Measurement of the CKM Angle ϕ_3 using B→DK at Belle II

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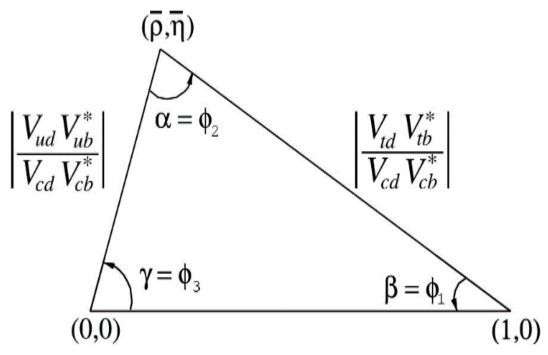
Physics Motivation

- The precise determination of the CKM angle ϕ_3 is highly desirable to independently measure the CKM Unitarity Triangle using either tree-level (Standard Model) or loop level (possibly New Physics contribution) processes.
- CKM angle ϕ_3 is defined as:

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

$|V_{ij}|^2$: Transition probability of i quark into j quark .



CKM Triangle

- Measurement of CKM angle ϕ_3 from B→ DK and B → $\bar{D}$K decays is theoretically clean due to tree-level diagram.
- The sensitivity of ϕ_3 comes from the interference of b → $c\bar{u}s$ and b → $u\bar{c}s$ decay amplitude.
- The amplitude of the $B^+ \to DK^+$, $D \to K_S^0\pi^+\pi^-$ decay:

$$A_B(m_+^2, m_-^2) = \bar{A} + r_B\, e^{i(\delta_B + \phi_3)} A$$

r_B is the ratio of the absolute values of the $B^+ \to DK^+$ and $B^+ \to \bar{D}K^+$ amplitudes.
δ_B is the strong – phase between them.

- Results of ϕ_3 from different experiments:

Exp.	ϕ_3	References
Belle	$(73^{+13}_{-15})^\circ$	CKM 2014
Babar	$(69.0^{+17}_{-16})^\circ$	PRD 87 (2013) 052015
LHCb	$(74.0^{+5.0}_{-5.8})^\circ$	LHCb-CONF-2018-002

- Due to small data samples produced so far, ϕ_3 is poorly determine.

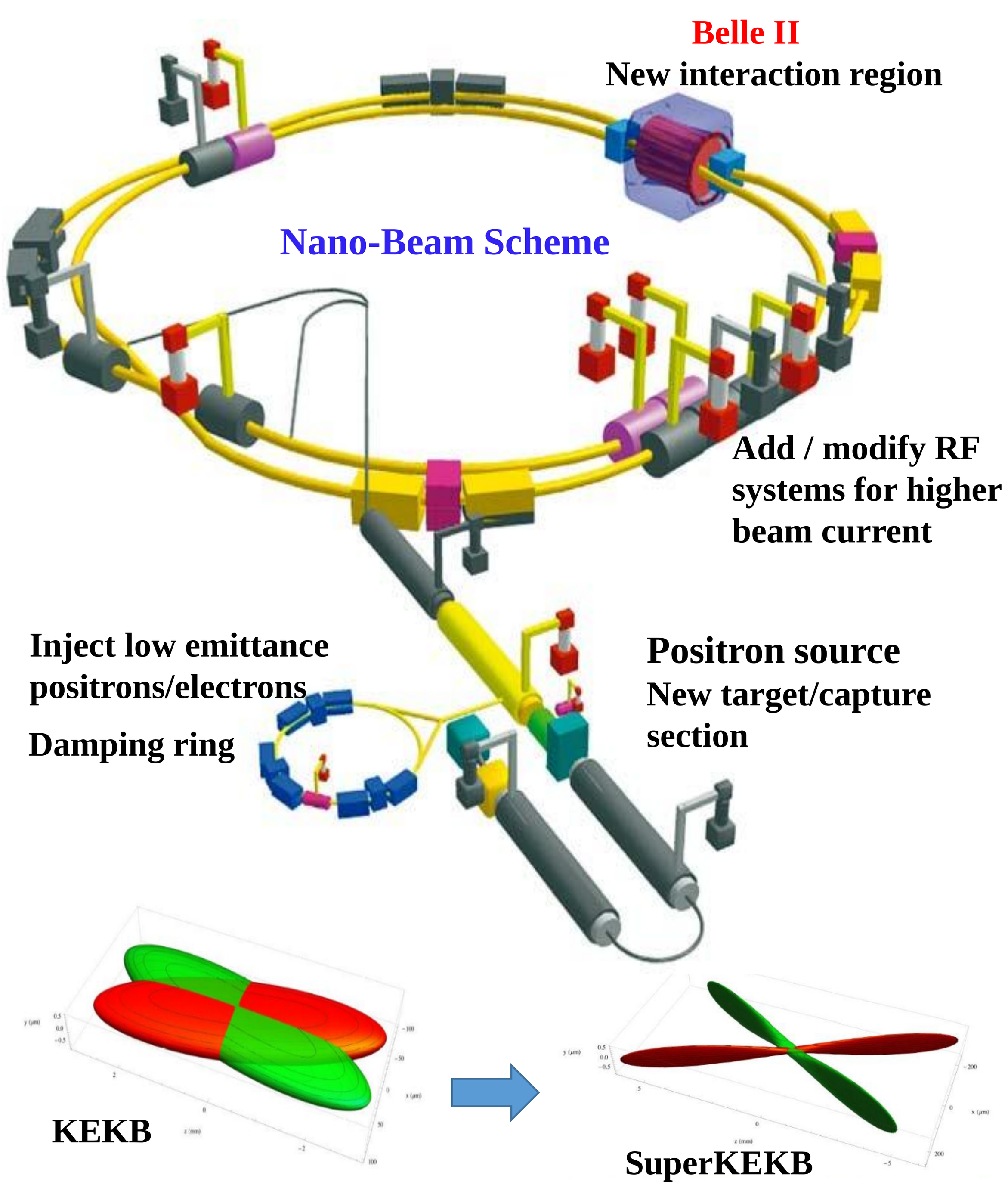
Signal and Background

- **Signal:** $B^\pm \to D(K_S^0\pi^+\pi^-)K^\pm$
  $D^0 \to K_S^0\pi^+\pi^-$ is the one of the golden mode.
  Branching Ratio: $(2.75 \pm 0.18) \times 10^{-3}$
  PDG 2018

- **Background:**
  Continuum Background: $e^+e^- \to q\bar{q}$
  (q: u, d, s, c)
  ✓ Major background due to three times larger cross-section than $e^+e^- \to \Upsilon(4S) \to B\bar{B}$
  Physics Background: $B^\pm \to D\pi^\pm$
  ✓ Due to misidentification of pion as a kaon.

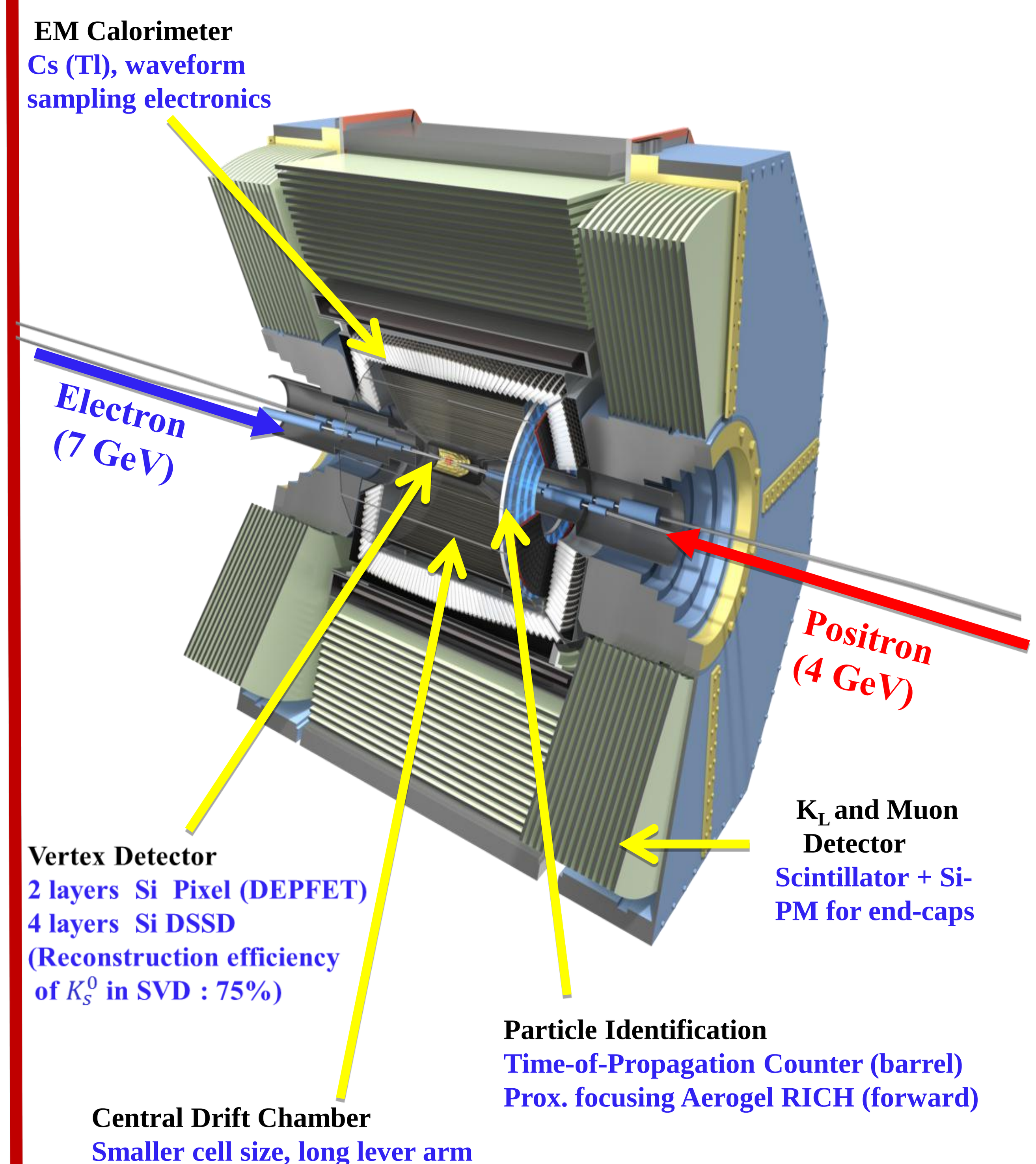
SuperKEKB

e^+ (4 GeV) + e^- (7 GeV) → $B\bar{B}$ at $\sqrt{s}$ =10.58 GeV [Υ (4S)]
Design luminosity = 8 × 10^{35} cm^{-2} s^{-1}



Parameters	KEKB	SuperKEKB
Beam Energy (GeV)	3.5/8.0	4.0/7.0
Crossing angle (mrad)	22	83
Vertical beta functions at IP (mm)	5.9/5.9	0.27/0.30
Beam currents (A)	1.6/1.2	3.6/2.6
Luminosity ($cm^{-2}s^{-1}$)	2.1 × 10^{34}	8 × 10^{35}

Belle II Detector

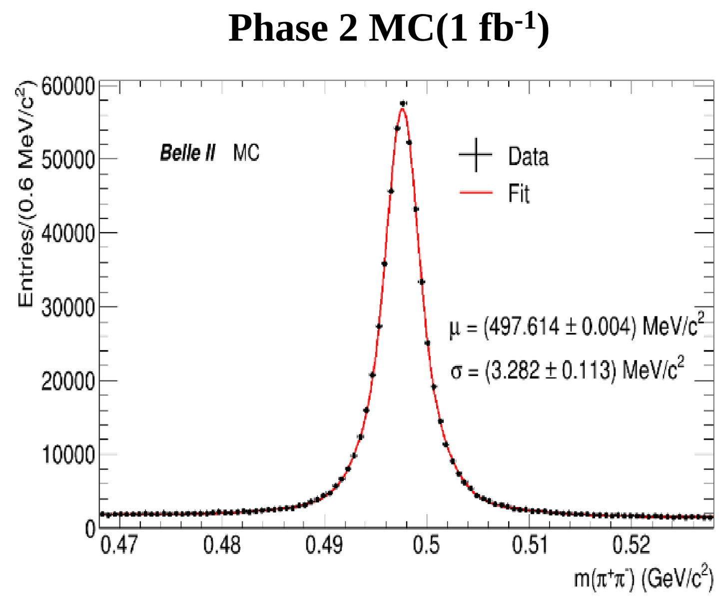


- **Improved tracking and better particle identification than Belle.**
- **Current Status:**
  First collision started at April 25, 2018.

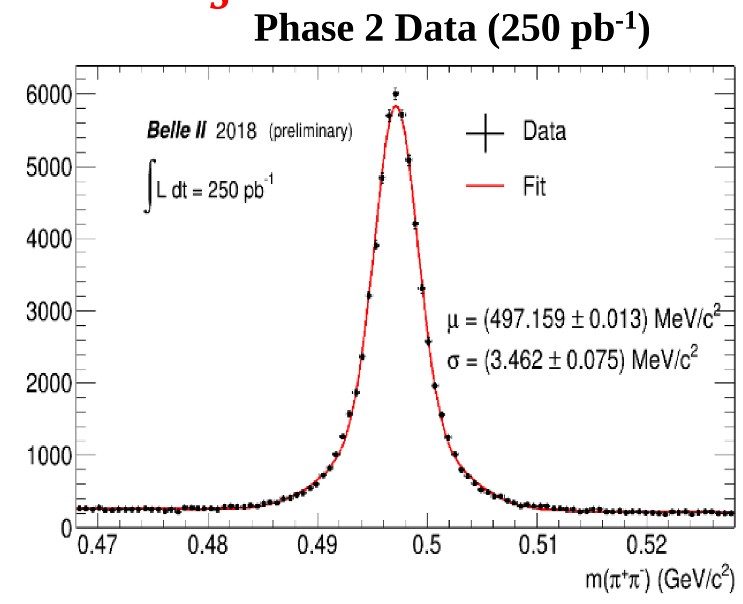
Physics Analysis of B → DK

Reconstruction of K_S^0

Phase 2 MC(1 fb^{-1})

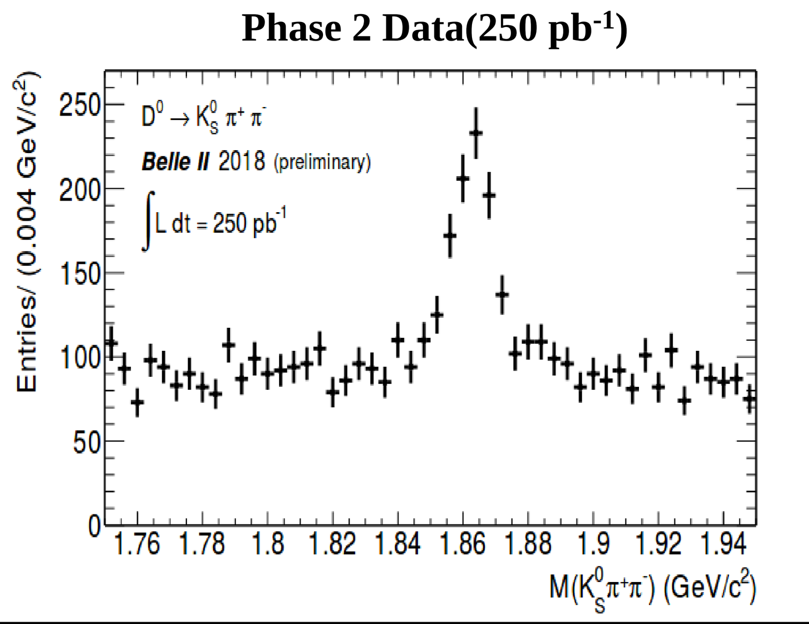


Phase 2 Data (250 pb^{-1})



Reconstruction of $D^0 \to K_S^0\pi^+\pi^-$

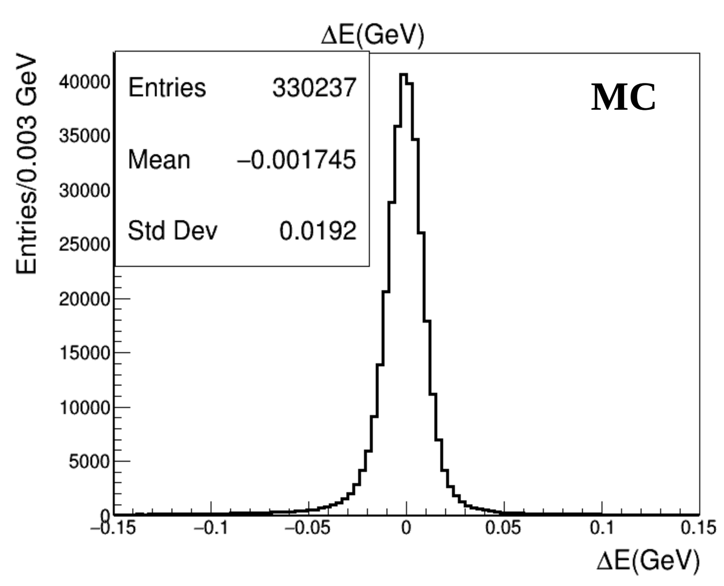
Phase 2 Data(250 pb^{-1})



Reconstruction of B meson (2×10^6 Events)

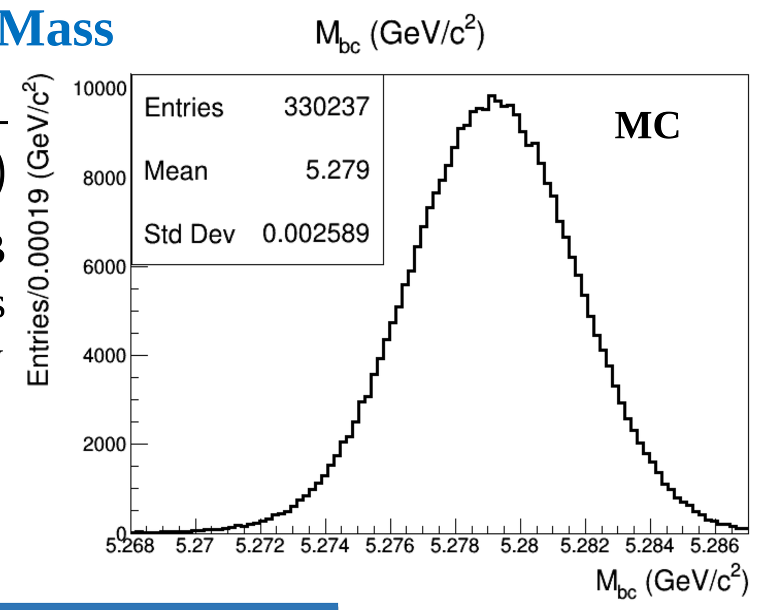
Energy Difference

$\Delta E = \sum E_i - E_{beam}$
E_i: CM energies of B candidate decay products
E_{beam}: CM beam energy



Beam Constrained Mass

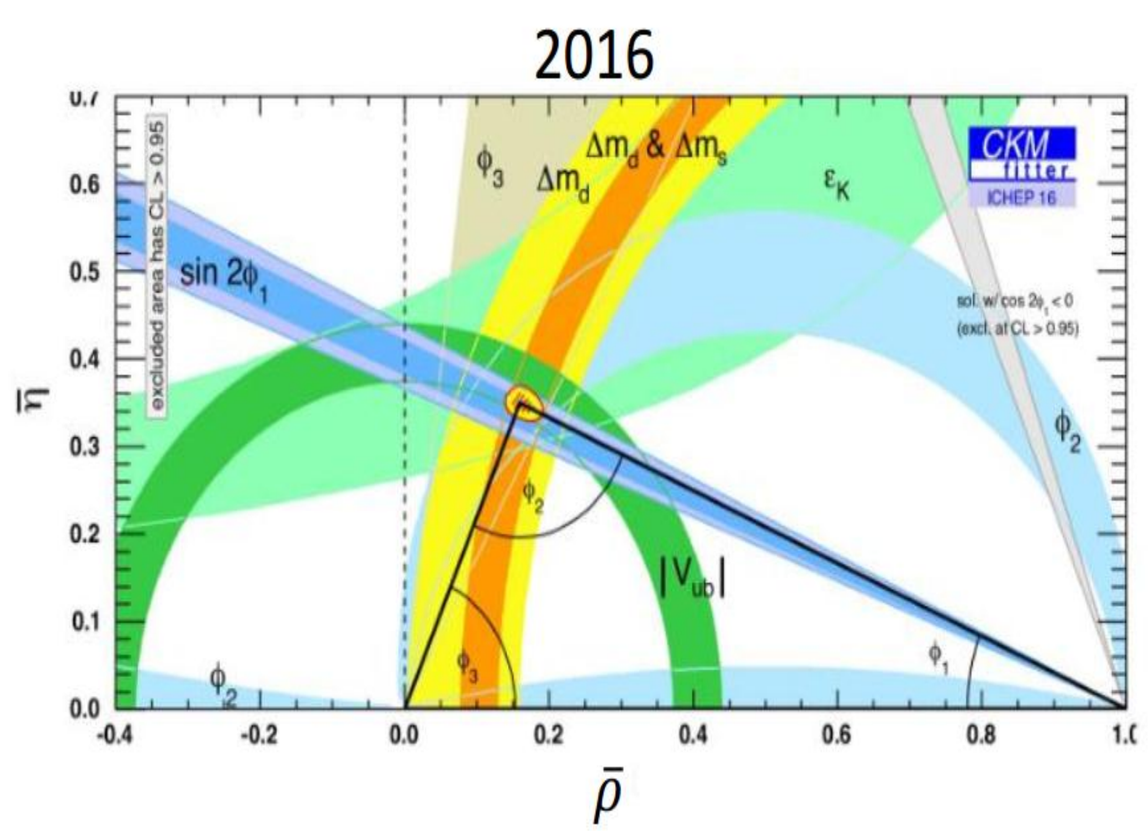
$M_{bc} = \sqrt{E_{beam}^2 - (\sum p_i)^2}$
p_i =:CM momentum of B candidate decay products
E_{beam}: CM beam energy

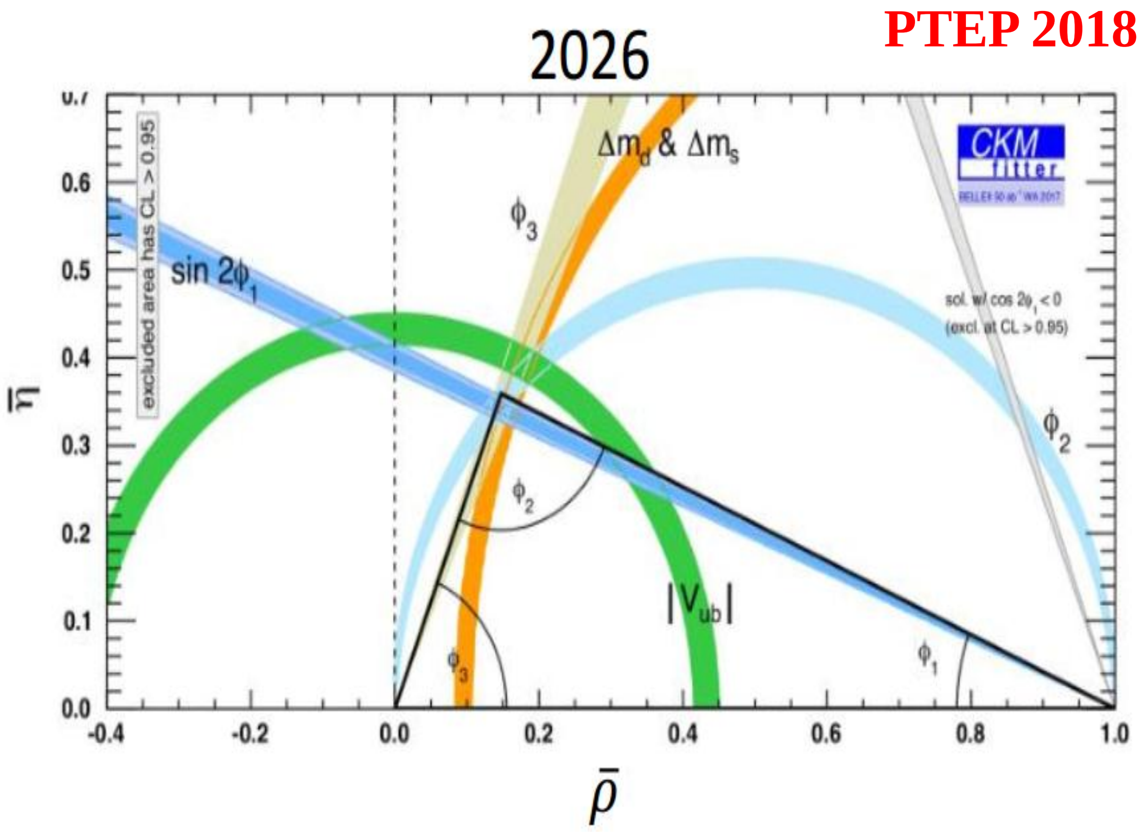


MC: Monte Carlo Simulations

Measurement of the CKM angle ϕ_3 at 50 ab^{-1} (Extrapolated Results)

PTEP 2018





An improved precision on the measurement of CKM ϕ_3 by extrapolating the measurement results at integrated luminosity of 50 ab^{-1} is excepted.

Summary

- Large statistics at Belle II will provide the precision measurement of ϕ_3.
- First collision on April 25, 2018.
- Simulation is performed for signal $B \to D(K_S^0\pi^+\pi^-)K$ and background (continuum and physics) channels:
  ✓ To optimize the efficiency of signal.
  ✓ To understand the behavior of background.
- Reconstruction of K_S^0 from Phase 2 MC and data at 1 fb^{-1} and 250 pb^{-1}, respectively.
- ΔE and M_{bc} are used to discriminate the signal.