Univerza v Ljubljani

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Flavour Physics at B-factories and Hadron Colliders

Part 8: angle $\phi_3(\gamma)$

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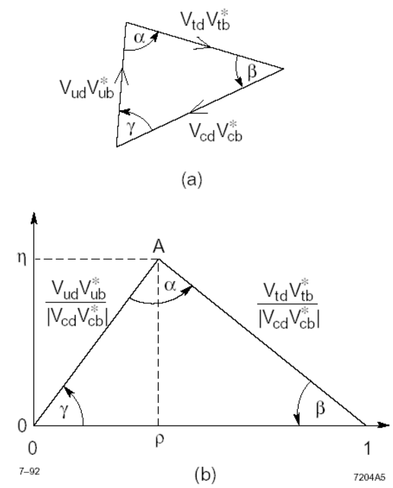
How to measure ϕ_3?

No easy (=tree dominated) channel to measure ϕ_3 through CP violation.

Any other idea? Yes.

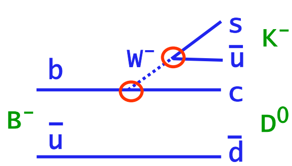


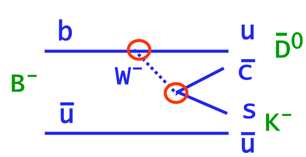
$$\gamma \equiv \phi_3 \equiv \arg\left(\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$

ϕ_3 from interference of a direct and colour suppressed decay

Basic idea: use $B^-\to K^-D^0$ and $B^-\to K^-\bar{D}^0$ with $D^0,\bar{D}^0\to f$
interference $\leftrightarrow$ ϕ_3

f: any final state, common to decays of both D^0 and $\bar{D}^0$





$T \sim V_{cb}^*V_{us} \sim A\lambda^3$ $T_c \sim V_{ub}^*V_{cs} \sim A\lambda^3\ (\rho+i\eta)$

$(\rho+i\eta) \sim e^{i\phi_3}$

ϕ_3 from interference of a direct and colour suppressed decay

Gronau,London,Wyler, 1991: $B^- \to K^- D^0_{CP}$
Atwood,Dunietz,Soni, 2001: $B^- \to K^- D^{0(*)}[K^+\pi^-]$
Belle;Giri,Zupan et al., 2003: $B^- \to K^- D^{0(*)}[K_s\pi^+\pi^-]$
Dalitz plot

or any other common 3-body decay

Density of the Dalitz plot depends on ϕ_3

Matrix element:

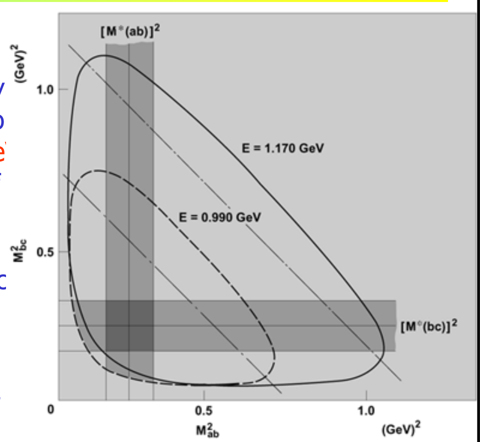
$$M_+ = f(m_+^2, m_-^2) + re^{i\phi_3+i\delta} f(m_-^2, m_+^2),$$

Sensitivity depends on

$$r = \sqrt{\frac{Br(B^- \to \overline{D}^{(*)0} K^-)}{Br(B^- \to D^{(*)0} K^-)}} \approx 0.1 - 0.3$$

What is a Dalitz plot?

Example: three body decay X->abc. M_{ij} denotes the invariant mass of the two-particle system (*ij*) in a three body decay. Kinematic boundaries: drawn fo equal masses $m_a = m_b = m_c = 0.14$ Ge and for two values of total energy *E* of the three-pion system. Resonance bands: drawn for states (*ab*) and (*bc*) corresponding to a (fictitious) resonanc with M=0.5 GeV and Γ=0.2 GeV; dot-dash lines show the locations a (*ca*) resonance band would have for this mass of 0.5 GeV, for the two values of the total energy *E*.



The pattern becomes much more complicated, if the resonances interfere.

Richard H. Dalitz, "Dalitz plot", in AccessScience@McGraw-Hill, http://www.accessscience.com.

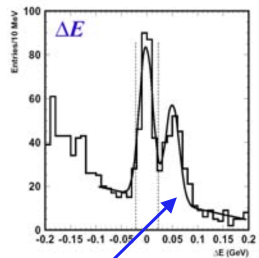
ϕ_3 from interference of a direct and colour suppressed decay

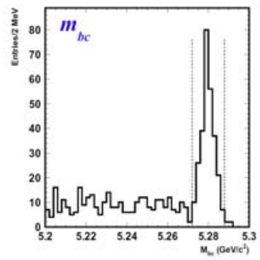
Reconstruct $B^- \to D^0 K^-$ decays.

$B^\pm \to D^0 K^\pm$
$D^0 \to K_s \pi^+ \pi^-$

253 fb^{-1}

$B^\pm \to D^0 K^\pm$:
$N = 209 \pm 16$
75% pure





$B^\pm \to D^0 \pi^\pm$ miss-id

ΔE M_{bc}

Use continuum D^0 from $D^{*-} \to D^0\pi^-$, $D^0 \to K_s\pi^+\pi^-$ decay to model Dalitz plot density.

ϕ_3 from interference of a direct and colour suppressed decay

Use D^0 decays from $D^{*-} \to D^0\pi^-$, $D^0 \to K_s\pi^+\pi^-$ decay to model Dalitz plot density in two variables:
$m^2(K_s\pi^+)=m_+^2$ and
$m^2(K_s\pi^-)=m_-^2$

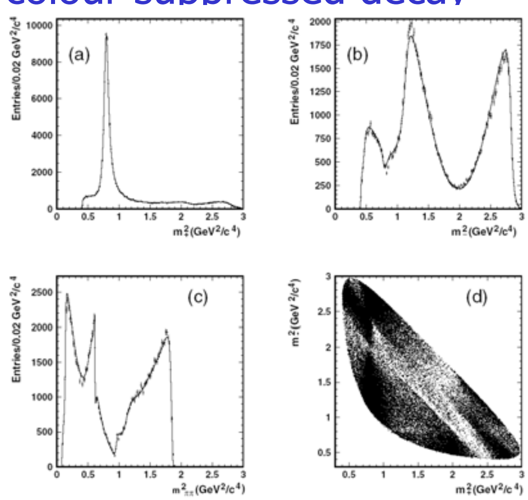
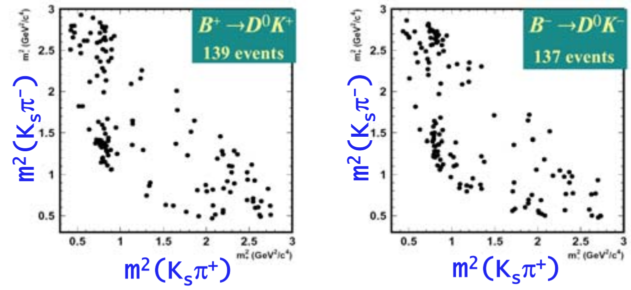


FIG. 5. (a) m_+^2, (b) m_-^2, (c) $m_{\pi\pi}^2$ distributions and (d) Dalitz plot for the $\bar{D}^0 \to K_S\pi^+\pi^-$ decay from the $D^{*\pm} \to D\pi_s^\pm$ process. The points with error bars show the data; the smooth curve is the fit result.

ϕ_3 from interference of a direct and colour suppressed decay

$B^+ \to D^0K^+$ $B^- \to D^0K^-$



⇨ Visible asymmetry

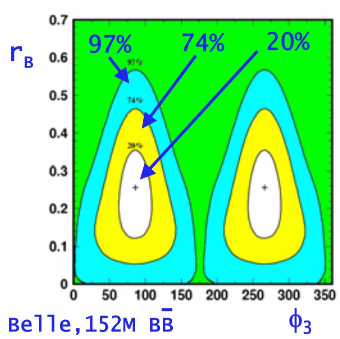
Fit with ϕ_3, δ, r_B free

$\phi_3 = (68 \pm {}^{14}{}_{15} \pm 13 \pm 11)^o$

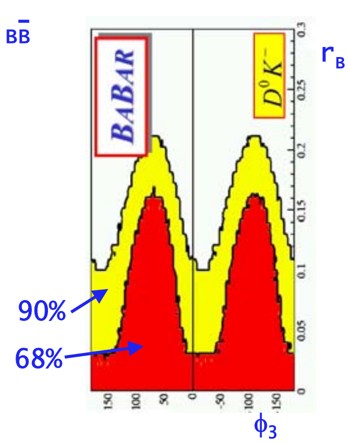
$22^o < \phi_3 < 113^o$ @ 95% C.L.

$r_B = 0.21 \pm 0.08 \pm 0.03 \pm 0.04$

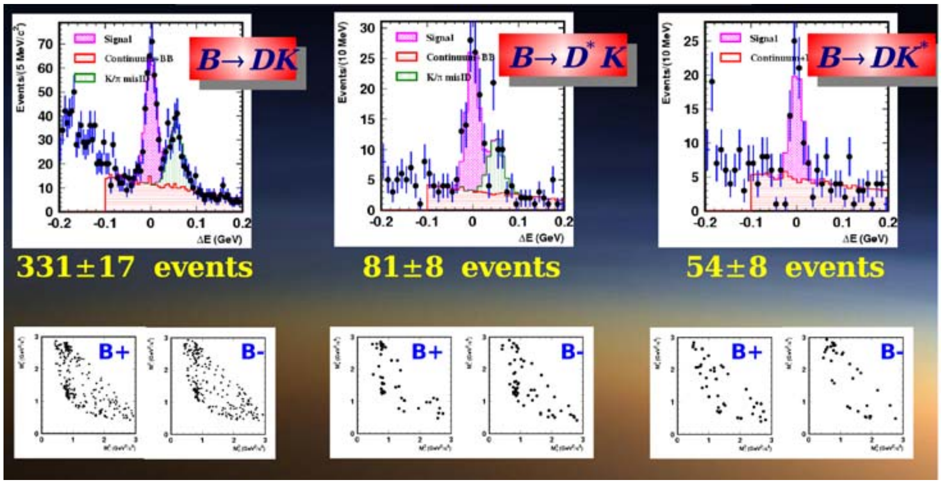
ϕ_3 vs. r_B plots



BaBar,211M $B\bar{B}$



Update 2006



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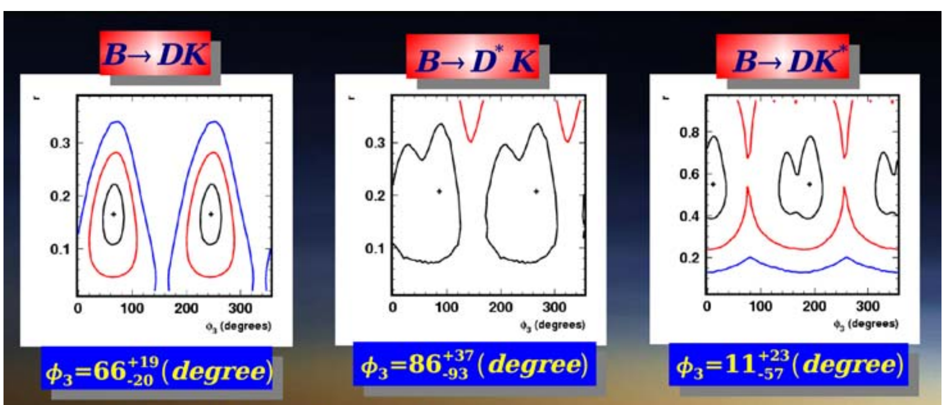

Combining 3 modes

$$\phi_3=53^{0}{}^{+15}_{-18}(stat.)\pm3^{0}(syst.)\pm9^{0}(model)$$