IFJ PAN Particle Physics Summer Student Programme

Projects '19

Projects will be done in pairs unless stated differently.

1 Study of acceptance effects in angular analysis at Belle II experiment

Supervisor: dr Karol Adamczyk
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 are collected by Belle II detector – the "super-B factory" upgrade of its predecessor, Belle. During practice we will analyze $B \to D^* h$ ($h = \pi, K^*, \rho$) decays, as testing ground for analysis of angular observables. Main task will be to study the factors, which decrease sensitivity in polarization measurements, in particular to check impact of acceptance effects and cross-feeds between decay modes at Belle II environment.

Tools: Belle II software, ROOT and Python libraries.

2 Measurement of the direct CP violation in $B \to D^0 D_s^*$ decays using software from Belle II experiment

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

There will be a possibility for students to walk through all the way from the very basic steps (event generation) to the analysis of the given decay channels using missing mass method and Belle II software. Study of CP violation for $B \to DDs^*$ decays should be made for the both: MC and Belle data. As a result, the script for B meson reconstruction should be written and a comparison between the results obtained by the (old) Belle software (given) and the Belle II software should be done.

3 Measurement of $B \to DD^{**}X$ decays in Belle II experiments

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

B mesons, due to large available energy in the reaction, decays to many particles. Partially, theses decays are unknown or produce poorly known particles. We will study on Belle II software framework reconstruction of decays when in the final state we have D^{**} mesons with is a generic name of several excited charm mesons.

4 Measurements of the Silicon On Insulator (SOI) pixel detector using the semiconductor laser

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 (SOI) particle pixel detectors. Using available equipment they start to use the detector readout system based on the Labview package. Next, the laser head positioning system, based also on the Labview, is glued to the readout system. Using the developed system the laser is calibrated and measurements of the detector parameters, like gain, linearity, Equivalent Noise Charge and full depletion voltage are performed.

5 DbExplorer migration from Linux SLC6 to Linux CC7

Supervisor: dr Elżbieta Banaś, mgr inż. Jolanta Olszowska
The ATLAS Experiment Department (NZ14), room 0221

DbExplorer is a browser of ATLAS Detector Control Data. It explores different Databases like DCS Archive or COOL (Database for data analysis). It is based on Atlas Trigger/DAQ libraries, Root package and APIs for Databases access. DbExplorer has been widely used by ATLAS Transition Radiation Tracker community.

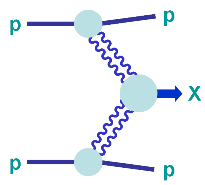
Students working on this project will be registered at CERN and using CERN computing infrastructure. They will collaborate remotely with DbExplorer developer and TDAQ software experts who will help them. Results of their job will be stored in CERN Git repository. It will be presented on ATLAS TRT Operation Meeting, where operational activities are reported by all TRT experts.

Project will be done by three students.

6 Search for invisible particles in exclusive processes at LHC

Supervisor: dr Rafał Staszewski, mgr inż. Krzysztof Cieśla
The ATLAS Experiment Department (NZ14), room 0204

In experiments carried out on hadron colliders, it is usually not possible to register all particles produced in an interaction. This is due to the fact that the interaction point cannot be fully surrounded with particle detectors. For example, there must be some empty space, through which the colliding beams arrive. However, a special class of interactions exists, they are called the exclusive processes, for which it is possible to register all produced particles. For example, the exclusive production of the Higgs boson is a process where the final state consists of only the Higgs boson and two protons: $p + p \to p + H + p$. Although the protons are produced at very small angles directly into the accelerator beam pipe, their energy is different than the energy of the protons of the beam. Thanks to this, their trajectories in the accelerator magnetic fields are different and it is possible to measure them in dedicated detectors located few hundred meters from the interaction point.



The goal of the project is to analyze data collected by the ATLAS experiment in order to search an exclusive process $p + p \to p + X + p$, where X is a particle or a pair of particles that do not interact neither electromagnetically nor strongly. Such particles are invisible for the detectors that surround the interaction point and escape undetected. An example of such particles could be neutrinos or some yet unknown dark matter particles. However, because the production takes place in an exclusive process, measuring the momenta of the produced protons and using the energy and momentum conservation, one can calculate the mass of the produced system. The project will consist of the following steps: selection of appropriate events, obtaining the distribution of missing mass, estimation of background.

7 Reconstruction of particle tracks using Deep Neural Networks and estimation of reconstruction errors

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 the novel methods of particle track reconstruction using DNNs are being developed.

The goal of the proposed task is to learn how to apply DNNs to various tracking problems using the packages TensorFlow and Keras. The task is to reconstruct particle tracks in a simulated, simple 2D detector, than the analysis could be extended to 3D. The proposed order of tasks is:

- Reconstruction of a straight track in the 2D detector and obtaining its parameters (slope and offset) from DNN,
- Repeat the above exercise, but adding some noise,
- Perform reconstruction using Mixture Density Network (MDM), which should allow to estimate the errors of track parameters.
- Repeat the above exercise for a track of a charged particle track in magnetic field. In this case the track has a shape of a helix (circle in 2D).

The project should be implemented using the Google Colaboratory http://colab.research.google.com, which allows creating iPython notebooks and offers free access to Graphic Processor Units (GPU), which speed up the network training. Therefore, the candidate should be willing to use the python language and to have the Google ID to be able to use the resources offered by Google.

8 Using Deep Neural for classification of multiparticle events

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

Deep Neural Networks (DNN) are a rapidly developing part of computer science. The techniques developed for various applications become also used in High Energy Physics, most frequently for event classification. The goal of the proposed task is to apply DNNs (implemented by packages TensorFlow and Keras) to classify the simulated particle collision events. Each event is described by a list of produced particles and each particle by a vector of variables. The important point is that the list of particles has variable length. Therefore, the DNNs have to be used in a non-straightforward way.

The task can be done in the following steps:

- Classification using a standard dense feed-forward network, in each event the list of particles has the same length, with "empty" particles added when needed.
- List of particles is replaced by histograms of each variable.
- Using the Long-Short Term Memory (LSTM) network to process the variable-length list of particles.

The results obtained by each method should be compared.

The project should be implemented using the Google Colaboratory http://colab.research.google.com , which allows creating iPython notebooks and offers free access to Graphic Processor Units (GPU), which speed up the network training. Therefore, the candidate should be willing to use the python language and to have the Google ID to be able to use the resources offered by Google.

9 Studies of properties of soft diffractive events based on output from Pythia Monte Carlo generator

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

Soft diffractive events are about a half of the total cross section for proton-proton collisions at the LHC energies. Measurement of their properties is, however, not easy since it requires tagging of forward protons. In last two years ATLAS Collaboration took such data. First distributions of number of events as a function of rapidity or particle multiplicity revealed disagreement with predictions from Monte Carlo generators obtained with default settings.

The aim of this project is to understand how a change of default settings in Pythia 8 Monte Carlo generator impacts distributions of diffractive events. During the project you should learn how to run MC generators with different settings and should create an automatic tool for a fast comparison of results from multiple samples.

10 Construction and tests of Arduino-based temperature readout

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

ATLAS Experiment, one of the four major detectors at the LHC, is equipped with special devices dedicated for measurement of scattered protons. Such system, called the ATLAS Roman Pots (AFP), is in operation since 2016. Roman pot technology allows to insert pots to close vicinity of the LHC beam, which is needed for data collection. On the other hand, close presence of the beam induces a significant amount of heat inside the pot. Pot structure is passively cooled by the AirCooler system. During 2016-2018 data-taking cooling was efficient enough. However, going to higher luminosities after the Long Technical Shutdown (LS2) may trigger the need to upgrade the AFP cooling system.

The aim of this project is to create an Arduino-based setup to monitor temperature. Setup should contain about 10, properly calibrated, temperature sensors. Information from sensors should be displayed in a simple GUI. After construction, system should be tested. Far a testbed a simple model containing heaters connected to the metal cylinder will be used. You should study the Ways of better heat dissipation like copper heat lines, passive and active radiators, etc.

11 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.

12 Detection of Cosmic-Ray Showers

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

The cosmic rays, since their first observation, have provided valuable information and discoveries. Even now the particles with the 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. The project for Summer Student Programme will include analysis of simulations of showers of particles created in the atmosphere by a single cosmic-ray particle in order to estimate the efficiency of their detection by a set of simple detectors. This result may be then used to obtain probability of detection of Cosmic-Ray Ensambles.

13 Search for the new physics in the ATLAS detector at the LHC

Supervisor: dr Bartłomiej Żabiński
The ATLAS Experiment Department (NZ14), room 0206

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 much more. Therefore, searches for the New Physics are so important. One of the signatures of new phenomena are heavy Higgs bosons predicted by supersymmetric models.

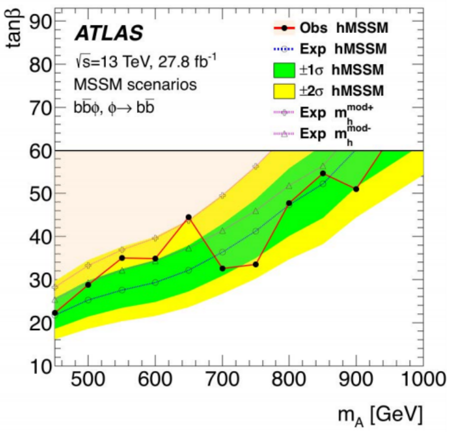


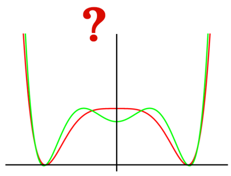
Figure 9: Observed and expected 95% CL exclusion limits for the hMSSM scenario as a function of m_A. The expected sensitivities for the $m_h^{\text{mod}+}$ and $m_h^{\text{mod}-}$ scenarios are also shown. The observed 95% CL limits for the $m_h^{\text{mod}+}$ and $m_h^{\text{mod}-}$ scenarios follow the same pattern with respect to their expected limits as the hMSSM observed limits. Limits are not shown for $\tan\beta > 60$ since the Higgs boson coupling becomes non-perturbative for very large values of $\tan\beta$ in the considered models.

In our project, we will focus on searching of heavy neutral Higgs bosons decaying into b-quarks. You will try estimate how we can improve results (see figure) of this analysis using multivariate methods such as Boosted Decision Trees or Neural Networks.

14 Two for the prize of one!

Supervisor: dr Bartłomiej Żabiński, dr Magdalena Sławińska
The ATLAS Experiment Department (NZ14), room 0206, 0220

Discovering the Higgs boson was the Holy Grail of LHC experiments. Since its discovery in 2012 the Higgs boson has been produced copiously and detected using various decay channels by the ATLAS and CMS experiments. Theory predicts that not only single Higgses, but also double Higgs bosons are produced in a single proton-proton collision! In some of these events the two Higgs bosons originate from the splitting of a single Higgs. Measuring the strength of these self-interactions will cast light onto the electroweak symmetry breaking: it could determine if the Higgs potential has the Mexican hat shape of the red line (as predicted by the SM), or a different one (the green line, for example), predicted by New Physics theories.



Double Higgs production is extremely rare. It requires sophisticated experimental techniques and analyzing many decay channels in order to observe signal events. A very recent idea adopted by the ALTAS experiment is to search for double Higgs events through its various leptonic decays. In this analysis we do not distinguish, if any of the Higgses decays to Z, W bosons or tau leptons but use all these processes at once to detect as many events as possible.

In your task you will use data events collected by the ATLAS experiment and these generated by Monte Carlo programs. The aim is to study feasibility of discovering double Higgs production through its semi-leptonic decays as predicted by different New Physics theories. To perform this task you will use ROOT framework and write scripts in Python or C++. In order to maximize sensitivity we plan to apply Machine Learning techniques such as Boosted Decision Trees and Neural Networks in the signal selection. During this project you will get acquainted with the work in the ATLAS Collaboration and will develop your programming skills. You will learn to apply Machine Learning packages such as TMVA and Keras.

15 Radiation damage of the silicon sensors and (on)detector electronics in ATLAS experiment on the LHC and beyond

Supervisor: dr hab. Ewa Stanecka
The ATLAS Experiment Department (NZ14), room 0204

The high-radiation levels in the detectors at the LHC arise primarily from the large number of minimum bias interactions that occur during each beams collision. The radiation environment comprises a full spectrum of particles, causing both ionizing and non-ionizing radiation effects on tracking detector electronics. The harmful effects of radiation on the silicon detectors affect both the sensor and the on-detector electronics. In the frame of the proposed project, students can realize one or two topics. The first is the analysis of the radiation induced changes of the ATLAS silicon sensor macroscopic properties, such as the leakage current, in course of the LHC data-taking. The second part of the project concerns analysis of the data from the irradiation tests of the electronics being prepared for the upgrade of the ATLAS detector for High Luminosity LHC.

16 Study of neutrino interactions in the T2K experiment

Supervisor: dr Marcela Batkiewicz-Kwaśniak, dr Tomasz Wąchała
Department of Cosmic Ray Research and Neutrino Studies (NZ15), room 0319

One of the goals of the T2K experiment is to measure neutrino-nuclei cross sections in order to improve our knowledge of neutrino interactions. The aim of the project is to test the methods of selection of the various channels of neutrino interactions and compare the predictions of various theoretical models.

17 Acquainting with the techniques of data analysis in large experiments of the high energy astrophysics (Baikal - GVD, Auger experiments, and CREDO)

Supervisor: Konrad Kopański, dr Paweł Malecki
Department of Cosmic Ray Research and Neutrino Studies (NZ15), room 0102

For over one hundred years cosmic rays, *i.e.* particles (atomic nuclei, neutrinos, photons, *etc.*) arriving to Earth from deep space, have been the subject of the continuing research using increasingly advanced detectors. Observations have revealed that the energy spectrum of these particles extends over many orders of magnitude in energy, from around 10^7 eV, up to the highest energy observed so far, exceeding 10^{20} eV. Thus the most energetic particles of the cosmic rays allow us to study phenomena occurring at energies significantly exceeding energies which can be reached in the most powerful terrestrial accelerators.

Among many cosmic ray experiments, the Institute of the Nuclear Physics PAN is involved in the Baikal Gigaton Volume Detector Neutrino Telescope (http://baikalgvd.jinr.ru), ultra-high energy cosmic rays detection by the Pierre Auger Observatory in Argentina (http://www.auger.org), and in CREDO, Cosmic-Ray Extremely Distributed Observatory (http://credo.science).

Apprenticeships will begin with a few short lectures, introducing to the high and ultra-high energy astroparticle physics, and getting acquainted with the main tool for data analysis and simulation – ROOT. Moreover, there will be a short presentation, showing the works during research expeditions, carrying out for the purpose of extension and service of BGVD underwater neutrino telescope. After their completion, trainees will be given a short tasks aimed at presenting a few selected issues using Root (statistical analysis, graphics), related to the previously discussed experiments.

Project will be done by four students.

18 Quark/gluon jet discrimination using Machine Learning

Supervisor: dr hab. Marcin Chrząszcz, dr Andrzej Siódmok
The LHCb Experiment Department (NZ17), room 0307, 4205

The task of this project is to develop an machine learning (aka AI) algorithm that will discriminate between jets originating from gluons and quarks. The discrimination between these two types of object is hard however if successfully performed the algorithm will be used in real data analysis by large collaborations like ATLAS and CMS. The importance of such measurement is the fact it posses the sensitivity to proton pdfs as well as to some New Physics Models.

19 Search for lepton violation in $B \to Ke\mu$ decay in the LHCb experiment

Supervisor: dr hab. Marcin Chrząszcz, prof. dr hab. Mariusz Witek
The LHCb Experiment Department (NZ17), room 0307, 5317

The aim is to perform one of the elements of data analysis using data collected by the LHCb experiment operating at the LHC collider at CERN. The starting point will be data in the reduced format of ROOT package, so-called ntuple, which contain all necessary information about the decay. The selection algorithm based on machine learning (TMVA package) will be developed using Monte Carlo as a signal and data outside B meson mass as background.

20 C++ interfaces for KaTie

Supervisor: dr Andreas van Hammeren
Department of Particle Theory (NZ42), room 4210

KaTie is a parton-level Monte Carlo generator written in Fortran 2003. It is a standalone program, that however includes a few modules that may be useful on their own. The task of the students will be to write C++ interfaces for these modules so that they can conveniently be used in C++ programs. The only requirement is some knowledge of C++. The project will start with a small introduction to the concepts and working of Monte Carlo generators.