How to measure γ from $B_s \to D_s K\pi\pi$ decays ?

FSP Meeting Siegen

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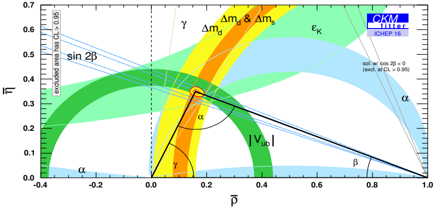
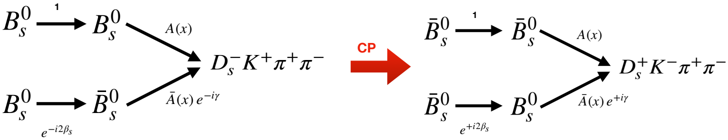
$$\begin{pmatrix} |V_{ud}| & |V_{us}| & |V_{ub}|e^{-i\gamma} \\ -|V_{cd}| & |V_{cs}| & |V_{cb}| \\ |V_{td}|e^{-i\beta} & -|V_{ts}|e^{i\beta_s} & |V_{tb}| \end{pmatrix}$$

$$\gamma = (72.1^{+5.4}_{-5.8})^\circ$$



Time-dependent Amplitude analysis of $B_s \to D_s K\pi\pi$

Measure CP violation in the interference of mixing and decay

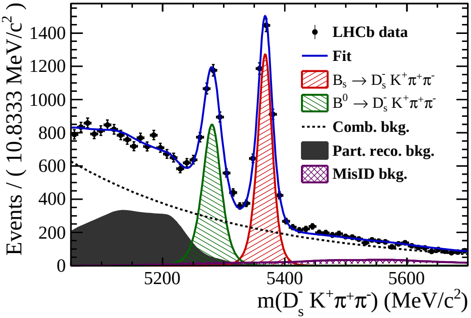


Full time-dependent amplitude PDF:

$$
\begin{aligned}
P(x, t, q_t, q_f) \propto \Big[& \left(|A(x)|^2 + |\bar{A}(x)|^2\right) \cosh\left(\frac{\Delta\Gamma\, t}{2}\right) \\
& + q_t q_f \left(|A(x)|^2 - |\bar{A}(x)|^2\right) \cos\left(\Delta m_s\, t\right) \\
& - 2\mathrm{Re}\left(A(x)^* \bar{A}(x)\, e^{-i q_f (\gamma - 2\beta_s)}\right) \sinh\left(\frac{\Delta\Gamma\, t}{2}\right) \\
& - 2 q_t q_f \mathrm{Im}\left(A(x)^* \bar{A}(x)\, e^{-i q_f (\gamma - 2\beta_s)}\right) \sin\left(\Delta m_s\, t\right) \Big] e^{-\Gamma t}
\end{aligned}
$$

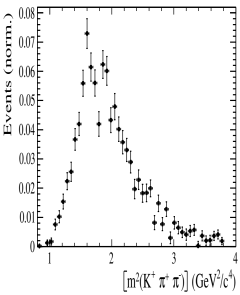
$q_t = +1, 0, -1$ for a B_s^0, no-, ($\bar{B}_s^0$) tag
$q_f = +1$(-1) for $D_s^- K^+ \pi\pi$ ($D_s^+ K^- \pi\pi$) final states.

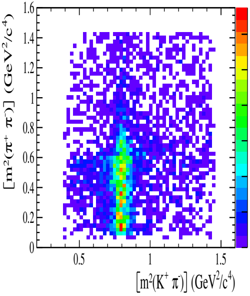
Selection

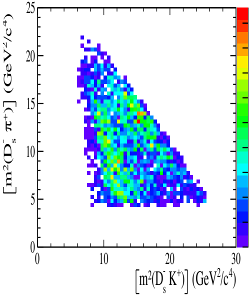


- Using Run-1 and 15/16 data (5.8 fb^{-1})
- Reconstruct two D_s final-states: $KK\pi$ and $\pi\pi\pi$
- Signal yield = 3700

Resonances

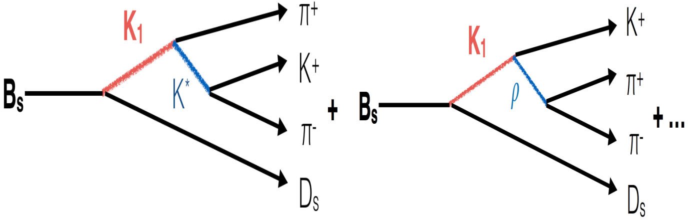






- $K_1(1270), K_1(1400), K_1^*(1410) \to K\pi\pi$
- $K^*(892) \to K\pi$
- $\rho(770) \to \pi\pi$

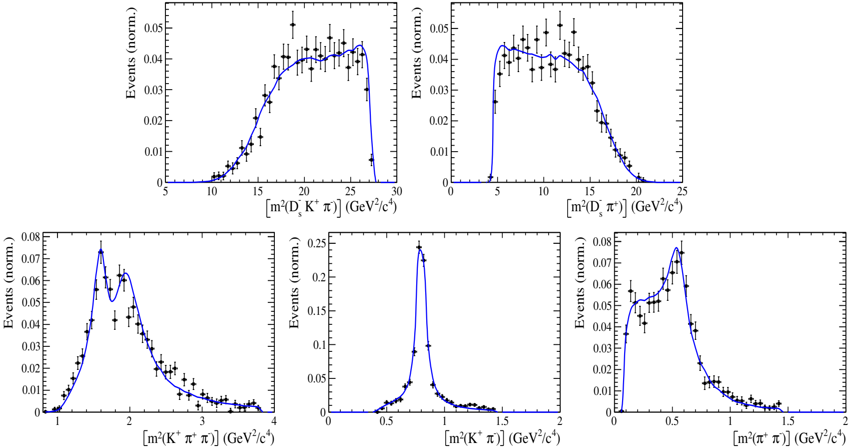
Amplitudes



Isobar formalism

- Single channel amplitudes:
  $A_1(x) \approx BW_{K_1} \cdot BW_{K^*} \cdot S_f$
  $A_2(x) \approx BW_{K_1} \cdot BW_{\rho} \cdot S_f$
- Total amplitude:
  $A_{B_s \to D_s K\pi\pi}(x) = \sum_i a_i A_i(x)$

Time-integrated Amplitude Fit



Decay channel	Fraction (%)
$B_s \to D_s^- \left[K_1(1270)^+ \to K^*(892)\,\pi^+\right]$	13.9 ± 1.4
$B_s \to D_s^- \left[K_1(1270)^+ \to \rho(770)\,K^+\right]$	9.6 ± 1.1
$B_s \to D_s^- \left[K_1(1270)^+ \to K_0^*(1430)\,\pi^+\right]$	4.7 ± 0.5
$B_s \to D_s^- \left[K_1(1400)^+ \to K^*(892)\,\pi^+\right]$	40.4 ± 2.5
$B_s \to D_s^- \left[K^*(1410)^+ \to K^*(892)\,\pi^+\right]$	16.5 ± 1.0
$B_s \to D_s^- \left[K^*(1410)^+ \to \rho(770)\,K^+\right]$	3.9 ± 0.4
$B_s \to (D_s^-\,\pi^+)\,K^*(892)$	3.5 ± 0.9
$B_s \to (D_s^-\,K^+)\,\rho(770)$	2.7 ± 0.8
$B_s \to (D_s^-\,K^+)\,\sigma$	3.7 ± 0.4
Sum	101.0 ± 3.1

Experimental challenges

$$\mathcal{P}(x,t,q_t) = [P(x,t',q_t) \otimes R(t,t')] \cdot \epsilon(t)$$

Time-Acceptance

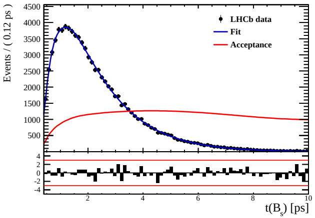
Determined on $B_s \to D_s\pi\pi\pi$ data

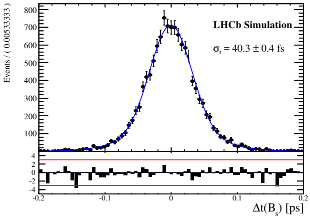
Time-Resolution

Calibrated on prompt D_s sample

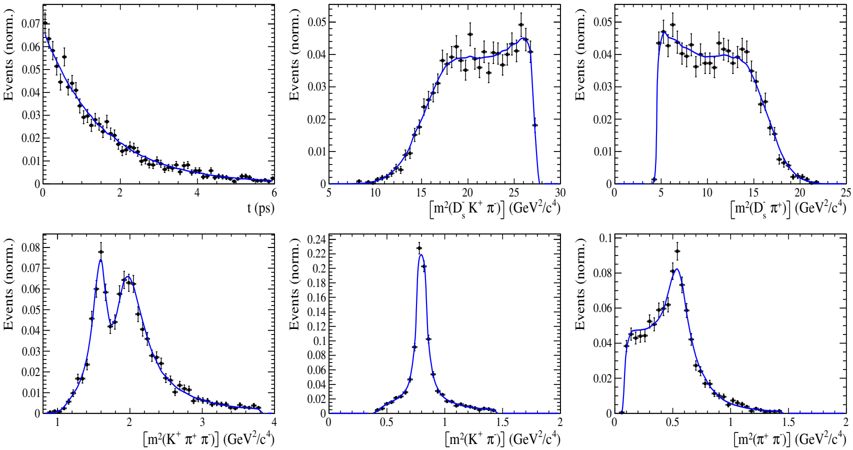
Tagging

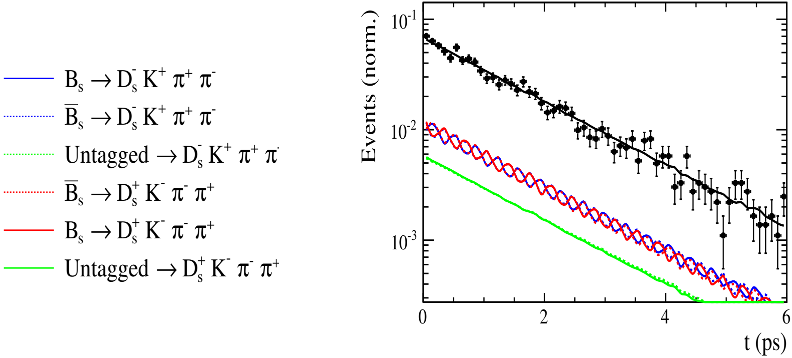
- From $B_s \to D_s K$ we know: $\epsilon_{Tag} \approx 0.66, <\omega> \approx 0.4$
- Can we reuse calibration ?





Sensitivity study: Example Toy-Fit





B_s → D_s^- K^+ π^+ π^-
B̄_s → D_s^- K^+ π^+ π^-
Untagged → D_s^- K^+ π^+ π^-
B̄_s → D_s^+ K^- π^- π^+
B_s → D_s^+ K^- π^- π^+
Untagged → D_s^+ K^- π^- π^+
Events (norm.)
10^-1
10^-2
10^-3
0
2
4
6
t (ps)

Outlook

Time-dependent amplitude analysis of $B_s \to D_s K \pi\pi$

- Estimated (statistical) precision: $\sigma(\gamma) \approx 15^\circ$ (5.8 fb^{-1})
- World average: $\sigma(\gamma) = 5.6^\circ$
- $B^\pm \to DK^\pm, D \to K_s\pi\pi$: $\sigma(\gamma) = 15^\circ$ (3 fb^{-1})
- $B_s \to D_s K$: $\sigma(\gamma) = 20^\circ$ (1fb^{-1})

Other applications

- $(\gamma + 2\beta)$ from $B^0 \to D^\mp K_s^0 \pi^\pm$ decays
- Charm mixing of multibody decays ($D^0 \to 4\pi$)

Backup: Motivation