【Grant-in-Aid for Scientific Research (S)】

Investigation of the flavor anomaly problem by the world's highest luminosity accelerator experiment

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Purpose and Background of the Research

● Outline of the research

Quarks and leptons, which make up matter, come in three generations, also referred to as **"flavors".** The three particles appear to have exactly the same properties except for their masses (**"universality").** The Standard Model (SM) of elementary particles is not considered the ultimate theory, and the discovery of new physics beyond SM is the next goal. In this context, precise measurements focusing on flavor are being emphasized. Figure 1 summarizes recent examples of flavor precision measurements showing deviations from SM, many of which are found in B-meson decays and referred to **as "B anomalies".** Among them, the most notable is the violation of "flavor universality," where the comparison between B meson decays to tau leptons and muons, and the ratio R(D) or R(D*), deviates from SM. On the other hand, the recent experimental results of **the anomalous magnetic moment of the muon $(g\text{-}2)_\mu$** in the United States show clearer deviations from the Standard Model, and these are collectively known as the **"Flavor Anomaly Problem",** which is a globally urgent research topic. In this research, we will explore this flavor anomaly problem with highly unique research in the Super B Factory experiment led by Japan.

● World's Highest Luminosity Experiment - SuperKEKB/Belle II Experiment -

The **SuperKEKB/Belle II**, boosting the world's highest collision performance (luminosity), provides a unique opportunity for solving the "Flavor Anomaly Problem" (Figure 2). The large statistical B decay data enables precise verification of B anomalies, and the precise electron-positron data collected simultaneously serves as crucial input for the verification of (g-2)μ. Moving forward, we aim to further improve the collision performance and accumulate data with 50 times more than KEKB/Belle. To achieve this, improvements in detector technology are essential, such as suppressing detector background due to increased beam currents. In this research, we aim to resolve the "Flavor Anomaly Problem" with the SuperKEKB/Belle II and advance the necessary improvements in experimental techniques to accomplish these goals.

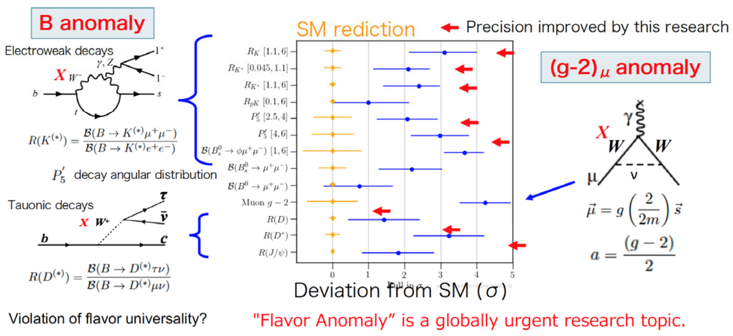

Figure 1. Flavor anomalies in several B meson decays and (g-2)μ

Expected Research Achievements

This research aims to lead the SuperKEKB/Belle II experiment and pursue the "Flavor Anomaly Problem" and the discovery of new physics beyond SM. The specific research objectives are as follows:

● Precise verification of lepton universality violation in B meson decays

Particular urgency is given to the verification of lepton universality violation in B meson decays. This involves determining the R(D(*)) ratios mentioned above with an error of a few percent and conducting detailed measurements of decay particle angular and momentum distributions. This increases sensitivity to new physics, and if the deviation is confirmed, narrows down potential new physics models.

● Experimental determination of the (g-2) quantum correction effect

The SuperKEKB/Belle II also provides crucial input for the $(g\text{-}2)_\mu$ anomaly. The strong interaction effect, which makes the largest uncertainty in the theoretical prediction of $(g\text{-}2)_\mu$, is challenging to calculate but can be determined using precise measurement data from electron-positron collisions at Belle II. In cooperation with researchers involved in the $(g\text{-}2)_\mu$ experiment at J-PARC and theorists, we pursue to improve the precision of the theoretical prediction and enhance the reliability of anomaly verification.

● Improvement of the Belle II detector for enhanced luminosity

The following research objectives, considered essential for conducting physics research in a high-background environment due to increased beam currents, are pursued:

1) Development of higher-performance optical sensors for the particle identification devices, such as the "TOP counter" and "Aerogel RICH", which we developed and introduced to Belle II.
2) Development of a Time-of-Flight (TOF) detector capable of measuring not only charged particles but also gamma rays with a high time resolution of 20 picoseconds. This enables the elimination of beam-induced background gamma rays.
3) Development of a next-generation trigger device that tracks particles in real-time using state-of-the-art FPGA circuits and instantly determines which events to record to reduce the data collection rate to an acceptable level.

● Expected outcomes

During this research period, we aim at accumulating more than ten times the current amount of data and achieve a definitive confirmation of the flavor anomalies that are currently emerging. If multiple flavor anomalies are confirmed in B decays and $(g\text{-}2)_\mu$, it would be a breakthrough in particle physics with a tremendous impact.

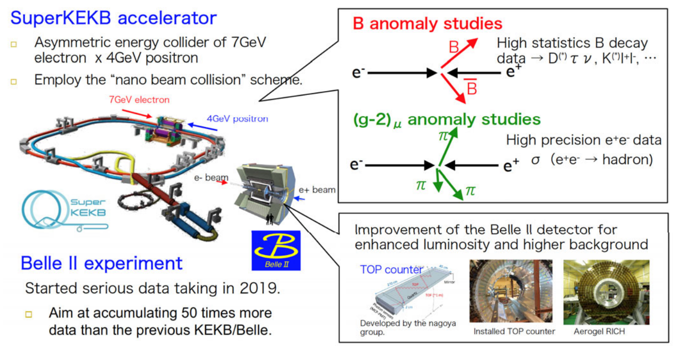

Figure 2. SuperKEKB/Belle II, by which we explore experimentally the flavor anomaly problem.

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