Projects for summer students 2022

P1. Quantum vortices in nontrivial superconductors

Supervisor: Egor Babaev (babaev@kth.se)
Division: Condensed matter theory
Time when project is available: any time during the summer

Superconductors, materials without resistance, can have tiny electronic tornadoes: quantum vortices. At least two Nobel prizes, to Abrikosov and to Kosterlitz and Thouless, were connected with the physics of these quantum vortices. These vortices can form "vortex crystals", "vortex glasses" or vortex-antivortex pairs. In recently discovered superconductors, they can form more complex structures. Those I can study by relatively simple methods by mapping vortices onto particles https://iopscience.iop.org/article/10.1088/1361-648X/29/3/035602 . Investigation of these structures will be the subject of this project

P2. Detector statistics for applications in microdosimetry

Supervisor: Torbjörn Bäck (back@kth.se)
Division: Nuclear Physics, in collaboration with SSM
Time when project is available: preliminary from early June to early/mid July, 2022

Measurements using micro-dosimetric techniques have a long tradition in Sweden and are today well established at the Swedish Radiation Safety Authority (SSM), for a wide range of radiation fields. In an ongoing research collaboration between KTH and SSM we are probing the limits for some of these techniques, to be applied in future dosimetric measurements, e.g. at proton therapy facilities.
Of particular success has been the so-called *variance-covariance* method, a method that in some cases is the best or only choice, i.e. at very high rates and/or at detector gas pressures below the gas multiplication region. In the variance method, extremely small current variations in a radiation detector is used to get information about the radiation quality, rather than the amplified energy signals of individual pulses.
The focus in this student project is to investigate some of the aspects of the statistical methods used for extracting information connected to the radiation quality from the signal. In particular, the connection between mathematical statistics theory and the measured detector signal is of interest. Both formulation and investigation of analytical expressions and statistical analysis of the acquired detector data can be part of the project.

P3. Real time data acquisition software for nuclear security and radioactive waste characterization

Supervisor: Bo Cedervall (bc@kth.se)
Co-supervisor: Jana Vasiljevic
Division: Nuclear Physics
Time when project is available: any time during the summer

Task: write a GUI that runs the real time data acquisition and data presentation for a radiation detection system for nuclear security or radioactive waste characterization. The GUI should be written in Python, integrating with C++ routines accessing the hardware and performing data analysis in real time.

More information on https://www.physics.kth.se/nuclear

P4. Physics of medical imaging at the cellular level

Supervisor: Mats Danielsson (md@mi.physics.kth.se)
Division: Physics of Medical Imaging
Time when project is available: any time during the summer

Medical imaging today is limited in resolution to the order of 1 mm for whole body imaging. We are proposing a new method with a factor 1000 higher resolution, down to 1 micrometer. For the first time medical imaging could be performed at the scale of individual cells and this could have far reaching impact on detection and diagnosis of the most common diseases such as stroke and cancer. The project will contain literature study, computer simulations using MATLAB or Python and input will be used to optimize the design of future prototypes for imaging hardware.

P5. Integrable systems

Supervisor: Edwin Langmann (langmann@kth.se)
Division: Condensed matter theory
Time when project is available: any time during the summer

I have several possible projects suitable for ambitious students related to Calogero-Moser systems and soliton equations. They require a combination of numerical and analytic methods. To get an impression what this is about, you can use Google and search for “soliton equations”, “Korteweg-de Vries equation”, “Calogero-Moser model” (Wikipedia and/or Scholarpedia have good introductions).

P6. Particle physics research with the ATLAS experiment at CERN

Supervisor: Christian Ohm (chohm@kth.se)
Co-supervisors: Jonas Strandberg**,** Alexander Leopold, Olle Lundberg
Division: Particle and Astroparticle Physics
Time when project is available: flexible as long as it ends before Aug

We offer a choice of two different projects related to our ongoing research activities as part of the ATLAS experiment at CERN. The first project concerns simulation studies and development of reconstruction algorithms for the new High-Granularity Timing Detector which will provide the ATLAS experiment with high-precision timing capabilities (~30 ps) using a novel type of silicon detector. This project will provide opportunities to learn about detailed simulations with Geant4, large-scale software frameworks, and/or modern machine-learning techniques. The second project concerns the development of techniques and strategies for finding new heavy and long-lived particles (e.g. in the context of supersymmetry) using timing information. If successful, the strategies could be deployed in Run 3 of the Large Hadron Collider in the coming year, and used in the real-time selection of events to be recorded by ATLAS. This project will provide opportunities to learn more about relativistic kinematics, real-time data processing, and physics beyond the Standard Model. Both projects will give insights into experimental particle physics research at the world's most powerful particle collider and experience from working the context of a large international collaboration.

Practical info: we will provide the candidate with office space, relevant computing resources and software frameworks, regular meetings and high availability to discuss progress and questions. We will encourage (and help organize) that the work is presented in a meeting of the relevant working group of the ATLAS collaboration at CERN.

P7. Development of deep-learning-based image reconstruction methods for photon-counting x-ray computed tomography

Supervisor: Mats Persson (mats.persson@mi.physics.kth.se)
Division: Physics of Medical Imaging
Time when project is available: any time during the summer

The Physics of Medical Imaging division at the Department of Physics, KTH, is one of the leading research groups in the world within the field of photon-counting spectral x-ray computed tomography, an emerging technology which will be the next major advance in medical x-ray imaging. In this project, you will take part in applying deep-learning methods for developing state-of-the art image reconstruction methods for photon-counting CT, in order to obtain the most accurate possible quantification of the distribution and atomic composition of the tissues in the body based on the measured spatial and energy distribution of transmitted x-ray photons. The main tasks will be training convolutional neural network for image reconstruction and evaluating their performance on simulated data, as well as contributing to writing research articles. If time permits, we will also look into using advanced statistical methods to tackle the largely unexplored problem of how to provide accurate error estimates of the resulting image estimates. This project lies right at the research front in the physics of medical imaging and will give a rare opportunity to work in a cross-disciplinary team and experience how fundamental physics and mathematics can be applied to developing important new tools for medical science.

P8. Project in theoretical nuclear physics

Supervisor: Chong Qi (chongq@kth.se)
Co-supervisors: Ramon Wyss, Roberto Liotta
Division: Nuclear Physics
Time when project is available: any time during the summer

We are looking for a student that can work on one of the following subjects:
a)Machine learning algorithms for nuclear physics. We will explore the possibility to apply various machine learning algorithms in solving complex quantum many body problems, in particular the nuclear alpha, pairing and nuclear mass prediction which are important for the nucleosynthesis of heavy elements. We have recently developed a tool for analyzing nuclear alpha decay with neutral network. **b) Development of Dirac equation solver.** The aim of this project to develop a user friendly and open source “Dirac equation solver” with all vector, scalar and tensor potentials with potential impact in both the research and teaching community. The student can start from scratch or rewrite the existing preliminary codes we wrote in python and Matlab. **c) The existence of a bound tetraneutron.** In this project we would like to develop a simple tool to study the tetraneutron and its stability. A tetraneutron is a hypothetical stable system consisting of four neutrons. There is some empirical evidence suggesting that this particle may exist as a bound state or a narrow resonance. The stability of tetraneutron may be critical for our understanding of the strong force.