

# Study of the Origin of CP Violation at the Belle Experiment

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## Résumé

L'expérience Belle auprès de l'accélérateur KEKB, détenteur du record du monde de luminosité, mesure avec précision la violation CP dans les désintégrations de mésons B. Ces recherches permettront une meilleure compréhension de l'asymétrie matière-antimatière qui est un des ingrédients nécessaires à la formation de l'univers.

## Abstract

Thanks to the luminosity world-record holding accelerator KEKB, the Belle experiment at KEK is presently performing very precise measurements of CP violation in B meson decays. This study will allow a better understanding of the matter–anti-matter asymmetry which has been essential for the creation of the universe.

## Introduction

The Belle Collaboration consists of about 300 physicists from 50 universities and research institutions from around the world. This team centred at KEK spent over five years designing and building the Belle detector (Fig. 1) — a collection of precise radiation sensors roughly the size of a small house completed in 1998. The advances in the study of B meson decays discussed below were made possible by the superb performance of the KEKB accelerator, an asymmetric  $e^+e^-$  collider producing collisions at a centre-of-mass energy of 10.58 GeV ( $\Upsilon(4S)$  resonance). Since breaking the world record for

accelerator performance in spring 2001, it has continued to produce B mesons at a rapid pace (Fig. 2) [1].

## Observation of Large CP Violation

If CP symmetry holds, all physical observables in the decays of particles should be identical to those of their anti-matter counterparts. This symmetry does indeed exist for most particle-anti-particle pairs and until recently the only place where CP violation had been observed was in the decay of neutral K mesons, where the effect is quite small. Yet a sizeable asymme-

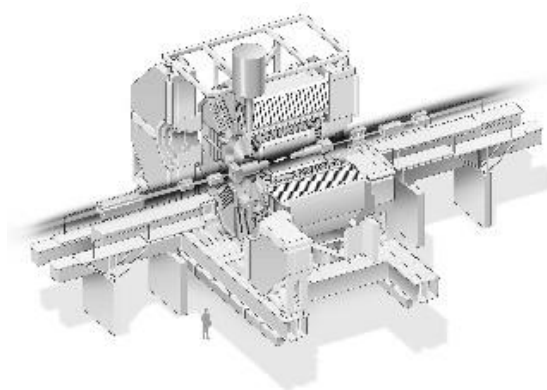


Figure 1: The Belle Detector.

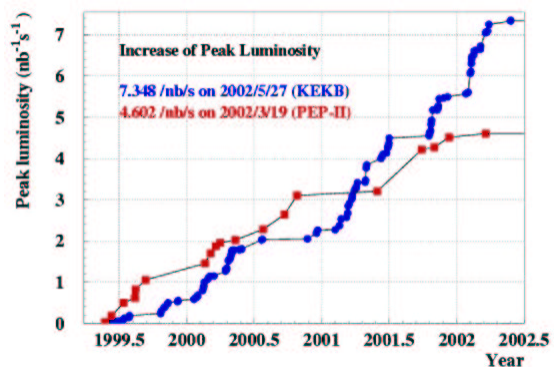


Figure 2: Peak luminosities at KEKB. PEP-II (Stanford) is shown for comparison.

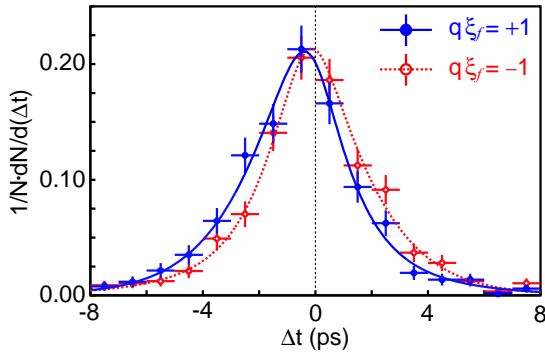


Figure 3: CP asymmetry in raw data [3].

try between matter and anti-matter exists, as can be observed in the universe where no evidence for anti-matter is seen.

Work based on a 1974 theory of Kobayashi and Maskawa [2] predicts the presence of significant CP violating effects in the decays of neutral B mesons. This inspired physicists to construct the Belle and BaBar (a competing experiment based at the Stanford Linear Accelerator Center) experiments which allowed to observe differences between the way in which the neutral B meson and neutral anti-B meson decay in the  $B \rightarrow J/\psi K_S^0$  and related decays [3] (Fig. 3). The asymmetry is found to be large.

### Rare decays of the B meson

Using a sample of 31 million B meson pairs obtained last year, the Belle group made the first observation of B mesons decaying to lighter particles, known as K mesons, and lepton-antilepton pairs ( $e$  and  $\mu$ )  $B \rightarrow K\ell^+\ell^-$  [4]. Belle has established that this type of decay definitely exists although its occurrence is extremely rare. It is believed to occur through quantum fluctuations that involve the heaviest particles observed to date, namely the top (or “t”) quark and the W boson. This decay (called “penguin”-decay) is sketched in Fig. 4.

Further work is needed to improve both the accuracy of theory and experiment, but this result is an important step that could lead to new discoveries through rare decays of B mesons.

### Future plans

Until the next summer shutdown the Belle experiment expects to double its total number of recorded B decays to about 200 million pairs and to pursue the studies described above and many others. The hint for a CP asymmetry in

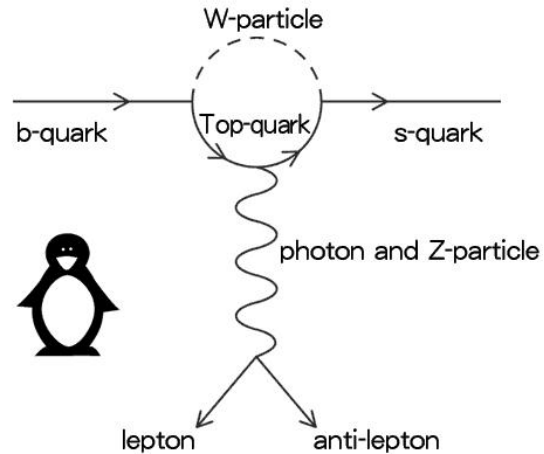


Figure 4: Penguin decay  $b \rightarrow s\ell\ell$ .

$B \rightarrow \pi\pi$  [5] decays for instance is very exciting and calls for more precise measurements.

## References

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- [5] K. Abe et al.: *Study of CP-Violating Asymmetries in  $B^0 \rightarrow \pi^+\pi^-$  Decays*. *Phys. Rev. Lett.* **89** (2002) 071801.

## Acknowledgements

The author would like to thank Abe Kazuo and the JSPS (Japan Society for the Promotion of Science).