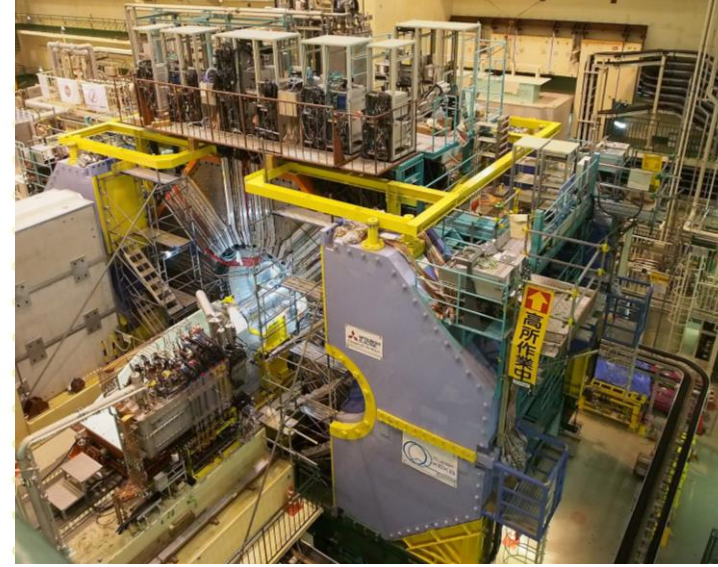
Master and Bachelor Topics



Belle II Group

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https://www.mpp.mpg.de/forschung/belle-ii

Belle II

MAX PLANCK INSTITUTE FOR PHYSICS

Boosting the performance of particle identification at Belle II

The Belle II detector in Tsukuba, Japan, detects asymmetric e+ e- collisions. These collisions produce different types of particles, such as B mesons or tau leptons, which decay into final state particles of different species, such as electrons, pions or protons. A major experimental challenge is to identify the species of the final state particles. To this end, Belle II is equipped with several special subdetectors for particle identification. Our group is taking a leading role in developing sophisticated algorithms to combine the information from these subdetectors.

You can help further improve these algorithms or study the performance of the particle identification at Belle II. You will learn the principles of particle identification, how to develop and implement particle identification algorithms using machine learning techniques, and how to measure their performance.

Are you interested in working with us on the fascinating and challenging particle identification at Belle II? Let's have a talk!

Contact: Stefan Wallner (swallner@mpp.mpg.de)
Level: Bachelor / Master

Fine tuning machine learning techniques for event selection

At Belle II detector in Tsukuba, Japan, we explore the frontiers of the unknown by recording asymmetric electron-positron collisions. In these collisions, various types of particles are produced, such as B mesons or tau leptons, which decay to final-state particles that are recorded with the detector. A major experimental challenge is the selection of a clean sample of candidate events for the reaction under study.

For the analysis of multi-body hadronic decays of tau leptons, we use a machine learning algorithm called Boosted Decision Tree (BDT), which is trained on a data sample of events from the Belle II simulation. Consequently, the quality of the trained BDT depends on the accuracy of the simulated data. Your talk can be to fine-tune the simulation using calibration samples from real data to refine our BDTs, pushing the boundaries of accuracy and discovery. You will gain hands-on experience with big data, master BDT training, and learn to evaluate their performance.

Are you interested in working in an exciting group and help us to get the best out of our data? Let's have a talk!

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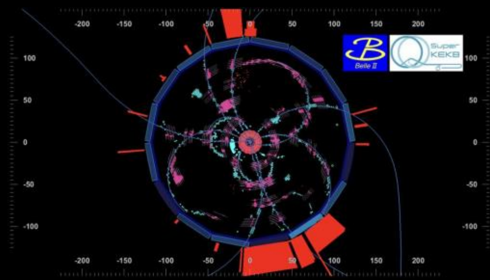

(MF3d / E+ via Getty Images)

Study of Quantum Entanglement and Coherence at Belle II

Entanglement is a fundamental property of quantum mechanics. Though well established with photons and light particles it hasn't been well studied with heave particles and at high energies. At Belle II B0/B0bar pairs are supposed to be in an entangled state. This is the basis of our measurement of time dependent CP violation. Though this assumption is well motivated it hasn't been tested rigorously. The topic of this thesis is to study various models of decoherence (spontaneous decoherence, finite coherence lifetime, etc) and investigate how these models can be tested (or excluded) with Belle II data.

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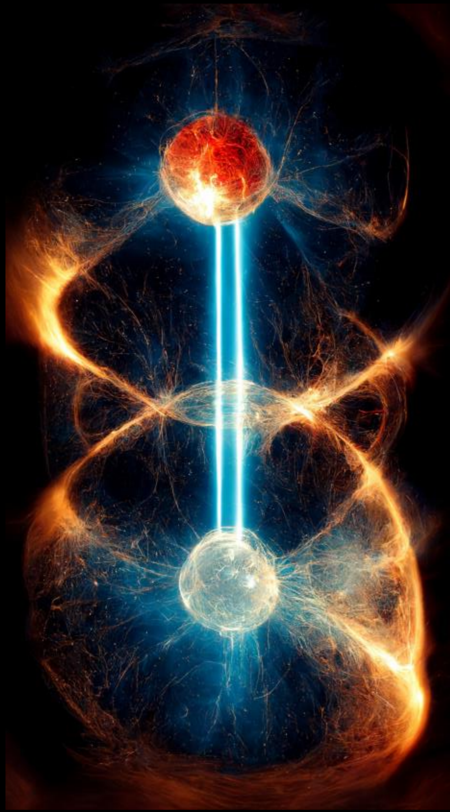

(Credit: Augusto / Adobe Stock)

Determination of Combinatorial Background using Event Mixing

Combinatorial background is a major background when reconstruction B.-Mesons in Belle II. It stems from B-events when random tracks are combined to form a fake signal events. Presently it is mainly determined using Monte-Carlo generators. Event mixing, however, opens the possibility to determine this background using real data. In events with a reconstructed B-Meson, the tracks of the meson are removed and two such events are combined to a new 'event' which is then used to search for random combinations faking certain signal events. The topic of this thesis is to develop this tool and study to what extend it offers a suitable tool for background determination.

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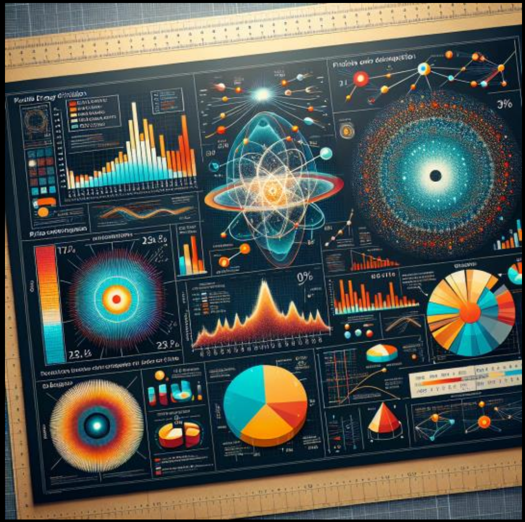
Level: Bachelor / Master

Estimation of various backgrounds in $B^0 \to J/\psi\ K^{*,0}$ decays

The study of how B^0 particles decay into J/ψ and $K^{*,0}$ particles gives us singular insights in understanding CP violation, which is the difference in the behavior of particles and their antiparticles. The Belle II experiment at KEK in Japan, with its high-precision detectors, provides an unique opportunity to study these decays accurately. By using the quantum entangled nature of $B^0\overline{B}^0$ pairs produced, we can measure the CP violation very precisely.

One of the crucial part of this analysis is to identify various backgrounds. By accurately modeling and subtracting various backgrounds, we can enhance the sensitivity as well as understand the systematic uncertainties or our measurement. The goal of your thesis can be to to identify and understand these backgrounds. You will learn to analyze data from the Belle II experiment and to understand the signal and background process of the $B^0 \to J/\psi\ K^{*,0}$ decays.



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Selecting Model Components in Partial-Wave Analyses using Regularization

At Belle II detector in Tsukuba, Japan, we explore the frontiers of the unknown by recording asymmetric electron-positron collisions. In these collisions, various types of particles are produced, such as B mesons or tau leptons. Decays of these particles into multi-body hadronic final states allow us study the Standard Model and probe for new physics. This is done using the so-called partial wave analysis, where the decay dynamics of these final states are modeled.

The models used typically consist of a large set of components, and it is not clear a priori which components need to be included. Your task can be to apply state-of-the-art regularization techniques from machine learning that allow us to infer the set of included components from the data. You will master partial wave analysis fits to data using your Python analysis framework, implement regularization in these fits to control the large model space, and interpret the obtained results.

Are you interested in working in an exciting and challenging environment with state-of-the-art technologies and push with us the high-precision frontier in particle physics? Let's have a talk!

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