BEPC-1

Hosting Laboratory	Available period	Contact person(s)
IHEP(Beijing, PRC)	**01/01/2024 – 30/11/2024**	**MICHELA GRECO (INFN-TO)** **GIULIO MEZZADRI (IHEP)**

BESIII/CGEM	Daily activity, skills required and to be acquired
The BESIII experiment is carried out at the BEPCII electron-positron collider at the Institute of High Energy Physics in Beijing, PR China. BESIII plays a leading role in the investigation of hadron spectroscopy in the energy range of the tau lepton and the charm quark. An upgrade program is underway for both the detector and the accelerator to compete with and complement the studies of the new generation of B-factories and hadron accelerators. A major upgrade of the detector is to replace the current inner drift chamber, which shows aging effects, with an innovative cylindrical gas electron multiplier (CGEM) with charge and time readout. The CGEM Inner Tracker consists of three concentric layers of triple GEM detectors. Installation is planned for summer 2024. A stand-alone cosmic run is currently underway to test the entire readout chain the slow- control system and evaluate performance with an external tracking system. After installation, commissioning will continue with a full cosmic data acquisition of the spectrometer to finalize the final alignment.	The candidate will participate in the preparation of the installation, installation and commissioning of the CGEM Inner Tracker under the supervision of his/her advisors as part of one of the main tasks. Basic knowledge of laboratory instrumentation and operation of particle physics detectors is required. Knowledge of the micro-pattern gas detector and/or hardware systems (FPGA, DAQ systems) is an advantage. The candidate will be part of an international collaboration and will learn from direct experience advanced techniques in the operation of an innovative detector, which will give a boost to his/her studies.

CERN-1

Hosting Laboratory	Available period	Contact person(s)
CERN	1/7/2024 – 30/9/2024	Francesco Terranova – Filippo Resnati

Performance of the ProtoDUNE Photon Detection System	Daily activity, skills required and to be acquired
During July-September 2024, the ProtoDUNE detector at CERN will be in data taking with a run of cosmics and charged particles. This run is crucial for the validation of the Photon Detection System (PDS), which is the device that collects, shifts, traps and detects the VUV liquid argon scintillation light. The purpose of this grant is to enable a master's degree student to take part in data taking and carry out a performance analysis of this system. Specifically, the participant will have the opportunity to join the onsite ProtoDUNE team and perform an analysis to evaluate the overall efficiency of the PDS using minimum ionizing particles (muons from cosmic rays and high-energy pions/muons from the beam). He/she will, therefore, perform the event selection using information from ProtoDUNE's TPC employing the automatic track reconstruction software and, for that sample, evaluate the signal produced in the PDS by photons shifted within ProtoDUNE's X-Arapuca modules. This information enables the determination of the absolute efficiency of the PDS, the assessment of its response uniformity, and the execution of specific signal-to-noise studies for shifted and trapped photons.	Daily activity: the student will join the onsite team (coordinator: Filippo Resnati, CERN, technical PDS coordinator: Francesco Terranova, INFN Mib) to monitor the response of the PDS during the run and survey the data quality using the online software of protoDUNE. He/she will get acquainted with the data production stream, including the automatic reconstruction of charged tracks in the TPC. Using the data produced by the DAQ in root format, s/he will perform the event selection and the evaluation of the signal response of the PDS modules. Skills required: basic knowledge of C++ programming and root. Skills to be acquired: the student will acquire solid instrumentation skills for elementary particle physics, analog electronics and optoelectronics with an activity designed specifically for a three-month internship.

CERN-2

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2024 – 30/11/2024	Marco Schioppa – Alessandro Polini

ATLAS phase 2 RPC with double edge readout: construction and test	Daily activity, skills required and to be acquired
L'esperimento ATLAS ha iniziato la realizzazione di uno strato di camere RPC da inserire, nel lungo shutdown LS3 (2026-2029), sopra le camere di tracciamento MDT dello strato più interno del barrel dello spettrometro per muoni. Questi rivelatori hanno il duplice scopo di fornire la coordinata ortogonale ai fili delle camere MDT e partecipare, insieme alle altre camere RPC già presenti nello spettrometro, alla selezione in tempi molto brevi di particelle in piccoli intervalli di impulso (trigger). Le camere RPC saranno formate da un triplo strato di rivelatori che alla luminosità di high luminosity LHC avranno una efficienza del 99%, una risoluzione temporale di 400ps e una risoluzione spaziale ordine 1cm.La realizzazione di questi nuovi rivelatori, opera di lavoro congiunto dei gruppi INFN Roma1, Roma2, Bologna, Cosenza, è iniziata a giugno 2023 e si protrarrà sino all'inizio di LS3 previsto per il 2026. L'integrazione di parte di questi rivelatori nella meccanica sarà svolta presso i laboratori del CERN, così come il loro commissionamento prima della loro installazione nell'esperimento, a cui lo studente potrà assistere. Nei laboratori è anche presente una stazione di test con raggi cosmici che serve a qualificare i rivelatori assemblati. La stazione comprende tutti i componenti che costituiscono una porzione del rivelatore a muoni di ATLAS, ovvero il sistema di controllo, il sistema di trigger e di acquisizione dati.	Il/la studente potrà familiarizzare con tutti gli strumenti dell'attività sperimentale e in particolare potrà gestire la presa dati di una frazione completa di rivelatore di trigger per muoni e partecipare allo sviluppo e utilizzo degli strumenti software di analisi dati. Il/la studente avrà modo di partecipare ad una esperienza unica, nel più grande laboratorio di fisica nucleare e subnucleare al mondo, lavorando a stretto contatto con ricercatori esperti del settore e acquisendo le più innovative tecniche sperimentali nel campo dei rivelatori di particelle. Avrà modo di lavorare in gruppo entro una collaborazione internazionale su tematiche di punta nel campo della fisica delle particelle elementari e delle interazioni fondamentali.

CERN-4

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 30/11/2024	Andrea Bocci – Ernesto Migliore

A next generation reconstruction software for the next generation Tracker of the CMS experiment at HL-LHC	Daily activity, skills required and to be acquired
The High Luminosity upgrade of LHC (HL-LHC) will be the main scientific instrument for investigating the subatomic world through the 2030s. To cope with the unprecedented particle rates and radiation levels expected at HL-LHC, the present Tracker of the CMS experiment will be replaced during the LHC long shutdown in 2026-2028. So far, the code describing the upgraded Tracker detector in the CMSSW software framework was primarily developed to support the main decisions on the configuration of the detector with the goal of providing a reliable description of the expected performance both on aspects related to the online data processing and on the main physics observables (tracking, identification of b-jets, and mitigation of pileup). With the final configuration of the detector frozen, it is time to start a revision of the CMSSW code of the upgraded Tracker to match the CMS computing model at HL-LHC, which requires the software to be accelerator and multi-platform compliant. The selected candidate will work with a team of experts contributing to refactoring selected parts of the code in use by the upgraded Tracker in view of running it on multi-platform architectures.	After an initial period in which the student will become acquainted with the code currently used for the upgraded Tracker, we propose the following activities: - review the performance of the track reconstruction using the offline workflows already running on GPUs; - identify a few modules of the current code which needs to be modified to run in a multi-platform environment; - compare the impact of the adopted solutions, evaluating the possible effects on physics and computing performance. Required skills: - programming in C++; - basic notions of tools for collaborative software development (git); - interest in advanced programming (multi-threading, GPUs, etc.).

CERN-5

Hosting Laboratory	Available period	Contact person(s)
CERN	**20/6/2024 – 20/9/2024**	**Fabrizio Ferro – Enrico Robutti - Silvano Tosi – Jonathan Hollar**

Identification of central exclusive production events using the CMS Proton Precision Spectrometer	Daily activity, skills required and to be acquired
The LHC beam protons often interact with each other without disintegrating. They may exchange for example photons, thereby modifying their momentum, and then continue their trip, effectively transforming in a way a proton collider into a photon collider. The interaction yields particles that are reconstructed by the central CMS detectors. Thanks to the CMS Proton Precision Spectrometer (PPS), the protons can be reconstructed, and the exchanged momentum determined. The matching between the momenta measured by CMS-PPS and by the central detectors imposes stringent kinematic constraints on the reconstructed particles, providing a unique tool to measure final states yielded by photon-photon collisions at very high energies, either precision measurements of standard model processes and searches for new physics.	The student will work within the data analysis group aimed at measuring cross sections of processes observed in central exclusive production, that can be collected thanks to the CMS-PPS detector. The student will work with senior physicists and with a group of other students that join the group every Summer. This is a unique opportunity to learn physics and advanced data-analysis techniques and to learn how to cooperate with fellows from other countries. The main task will be to apply a proper set of selections to separate signal events from background events exploiting the opportunities offered by the combination of information from the central CMS detectors and CMS-PPS. The skills required are: basic programming in Python and ROOT, basic English, basic knowledge of particle physics. The skills to be acquired are: advanced C++ programming and python scripting, deeper knowledge of experimental physics challenges in high energy physics, team working in an international environment.

CERN-6

Hosting Laboratory	Available period	Contact person(s)
CERN	20/6/2024 – 20/9/2024	Fabrizio Ferro – Valentina Avati

Code development for proton detection with CMS-PPS	Daily activity, skills required and to be acquired
The CMS Proton Precision Spectrometer at the LHC detects the protons that survive the interaction and that are scattered at very small angles. These protons keep moving inside the beampipe with a trajectory slightly bended with respect to the beam protons that did not interact. Therefore, they can be detected ~200m downstream from the interaction point by means of detectors that access the beampipe up to a few mm close to the beam. The parameters of the track allow to reconstruct the proton momentum loss at the interaction point providing fundamental information about the scattering kinematics. The detector operation and data reconstruction require the development of code (mainly using C++ and python languages) to be integrated in the general CMS framework CMSSW. In 2024 PPS will take data with its tracking and timing detectors as in the previous years. An extensive activity of maintenance, update and development of the code for reconstruction and simulation is foreseen along the entire year.	The student will work in the CMS-PPS Offline group with senior physicists and with a group of other students that join the group every Summer. It can be a unique opportunity to learn physics and software development from a team of experienced people and to share working and everyday life with students from other countries. The main task will be developing algorithms and applications devoted to the physics studies and to the detector operations that are done within CMS-PPS. The skills required are: basic C++ programming, basic Python scripting, basic English, basic knowledge of particle physics. The skills to be acquired are: advanced C++ programming and python scripting, deeper knowledge of experimental physics challenges in high energy physics, team working in an international environment.

CERN-7

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 30/09/2024	Marta Calvi –Julià̀n Garcia Pardiñas

New strategies for signal identification using GNNs	Daily activity, skills required and to be acquired
The new era of running at high luminosity at the LHC proton-proton collider poses several challenges to the trigger, selection and analysis of data collected by the LHCb detector. A new strategy has been devised based on AI that uses Graph Neural Networks to perform a Deep Full Event Interpretation of the events (DFEI). The algorithm aims at reconstructing the decay chain of all beauty hadrons present in the event providing their full hierarchical structure. It can be used at trigger level, for the inclusive selection of interesting events and the determination of sub-sample of particles to be saved. A second use of DFEI is in the offline selection of signal candidates and the rejection of “background” ones. Background candidates in standard selection algorithms can come from multi-tracks decay chains that are only partially reconstructed, or from random combinations of tracks emerging from different hadrons. This project aims at exploring the use of DFEI to recognize these types of background by reconstructing the full decay chains of heavy hadrons. The algorithm will be used in the selection of semileptonic decays of beauty hadrons, and will be compared with other isolation strategies.	First step: introduction to the context - concept, structure, and performance of a Graph Neural Network - basic properties of b hadron semileptonic decays, - use of Root ntuples containing semileptonic events simulated in Run3 conditions. Second step: running DFEI algorithm, evaluating performance, validating against standard tools. The activity will allow to acquire knowledge and skills on Machine Learning in general and GNN in particular. The candidate will profit from the supervision of the IML LHCb coordinator in the use of AI in HEP. The candidate will also acquire some experience in the analysis of physics data, in signal selection strategies and background treatment. Required skills: basic use of python and ROOT software, basic knowledge of Machine Learning methods.

CERN-8

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 30/09/2024	Margherita Primavera

Search for stop pair production and decay in 4-body in the Run3 data collected by ATLAS	Daily activity, skills required and to be acquired
The supersymmetric partner of the top quark (top squark or `stop') is of particular interest for the SUSY searches because it is predicted to have the lightest mass among the squarks and its production at LHC is expected to be favoured. The stop decay in 4-body, i.e. stop->bff'Chi_1^0, where b is the b-quark, f and f' are two fermions and Chi_1^0 is the first neutralino, occurs if the mass difference between stop and neutralino is smaller than m(b)+m(W). This kinematic region is especially challenging: in final states where both stop decay through the 4-body channel and f and f' are a lepton(antilepton) and its antineutrino(neutrino), leptons are expected to have very low transverse momentum, and the fake and non-prompt lepton rate becomes one of the most important contribution to the background. The new ATLAS searches for this channel on Run3 data will apply improved selections, adopting new lepton isolation criteria and low-momentum lepton taggers, and making use of analysis techniques based on Machine Learning. Contributions to the definition of the optimized Signal Regions for the stop decaying in 4-body with two leptons in the final state can be given by a master student during the time of the project.	The student will be introduced to experimental analysis techniques used in High Energy Physics, within the stimulating environment of the ATLAS SUSY group. He/She will start to get familiar with the basics of event reconstruction and selection at ATLAS, and with Machine Learning techniques. Real ATLAS Run3 data will be used, as well as (signal and background) Monte Carlo samples. A basic knowledge of C++ or Python computing language and familiarity with ROOT data analysis framework is required, as well as a good knowledge of English.

CERN-9

Hosting Laboratory	Available period	Contact person(s)
CERN	01/03/2024 – 30/11/2024	Marcello Maggi – Maria Girone

Development of the Digital Twin for the CMS ME0 system	Daily activity, skills required and to be acquired
The concept of Digital Twins involves creating virtual replicas of physical objects or systems. In the context of particle detector development, applying the Digital Twins approach can offer several benefits, including simulation, monitoring, and optimization. The Phase-2 upgrade of the CMS detector will include a new triple-GEM detector station, ME0, to increase the acceptance of the CMS muon spectrometer. The development of the Digital Twins offers the possibility of integrating tools to optimize the assembly procedure of the ME0 foreseen in 2024. The student will be at the core of this first development participating in the setting up of the Digital Twin approach with the help of the CERN-OpenLab/NVIDIA experts. In particular, the student will simulate physical assembly operations starting from the CAD models developed during the design phase. This is a task of key importance as it will enable the team to discover potential integration problems and explore new tools and techniques, meant to simulate the integration of complex 3D objects in the virtual world. Any assembly problem emerging from the simulation will be easily solved by adjusting the CAD models before going to production, saving time and costs.	The student will gather requirements for the Digital Twin environment (CAD of the ME0). She/he will integrate the CAD modeling creating a digital representation of the ME0 system. She/he will regularly assess the performance of the Digital Twin environment. Required skills are the basic knowledge particle detectors. Basic knowledge of some scientific programming language (e.g., Python) might be an advantage. The student will acquire a deeper knowledge of the particle detectors and an insight of the new concept of Digital Twin and its use in HEP. The student will learn CAD modelling as well.

CERN-10

Hosting Laboratory	Available period	Contact person(s)
CERN	15/03/2024 – 15/06/2024	Stefano Perazzini – Vincenzo Vagnoni

Measurement of time-dependent CP violation with $B_s^0 \to \pi^+\pi^-$ decays at LHCb	Daily activity, skills required and to be acquired
The measurement of time-dependent CP violation (CPV) with charged two-body B decays to charmless final states ($B \to h^+h'^-$) is a promising opportunity to look for physics beyond the Standard Model (SM). According to the SM, CPV in the $B_s^0 \to \pi^+\pi^-$ decay is expected to be very small, hence any deviation from a null value may indicate the presence of New Physics. The LHCb collaboration already published several measurements of time-integrated and time-dependent CPV with $B \to h^+h'^-$ decays, but the $B_s^0 \to \pi^+\pi^-$ remains unexplored from this point of view, mainly because of its small branching ratio. However, exploiting the full LHCb Run2 sample, a measurement of the direct and mixing-induced CPV of the decay with 20% precision seems feasible. The objective of the research project is to realise a preliminary measurement of these quantities. In addition, profiting from the start of the new LHCb Upgrade-I detector, new and optimized software trigger algorithm to acquire $B \to h^+h'^-$ decays will be developed, together with online monitoring tools to check the physics performance regarding these decays.	The student will learn directly from experts based at CERN how to conduct time-dependent CPV measurements, participating in all its phases: the optimization of event selection using multivariate algorithms, the calibration of experimental efficiencies using simulation and data-driven techniques, the realization of multidimensional fitting models to extract the relevant physics quantities from data. In addition, the student will participate to the final commissioning phase of the software trigger of the experiment, optimizing dedicated selection algorithms and the corresponding online monitoring tools. Within this program the student will also learn and familiarise with the most used analysis frameworks used in High-Energy Physics experiments (ROOT, RooFit, python, scikit,…).

CERN-11

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2024 – 31/10/2024	Roberto Covarelli – Chiara Mariotti

Rare hadronic decays of Higgs and vector bosons at CMS	Daily activity, skills required and to be acquired
Rare hadronic and radiative decays of W, Z and H bosons have been theoretically studied as precision tests of the factorization approach in QCD. For W bosons such decays could be fully reconstructed in the CMS detector, paving the way for much less model-dependent measurements of the W mass and other particle properties, than in the lepton-neutrino channels. For the Higgs boson, such decays are unique probes of Higgs-to-light-quark couplings. In the LHC Run3, CMS HLT strategies for W, Z, H -> mesons (+ gamma) final states have been introduced and/or improved, thus expecting large efficiency gains in inclusive searches. The project will consist on building a framework with a twofold purpose: 1. Producing customized nanoAOD, with specific focus on light mesons from W, Z, and H boson decays, decaying to charged tracks and neutral pions and selected with suitable isolation and vertex-fitting strategies. 2. Defining an analysis baseline, from which estimating HLT efficiencies (also establishing methods for data-driven measurements) and low-level selections for a streamlined analysis flow.	The candidate will collaborate with the CMS SMP-V and CAT groups. Experience will be acquired on all the needed software aspects which are needed to build an analysis framework in the context of the most recent CMS physics analysis tools. The breakdown of the project is as follows: 1.5 months. Preparation of the common analysis framework 0.5 months. Generation of small signal MC samples and preparation of official requests. Study of main signal efficiencies 1 month. Common event processing and preselection. The following skills are required during the project: python and C++ programming, knowledge of ROOT. The candidate will get familiar with advanced CMSSW programming and state-of- the-art MonteCarlo generators during the project.

CERN-12

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2023-31/11/2024	Leonardo Carminati – Stefano Manzoni

Photon identification optimization for the HH->bbyy search with the ATLAS detector at the LHC	Daily activity, skills required and to be acquired
This project aims to improve the identification performance of photons with the ATLAS detector using advanced ML techniques. Currently, a photon is defined at the analysis level by a series of rectangular selections on calorimeter-based discriminant variables. Three different working points in terms of signal efficiency/background rejection are defined for these requirements. In this project, we aim to improve the current photon identification selections using advanced ML techniques and compare the performance with existing menus. In addition, the ML approach will provide an opportunity to overcome the limitations of the fixed working point of the selection by providing a (pseudo)continuous identification menu. The main challenge of the project will be to measure in situ the efficiency and scaling factors for the new identification algorithm using photons from Z->ee/mumu radiative decays data events. The main physical target of this project is to improve the sensitivity on the production of di-higgs in the final yybb state with Run data 3 by increasing the efficiency of signal selection. One possibility that we would like to explore is the inclusion of the photon identification score directly into the optimization of the analysis, so that the analysis can exploit photons of different qualities depending on the specific kinematic features of a given event category.	Daily activity will consist in guided and free coding sessions and study of existing literature. The project will be developed in autonomy by the candidate with frequent discussions with the supervisors. We foresee presentations in the relevant working groups meetings. For this project we expect students with a strong interest in working in software and computing areas. The project will require some basic knowledge of programming in C++ and python libraries. Some knowledge of the basics of ML algorithm would be beneficial although not strictly required. During the project the student will have the possibility to work on a real physics analysis learning how to deal with big bunches of data and MC events. In addition, the student will have the possibility to familiarize with the state-of-the-art machine learning tools.

CERN-13

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 31/08/2024	Lorenzo Bonechi – Eugenio Berti

LHCf experimental program 2024: proton-oxygen collisions for cosmic ray studies	Daily activity, skills required and to be acquired
Description of the project (font Calibri pt11), stay within the allocated space. The LHCf experiment is designed to study a region of phase space in collisions at the LHC accelerator of considerable interest for cosmic ray physics. The LHCf detectors are compact and slim imaging sampling calorimeters optimized to fit a narrow instrumentation slot located 140 m far from the interaction point IP1, at zero degree with respect to the beams collision line. This position allows detecting the most energetic and forwardly emitted secondary particles produced in the high enery particle collisions, which determines the development of the cosmic ray atmospheric showers. In 2024, collisions between proton and oxygen ions will be carried out for the first time at an energy never achieved before, an ideal configuration for studying the interactions between primary cosmic rays and atmospheric gas nuclei. A calibration test is also planned at the SPS accelerator following data collection.	Description (font Calibri pt11), stay within the allocated space. The student will participate in the preliminary testing and final preparation phase of the experimental apparatus, the DAQ and control system, carrying out laboratory activities both in the surface laboratories and in the underground counting room where the LHCf electronic systems will be installed. Subsequently, the student will actively participate in the data taking and monitoring rounds of the experiment and in the uninstallation phase of the apparatus. In the second part of the period at CERN the student will contribute to the preparation and conduction of a calibration test of the apparatus with particle beams at the SPS accelerator.

CERN-14

Hosting Laboratory	Available period	Contact person(s)
CERN	03/06/2024 – 03/09/2024	Marco Lucchini – Etiennette Auffray

Characterization of scintillating crystals for maximum information calorimetry at future colliders	Daily activity, skills required and to be acquired
This project is part of the ongoing R&D in the context of next generation detectors for future particle collider experiments, such as the Future Circular Collider (FCC) at CERN, designed to further improve our understanding of the Higgs boson properties and fundamental interactions between elementary particles. In particular, the development and construction of an innovative electromagnetic calorimeter concept made of segmented scintillating crystals read out with pairs of Silicon Photomultipliers (SiPMs) for the simultaneous readout of scintillation and Cherenkov light is considered highly attractive for its potential, e.g. in flavor physics and axions searches with low energy photons in the final state. The path towards the construction of a prototype, identified as a short term deliverable in the forming DRD6 collaboration and a strategic R&D by the ECFA community, requires a survey of existing crystal technologies to identify viable candidates. The CERN Crystal Laboratory located in building 27 has a long history for its expertise in the field of crystals for medical imaging and high energy physics and stands out for its state-of-the-art instrumentation that enables a comprehensive characterization of the crystal scintillation properties. This project will represent a unique opportunity to enhance and broaden the candidate's skills in a multidisciplinary field.	Characterization of scintillating crystals (such as PWO, BGO, BSO) in terms of light yield, decay time, transmittance and photoluminescence exploiting the advanced instrumentation available at the lab 27 crystal laboratory. Depending on the exact dates the candidate may take part in test beam activities occurring at PS/SPS beamline over summer. Basic knowledge of C++, ROOT and Python is required. The candidate will learn: - the basics principles of the scintillation mechanism in crystals; - how to handle data analysis with C++, ROOT, python; - how to summarize and present results in an international collaboration framework.

CERN-15

Hosting Laboratory	Available period	Contact person(s)
CERN	15/06/2024 – 15/10/2024	Livia Soffi – Bryan Cardwell

Search for long lived particles with the CMS MTD detector at the High Luminosity phase of LHC	Daily activity, skills required and to be acquired
The High Luminosity LHC program is expected to start in 2029, based on a major improvement of the accelerator to increase the instantaneous luminosity by a factor of 10. To cope with the multiple collisions belonging to the same bunch crossing, CMS will install a specialized detector dedicated to minimum ionizing particles (MTD). The inclusion of this 30 ps precision timing detector, offers the unique opportunity to enhance analysis capabilities for signatures with characteristic time. These signatures require dedicated reconstruction and identification strategies which go beyond the standard algorithms. In this context, the precise timing information from the MTD and from the calorimeters provide new, powerful information to measure the time of flight of the long-lived particles (LLPs) from the time difference between their decay vertex and the primary vertex. The better the timing resolution, the better the signal versus background discrimination, the shorter the LLP lifetime that can be probed. At the same time the LHC Run 3, started in 2022, offers a unique opportunity to prepare the ground for this work, thanks to the lower instantaneous luminosity compared to the HL-LHC and the possibility to exploit timing information from already existing calorimeters to test novel algorithms and approaches both online and offline.	The activity of this project consists in: 1) Learning the main features of the LHC and of CMS. 2) Reviewing the MTD TDR and the LHC LLPs white paper where scenarios that predict LLPs are highlighted. 3) The student will perform detailed study of identification capabilities of delayed leptons and slow-moving charged particles w/ MTD simulated reconstruction. A comparison with Run 3 actual performance will lay the bases for the future development of the usage of the MTD information in the discrimination of LLPs. Several presentations of the progress of the student's activity will be given at the CMS EXO group and at the CMS MTD group at CERN. Requirements are knowledge of fundaments of collider physics, detectors, and c++/python. At the end of the project, he/she will gain knowledge about how pursue research for new physics at colliders. He/she will be able to critically understand the details of a data analysis in HEP and how to present physics results to the scientific community and interact with colleagues in an international and diverse environment.

CERN-16

Hosting Laboratory	Available period	Contact person(s)
CERN	Apr.–Jul. or Sep.–Nov. 2024	M. Casarsa/V. Candelise – D. Calzolari

Study of the beam-induced background at a multi-TeV muon collider	Daily activity, skills required and to be acquired
At a muon collider, both the machine and the experimental apparatus are expected to operate under unique background conditions because of the unstable nature of muons. The decay products of the muons in the circulating beams interact with the machine components, causing high fluxes of background particles along the beam path (beam-induced background). In particular, the amount of background entering the detector depends on the configuration of the machine-detector interface (MDI) and the layout of the collider elements (machine lattice) around the interaction region. Understanding the characteristics of the beam-induced background in the detector is crucial for the optimal design of the detector and, subsequently, the event reconstruction algorithms. The student's work program will consist of characterizing the beam-induced background for different MDI configurations and different machine lattices. The MDI and accelerator experts will provide the configurations to be studied. The student will use the Monte Carlo simulation package FLUKA, in which a detailed model of the collider is implemented, to generate samples of background particles in the detector region. The samples will then be analyzed to determine the background characteristics: the number and type of the background particles entering the detector, their energy spectra and spatial distributions, and their arrival times.	Daily activity: • the student's activity will be carried out in close collaboration with his/her Supervisors, with a fraction of independent work that is expected to increase over time; • he/she will participate in the activities of the muon collider machine-detector interface group of the International Muon Collider Collaboration, will attend the group meetings and present his/her results. Required skills: • principles of radiation interactions with matter; • basic knowledge of the Linux operating system, some experience with programming languages (FORTRAN, C++), and Python scripting. Skills to be acquired: • general knowledge about the Muon Collider (motivation, physics goals, working principles, and technical challenges; • basic concepts of collider lattice and beam dynamics; • experience with the Monte Carlo simulation package FLUKA and its graphical interface Flair.

CERN-17

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/05/2024 – 31/10/2024**	**M. Pizzichemi – L. Martinazzoli**

Development and characterization of scintillator-based electromagnetic calorimeter prototypes for LHCb PicoCal and experiments at future colliders	Daily activity, skills required and to be acquired
The upcoming High-Luminosity (HL) phase of the LHC will pose new technological challenges to the detectors. The LHCb Electromagnetic Calorimeter (PicoCal) will have to keep its energy resolution while dealing with increased radiation exposure and higher detector occupancy. Timing resolution in the order of O(10ps) and radiation-hard materials will be necessary, requiring novel solutions to be studied and implemented. The same considerations will also drive the design of the experiments foreseen to work at future colliders, such as FCC-ee and FCC-hh. Scintillator-based detectors represent an attractive solution to fulfill these needs thanks to their unparalleled energy resolution. The student will participate in the laboratory characterization of novel radiation-hard and ultrafast scintillating samples and in the assembly and characterization at test beam of modules based both on the SpaCal and the Shashlik sampling calorimeter technologies, which combine scintillators to dense absorbers. The results will be compared with detailed Monte Carlo simulations, in order to predict the performance of modules based on these materials in future calorimeters.	The research will involve both experimental and data analysis activities. On one side, the student will acquire knowledge in the field of characterization of scintillating materials and particle detectors, familiarize themselves with the most advanced tools used in the field, and acquire great practical experience in the everyday challenges of high-energy physics experiments. On the other hand, they will develop significant experience in data analysis, exploiting the opportunity to work side by side with top-level experts in the field, while interacting with the deeply stimulating international environment of CERN. Basic knowledge of detector principles and the use of ROOT libraries is required.

CERN-18

Hosting Laboratory	Available period	Contact person(s)
CERN	01/04/2024 – 30/07/2024	Nicola Neri – Paolo Gandini - Massimiliano Ferro-Luzzi (CERN)

Proof-of-principle test for an experiment for charm baryon dipole moments at LHC	Daily activity, skills required and to be acquired
Electromagnetic dipole moments of charm baryons are sensitive to physics within and beyond the Standard Model. However, they have never been measured due to the difficulties imposed by their short lifetimes. The proposed experimental technique is based on a fixed-target experiment where charm baryons, i.e. Lc+ and Xic+, are produced and channelled in a bent crystal positioned right after the target. The precession of the spin polarization vector of the charm baryons is induced by the interaction of their spin with the strong electromagnetic field inside the bent crystal. A proof-of-principle test, named TWOCRYST, is foreseen in 2025 at the LHC insertion region 3. A silicon pixel detector positioned in a Roman Pot is necessary to measure the channelling efficiency of the bent crystal positioned after the target, and also to measure the level of background originated in fixed-target collisions. The student will contribute to the assembly and integration of the silicon pixel sensors inside the Roman Pot and to the control and characterization of the system in laboratory at CERN.	The student will work in the laboratory at CERN dedicated to the developments of silicon detectors. The activity is done in collaboration with the LHCb VELO group that provided the VELO sensors and electronics. The student will learn how to assembly and operate a silicon pixel detector inside the secondary vacuum of a Roman Pot. How to control and acquire the data of the detector. In addition, the student will learn how to analyze the data from the detector and measure its performance in laboratory, e.g. measurement of noise, response to MIPs. Skills required: basic knowledge of silicon detectors; knowledge of python, ROOT.

CERN-19

Hosting Laboratory	Available period	Contact person(s)
CERN	01/03/2024 – 31/07/2024	Henric Wilkens – Fabrizio Scuri

Readout photomultipliers upgrade for TileCal, the ATLAS barrel hadron calorimeter.	Daily activity, skills required and to be acquired
TileCal, the ATLAS barrel hadron calorimeter, is equipped with fine-mesh photomultipliers (PMTs) reading out the light emitted by the scintillating tiles that are the active material of the detector. Aging effects such as the PMT response loss were detected during TileCal operation, the loss being larger for PMTs reading out the most exposed detector cells. To avoid any degradation of the detector performance, it was decided to replace 10% of the about 10,000 TileCal PMTs, after completion of present LHC run 3. An accurate procedure to qualify the replacement PMTs is needed. Also, a re-qualification of the legacy, not replaced PMTs is needed to certify their capability to be operated at full performance until the end of the High Luminosity LHC (HL-LHC) program. For this purpose, identical test benches were set-up in different labs, the most important being the arrangement prepared at CERN. With this set-up a large fraction (up to 20%) of legacy PMTs will be tested as well as random picked-up fraction of new PMTs qualified by the other labs. The main task of this project is the certification of the CERN test bench capability to measure PMT parameters such as Quantum Efficiency, multiplication gain, linearity, response stability and the correctness of the qualification procedures. In parallel with the main PMT qualification activity, feasibility studies of using multi-anode PMTs (MA-PMTs) for increasing the TileCal readout granularity for future calorimeter upgrades will be performed by comparing different configurable cards for data reduction of the MA-PMT analog signals. Preliminary tests will be performed on a TileCal spare module available in the TileCal test area at CERN	**Month 1:** Getting familiar with the PMT qualification **t**est bench HW and with SW package adopted for the qualification procedures. **Month 2:** Running the qualification procedures, analyzing results. **Month 3:** Checking the internal consistency of the database for the qualification results and making it user friendly. First tests with prototypes of custom designed readout cards for MA-PMTs **Required skills:** basic knowledge of C++ programming language and of the ROOT program. Basic knowledge of Python programming and bash scripting language would be a plus. **Skills to be acquired**: Good knowledge for programming in the LabView environment.

CERN-20

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2024 – 01/10/2024	Federica Simone – Anton Dimitrov

Deep learning techniques for the anomaly detection in the muon system	Daily activity, skills required and to be acquired
Anomaly detection refers to the identification of exceptional occurrences that deviate significantly from the norm within a given dataset. In HEP experiments, anomaly detection can be used to ensure the quality of data in complex detectors like the CMS experiment at the LHC. The DQM and Data Certification procedures in CMS heavily rely on manual procedures, consisting in the inspection of a set of reference histograms (monitoring elements, ME), providing a concise overview of the detector performance. In this context, unsupervised machine learning techniques are being used for implementing automatic anomaly detection tools, allowing for computer-assisted data quality monitoring at CMS. In this project, an algorithm based on an artificial neural network (NN) known as AutoEncoder will be used to inspect MEs specific for the Muon System of the CMS experiment. The support of detector and data certification experts will be crucial for targeting specific issues during data taking. The student will perform the optimisation of the training hyperparameters and study how resampling the input data can impact the classification performance.	The selected candidate will work on NN training and optimisation for the Muon data quality monitoring. In parallel, she/he will be able to join the CMS DQM operations as well as in-person meetings with experts at CERN. Basic python coding skills are required. The candidate will acquire knowledge on the basics of Deep Learning for the theoretical point of view, while acquiring practical skills on the most common python libraries (scikit-learn and pyTorch) and API (keras) commonly used in HEP. She/he will also acquire expertise on the CMS Muon System detector operation and performance.

CERN-21

Hosting Laboratory	Available period	Contact person(s)
CERN	1/06/2024 – 31/10/2024	Marcello Rotondo - Michel De Cian

Studies of low energy hadrons identified as muons at LHCb	Daily activity, skills required and to be acquired
LHCb is a forward-spectrometer located at LHC and specialised in the study of hadrons containing charm and beauty quarks. For the study of many decays of heavy hadrons, it is crucial a good identification of the muons (Muon ID). The Muon ID is affected by the pollution of charged particles, like pions and kaons, that traverse the full detector and mimic a muon (muon MisID). At low momentum, the largest contribution to the muon MisID is the decay in flight of pions and kaons occurring before the muon detector. At present this component to the MisID is treated by the various analyses with “had oc” procedure added on top of the standard tools to evaluate the muon MisID. The goal of the project is to define a consistent approach to the determination of the muon MisID probability that can be useful to any analysis using muons. At present the MisID is evaluated using D meson decay into a kaon and a pion using an approach called tag-and-probe. While these decays are reconstructed with very large rates in LHCb, they cover mainly the region useful for high momentum muons. The study of additional control samples, in particular the three-body decays of the D mesons, is paramount to cover with large statistics also the low momentum region.	The selected student will analyse various control samples, using the tag-and-probe approach, to determine the probability of muon MisID. The control samples that will be use, in addition to the standard D->K pi, are various three body decays as D->K pi pi, and Lambda_c -> pK pi. The analysis will be done using both data collected in 2016-2018 and data collected in 2023-2024. The analysis will be done with the support of experts at CERN. Skill acquired: - learn how to analyse large data samples, in particular in designing the offline signal selection, and the fitting of parameters of interests; - advanced coding in Python/C++ and learning the ROOT/RooFit analysis framework Skill required: some knowledge of the Linux operating system is required. Basic programming skill in Python and C++ may be useful.

CERN-22

Hosting Laboratory	Available period	Contact person(s)
CERN	20/06/2024 – 20/09/2024	Enrico Robutti – Ksenia Shchelina

Studies for the new silicon pixel tracker of the CMS Precision Proton Spectrometer for HL-LHC	Daily activity, skills required and to be acquired
The CMS Precision Proton Spectrometer (PPS) reconstructs protons escaping intact from proton-proton interactions in the Large Hadron Collider (LHC) at CERN. It is located in the LHC tunnel about 200 m from the interaction point of the CMS experiment, on both sides. It has been collecting data since 2016, and its data used for several published searches for rare Standard Model processes or signatures of New Physics. The extension of its physics program to the high-luminosity phase of LHC, from 2029 (`PPS2'), has recently been approved. For that purpose, the detectors must be completely redesigned, to cope with very different working conditions. The project will be integrated in the framework of the ongoing studies for the new silicon pixel tracker: it will contribute to the development of a realistic and effective proposal for the new detector, possibly including different practical aspects, from the base layout of the readout electronics to relevant features of the support mechanics and studies on the cooling system.	The project is an interdisciplinary task and will require initiative and creativity. It will involve accurate, realistic evaluation of working conditions and performance required, and will need gathering information, through appropriate documentation or personal contacts, on projected operating environment and available technologies. This will be done in close contact and under the guidance of people already working on the tracker design for PPS2. Basic notions of particle detectors, digital electronics and thermodynamics are required. The task may involve the development of simple simulations and the participation to laboratory tests on site.

CERN-23

Hosting Laboratory	Available period	Contact person(s)
CERN	**15/06/2024 – 15/09/2024**	**Marco Ferrero/Nazar Bartosik – Michael Moll/Bilal Kiani**

Silicon-tracker at the Muon Collider experiment – sensors testing and tracker simulation	Daily activity, skills required and to be acquired
The project is focused on the silicon-tracker at the Muon Collider experiment, the topics that will be explored by the candidate will be: - Characterization of planar silicon sensors (LGAD and RSD) of interest for instrumentation of Muon Collider Tracker. This work will concern the laboratory characterization of LGAD for extreme irradiation fluences and RSD for 4D tracking applications. - Studies of silicon-tracker performance at a Muon Collider experiment using GEANT4 simulations and realistic digitization algorithms. This work will involve multiple detector simulations with different configurations of sensor granularity and readout performance to evaluate the possibility of on-detector rejection of beam-induced background.	The candidate will carry out daily activities on sensor testing at the Solid-State Detector laboratory at CERN and of GEANT4 simulations. The skills required are: - Basics operation of a particle tracker - Basics operation of planar silicon sensors - Basics of the C++ programming language The candidate will acquire skills in the most advanced techniques (TCT, TPA, electrical tests) of characterization of silicon sensors and the use of the GEANT4 platform.

CERN-24

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 01/09/2024	Pierluigi Paolucci – Brieuc Francois

Study and simulation of dual-readout crystals for applications at FCC	Daily activity, skills required and to be acquired
The technology of dual readout calorimeters, able to simultaneously detect scintillation (S) and Chernekov (C) light, represents a promising research avenue for potential deployment at future colliders after the LHC era. The community performing R&D for the IDEA experiment at the Future Circular Collider, FCC-ee, is currently studying a concrete working hypothesis for a homogenous S/C detection in crystals. Several crystal options are being considered and tested via experimental setups at different sites and at CERN, including test-beams foreseen in the upcoming year. The proposed project will consist of studying the features of a single crystal in DD4HEP, the software tool for the IDEA detector simulation, implementing results of the tests developed in the different sites and at CERN in this framework. The ultimate goal is to test the impact of the crystal choice in the reconstruction in the layout currently developed by the experts at CERN for the IDEA electromagnetic calorimeter. A study will be dedicated to a setup for a possible test-beam at CERN.	Study of the DD4HEP toolkit, interface with Geant4 simulation output, description of an experimental setup by including scintillation and Cherenkov components. A basic knowledge of python is necessary, as well as a good familiarity with particle-matter interaction processes, particularly for what concerns the phenomena in exam. A daily interaction with the experts at CERN will allow to learn the mechanics of the DD4HEP simulation, and to adapt it to the usecase of a realistic experimental setup within the IDEA project, and potentially partaking in test beams at CERN in the Summer period.

CERN-25

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2024 – 31/09/2024	Giovanni De Lellis – Richard Jacobsson

Emulsion handling and analysis in the SND@LHC experiment at CERN	Daily activity, skills required and to be acquired
The project is part of the SND@LHC experiment at CERN. It is focused on operations related to the emulsion film handling and the emulsion scanning and analysis. In summer 2024 three emulsion targets will be replaced, each consisting of about 1200 emulsion films. The target, consisting of five emulsion/tungsten walls, is assembled in the dark room, transported to TI18, installed, and then emulsion films undergo chemical development in the emulsion facility. In parallel, a new scanning station at CERN equipped with automated optical microscopes is in operation. The project involves data taking at the scanning station, the reconstruction of tracks and vertices induced by neutral and charged particles, with the emulsion data produced.	The candidate will be involved in all the activities related to emulsion handling, including the assembly in the dark room, the transportation to TI18 and the installation in the target, and the emulsion development. In parallel, she/he will work at the scanning station, taking care of the daily scanning of emulsion films, performing the data quality checks, and applying reconstruction procedures. The reconstruction of tracks and vertices induced by neutral and charged particles is part of the work. Experience with Root, C++ software and Python is preferable. The candidate will actively join all the operation performed at CERN, gaining relevant experience on the operation of a detector at CERN.

CERN-26

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2024 – 30/09/2024	Paolo Vitulo – Roberto Guida

Evaluation of the performance of gaseous detectors operated with eco-friendly gas mixtures	Daily activity, skills required and to be acquired
Several gaseous detectors, developed for high-energy physics but also for various applications, use gas mixtures containing components potentially harmful to the environment. A classic case is Resistive Plate Chambers (RPC), which use fluorinated compounds, but the same consideration applies to various MicroPattern Gaseous Detectors (MPGD). The European Union is severely restricting the use of such components, therefore the study of so-called “eco-gas mixtures” will become increasingly important in the future. In this project we propose an R&D study aimed at validating these new eco-gas mixtures through the measurement of the performance of technologies operated with them, in particular new generations Micropattern Gaseous Detectors which have been proposed for the future colliders, especially the Muon Collider. The student will be involved in the preparation of the measurement setup but will also take care of the analysis of the data collected. In parallel, the impact of possible reuse of the exhausted gas mixtures, through the so-called "Gas recirculation and recuperation systems", currently under development for the LHC experiments, will also be evaluated. By the end of the project, the student will have gained experience on the characterization of gas detector technologies, but also on the impact of gas systems on detector operation and on the most common gas analysis techniques.	The activity will consist in the simulation, preparation, and management of small tests in which gaseous detectors are operated with different gas mixtures. The goal is to measure their performance with different gas mixtures and evaluate possible sources of ageing effects. The competencies required include basic knowledge of gaseous detectors, especially MPGD; basic experience with laboratory instrumentation for gaseous detectors characterization. A prior knowledge of programming languages (C++, python) and software analysis packages (ROOT) will be appreciated.

CERN-27

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 31/08/2024	Antonio Cassese – Stefano Mersi

DAQ testing activities for the CMS Phase 2 Inner Tracker	Daily activity, skills required and to be acquired
The High Luminosity upgrade of LHC (HL-LHC) is currently one of the biggest and fascinating challenges in particle physics. The unprecedented particle rate and radiation levels expected at HL-LHC, lead to the need of the replacement of the present Tracker of the CMS. The CMS Tracker for the HL-LHC phase will be a brand-new detector: hardware, firmware, and software completely different from the one currently in use are in development. The first prototype of the CROC has been released about one year ago and the full characterization of the full acquisition chain has immediately started and still ongoing. After a first phase where the candidate will get used to the tracker full readout chain usage, a deeper focus on Inner Tracker DAQ characterization will be carried on. In particular, low-level studies and characterization of the front-end characteristics as well as dedicated calibration and timing studies will be performed.	The project consists in laboratory activities with hardware set-up to be installed, dedicated acquisition software to be developed and analysis of collected data to be performed. The main required skills are: • Basic knowledge of electronic lab equipment such as power supplies, digital scopes, pulse generator and so on. • Knowledge of C++ programming language and usage of ROOT data analysis framework. • Experience in Linux environment.

CERN-28

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 31/08/2024	Lorenzo Viliani – Roberto Seidita

Development and application of graph autoencoders to searches for semivisible jets in the CMS experiment	Daily activity, skills required and to be acquired
In the search for physics beyond the Standard Model (SM), a particularly interesting set of extensions is the class of Hidden Valleys (HV) models, in which a hidden sector extends the SM with unknown particles and interactions. The hidden sector can communicate with the SM via portal particles (e.g., Z, H) allowing for production and decay of hidden states from/to SM particles. Hidden valley models provide natural candidates for dark matter in the form of stable states in the hidden sector. A particularly intriguing class of HV models is the one in which hidden sector particles are produced in proton collisions via a portal particle; a fraction of them decays back to the SM, leading to a hadronic jet with an invisible component, referred to as a semivisible jet (SVJ). A key aspect of the search for SVJs is rejecting jets originating from abundant QCD processes at the LHC. While machine learning (ML) can provide a powerful handle to do so, supervised approaches suffer from a strong dependence on the modelling of the hadronization in the hidden sector, leading to a limited exclusion range. An unsupervised ML model can be trained on QCD data and subsequently used to tag anomalous jets in a way that is robust against the details of the hidden sector shower. Graph autoencoders have been developed for this task, exploiting the full visible information of jets to maximize sensitivity to potential anomalies. The student will contribute to the development and application of graph autoencoders to the SVJ search.	The candidate will work in collaboration with CMS experts in the fields of statistical data analysis and advanced Machine Learning techniques. After learning the basics of graph neural networks and autoencoders, the candidate will focus on the application of these techniques to the search of semivisible jets using data recorded by the CMS experiment. The candidate is required to have a basic knowledge of python, which will be sharpened during the project. A basic knowledge of commonly used Machine Learning frameworks is a plus, although not mandatory. At the end of the project the candidate will be acquainted with bleeding edge methodologies in the field of Machine Learning for data analysis.

CERN-29

Hosting Laboratory	Available period	Contact person(s)
CERN	1/05/2024 – 1/08/2024	Rosamaria Venditti- Angela Zaza

Jet flavor tagging with Machine Learning at CMS	Daily activity, skills required and to be acquired
The jet flavor tagging is paramount in present and future LHC runs , both to assess the standard model and probe the presence of new physics. The decay topologies with resolved and merged jets, arising from the high relativistic boost of the mother resonance, needs dedicated flavor tagging strategies. Machine learning techniques are nowadays widely used for the jet flavor tagging, but due to the growing sophistication of the involved models, validation campaigns, robustness tests, and commissioning in physics searches are needed, especially with new datasets such as the one collected in Run3 by CMS. In this project, we propose a study of one of the machine-learning-based jet flavor taggers used in CMS experiment with Run3 data, by performing a validation campaign in a dedicated control region, where a Z boson decays in heavy flavor jets and comparing the data with Monte Carlo simulations using an existing analysis framework. Moreover the application of such a flavor tagging algorithm in the search for the Higgs boson decaying in charmed quark pairs could also be studied to improve the background from light flavor jets and b jets.	Required skills: Basic knowledge of elementary particle physics. Basic knowledge of c++ or python. Acquired skills: The student will acquire a basic knowledge of the architecture of a neural network (NN). She/he will learn how to handle big data and to measure the performance of a NN output. She/he will get familiar with flavor tagging techniques. Daily activity: The selected candidate will analyze pre-processed CMS Run3 data, performing a data to Monte Carlo comparison in dedicated control regions. Simulated process of Higgs boson decaying in heavy flavor jets will also be used.

CERN-30

Hosting Laboratory	Available period	Contact person(s)
CERN	15/03/2024 – 30/09/2024	Giovanni Punzi - Riccardo Fantechi

Real-Time track reconstruction with advanced heterogenous computing	Daily activity, skills required and to be acquired
To pursue exploration of physics phenomena in experiments with ever increasing flows of data, new technological solutions are continuously being developed in HEP to perform complex data reconstruction in real time. To this purpose, a Coprocessor TestBed facility is operating at LHCb, in order to develop and test prototypes of new processors based on heterogenous computing devices (GPUs, FPGA) in a realistic DAQ environment, where live LHCb data can be opportunistically accessed during regular physics run, without disturbing data taking. In this facility is currently operating a highly-parallelized custom tracking processor developed by INFN. The device is based on neural-like “Artificial Retina” architecture implemented in state-of-the-art FPGAs interconnected by fast optical network, and will process real LHCb physics data during the 2024 run of the LHC. The candidate will participate to setting up the system, optimize its performance, and analyze its results.	The participant to this program will work in everyday contact with the team of experts that have designed and built the FPGA processor, participating to all everyday activities, starting from assembling, configuring and programming the system, monitoring data taking, to analyzing the results of the processor to compare its performance with the standard track-reconstruction system of LHCb. The participant will learn and acquire hands-on experience with modern DAQ system, advanced real-time data processing, reconstruction of tracks and particle decays in LHC experiments. Candidates to this program are required to have good general computing skills, knowledge of C/C++ language, and preferably some familiarity with servers in Linux environment.

CERN-31

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2024 – 30/11/2024	Brieuc Francois – Patrizia Azzi

Tracking activities for the FCC-ee IDEA detector	Daily activity, skills required and to be acquired
The first stage of the Future Circular Collider (FCC) project envisages e+e- collision at unprecedented luminosities at centre-of-mass energies between the Z pole and the top pair production threshold. A FCC Feasibility Study has been setup to investigate the relevant aspects of the project, including the identification of detector technologies enabling the full exploitation of the expected integrated luminosity. In particular, the novel IDEA Detector Concept, features a tracking system composed by several layers of silicon sensors for vertexing and tracking and a complex drift chamber as main tracker. The candidate will integrate the FCC Software and Computing team to work in particular on the digitization, reconstruction and validation, of the IDEA tracker system that includes silicon and gaseous detectors. Close interactions with the relevant Detector Concepts groups will be essential to collect the relevant information. All activities will be carried on in close synergy with the Turnkey Software Stack, key4hep, project. Given the timescale of the conclusion of the feasibility study in 2025, efficient track reconstruction for IDEA is a critical item needed by the end of 2024.	**Daily activity:** The project consists of software development activities to be carried out on the CERN network in collaboration with software and detector experts. Candidates will be required to follow and share their progress in weekly technical meetings concerning Key4hep and Edm4hep, and monthly FCC Software meetings. **Required skills:** Some knowledge of C++ and python is required. Expertise with modern HEP analysis tools and development workflows, including a good mastering of C++ and Python, will be considered an advantage. **Skills to be acquired:** - Expertise in modern HEP analysis tools and development workflows – Knowledge of track reconstruction for a silicon+ gas detector - Knowledge of statistical analysis for performance interpretation - Experience of teamwork in international environment and presentation skills to communicate work

CERN-32

Hosting Laboratory	Available period	Contact person(s)
CERN	15/06/2024 – 15/10/2024	Livia Soffi – Riccardo Salvatico

Search for low mass resonances with dedicated data streams at CMS Run III	Daily activity, skills required and to be acquired
Several scenarios of physics beyond the standard model predict the existence of new, massive, electrically neutral gauge bosons whose decay to leptons can be significantly enhanced under specific assumptions of the model. With a more inclusive approach, It is interesting to explore any potential new particle that is expected to materialize in the LHC data as a narrow peak onto a smooth dilepton mass spectrum, specifically in kinematic regions not accessible by other collider experiments. To enhance the sensitivity of such searches, the CMS experiment at the CERN LHC has developed a novel technique, termed data parking, to overcome limitations imposed by the standard online data collection strategies (triggers), achieving particularly high sensitivity to low-mass signals. Recently VBF production and inclusive dielectron parking strategies have been deployed at CMS Run III. These new triggers will accumulate large data samples with substantially improved acceptances to many new physics processes, opening the path to the exploration for new particles in never investigated corners of the phase space. Machine-learning based approaches cover a key role to further boost the sensitivity to such peculiar signals at CMS.	The activity of this project consists in: 1) Learning the main features of the LHC and of CMS. 2) Reviewing the recent CMS search for low mass dark photons and the recent CMS paper on parking strategies 3) Contributing to an end-to-end analysis that exploits Run III data to search for prompt low mass signals in the dielectron final state. The student will take care of the identification of low energy electrons, together with the usage of advanced machine learning techniques to enhance the signal sensitivity in the case of boosted resonances, i.e. merged dielectrons. Several presentations will be given at the CMS EXO group and at the CMS EGM group at CERN. Requirements are knowledge of fundaments of collider physics, detectors, and c++/python. At the end of the project, he/she will gain knowledge about how pursue research for new physics at colliders. He/she will be able to critically understand the details of a data analysis in HEP and how to present physics results to the scientific community and interact with colleagues in an international and diverse environment.

CERN-33

Hosting Laboratory	Available period	Contact person(s)
CERN	01/04/2024 – 30/06/2024	Ilirjan Margjeka – Stefano Mersi

Integration test and synchronous data acquisition of cosmic rays with the kick-off bench PS modules for the Phase-2 CMS Outer Tracker	Daily activity, skills required and to be acquired
The CMS Tracker phase-2 upgrade of the silicon modules is conditioned by the planned high luminosity of the HL-LHC project (≥ 3000fb−1). This upgrade will require improved radiation hardness, higher detector granularity to reduce occupancy, increased bandwidth to accommodate higher data rates, and an improved trigger capability to maintain an acceptable trigger rate. The CMS Tracker modules will provide to the Level 1 Trigger track segments allowing trigger rates to be kept at a sustainable level. Such conditions are fulfilled by the silicon pixel detectors for the Inner Tracker and silicon pixel-strip (PS) and silicon two-strip (2S) modules for the CMS Outer Tracker. In order to simulate the HL-LHC L1 trigger track segments and stubs formation, a cross section of the CMS tracker has been built within a burn-in cooling box, which consists into a set of three kick-off bench 2S modules and three PS modules (assembled at INFN-Bari), as well as two units of the inner pixel detector. The modules will be cooled down to −35◦C and flushed with dry air to exclude any water condensations and ice cluster formation over the modules. Each module will be powered up by a CAEN power supply, which will provide for each module, HV for the silicon sensors and LV for the hybrids. This project aims: 1)The integration of the kick-off bench PS modules and their qualification; 2) The characterization of the trigger capability of the CMS tracker Phase-2 using cosmic rays as a source, specially the study of the Level 1 Trigger track segments (stubs formation).	The student will have to perform integration, qualification and data analysis for the synchronous data acquisition of cosmic rays with the layers of the silicon pixel, pixel-strip and two-strip modules and the study of the stubs formation. Basic knowledge of electronics laboratory practice is required. Basic programming skills will be beneficial both for the measurements and data analysis. The candidate will acquire a detailed knowledge of the different contributions to the time resolution of scintillating hetero-structures. She/he will learn how to operate high time resolution test benches. This study allows the student to understand how the new CMS Phase II Outer Tracker will work in principle and the synchronous data acquisition of the silicon modules using cosmic rays. The synchronous data acquisition of cosmic rays and stubs formation with the Phase-2 CMS tracker modules will be performed at the CMS Tracker laboratory at CERN. The student will join an international research group of physicists working on the development of silicon tracking detectors for LHC upgrade and future collider experiments and will be part of the PS modules task-force of the CMS OT group.

CERN-34

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2023-31/11/2024	Ruggero Turra – Davide Mungo

Electrons and Photons classification using machine learning techniques with the ATLAS detector at the LHC	Daily activity, skills required and to be acquired
In this project an attempt to reduce the number of electrons faking photons with the ATLAS detector will be performed using advanced ML techniques. The optimization will be performed using as a benchmark the search for new resonances in the yy channel in a diphoton mass range between 60 and 110 GeV where the CMS experiment reported an excess of events over the expected background contribution. The project will be performed in two steps: in the first part the student will concentrate on developing a ML based algorithm to replace the existing one trained on run 2 simulations. Since the electrons reconstruction software has substantially changed in run3 with respect to the one used in run2 we expect a rather poor performance of the existing algorithm on more recent dataset. Secondly the candidate will develop a measurement of data to MC scale factors for the electrons faking photons probability using Zee events where one of the electrons is mis-identified as a photon. An accurate modelling of the contribution of Zee events in the di-photon final state will constitute a fundamental building block to be able to exclude a signal from additional Higgs boson in a mass range close to the Z boson peak exploiting the existing and upcoming run3 data.	Daily activity will consist in guided and free coding sessions and study of existing literature. The project will be developed in autonomy by the candidate with frequent discussions with the supervisors. We foresee presentations in the relevant working groups meetings. For this project we expect students with a strong interest in working in software and computing areas. The project will require some basic knowledge of programming in C++ and python libraries. Some knowledge of the basics of ML algorithm would be beneficial although not strictly required. During the project the student will have the possibility to work on a real physics analysis learning how to deal with big bunches of data and MC events. In addition, the student will have the possibility to familiarize with the state-of-the-art machine learning tools.

CERN-35

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2024 – 30/11/2024	Fabio Cossutti – Felice Pantaleo – Aurora Perego

Optimization of timing use in particle flow reconstruction for the CMS detector at HL-LHC	Daily activity, skills required and to be acquired
The CMS Collaboration, in the context of the upgrade for the HL-LHC phase, is enhancing the capability of the apparatus to precisely measure the crossing time of particle. To achieve this goal, besides the exploitation of the calorimeters' response, a dedicated Mip Timing Detector (MTD) is being built, with the purpose of measuring the time of minimum ionizing particles with a resolution of about 40 ps. The goal of the project is to optimize the use of the available timing information in the reconstructed particle flow candidates within the forward region of the CMS detector. By leveraging data from both the calorimeter and MTD, each particle flow candidate is assigned a time at the vertex that can be studied to further refine its accuracy. Moreover, the project aims to explore the scenario of spatially overlapping particles with distinct temporal signatures. The goal is to evaluate the effectiveness of time information in discriminating the different particles. By engaging in this research, the student will not only contribute to improve the accuracy of the global event reconstruction but will also gain invaluable experience in leveraging cutting-edge technology for particle physics research.	Daily activity: the candidate, with the help and supervision of the contact persons and other members of the team, will perform the analysis of simulated data to evaluate the performance of the existing reconstructed algorithms, to critically review the results and contribute in developing algorithmic solutions to improve them, with the target to achieve the best possible global event description. Required skills: basic knowledge of Linux shell and possibly ROOT analysis framework. A basic knowledge of python and C++ languages is needed. Skills to be acquired: the candidate will gain a direct experience of the daily work of development and optimization of reconstruction algorithms for a complex experimental apparatus in particle physics. The candidate will be guided in a critical analysis of the results obtained, combining professional methodology of development and personal creativity in proposing possible new solutions.

FNAL-1

Hosting Laboratory	Available period	Contact person(s)
FNAL	**01/07/2024 – 30/09/2024**	**Fabio Ravera - Patrizia Azzi**

CMS Phase 2 Silicon Tracker: sensor characterization and tracker assembly	Daily activity, skills required and to be acquired
The High Luminosity upgrade of LHC (HL-LHC) will be the main scientific instrument for the investigation of the subatomic world through the 2020s and 2030s. To cope with the unprecedented particle rates and radiation levels expected at HL-LHC, the present Tracker of the CMS experiment will be replaced during the LHC long shutdown in 2026-2028. The new Tracker detector is at the heart of the CMS upgrade, and it is starting construction of production silicon modules in 2024. Presence at the lab is required since the project is entering the production phase. In this project we propose two complementary activities on the CMS Outer Tracker: - characterization and testing of the production modules both Strip-Strip and Pixel-Strip types - development of software algorithms for improving analysis of the tested module. This is a unparalleled opportunity to participate in the construction of the most challenging tracker at hadron collider ever designed and integrate in an international research environment	**Daily activity:** The project consists of laboratory activities, using the current developed setup for testing and thermal cycling of the sensor modules for the CMS Outer Tracker. Candidates will also be required to work in a clean-room where modules are assembled and help in the basic steps of the assembly process. **Required skills:** - knowledge of basic electronic lab equipment. - good knowledge of C++ programming language and usage of ROOT data analysis framework. - basic experience in reading and understanding technical documentation. - basic skills for handling delicate silicon sensors - prior experience in characterization of silicon detectors preferred **Skills to be acquired:** - Silicon detector testing and handling - Improved knowledge of software C++/python7Root etc. - Improved statistical data analysis to determine detector performance - Close contact with physicists to expand knowledge of physics at HL-LHC - Improved presentation and writing skills

FNAL-2

Hosting Laboratory	Available period	Contact person(s)
FNAL	01/03/2024 – 31/05/2024	Simone Donati – Pavel Murat

Development of the Mu2e TDAQ system for the straw-tracker and electromagnetic calorimeter vertical slice test	Daily activity, skills required and to be acquired
The Mu2e experiment will search for the neutrinoless muon-to-electron conversion in the field of an aluminum nucleus. With the expected sensitivity for Run I, Mu2e will improve the previous limit set by the SINDRUM II experiment by three orders of magnitude. To achieve the very ambitious Mu2e sensitivity goals, an adequate level of detector complementarity and redundancy is required to accurately measure the single conversion mono-energetic electron track that constitutes the final state of signal events, and to minimize and/or keep under control the expected sources of background. Mu2e is now entering the detector integration and commissioning phase. The Trigger and Data AcQuisition System (TDAQ) collects digitized data from the tracker, calorimeter, cosmic ray veto and will be fundamental for the vertical slice test of the detectors. The proposed research program is aimed at developing the TDAQ system and perform the vertical slice test of the tracker. We plan to use a small part of the tracker (a single plane, and later – a station) to collect a data sample of cosmic muons, commission the detector readout and perform initial reconstruction and analysis of the collected data. This will be an intense hands-on introduction to Mu2e, Mu2e data acquisition, Mu2e tracking, and data analysis and is aimed on students interested in lepton flavor physics.	**Required knowledge:** general confidence with particle physics, particle accelerators and detectors, and a reasonable knowledge of computing methods, Unix/Linux environment, programming languages (C, C++, Python) and Root package. Pre-existing "beginner" expertise in statistical data analysis will be beneficial. **Acquired knowledge:** improved usage/learning of C, C++, Python languages and Root package, Improved capability in statistical data analysis. Learning of the Mu2e reconstruction software, GEANT4, data acquisition system, *art* framework and grid and cloud computing usage. Improved oral and written communication skills. **Daily activity:** generation of needed Monte Carlo samples, development of analysis code, attendance / report to weekly meetings (Mu2e- Tracker, Calorimeter, Software, DAQ, General Groups).

FNAL-3

Hosting Laboratory	Available period	Contact person(s)
Fermilab	July-Sept. / Aug.-Oct. 2024	D. Lucchesi/M. Casarsa – Luciano Ristori

Optimization of multi-TeV muon collider tracker detector	Daily activity, skills required and to be acquired
Detector at muon collider will have to face a high level of background coming from the muon beams decay particles, the so-called beam-induced background (BIB). In order to mitigate this effect, two conical shaped structures made of absorber materials are proposed to be placed around the interaction region. They absorb the high energy part of such a background and generate high fluxes of low energy particles. The electromagnetic component, in particular electrons and positrons have a large impact on the first layers of the tracking detector. Several strategies are considered to deal with the high occupancy in these layers. This study proposes to design a tracker detector with a standalone program that reproduces the muon collider one but in a very flexible way such that changes can be very quickly. The effect of the BIB is reproduced. Pattern recognition and tracks fitting can be performed to determine the efficiency and purity as function of the tracker configuration including the dimensions. The student together with the supervisors will define the figures of merit to decide the best tracker configuration. Then she/he will use simulated data, including the BIB, to study different configuration of the tracker and the its dimensions layer by layer to assess the best configuration.	Daily activity: The student will work together with his/her supervisors in close contact at the beginning to learn how to use the tools and to set the goals of the activities. Then he/she will work independently with regular meetings with the supervisors. She/he will follow the muon collider collaboration meetings and will discuss the results. Required skills: - Basic knowledge of muon collider physics and challenges - Sufficient knowledge of the Linux operating system, root, and C++ - Sufficient English understanding and speaking Skills to be acquired: - First principles and methodology of tracking detector design. - Background handling in a tracker system. - Present and discuss the progress of the activity with international collaboration.

FNAL-4

Hosting Laboratory	Available period	Contact person(s)
FNAL	**01/06/2024 – 30/09/2024**	**Daniele Gibin – Angela Fava**

ICARUS detector tuning and analysis of the collected neutrino interactions at Fermilab beams	**Daily activity, skills required and to be acquired**
The ICARUS detector consists of a 760 tons Liquid Argon Time Projection Chamber (LAr-TPC) exposed to Fermilab Booster and NuMI neutrino beams within the Short Baseline Neutrino program aiming at investigating the existence of sterile neutrinos as claimed by several anomalies recorded in experiments at nuclear reactors and accelerators. The data taking started in 2021 will extend over the next three years. The proposed activity is focused on both data taking, trigger system studies and monitoring of the ICARUS sub-detectors, and data analysis selecting and reconstructing neutrino interactions. The collected data will be analyzed reconstructing recorded events using the physical signals of the different sub-detector systems, including the TPC, the photomultipliers and the CRT Cosmic Ray Tagger surrounding the ICARUS TPC. The measurement of the efficiency and precision of the event timing and localization of the Trigger system which is based on the signal recognition from 360 PMTs inside the beam spill will be studied. The student will be involved in the planned activities on the detector during the summer shutdown. He will have the opportunity to work directly with the physicists who have developed and constructed the LAr-TPC detector, and to be involved in the event software reconstruction, contributing to the optimization of the algorithms and the related performance.	During the three months of the research program, the candidate will collaborate with the ICARUS DAQ and trigger groups. The candidate will also contribute to the neutrino event analysis, collaborating directly with groups involved in the event reconstruction and analysis. Skills required during the project: python and C++ programming, exploitation of ROOT. The candidate will also get familiar with LabView programming, with the exploitation of FPGA to generate the trigger, and with the LAr-TPC reconstruction and analysis framework.

FNAL-5

Hosting Laboratory	Available period	Contact person(s)
Fermilab	**01/05/2024 – 31/09/2024**	**Simona Giovannella – R. Kutschke**

Commissioning and calibration of the Mu2e calorimeter	Daily activity, skills required and to be acquired
The calorimeter of the Mu2e experiment is composed by two disks of pure CsI crystals, readout by two custom array of large area UV-extended Silicon Photo-Multipliers (SiPMs). The experiment is currently in the construction phase, with the calorimeter assembly expected to be completed by Spring 2024. The calorimeter will then start the commissioning and calibration phase, where its performance will be assessed. This will be obtained by acquiring half calorimeter disk at a time, corresponding to about 350x2 channels, on a Vertical Slice Test with final detector components and electronics. Laser runs will be used to monitor and calibrate the gain of the SiPMs, and to measure the time resolution of the readout channels. Validation and calibration of the calorimeter response will be carried out with Cosmic Ray data using 3D-traced minimum ionizing particles selected by two segmented scintillator counters to be installed above and below the calorimeter disk under test. Selected events will provide calibration of the energy response (<1%) , time offset alignment (< 50 ps), and measurement of the crystals Longitudinal Response Uniformity. A dedicated data-MC comparison of energy and time resolution will also carried out before and after calibration.	Required skills are to have a basic knowledge of C++ and ROOT as well as of electromagnetic calorimetry and calibration processes. The daily activity will be focused on preparation for data collection, trigger development, tuning of the reconstruction and calibration algorithms and finally on software development of the code used in the experiment for this purpose. Development of the DB side of the calibration process is also foreseen. The candidate will acquire a lot of technical competence on electromagnetic calorimetry and its calibration techniques, he/she will get hands on experience on a real, full size, detector *in operation* with all the complication related to triggering and data collection. Finally, he/she will gain a lot of expertise in professional software coding in C++ and in writing technical reports, papers, and dedicated presentations.

FNAL-6

Hosting Laboratory	Available period	Contact person(s)
FermiLab	1/04/2024 – 31/12/2024	Francesco Di Capua - Flavio Cavanna

Determination of the Photon Collection Efficiency of the Vertical Drift Optical Module in Liquid Argon	Daily activity, skills required and to be acquired
DUNE Far Detector is based on the liquid argon TPC technology and will implement the novel X-ARAPUCA photodetector to collect scintillation light from neutrino interactions. X-ARAPUCA is a light trap, capturing wavelength-shifted photons inside a box with high-reflective internal surfaces. The entrance window of the box is made of a short-pass dichroic filter which has the properties of being highly transparent to photons with wavelength below a given cut-off (400 nm), while being highly reflective to photons with wavelength above the same cut-off. The dichroic filter is coated on the external side of the entrance window with para-Terphenyl (pTP), a wavelength shifter downshifting photon from 128 nm to 350 nm. An X-ARAPUCA module is read-out by 160 SiPMs distributed around the perimeter of the photodetection module. In the Vertical Drift (VD) geometry for LArTPC, proposed for the second FD module, the light collection will be optimized by embedding photon detectors within the LArTPC cathode, which is biased at –300 kV. As result, power must arrive to the Photon Detection System (PDS) and signal must be transmitted via non-conductive material. The proposed solution is to use Power-over-Fiber (PoF) and Signal-over-Fiber (SoF). A whole X-ARAPUCA module biased with PoF and with signal transmitted via PoF will be tested in term of Photon Collection Efficiency in liquid argon. The selected student will participate in laboratory activities at FermiLab acquiring experience in this PoF and SoF technology and with cryogenic systems, signals in liquid argon, silicon photomultipliers and data-analysis.	Required skills are to have a basic knowledge of data analysis tools: Python, C++ and ROOT. In addition, to have basic knowledge of radiation interactions in the matter and of the scintillation mechanism. The daily activity will be focused on preparation for a long run campaign of the XARAPUCA optical module in LAr. PoF and SoF electronics will be preliminary tested in standalone experiments at cryogenic conditions, the electronic connections for PoF and SoF systems through the flange cryostat will be prepared and tested, calibration and reconstruction algorithms will be tested and a full Monte Carlo simulation of the apparatus will be employed and improved. The candidate will acquire a lot of technical competence on cryogenics, vacuum and electronics. He/She will get hands on experience on a real detector in operation. Finally, he/she will gain a lot of expertise in professional data analysis software tools and in writing technical reports and dedicated presentations.

KEK-1

Hosting Laboratory	Available period	Contact person(s)
KEK	01/06/2024 – 30/11/2024	Alessandro Gaz – Kenta Uno

Study of the PID performance of the Belle II detector in Run2 data taking	Daily activity, skills required and to be acquired
The Belle II detector has just gone through the Long Shutdown 1 maintenance and upgrade period and is preparing for the start of the Run2 data taking campaign in January 2024. Part of the photodetectors of the Time Of Propagation (TOP) detector has been replaced with more efficient and radiation tolerant devices and new electronic boards have been installed in place of some faulty components. On the other hand, during Run2 we expect a large increase in the instantaneous luminosity which will possibly be associated to harsher background conditions. In this context, it will be important to quickly assess the Particle Identification (PID) performance of the detector, re-evaluate the recommendations for physics analysis, and optimize the mitigation strategies against high beam background conditions.	The timing of the project is suitable for having the first Run2 data reconstructed and available for analysis. The student will become familiar with the techniques utilized to get high purity control samples to be used for the characterization of PID performance. Depending on the sample, the tag-and-probe or other background subtraction methods will be utilized to determine the efficiencies and mis-identification rates of the currently supported PID selection strategies. If the student is interested, there will be the possibility of re-optimizing PID selectors based on machine learning. Prerequisites: some familiarity with the python and C++ programming languages and with the ROOT analysis framework.

KEK-2

Hosting Laboratory	Available period	Contact person(s)
KEK	**01/03/2024 – 31/10/2024**	**Taichiro Koga – Shohei Nishida – Diego Tonelli**

Novel, precise determination of the π^0 reconstruction efficiency in Belle II	**Daily activity, skills required and to be acquired**
This is a project based on the analysis of 10 GeV e^+e^- collision data collected by the Belle II experiment. The project targets a novel and precise determination of the π^o reconstruction efficiency. The efficiency for reconstructing $\pi^o \to \gamma\gamma$ decays in the calorimeter is a critical performance driver for many Belle II measurements sensitive to absolute rates involving π^o's. Multiple factors affect π^o efficiency, such as calorimeter energy thresholds, photon conversions, early development of electromagnetic showers, and errors in the algorithms of energy-depositions merging. The simulated description of these effects is approximated or lacking, making determinations based solely on simulation unreliable. Belle II has been using so far data samples of *D, B, ω, η, or* $\tau \to$ *3* prong decays to determine corrections for simulation-based efficiencies. However, sample size, irreducible uncertainties, or incomplete momentum coverage currently limit to 3% the final precision on the π^o efficiency. This is the dominant contribution to the uncertainty in several physics results. This project aims at the first Belle II determination of (relative) π^o efficiency based on the ratio between $\tau^- \to \pi^-\pi^o\nu$ and $\tau^- \to \pi^-\nu$ yields. These are abundant, low-background, and well-known decays with final-state π^o*'s* covering a generous momentum range. Experience from previous experiments and early simulation studies show that this approach may achieve a 1% precision, offering a decisive benefit for several Belle II analyses.	By performing a small, but full-fledged analysis of Belle II experimental data, the student will learn the conceptual and technical fundamentals of HEP statistical analysis. The project involves simulated- and collision-data reduction and calibration (2 weeks), optimization of the event selection (2 weeks, possibly involving machine-learning-based classifiers), sample-composition fitting (3 weeks), determination of systematic uncertainties (3 weeks), documentation and contingency (2 weeks). Results will be presented in Belle II meetings, documented in a Belle II internal note, and possibly approved for public showing. No technical or scientific prerequisites are needed, but some familiarity with the basics of collider physics and ROOT/python programming will allow for a faster learning curve.

KEK-3

Hosting Laboratory	Available period	Contact person(s)
KEK	**01/02/2024 – 31/10/2024**	**Mirco Dorigo – Taichiro Koga/Shohei Nishida**

Improving the |Vcb| determination from $B^0 \to D^{*-} l^+ \nu$ decays at Belle II	Daily activity, skills required and to be acquired
This is a data analysis project aimed at exploring an improved determination of the Cabibbo-Kobayshi-Maskawa matrix element $\|V_{cb}\|$ using $B^0 \to D^{*-} l^+ \nu$ decays. We will analyze decay candidates reconstructed in a sample of 390 million bottom-antibottom meson pairs recorded in 10 GeV electron-positron collisions at the Belle II experiment. Analyses of $B^0 \to D^{*-} l^+ \nu$ provide the most effective way to access $\|V_{cb}\|$. However, they are affected by two major limitations: knowledge of the reconstruction efficiency of the soft-pion in the decay $D^{*+} \to D^0 \pi^+$ – currently giving the dominant uncertainty on the measurement – and model-dependent description of strong-interaction effects for the b and c quarks bound in mesons (so-called form factors). For the soft-pion, the current method to determine the efficiency exploits $B^0 \to D^*(\to D^0 \pi^-) \pi^+$ control data, which offer a clean but small sample. The project target is twofold: (i) to extend the soft-pion efficiency study using a different control sample, i.e. prompt $D^* \to D^0 \pi$ decays produced in $e^+e^- \to D^*X$ events, which would offer a larger sample size for improving the current uncertainty on this efficiency (~3%); (ii) to explore the analysis of $B^0 \to D^{*-} l^+ \nu$ decays with newly devised observables that reduce model-dependence for a novel measurement of decay form-factors and $\|V_{cb}\|$.	Depending on the student's interest, we will focus on the soft-pion efficiency study or on the development and feasibility study of the analysis with new model-independent observables. The student will be co-supervised by Belle II experts on semileptonic decays and tracking, who will guide him/her in the development of the project. The project is synergic to other semileptonic analyses ongoing in the Belle II Trieste group. Basic knowledge of particle physics, relativistic kinematics, and statistical methods for data analyses are highly desired as well as some familiarity with root software and C++/python. Results will be presented in internal Belle II meetings and documented in an internal note.

PSI-1

Hosting Laboratory	Available period	Contact person(s)
PSI	01/05/2024 – 20/12/2024	Angela Papa – Stefan Ritt

MEGII detectors: From new calorimetry to the beam monitoring tools at the intensity frontiers	Daily activity, skills required and to be acquired
The MEG experiment searches for the $\mu^+ \rightarrow e^+ \gamma$ decay and has set the most stringent upper limit on its branching ratio $B(\mu^+ \rightarrow e^+ \gamma) < 4.2\ 10^{-13}$ at 90% C.L. The MEG upgrade (MEGII) has been approved at PSI and by the institutions of the international collaboration aiming at improving the sensitivity on this channel by one order of magnitude. MEGII has started data taking since fall 2021. In the context of MEGII, some R&D are going to develop auxiliary detectors for the ongoing data-taking for the calibration and monitoring of the apparatus. Among that a new auxiliary calorimeter, a LYSO detector, is under construction. Furthermore a new generation of beam monitoring tools have been studied and tested via large prototypes, based on either small plastic scintillators or very thin fibres coupled to Silicon Photomultiplers, SiPM. The candidate could select one of these detectors under construction and to contribute on new auxiliary detectors for MEGII and first generations of monitoring tools for future cLFV searches.	The program includes both software and hardware activities. The student will collaborate in performing Monte Carlo simulations based on GEANT4 to optimise the reconstruction algorithms for the kinematical variables of the detected particle. He/she collaborate on the assembly and the commissioning of one of the selected detectors. He/she will be involved in setting up of the experimental apparatus during the beam time, in studying the trigger strategy and in carrying out the data analysis for the final assessment of the detector performances. Required knowledge: Good English, C++, Python. By the end of the program the student will gain good skill in experimental techniques.

PSI-2

Hosting Laboratory	Available period	Contact person(s)
PSI	01/05/2024 – 20/12/2024	Angela Papa – Stefan Ritt

The muEDM experiment at PSI	Daily activity, skills required and to be acquired
A new experimental effort is taking shape at PSI aim at searching for the Electric Dipole Moment (EDM) of the muon with a sensitivity of 10^{-21} e·cm using for the first time the frozen-spin technique in a compact storage ring. This staged search for a non-zero muon EDM (muEDM) is a unique opportunity to probe previously uncharted territory and to test theories of Beyond Standard Model physics. In this project the student can select to work either on the so called muon entrance detector system, used to generate a signal for muons within the acceptance phase space to trigger a magnetic pulse in the center of the muEDM solenoid, or the fibre tracker that will be used to extract the signature of the muEDM. Both detectors have several challenges, from the minimal amount of material to minimize the multiple scattering to the control of systematic that could mimic a fake muEDM signature.	The program includes both software and hardware activities. The student will collaborate in performing the Monte Carlo simulations based on GEANT4 to optimize the experimental setup of the selected detector. He/she will collaborate on the assembly and the commissioning of the detector. He/she will be involved in setting up of the experimental apparatus during the beam time, in studying the trigger strategy and in carrying out the data analysis for the final assessment of the detector performances. Required knowledge: good English, C++, Python. By the end of the program the student will gain good skill in experimental techniques.

PSI-3

Hosting Laboratory	Available period	Contact person(s)
PSI	02/05/2024 – 31/11/2024	Stefan Ritt – Marco Francesconi

TDAQ Commissioning for MEG II experiment	Daily activity, skills required and to be acquired
The MEG II experiment will start its fourth year of physics data-taking in 2024, following three years of successful data production. In February, the PSI Committee will likely allocate a large chunk of beam time to the MEG II experiment, starting between May and July until the end of the year. An extensive maintenance schedule will take place in the winter requiring a careful re-commissioning of all detectors and the complete TDAQ chain. It is therefore a very interesting moment for a student to join the experiment during the commissioning phase where he/she will experience the detectors being restarted after several months of maintenance. In particular, the MEG II Trigger and Data acquisition system connects to all the detectors and plays a crucial role in rejecting background events from the 40 MHz muon beam, allowing MEG II to be one of the forerunners in the high-intensity frontier. Following the reinstallation of the detectors, of the experiment Trigger system has to be reconfigured for the start of the datataking and its performances will be closely monitored throughout the physics run.	The student will join the Trigger and Data acquisition team re-commissioning the online architecture, including each detector in the system as they get ready. Some basic programming skills are required as well as some basic knowledge of the ROOT framework and of Linux shell. The student will learn basic Trigger and Data acquisition design schemes and will acquire skills in performing data analyses both within and outside the Experiment framework. The student will experience the challenges and gratifications of working on a running experiment interacting with a small but international collaboration. Some firmware modifications may be needed, so the student will also acquire some basic skills in FPGA programming in VHDL and/or Verilog.

PSI-4

Hosting Laboratory	Available period	Contact person(s)
PSI	**01/03/2024 – 31/05/2024**	**Cecilia Voena (INFN Roma)** **Philipp Schmidt-Wellenburg (PSI)**

Electric and magnetic field measurement system for the muonEDM experiment	Daily activity, skills required and to be acquired
The presence of a permanent electric dipole moment in an elementary particle implies Charge-Parity symmetry violation and thus could help explain the matter-antimatter asymmetry observed in our universe. Within the context of the Standard Model, the electric dipole moment of elementary particles is extremely small. However, many Standard Model extensions such as supersymmetry predict large electric dipole moments. The muEDM experiment has been proposed at the Paul Scherrer Institute in Switzerland to search for the muon electric dipole moment using a 3-T compact solenoid storage ring and O(1 MV/m) electric fields to freeze the spin of the muon along its flight direction. A non-null EDM would break the freezing condition and produce an observable precession of the spin. This technique could reach a sensitivity of 6×10^{-23} e*cm after a year of data taking with the PSI's muon beam. The collaboration is composed by various international research institutions/universities. A precursor experiment is planned before 2027 and the Rome group (INFN/Department of Physics) is building the muon entrance detector and is contributing to other different construction aspects. One of the critical elements to reach the target sensitivity is the accurate measurement and monitoring of the magnetic and electric fields in the detector.	The students will collaborate with the muonEDM group based at PSI to setup measurement systems for the electric and magnetic field, to be used for a continuous monitoring of the fields inside the detector. These systems will exploit nonlinear optic phenomena, affecting the propagation of light in specific crystals under the effect of electric and magnetic fields: the Pockels and Faraday effect respectively. The effects can be measured as a change of intensity downstream the crystal, by using interferometric techniques. The thesis work is focused on the design and the realization of a test bench for the two systems, as well on data analysis. For the hardware part of the work, the student will be based at PSI. Required knowledge: good knowledge of English; basic knowledge of optics; basic knowledge of C++ or phyton /ROOT. Acquired knowledge: understanding of the relevant nonlinear optic phenomena; use of photosensors for light intensity measurements; development of measurement procedures with control of statistical and systematic uncertainties.