CP violation and related issues

Part 7.5: direct CP

Peter Križan

University of Ljubljana and J. Stefan Institute

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CP in decay: $|\bar{A}/A| \neq 1$

$$a_f = \frac{\Gamma(B^+ \to f, t) - \Gamma(B^- \to \bar{f}, t)}{\Gamma(B^+ \to f, t) + \Gamma(B^- \to \bar{f}, t)} = \frac{1 - |\bar{A}/A|^2}{1 + |\bar{A}/A|^2}$$

Also possible for neutral B.

$$\left|A_f\right|^2 - \left|\bar{A}_{\bar{f}}\right|^2 = \sum_{i,j} A_i A_j \sin(\varphi_i - \varphi_j)\sin(\delta_i - \delta_j)$$

CPV in decay: need at least two interfering amplitudes with different weak and strong phases.

$$a_{f_{CP}} = S\sin(\Delta m \Delta t) + A\cos(\Delta m \Delta t)$$

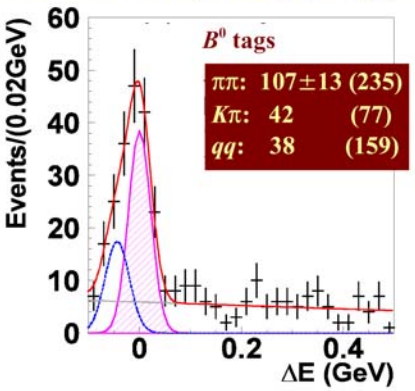
→ ≠0 direct CPV; $|A(B \to f)| \neq |A(\bar{B} \to \bar{f})|$ only when multiple proc. contribute to f (tree+penguin)

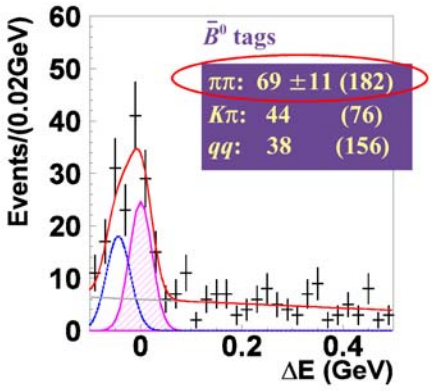
Direct CPV also in time integrated decay rates:

$$\mathcal{A}_{CP} = \frac{\Gamma(\bar{B} \to \bar{f}) - \Gamma(B \to f)}{\Gamma(\bar{B} \to \bar{f}) + \Gamma(B \to f)}$$

Direct CPV in $\pi^+\pi^-$

KLR > 0.86 and good tags (all tags):





⇒ direct *CP* violation is clear

$$f_{\pi\pi}^{(q)} \propto 1 - q\Delta w_\ell + \frac{q(1-2w_\ell)}{1+x^2} A_{\pi\pi} \quad \Rightarrow \quad A_{\pi\pi} = 0.52 \pm 0.14$$

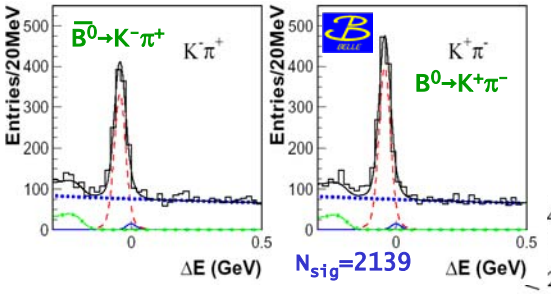
consistent with Δt fit

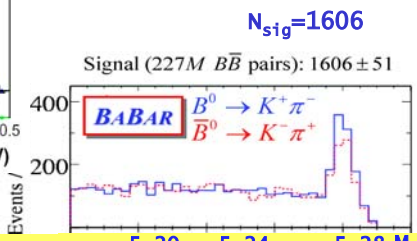
Direct CPV in $\pi^+\pi^-$

Belle $B \to \pi^+\pi^-$ first evidence from dependent analysis
$A_{+-} = 0.58 \pm 0.21 \pm 0.07$ not confirmed by BaBar.

Time integrated analysis result in good agreement with the time dependent analysis.

Direct CPV in $K^+\pi^-$



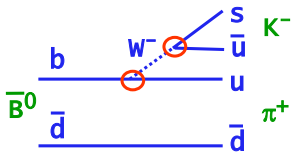


$\mathcal{A}_{CP}$= -0.133±0.030±0.009

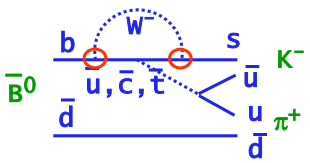
$\mathcal{A}_{CP}$= -0.101±0.025±0.005

Direct CPV in $K^+\pi^-$

Contributions to $B^0 \to K^-\pi^+$

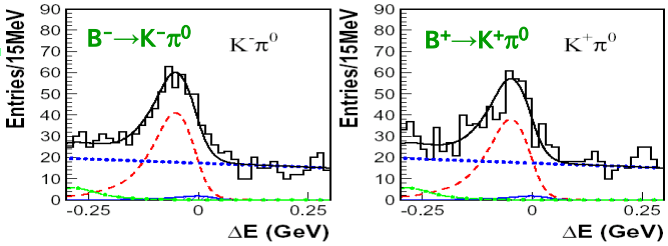


$T \sim V_{ub}^*V_{us} \sim A\lambda^4$



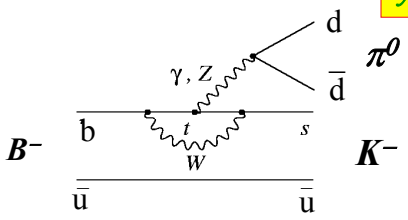
$P \sim V_{tb}^*V_{ts} \sim A\lambda^2$

Direct CPV in $K^+\pi^0$



$\mathcal{A}_{CP}$= 0.04 ± 0.05 ± 0.02 Belle

$\mathcal{A}_{CP}$= 0.06 ± 0.06 ± 0.01 BaBar



c.f. in $B\to K^+\pi^-$
$\mathcal{A}_{CP}$= -0.101±0.025±0.005
2.4σ diff.

Large EW penguin?