Background studies for $B^0\overline{B^0}$ mixing with hadronic final states at the Belle II experiment

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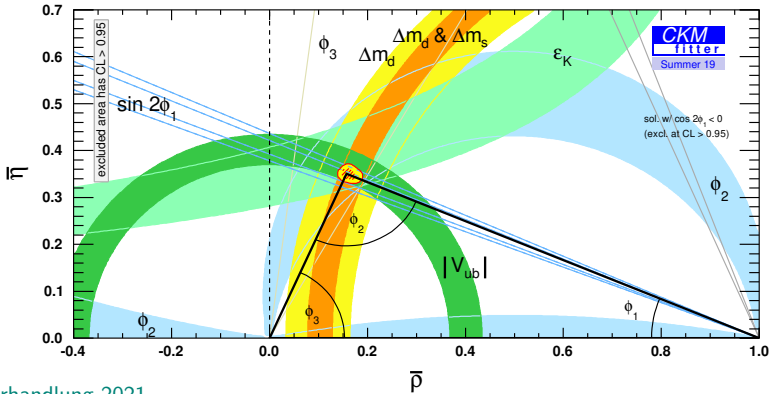
Cabibbo-Kobayashi-Maskawa Matrix

Unitary CKM-matrix relates weak quark eigenstates to strong quark eigenstates and governs flavor-changing quark-transitions.

Unitarity yields 6 relations, i.e. unitarity triangles, that serve as SM precision test. Non-trivial angles indicate CP-violation.

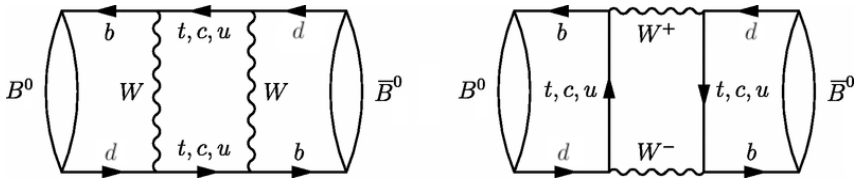


CKM fitter

Motivation

All-hadronic charmed $B \to \pi D$ decays have high branching ratios and provide high statistics.

This talk focusses on estimating systematic uncertainties related to backgrounds in measurements of the mixing frequency Δm_d and the lifetime τ_{B^0}.



These measurements are systematically limited at B-factories, such as Belle II. Given the large statistics, we expect to be able to make precise measurements with only $64\,\mathrm{fb}^{-1}$ of data available[1][2].

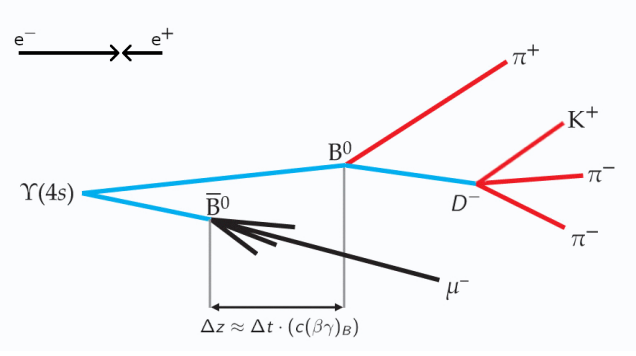
[1] Belle II note on time-dependent CP-violation and mixing

[2] $B^0\overline{B^0}$ mixing Feynman diagram

Time-dependent measurements at B-factories

Asymmetric electron-positron collider SuperKEKB at $Y(4S)$ resonance produces boosted coherent B meson pairs at record luminosities with low backgrounds.

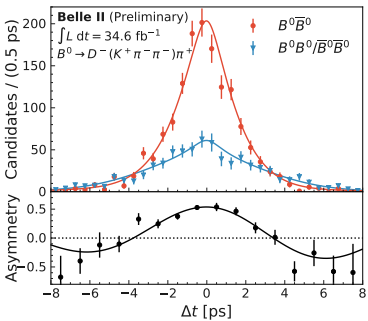
Proper-time difference measurement of B meson pairs yields lifetime. In the following, we neglect detector resolution, wrong tags and CP-violation in mixing.



$$N(\Delta t) = \frac{1}{2\tau_{B^0}} \cdot \exp\left[\frac{-|\Delta t|}{\tau_{B^0}}\right]$$

Mixing measurements at B-factories

The B mixing parameter Δm_d can be extracted from the mixing asymmetry in flavor-specific decays[1].



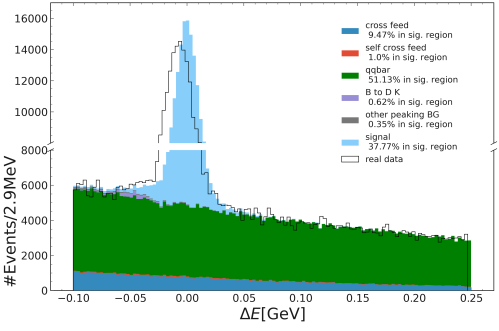
$$A_{mix}(\Delta t) = \frac{P_{OF}(\Delta t) - P_{SF}(\Delta t)}{P_{OF}(\Delta t) + P_{SF}(\Delta t)} = \cos(\Delta m_d \Delta t)$$

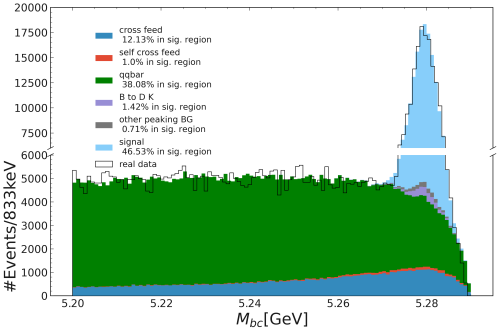
$$\text{with } P_{OF(SF)} = \exp\left[\frac{-|\Delta t|}{4\tau_{B^0}}\right] \cdot [1 + (-)\cos(\Delta m_d \Delta t)]$$

Uncertainties on Δt and (peaking) backgrounds enter as systematic uncertainties.

MC studies of backgrounds in $B \to \pi D(\to K \pi \pi)$

Signal B decays peak in both the energy difference $\Delta E \equiv E_B^{cms} - E_{beam}^{cms}$ and in the beam-energy constrained mass $M_{bc} \equiv \sqrt{(E_{beam}^{cms})^2 - (p_B^{cms})^2}$.



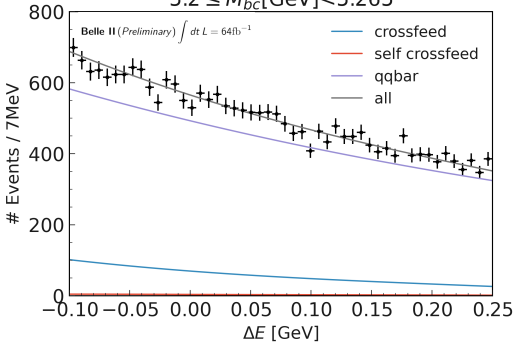


continuum backgrounds	peaking backgrounds
combinatorial crossfeed	$B \to D K$
combinatorial self-crossfeed with signal decay	partly reconstructed $B \to \pi D^*, B \to \rho D$
$q\overline{q}$	mis-identified e, μ as π

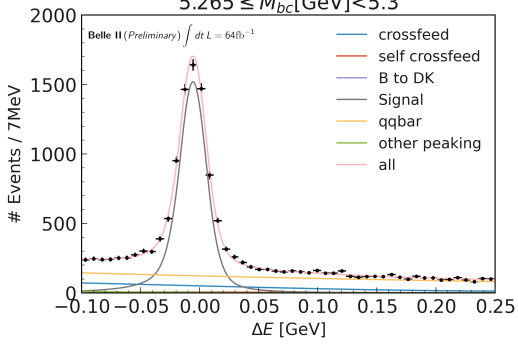
Fit on 64fb^{-1} Belle II data

We fit the fixed shapes from MC on data in two slices in M_{bc}. We fix the relative yields of crossfeed to self-crossfeed and of $B \to D\,K$ to other peaking backgrounds.

$5.2 \leq M_{bc}$[GeV]<5.265



$5.265 \leq M_{bc}$[GeV]<5.3

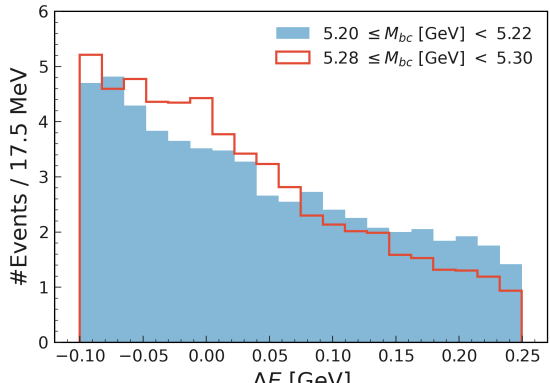


yields	data	MC truth
crossfeed	1840 ± 250	1747 ± 11
$q\bar{q}$	5460 ± 110	5485 ± 19
$B \to D\,K$	8 ± 9	204 ± 4
signal	7150 ± 110	6732 ± 21

Why no 2D-fit?

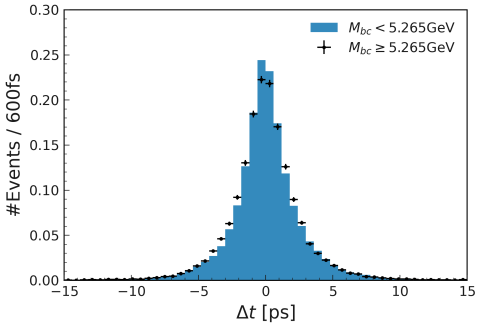
To further increase the distinction power of the fit, a full 2D-fit in the $(\mathrm{deltaE}, \mathrm{M}_{bc})$ plane would be useful.

However, we find non-negligible correlations between the two variables, which forbids an independent modelling of the shapes. For peaking components, the Pearson correlation coefficients are $\mathcal{O}(0.2) \gg 0$.

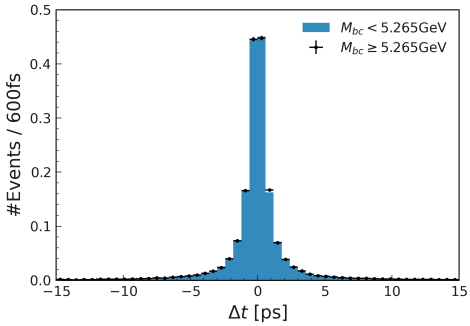


MC studies of backgrounds in Δt

We aim to constrain the continuum backgrounds in Δt from the sidebands $M_{bc} < 5.265\mathrm{GeV}$ and $|\Delta E| > 0.05\mathrm{GeV}$. In both the crossfeed and $q\overline{q}$ background components, we find that the shapes in sideband and signal region allow for interpolation.



crossfeed in signal region and sideband.



$q\overline{q}$ in signal region and sideband.

Summary and outlook

- Study of systematic uncertainties related to backgrounds in time-dependent measurements of mixing frequency Δm_d and lifetime Δt_{B^0} at Belle II.
- MC studies of background shapes in $B \to \pi D(\to K \pi \pi)$ decay mode.
- Fit shapes from MC fitted onto data in two slices in M_{bc}. Good discrimination in continuum backgrounds, while non-negligible correlations in peaking backgrounds.
- MC background shapes in Δt look promising for background constraint from sideband.

Outlook

- Extend analysis to multiple decay modes, notably to $B \to \pi D^*(\to \pi_{\mathrm{slow}} D)$.
- Analyse data in segments of flavor-tag figure of merit.
- Evaluate systematic uncertainties related to backgrounds for first full Belle II mixing parameter measurement.