IFJ PAN Particle Physics Summer Student Programme

Projects '18

Note that projects will be done in pairs.

1 Measurement of the direct CP violation in $B^+/B^- \to D_0 D_s$ using software from Belle II experiment

Supervisor: dr Karol Adamczyk, dr Olga Werbycka
Department of Leptonic Interactions (NZ11), room 0212

SuperKEKB, particle accelerator located at the KEK laboratory in Tsukuba (Japan), runs beams of electrons and positrons into each other to produce enormous quantities of B mesons. Products of collisions will be collected by Belle II detector – the 'super-B factory' upgrade of its predecessor, Belle. The first physics run with the complete detector is projected to start in February 2019. Until then we can process data from Belle experiment using the new software and algorithms developed for the analysis of data collected with the Belle II detector.

One of the physics goals of Belle II experiment is to investigate whether there are new CP-violating phases in the quark sector, what can improve our understanding of the subtle differences between matter and antimatter. The task for students is to perform physics analysis in which we want to measure difference between numbers of decays in $B^+/B^- \to D_0 D_s$ mode, what corresponds to estimation of direct CP violation.

2 Determination of the intrinsic resolution of Silicon Vertex detector of Belle II experiment

Supervisor: dr hab. Andrzej Bożek, mgr Mateusz Kaleta
Department of Leptonic Interactions (NZ11), room 0211

We will determine the intrinsic resolution of SVD detector. Belle II detector started to take data from April 2018. One of the first goal is to validate the detector performance and check the impact of improved detector on the measurements. We will also try to measure the impact parameters resolution. Students have to learn root and c++ code with embedded root libraries.

3 Readout and data processing of the SOI pixel detector

Supervisor: dr inż. Piotr Kapusta
Department of Leptonic Interactions (NZ11), room 0113

Students gather knowledge about operational principles and design of the Silicon On Insulator particle pixel detectors. Using available equipment they start to use the detector readout system under running on Linux, based on gcc and Socket API. Simultaneously, the acquire base knowledge about firmware development for FPGA components. Using the knowledge from the lectures, students develop their own readout system, exploiting capabilities of the ROOT package. Data collected with the new system is next used for evaluation of a quality of tested detectors.

4 Search for New Physics in the ATLAS detector at the LHC

Supervisor: dr Paweł Malecki
The ATLAS Experiment Department (NZ14), room 0218

After the discovery of the Higgs boson in 2012 by the ATLAS and CMS experiments the Standard Model, a theory describing the world of elementary particles, has been completed. Strong hints of existence of phenomena from Beyond Standard Model are however present. They include Dark Matter, the matter - antimatter imbalance and many more. Therefore, searches for New Physics are so important currently. The proposed project would involve participation in analyses searching for additional heavy Higgs bosons decaying into b-quarks or tau-leptons.

5 QCD scattering with and without transfer of colour charges

Supervisor: dr Rafał Staszewski
The ATLAS Experiment Department (NZ14), room 0204

In particle physics the interactions between particles in described as a particle exchange. For example, an electron-electron scattering is an exchange of a photon between the two electrons. In quantum electrodynamics, the particle responsible for the interaction – the photon – is not electrically charged.

The situation is quite different in the quantum chromodynamics (QCD) – the theory of strong interactions. Here, the carriers of the strong force – the gluons – carry colour charges (charges responsible for the strong interaction). This means that in a quark–quark scattering, one has a transfer of a colour charge between the interacting quarks. However, it is possible to consider an interaction in which more than a single gluon is exchanged. Then, it is possible that no overall colour transfer takes place.

The aim of the project it to study quark-quark interactions that occur in proton-proton collisions at the LHC accelerator. The analysis will be using a Monte Carlo generator that can simulate such interactions with and without the colour transfer. The ultimate goal is to understand the differences and identify the best observable for experimental discrimination between them.

6 Kinematic properties of scattered protons reconstructed in ATLAS forward detectors

Supervisor: dr Maciej Trzebiński
The ATLAS Experiment Department (NZ14), room 0207

Large Hadron Collider is the most powerful particle accelerator in the world. There are many theories which can be tested using the LHC data. One of them is so-called diffractive physics. Diffractive interactions are usually due to the exchange of a colourless object. It can be a photon (electromagnetic interactions) or so-called Pomeron/Reggeon (strong force). A colourless exchange does not change the quantum numbers – the interacting protons may stay intact. Such protons are usually scattered with very low angles, therefore one needs a dedicated detector installed far away from the interaction point in order to measure them. This is why such detectors, installed usually couple hundreds of meters from the interaction point, are often called 'forward detectors'.

Forward detectors allow not only to measure position of scattered protons, but also, using special unfolding methods, to reconstruct their kinematics (four-momentum). The goal of this project is to validate code for forward proton kinematic reconstruction based on data collected by ATLAS Forward Proton Detectors (AFP) in years 2016 – 2018.

7 Reconstruction of particle tracks using Deep Neural Networks

Supervisor: dr hab. Marcin Wolter
The ATLAS Experiment Department (NZ14), room 0219

Image classification using Deep Neural Networks (DNN) is a rapidly developing part of computer science. The techniques developed for various applications become also used in High Energy Physics, presently mostly for event classification. In the recent years DNNs the novel methods of particle tracks reconstruction in detectors are being developed.

The goal of the proposed task is to learn how to apply DNNs to various problems using the packages TensorFlow and Keras. After an introduction and exercises (like recognition of hand-written digits) I propose to reconstruct particle tracks in a simulated, simple 2D detector. The possible tasks are:

- reconstruction of a straight track in the detector and obtaining its parameters (slope and offset) from DNN,
- repeat the above exercise, but adding some noise,
- eventually we can try to reconstruct few particle tracks in one event.

8 Charged particle production in Xe+Xe collisions

Supervisor: dr hab. Krzysztof Woźniak
The ATLAS Experiment Department (NZ14), room 0206

The Large Hadron Collider at CERN accelerates beams of particles to the highest energies available in laboratories. Most of the time beams of protons are collided, however collisions of nuclei are also possible. In October 2017 for the first time beams of xenon nuclei were collided with the total energy of 5.44 TeV. Some results based on the data from these collisions were already obtained, however even some basic studies were not performed yet. During the three weeks of practical part of the Summer Student Programme the data from the ATLAS experiment will be analyzed. As a result first measurements of the properties of charged particles produced in the new type of colliding system at extremely high collision energy can be obtained. This project can be easily extended as a study for master thesis.

9 Detection of Cosmic-Ray Ensembles

Supervisor: dr hab. Krzysztof Woźniak
The ATLAS Experiment Department (NZ14), room 0206

The cosmic rays since their discovery have provided valuable information and discoveries. Even now the particles with highest energies are not those studied in laboratories and obtained form accelerators, but form the cosmic rays. Particles with highest energies are rare, so to detect them large observatories, like Auger Observatory, are build. However, new phenomena may manifest themselves not as a single particle, but as correlated ensembles of cosmic rays. If their origin point is far from the Earth, for example near the Sun, they may arrive to the Earth in places hundreds km apart. The CREDO project aims to combine data from all available detectors, including even individual smartphones, to find Cosmic-Ray Ensembles. Currently the development of reconstruction methods is necessary. The project for Summer Student Programme will include analysis of simulations of Cosmic-Ray Ensembles in order to reconstruct the direction of the incoming particles and visualize the results.

10 Development of the algorithm for a study of radiative charm decays at the LHCb experiment

Supervisor: dr Jolanta Brodzicka
The LHCb Experiment Department (NZ17), room 0313

Radiative decays of charm particles are very promising for New Physics searches owing to a presence of the final-state photon. The goal of this project is to contribute to the analysis of the data collected at the LHCb detector operating at the LHC collider at CERN. You will be working with the data in a ROOT ntuple format containing all the necessary information about the processes of interest. Based on the data simulations for the signal and background, you will optimize the signal selection procedure and criteria by employing a multivariate data analysis.

11 Data/simulation Corrections for the $B \to DX$ Decays

Supervisor: dr Agnieszka Dziurda
The LHCb Experiment Department (NZ17), room 0313

The fundamental particles and their interactions are described within Standard Model. This theory has been remarkably successful at predicting the behaviour of elementary particles. However it does not explain the visible asymmetry between matter and antimatter in the universe. One of the three conditions required for this asymmetry is charge-parity (CP) violation, which can be efficiently studied in the decays of beauty mesons.

The proposed Summer Student project focuses on the evaluation of the data/simulation corrections, which play a crucial role in obtaining unbiased CP measurements from the $B \to DX$ decays. In order to understand those corrections, the summer student would extend his/her knowledge about the kinematic and geometric properties of the decays in question, learn principles of performing a data analysis in a big experiment and investigate background subtraction method, which allows to quantify the difference. It is also a good occasion to develop C++/python skills which are needed for data analysis.

12 Study of the femtoscopic effects in LHCb experiment

Supervisor: dr hab. inż. Marcin Kucharczyk
The LHCb Experiment Department (NZ17), room 0315

The project concerns the study of the quantum interference effects using the analysis technique called femtoscopy with the data collected by the LHCb experiment. The method is based on measuring the two-particle density function describing the correlations between particles as a function of their four-momenta difference. The correlations originate from the effects of quantum statistics as well as the strong and Coulomb final state interactions. The parameters of the density function in the region of small four-momenta difference allow to determine the space-time properties of the hadron emission volume based on the quantum interference effect between indistinguishable particles emitted by a finite-size source.

13 Ultraperipheral muon production in ultraperipheral xenon-xenon collisions at the LHC

Supervisor: dr Mariola Kłusek-Gawenda
Zakład Teorii Silnych Oddziaływań i Układów Wielu Ciał (NZ21), room 0314

This Project aims at the theoretical analysis of ultraperipheral high energy collisions of heavy atomic nuclei. Ultraperipheral collisions are reactions in which an impact parameter (distance between two nuclei) is required to be larger than the sum of the two nuclear radii. The central issue in the Project is a calculation of the cross section for $Xe + Xe \to Xe + Xe + (\mu^+\mu^-)$ reaction. Results will be compared with the existing predictions for lead-lead collisions.

14 Time calibration of EMCal ALICE detector

Supervisor: dr Adam Matyja
Department of the Ultra-relativistic Nuclear Physics and Hadron Interactions (NZ23), room 0314

Time calibration of electromagnetic calorimeter (EMCal) of the ALICE detector is one of the most important calibration of this detector. It corrects readout time for both the electronic response and the cable length. The time information of a cell and a cluster is used for the pile-up rejection, hight voltage equalization and bad channel map determination. The time calibration coefficients are calculated for every period of data taking. The major goal of this task is to calculate time calibration coefficients for few periods and check the annual stability of the calibration.

15 Studies of photon-jet correlation in the ALICE experiment at the LHC

Supervisor: dr Adam Matyja
Department of the Ultra-relativistic Nuclear Physics and Hadron Interactions (NZ23), room 0314

A measurement of parton to jet fragmentation function can be done via studies of the back-to-back photon and jet events. Photons are ideal probes for jet energy estimation because they are colorless and so do not interact strongly. However, the photon-jet correlated events are approximately 100 times less frequent in comparison to jet-jet events. The main goal of the task are feasibility studies of photon and jet correlated events analysis in ALICE in Run 2.

16 Quark/gluon jets

Supervisor: dr Andrzej Siódmok
Department of Particle Theory (NZ42), room 4205

Experimentally partons (quarks and gluons) can be studied by analysing so-called jets (collimated spray of particles and energy) whose kinematic properties reflect those of an initiating (unmeasurable) parton. With a suitable jet definition, one can connect jet measurements made on clusters of hadrons to calculations made on clusters of partons. More ambitiously, one can try to tag jets with a suitably-defined flavour label, thereby enhancing the fraction of, say, quark-tagged jets over gluon-tagged jets. Being able to distinguish quark jets from gluon jets on an event-by-event basis could significantly enhance the reach for many new physics searches at the Large Hadron Collider. This is because BSM signals are often dominated by quarks (see for example a typical gluino-pair production topology is pictured in Fig. 1 while the corresponding SM backgrounds are dominated by gluons.

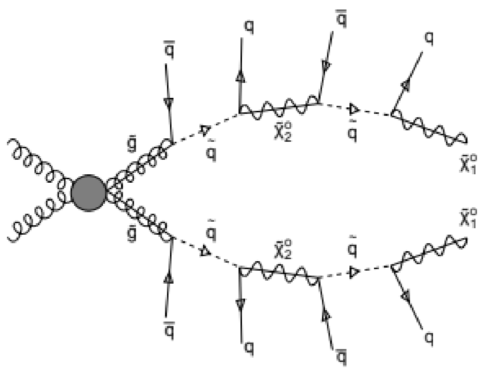

Figure 1: Gluino decay as an of a quark-heavy signal, in this case with 8 quark jets and no gluon jets produced. Multi-jet events in standard model backgrounds are extremely unlikely to have so many quark jets.

The aim of the proposed project is to construct observables which are sensitive to the differences between quark and gluon jets and study them using general purpose Monte Carlo generators.

General Purpose Monte Carlo (GPMC) event generators are designed to bridge that gap between theory and experiment. One can think of a GPMC as a 'Virtual Collider' that produces simulated collisions similar to those that are produced in the actual LHC experiments, and therefore its results can be directly compared against the experimental data. This is the reason why the GPMC event generators are central to high energy physics (HEP) and are an indispensable part of HEP experiments.