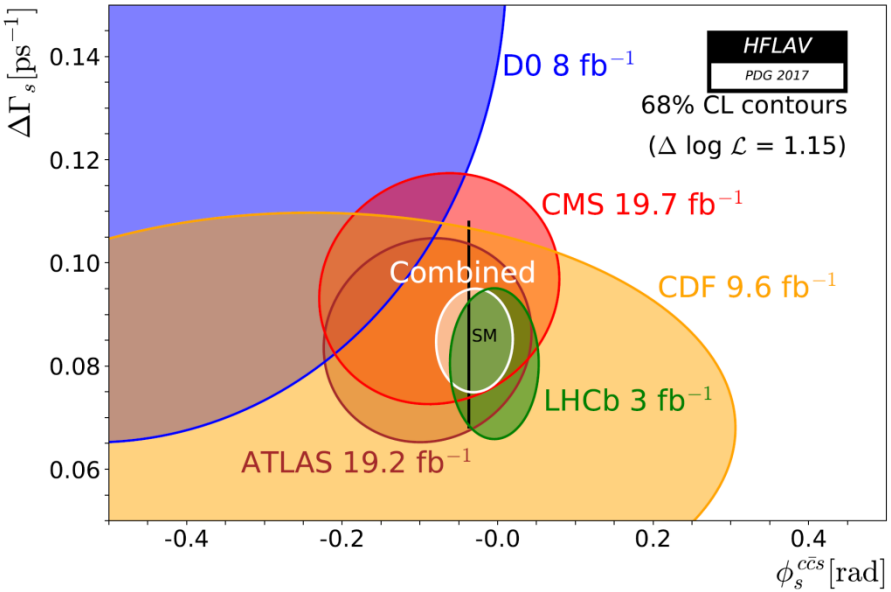
$\mathcal{CP}$ ➡ $q/p = 1$ ➡ $\left|P_{1,2}\right\rangle = \frac{1}{\sqrt{2}}\left(\left|P^0\right\rangle \mp \left|\bar{P}^0\right\rangle\right)$, $\mathcal{CP}\left|P_{1,2}\right\rangle = \pm\left|P_{1,2}\right\rangle$

B_s Asymmetries



$$\phi_s^{c\bar{c}s} \equiv 2\left(\phi_s^M + \phi_s^D\right)$$

$$\phi_s^{c\bar{c}s}\Big|_{\rm SM} \approx -2\beta_s \equiv -2\arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$

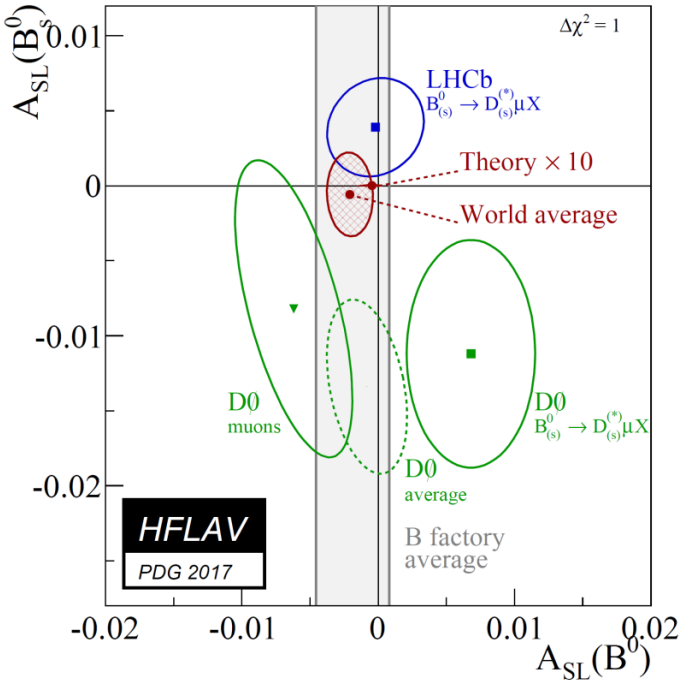


$$\Delta\Gamma_s = (0.085 \pm 0.007)\ \text{ps}^{-1} \quad , \quad \phi_s^{c\bar{c}s} = (-0.030 \pm 0.033)\ \text{rad}$$

$$A_{\rm SL}(B_q^0) \equiv \frac{\Gamma(\bar{B}_q^0 \to \ell^+ X) - \Gamma(B_q^0 \to \ell^- X)}{\Gamma(\bar{B}_q^0 \to \ell^+ X) + \Gamma(B_q^0 \to \ell^- X)} = \frac{|p|^4 - |q|^4}{|p|^4 + |q|^4}$$

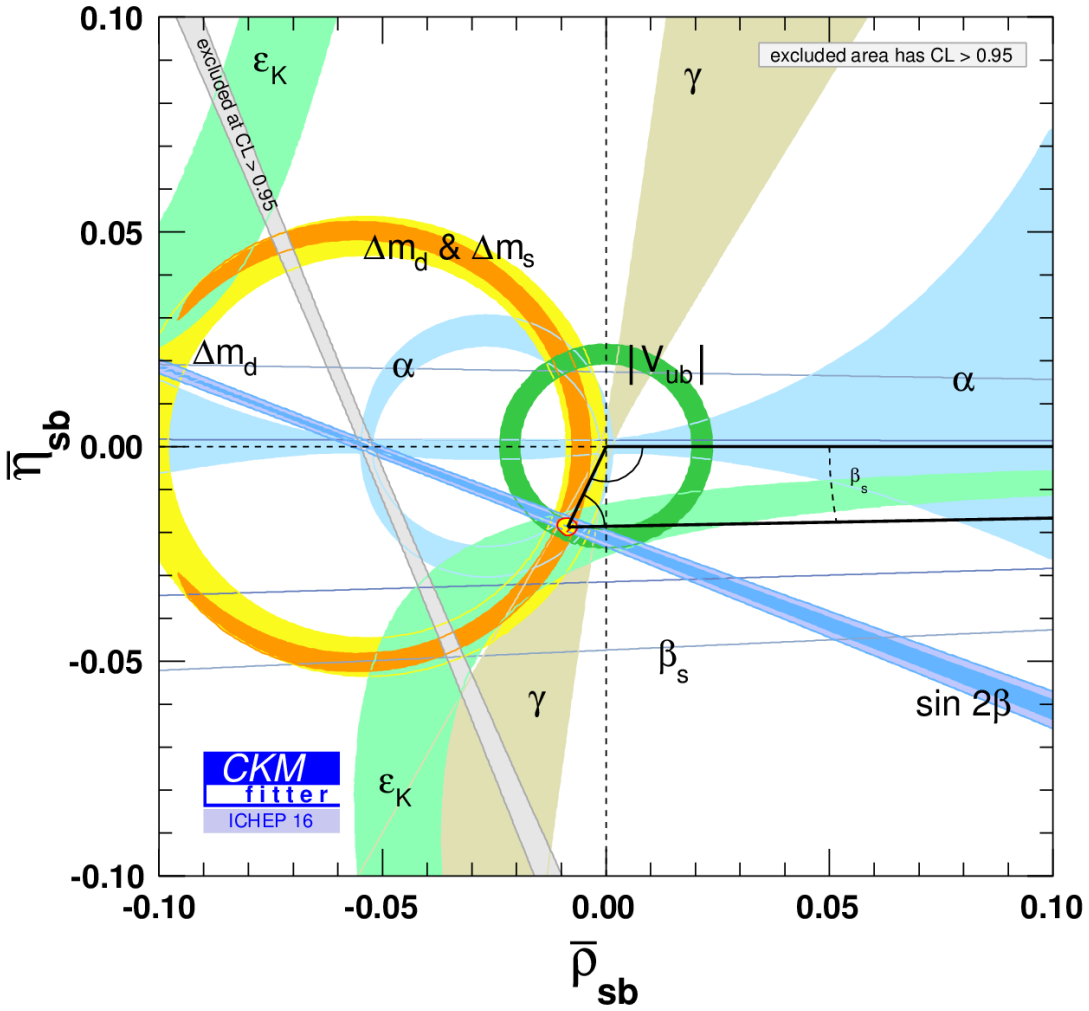
$$\approx 4\,{\rm Re}(\bar{\varepsilon}_{B_q^0}) \approx \frac{|\Gamma_{12}|}{|M_{12}|}\sin\phi_q \approx \frac{|\Delta\Gamma_{B_q^0}|}{|\Delta M_{B_q^0}|}\tan\phi_q$$

$$\phi_q \equiv \arg\left(-M_{12}^q/\Gamma_{12}^q\right) \sim \frac{m_c^2}{m_b^2}$$



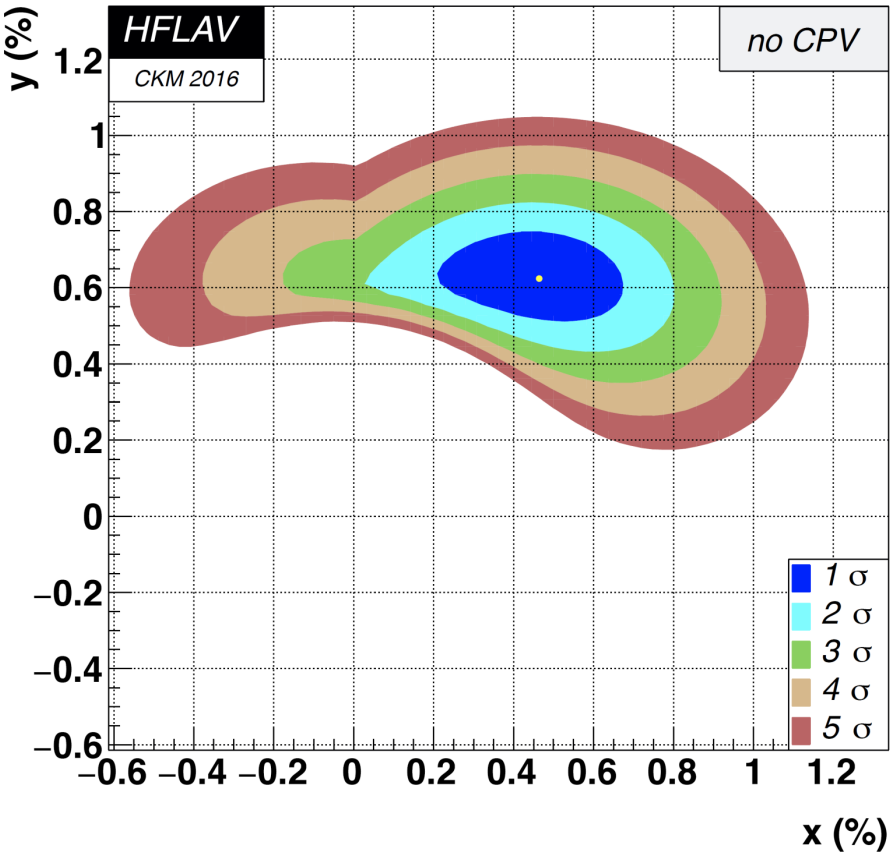
$$A_{\rm SL}(B_d^0) = -0.0021 \pm 0.0017 \quad , \quad A_{\rm SL}(B_s^0) = -0.0006 \pm 0.0028$$

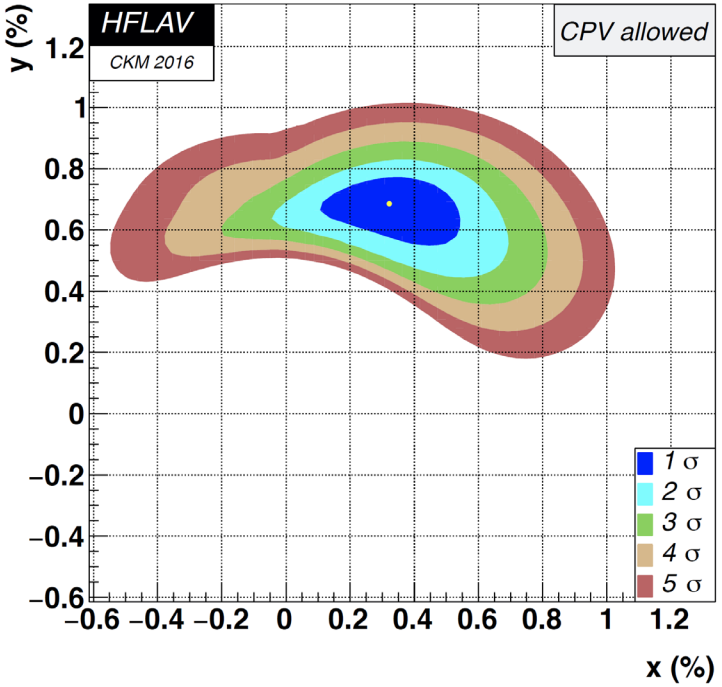
$$\underbrace{V_{us}\,V_{ub}^*}_{\lambda^4} + \underbrace{V_{cs}\,V_{cb}^*}_{\lambda^2} + \underbrace{V_{ts}\,V_{tb}^*}_{\lambda^2} = 0$$

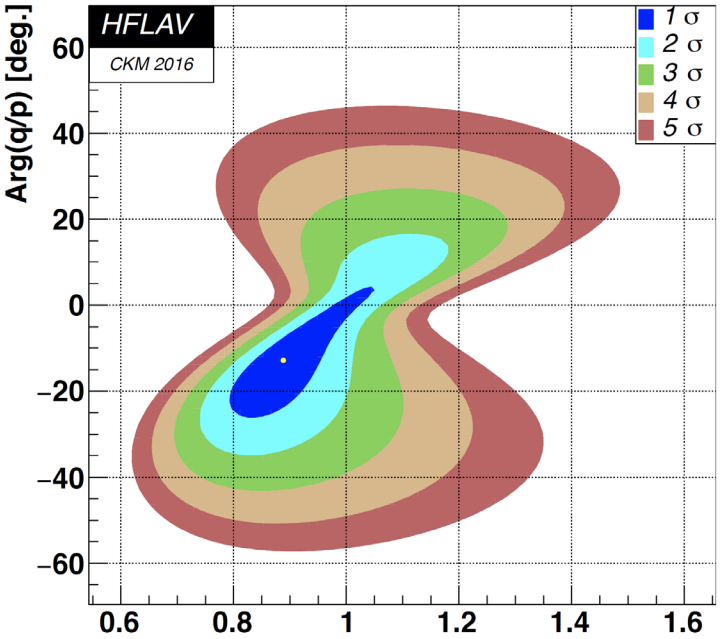


$$\bar{\rho}_{sb} + i\,\bar{\eta}_{sb} = -V_{us}\,V_{ub}^* \Big/ V_{cs}\,V_{cb}^*$$

$D^0 - \bar{D}^0$ MIXING



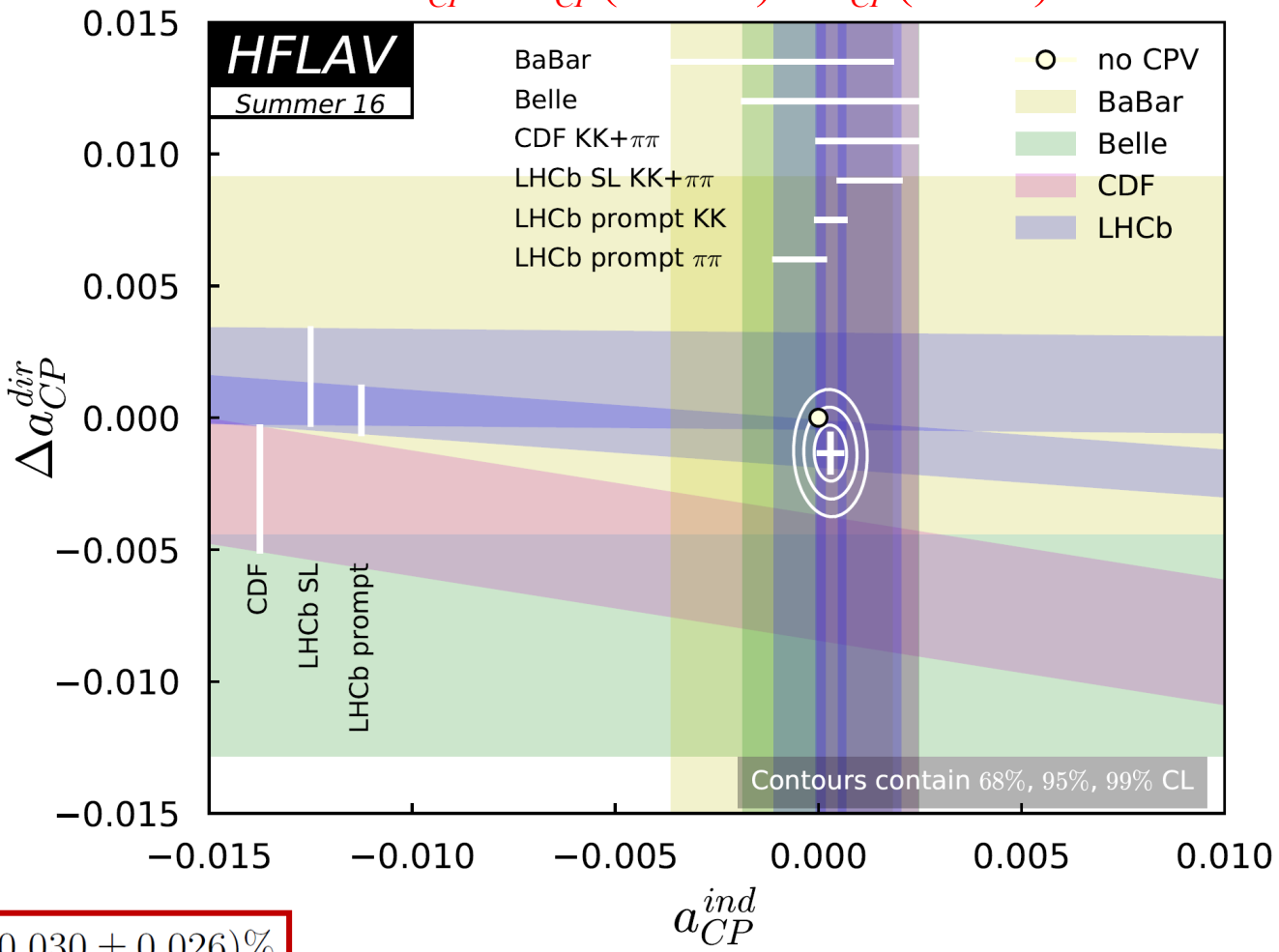




$$x \equiv -\frac{\Delta M}{\Gamma} \quad , \quad y \equiv -\frac{\Delta \Gamma}{2\Gamma}$$

$D^0 - \bar{D}^0$ MIXING: No evidence of $\not{CP}$

$$\Delta a_{CP} = a_{CP}(K^+K^-) - a_{CP}(\pi^+\pi^-)$$



$$a_{CP}^{\rm ind} = (+0.030 \pm 0.026)\%$$
$$\Delta a_{CP}^{\rm dir} = (-0.134 \pm 0.070)\%$$