DESY Ukraine Winter School 2023

Tuesday, 31 January 2023 - Friday, 10 March 2023

Book of Abstracts

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IceCube Upgrade optical module characterisation

Authors: Sarah Mechbal[1]; Summer Blot[2]

[1] *DESY Zeuthen*

[2] *Z_ICE (IceCube+NG)*

Corresponding Author: summer.blot@desy.de

In 2025/26 hundreds of new optical modules, which use photomultiplier tubes, will be deployed in the deep ice at the South Pole to detect Cherenkov radiation produced by high energy neutrinos. At DESY we are building and testing these modules to ensure they meet the desired performance requirements. This project will involve characterising the response of modules in realistic (sub-zero) temperatures and using external light sources (e.g. pulsed laser) to determine essential optical performance parameters.

Field:

C2: Instrumentation for Astroparticle Physics

DESY Place:

Zeuthen

DESY Division:

AP

DESY Group:

IceCube/Neutrino

Special Qualifications::

experience with python programming, interest in hardware calibration

3

Long-lived Particles at the FCC-ee

Author: Juliette Alimena[1]

Co-author: Freya Blekman [2]

[1] *Ohio State University*

[2] *DESY/University of Hamburg*

Many physics problems such as the nature of dark matter predict particles with long lifetimes as an important possibility in the search for new phenomena. When produced at colliders, these long-lived particles (LLPs) have a distinct experimental signature: they can decay far from the collision point, or even completely pass through a detector before decaying. Since most of the trigger and reconstruction algorithms are optimized for short-lived particles, searches for LLPs can be challenging, usually requiring dedicated methods and sometimes also dedicated hardware to spot them. This project aims to study the sensitivity that a proposed circular electron-positron collider, the FCC-ee, will have to LLPs. The clean collision environments at electron-positron colliders will provide exciting opportunities to search for several types of LLPs. This project will focus on one example LLP

physics case, namely, axion-like particles (ALPs), which were introduced in the 1980s in theories beyond the standard model to address the strong CP problem. Building on previous work, the student will analyze a long-lived ALP signature in the future FCC-ee environment.

70% physics, 30% computing, 0% engineering

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

The student should have a basic understanding of and experience with Linux and C++/python programming. Experience with ROOT and RDataFrame is a plus. Advanced lectures in particle physics would be helpful.

4

Model-based analysis of nanoscale interface evolution during spray coating

Author: Stephan Roth[1]

[1] *FS-SMA (Sustainable Materials)*

In modern thin film technology, spray coating plays a crucial role in fabricating flexible electronics and photovoltaics. The complex interface and multilayer structure are deduced by surface-sensitive scattering methods [1]. Spray coating was applied to create functional layers, from novel latex colloids to complex biomaterials templates [2,3]. There is a strong need to go beyond a one-dimensional analysis and to investigate the use of simulation-based analysis. The real-space structure is modeled (size and distribution of the nanostructures in three dimensions), the scattering pattern is calculated and compared to the experimental data. Hence, the goal of this project is to simulate the scattering pattern based on established algorithms and based on our results recently obtained [2,3,4]. The project includes image analysis, machine learning, supercomputing, as well as establishing reliable and feedback fitting routines. The simulations will be compared to previously acquired data [2,3,4]. Ultimately, the project participates in establishing a digital twin of the real experiments. The project is 50% physics and 50% computing.

Literature:
[1] S. V. Roth: "A deep look into the spray coating process in real-time—the crucial role of x-rays", J. Phys.: Condens. Matter 28, 403003 (2016)
[2] J. Engström, C. J. Brett, V. Körstgens, P. Müller-Buschbaum, W. Ohm, E. Malmström, and S. V. Roth: "Core–Shell Nanoparticle Interface and Wetting Properties", Adv. Funct. Mater. 30, 1907720 (2020)
[3] C.J. Brett, N. Mittal, W. Ohm, M. Gensch, L. P. Kreuzer, V. Körstgens, M. Månsson, H. Frielinghaus, P. Müller-Buschbaum, L.D. Söderberg, and S. V. Roth: "Water-Induced Structural Rearrangements on the Nanoscale in Ultrathin Nanocellulose Films", Macromolecules 52, 4721 (2019)
[4] C. J. Brett, W. Ohm, B. Fricke, A. E. Alexakis, T. Laarmann, V. Körstgens, P. Müller-Buschbaum, L. D. Söderberg, and S. V. Roth: "Nanocellulose-Assisted Thermally Induced Growth of Silver Nanoparticles for Optical Applications", ACS Appl. Mater. Interfaces 13, 27696 (2021)

Field:

A3: Soft-matter sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-SMA

Special Qualifications::

Programming experience is helpful

5

Quantum dynamics with normalizing flows

Authors: Andrey Yachmenev[1]; Yahya Saleh[1]

[1] *FS-CFEL-1-CMI (CFEL-CMI Controlled Molecular Imaging)*

In this project, we are investigating the viability of applying machine learning to quantum mechanical simulations of molecular dynamics, such as molecular vibrations and rotations in external fields and electron ionization by strong laser fields. The underlying concept of this method is to find solutions to the Schrödinger equation using recurrent neural networks combined with normalizing flows, also known as recurrent flow networks. Depending on the student's qualifications, the student's role will be to examine, through numerical simulations, the performance of various model modifications in dynamics simulations or to conduct a rigorous mathematical analysis of convergence properties.

Field:

A6: Theory and computing

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

CFEL-CMI

Special Qualifications::

experience in machine learning and Python programming, good knowledge of mathematics

6

Upgrade of CMS LHC beam pickup logic

Author: Alan Campbell[1]

[1] *CMS (CMS Fachgruppe DAQ, SW, Computing)*

The beam pickup signals are processed at the CMS experiment at CERN by a programmable logic board programmed in VHDL. Coincidences between the signals from clockwise and counterclockwise beams are formed and provided to the CMS trigger logic. This project will reimplement the logic on a modern Cyclone V based FPGA and verify its operation by simulating LHC bunch patterns. Additional monitoring and readout capabilities will be developed.

Field:

B3: Development of experimental particle physics equipment (hardware-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Some experience in electronics and FPGA programming desirable.

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ATLAS ITk Strips EC System Test Instrumentation

Author: Maximilian Felix Caspar[1]

Co-authors: Jan-Hendrik Arling [2]; Sergio Diez Cornell [3]

[1] *ATLAS (ATLAS-Experiment)*

[2] *DESY*

[3] *ATLAS (ATLAS Upgrade)*

Context of the project

The ATLAS detector is one of the four LHC experiments and will be upgraded for the upcoming high luminosity runs. The inner detector is going to be entirely replaced by an all-silicon tracker (ITk). The System Test is the main testbench for detector modules. The goal is to have a realistic environment close the the real detector in terms of electrical noise, atmosphere, cooling and detector systems.

Scope of work

The student will have the opportunity to work on the interlock & monitoring system of the system test. This includes work on topics such as CO2 cooling, environmental monitoring and personnel safety switches. Students should already have some basic experience with Python, since this is the

language all PLCs, GUIs and data servers are written in. Also, there will be an opportunity to test the first silicon detector elements once they arrive at DESY.

Deppending on the project state at their arrival, they can also perform one or more of the following studies:

1. Measurement of coldbox atmosphere under the influx of dry air supply, determination of an ideal flow rate for flushing and atmosphere maintainance
2. Measuring pedestals & noise in different detector positions and mapping the electrical noise environment of the ST.
3. Simulation of cosmic muon measurements with the ST structure.
4. Determination and implementation of interlock rules for the coldbox, HV system and cooling plant.
5. CO2 cooling measurements (e.g. maximum power, lowest temperature, cooling cycle times, …)

Field:

B3: Development of experimental particle physics equipment (hardware-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

Some knowledge of Python and Basic Electronics

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CMS Tracker Alignment, DESY CMS group

Authors: Sandra Consuegra Rodriguez[1]; Henriette Petersen[2]; Rainer Mankel[3]

[1] *CMS (CMS Fachgruppe HIGGS)*

[2] *CMS (CMS Fachgruppe TOP)*

[3] *DESY*

The DESY CMS tracker alignment group is a team responsible for development and operation of the software tools performing the alignment of the CMS silicon tracker detector. In the context of this project, the student will join the DESY tracker alignment group, learn to work with the data-driven methods used to derive the alignment parameters & their validation, and participate in the ongoing group efforts.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Python, C++, shell

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GPUs 4 top quarks

Authors: Freya Blekman[None]; Matthias Komm[1]

[1] *CMS (CMS Fachgruppe Searches)*

Top quarks are important particles that, due to their large mass, provide a direct probe to the Higgs sector and possible extensions of the standard model of particle physics. At the LHC, the standard model predicts top quarks to be produced in pairs, alone, or in groups of four, of which the CMS experiment recently observed evidence. The production of three top quarks is another order of magnitude rarer than the production of four top quarks.

The reconstruction of multiple top quarks from events with many jets, leptons, and missing transverse energy is challenging at the LHC. In particular, disentangling the individual neutrino momenta from the measured momentum imbalance is crucial for reconstructing the mass of new, exotic particles decaying to top quarks. The method of choice to solve such problems is kinematic fitting yet the currently available tools, developed primarily for top quark pair production, are computationally inadequate for handling the increased complexity of final states with 3 or 4 top quarks.

The project consists of a novel implementation of kinematic fitting for reconstructing events with multiple top quarks by harnessing the parallelization capabilities of modern GPUs. Technically, the task will be solved by repurposing existing frameworks and minimization algorithms developed initially for training neural networks. Hence no detailed knowledge of GPU computing is required. If successful, the resulting kinematic fitting framework will open entirely new analysis channels to search for beyond the standard model physics.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Python

10

The effect of the atmospheric composition on CTA performance

Authors: Gernot Maier[1]; Orel Gueta[1]; Victor Barbosa Martins[2]

[1] *Z_CTA (Cherenkov Telescope Array)*

[2] *Z_CTAS (CTA IKC)*

Studying the Universe at the highest energies with photons above 10s of GeV requires a very special detector, the atmosphere. When very-high-energy (> 10 GeV) gamma rays hit the atmosphere, they produce an extended air shower of electromagnetic particles, which in turn induce Cherenkov radiation. The distribution of Cherenkov light induced and its probability of reaching the detectors on the ground depend on the atmospheric conditions. In this project, simulations of air showers including all relevant particle interactions will be used to estimate the effect of various atmospheric compositions on the performance of the Cherenkov Telescope Array (CTA), taking into account e.g., the increase of CO_2 due to anthropogenic activity.

Field:

C1: Astroparticle physics analysis and observations

DESY Place:

Zeuthen

DESY Division:

AP

DESY Group:

CTA

Special Qualifications::

Basic knowledge of Unix and Python would be useful. The project would consist of 60% Computing, 40% Physics.

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TANGERINE –Test beam characterization of Monolithic Active Pixel Sensors

Author: Finn Feindt[1]

Co-author: Gianpiero Vignola [1]

[1] *ATLAS (ATLAS-Experiment)*

Tracking detectors are key parts of the instrumentation in high energy physics experiments, and their majority is making use of silicon pixel sensors to detect charged particles. A new generation of Monolithic Active Pixel Sensors (MAPS), produced in a 65 nm CMOS imaging process, promises higher densities of on-chip circuits and hence smaller pixel sizes or more sophisticated circuitry. MAPS offer the possibility to build cost-effective and light silicon detectors with a low power consumption.

The TANGERINE project aims for a sensor with a spatial resolution below 3 µm, temporal resolution between 1 ns to 10 ns and a physical thickness below 50 µm, suitable for future Higgs factories or as beam telescope in beam-test facilities, to serve as reference for other detector developments. To

optimize the layout of the new sensor, an extensive program of simulations is pursued, which needs to be validated in terms of comparison to measurements.

A batch of test chips, produced in the same 65 nm CMOS imaging process, was tested at the DESY II Test Beam facility early summer 2022. DESY II provides electrons with an energy of up to 6 GeV at rates on the order of 10 kHz. To reconstruct reference tracks, a EUDET-type beam telescope was used. A track based analysis of the data set is performed using the CORRYVRECKAN framework –a standard tool for the analysis of test beam data –to reconstruct observables like hit efficiency, cluster size, spatial and temporal resolution. Within this framework, advanced algorithms for the reconstruction of the particle hit position will be employed.

The student will learn the basics of hit reconstruction in segmented detectors, particle tracking, and pixel sensor characterization. The analysis will be based on the open source software frameworks ROOT and CORRYVRECKAN, both written in C++. Prior knowledge in linux, shell, C++ and ROOT will be helpful but are not required.

Field:

B3: Development of experimental particle physics equipment (hardware-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS, Tangerine

Special Qualifications::

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Tangerine Project: Transient Simulation Studies in a 65 nm CMOS Imaging Process

Author: Anastasiia Velyka[1]

Co-author: Manuel Alejandro Del Rio Viera [2]

[1] *DESY*

[2] *ATLAS (ATLAS-Experiment)*

The implementation of new detector technologies is mandatory to continue the rapid evolution of High Energy Physics Experiments. The goal of the Tangerine project is to develop the next generation of monolithic silicon pixel detectors using a 65 nm CMOS imaging process, which offers a higher logic density and overall lower power consumption compared to previously used processes.

The performance aim of the project is to achieve excellent spatial and time resolutions, below 3 µm and around 1 ns respectively. In order to understand the processes and parameters that are involved in the developments in the new 65 nm technology, a combination of Technology Computer-Aided Design (TCAD) and Monte Carlo (MC) simulations are utilized. The simulation results can later be compared to results from test beam experiments.

Transient simulations enable the study of the response of a sensor over time, i.e. the pulse produced after a charged particle passes through the sensor. The study of these signals is important to understand the time response of the simulated sensors, and enabling the use of time-overthreshold and time-of-arrival measurements in simulated data. One approach to this is by tuning physical parameters that intervene during the signal formation. Although TCAD simulations alone are very precise, the time to produce a pulse is several orders of magnitude larger compared to a combination of Monte Carlo and TCAD simulations.

This project will validate the pulse signals obtained with a Monte Carlo and TCAD combination by comparison with pure TCAD results, using different mobility and recombination models as tuning parameters.

The selected student will learn the basics of TCAD and Monte Carlo simulations and how to implement simulations to analyze the response of pixel sensors. The simulations will be performed using Synopsys TCAD and the Allpix Squared framework. Prior knowledge in Linux, Shell, C++ and ROOT will be helpful but is not required.

Field:

B3: Development of experimental particle physics equipment (hardware-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS (Tangerine)

Special Qualifications::

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CMS Tracker Module Testing

Author: Andreas Nuernberg[1]

Co-author: Doris Eckstein [1]

[1] *CMS (CMS Fachgruppe Detektor)*

We offer a project related to the CMS Outer Tracker Upgrade. At DESY, we will produce 1200 PS modules, whose components have to be tested prior to assembly. Moreover, assembly procedure are currently being verified as well as the testing procedures for final modules.
The student will involved in these activities working in the Detector Assembly Facility.

Field:

B3: Development of experimental particle physics equipment (hardware-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

15

UV laser beamline diagnostics @REGAE

Author: Max Hachmann[1]

Co-author: Klaus Floettmann [2]

[1] *MPY (Beschleunigerphysik)*

[2] *Desy*

For the new UV GUN laser beamline @REGAE there is a huge need to get a highly precise virtual cathode diagnostic. The design is done and the diagnostic has to be set up in cooperation with experienced members of the group. If the setup is ready the optimization of the laser beam alignment and characterization of the laser beam is the main topic. Some knowledge about data analysis would be required.
The aim is to impart basic concepts of beam transport and practical experience/knowledge about the interplay of lasers and particle accelerators.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MPY

Special Qualifications::

Experience with Matlab would be beneficial

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CMS Phase-2 Tracker Integration

Author: Anastasiia Velyka[1]

Co-author: Moritz Guthoff [1]

[1] *DESY*

The student will participate in various activities related to the integration of the CMS Phase-2 Tracker Endcap.
The integration of detector modules onto the supporting mechanical structure brings various challenges that have to be addressed. The thermal coupling of the PS detector modules using a thermal interface material has to be established. Candidate materials are being studied. The thermal and mechanical properties are evaluated and material application techniques have to be developed und conjunction with a module integration procedure that needs to be established. The quantification of the thermal conductivity of various materials used in the detector construction is needed, using a dedicated measurement setup. Module integration needs to be exercised including service routing.
These ongoing activities provide ample opportunities for a student to engage in hands on activities in the detector construction. Exact task descriptions have to be defined close in time depending on the progress of the project.

Field:

B3: Development of experimental particle physics equipment (hardware-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

17

Capacitance Studies of a Monolithic Active Pixel Sensor in a 65 nm CMOS Imaging Technology

Author: Adriana Simancas[1]

Co-author: Anastasiia Velyka [1]

[1] *DESY*

Monolithic CMOS sensors have found their way into High Energy Physics thanks to multiple advantages in particle detection. Their main characteristic is the integration of the sensor and the readout electronics in a single chip, which provides a reduction in production effort, costs and material. As part of the next generation of silicon pixel sensors, that are usually employed as tracker and vertex detectors, a sensor produced in a 65 nm CMOS imaging process is being investigated at DESY. Device (TCAD) and Monte Carlo (Allpix^2) simulations are needed to develop an understanding of this technology and to obtain insight into performance parameters of the sensor, which can be tested in experiments. The capacitance of a sensor has a crucial impact on its signal-to-noise ratio, and this information can be obtained by performing a small-signal AC analysis in TCAD. This project will study the capacitance of a 65 nm CMOS imaging sensor by means of TCAD simulations (90%), as well as comparing the simulation results with laboratory measurements (10%).

Field:

B3: Development of experimental particle physics equipment (hardware-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

Basic knowledge on silicon detectors and notions on programming (any language).

18

Completion and documentation of a public Open Data analysis example combining CMS and ATLAS Higgs->four lepton signals in the the context of PUNCH4NFDI

Authors: Achim Geiser[1]; Yewon Yang[None]

[1] *CMS (CMS Fachgruppe QCD)*

Open Data analysis examples in High energy physics are so far available
in simplified approaches for educational purposes, or at research level
in dedicated technically rather demanding environments.
Recently an example has been set up successfully within the PUNCH4NFDI
project, compiling a significant Higgs->4L signal peak reminiscent of the original discovery, which combines public data from CMS and ATLAS at research analysis level using a common simplified format. A few recently newly available datasets should be added, the example needs to be finally streamlined, and documentation will be completed and integrated into the PUNCH4NFDI portal in a form that makes it easy for outsiders to reproduce it.
The output is expected to be a fully working and documented PUNCH usecase
example that can be released to the public.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS (with PUNCH)

Special Qualifications::

Some prenowledge in particle physics and/or computing would be helpful.

19

Implementation, test and documentation of a public analysis example combining Quarkonium data from the CMS and ZEUS detectors in the context of PUNCH4NFDI

Authors: Achim Geiser[1]; Florian Lorkowski[1]

[1] *CMS (CMS Fachgruppe QCD)*

Quarkonium, and in particular J/psi final states have been measured in both the ZEUS (ep) and CMS (pp) experiments. These measurements mainly focused on dimuon final states. A common research level analysis format for ZEUS and CMS data has recently been extended to contain electrons. The measurement of J/psis in both muon and electron final states will be exploited in this project.
This might allow a more complete coverage of the available phase space, and a more direct comparison of the respective physics processes in ep and pp collisions.
Different ways of handling the data with modern analysis tools will also be explored.

Once successfully completed and documented, the project will eventually be made available as a public use case example in the context of the PUNCH4NFDI project.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS (with ZEUS)

Special Qualifications::

Some pre-knowledge in Particle Physics and/or Computing would be helpful.

20

Exploratory study for the combined analysis of particle physics and astroparticle physics data in the context of PUNCH4NFDI

Author: Achim Geiser[1]

[1] *CMS (CMS Fachgruppe QCD)*

Recently combined analysis of data from different High Energy Physics experiments in a common basic research level data format has started to be achieved in the context of the PUNCH4NFDI initiative.
In this exploratory study the concept will be extended to include data from an Astroparticle Physics experiment. In particular, public cosmic air shower data from the Karlsruhe air shower array KCDC will be compared to proton-proton and heavy ion collision data of the CMS experiment.
Both the further technical design of the common data format as well as ideas how to relate the physics between the two experiments will be part of the project.

Field:

C1: Astroparticle physics analysis and observations

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS (with KCDC)

Special Qualifications::

Some preknowledge in (Astro)Particle Physics and/or Computing would be helpful.

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Analysis of ultra-short XUV FEL pulses

Author: Mahdi Mohammadi Bidhendi[1]

Co-author: Stefan Duesterer [1]

[1] *FS-FLASH-D (FLASH Photon Diagnostics and Controls)*

In our group at FLASH (Free Electron Laser in Hamburg), we measure the temporal duration of the free-electron laser pulses by terahertz streaking. Photo-electrons are generated in the interaction of the XUV FEL pulse and noble gases like neon. If the ionization takes place in the presence of a THz field, the photo-electron spectrum is altered and contains information about the arrival time and the temporal duration of the FEL pulse. We use different analytical methods to evaluate our THz streaking data, therefore we are looking for an intern to join our effort in the experiment and data analysis and bring new ideas to analyze and visualize the data.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FLASH

Special Qualifications::

Experience in programming, Atomic physics knowledge, Good team skills, Good English language skills

22

Test of a new Beam Position Monitor readout system for PETRA IV

Author: Gero Kube[1]

[1] *MDI (Diagnose & Instrumentierung)*

For synchrotron light sources undergoing upgrades to 4th generation facilities, the importance of beam stability has grown substantially, i.e. tighter stability requirements over greater bandwidths over various timescales. From the electron beam diagnostic's point of view, Beam Position Monitors (BPMs) form the monitor system which provides the required data in order to keep the beam orbit stable to < 1 micrometer over one week of operation. The PETRA IV project at DESY aims to upgrade the present synchrotron radiation source PETRA III. For this new machine it is planned to install a new high resolution BPM system which consists of about 800 individual monitors. The idea of this project is to perform first test measurements at PETRA III with a prototype system consisting of 12 BPMs. Readout scripts and analyzing software will be developed in frame of this task (preferable programming languague is Matlab).

Field:

B4: Research on Accelerators

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MDI

Special Qualifications::

First experience in programming, preferably with Matlab.

23

V0-Finding at a Future Higgs Factory

Author: Ulrich Einhaus[1]

Co-author: Bohdan Dudar [2]

[1] *FTX (Fachgruppe SLB)*

[2] *FTX (FTX Fachgruppe SLB)*

The next big particle collider project is foreseen to be an e+e- Higgs factory. Various detector concepts with advanced detector technologies have been proposed for such colliders, aiming to probe the Standard Model to unprecedented precision. In order to optimise the physics performance of these detectors, sophisticated reconstruction algorithms are being developed and benchmarked on detailed simulations.

One such algorithm is the identification of in-flight decays of neutral particles, so called V0s, in the sensitive volume of gaseous trackers, which offer continuous tracking and thus significant advantages in pattern recognition with respect to a silicon tracker.
A winter student joining our Software&Analysis team will assess the performance of the current, somewhat basic implementation of the V0-Finder, in a generic calibration case as well as with physics samples. The student will connect the V0-Finder with information from recently developed algorithms like a reconstructed-mass track refit. Based on this assessment, the student will study a possible adaption of the current default V0 reconstruction parameters.

Physics / Computing / Engineering Content of the project : 33% / 67% / 0%
- Computing: Studying advanced reconstruction algorithms in particle detectors, making connections between state-of-the-art detector technologies and reconstruction performance
- Physics: Applying these algorithms to a physics case to show its impact

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX

Special Qualifications::

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Deep Learning-Based Time-of-Flight Reconstruction for Future Higgs Factories

Author: Peter McKeown[1]

Co-authors: Bohdan Dudar [2]; Engin Eren [3]

[1] *FTX (FTX Fachgruppe SFT)*

[2] *FTX (FTX Fachgruppe SLB)*

[3] *FLC (FTX Fachgruppe SFT)*

Experiments at future e+e- collider Higgs factories present the opportunity to perform measurements of the Higgs boson and electroweak observables with unprecedented levels of precision. Utilizing such machines to their full physics potential places stringent requirements on the performance of the detector. As a high level reconstruction task, highly performant particle identification is crucial for broader event reconstruction and the precision measurements that are targeted. To this end time-of-flight reconstruction, relying on silicon sensor technologies with excellent time resolution, offers the possibility to significantly improve the identification of low momentum charged hadrons.

This project focuses on the development of a deep learning-based time-of-flight reconstruction algorithm. The algorithm will be designed to operate directly on the energy and time information contained in calorimeter shower measurements. The student would be embedded in the FTX Software (SFT) group, which is actively involved in the development of cutting-edge machine learning algorithms for future particle physics experiments. While the ultimate goal of the project would be a comparison with the existing tools, the exact direction of the project would be led by the interests of the students, with the possibility to explore a number of different deep learning approaches.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX

Special Qualifications::

Programming knowledge in python is essential. Basic statistics and particle physics knowledge is needed. Some basic machine learning knowledge, possibly including python libraries such as pytorch, would be advantageous but is by no means required.

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BELLE II: analysis project: tau lifetime or detector alignment related project

Author: Daniel Pitzl[1]

[1] *DESY FH/Belle II*

BELLE II: analysis project: tau lifetime or detector alignment related project

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Belle II

Special Qualifications::

27

BELLE II: Analysis project

Author: Tommy Martinov[1]

[1] *BELLE (BELLE II Experiment)*

At the Belle II experiment, B meson decays can be studied with highest precision and in particular so called semi-leptonic decays where the B meson decays to a
hadron, a lepton and a neutrino. In this context, when the hadron contains an up quark (B ⟶ Xu l nu), important Standard Model parameters can be measured.
However, this process is overwhelmed by the much more likely decay to a hadron containing a charm quark (B ⟶ Xc l nu). Nowadays, most high energy physics
analyses make use of Machine Learning (ML) in order to improve the separation between signal and background. ML has already been used to distinguish B ⟶ Xu l
nu events from B ⟶ Xc l nu events at Belle II. Various algorithms can be compared in order to choose the most performant one. We propose the student to develop
a ML classifier (typically a Neural Network) for the B ⟶ Xu l nu analysis and compare its performance with other classifiers already used. Prior knowledge of
ML is not required (but could obviously help).

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Belle II

Special Qualifications::

28

A Neural Network parametrisation for Parton Distribution Functions in xFitter

Author: Simone Amoroso[1]

Co-author: Alexander Glazov [2]

[1] *CMS (CMS Fachgruppe QCD)*

[2] *DESY*

The knowledge of the proton structure, embedded in the parton distribution functions (PDFs) is of fundamental importance to make predictions for proton-proton collisions at the Large Hadron Collider. PDFs are determined through fits to experimental data, and the functional form assumed plays an important role. Using too few PDF parameters, or a constrained parametrisation, can lead to artificially small PDF uncertainties in certain regions of the phase-space, or to difficulties in minimising the PDF parameters.

Aim of this project is to interface the Neural Networks Analytic Derivatives (NNAD) package to the xFitter code. This will allow for a PDF parametrisation based on NN, thus with minimal assumptions on their functional behavior, and, thanks to the implementation of analytic derivatives, for a fast and efficient minimisation using the CERES non-linear least squares solver. The NN parametrisation will be tested using an ongoing extraction of PDFs using measurements from the CMS experiment.

Field:

B6: Computing

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

- knowledge of C++

29

Characterization of digital cameras based on photon transfer measurements

Authors: Artem Novokshonov[1]; Gero Kube[1]

[1] *DESY*

Area scan sensors (CCD or CMOS cameras) are widely used for beam profile
measurements in particle beam diagnostics. They provide the full two-dimensional information about the beam distribution, allowing in principle to investigate shot-to-shot profile fluctuations at moderate repetition rates. In order to study the performance and to characterize these cameras, photon transfer is a widely applied popular and valuable testing methodology (see e.g. the EMVA 1288 standard). The idea of this project is to study the performance of several digital cameras based

on signal-to-noise and photon transfer measurements which are in use for beam profile diagnostics at different DESY accelerators.

Field:

B4: Research on Accelerators

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MDI

Special Qualifications::

30

Constraints on the proton structure from CMS measurements of Standard Model processes

Author: Federico Vazzoler[1]

Co-author: Simone Amoroso [1]

[1] *CMS (CMS Fachgruppe QCD)*

The knowledge of the proton structure, embedded in the parton distribution functions (PDFs) is of fundamental importance to make predictions for proton-proton collisions at the Large Hadron Collider. PDFs cannot be calculated through perturbative methods, but are determined through fits to a variety of experimental data.

Aim of this project will be to investigate the sensitivity to PDFs of two recent measurements of Drell-Yan cross-sections performed by the CMS Collaboration at 13 TeV of center-of-mass energy. The student will implement the measurement data within the xFitter framework together with their systematic uncertainties and produce theoretical predictions at next-to-next-to-leading order in the strong coupling. The agreement of between the data and predictions, including the PDF uncertainties, will then be quantified with a PDF profiling procedure using xFitter.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

- basic programming skills (C++, python)

31

Pulsars at very-high energies: developing and testing pulsar analysis

Authors: Emma Maria de Ona Wilhelmi[1]; Stefan Ohm[2]

[1] *Z_GA (Gammaastronomie)*

[2] *Z_HESS (High Energy Steroscopic System)*

The discovery of a new radiation component at TeV energies in the Vela pulsar, beating at the same frequency that the rotational period of the pulsar, has opened the door for new, exciting interpretations of acceleration of particles in extreme environments. The H.E.S.S. archival dataset with more than 15 years of observations offers a fantastic opportunity to search for more of these objects. Within this project, we will develop analysis tools (using python/GammaPy) to perform timing analysis, and search for high energy pulsation for the best pulsar candidates, using H.E.S.S. and LAT data.

Field:

C1: Astroparticle physics analysis and observations

DESY Place:

Zeuthen

DESY Division:

AP

DESY Group:

HESS

Special Qualifications::

Programming Languages: python

32

Sample preparation and characterization for time-resolved serial crystallography with MurA

Author: Huijong Han[1]

Co-authors: Joachim Schulz [1]; Kristina Lorenzen [1]

[1] *Eur.XFEL (European XFEL)*

The basic concept of serial femtosecond crystallography (SFX), diffraction-before-destruction, made it possible to collect radiation-free data with nano- and micro-crystals at room temperature. As the crystals are usually only shot once by a single short X-ray pulse and destroyed, sample preparation requires production of large numbers of crystals with homogeneous size distribution and high density. While more research groups are interested in conducting SFX experiments, the know-how on sample preparation and characterization has not been widely shared. In addition, the equipment for the microcrystal characterization is not available in all institutes. Thus, the winter school would provide the student the opportunity to learn and practice the entire process of protein crystal sample preparation and characterization for serial crystallography. [1]
The target protein for this project will be MurA (UDP-N-acetylglucosamine 1-carboxyvinyltransferase), a key enzyme in the biosynthesis of peptidoglycan, which is a major component of the bacterial cell wall. The pathway of peptidogycan biosynthesis has been an important target for antibacterial

agents, such as the beta-lactams. MurA is of particular interest because it is inhibited by the naturally occurring antibiotic fosfomycin. The enzyme catalyzes the enolpyruvyl transfer from phosphoenolpyruvate (PEP) to a second substrate (UNAG), however, the detailed molecular mechanism is controversial due to lack of direct evidence. [2, 3] To design novel drugs, it is important to know the precise enzymatic mechanism as it provides the reaction intermediate structure to mimic.
The ultimate objective of this project is to visualize the intermediate structure and identify the actual mechanism. We would begin with MurA+UNAG crystals and plan to observe the structural changes caused by addition of PEP using mixing injection for time-resolved serial crystallography. During the winter school, we will work on protein preparation and micro-crystallization. As MurA has a well-established preparation protocol and macro-crystallization conditions, the student should be able to complete the entire process of sample preparation, from cell culture to micro-crystallization and injection test, for serial crystallography within five weeks. In addition, if there is a possibility (i.e. if any SFX experiment is scheduled during winter school period), the student can also join in our sample delivery experts to learn how the actual SFX experiment is performed at the XFEL beamline. Overall, the effort to optimize the crystallization conditions for the production of micro-crystals and to gain experience with characterization and injection tests would be beneficial for student to be involved in future SFX experiment.
References
1. Han H et al. (2021), J Appl Cryst, 54, 7-21.
2. Eschenburg S et al. (2003), J Biol Chem, 278, 49215-49222.
3. Zhu JY et al. (2012), J Biol Chem, 287, 12657-12667.

Field:

A2: Molecular sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

EuXFEL-SEC

Special Qualifications::

Bio chemistry lab experience

33

Modelling the evolution of X-ray-irradiated materials on femtosecond to nanosecond timescales

Author: Vladimir Lipp[1]

Co-author: Beata Ziaja-Motyka [2]

[1] *FS-CFEL-XM (Gruppe CFEL-XM)*

[2] *FS-CFEL-X (Gruppe CFEL-XM)*

Modern X-ray free-electron lasers (XFELs) produce femtosecond X-ray pulses sufficiently intense to modify material properties or damage the target. On the femtosecond timescales, energetic photoelectrons (created upon the X-ray absorption) and Auger electrons (emitted after relaxation of core-hole states) trigger secondary electron cascades, which contribute to the increasing transient free electron density. We simulate these cascades using an in-house classical Monte Carlo code XCascade3D [1], which can provide temporal and spatial characteristics of the excited electrons, including their energy distribution. The latter can serve as initial conditions for further simulation on longer timescales.

On the nanosecond timescales, the target evolution may involve energy/particle diffusion and lattice heating. We simulate it on the example of silicon using an extended Two-Temperature Model with electron density dynamics, nTTM [2]. It takes into account electron-hole diffusion, electronic and atomic heat conduction, as well as the electron-phonon coupling. To solve the nTTM system of equations in two dimensions, we developed a dedicated finite-difference integration algorithm based on Alternating Direction Implicit method with an additional predictor-corrector scheme.
In this work, the student should help us connect the two above computer programs by generating the output files from the XCascade3D and reading them in nTTM, thus making it possible to provide a more consistent simulation results, which would be compared with the experiments. Programming skills in Fortran 90 would be very helpful.
The full combined model would then be able to reliably evaluate timescales of material excitation during high-repetition-rate operation of XFELs, which is relevant for beam diagnostic applications.
[1] Lipp, Milov, Medvedev, J. Synchrotron Rad. 29, 323 (2022).
[2] Lipp, Rethfeld, Garcia, Ivanov, Appl. Sci. 10, 1853 (2020).

Field:

A6: Theory and computing

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-CFEL-XM

Special Qualifications::

Programming skills in Fortran would be very helpful.

34

Next generation of photovoltaics development

Author: Simone Techert[1]

Co-authors: Jose Velazquez Garcia [1]; Krishnayan Basuroy [1]; Sreeju Sreekantan Nair Lalithambika [1]

[1] *FS-SCS (Strukturdynamik Chemischer Systeme)*

Inorganic catalyst composites - organic polymers can be used as light harveting devices with a similar efficiency as silicon. When coupled to a water splitting unit like minerals / perovskites we can build novel type of energy converter and energy storage materials.
In this proposal we will develop such novel classes of materials and study them with advanced optical spectroscopy and advanced X-ray scattering methods.

Field:

A1: Solid-state physics and nanoscience (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-SCS

Special Qualifications::

of advantage but not necessary: experience in optical spectroscopy

35

Novel generation of photovoltaics and energy converter

Author: Simone Techert[1]

Co-authors: Elisabeth Erbes [1]; Jose Velazquez Garcia [1]; Krishnayan Basuroy [1]

[1] *FS-SCS (Strukturdynamik Chemischer Systeme)*

Organic polymers can be used as light harveting devices with a similar efficiency as silicon. When coupled to a water splitting unit like minerals / perovskites we can build novel type of energy converter and energy storage materials.
In this proposal we will advance our data analysis capabilties in X-ray scattering / diffraction.

Field:

A3: Soft-matter sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-SCS

Special Qualifications::

programming skills in advanced programming languages (like C) are of advantage (but they are not necessary).

36

Liquid flat sheet jets characterization

Author: Joana Ripado Valerio[1]

[1] *Eur.XFEL (European XFEL)*

The development of sub-micrometer-thickness flat sheet jets has enabled several novel achievements in science. The micrometer thickness, high stability, and optical flatness of the flat sheets are key characteristics required for the successful exploitation of these systems, especially for the spectroscopic study of aqueous samples [1,2].
Recently, several methods of achieving flat jets of ~µm thickness in a vacuum have been described, in our case, we focus on the use of a commercially available glass chip based on the gas dynamic virtual nozzles principle [3].

To be able to offer, in the recent future, the micro-thickness flat-sheet to the user community, a novel prototype of the glass-chips adapter has been developed. Thus, the main objective of this project is to implement and commission the new design of the flat-sheet chip adapter as well as the resultant flat-sheet characterization.
The flat sheet characterization (study of the sheet dimensions depending on the flow and aqueous solutions) includes the implementation of a new system to characterize the jet thickness based on the white light interferometer and the use of the advanced laser setup to characterize the jet speed.

At the end of the project, the student will be familiar with the microfluidics environment (experimental science), more specifically liquid flat sheets, and with advanced optical and technical lab equipment.

[1] Ekimova M., et al. A liquid flat jet system for solution phase soft-x-ray spectroscopy. Struct. Dyn. 2015, 2, 054301.
[2] Menzi S., et al. Generation and simple characterization of flat, liquid jets. Rev. Sci. Instrum. 2020, 91, 105109.
[3] Koralek, J. et al. Generation and characterization of ultrathin free-flowing liquid sheets. Nat. Commun. 2018, 9, 1-8.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

EuXFEL, SEC

Special Qualifications::

37

Processing serial crystallography data measured at FELs and synchrotrons

Author: Oleksandr Yefanov[1]

[1] *FS-CFEL-1 (Forschung mit Photonen Experimente 1)*

Our group (group leader H.N.Chapman) is one of the inventors of Serial Crystallography (SX) – the method when many protein crystals are measured in random orientations to get the full 3D structure of the protein. This technique was developed for Free Electron Lasers (FELs) but now it is also becoming a standard technique used at modern synchrotrons. Having a lot of experience and expertise in SX our group is involved in many experiments at the most advanced x-ray sources in the world (LCLS, eXFEL, Petra3, APS, ESRF). Each experiment produces 50-1000Tb of data and we are involved in approximately one experiment per month. Therefore, we have a lot of interesting data to process. And such experiments often results in a high impact publication.

The winter student has a chance to participate in some experiments –depending on the schedule of our beamtimes. If the student likes the data processing activity, the scientific collaboration can be extended outside the time frame of the winter school.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

CFEL-FS-1

Special Qualifications::

Programming skills with at least Python

38

Coherent X-ray Diffraction Imaging on mesocrystals and catalytic nanoparticles

Author: Ivan Vartaniants[1]

Co-author: Gerard Hinsley [2]

[1] *FS-PS (FS-PS Fachgruppe CXI)*

[2] *DESY*

Coherent X-ray Diffraction Imaging is a comparably new technique that allows to reconstruct the real space image of the particle illuminated by coherent X-rays. In this project we propose to perform reconstruction of previously measured data from mesocrystals and catalytic nanoparticles.
These data were obtained at PETRA III synchrotron source at DESY or at ESRF synchrotron source in Grenoble.

Field:

A1: Solid-state physics and nanoscience (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-PS

Special Qualifications::

It will be good if the student will know basics of MATLAB or Python

39

Di-top mass reconstruction using advanced Machine Learning methods

Author: Evgeniya Cheremushkina[1]

Co-authors: Thorsten Kuhl [1]; Klaus Moenig [1]

[1] *Z_ATLAS (Experiment ATLAS)*

In the Standard Model fermions obtain their masses (m_f) via the spontaneous symmetry breaking mechanism. To describe the coupling between Higgs and fermion fields a Yukawa coupling is introduced. The masses are then proportional to the vacuum expectation value of the Higgs field and the Yukawa coupling ($g_f = \sqrt{2}m_f/\nu, \nu = 246.22$ GeV). Since the top quark is the heaviest known fundamental fermion, the top-Higgs interaction provides an access to the largest Yukawa coupling.

We measure the top quark pair production cross section in the decay channel where one top decays fully hadronic and the other into a b-quark, a charged lepton and a neutrino. This cross section is affected by a virtual Higgs boson exchange between the two outgoing top quarks. The variable in this analysis, which is mostly sensitive to the Yukawa coupling, is the invariant mass of the top-quark pair. This mass is reconstructed from the measured decay products of the two top quarks, which contain a neutrino. Since we cannot fully reconstruct the neutrino momentum, this increases the difficulties to reconstruct the di-top invariant mass. There are several mass reconstruction techniques, among others a Machine Learning method.

The challenge is to choose an appropriate Machine Learning algorithm, train it using simulated data samples (supervised machine learning) and finally obtain the variable of interest - m_{tt}, from the real data, collected by the ATLAS detector at the LHC during 2015-2018 data taking period.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Zeuthen

DESY Division:

FH

DESY Group:

ATLAS_Z

Special Qualifications::

- Knowledge of particle physics;
- Relativistic kinematics;
- Programming skills (C++, Python).

40

Absolute gain calibration of 1 Mpix AGIPD detector at SPB/SFX instrument using EuXFEL X-ray beam

Author: Jolanta Sztuk-Dambietz[1]

Co-author: Marcin Sikorski [1]

[1] *Eur.XFEL (European XFEL)*

The European X-ray Free Electron Laser (EuXFEL) [1] is the world's most brilliant X-ray free-electron laser delivering up to 27.000 ultrashort (< 100 fs) spatially coherent X-ray pulses in the energy range between 0.25 and 20 keV, organized in 10 equidistant X-ray pulse trains per second. The facility went into its operation phase on July 1, 2017.

The 1 Megapixel AGIPD detector [2] is the primary detector used for User Experiments at one of the EuXFEL experimental end-station, SPB/SFX [3]. This 1 MPixel 2D X-ray imaging detector consists of 16 modules, grouped in four quadrants. Analogue memory cells built into each detector pixel, allow storage of up to 352 pulse-resolved images at MHz repetition rate. The images are subsequently read out and digitized during the 99.4 ms break between the XFEL X-ray pulse trains.

Precise absolute calibration of the detector gain, i.e. conversion of detector arbitrary units (ADU) to energy units (eV) using X-rays signal is essential to its performance. To perform the gain calibration for each detector pixel and memory cell we acquire low-intensity (~1-3 photons/pixel/pulse) fluorescence data. Using the collected data, we produce a signal spectrum for each pixel and memory cell. The distance between the 0-photon peak and 1,2,3 photon peaks provides information needed for the extraction of absolute gain value.

During the winter shutdown (December 2022-January 2023), we are going to upgrade the AGIPD detector at SPB/SFX by installing new modules. These modules have to be fully calibrated. For this purpose, together with SFX/SPB instrument, we planned the commissioning experiment with XFEL beam at the beginning of February 2023. A student will be given the possibility to participate in the dedicated calibration experiment at one of the EuXFEL beamlines (i.e. SPB/SFX) and later be involved in the analysis of collected data.

The amount of

- "physics" = 40-50%
- "computing" = 50%
- "engineering" < 5%

References

[1] W. Decking et al.:"A MHz-repetition-rate hard X-ray free-electron laser driven by a superconducting linear accelerator"Nature Photonics 14, 391–397 (2020)
[2] A. Allahgholi et al.,"The Adaptive Gain Integrating Pixel Detector at the European XFEL", Journal of Synchrotron Radiation, 26:74–82, (2019)
[3] A. P. Mancuso et al, "The Single Particles, Clusters and Biomolecules and Serial Femtosecond Crystallography Instrument of the European XFEL: Initial installation", Journal of Synchrotron Radiation, 26(3):660–676, (2019)

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

EuXFEL Detector Grop

Special Qualifications::

Basic knowledge of Python would be an asset.

41

Semantic Segmentation Of Pileup Particle Identification In The ATLAS Detector

Authors: Judith Katzy[1]; Stephen Jiggins[2]; judith katzy[3]

[1] *ATLAS (ATLAS Top Physics)*

[2] *ATLAS (ATLAS-Experiment)*

[3] *desy*

Simulating pileup at the Large Hadron Collider (LHC) involves the simulation of multiple proton interactions via soft QCD Monte Carlo models that are then overlaid onto a single primary interaction (or hard scatter event). This poses a significant challenge moving into the high luminosity era due to the increased average number of interactions per bunch crossing, and the growing complexity of the detector. In tandem these two factors lead to a rapid growth in the computational resources required to generate simulated datasets. To combat this problem, generative machine learning models are currently in development that aim to replace parts of the detector simulation with fast and efficient algorithms in order to reduce the CPU required to generate a single event.

One of these projects is the simulation of the ATLAS calorimeter using a generative machine learning model trained on LHC zero-bias data in order to more accurately replicate multi-proton pileup. Whilst such models can be trained to emulate calorimeter layer images on average, localised calorimeter cell activity driven by charged and neutral particles is potentially lost. The proposed project is to develop particle identification algorithms (e.g. Pileup Per-Particle Identification [1]) to associate localised cell activity in zero-bias data to charged/neutral particles originating from proton collisions. With this identification information, graph neural network architectures can then be developed to augment the generative models by encoding layer-to-layer cell correlations arising due to particle flight paths.

In summary the project aims to improve the emulation of calorimeter layer images generated via generative machine learning models by encoding particle flight information between layers using graph neural networks, which requires particle identification algorithms in zero-bias data to be developed.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

42

Tau reconstruction exploiting ML techniques

Author: Andrea Cardini[1]

Co-authors: Mykyta Shchedrolosiev [2]; Soham Bhattacharya [2]

[1] *CMS (CMS Fachgruppe HIGGS)*

[2] *CMS (CMS Fachgruppe Searches)*

Hadronically decaying tau leptons are powerful probes for electroweak physics. The precise measurement of their properties is key to measuring the properties of vector and scalar bosons, as well as the structure of the Yukawa coupling. This project focuses on exploiting machine learning techniques to reconstruct tau decays in collider experiments, as well as achieve an optimal reconstruction of their properties.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Decent knowledge of python programming language.
A basic understanding of physics reconstruction at collider experiments would be useful to expedite the start of the project.

43

study of compressible turbulence

Author: Huirong Yan[1]

[1] *Z_THAT (Theoretische Astroteilchenphysik)*

Interstellar turbulence is magnetised and compressible. Compressible turbulence plays a key role in both cosmic ray transport and star formation. In this project, the properties of compressible turbulence will be the focus, in particular, their cascade and statistical properties.

Field:

C3: Theory of Astroparticle Physics

DESY Place:

Zeuthen

DESY Division:

AP

DESY Group:

THAT

Special Qualifications::

44

Multi-wavelength study of cosmic rays and turbulence

Author: Huirong Yan[1]

[1] *Z_THAT (Theoretische Astroteilchenphysik)*

A new chapter of cosmic ray (CR) propagation research has begun when studies of particle transport and interstellar turbulence can confront each other.
In this project, multi-wavelength observations from radio to gamma ray shall be utilized to study magnetic turbulence and the propagation of CRs based on the theoretical understandings.

Field:

C3: Theory of Astroparticle Physics

DESY Place:

Zeuthen

DESY Division:

AP

DESY Group:

THAT

Special Qualifications::

45

Muon Collider Sensitivity to BSM Models with Extra Gauge Bosons and Heavy Neutral Leptons

Authors: Juergen Reuter[1]; Krzysztof Mekala[1]; Maximilian Loeschner[1]

[1] *T (Phenomenology)*

The projects is 50% physics and 50% software roughly. The goal is to study the sensitivity of future high-energy muon colliders on models beyond the Standard models that contain both additional gauge bosons (Z') and heavy neutral leptons, i.e. heavy neutrinos. Heavy neutrinos shall be studied in prompt production and via decays of the Z'. In addition, the properties of the additional gauge bosons (Z', eventually also W') should be studied. As an add-on, transverse polarization of the muon beams can be studied and its influence on the phenomenology of heavy gauge bosons and heavy neutral leptons.

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Theorie

Field:

B5: Theory of Elementary Particles

Special Qualifications::

Knowledge of quantum mechanics, familiarity with computers and software (e.g. numerical simulation), introductory knowledge on/basics of particle physics and the Standard Model

46

Characterisation of CMOS Cameras for the LAST Optical Telescope

Authors: Jowita Borowska[1]; Robert Daniel Parsons[2]; Ruslan Konno[3]

[1] *Z_HESS (High Energy Steroscopic System)*

[2] *Z_GA (Gammaastronomie)*

[3] *DESY*

The LAST telescope is a project to create an extremely wide field of view optical telescope, capable of searching for a wide range of transient source including tidal disruption events, compact binary mergers and many other violent astrophysical phenomena. LAST will be constructed from forty eight 28 cm telescopes with high performance CMOS cameras, working together to cover a sky area of hundreds of square degrees.
At DESY we are currently involved in the design and planning of this telescope, as well as the analysis of first data from the prototype currently being constructed in Israel. This project will be based around the characterisation of the performance of the cameras, filters and polarisation filters planned for use with LAST, using the DESY optics lab.

Field:

C2: Instrumentation for Astroparticle Physics

DESY Place:

Zeuthen

DESY Division:

AP

DESY Group:

Gamma

Special Qualifications::

47

Facilitating X-ray beamline alignment with machine learning

Author: Siarhei Dziarzhytski[1]

Co-authors: Günter Brenner [1]; Elke Ploenjes-Palm [1]

[1] *Deutsches Elektronen Synchrotron (DESY)*

Large scale research facilities for top-level science, such as synchrotrons, free-electron lasers and optical lasers like FLASH/DESY, European XFEL, CELIA etc., operate complex beamlines, where a set of optical elements is used to guide and shape photon pulses, and to perform advanced fundamental and applied science experiments. Such experiments place high demands on the quality of the delivered photon beam. One of the main requirements of a successful experiment is the optimized alignment and stability of such beamlines. To facilitate and even improve the alignment of a beamline, a self-optimization of a beamline based on machine learning can be applied which in turn would actively react on natural fluctuations of the photon beam characteristics. The project aims to develop such a tool and implement it at the newly constructed pulse length preserving double monochromator beamline FL23 at the world's first soft x-ray free electron laser FLASH.
For the current project the successful candidate should have a profound knowledge of geometrical and diffractive optics, as well as practical skills in programming, preferably also knowledge in machine learning.
Work on this project involves 70% of the tasks related to programming and 30% of the tasks directly related to physics.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FLASH-B

Special Qualifications::

Python + machine learning
Physical optics
Good English and/or German

48

AFM characterization of FEL irradiated samples

Author: Sven Toleikis[1]

Co-authors: Beata Ziaja-Motyka [2]; Heshmat Noei [3]; Vladimir Lipp [4]

[1] *FS-FLASH-O (FLASH Scientific User Operation)*

[2] *FS-CFEL-X (Gruppe CFEL-XM)*

[3] *FS-NL (FS-NL Fachgruppe Spektroskopie)*

[4] *FS-CFEL-XM (Gruppe CFEL-XM)*

The aim of this project is to achieve better understanding of the interaction of intense XUV radiation with solid materials, in view of its prospective technological applications. The CFEL XM theory group is developing a modeling software which can simulate the interaction of intense XUV radiation with technologically relevant materials such as silicon and diamond. It is essential to check the accuracy of
this code by comparing its predictions with experimental data. For this purpose, silicon and diamond samples were irradiated with single XUV FEL pulses with well known fluence parameters. The task is now to characterize the laser generated craters in these materials by means of AFM microscopy and to compare size and depth of these craters with the prediction of the software. This will validate the code accuracy and eventually help to improve it. Publication of the results is expected.

Field:

A1: Solid-state physics and nanoscience (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-FLASH-O

Special Qualifications::

49

Ultra-High-Energy Cosmic Rays propagation in extragalactic space from a single source

Authors: Marc Klinger[1]; Pavlo Plotko[1]; Walter Winter[1]

[1] *Z_THAT (Theoretische Astroteilchenphysik)*

Investigating the ultra-high-energy cosmic rays (UHECRs) is crucial to understand the most energetic phenomena in the Universe. The main focus of this project is to study the propagation of cosmic rays at energy about 10^{18} eV. You will learn to calculate cosmic ray flux at Earth from a single source for different parameters . The results will be compare to the measurement of energy spectrum and the composition from the Pierre Auger Observatory

Field:

C3: Theory of Astroparticle Physics

DESY Place:

Zeuthen

DESY Division:

AP

DESY Group:

THAT

Special Qualifications::

Basic knowledge of python. Also familiarity with high-energy astrophysics

50

Variational Quantum Algorithms

Author: Cenk Tüysüz[1]

[1] *DESY*

Variational Quantum Algorithms are a class of hybrid quantum-classical algorithms. This technique makes use of a parametric quantum circuit that is executed on quantum device as an ansatz whose parameters are optimized using a classical computer based on the measurement outcome of the quantum device. Running the feedback loop between the classical computer and the quantum co-processor until convergence, this approach allows for tackling a variety of problems ranging from combinatorial optimization tasks to approximating the ground state of a given Hamiltonian.

A central part of Variational Quantum Algorithms is the optimization of the parameters in the parametric circuit. In this project we will take a closer look at this aspect. We will implement a simple Variational Quantum Algorithm using the quantum Ising model as a benchmark model and explore its performance. In particular, we will examine how various factors impact the optimization procedure. If time permits, we are going to benchmark the simulations on real quantum hardware.

Field:

B6: Computing

DESY Place:

Zeuthen

DESY Division:

FH

DESY Group:

CQTA

Special Qualifications::

Python programming, experience in Quantum Computing would be a plus

51

FEL and HHG-based time-of-flight momentum microscopy: 3 time-resolved photoemission modalities in 1 experiment

Author: Dmytro Kutnyakhov[1]

Co-authors: Kai Rossnagel [2]; Lukas Wenthaus [3]; Markus Scholz [3]; Nils Wind [2]

[1] *DESY Photon Science*

[2] *FS-SXQM (Soft X-ray Spectroscopy of Quantum Mat.)*

[3] *FS-FLASH (FLASH)*

Time-resolved photoemission spectroscopy with ultrashort pump and probe photon pulses is an emerging technique with wide application potential. The ultimate combination of valence-band and core-level spectroscopy with photoelectron diffraction in a single experiment for electronic, chemical, and structural dynamics analysis specifically requires tunable monochromatic VUV or soft X-ray pulses at a high repetition rate as well as highly efficient single-shot electron detectors with increased multi-hit capabilities. Thus, combining the table-top experiment with a big scale facility sets the stage for measuring the k_z-dependent ultrafast dynamics of 3D electronic structure,

including band structure, Fermi surface, and carrier dynamics in 3D materials as well as 3D orbital dynamics in molecular layers. We have realized such a 3-in-1 ultrafast photoemission experiment at a high-harmonic-generation (HHG) table-top source in combination with PG2/FLASH, DESY merging free-electron-laser capabilities with a multi-dimensional recording scheme.
During the training period, the candidate will take part in two beamtimes at the free-electron laser FLASH, as well as be involved in laboratory-based experiments. The proportion of typical daily work will be distributed as follows: "physics" –40 %, "computing" –25% and "engineering" –35%.
Since this experimental technique produces multi-dimensional data and deals with "big data", candidates with a focus on the area "B2: Data processing (software-oriented)"are also very welcome to apply.

Field:

A1: Solid-state physics and nanoscience (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-FLASH-O

Special Qualifications::

Good team skills, good English language skills, experience in programming,

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Data and Metadata Processing Workflow for Multi Dimensional Photoemission Spectroscopy

Author: Dmytro Kutnyakhov[1]

Co-authors: Kai Rossnagel [2]; Nils Wind [2]; Steinn Ymir Agustsson [3]

[1] *DESY Photon Science*

[2] *FS-SXQM (Soft X-ray Spectroscopy of Quantum Mat.)*

[3] *Institute for Physics and Astronomy, Aarhus University, Denmark*

Rapidly increasing development of accelerator-based light sources like synchrotron radiation or free-electron-laser (FEL) facilities and detectors have brought photoemission spectroscopy to a new regime in data acquisition. Data streams resolving each individual photoelectron event enable correlation of each detected electron to the full state of the experimental apparatus, allowing drift and jitter corrections. This increases the quality and control over acquired data at the cost of complexity in data post-processing and data size.
We developed a distributed workflow pipeline which takes advantage of single event resolution to correct and calibrate Multi-Dimensional Photoemission Spectroscopy (MPES) data and generate an open-source data structure ready for analysis and storage with complete metadata description. The post-processed data is stored in the NeXus format, following metadata definitions which are built as a community effort. A universal set of descriptors for MPES is inherited by the application definitions for the single experiment specific data-structures (trARPES, spin-ARPES, nanoARPES, etc.). The flexible structure of the single-event data-frames, recorded together with the experiment-agnostic workflow and unified metadata descriptors, allow this pipeline to be applied to different experimental setups, from table-top to large scale facilities, enabling not only sharing of advanced analysis and data visualization methods within
a large community, but also following the F.A.I.R. principles of scientific data management.
During the training period, the candidate will take part in two beamtimes at the free-electron laser

FLASH, as well as be involved in laboratory-based experiments. The proportion of typical daily work will be distributed as follows: "physics" –20 %, "computing" –70% and "engineering" –10%.
Since this multi-dimensional data are produced during real experiments, candidates with a focus on the area "A1: Solid-state physics and nanoscience (application oriented)"or "A2: Molecular science (application oriented)" are also very welcome to apply.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-FLASH-O

Special Qualifications::

Experience in programming, good team skills, good English language skills.

53

Detailed investigation of multidimensional serial crystallography

Authors: Alessandra Henkel[1]; Dominik Oberthuer[1]

[1] *FS-CFEL-1 (Forschung mit Photonen Experimente 1)*

We are developing methods for serial crystallography at synchrotrons and XFELs to investigate structure and dynamics of biological macromolecules. Here we focus on temperature and pH-control to combine with mix-and-diffuse triggering of biochemical reactions for multidimensional crystallography (temperature-, pH- and time-resolved). You would be working with us for detailed investigations of the mix-and-diffuse and temperature control properties of our instrumentation with the goal to optimize it for more accurate measurements.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-CFEL-1

Special Qualifications::

Experience in one ore more fields of the following: crystallography, biophysics, microscopy, fluid dynamics.

54

Acousto-optic integrated microfluidic device for particle manipulation

Author: Anusha Keloth[1]

[1] *FS-CFEL-1 (Forschung mit Photonen Experimente 1)*

Devices to handle small volumes in narrow streams is of great use in the serial x-ray crystallography experiments. We are developing a microfluidic device integrated with optical and acoustic components to facilitate the manipulation of flow as well as particles in the microchannel. We will offer the possibility for the student to work on the charecterisation of fluid flow for the fabricated microfluidic devices and optimization of acoustic and optical force parameters to manipulate the particles. The major part of the project would involve experimental work with some flow simulation work.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

CFEL

Special Qualifications::

55

3D printing accelerator structures

Author: Francois Lemery[1]

[1] *MPY1 (MPY Fachgruppe 1)*

The student will work to design and 3D print dielectric structures for applications in accelerator science. With sufficient progress, the structures could also be tested with radiofrequency equipment.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MPY1

Special Qualifications::

Understanding of electromagnetics, and simulation experience would be useful.

56

Impact of missing transverse momentum resolution on sensitivity to Dark Matter in top quark events

Authors: Alexander Grohsjean[1]; Christian Schwanenberger[1]; Danyer Perez Adan[1]; Dominic Stafford[1]

[1] *CMS (CMS Fachgruppe TOP)*

The main signature in searches for Dark Matter at the Large Hadron Collider is the presence of missing transverse energy in the final state, given the invisible nature of these particles and thus the impossibility of identifying them when traversing the detectors. The success of finding the dark particles relies then on a good and precise measurement of the missing momentum along the transverse component. In this project, a study to assess the impact of the resolution of this quantity in the separation between the Standard Model background and the Dark Matter signal in final states with two leptons produced from decays from two top quarks will be carried out. The study targets the so-called S-transverse mass variable, which presents a characteristic high value in a process involving invisible decays and that could potentially be affected by the resolution of the missing transverse energy. The project aims to evaluate the quality of the limits imposed on the cross-section for the associated production of Dark Matter with top quarks when varying the resolution of the missing transverse energy. This investigation is intended to be done using fast simulation tools such as Delphes in the context of the simplified phenomenological framework MadAnalysis.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS Exotics

Special Qualifications::

Required - C++, Python
Desirable - ROOT, Statistical analysis

57

Improved sensitivity to BSM Higgs bosons from final states with unreconstructed particles and a modified approach to kinematic event reconstruction

Authors: Afiq Aizuddin Anuar[1]; Alexander Grohsjean[1]; Christian Schwanenberger[1]; Jonas Ruebenach[2]

[1] *CMS (CMS Fachgruppe TOP)*

[2] *DESY*

Searches for heavy Higgs bosons decaying into pairs of top quarks is a promising avenue to discover new physics at the LHC. Due to the so-called peak-dip structure from interference effects with Standard Model ttbar production, current searches rely on fully reconstructed final states, which require the presence of at least 2 jets and 2 leptons. In this work, the inclusion of final states with just a single jet and two leptons will be explored. Several novel observables in this event category will be explored and the sensitivity increase estimated. Besides adding a new category of final states, a modified approach to kinematic event reconstruction will be explored. The outcome of the project will be the base for a future search for heavy scalar particles at the LHC Run 3 and has huge potential for significant gains in searches for BSM physics with top quark final states.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS Exotics

Special Qualifications::

Required - Python
Desirable - Statistical analysis, phenomenology background

58

Study of the performance for identification of charged kaons in the Belle II experiment

Author: Michel Hernandez Villanueva[1]

[1] *BELLE (BELLE Gruppe)*

Collisions produced in the interaction region of the Belle II experiment produce as final states charged and neutral particles that travel across the different subdetectors. A proper charged particle identification system is a critical requirement for the success of the physics program at Belle II. In particular, the tau lepton physics program require the identification of charged kaons from reconstructed tracks keeping fake rates low. In the proposed project, the student will use data collected from collisions between 2019-2022 at the Belle II experiment for tagging tau pair events containing a kaon, and compare the efficiency between data and simulations of the global kaonID calculated from information produced in the subdetectors,
aiming to determine correction factors for simulated collisions.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Belle II

Special Qualifications::

Basic knowledge of Python and notions of machine learning are desired but not required.

59

Plasma wakefield acceleration

Authors: Jens Osterhoff[1]; Maxence Thevenet[2]; Vasyl Maslov[1]

[1] *DESY*

[2] *MPA1 (Plasma Theory and Simulations)*

The most impressive experimental results (see [1, 2]) until now in electron accelerating by a wakefield, excited in a plasma, have been achieved using capillary-generated plasma. Plasma-wakefield acceleration provides high accelerating gradients (see [1, 3, 4]), promises compact accelerators of high-brightness and high-energy electron beams. Applications of plasma-wakefield accelerators, in particular, particle colliders (see [5]) and free-electron lasers demand low energy spread beams, their small emittance, high current of accelerated bunches, large transformer ratio and high-efficiency operation. Achievement of these requires plateau formation on both the accelerating field for witness-bunch and the decelerating fields for driver-bunches. As it is known plateau formation is possible by controlled beam loading with careful shaping current profile and beam charge selection. We will demonstrate by numerical simulation by PIC code such optimal beam loading in a linear and blowout electron-driven plasma accelerators. Beams for plasma accelerator are prepared with RF linear accelerator with high beam quality.
Problems of acceleration of positron bunches in plasma (see [6]), focusing and stable transport of electron and positron bunches in plasma (see [7]) are important.
We will investigate in the project problems:
- ideal wakefield plasma lens (due to loading effect) for identical focusing of train of homogeneous bunches or Gaussian bunches depending on their lengths, gaps, charges for stable electron or positron beam propagation in a plasma column;
- optimal beam loading for the self-consistent distributions of a decelerating wakefield of plateau type for a driver-bunch and an accelerating wakefield of plateau type for a witness-bunch during all time of acceleration;
- control of optimal field shape (by loading effect), accelerating electron and positron bunches in plasma wakefield;
- obtaining long accelerated electron bunch of good quality (due to loading effect) in plasma wakefield accelerator at high transformer ratio.

Literature:
1. Leemans W.P., Gonsalves A.J., MaoH.-S. et al. Multi-GeV Electron Beams from Capillary-Discharge-Guided Subpetawatt Laser Pulses in the Self-Trapping Regime. Phys. Rev. Lett. 2014. v. 113. p. 245002.
2. Gonsalves A.J., Nakamura K., Daniels J. et al. Petawatt Laser Guiding and Electron Beam Acceleration to 8 GeV in a Laser-Heated Capillary Discharge Waveguide. Phys. Rev. Lett. 2019. v. 122. p. 084801.
3. Blumenfeld I., Clayton C.E., Decker F.-J. et al. Energy doubling of 42 GeV electrons in a metre-scale plasma wakefield accelerator. Nature, Letters. 2007. v. 445. p. 741-744.
4. Assmann R., Gschwendtner E., Cassou K. et al. High-gradient plasma and laser accelerators. CERN Yellow Reports: Monographs 1. 2022. p. 91.
5. Benedetti C., Bulanov S.S., Esarey E. et al. Linear collider based on laser-plasma accelerators. arXiv preprint arXiv:2203.08366. 2022.
6. Diederichs S., Benedetti C., Thévenet M., Esarey E., Osterhoff J. et al. Self-stabilizing positron acceleration in a plasma column. arXiv preprint arXiv:2206. 2022. 11967.
7. Diederichs S., Benedetti C., Esarey E., Thévenet M., Osterhoff J. et al. Stable electron beam propagation in a plasma column. Physics of Plasmas. 2022. v. 29 (4). p. 043101.

Field:

B4: Research on Accelerators

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MPA

Special Qualifications::

Programming experience is helpful

60

Time-resolved single particle imaging study on nano structures

Author: Chan Kim[1]

Co-authors: Johan Bielecki ; Juncheng E [2]; Richard Bean [1]

[1] *Eur.XFEL (European XFEL)*

[2] *European XFEL*

This project introduces the concepts of x-ray coherent diffraction imaging and the application of these concepts to single particle imaging experiments at free electron laser sources. The project is hosted by scientists of the SPB/SFX (Single Particle, clusters & Biomolecules and Serial Femtosecond Crystallography) scientific instrument at the European XFEL.

The computational tools used to simulate this type of experiment will be explained and the student given the opportunity and guidance to explore their use. The end goal of the project is to assist SPB/SFX instrument scientists to process experimental data from the x-ray instrument, leading to a reconstruction result.

Program outline:
1. Introduction to coherent X-ray diffraction imaging
2. Introduction to single-particle imaging at XFEL facilities
3. Basic coding, phase retrieval processes, EMC reconstruction, etc.
4. EMC reconstruction with real dataset (nano particles)

The program is spilt approximately 40% physics, 50% computing, 10% instrumentation (introduction to EuXFEL instrument)

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

EuXFEL - SPB/SFX

Special Qualifications::

Some knowledge of python (or other programming language) will be an advantage although not essential. Some previous knowledge of x-ray physics will be an advantage although not essential.

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Wavefront analysis using python

Author: Mabel Ruiz Lopez[1]

[1] *FS-FLASH-B (FLASH Photon Beamlines and Optics)*

At-wavelength wavefront metrology techniques are used at FLASH to characterize the beam aberrations. Our group has a long expertise trajectory using Hartmann Wavefront Sensors in the Extreme Ultraviolet regime. These methods, in combination with focusing optics, are a fast approach to describe the focus in situ. However, for strongly focusing optics, or telescope-kind optics a specific treatment in the wavefront analysis is required. For the current project we are looking for a student with profound skills in programming and enthusiastic about optics and physics to join our efforts to develop a new tool base on Python for the analysis of complex wavefronts.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FLASH-B

Special Qualifications::

Python knowledge, knowledge in physics and optics.

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Studies of the proton structure with the xFitter framework

Author: Oleksandr Zenaiev[1]

[1] *Hamburg University*

Parton distribution functions (PDFs) are essential to make theoretical predictions for experimental measurements of collider experiments with initial state hadrons. The xFitter project is an open source QCD fit framework ready to extract PDFs and assess the impact of new data.
The student will study constraints of recent LHC data on the proton PDFs and SM parameters by implementing the data and novel theoretical calculations within the xFitter framework. The impact of the data will be studied using various methods, such as profiling and reweighting techniques.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

UNIHH

Special Qualifications::

Basic programming skills in C/C++, Fortran, Python, Bash, Linux.