BEPC-1

Hosting Laboratory	Available period	Contact person(s)
IHEP	**01/01/2024 – 30/11/2024**	**MICHELA GRECO (INFN-UNITO) 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 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 and installation 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 is required. Basic knowledge of microcontrollers like Arduino or Raspberry Pi is an advantage. The candidate will collaborate with an international team and will learn from direct experience experimental 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	**01/04/2024 – 30/10/2024**	**Andrea Massironi - Simone Gennai**

CMS ECAL transparency updates for HLT and scouting: time based predictions during a fill of LHC	Daily activity, skills required and to be acquired
The transparency of the electromagnetic calorimeter of CMS changes with time, due to irradiation from collisions, and recovers during non irradiation periods. The transparency is measured with a 40 minutes granularity, but its measurement is available only for offline reprocessing of data (e.g. prompt reconstruction), but it is not updated live in the High Level Trigger (HLT) of CMS, but at most only once per LHC fill. The project concentrates on the implementation in the CMS software of a way to apply the transparency estimation using a predictive model based on the expected instantaneous luminosity in an LHC fill for HLT. This would improve the stability of the High Level Trigger (HLT) of CMS and the performance of the scouting data.	Required skills: basic coding, c++, python Skills acquired: coding, working in a big collaboration, learn how to present results Daily activity: development of the CMS software (CMSSW) code to implement time dependent transparency corrections using a predictive model, based on the assumption of a standard LHC fill luminosity profile. Tests of this new procedure should aim at demonstrating the improvement in stability and performance.

CERN-2

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2024 – 30/09/2024**	**Francesco Giuseppe Gravili – Zachary Marshall**

Interactive analysis within the ATLAS Open Data project	Daily activity, skills required and to be acquired
The ATLAS Open Data is an educational project mainly for physics undergraduate and master students, to educate them in experimental high energy particle physics, generating excitement and enthusiasm, as well as inspiring future physicists. Data collected by the ATLAS experiment at the Large Hadron Collider (LHC) at a center of mass energies of 8 and 13 TeV are released publicly, corresponding to an integrated luminosity of 1 fb^{-1} and 10 fb^{-1}, respectively. Monte Carlo simulation samples are included in the public datasets: they describe several Standard Model and Beyond Standard Model processes, used to model expected distributions of different signal and background physics processes. Virtual machines with educational tools to perform interactive data analysis and interpretation of results are provided too at different level of complexity. Online data visualisation with graphical user interface can simplify the analysis, by using built-in histograms to differentiate between signal and background processes, based on the signature of the final state.	The candidate will be introduced to experimental analysis techniques used by high energy physics researchers, within the environment provided by the ATLAS Open Data project. The candidate will get familiar with the basics of event reconstruction and selection at hadron colliders, learning how to deploy and run a simple physics analysis using Jupyter notebooks and other interactive tools: real data recorded by the ATLAS experiment during the LHC Run I and Run II data taking campaigns will be used, as well as simulated Monte Carlo samples. New analysis workflows will be evaluated and developed, including dedicated documentation and tutorials. It is required a basic knowledge of C++ or Python computing language and familiarity with ROOT data analysis framework. Good knowledge of English and/or French for everyday communication.

CERN-3

Hosting Laboratory	Available period	Contact person(s)
CERN	15/07/2024 – 15/09/2024	Livia Soffi –Cecile Caillol

Analysis techniques in high energy physics: how we look for new physics at the LHC	Daily activity, skills required and to be acquired
Novel analysis techniques in high energy physics draw upon principles from multiple fields including statistics, algebraic geometry and machine learning. Very often the data collected by the experiments at the LHC are directly to design and estimate the more relevant background processes that can mimic the signals of new physics at collider, the so called data-driven techniques. At CMS the real data are used to define analysis selectors and categorizers that maximize the statistical significance of a potential signal of physics beyond the standard model. The prime example of a background estimation that follows a data-driven method and exploits the uncorrelation between two or three additional selection criteria is known as ABCD method. This method allows to indirectly take into account all the sources including non-collision background (e.g. cosmic rays) very common when searching for non conventional signatures. Eventually this method does not require knowledge of the signal shapes of the considered variables, which reduces the model-dependence of the analysis. This is an advantage for this type of search, in which the signal model is not known unambiguously.	The activity of this project consists in: 1) Learning the main features of the LHC accelerator and the basic principles of the CMS experiment at CERN 2) Reviewing an example of a recent analysis at CMS based on the ABCD method: the Soft Unclustered Energy Patterns 3) Setting up a simple simulation (python or c++) of the ABCD method selection for a given and simple physics case. 4) Preparing a short final presentation of the activity to be presented at the CMS EXO group at CERN Requirements: basics of particles interaction with matter, principles of SM physics and minimal programming skills (topics usually discussed in the first exams of particle physics and computing methods during the bachelor curriculum). At the end of the project, he/she will gain knowledge about how a general-purpose experiment of high energy physics (HEP) and a huge collaboration work. He/she will be able to critically understand the basics of a data analysis in HEP and how to present a physics results to the scientific community.

CERN-4

Hosting Laboratory	Available period	Contact person(s)
CERN	**15/05/2024 – 30/11/2024**	**Alessia Bruni – Davide Boscherini**

ATLAS upgrade for the muon system: construction and test of trigger detectors based on Resistive Plate Chamber technology	Daily activity, skills required and to be acquired
The ATLAS muon Collaboration approved a major upgrade plan for the Muon system, involving both detector and trigger-readout electronics, to guarantee the performance required by the physics program. This plan pivots on installing a layer of ~300 new generation Resistive Plate Chambers in the inner barrel (BI), to increase the redundancy, the selectivity, and provide almost full acceptance. The chambers will consist of a triple layer of RPC detectors with the aim to provide an efficiency of 99%, a temporal resolution of 400ps and a spatial resolution of the order of 1cm. The construction of these new detectors began in June 2023 and will continue until the start of long shutdown scheduled for 2026, as joint work of the INFN groups Roma1, Roma2, Bologna, Cosenza and other groups. The integration of these detectors into the mechanics will be carried out at the CERN laboratories, where the detectors will be commissioned before the installation in the experiment. A cosmic ray test station is used to qualify the detectors. The station includes all the components active in a slide of the ATLAS muon detector, namely the control system, the trigger and the data acquisition system.	The student will be able to familiarize with all the tools of the experimental activity and in particular will be able to manage the data collected using a full slide of the muon trigger detector. He/she will participate in the development and use of the data analysis software tools. The student will have the opportunity to participate in a unique experience, working closely with expert researchers and acquiring the most innovative experimental techniques in the field of particle detectors. He/she will have the opportunity to work in a group within an international collaboration on cutting-edge topics in the field of elementary particle physics and fundamental interactions.

CERN-5

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2024 – 01/10/2024	Luigi Longo - Djunes Janssens

µRWELL Gain measurement for HCAL for future colliders	Daily activity, skills required and to be acquired
In the context of future collider experiments, an R&D on a sampling hadron calorimeter based on micro pattern gas detectors (MPGD-HCAL) is currently on-going. Two main technologies are currently considered as best candidates: micromegas and micro-rwell. During the test beam 2023 campaign, micro-rwell modules have been shown a lower efficiency than expected, indicating a non optimal operational working point. The candidate will perform gain measurements at the GDD lab at CERN, varying the potential applied to top and drift electrodes. She/he will prepare the setup to monitor the current collected from the top electrode and to read signals collected through an MCA. Variations in the gain, as a function of the voltage applied, will be compared with a garfield simulation, which the candidate will prepare in collaboration with GDD lab garfield expert.	Skills: coding skill is desirable. The student will learn the physics principle of gaseous detectors. She/he will learn how to operate lab equipment for data acquisition and to work with garfield. Skills on basic data monitoring and analysis will also be acquired.

CERN-6

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2024 – 30/09/2024**	**Pietro Govoni – Giulia Lavizzari**

Development of DAQ software tools for testing ECAL Upgrade electronics	Daily activity, skills required and to be acquired
The CMS electromagnetic calorimeter (ECAL) is a homogeneous detector made of lead tungstate scintillating crystals, designed to measure the energy of electrons and photons with extremely high precision. ECAL is currently operating in the LHC Run 3, and it will keep playing a crucial role for the CMS physics program also in the high-luminosity phase of the LHC. This upcoming period, referred to as Phase 2, will present significant technical challenges as the operating conditions of the apparatus will be pushed to the limits, with increased trigger latency and a higher rate. To cope with such stringent requirements, ECAL will need a full refurbishment of its electronic components. ECAL will be equipped with new Very Front-End and Front-End electronics, providing better timing resolution and noise filtering, as well as new off-detector electronics, which will be able to run more sophisticated trigger algorithms. At the present day, the first prototypes are already available and undergoing tests, and some components are in production. The student will join the ECAL data acquisition (DAQ) team in the development of the software used for testing and validating the new electronic components. The student will interface with the electronics experts, testing the new prototypes and checking that they match the technical prerequisites and the expected performances. In particular, the student will design and implement a standard test of the FE cards, which will be employed to validate in a fast and reliable way the cards once they are produced on a large scale.	The student will work on a daily basis with a spare section of ECAL, known as supermodule (SM) 36, on which the new electronic components are installed for testing. The experimental setup of SM 36 allows to simulate the full DAQ chain of ECAL in Phase 2. The student will thus gain familiarity with the whole DAQ process, learning all the steps from the configuration of the electronics to the collection data from SM 36. A basic knowledge of RLC circuits is required. Specific notions about the technologies and electronic components used will be acquired along the way. The student will focus in particular on FE electronics, which is responsible for handling the signals coming from the detector elements and for transmitting them to the off-detector processors. Knowledge of some programming language is required. Most of the DAQ code the student will be using is python-based. However, knowledge of this language is not mandatory, as it will be acquired along the way. Knowledge and expertise with specific DAQ strategies and tools will also be part of the set of skills that the student will develop during the project.

CERN-7

Hosting Laboratory	Available period	Contact person(s)
CERN	01/06/2024 – 30/09/2024	Mauro Piccini, Viacheslav Duk

Title of the project: Luminosity measurement with the Light Leak Detectors of the RICH2 of the LHCb experiment	**Daily activity, skills required and to be acquired**
The Light Leak Detectors (LLD) of the LHCb RICHs are 12 sensors (photomultipliers) measuring the light intensity inside the four boxes (three for each box) containing the main subdetector sensors of RICH1 and RICH2. In each box, one of the LLD sensors is pointing to the transparent entrance window and it is then directly illuminated by the Cherenkov light of the charged particles produced in the beam interactions at LHCb and travelling in the RICH radiator. The amount of light collected by these sensors is proportional to the number of particles in the LHC accelerator and to the number of proton-proton interactions happening every bunch crossing. In 2024 a new readout electronics, based on Trans Impedance Amplifiers, will be installed in the two LLD sensors of the RICH2 pointing to the entrance windows to improve their sensitivity as luminosity monitors. After the installation, the data collected during the 2024 run, will be used to calibrate the two readout chains, comparing the LLD analog signal with the luminosity measurements obtained by other subdetectors (PLUME, VELO). The linearity of the response will be studied, and a set of calibration will be extracted to use the output of the two sensors to directly measure the average number of proton-proton interactions per bunch crossing with time step of few hundreds' microsecond.	The student will take part in the analysis of the data that will be collected during the 2024 run by LHCb: he/she will learn how to extract the information relevant to the project and to produce a root file where to store such data. From their analysis then the student will learn the main methodologies of a physics analysis, increasing the expertise and skills in computing and python/C++ coding. He/ she will learn how to extract the relevant parameters from the analysis of the data and how to evaluate statistical and systematic uncertainties. He/she will experience to work as a part of an international collaboration, with the opportunity to discuss the work progress during the "RICH operation" meetings. The student will also have the possibility of taking part in the 2024 data taking of the LHCb experiment, learning the basic functioning of the RICH subdetectors, and monitoring their performance. A student with a physicist profile and a basic knowledge of C++ and ROOT is preferred.

CERN-8

Hosting Laboratory	Available period	Contact person(s)
CERN	**15/07/2024 – 15/09/2024**	**Livia Soffi – Raffaella Tramontano**

The Bethe-Bloch at the LHC: probing new physics with slow moving particles	Daily activity, skills required and to be acquired
There are several phenomena in nature that cannot be explained by the Standard Model of particle physics (SM), thereby prompting the exploration of possible extensions. These explorations share a common assumption that the new particles decay promptly. One way to extend the portfolio of these searches is to look for particles with longer lifetimes. Possible signatures of long-lived (or stable) charged particles at the Large Hadron Collider (LHC) are characterized by quite low speed. Due to this fact, in some cases they can be very clearly distinguished from the SM particles as electrons, muons, protons, or pions, exploiting the dE/dX measurements in the inner tracker detector of the CMS experiment. By comparing the estimated energy released by such predicted new particles with that of typical standard particles, using the Bethe-Bloch formula, it is possible to probe the existence of physics beyond the standard model at the CMS experiment at LHC.	The activity of this project consists in: 1) Learning the main features of the LHC accelerator and the basic principles of the CMS experiment at CERN 2) Reviewing the most recent CMS search for heavy stable charged particles which exploits dE/dX estimates at Run 2. 3) Setting up a simple simulation (python or c++) of the Bethe-Bloch formula to compare the scenario of a SM muon and a heavy slow-moving particle predicted by models BSM. 4) Preparing a short final presentation of the activity to be presented at the CMS EXO Long-Lived group at CERN Requirements: basics of particles interaction with matter, principles of SM physics and minimal programming skills (topics usually discussed in the first exams of particle physics and computing methods during the bachelor curriculum). At the end of the project he/she will gain knowledge about how a general purpose experiment of high energy physics (HEP) and a huge collaboration work. He/she will be able to critically understand the basics of a data analysis in HEP and how to present a physics results to the scientific community. .

CERN-9

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2024 – 30/06/2024**	**Lorenzo Bonechi – Eugenio Berti**

Run of the LHCf experiment with 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 are installed. Subsequently the student will have the opportunity to participate in the data taking and monitoring phase of the experiment and to the final uninstallation of the apparatus.

CERN-10

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

Development 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 perform detailed Monte Carlo simulations of calorimeter modules built on both the SpaCal and Shashlik sampling technologies, which are based on the combination of fast scintillators and dense absorbers. The results will be compared to experimental data acquired in previous test beam campaigns in order to predict the performance of modules based on these materials in future calorimeters.	The research will involve data simulation and analysis activities. On one side, the student will acquire knowledge in the field of Monte Carlo simulations, with particular focus on 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-11

Hosting Laboratory	Available period	Contact person(s)
CERN	**15/07/2024 – 15/09/2024**	**Livia Soffi –Bryan Cardwell**

The effects of multiple interactions at the LHC: discovering new physics in an harsh environment	Daily activity, skills required and to be acquired
The Large Hadron Collider at CERN (LHC) involves the collision of hadrons. Since hadrons are composite particles, in any collision there will typically be multiple collisions of the constituents. The spatial overlap of tracks and energy deposits from these concurrent collisions can degrade the identification and the reconstruction of the hard interaction, making it hard the quest for rare signals of new physics. Novel strategies are being developed at CMS experiment to mitigate the effects of the multiple interactions. In this context, for the High Luminosity phase of LHC (HL-LHC, from 2029) CMS is building the Mip Timing Detector (MTD). This novel detector will precisely provide for the very first time, the time-of-flight information of charged particles produced in the LHC collision at CMS. This information would help to separate in time collisions very close in space and would therefore reduce the effective multiplicity of concurrent collisions. MTD will help to recover the current quality of the event reconstruction at HL-LHC and will boost new physics searches potential at CMS.	The activity of this project consists in: 1) Learning the main features of the LHC accelerator and the basic principles of the CMS experiment at CERN 2) Reviewing the MTD TDR section about pileup and the approaches investigated at CMS for its mitigation. 3) Setting up a simple simulation (python or c++) of the LHC bunch crossing collisions with a basic montecarlo hit and miss approach for the LHC High Luminosity scenario. 4) Preparing a short final presentation of the activity to be presented at the CMS MTD group at CERN Requirements: basics of particles interaction with matter, principles of SM physics and minimal programming skills (topics usually discussed in the first exams of particle physics and computing methods during the bachelor curriculum). At the end of the project, he/she will gain knowledge about how a general purpose experiment of high energy physics (HEP) and a huge collaboration work. He/she will be able to critically understand the basics of a data analysis in HEP and how to present physics results to the scientific community.

CERN-12

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2024 – 30/09/2024**	**Mauro Iodice – Michela Biglietti**

Large size resistive pixelized Micromegas for future detectors	Daily activity, skills required and to be acquired
Following the design and construction phase of the resistive micromegas for the upgrade of the ATLAS muon spectrometer, we initiated an R&D project aimed at pushing this technology to operate at high gains, superior stability, and with the capability to handle high particle fluxes. The project, known as Resistive High-Granularity Micromegas (RHUM), has successfully completed its initial phase, achieving excellent performance on small-size prototypes configured with double Diamond-Like Carbon (DLC) resistive layers. The focus of the R&D has now shifted towards demonstrating the scalability of this technology for large-size detectors, which will be compatible with the next generation of detectors at future research facilities. At present, we are in the process of constructing two large-size modules (50x50 cm2) of high-granularity resistive Micromegas. These modules differ in terms of their resistive layout. We intend to conduct a comprehensive characterisation of these new detectors using radioactive sources (such as 55Fe) and an X-ray gun available at the GDD Lab at CERN. Additionally, depending on the availability of beam time at the SPS test-beam facility, we may further evaluate their performance.	The student will be involved in one of the foreseen activities: tests and characterization of the detectors in the Lab with 55Fe and X-rays, or, test-beam. He/she will participate and learn the steps of setting up the experiment, the data taking and the data analysis. Knowledge of C++ and Root would be an advantage but not mandatory. The student will have the opportunity to acquire hands-on experience on: - Micromegas detectors - HV and gas systems - readout electronics and acquisition packages - particle physics data analysis too

CERN-13

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2024 – 30/09/2024**	**Giuseppina Anzivino, Francesco Brizioli**

Title of the project: Identification of charged kaons with the RICH detector of the NA62 experiment at CERN	**Daily activity, skills required and to be acquired**
The NA62 experiment at CERN [1] is aimed to study the very rare decay $K^+ \to \pi^+ \nu\nu$. A BR measurement with O(10%) precision will allow to probe New Physics at mass scales up to O(100) TeV. A crucial role in the rejection of the background coming from the $K^+ \to \mu^+ \nu$ decays is played by the RICH detector, that provides a rejection power of a factor greater than 100 in the momentum range of interest. The data collected by NA62 show that tracks of charged kaons scattered from the beam line are clearly visible in the RICH detector [1]. Such tracks can be studied using the information coming from the RICH detector and the magnetic spectrometer, in order to reconstruct the charged kaon mass. Therefore, the study can be used as a tool to provide an independent procedure to calibrate the RICH and/or the momentum scale measured by the magnetic spectrometer. Moreover, it can become the basis of a project to measure the charged kaon mass with the RICH detector, has done in other experiments for several charged hadrons, for example [2]. [1] NA62 Collaboration, JINST 12 (2017) P05025. [2] Cooper and Engelfried, NIM A 639 (2011) 246.	The student will take part in the analysis of the data already collected: with the NA62 framework, he/she will learn how to build an event selection, to produce histograms and to statistically interpret the data and evaluate uncertainties. The student will learn the main methodologies of a physics analysis, increasing the expertise and skills on computing and coding. He/she will experience to work as a part of an international collaboration, with the opportunity to discuss the work progress during the collaboration meetings. The student will have also the possibility of taking part in the operation of the NA62 data taking in 2024, learning the basic functioning of the RICH detector and monitoring its performance. A student with a Physicist profile and a basic knowledge of C++ and ROOT is preferred.

CERN-14

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2024 – 31/09/2024**	**Michela Biglietti – Biagio Di Micco**

Sensitivity estimation for the HH→bbγγ analysis	Daily activity, skills required and to be acquired
One of the main target of the Run-3 of LHC is to push the sensitivity of the analysis of the pp → HH production to a level for which a first evidence of a non-null Higgs boson self-coupling can be achieved. This can be obtained by combining multiple decay final states of the Higgs boson. The HH → bbγγ channel is particularly suited for this target being sensitive for values of the Higgs boson self-coupling close to zero, where a non-null value of such coupling should be tested. ATLAS has recently submitted a paper on this channel using the Run-2 dataset and it is going to analyze the Run-3 dataset collected in 2022 and 2023. By the summer of 2024 new data at 13.6 TeV center of mass energy will be available and in this context the work of the student will be inserted. The student will learn to use a c++ based analysis software based on the ROOT analysis framework and perform signal extraction and background estimation as a function of several analysis cuts and optimized algorithms. In particular he will study the performances of a kinematic fit algorithm recently implemented.	The student will work in close collaboration with one of the contact persons that will be at CERN lab during his fellowship. He will interact with the HH→ bbγγ analysis group to learn how to use the software tools of the group and produce the first results. In the first week of his fellowship the student will learn the basic of the ROOT analysis framework and will strengthen his c++ programming skills. A basic, university level, knowledge of the c or c++ programming language is required. In the following week he will start using and modifying the HH→ bbγγ analysis software to produce first kinematic distributions and extract the expected number of signal and background events. The third and the fourth week of his fellowship will be dedicated to his original work. The student will test several analysis algorithms and analysis cuts in order to evaluate their performance and their impact on the HH→ bbγγ analysis sensitivity. The student will work in a stimulating environment and will have the opportunity to acquire hands-on experience on particle physics and data analysis tools.

CERN-15

Hosting Laboratory	Available period	Contact person(s)
CERN	**15/06/2024 – 15/07/2024**	**Raffaella Radogna – Archie Sharma**

Muon reconstruction at the CMS experiment	Daily activity, skills required and to be acquired
The Muon System of the CMS experiment at the LHC played a key role for many physics results during Run 2, thanks to the excellent momentum resolution and the high reconstruction and identification efficiencies. A large variety of identification algorithms was developed to meet the needs of the different physics analyses in terms of purity and fake rates. During Run 3, higher instantaneous luminosities are provided by the LHC, and monitoring the muon performance is crucial for keeping the physics potential of the new datasets. In this project, the student will learn how tag&probe analysis is exploited at CMS for measuring the muon reconstruction and identification efficiencies of the different algorithms adopted in physics analyses. GIven the size of the datasets and the large number of variables involved, the tag&probe analysis uses cutting-edge tools typical of Big Data, an added value for early career students interested in the topic.	The selected candidate will work on the tag&probe framework used at CMS for measuring the muon trigger, reconstruction and identification efficiencies. She/he will be able to look at newly collected data with the assistance of experts at CERN. Basic python coding skills are desirable. The candidate will acquire knowledge both on CMS muon detector and the most commonly adopted muon identification algorithms. She/he will learn how the tag&probe method works, while acquiring practical skills on some basics python coding and the ROOT/ROOFit framework.

CERN-16

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2024 – 10/08/2024** **01/09/2024 – 30/09/2024**	**Fabio Cossutti – Giulia Sorrentino**

Test of the readout chain of CMS Mip Timing Detector	Daily activity, skills required and to be acquired
The CMS Collaboration is building an innovative Mip Timing Detector (MTD) in the context of the upgrade for the HL-LHC phase, with the goal to measure the production time of particles with an initial resolution of about 40 ps. With an average of 200 proton-proton collisions per bunch crossing, the pileup of tracks from additional collisions superimposes to the interesting physics events, spoiling their reconstruction. The precise knowledge of the time of each collision vertex will allow the separation of vertices spatially overlapping at a level comparable to the current situation with a much lower pileup, where existing reconstruction algorithms can successfully correct for this contamination. The Barrel section of the MTD detector, based on scintillating LYSO crystals read by Silicon Photomultipliers, will be assembled starting in 2024. The readout electronics components will be at that time already available, and a program of tests is planned at CERN, to verify and ensure the correct interoperability of the various electronic boards, progressively developing the readout software, up to testing the functionality of the complete readout chain. The candidate will have the opportunity to work daily with the team of experts performing these test operations, and participate to the data taking and analysis, with a direct experience of a crucial phase of the construction of a detector for high energy physics.	Daily activity: the candidate, with the help and supervision of the contact persons and other members of the team, will have to verify that the system is operational, check for possible problems happened during past tests rounds, prepare input instructions and calibration data for dedicated tests, inspect the corresponding output with the help of testing software, ensuring its correctness according to expectations, contribute to understand and debug possible issues observed. Required skills: basic knowledge of Linux shell scripting and possibly ROOT analysis framework. A basic knowledge of python or C++ languages is useful. Previous attendance of basic laboratory courses is an essential prerequisite. Skills to be acquired: the candidate will gain a direct experience of the operation and test of a complex electronic readout chain in a real experiment environment. He/she is expected to understand the basics of the behavior of a readout ASIC chip and of its practical operation: communication with other components, configuration, correctness of the readout output, calibration of relevant operational parameters.

CERN-17

Hosting Laboratory	Available period	Contact person(s)
CERN	**20/07/2024 – 20/08/2024**	**Enrico Robutti – Ksenia Shchelina**

Operation and monitoring of performance of the silicon pixel tracker of the CMS Precision Proton Spectrometer	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. For the LHC Run3 (2022-2025), PPS detectors have been upgraded. The new setup has collected data in 2022 and 2023 and will continue in 2024. This project consists in contributing to the regular operations of the silicon pixel tracker of PPS and to the monitoring of its performance, so as to assure the most continuous and effective working conditions during data taking.	The students will learn the basics of the physics investigated at the LHC and of the CMS experiment, with particular focus on the processes studied by PPS and the operating principles of its tracking detectors. The task will involve participating to data taking shifts, monitoring the detector performance through the standard tools available, and discussing possible concerns and maintenance operations with the PPS crew working on the project. Some familiarity with the Linux operating system environment is required. Basic programming skills in C++ and/or phyton may be occasionally useful.

CERN-18

Hosting Laboratory	Available period	Contact person(s)
CERN	**15/06/2024 – 15/09/2024**	**Pietro Govoni – Michele Grossi**

Inclusion of error mitigation routines in Variational Quantum Circuit model training	Daily activity, skills required and to be acquired
State-of-the-art quantum error mitigation methods cannot address the exponential concentration loss induced by noise in current devices. We propose to test and combine different routines to enhance Variational Quantum Circuits trainability by reducing the corruption of the loss function. The algorithm under consideration could be the fit of a mono-dimensional Parton Distribution Function (PDF) on a superconducting single-qubit device. Starting from the paper https://arxiv.org/abs/2309.03279, we would test its applicability under real noisy scenario.	Daily activity: development of quantum machine learning algorithms on simulated quantum computers, test on actual quantum computers once the development reaches a mature state Skills required: basic coding, python, Qiskit/Qibo Skills acquired: coding, working in a big collaboration, learn how to present results

CERN-19

Hosting Laboratory	Available period	Contact person(s)
CERN	**One month between 01/06/2024 and 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, learning how to implement simulate a single-crystal system that could be used within the context of the IDEA electromagnetic calorimeter.	Study of the DD4HEP toolkit, A basic knowledge of python and particle-matter interaction is recommended. A daily interaction with the experts at CERN will allow to learn the mechanics of the DD4HEP simulation, and to apply it to the required usecase.

CERN-20

Hosting Laboratory	Available period	Contact person(s)
CERN	1/7/2024 – 1/8/2024	Antonello Pellecchia - Camilla Galloni

Operation of GEM detectors in CMS during data taking in the Run 3 of LHC	Daily activity, skills required and to be acquired
The student will work on the operation of the GEM system in the CMS experiment during the Run-3 data taking of LHC. The activity will take place at the CERN point 5, where the CMS control room is located, and it will be carried out with the GEM operations team. The student will learn the principles of operation of the triple-GEM detectors, their readout electronics and their integration with the CMS data acquisition system. They will calibrate the readout electronics for optimal data taking and analyze offline the GEM trigger data to measure both the GEM standalone detector performance, such as efficiency and time resolution, as well as its integration with the rest of the system, such as the matching with the muon segments reconstructed in the companion CSC system.	A basic skill in a programming language between C or Python for scripting and data analysis would be preferred but is not required. The student will learn the physics principles of micro-pattern gaseous detectors, the architecture of a DAQ and the operation of a large-size experiment and how to perform a simple data analysis of detector performance.

CERN-21

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/02/2024 – 01/05/2024**	**Gianluca Cerminara (CERN) - Pierluigi Bortignon (INFN Cagliari)**

Particle flow isolation on low pt electron in the L1T upgrade	Daily activity, skills required and to be acquired
The High Luminosity run of LHC (HL-LHC) will impose to the CMS detector huge challenges. The CMS Physics program will have to keep exploring the existence of New Physics (NP) at the electroweak scale in the very harsh hadronic environment of 200 pile-up proton-proton interactions. The biggest challenge is imposed to the hardware L1 Trigger, which will have to select events with same or lower thresholds with respect to today. In order to face these challenges, the L1 Trigger will be upgraded to access highly granular calorimeter information and online tracking: the perfect conditions to implement for the first time the Particle-Flow event reconstruction in the hardware of the Trigger system. As already proven in the offline reconstruction, the usage of Particle Flow can improve the identification and energy resolutions of many physics objects: in this project we plan to understand the potentiality of the Particle Flow isolation to lower the thresholds of the electron triggers.	Daily activities include data analysis and collaboration meetings. The skills required are a good knowledge of programming languages like C++ and/or python, a basic ability to use unix systems, and being able to discuss and collaborate in english. The skills to be acquired is the understanding of the upgrade trigger, its connection with the research or new physics, the use of advanced data analysis techniques.

CERN-22

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/05/2024 – 31/10/2024**	**Piet Verwilligen – Michele Bianco**

Performance measurement of Triple-GEM detectors	Daily activity, skills required and to be acquired
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 ME0 system will be made of stacks of six detector layers for standalone track segment reconstruction. The first production-grade ME0 stack is under assembly at CERN in Spring 2024. The student will be involved in the construction and quality control tests of the detector modules that will constitute the ME0 stack. He/She will perform the integration of its front-end electronics and build-up the ME0 stack layer by layer. He/She will optimize the electronics for low-noise performance by grounding all components correctly. He/She will operate the stack to take cosmic data and perform data analysis to measure its efficiency, spatial and time resolution.	The student will construct and operate Triple-GEM detectors starting from basics up to using a modern DAQ system. The activity will consist of detector construction and quality control tests, followed by electronics calibration measurements, noise-busting and cosmic-ray data taking. He/She will analyze the data and reconstruct tracks with multiple hits in the muon detectors. Desirable skills: basic programming, basic lab experience (Oscilloscope, NIM electronics, HV) Acquired skills: Advanced programming (C++) & Data Analysis (ROOT); Triple-GEM Detectors operation; hardware problem solving skills; Analysis of Cosmic Ray data to extract detector performance; Work & collaborate in international scientific environment

CERN-23

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/07/2024 – 01/08/2024**	**Ilirjan Margjeka – Stefano Mersi**

Integration test and noise measurements of 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 he HL-LHC project (≥ $3000fb^{-1}$). The CMS Tracker modules will provide to the Level 1 Trigger track segments allowing trigger rates to be kept at a sustainable level. 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 hybryds. This project aims the integration of the kick-off bench PS modules and their qualification and the characterization of the of the noise value of the pixel-strip (PS) modules. This study allows the student to understand how the new CMS Phase II Outer Tracker will work in principle. The study 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.	The student will have to perform integration, qualification and data analysis of the performance of the piexel-strip modules. 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 heterostructures. She/he will learn how to operate high time resolution test benches.

DESY-1

Hosting Laboratory	Available period	Contact person(s)
DESY	**01/04/2024 – 31/10/2024**	**Eldar Ganiev – Alexander Glazov – Diego Tonelli**

Measurement of the K^0_L meson reconstruction efficiency at low momentum for the $B^0 \rightarrow K^{*0}\nu\bar{\nu}$ analysis 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. Quark b-to-s transitions are sensitive probes of non-standard-model (SM) physics, which can contribute amplitudes mediated by yet-unknown particles in the rates associated with these. Hermetic geometry and known initial state offer Belle II unique opportunities to study the important class of such decays involving final state neutrinos. Belle II recently reported first evidence of the $B^0 \rightarrow K^+\nu\bar{\nu}$ decay, with a 2.7-standard-deviation excess over SM expectations, and is now exploring $B^0 \rightarrow K^{*0}\nu\bar{\nu}$ decays, which offer distinct sensitivity. The analysis hinges on a comprehensive understanding of detector response to K^0_L mesons, which renders $B^0 \rightarrow K^{*0}K^0_LK^0_L$ decays insidiously signal-like, if mismodeled. However, modeling K^0_L is challenging and cannot be achieved reliably using simulation only. A proper, robust modeling calls for data-driven studies. In this project, the student will use, for the first time, $B^0 \rightarrow \pi^+ D^{*-}[\rightarrow \bar{D}^0(\rightarrow K^0_L\pi^+\pi^-)\pi^-]$ decays to probe low-momentum K^0_L. The peculiar topology of this decay provides sufficient kinematic constraints to allow the indirect reconstruction of the K^0_L kinematics without explicitly reconstructing its detector signature. This offers a precious unbiased sample to study low-momentum K^0_L efficiency, which might be a game changer for the upcoming analyses of $b \rightarrow s\,\nu\bar{\nu}$ processes.	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 optimization of the event selection, sample-composition fitting, and determination of systematic uncertainties. The student will be provided with ready-to-use ntuples of experimental and simulated data. In the first 1.5 weeks, the student will warm up by replicating an existing determination of the efficiency of high-momentum K^0_L mesons using $e^+e^- \rightarrow \phi(\rightarrow K^0_SK^0_L)\gamma$ processes, based on the same conceptual principle, but facilitated by larger sample size and previous experience of the supervisors. In the ensuing 2.5 weeks, the student will pursue the more innovative part of the project. Results will be presented in Belle II meetings and documented in a Belle II internal note. 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.

DESY-2

Hosting Laboratory	Available period	Contact person(s)
DESY	**01/04/2024 – 31/09/2024**	**Mirco Dorigo – Daniel Piztl/Eldar Ganiev**

Improving soft π^0 efficiency determination at Belle II	Daily activity, skills required and to be acquired
This is a data analysis project aimed at improving the determination of the π^0 reconstruction efficiency at low momentum in the Belle II experiment. Belle II is designed to reconstruct billions of weak-interaction decays of bottom mesons and τ leptons from 10 GeV electron-positron collisions in search for indirect indications of non-Standard-Model physics. The efficiency for reconstructing π^0 mesons through their photon decay-products in Belle II's calorimeter is a key performance driver for many Belle II analyses involving absolute-rate measurements with final-state π^0 mesons. The variety and nature of the multiple factors affecting this efficiency makes efficiencies determined from simulation alone unreliable. The Belle II collaboration has been using various samples of π^0 decays reconstructed in collision data to validate and correct the simulation-based efficiency determinations. For soft π^0 (i.e. with momentum smaller than 200 MeV) the current method exploits $B^+ \to D^*(\to D^0\pi^0)\,\pi^+$ control data, which offer a clean but small sample. The project targets to study the soft π^0 reconstruction efficiency using a different control sample, i.e. prompt $D^* \to D^0\pi^0$ decays produced in $e^+e^- \to D^*X$ events, which would offer a larger sample size to improve over the current uncertainty on this efficiency (~6%).	No prerequisites are required. The student will learn the conceptual and technical fundamentals of HEP statistical data analysis during the project. The student will be supervised by a Belle II neutral-reconstruction leader based at DESY who will guide him/her in the analysis of Belle II simulated and experimental data to select the control channel, inspect the key features, and develop the method to determine the soft π^0 reconstruction efficiency. Results might be presented in internal Belle II meetings and documented in a short internal note.

KEK-1

Hosting Laboratory	Available period	Contact person(s)
KEK	**01/05/2024 – 30/09/2024**	**Antonio Passeri – Shoei Nishida**

Study of K-long reconstruction with the Belle II detector	Daily activity, skills required and to be acquired
K-long mesons are formed by a quark d and a quark s, they have no electric charge and they are produced in large quantities by the electron-positron collisions at SuperKEKB accelerator. Due to their long lifetime and the boost with which they are produced, they can be detected only by their hadronic interactions in the two calorimeters of Belle II experiment: the electromagnetic calorimeter ECL, and the external flux return calorimeter, KLM. Detection of K-long meson is very important in many physics analyses, both for the precise measurement of standard model expected processes, both as a subtle background for new physics searches. Identification of K-long signals in the detector requires very good control of neutral cluster reconstruction and capability of discriminating from other types of neutral particles or fake signals, which is enhanced via machine learning techniques. K-long reconstruction efficiency and identification algorithm discriminating power have to be checked using specific control samples covering different momentum regions, both in data and Monte Carlo. Assessment of efficiency vs K-long momentum and other variables has to be worked out for different run periods and software versions.	A basic knowledge of python, root and C++ is very useful, but can also be acquired during the project. Principles of interaction of particles with matters must be already known and mastered. Reference groups are available to train the interested student, before going to KEK, to the basic usage of Belle II software. Work at KEK will consist mainly in software activity: selecting control samples, running the reconstruction software, testing efficiency and discriminating variables. Analysis work to improve the performance is also possible. Everything will be supervised not only by the reference persons, but specially by dr. Michele Veronesi, a post-doc of Iowa State University living permanently at KEK, who is a physics analysis expert. Veronesi will be in touch daily with the student.

KEK-2

Hosting Laboratory	Available period	Contact person(s)
KEK	01/05/2024 – 30/09/2024	Paolo Branchini – Haruki Kindo

Monitor of the KLM detector with cosmic rays	Daily activity, skills required and to be acquired
The KLM detector is the most external part of the Belle II experiment, and it is designed to detect muons and K-long mesons. The KLM detector consist of a barrel and two end-caps: the barrel has 2 layers of scintillators and 13 layers of RPC (resistive plate chambers) with glass electrodes, alternated with 4.7 cm thick iron plates, while the endcaps consists of 14 layers of scintillators and 14 iron plates. Signals produced in the scintillators and in the RPCs by the passage of particles is collected and processed in about 19000 electronics channels for scintillators and another 19000 electronic channels for RPCs. Regular monitoring and maintenance of all these channels is essential to correctly interpret the data collected by the detector. During the summer shutdown of the SuperKEKB accelerator it is very important to collect a large statistics of cosmic rays data, and a number of electronic noise runs, to study the reponse of all the channels, track dead and noisy channels, measure the efficiency of different layers and sectors. Comparison of the results with the detector study performed before the last data taking is essential to plan hardware maintenance when needed. HV adjustement, both for RPCs and photomultipliers, can also be considered and implemented. Knowledge of detector working principles will be very important and will be improved by this experience.	A basic knowledge of python, root and C++ is very useful, but can also be acquired during the project. Principles of interaction of particles with matters must be already known and mastered. Reference groups are available to train the interested student, before going to KEK, to the basic usage of KLM detector software. Work at KEK will partly require to stay in the Belle II control room, learn how to acquire cosmic and random events, run and check data quality histograms, and KLM efficiency analysis. Usage of other KLM detector slow control interfaces will be needed in some cases. Training will be provided for all of them. The local KLM detector expert, dr. Haruki Kindo, will be the reference person and can help in case of problems. Italian reference group will constantly follow the student.

LNF-1

Hosting Laboratory	Available period	Contact person(s)
CERN or LNF	01/07/2024 – 31/07/2024 or 01/08/2024 - 31/08/2024	Marcello Rotondo – Michel de Cian

Muon mis-identification studies at LHCb	Daily activity, skills required and to be acquired
The LHCb experiment at the LHC is a single-arm forward spectrometer specialised in studying particles containing b or c quarks. The LNF group is leader in the development and in the maintenance of the algorithms devoted to the identification of the muons (MuonID). These algorithms are based on the readout of the LHCb Muon Detector, and are extremely important for the selection of data samples enriched of b and c hadrons. The LNF group is also deeply involved in the study of semileptonic decays of the Bs mesons (constituted by an anti-b quark and s quark), as an example the Bs -> Ds μ ν decays; the performances of the MuonID algorithms are crucial for the selection of such decays. Very important is the study of the pollution introduced by the MuonID due to hadrons (pions, kaons and/or protons) mis-identified as muons. The goal of the project is to introduce the student to the selection techniques of pure samples of hadrons (mainly pions and kaons from D mesons into two-bodies decays) with which to evaluate unbiased muon mis-identification probabilities.	First the student will acquire knowledge both of the LHCb Muon Detector and of the main characteristics of the MuonID algorithm. Then she/he will have the opportunity to acquire skills in using ROOT and ROOFit to analyze samples of Run2 data (if we will have the opportunity, we could manage to study also Run3 data samples). The student will finally learn how to select two bodies decays in two hadrons, and the tag-and-probe technique to evaluate the mis-identification probabilities. Skills required: some knowledge of the Linux operating system and basic programming in Python and C++ may be useful.

LNF-2

Hosting Laboratory	Available period	Contact person(s)
LNF	01/06/2024 – 31/07/2024	Paola Gianotti – Tommaso Spadaro

Dark matter search with positron annihilations	Daily activity, skills required and to be acquired
The Positron Annihilation into Dark Matter Experiment - PADME, by studying the annihilation of the positrons of the Frascati National Laboratory LINAC with the electrons of a carbon target, is searching for feebly interacting light particles as possible candidates of dark matter (*i.e.* dark photons, Axion-like-particles, dark Higgs, X-bosons…). These studies rely on the response of a multipurpose detector measuring the final state charged and neutral particles. PADME is an international collaboration that comprises Bulgarian, Italian and American researchers. The detector has been installed on the LNF positron beam-line in 2018 and took data in three different run periods. Now, an intense activity of data analysis is ongoing and next data taking will take place in the second half of 2024.	Description (font Calibri pt11), stay within the allocated space. The student activity will be devoted to: - Data analysis: detectors response calibration, physical quantities extraction; - Monte Carlo codes development; - Detectors setup and beam-time preparation. Skills required are: - C++ and/or Python programming capability; - ROOT package knowledge; - Basic knowledge of laboratory instruments operation (*i.e.* oscilloscope, multimeter, pulser…).