BEPC - 1 -

Hosting Laboratory	Available period	Contact person(s)
IHEP(Beijing, PRC)	01/01/2025 – 30/11/2025	GIANLUIGI CIBINETTO (INFN-FE) 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. CGEM has been successfully installed in October 2024. From January 2025, BESIII operation will resume and CGEM commissioning under beam will start.	The candidate will participate in the commissioning under beam of the CGEM Inner Tracker under the supervision of his 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, hardware systems (FPGA, DAQ systems) and/or data analysis techniques 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	**15/01/2025 – 30/09/2025**	**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-2 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**1/3/2025 – 30/11/2025**	**Francesco Terranova – Filippo Resnati**

<u>Validation of the ProtoDUNE-VD trigger system</u>	Daily activity, skills required and to be acquired
DUNE is the largest neutrino oscillation experiment currently under construction in the USA, utilizing an innovative liquid argon Time Projection Chamber (LArTPC) technology. Two 400-ton demonstrators, ProtoDUNE-HD and ProtoDUNE-VD, have been built at CERN and are being operated in 2024-2025. ProtoDUNE-VD is designed to detect cosmic rays and beam-produced charged particles from the CERN North Experimental Area, which interact with liquid argon, generating both ionization and scintillation light. In 2025, we will validate a novel trigger method designed to identify light bursts from high-energy neutrino interactions and low-energy astrophysical neutrinos. This method utilizes trigger primitives that detect energy deposits generating light flashes within the detector. The DUNE front-end readout board (DAPHNE) has been specifically adapted for this purpose, currently supporting self-trigger algorithms at a 1.5 photoelectron (p.e.) threshold and offering a custom header for the DAQ system to build trigger primitives down to a 0.5 p.e. threshold. The aim of this project is to validate this system using physics runs at ProtoDUNE-VD, which will involve both beam-charged particles and cosmic ray muons.	The student will join the ProtoDUNE-VD onsite team, participating in data collection as a Photon Detection System shifter/expert and contributing to data analysis. The analysis will focus on evaluating trigger efficiency in both self-trigger mode and using trigger primitives. The primary tool for this work will be a series of calibration runs conducted with LED sources, supplemented by physics runs with charged particles and cosmic muons. The student will gain expertise in liquid argon detector physics, analog and digital electronics, and data analysis. Required Skills: Basic knowledge of C++ programming and ROOT. Familiarity with Python is also welcome.

CERN- 3 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**1/2/2025 – 31/10/2025**	**Francesco Terranova – Nikolaos Charitonidis**

The implementation of the ENUBET beam at CERN	**Daily activity, skills required and to be acquired**
ENUBET/SBN@PBC is a high-precision neutrino beam designed to measure neutrino cross sections with a precision ten times greater than current standards. Following a successful R&D phase, CERN and the ENUBET Collaboration are now exploring its integration into the CERN accelerator complex. A critical aspect of this project is assessing the beam's impact on existing experimental areas, focusing on radiation doses, irradiation effects, and proton economics. The objective of this project is to conduct this comprehensive assessment. The ENUBET beamline will be modeled using FLUKA, CERN's reference code for dose assessment. This study will include the design of shielding, evaluation of radiation damage to beamline components, and addressing radioprotection concerns. Additionally, the student will join the ENUBET onsite team to support the validation of the instrumented hadron dump, which utilizes PICOSEC detectors and is scheduled for testing at the PS Experimental Area in 2025.	The student will join the CERN BE-EA department under the supervision of N. Charitonidis. They will receive training in the use of FLUKA to model beam components, optimize shielding designs, and address radioprotection issues. Throughout the project, the student will gain expertise in accelerator physics, beamline design, radioprotection, and numerical methods applied to particle physics. They will become proficient in using scientific software, Monte Carlo simulation techniques, and will develop a solid understanding of gaseous particle detectors. Required Skills: Basic knowledge of C++ programming and ROOT. Familiarity with FLUKA or GEANT4 is preferred but not mandatory.

CERN– 4 –

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/03/2025 – 30/09/2025**	**Sandra Leone - Henric Wilkens**

Integration and commissioning of the new Laser Calibration system of the ATLAS hadron calorimeter for HL-LHC upgrade.	**Daily activity, skills required and to be acquired**
In the ATLAS hadron calorimeter the drift of photomultiplier (PMT) response is a relevant source of systematic uncertainty for the energy scale. To maintain the performance within requirements a calibration of each PMT at percentage level is required. A laser system, used to measure the stability of the PMTs response, is undergoing an upgrade for the high luminosity (HL)-LHC phase. Response to laser pulses may vary as a function of the current induced by Minimum Bias events. Therefore, it was decided to add to the laser system a tool for controlling the PMT response as a function of the anode current. The simplest way to mimic what happens during collisions is to add a continuous light component to laser light pulses. For this purpose, the current laser light mixer will be replaced with an integrating sphere to simultaneously inject pulsed laser light and continuous light and to uniformly mix them. The DC light component will be provided by a power LED array. The new prototype optical line was installed at CERN in 2024. The 2025 activity at CERN will be crucial to finalize the optical part and to integrate it with the new readout electronics and commission the whole system.	Month 1: Finalization of the optical line, of the LED array setup and of the monitors at various positions along the line. Month 2: Study of the PMT response stability using an existing readout system based on NIM and VME units. Month 3: Integration with the new readout electronics designed for the laser data acquisition and commissioning of the whole system. All activities will be conducted with the supervision of experts at CERN. Required skills: basic knowledge of C++ programming language and of the ROOT program. Acquired skills: Good knowledge for programming in the LabView environment. Good knowledge of optical lines for laser calibration systems.

CERN– 5 –

Hosting Laboratory	Available period	Contact person(s)
CERN	**1/2/2025 - 30/6/2025**	**Luigi Guiducci – Wolfgang Funk**

Upgrade of the SND@LHC muon detectors with Drift Tubes	**Daily activity, skills required and to be acquired**
The project is related to the upgrade of the SND@LHC detector with additional muon chambers, built as miniature versions of CMS Drift Tubes (miniDTs). The better muon tracking is expected to improve the reconstruction of the kinematics of muon neutrino interactions. The miniDTs exist and are being commissioned with cosmics, in Legnaro. A standalone and triggerless readout system is in preparation and will be available at the beginning of 2025. Other aspects such as gas plant design, services and mechanics are also being finalized. The project is focused on the integration of the miniDTs in the SND@LHC detector. In the first part, the student will participate in the final steps of integration of DAQ and DCS functions. In the second part, event building and muon tracking will be tuned, analyzing the first data from LHC run in 2025. The main goals of the project are the validation of the new system and the assessment of its performance.	The candidate will be involved in the last phases of the integration of miniDTs in SND@LHC, and in particular will work at the offline synchronization of the minDT and SND@LHC data streams in order to build common events. The analysis of the first muon background data from LHC collisions will enable the verification of the performance of the upgraded muon system. The candidate will work at developing C++ and Python code, and experience with ROOT is also important. The candidate will improve data analysis skills and, contributing to the operations of SND@LHC electronic detectors, will gain relevant experience on the activities related to running detectors at CERN.

CERN - 6 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/07/2025 – 30/10/2025**	**Stefano Giagu – Davide Fiacco**

Modular Explainable AI for Scientific Discovery in the ATLAS experiment	**Daily activity, skills required and to be acquired**
Current commercial and open-source AI models demonstrate remarkable textual reasoning and conversational abilities, and are rapidly expanding to other modalities, including image, audio, and video (e.g., GPT-4o). AI models specialized for scientific tasks—informally called scientific foundation models—have been applied to various scientific problems, such as collision detection in high-energy physics. However, all successful scientific applications of AI thus far have required treating models as opaque black boxes. Consensus suggests that AI has yet to provide genuinely novel scientific insights, as “transparent deep-learning models remain elusive despite numerous explainability techniques.” This project aims to redefine a new generation of AI tools for scientific discovery in high-energy physics and other fields requiring transparent decision-making. The methodology centers on building AI models with explainability as a core focus by modularizing components to clarify information processing and prediction-making. The models will be validated on realistic high-energy physics benchmarks, where they will reconstruct and explain collisions from the ATLAS experiment. Specifically, the methodology will be tested on analyzing the simultaneous production of two Higgs bosons, a rare, critical process predicted but not yet observed by the Standard Model of particle physics.	The candidate will collaborate with ATLAS experts in fields of statistical data analysis and advanced Machine Learning techniques. After gaining an understanding of deep neural networks and modular AI models, the candidate will focus on applying these algorithms to the to the search of di-Higgs production in the $bb\tau\tau$ final state, using data recorded by the ATLAS experiment. The candidate should have basic knowledge of Python and deep learning frameworks, which will be further developed throughout the project. By the end of the project, the candidate will be proficient in cutting-edge methodologies for applying deep learning techniques in data analysis of complex and high-dimension data.

CERN - 7 -

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2025 – 30/10/2025	Stefano Giagu – Claudio Luci

Graph Neural Networks on FPGAs for the ATLAS L0 RPC Muon Barrel Trigger Upgrade	**Daily activity, skills required and to be acquired**
The Level-0 muon trigger system of the ATLAS experiment will undergo a comprehensive upgrade for the High Luminosity LHC to meet the stringent demands created by the increased instantaneous luminosity. This upgraded trigger system will transfer raw hit data to off-detector processors, where advanced trigger algorithms will run on a new generation of FPGAs. To take full advantage of FPGA flexibility, ATLAS is developing innovative algorithms that incorporate both conventional techniques and cutting-edge deep neural network architectures with quantized weights and activations. These algorithms are specifically optimized to run on FPGAs, enabling efficient muon reconstruction and identification in the ATLAS Level-0 trigger. FPGAs provide an ideal solution due to their flexibility, extensive logical resources, and high processing speeds. In this project, the student will work with the ATLAS Level-0 Muon Barrel trigger group, focusing on designing and deploying novel fast tracking and trigger algorithms based on Graph Neural Network architectures. The project will involve the full cycle of algorithm design, development, and implementation, including evaluating physics performance in terms of efficiency, fake rates, FPGA resource usage, and timing. The student will also deploy and test these algorithms on the trigger test slice available in the CERN laboratory.	The candidate will collaborate with ATLAS experts in trigger/DAQ systems, FPGA programming, and advanced machine learning techniques. After gaining an understanding of graph neural networks, the candidate will focus on applying these algorithms to reconstruct muon tracks in the RPC detector, implementing the trained model on the FPGA processor, and measuring performance. The candidate should have basic knowledge of Python and deep learning frameworks (PyTorch and PyG), which will be further developed throughout the project. Familiarity with the VHDL programming language and FPGA technology is beneficial but not essential. By the end of the project, the candidate will be proficient in cutting-edge methodologies for applying deep learning techniques in low-latency, real-time environments and will have a solid understanding of trigger systems used in high-energy physics experiments.

CERN - 8 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**1/07/2025 – 1/11/2025**	**Livia Soffi – Raffaella Tramontano**

Search for new 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 PF 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 - 9 -

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2025 – 31/07/2025	Antonio Cassese – Styliani Orfanelli

Optical readout 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 final version of the readout chip is now available (CROCv2), before the end of 2024 final module version will be available (new hybrid, final geometry), as well as e-link prototypes and the electrical to optical boards, called portcard. After a first phase where the candidate will get used to the tracker electrical full readout chain usage, a deeper focus on optical readout will be carried on by characterizing the performances of the various pieces of the chain. We expect the candidate to carry out performance test by using the lab equipment and in case adapt the DAQ software with the changes that are needed.	The project consists of 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: - 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.

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Hosting Laboratory	Available period	Contact person(s)
CERN	**15/6/2025 – 15/10/2025**	**Patrizia Azzi - Stefano Mersi**

Development of calibration procedures for PS and 2S modules of the CMS tracker in HL-LHC	Daily activity, skills required and to be acquired
The project aims to develop calibration procedures for the PS and 2S modules of the Phase-2 upgrade for the CMS tracker. The work will focus on achieving the required performance for the final data acquisition system for the Outer Tracker (OT) modules, which will utilize a Data, Trigger, and Control (DTC) board called Serenity. Specifically, this includes ensuring the resolution needed for data readout and optimized implementation for execution on SoC (System on Chip) components of the DTC. The student will work on calibration algorithms in C++ and may also develop firmware components in VHDL.	• **Development and testing of calibration algorithms** in C++ specifically for the PS and 2S modules. • Firmware implementation in VHDL to optimally integrate the calibration procedures, with data processing offload from the CPU to the FPGA on the DTC. • **Optimization and performance analysis** to ensure resolution requirements and computational efficiency are met.

CERN - 11 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/07/2025 – 30/10/2025**	**Patrizia Azzi - Brieuc Francois**

Reconstruction with GNN for FCC-ee	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 on the machine learning track reconstruction based on GNN approach and its validation. The novel software framework, key4hep, represents the state-of-the-art approach to data processing, and the proposed reconstruction method with GNN has never been applied before to a collider experiment. All activities will be carried on in close synergy with both physicists, and software experts. Pure, efficient and fast track reconstruction is a critical component of any further reconstruction step and analyses.	**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 –12 –

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/04/2025 – 30/10/2025**	**Andrea Massironi – Simone Gennai**

New and challenging Higgs boson decay searches	**Daily activity, skills required and to be acquired**
As of today, the ATLAS and CMS collaborations have studied the Higgs boson production at the LHC for several years, giving a lot of attention to its most probable production and decay mechanisms. To complete the overall picture about the Higgs boson decay searches, few additional and more challenging decay channels are missing from the current landscape, which are becoming accessible thanks to the increased statistics delivered by the LHC. A systematic test and optimization of new analyses targeting the Higgs boson decaying into gluons will be developed with the data from CMS, based on run 2 and run 3 data. A parton level analysis will be followed by a detector level analysis with real CMS 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 code to perform new analyses, develop machine learning based approaches, and finalize new searches. The results will be then presented in working meeting and general CMS meetings

CERN – 13 –

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/04/2025 – 30/10/2025**	**Andrea Massironi – Dave Barney**

Exploiting current CMS detector to its limits	**Daily activity, skills required and to be acquired**
With the current accumulated data of LHC in CMS, almost 10% of the total integrated luminosity that the High-Luminosity LHC will collect, the full exploitation of the detectors currently installed in CMS could profit from new ideas and new use, also for dedicated and specialized new searches. We propose the test of the timing performance of the current preshower detector of CMS, that could bring new potential to physics searches and improvements in final state particle reconstruction, for example for pileup suppression or late signal tagging. Tests with the current data collected will be developed, in order to assess the current performance, possible improvements, and eventually application of these new data in CMS.	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 code to test new features in the current CMS detector. Calibrate the preshower for timing reconstruction, and use this additional information in object reconstruction or dedicated analysis signature. The results will be then presented in working meeting and general CMS meetings

CERN-14 –

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/03/2025 – 31/07/2025**	**Pietro Govoni – Felice Pantaleo – Aurora Perego**

Development of a tagger for particle flow candidates for the Phase-2 of CMS	**Daily activity, skills required and to be acquired**
To address the challenges posed by the High Luminosity phase of the Large Hadron Collider (HL-LHC), the CMS Collaboration is upgrading its sub-detectors, including replacing the endcap calorimeters with the High Granularity Calorimeter (HGCAL) and adding the MIP Timing Detector (MTD), a new layer designed for precise timing of charged particles. This project aims to **enhance the performance of the event reconstruction by combining at best the information from different sub-detectors**. The focus will be a tagger to identify the signal candidates with sufficient energy collected relative to the particle energy. The work will also involve studying and improving Monte Carlo (MC) truth information to address challenges such as overlapping showers, which complicate reconstruction. The student will analyze these cases to refine the MC truth data and improve the quality of associators, ultimately contributing to more accurate particle reconstruction. Participating in this project will provide the student with valuable insights into advanced particle flow techniques at the forefront of calorimeter-based reconstruction.	**Daily activities**: The candidate, with guidance from supervisors and team members, will analyze simulated data using existing tools, evaluate the performance of current MC truth information, and contribute to developing solutions for optimizing the truth-reconstruction association. **Required skills**: Familiarity with the Linux shell and basic skills in the ROOT analysis framework are recommended. Basic knowledge of Python and C++ programming languages is also needed. **Skills to be acquired**: practical experience in high-energy physics reconstruction, working with MC truth information and improving its ability to describe realistically the physics processes. Foster critical thinking and innovation, as the candidate explores novel methods to address complex problems posed by the LHC high-luminosity conditions.

CERN - 15 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/05/2025 – 31/10/2025**	**M. Pizzichemi – L. Martinazzoli**

Study of scintillation-based electromagnetic calorimeter prototypes for LHCb PicoCal	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. Similar considerations will also drive the design of experiments at future colliders, such as the FCC. The LHCb Picocal baseline option foresees the development of new SpaCal and Shashlik modules featuring innovative scintillating materials and dense absorber technologies. The student will participate in the characterization of the final design of the modules produced for the Long Shutdown 3 Enhancement, via laboratory and test beam measurements. The results will be compared to detailed Geant4-based Monte Carlo simulations. The student will also study the timing performance of the prototypes for the Upgrade II in Long Shutdown 4, understanding the factors contributing to time resolution and how to optimise the design of the prototype.	The research will involve both experimental and data analysis activities. On one hand, the student will acquire knowledge in the field of characterization of scintillating materials and particle detectors, familiarise 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 world-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-16 –

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/05/2025 – 30/11/2025**	**Valentina Mariani – Cecile Caillol**

Search for rare W boson decay	**Daily activity, skills required and to be acquired**
The large production cross-sections of W boson at hadron colliders offers unique opportunities to search for rare decays, which can be used to test the Standard Model (SM) and probe for physics beyond the SM. Particularly interesting are the radiative decays of the W boson, like W->D_s gamma, that has a predicted branching ratio of $(3.7 \pm 1.5)\times 10^{-8}$ in the SM. The power corrections in W boson decays are under good control due to the large energy released to the final state hadrons. Thus, the study of hadronic-radiative W boson decays can provide stringent tests of the QCD factorization formalism. So far only limits have been put on the branching ratio for this final state, the most stringent one by LHCb at 6.5×10^{-4} at 95% CL, using 2/fb of data from Run2. The very large statistics collected by CMS in Run2 and Run3 may be enough to improve this limit.	**Daily activity:** The activity of this project consists in learning the main features of the LHC and of CMS, reviewing the recent CMS search for rare W boson radiative decay (W->D_s gamma) and contributing to an analysis that exploits Run2 + Run3 data to study the sensitivity of CMS to such decay. The student will take care of the signal samples production, the signal reconstruction characterization, together with the usage of advanced machine learning techniques to enhance the signal sensitivity over the expected backgrounds. **Required skills:** knowledge of fundaments of collider physics, detectors, and c++/python. **Skills to be acquired:** At the end of the project, he/she will gain knowledge about how pursue research for particle decays 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 - 17 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/05/2025 – 31/07/2025**	**Marco Ferrero (INFN) / Valentina Sola (UNITO) – Michael Moll (CERN)**

Development and characterization of planar silicon sensor of interest in DRD3 collaboration	Daily activity, skills required and to be acquired
In the context of the future colliders and DRD3 (R&D in the field of Solid-State-Detectors) collaboration, there is an ongoing R&D activity to design and produce planar silicon sensors with internal gain with 4D-tracking capability, able to operate in an environment with very high levels of fluence. The compensated Low-Gain Avalanche Diode (LGAD) is currently considered one of the main candidate technologies of silicon sensors to operate at high fluence. To define a production process to successfully deliver radiation-resistant compensated LGAD, a batch of LGAD sensors on *p-in-n* substrates is now under production and will be released by FBK in spring 2025. The purpose of this grant is to enable a master's degree student to take part in the characterization campaign for the upcoming *p-in-n* LGAD batch. In particular, the candidate will perform DC electrical characterizations with a probe station to assess the quality of different process parameters. Moreover, he/she will perform transient characterizations with TCT, TPA and radioactive sources (α, β) to quantify the gain response of the devices under test. The candidate will primarily perform the characterization of unirradiated silicon sensors. Then, the activity will evolve to the investigation of the radiation damage effects on the samples. Irradiations with protons and neutrons will be organized and coordinated by the CERN partners.	The winning candidate will participate in sensor development and characterization activity at the Solid-State-Detector (SSD) laboratory at CERN, focusing on topics of significant interest for DRD3 collaboration. Knowledge of laboratory instrumentations and methodology (probe station and TCT) for the characterization of planar silicon sensors is required. Understanding the basic operation principles of silicon sensor operation is mandatory. Also, familiarity with the analysis techniques to elaborate the acquired data is expected. The candidate will daily work in a cutting-edge laboratory dedicated to the study and development of silicon sensors and participate in group meetings and day-to-day discussions with the SSD team members. Collaborating with top experts in the field will provide a valuable opportunity to enhance his/her expertise and skills.

CERN - 18 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2025 – 01/10/2025**	**Claudia Gemme – Joleen Pater**

Irradiation and test on beam of ITk Pixel modules for the innermost layer	**Daily activity, skills required and to be acquired**
The ATLAS detector is planning to replace the full tracker to face the new environment that HL-LHC phase will create. The new tracker, ITk, hosts a pixel detector in its innerpart. Thanks to their extreme radiation hardness, 3D sensors will be used in the layer closest to the impact point, and planar sensors everywhere else. The detectors are now in construction. With this project we focus on an activity for the 3D sensors that is still mandatory to ensure that the modules will be working up to the end-of-life. While several individual single-ASIC modules (SBM) have been irradiated and tested, a full module, assembled with three SBMs and a PCB has never tested. We will therefore irradiate at CERN-IRRAD and other facilities few modules and test them on beam at CERN. We will have to prepare the mechanical supports to fit in the testbeam box, currently optimized for the planar modules, and find a way to properly cool the detector. We will then test unirradiated and irradiated 3D modules on the H6 beam line.	The student will help to: verify the mechanics of the setup and test the cooling; run the spectroscopy of Al foils to measure the dose received by the modules at IRRAD; participate to data taking when the irradiated and un-irradiated modules are on the beam line; run the data analysis to measure efficiency vs bias voltage and inclination angle. A basic knowledge in particle physics is required as well as in python/root. He/She will acquire knowledge in silicon sensors operation, data taking, Spectroscopy, construction and operation of a complex test setup.

CERN - 19 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/03/2025 – 01/11/2025**	**Martino Margoni – Maurizio Pierini**

Measurement of Mixing Parameters and CP Violation in B Meson Decays using t-tbar Events at CMS	**Daily activity, skills required and to be acquired**
The decays of B mesons provide a powerful tool for testing the Standard Model's predictions regarding CP violation in the quark sector and for probing potential effects of new physics that could alter these processes. This project aims to measure B-meson mixing and investigate CP violation in B-meson mixing within t-tbar events produced in high-energy proton-proton collisions during Run 2 of the LHC. The proposed strategy involves tagging the flavor of the B-meson at production using the charge of a high-pT muon produced in the semileptonic decay of one of the top quarks, while the flavor at the decay time is inferred from the charge of a second low-pT muon. Key aspects of the analysis include associating the B meson with the correct top quark in the pair, tagging the B-meson flavor at production, and distinguishing between direct and cascade semileptonic decays of the B meson. These objectives will be tackled using advanced machine learning techniques.	The selected candidate will be trained in analysis techniques commonly used in experiments within the field of fundamental interaction physics. She/he will develop expertise in event reconstruction, signal selection, background reduction, flavor tagging, and machine learning methods. Additionally, the candidate will develop skills in presenting and sharing scientific results. A basic knowledge of C++ or Python programming languages and familiarity with the ROOT data analysis framework are required.

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Hosting Laboratory	Available period	Contact person(s)
CERN	20/6/2025 – 20/9/2025	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.

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Hosting Laboratory	Available period	Contact person(s)
CERN	20/6/2025 – 20/9/2025	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-22-

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/03/2025 – 30/11/2025**	**Marco Vanadia & Umberto De Sanctis – Rosy Nikolaidou**

Development of Deep Learning based soft muon identification for the ATLAS experiment for Run-3 data	**Daily activity, skills required and to be acquired**
An efficient and robust identification of low-pt (soft) muons is crucial for a relevant part of the physics program of the ATLAS collaboration. It is essential to properly reconstruct semi-leptonic decays of b-hadrons and c-hadrons, which are the target of measurements and searches e.g. in the context of flavour physics or top quark physics. The challenge is to identify those muons, at the low end of the kinematic acceptance of the detector, rejecting the significant background due to soft muons resulting from light hadrons decays (mostly pions and kaons). Several properties related to the quality of the muon reconstruction can be exploited for this purpose, and the usage of modern Deep Learning (DL) techniques can significantly improve soft muon identification. The selected candidate will work under the supervision of a muon performance expert to develop, optimise and calibrate new DL-based algorithms for soft muons.	The selected candidate will start by learning the basics of muon reconstruction at high energy experiments, and then proceed at a thorough study of relevant quantities to identify signal soft muons and reject background ones. Different DL architectures will then be explored and performance of developed algorithms will be compared with cut-based selections. A preliminary study on a possible calibration of the algorithm in data using J/Psi decays to muons will finally be performed. Required skills: - Python programming - (Desirable) C++ programming

CERN–23 –

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2025 – 01/11/2025**	**Stefano Argirò (TO) Riccardo Salvatico (CERN)**

Upgraded Electronics for the readout of the Electromagnetic Calorimeter of CMS	**Daily activity, skills required and to be acquired**
Starting from 2030 LHC will enter the High-Luminosity phase, in which the detectors will be challenged by the increased interaction rate. The CMS Electromagnetic Calorimeter (ECAL) will be equipped with a completely revised electronic readout to cope with the new running environment. INFN designed and produced an ASIC chip to sample the signal at high frequency and manage its transmission, which will equip the Very Front End boards. The production of the Very Front End cards is expected to start in Spring 2025 and their qualification is the subject of this proposal.	The candidate will be involved in the setup of the environmental testing and calibration of the new Very Front End cards. The student will familiarize with laboratory equipment, automation and control software. He will contribute to the setup of the databases needed to track construction parameters. Collection, storage and statistical analysis of the test results will be a very important aspect of the work. Python is expected to be the prime software and analysis tool, with SQL database backend. Basic FPGA programming skills might be useful. As the internship will happen during a period of running, the candidate will be encouraged to take part in data taking operations.

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Hosting Laboratory	Available period	Contact person(s)
CERN	15/06/2025 – 31/10/2025	Luigi Longo (INFN Bari) – Eraldo Oliveri (CERN)

<u>Medium size µRWELL and Micromegas detectors for a future collider hadronic calorimeter</u>	**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. In particular, two detector technologies are currently being considered: micromegas and micro-rwell. During previous test beam campaigns, detector prototypes of both technologies with a 20x20 cm2 active surface were tested, showing good performance. However, the key for future application is to instrument large areas, thus requiring the development and testing of larger prototypes to identify potential problems in the detector scalability. The production of 50x50 cm2 prototypes is planned for early 2025 and this project focuses on their characterization. The candidate will operate and test four 50x50 cm2 detectors (2 micro-rwell and 2 micromegas) in terms of efficiency, space and time resolution, and response uniformity. The characterization will be performed at the GDD lab at CERN with cosmic muons and with a muon/pion beam at the CERN Super Proton Synchrotron (SPS). The candidate will work in close contact with the MPGD experts from the GDD group.	The student will work with the Gaseous Detector Development (GDD) Group at CERN, in an international and inspiring environment with a long-standing tradition on MPGD detectors. She/he will operate the detectors in the lab and set up the data acquisition system for cosmic muons. The candidate will also join a test beam measurement at the SPS accelerator and analyze the test beam data for measuring the detector efficiency and space and time resolutions. Skills required: - coding skills for data analysis are desirable - working principle of gaseous detectors and calorimeters Skills to be acquired: - operational concepts of gaseous detectors - principles of data acquisition systems - how to operate lab equipment - advanced data analysis

CERN – 25 -

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2025 – 15/12/2025	Piet Verwilligen (INFN Bari) – Pieter Everaerts (Wisconsin/CERN)

Performance of full-stack ME0 detectors for the CMS Muon Upgrade	**Daily activity, skills required and to be acquired**
In preparation for the High-Luminosity LHC, the CMS experiment is undergoing a major upgrade, particularly in the challenging forward region where particle rates and radiation levels are highest. This upgrade includes the introduction of the ME0 station, a six-layer triple-GEM (Gas Electron Multiplier) detector system designed to enhance muon identification and momentum resolution while extending the CMS geometrical acceptance at high pseudorapidity, significantly improving the CMS trigger system in HL-LHC. One of the key aspects for a trigger detector to handle high event rates is the time resolution. This project aims at measuring the time resolution of the final six-layer ME0 stacks in the CMS-GEM lab at CERN with cosmic muons. The student will analyze the data to obtain fine-grained 2D efficiency maps for each layer of the stack and for the stack as a whole. Assessing the time response uniformity of the final ME0 detectors will ensure their trigger capabilities ahead of the integration in the CMS experiment.	The student will work in the GEM laboratory at CERN, equipped with several test benches and advanced instrumentation for the detector characterization. In the lab, she/he will work with GEM experts and with the large team devoted to the ME0 project. The candidate will learn to use the data acquisition system for the measurements and develop the offline data analysis. Skills required: - coding skills for data analysis - principles of detector physics and readout electronics Skills to be acquired: - operational concepts of gaseous detectors - how to operate a detector DAQ system - advanced data analysis

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Hosting Laboratory	Available period	Contact person(s)
CERN (Geneva, CH)	01/03/2025 – 31/10/2025	MARCELLO ROTONDO (LNF) ABHIJIT MATHAD (CERN)

Neutral isolation for semileptonic decays at LHCb	Daily activity, skills required and to be acquired
LHCb is a forward-spectrometer located at LHC and it is specialized in studying hadrons containing charm and beauty quarks. The semileptonic decays of the b-hadrons, e.g. B(s) —> D(s) mu nu or B(s) —> D(s) tau nu (with tau--> mu nu nu), are powerful probes to test the SM and open new windows to search for New Physics processes. In the current data taking (Run3) started in 2023, the amount of data collected is significantly higher than in Run2. To keep the size of the stored data under a reasonable level, only information of tracks considered relevant for the following analyses are saved as persistent objects. A special tool, called "track-isolation", has been developed to identify a list of additional tracks consistently associated with a given signal candidate. This track-isolation tool ranks the tracks in an event based on the results of a multivariate algorithm. At present, all neutral objects identified in the Calorimeter (ECAL) are saved for each event. Due to the high activity in the ECAL, which is expected to increase with the higher luminosity in Run3, it is essential to save only the relevant neutral particles for the analyses while reducing the background neutrals as much as possible. The goal of this project is to define the requirements for a neutral-isolation tool. The challenge we face is to minimize the amount of data saved while maintaining high efficiency for various significant B-hadron semileptonic decay modes.	The selected Candidate will use a variety of simulated samples, as well as data collected in 2024 and early 2025, to define the requirements of a neutral-isolation tool. This algorithm will rank the neutral particles surrounding the signal candidate based on their likelihood of being associated with the signal. The analysis will fully use information from the shapes of clusters in the ECAL and the correlation between the deposited energy, the positions of the clusters, and the momentum of the tracks from the signal candidates. The analysis will be done with the support of experts at CERN. Skill acquired: - learn how to use machine learning tools; - 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.

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Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2025 – 01/10/2025	Federica Simone (INFN Bari) - Archana Sharma (EWTH/CERN) - Roberto Seidita (ETH/CERN)

Anomaly Detection for the online monitoring of the CMS Muon detectors	**Daily activity, skills required and to be acquired**
Ensuring the quality of data in large HEP experiments such as CMS at the LHC is crucial for producing reliable physics outcomes. The CMS protocols for Data Quality Monitoring (DQM) are based on the analysis of a standardized set of histograms offering a condensed snapshot of the detector's condition. Recently, unsupervised machine learning (ML) models such as (variational) autoencoders have been successfully employed for the anomaly detection in DQM, with the goal to improve the certification of the data collected in Run3 and the online monitoring of the detector. In this project, the development will focus on the monitoring of the CMS Muon sub-detectors, using one- and two-dimensional data (histograms and images) recorded during the Run-3. The CMS Muon system features different detector technologies with different readout geometries, therefore requiring some dedicated data pre-processing to extend existing tools to different detector regions. The student will work on the training and optimization of the algorithm on Run-3 data collected in 2024, integrating occupancy plots from different detector regions. She/he will interact with the Muon DQM experts and contribute to the online DQM operations during data taking.	The selected candidate will work on the training and optimisation of an autoencoder NN which has been designed for the data quality monitoring of the CSC muon detectors, aiming at extending the model to different detector regions. She/he will join working meetings and hackathons with ML experts while also contributing to the CMS DQM operations. Skills required: - basics of python programming. Skills to be acquired: - knowledge on the basics of ML from a theoretical point of view - practical skills on the most common ML python libraries (scikit-learn and pyTorch) and API (keras). - expertise on the CMS Muon System detector operation and performance

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Hosting Laboratory	Available period	Contact person(s)
CERN	**15/06/2025 – 15/09/2025**	**Marco Costa – Roberto Bedogni**

Commissioning and running of the first "TetraBall" neutron spectrometer for the CMS BRIL upgrade	**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. The unprecedented particle rates and radiation levels expected at HL-LHC create extremely harsh working conditions for particle detectors and related electronics. The CMS BRIL collaboration has started the construction of a novel neutron spectrometer with a wide range energy response, from meV to GeV, being neutrons the main cause of radiation damage of the detectors and the electronics. Benchmarking the simulated neutron environment in the HL-LHC conditions, with direct experimental measurements, it is of great importance for the CMS experiment. The TetraBall neutron spectrometer, based on technological solutions developed at INFN, is expected to meet the specifications and is under construction. The time period indicated is an extremely important phase for the project, because in June 2025 the first TetraBall protosample will be installed in the CMS cavern and the following months of data taking will be crucial to commission the new neutron spectrometer, to properly integrate it in the CMS DAQ, to setting up the analysis framework and unfold the neutron spectra from the measured data and comparing the results with the FLUKA simulations. These experimental activities are expected to be essential to meet the project deliverables in 2025.	After an initial period in which the student will become acquainted with the CMS BRIL experimental environment, we propose the following activities under the supervision of BRIL experts: - monitoring of data quality - commissioning of the unfolding codes to extract the neutron spectra from the measured data - comparing the results with the FLUKA simulations - contribution to interfacing the TetraBall local DAQ within the extended CMS BRIL DAQ architecture Required skills: - programming in C++; - basic notions of neutron spectrometry - basic notions of the unfolding procedure in neutron spectrometry 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.

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Hosting Laboratory	Available period	Contact person(s)
CERN	**01/06/2025 – 31/10/2025**	**Giovanni De Lellis – Duccio Abbaneo**

Development and Testing of a Silicon Detector Prototype for the upgrade of the SND@LHC experiment	**Daily activity, skills required and to be acquired**
The project is part of the upgrade program for the SND@LHC experiment at CERN to run during the High Luminosity of the LHC starting from its Run 4. The upgrade foresees the use of silicon strip technology to instrument, for the first time, a neutrino detector with a high-resolution tracking station that will allow complementing kinematical measurements with topological information at the vertex. The project will focus on the development and initial testing of a silicon detector prototype. The candidate will participate in the assembly of the experimental setup, integration of the silicon detector with the data acquisition system and testing at a CERN beamline. The work involves contributing to the test beam campaign, collecting data, and performing the first data analysis to evaluate the detector performance. This project provides a hands-on opportunity to work on state-of-the-art detector technologies and gain experience in experimental particle physics within the CERN environment.	The candidate will contribute to the development and testing of the first silicon detector prototype for the SND@LHC upgrade. Activities include assembling the detector, integrating it into the experimental setup, and participating in the test beam campaign. During the test beam, the candidate will assist with alignment, data acquisition, and troubleshooting, followed by an initial analysis of the collected data to assess detector performance. The project requires basic knowledge of detector physics and programming (e.g. Python, C++ and ROOT). At the end of the project, the candidate will have gained hands-on experience with silicon detector technologies, experimental setups, and test beam campaigns, as well as data analysis in a high-energy physics context.

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Hosting Laboratory	Available period	Contact person(s)
CERN	01/02/2025 – 31/10/2025	Marina Cobal – Michele Pinamonti

Development of a machine-learning tagger for jets from the hadronisation of quarks in the Dark Sector	**Daily activity, skills required and to be acquired**
Explaining the nature of dark matter (DM) is nowadays at the heart of the high-energy physics experimental programme. A promising approach at hadron colliders for understanding DM involves exploring the so-called Dark Sector (DS), a theoretical framework proposing a new set of particles and interactions beyond the Standard Model (SM). Communication between the DS and the SM occurs through mediator particles, which may decay into dark quarks (DQ). These DQs hadronize into SM particles, producing jets with distinctive properties tied to the underlying DS model parameters. Within the ATLAS experiment at the LHC, various studies have already investigated the phenomenology of "dark jets" arising from DS models. However, a comprehensive tagging strategy accounting for the diverse topologies of such jets remains an open challenge. A promising approach for developing such a tagger, is to use the same architecture as the state-of-the-art b-quark-jet tagger in ATLAS, namely the GN2 tagger. This tagger is based on graph neural networks (GNNs) applied to charged-particle tracks associated with hadronic jets. The project proposes to test such architecture for building an ad-hoc dark-jet tagger sensitive to a set of different topologies, such as so-called emerging jets and semi-visible jets.	The student will participate in the development of this project, under the supervision of his/her advisors. He/she will have the chance to get in contact with the physics working group within the ATLAS experiment specialized in dark-matter searches and with the combined-performance group developing and maintaining flavour-tagging algorithms. He/she will be introduced to the concepts of machine learning and graph neural networks. Later he/she will use test samples of simulated SM and dark jets to perform comparison tests between the performance of normal b-tagging algorithms and ad-hoc GNN ones. The candidate will be part of an international collaboration and will learn from direct experience advanced techniques in data analysis, in particular in the context of machine learning, which will give a boost to his/her studies. The candidate will benefit from the supervision of the machine-learning and b-tagging experts and coordinators in ATLAS. A basic knowledge of c++, python and root is required.

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Hosting Laboratory	Available period	Contact person(s)
CERN	**01/03/2025 – 30/10/2025**	**FrancoSimonetto – AlbertoBragagnolo**

Measurement of the time-integrated mixing probability for neutral B mesons with CMS	**Daily activity, skills required and to be acquired**
The measurement of the integrated mixing probability $\bar{\chi} = f_d \chi_d + f_s \chi_s$ enables the determination of the production fractions of B^0 and B_s mesons at the LHC, which is now the primary source of systematic uncertainty in the measurement of the $B_s \to \mu\mu$ decay branching fraction. This proposal exploits the sample of several hundred thousand fully reconstructed $B^{\pm} \to J/\psi(\mu\mu)K^{\pm}$ decays ("tag"), collected by CMS with a dedicated trigger, along with an additional ("probe") muon from the decay of the other b-hadron. The fraction of same charge events ($B^+\mu^+ + B^-\mu^-$) provides the value of $\bar{\chi}$. Subtraction of background from the probe side, which includes contributions from cascade $b \to c \to \mu$, double gluon splitting to four b-hadrons, $\pi/K \to \mu$ decays, etc., is addressed by combining multiple features that discriminate between signal and background, using a multivariate technique to form a single variable. The resulting data distribution is fitted with the predicted contributions from both signal and background, as determined by simulation. By conducting the measurement in different intervals of the μ impact parameters, the values of f_d and f_s can be extracted independently.	The selected candidate will be trained in analysis techniques commonly used in HEP experiments. They will develop expertise in signal selection, background reduction, flavor tagging, use of machine learning methods, and of data fitting algorithms. Additionally, the candidate will develop skills in presenting and sharing scientific results. A basic knowledge of C++ or Python programming languages and familiarity with the ROOT data analysis framework are required.

CERN – 32 -

Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2025 – 31/08/2025	Marta Calvi – – Andreas Jüttner

Development of a fit framework to determine $\lvert V_{ub} \rvert$ from the study of semileptonic B_s decays	Daily activity, skills required and to be acquired
The precise determination of the CKM parameters and the test of the unitarity of the matrix provide an important check of the Standard Model paradigm. $\lvert V_{ub} \rvert$ is currently the least known among the CKM matrix elements. LHCb has provided the first measurement of $\lvert V_{ub} \rvert$ from the analysis of $B_s \to K \mu \nu$ decays with LHC Run1 data and a new measurement is ongoing with Run2 data. Different predictions are available for the form factor that describe the decay, and different schemes for the extrapolation of the LQD calculations to the entire kinematical range. The purpose of the project is to develop a fit framework to interpret the upcoming experimental results of the differential decay rate and to determine $\lvert V_{ub} \rvert$, in a similar way as it has been done for the determination of $\lvert V_{cb} \rvert$ from $B_d \to D^* \mu \nu$ decays. Different fitting strategies might be considered to compare the data and the theoretical predictions, to find the best configuration and optimize the final precision.	The student will start with an overview of semileptonic B decays and form factor calculations and learning the main features of the analysis of $B_s \to K \mu \nu$ decays in LHCb. The student will have the opportunity to work directly with theory experts based at Cern to learn how to adapt the existing fit, previously developed for $B_d \to D^* \mu \nu$ decays, to the case of $Bs \to K \mu \nu$ decays, using mock data to extract $\lvert V_{ub} \rvert$. Different experimental conditions will be tested, varying the number of q^2 bins and ranges to find the best sensitivity to $\lvert V_{ub} \rvert$. Basic knowledge of python programming is required.

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Hosting Laboratory	Available period	Contact person(s)
CERN	**Three months between** **01/05/2025 – 01/10/2025**	**Pierluigi Paolucci – Paolo Iengo**

Tracking system with micropattern gaseous detectors for future applications at FCC	Daily activity, skills required and to be acquired
The proposed project focuses on developing and implementing a tracking system using micropattern gaseous detectors for potential future applications at the Future Circular Collider (FCC). This study will investigate the integration of tracking systems with ongoing tests on dual-readout crystals, offering the possibility of enhancing the performance of test beams scheduled for the upcoming year. The effort will also align with the broader initiative to prototype the IDEA detector, a key component of the FCC-ee project. The tracking system will be designed to complement the detector's dual-readout calorimeter, contributing to the overall optimization of particle detection capabilities. Key activities will include the design, assembly, and calibration of the tracking system, as well as simulations to assess its performance. Collaboration with CERN experts and IDEA project teams will ensure the setup adheres to experimental requirements. This project aims to conduct its first functional test during a CERN test beam campaign in spring-summer 2025, providing valuable feedback for further development and integration efforts.	A good understanding of Python and C++ is essential, along with a strong familiarity with particle-matter interaction processes, particularly those relevant to the phenomena under study. Additionally, a basic knowledge of micropattern gaseous detectors is required. Daily interactions with CERN experts will provide opportunities to deepen understanding of both the detectors and the experimental setup. This will include studying detector performance and potentially participating in test beam activities at CERN during the summer.

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Hosting Laboratory	Available period	Contact person(s)
CERN	**01/03/2025 – 30/10/2025**	**FrancoSimonetto – Clara Matteuzzi**

Prompt analysis of MuOnE 2025 Physics run	**Daily activity, skills required and to be acquired**
In the spring of 2025, the MuOnE experiment will conduct its first physics run using a small-scale prototype. This prototype will consist of a few tracker stations and a compact electromagnetic calorimeter. The goal of this run is to measure the running of the electromagnetic constant in $\mu e \rightarrow \mu e$ elastic scattering, using a 160 GeV muon beam directed at a graphite target. This measurement will help validate the more ambitious long-term MuOnE program. To prepare for the run, the student will develop an algorithm to mitigate the effects of muon pile-up on the measurement of the electron shower in the calorimeter: up to seven beam muons are expected to overlap with the electromagnetic shower in a fraction of events. The student will also contribute to setting up the apparatus in the experimental area, assist with data acquisition, and ultimately apply the pile-up subtraction to the data collected during the run.	The selected candidate will gain expertise in both the software and hardware aspects of High Energy Physics (HEP). They will adapt the pile-up reduction algorithm developed by CMS, which is based on fitting template distributions to the data, to the MuOnE analysis framework. Additionally, they will develop a new algorithm using machine learning techniques. The student will also participate in the setup of the experimental facility in the beam area, assist with data acquisition, and conduct a rapid analysis of the collected data. A basic knowledge of C++ or Python programming languages, as well as familiarity with the ROOT data analysis framework, is required.

CERN-35 -

Hosting Laboratory	Available period	Contact person(s)
CERN	01/04/2025 – 31/10/2025	Lorenzo Viliani – Roberto Seidita

Systematics-aware neural networks for Higgs boson precision measurements with the CMS experiment	Daily activity, skills required and to be acquired
With the ever growing amount of data collected by the CMS experiment at the CERN LHC, even the measurements of rare processes such as the Higgs boson production are reaching high precision. These measurements will still benefit from larger datasets but as the statistical uncertainty will decrease, the systematic component will remain roughly constant, thus limiting further improvements. The goal of this project is to develop a novel method based on Machine Learning techniques to reduce the impact of systematic uncertainties in the final measurement. This can be achieved with a systematics-aware deep neural network which is trained to be agnostic of the most relevant sources of systematic uncertainty. The student will contribute to the development and comparison of various techniques to achieve a reduction of the systematic uncertainties, and will apply them to the measurement of the Higgs boson production in the WW decay channel using proton-proton collision data recorded by the CMS detector during the Run 3 data taking.	The candidate will work in collaboration with CMS experts in the fields of statistical data analysis and novel Machine Learning techniques. After learning the basics of systematics-aware neural networks, the candidate will focus on the development of new techniques based on this concept and will apply them to the measurement of the Higgs boson production in the WW decay channel using Run 3 CMS data. The candidate is required to have a good knowledge of python, which will be sharpened during the project. A basic knowledge of standard Machine Learning techniques is also a plus, although not mandatory. At the end of the project, the candidate will be acquainted with cutting edge methodologies in the field of Machine Learning and data analysis.

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Hosting Laboratory	Available period	Contact person(s)
CERN	01/05/2025-31/11/2025	Ruggero Turra – Stefano Manzoni

Enhancing particle simulation accuracy in ATLAS using Normalizing Flow	**Daily activity, skills required and to be acquired**
This project aims to leverage machine learning (ML) techniques to improve the simulation of particle interactions in the ATLAS detector at the LHC. The most accurate current simulation, the *Full Simulation*, employs Geant4 to model particle physics processes. Despite extensive advancements over the years, discrepancies persist between simulated and real collision data. These mismatches are particularly problematic in tasks such as photon identification. In ATLAS, several procedures are in place to align simulation and real data for the variables used in photon identification. However, these approaches typically rely on linear transformations applied to individual variables. Such methods are overly simplistic, as they fail to account for the complex differences between data and simulation, including correlations between variables. Among ML techniques, Normalizing Flows have demonstrated their effectiveness in learning transformations between datasets. Moreover, they enable the generation of synthetic datasets that closely mimic real collision data. In this project, Normalizing Flows will be applied to improve the simulation of the inputs used by the photon identification algorithm using data from the radiative decay of the Z boson. By learning the intricate transformations and correlations between simulated and real data, this approach seeks to provide a more accurate modeling of particle interactions and, ultimately, enhance the reliability of the analyses conducted within the ATLAS collaboration.	Daily activity will consist of 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 and statistics. Some knowledge of the basics of ML algorithms would be beneficial although not strictly required. Through this project, the student will gain experience working with real physics datasets, including large-scale data and Monte Carlo simulations. Additionally, the candidate will have the opportunity to explore cutting-edge machine learning techniques, such as Normalizing Flows, and their application to particle physics simulations, contributing to a critical area of research within the ATLAS collaboration.

CERN – 37 –

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2025 – 01/10/2025	Mariagrazia Alviggi – Paolo Iengo

Performance test with particle beam of ATLAS Micromegas detectors with new gas	Daily activity, skills required and to be acquired
Resistive Micromegas are the detectors installed in ATLAS during the Phase1 upgrade as main tracking device in the New Small Wheel system, the innermost layer of the end-cap Muon system spectrometer. They are successfully contributed to the ATLAS data taking since 2022. The ATLAS Micromegas use an Argon-based gas mixture with 5% of CO2 and 2% of iC4H10. To validate the long-term behaviour of the detectors operated with such gas an irradiation test has been conducted on spare detectors at the CERN GIF++ irradiation facility in the last few years. The timing performance of the ATLAS Micromegas can be improved by exploiting the use of gas with higher electron drift velocity, achievable with the addition of a fast gas as CF4. The ATLAS Micromegas team has planned a test at the H8 beam line at CERN to test the detectors performance with such a gas. The goal of the test is to compare the tracking, timing and triggering capability of an ATLAS Micromegas operated with the standard mixture and with the one with CF4. A complete detector set-up including the DAQ and the trigger chain used in ATLAS and will be installed in the test beam.	She/he would be involved in the set-up and operation of the system, including the detector under test and several other Micromegas for external tracking, the data acquisition and the detector control systems. The student will also contribute to the preliminary data analysis, having the possibility to actively contribute to all the steps pf a small-scale experiment. 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 • Readout electronics chain and acquisition system • particle physics data analysis tools • 'handling' of a small scale experiment

CERN – 38 –

Hosting Laboratory	Available period	Contact person(s)
CERN	01/07/2025 – 01/10/2025	Mariagrazia Alviggi – Paolo Iengo

Performance of the Small Pads resistive Micromegas prototypes for operation at very high rates	Daily activity, skills required and to be acquired
Resistive strips Micromegas detectors in ATLAS experiment have already proved to be suitable for precision tracking in dense particle rate environment up to few kHz/cm^2. To achieve higher rate capability with low occupancy (at future colliders or LHC upgrades) fine-segmented strips have been replaced by few mm^2 pads. To protect the pads from sparks, a resistive structure has been implemented using two different techniques to realize the charge evacuation route to ground: 1) embedded resistors are produced (using a resistive paste) between each readout pad and the superimposed resistive pad (placed towards the gas gap); 2) two uniformly resistive DLC (Diamond Like Carbon) coated layers are used: the first one faces the gas gap, the second one connects the first layer with the readout pads, through silver vias every few mm. Within the RD51 and the DRD1 projects, many prototypes have been constructed at CERN and tested using ^{55}Fe, high-rate X-rays generator and charged particles beams. Recently, to reduce the number of readout channels, we are also testing prototypes with charge capacity sharing among pads. Very good results have been already achieved about space resolution and rate capability and we are now focused on the optimization of the time resolution.	She/he would be involved in one (or two) of the foreseen activities, 'tests in lab with ^{55}Fe and Xrays' and 'test beam', participating to the setting up of the needed instrumentation, to the data taking and to the data analysis. Knowledge of C++ and Root would be an advantage but not mandatory. The student will have the opportunity to acquire hands-experience on: • Micromegas detectors • Small readout electronics chain and acquisition packages • particle physics data analysis tools • 'handling' of a small scale experiment

CERN – 39 –

Hosting Laboratory	Available period	Contact person(s)
CERN	01/09/2025 – 31/11/2025	Matteo Franchini – Michele Grossi

Development and Evaluation of Quantum Unfolding Algorithms for ATLAS Data Analysis	**Daily activity, skills required and to be acquired**
The development and testing of quantum unfolding algorithms represent an innovative project aimed at enhancing data analysis techniques in high-energy physics (HEP). Leveraging D-Wave's quantum annealer and the QUnfold software, this project seeks to solve the unfolding problem, a crucial step in correcting data distortions due to detector limitations. This process enables accurate comparisons with theoretical predictions and enhances the reliability of analyses related to physical phenomena. The project will utilize ATLAS simulated data from different physics analyses in the top quark sector, i.e. the tt entanglement measurement. By comparing quantum-based unfolding with traditional methods, the project will explore the benefits and limitations of this novel approach..	The candidate will gain hands-on experience with cutting-edge quantum computing applications and HEP data analysis within the ATLAS environment. Activities will include: • Learning and applying quantum annealing algorithms using the QUnfold software. • Preprocessing and analyzing ATLAS simulated data for algorithm implementation. • Running quantum unfolding on the D-Wave system and testing different annealing techniques, such as reverse annealing and pausing. • Comparing quantum and classical methods in terms of accuracy, computational efficiency, and robustness. • Preparing documentation and presentations of results for research team discussions. The candidate is expected to have basic knowledge of Python and familiarity with data analysis tools like ROOT. Good communication skills in English and/or French are essential for effective collaboration and reporting.

CERN - 40 -

Hosting Laboratory	Available period	Contact person(s)
CERN	01/08/2025 – 31/10/2025	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 implementing a setup for single- and multiple-crystal test in DD4HEP, the software tool for the IDEA detector simulation, and investigate the scalability of the results obtained in such tests in a larger scale module. This activity will be carried out in conjunction with the ongoing effort to prototype the IDEA ECAL geometry and layout. A study could be dedicated to a setup for a possible test-beam at CERN.	Study of the DD4HEP toolkit and GEANT4 simulation, interface among the two, description of an experimental setup by including scintillation and Cherenkov components. A basic knowledge of python and C++ 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 use case of a realistic experimental setup, and potentially partaking in test beams at CERN in the Summer period.

CERN - 41 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/03/2025 – 31/07/2025**	**Fabio Cossutti – Felice Pantaleo – Aurora Perego**

Particle flow reconstruction for the Phase-2 of CMS	Daily activity, skills required and to be acquired
The CMS Collaboration is upgrading its apparatus to address the challenges posed by the increased luminosity and pileup of the High Luminosity LHC (HL-LHC). Some sub-detectors will be replaced, including the endcap calorimeters, other will be upgraded in their electronic readouty system, and besides that a new dedicated timing layer, the MIP Timing Detector (MTD), will be installed. MTD will measure the arrival time of charged particles with a resolution of approximately 30-40 picoseconds. This timing information coupled with that of the new calorimeter will enable or improve tasks such as 4D vertex reconstruction, particle identification, and pileup rejection, which are especially valuable in the high-multiplicity environment of the HL-LHC. The event reconstruction and particle flow interpretation must be redesigned to make full use of these enhancements. This project aims to optimize the reconstruction of particle flow candidates in the forward region of the CMS detector and improve the integration of timing information. The student will also explore alternative algorithms for linking tracker tracks with calorimeter energy deposits and evaluate their performance relative to the current baseline. The linking algorithm should assign a quality score to each link that could be useful to aid the global event interpretation. Participation in this project will offer the student a unique opportunity to contribute to advanced methods for improving the accuracy of global event reconstruction while gaining hands-on experience with state-of-the-art detector technology.	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 reconstruction 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 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.

CERN - 42 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/04/2024 – 30/06/2024**	**Angelo Carbone – Marianna Fontana – Vincenzo Vagnoni**

Search for Lepton Flavor Universality with $D^0 \rightarrow h^+h^- e^+ e^-$ decays at LHCb	**Daily activity, skills required and to be acquired**
Rare four-body charm decays such as $D^0 \rightarrow h^+h^- e^+ e^-$ serve as probes for new physics effects, receiving contributions from Flavour Changing Neutral Currents (FCNC) $c \rightarrow u\, \ell^+\ell^-$ transitions, which may be influenced by the presence of new heavy particles. This analysis aims to measure the branching fractions of these decays relative to the Cabibbo-favored normalization channel $D^0 \rightarrow K^+\pi^- e^+ e^-$, using LHCb Run 3 proton-proton data. By comparing the results to the analogous muonic decay $D^0 \rightarrow h^+h^- \mu^+ \mu^-$, it is also possible to set constraints on Lepton Flavour Universality. Since previous measurements using Run 2 data were statistically limited, the analysis benefits from the significantly larger dataset collected during Run 3, offering a high probability of observing for the first time the decay $D^0 \rightarrow K^+K^- e^+ e^-$. The analysis will be performed across several dilepton mass regions dominated by different resonances or FCNC processes. Additionally, the project aims to optimize the software trigger algorithm for $D^0 \rightarrow h^+h^- \mu^+ \mu^-$ decays based on 2024 data, to enhance signal yields for the 2025 and 2026 data-taking campaigns.	The student will gain hands-on experience from experts in conducting rare decay branching ratio measurements, actively participating in all phases of the process. This includes optimizing event selection using multivariate algorithms, calibrating experimental efficiencies through simulations and data-driven techniques, and developing multidimensional fitting models to extract relevant physics quantities from the data. Additionally, the student will contribute in optimizing the experiment's software trigger, focusing on optimizing selection algorithms. Throughout the program, the student will become proficient in widely used analysis frameworks in High-Energy Physics, such as ROOT, RooFit, Python, and scikit-learn.

CERN - 43 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/05/2025 – 31/07/2025**	**Mauro Dinardo and Styliani Orfanelli**

DAQ and powering system testing for the CMS Phase 2 Inner Tracker	Daily activity, skills required and to be acquired
The High-Luminosity LHC (HL-LHC) is an upgrade of the CERN LHC expected to operate for 10 years starting in 2030. It will run at a nominal center-of-mass energy of 14 TeV with a 25 ns bunch-crossing period. In the ultimate performance scenario, the peak instantaneous luminosity will reach 7.5×10^{34} $cm^{-2}s^{-1}$ with an average of up to 200 overlapping pp collisions per bunch crossing. This will enable the CMS experiment to collect an integrated luminosity of up to 3000 fb^{-1} over its lifetime. The increased luminosity will greatly expand the physics potential of the LHC, allowing precision studies of the Standard Model and searches for rare beyond Standard Model processes. To this extent, CMS has carried out an upgrade program of its subdetectors, in particular, the vertex detector was re-designed to cope with the extreme radiation fluence expected at HL-LHC. The new silicon pixel sensors and readout chip are now ready for the production phase. At CERN a "System Test" stand is being set up to perform tests of the whole readout chain which includes the readout chips mounted on modules (i.e. multiple readout chips), together with ad-hoc current driven, rad-hard, power supplies, and a rad-hard optical readout. The successful candidate must assemble a few full readout chains, and thoroughly test them to spot possible weak points. In particular, the candidate must verify that the new power supplies respect the design specs in terms of delivered power, and noise. This is a very important test to validate key aspects of the full readout chain.	The project proposal is set in the experimental particle physics field. It consists of laboratory activities that involve the preparation of the experimental apparatus, the acquisition of the relevant measurements, and ultimately the critical analysis of the collected data. More specifically the successful candidate must have basic knowledge of the instruments present in an electronic laboratory, such as power supplies, digital scopes, pulse generators, and so on, together with a basic understanding of the C++ programming language, and the ROOT data analysis package. Experience with the Linux operating system, even though it's not required, would be extremely beneficial. The candidate will acquire knowledge on cutting-edge readout systems, together with the application of the scientific method for qualifying it.

CERN-44 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/07/2025 – 30/09/2025**	**Francesco Armando Di Bello – Carlo Schiavi – Lorenzo Santi – Martino Tanasini**

Optimization of Flavour Tagging techniques for the ATLAS Experiment and Application to di-Higgs searches	**Daily activity, skills required and to be acquired**
This research project aims to advance the flavor tagging techniques employed in the ATLAS experiment at CERN. In recent years, flavor tagging performance has significantly improved through the adoption of advanced machine-learning algorithms, particularly transformer-based models known as “GN2.” This study focuses on two key objectives: the first is incorporating low-level input variables, such as detector hits instead of reconstructed tracks, as inputs to GN2. This approach paves the way for GN2 to evolve into an end-to-end machine-learning algorithm capable of integrating region-of-interest tracking with flavor tagging. The second objective is the development of a unified tagger that can simultaneously identify heavy flavors and hadronic tau decays, addressing their current separate treatment and the need for overlap removal algorithms applied at a later stage. These ML advancements are expected to significantly enhance the precision and efficiency of identifying various quark types and hadronic tau decays. One of the most important analyses that could profit from these developments is $HH \rightarrow bb\tau\tau$.	The daily activities will include both discussions with experts based at CERN and in-person sessions for understanding the flow and the technical tools currently in use in a large particle-physics experiment. The existing literature on the subject will also be reviewed in a both guided and independent fashion. The project will be carried out mainly autonomously by the candidate, with regular discussions and feedback from the supervisors and other colleagues collaborating on the same project line. Presentations at relevant working group meetings are also possible and will be encouraged. The project will require a basic understanding of programming in C++ ,Python and Pytorch libraries. Knowledge of basic machine learning algorithms would be an advantage, though it is not a strict requirement.Throughout the project, the student will have the opportunity to work on both simulated and data events and will become familiar with cutting-edge machine learning tools.

CERN- 45 -

Hosting Laboratory	Available period	Contact person(s)
CERN (Geneva)	**1/05/2025 – 31/12/2025**	**Francesco Di Capua – Francesco Pietropaolo**

Validation of a new Photon Detection System concept for the third Far Detector Module of DUNE	**Daily activity, skills required and to be acquired**
The Deep Underground Neutrino Experiment (DUNE) will address a range of fundamental questions through its multidecadal science program including the dominance of matter over antimatter in the early universe, the mechanisms behind supernova neutrino bursts, the nature of dark matter, and the potential decay of protons. DUNE will feature two neutrino detectors: the first one, located at FermiLab, and the second, significantly larger detector and composed by four big modules (FDs), will be situated over a kilometer underground at the Sanford Underground Research Laboratory, 1300 kilometers downstream from the source. The construction of the first project phase (Phase I) is well underway. Fabrication of various beamline and detector components for construction of FD1 and FD2 is ongoing. Phase II of DUNE includes an enhanced 2.1 MW beam, a third and fourth far detector module, and an upgraded ND complex. To improve the performance of the Photons Detection System for third module, at low incremental costs, an attractive solution involves the use of fully silicon-based large light collection units with an area approximately of 100 cm^2, large panels of wavelength-shifting foils made of polyethylene naphthalate and large reflector foils panels. The selected student will participate in small scale experiments using a 50 lt Time Projection Chamber to validate the feasibility of this simple and innovative approach for Photon Detection System in the third Far Detector module.	The required skills include a basic knowledge of data analysis tools: Python, C++ and/or ROOT. Additionally, a fundamental understanding of radiation interactions with the matter and the scintillation mechanism is essential. Daily activities will focus on implementing the proposed photon detection prototype in an existing TPC. The role will also involve performing a complete Monte Carlo simulation of the apparatus. The candidate will gain extensive technical expertise in cryogenics, vacuum systems and electronics. They will also acquire hands-on experience with a functioning detector. Furthermore, the candidate will develop expertise in professional data analysis software tools as well as in writing technical reports and preparing dedicated presentations.

CERN - 46 -

Hosting Laboratory	Available period	Contact person(s)
CERN	**01/04/2025 – 30/07/2025**	**Nicola Neri - Paolo Gandini - Victor Coco (CERN)**

ALADDIN: An Lhc Apparatus for Direct Dipole moment INvestigation	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 experiment is based on a fixed-target experiment where charm baryons, i.e. Lc+ and Xic+, are produced and channelled in a bent crystal positioned after the target. The precession of the spin polarization vector of the charm baryons is induced by the strong electromagnetic field inside the bent crystal. A prototype pixel detector based on VELO pixel sensors is currently under development. It will be optimized to operate inside a Roman Pot as part of a spectrometer to measure charged particle momenta of charm baryon decay products. 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.

DESY – 1 -

Hosting Laboratory	Available period	Contact person(s)
DESY	15/06/2025 – 30/11/2025	Rosamaria Venditti (INFN Bari) – Federico Meloni (DESY)

MPGD HCAL full simulation for the Muon Collider	**Daily activity, skills required and to be acquired**
In the context of future muon collider experiments, studying the Higgs boson's properties with sub-percent precision in its hadronic decay channels demands a 3-4% jet energy resolution. These challenging requirements can be reached through a hadronic calorimeter performing 5D particle reconstruction with a position measurement precision of O(1cm2), precise matching of energy deposit with tracker tracks, few ns time resolution and at least a 60%/√E energy resolution. A hadronic sampling calorimeter, based on micro pattern gaseous detectors (MPGD-HCAL), can meet all requirements. However, an optimization of the design parameters is mandatory and must be performed for the case of a muon collider with a center of mass energy of 10 TeV. The candidate will perform a full simulation of the experimental set-up at a muon collider at 10 TeV, adapting the current algorithms, implemented within the muon collider framework, to the proposed layout. The multiple scattering effects on muons passing through the calorimeter will be evaluated. The candidate will work in close contact with the software experts, currently in charge of the muon collider software development.	The student will work with the research group in DESY in charge of the full simulation muon collider software. She/he will work in close contact with software experts and have access to the DESY facilities and computing resources. Weekly meetings on the progress as well as seminars and training activities will further enrich the student's experience. Skills required: - coding skills for data analysis - principles of radiation-matter interaction Skills to be acquired: - the physics principle of gaseous detectors and a hadronic calorimeter. - the basics of reconstruction algorithms for a hadronic calorimeter - knowledge of the simulation software within the muon collider framework. - data analysis and plotting skills

FNAL- 1 -

Hosting Laboratory	Available period	Contact person(s)
FNAL (Batavia, IL, USA)	01/01/2025 – 30/11/2025	Massimo Casarsa – Luciano Ristori

A Space-Time tracking algorithm for high occupancy events at a 10 TeV muon collider	**Daily activity, skills required and to be acquired**
A muon collider represents a highly appealing option as a future collider to explore the energy frontier after the high-luminosity phase of the LHC, enabling a broad physics program that includes direct and indirect searches for new physics, precise Standard Model measurements in an unexplored energy regime, and significant advancements in the Higgs sector. Due to the unstable nature of muons, a muon collider detector is expected to operate under unprecedented background conditions. The fulfillment of the muon collider's physics potential crucially depends on the detector's capability to efficiently and accurately reconstruct the products of the $\mu^+\mu^-$ collisions. In particular, the reconstruction of charged particle trajectories (tracks) will be one of the most challenging tasks due to the huge number of spurious hits in the tracker from the background and the overwhelming number of hit combinations to be processed. A novel track-finding algorithm, loosely inspired by the Hough transform concept (L. Ristori, 2024 *JINST* 19 P05011), is under development to cope with the severe background levels. Notably, this algorithm includes the time of arrival of each hit as an additional coordinate, and its execution time is proportional to the total number of hits to be processed.	Daily activity: The student will participate in the activities of the Physics & Detector Group of the Muon Collider International Collaboration. He/she will contribute to the development, characterization, and performance studies of a novel pattern-recognition algorithm based on a multi-dimensional extension of the Hough transform, as well as to the optimization of the tracker layout for a 10 TeV muon collider. Required skills: Basic knowledge of the Linux operating system and C++ programming basics. Skills to be acquired: Collaborative work in the international high-energy physics environment; understanding of track finding concepts in particle physics experiments; enhanced skills in C++ programming, Monte Carlo simulations, and data analysis with the ROOT package.

FNAL– 2 –

Hosting Laboratory	Available period	Contact person(s)
FNAL	01/07/2025 – 30/09/2025	Mia Tosi – Cristian Peña

Title: Search for Higgs decay to a pair of muons with the Run 3 dataset collected by the CMS experiment	**Daily activity, skills required and to be acquired**
The Higgs boson decay to muon pairs (H→μμ) provides a unique opportunity to probe the Higgs boson's couplings to second-generation fermions, offering critical insights into the Standard Model and potential new physics. This is a rare process, with only about one in five thousand Higgs bosons predicted to decay to muons. The CMS experiment found the first evidence (3 standard deviations) of this process with the Run 2 dataset (138 fb-1) collected at 13 TeV centre-of-mass pp-collisions. Using the full Run2+Run 3 dataset (~350 fb-1), a luminosity based scaling projection predicts a ~4.7 sigma excess above the null hypothesis for this process. Analysis efforts on a partial Run 3 dataset are now underway in CMS, and provides exciting new opportunities to improve upon the Run 2 result.	The candidate will be introduced to experimental analysis techniques used by the CMS experiment. The candidate will familiriaze themselves with event reconstruction and object selection at hadron collliders, using C++ and python based coding software. The candidate will then proceed to deploying an analysis workflow that studies the Vector Boson Fusion production of the Higgs boson. The candidate will develop a machine-learning based classifier to distinguish signal event from the background process (such as Z →μμ), and perform a preliminary sensitivity estimate for the signal strength in this channel. The candidate should have a basic knowledge of coding in C++/python.

FNAL– 3 -

Hosting Laboratory	Available period	Contact person(s)
FNAL	**01/04/2025 – 30/06/2025**	**Simone Donati – Pavel Murat**

Development of pattern recognition algorithms and the Mu2e straw-tracker 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 Mu2e sensitivity goals, an adequate level of detector complementarity/redundancy and sophisticated reconstruction algorithms are required to 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. In particular, track reconstruction is a multi-step process. The first step is hit clustering, in space and time. Pattern recognition is performed for each time cluster to identity hit combinations compatible with a 3D helix and remove background hits. Track fitting acts on the hit combinations to determine track parameters. The existing algorithms have been optimized for the topologies of interest for the principal physics analyses. We are developing pattern recognition algorithms to allow a more robust and efficient track reconstruction applicable also to multi-particle events which could be important for background estimates through data-driven procedures. The proposed research program is aimed at developing and testing the tracking algorithms while commissioning the detector readout and performing initial reconstruction and analysis of the vertical slice test cosmic muons data. This will be an intense hands-on introduction to Mu2e, Mu2e tracking, Mu2e data acquisition, and data analysis and is aimed at 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– 4 -

Hosting Laboratory	Available period	Contact person(s)
FNAL	01/07/2025 – 30/09/2025	Patrizia Azzi - Irene Zoi

Proposal for Characterizing the ARCADIA Monolithic Active Pixel Sensor	Daily activity, skills required and to be acquired
Monolithic Active Pixel Sensors (MAPS) are a key technology for high-resolution particle tracking and imaging. Their compact design, low material budget, and ability to integrate sensing and readout circuitry on a single silicon substrate make them ideal for applications in high-energy physics and more. This project focuses on characterizing the ARCADIA chip's performance under controlled conditions using a laser system mounted on high-precision motion stages. The study will provide critical insights into the chip's sensitivity, spatial resolution, noise behavior, and charge collection efficiency—key parameters for evaluating its potential in future detector systems. The selected student will leverage this setup to explore the ARCADIA chip's response under varying operational conditions, such as different bias voltages and chip parameters. The motion stages enable precise scanning across the ARCADIA surface to assess response uniformity and the special laser allows detailed in-pixel studies to evaluate charge sharing and other fine-scale effects. This project is part of a broader effort to advance MAPS R&D and will further strengthen the collaborative ties between INFN and Fermilab	**Daily activity:** The project consists of laboratory activities, using the current developed setup for laser testing. **Required skills:** - basic understanding of silicon detector technologies - basic programming skills for data acquisition and analysis. - basic knowledge of electronic lab equipment. - basic experience in reading and understanding technical documentation. - basic skills for handling delicate silicon sensors **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 state-of-the-art technologies for future detector design - Improved presentation and writing skills

FNAL – 5 –

Hosting Laboratory	Available period	Contact person(s)
FNAL (Chicago)	**1/05/2025 – 31/12/2025**	**Francesco Di Capua – Marco Del Tutto**

Study different neutrino fluxes with PRISM	**Daily activity, skills required and to be acquired**
The near detector of the DUNE neutrino experiment can move to take data in positions off the beam axis. As the detectors move off-axis, the incident neutrino flux spectrum changes. The innovative technique Precision Reaction Independent Spectrum Measurement (PRISM) opens several analysis opportunities, including the study of the neutrino cross sections at different off-axis angles (and consequently different neutrino energies), the study of neutrino oscillations by constraining the flux with different off-axis measurements, and the search of Beyond Standard Model physics. The selected student will use data from a current LArTPC neutrino detector at Fermilab to study the PRISM feature, looking at event distributions of muon neutrinos in the detector to demonstrate the variation of the neutrino flux with the off-axis angle.	Required skills are to have a basic knowledge of data analysis tools: Python, C++ and ROOT. In addition, to have basic knowledge of particle interactions in matter and scintillation mechanisms. The student will gain knowledge of neutrino beams, Monte Carlo simulations, event reconstruction, and data

KEK- 1 -

Hosting Laboratory	Available period	Contact person(s)
KEK	**April-November 2025**	**Laura Zani – Kodai Matsuoka**

Study of tau pair reconstruction for precision measurements at Belle II	Daily activity, skills required and to be acquired
Leptons are powerful tools for searching for new physics beyond the Standard Model. Particularly, tau leptons offer an ideal testbed since they are the only lepton heavy enough to decay into hadrons, allowing for precision tests of the Standard Model, through the measurement of several fundamental parameters, interactions structure, and investigation of the mechanism of hadronization. Belle II experiment at the electron-positron asymmetric energy collider SuperKEKB will collect the largest data set of more than ten billion tau pairs at the end of its data taking. However, taus reconstruction is challenging. Tau leptons decay before being detected into final states including neutrinos, and they need to be reconstructed from the stable particles produced in their decays. Improvement of tau rest frame reconstruction from the clean decay topology at Belle II is a very important step for most of the precision studies aiming at a final accuracy below fraction of percent. The possibility to exploit the known initial state of the electron-positron collisions and the hermeticity of our detector allows to close the kinematic of the event and reconstruct the direction of flight of the parent particle, also in decays with neutrinos. Event-by-event based maximum likelihood fit can be developed to precisely reconstruct the tau momentum and its rest frame. This will allow to improve on measurements involving the knowledge of tau polarization, and to extract fundamental properties as the tau mass, lifetime or Michel parameters of leptonic decays. Moreover, the knowledge of the tau rest frame would allow for direct searches for new mediators in tau decays to a lepton and an invisible particle.	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 specific final state topologies for tau samples, running the reconstruction software, and testing efficiency, purity and reconstruction performance on simulation. Analysis work to improve the kinematic fit to estimate the tau momentum reconstruction is also foreseen. Everything will be supervised not only by the reference people, but also by Dr. Marcela Garcia, a post-doc at KEK, who is a tau physics expert. Dr. Garcia will be in touch daily with the student.

KEK-2-

Hosting Laboratory	Available period	Contact person(s)
KEK	**1/5/2025 – 30/9/2025**	**Stefano Lacaprara - Michele Veronesi**

Time Dependent CP violation analysis for B→η'K in BelleII	**Daily activity, skills required and to be acquired**
Time-dependent CP violation analysis is a flagship technique used at B-factories to extract information about the CKM matrix of quarks. Belle II is currently collecting data at the SuperKEKB electron-positron collider at KEK in Tsukuba, Japan. It is the second-generation experiment at the Super B-factory, playing a leading role in the study of B-physics. The decay B0→η′K is of particular interest because precise measurements can be sensitive to potential new CP-violating phases. The goal of this project is to optimize the selection of η′ and K candidates while managing background levels, ultimately enabling a time-dependent CP violation fit on the ΔT distribution to extract CP violation parameters.	A basic knowledge of Python, ROOT, RooFit, and C++ is very useful, but these skills can also be acquired during the project. Some understanding of particle physics is required. Training on specific Belle II software can also be provided before going to KEK. The work at KEK will primarily involve analysis and software-related activities. This includes studying signal and control samples, reducing background, and potentially applying multivariate or machine learning techniques. Supervision will be provided by the reference team, with Dr. Veronesi based at KEK, ensuring daily contact and guidance.

KEK- 3 -

Hosting Laboratory	Available period	Contact person(s)
KEK	**01/06/2025 – 30/11/2025**	**Alessandro Gaz – Kenta Uno**

Improvement of the PID performance of the Belle II detector on the Run2 data set	Daily activity, skills required and to be acquired
After the Long Shutdown 1, in which part of the photodetectors of the Time-Of-Propagation (TOP) subdetector have been replaced and the full PXD2 detector has been installed), the Belle II detector has resumed data taking in Spring 2024. Data taking at the beginning of Run2 proved to be challenging, with very severe background conditions that affected the performance of some of the subdetectors. This situation, together with the expected increase in the instantaneous luminosity that we foresee for the coming years, demands an increased effort in the design, calibration, and maintanance of the software tools that make Particle IDentification (PID) strategies available to physics analysis. In this project, the student will become familiar with the data control samples that are utilized to monitor the PID performance of the detector, identify the main background effects that have a negative impact on the performance, and study countermeasures to recover PID efficiency.	This will be mostly a data analysis project. The data necessary for the study will be available at the start of the project. In the first 2 weeks, the student will become familiar with the Belle II software analysis environment and will create the ntuples for one specific control channel, that include high and low background data taking periods. In the following 4 weeks, the student will identify the variables that mostly correlate with the background conditions and loss of PID efficiency. In the final weeks, the student will propose and test strategies aimed at minimizing the negative effects of the backgrounds and recovering PID performance. Prerequisites: some familiarity with python and C++ and with the ROOT analysis framework. In Summer 2025 Belle II will not be in data taking mode, so some hands-on detector work could be possible, if the student is interested.

KEK-4 -

Hosting Laboratory	Available period	Contact person(s)
KEK	**1/07/2025 – 30/11/2025**	**Giuliana Rizzo – Katsuro Nakamura**

Characterization of CMOS MAPS chips for the Belle II VTX upgrade	Daily activity, skills required and to be acquired
The Belle II collaboration is in the process of designing a replacement vertex detector based on CMOS Monolithic Active Pixel Sensors. This new vertex detector (VTX) will improve the tracking performance of the experiment and will be more resilient to harsh machine background conditions. Prototype sensors (TowerJazz Monopix2: TJMP2) have been produced and are under test. In Japan the TJMP2 chips have been irradiated with 90 MeV e- up to 5x10^14 neq/cm2, and are now undergoing an extensive characterization program, with both lab measurements and beam test at KEK, which is planned before summer 2025. The student will participate in electrical measurements in the laboratory and analyze the beam test data with the goal of understanding the changes in performance of the chips after irradiation in terms of noise, fake rate, cluster properties, efficiency and resolution.	The student will learn the basics CMOS MAPS and the laboratory measurement techniques needed to characterize them. Basic knowledge of radiation detectors would be very useful. The main data acquisition and analysis interface will be through Python notebooks connected to the lab equipment. Some knowledge of Python is required. The student will learn how to operate lab equipment and perform analysis on a large pixel matrix. Basic knowledge of analysis techniques and statistics will be necessary. Depending on the student's interest and ability, ROOT-based analysis on the beam test data can also be performed to extract efficiency and resolution of the irradiated sensors. The student will learn to perform the analysis of tracking device in a simple geometry and compute the basic performance indicators.

KEK-5-

Hosting Laboratory	Available period	Contact person(s)
KEK	01/06/2025 – 30/11/2025	Luigi Corona – Shohei Nishida

Feasibility studies for the search for a LFV *Z′* through the process $e^+e^- \to \mu^+\mu^- Z'$, $Z' \to \tau\mu$ at Belle II.	Daily activity, skills required and to be acquired
Dark matter is one of the most compelling phenomena in support for physics beyond the Standard Model. Several theoretical framework introduce light dark matter with a mass in the MeV–GeV range, which might solve the dark matter puzzle and explain some long-standing anomalies like the (g-2) of the muon. In these theoretical frameworks, dark matter can feebly interact with the Standard Model through new interactions mediated by light dark sector mediators. Belle~II has a unique sensitivity to light dark sectors thanks to the excellent reconstruction capabilities for low multiplicities and missing energy signatures,a nd dedicated low-multiplicity triggers. The proposed program consists in studying the feasibility for the search of a lepton-flavor violating dark boson *Z′* through the process $e^+e^- \to \mu^+\mu^- Z'$, $Z' \to \tau\mu$. The proposed program is broad: study of the theoretical model, generation and simulation of signal events, evaluation of the signal efficiency reconstruction, and preliminary studies on background rejection methods. Depeding on the time of permanence, the work will also include the study of initial-state radiation (ISR) effects with a new generator, WHIZARD. This new generator includes ISR for 4-lepton final state processes, which are expected to be a significant background component for this analysis. The generator for 4-lepton final state processes currently used at Belle~II does not include ISR effects, leading to a large discrepancy between data and simulation. For this reason, this study is very interesting for the Belle~II experiment.	The candidate will work, inside a team of experts and assisted by a tutor. The candidate will learn how to perform a physics analysis, in particular a dark sector search, with the goal of determine the feasibility of the search for a *Z′* boson through the process through the process $e^+e^- \to \mu^+\mu^- Z'$, $Z' \to \tau\mu$. The candidate will learn the basics of dark sector analysis: the physics of dark sectors; how to simulate and reconstruct events with the Belle~II analysis software; how to deal with new physics generators; the kinematics of signal and background events; how to exploit kinematic features to discriminate between signal and background events. The candidate will also develop the software needed to perform generation, simulation, reconstruction, and preliminary data analysis. The required skills are basic knowledge of the most popular operating systems, and some experience with the ROOT and python analysis software. Program of study or thesis in experimental high energy physics is preferred.

KEK - 6 -

Hosting Laboratory	Available period	Contact person(s)
KEK	01/02/2025 – 31/10/2025	Michele Veronesi (KEK) – Mirco Dorigo (Trieste)

Improving low-momentum tracking-efficiency corrections for a new measurement of $\|V_{cb}\|$ at Belle II	**Daily activity, skills required and to be acquired**
This is a data analysis project aimed at improving the measurement of the tracking efficiency for tracks with low momentum (smaller than 200 MeV). We will analyze decay candidates reconstructed in billions of charm-anticharm meson pairs recorded in 10 GeV electron-positron collisions at the Belle II experiment. Precise knowledge of this efficiency is essential to obtain a new measurement of $\|V_{cb}\|$, the strength of the bottom-to-charm weak-interaction coupling, a fundamental parameter of quark weak-interaction of the Standard Model. The golden decay to access $\|V_{cb}\|$ is $B^0 \to D^{*-} l^+ \nu$. Currently, the dominant uncertainty on the measurement is due to the tracking efficiency of the slow-pion from the D^*decay. The current method to determine this efficiency exploits $B^0 \to D^*(\to D^0 \pi^-) \pi^+$ control data, which offers excellent kinematic overlap with the signal, but features a small sample, limiting the precision. We propose to exploit a different control channel, *i.e.*, prompt $D^* \to D^0\pi$ decays produced in $e^+e^- \to D^*X$ events, which would offer a very clean large sample, enabling both an improvement of the statistical precision and an exploration of the key dependences of the efficiency on track variables.	The student will be co-supervised by a tracking expert at KEK, who will guide him/her in the development of the project. By performing a limited but full-fledged analysis of simulated and experimental data, the student will learn the conceptual and technical fundamentals of HEP statistical analysis. The project involves development of a new analysis, optimization of the event selection, sample-composition fitting, and determination of systematic uncertainties. The student will be provided with ready-to-use ntuples. In the first 2 weeks, she/he will warm up by replicating an initial study done with prompt $D^* \to D^0\pi$ data that compares directly with the $B^0 \to D^*(\to D^0 \pi^-) \pi^+$ results. In the remaining 10 weeks, the student will pursue the more innovative part of the project based on simulated and real data. Results will be presented in Belle II meetings and documented in a Belle II internal note. 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.

PSI - 1 -

Hosting Laboratory	Available period	Contact person(s)
Paul Scherrer Institute	**01/05/2025 – 30/11/2025**	**Giovanni Gallucci**

Commissioning of the MEG II detectors for data taking 2025	Daily activity, skills required and to be acquired
The MEGII experiment is searching for the lepton flavor violating decay $\mu \rightarrow e\gamma$ with unprecedented sensitivity. Several detector and calibration procedures will be commissioned for the run 2025: among the others, a cylindrical drift chamber (CDCH), with unprecedented positron track performances, a full custom trigger and acquisition (TDAQ) system, that efficiently selects signal candidate events with a background rejection of 7 orders of magnitudes, a LYSO detector, for calibration purpose. She/he will be involved in one or more of the following activities: 1) for CDCH, the detector commissioning and calibration, using cosmic ray events to calibrate and compare the obtained results with the performances measured by means of muon and positron beam induced events. 2) for TDAQ system, the preliminary data taking to tune the trigger variables and optimize the background rejection and data taking. 3) for LYSO, the commissioning of a LYSO detector to measure gamma from the charge exchange reaction to calibrate the xenon detector. During the contract period, she/he will benefit of deep interactions with local experts and other collaboration members for the above-mentioned activities.	The candidate will collaborate with experts responsible for calibrations and detectors commissioning. At the beginning of the activity the contract holder must have a good knowledge of particle detector physical principles. A basic experience in C++ programming language and a good autonomy in the use of analysis software like ROOT will be useful for TDAQ, CDCH and LYSO.

PSI - 2 -

Hosting Laboratory	Available period	Contact person(s)
Paul Scherrer Institute	**01/05/2025 – 30/11/2025**	**Giovanni Gallucci**

MuEDM positron tracker detector development	**Daily activity, skills required and to be acquired**
The Electrical Dipole Momentum (EDM) of fundamental particles are intimately connected to the violation of time invariance T and the combined symmetry of charge and parity CP. The MuEDM experiment, using for the first time worldwide the innovative frozen spin technique, aims to measure the muon EDM with heightened sensitivity studying the asymmetry up/down of the positron from the muon decay. The muon beam of Paul Scherrer Institute (PSI) will enter in a uniform magnetic field region and the muons will be trapped inside the region. The positron from decay will be measured by a dedicated scintillating fibers detector coupled with silicon photomultipliers (SiPMs) and read by CAEN FERS electronics. The contract holder will be involved in the different phases of the tracker development: first tests of fibers, SiPMs and readout electronics; construction, assembly and integration of the detector; tracker commissioning during the beam time. During the contract period, she/he will benefit of deep interactions with local experts and other collaboration members for the above-mentioned activities.	The candidate will collaborate with the detector and electronic experts responsible for the positron tracker. At the beginning of the activity the contract holder must have a good knowledge of particle detector physical principles especially of scintillating materials and SiPM. A basic experience in C++ programming language and a good autonomy in the use of analysis software like ROOT will be useful.

PSI - 3 -

Hosting Laboratory	Available period	Contact person(s)
Paul Scherrer Institute	**01/05/2025 – 30/11/2025**	**Giovanni Gallucci**

Commissioning of the MEG II beams for data taking 2025	Daily activity, skills required and to be acquired
The MEGII experiment is searching for the lepton flavor violating decay $\mu \rightarrow e\gamma$ with unprecedented sensitivity using the most intense continuous muon beam in the world O(10^8 muon/s) of Paul Scherrer Institute (PSI). The fine tuning and monitoring of the muon beam, before and during the physics run, is essential. Furthermore, a Cockroft-Walton (CW) 1MeV-proton accelerator is used to perform energy calibration using 17.6 MeV gamma from nuclear lithium reaction. The contract holder will be involved in one or more of the following activities: 1) He/she will participate at the commissioning and monitoring of the muon beam. Furthermore, she/he will be involved in the development and construction of a new generation of beam diagnostic tools. 2) He/she will be involved in commissioning and tuning of the CW accelerator beam line and in the collection and the analysis of the data for calibrating the liquid xenon detector. During the period, she/he will benefit of deep interactions with local experts and other collaboration members for the above-mentioned activities.	The candidate will collaborate with the muon beam and CW experts responsible for the beam commissioning. At the beginning of the activity the contract holder must have a good knowledge of accelerator physical principles. A basic experience in C++ programming language, LabVIEW and a good autonomy in the use of analysis software like ROOT will be useful.

PSI– 4 –

Hosting Laboratory	Available period	Contact person(s)
PSI (Villigen, CH)	01/03/2025 – 31/05/2025	Cecilia Voena (INFN-Roma) – Philipp Schmidt-Wellenburg (PSI)

Development of the entrance detector of the muEDM 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 muonEDM 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 the frozen-spin technique. This technique could reach a sensitivity of $6*10^{23}$ e*cm after a year of data taking with the muon beam at the Paul Scherrer Institute. The collaboration is composed by various international research institutions/university. MuonEDM is in currently in the advanced prototyping phase and the Rome group (INFN/Department of Physics) is contributing to different construction aspects. One of the critical elements to reach the target sensitivity is maximizing the detection efficiency of the entrance detector, which provides a fast trigger pulse for the magnetic kicker, whilst minimizing its thickness to limit the effects of multiple scattering.	The student will collaborate with the muonEDM group based at the Paul Scherrer Institut to improve on the current performance of the entrance detector which consists of thin plastic scintillators and photodetectors (MPPC), in particular to recover deterioration of efficiency due to small signals and thermal noise. The work is focused on the hardware development in lab, 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, possibly basic knowledge of C++ or phyton /ROOT, particle detectors. The student will acquire experience in working within an international collaboration on advanced detector techniques in the context of a real particle physics experiment, in the specific field of scintillating detectors.

PSI - 5 -

Hosting Laboratory	Available period	Contact person(s)
Paul Scherrer Institute	**01/05/2025 – 30/11/2025**	**Giovanni Gallucci (INFN - Pisa)** **Angela Papa (PSI)**

muEDM precursor: The pre-engineering run 2025	Daily activity, skills required and to be acquired
A new experimental effort is taking shape at PSI with the aim at searching for the EDM of the muon with a final sensitivity of 10^{-23} e·cm using, for the first time worldwide, the frozen-spin technique in a compact storage ring. This search for a non-zero muon EDM (muEDM) is a unique opportunity to probe previously uncharted territory and to test theories of Behind Standard Model physics. The experiment will follow a two-stage approach, the first one, the precursor experiment, aims at collecting a first data sample by 2026. The key point of the experiment is to accumulate muons on the proper orbit and then measuring the asymmetry of the positrons from the muon decays as a signature of a non-zero muon EDM. This project will focus on the assembly and commissioning of the muEDM apparatus of the precursor experiment during the engineering run 2025. It will be a unique opportunity for the student to get acquainted with the main sub detectors of the apparatus, gained a general overview of the experiment and participate to the first data collection, to be used as proof-of-principle of the new experimental method proposed here.	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. 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++. By the end of the program the student will gain good skill in experimental techniques.