Time-dependent CP violation measurements in B^0 to charm and charmonium modes

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Outline

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- B to Double charm decays
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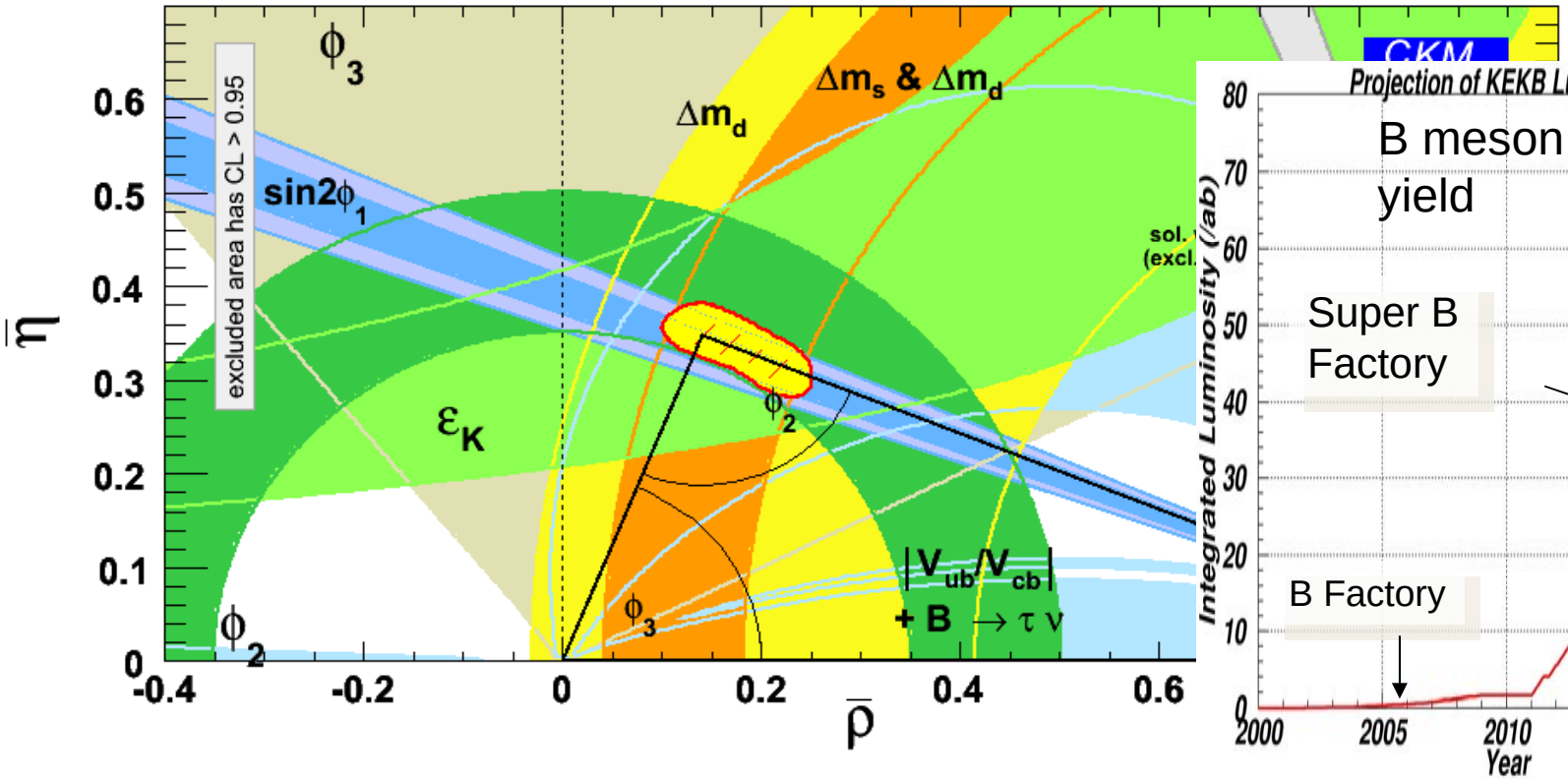
- Summary

Introduction

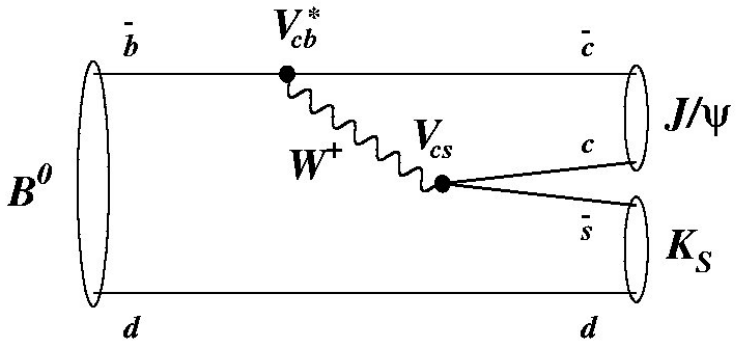


- SM perfectly works at the moment
- Even if there is a discrepancy, it is very small
- Precise measurements are needed to search for New Physics contribution

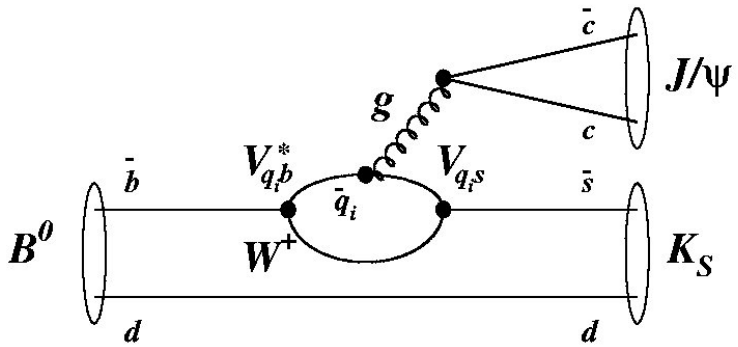
B to charmonium

- B^0 meson decays to charmonium via b->c c-bar q transition, which provides $\sin(2\varphi_1)$ measurement:

$$\lambda_{J/\psi K_S} = \eta_{J/\psi K_S}\left(\frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*}\right)\left(\frac{V_{cb}^* V_{cs}}{V_{cb} V_{cs}^*}\right)\left(\frac{V_{cs}^* V_{cd}}{V_{cs} V_{cd}^*}\right) = -\left(\frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*}\right)\left(\frac{V_{cb}^* V_{cd}}{V_{cb} V_{cd}^*}\right) \Rightarrow \Im m(\lambda_{J/\psi K_S}) = \sin 2\phi_1$$



tree



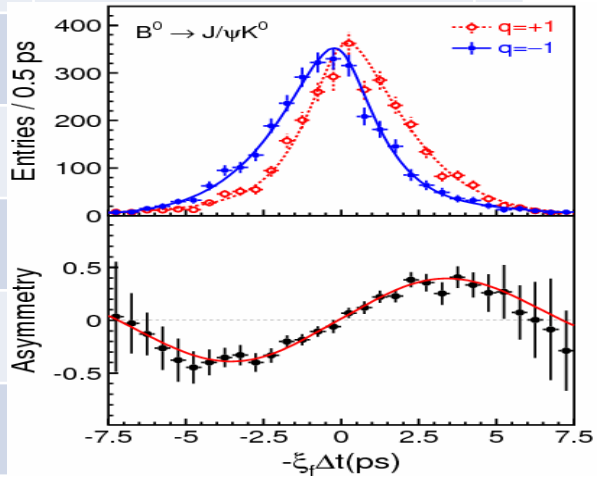
penguin

B to charmonium (cont'd)

- Pair c c-bar can form several charmonium states, like J/ψ, $\psi(2S)$, χ_{c0}, χ_{c1}, χ_{c2}, η_{c}...
- From reconstruction point of view J/ψ is the most effective one and has the smallest theoretical uncertainty
- But with higher statistics also less effective modes can be measured

"Golden mode" & K^0

Mode	Current $\sin(2\varphi_1)$	Error on 10 ab^{-1}	Error on 50 ab^{-1}
$J/\psi\ K^0$	$+0.642\pm0.036\pm0.0$	$\pm0.008\pm0.012$	$\pm0.004\pm0.012$
$J/\psi\ K^{*0}$	$+0.24\pm0.31\pm0.05$	$\pm0.07\pm0.04$	$\pm0.03\pm0.04$
$J/\psi\ \pi^0$	$-0.65\pm0.21\pm0.05$	$\pm0.05\pm0.04$	$\pm0.02\pm0.04$
$J/\psi\ \varphi$	N(657M)=5±3	76 events	380 events
$\Psi(2S)$	$+0.72\pm0.09\pm0.03$	$\pm0.02\pm0.02$	
χ_{c0}	$\varepsilon = \varepsilon(J/\psi)/10$		
χ_{c1}	$\varepsilon = \varepsilon(J/\psi)/4$	~2 x error (J/ψ)	
χ_{c2}	$\varepsilon = \varepsilon(J/\psi)/8$		
η_c	$\varepsilon = \varepsilon(J/\psi)/10$	~3 x error (J/ψ)	



- For the "golden mode" errors will be systematics dominated
- Only part of the systematical error is statistically dependent and so can be reduced
- The main systematics comes from the vertex reconstruction

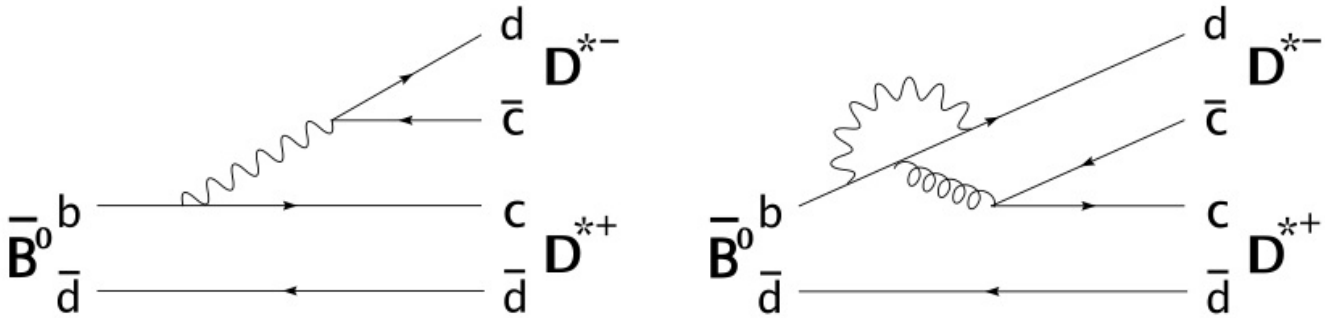
B -> Double Charm

- The main decay modes are:
  - $B^0 \to D^+ D^-$
  - $B^0 \to D^{*+-} D^{-+}$
  - $B^0 \to D^{*+} D^{*-}$
  - $B^0 \to D^{*+} D^{*-} K_S$
- As well as in B to charmonium

  $B \to D^{(*)+} D^{(*)-}$ occurs via b->c c-bar d
- The same matrix elements are involved, which rises CP asymmetry ~ $\sin(2\varphi_1)$

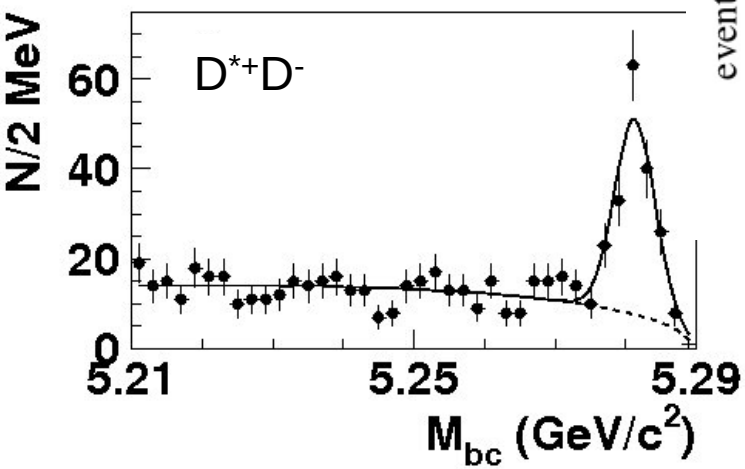
B -> Double Charm

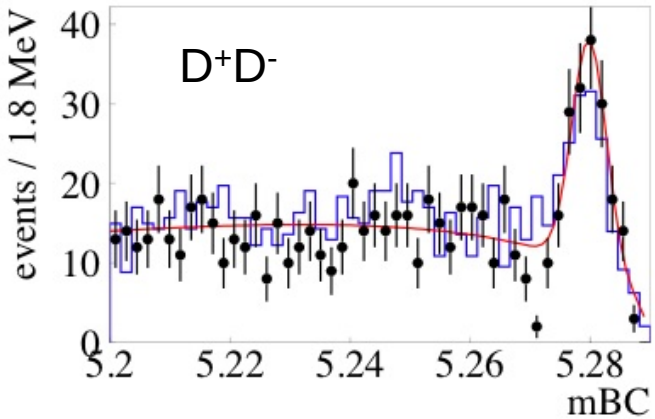
- The dominant contribution is due to tree diagram
- Unlike "golden modes" penguin contribution is due to b -> d loop. Even in SM its phase is different from tree one. Small DCPV is expected and small difference in ICPV phase is possible.
- If NP contributes to b->d penguin additional discrepancy with "golden modes" can be observed. It is challenge how to distinguish NP from QCD uncertainties in SM penguin calculation.

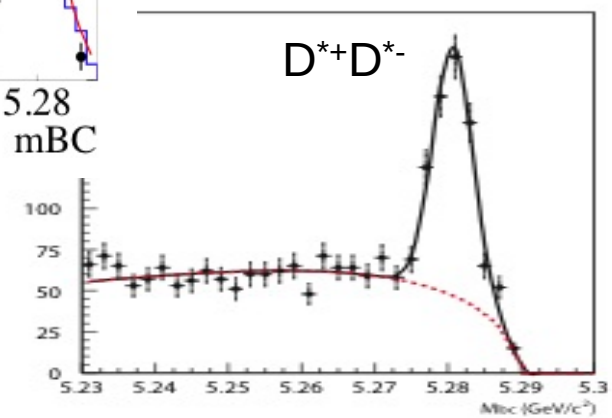


Current measurements

- On the current Belle statistics pure signals are observed in all of the decay modes and CPV measurements are performed: about 3 sigma CPV in each of the decays
- No significant discrepancy with SM is observed
- ~3 sigma DCPV effect is seen in B^0 -> D^+ D^- channel







Expected errors on SuperKEKB

	Used	S value	Error on 10	On 50 ab^{-1}
$B^0 \to D^+ D^-$	535M	-	$\pm 0.07 \pm 0.05$	$\pm 0.03 \pm 0.05$
$B^0 \to D^{*+-} D^{-+}$	152M	$-0.55 \pm 0.39 \pm 0.$	$\pm 0.05 \pm 0.05$	$\pm 0.02 \pm 0.05$
$B^0 \to D^{*+} D^{*-}$	657M	-	$\pm 0.06 \pm 0.07$	$\pm 0.03 \pm 0.07$
$B^0 \to D^{*+} D^{*-} K_S$	449M	$+0.06 \pm 0.45 \pm 0.06$	$\pm 0.10 \pm 0.05$	$\pm 0.04 \pm 0.05$

- Final precision is comparable with current precision from the "Golden mode"
- Statistical error expected to be of the same order as systematical

Summary

- For the most precise and important measurement B^0 -> J/ψ K_S, which is used as a reference point, the error will be dominated by systematics
- In most of the decay modes CPV could be measured with the same precision as current "golden mode" one
- B to Double Charm can examine NP in b->d penguins