INFN

Istituto Nazionale di Fisica Nucleare

PROGETTO FORMATIVO
"LA FISICA DELLE PARTICELLE PER ESPLORARE L'UNIVERSO"

ELENCO PROGRAMMI DI RICERCA PER BORSE DI STUDIO TRIMESTRALI PER LAUREANDI o NEOLAUREATI MAGISTRALI IN FISICA DELLE PARTICELLE

CERN-1

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 April 2019 – 1 June 2019**	**Giulio Aielli (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Assembly and test of a new generation of RPC detector within the ATLAS BIS7/8 Project The research program consists in assembling and testing a new type of RPC detector and related FE electronics within the BIS 7/8 project to be installed in the barrel- endcap transition region of the ATLAS muon spectrometer as part of the Phase I upgrade for the HL-LHC. These new chambers will improve the acceptance (of about 20%) of the LVL1 muon trigger, its efficiency and selectivity. The new type of RPC has a gas gap reduced to 1 mm and a better time resolution. Moreover the thickness of the electrodes is reduced from 1.8 mm to 1.2 mm to increase the charge fraction that is transferred to the pick up electrodes and so improving the signal-noise ratio. A very important part of this program is the test of the front-end electronics, based on a new SiGe chip amplifier.	The requested skill is a basic knowledge of hardware and software tools needed to test the RPC chamber with a cosmic ray test-stand to verify: 1) the overall functionality of this new chambers mapping the x-y read-out efficiency; 2) the cluster size to adjust the FE electronics threshold; 3) the spatial and time resolution

CERN-2

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 April 2019 – 1 August 2019**	Heinz Pernegger (CERN)

Scientific program	Daily activity, skills required and to be acquired
Radiation hard monolithic CMOS detectors Highly segmented monolithic silicon pixel detectors built in CMOS technologies have been very successful in particle and applied physics, but till now their range of application has been limited to event rate and radiation hardness much lower than what is required by for operation at the HL-LHC and future high-energy colliders. Monolithic devices, built on a high resistivity substrate with a sizeable depleted region for charge collection, promise to be a breakthrough for charged particle detection, providing high rate capabilities and radiation hardness, accompanied by lower cost and power consumption with respect to hybrid pixel detectors. Prototypes using sensor designs meant to guarantee short collection time and high signal efficiency are in production in the TowerJazz 180 nm process. They also include the necessary components to build a high-rate readout architecture. After an initial characterization, these prototypes will undergo an extensive study to assess their performance after irradiation and their sensitivity to single event effects. The candidate will join the CERN team in the measurement of the detector properties, in particular the efficiency, noise, uniformity of response and time resolution for different detector designs.	The activity will mainly consist of laboratory measurements and the associated data analysis. Prototype sensors irradiated with difference particles (neutron, proton and photon) will be provided and their response to different radiation source tested. The activity will include also data analysis for the measurement of efficiency and resolution in test beam data collecting in other laboratories. Basic knowledge of electronics laboratory practice is required. Programming skills will be beneficial both for the measurements and data analysis.

CERN-3

Hosting Laboratory	Available starting date	Contact person(s)
CERN	1 March 2019 – 1 October 2019	Paolo Mastrandrea (CERN)

Scientific program	Daily activity, skills required and to be acquired
Commissioning of the Fast Tracker Associative Memory The student will join the team commissioning the Fast-Tracker (FTK) trigger processor at CERN. FTK is one of the ATLAS trigger upgrades. The FTK will be under intense commissioning activities also during the long shutdown (LS2) period with the goal to have the system ready for ATLAS integration runs planned for 2020. The FTK will reconstruct all the inner detector tracks with transverse momentum larger than 1 GeV at the input rate of the High Level Trigger greatly increasing the physics reach for b-jet and tau-lepton signatures. Moreover it will allow multiple vertex reconstruction at trigger level reinforcing pile-up suppression strategies. FTK is based on custom electronic boards, associative memories and FPGAs. The commissioning phase is in its intensive phase. We believe this is a very formative experience for a student to join the project since it will allow him/her to participate to the system commissioning. The candidate will be involved in the operation of the electronics cards, in the development of control and monitoring software and the debugging of the Associative Memory board. He will study the FTK performances on the first real data and compare his results with those obtained on simulated samples.	The daily activity will include: - participation and report to the FTK daily integration meetings - software development for the Associative Memory board online and control software - integration testing of the Associative Memory board followed by analysis of the results with the rest of the team at CERN The initially required expertise is C++ software experience. During the program the student will learn about - experience with team work - how to write software in an online environment - commissioning of a trigger element

CERN-4

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 April 2019 – 1 August 2019**	**Giuliano Gustavino (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Development of new fast Deep Learning algorithms on FPGAs for muon reconstruction and identification in the ATLAS L0 Muon Barrel Trigger The first level hardware trigger system of the ATLAS experiment will undergo a full upgrade for HL- LHC to stand the challenging performances requested with the increasing instantaneous luminosity. The Level-0 Muon Trigger system has to maintain or increase its data selection capability during HL- LHC, despite of the higher detector hit rate, cavern background and trigger rate. The Resistive Plate Chamber detector provides the main trigger source in the barrel region of the Muon Spectrometer. The upgraded trigger system foresees to send RPC raw hit data to the off-detector trigger processors, where the trigger algorithms run on new generation of Field-Programmable Gate Arrays FPGAs. The FPGA represents an optimal solution in this context, because of its flexibility, wide availability of logical resources and high processing speed. In this context the student will work within the ATLAS L0 Muon Barrel trigger group, in the design and deployment of novel fast trigger algorithms based on state-of-the-art machine learning algorithms. In particular the work will be focused in the porting and optimization of new low precision deep neural network	Student activity at CERN: - Development of DNN and CNN based on ternary networks for reconstruction, measurement of transverse momentum and classification of muons based on RPC information available at L0 of the upgraded ATLAS barrel trigger - Porting of the algorithm inside the latest generation Xilinx FPGAs using available HLS tools for code synthesis for FPGA - Integration of the developed algorithm in the FPGAs used in the permanent trigger test slice of the ATLAS experiment - Evaluation of physics performances in terms of efficiency and fake rates of the developed algorithms, and technical performances (FPGA logic resource occupancy and timing/latency), obtained with the developed algorithms - Dayly report on progress/issues with group collaborators and every week in the relevant ATLAS involved TDAQ groups

architectures (based on ternary dense and convnet networks) designed to run on FPGAs and to cope with sparse data developed by the ATLAS Rome L0 Muon Barrel group, and to test them in the permanent detector/trigger slice test available in the ATLAS facility at CERN.	Required initial competences: - knowledge of fundamentals in particle physics - knowledge of fundamentals in machine learning - basic knowledge of python and C programming languages - basics knowledge of FPGA functioning and/or programming would be a plus

CERN-5

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 March 2019 – 1 September 2019**	**Hideyuki Oide (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Study of the long term stability of the ATLAS pixel detector: what we can learn for the construction of a new tracker The ATLAS Pixel detector has been taking data without major problems since 2009 and is now approaching a two-year stop during the LHC shutdown. In this project we propose to perform an analysis of the damages in the detector modules induced by thermal variations the pixel detector have suffered during these ten years of operation. Particular attention will be addressed to study the failures in the bumps connection between sensors and readout chips. These damages can be easily identified as clusters of inefficient pixels located at the edges of the readout chips. The bump connectivity was monitored closely during the integration of the detector, as bumps were known to be a weak point, but it was never studied as a function of time and thermal cycles or other stresses after installation. Differences between In or PbSn bumps that are present in the detector will also be addressed to check if one is more robust than the other. Indeed, the interest in the bump connectivity failure mode is now revamped due to the start of the construction of the new Pixel detector foreseen to replace the current one during the long shutdown in 2024. In fact, several technologies have been developed to join with bumps sensors and readout, but robustness against mechanical stresses, mainly coming from handling and thermal cycles, needs to be proven.	The candidate will have to get a sample of data that covers the full data-taking period. Then he/she will have to identify “inefficient” pixels and define “clusters of inefficient” pixels. Once these definitions are set, the study of their behavior versus time and mechanical stresses will be possible. In parallel, test of bumps connectivity under mechanical stresses will also be performed on real devices in the new tracker assembly facility. In order to efficiently work on this project, the applicant must be familiar with basic computing skills of handling of large-scale database, namely shell script or python programming. The applicant should be also familiar with basic data analysis using C++ and ROOT. Familiarity to imaging analysis is also recommended.

CERN-6

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**15 February 2019 – 15 September 2019**	**Emilio Meschi (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Trigger-less readout and data processing with CMS Drift Tube chambers Availability of low cost, high throughput optical links and the evolution of FPGA I/O capabilities and processing power brought a dramatic change in the data acquisition architectures and triggering models. On detector electronics can be reduced to the minimum required for digitization and time-stamping, data being then streamed in parallel to centralized units, with an asynchronous merging and processing. Such a solution relaxes triggering constraints, opening up to an unbiased continuous, realtime monitoring and reconstruction of physics quantities even before the event data are stored. Aiming to explore solutions for the LHC Phase 2 upgrade, a CMS Drift Tube spare chamber has been equipped with a prototypal readout chain, and is being operated at SX5 to demonstrate the effectiveness of the upgraded architecture, on a first instance by direct comparison with the legacy system by mimicking the original behavior. A further ongoing step foresees the integration with a CMS DAQ2 node prototype, which carries appropriate hardware interfaces to feed incoming streamed data to high level processing code and Big Data tools.	Having to deal with a working detector, most of the activity will focus on exercising the data taking (e.g. latencies measurements), defining performance indicators and evaluating different algorithms efficiencies through cosmic muons runs. Existing detector performance monitoring tools will have to be adapted or evolved accordingly, also through excerpts from the fast reconstruction software (e.g. the present CMS HLT). Previous experience with scalable data handling and processing tools (e.g. Python Data Analysis Library) would be useful, as well as a general awareness of data acquisition systems components and online software architectures.

CERN-7

Hosting Laboratory	Available starting date	Contact person(s)
CERN	1 March 2019 – 1 May 2019	Francesco Fallavollita (CERN)

Scientific program	Daily activity, skills required and to be acquired
Advanced studies on the aging of some gaseous detector technologies A program is proposed based on advanced longevity tests on different gaseous detector technologies: Triple-GEMs and RPCs. These detectors will be installed and/or upgraded in the muon spectrometer of the CMS experiment and are expected to operate efficiently at high flux of particles. Many traditional longevity tests have already been performed irradiating detectors with photons and clean gas mixtures. New advanced tests are here proposed. In this work, outgassing of particular materials is created, enhanced and released into the detectors' inlet gas line in order to contaminate their gas mixture. This would reproduce pollutants' release into their gas volume during many years of operation. Moreover, irradiation of the detectors with particles of different specific ionization allows to understand how the primary charge density can affect the detector performances and trigger different aging processes. CERN laboratories offer the possibility of using various radiation sources, including neutrons, which are necessary for this project and provide adequate radiation safety. Moreover, such longevity studies could provide information about discharge probability. It is expected that a better accuracy of the results will be achieved over a continuous test period of 4-6 months but interesting outcomes are foreseen already at the end of the proposed internship.	The activity will consist in the design, configuration and management of small tests in which different technologies of gaseous detectors are exposed to particles of different specific ionization with the aim of comparing induced aging. The aging environment will be created by poisoning the gas mixture through the outgassing of specific materials. Calibrations and data analysis will also be necessary and the related associated competences will be in line with experimental physics, the management of electronic circuits for data processing and the typical methodology of high energy physics. A knowledge of programming languages and software analysis packages will be appreciated.

CERN-8

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 March 2019 - 1 September 2019**	**Stella Orfanelli CERN)**

Scientific program	Daily activity, skills required and to be acquired
Serial Powering for HL-LHC CMS Inner Tracker The CMS Inner Tracker for HL-LHC will be a pixel detector powered by using an innovative *serial powering* (SP) scheme, for the first time in a particle physics experiment. This method allows to feed the 50kW power needed by the Inner Tracker within a very limited space and with a minimum material budget, so as not to jeopardize the excellent physics performance of the detector. The implementation of the SP scheme is achieved thanks to a special functional block, known as *ShuntLDO*, placed inside the readout chip (ROC). The ShuntLDO is already implemented on RD53A, the ROC prototype chip that will be the R&D and system test workhorse in the next months. Refined ShuntLDO prototypes will also be soon available as standalone ASICs. The ShuntLDO, either in the standalone or in the on-chip version, needs to be fully tested and characterized also after the irradiation campaign reproducing the harsh environmental conditions of the running in the experiment. The characterization requires the low level study of the circuit behavior in terms of regulation capability (time domain, frequency response, etc.), with respect to the typical load variations. It will also require the verification of its functionality, in terms of noise and stability, with a SP chain with real sensors plus ROC assemblies.	The activity consists of the study of a table-top SP chain made up of ShuntLDOs and/or ROCs. Currents and voltages will be measured in various conditions, also in the time-domain by using a fast scope; the student will also run the ROC DAQ system, will calibrate the devices, and then analyze the resulting data to measure noise and other relevant parameters. The required skills are: basic laboratory experience to operate bench power supplies, laboratory instruments and the scope; basic computing skills to operate a DAQ system running on a PC; basic programming and ROOT capabilities for script editing and data analysis.

CERN-9

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 March 2019 – 1 August 2019**	**Marco Lucchini (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Characterisation of LYSO matrices and Silicon Photomultiplier for the CMS Barrel Mip Timing Detector CMS is proposing within the upgrade program for HL-LHC a novel hermetic timing detector for charged particles (MTD) with a target resolution of 30ps. The barrel part of the detector (BTL) will use as sensors small LYSO crystals readout by Silicon Photomultipliers (SiPM). During the last year, R&D studies have been carried out to optimize the BTL design. The reference design now envisages a 3x4x56 mm^3 LYSO crystal, readout on both sides by 3x3 mm^2 SiPM. This design achieves the target resolution at the begin of the HL-LHC, and limits the contribution to the time resolution of the SiPM dark count rate thanks to the double ended readout. Several aspects still need to be studied before moving into a pre-production phase envisaged to start in 2020. We propose to carry out some of these studies within this project. Optimization of the final sensor design will involve characterization of crystals from different producers, systematic studies of the material used to wrap crystal matrices, study of the optical cross-talk and optical matching between the LYSO and SiPMs. Studies on irradiated SiPMs are also needed to characterize the performance of different packaging. All the studies will be carried out at the crystal laboratory at CERN Lab 27.	The selected candidate will perform laboratory measurements on dedicated crystal benches, will analyze the data and produce reports. A good knowledge of laboratory equipment to perform crystal light yield measurements is preferential. Knowledge of an analysis framework (ROOT or python) is required. The candidate will acquire a detailed knowledge of the different contributions to the time resolution of a sensor made of a scintillating crystal and a photodetector.

CERN-10

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 March 2019 - 1 April 2019**	**Sophie Mallows (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Simulation of Neutron induced background in the CMS Muon detectors The HL-LHC is expected to operate with a pile-up rate 5 times higher than the current machine, requiring a dedicated upgrade programme of the CMS experiment: new inner & outer tracker in silicon, a new high-granularity calorimeter for the endcaps, muons system electronics improvements plus reinforcement and extension of the muon system endcap where the highest background rates are expected. The main source of background in the muon system is due to the absorption of the high energy particles produced in pp-collisions in the hadron calorimeters and in the magnet protection systems of LHC in which neutrons are liberated. These neutrons have very low interaction cross section and can live up to milliseconds after their creation, travelling many meters through steel and detectors of the CMS experiment, resulting in the CMS experiment practically “embedded” in a neutron gas. These neutrons upon capture emit 2.2MeV photons which induce background hits in the muon system. The design of the new endcap calorimeters is being finalized as we speak, after which the backgrounds in the muon system need to be re-evaluated and updated w.r.t. the studies performed for the CMS Upgrade Technical Proposal (2015). As a first step the pp-induced background (neutrons, photons, charged particles) need to be evaluated with the FLUKA code.	The student will perform analysis of data extracted from FLUKA simulations with the final design of the CMS Phase-2 detector and extract neutron, photon and charged particle fluxes at the surface of the upgraded muon detectors (ME0, GE1/1, GE2/1, RE3/1 & RE4/1). She/he will interact at CERN with the CMS BRIL group, who is responsible for the particle transport simulation with FLUKA code. She/he will work & collaborate in an international scientific environment. Basic programming skills (C++) are required.

CERN-11

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 March 2019 – 1 June 2019**	**Maurizio Martinelli (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Search for CP violation in $D^0 \rightarrow K^0_S K^- K^+$ decays at the LHCb experiment The study of Charm hadrons offers a unique opportunity to search for physics beyond the Standard Model in the up-type quark sector. Unknown particles in loop processes may induce significant CP violation effects in addition to the very small predictions from the Standard Model. Additionally, CP violation in charm hadrons is not yet observed and remains an important aspect of the Standard Model seeking clarification. The LHCb experiment collected the world's largest sample of charm hadrons to date, thanks to the large cc cross-section in pp collisions at LHC. The selected student will work on an analysis searching for CP violation in the decays of $D^0 \rightarrow K^0_S K^- K^+$ decays, using the LHCb Run2 data. This would be the first time that such analysis is studied at LHCb using a novel technique for hadron colliders, which exploits the variation of CP-odd and CP-even content of the decay with respect to the decay time of the meson. Spending a period at CERN is of primary importance for conducting the analysis efficiently, in order to participate actively to the activities of the Charm working group and to be in close contact with the LHCb charm physics experts on site.	The candidate will work in close contact with charm physics experts from the LHCb collaboration, under the supervision of the charm working group convener (Maurizio Martinelli). He/she will optimize the algorithms aimed at selecting the decays of interest, also using multivariate analysis techniques. Then, the sensitivity to CP violation will be assessed. He/she will have the opportunity to present regularly his/her results at the working group meetings. Basic knowledge of the UNIX/LINUX environment, C/C++ programming languages and ROOT/ROOFIT packages are required. By the end of his/her period at CERN, he/she will have knowledge of advanced analysis techniques employed in high energy physics, and will have developed team working and communication skills.

CERN-12

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 September 2019 – 1 November 2019**	**Giovanni Passaleva (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Development and integration of Generative Adversarial Networks for the Ultra-Fast Simulation framework of the LHCb experiment Among the large experiments at the LHC, LHCb has been designed to study the heaviest hadrons in Nature, containing *b* and *c* quarks. Heavy hadrons are copiously produced in the proton-proton collisions at the LHC, and their decays are efficiently reconstructed by the LHCb detector, resulting in huge and pure datasets that physicists from all over the world analyze to identify discrepancies from the Standard Model that could be interpreted as evidence of New Physics. Large datasets offer the opportunity of reducing the statistical uncertainty to unprecedented levels, requiring an outstanding model of the detector and of the reconstruction procedure to distinguish artifacts from real physics effects. In practice, the detector response is described using large-scale Monte Carlo simulations translating a simulated signal process (*e.g.* a particle decay) into the same reconstructed variables as available for real data, by modelling every step: the collision, the decays, the radiation-matter interactions in the detector, and the read-out electronics. Unfortunately, the available computing resources will never be sufficient to perform such a full simulation for samples as abundant as those expected for real data during the future runs of the LHC. Hence, new Fast-Simulation technologies are under development.	The selected candidate will study an innovative and promising approach based on the parametrization of the detector response using Deep Neural Networks trained in an Adversarial configuration (Generative Adversarial Networks, GAN). An interesting feature of this approach is that Neural Networks can be trained directly on the collision data collected to monitor and calibrate the detector response, achieving good reliability for algorithms designed to be orders of magnitude faster than the full simulation. The ideal candidate has experience on High Energy Physics data analysis, Neural Networks and other machine learning technologies. He/she is proficient in Python and TensorFlow.

CERN-13

Hosting Laboratory	Available starting date	Contact person(s)
CERN	15 April 2019 – 1 June 2019	Tatsuya Masubuchi (University of Tokyo)

Scientific program	Daily activity, skills required and to be acquired
Higgs boson HVV coupling structure in pp→VH, H→b(bbar) Five years after the Higgs boson discovery, ATLAS and CMS reported this summer the first observation at the LHC for the Higgs boson decay in b- quarks. The coming years will be very important to exploit at best all the potentiality of this decay channel. Measurements of H→b\bar{b} produced in association with a vector boson V(W or Z) are already providing information on the structure of the Higgs coupling with the vector bosons. In this project we want to exploit the use of kinematic variables, especially at high transverse momentum (which is particularly sensitive to physics beyond the Standard Model) and angular information to extract information on the CP properties of the HVV coupling structure. These studies will cover the needs for the future analysis of the pp→VH,H→b\bar{b}, optimizing the strategy for the measurement, and investigating how to compare and combine the results with the other available channels (Vector boson fusion, or Higgs decays in WW and ZZ). These studies will be done coherently with the plans and recommendations of the LHC Higgs Cross Section WG.	**Month1:** learning the existing tools/data format (i.e. truth-DxAOD, CxAOD); getting familiar with the proposed strategies to extract information from the pp→VH,H→b\bar{b} channel. **Month2:** Preparation of samples with anomalous couplings, using the most updated tools, including the production of samples for different EFT basis, pseudo-observables, and anomalous couplings. **Month3:** Detailed studies of the proposed variables on data, optimization of the analysis strategy, extraction of expected results and first comparisons with existing or planned results in other channels.

CERN-14

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 March 2019 – 1 August 2019**	**Johannes Bernhard (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Optimization of a muon beam to measure in the space-like region the leading hadronic corrections to the muon g-2 (the MuonE project) A proposal was presented to measure the differential cross section of the elastic μ − e scattering, as a function of the transfer momentum t, to determine the hadronic contribution the running of α, the electromagnetic constant. A high energy muon beam is necessary in order to cover the range of large t, where the hadronic corrections are measurable. The energy of the M2 muon beam in the North Area at CERN is adequate for such measurement. The parameters of the beam must be optimized for the wanted application, and the location of the μ − e detector must be specified accordingly. The work program will be: 1. Work on the beam line: in close contact with the EN-EA group, design in detail beam optics for the final MuonE experiment length of 40 m, without significant interference with the COMPASS apparatus. Take into account the MuonE requirements for beam flux, size and momentum spectrum as well as Halo contributions. Prepare a detailed layout of the beam line and experimental set-up inside the last section of the beam zone PPE211. In collaboration with members of the EN-EA team, perform initial integration studies and costing. 2. Work on the testbeam data analysis: in 2018, large samples of data have been taken with an apparatus made by eight Si-planes tracker and a graphite target, located behind COMPASS.	The student will participate in the different steps of the analysis: selection criteria of elastic events, and determination of the cross-section ratio between the two kinematical regions, the one at high t and the one at low t. The student is required to have notions of C++ and ROOT. She/He will learn to use these tools extensively, to use GEANT4 simulation, to learn techniques of analysis (NN, TMVA, etc). The fraction of time (20-30%) dedicated to subject 2. will help the student to understand the use of the μ beam for the final measurement.

CERN-15

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 June 2019 – 1 July 2019**	**Michael Moll (CERN)**

Scientific program	Daily activity, skills required and to be acquired
Tracking particles in 4 Dimensions Tracking particles in space and time is the new frontiers in the design of the next generation of experiments. This goal requires the design of a new type of Silicon sensors, the so called Ultra-Fast Silicon Detectors (UFSD). The student in this project will be engaged on two fronts: (1) the study of the radiation hardness of UFSD in the CERN Silicon lab. and (2) the analysis of the impact on key physics channels of the addition of a Timing Layer to the CMS detector. The student will therefore benefit from a combination of hardware and software activities. A three months training in an advanced Silicon laboratory, carrying on the characterization of the radiation hardness of the Silicon sensors chosen for the CMS and ATLAS timing layer, will provide to the student a relevant experience for his/her future activities. At the same time, the student will be engaged in the simulation group of the CMS Timing layer, and he/she will develop the tools for evaluating the impact of the addition of the Timing Layer on the CMS physics reach at HL-LHC.	The student needs to have had a previous training in a Silicon laboratory and she/he should have a basic understanding of the CMS physics analysis environment. A period in the CERN Silicon laboratory will provide the student with a good training in the techniques needed to characterize new and irradiated Silicon sensors. Likewise, the software activities will allow the student to meet and interact with the CMS analysis teams and to be engaged in relevant simulation work. The workday will be split between the CERN Silicon Lab and the analysis work, either in meeting or in the office.

DESY-1

Hosting Laboratory	Available starting date	Contact person(s)
CERN	**1 April 2019 – 1 August 2019**	**Christian Sander (DESY)**

Scientific program	Daily activity, skills required and to be acquired
Measuring Efficiency and resolution of pixel modules prototypes for ATLAS ITK upgrade The proposed project aims to measure the efficiency and spatial resolution of various kinds of pixel detectors before and after irradiation. Pixels with various dimensions and technological details are being evaluated, before proceeding with production. Primarily, the baseline hybrid sensors will be tested, both in the planar and 3D geometry. These have a minimum pitch of 50 microns and thickness ranging from 100 to 250 microns. Also monolithic CMOS sensors, with same pitch will be produced and tested. A summer student with adequate basic knowledge of root and NIM instrumentation can contribute to the data taking and to data analysis to extract efficiency and spatial resolution obtained using a beam telescope.	Initial requirements: basic knowledge of root and statistical data analysis; basic knowledge of nuclear instrumentation: scintillation detectors, photomultipliers, amplifiers, basic knowledge of coincidence and trigger concepts. After the programme the student will have gained a knowledge of particle tracking techniques, improved statistical analysis methods on tracking and first hand experience of data taking and data analysis. The student will also be attending seminars and lectures at the host laboratory.

FERMILAB-1

Hosting Laboratory	Available starting date	Contact person(s)
FERMILAB	**1 March 2019 – 1 April 2019**	**Pavel Murat (Fermilab)**

Scientific program	Daily activity, skills required and to be acquired
Reconstruction of proton from muon nuclear capture as Mu2e normalization source The Mu2e experiment aims to discover the conversion of a muon into an electron by improving the previous limit by four orders of magnitude (8×10^{-17}). The conversion rate will be normalized with respect to the rate of muon capture in nucleus. The muon capture rate is around 60% of the muon stopping rate and it needs to be determined with high precision due to the expected large variation of the proton intensity along the running period. Apart looking for significant X-ray lines with a dedicated stopping monitor detector (located in an external region of Mu2e), the possibility to use an in-situ event reconstruction is being studied. One of the monitoring sources with very high rate is provided by the protons produced from de-excitation of the muons captured by the nucleus. This rate corresponds to 0.18 GHz. Preliminary proton reconstruction with the tracking system indicates that this road is feasible and that the proton counting could be sensitive to beam intensity variation down to around 1 ms. The proposed work is that of optimizing the proton reconstruction and evaluate the time budget needed to perform such a task in real data.	**Required knowledge:** to have a reasonable knowledge of programming languages (C, C++) and Root package. Pre-existing “beginner” expertise in data analysis. **Acquired knowledge:** improved usage/learning of C++ language and Root package. Improved capability in data analysis. Learning of the Mu2e software, *art* framework and grid usage. Improved communication skills. **Daily activity:** creation of needed simulated samples, development of analysis code, attendance / report to weekly meetings (Calorimeter, Software, Mu2e- general, mu-e+ group).

FERMILAB-2

Hosting Laboratory	Available starting date	Contact person(s)
FERMILAB	**1 March 2019 – 1 October 2019**	**Fabio Ravera (Fermilab)**

Scientific program	Daily activity, skills required and to be acquired
CMS Phase II Tracker: characterization of first prototypes in laboratory and test beams along with DAQ development The LHC will be upgraded to the High Luminosity (HL-LHC) in the late 2020 to further increase the discovery potential of the machine. During the HL-LHC the instantaneous luminosity may be as high as 7x1034 cm−2s−1 in order to collect 10 times more proton-proton collision data than at the LHC. The HL-LHC upgrade will set unprecedented challenges from the point of view of both detector and electronics capabilities and radiation hardness. In order to maintain its physics reach, the CMS detector will be significantly upgraded and Fermilab will be have a major role in the development of the Tracker. In particular the Laboratory is one of the main centers for the test, both in laboratory and on beam, of the new Tracker prototypes and it is leading the DAQ software development.	During the activity the student will be integrated in the Fermilab team testing prototypes and developing the DAQ and they will contribute to the optimization of the calibration procedures used both for the production and the monitoring during the data taking. The student will acquire a good knowledge of the electronics that will be used in the Phase II Tracker. They will also have the opportunity to present the outcome of their activity within CMS and thus to acquire an international profile. Required skills: knowledge of the linux environment, good C++ programming skills, basic knowledge of electronics, experience in laboratory, capability of working in a team.

FERMILAB-3

Hosting Laboratory	Available starting date	Contact person(s)
FERMILAB	**1 March 2019 – 1 June 2019**	**Brendan Casey (Fermilab)**

Scientific program	Daily activity, skills required and to be acquired
Measurement of the muon anomalous magnetic moment in the Muon g-2 experiment The subject of this research program is the analysis of the g-2 oscillation frequency within the E989 (*Muon g-2*) experiment at Fermilab. The *Muon g-2* experiment aims to measure the anomalous magnetic moment of the muon to an unprecedented accuracy to verify the current discrepancy of 3.7σ observed between the theoretical prediction and the value measured by the previous experiment (E821 at Brookhaven National Laboratory), discrepancy which leaves room for new physics beyond the Standard Model. The final result of the experiment will be the ratio of two frequencies measured independently, and with very different techniques: the muon precession frequency relative to the momentum (ω_a) and the free proton precession frequency (ω_a). Both quantities have to be measured with an accuracy of 0.07 ppm, therefore few independent analyses will be performed on each frequency to crosscheck central value and systematic errors. One of the ω_a analyses will be performed by the ω_a-europa group, in which INFN has a leading role. The Muon g-2 experiment collected the first set of data in the period March-July 2018 reaching a statistics which is almost twice the one collected by E821. While the Run2 just started in November 2018, with the aim of collecting 10 times the statistics of E821, an analysis effort has started to publish in Summer 2019 a first result with the same total error as the current one. The successful candidate will be involved in data analysis and will contribute to this first, very important, result which will confirm, or disproof, the current difference between theory and experiment, thus participating to the search of physics beyond the Standard Model.	The program is a three-month stay at Fermilab during which the candidate will contribute to the data analysis of Run1 as well as to the detector operation during Run2. General confidence with particle detectors and skills towards software activities are prerequisites of this research program. At the end of the program the student will gain the experience of participating in the realization and commissioning of a modern elementary particles experiment.

KEK-1

Hosting Laboratory	Available starting date	Contact person(s)
KEK	1 March – 1 April 2019	Hiroyuki Nakayama (KEK)

Scientific program	Daily activity, skills required and to be acquired
Initial operation and first data analysis of the full Belle II diamond- detector The program focuses on early operations and data analysis of the full Belle II diamond-detector system for radiation monitoring and beam abort. The SuperKEKB electron-positron collider will provide the Belle II detector with unprecedented luminosity, yielding 50x more data than at previous B-factories. This positions Belle II at the forefront of indirect searches for non-standard-model physics in the next decade. "Phase 3" operations (Mar-Jul 2019) aim at commissioning the accelerator and the full detector for physics. High collision intensity implies higher beam-induced radiation. Radiation can damage the vertex detector, which is essential for the Belle II program. Early Phase 3 will be key for characterizing the radiation environment in the vertex-detector and optimizing strategies for protecting the sensitive components. This is the task of the diamond detectors, which monitor instantaneous dose-rates, record integrated doses, and trigger beam aborts. Diamond sensors operate effectively as solid-state ionization-chambers, providing measurements of pA-nA currents proportional to the dose rates. In-situ monitoring of noise, pedestals, radiation rates along with timely operation improvements that mirror the changing data-taking conditions will be essential in Phase 3. Eight sensors read by purpose-built electronics were operated last year in a preliminary commissioning. The system is now complete with twelve additional sensors to protect the detector and the neighboring superconducting quadrupole-magnets. The readout electronics is also being upgraded to allow for multiple-diamond logic toward more flexible beam-abort triggers.	The candidate will contribute to daily operations and will analyze diamond data, in correlation with detector and accelerator data, to identify sources of radiation and mitigate risks. The fluid conditions associated with the commissioning and the need for timely and close collaboration with detector and SuperKEKB experts require continuous presence on site. Required skills include basic knowledge of the interaction of particles with matter and familiarity with standard lab equipment, programming, and data-analysis packages, along with communication capabilities. The candidate will refine these skills in a real research environment during the most intense and exciting time for an experiment.

KEK-2

Hosting Laboratory	Available starting date	Contact person(s)
KEK	**1 March 2019 – 1 May 2019**	**Katsuro Nakamura (KEK)**

Scientific program	Daily activity, skills required and to be acquired
Operation and Commissioning of the Belle-II Silicon Vertex Detector for its first physics run at the SuperKEKB accelerator A Silicon Vertex Detector (SVD) is the central part of the tracking system of the Belle II experiment, crucial to perform a precise measurement of the position of the decay vertices, with the capability of reconstruction of low momentum tracks. The SVD is composed of four layers of 300 um-thick double-sided silicon strip detectors (DSSD), covering the polar angle from 17 to 150 degrees and radius from 39 to 135 mm. The construction and assembly of the SVD ladders on the support structure has been recently completed and the full SVD is now installed inside the Belle II detector. In spring 2019 SuperKEKB will start the first physics run with the new complete vertex detector installed. The participation to the operation and commissioning of the SVD during the first months with beams will be an extremely valuable and exciting experience for a young researcher. Several different important aspects can be covered during this project: from the monitoring of the detector stability during data taking (including the evolution of the calibration constants and number of defective strips), to the study of the detector performance and their dependence on machine background.	The student will work, inside a team of experts and assisted by a tutor, participating to the operation and commissioning of the SVD. He/she will learn how to acquire the calibration constants of the SVD (noise and gain), using the standard DAQ system of the experiment, and will collaborate to the setup of the SW tools needed to study the stability of the calibration constants and the evolution of the defective strips of the detector. He/she will be involved in the offline analysis the SVD data, taken during physics runs, to study the detector performance and its dependence on machine background conditions. This analysis will concern cluster charge and time reconstruction, as well as reconstruction efficiency of SVD hits. The required skills are basic knowledge of the most popular operating systems. Some experience with the ROOT analysis software is desirable. Program of study or thesis in experimental high energy physics is preferred.

BEPC-1

Hosting Laboratory	Available starting date	Contact person(s)
BEPC	**1 May 2019 – 1 September 2019**	**Ilaria Balossino (INFN Ferrara)**

Scientific program	Daily activity, skills required and to be acquired
Commissioning of the Cylindrical GEM Inner Tracker for the BESIIII experiment The BESIII experiment is playing a leading role in the study of charmonium physics, light hadrons studies, and exotic searches owing to the high performance of the lepton collider BEPCII. The BESIII data taking will exceed the original terms; an upgrade program is on-going from both the detector and the accelerator sides. One spectrometer core upgrade is the replacement of the present inner tracker with a new detector based on Cylindrical GEM (Gas Electron Multiplier) technology with charge and time readout. The CGEM-IT is composed of three concentric layers of triple-GEM. The layers have been designed, built and tested in Italy, and have been finally shipped to IHEP separately at the end of 2018 for the final assembly. The installation is foreseen for Summer 2019. Before the installation, a long standalone cosmic run will be performed to test the full readout chain, the slow-control system, and assess the performance using an external tracking system. After the removal of the present inner tracker, the CGEM-IT will enter the BESIII pit ready for the final insertion inside the BESIII spectrometer. After the installation, the commissioning will proceed with a full spectrometer cosmic data taking to complete the final alignment.	The activity plan can be modified according to the availability of the candidate during any period of the year. The candidate will contribute to the commissioning of the detector in one of the main tasks, supervised by the INFN advisor. Knowledge of laboratory instrumentation, C++ programming skills, particle physics detector operation are required at basic level. Knowledge of the Micro Pattern Gas Detector is desirable. The candidate will be part of an international collaboration. The candidate will learn from direct experience in the laboratory advance techniques in the operation of a highly technological detector, providing a boost to his/her study.

BEPC-2

Hosting Laboratory	Available starting date	Contact person(s)
BEPC	**1 April 2019 – 1 August 2019**	**Rinaldo Baldini (INFN Frascati)**

Scientific program	Daily activity, skills required and to be acquired
Measurement of the relative phase between EM and strong amplitudes in ψ(2s) → ppbar, ll decays An unexpected relative phase $\|\Delta\Phi\|$=90° between strong and EM decay amplitudes of J/ψ has been observed. Such evidence could be compatible with the unconventional hypothesis of a J/ψ being combination of two resonances, one decaying through EM processes only, one strongly. Recent and unprecedented data available from BESIII, collected within the 2018 ψ(2S) scan, could shed light on the underlying processes. A measurement proposed by the Italian researchers, since the investigation of the relative phase is the core of the INFN BESIII analyses. The two-stage program will focus first on the reconstruction of pure strongly decays: ψ(2S)→ppbar. The candidate will investigate the EM and strong amplitudes no-interference scenario, taking advantage of the newly collected BESIII data and of the tools originally developed for the J/ψ scan. The investigation will then focus on the completely interfering scenario: lepton pairs production. A confirmation of a double nature of the aforementioned vector charmonium would imply that something significant is missing in the understanding of the Zweig rule. The additional existing question of whether this double nature also extends to the exotic charmonium states of the Y family could most likely only be clarified exploiting the enormous datasets expected from BELLEII.	C++/ROOT programming skills, intermediate English are prerequisites. Experience in data analysis, not necessarily in particle physics, is welcomed. The candidate must first select in the ψ(2S) scan dataset ppbar/ll events from both ψ(2S)→ppbar,ll decays and continuum; then, produce and exploit Montecarlo simulations to evaluate $\|\Delta\Phi\|$. The candidate will gain deep understanding of a complex generation, simulation, reconstruction and analysis framework as the BESIII one. The extended direct interaction at BEPC with highest experts in the field, both on the experimental and theoretical sides, as Rinaldo Baldini, will strongly boost candidate's skills in both data analysis and understanding the underlying physics.

PSI‒1

Hosting Laboratory	Available starting date	Contact person(s)
PSI	**1 March 2019 – 1 June 2019**	**Stephan Ritt (PSI)**

Scientific program	Daily activity, skills required and to be acquired
Commissioning of the MEG II experiment drift chamber The MEG II experiment is searching for the lepton flavor violating decay $\mu \rightarrow e\gamma$ with unprecedented sensitivities. The cylindrical drift chamber plays a crucial role in the background suppression by performing an unprecedented precise positron tracking in an ultralow mass drift chamber. The detector is being commissioned in fall 2018 and is supposed to be ready to look at the first positron tracks in 2019. The contract holder will be involved in the final steps of drift chamber HW commissioning and, in parallel, in the development and optimization of signal processing codes and detector calibration techniques. She/he will benefit of deep interactions with local experts and other collaboration members in the development of software programs for data acquisition, detector calibration and monitoring and will be an active member of analysis groups for data collected during the beam tests envisaged for summer 2019. Cosmic rays will be used to calibrate the chamber in the first half of the contract period. The calibration will consist in time and gain factors assessment and the obtained results will be compared with the performance measured by means of muon and positron beam induced events. The beam will be available since July the 1st 2019.	At the beginning of the activity the contract holder must have a good knowledge of particle detectors and especially of drift chambers and a good autonomy in the use of analysis software. Experience in C++ programming is also required. During the contract period she/he will acquire skills and experience about the setting up and starting up procedures of a new experiment and on the signal handling, for real and calibration events too. She/he will also acquire a deep knowledge of the structure of data acquisition and trigger systems and of on-line software.

PSI–2

Hosting Laboratory	Available starting date	Contact person(s)
PSI	**1 March 2019 – 1 2019**	**Angela Papa (PSI)**

Scientific program	Daily activity, skills required and to be acquired
Light neutral boson search with the MEGII detector Dark matter is one of the big unknown in the context of modern science and is attracting a lot of effort inside the scientific community. Among possible candidates there are short lived light neutral bosons; recently several attempts have been done to observe such particles in the mass range of 10 MeV-10 GeV but so far no evidence has been found. In the near future new experiments are expected to extend those limits in a region of couplings and/or masses unexplored so far. New approaches to search for that include nuclear reaction studies. Recently an evidence for an anomaly in the internal pair creation angular distribution in transitions $^{7}Li(p,e^{+}e^{-})^{8}Be$, possibly due to a new neutral boson has been claimed. The MEG experiment has set the most stringent limit on the $\mu \rightarrow e\gamma$ decay: BR($\mu \rightarrow e\gamma$ <4.2 x 10^{-13})@90% C.L. An upgrade of the experiment (MEGII) is ongoing to increase the sensitivity by one order of magnitude. The upgrade includes a completely new re-designed and highly performing spectrometer that together with the availability of 1MV Cockcroft-Walton (C- W) accelerator used for MEGII calibrations, offer the opportunity to study the $^{7}Li(p,e^{+}e^{-})^{8}Be$ reaction with higher statistics and increased detector resolutions to either confirm or to reject the anomaly.	The student will collaborate in performing Monte Carlo simulations in the GEANT4 MEGII soft- ware framework to optimize the tracking reconstruction algorithm for the e+e- pair, to define the trigger strategy and to set the final sensitivity that can be achieved. He/She will be also involved in setting up the experimental apparatus including the preparation and the test of new C-W Li and LiF targets to be used in the experiment. Required knowledge: good knowledge of English, C++, possibly basic knowledge of ROOT. By the end of the program the student will gain good expertise in GEANT4, ROOT and experimental techniques.