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Study of Bπ-tagging Method at the Y(5S) Resonance for Measurement of CP-violation Parameter sin2ϕ_1

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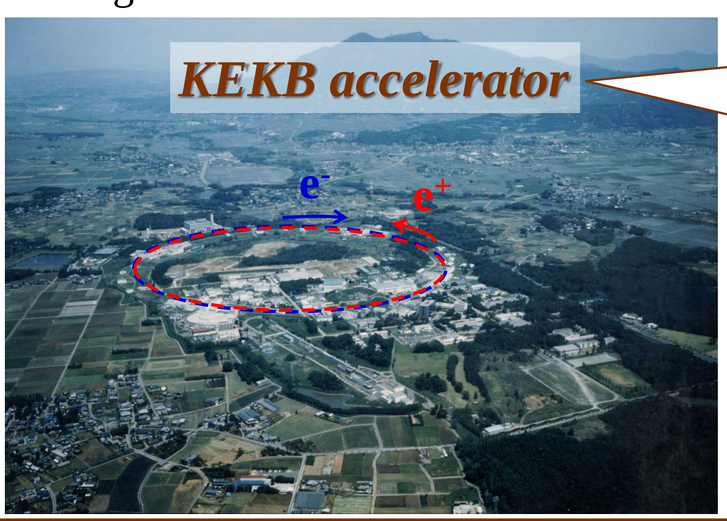
Belle experiment is B-factory experiment at High Energy Accelerator Research Organization (KEK) at Tsukuba. A large number of B mesons are generated at the KEKB accelerator and the B decay is measured precisely by the Belle detector surrounding the collision point.

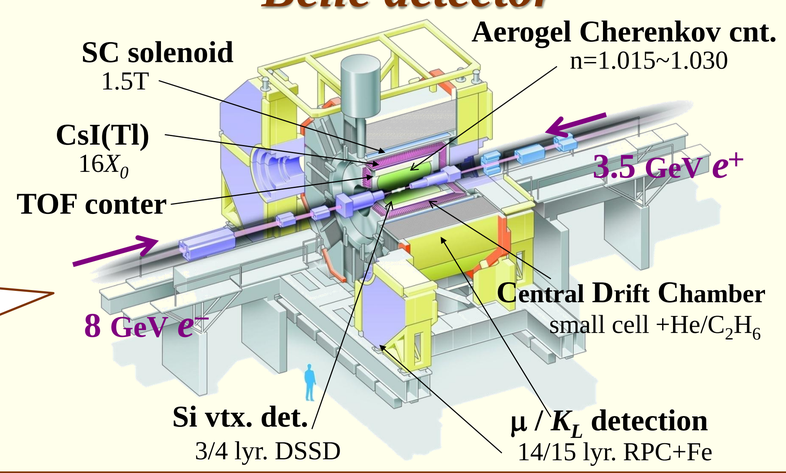


Asymmetric-energy e^+ e^- collider
- Energy : 3.5 GeV (e^+), 8 GeV (e^-)
- Circumference : ~ 3 km

World's highest luminosity collider
- Instantaneous luminosity : 2.11×10^{34} cm^{-2} s^{-1}
- Integrated luminosity : ~ 1000 fb^{-1}

Designed to measure B decay
- Large solid angle coverage
- Good particle identification
- Vertex location with precision on the order of tens of micrometers.

Belle detector



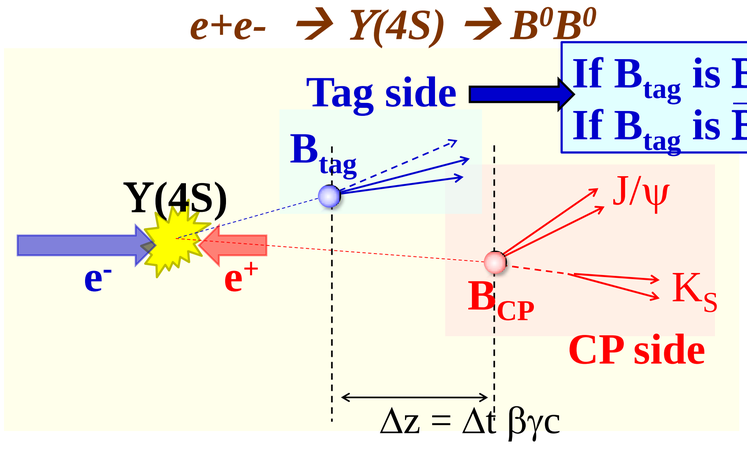
What is sin2ϕ_1 ?

M. Kobayashi and T. Maskawa were awarded the 2008 Nobel Prize in physics for their Kobayashi-Maskawa theory. Belle experiment contributed greatly to confirmation of the theory. The measured parameter is CP-violation parameter sin2$\phi_1$then.

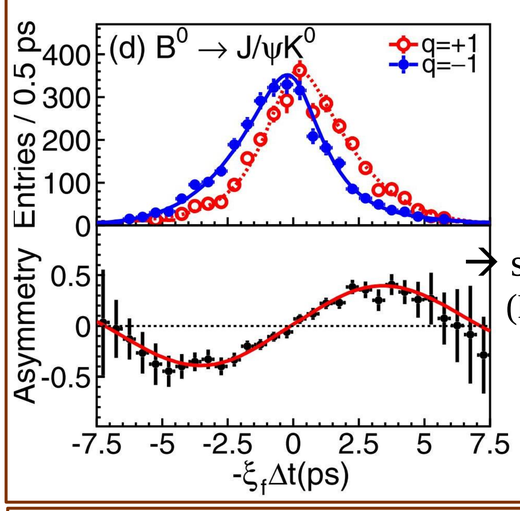
sin2ϕ_1 measurement

sin2ϕ_1 was measured through the Y(4S) decay. We need to know initial state of neutral B meson for the measurement of CP-violation in the B meson (flavor tagging). In Y(4S) decay, the flavor of B meson(B_{CP}) in a CP side is tagged from B meson(B_{tag}) in a tag side using quantum interference.

e+e- → Y(4S) → B^0B^0

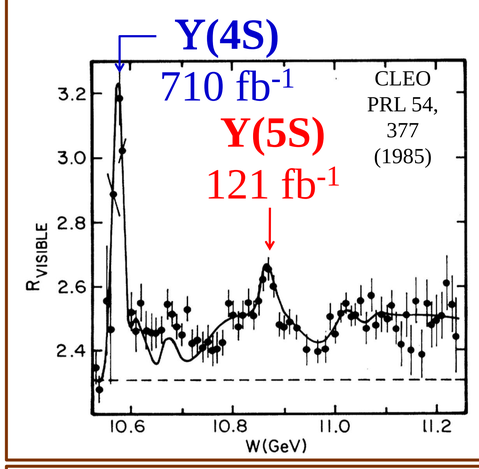


The excellent flavor tagging algorithm and precise vertexing produced precise measurement of sin2ϕ_1. sin2ϕ_1 can be observed in proper time (Δt) distribution.



→ sin2ϕ_1 = 0.642±0.031±0.017
(Phys. Rev. Lett. 98, 031802(2007) @ Belle experiment)

Y(4S) and Y(5S)



Upsilon meson(Y) is a bound state, which formed from a bottom quark and its anti-particle (bottomonium).
Y(4S) has a mass above the threshold for BB pair production. Most data in Belle was recorded on the Y(4S) resonance.
- Y(4S) → BB (> 96 %)

Y(5S) is about 286 MeV heavier than Y(4S).
- Y(5S) → $B^{(*)}B^{(*)}$ $(\pi)(\pi)$ (~ 60 %)
- Y(5S) → $B_S^{(*)}B_S^{(*)}$ (~ 20 %)
- Y(5S) → Y(nS) + X

Bπ-tagging method

sin2ϕ_1 can be measured through the Y(5S) decay using Bπ-tagging method. Y(5S) decays to charged-neutral B pair with pions. In such decay, the initial flavor of the neutral B meson can be tagged only from the charge of the pion.
Bπ-tagging method can produce independent physics results.

Neutral B meson has a flavor quantum number opposed to the charged B meson at the moment of Y(5S) decay.

$e^+e^- \rightarrow Y(5S) \rightarrow B^0\ B^-\ \pi^+$ or $\rightarrow \bar{B}^0\ B^+\ \pi^-$

If direct π is π^+, neutral B is B^0
If direct π is π^-, neutral B is $\bar{B}^0$

Charged B meson has a charge opposed to the pion.

Analysis procedures

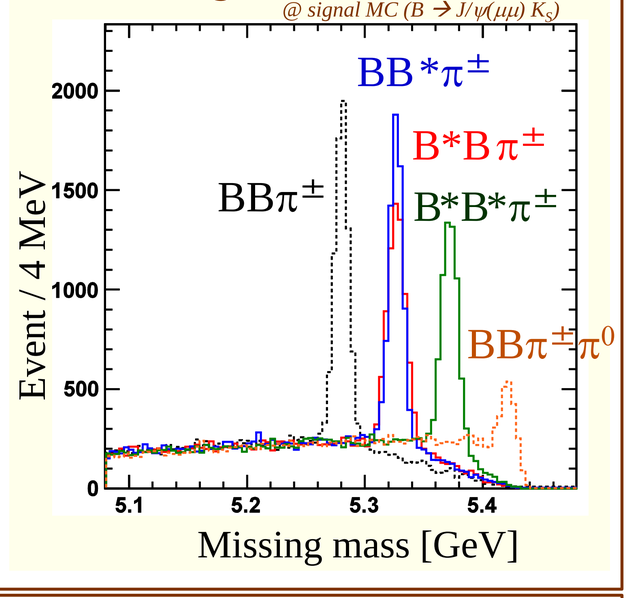
1. Reconstruct neutral B meson from J/ψ K_S
2. Combine reconstructed B meson with direct $\pi^\pm$ and calculate the missing mass
3. Simultaneous fit the data tagged as $B^0B^-\pi^+$ and $B^0B^+\pi^-$, and extract sin2ϕ_1 from A_{charge}.

$$\sin 2\phi_1 = \frac{1+x^2}{x} \cdot \frac{N_+ - N_-}{N_+ + N_-}$$

$\approx$ Charge asymmetry (A_{charge})

(N_+ : # of Y(5S) → B^0 B^+ π^-
N_- : # of Y(5S) → $\bar{B}^0$ B^- π^+)

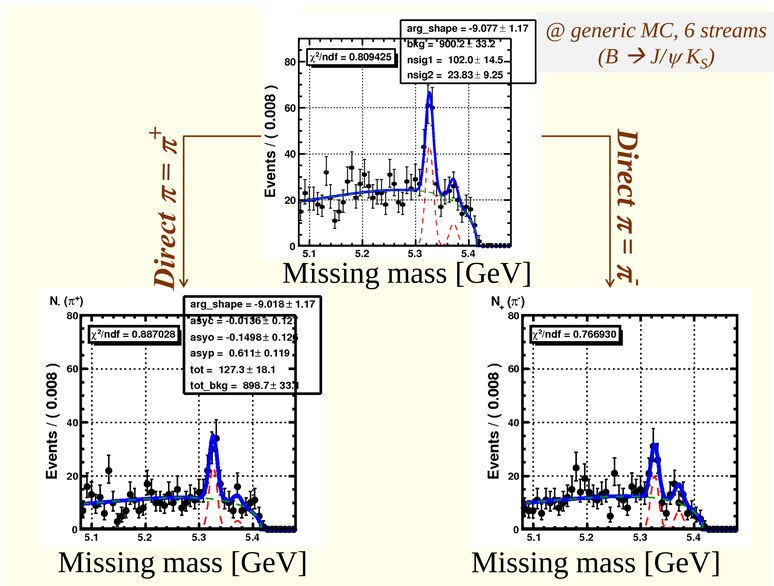
Missing mass distribution
@ signal MC (B → J/ψ(μμ) K_S)



Evaluate the measurement accuracy of sin2ϕ_1

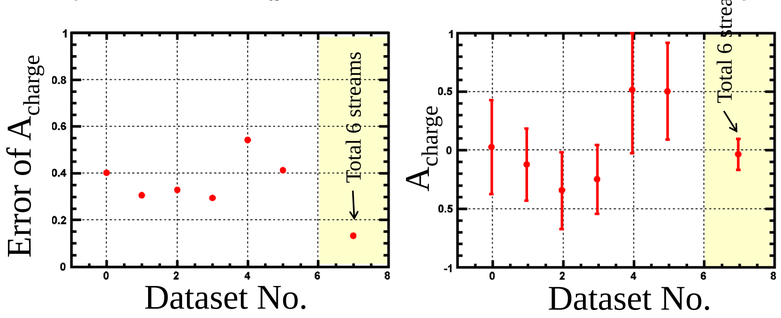
The expected measurement accuracy of sin2ϕ_1 was estimated with 6 Montecarlo datasets.

Simultaneous fit the missing mass distribution



Measurement accuracy of A_{charge} (sin2ϕ_1)

(sin2ϕ_1 error is about twice A_{charge} error because $\frac{1+x^2}{x}$ is about 2.)



A_{charge} is consistent with zero as expected.
(Montecarlo data doesn't include CP-violation effect)
sin2ϕ_1 error is about 0.8.

Summary

Bπ-tagging method
is a flavor tagging method used in Y(5S) decay.
can produce independent physics results.
The measurement accuracy of sin2ϕ_1 was estimated with Montecarlo datasets.
- sin2ϕ_1 error is about 0.8.

Belle is upgrading to Belle II.