Summer Student Projects Submission 2022

Tuesday, July 19, 2022 - Thursday, September 8, 2022

Book of Abstracts

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Symetry-adapted graph neural networks for molecular vibrational wave functions

Authors: Andrey Yachmenev[1]; Yahya Saleh[2]

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

[2] *FS-CFEL-1-CMI (FS-CFEL-1 Fachgruppe CMI)*

Neural networks have been widely used to solve partial differential equations, which also includes solutions of the *Schrödinger equation* for quantum mechanical problems. The accurate symmetry properties of solutions of the Schrödinger equation are crucial for getting the correct results. However, up to date only permutational symmetry of particles have been considered for electronic wave functions.
Graph neural networks have grown in popularity for modeling chemical systems, due to their ability to conform to the symmetries of molecules. In this project, student will learn and implement *graph neural network* for vibrational wave functions of small molecules (e.g., water, ammonia), that transform according to irreducible representations of molecular symmetry group and represent solutions of the corresponding vibrational Schrödinger equation.

Field:

A2: Molecular sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

CFEL-CMI

Special Qualifications::

background in machine learning and programming with Python

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Autoregressive normalising flows for computing molecular vibrational wave functions

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

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

Neural networks are a promising tool to approximate wave functions and solutions of partial differential equations in general. They were shown to be free from the curse of dimensionality in some cases. However, methods employing neural networks are far from being reliable because of the lack of convergence guarantees. Normalising flows are a promising tool where accurate numerical results as well as convergence guarantees can be obtained.

In this project, the student will learn about the general framework of approximating solutions to the Schrödinger equation *via* neural networks. The student will implement autoregressive normalising flows to compute molecular vibrational wave functions of small molecules (e.g., water or ammonia) and will analyse the developed numerical scheme.

Field:

A6: Theory and computing

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

CFEL-CMI

Special Qualifications::

Background in machine learning, programming with Python and differential equations.

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Performance Comparison of Machine Learning Classifiers for the Calibration of the Hard X-Ray Single-Shot Spectrometer at the European XFEL

Author: Christian Grech[1]

[1] *MXL (XFEL)*

Single-crystal monochromators are used in free electron lasers for hard x-ray self-seeding, selecting a very narrow spectral range and further amplifying the original SASE signal. When a crystal is rotated, one can exploit several symmetric and asymmetric reflections as established by Bragg's law. A ML classifier is used during experimental setup to identify the crystal indices corresponding to a given reflection, and eventually calculate the difference between the photon energy as measured by the single-shot spectrometer and the actual one.

By comparing a range of ML classifiers in terms of their performance, the student will have the opportunity to work with experimental data from the European XFEL. Moreover, the student will obtain a general overview of several ML classifiers and will be able to carry such knowledge into their future studies.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MXL

Special Qualifications::

- Good level of programming in Python (required)
- Prior knowledge in ML tools like Scikit-learn, TensorFlow/Keras, PyTorch (beneficial, but not required)

10

Noble metal sputter deposition on nanostructured polymer templates

Author: Matthias Schwartzkopf[1]

Co-authors: Stephan Roth [2]; Yusuf Bulut [1]

[1] *FS-PETRA-D (FS-PET-D Fachgruppe P03)*

[2] *FS-PE (FS-PE Fachgruppe P03)*

Vacuum deposition of functional thin films has applications in numerous fields ranging from structural materials to solar cells, sensors, catalysis and medicine. Time-resolved X-ray scattering under high-speed industrial conditions in combination with spectroscopic methods provide ultimate insights to answer crucial questions about structure-property relationships. This knowledge is essential for the known understanding and design of next-generation nanomaterials with specific properties. Reference: Schwartzkopf et al., Nanoscale Horiz., 2021,6, 132-138 https://doi.org/10.1039/D0NH00538J

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In this summer student project, you will:
- Fabricate metal-polymer thin film nanocomposites for optical applications (20%)
- Perform noble metal co-deposition on nanostructured polymer templates (20%)
- Characterize thin film morphology using X-rays and AFM (20%)
- Correlate thin film nanostructures to optical properties using Ellipsometry and UV-Vis spectroscopy (20%)
- Perform acquisition, analysis and simulation of X-ray and optical data (20%)

This summer student project will be mainly performed on-site at Deutsches Elektronen-Synchrotron (DESY), Hamburg.
Contact:
Dr. Matthias Schwartzkopf, DESY Hamburg; matthias.schwartzkopf@desy.de
M.Sc. Yusuf Bulut, DESY, Hamburg; yusuf.bulut@desy.de
Prof. Dr. Stephan V. Roth, DESY, Hamburg; stephan.roth@desy.de

Field:

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

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-PET-D P03

Special Qualifications::

11

Sustainable spraying of functional nanoparticles and polymers diluted in green solvents for flexible electronics

Authors: Marie Betker[1]; Stephan Roth[2]

[1] *FS-PETRA-D (PETRA-D)*

[2] *FS-PE (FS-PE Fachgruppe P03)*

Cellulose is a sustainable material with many beneficial properties which makes it a suitable candidate as carrier material in multilayered systems. Part of our work is to functionalize thin films of cellulose nanofibrils (CNF) with various materials dispersed in different solvents via spray deposition. The majority of polymers are dissolved in toxic solvents like chloroform. We aim to exchange toxic standard solvents against safe and sustainable green solvents.
In the first step of this project, sprayable inks of various combinations of green solvents, functional polymers, and nanoparticles shall be prepared and tested. In the second step, the inks shall be sprayed on cellulose layers. The best spray parameters shall be investigated. Finally, the electronic properties and structure of the most promising samples shall be investigated using four-point measurements, atomic force microscopy, and grazing incidence wide-angle X-ray scattering.

Literature:
Q. Chen, M. Betker, C. Harder, C. J. Brett, M. Schwartzkopf, N. M. Ulrich, M. E. Toimil-Molares, C. Trautmann, L. D. Söderberg, C. L. Weindl, V. Körstgens, P. Müller-Buschbaum, M. Ma, and Stephan V. Roth: "Templated Deposition of Ordered and Polymorph Titanium Dioxide Thin Films for Improved Surface-Enhanced Raman Scattering Sensitivity", Adv. Funct. Mater., 2108556 (2021)

Field:

A3: Soft-matter sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-PE (beamline P03)

Special Qualifications::

Student should have basic knowledge (bachelor) in chemistry or physics, some experience in practical work/lab work and enjoy hands-on work.

12

Data analysis of photoelectrons from high-intensity x-ray free electron laser pulses

Authors: David Doblas Jimenez[1]; Manuel Izquierdo[1]

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

FLASH and European XFEL are both X-ray free-electron laser facilities where ultra-short X-ray pulses are produced using the SASE (Self Amplified Spontaneous Emission) process. One of the key differences between these facilities is the amount of X-ray pulses produced, and therefore the

data recorded, being at least one order of magnitude higher for the EuXFEL. We have developed a flexible framework (EXtra-metro) to cope with this amount of data being able to analyze it in real time using an event-driven pipeline. You will be testing the implementation of a library developed for the HEXTOF (high energy X-ray time of flight) momentum photoelectron spectrometer at FLASH within the EXtra-metro framework.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

European XFEL

Special Qualifications::

Good programming skills (Python) and experience with Linux

13

Laser-based commissioning of a momentum microscope

Authors: Manuel Izquierdo[1]; Patrik Grychtol[2]

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

[2] *European XFEL*

Description: The purpose of this project is to set up a laser beam path at the SXP instrument to commission the momentum microscope in combination with the laser in-coupling unit.
To this end, the stability and focus properties of the laser beam should be characterized using an alignment laser and CCD cameras. The beam properties of the optical reflectivity of the sample will also be investigated. Once accomplished, it is envisioned to install a laser pulse compression setup reducing the pulse length of our fiber-laser amplifier system from about 200fs to the sub-40fs level. These laser pulses are then supposed to be used for generating the first electron spectra with the momentum microscope.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

European XFEL

Special Qualifications::

Interest in femtosecond laser systems and laser beam alignment

14

Machine Learning for Predictive Maintenance.

Authors: Danilo Enoque Ferreira de Lima[1]; Arman Davtyan[1]; Luca Gelisio[2]; Steffen Hauf[1]

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

[2] *European XFEL*

The European XFEL generates extremely intense X-ray flashes used to explore the structure and dynamics of matter. In the Data Analysis team, we are researching and developing Machine Learning methods to automatize the analysis pipeline and optimize the beamtime taken by scientists when collecting data. One of the projects under development aims to detect anomalies within the system monitoring the machine, to minimize failures and downtime periods. In this project, a Python software should be developed to collect and pre-process data from a database containing information from thousands of devices, and perform a comparison of different Machine Learning methods to establish which method would be ideal to detect and prevent anomalies.

Field:

B6: Computing

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

EuXFEL Data Analysis

Special Qualifications::

The ideal candidate is expected to have experience on the following areas:

- Python
- Scikit-learn
- pandas
- Machine Learning is an asset

15

Evaluation of Machine Learning method for automated real-time analysis.

Authors: Danilo Enoque Ferreira de Lima[1]; Arman Davtyan[1]; Luca Gelisio[2]

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

[2] *European XFEL*

The European XFEL generates extremely intense X-ray flashes used to explore the structure and dynamics of matter. In the Data Analysis team, we are researching and developing Machine Learning methods to automatize the analysis pipeline and optimize the beamtime taken by scientists when taking data. One of the projects under development aims to automatize the tuning of several parameters of a standard real-time analysis pipeline. The parameters need to be adapted to the data sample being collected during the experiment, so that the experimenter has fast feedback on the data

quality and may adapt its experiment as needed. In this project, the master student shall study and compare the effects of the automatic tuning developed using different Machine Learning techniques on different scenarios and realistic datasets at the EuXFEL and possibly propose improvements on how the project may be improved based on it.

Field:

A6: Theory and computing

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

EuXFEL Data Analysis

Special Qualifications::

The ideal candidate is expected to have experience on the following areas:

- Python
- Matplotlib
- Crystallography is an asset
- Machine Learning is an asset

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Model-based analysis of interface evolution during spray coating

Author: Stephan Roth[1]

[1] *FS-PE (FS-PE Fachgruppe P03)*

Duration: around 7 weeks.

Short description: 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.

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-PETRA-D

Special Qualifications::

programming experience would be desirable

17

Laser ablation for diamond X-ray optics

Author: Frank Seiboth[1]

[1] *FS-PETRA (PETRA III)*

The material diamond is ideally suited for refractive X-ray optics that are used in synchrotron radiation facilities such as EuXFEL and PETRA III. However, material properties pose a challenge for fabrication. Laser ablation is one tool to shape diamond substrates into lenses, but surface roughness is a critical parameter. The student will investigate the ablation process, optimize parameters, and explore new opto-chemical etching techniques. The work is lab based and will involve ablation studies (40%) and sample investigations with a laser scanning microscope (40%). Basic programming skills are needed to control the ablation process and evaluate data (20%).

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-PETRA

Special Qualifications::

Experience with lasers

18

Investigating white light continuum generation for ultrafast time-resolved optical absorption spectroscopy studies on functional molecules

Authors: Christian Bressler[1]; Katharina Kubicek[2]

[1] *EuXFEL*

[2] *Eur.GPEX*

Scientific research questions
Our young, dynamic work group focusses on understanding photochemical reactivity in molecular systems with ultrafast x-ray and optical sources. In particular, we concentrate on smaller molecular model systems in solution as well as complex transition metal coordination compounds with relevance for e.g. solar energy or photoswitching applications, with the goal of tracking and controlling their excited state dynamics. Many of the light driven phenomena of direct relevance to molecular functionality occur on the femtosecond to picosecond time scale and involve rearrangements of electronic and nuclear structure on the Ångström length scale. This makes ultrafast x-ray methods ideally suited to advancing our understanding of these ultrafast chemical processes. Specifically, we develop and exploit ultrafast x-ray methods to track charge, spin, solvation, and coordination dynamics with atomic specificity and resolution following optical excitation. These experiments are performed at X-ray Free-Electron Laser (XFEL) and synchrotron sources worldwide. These studies are combined with complementary ultrafast optical spectroscopy experiments, simple inorganic synthesis, and simulation to identify the molecular properties that dictate excited state and photochemical processes.
In our femtosecond transient absorption spectroscopy (TAS) experiments the quality of our measured spectra depends critically on the properties and stability of our probe source, a broad-band white light continuum (WLC). For our setup we employ different WLC generation schemes using solid state conversion crystals or noble gases, and each of them produces WLC with different characteristics, including the wavelength range that is covered. In this internship we will explore the signal quality of pump-probe TAS spectra for the different WLC probes with respect to the input parameters, such as input laser intensity, gas pressure etc. The results from these studies will then i) serve as an input to select the most suitable parameters and WLC generation scheme for different research cases and ii) be used to perform such measurements on functional molecular photoswitches in order to unravel their ultrafast excited state kinetics. These will be analyzed with customized Matlab or Python codes. This is a great opportunity to get insight and intuition in modern time-resolved experiments in the field of physical chemistry, in particular with femtosecond optical lasers, and in addition different liquid sample delivery methods.
Experimental approach
The work will consist in its majority of work with the optical transient absorption setup with the amplified kHz laser system at European XFEL. The intern will investigate the influence of different WLC schemes on the quality and properties of the TAS spectra. Based on the results an appropriate WLC scheme will be selected for subsequent TAS measurements, where the intern will also be involved in studies on functional molecular photoswitching systems. To analyze the measured data he/she will perform a multi-parameter data analysis in Matlab or Python, with codes co-developed by the internship supervisor. If the timeframe of the internship coincides with a suitable synchrotron or XFEL experiment (currently we have a SACLA FEL (Japan) beamtime scheduled in May 2022 but due to the ungoing pandemic we cannot exclude re-scheduling), the intern may also participate in that and gain practical synchrotron or XFEL experience.
Tasks of the intern
• Characterization of different white-light continuum generation schemes for the transient absorption spectroscopy setup at the laser laboratory on-site in Schenefeld; evaluation of their spectral stability and relation to the input parameters and quality of the measured TAS spectra
• Participation in TAS measurements on functional molecular photoswitches on-site in Schenefeld
• Analysis of the measured spectra using own codes/codes co-developed by the supervisor (Matlab or Python)
• Participation in a suitable synchrotron and XFEL beamtime may occur during the internship
• Documentation of the results and presentation to the group at the end of the internship

General information about the work group, the university and the region
Our work group is located on the campus of European XFEL in the Greater Hamburg Metropolian Region. European XFEL is an international research organization operating a 3.4 km long XFEL producing femtosecond flashes of X-rays with unprecedented brilliance. Three beamlines and six instruments allow international research teams to conduct experiments in the fields of physics, chemistry, biology, medicine and material science. European XFEL also hosts several (femtosecond) optical laser laboratories. The combination of ultrafast x-ray and laser sources makes the campus ideal for our research. The nearby Campus of the Deutsches Elektronen-Synchrotron (DESY) operates a VUV FEL (FLASH) and a third-generation synchrotron (PETRA III) and hosts several research institutes, e.g. from the University of Hamburg and the Max Planck Society, and offers additional exciting research and collaboration opportunities within our ongoing scientific collaborations.

Eligibility and qualification of the applicant.
• The candidate is required to study physics or chemistry or a related discipline.
• Required: basic knowledge about optics and ultrashort optical laser pulses as is taught in undergraduate physics lectures.
• Good organization and communication skills are expected.
• Required: Good English language skills.
• Desired: Programming skills in Matlab or Python.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

other

DESY Group:

EuXFEL

Special Qualifications::

• The candidate is required to study physics or chemistry or a related discipline.
• Required: basic knowledge about optics and ultrashort optical laser pulses as is taught in undergraduate physics lectures.
• Good organization and communication skills are expected.
• Required: Good English language skills.
• Desired: Programming skills in Matlab or Python.

19

Ultrashort laser pulse guiding in hollow core optical fibers

Authors: Christoph Heyl[1]; Hanna Izabela Stawska[2]

[1] *DESY / Helmholtz-Institut Jena*

[2] *FS-LA (XUV Combs)*

Optical fibers provide the possibility to guide light in a wide parameter range over large distances, playing a very important role for everyday life applications and science. In particular, hollow-core fibers (HCFs) have attracted scientists' interest, supporting low optical loss, dispersion, and nonlinearity. Their ability to propagate light in vacuum or gases makes them highly suitable for delivering high-energy laser pulses. This project focuses on exploring parameter limits for ultrashort, high-energy pulse propagation inside HCFs including both experimental and theoretical research. The anticipated tasks can be adapted depending on the skills and preferences of the candidate. The candidate will be able to work closely together with laser experts (supervised by Dr. Hanna Stawska,

research team led by Dr. Christoph Heyl) and participate in research on the following problems:
1. Design of HCF based mode converters and beam combiners suitable for high-power pulse delivery.
2. Simulations of propagation of high-power, ultrashort pulses through hollow core optical fibers and devices, including the development of efficient semi-analytical methods (e.g. using the conformable derivative and the generalized exponential rational function method).
3. Participating in the experimental part of the project with close contact to researchers at the DESY Photon Science and DESY Accelerator divisions.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-LA

Special Qualifications::

20

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 summer student has a chance to participate in some experiments (most probably remotely) – depending on the schedule of the beamtimes during summer. If the student likes the data processing activity, the scientific collaboration can be extended outside the time frame of the summer school.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

CFEL-FS1

Special Qualifications::

Some knowlege of Python or C.

21

Functional cellulose-lignin-coating on porous materials

Authors: Constantin Harder[1]; Stephan Roth[2]

[1] *FS-PETRA-D (FS-PET-D Fachgruppe P03)*

[2] *FS-PE (FS-PE Fachgruppe P03)*

Lignins are wood-based sustainable materials with specific absorption of UV wavelengths. This makes them suitable and sustainable candidates for functionalized coatings in view of being impermeable for UV light. We investigate functionalized, nanocomposite coatings of cellulose nanofibrils (CNF) and different lignins. Our challenge is to make them robust again all common external influences. Especially coating on porous templates becomes more and more important. We focus on the robustness of these coating and their UV impermeability. This project aims to explore the best parameters to fabricate these coatings. In addition, the structure of the CNF-lignin networks will be characterized by small-/wide-angle X-ray scattering (SAXS/WAXS), atomic force microscopy (AFM) and scanning electron microscopy (SEM).

Field:

A3: Soft-matter sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

PETRAD-P03

Special Qualifications::

22

Piezo system for X-ray beam steering

Author: Mikhail Lyubomirskiy[1]

[1] *FS-PETRA (PETRA III)*

The project is for assembling and commissioning an optical test set-up to steer the X-ray beam at the beamline. The assembling is planned in the lab with commissioning with the laser beam. After that, depending on the progress of commissioning in the lab tests experiments foreseen at the beamline.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-PETRA

Special Qualifications::

23

Adhesion of coinage metals on thin polymer films

Authors: Stephan Roth[1]; Yusuf Bulut[2]

[1] *FS-PE (FS-PE Fachgruppe P03)*

[2] *FS-PETRA-D (FS-PET-D Fachgruppe P03)*

High Power Impulse Magnetron Sputtering (HiPIMS) is an emerging physical vapor deposition technique in industry and research which allows for creating novel polymer-metal composites. One reason is its higher ionized fraction of ions during deposition compared to conventional sputter and evaporation techniques. First results in the literature show a big advantage over conventional sputter or evaporation processes: Metal layer deposited by HiPIMS have shown an increased adhesion compared to the conventional deposition techniques and it does not require any post and pretreatments, which usually are detrimental for the polymer film,e.g. in solar cells. Yet, the microscopic reasons for the increased adhesion remain unknown.
In this project you are going to prepare polymer thin films on silicon with certain thicknesses via spin coating, which will be sputter-coated with coinage metals. Afterwards, you are going to characterize the samples with atomic force microscopy (AFM), electric conductivity, optical microscopy, ellipsometrie, X-ray reflectometry (XRR), grazing incidence small angle x-ray scattering (GISAXS) and grazing incidence wide-angle scattering (GIWAXS).

Field:

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

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-PETRA-D

Special Qualifications::

24

Characterization of conducting polymer films for thermoelectric applications

Author: Benedikt Sochor[1]

Co-author: Stephan Roth [2]

[1] *FS-PETRA-D (FS-PET-D Fachgruppe P03)*

[2] *FS-PE (FS-PE Fachgruppe P03)*

Short description: Poly(3-hexylthiophen-2,5-diyl) (P3HT) is one of the most prominent semiconducting, conjugated polymers in the fields of organic electronics and photovoltaics. Besides its high electric conductivity, it shows thermoelectric properties when doped with metal chlorides or nanoparticles, for example gold (Au). Thin thermoelectric P3HT films are of utmost importance and interest for future industrial applications. Here, it is essential to investigate the influence of different future large-scale fabrication techniques on the film quality and structure and, hence, its thermoelectric performance.
In the first step of this project, multiple polymer films of different thicknesses will be prepared using different P3HT-variants and dopant concentrations. Here, spin casting, spray deposition and slot-die coating will be used. In the second step, these samples key structural parameters, e.g. film thickness, surface roughness and electric conductivity, will be analyzed using different experimental techniques including atomic force microscopy (AFM) and ellipsometry as well as grazing incidence small-angle X-ray scattering (GISAXS) and X-ray reflectrometry (XRR). In the last step, all the obtained experimental data should be analyzed using the existing routines and the DPDAK software kit.

Duration: 6 weeks (2 weeks: lab introduction + preparation of samples using spin casting, spray depositon and slot die coating; 2 weeks: multi-method characterization of the samples including AFM, ellipsometry, electric conductivity measurements and possibly GISAXS as well as XRR; 2 weeks: data analysis using DPDAK)

Literature:
R. M. Kluge, N. Saxena, W. Chen, V. Körstgens, M. Schwartzkopf, Q. Zhong, S. V. Roth, and P. Müller-Buschbaum: “Doping Dependent In-Plane and Cross-Plane Thermoelectric Performance of Thin n-Type Polymer P(NDI2OD-T2) Films”, Adv. Funct. Mater. 2003092 (2020)

Field:

A3: Soft-matter sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-PETRA-D

Special Qualifications::

25

Characterization of digital cameras based on photon transfer measurements

Authors: Artem Novokshonov[1]; Gero Kube[2]

[1] *DESY*

[2] *MDI (Diagnose & Instrumentierung)*

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 build a test set up and to study the performance of 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::

26

Cherenkov detector development for LUXE

Author: Louis Helary[1]

Co-author: Ruth Magdalena Jacobs [2]

[1] *DESY - FTX*

[2] *ATLAS (ATLAS SM and Beyond)*

The LUXE experiment (LASER Und XFEL Experiment), currently being planned at DESY, will probe Quantum Electrodynamics (QED) in the vicinity of extremely strong electromagnetic fields, by studying the interaction of high-energy electrons and photons with a high-intensity LASER beam. In such extreme strong-field conditions, the processes of QED can no longer be described by a perturbative expansion and highly non-linear effects such as spontaneous vacuum polarization and non-linear Compton scattering are expected to occur. LUXE will explore a new territory in high-intensity particle physics, which has never before been accessed by experiments.

One detector technology currently under study for measuring electrons in the LUXE system consists of gas-filled Cherenkov straws. A summer student joining our LUXE team will work on the optimization of the Cherenkov detector geometry for the high-electron-rate environment in LUXE. In addition, the student will gain hands-on lab experience performing measurements and analyzing

data taken during different test-beam campaigns with the Cherenkov straw prototype available at DESY.

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX - LUXE

Special Qualifications::

Basic skills programming (C++ or python) to perform simple data analysis. Lab experience is a plus.

Physics / Computing/ Engineering Content of the project : 20% / 40% / 40%

27

Timepix4

Author: Jonathan Correa Magdalena[1]

Co-authors: David Pennicard [1]; Alexandr Ignatenko [1]

[1] *FS-DS (Detektorsysteme)*

Timepix4 is a versatile readout chip with 55 μm pixels, recently developed by CERN on behalf of the Medipix4 collaboration. It can operate both in a photon counting mode with frame readout, and a timestamping mode with event readout. Both of these modes offer higher performance than existing Medipix3 and Timepix3 chips. This makes Timepix4 appealing to a wide range of X-ray experiments at synchrotrons.
At FS-DS, a new readout system is being developed that is designed to cope with the chip's high readout bandwidth (up to 162 Gbps per chip). A single chip carrier board has been designed, and it is currently under production. First tests of these devices are scheduled for Q2/3 of 2022. They will require both hardware skills for the tests of the different parts of the set up, both alone and combined, as well as and software skills for chip communication, and data analysis.
This project constitutes a great opportunity for students interested in scientific instrumentation, and technology.

Field:

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

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

DS

Special Qualifications::

Experience in hardware and some programming languages.

28

Correlation Functions in N=4 Super Yang-Mills Theory

Author: Till Bargheer[1]

[1] *DESY (Deutsches Elektronen Synchrotron)*

In this project, the student will work on state of the art bootstrap and integrability techniques for the computation of correlation functions in N=4 super Yang-Mills theory and/or the related AdS/CFT dual string theory.

This is a purely mathematical physics project.
Computer algebra systems might be employed, but there will be no heavy computing.

Field:

B5: Theory of Elementary Particles

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Theory

Special Qualifications::

Advanced Quantum Field Theory

29

Development of ultrafast laser sources and devices for the characterization of femtosecond pulses

Authors: Andrea Trabattoni[1]; Francesca Calegari[1]; Erik Maansson[2]; Vincent Wanie[2]

[1] *CFEL-DESY*

[2] *FS-ATTO (Attosecond Science and Technology)*

In the attosecond science group at CFEL (https://atto.cfel.de), we generate ultrashort laser pulses with attosecond (1 fs = 10−18 s) or few-femtosecond (1 fs = 10−15 s) duration. These pulses are used to trigger ultrafast dynamics in a variety of systems, from bio-relevant molecules to clusters and nanosystems, and to follow in real-time how the atoms and electrons move and interact. With our research we aim at understanding and potentially manipulating these ultrafast processes that govern the early steps of photochemistry.

In this project, you will be fully involved in our research activity and learn about experimental methods for the characterization of ultrashort laser pulses. You will develop and operate diagnostic tools

to evaluate the spatial and temporal properties of femtosecond pulses. The training will consist in experimental activity with ultrafast laser sources, as well as writing programs/scripts to control small devices such as motorized translation stages, cameras and optical spectrometers in order to acquire and analyse experimental data. You will finally build an optical setup to perform measurements and evaluate the properties of the laser pulses used by the attosecond science group.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-ATTO

Special Qualifications::

30

Identification of non isolated tau leptons with ML techniques

Author: Andrea Cardini[1]

[1] *DESY*

Among charged leptons, taus are the only ones able to decay hadronically. Their hadronic decays are characterized by the presence of charged hadrons occasionally accompanied by an electromagnetic shower. This makes their identification challenging when the tau is produced close to jets, and limits the efficiency of studies involving tau leptons produced in high multiplicity events like HHH -> 2 tau + 4 b-jets or ttX -> 2 tau + jets.
The project aims at constructing a dedicated machine-learning algorithm to identify taus in such high multiplicity processes.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

The project will be mostly focused on the use of machine learning techniques. As such the student should have a decent level of preparation with the following programming languages:
-python
-bash
-basic knowledge of ROOT is preferred but not required.

If the student has prior knowledge of particle physics and/or machine learning techniques it would also be useful.

31

Topping the artificial intelligence

Author: Freya Blekman[1]

Co-authors: Matthias Komm [2]; Gabriele Milella [2]

[1] *DESY/University of Hamburg*

[2] *CMS (CMS Fachgruppe Searches)*

Elementary particles like top quarks create a signature that can be three different particles (and the jets that come from these particles). Distinguishing resolved top quarks from other particles/three-jet combinations is a difficult problem that particle physicists have been tackling for a very long time. But now there are many new ways of machine learning available, and it is worthwhile examining if this cannot be done even smarter.

The project, which relies on software and physics expertise, is to use new artificial intelligence tools such as graph neural networks to identify hadronically decaying (resolved) top quarks. Or maybe these algorithms are now even smart enough to learn how to identify top quarks without us telling them what to do? (this is called unsupervised learning) If successful, these new software tools will then be used to find top quarks in the CMS experiment at the LHC, and maybe even to search for new particles that are made together with top quarks.

This project can be classified as 60% software and 40% physics, and any physics student that already has experience with python and is enthusiastic to learn more about particle physics and artificial intelligence should be able to contribute to this exciting project!

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

python
machine learning is bonus, enthusiasm to learn is sufficient

32

Search for high-mass Higgs bosons in the final state with b-quarks with CMS Run 2 data

Author: Sandra Consuegra Rodriguez[1]

Co-author: Daina Leyva Pernia [1]

[1] *CMS (CMS Fachgruppe HIGGS)*

The discovery of the Higgs boson in 2012 marked a major breakthrough for particle physics. Up to this date, precision measurements that followed have indicated that the found particle agrees with the Standard Model predictions. However, there is still room for an extended Higgs sector as predicted by theories beyond the Standard Model, including Supersymmetry or general Two Higgs Doublet models. These models feature additional Higgs bosons, and they also allow for a significantly enhanced coupling of the Higgs boson to b quarks.

The summer student will participate in an analysis that searches for heavy neutral Higgs bosons, which decay into two b quarks, using the full Run 2 dataset of the CMS experiment, with data collected in the years 2016-2018. This work involves the use of tools for the processing of the data and the extraction of signal peaks. It is expected that this analysis will improve significantly on all previous studies in this channel.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

The student should have some familiarity with object-oriented programming, e.g. in C++. Ideally, also knowledge of Linux, Python, and the Root analysis tool would be helpful

33

Colloidal lithography for plasmonic particles

Authors: Anton Davydok[1]; Matthias Schwartzkopf[2]; Stephan Roth[3]

[1] *Hereon (Helmholtz-Zentrum Hereon)*

[2] *FS-PETRA-D (FS-PET-D Fachgruppe P03)*

[3] *FS-PE (FS-PE Fachgruppe P03)*

Duration: 6 weeks (1 week to get knowledge about the lab setups and the process of colloidal lithography; 3 weeks for mask preparation with variation of colloids (size, shape etc.) for further materials deposition (Au-Ag, Au-Cu, Ag-Cu by spin-coating and sputtering) to find optimal controlled way to produced plasmon particles; 2 weeks to characterize the samples with optical microscopy, AFM, SEM, EDX and X-rays diffraction measurements).

Short description: Heterostructure metal clusters, such as Ag-Au particles, attract huge scientific interest due to their unique and tunable size- and composition-dependent optical and electrical properties. Morphology of the interface between two materials inside the nanoscale particle has a high influence on properties of the final device, e.g. by tuning the plasmon resonance. We are aiming to optimize exciting recipes by modulating of deposition parameters and preparation conditions to be able to fully control shape, size and particle distribution. A key aspect is a mask preparation where metallic particles will be deposited and form the final structure. Prepared mask will be used for preparation of plasmonic Au-Ag, Au-Cu, Ag-Cu core-shell particles and characterized by small/wide-angle X-ray scattering with high spatial resolution (nanoSAXS/WAXS), atomic force microscopy (AFM) and scanning electron microscopy (SEM).

Field:

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

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

P03, hereon

Special Qualifications::

34

Test Beam Characterisation of a thin pixel sensors

Authors: Adrian Herkert[1]; Lennart Huth[2]

[1] *FTX (FTX Fachgruppe TBT)*

[2] *DESY*

The TelePix HV-MAPS sensor is a fast, thin timing layer for the telescopes. The pixel pitch of 25 um in one dimension also has the potential to precisely determine the position of passing particles, depending on the rotation angle. The student will get familiar with the sensor in the beginning of the project and then carry out measurements at different rotations to check for an optimal angle to determine the best possible spatial resolution. After a test beam campaign, the data will be analysed and if possible compared to simulation.

30% detector/ hardware calibration
30% software work
40% Interpreting/understanding results/physics

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX-TBT

Special Qualifications::

basic programming and hardware experiences is a plus

35

V0-Finding at a Future Higgs Factory

Author: Ulrich Einhaus[1]

Co-author: Bohdan Dudar [2]

[1] *FTX (SLB, TBT)*

[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 summer 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::

Basic skills programming (C++ or python) to perform a data analysis

36

Exploring different data analysis approaches in EDM4hep

Author: Thomas Madlener[1]

Co-author: Frank Gaede [2]

[1] *FLC (FTX Fachgruppe SFT)*

[2] *FTX (FTX Fachgruppe SFT)*

The FTX Software (SFT) group is very actively involved in the Key4hep project, which aims to develop common software for future collider projects. The group is currently involved in the development of a new and common event data model (EDM) at the core of the common software stack, EDM4hep. An important aspect of the Key4hep project, and EDM4hep in particular, is its ease of use for physicists.

EDM4hep offers several different ways of analysing physics data natively. The possibilities span from a c++ interface over python bindings, up to doing columnar data analysis with RDataFrame or uproot. The goal of this summerstudent project is to investigate a few of these approaches by doing an actual physics analysis on data in the EDM4hep format and comparing them. Existing examples serve as starting point and the choice of the considered approaches depends on the interests of the student. This is an ideal project for students who want to explore different ways of doing data analysis and potentially find ways to improve them.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX

Special Qualifications::

Programming knowledge in either c++ or python (or both) is essential. Basic knowledge of particle physics and statistics is needed. First experiences with ROOT or the scipy stack and python data analysis libraries is useful but not strictly necessary.

37

Particle track reconstruction using quantum computers

Authors: Annabel Kropf[1]; Yee Chinn Yap[2]; David Spataro[2]; Federico Meloni[3]

[1] *DESY*

[2] *FTX (FTX Fachgruppe SLB)*

[3] *ATLAS (ATLAS SM and Beyond)*

Quantum computing holds the potential to solve the ever increasingly challenging problems in high energy physics, one of which is particle tracking in a dense environment. The student will learn about the basics of particle tracking and apply quantum computing algorithms to solve real-world problems in high energy physics. The student will be guided through Jupyter notebook and use

Qiskit toolkit from IBM to solve standard example problems before applying it to particle tracking.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX

Special Qualifications::

38

Research on sustainable new generation organic solar cells with cellulose

Authors: Elisabeth Erbes[1]; Simone Techert[2]; Stephan Roth[3]

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

[2] *DESY*

[3] *FS-PETRA-D (FS-PET-D Fachgruppe P03)*

Organic photovoltaic (OPV) cells have unique features such as flexibility, lightweight, nontoxic, transparency and large-area OPV panels can be fabricated by low-cost solution processing methods.
In the past few years a novel polymer PBDB-T-2F (PM6) and the combination of the new non-fullerene acceptors BTP-4F (Y6) with PC71BM were highly studied. These organic solar cells (OSC) show efficiencies up to 17%, not only on rigid glass but also on flexible substrates. Besides the advantage of a big bandgap in PM6, the active layer shows also an extraordinary long diffusion length (100-300 nm) of the exiton. This enhances the probability to transfer the charges successfully to the electrodes and therefore increases the efficiency of the OSC.
The aim of this project is to study the influence of cellulose on the efficiency of the OSC. In the first step fully functional organic solar cells will be prepared by spin and spray coating. In the next step the cellulose will be spray deposited on the back of OSC. Afterwards the characteristic parameters of the solar cells need to be determined, e.g. power conversion efficiency, EQE. In an additional step the surface roughness and the thickness will be measured using AFM. In the last step the results should be analyzed and interpreted.

Field:

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

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-SCS

Special Qualifications::

39

Investigation of the plasma relaxation process in a high-repetition-rate plasma-wakefield accelerator

Authors: Judita Beinortaite[1]; Sarah Schröder[2]

[1] *DESY-FTX-AST*

[2] *FTX-AST*

High electric fields in excited plasma wakes make them an attractive medium for electron-bunch acceleration with broad applicability to industry and medicine, as well as research facilities such as particle colliders and free-electron lasers. For such facilities, the luminosity and brilliance, respectively, scale with the achievable repetition rate, thus making it a crucial performance parameter.

FLASHForward is an electron-beam-driven plasma-wakefield accelerator, on which experimentation into the limitations of repetition rates in plasma is performed. After a particle bunch drives a wakefield, a subsequent later-arriving bunch may witness a plasma perturbed by the preceding bunch if it arrives very soon after. The shorter the separation between such bunches, the greater the magnitude of perturbation. The lifetime of this perturbation places the most fundamental limit on the repetition rate of plasma acceleration.

In this project the limitations on beam-quality preservation in high-repetition-rate plasma-wakefield accelerator will be investigated by setting up realistic particle-in-cell and beam-tracking simulations. The final goal of the project will be to test the efficacy of the simulation packages by comparing their results to experimental data from FLASHForward.

Field:

B4: Research on Accelerators

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX-AST

Special Qualifications::

Excellent Python scripting;
Knowledge of MATLAB would be beneficial.

40

Calorimeter energy regression with Graph Neural Networks

Authors: Moritz Scham[1]; Dirk Kruecker[1]; Isabell Melzer-Pellmann[2]

[1] *CMS (CMS Fachgruppe Searches)*

[2] *CMS (CMS-Experiment)*

In high energy physics we study the fundamental properties of particles by recording their interaction with our detectors. In calorimeters, the particles create showers and deposit energy in the individual calorimeter cells. CMS will build a new calorimeter (HGCAL) with an extremely large number of cells. As these cells are distributed somewhat irregularly, the most natural representation of these energy deposits are point clouds which can represented as graphs. We aim to reconstruct the properties of such events with graph neural networks.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Experience in programming is essential, best in python, experience with neural networks, Linux and object-oriented programming would be useful.

41

Testing new hardware prototypes for the CMS HGCAL calorimeter upgrade

Authors: Katja Krueger[1]; Lindamulage Malinda Shiram De Silva[1]; Mathias Reinecke[2]

[1] *FLC (FTX Fachgruppe DTA)*

[2] *FE (FEB Analog Electronik)*

The CMS experiment will need to upgrade its calorimeter endcaps for the HL-LHC phase. The backward part of the High Granularity CALorimeter (HGCAL) upgrade will consist of small scintillator tiles read out by silicon photomultipliers (SiPMs). DESY develops the readout units and the production and testing procedures for this part. The HGCAL will operate at -30 degrees C, in a high radiation environment, so the components as well as the readout units will have to be thoroughly tested in harsh conditions. We expect the first units with final components this year, for which we will check that they fulfil all the requirements.

The project consists of participation in setting up these tests, performing them, and analysing the data.
Estimated shares: 20% physics, 40% programming, 40% hardware & measurement

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX-DTA, CMS

Special Qualifications::

Interest in detector technologies. Prior experience with electronics would be a bonus.

42

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

Author: Peter McKeown[1]

Co-authors: Engin Eren [2]; Frank Gaede [1]; Lennart Rustige [1]

[1] *FTX (FTX Fachgruppe SFT)*

[2] *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 student, with the possibility to explore a number of different deep learning approaches. While this project is computational and can be conducted remotely, onsite presence could be beneficial.

Physics / Computing/ Engineering Content of the project :

20 % / 80 % / 0 % to

40 % / 60 % / 0 %

depending on the interests of the student.

Field:

B2: Data processing (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX SFT

Special Qualifications::

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

43

Charge collection simulations in monolithic silicon sensors, based on Allpix2

Authors: Håkan Wennlöf[1]; Lennart Huth[2]

[1] *ATLAS (ATLAS-Experiment)*

[2] *DESY*

Novel silicon sensor developments in CMOS imaging processes pose new challenges; in contrast to traditional hybrid sensors the shape and amplitude of the electric field, which is required to collect deposited charge, is highly non linear. Finite element simulations - with Synopsys TCAD - are used to precisely model the electric fields based on doping profile estimations. The time dependent charge collection can also be simulated for a constant charge deposition along a straight line. Unfortunately these simulations are time consuming and are hence not suited to also include charge deposition fluctuations, or generate high statistics samples.
This issue is tackled by the Allpix2 framework, which combines the precise knowledge of electrostatic fields from TCAD with the well understood charge deposition models from Geant4, allowing for rapid and detailed simulation. Allpix2 models the charge deposition, transport, transfer, and digitisation. The summer student will work within the Tangerine team and will be provided with electrostatic fields from TCAD, and is supposed to study the charge collection for different impact positions and extract the detection efficiency, spatial resolution and cluster size using Allpix2. Since we are currently actively working on the sensor design, we cannot further specify the project today, but the student will have the possibility to work on cutting-edge technology developments.

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

Prerequisites: Basics in Linux, ROOT, Unix shell
Nice to have: simulation/silicon experience, Geant4 basics

44

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 of about 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, will be tested at the Mainzer Mikrotron (MAMI) end of spring 2022. MAMI provides an electron beam with currents up to 100 µA and an energy up to 1.5 GeV. To reconstruct reference tracks, the ALPIDE beam telescope will be used. A track based analysis of the data set will be 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.

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. Can be online-only if necessary.

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS – TANGERINE

Special Qualifications::

Prior knowledge in linux, shell, C++ and ROOT would be helpful. A remote student would be preferred to work approximately during UTC+2 working hours.

45

Analysis of the structure massoia lactone through light-matter interaction

Authors: Himanshi Singh[1]; Pablo Pinacho Morante[2]

[1] *Deutsches Elektronen-Synchrotron DESY*

[2] *FS-SMP (Spectroscopy of molecular processes)*

We propose to investigate the same compound, massoia lactone (MAL), using two spectroscopic techniques, Fourier transform infrared (FTIR) spectroscopy and Fourier transform microwave (FTMW) spectroscopy to analyze and compare their spectral features. Massoia lactone (MAL) is the intermediary product between 6-amyl-α-pyrone and delta-decalactone, both molecules important in several fields of industry. Although both 6-amyl-alpha-pyrone and delta-decalactone have been widely studied with different spectroscopic techniques, there is almost no study about MAL. Our goal is to explore the structural landscape and to identify the intramolecular interactions of MAL, to better understand its physical and chemical properties by using two powerful spectroscopic techniques. In FTIR spectra, the observation of certain bands can be associated with the presence of specific functional groups in the molecule arising from their vibrations. The FTMW spectra are denser with hundreds of lines arising from transitions between two rotational levels and corresponding to many conformers present at the same time. The rotational constants extracted from the analysis of the FTMW spectra are directly related to the arrangement of the atoms in the molecule. Thus, rotational spectroscopy allows identifying several conformers and determining very precisely their molecular structures. MAL features several functional groups and a great conformational flexibility, which make it interesting to study using both FTIR and FTMW spectroscopy. We aim that the student will get a hands-on experience on quantum-chemical calculations, on instrumentation using two instruments, with the rotational spectrometer being home-built, and to analyze the spectra from two spectroscopic techniques that provide complementary information to each other.

Field:

A2: Molecular sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

SMP

Special Qualifications::

46

Ultrafast Mode-locked Fiber Laser and Amplifier

Authors: Marvin Edelmann[1]; Mikhail Pergament[2]

[1] *FS-CFEL-2*

[2] *FS-CFEL-2 (Ultrafast X-rays Group)*

The Project is aimed at the construction and characterization of a fiber laser mode-locked with the optical Kerr-effect for the generation of femtosecond pulse trains. The construction of the laser cavity includes the alignment of free-space components such as grating-pairs and collimators as well as the fabrication of a fiber-optic segment with fusion-splicing technology. All the required

tools and skills will be taught throughout the course. Once mode-locked, the output of the laser will be characterized with different measurement tools that are widely used in the field of ultrafast optics such as autocorrelator, signal-source-analyzer, RF-spectrum analyzer, optical spectrometer and oscilloscope. Different lengths of the Ytterbium-doped active gain fiber will be implemented to investigate their influence on the laser parameters and the self-starting ability of the system with the goal to find the optimal configuration.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-CFEL-2

Special Qualifications::

47

EM energy resolution studies with ATLAS detector

Authors: Filip Nechansky[1]; Ludovica Aperio Bella[2]

[1] *ATLAS (ATLAS Standard Model Physics)*

[2] *ATLAS (ATLAS SM and Beyond)*

Many measurements performed by the ATLAS collaboration rely on an accurate understanding of the electron and photon energy response. The parametrization of the energy resolution is an fundamental piece that could be improved thanks to a special dataset collected by ATLAS during the Run 2 of the LHC.

Our current knowledge of the relative energy resolution, σ/E, is so far limited by our understanding of its energy dependence. This dependence has never been fully measured in-situ, and one of the terms (so-called sampling term), is determined from a combination of simulation and test-beam data.The imperfect knowledge of this terms is resulting in an additional 10% uncertainty on the parameterization of the energy resolution, that could be further constrained using ATLAS data taken in special conditions.

In standard LHC runs, the impact of energy deposition coming from additional proton collisions in the event is too important to make an extraction of the sampling term feasible. However, the ATLAS collaboration recorded an unique dataset of low pile-up events where the noise-term is expected to be negligible.

The aim of this project is to use this data to check the relative importance of the various terms of the electron energy resolution parametrization, and especially to study the sampling-term. This term has the most impact at low energy, hence it is possible to extract it from the $J/\psi \longrightarrow ee$ mass distribution. Combining this result with similar measurements done in standard data taking conditions would allow a significant decrease of the uncertainty on the electron and photon energy resolution.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

Basic programming skills necessary
Previous experience with data analysis desirable
Experience with Python and/or ROOT is required
Berlin/Paris Time Zone –> strongly preferred

48

Making the top quark open in the CMS open data

Author: Freya Blekman[1]

Co-author: Achim Geiser [2]

[1] *DESY/University of Hamburg*

[2] *CMS (CMS Fachgruppe QCD)*

The top quark is one of the building blocks of the Standard Model, and the heaviest known particle. Up to now, top quarks have been only visible at the Tevatrong Collider at Fermilab and at the LHC. Top quarks are important to many studies of the strong force and the production probabilities are sensitive to the ratio of gluons and quarks in the protons.

The goal of this summer student project is to, for the first time, design an analysis that isolates top quarks on the CMS open data, so the rest of the world can also study the top quark. This would involve:

- designing an analysis to select top quark events in the CMS open data, using the guidance of the first top quark observations at the LHC. In practice this would mean selecting LHC collisions with an electron, muon and two b quark tagged jets. To achieve this, substantial work will need to be performed on the level of software and coding, both in c++ and python, and the work will need to also include accessible documentation. When successful, this work will be made available to physicists worldwide, including students, via open science collaboration tools such as the CERN open data portal. There already was a previous project using the open data, and that will help to make an excellent start to this exiting topic.
- A more advanced later step would be to perform this selection including a study of all theoretical and experimental uncertainties, which could lead to a measurement of the top quark pair production cross-section in the open data at different energies, with exactly the same theoretical assumptions for all years. Such a complicated analysis has not been performed on the CMS open data and may potentially lead to a journal publication.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

python
c++
willingness to learn the CMS framework CMSSW
basic particle physics
special relativity

49

Generative Adversarial Networks for Fast Calorimeter Shower Simulations

Author: Dirk Kruecker[1]

Co-authors: Simon Patrik Schnake [1]; Isabell Melzer-Pellmann [2]

[1] *CMS (CMS Fachgruppe Searches)*

[2] *CMS (CMS-Experiment)*

Simulation of Calorimeters is a computational-costly process. Different strategies to replace these simulations with generative models are currently developed. This is especially important for the High Luminosity LHC and the coming high granularity upgrade of the CMS forward calorimeter. The summer student will have opportunities to learn about generative modelling and calorimetry. We will explore different strategies to use Generative Adversarial Networks with different complexities.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

- Experience in programming is essential
- Exposure to Deep Learning considered an asset

50

Characterization and Calibration of 2nd Gen AGIPD Electronics

Author: Torsten Laurus[1]

Co-author: Alexander Klujev [1]

[1] *FS-DS (Detektorsysteme)*

The Adaptive Gain Integrating Pixel Detector (AGIPD), a megahertz frame-rate, high-dynamic range integrating pixel detector, was developed for photon science experiments at the European X-Ray Free Electron Laser (European XFEL) and tailored to its unique specifications. Two 1-Megapixel AGIPD detector systems have been installed at the European XFEL and are producing numerous scientific publications. Two completely new AGIPD detector systems are currently being developed for the European XFEL: one 1Mpixel detector for the HED Instrument and one 4Mpixel AGIPD as a second detector for the SPB/SFX instrument.

This summer student project deals with the characterization and calibration of the new detector electronics (readout electronics and ASIC).
For this purpose, various measurements will be performed on our laboratory system as well as on the 500k prototype system, that is in operation at the HED instrument at European XFEL. Data analysis will be performed on Desy's HPC cluster Maxwell.

Field:

A4: Development of experimental techniques (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-DS

Special Qualifications::

data analysis
no fear for electronics

51

Machine learning algorithm development for jet flavour tagging

Authors: Krisztian Peters[1]; Paul Philipp Gadow[2]

[1] *DESY*

[2] *ATLAS (ATLAS Beyond Standard Model)*

The identification of jets containing b-hadrons (flavour tagging) underpins the results in many areas of the physics programme of the ATLAS experiment, such as the observations of the Higgs boson decay into bottom quarks or recent searches for resonant pair production of Higgs bosons.

The long lifetime (τ = 1.5 ps), large mass (m_b = 5 GeV), and decay properties of b-hadrons enables the experimental identification of b-jets exploiting track properties and reconstruction of secondary vertices.

Complex multi-variate jet tagging algorithms are used to classify jets by the flavour of the initial parton. Various architectures of deep neural networks are employed for this task. These networks operate on a range of observables which are sensitive to the properties of b-hadron decays and are trained on a large number of simulated LHC proton-proton collision events.

The student will study improvements in the jet flavour tagging algorithms by training deep neural networks and evaluating their performance in simulated events. This project will enable the student to engage in LHC data analysis using widely used computing tools such as the python programming language and toolkits for machine learning.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

Existing knowledge of Linux/UNIX, Shell and the python programming language is highly preferable. If the project cannot take place on-site, we can only work in a similar time zone (i.e. CEST +/- few hours).

52

Experimental studies on the strip end-cap system test for the new ATLAS Inner Tracker

Author: Jan-Hendrik Arling[1]

Co-author: Maximilian Felix Caspar [2]

[1] *DESY*

[2] *ATLAS (ATLAS-Experiment)*

The ATLAS Inner Tracker (ITk) is the new foreseen all-silicon tracking detector for the ATLAS experiment at the High-Luminosity LHC starting in 2026. A substantial part of the new detector, one of the strip detector end-caps, will be assembled at the DESY site.
In the phase of the production, a large number of different detector components ranging from sensors over modules to populated detector structures will be built and tested by worldwide distributed production sites, with DESY among them.
In parallel, a fraction of the full end-cap, the so-called strip end-cap system test, will be assembled and tested at DESY.
The student will contribute in the planned measurements of the system test, in the development of necessary software for the readout and DAQ system, and in the analysis of the measured data from the system. Optionally, the student will have the opportunity to contribute to the testing and quality control of detector components for the ATLAS upgrade.

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

Some programming experience (python preferred), hardware and/or lab work experience, if remote (we really prefer this not to be remote): (close to) DESY timezone

53

Double parton scattering and models for double parton distributions

Authors: Markus Diehl[1]; Peter Josef Ploessl[1]

[1] *T (Phenomenology)*

A brief overview about the project. The main subjects of this project are:

- LHC physics, in particular QCD.
- double parton scattering (DPS), i.e. hadron-hadron collisions with two simultaneous hard interactions.
- double parton distributions (DPDs), the DPS counterpart of regular parton distribution functions (PDFs).
- models for DPDs.

DPS reactions are often neglected when theory predictions for the LHC are calculated. While this is justified in many situations, there are also processes where this is not the case. In these cases one needs DPDs in order to calculate DPS cross sections, but right now an experimental determination of these distributions is not yet possible. Therefore one has to rely on models for DPDs. The goal of this project is to construct and refine such models.

What you will learn in the course of this project. The idea of this project is to construct models for DPDs using PDFs as building blocks and refine these models with the help of the DPD number and momentum sum rules. While doing this you will:

- familiarize yourself with physics at the LHC.
- learn the basics about DPS and DPDs.
- get to know more about PDFs.
- gain practical experience in writing C++ code.

Which knowledge is required? Of course the intent of this project is to learn something, but nevertheless some basics are required, or would at least be very beneficial:

- an introductory course to particle physics.

- some experience writing C++ code.

What exactly is double parton scattering? What exactly is double parton scattering? When we talk about DPS what we have in mind are hadron-hadron collisions with two distinct hard interactions, i.e. from each colliding hadron two partons (quarks or gluons) enter a separate hard scattering reaction, respectively. This produces a final state with two subsets of final state particles with two associated hard scales.
While for a given final state the contribution from DPS is generically less important than the one from single parton scattering (SPS), there are cases where it should be included in order to get a good theoretical estimate. The most well-known example for this DPS enhancement is probably the production of two W gauge bosons with identical charge. Since this channel is an important background for the search for physics beyond the standard model of particle physics (SM) in channels with like-sign leptons it is important to include DPS contributions there.
Besides being of importance for precision calculations for the LHC, DPS is also very interesting to study in its own right, as it gives access to information about the internal structure of the colliding hadrons that is not accessible in SPS. In particular DPS allows us to study correlations between two partons inside a hadron. For instance we can obtain information about the spatial distribution of two partons inside a hadron, or how the spins of two partons are correlated.

What are open issues in the theoretical description of DPS? A theory for the description of DPS processes can be formulated as a generalization of the familiar factorization theorems from SPS and in recent years a lot of progress has been made in this direction.
The double parton distributions (DPDs) in the DPS factorization theorems generalize the concepts of SPS parton distribution functions (PDFs) to two partons and can be thought of as probability distributions for finding two partons with given momentum fractions at a given separation inside a hadron. Unfortunately an experimental determination of DPDs has not been possible yet, since at the one hand DPDs contain more information than regular collinear PDFs, such that also more data is needed to obtain them, while on the other hand the amount of data on DPS is still comparatively small at present.
This necessitates the construction of physically motivated models for DPDs. One important constraint that can guide us in the construction of such models are number and momentum sum rules for DPDs, which are quite similar to those familiar from PDFs.

Introductory reading. f you want to know more about DPS and DPDs, some – hopefully accessible – introductory material can found in the following slides:

- “Double parton scattering in QCD” by Jonathan Gaunt @ DIS 2019
- “Double parton scattering” by Markus Diehl @ QCD@LHC 2019
- “Double parton distributions: An introduction” by Peter Plößl @ QCD-N2021
- “Constraining DPD models using sum rules” by Peter Plößl @ MPI@LHC 2018

Field:

B5: Theory of Elementary Particles

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Theory

Special Qualifications::

Introductory course in particle physics.
Some experience writing C++ code.

54

Calibration of the new CMS luminosity detector BCM1F

Author: Andreas Meyer[1]

[1] *DESY*

The BCM1F detector of the CMS experiment consists of 48 silicon pad sensors situated close to the beam pipe on both sides of the interaction point. The detector provides an online, quasi-real-time measurement of the instantaneous luminosity the CMS and the LHC control rooms. For the Run-3 data taking, BCM1F was completely refurbished.
The topic of the Summer Student project is data analysis and calibration of the detector using the new Run-3 data, recorded in Spring and Summer 2022. The results of the analysis will be implemented in the online software calculation of the instantaneous luminosity of the LHC.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Basic knowledge in particle physics. Experience with the programming language python is very useful. C++ is a nice to have.

55

Implementation, test and documentation of a public Open Data analysis example with LHC and other HEP Open Data in the context of PUNCH4NFDI

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

[1] *CMS (CMS Fachgruppe QCD)*

Open Data analysis examples in HEP are so far available in simplified approaches for educational purposes, or at research level in dedicated technically rather demanding environments.
Based on previous work, e.g. the analysis of decays of the Higgs boson to four leptons, or the analysis of Z boson and J/psi meson production with decays to two leptons, the main goal is to bring such an analysis example using HEP data from different experiments in a common format to a level that it can be made public on the new PUNCH4NFDI data portal.
This includes both work on the analysis itself, its documentation, as well as on the accompanying metadata handling. It may include tools such as python-based Jupyter notebooks.

Physics: 30%, Computing: 30%, Documentation: 30%

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Learning on the job. Some previous computing experience required. Preknowledge in linux, ROOT/C++ or python, and particle physics helpful, but not strictly required

56

Data analysis of D mesons in CMS and its phenomenological results

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

[1] *CMS (CMS Fachgruppe QCD)*

There are on-going projects of measuring charm production at 0.9, 5, 7 and 13 TeV in CMS. Measuring D mesons like D0 and D* by reconstruction of pion and kaon particles detected from CMS experiment is to derive charm total cross section at different energies, which follows extrapolation of cross section from not only CMS measurement and also other LHC measurements.
This summer student project then aims to follow the above on-going project by running analysis codes, deriving result plots of charm production from different meson states.
Physics: 60%, Computing: 40%

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS-D

Special Qualifications::

Basic knowledge and exercise on programming languages like C, C++, Python and on ROOT

57

Translation and combined analysis of jet production at ZEUS and CMS

Author: Florian Lorkowski[1]

Co-author: Achim Geiser [1]

[1] *CMS (CMS Fachgruppe QCD)*

The study of jet production in ep and pp collisions is one of the most important tools to investigate Quantum Chromodynamics (QCD) across different domains.
In a previous summer student project, work has started to translate the ZEUS common ntuples into a format similar to CMS nanoAOD. Doing such a translation allows a common analysis and direct comparison of the resulting distributions with the same analysis code. So far variables associated with reconstructed muons have been implemented.
The goal of this project is to extend the translation to also include electron and jet quantities. The inclusion of these quantities will greatly extend the scope of possible analyses using the common format. After implementing the translation, kinematic distributions will be derived and compared to those from ongoing and completed analyses at ZEUS and CMS.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

58

Investigation of photo-induced ultrafast processes in purely organic molecular crystals by time-resolved photocrystallography.

Author: Krishnayan Basuroy[1]

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

The internship will be an opportunity offered by FS-SCS group in photon science division of DESY to work for a limited period of time, in an onsite project. Interns are usually undergraduate students with physics or related background and the internship last for close to 6-7 weeks.
The FS-SCS group is mostly invested in investigating energy conversion and structural changes in molecules during chemical reactions, using different photon-based technologies. The group is well known for studying the time-dependent electronic and spatial behaviors of the molecules under external stimuli such as light photons, in real time. The group continue to pursue the elusive “molecular movie methods” in the fields related to time-resolved and ultrafast X-ray physics, which include various types of ultrafast X-ray and optical spectroscopy techniques as well as high-resolution ultrafast X-ray diffraction and scattering methodologies. Our study helps to shed light on how different processes that takes place at different time scales in the event of a photo-induced chemical reaction, in solids or solutions, are correlated. The results also help us to understand how much of the structural

changes are local and how much of the structural dynamics is distributed through inter-atomic or inter-molecular interactions, in the system. We also spend a lot of time in researching what type of apparatus needs to be built and which kind of methods need to be developed for investigating the created ultrafast "time stamps" in the structure of complex matters during the course of a chemical or biochemical reaction.
During his/her stay at the group, the student will get a taste of dealing with time-resolved photocrystallography datasets collected at synchrotron facilities. The training will help them to understand the geometry and logistics of these experiments. How different software packages or programming codes are used to process these datasets. The student will also gain a hands-on experience in steady-state optical spectroscopic and single crystal X-ray diffraction measurements. Moreover, the student will gain the important knowledge on how to combine spectroscopy and crystallography while deciphering solid state reactions, in real time. The opportunity will provide a firsthand learning experience to an undergraduate student with physics or related background, to go through the cutting-edge experimental and theoretical techniques that involves our research at FS-SCS. We believe the experience will be quite helpful for the students aspiring a future in the field of scientific research, in academia or industry.

Field:

A2: Molecular sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-SCS

Special Qualifications::

knowledge in a pogramming language will be a plus.

59

CMS Phase-2 Tracker endcap integration.

Author: Moritz Guthoff[1]

Co-authors: Anastasiia Velyka [1]; Andreas Mussgiller [2]

[1] *DESY*

[2] *CMS*

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.

A related activity studies the procedure of constructing double disks from individual half disks. The prototype tooling for the double disk integration is currently being developed and will be assembled

over the next months. The procedure for the assembly has to be defined and tested using dummy structures. This involves various measurements of the tooling system using the precision metrology system.

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::

60

Detecting FIPs at a FutuDetecting FIPs at a Future Higgs Factoryre Higgs Factory

Author: Carl Mikael Berggren[1]

Co-author: Ulrich Einhaus [2]

[1] *FLC (FTX Fachgruppe SLB)*

[2] *FTX (SLB, TBT)*

FIPs (Feebly Interacting Particles) are proposed entities that can explain dark matter and the non-observation of such states at accelerators: The reason they have not yet been seen is rather than that they are too massive (the explanation of non-observation of SUSY), they are too feebly interacting to have been observed at LHC or LEP. Future e+e- machines opens up new ways to search for such states: while still having the same low-background conditions and known initial state as at LEP, the future machines will feature 1000 times higher luminosities compared to LEP.

FIPs could manifest themselves in different ways. This project intends to study one possibility, namely that the new particle can decay into detectable standard model (SM) particles, but are so weakly coupled that these decays happens at macroscopic distances from their production point,so called Long Lived Particles, LLPs. In the project, it will be assumed that the FIP itself is not detectable.

The project requires full detector simulation of such signals, using the available tools, but modifying aspects of the signal to evaluate the performance for different FIPs decay-lengths and decay modes. These simulated events should then be analysed with the tools at hand. For the latter part, the student can profit from collaboration with the student of another project proposed by our group (”V0-Finding at a Future Higgs Factory”).

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX

Special Qualifications::

Basic skills programming (C++ or python) to perform a data analysis

61

Charge collection studies in HV-CMOS

Authors: Håkan Wennlöf[1]; Lennart Huth[2]; Simon Spannagel[2]

[1] *ATLAS (ATLAS-Experiment)*

[2] *DESY*

HV-CMOS sensors are a promising technology for new silicon pixel sensors and advanced to a high level of complexity during more than a decade of developments. These pixel sensors profit from the HV capabilities of the manufacturing process and allow for large depletion zones of above 50um at moderate substrate resistivity. This approach is complementary to the usage of imaging sensors and features intrinsic radiation tolerance and good timing. Extensive laboratory and test beam campaigns have been carried out to understand the performance in detail. TCAD studies have been carried out to understand the breakdown, but have not yet been combined with Monte-Carlo simulations to systematically study the charge collection and compare it to the testing results. The student will perform Allpix2 based simulations of a sensor called TelePix that is envisioned to serve as a timing layer at the DESY II testbeam. The required electrostatic potentials will be provided by colleagues from Heidelberg. The student will get the chance to compare his results with measurements from recent campaigns and will possibly be in exchange with students measuring at the test beam.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

FTX-TBT and ATLAS

Special Qualifications::

Prerequisites: Basics in linux, root, shell
Nice to have: simulation/silicon experience, Geant4 basics

62

Performance Evaluation of Stitched Passive CMOS Strip Sensors

Author: Surabhi Sharma[1]

Co-authors: Jan-Hendrik Arling [2]; Ingrid-Maria Gregor [3]

[1] *ATLAS (ATLAS Upgrade)*

[2] *DESY*

[3] *DESY/Uni Bonn*

The next generation of tracking detectors for future particle physics experiments will be mostly all-silicon detectors. For their realization, apart from the physics specifications, also the cost effectiveness will play an important role. Here, the commercial CMOS technology is a prime candidate, which allows the use of large and high-resistivity wafers and also provides the advantage of widely established industrial production processes. In the ATLAS group at DESY, we are exploring passive CMOS silicon strip sensors produced in a 150nm technology using a stitching of individual reticles to form strip sensors in 2 and 4 cm in length and with currently three different strip designs under study.
The student will contribute to the characterization measurements performed on non-irradiated and irradiated sensors to compare the different designs and determine the important physical properties (e.g. charge collection efficiency). The measurements are conducted either in the lab using radioactive source tests and a probe station for characterizing electrical properties; or at the DESY test beam to determine the sensor performance with several GeV electron beams and using a telescope for particle tracking.

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ATLAS

Special Qualifications::

C++/python programming, lab work experience

63

Continuous scale factor measurements for MVA-based electron identification

Authors: Abideh Jafari[1]; Andreas Meyer[2]; Federica Cecilia Colombina[1]

[1] *CMS (CMS Fachgruppe TOP)*

[2] *DESY*

CMS is one of the two large multipurpose proton-proton collider experiments at the LHC at CERN. The focus of this project is on the measurement of identification efficiencies for electrons in the

CMS detector. The identification algorithm is based on multivariate analysis (MVA) using machine-learning techniques. MC simulations of the data are used to model the detector response and to correct for inefficiencies. Corrections to the simulation, so-called data-to-MC scale factors, are derived to optimize the description of the data. Identification efficiency and purity and corresponding scale factors depend on the exact selection criteria. The determination of such "continuous" scale factors has already been developed for muons. The goal of this Summer Student project is to determine continuous scale factors for electrons.

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

The student should have attended at least one introductory course about Particle Physics. Some basic knowledge about C++ and/or Python programming is also required.

Field:

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

64

Towards modeling of tWGamma at NLO

Authors: Abideh Jafari[1]; Alessia Saggio[1]; Beatriz Ribeiro Lopes[2]; Michele Mormile[1]

[1] *CMS (CMS Fachgruppe TOP)*

[2] *CMS-DESY*

The electroweak couplings of the heaviest known particle, the top quark, has recently gained much attention because of their important role in connection with physics beyond the standard model. Top quark interactions with photon and the Z boson can be directly accessed in the associated ttbar+ɣ/Z production. The measurement of these processes have entered the precision era during Run-II LHC where differential distributions are also measured in addition to the inclusive cross section. There is a non-negligible contribution of tW+ɣ/Z in such analyses, which if analyzed properly, sheds additional light to the picture of top-V interactions (V=ɣ/Z). Depending on the type of the new physics model, the contribution of tWV can become even more important. The main challenge of tWV is its quantum interference with ttV at NLO which calls for studies of the MC models. This has been less explored for tWɣ since photon is massless and the usual solutions work for massive cases. We would like to study, for the first time in CMS, the production of tWɣ at LO while considering an additional emission (i.e. LO+J). This is the first step towards including the next order of corrections in the modeling. Nevertheless, it will have an important impact on the ongoing ttɣ analysis in CMS. The study relies on the existing framework, knowledge and expertise in the group for tWZ.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Introductory knowledge of particle physics and basic computing skills are required. In particular, the student should know at least one programming language (e.g. C++ and/or python).

65

Metrology measurements of CMS Outer Tracker Modules

Authors: Federico Vazzoler[1]; Paul Schuetze[2]

[1] *CMS (CMS Fachgruppe QCD)*

[2] *DESY*

We offer a project related to metrology measurements of CMS Outer Tracker Modules. A SmartScope, a device to measure objects with a high spacial accuracy, will be used to evaluate the precision of the built modules. The student will also get involved in the assembly of CMS Outer Tracker modules.

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

66

Silicon Sensor Testing

Authors: Andreas Nuernberg[1]; Daniil Rastorguev[1]

[1] *CMS (CMS Fachgruppe Detektor)*

We offer a project related to silicon sensor testing. The student will get involved in the CMS Outer Tracker Module assembly and testing and/or the evaluation of silicon test structures.

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

C++ knowledge would be an asset

67

Ultrafast relaxation and fragmentation dynamics of astrochemically-relevant molecules investigated by pump-probe experiments at Free-Electron Lasers

Authors: Diksha Garg[1]; Melanie Schnell[2]; Pragya Chopra[1]

[1] *FS-SMP (Spectroscopy of molecular processes)*

[2] *DESY*

Polycyclic aromatic hydrocarbons (PAHs) are a set of molecules consisting of multiple fused aromatic rings. They are especially interesting in the context of the complex chemistry occurring in the interstellar medium (ISM). The first few (substituted) PAHs, indene, 1-cyanonaphthalene, and 2-cyanonaphthalene have been detected in the ISM [1,2,3], and many more are thought to exist because of characteristic infrared emission signatures of PAHs measured as Unidentified Infrared Bands 4. PAHs are particularly relevant for studies involving FELs since the extreme conditions in the ISM can be mimicked in a laboratory set-up and studied using intense XUV and X-ray radiation, also known to be ubiquitous in the ISM. With such experiments we can delve deeper into the photophysical and photochemical processes that are thought to occur in the ISM. To study the various chemical processes which occur under such conditions, such as ionisation, fragmentation, and isomerisation, we use ultrashort pulses provided by intense free-electron lasers (FELs). This is because such processes happen on very short timescales (~femtoseconds) [5,6] and FELs provide unprecedented opportunities to explore such processes.

The measurements for the ultrafast pump-probe experiments of PAHs have already been performed at Free-electron LASer at Hamburg, FLASH, where time-of-flight mass spectrometry (TOF-MS) and velocity-map imaging (VMI) techniques were employed. Apart from analysis of this TOF-MS and VMI data, a well known covariance analysis method [7] can also be applied to get a deeper insight into the reactions occurring at these timescales.

This project focuses on handling the complex data acquired during these experiments while also learning the analysis tools for the same. Handling the data, which is in h5 or binary file format, will involve usage and development of the libraries using Python programming language. To gain a deeper understanding of the experimental data, it can also be corroborated with theory using quantum chemical calculations. Further, an interpretation of the results would lead to an understanding of the fragmentation patterns and dynamics of the astrochemical relevant PAHs through a combination of TOF-MS, VMI, and covariance analysis. Overall, the project would be composed of around 40% of time spent in learning and applying the software, and 60% of time spent in analysing the results using physics and chemistry principles. The investigation of PAHs using these techniques will append our knowledge of the complex femtochemistry occurring in the ISM.

References:
1 McGuire, Brett A., et al. “Detection of two interstellar polycyclic aromatic hydrocarbons via spectral matched filtering.” Science 371.6535 (2021): 1265-1269.
2 Doddipatla, Srinivas, et al. “Low-temperature gas-phase formation of indene in the interstellar

medium." Science advances 7.1 (2021): eabd4044.
3 Cernicharo, José, et al. "Pure hydrocarbon cycles in TMC-1: Discovery of ethynyl cyclopropenylidene, cyclopentadiene and indene." Astronomy and astrophysics 649 (2021).
4 Peeters, E., et al. "The rich 6 to 9 m spectrum of interstellar PAHs." Astronomy & Astrophysics 390.3 (2002): 1089-1113.
[5] Lee, J. W. L., et al. "Time-resolved relaxation and fragmentation of polycyclic aromatic hydrocarbons investigated in the ultrafast XUV-IR regime." Nature Communications 12.1 (2021): 1-11.
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[7] Frasinski, Leszek J. "Covariance mapping techniques." Journal of Physics B: Atomic, Molecular and Optical Physics 49.15 (2016): 152004.

Field:

A2: Molecular sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-SMP

Special Qualifications::

Elementary knowledge in Python programming would be beneficial.

68

Tau lepton kinematics reconstruction using Deep Learning.

Author: Mykyta Shchedrolosiev[1]

Co-authors: Isabell Melzer-Pellmann [2]; Dirk Kruecker [1]

[1] *CMS (CMS Fachgruppe Searches)*

[2] *CMS (CMS-Experiment)*

Searches for the new phenomena that consider signature with τ leptons is of big interest at the CERN LHC. The reconstruction of tau decaying to hadrons (τ_h) is based on the hadron-plus-strip (HPS) algorithm, which combines the charged hadrons and π^0 candidates, obtained by clustering photon and electron candidates. However, in contrast to this combinatorial approach this problem can be solved with using constituent particles (electrons, photons, charge hadrons) and its properties as an input to the neural network to regress the visible component of τ_h momentum. This project is aimed at studying of applicability of different neural network architectures and input representations for the tau lepton reconstruction. Such flexible algorithm would give an opportunity to optimize tau reconstruction in the regions where current HPS algorithm has poor performance, for instance significantly displaced taus.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

Basic knowledge of Particle Physics, good knowledge of python, experience with neural networks and Linux system.

69

Merging 3D reciprocal space from individual diffraction patterns

Author: Oleksandr Yefanov[1]

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

The measurements of diffraction are usually performed using a 2D detector and the actually measured diffraction pattern corresponds to a spherical cut through the reciprocal space. By collecting many of such patterns, corresponding to different orientations of a measured sample, one can reconstruct a full 3D reciprocal space of the measured object. This is very useful for the accurate analysis of the internal structure of the measured sample.
Our group (group leader H.N.Chapman) has a lot of experience in performing experiments at the most advanced x-ray sources in the world (LCLS, eXFEL, Petra3, APS, ESRF). And we are performing diffraction experiments in different fields: from material science to structural biology. Also, we are analyzing the measured data and developing new methods for structure determination. Therefore, we have several Pb of measured diffraction patterns that can be further analyzed using the developed program.
The development of the new program for 3D merging was started last year and a lot of progress have been achieved already. But the development of the GUI was just started. Further development is needed together with the successful demonstration of application to the experimental data.

Field:

A6: Theory and computing

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

CFEL-FS1

Special Qualifications::

Python and some knowlege of C++

70

Precision Gravity

Author: Rafael Alejandro Porto Pereira[1]

[1] *Z_THAT (Theoretische Gravitationswellenastrophys)*

EFT approach to gravitational dynamics, scattering amplitudes, Gravitational Waves

Field:

C3: Theory of Astroparticle Physics

DESY Place:

Hamburg

DESY Division:

AP

DESY Group:

GWAT

Special Qualifications::

71

High precision polarized photons at future lepton colliders

Author: Juergen Reuter[1]

[1] *T (Phenomenology)*

The potential of future electron and muon colliders can only be assessed with the help of precision theoretical predictions. This applies especially to the description of exclusive photon radiation. There are many theoretical approximations, that become theoretically demanding when lepton beams and/or photons are polarized. Several theoretical approximations are to be investigated regarding their numerical precision and quality. Depending upon the progress this can be extended towards new physics searches with photon backgrounds or precision calculations/simulations for processes with photons.

Field:

B5: Theory of Elementary Particles

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Theory

Special Qualifications::

Knowledge in basics of advanced quantum mechanics and quantum field theory and connection to software might help, though is not necessary

72

Higgs and BSM physics

Author: Georg Weiglein[1]

[1] *T (Phenomenology)*

Theoretical investigations of Higgs physics and possible effects of physics beyond the Standard Model of particle physics

Field:

B5: Theory of Elementary Particles

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Theory

Special Qualifications::

73

Designing nanomechanical resonators for high-frequency gravitational wave detection

Authors: Axel Lindner[1]; Udai Raj Singh[1]; Christoph Reinhardt[1]

[1] *ALPS (ALPS _ Any Light Particle Search)*

Background
The levitated sensor detector is a novel kind of gravitational wave detector targeting signals in the frequency range of 10 – 300 kHz [1,2]. It comprises a dielectric disk trapped by the light field inside an optical cavity. A passing gravitational wave displaces the disk from its equilibrium position (i.e., the antinode of the trapping field), which results in a restoring force. This interaction is resonantly enhanced if the frequency of the gravitational matches the frequency of the optical trap. An additional probe field is used for measuring the disk's motion via phase modulation. As a complementary approach, we investigate a similar setup comprising a "partially-levitated" membrane instead of a "fully-levitated" disk. A goal of this approach is to enable using a cavity end mirror compatible with current technology, by virtue of the design flexibility for the membrane.

Tasks
- Simulate mechanical resonance frequency and Q factor of a membrane in COMSOL (with and without optical trap)
- Identify optimal designs by systematic variation of design parameters
- Carry out supporting data analysis in Python, Matlab, or similar
- Take part in the experimental characterization of mechanical membrane resonators (if the pandemic situation permits it)

- Bonus: investigate advanced approaches for design optimization (e.g., topology optimization, Bayesian optimization/machine learning)

References

1 Arvanitaki, Asimina, and Andrew A. Geraci. "Detecting high-frequency gravitational waves with optically levitated sensors." Physical review letters 110.7 (2013): 071105
2 Aggarwal, Nancy, et al. "Searching for new physics with a levitated-sensor-based gravitational-wave detector." arXiv preprint arXiv:2010.13157 (2020)

Field:

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

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

ALPS

Special Qualifications::

74

Analysis of Belle II data

Author: Daniel Pitzl[1]

[1] *DESY FH/Belle II*

Belle II is the detector observing electron-positron annihilations at the asymmetric energy Super-KEKB factory in Japan since 2019. More than a billion processed and calibrated events are available at DESY. Physics topics being pursued include precision lifetime measurements for tau leptons and charm hadrons, which exploit the unique pixel vertex detector. Further analysis techniques being developed include time-dependent Dalitz plots for charm mixing and CP violation studies and recoil mass spectra for B decay measurements and searches. A student project would be defined in one of these areas. The data are stored as ROOT trees and analyzed in C++ and optionally Python. Some programming and particle physics knowledge would be beneficial but most of the learning will come from using examples on the data.

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

Belle II

Special Qualifications::

75

Operation of an accelerator

Authors: Florian Burkart[1]; Sonja Meike Jaster-Merz[1]; Willi Kuropka[1]

[1] *MPY1 (MPY Fachgruppe 1)*

Join the ARES operation team
We are looking for a summer student joining the ARES operation team. The student will participate in the daily operation of an accelerator for research and development studies. The student will focus on different methodes to diagnose the beam parameters, like beam size, beam position, intensity and pulse length.
In addition, the student will learn the working principle of a conventional accelerator from electron generation, acceleration and use of the electrons for experiments.

Field:

B4: Research on Accelerators

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MPY

Special Qualifications::

76

3D Modelling of Self-Amplified X-ray Emission

Authors: Stasis Chuchurka[1]; Andrei Benediktovitch[1]; Nina Rohringer[2]

[1] *FS-TUX (Theoretical ultrafast X-ray science)*

[2] *DESY*

The ultrashort high-intensity pulses from x-ray free-electron lasers can drive the matter in novel states. In our group, we investigate the self-amplified x-ray emission caused by massive inner-shell photoionization. In these conditions, spontaneously emitted x-ray fluorescence develops into collective emission resulting in short and intense x-ray bursts. This phenomenon can give rise to new spectroscopic tools or x-ray sources with unique properties.

Due to the short wavelengths, the numerical description of the propagation of x-ray pulses is a challenging task. So far, we rely heavily on the paraxial approximation, which only accounts for the light traveling within a narrow solid angle. Choosing an appropriate geometry of the medium can justify the use of this approximation. However, in the general case, one must consider all the modes of the field.

Within the summer student program, we would like to take a step forward in the rigorous treatment of the x-rays. A potential solution is to decompose the x-ray field into several paraxial beams. Then, the interaction between introduced beams can model real propagation and diffraction. The project will help understand the role and properties of the emission going sideways and its effect on the overall properties of the x-ray pulse. The presented problem requires knowledge of electrodynamics, quantum mechanics (quantum optics), and basic skills in numerical modeling.

Field:

A6: Theory and computing

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-TUXS

Special Qualifications::

Quantum Mechanics (Quantum Optics)

77

Building an agile platform for web-based testing.

Author: Alexander Paul Millar[1]

Co-author: Thomas Beermann [2]

[1] *IT (Research and Innovation in Scientific Co)*

[2] *IT (Informationstechnik)*

Scientific work is placing increased dependency on web technologies, with the web-browser being a key tool for certain activities. As DESY is providing an ever increasing number of services with web front-ends, it is becoming important to build a robust, agile platform for testing these services.

This project involves building a Proof of Concept testing platform using industry standard technologies, including Selenium Grid, Kubernetes and Linux. Depending on progress, also help demonstrate cross-platform testing (Windows and MacOS), and also help develop tests that take advantage of this platform to verify that services are running correctly. Such tests can then be integrated in to DESY's testing infrastructure.

Through this project, you will gain experience in key industry technologies, including CI/CD pipelines, acceptance and functional testing, and various web technologies.

[100% Computing]

Field:

B6: Computing

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

IT

Special Qualifications::

Linux experience greatly appreciated. Programming experience (e.g., Python) may be helpful.

78

Development of Laser Beam Profiler Software

Authors: Henrik Tuennermann[1]; Ingmar Hartl[2]

[1] *FS-LA (Research Topics)*

[2] *FS-LA (Lasergruppe)*

The group FS-LA, Laser Science and Technology, is responsible for the research, development, and operations of laser systems for the large-scale facilities at DESY in Hamburg. The current spectrum of lasers in the group range from low power, high stable mode-locked oscillators up to multi kW ultra-short pulsed laser systems for pump-and-probe experiments at FELs.
Many of those lasers include diagnostics systems to monitor the performance. One key component are cameras to record the position and beam size of the laser beams at different locations. For this purpose industrial cameras integrated into the facility control systems are used.
For the initial setup of those cameras a stand-alone software, including beam profile analysis, is required. As commercial solutions do not interface with our industrial cameras we are looking for a summer student, who is interested in:
- Programming a user-friendly interface to show, process, and analyze images taken with our industrial cameras
- Work together with our software and electronics team to improve our existing camera server interface to the machine control system to enable beam profile analysis throughout the control system interfaces
- Set up an experimental test station for qualification of the software to follow ISO 11146 standard
Working in our multi-cultural team at the FS-LA group will give you a very good inside into the daily business of a large optics and laser research and development group.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-LA

Special Qualifications::

Basic level in programming in Python
Some experience in work with optical systems (lasers and geometrical optics) are a plus

79

Conventional FTIR and novel frequency comb spectroscopy of molecular vibrations in Fabry-Pérot cavities

Author: Dominic Laumer[1]

Co-authors: Ingmar Hartl [2]; Marcus Seidel [3]

[1] *FS-LA (Research Topics)*

[2] *FS-LA (Lasergruppe)*

[3] *FS-LA (FLASH 2020+ flexible pump probe lasers)*

Infrared radiation is absorbed by molecules if the frequency of the radiation matches the oscillation period of interatomic motions in the molecule. In our lab we study how those absorption features can be modified when the molecule is placed inside an optical resonator where continuous energy exchange between molecule and resonator can occur. We are characterizing those molecule-resonator systems by conventional Fourier-transform infrared (FTIR) spectroscopy and optical infrared frequency combs, which can provide ultimate spectral resolution.

During this project you mainly will perform FTIR measurements on molecules confined in a recently developed flexible Fabry-Pérot resonator. Both the resonance frequencies and the degree of energy confinement can be tuned in the cavity. The goal of the investigation is to study the limits of the tuning range imposed by the coherence of the thermal light source. Furthermore, the student can assist in setting up a fiber-laser based mid-infrared frequency comb which is supposed to overcome the limitations of conventional spectroscopy. Consequently, the project provides insights into the development of modern spectroscopic tools as well as into novel hybrid cavity-molecular samples that become of increasing interest in infrared spectroscopy.

We are looking for a curiosity-driven, highly motivated student who is keen on applying the basic knowledge acquired in undergraduate and possibly graduate courses to state-of-the-art spectroscopy experiments. In order to get started quickly within the short internship time, we would prefer if the applicant has studied physics, chemistry or a related subject for at least two years. Having completed an atomic, molecular and optical physics course or a physical chemistry course in molecular spectroscopy is desirable. The project focuses on experimental work, i.e. the applicant should enjoy spending the majority of work time inside a modern laboratory.

Field:

A2: Molecular sciences (application oriented)

DESY Place:

Hamburg

DESY Division:

FS

DESY Group:

FS-LA

Special Qualifications::

- Studied physics, chemistry or related fields for at least two years
- Completed some advanced courses on atomic, molecular and optical physics
- Ideally already experienced with work in a modern laser laboratory

80

Machine Learning Techniques for Laser-Plasma Accelerators

Author: Andreas Maier[1]

[1] *MLS (Laser fuer Plasmabeschleunigung)*

Laser-plasma acceleration promises a next-generation compact source of electron beams for a large variety of applications. However, the non-linear, complex interaction between drive laser pulse and plasma results in a large parameter space, and tuning a plasma accelerator to produce useful electron beams is extremely complex. Here, we want to use machine learning techniques to autonomoulsy tune and optimize a laser-plasma accelerator, both in experiments and simulations. This project will include coding (in Python), running simulations (code: FBPIC) as well as hands-on work at the experiment (laser lab and accelerator tunnel).

Field:

B4: Research on Accelerators

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MLS

Special Qualifications::

Knowledge in Python is expected. Experience with lasers is beneficial.

81

High-Power Lasers for Laser-Plasma Acceleration

Author: Andreas Maier[1]

[1] *MLS (Laser fuer Plasmabeschleunigung)*

Laser-plasma acceleration promises a next-generation compact source of electron beams for a large variety of applications. The high-power terrawatt-class lasers required to drive these machines are extremely complex and challenging. This project will address current topics in laser development for plasma accelerators. The summer student will join the laser development team spending time in the lab, performing measurements and analyzing data. The actual task will be defined based on the specific background and qualification of the student.

Field:

A5: Lasers and optics (methodology oriented)

DESY Place:

Hamburg

DESY Division:

M

DESY Group:

MLS

Special Qualifications::

Some experience with lasers is required. Coding experience (python) is a benefit.

82

Drell Yan pT resolution at low pT

Authors: Armando Bermudez Martinez[1]; Qun Wang[2]

[1] *CMS (CMS Fachgruppe QCD)*

[2] *DESY*

We will study the limits on the resolution of the DY pT at very small pT, using CERN open data. We will first focus on the muon pT resolution as main source of smearing of the DY pT at small pT. We will also study the DY pT spectrum at low DY mass as a way of improving the muon pT resolution. The work will be done primarily using python jupyter notebooks that will then be released as tutorials.

Physics / Computing/ Engineering Content of the project :
Physics: DY measurement at the LHC, data analysis.

Computing: Basic knowledge of Linux is welcome, as well as some basic knowledge of C++/python

Supervisors:

Name: Armando Bermudez Martinez email :
armando.bermudez.martinez@desy.de

Name: Qun Wang email :
qun.wang@desy.de

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

83

Collin-Soper kernel determination in Higgs boson production using PB-TMDs

Authors: Armando Bermudez Martinez[1]; Sara Taheri Monfared[2]

[1] *CMS (CMS Fachgruppe QCD)*

[2] *DESY*

We will study Higgs boson production at the LHC, specifically its transverse momentum spectrum using PB-TMDs with the CASCADE generator. We will transform the pT spectrum to physical space and determine the Collin-Soper kernel for gluon parton densities, which is sensitive to non-perturbative physics.

Physics / Computing/ Engineering Content of the project :
Physics: QCD and parton evolution, Monte Carlo techniques,
and simulation of physics processes at the LHC.

Computing: Basic knowledge of Linux is welcome, as well as some basic knowledge of C++/python

Supervisors:

Name: Armando Bermudez Martinez email :
armando.bermudez.martinez@desy.de

Name: Sara Taheri Monfared email :
sara.taheri.monfared@desy.de

Field:

B1: Particle physics analysis (software-oriented)

DESY Place:

Hamburg

DESY Division:

FH

DESY Group:

CMS

Special Qualifications::

84

Investigation on the beam based alignment (BBA) in the booster accelerator at PITZ

Author: Xiangkun LI[1]

[1] *DESY Zeuthen*

At the photo injector test facility at DESY in Zeuthen (PITZ), the trajectory of the electron beam (6-7 MeV) in the booster accelerator is optimized routinely for improving the transverse phase space, which is crucial to the performance of the photo-injector. If entering the booster tilted and/or displaced, the electron beam will suffer asymmetric RF fields, which is axially symmetric and will kick

and distort the beam. The fact that the RF kicking depends on the RF phase is employed to correct the beam trajectory at PITZ. The earth magnetic field also affects the beam trajectory and its effect on the correction procedure should be analyzed.

In this project, the candidate will perform particle tracking first, which tells the behaviors of the beam when passing the booster off-axis. Then by fitting the simulation results to the measurement data, the beam centroid position and angle at the booster entrance can be obtained, predicting the correction that can be realized by tuning the steering magnets before the booster. Finally, whether the beam trajectory improves or not can be verified by measurement.

This project will give us a better understanding of the booster BBA: its capabilities and limits. Besides particle tracking and data fitting, script development using MATLAB or python is also expected, which may finally help establish a routine procedure for booster BBA at PITZ.

Field:

B4: Research on Accelerators

DESY Place:

Zeuthen

DESY Division:

M

DESY Group:

PITZ

Special Qualifications::