

Discussion session: CP violation in the B System

1) CPV in B mixing

$$a_{fs}^s = \frac{\Gamma(\bar{B}_s^0(t) \rightarrow f) - \Gamma(B_s^0(t) \rightarrow \bar{f})}{\Gamma(\bar{B}_s^0(t) \rightarrow f) + \Gamma(B_s^0(t) \rightarrow \bar{f})} \equiv a_{sl}^s .$$

$$= \Im \left(\frac{\Gamma_{12}^s}{M_{12}^s} \right) = \left| \frac{\Gamma_{12}^s}{M_{12}^s} \right| \sin \phi_{12}^s .$$

with
$$\phi_{12}^s := \arg \left(-\frac{M_{12}^s}{\Gamma_{12}^s} \right) = \pi + \phi_M - \phi_\Gamma .$$

Is there an indirect bound on the semi-leptonic CP asymmetry a_{sl}^s , that is considerably stronger than the direct experimental bound? This was claimed by Fleischer, Vos in 1606.06042v1 and to a lesser extent in v2

$$a_{sl}^s = \begin{cases} (2.22 \pm 0.27) \cdot 10^{-5} & \text{SM} \\ (170 \pm 300) \cdot 10^{-5} & \text{Exp} \\ (14 \pm 18) \cdot 10^{-5} & 1606.06042v1 \\ (4 \pm 75) \cdot 10^{-5} & 1606.06042v2 \end{cases}$$

FV consider only the cc contribution. Possible failures:

- Bs to J/Psi Phi, Ds+ Ds-, ... do not saturate Delta Gamma_s.
- uc and uu are missing, this is important for a_{sl}^s !
- Are there any experimental bounds on Bs to invisible, which might contribute to Delta Gamma_s? Similar to Bs to tau tau.

2) CPV in interference

$$\mathcal{A}_{\text{CP}}^{\text{mix}} = -\frac{2|\lambda_f|}{1+|\lambda_f|^2} \sin[\arg(\lambda_f)] = +\frac{2|\lambda_f|}{1+|\lambda_f|^2} \sin[\phi_s] , \quad (143)$$

$$\mathcal{A}_{\Delta\Gamma} = -\frac{2|\lambda_f|}{1+|\lambda_f|^2} \cos[\arg(\lambda_f)] = -\frac{2|\lambda_f|}{1+|\lambda_f|^2} \cos[\phi_s] , \quad (144)$$

With

$$\mathcal{A}_f = \langle f | \mathcal{H}_{eff} | B_s^0 \rangle , \quad \bar{\mathcal{A}}_f = \langle f | \mathcal{H}_{eff} | \bar{B}_s^0 \rangle .$$

$$\lambda_f = \frac{q}{p} \frac{\bar{\mathcal{A}}_f}{\mathcal{A}_f}$$

In the case of only one CKM structure

$$A_{CP,f}(t) \approx \frac{\sin \phi_s \sin(\Delta M_s t)}{\cos \phi_s \sinh(\frac{\Delta\Gamma_s t}{2}) - \cosh(\frac{\Delta\Gamma_s t}{2})} .$$

$$\phi_s = -2\beta_s ,$$

$$\begin{aligned} \beta_s &= -\arg \left[-\frac{V_{ts}^* V_{tb}}{V_{cs}^* V_{cb}} \right] \\ &= 0.0183 \pm 0.0010 = (1.05 \pm 0.05)^\circ \end{aligned}$$

Be aware of any assumptions, that might not be justified anymore due to the high experimental precisions. Penguin pollution?

3) direct CPV

$$A_{\text{dir.CP},f}(t) = \frac{\Gamma(\bar{B}_s^0(t) \rightarrow \bar{f}) - \Gamma(B_s^0(t) \rightarrow f)}{\Gamma(\bar{B}_s^0(t) \rightarrow \bar{f}) + \Gamma(B_s^0(t) \rightarrow f)},$$

Status of the B to K pi puzzle: Tobias Huber,
Christoph Bobeth, Martin Beneke

- Rough pattern of size of CP violating effects reproduced by QCD factorisation.
- Create combinations, where unknown 1/m² corrections might cancel to a large extent: delta, Delta
- But B to K pi puzzle still present, despite NNLO-QCD corrections

Not discussed:

- multi-body decays - are discussed on Thursday
- CP asym in all kinds of "b to Xgamma" - afternoon talk

Comments added by B. Golob:

Few experimental questions were raised during the discussion:

- are there results on $B_{(s)}$ -> invisible decays?

There are few, the ones from Belle (that I'm aware of) are

a) $B^+ \rightarrow e^+ (\mu^+) X^0$,

X^0 is invisible;

arXiv:1605.04430 by Belle; UL on the Br depends on the mass of X^0 , typically below $(3-4) \times 10^{-6}$ for $M_{X^0} < 1.4 \text{ GeV}/c^2$.

b) $B \rightarrow$ invisible,

arXiv:1206.5948 by Belle; UL on $Br(B \rightarrow$ invisible) is 1.3×10^{-4} @ 90% C.L.

c) there's an ongoing study on $D^0 \rightarrow$ invisible, expected UL on Br is in the range 10^{-4} .

- what is the situation with Belle new result on $B^0 \rightarrow \pi^0 \pi^0$?

The preliminary results has been shown long ago (CKM 2014); it was realized that the selection of events needs to be revised and the central value will change to some extent. The final result is close to publication.

- comment received: in various modes where TCPV is measured it would be appreciated by the theory community if individual S and C terms are quoted for each mode individually; moreover, even if there are strong indications that for example $C=0$ in particular mode it would be appreciated if fits with C as a free parameter are also performed.