Theoretical uncertainty in B->J/ψ K

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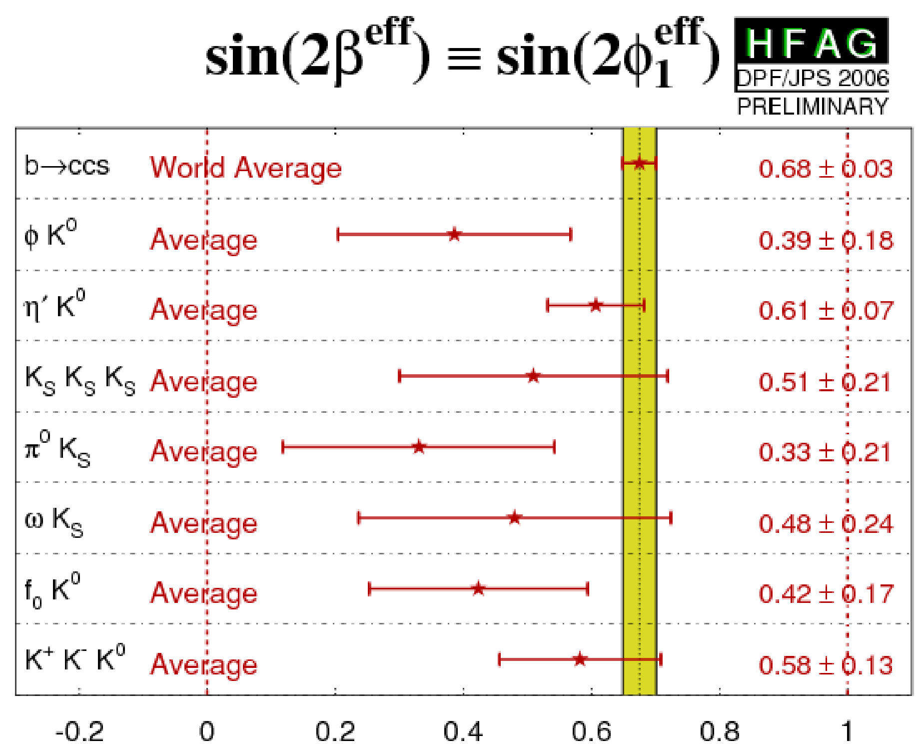
The time-dependent CP asymmetry in the golden mode B -> J/ψ K gives sin 2β with negligible theoretical uncertainty: how negligible?

I discuss a data-driven method to estimate the theoretical uncertainty in sin 2β extracted from $a_{CP}(t)$ in B -> J/ψ K



MC, Pierini, Silvestrini, hep-ph/0507290 notation from Buras, Silvestrini, hep-ph/9812392

$$A(B^0 \to J/\psi K^0) = \overset{\lambda^2}{V^*_{cb} V_{cs}} (\underbrace{E_2 + P_2}_{T}) - \overset{\lambda^4}{V^*_{ub} V_{us}} (\underbrace{P_2^{GIM} - P_2}_{P})$$

In $B^0 \to J/\psi K^0$:

- T is not only tree, but the c-penguin P_2 has the same weak phase as the emission parameter E_2

  may affect the BR, not the extraction of $\sin 2\beta$

- the "penguin pollution" P is doubly Cabibbo suppressed w.r.t. the main amplitude T
- the "polluting" amplitude $P = P_2^{GIM} - P_2$ is a pure u-penguin

  naïve estimate: $V_{cb}^* V_{cs} P / V_{ub}^* V_{us} T \sim \lambda^2 \alpha(m_b)/4\pi \sim 10^{-3}$

How large is really P? Can we bound it using the data?

$BR(B^0 \to J/\psi K^0)$ is not sensitive to P

Getting a little help from a friend:

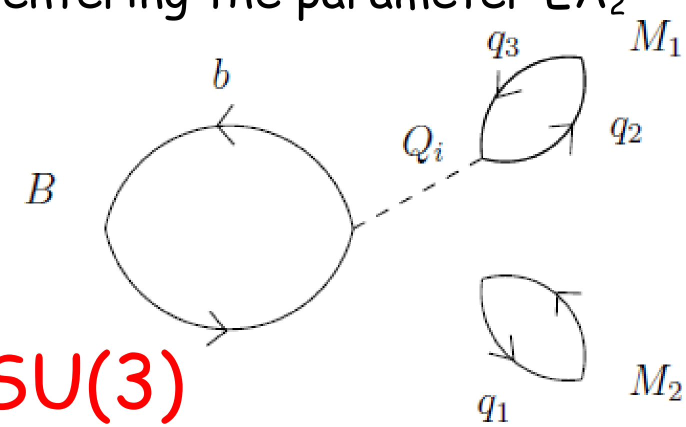
$$A(B^0 \to J/\psi\pi^0) = \overset{\lambda^2}{V^*_{cb} V_{cd}} \underbrace{(E_2 + P_2)}_{T} - \overset{\lambda^2}{V^*_{ub} V_{ud}} \underbrace{(P_2^{\rm GIM} - P_2 - EA_2)}_{P}$$

In $B^0 \to J/\psi\ \pi^0$:

- the amplitudes T and P has similar flavour couplings
  can be fitted from the data on BR, S, C

- T and P are the same amplitudes entering $B^0 \to J/\psi\ K^0$ in the limit of exact flavour SU(3) symmetry as long as EA_2 can be neglected

example of Wick contraction entering the parameter EA_2



Strategy:

1. fix the *range* of |P| from $J/\psi\ \pi^0$
2. use it to evaluate ΔS in $J/\psi\ K^0$

range instead of value: weaker use of SU(3) amps in units of factorized E_2

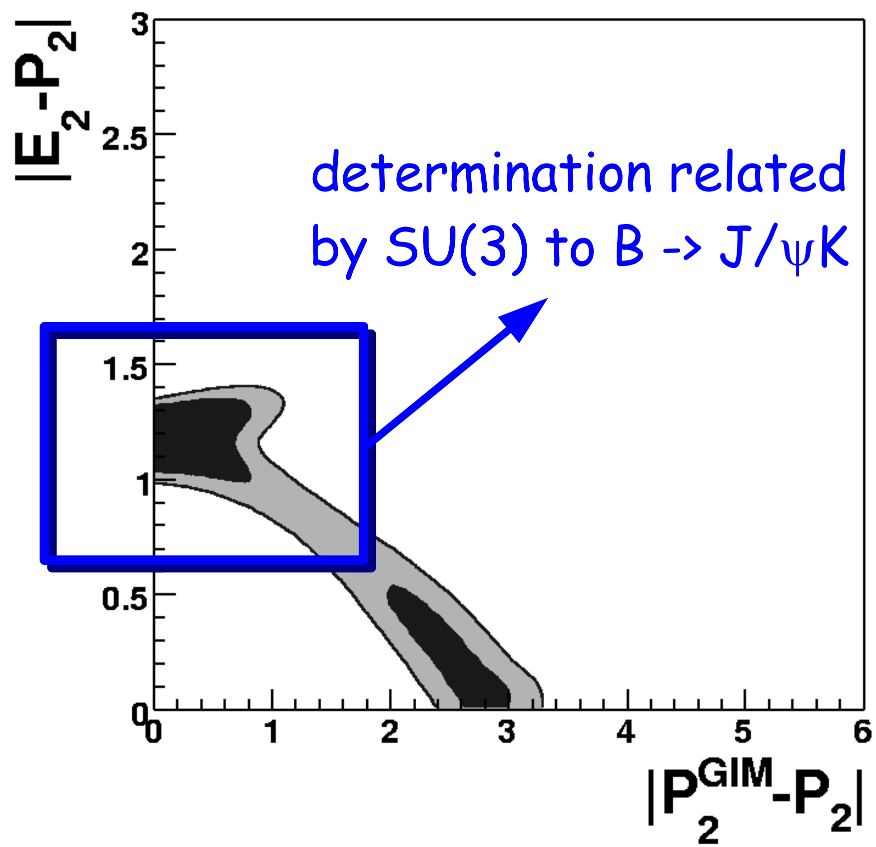
From $B^0 \to J/\psi\, K^0$:

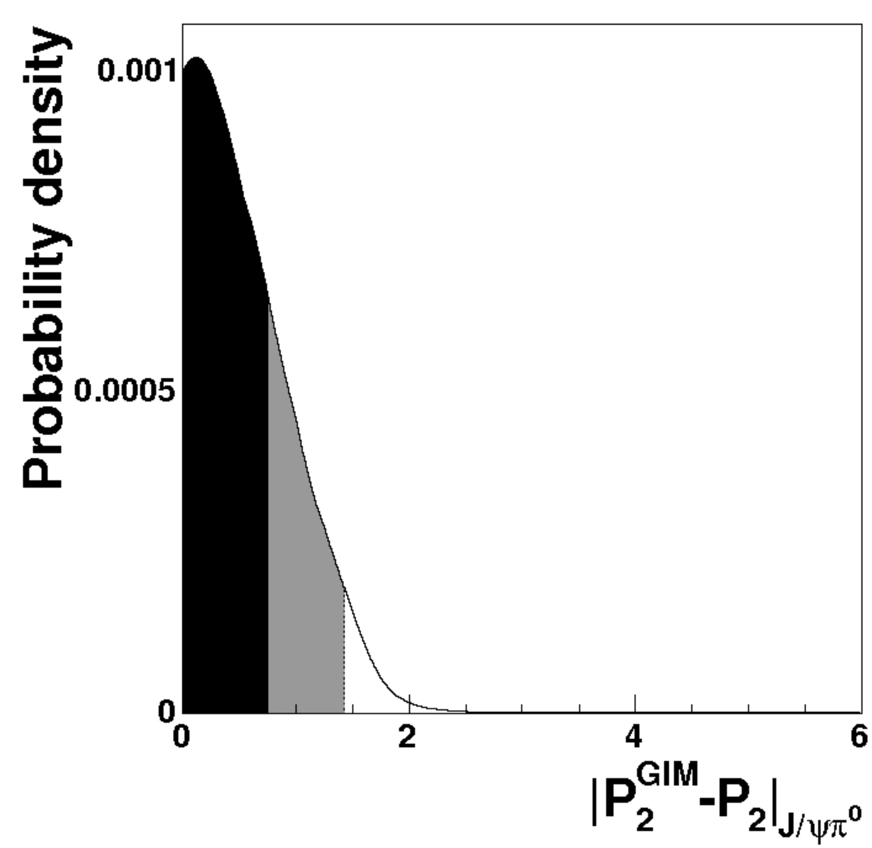
$$|E_2+P_2|=1.46\pm0.04$$

no evidence of large SU(3) breaking

From $B^0 \to J/\psi\, \pi^0$:

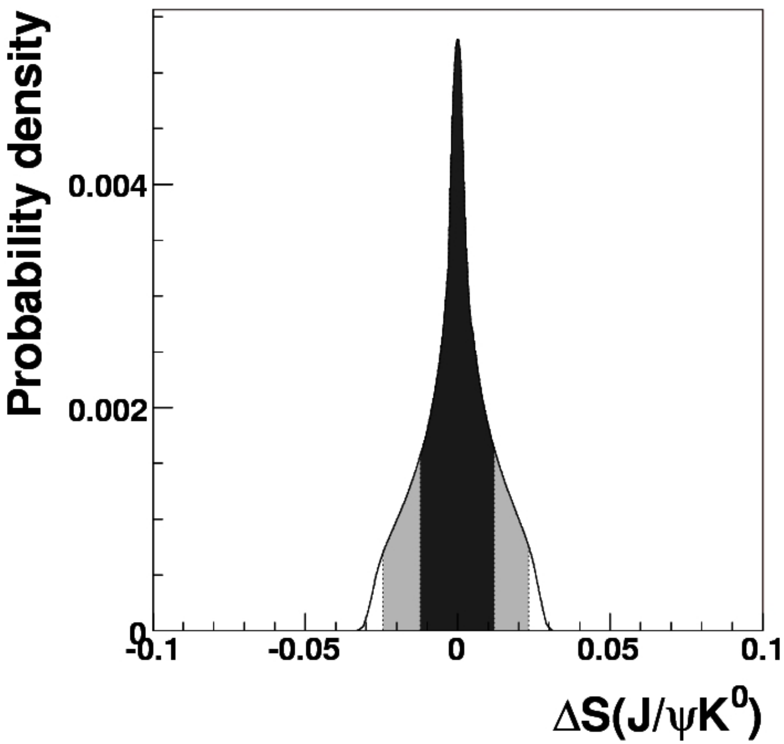
$\mathrm{BR}^{\mathrm{th}}\times10^5$	2.2 ± 0.4	$\mathrm{BR}^{\mathrm{exp}}\times10^5$	2.2 ± 0.4	$\mathcal{C}_{CP}^{\mathrm{th}}$	0.09 ± 0.19
$\mathcal{C}_{CP}^{\mathrm{exp}}$	0.12 ± 0.24	$\mathcal{S}_{CP}^{\mathrm{th}}$	-0.47 ± 0.30	$\mathcal{S}_{CP}^{\mathrm{exp}}$	-0.40 ± 0.33
$\lvert E_2-P_2\rvert$	$\begin{cases}1.22\pm0.15\\0.15\pm0.15\end{cases}$	$\lvert P_2^{\mathrm{GIM}}-P_2\rvert$	$\begin{cases}0.43\pm0.43\\2.87\pm0.43\end{cases}$	δ_P	$\begin{cases}(-24\pm41)^\circ\\(-146\pm50)^\circ\end{cases}$





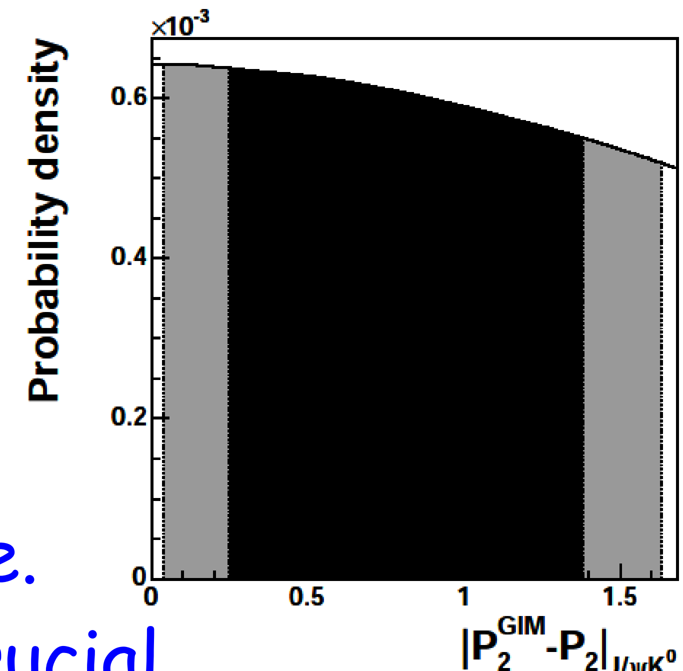
Using this info in the $B^0 \to J/\psi\, K^0$ fit :

$\mathcal{BR}^{th}[10^{-4}]$	8.61 ± 0.35	$\mathcal{BR}^{exp}[10^{-4}]$	8.63 ± 0.35
C_{CP}^{th}	0.00 ± 0.015	C_{CP}^{exp}	0.001 ± 0.031
S_{CP}^{out}	0.759 ± 0.040	S_{CP}^{in}	0.759 ± 0.037
$\lvert E_2 - P_2 \rvert$	1.465 ± 0.035		



$\Delta S(J/\psi\, K^0) = \sin 2\beta_{eff} - \sin 2\beta$
$= 0.000 \pm 0.012$

not far from the present systematic exp. error



The input from $B^0 \to J/\psi\, \pi^0$ i.e. $|P| < 1.7$ (99% probability) is crucial

Looking into the future

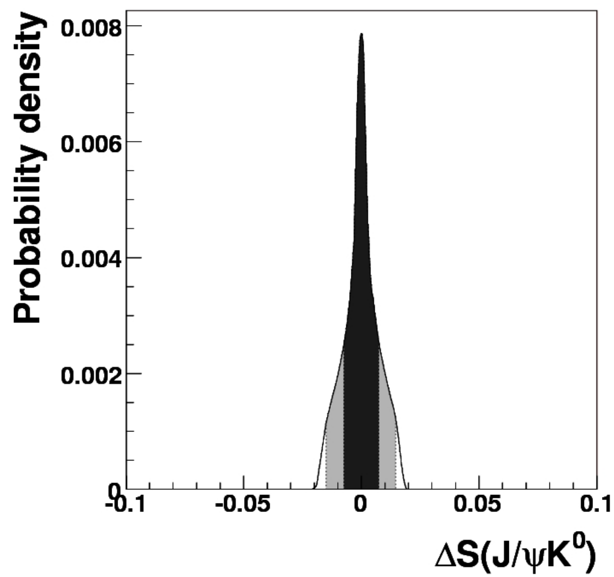
2 ab^{-1} scenario:

$\sigma(S) = 0.08$, $\sigma(C) = 0.08$ } Scaled statistical error; Systematic from $J/\psi\, K^0$

$\sigma(A_{CP}) = 0.032$ } Scaled statistical error; Systematic = smallest now

For BR
same than now (systematic dominated)

$\Delta S = 0.000 \pm 0.007$



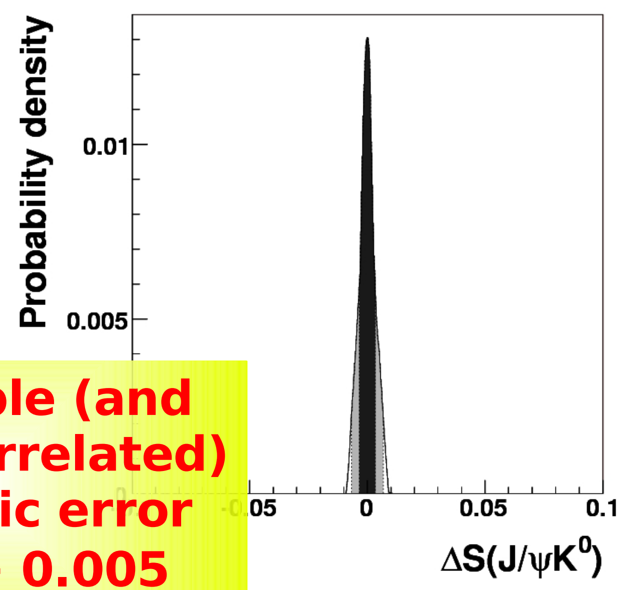
30 ab^{-1} scenario:

$\sigma(S) = 0.024$, $\sigma(C) = 0.030$ } Scaled statistical error; Systematic from $J/\psi\, K^0$

$\sigma(A_{CP}) = 0.011$ } Scaled statistical error; Systematic = smallest now

For BR
same than now (systematic dominated)

$\Delta S = 0.000 \pm 0.003$



irreducible (and largely correlated) systematic error $\sigma^{sys}(S) > 0.005$

thanks to M. Pierini

Conclusions

The theoretical uncertainty of sin 2β extracted from the time-dependent CP asymmetry in $B \to J/\psi\, K$ can be estimated using data on $B \to J/\psi\, \pi$

The theoretical assumptions behind the method are:

1. EA_2 is negligible – true in any model and testable to some extent measuring $BR(B^0 \to \phi\, D^0)$
2. SU(3) symmetry gives reasonable estimates of the range of variation of related parameters

The accuracy of the method improves with the data on $B \to J/\psi\, \pi$. The th. error can be kept smaller than the foreseen exp. systematic error on sin 2β from $B \to J/\psi\, K$

Inputs

$F(B \to \pi) = 0.27 \pm 0.08$

$F(B \to K)/F(B \to \pi) = 1.2 \pm 0.1$

$f_{J/\psi} = 405$ MeV

$m_B = 5.2794$ GeV

CKM from UTfit w/o $\sin 2\beta$