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Recent results and perspective for Belle II experiment

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The Belle II experiment, operating at the SuperKEKB asymmetric-energy electron-positron collider in Tsukuba, Japan, represents a major advancement in precision flavor physics. With a target luminosity of $50ab^{\ 1}$, Belle II is poised to collect a dataset approximately 50 times larger than that of its predecessor, Belle. This significantly increased data sample, combined with the clean experimental environment of an $e\ e$ collider and a highly efficient detector system, opens up a broad range of physics opportunities, particularly in areas where missing energy in the final state plays a critical role.

One of the distinctive strengths of Belle II is its ability to study processes involving invisible particles — such as neutrinos or hypothetical dark sector candidates — with high sensitivity. Transitions with missing energy are particularly challenging in hadron collider environments due to the large and complex background, but they are much more tractable at Belle II thanks to the well-defined initial state and full event reconstruction techniques. These methods allow us to infer the presence of invisible particles and perform precision measurements of decay modes such as $B \to \tau\nu$, $B \to D^{(*)}\tau\nu$, and $B \to K^{(*)}\nu\bar{\nu}$, which are crucial probes of lepton flavor universality and potential signs of new physics beyond the Standard Model.

Recent results from Belle II already demonstrate its strong physics potential. Precision measurements of semileptonic B decays have begun to test the consistency of current tensions in the flavor sector, while early data on τ lepton decays and radiative transitions have set competitive constraints. Additionally, Belle II's ability to study rare and forbidden processes — including lepton flavor-violating τ decays, searches for light dark matter candidates, and invisible decays of the Υ(1S) — highlights the breadth of its physics reach.

This talk will present an overview of the most recent Belle II results, with particular focus on analyses that involve missing energy final states. We will discuss the methods used to identify these challenging processes, including full event interpretation (FEI), tag-side reconstruction, and advanced machine learning techniques to suppress background and maximize signal sensitivity. These tools enable Belle II to provide world-leading sensitivity in several key channels, offering a unique and complementary probe to the LHC experiments.

Looking forward, Belle II is accumulating data and improving detector performance. With each increase in integrated luminosity, the experiment's reach into rare processes deepens. The full physics program will be sketched not only the existing anomalies in the flavor sector — such as those related to $R(D)$ and $R(D^{\star})$ — but will also search for entirely new phenomena that could reveal the limitations of the Standard Model.

In summary, Belle II is entering a highly productive phase, with a diverse and growing portfolio of physics results. Its unique capability to explore transitions involving missing energy sets it apart as a key player in the global effort to uncover new physics in the flavor sector.

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